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Subcontractor Report

WindPACT Turbine Design Scaling Studies: Technical Area 4— Balance-of-Station Cost

21 March 2000—15 March 2001

D.A. Shafer, K.R. Strawmyer, R.M. Conley,
J.H. Guidinger, D.C. Wilkie, and T.F. Zellman
With assistance from D.W. Bernadett

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EXECUTIVE SUMMARY

INTRODUCTION

The United States Department of Energy has implemented the Wind Partnerships for Advanced Component Technologies (WindPact) program to explore the most advanced wind-generating technologies for improving reliability and decreasing energy costs. The first step in the WindPact program is a scaling study to bound the optimum sizes for wind turbines, to define size limits for certain technologies, and to scale new technologies. The technical activities are divided into the following four projects:

Technical Area 1 – Composite Blades for 80–120-meter Rotors
Technical Area 2 – Turbine, Rotor, and Blade Logistics
Technical Area 3 – Self-Erecting Tower and Nacelle Feasibility
Technical Area 4 – Balance-of-Station Cost

This report covers Technical Area 4 – Balance-of-Station Cost, which includes the electrical power collector system, wind turbine foundations, communications and controls, meteorological equipment, access roadways, crane pads, and the maintenance building. Technical Areas 2 and 4 are both based on a conceptual 50-megawatt (MW) wind farm site near Mission, South Dakota. Cost comparisons are provided for four sizes of wind turbines: 750 kilowatt (kW), 2.5 MW, 5.0 MW, and 10.0 MW.

SUMMARY OF COSTS

The table below summarizes the balance-of-station costs (in millions of 2000 dollars) for the smallest and largest sizes studied. The 750-kW turbine requires 66 units to provide 50 MW compared with the 10.0-MW size, which requires only five units.

Category	**66 – 750 kW**		**5 – 10 MW**	
	$ x 10^6	**Percent**	**$ x 10^6**	**Percent**
Foundations	*5.2*	*26*	*8.0*	*42*
Service Roads	*2.3*	*12*	*.7*	*4*
Crane Pads	*1.4*	*7*	*1.6*	*8*
Total Civil	8.8	45	10.3	54
Total Electric System	4.5	23	3.7	19
Total Misc. Infrastructure	1.7	9	0.6	3
Land, Overheads, and Contingency	4.6	23	4.4	23
Total Balance of Plant ($ millions)	**19.7**	**100**	**18.9**	**100**

CONCLUSIONS

1. The largest component of the balance-of-station cost is the civil infrastructure (45%–54%), which comprises foundations, service roads, and crane pads. The largest-cost item

is the foundations, and the second is crane pads. Both of these items show increasing costs for the larger turbine sizes. This is one area that can benefit from additional research. To achieve the lowest total cost, we recommend that future studies evaluate the combined tower and foundation designs. Another area that could also benefit from additional research is eliminating or minimizing crane pads (e.g., by using self-erecting towers, Technical Area 3).

2. The electrical system comprises 19%–23% of the balance-of-station costs. The electrical system can be built using conventional utility-grade equipment for the turbine ranges being studied. No new technology or scaling of existing technology is required. The larger units provide some economy of scale with regard to the electrical system.

3. Communications, tower lighting, meteorological towers, and the maintenance building are lumped together under miscellaneous infrastructure in the above table. These items are not a large part of the balance-of-station costs and do demonstrate decreasing costs for the larger units. The decreasing cost results from fewer units, thereby reducing tower lighting costs and communications costs. Existing technology is satisfactory for these needs, and no additional research is needed in these categories.

4. Land, overhead, and contingency are lumped together in the final category above. Because this is a conceptual study, we used a contingency of 20%, which is the largest component of this category. The overhead costs are for balance-of-plant items only and include engineering, surveying, licensing, land acquisition, construction inspection, and the owner's project management. This category does not include land or land acquisition costs for leasing the land for the wind farm itself. It only includes the incremental land costs for transmission lines away from the wind farm and the purchase of property for the maintenance building and substation. This last category is added to provide a total balance-of-plant cost.

CHAPTER 1 INTRODUCTION

BACKGROUND

As wind energy has grown more and more competitive with other forms of energy generation, the margin of improvement from one generation of technology to another has become smaller and smaller. And yet, to achieve the decrease in cost of energy necessary to place wind energy on an equal playing field with fossil-fuel-generated electricity such as natural gas, a reduction in cost of energy of up to 30% is still required. Wind turbine manufacturers have achieved great results by improving manufacturing techniques, taking advantage of the latest in engineering tools, and applying new concepts to existing designs. However, to achieve the required 30% reduction, a much greater level of innovation is required.

The United States Department of Energy (DOE) has implemented the Wind Partnerships for Advanced Component Technologies (WindPACT) program to explore the most advanced wind-generating technologies for improving reliability and decreasing the cost of energy. This work is being carried out through the Midwest Research Institute and the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

One of the first steps in the WindPACT program is a set of preliminary Scaling Studies to bound optimum sizes for turbines of the future, to help define sizing limits for certain critical technologies, and to explore the scale possibilities for new advanced concepts. The technical activities for the scaling study are divided into the following four projects:

Technical Area 1 - Composite Blades for 80- to 120-meter Rotors
Technical Area 2 - Turbine, Rotor, and Blade Logistics
Technical Area 3 – Self-Erecting Tower and Nacelle Feasibility
Technical Area 4 – Balance-of-Station Cost

SCOPE OF TECHNICAL AREA 4–BALANCE-OF-STATION COST

The subject of this report is Technical Area 4–Balance-of-Station Cost, which includes the electrical-power-collector system, wind turbine foundations, communications and controls, meteorological equipment, access roadways, crane pads, and maintenance offices.

Technical Areas 2 and 4 are both based on a conceptual 50-megawatt (MW) wind farm site near Mission, South Dakota (Figure 1). Cost comparisons are provided for four sizes of wind turbines: 750 kilowatt (kW), 2.5 MW, 5 MW, and 10 MW.

We prepared a draft report in June 2000. NREL held a workshop on November 2 and 3, 2000, to facilitate exchange of information among the various contractors and other interested parties. This final report incorporates comments received at this workshop.

PHYSICAL LAYOUT OF WIND FARM

We developed conceptual wind farm layouts for the four turbine sizes (Figures 3 through 8). The 50-MW wind farm requires 66 of the 750-kW-size turbines, 20 of the 2.5-MW-size turbines, 10 of the 5-MW-size turbines, or 5 of the 10-MW-size turbines. We arbitrarily numbered each turbine location for identification purposes.

Wind roses from Pierre, South Dakota, and Valentine, Nebraska (Figure 2), show a strong predominance of energy from the northwest and north-northwest. Therefore, the turbines were oriented perpendicular to an assumed prevailing wind direction of 343^{o} to best use the natural landforms in the study area.

As shown on Figures 3 through 8, the turbines are arranged in a rectilinear array. This approach has been taken for three reasons. First, the gentleness of the terrain allows for array layouts to be constructed without regard for topography. Second, the general scaling nature of the WindPACT study makes rectilinear layouts desirable to facilitate linear interpolation of results to intermediate turbine sizes. Third, site-specific layout optimization is beyond the scope of this project. However, we did some site-specific tailoring of the rectilinear layouts to make them more realistic.

Taking into account the distribution of wind energy, the spacing for lowest cost of energy was determined to be 2.3 rotor diameters between turbines and 12 rotor diameters between rows. We summarized the dimensions for the wind farm layouts below.

Plant Size kW	Rotor Diameter	Minimum Distance Between Turbines	Minimum Distance Between Rows
750	50 m (164 ft)	115 m (378 ft)	600 m (1,969 ft)
2,500	85 m (279 ft)	196 m (642 ft)	1,020 m (3,347 ft)
5,000	120 m (394 ft)	276 m (906 ft)	1,440 m (4,725 ft)
10,000	170 m (558 ft)	391 m (1,283 ft)	2,040 m (6,693 ft)

UTILITY POWER GRID

The local transmission company is the Western Area Power Administration (WAPA). A 115-kilovolt (kV) transmission line is within one mile of the area of the proposed wind farm. We developed the technical requirements and costs for the electrical-collector system to interconnect the turbines and to connect them via a new substation to this 115-kV line. There is an existing substation on the line, which serves the town of Mission. However, for this study, we assumed that a new substation would be constructed as the interconnection point.

CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

Balance-of-Station Cost ($ x 1000)

	Plant Size			
	750 kW	**2.5 MW**	**5 MW**	**10 MW**
Generator Step-up Transformers	1,153	676	1,177	819
Underground Cable	610	334	221	154
Risers and Reclosers	129	103	77	77
Overhead Lines	123	121	333	98
Substation	2,528	2,528	2,528	2,528
Subtotal 25 kV Electrical System	**4,543**	**3,762**	**4,337**	**3,677**
Generator Foundations	5,148	7,000	8,300	8,000
Service Roads (Option 2)	2,310	1,156	1,000	680
Crane Pads	1,386	1,200	1,900	1,585
Subtotal Civil	**8,844**	**9,356**	**11,200**	**10,265**
Communications	823	380	335	209
Tower Lighting	660	200	100	50
Meteorological Towers	74	88	106	160
Maintenance Building	156	156	156	156
Subtotal Misc. Infrastructure	**1,730**	**824**	**697**	**575**
Land and Right-of-Way	47	47	76	44
Clearing and Site Preparation	5	5	5	5
Project Overheads	1,268	1,161	1,334	1,186
Subtotal Land and Overheads	**1,319**	**1,213**	**1,414**	**1,234**
Balance-of-Station Subtotal	16,419	15,155	17,648	15,751
Contingency = 20%	3,284	3,031	3,530	3,150
Balance-of-Station Total ($ x 1000)	**19,700**	**18,190**	**21,180**	**18,900**
Balance-of-Station Total ($/kW)	$394/kW	$364/kW	$424/kW	$378/kW

Electrical-System Conclusions

1. The electrical-power-collector system represents 23% to 27% of the balance-of-station cost. More than half of the electrical-collector system cost is the substation, which connects the wind farm to the existing power grid. The substation is designed for 50 MW, and its design and cost are independent of the wind turbine size.

2. The electrical-collector system comprises conventional utility equipment and facilities. All proposed sizes of wind turbine generators considered in this study are well within the current designs and capability of this equipment. Thus, there are no new technology or

scaling issues with regard to the power system that would impede future application of larger-size wind turbines.

3. There is some economy of scale demonstrated in the electrical-system cost, especially in the 750- to 2500-kW size.

Chapter 3 provides additional details and conclusions on the electrical power system.

Civil Conclusions

1. The civil infrastructure cost comprises wind turbine foundations, access roads, and crane pads. These three items total 54% to 65% of the total balance-of-station cost, the majority of which comes from the wind turbine foundation.

2. The foundations and crane pads show an increasing unit cost for the larger turbine sizes, which identifies them as an area for additional study.

3. The size of access road and crane pad depends upon the size of crane needed for construction and maintenance. At the November 2 and 3, 2000, workshop, there was discussion on the use of self-erecting towers for the taller towers. This type of construction would help to minimize roadway width and crane pad sizes. Future research on this topic should be pursued.

4. More research needs to be done on foundation design and cost. We recommend that the foundation and tower be evaluated together. Modifications to the tower (greater diameter by flaring, or use of a four-legged tubular base) may result in much-reduced foundation costs.

Chapters 4 and 5 provide additional details and conclusions regarding foundations, roads, and crane pads.

Miscellaneous Infrastructure Conclusions

1. Miscellaneous infrastructure includes communications, tower lighting, meteorological towers, and the maintenance building, representing 10% of the total balance-of-station costs for the 66 x 750-kW wind farm, and a decrease to 4% for the 5 x 10-MW wind farm. The larger components of these costs for the 750-kW wind farm are communications and tower lighting, which are a function of the number of towers. Because of the need for fewer towers, considerable cost savings can be achieved with the larger turbines.

2. We originally intended to study how maintenance building requirements and costs might vary with the larger turbine sizes. We never achieved this objective, however, because we were never able to quantify how the maintenance on a 5 x 10-MW wind farm might differ from that of the 66 x 750-kW wind farm. We believe the most practical means for maintaining the electrical power system and the communication system would be to

contract with the local utility or a private contractor who does this type of work. For stocking of spare parts and maintenance on the wind turbines, there may be some economy by having one or more regionally located maintenance centers, which would have equipment and trained staff to call upon when needed rather than maintaining parts, equipment, and staff at each wind farm location. Our building cost is reflected in the minimal maintenance effort required at the wind farm.

Chapter 6 provides additional details and conclusions regarding miscellaneous infrastructure.

Land, Overhead, and Contingency Cost Conclusions

1. The land cost does not include land for the wind farm, but rather any land or land rights that would be required in addition to the wind farm. The land costs include land for the substation and the administrative building, as well as right-of-way for the power line between the substation and the wind farm. The clearing costs are minimal because the project is located in South Dakota.

2. The overhead costs include engineering, surveying, licensing, land acquisition, construction inspection, and owners' project management.

3. We included land, overhead, and contingency costs to provide an overall project total cost.

CHAPTER 3 ELECTRICAL SYSTEM

COST SUMMARY AND CONCLUSIONS

The cost of the electrical system is divided into components, starting at the wind turbine and following the electrical system back to the interconnection with the utility transmission grid. The components are: generator step-up transformers (GSUs), underground cable, risers and reclosers, overhead line, and substation.

We studied two collector-system voltage levels for each of the four wind turbine sizes. For the 750-kW size, 15 and 25 kV were studied. For the other sizes, we studied 25- and 35-kV systems.

The costs for equipment and materials and construction labor for installation of the equipment and material for the electrical-collector system for the 50-MW wind farm are summarized in the following table. The costs, which are in today's dollars ($ x 1000), do not include land; clearing; overhead costs such as engineering, surveying, and material procurement; or project management.

System Component	750-kW Plan		2,500-kW Plan		5,000-kW Plan		10,000-kW Plan	
	15 kV	**25 kV**	**25 kV**	**35 kV**	**25 kV**	**35 kV**	**25 kV**	**35 kV**
GSU	1,147	1,153	676	710	1,177	1,196	819	870
Cable	643	610	334	356	221	237	154	174
Risers/Reclosers	126	129	103	83	77	83	77	83
Overhead Line	188	123	121	121	333	301	98	98
Substation	2,612	2,528	2,528	2,729	2,528	2,729	2,528	2,729
Subtotal	4,716	4,543	3,762	3,999	4,337	4,545	3,677	3,954

Conclusions: Electrical-Power-Collector System Costs

1. The 25-kV collector system was the least-cost plan for each wind turbine size studied, though there was no significant cost increase for the alternative voltage level. It might be beneficial to have the local utility maintain the electrical power system, in which case the best voltage for the collector system would be one that matches the local utility voltage.

2. The 750-kW and 2,500-kW plans show decreasing costs for the generator step-up transformers. These transformers are commonly used sizes and show a decreasing cost per unit. The generator step-up transformer for the 5,000-kW plan is at the upper limit of commonly used sizes, and the cost estimate reflects a higher cost per unit than the more common, smaller sizes. Similarly, for the 10,000-kW plan, a substation-type transformer was required. The total cost was lower than the 5,000-kW plan because fewer units were required.

3. The underground cable shows a decreasing cost for the larger turbine sizes because of shorter cable lengths and fewer terminations.

4. The reclosers show a declining cost for the larger turbine sizes because fewer reclosers were required.

5. The overhead line costs also show a general decline for the larger turbine sizes because of the shorter distance required. The 5,000-kW plan shows an anomaly because the layout required splitting the wind turbines to two locations, which necessitated doubling the length of overhead line over what would have been needed if the turbines were all located at one location.

6. The substation is the dominant cost component of the electrical-collector system. This cost is independent of wind turbine size.

7. The study confirmed that conventional utility equipment and design practices could be used for the electrical-power-collector system for all sizes of wind turbines.

8. There is some economy of scale with regard to larger wind turbine sizes. The cost for the electrical-collector system for a 50-MW wind farm for the 750-kW size is approximately $91/kW. This reduced to $75/kW and $74/kW for the 2.5 MW and 10 MW turbines, respectively. These do not include costs for land, clearing, and overhead.

DESIGN GUIDELINES AND ASSUMPTIONS

The following design guidelines were established as the basis of the study of the electrical-collector systems.

1. Conventional utility-grade equipment will be used to interconnect the wind turbines. Typical medium-voltage equipment used by utilities is rated 15, 25, or 35 kV. We evaluated two voltage levels for each size wind turbine. We studied 25 kV for all plans. Alternatives using 15-kV-class equipment for the 750-kW plan and 35 kV for the 2,500-kW, 5,000-kW and 10,000-kW plans were considered to determine if there might be a significant cost difference for the alternative voltage.

2. Under the umbrella of 15-kV-class equipment, different utilities have standardized on different operating voltages; for example, 12.47, 13.2, and 13.8 kV. For this study, we chose 13.8 kV as our operating voltage for the 15-kV plan. Similarly, for the 25- and 35-kV-class equipment, we chose 24.9 and 34.5 kV as the operating voltages.

3. The generator step-up transformer will be designed to match the generator voltage on the low-voltage side and to match the medium-voltage system on the other side. One consideration is the impact of the generator voltage on the collector-system costs. The transformer manufacturers have considerable control and latitude with regard to the design of the low-voltage winding of the transformer. There should not be a significant cost difference in the generator step-up transformers as long as the voltages are within

typical ranges. We arbitrarily chose typical voltages of 480 V for the 750-kW wind turbines, 690 V for 2.5 MW, 2,400 V for 5 MW, and 4,160 V for the 10-MW size. Optimization of the generator voltage should be based on optimization of the generator and associated power electronics design; therefore, we do not consider it a design issue for the collector system.

4. The generator step-up transformers will be padmount transformers with all cables entering the transformer underground. Standard padmount transformers will be used as follows:

   a. 750 kW - 1,000-kVA transformer
   b. 2,500 kW - 3,000-kVA transformer
   c. 5,000 kW - 7,500-kVA transformer

   Because 7,500 kVA is the largest standard padmount transformer, the 10,000-kW wind turbines will be provided with a 10/12.5-MVA substation transformer with separate padmounted switchgear installed on the high side of the transformer.

5. The medium-voltage cables, which comprise the power system between and around the wind turbines, will be underground to maintain visual aesthetics. Standard utility-grade underground cable will be used. Utilities use three types of construction for underground systems: direct-bury cable, direct-bury cable in conduit, and cable installed in concrete-encased duct bank. Concrete-encased duct bank is the most expensive and is used in urban areas where there is high probability of someone digging into the cable and where expensive streets and sidewalks exist over the duct bank. The duct bank protects the cable and allows a failed cable to be removed and a new cable installed without disturbing the activities or facilities above. Cable in a buried conduit is the next most expensive option, because a conduit is required in addition to the cable. The conduit provides some protection to the cable, and allows a cable to be replaced without digging it up. The least expensive option with regard to first-installation cost is to directly bury the cable. The cable manufacturer warrants the direct-buried cable the same as if the cable is installed in conduit. The disadvantage of direct-buried cable is that it is more likely to be damaged if someone digs into it. Also, if a direct-buried cable fails, it is necessary to dig up the cable at the location of the failure to repair it. For the purpose of this study, we are assuming direct-buried cable.

6. The underground cable would connect from one windmill to the next until a convenient roadway location is encountered, at which point the underground cable would be connected to a main collector line. For the main collector line, we assumed that a conventional three-phase overhead distribution line would be built, and that the line would be built along a roadway, as is the practice of the local utility. Thus, the overhead line would aesthetically blend into the landscape as "just another distribution line."

7. At the interface between the underground and the overhead collector lines, we have assumed a fault-interrupting device called a "recloser." This is a conventional utility "circuit breaker" that is used to isolate a section of the line automatically should there be

an electrical fault. Each string of windmills would connect to the overhead main by a recloser. Thus, should there be an underground cable or transformer failure, only those windmills connected together on the string would be disconnected. All other windmills would continue to operate and remain connected to the main line.

8. We assumed that the existing utility substation serving the area cannot be used to connect the collector system to the 115-kV line. Therefore, cost estimates are provided for a new 30/40/50-MVA, 115-kV distribution substation to make this connection.

ELECTRICAL-SYSTEMS ANALYSIS

We analyzed power flow to verify the feasibility of the proposed 15-kV plan to interconnect 66 x 750-kW generators as described above. Likewise, power flow analyses were performed to verify the feasibility for the 24.9-kV and 34.5-kV plans for the four sizes of wind turbines. The power flow analysis calculates the line flows, kW and kVAR line losses, line voltage drops, and VAR requirements at each generator. The assumptions and data for this analysis are provided in Appendices A and B. The power flow results are provided in Appendix C.

We conducted a short-circuit analysis for the proposed plans. The short-circuit analysis determines the expected fault levels, and is used to assure that the equipment will operate as intended. Because the results were similar for all plans, only the results for the 750-kW turbines at 15 kV are shown in Appendix D.

CHAPTER 4 FOUNDATIONS

To calculate foundation costs, the wind turbine tower was assumed to be a single shaft of the heights and diameters shown in the table below. The wind turbine mass, overturning moment, and base diameter are factors used to determine the costs of the foundation. The rotor diameter, hub height, and base diameter increase about three-and-one-half times for the range of plant sizes from 750 to 10,000 kW. However, the total mass and overturning moment increase by 30 to 40 times.

Plant Size kW	Rotor Diameter	Hub Height	Base Diameter	Total Mass* kg	Overturning Moment kN-m
750	50 m (164 ft)	65 m (213 ft)	3.7 m (12.1 ft)	104,927	38,718
2,500	85 m (279 ft)	111 m (364 ft)	6.4 m (21 ft)	466,061	190,185
5,000	120 m (394 ft)	156 m (512 ft)	9.0 m (29.5 ft)	1,237,715	535,070
10,000	170 m (558 ft)	221 m (725 ft)	12.7 m (41.7 ft)	3,338,895	1,521,106

*Corrected values from those presented at the November 2 & 3 workshop.

The foundation costs can vary significantly depending on soil conditions, rock, and proximity of concrete supplies. To compare foundation designs and costs, a square pad-and-pier foundation geometry was assumed (Figure 11). As shown in the table below, the foundation width increases from 42 to 130 feet and the volume of concrete increases from 340 cubic yards for the 750-kW size to 7,250 cubic yards for the 10-MW size. The cost for each foundation increases from $78,000 to $1,600,000. These estimates can be 40% to 50% conservative.

Plant Size kW	Width	Concrete m^3 (Cu.yd.)	Cost Each $x1,000	Number of Foundations	Total Cost $x1,000
750	13 m (42 ft)	260 (340)	78	66	5,148
2,500	21 m (70 ft)	1,185 (1,550)	350	20	7,000
5,000	30 m (100 ft)	2,944 (3,850)	830	10	8,300
10,000	40m (130 ft)	5,543 (7,250)	1,600	5	8,000

We also considered a rock-anchor foundation (Figure 14), which is required only when bedrock is close to the surface. The estimated cost for the rock-anchor design is slightly higher than that for the pad-and-pier design; again, however, the estimate is conservative.

Alternative foundation concepts would include cylindrical designs. These designs have implications with regard to excavating and forming, which makes it more difficult to provide cost estimates without knowing soil conditions.

There was discussion at the November 2 and 3 workshop that these foundation costs (for the 750-kW size) may be approximately twice those of existing installations. As stated previously, the costs given are conservative, but they are relative. We believe the location of the site with regard to soil conditions and proximity to concrete supplies may result in a large variation in costs for foundations.

Conclusions on Foundation Costs

1. The foundation cost, based on extrapolating the existing design of a single-shaft tower, results in an increasing unit cost for the larger sizes.

2. It is difficult to optimize the foundation design independent of the tower design. It would be better to consider the tower and foundation together in future studies.

CHAPTER 5 OTHER CIVIL INFRASTRUCTURE

ROADS

We assumed that maintenance and construction roadways would be located along the line of turbines parallel to the cable routes shown on the layout drawings. The cost includes labor and material to build the roadways, including culverts. The cost does not include overhead costs, such as engineering, surveying, and management. In addition, we assumed that county or township roads would exist in the vicinity of the wind farm, and that the only wind farm roadways would be those between the turbines, as shown on the layout drawings. No costs have been included for paving or upgrading the county or township roads.

We considered three alternative road concepts. Option 1 would be a minimal, 20-foot-wide gravel road. This assumes that construction and maintenance access is not needed for heavy and large equipment. In other words, the towers and heavy equipment would be shipped in small pieces and assembled and erected at each site. Any equipment too big or heavy to be moved on a minimal road would have to be moved by helicopter or by building temporary roads.

Option 2 would be a paved road wide enough for moving cranes and maintenance equipment but not sufficient for equipment (cranes) that may be needed for the initial construction of the towers and rotors. If a very large crane is needed for initial construction, it might need to be disassembled to move it from one tower site to the next.

Option 3 would be a paved road wide enough for moving the largest crane from site to site for the initial erection of towers and rotors without disassembly of the crane.

Plant Size kW	Total Length mx1,000 (ftx1,000)	Option 1 Gravel Road		Option 2 Paved Road		Option 3 Paved Road	
		Width m (ft)	Cost $x1,000	Width m (ft)	Cost $x1,000	Width m (ft)	Cost $x1,000
750	7.8 (25.6)	6 (20)	1,290	8 (26)	2,310	9 (30)	2,830
2,500	3.9 (12.8)	6 (20)	643	8 (26)	1,156	9 (30)	1,413
5,000	2.8 (9.1)	6 (20)	460	10 (32)	1,000	12 (40)	1,270
10,000	1.9 (6.1)	6 (20)	310	10 (32)	680	12 (40)	870

Conclusions on Roads

1. The maintenance and access road costs show a decreasing cost for the larger turbine sizes because considerably less length is required for these sizes. As mentioned above, this cost estimate does not include any work that may be needed on the county or township roads to accommodate the larger turbines. This issue is addressed in the Technical Area 2 study.

CRANE PADS

Crane pads are another related cost. If a large crane is needed to erect the tower and rotor, then a crane pad may be needed for safe operation of the crane. The estimated size and cost of the crane pads are summarized below.

Plant Size kW	Area m^2 (ft^2)	Concrete m^3 (cu.yd.)	Cost Each $x1,000	No. Pads	Total Cost $x1,000
750	243 (2,616)	81 (106)	21	66	1,386
2,500	1,000 (10,764)	175 (299)	60	20	1,200
5,000	2,400 (25,834)	732 (957)	190	10	1,900
10,000	4,000 (43,056)	1,220 (1,595)	317	5	1,585

Conclusions on Crane Pads

1. If crane pads are required to erect the very large towers, not only is the cost significant, but it also increases for the larger plants.

CHAPTER 6 MISCELLANEOUS INFRASTRUCTURE

COST SUMMARY AND CONCLUSIONS

Miscellaneous infrastructure includes communications, tower lighting, meteorological towers, and the administrative building. For data acquisition and control, the communications fiber-optic system is routed between the administrative building and each wind turbine, the electrical reclosers, and the meteorological towers. The tower lighting consists of aircraft warning lighting located on top of each wind turbine tower. The meteorological towers provide wind and other weather data. The administrative building provides housing for the wind farm administrative and maintenance functions on-site.

	Plant Size			
System Component	**750 kW**	**2,500 kW**	**5,000 kW**	**10,000 kW**
Communications	823	380	335	209
Tower Lighting	660	200	100	50
Meteorological Towers	74	88	106	160
Maintenance Building	156	156	156	156
Subtotal Misc. ($x1,000)	$ 1,713	$ 824	$ 697	$ 575

Conclusions on Miscellaneous Infrastructure:

1. The communications costs are a function of total linear distance from the administrative building to each wind turbine, as well as the number of turbines. As shown, there is a significant cost saving in the larger turbine plan because there are fewer turbines and shorter distances involved.

2. Tower lighting is a function of number of turbines and favors the larger wind turbines because fewer towers are needed.

3. Only two meteorological towers are required for the wind farm site regardless of the size and number of turbines for the 50-MW wind farm studied. The larger wind turbines require higher meteorological towers, resulting in increasing cost for the meteorological towers as wind turbine size increases.

4. We estimate that the cost of the administrative building is independent of wind turbine size.

5. Considering the sum of the miscellaneous items, the larger turbine sizes demonstrate a decreasing cost for a 50-MW wind farm.

COMMUNICATIONS SYSTEM

Figure 10 shows a one-line diagram of a communications system that would apply to plans for any of the proposed generator capacities. The proposed communications system consists of a master station located in the administrative building connected to remote terminal units at each of the generators, reclosers, and meteorological towers by way of multiple overhead and underground fiber-optic circuits. Costs for the substation include providing the local utility with output data from the wind farm's communications system by way of a fiber-optic circuit.

Plant Size kW	Number RTU*	RTU Cost $x1,000	Length Fiber mx1,000 (ftx1,000)	Fiber Cost $x1,000	Master Station $x1,000	Total Cost $x1,000
750	66+5+2	588	10.3 (33.9)	168	67	823
2,500	20+3+2	201	6 (19.6)	104	67	372
5,000	10+3+2	121	7.4 (24.4)	148	67	335
10,000	5+3+2	81	3.4 (11.1)	62	67	209

* Based on number of turbines + number of reclosers + number of meteorological towers.

TOWER LIGHTING AND METEOROLOGICAL TOWERS

Tower lighting is provided on each wind turbine tower as required by Federal Communications Commission (FCC) regulations for aircraft warning.

Two meteorological towers are required for the 50-MW wind farm site regardless of the number of turbines. The tower height for the meteorological tower is based on approximately 83% of the hub height.

	Tower Lighting		Meteorological Towers		
Plant Size kW	No.	Cost $x1,000	No.	Height m	Cost $x1,000
750	66	660	2	54	74
2,500	20	200	2	92	88
5,000	10	100	2	130	106
10,000	5	50	2	180	160

MAINTENANCE BUILDING

Description		Total
2,400-Square-Foot Service Building	100,200	
Water	5,000	
Septic	10,000	
Driveway/Parking	5,400	
Security Fence	32,400	
Gates	2,900	
Subtotal	155,900	
Subtotal (Rounded)	**$ 156,000**	
Land (Acres)	15,000	
Site Clearing	0	
Site Preparation	2,400	
Total	**$ 173,400**	

We have not determined how the maintenance building requirements might vary as a function of turbine size. The building costs we have provided are for a minimal building. We used the same building cost for all four plans. This is one item that would benefit from additional effort, though we do not expect that there are any new technology or research items associated with this effort. Furthermore, we do not expect this to be a major cost item. However, it does need to be included in the overall balance-of-station cost for computing the cost of wind energy.

For a utility, a 50-MW plant is considered small. Economic considerations dictate keeping the operating and maintenance costs for a 50-MW plant as low as possible. An area of future research might be to consider building a regional operating and maintenance facility that would be responsible for many 50-MW wind farms. This might eliminate the need for an administrative and maintenance building (and the need for staff and equipment) at each wind farm site. If space for on-site maintenance or storage were needed, one possibility would be to use one or more specially designed semi-trailers. These could be constructed in a factory and provided to as many wind farm sites as needed.

CHAPTER 7 QUESTIONS AND ANSWERS

Commonwealth Associates, Inc. (CAI) prepared a draft report in June 2000. Questions with regard to that report and our responses are provided in this chapter.

1. The turbine layout seems somewhat simplistic with regard to terrain. Wouldn't the layout follow more of the contours of the land, particularly in the layout for the 750-kW turbine, where the second (downwind) row is below the ridgeline? A layout that conforms more to the land may result in changes in inter-turbine electric-line lengths. How was the spacing of 2.3 rotor diameters between turbines, and 12 rotor diameters between rows, determined?

    The layouts have been constructed based on wind roses from Pierre, South Dakota, and Valentine, Nebraska, applied to the research of Germain and Bain ("Economics of Wind Farm Layout," Proceedings of WindPower '97). The wind roses show a strong predominance of energy from the northwest and north-northwest. The turbines have been oriented perpendicular to an assumed prevailing wind direction of 343° to best utilize the natural landforms in the study area north of Mission, South Dakota. The wind roses from sites in this area of the country will share very similar characteristics. Sites from Kansas southward may have strong southern prevailing winds, and sites in Iowa may have bi-modal south-northwest flow, but sites in the Dakotas and Nebraska should have very similar characteristics to the Pierre and Valentine data referenced here.

    Taking the distribution of wind energy by sector and interpolating between the Isotropic and Preferred Direction results of Tables 4 and 5 from Germain and Bain, the spacing for lowest cost of energy was determined to be 2.3 rotor diameters between turbines and 12 rotor diameters between rows.

    A rectilinear-array approach has been taken in this case for three reasons. First, the gentleness of the terrain allows for array layouts to be constructed without regard for topography. Second, the general scaling nature of the WindPACT study makes rectilinear layouts desirable to facilitate linear interpolation of results to intermediate turbine sizes. Third, site-specific layout optimization is beyond the scope of this project. However, some site-specific tailoring of the rectilinear layouts has been done to make them more realistic.

    Actual project implementation would typically not include rectilinear turbine layout, but would instead utilize numerical simulation programs such as WindFarmer or WindPro. These programs use complete descriptions of the wind resource by speed and direction, digital terrain data, property boundary information, and setback distances as inputs into a numerical optimization routine that determines the layout that maximizes the energy output. These layouts group turbines in the highest-energy-production regions, which are *typically the highest-elevation sites. Because the terrain in the study area does not present a large enough feature perpendicular to the prevailing flow to contain the required number of turbines, the model would probably utilize a larger spacing between turbines. The space between rows would not be a relevant parameter because the model would not assume the turbines are arranged in rows.*

2. Would changing the inter-turbine spacing to more than the 2.3 diameters affect the conclusions? It seems a bit tight, though some commercial installations in Texas seem to be using this spacing, whereas wind farms in Minnesota and Iowa are not.

   Changing the spacing between turbines would change the cost of cable, the cost of roads, and the cost of communication fiber optics. Also, changing distance between rows could increase the length of the overhead line. Approximate unit costs for these items are provided in Tables E2.1 through E2.4. We would expect increased spacing would impact the 66 x 750-kW plan more than wind farms with the larger turbines. We concluded that these items demonstrate decreasing unit costs for the larger turbine wind farms. Thus, our conclusion would not change if we had spaced the turbines farther apart.

3. Why are three of the 5-MW turbines located so far from the substation compared to the 750-kW plan? Were closer alternatives considered?

   Three of the 5-MW turbines were located at a distance from the others due to the spacing assumptions explained in question #1 above. Closer alternatives were not examined.

4. Can you relate the costs to installed kW and swept area to allow observation of implications to cost of energy?

   The cost tables compare and summarize the balance-of-station costs (in today's dollars) for the four sizes of wind turbines. All four plans provide a wind farm with a total of 50 MW and presumably the same annual energy production. Thus, relative ranking of the plans is the same whether you compare the plans on total dollars, dollars per kW, or dollars per kWh. We have added a dollars per kW number on the bottom of the summary table in Chapter 2.

5. Why do the 25-kV electrical plans turn out cheaper for each of the turbine sizes? Some explanation would be helpful.

   The industry uses three standard voltages for power distribution equipment and cable that are applicable for building the wind farm collector system: 15, 25, and 35 kV. Also, the industry standard ratings for underground cable terminations are 200 and 600 amps. Based on unit costs for these standard components, the distances involved, and the power to be transported, the 25-kV plan has a slight cost advantage, as our calculations show. Under different assumptions with regard to power and distance, another voltage may be better.

6. The X/R ratio for substation transformers appears too large. Please review and comment.

Table A2 lists our X/R assumption of nine for the generator step-up transformers. In Appendix B we used 19 for the 30-MVA substation transformer. The X/R ratio is used to calculate the resistance of the transformer for power flow and short-circuit modeling. Institute of Electrical and Electronics Engineers (IEEE) C37-010-1979 and IEEE 141-1993 provide the following typical X/R ratios for transformers:

1,000 kVA – 7, range not available
5,000 kVA – 12, 5-18
10,000 kVA – 15, 6-20
30,000 kVA – 23, 11-30

Our assumed values are within the range of transformer X/R ratios and, perhaps, too low with regard to typical values. The transformer resistance is a design function. A higher X/R ratio implies a lower resistance and, hence, a more efficient transformer. Thus, our calculations of losses may be a pinch high. The calculation of load losses is provided as part of the power flow simulation. We tabulated these numbers and reviewed them for reasonableness; however, they do not directly impact the study conclusions. Because we believe the resistance values we assumed do not affect our study, we recommend no changes in our assumptions at this time.

We would like to offer one additional comment with regard to transformer design and efficiency. We did not model or tabulate transformer no-load losses. This is also a design variable that the manufacturer can modify. The no-load loss is present any time that the transformer is energized; presumably, this would be 100% of the time (except when the transformer is out of service for maintenance). On the other hand, the load losses, which are a function of transformer resistance, will be less of a factor because of the low capacity factor of the wind generators. A candidate for a future study would be an economic evaluation of transformer costs versus no-load and load losses.

7. The wind farm is expected to be composed of variable-speed wind turbines. Thus, the wind turbine generator will be a current source generator (with power converter). This would reduce the need for capacitors and power factor correction, and reduce short-circuits. In the event of a short-circuit, the current output of the generator will be automatically limited within a half cycle by the power electronics.

The power flow and short-circuit modeling was done to confirm that the proposed collector system would indeed work as we intended. With the power flow model, we wanted to determine the expected voltage drop across the system from no generation to full generation. Our criteria were to have the voltage within plus or minus 5% of the substation bus voltage, over the range of no generation to full *generation. To model the generator, we assumed that the power electronics could be designed to provide any reasonable power factor at the machine. For this first-cut model, we set generators to hold 1.00 pu voltage on their terminals within the limits of plus or minus 95% power factor. We also considered the line-charging kVAR of the underground cable (though this proved to be negligible). The results of the power flow simulations confirmed that we did indeed have a viable high-voltage collector system, with a flat voltage profile from no generation to full generation. Also, we determined that some generators were operating at slightly leading and others at slightly lagging power factors, and that all were well within the plus or minus 95% power factor limit. From this we conclude the following: that there should be no problem in designing the power electronics to provide sufficient kVAR at each machine as necessary to regulate the voltage, and that the machine terminal voltage can serve as the control variable of the kVAR at each machine (i.e., simple local control of each machine).*

From the above calculations, we determined that we have an acceptable voltage profile across our collector system and, consequently, we will not need a voltage regulator or load-tap-changing (LTC) transformer at our substation. This is good news from two perspectives. First, we save the cost of this equipment, and second, LTC transformers are mechanical devices that can be a maintenance problem with frequent operation. (We do not have experience with any actual wind farms; however, our seat-of-the-pants expectation is that the output of the wind plant may change frequently and, thus, cause many LTC operations, leading to a maintenance concern.)

The power flow model provides a calculation of the kW and kVAR losses on the high-voltage collector system. We determined that our collector system would have approximately 10-MVAR losses at full generation. These losses are a function of the square of the current flow on the collector system. Hence, the MVAR losses will be expected to change even more rapidly than the generation. Depending upon the relative stiffness of the transmission system, a 10-MVAR fluctuating load on the utility system may very likely cause the utility transmission voltage in the vicinity to fluctuate. For example, the voltage at the Mission Distribution Substation may be affected. If so, the voltage regulator or LTC at Mission would continually be operating in an attempt to hold voltage, thus leading to more frequent maintenance. Because of these types of problems, we would expect the utility to insist that the wind farm supply power to the system at unity power factor.

Although it is possible to design a control system that would provide these MVAR losses from the wind machines themselves, we believe a simpler and more direct approach is to provide the MVAR losses by capacitors at the substation. Because we expect the capacitors will need to be switched frequently, we would propose to use power electronic switching rather than mechanical switching. The control of the switching would be the power factor at the substation. A commercial product that provides this type of capacitor switching and control is on the market. We *believe this would be the most cost-effective approach to providing unity power to the utility.*

We included the cost of this device in our estimates of the substation. It is the same for all plans. We recommend that we keep this feature in our report, as we presently have it.

The other comment above deals with the short-circuit contribution of the generator power electronics. We prepared a short-circuit model of the power system to determine if we can apply standard distribution-type equipment, primarily the reclosers. We are using a recloser as the switching device between the overhead and underground cables. We are proposing to use this device because it is standard equipment familiar to utility maintenance people, it can be used as a fault-interrupting device, it can be used as a remotely controlled switching device, it is a three-phase switching device, it is lower in cost than a full-fledged circuit breaker, and it can provide data to the supervisory control and data acquisition (SCADA) system. The standard short-circuit rating of this device is 12 kA. We did not have a good short-circuit model for the power electronic wind machines, so we just modeled them as conventional generators to get an order-of-magnitude feel for the approximate fault levels we might expect. We determined that the greatest contribution to the fault current was not the generators, but rather the power system. We concluded that we could use standard reclosers for most applications except very close in to the substation. Thus, it was not necessary for us to have a more sophisticated short-circuit model of the generators. We believe the assumptions and calculations in our report are adequate for the purpose intended.

8. Did the design consider harmonics mitigation for the static VAR compensation?

One form of static VAR compensator uses power electronics to provide continuous control of current through a reactor, which is in parallel with a capacitor. The VAR output can be designed for a range of both lagging and leading VARs, depending upon the size of the reactor and capacitor. The power electronics can provide very fast response and virtually any output within the design limits. These types of devices are ideally suited for compensating rapidly fluctuating VAR loads, such as those encountered with arc furnaces and welding machines. The disadvantages of these devices are:

a) They generate harmonics (usually mitigated by design of the capacitor banks, which provide leading VARs and act as harmonic filters).
b) They are expensive.

The capacitors that we are proposing are not a static VAR compensator as defined above. Instead, they are standard distribution-type capacitors, which are switched by power electronics. One supplier of this type of equipment is Power Quality Systems, Inc. More information on their product is provided at www.pwrqualitysys.com. The power electronics cause switching on the zero axis *crossing of the current to minimize harmonic generation. No harmonic mitigation would be required.*

9. What would be the impact on total facility cost of radio communications to a central location and cellular communications to outside of the wind park?

    Our preliminary estimate for radio communications is $3,000/Remote Terminal Unit (RTU) (at each wind turbine) and $20,000 for the Master Station. For 66 x 750-kW wind turbines, the cost for radio is slightly higher than our estimated cost for fiber-optic communication. However, for the other three larger turbines (fewer units), the preliminary cost for radio is significantly less (approximately 50%) than the cost for fiber. These preliminary numbers indicate that additional work to evaluate both fiber-optic and radio communications may be warranted.

    Cost for cellular is essentially the cost of a Remote Master communicating with the Master (estimated at $25,000).

10. Why are crane pads required? Have not seen them used in many, if any, wind farms (at least up to 1.6 MW).

    Crane pads are required if the site is not already level and does not provide sufficient soil-bearing capacity for the crane to be used. Cost estimation of crane pad construction will depend on the soil-bearing requirements of the particular crane, and the bearing strength of the native soil. The "Vestas Standard Civil Specifications" for the V-47 (660 kW) turbine require that crane pads be constructed with an area of 139-260 m^2. (We used 243 m^2.) The crane pads are required to provide a bearing capacity of 3,000 lb/ft^2 with a Standard Proctor (percentage compaction) of 95% and a maximum elevation variation of 2" across the pad.

11. Overhead collector lines between turbines and substation would most likely be maintained by the project owner/operator, not by a local utility. In addition, considering the project's location, utilizing the overhead poles for distribution to customers appears unlikely.

    It will probably be cheaper to contract with the local utility to maintain the overhead and underground high-voltage system than to attempt to maintain trained staff, maintenance equipment, and spare parts yourself. That is one of the reasons we were careful to use conventional utility-type equipment in the design of the collector system. We agree that, for the South Dakota site, there may be little opportunity for joint use of the overhead poles to service utility customers. However, as a general practice, offering access to electrical power where it previously was not available (except at the additional cost to build a power line) may be added economic incentive to the landowner with whom you are negotiating to obtain the easement for your power line.

12. Did you consider lightning protection for the overhead line?

> *Our concept design uses the neutral placed above the phase conductors to serve the dual purpose of neutral and lightning shield wire on the overhead line. We have also shown lightning arrestors on the substation transformer, at each overhead switching device, at each transition from overhead to underground cable, and at the last transformer in the underground string. Lightning protection needs to be custom designed for the particular isokeraunic level and grounding. What we have included in our estimates, we believe, is adequate for the scope of this study.*

13. Power quality meters for each row of turbines could be a helpful maintenance/project performance evaluation device. These meters would also require RTUs.

> *We proposed a recloser device at the point where a row of turbines is connected to the overhead line. The recloser serves as a protective device to detect and open for faults downstream (on the windmill side), as a remote-controlled three-phase switch, and as a point to gather data, such as metering and status (i.e., open or closed). We included an RTU at these points to provide data and control back to the master station.*

GLOSSARY

The following definitions are for a general understanding of the terms used in this report. A technical user should refer to the scientific definitions.

ACSR: Aluminum conductor steel reinforced. This refers to a wire cable used for overhead lines that comprises one or more strands of steel wire surrounded by strands of aluminum wire.

Active Power or Power: The product of voltage and the in-phase component of alternating current. The active power does work and is measured in watts.

Ampere or Amp (A): Unit of current. One volt across one ohm of resistance gives a current flow of one ampere.

Capacitor: A device that stores electrical charge and provides leading VARs in a power circuit. Refer to "Reactive Power" below.

Circuit Breaker: A device designed to open and close an electrical circuit.

Current: The flow of electric charge.

Hertz (Hz): Unit for frequency in cycles per second.

kcmil: Thousand circular mils, used to define the size of a wire.

Kilovolts (kV): 1,000 volts.

Kilowatts (kW): 1,000 watts.

kVA: 1,000 volt-amps.

Load Tap Changer (LTC): A device on a transformer that adjusts the output voltage.

Megawatts (MW): 1,000,000 watts.

MVA: 1,000,000 volt-amps.

Power: Refers to active power.

Ohm: Unit of electrical resistance. One volt across one ohm of resistance gives a current flow of one ampere.

Resistance: Opposition that a conductor or electrical device offers to current flow, measured in ohms.

Transformer: An electrical device with two or more magnetically coupled windings that connects power system elements of different voltages.

Reactive Power: The product of voltage and the out-of-phase component of alternating current. A current wave ahead of or leading the voltage wave provides leading reactive power (or leading VARs). A current wave behind or lagging the voltage wave provides lagging reactive power (or lagging VARs). Line losses are lagging reactive power. A capacitor provides leading reactive power that compensates for the line losses.

RTU: For Remote Terminal Unit. An electronic device that connects to the communication media (fiber optic in this case) and used to communicate data to and from a location.

SCADA: For System Control and Data Acquisition. Equipment used to send data from a remote location to a central location and to communicate control commands from a central location to remote devices.

VAR: Unit of reactive power. Var is Volt-Amp-Reactive.

Volt-Amp (VA): The product of voltage and current, used for rating generators and transformers.

Volt (V): Unit of electromotive force. One volt across one ohm of resistance gives a current flow of one ampere.

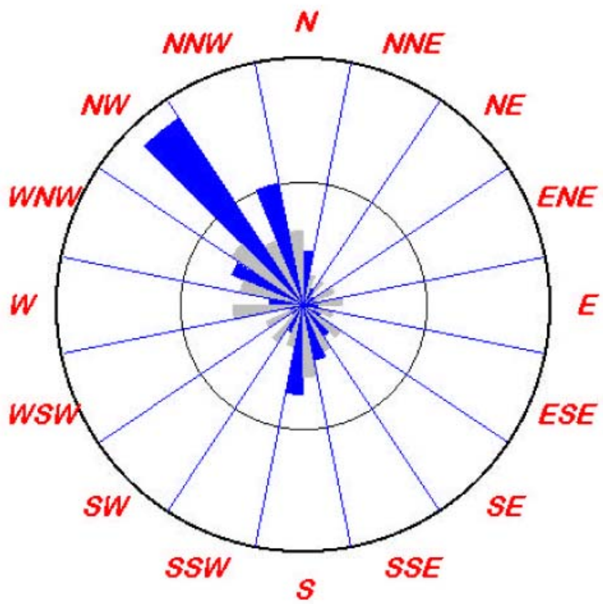
FIGURES

Figure 1
Great Plains Region

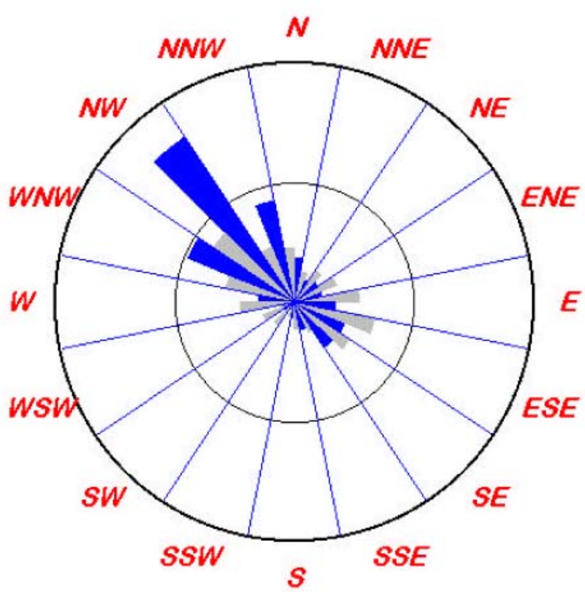
+ Wind Energy Monitoring Site
● City

Figure 2
10-m Wind Rose Graph
1996-97

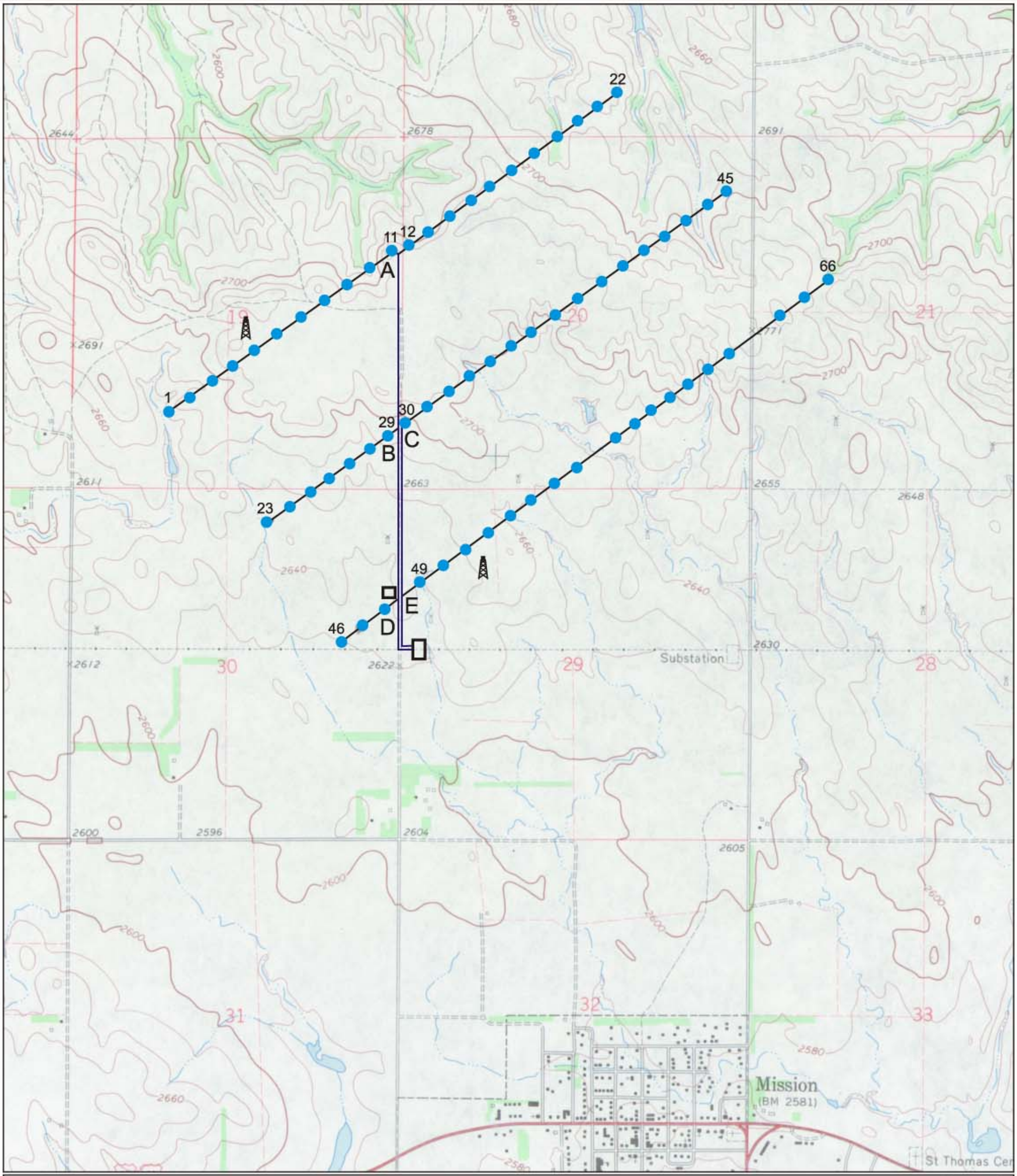
Valentine, Nebraska



Pierre, South Dakota



Percent of Total Wind Energy (Wh/m²):
Percent of Total Time:
Circle Center: 0.0%
Inner Circle: 15.0%
Outer Circle: 30.0%



- Overhead Cable
- Underground Cable
- Turbine Location
- A Riser Location
- Substation
- Meteorological Tower
- Maintenance Building

Basemap: USGS 7.5 Minute Topographic Quadrangle Map - Mission, 1969.

Scale: 1" = 2000'

0 — 1 Mile

0 — 1000 — 2000 Feet

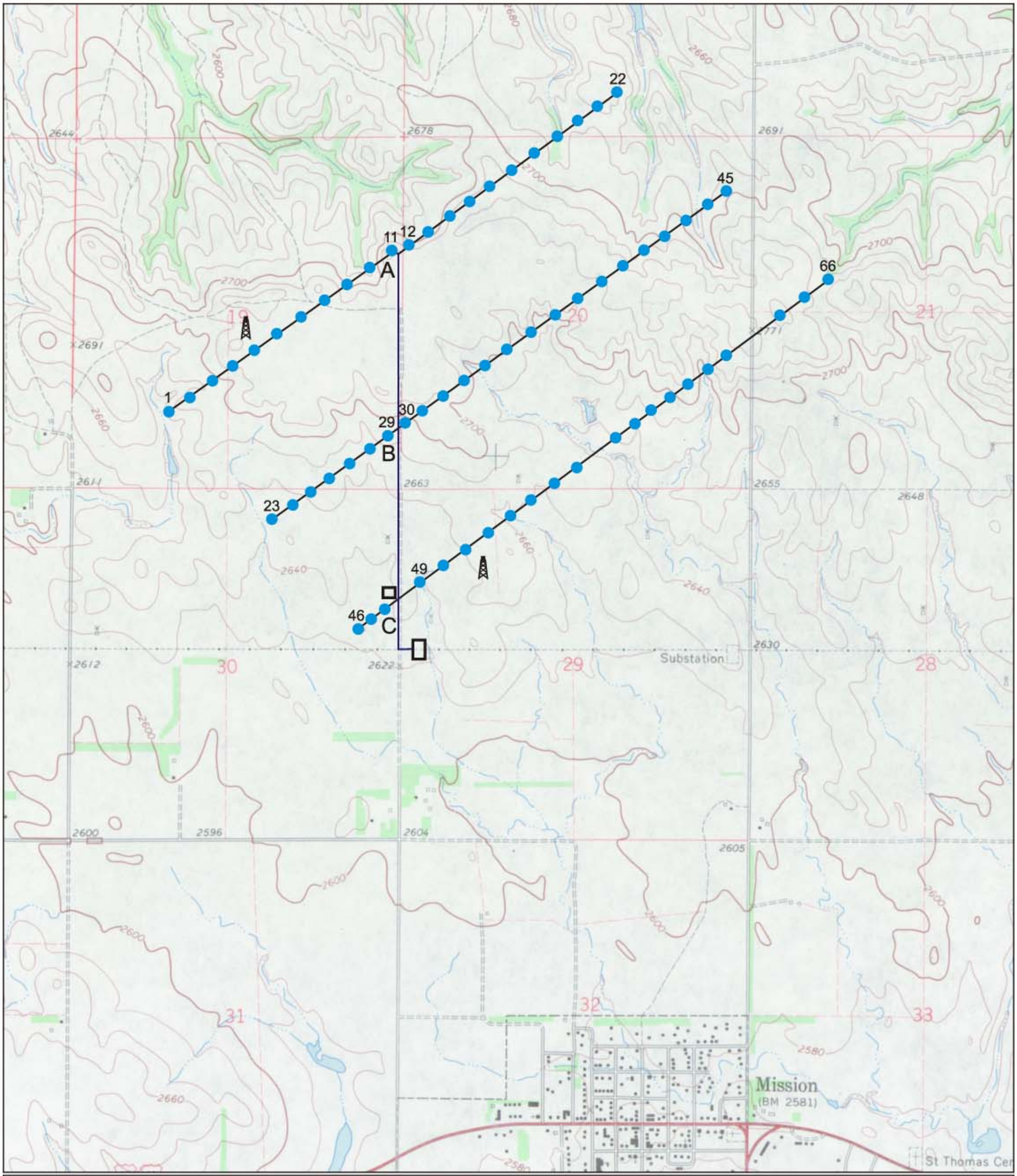
Figure 3

750-kW 15-kV Plan

WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota

February 19, 2001

Prepared by
CAI Commonwealth Associates Inc.
Jackson, Michigan
engineers • consultants • construction managers



Overhead Cable
Underground Cable
Turbine Location
A Riser Location
Substation
Meteorological Tower
Maintenance Building

Basemap: USGS 7.5 Minute Topographic Quadrangle Map - Mission, 1969.

N W E S

South Dakota
Map Area

Scale: 1" = 2000'
0 1 Mile
0 1000 2000 Feet

Figure 4

750-kW 25-kV Plan

WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota

February 19, 2001

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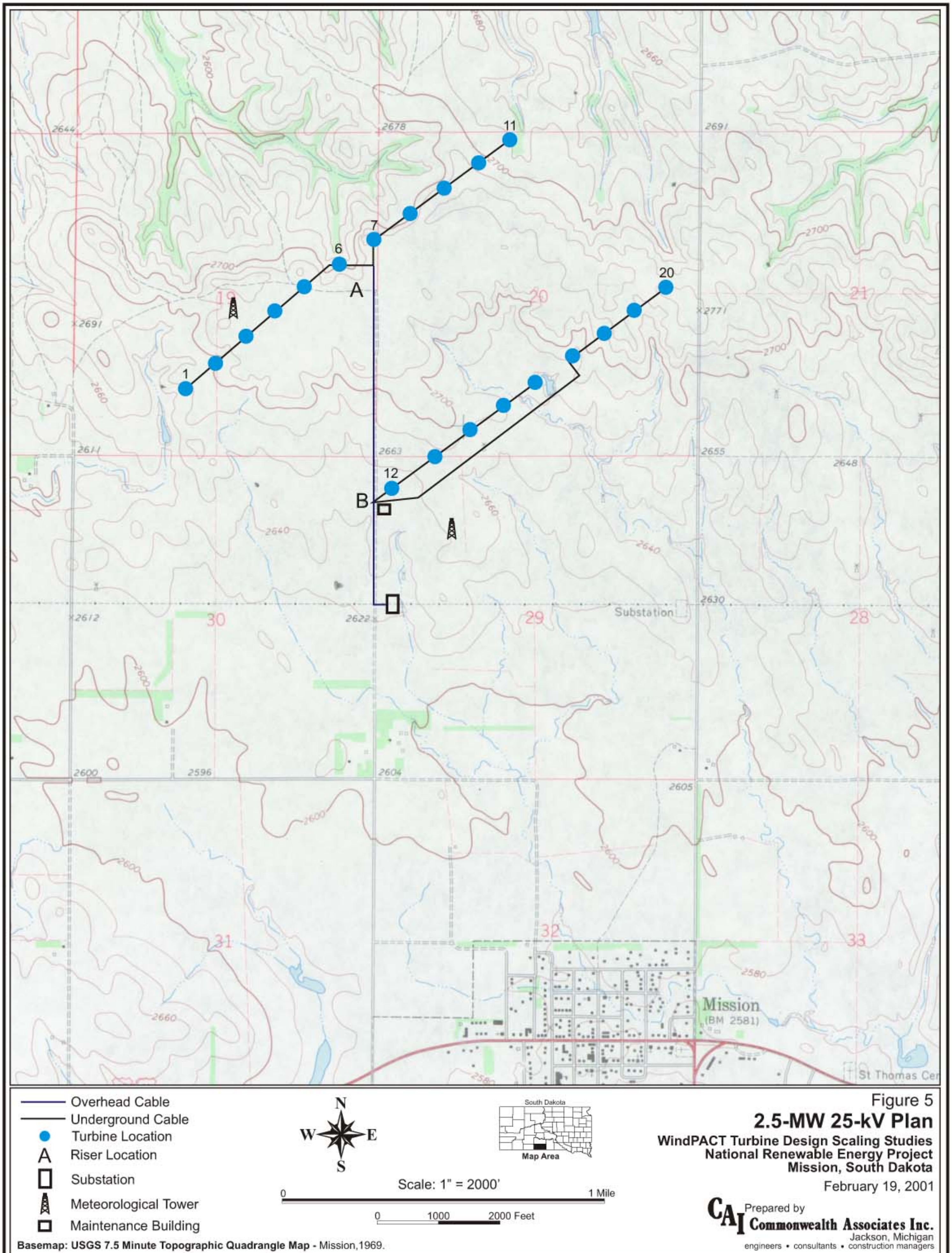
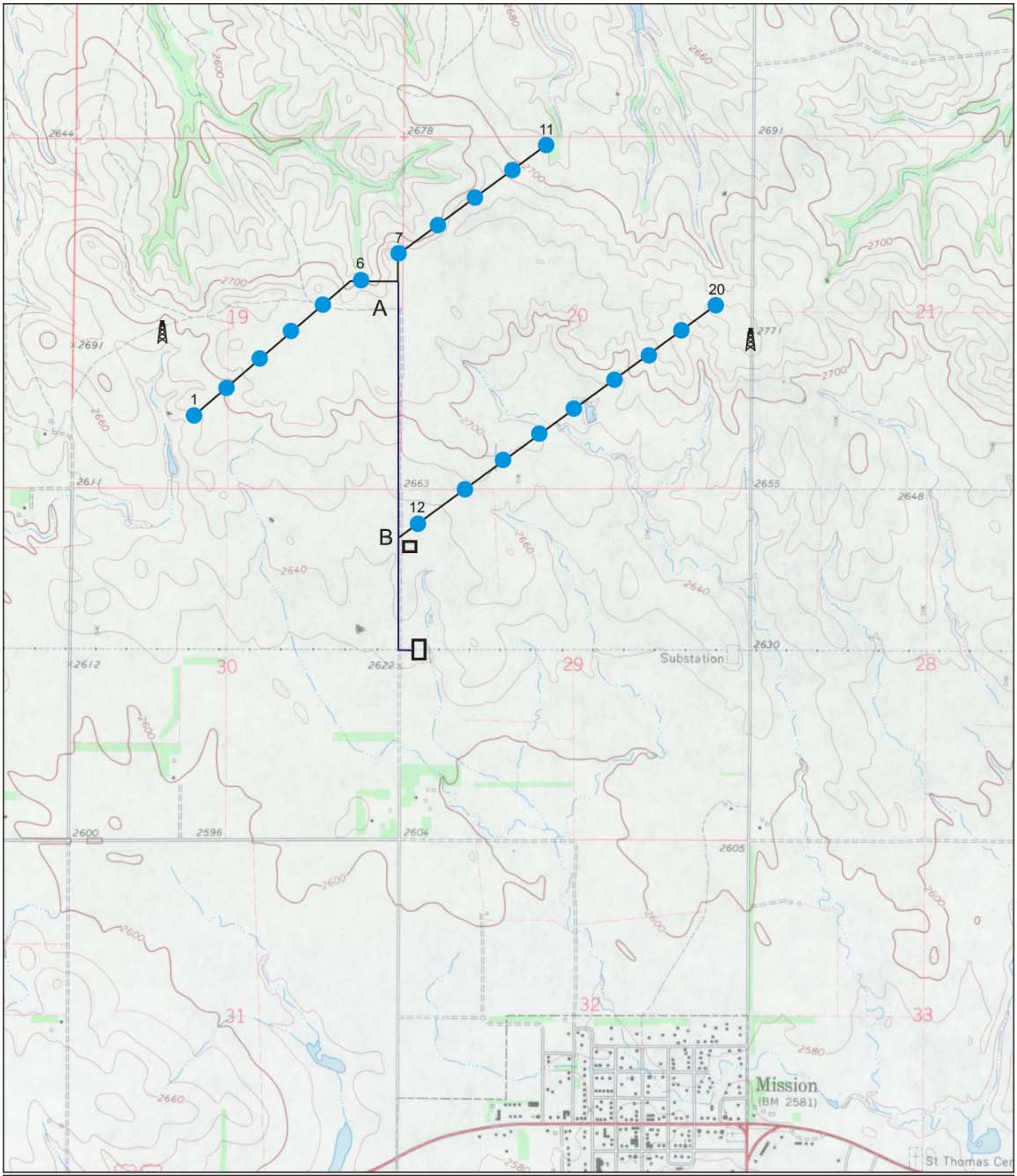


Overhead Cable
Underground Cable
Turbine Location
Riser Location
Substation
Meteorological Tower
Maintenance Building
Scale: 1" = 2000'
0
1 Mile
0
1000
2000 Feet
South Dakota
Map Area
Figure 5
2.5-MW 25-kV Plan
WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota
February 19, 2001
Prepared by
Commonwealth Associates Inc.
Jackson, Michigan
engineers • consultants • construction managers
Basemap: USGS 7.5 Minute Topographic Quadrangle Map - Mission, 1969.



Overhead Cable
Underground Cable
Turbine Location
Riser Location
Substation
Meteorological Tower
Maintenance Building

Scale: 1" = 2000'
0 — 1 Mile
0 1000 2000 Feet

South Dakota
Map Area

Figure 6
2.5-MW 35-kV Plan
WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota
February 19, 2001

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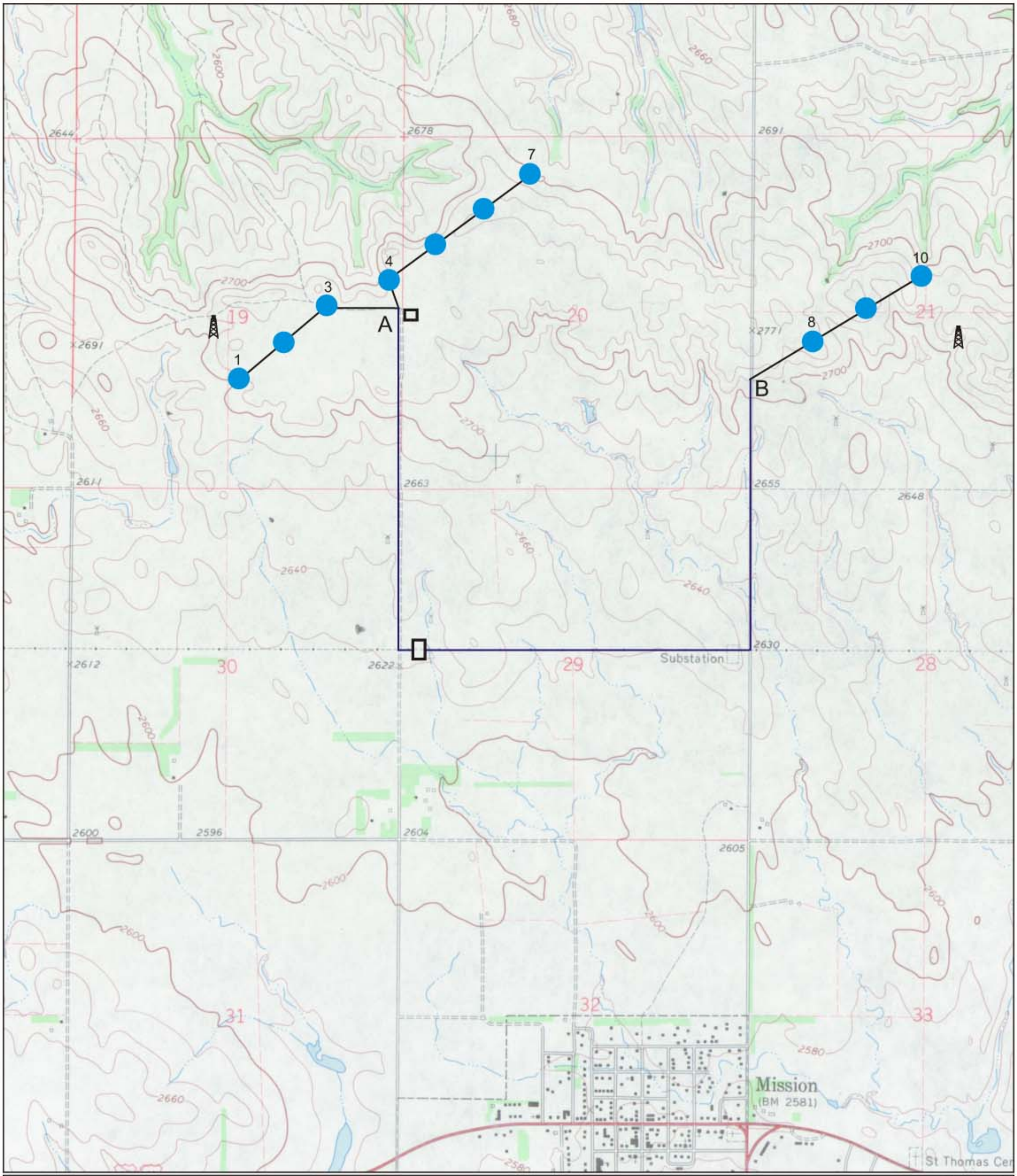

Figure 7
5-MW 25/35-kV Plan
WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota
February 19, 2001

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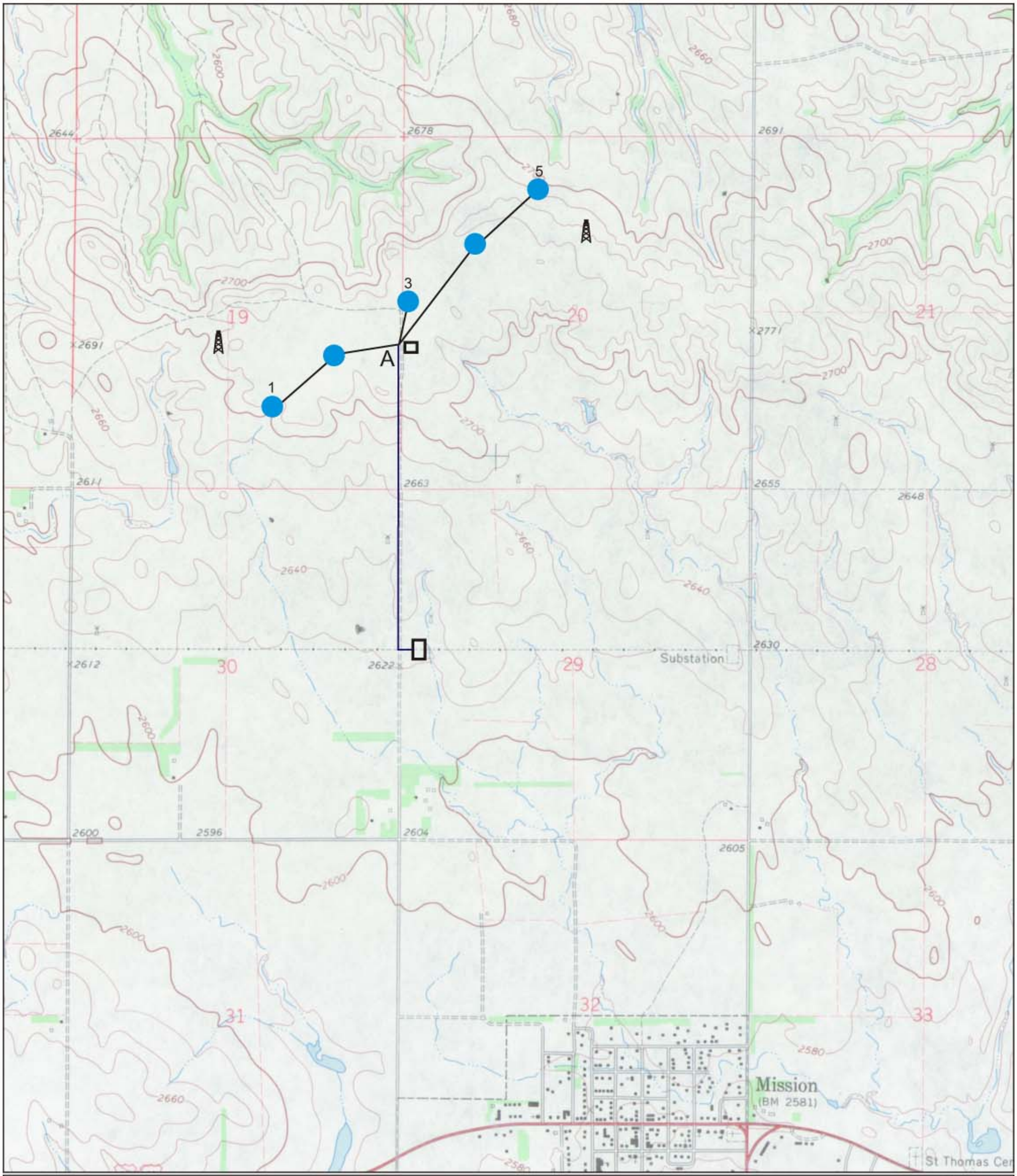
Basemap: USGS 7.5 Minute Topographic Quadrangle Map - Mission,1969.



Overhead Cable
Underground Cable
Turbine Location
A Riser Location
Substation
Meteorological Tower
Maintenance Building

N W E S

Scale: 1" = 2000'

0 1 Mile

0 1000 2000 Feet

South Dakota Map Area

Figure 8
10-MW 25/35-kV Plan
WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota
February 19, 2001

Prepared by
Commonwealth Associates Inc.
Jackson, Michigan
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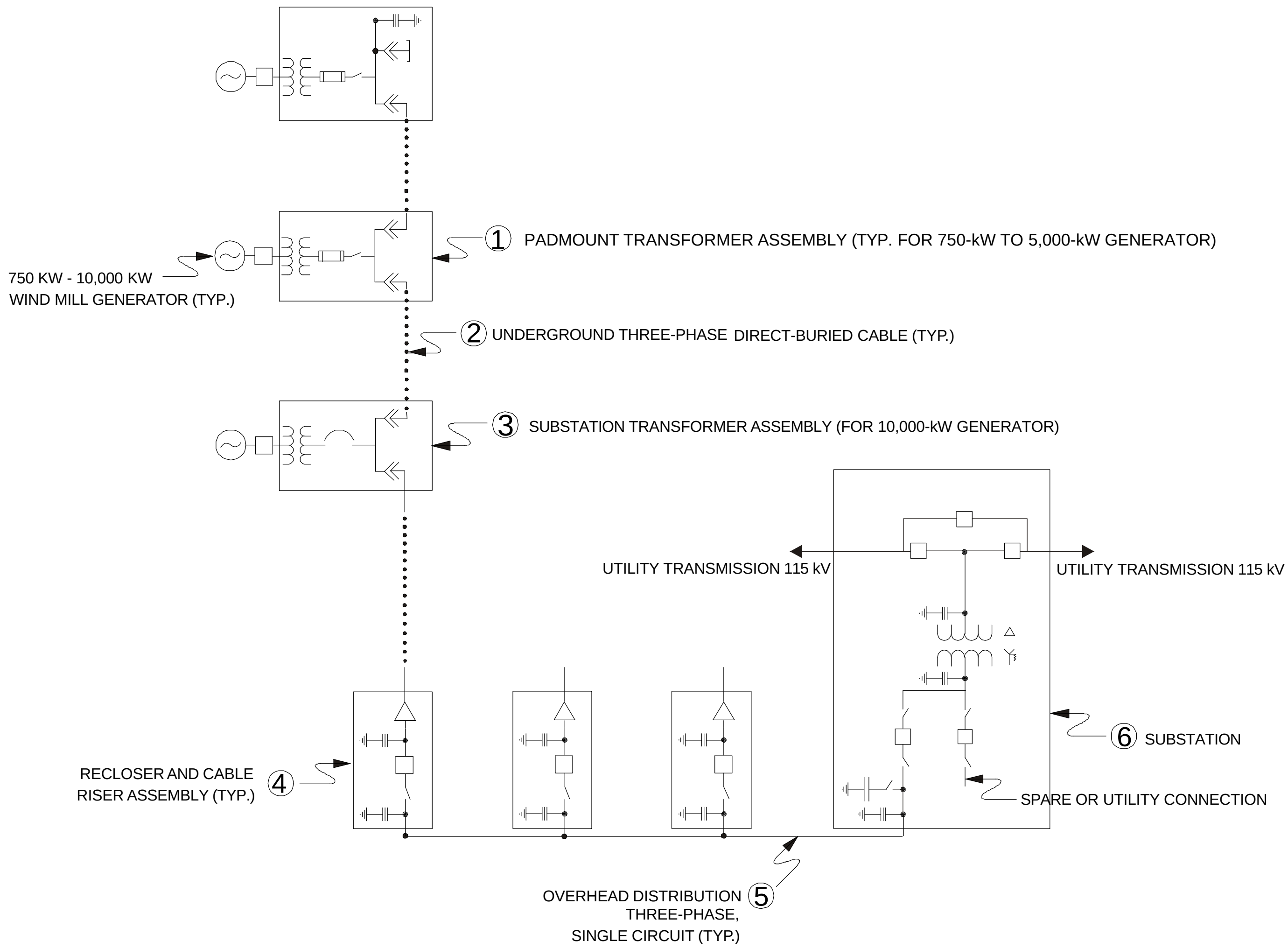
Basemap: USGS 7.5 Minute Topographic Quadrangle Map - Mission,1969.



Symbol Key

Symbol	Meaning
—◁—	Pothead
—⌒—	Circuit Breaker
—□—	Circuit Breaker
—▭—	Fuse
⊣⊢•	Surge Arrestor
(~)	Generator
∃∈	Transformer
≪	Disconnect Device
⊣⊢/	Capacitor
·········	Underground Cable

WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota

FIGURE 9

COLLECTOR SYSTEM

ONE-LINE DIAGRAM

CAI Prepared by Commonwealth Associates Inc. Jackson, Michigan engineers • consultants • construction managers	DATE 02/19/01	PROJECTNUMBER 228001
	BY RMC	PROJECTMANAGER DA SHAFER
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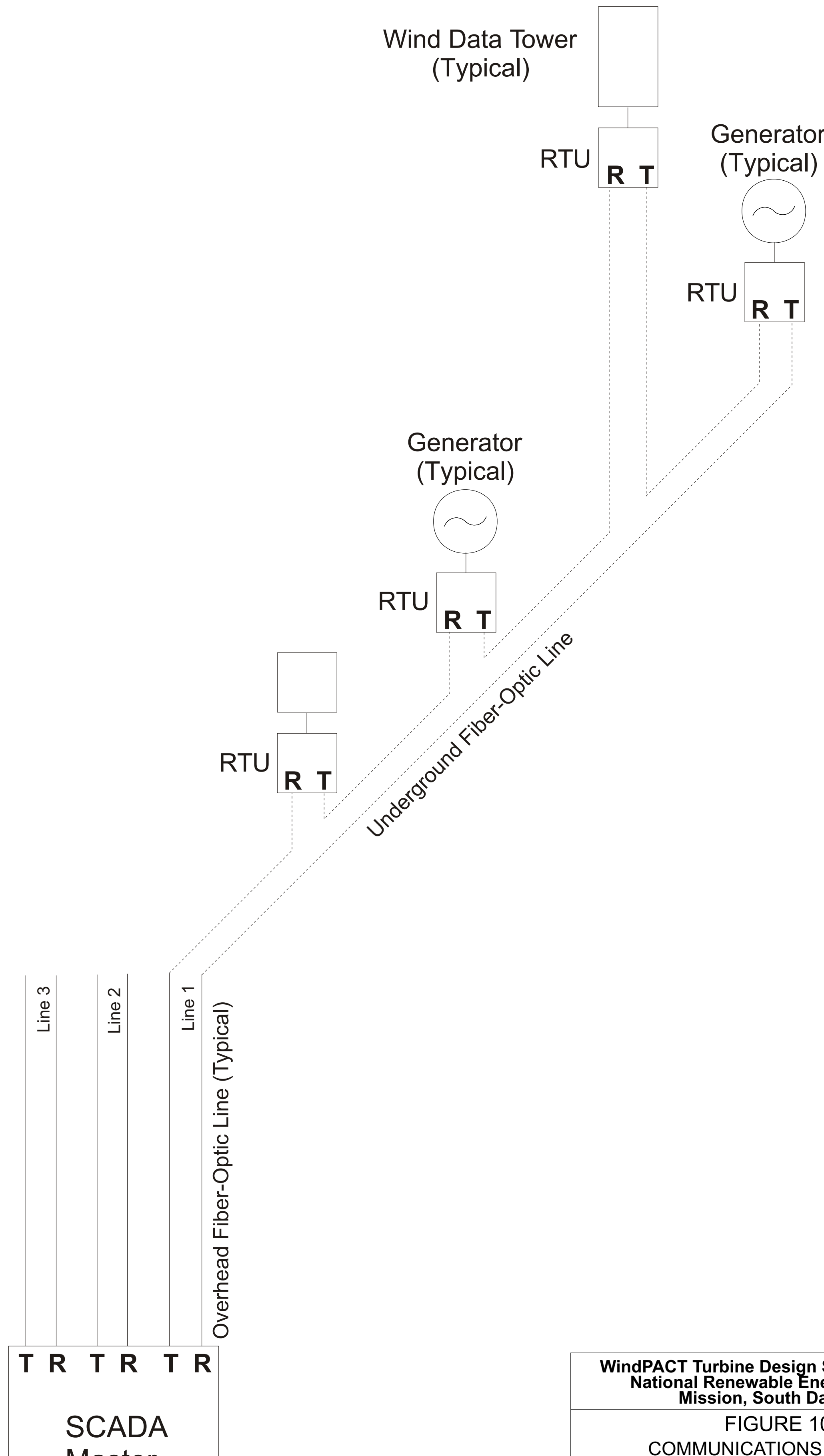

WindPACT Turbine Design Scaling Studies
National Renewable Energy Project
Mission, South Dakota

FIGURE 10
COMMUNICATIONS SYSTEM
ONE-LINE DIAGRAM

CAI Prepared by Commonwealth Associates Inc.
Jackson, Michigan
engineers • consultants • construction managers

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RMC	DA SHAFER

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Figure 11
Relative Foundation Geometry

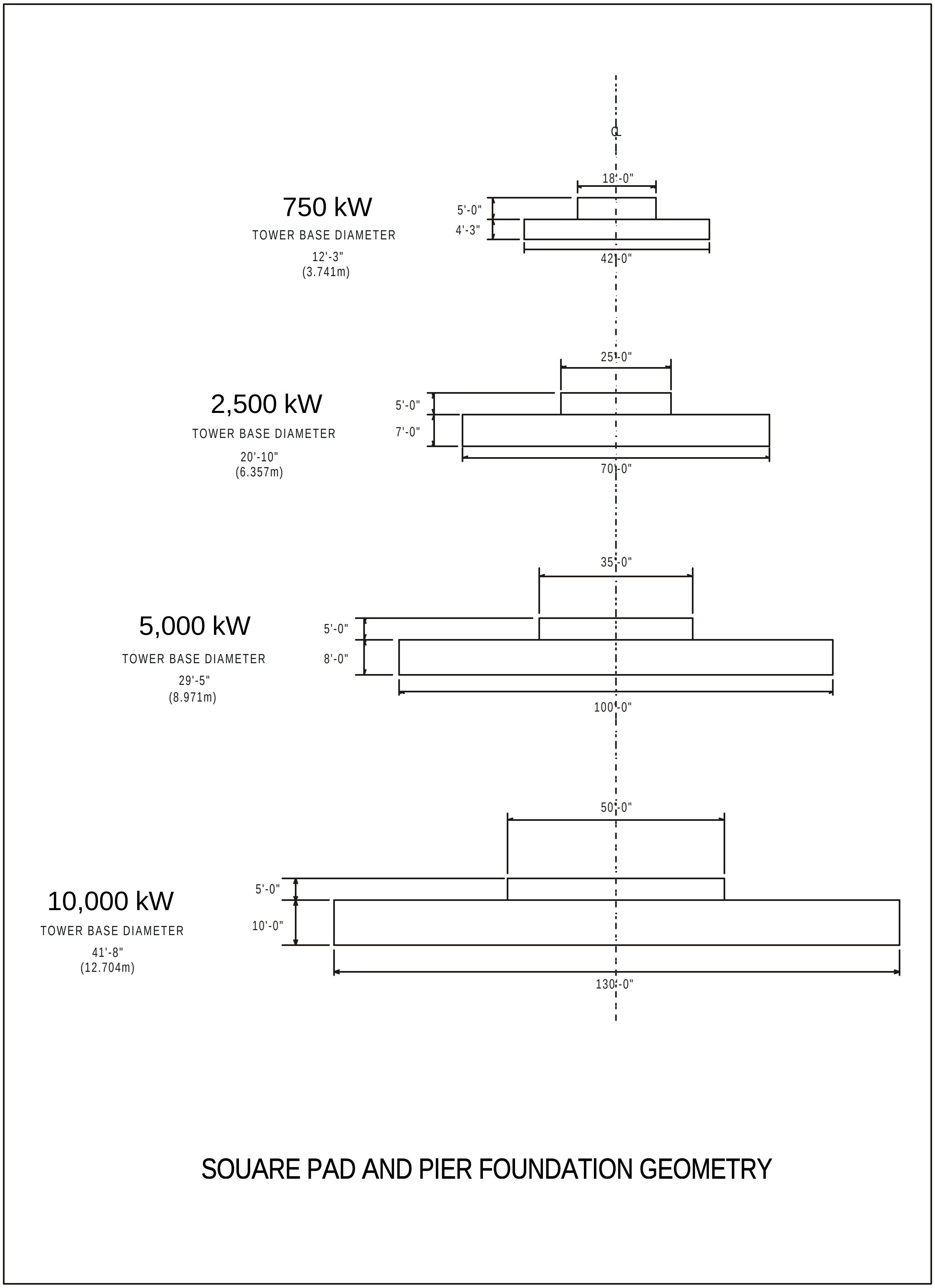


Figure 12
Windmill Size and Foundation Comparison

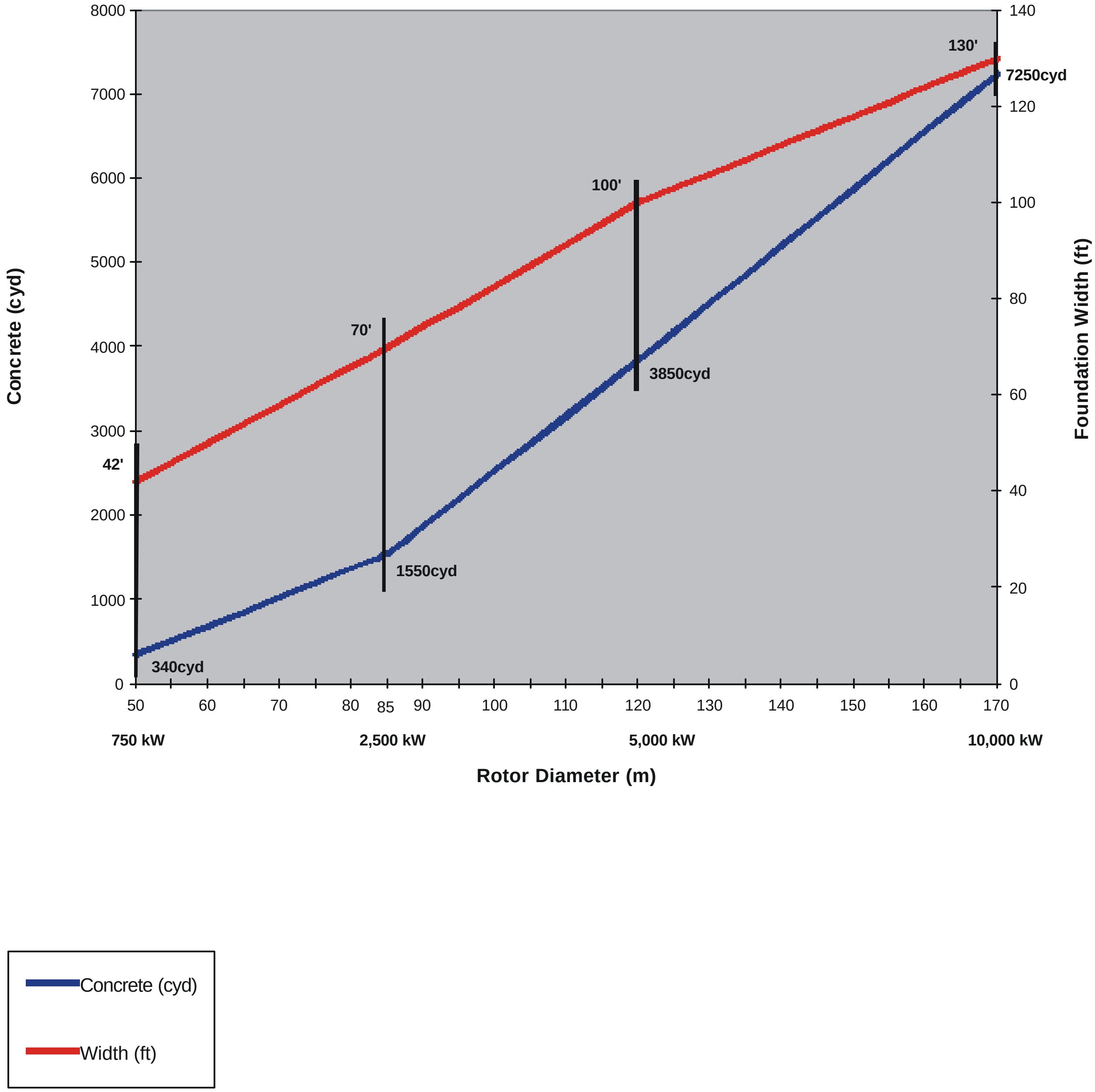


Figure 13
Foundation Cost

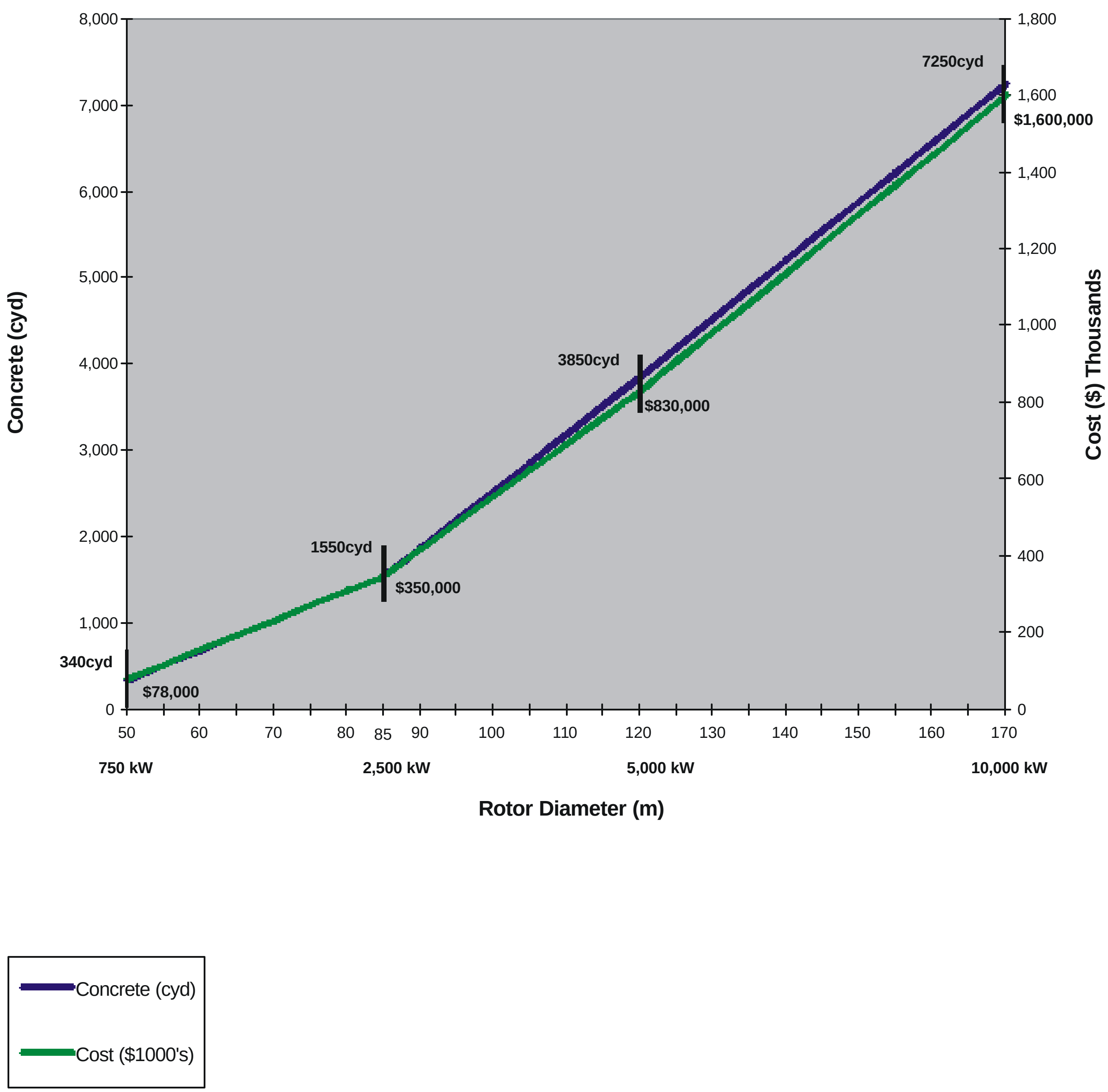


Figure 14
Rock Foundation

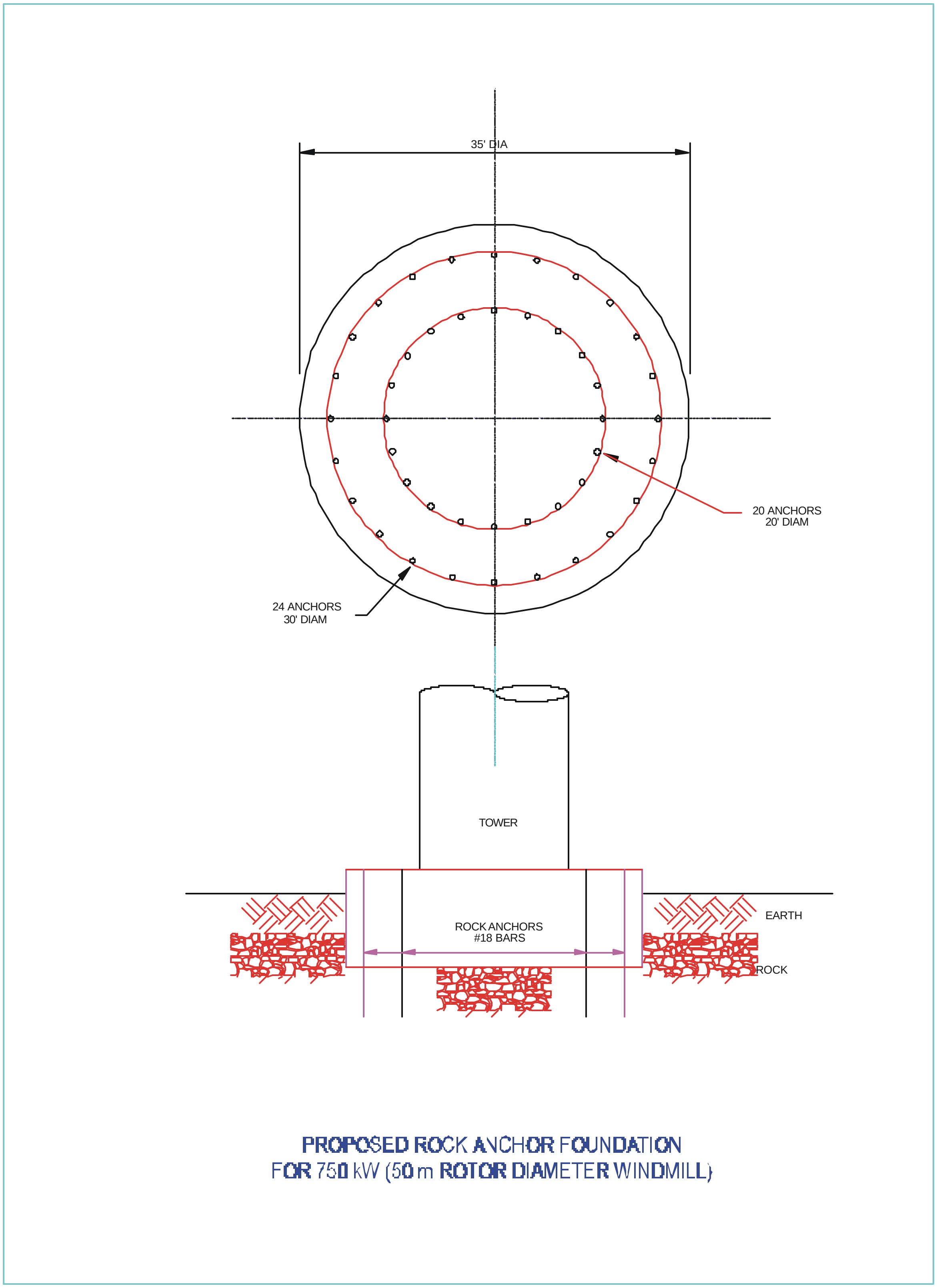
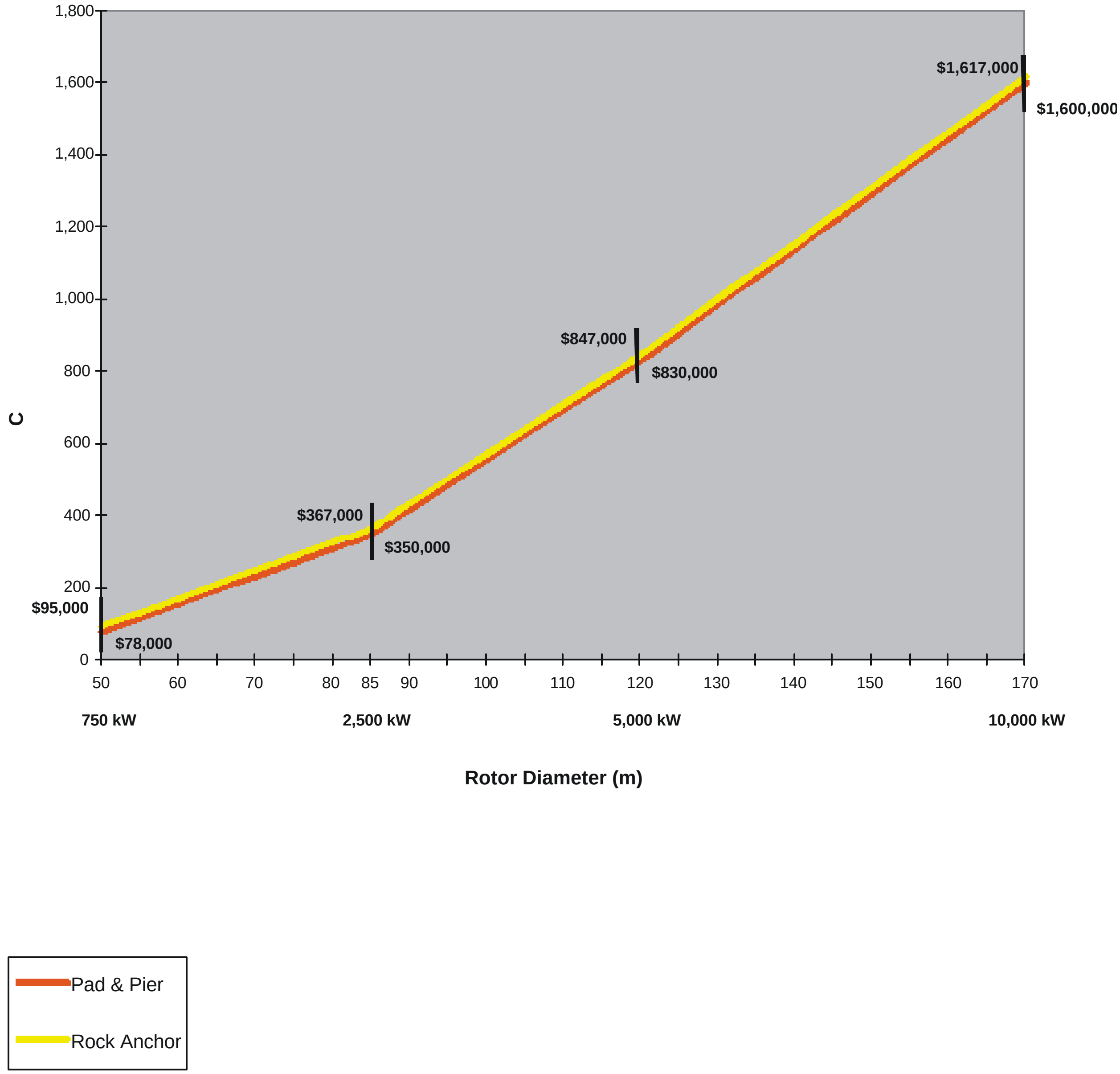


Figure 15
Cost Comparison: Pad and Pier vs. Rock Anchor



APPENDIX A
ENGINEERING ASSUMPTIONS AND DATA

APPENDIX A
ENGINEERING ASSUMPTIONS
AND DATA

WIND TURBINE PARAMETERS AND ASSUMPTIONS

Table A1 shows the parameters and assumptions used in this study to model the wind turbines.

TRANSFORMER ASSUMPTIONS

Table A2 provides the parameters for the generator step-up transformers. Assumptions are listed below:

1. Standard three-phase padmount transformers were used for the 750-kW (1,000 kVA, 480V), 2,500-kW (3,000 kVA, 690V), and 5,000-kW (7,500 kVA, 2,400V) plans. For this study, we assumed grounded-wye low-side and delta high-side connections. The primary (13.8 kV, 24.9 kV, or 34.5 kV) would be dead front design. The manufacturer provides a "loop" design, which allows the primary cable to be "looped" from one transformer to the next, as we are proposing. We have also included a high-voltage switch that would allow one wind turbine to be disconnected while still keeping all others in the string in service. The transformer would be protected by the manufacturer's standard fusing arrangement.

2. The manufacturers standardize on two sizes of transformer and cable terminations: 200 amps and 600 amps. For this study, we assumed that we would purchase identical transformers with the high-side connections and cable terminations rated for 600 amps.

3. Since 7,500 kVA is the largest standard padmount transformer capacity, a 10/12.5-MVA substation transformer (grounded-wye low-side, delta high-side, 4,160 V) was used for the 10,000 kW plan. While not considered a dead front design, cabinets can be installed on this transformer to cover otherwise exposed electrical connections and to allow both low- and high-side connections to be fed underground. To protect the transformer, pad-mounted switchgear with a vacuum interrupter (circuit breaker) was connected to the high side. This will allow the primary cable to be "looped" from one transformer to the next where necessary.

CABLE ASSUMPTIONS

Parameters for the underground cables are provided in Table A3. Assumptions are listed below:

1. We assumed all underground collector lines were constructed using standard 1/0, 4/0, 500-kcmil, or 750-kcmil aluminum underground cables. Three individual cables were used to create the three-phase circuit rather than a manufactured single three-conductor cable. The advantages of using three separate conductors are lower cost and longer runs

between splices. A single three-phase 1/0 aluminum cable is rated approximately 216 amps. At 13.8 kV, each 750-kW wind turbine produces 32.3 amps. Thus, six wind turbines can be carried on a 1/0 cable before exceeding its 216-amp rating. Similarly, nine turbines can be carried on 4/0 cable, 15 on 500-kcmil cable, and up to 18 on 750-kcmil aluminum cable. Table A3.1 summarizes cable ampacities.

2. Where the rating of 1/0 aluminum conductor would have been exceeded, larger conductor was used. An alternative would have been to parallel two or more sets of 1/0 cable. For this analysis, the choice was to use multiple conductor sizes in an attempt to optimize the cable size based on costs and losses.

OVERHEAD LINE ASSUMPTIONS

Table A3.5 provides parameters for the overhead cables. Assumptions are listed below:

1. The overhead line is assumed to be conventional utility distribution design using wood poles and cross arms. At 13.8 kV, 50 MW translates to approximately 2,091 amps. This is more than is typically served by a single 13.8-kV feeder. One standard equipment size is 1,200 amps. Therefore, we assumed that a 13.8-kV design would require two main collector lines and substation feeder breakers. We assumed that both circuits would be constructed on a single pole. At 24.9 kV, 50 MW translates to approximately 1,159 amps. Therefore, 24.9- and 34.5-kV designs require only single-circuit overhead construction.

2. For six of the eight plans, we chose 795 kcmil ACSR conductors for the overhead line. This conductor is nominally rated for 907 amps. However, this rating is based on high ambient temperatures and calm conditions. Since we are expecting to hit peak generating capabilities during windy conditions, we expect that 795 ACSR will be suitable. Similar to our selection for underground cable, we attempted to optimize the conductor size for overhead installation. For the 5,000-kW layout, two overhead lines are needed because the wind turbines are placed in two separate groups. For this layout, 795-kcmil ACSR was used for the 24.9-kV plan, and 4/0 ACSR was used for the 34.5-kV plan.

3. Our cost estimates are based on installing a neutral on top of the pole. This wire serves a dual purpose as a neutral and shield wire. The purpose of a shield wire is to provide lightning protection to the circuit. A neutral is needed for connecting line-to-neutral single-phase transformers. Because the windmills are three-phase, we could design the collector line without a neutral. However, we have provided a neutral, as this is common practice and could be used by the utility for serving single-phase loads.

SUBSTATION ASSUMPTIONS

1. For this study, we used a packaged 30/40/50-MVA substation, a Power Delivery System (PDS), that is manufactured by Waukesha Electric Systems. The packaged substation includes a 115/13.8-kV transformer and three 13.8-kV and two 24.9- or 34.5-kV feeder circuit breakers. The PDS includes all of the above assembled, factory-tested, and

shipped to the customer's site. The customer provides a foundation, grounding, oil containment, and fencing, and connects the 115-kV and low-side feeders to complete the substation.

2. We assumed a three-breaker 115-kV ring bus would be used to connect to the existing 115-kV line.

Table A1

WindPACT Turbine Design Scaling Study

Turbine Parameters and Assumptions

Plant Size kW	Rotor Diameter	Min. Distance[1] Between Turbines	Min. Distance[1] Between Rows	Machine Base[2] kVA	Machine Base[2] kV	SC Model X"d	Total[3] Turbines
750	50m (164 ft)	115m (378 ft)	600m (1969 ft)	833	0.48	0.107	66
2500	85m (279 ft)	196m (642 ft)	1020m (3347 ft)	2,778	0.69	0.107	25
5000	120m (394 ft)	276m (906 ft)	1440m (4725 ft)	5,556	2.40	0.107	10
10000	170m (558 ft)	391m (1283 ft)	2040m (6693 ft)	11,111	4.16	0.107	5

Plant Size kW	Total Mass[4]	Total Overturning Moment	Tower Base Diameter	Hub Height	Meteorological Tower Height	Meteorological Tower Qty
750	104,927 kg	38,718 kN-m	3.7 m	65 m	54 m	2
2500	466,061 kg	190,185 kN-m	6.4 m	111 m	92 m	2
5000	1,237,715 kg	535,070 kN-m	9.0 m	156 m	130 m	2
10000	3,338,895 kg	1,521,106 kN-m	12.7 m	221 m	184 m	2

Plant Size kW	Crane Pad(s) Size	Maintenance Building Size	Option 2 Access Road Width	Communications
750	243 m^2	40' W x 60' L x 16' H	8 m (26 ft)	One RTU / Recloser,
2500	1000 m^2	40' W x 60' L x 16' H	8 m (26 ft)	Meteorological Tower,
5000	2400 m^2	40' W x 60' L x 16' H	10 m (32 ft)	and Turbine for all
10000	4000 m^2	40' W x 60' L x 16' H	10 m (32 ft)	four Plant Sizes

NOTES:

1. Based on a turbine spacing of 2.3 rotor diameters by a row spacing of 12 rotor diameters.
2 Assumed rated power factor of 90%.
3. Number of Turbines needed for 50MW.
4. Corrected values from those presented at the November 2 & 3 workshop.

Table A2

WindPACT Turbine Design Scaling Studies
Three-Phase Transformer Data
Estimated Values

Pad-mount Transformers

Gen. Rating kW	kVA[1]	Voltage kV	Z%	X/R	Fluid Gal.	Approx. Weight lbs.	Pad Dimensions[2] X	Y
750	1000	0.48/13.8	5.75	9	480	10100	93	63
750	1000	0.48/24.9	5.75	9	480	10100	93	63
2500	3000	0.69/13.8	5.5	9	760	18850	76	103
2500	3000	0.69/24.9	5.5	9	760	18850	76	103
2500	3000	0.69/34.5	7.0	9	760	18850	76	103
5000	7500	2.40/24.9	6.50	9	1580	41900	100	126
5000	7500	2.40/34.5	6.50	9	1580	41900	100	126
Substation Transformers								
10000	12500	4.16/24.9	6.50	9	1600	46500	157	153
10000	12500	4.16/34.5	7.00	9	1600	46500	157	153

NOTES

1. OA Self-cooled rated, 65° C temperature rise.
2. Pad Dimensions measured in inches.

Table A3.1

WindPACT Turbine Design Scaling Studies

Estimated Cable Size for Radially Connected Wind Turbines

Cable Rating	Plant Size (kW)	Collector Line Voltage (kV)	Amps[1] Per Turbine	Turbines per Cable Type[2] 1/0 Al 216	4/0 Al 318	500 Al 502	750 Al 604	1000 Al 716	Total[3] Turbines Needed
	750	13.8	32.3	6	9	15	18	22	66
	750	24.9	17.9	12	17	28	-	-	66
	2500	13.8	107.8	2	2	4	-	-	20
	2500	24.9	59.8	3	5	8	-	-	20
	2500	34.5	43.1	5	7	11	-	-	20
	5000	24.9	119.5	1	2	4	-	-	10
	5000	34.5	86.3	2	3	5	-	-	10
	10000	24.9	239.0	-	1	2	-	-	5
	10000	34.5	172.5	1	1	2	-	-	5
	10000	46.0	129.4	1	2	3	-	-	5

NOTES

1. The amps per turbine is based on a net turbine power factor of 97%.
2. The number of turbines radially connected based on cable capacity. The cable rating is based on a load factor rating of 75%.
3. The number of wind turbines needed to produce 50 MW.

Table A3.2

WindPACT Turbine Design Scaling Studies

Typical 15 kV Underground Primary Distribution Cable
Three 1/C Aluminum Conductor
One-Third Copper Concentric Neutral with Jacket
220 Mil Insulation (133%)

Size (AWG/ kcmil)	No. Of Str.	Overall Cable O.D. (Inches)	Cable Weight (Lbs/Kft)	Capacitance (pf/ft.)	Amps per Circuit Direct Buried		Cable Impedance Data (ohms/1,000 ft.)	
					1 Circuit	2 Circuit	Positive/Negative	Zero Sequence
1/0	19	1.19	661	66	216	189	0.212 + j 0.048	0.543 + j 0.237
4/0	19	1.34	933	84	318	276	0.107 + j 0.043	0.335 + j 0.105
500	37	1.74	1742	115	502	428	0.048 + j 0.037	0.159 + j 0.037
750	61	1.98	2380	136	604	510	0.034 + j 0.035	0.106 + j 0.025
1000	61	2.16	2983	152	716	600	0.028 + j 0.033	0.081 + j 0.021

NOTES

1. All values from IEEE Std 835-1994, IEEE Standard Power Cable Ampacity Tables.
2. Conductor Temperature: 90° C
3. Insulation: EPR
4. Installation: Direct buried, triplexed cable
5. Load Factor: 75%
6. Earth Temperature: 25° C
7. Earth Thermal Resistivity: 90 Rho

Table A3.3
WindPACT Turbine Design Scaling Studies

Typical 25 kV Underground Primary Distribution Cable
Three 1/C Aluminum Conductor
One-Third Copper Concentric Neutral with Jacket
320 Mil Insulation (133%)

Size (AWG/ kcmil)	No. Of Str.	Overall Cable O.D. (Inches)	Cable Weight (Lbs/Kft)	Capacitance (pf/ft.)	Amps per Circuit Direct Buried		Cable Impedance Data (ohms/1,000 ft.)	
					1 Circuit	2 Circuit	Positive/Negative	Zero Sequence
1/0	19	1.42	906	52	212	185	0.212 + j 0.051	0.549 + j 0.263
4/0	19	1.57	1200	64	312	269	0.107 + j 0.046	0.334 + j 0.110
500	37	1.93	2025	86	490	416	0.048 + j 0.040	0.158 + j 0.040
750	61	2.20	2722	101	596	500	0.034 + j 0.037	0.106 + j 0.028
1000	61	2.35	3265	112	704	586	0.028 + j 0.035	0.081 + j 0.024

NOTES

1. All values from IEEE Std 835-1994, IEEE Standard Power Cable Ampacity Tables.
2. Conductor Temperature: 90° C
3. Insulation: EPR
4. Installation: Direct buried, triplexed cable
5. Load Factor: 75%
6. Earth Temperature: 25° C
7. Earth Thermal Resistivity: 90 Rho

Table A3.4
WindPACT Turbine Design Scaling Studies

Typical 35 kV Underground Primary Distribution Cable
Three 1/C Aluminum Conductor
One-Third Copper Concentric Neutral with Jacket
420 Mil Insulation (133%)

Size (AWG/ kcmil)	No. Of Str.	Overall Cable O.D. (Inches)	Cable Weight (Lbs/Kft)	Capacitance (pf/ft.)	Amps per Circuit Direct Buried		Cable Impedance Data (ohms/1,000 ft.)	
					1 Circuit	2 Circuit	Positive/Negative	Zero Sequence
1/0	19	1.65	1169	37	212	185	0.212 + j 0.055	0.545 + j 0.267
4/0	19	1.82	1564	45	312	269	0.107 + j 0.049	0.333 + j 0.113
500	37	2.18	2446	60	490	416	0.047 + j 0.042	0.158 + j 0.044
750	61	2.41	3126	69	596	500	0.034 + j 0.039	0.106 + j 0.031
1000	61	2.56	3696	77	704	586	0.028 + j 0.037	0.080 + j 0.026

NOTES

1. All values from IEEE Std 835-1994, IEEE Standard Power Cable Ampacity Tables.
2. Conductor Temperature: 90° C
3. Insulation: EPR
4. Installation: Direct buried, triplexed cable
5. Load Factor: 75%
6. Earth Temperature: 25° C
7. Earth Thermal Resistivity: 90 Rho

Table A3.5
WindPACT Turbine Design Scaling Studies

Overhead Distribution Cable

Cable Type	Voltage kV	Capacitance (pf/ft.)	Amps per Circuit	Cable Impedance Data (ohms/1,000 ft.)	
				Positive/Negative	Zero Sequence
795 ACSR Drake / Single Circuit	13.8	3.59	907	0.02420 + j 0.11347	0.0795 + j 0.5552
795 ACSR Drake / Double Circuit	13.8	3.86	907	0.02420 + j 0.10564	0.0795 + j 0.3714
795 ACSR Drake / Single Circuit	24.9	3.59	907	0.02061 + j 0.09663	0.0795 + j 0.5552
4/0 ACSR Penguin / Single Circuit	24.9	3.14	360	0.09242 + j 0.12147	0.1650 + j 0.5850
477 ACSR Pelican / Single Circuit	34.5	3.37	646	0.04055 + j 0.12142	0.0960 + j 0.5630
2/0 ACSR Quail / Single Circuit	34.5	3.01	276	0.15966 + j 0.14964	0.2170 + j 0.5920

APPENDIX B
SYSTEM MODELING DATA

Table B1.1
Bus Description and Generator Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage = 13.8

			Power Flow Model							
		Base	**Pgen**	**Qmax**	**Qmin**		**Bus Type**		**SC Model**	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_13.8	13.8					Load	0		
10	Riser_A	13.8					Load	0		
15	Riser_B	13.8					Load	0		
20	Riser_C	13.8					Load	0		
25	Riser_D	13.8					Load	0		
30	Riser_E	13.8					Load	0		
101	Wind_01	13.8					Load	0		
102	Wind_02	13.8					Load	0		
103	Wind_03	13.8					Load	0		
104	Wind_04	13.8					Load	0		
105	Wind_05	13.8					Load	0		
106	Wind_06	13.8					Load	0		
107	Wind_07	13.8					Load	0		
108	Wind_08	13.8					Load	0		
109	Wind_09	13.8					Load	0		
110	Wind_10	13.8					Load	0		
111	Wind_11	13.8					Load	0		
112	Wind_12	13.8					Load	0		
113	Wind_13	13.8					Load	0		
114	Wind_14	13.8					Load	0		
115	Wind_15	13.8					Load	0		
116	Wind_16	13.8					Load	0		
117	Wind_17	13.8					Load	0		
118	Wind_18	13.8					Load	0		
119	Wind_19	13.8					Load	0		
120	Wind_20	13.8					Load	0		
121	Wind_21	13.8					Load	0		

Table B1.1
Bus Description and Generator Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			13.8		Power Flow Model			
		Base	Pgen	Qmax	Qmin		Bus Type	
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT
122	Wind_22	13.8					Load	0
123	Wind_23	13.8					Load	0
124	Wind_24	13.8					Load	0
125	Wind_25	13.8					Load	0
126	Wind_26	13.8					Load	0
127	Wind_27	13.8					Load	0
128	Wind_28	13.8					Load	0
129	Wind_29	13.8					Load	0
130	Wind_30	13.8					Load	0
131	Wind_31	13.8					Load	0
132	Wind_32	13.8					Load	0
133	Wind_33	13.8					Load	0
134	Wind_34	13.8					Load	0
135	Wind_35	13.8					Load	0
136	Wind_36	13.8					Load	0
137	Wind_37	13.8					Load	0
138	Wind_38	13.8					Load	0
139	Wind_39	13.8					Load	0
140	Wind_40	13.8					Load	0
141	Wind_41	13.8					Load	0
142	Wind_42	13.8					Load	0
143	Wind_43	13.8					Load	0
144	Wind_44	13.8					Load	0
145	Wind_45	13.8					Load	0
146	Wind_46	13.8					Load	0
147	Wind_47	13.8					Load	0
148	Wind_48	13.8					Load	0
149	Wind_49	13.8					Load	0

Table B1.1
Bus Description and Generator Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage = 13.8 **Power Flow Model**

Bus No.	Name	Base kV	Pgen MW	Qmax MVAR	Qmin MVAR	Vhold	Bus Type BType	BT
150	Wind_50	13.8					Load	0
151	Wind_51	13.8					Load	0
152	Wind_52	13.8					Load	0
153	Wind_53	13.8					Load	0
154	Wind_54	13.8					Load	0
155	Wind_55	13.8					Load	0
156	Wind_56	13.8					Load	0
157	Wind_57	13.8					Load	0
158	Wind_58	13.8					Load	0
159	Wind_59	13.8					Load	0
160	Wind_60	13.8					Load	0
161	Wind_61	13.8					Load	0
162	Wind_62	13.8					Load	0
163	Wind_63	13.8					Load	0
164	Wind_64	13.8					Load	0
165	Wind_65	13.8					Load	0
166	Wind_66	13.8					Load	0

Table B1.1
Bus Description and Generator Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

			System Base =	100	**MVA**			**Data for Short Circuit Model**		
				Data for Power Flow Model				**Machine**	**System**	
	Machine Base		**pf =**	-0.95	0.95			**Base**	**Base**	**Isc**
	kVA	**kV**	**Pgen**	**Qmax**	**Qmin**	**Vhold**		**X"d**	**X"d**	**Amps**
Windmill Model	833	0.48	0.75	0.246513	-0.246513	1.0000		0.107	12.8451	9,364
System Equivalent		115.00							0.0100	50,206

Power Flow Model

		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
201	Turbine_01	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
202	Turbine_02	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
203	Turbine_03	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
204	Turbine_04	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
205	Turbine_05	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
206	Turbine_06	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
207	Turbine_07	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
208	Turbine_08	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
209	Turbine_09	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
210	Turbine_10	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
211	Turbine_11	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
212	Turbine_12	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
213	Turbine_13	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
214	Turbine_14	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
215	Turbine_15	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
216	Turbine_16	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
217	Turbine_17	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
218	Turbine_18	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
219	Turbine_19	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
220	Turbine_20	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
221	Turbine_21	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779

Table B1.1
Bus Description and Generator Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

		Power Flow Model							SC Model	
		Base	Pgen	Qmax	Qmin		Bus Type			
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
222	Turbine_22	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
223	Turbine_23	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
224	Turbine_24	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
225	Turbine_25	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
226	Turbine_26	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
227	Turbine_27	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
228	Turbine_28	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
229	Turbine_29	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
230	Turbine_30	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
231	Turbine_31	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
232	Turbine_32	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
233	Turbine_33	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
234	Turbine_34	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
235	Turbine_35	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
236	Turbine_36	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
237	Turbine_37	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
238	Turbine_38	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
239	Turbine_39	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
240	Turbine_40	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
241	Turbine_41	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
242	Turbine_42	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
243	Turbine_43	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
244	Turbine_44	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
245	Turbine_45	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
246	Turbine_46	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
247	Turbine_47	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
248	Turbine_48	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
249	Turbine_49	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779

Table B1.1
Bus Description and Generator Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

		Power Flow Model							SC Model	
		Base	Pgen	Qmax	Qmin		Bus Type			
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
250	Turbine_50	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
251	Turbine_51	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
252	Turbine_52	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
253	Turbine_53	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
254	Turbine_54	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
255	Turbine_55	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
256	Turbine_56	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
257	Turbine_57	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
258	Turbine_58	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
259	Turbine_59	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
260	Turbine_60	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
261	Turbine_61	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
262	Turbine_62	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
263	Turbine_63	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
264	Turbine_64	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
265	Turbine_65	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
266	Turbine_66	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779

Table B1.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 13.80
Z Base= 1.904

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-15	1/0 Al	13.80	0.2120	0.0480	66	0.1113	0.0252	0.000047	216	0.543	0.237	0.285	0.124
2	UG-4/0-15	4/0 Al	13.80	0.1070	0.0430	84	0.0562	0.0226	0.000060	318	0.335	0.105	0.176	0.055
3	UG-500-15	500 Al	13.80	0.0480	0.0370	115	0.0252	0.0194	0.000083	502	0.159	0.037	0.083	0.019
4	UG-750-15	750 Al	13.80	0.0340	0.0350	136	0.0179	0.0184	0.000098	604	0.106	0.025	0.056	0.013
5	UG-1000-15	1000 Al	13.80	0.0280	0.0330	152	0.0147	0.0173	0.000109	716	0.081	0.021	0.043	0.011
6	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0127	0.0596	0.000003	910	0.126	0.529	0.066	0.278
7	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0127	0.0555	0.000003	910	0.126	0.492	0.066	0.258

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	377	1	UG-1/0-15	Wind_01 - Wind_02	13.8	101	102	1	0.0420	0.0095	0.000018	5	0.107	0.047
2-3	377	1	UG-1/0-15	Wind_02 - Wind_03	13.8	102	103	1	0.0420	0.0095	0.000018	5	0.107	0.047
3-4	377	1	UG-1/0-15	Wind_03 - Wind_04	13.8	103	104	1	0.0420	0.0095	0.000018	5	0.107	0.047
4-5	377	1	UG-1/0-15	Wind_04 - Wind_05	13.8	104	105	1	0.0420	0.0095	0.000018	5	0.107	0.047
5-6	377	1	UG-1/0-15	Wind_05 - Wind_06	13.8	105	106	1	0.0420	0.0095	0.000018	5	0.107	0.047
6-7	377	2	UG-4/0-15	Wind_06 - Wind_07	13.8	106	107	1	0.0212	0.0085	0.000023	8	0.066	0.021
7-8	377	2	UG-4/0-15	Wind_07 - Wind_08	13.8	107	108	1	0.0212	0.0085	0.000023	8	0.066	0.021
8-9	377	2	UG-4/0-15	Wind_08 - Wind_09	13.8	108	109	1	0.0212	0.0085	0.000023	8	0.066	0.021
9-10	377	2	UG-4/0-15	Wind_09 - Wind_10	13.8	109	110	1	0.0212	0.0085	0.000023	8	0.066	0.021
10-11	377	3	UG-500-15	Wind_10 - Wind_11	13.8	110	111	1	0.0095	0.0073	0.000031	12	0.031	0.007
11-A	377	3	UG-500-15	Wind_11 - Riser_A	13.8	111	10	1	0.0095	0.0073	0.000031	12	0.031	0.007
12-A	377	3	UG-500-15	Wind_12 - Riser_A	13.8	112	10	1	0.0095	0.0073	0.000031	12	0.031	0.007
12-13	377	3	UG-500-15	Wind_12 - Wind_13	13.8	112	113	1	0.0095	0.0073	0.000031	12	0.031	0.007
13-14	377	2	UG-4/0-15	Wind_13 - Wind_14	13.8	113	114	1	0.0212	0.0085	0.000023	8	0.066	0.021
14-15	377	2	UG-4/0-15	Wind_14 - Wind_15	13.8	114	115	1	0.0212	0.0085	0.000023	8	0.066	0.021
15-16	377	2	UG-4/0-15	Wind_15 - Wind_16	13.8	115	116	1	0.0212	0.0085	0.000023	8	0.066	0.021
16-17	377	2	UG-4/0-15	Wind_16 - Wind_17	13.8	116	117	1	0.0212	0.0085	0.000023	8	0.066	0.021
17-18	377	1	UG-1/0-15	Wind_17 - Wind_18	13.8	117	118	1	0.0420	0.0095	0.000018	5	0.107	0.047
18-19	377	1	UG-1/0-15	Wind_18 - Wind_19	13.8	118	119	1	0.0420	0.0095	0.000018	5	0.107	0.047
19-20	377	1	UG-1/0-15	Wind_19 - Wind_20	13.8	119	120	1	0.0420	0.0095	0.000018	5	0.107	0.047

Table B1.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 13.80
Z Base= 1.904

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-15	1/0 Al	13.80	0.2120	0.0480	66	0.1113	0.0252	0.000047	216	0.543	0.237	0.285	0.124
2	UG-4/0-15	4/0 Al	13.80	0.1070	0.0430	84	0.0562	0.0226	0.000060	318	0.335	0.105	0.176	0.055
3	UG-500-15	500 Al	13.80	0.0480	0.0370	115	0.0252	0.0194	0.000083	502	0.159	0.037	0.083	0.019
4	UG-750-15	750 Al	13.80	0.0340	0.0350	136	0.0179	0.0184	0.000098	604	0.106	0.025	0.056	0.013
5	UG-1000-15	1000 Al	13.80	0.0280	0.0330	152	0.0147	0.0173	0.000109	716	0.081	0.021	0.043	0.011
6	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0127	0.0596	0.000003	910	0.126	0.529	0.066	0.278
7	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0127	0.0555	0.000003	910	0.126	0.492	0.066	0.258

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
20-21	377	1	UG-1/0-15	Wind_20 - Wind_21	13.8	120	121	1	0.0420	0.0095	0.000018	5	0.107	0.047
21-22	377	1	UG-1/0-15	Wind_21 - Wind_22	13.8	121	122	1	0.0420	0.0095	0.000018	5	0.107	0.047
22-23	377	1	UG-1/0-15	Wind_22 - Wind_23	13.8	122	123	1	0.0420	0.0095	0.000018	5	0.107	0.047
24-25	377	1	UG-1/0-15	Wind_24 - Wind_25	13.8	124	125	1	0.0420	0.0095	0.000018	5	0.107	0.047
25-26	377	1	UG-1/0-15	Wind_25 - Wind_26	13.8	125	126	1	0.0420	0.0095	0.000018	5	0.107	0.047
26-27	377	1	UG-1/0-15	Wind_26 - Wind_27	13.8	126	127	1	0.0420	0.0095	0.000018	5	0.107	0.047
27-28	377	1	UG-1/0-15	Wind_27 - Wind_28	13.8	127	128	1	0.0420	0.0095	0.000018	5	0.107	0.047
28-29	377	1	UG-1/0-15	Wind_28 - Wind_29	13.8	128	129	1	0.0420	0.0095	0.000018	5	0.107	0.047
29-B	377	2	UG-4/0-15	Wind_29 - Riser_B	13.8	129	15	1	0.0212	0.0085	0.000023	8	0.066	0.021
30-C	377	3	UG-500-15	Wind_30 - Riser_C	13.8	130	20	1	0.0095	0.0073	0.000031	12	0.031	0.007
30-31	377	3	UG-500-15	Wind_30 - Wind_31	13.8	130	131	1	0.0095	0.0073	0.000031	12	0.031	0.007
31-32	377	3	UG-500-15	Wind_31 - Wind_32	13.8	131	132	1	0.0095	0.0073	0.000031	12	0.031	0.007
32-33	377	3	UG-500-15	Wind_32 - Wind_33	13.8	132	133	1	0.0095	0.0073	0.000031	12	0.031	0.007
33-34	377	3	UG-500-15	Wind_33 - Wind_34	13.8	133	134	1	0.0095	0.0073	0.000031	12	0.031	0.007
34-35	377	3	UG-500-15	Wind_34 - Wind_35	13.8	134	135	1	0.0095	0.0073	0.000031	12	0.031	0.007
35-36	377	3	UG-500-15	Wind_35 - Wind_36	13.8	135	136	1	0.0095	0.0073	0.000031	12	0.031	0.007
36-37	377	2	UG-4/0-15	Wind_36 - Wind_37	13.8	136	137	1	0.0212	0.0085	0.000023	8	0.066	0.021
37-38	377	2	UG-4/0-15	Wind_37 - Wind_38	13.8	137	138	1	0.0212	0.0085	0.000023	8	0.066	0.021
38-39	377	2	UG-4/0-15	Wind_38 - Wind_39	13.8	138	139	1	0.0212	0.0085	0.000023	8	0.066	0.021
39-40	377	1	UG-1/0-15	Wind_39 - Wind_40	13.8	139	140	1	0.0420	0.0095	0.000018	5	0.107	0.047

Table B1.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 13.80
Z Base= 1.904

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-15	1/0 Al	13.80	0.2120	0.0480	66	0.1113	0.0252	0.000047	216	0.543	0.237	0.285	0.124
2	UG-4/0-15	4/0 Al	13.80	0.1070	0.0430	84	0.0562	0.0226	0.000060	318	0.335	0.105	0.176	0.055
3	UG-500-15	500 Al	13.80	0.0480	0.0370	115	0.0252	0.0194	0.000083	502	0.159	0.037	0.083	0.019
4	UG-750-15	750 Al	13.80	0.0340	0.0350	136	0.0179	0.0184	0.000098	604	0.106	0.025	0.056	0.013
5	UG-1000-15	1000 Al	13.80	0.0280	0.0330	152	0.0147	0.0173	0.000109	716	0.081	0.021	0.043	0.011
6	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0127	0.0596	0.000003	910	0.126	0.529	0.066	0.278
7	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0127	0.0555	0.000003	910	0.126	0.492	0.066	0.258

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
40-41	377	1	UG-1/0-15	Wind_40 - Wind_41	13.8	140	141	1	0.0420	0.0095	0.000018	5	0.107	0.047
41-42	377	1	UG-1/0-15	Wind_41 - Wind_42	13.8	141	142	1	0.0420	0.0095	0.000018	5	0.107	0.047
42-43	377	1	UG-1/0-15	Wind_42 - Wind_43	13.8	142	143	1	0.0420	0.0095	0.000018	5	0.107	0.047
43-44	377	1	UG-1/0-15	Wind_43 - Wind_44	13.8	143	144	1	0.0420	0.0095	0.000018	5	0.107	0.047
44-45	377	1	UG-1/0-15	Wind_44 - Wind_45	13.8	144	145	1	0.0420	0.0095	0.000018	5	0.107	0.047
46-47	377	1	UG-1/0-15	Wind_46 - Wind_47	13.8	146	147	1	0.0420	0.0095	0.000018	5	0.107	0.047
47-48	377	1	UG-1/0-15	Wind_47 - Wind_48	13.8	147	148	1	0.0420	0.0095	0.000018	5	0.107	0.047
48-D	377	1	UG-1/0-15	Wind_48 - Riser_D	13.8	148	25	1	0.0420	0.0095	0.000018	5	0.107	0.047
49-E	377	4	UG-750-15	Wind_49 - Riser_E	13.8	149	30	1	0.0067	0.0069	0.000037	14	0.021	0.005
49-50	377	4	UG-750-15	Wind_49 - Wind_50	13.8	149	150	1	0.0067	0.0069	0.000037	14	0.021	0.005
50-51	377	4	UG-750-15	Wind_50 - Wind_51	13.8	150	151	1	0.0067	0.0069	0.000037	14	0.021	0.005
51-52	377	4	UG-750-15	Wind_51 - Wind_52	13.8	151	152	1	0.0067	0.0069	0.000037	14	0.021	0.005
52-53	377	3	UG-500-15	Wind_52 - Wind_53	13.8	152	153	1	0.0095	0.0073	0.000031	12	0.031	0.007
53-54	377	3	UG-500-15	Wind_53 - Wind_54	13.8	153	154	1	0.0095	0.0073	0.000031	12	0.031	0.007
54-55	377	3	UG-500-15	Wind_54 - Wind_55	13.8	154	155	1	0.0095	0.0073	0.000031	12	0.031	0.007
55-56	377	3	UG-500-15	Wind_55 - Wind_56	13.8	155	156	1	0.0095	0.0073	0.000031	12	0.031	0.007
56-57	754	3	UG-500-15	Wind_56 - Wind_57	13.8	156	157	1	0.0190	0.0146	0.000062	12	0.063	0.015
57-58	377	2	UG-4/0-15	Wind_57 - Wind_58	13.8	157	158	1	0.0212	0.0085	0.000023	8	0.066	0.021
58-59	377	2	UG-4/0-15	Wind_58 - Wind_59	13.8	158	159	1	0.0212	0.0085	0.000023	8	0.066	0.021
59-60	377	2	UG-4/0-15	Wind_59 - Wind_60	13.8	159	160	1	0.0212	0.0085	0.000023	8	0.066	0.021

Table B1.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 13.80
Z Base= 1.904

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-15	1/0 Al	13.80	0.2120	0.0480	66	0.1113	0.0252	0.000047	216	0.543	0.237	0.285	0.124
2	UG-4/0-15	4/0 Al	13.80	0.1070	0.0430	84	0.0562	0.0226	0.000060	318	0.335	0.105	0.176	0.055
3	UG-500-15	500 Al	13.80	0.0480	0.0370	115	0.0252	0.0194	0.000083	502	0.159	0.037	0.083	0.019
4	UG-750-15	750 Al	13.80	0.0340	0.0350	136	0.0179	0.0184	0.000098	604	0.106	0.025	0.056	0.013
5	UG-1000-15	1000 Al	13.80	0.0280	0.0330	152	0.0147	0.0173	0.000109	716	0.081	0.021	0.043	0.011
6	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0127	0.0596	0.000003	910	0.126	0.529	0.066	0.278
7	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0127	0.0555	0.000003	910	0.126	0.492	0.066	0.258

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
60-61	377	2	UG-4/0-15	Wind_60 - Wind_61	13.8	160	161	1	0.0212	0.0085	0.000023	8	0.066	0.021
61-62	377	1	UG-1/0-15	Wind_61 - Wind_62	13.8	161	162	1	0.0420	0.0095	0.000018	5	0.107	0.047
62-63	377	1	UG-1/0-15	Wind_62 - Wind_63	13.8	162	163	1	0.0420	0.0095	0.000018	5	0.107	0.047
63-64	754	1	UG-1/0-15	Wind_63 - Wind_64	13.8	163	164	1	0.0839	0.0190	0.000036	5	0.215	0.094
64-65	377	1	UG-1/0-15	Wind_64 - Wind_65	13.8	164	165	1	0.0420	0.0095	0.000018	5	0.107	0.047
65-66	377	1	UG-1/0-15	Wind_65 - Wind_66	13.8	165	166	1	0.0420	0.0095	0.000018	5	0.107	0.047

Table B1.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 13.80
Z Base= 1.904

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-15	1/0 Al	13.80	0.2120	0.0480	66	0.1113	0.0252	0.000047	216	0.543	0.237	0.285	0.124
2	UG-4/0-15	4/0 Al	13.80	0.1070	0.0430	84	0.0562	0.0226	0.000060	318	0.335	0.105	0.176	0.055
3	UG-500-15	500 Al	13.80	0.0480	0.0370	115	0.0252	0.0194	0.000083	502	0.159	0.037	0.083	0.019
4	UG-750-15	750 Al	13.80	0.0340	0.0350	136	0.0179	0.0184	0.000098	604	0.106	0.025	0.056	0.013
5	UG-1000-15	1000 Al	13.80	0.0280	0.0330	152	0.0147	0.0173	0.000109	716	0.081	0.021	0.043	0.011
6	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0127	0.0596	0.000003	910	0.126	0.529	0.066	0.278
7	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0127	0.0555	0.000003	910	0.126	0.492	0.066	0.258

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
A-B	2,300	6	OH-SC-795	Riser_A - Riser_B	13.8	10	15	1	0.0292	0.1371	0.000006	22	0.152	0.639
B-D	2,300	7	OH-DC2-795	Riser_B - Riser_D	13.8	15	25	1	0.0292	0.1275	0.000006	22	0.152	0.594
D-F	1,000	7	OH-DC2-795	Riser_D - Mission_13.8	13.8	25	2	1	0.0127	0.0555	0.000003	22	0.066	0.258

Table B1.3
Transformer Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	Voltage kV	MVA	Rating	Z%	X/R	R(pu)	X(pu)
Station Transformer	115/13.8	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	13.80/.480	1	1	5.75%	9	0.6389	5.7500

		Rating	Tap	To	Ckt.	Imped. (Syst. Base)		
Transformer Name	Voltage kV	MVA	No.	No.	Id.	R(pu)	X(pu)	Tap
Mission_115 - Mission_13.8	115/13.8	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	13.80/.480	1	101	201	1	0.6389	5.7500	1.000
Wind_02 - Turbine_02	13.80/.480	1	102	202	1	0.6389	5.7500	1.000
Wind_03 - Turbine_03	13.80/.480	1	103	203	1	0.6389	5.7500	1.000
Wind_04 - Turbine_04	13.80/.480	1	104	204	1	0.6389	5.7500	1.000
Wind_05 - Turbine_05	13.80/.480	1	105	205	1	0.6389	5.7500	1.000
Wind_06 - Turbine_06	13.80/.480	1	106	206	1	0.6389	5.7500	1.000
Wind_07 - Turbine_07	13.80/.480	1	107	207	1	0.6389	5.7500	1.000
Wind_08 - Turbine_08	13.80/.480	1	108	208	1	0.6389	5.7500	1.000
Wind_09 - Turbine_09	13.80/.480	1	109	209	1	0.6389	5.7500	1.000
Wind_10 - Turbine_10	13.80/.480	1	110	210	1	0.6389	5.7500	1.000
Wind_11 - Turbine_11	13.80/.480	1	111	211	1	0.6389	5.7500	1.000
Wind_12 - Turbine_12	13.80/.480	1	112	212	1	0.6389	5.7500	1.000
Wind_13 - Turbine_13	13.80/.480	1	113	213	1	0.6389	5.7500	1.000
Wind_14 - Turbine_14	13.80/.480	1	114	214	1	0.6389	5.7500	1.000
Wind_15 - Turbine_15	13.80/.480	1	115	215	1	0.6389	5.7500	1.000
Wind_16 - Turbine_16	13.80/.480	1	116	216	1	0.6389	5.7500	1.000
Wind_17 - Turbine_17	13.80/.480	1	117	217	1	0.6389	5.7500	1.000
Wind_18 - Turbine_18	13.80/.480	1	118	218	1	0.6389	5.7500	1.000
Wind_19 - Turbine_19	13.80/.480	1	119	219	1	0.6389	5.7500	1.000
Wind_20 - Turbine_20	13.80/.480	1	120	220	1	0.6389	5.7500	1.000
Wind_21 - Turbine_21	13.80/.480	1	121	221	1	0.6389	5.7500	1.000
Wind_22 - Turbine_22	13.80/.480	1	122	222	1	0.6389	5.7500	1.000

Table B1.3
Transformer Characteristics
Plan A 750 - 15 kV
WindPACT Turbine Design Scaling Studies

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	**Voltage kV**	**MVA**	**Rating**	**Z%**	**X/R**	**R(pu)**	**X(pu)**
Station Transformer	115/13.8	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	13.80/.480	1	1	5.75%	9	0.6389	5.7500

Transformer Name	Voltage kV	Rating MVA	Tap No.	To No.	Ckt. Id.	Imped. (Syst. Base) R(pu)	Imped. (Syst. Base) X(pu)	Tap
Wind_23 - Turbine_23	13.80/.480	1	123	223	1	0.6389	5.7500	1.000
Wind_24 - Turbine_24	13.80/.480	1	124	224	1	0.6389	5.7500	1.000
Wind_25 - Turbine_25	13.80/.480	1	125	225	1	0.6389	5.7500	1.000
Wind_26 - Turbine_26	13.80/.480	1	126	226	1	0.6389	5.7500	1.000
Wind_27 - Turbine_27	13.80/.480	1	127	227	1	0.6389	5.7500	1.000

Table B2.1
Bus Description and Generator Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			24.9			**Power Flow Model**				
		Base	**Pgen**	**Qmax**	**Qmin**		**Bus Type**		**SC Model**	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_25	24.9					Load	0		
10	Riser_A	24.9					Load	0		
15	Riser_B	24.9					Load	0		
20	Riser_C	24.9					Load	0		
101	Wind_01	24.9					Load	0		
102	Wind_02	24.9					Load	0		
103	Wind_03	24.9					Load	0		
104	Wind_04	24.9					Load	0		
105	Wind_05	24.9					Load	0		
106	Wind_06	24.9					Load	0		
107	Wind_07	24.9					Load	0		
108	Wind_08	24.9					Load	0		
109	Wind_09	24.9					Load	0		
110	Wind_10	24.9					Load	0		
111	Wind_11	24.9					Load	0		
112	Wind_12	24.9					Load	0		
113	Wind_13	24.9					Load	0		
114	Wind_14	24.9					Load	0		
115	Wind_15	24.9					Load	0		
116	Wind_16	24.9					Load	0		
117	Wind_17	24.9					Load	0		
118	Wind_18	24.9					Load	0		
119	Wind_19	24.9					Load	0		
120	Wind_20	24.9					Load	0		
121	Wind_21	24.9					Load	0		
122	Wind_22	24.9					Load	0		

Table B2.1
Bus Description and Generator Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			24.9			Power Flow Model				
		Base	**Pgen**	**Qmax**	**Qmin**		**Bus Type**		**SC Model**	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
123	Wind_23	24.9					Load	0		
124	Wind_24	24.9					Load	0		
125	Wind_25	24.9					Load	0		
126	Wind_26	24.9					Load	0		
127	Wind_27	24.9					Load	0		
128	Wind_28	24.9					Load	0		
129	Wind_29	24.9					Load	0		
130	Wind_30	24.9					Load	0		
131	Wind_31	24.9					Load	0		
132	Wind_32	24.9					Load	0		
133	Wind_33	24.9					Load	0		
134	Wind_34	24.9					Load	0		
135	Wind_35	24.9					Load	0		
136	Wind_36	24.9					Load	0		
137	Wind_37	24.9					Load	0		
138	Wind_38	24.9					Load	0		
139	Wind_39	24.9					Load	0		
140	Wind_40	24.9					Load	0		
141	Wind_41	24.9					Load	0		
142	Wind_42	24.9					Load	0		
143	Wind_43	24.9					Load	0		
144	Wind_44	24.9					Load	0		
145	Wind_45	24.9					Load	0		
146	Wind_46	24.9					Load	0		
147	Wind_47	24.9					Load	0		
148	Wind_48	24.9					Load	0		
149	Wind_49	24.9					Load	0		

Table B2.1
Bus Description and Generator Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			24.9			Power Flow Model				
		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
150	Wind_50	24.9					Load	0		
151	Wind_51	24.9					Load	0		
152	Wind_52	24.9					Load	0		
153	Wind_53	24.9					Load	0		
154	Wind_54	24.9					Load	0		
155	Wind_55	24.9					Load	0		
156	Wind_56	24.9					Load	0		
157	Wind_57	24.9					Load	0		
158	Wind_58	24.9					Load	0		
159	Wind_59	24.9					Load	0		
160	Wind_60	24.9					Load	0		
161	Wind_61	24.9					Load	0		
162	Wind_62	24.9					Load	0		
163	Wind_63	24.9					Load	0		
164	Wind_64	24.9					Load	0		
165	Wind_65	24.9					Load	0		
166	Wind_66	24.9					Load	0		

Table B2.1
Bus Description and Generator Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

			System Base =	100	**MVA**			**Data for Short Circuit Model**		
				Data for Power Flow Model				**Machine**	**System**	
	Machine Base		**pf =**	-0.95	0.95			**Base**	**Base**	**Isc**
	kVA	**kV**	**Pgen**	**Qmax**	**Qmin**	**Vhold**		**X"d**	**X"d**	**Amps**
Windmill Model	833	0.48	0.75	0.246513	-0.246513	1.0000		0.107	12.8451	9,364
System Equivalent		115.00							0.0100	50,206

Power Flow Model

Bus No.	**Name**	**Base kV**	**Pgen MW**	**Qmax MVAR**	**Qmin MVAR**	**Vhold**	**Bus Type BType**	**BT**	**SC Model X"d**	**B(pu)**
201	Turbine_01	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
202	Turbine_02	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
203	Turbine_03	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
204	Turbine_04	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
205	Turbine_05	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
206	Turbine_06	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
207	Turbine_07	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
208	Turbine_08	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
209	Turbine_09	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
210	Turbine_10	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
211	Turbine_11	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
212	Turbine_12	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
213	Turbine_13	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
214	Turbine_14	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
215	Turbine_15	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
216	Turbine_16	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
217	Turbine_17	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
218	Turbine_18	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
219	Turbine_19	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
220	Turbine_20	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779

Table B2.1
Bus Description and Generator Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

		Power Flow Model					Bus Type		SC Model	
		Base	Pgen	Qmax	Qmin					
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
221	Turbine_21	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
222	Turbine_22	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
223	Turbine_23	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
224	Turbine_24	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
225	Turbine_25	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
226	Turbine_26	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
227	Turbine_27	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
228	Turbine_28	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
229	Turbine_29	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
230	Turbine_30	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
231	Turbine_31	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
232	Turbine_32	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
233	Turbine_33	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
234	Turbine_34	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
235	Turbine_35	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
236	Turbine_36	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
237	Turbine_37	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
238	Turbine_38	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
239	Turbine_39	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
240	Turbine_40	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
241	Turbine_41	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
242	Turbine_42	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
243	Turbine_43	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
244	Turbine_44	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
245	Turbine_45	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
246	Turbine_46	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
247	Turbine_47	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779

Table B2.1
Bus Description and Generator Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

		Power Flow Model							SC Model	
		Base	Pgen	Qmax	Qmin		Bus Type			
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
248	Turbine_48	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
249	Turbine_49	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
250	Turbine_50	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
251	Turbine_51	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
252	Turbine_52	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
253	Turbine_53	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
254	Turbine_54	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
255	Turbine_55	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
256	Turbine_56	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
257	Turbine_57	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
258	Turbine_58	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
259	Turbine_59	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
260	Turbine_60	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
261	Turbine_61	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
262	Turbine_62	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
263	Turbine_63	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
264	Turbine_64	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
265	Turbine_65	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779
266	Turbine_66	0.48	0.75	0.24651	-0.246513	1.0000	V-Control	2	12.8451	0.0779

Table B2.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0370	86	0.0077	0.0060	0.000201	395	0.250	0.172	0.040	0.028
4	UG-750-25	750 Al	24.90	0.0340	0.0350	101	0.0055	0.0056	0.000236	475	0.177	0.163	0.029	0.026
5	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0039	0.0183	0.000009	395	0.126	0.529	0.020	0.085
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	395	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	377	1	UG-1/0-25	Wind_01 - Wind_02	24.9	101	102	1	0.0129	0.0031	0.000046	9	0.033	0.016
2-3	377	1	UG-1/0-25	Wind_02 - Wind_03	24.9	102	103	1	0.0129	0.0031	0.000046	9	0.033	0.016
3-4	377	1	UG-1/0-25	Wind_03 - Wind_04	24.9	103	104	1	0.0129	0.0031	0.000046	9	0.033	0.016
4-5	377	1	UG-1/0-25	Wind_04 - Wind_05	24.9	104	105	1	0.0129	0.0031	0.000046	9	0.033	0.016
5-6	377	1	UG-1/0-25	Wind_05 - Wind_06	24.9	105	106	1	0.0129	0.0031	0.000046	9	0.033	0.016
6-7	377	1	UG-1/0-25	Wind_06 - Wind_07	24.9	106	107	1	0.0129	0.0031	0.000046	9	0.033	0.016
7-8	377	1	UG-1/0-25	Wind_07 - Wind_08	24.9	107	108	1	0.0129	0.0031	0.000046	9	0.033	0.016
8-9	377	1	UG-1/0-25	Wind_08 - Wind_09	24.9	108	109	1	0.0129	0.0031	0.000046	9	0.033	0.016
9-10	377	1	UG-1/0-25	Wind_09 - Wind_10	24.9	109	110	1	0.0129	0.0031	0.000046	9	0.033	0.016
10-11	377	1	UG-1/0-25	Wind_10 - Wind_11	24.9	110	111	1	0.0129	0.0031	0.000046	9	0.033	0.016
11-A	377	1	UG-1/0-25	Wind_11 - Riser_A	24.9	111	10	1	0.0129	0.0031	0.000046	9	0.033	0.016
12-A	377	1	UG-1/0-25	Wind_12 - Riser_A	24.9	112	10	1	0.0129	0.0031	0.000046	9	0.033	0.016
12-13	377	1	UG-1/0-25	Wind_12 - Wind_13	24.9	112	113	1	0.0129	0.0031	0.000046	9	0.033	0.016
13-14	377	1	UG-1/0-25	Wind_13 - Wind_14	24.9	113	114	1	0.0129	0.0031	0.000046	9	0.033	0.016
14-15	377	1	UG-1/0-25	Wind_14 - Wind_15	24.9	114	115	1	0.0129	0.0031	0.000046	9	0.033	0.016
15-16	377	1	UG-1/0-25	Wind_15 - Wind_16	24.9	115	116	1	0.0129	0.0031	0.000046	9	0.033	0.016
16-17	377	1	UG-1/0-25	Wind_16 - Wind_17	24.9	116	117	1	0.0129	0.0031	0.000046	9	0.033	0.016
17-18	377	1	UG-1/0-25	Wind_17 - Wind_18	24.9	117	118	1	0.0129	0.0031	0.000046	9	0.033	0.016
18-19	377	1	UG-1/0-25	Wind_18 - Wind_19	24.9	118	119	1	0.0129	0.0031	0.000046	9	0.033	0.016
19-20	377	1	UG-1/0-25	Wind_19 - Wind_20	24.9	119	120	1	0.0129	0.0031	0.000046	9	0.033	0.016

Table B2.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0370	86	0.0077	0.0060	0.000201	395	0.250	0.172	0.040	0.028
4	UG-750-25	750 Al	24.90	0.0340	0.0350	101	0.0055	0.0056	0.000236	475	0.177	0.163	0.029	0.026
5	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0039	0.0183	0.000009	395	0.126	0.529	0.020	0.085
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	395	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
20-21	377	1	UG-1/0-25	Wind_20 - Wind_21	24.9	120	121	1	0.0129	0.0031	0.000046	9	0.033	0.016
21-22	377	1	UG-1/0-25	Wind_21 - Wind_22	24.9	121	122	1	0.0129	0.0031	0.000046	9	0.033	0.016
22-23	377	1	UG-1/0-25	Wind_22 - Wind_23	24.9	122	123	1	0.0129	0.0031	0.000046	9	0.033	0.016
24-25	377	1	UG-1/0-25	Wind_24 - Wind_25	24.9	124	125	1	0.0129	0.0031	0.000046	9	0.033	0.016
25-26	377	1	UG-1/0-25	Wind_25 - Wind_26	24.9	125	126	1	0.0129	0.0031	0.000046	9	0.033	0.016
26-27	377	1	UG-1/0-25	Wind_26 - Wind_27	24.9	126	127	1	0.0129	0.0031	0.000046	9	0.033	0.016
27-28	377	1	UG-1/0-25	Wind_27 - Wind_28	24.9	127	128	1	0.0129	0.0031	0.000046	9	0.033	0.016
28-29	377	1	UG-1/0-25	Wind_28 - Wind_29	24.9	128	129	1	0.0129	0.0031	0.000046	9	0.033	0.016
29-B	377	1	UG-1/0-25	Wind_29 - Wind_30	24.9	129	130	1	0.0129	0.0031	0.000046	9	0.033	0.016
30-B	377	2	UG-4/0-25	Wind_30 - Wind_31	24.9	130	131	1	0.0065	0.0028	0.000056	13	0.020	0.007
30-31	377	2	UG-4/0-25	Wind_31 - Riser_B	24.9	131	15	1	0.0065	0.0028	0.000056	13	0.020	0.007
31-32	377	2	UG-4/0-25	Wind_32 - Riser_B	24.9	132	15	1	0.0065	0.0028	0.000056	13	0.020	0.007
32-33	377	2	UG-4/0-25	Wind_32 - Wind_33	24.9	132	133	1	0.0065	0.0028	0.000056	13	0.020	0.007
33-34	377	2	UG-4/0-25	Wind_33 - Wind_34	24.9	133	134	1	0.0065	0.0028	0.000056	13	0.020	0.007
34-35	377	2	UG-4/0-25	Wind_34 - Wind_35	24.9	134	135	1	0.0065	0.0028	0.000056	13	0.020	0.007
35-36	377	2	UG-4/0-25	Wind_35 - Wind_36	24.9	135	136	1	0.0065	0.0028	0.000056	13	0.020	0.007
36-37	377	1	UG-1/0-25	Wind_36 - Wind_37	24.9	136	137	1	0.0129	0.0031	0.000046	9	0.033	0.016
37-38	377	1	UG-1/0-25	Wind_37 - Wind_38	24.9	137	138	1	0.0129	0.0031	0.000046	9	0.033	0.016
38-39	377	1	UG-1/0-25	Wind_38 - Wind_39	24.9	138	139	1	0.0129	0.0031	0.000046	9	0.033	0.016
39-40	377	1	UG-1/0-25	Wind_39 - Wind_40	24.9	139	140	1	0.0129	0.0031	0.000046	9	0.033	0.016

Table B2.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA=	100
Volt Base=	24.90
Z Base=	6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0370	86	0.0077	0.0060	0.000201	395	0.250	0.172	0.040	0.028
4	UG-750-25	750 Al	24.90	0.0340	0.0350	101	0.0055	0.0056	0.000236	475	0.177	0.163	0.029	0.026
5	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0039	0.0183	0.000009	395	0.126	0.529	0.020	0.085
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	395	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet	Construction Type		Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
40-41	377	1	UG-1/0-25	Wind_40 - Wind_41	24.9	140	141	1	0.0129	0.0031	0.000046	9	0.033	0.016
41-42	377	1	UG-1/0-25	Wind_41 - Wind_42	24.9	141	142	1	0.0129	0.0031	0.000046	9	0.033	0.016
42-43	377	1	UG-1/0-25	Wind_42 - Wind_43	24.9	142	143	1	0.0129	0.0031	0.000046	9	0.033	0.016
43-44	377	1	UG-1/0-25	Wind_43 - Wind_44	24.9	143	144	1	0.0129	0.0031	0.000046	9	0.033	0.016
44-45	377	1	UG-1/0-25	Wind_44 - Wind_45	24.9	144	145	1	0.0129	0.0031	0.000046	9	0.033	0.016
46-47	377	1	UG-1/0-25	Wind_45 - Wind_46	24.9	145	146	1	0.0129	0.0031	0.000046	9	0.033	0.016
47-48	377	1	UG-1/0-25	Wind_46 - Wind_47	24.9	146	147	1	0.0129	0.0031	0.000046	9	0.033	0.016
48-C	377	1	UG-1/0-25	Wind_47 - Wind_48	24.9	147	148	1	0.0129	0.0031	0.000046	9	0.033	0.016
49-C	377	2	UG-4/0-25	Wind_49 - Wind_50	24.9	149	150	1	0.0065	0.0028	0.000056	13	0.020	0.007
49-50	377	2	UG-4/0-25	Wind_50 - Wind_51	24.9	150	151	1	0.0065	0.0028	0.000056	13	0.020	0.007
50-51	377	2	UG-4/0-25	Wind_51 - Riser_C	24.9	151	20	1	0.0065	0.0028	0.000056	13	0.020	0.007
51-52	377	2	UG-4/0-25	Wind_52 - Riser_C	24.9	152	20	1	0.0065	0.0028	0.000056	13	0.020	0.007
52-53	377	2	UG-4/0-25	Wind_52 - Wind_53	24.9	152	153	1	0.0065	0.0028	0.000056	13	0.020	0.007
53-54	377	2	UG-4/0-25	Wind_53 - Wind_54	24.9	153	154	1	0.0065	0.0028	0.000056	13	0.020	0.007
54-55	377	1	UG-1/0-25	Wind_54 - Wind_55	24.9	154	155	1	0.0129	0.0031	0.000046	9	0.033	0.016
55-56	377	1	UG-1/0-25	Wind_55 - Wind_56	24.9	155	156	1	0.0129	0.0031	0.000046	9	0.033	0.016
56-57	754	1	UG-1/0-25	Wind_56 - Wind_57	24.9	156	157	1	0.0258	0.0062	0.000092	9	0.067	0.032
57-58	377	1	UG-1/0-25	Wind_57 - Wind_58	24.9	157	158	1	0.0129	0.0031	0.000046	9	0.033	0.016
58-59	377	1	UG-1/0-25	Wind_58 - Wind_59	24.9	158	159	1	0.0129	0.0031	0.000046	9	0.033	0.016
59-60	377	1	UG-1/0-25	Wind_59 - Wind_60	24.9	159	160	1	0.0129	0.0031	0.000046	9	0.033	0.016

Table B2.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0370	86	0.0077	0.0060	0.000201	395	0.250	0.172	0.040	0.028
4	UG-750-25	750 Al	24.90	0.0340	0.0350	101	0.0055	0.0056	0.000236	475	0.177	0.163	0.029	0.026
5	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0039	0.0183	0.000009	395	0.126	0.529	0.020	0.085
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	395	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
60-61	377	1	UG-1/0-25	Wind_60 - Wind_61	24.9	160	161	1	0.0129	0.0031	0.000046	9	0.033	0.016
61-62	377	1	UG-1/0-25	Wind_61 - Wind_62	24.9	161	162	1	0.0129	0.0031	0.000046	9	0.033	0.016
62-63	377	1	UG-1/0-25	Wind_62 - Wind_63	24.9	162	163	1	0.0129	0.0031	0.000046	9	0.033	0.016
63-64	754	1	UG-1/0-25	Wind_63 - Wind_64	24.9	163	164	1	0.0258	0.0062	0.000092	9	0.067	0.032
64-65	377	1	UG-1/0-25	Wind_64 - Wind_65	24.9	164	165	1	0.0129	0.0031	0.000046	9	0.033	0.016
65-66	377	1	UG-1/0-25	Wind_65 - Wind_66	24.9	165	166	1	0.0129	0.0031	0.000046	9	0.033	0.016

Table B2.2
Distribution Cable and Overhead Line Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0370	86	0.0077	0.0060	0.000201	395	0.250	0.172	0.040	0.028
4	UG-750-25	750 Al	24.90	0.0340	0.0350	101	0.0055	0.0056	0.000236	475	0.177	0.163	0.029	0.026
5	OH-SC-795	795 ACSR		0.0242	0.1135	3.86	0.0039	0.0183	0.000009	395	0.126	0.529	0.020	0.085
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	395	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet	Construction	Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
A-B	2,300	5	OH-SC-795	Riser_A - Riser_B	24.9	10	15	1	0.0090	0.0421	0.000021	17	0.047	0.196
B-C	2,300	5	OH-SC-795	Riser_B - Riser_C	24.9	15	20	1	0.0090	0.0421	0.000021	17	0.047	0.196
C-F	1,000	5	OH-SC-795	Riser_C - Mission_25	24.9	20	2	1	0.0039	0.0183	0.000009	17	0.020	0.085

Table B2.3
Transformer Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling System

Transformer	Voltage kV	Base MVA	Top Rating	Z%	X/R	Imped. (Syst. Base) R(pu)	Imped. (Syst. Base) X(pu)
Station Transformer	115/24.9	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	24.90/.480	1	1	5.75%	9	0.6389	5.7500

Transformer Characteristics — Transf. Model Data — System Base MVA= 100

Transformer Name	Voltage kV	Rating MVA	Tap No.	To No.	Ckt. Id.	Imped. (Syst. Base) R(pu)	Imped. (Syst. Base) X(pu)	Tap
Mission_115 - Mission_25	115/24.9	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	24.90/.480	1	101	201	1	0.6389	5.7500	1.000
Wind_02 - Turbine_02	24.90/.480	1	102	202	1	0.6389	5.7500	1.000
Wind_03 - Turbine_03	24.90/.480	1	103	203	1	0.6389	5.7500	1.000
Wind_04 - Turbine_04	24.90/.480	1	104	204	1	0.6389	5.7500	1.000
Wind_05 - Turbine_05	24.90/.480	1	105	205	1	0.6389	5.7500	1.000
Wind_06 - Turbine_06	24.90/.480	1	106	206	1	0.6389	5.7500	1.000
Wind_07 - Turbine_07	24.90/.480	1	107	207	1	0.6389	5.7500	1.000
Wind_08 - Turbine_08	24.90/.480	1	108	208	1	0.6389	5.7500	1.000
Wind_09 - Turbine_09	24.90/.480	1	109	209	1	0.6389	5.7500	1.000
Wind_10 - Turbine_10	24.90/.480	1	110	210	1	0.6389	5.7500	1.000
Wind_11 - Turbine_11	24.90/.480	1	111	211	1	0.6389	5.7500	1.000
Wind_12 - Turbine_12	24.90/.480	1	112	212	1	0.6389	5.7500	1.000
Wind_13 - Turbine_13	24.90/.480	1	113	213	1	0.6389	5.7500	1.000
Wind_14 - Turbine_14	24.90/.480	1	114	214	1	0.6389	5.7500	1.000
Wind_15 - Turbine_15	24.90/.480	1	115	215	1	0.6389	5.7500	1.000
Wind_16 - Turbine_16	24.90/.480	1	116	216	1	0.6389	5.7500	1.000
Wind_17 - Turbine_17	24.90/.480	1	117	217	1	0.6389	5.7500	1.000
Wind_18 - Turbine_18	24.90/.480	1	118	218	1	0.6389	5.7500	1.000
Wind_19 - Turbine_19	24.90/.480	1	119	219	1	0.6389	5.7500	1.000
Wind_20 - Turbine_20	24.90/.480	1	120	220	1	0.6389	5.7500	1.000

Table B2.3
Transformer Characteristics
Plan A 750 - 25 kV
WindPACT Turbine Design Scaling System

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	**Voltage kV**	**MVA**	**Rating**	**Z%**	**X/R**	**R(pu)**	**X(pu)**
Station Transformer	115/24.9	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	24.90/.480	1	1	5.75%	9	0.6389	5.7500

		Rating	Tap	To	Ckt.	Imped. (Syst. Base)		
Transformer Name	**Voltage kV**	**MVA**	**No.**	**No.**	**Id.**	**R(pu)**	**X(pu)**	**Tap**
Wind_21 - Turbine_21	24.90/.480	1	121	221	1	0.6389	5.7500	1.000
Wind_22 - Turbine_22	24.90/.480	1	122	222	1	0.6389	5.7500	1.000
Wind_23 - Turbine_23	24.90/.480	1	123	223	1	0.6389	5.7500	1.000
Wind_24 - Turbine_24	24.90/.480	1	124	224	1	0.6389	5.7500	1.000
Wind_25 - Turbine_25	24.90/.480	1	125	225	1	0.6389	5.7500	1.000
Wind_26 - Turbine_26	24.90/.480	1	126	226	1	0.6389	5.7500	1.000
Wind_27 - Turbine_27	24.90/.480	1	127	227	1	0.6389	5.7500	1.000

Table B3.1
Bus Description and Generator Characteristics
Plan A 2,500 - 25 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage = 24.9

						Power Flow Model				
		Base	**Pgen**	**Qmax**	**Qmin**		**Bus Type**		**SC Model**	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_25	24.9					Load	0		
10	Riser_A	24.9					Load	0		
15	Riser_B	24.9					Load	0		
101	Wind_01	24.9					Load	0		
102	Wind_02	24.9					Load	0		
103	Wind_03	24.9					Load	0		
104	Wind_04	24.9					Load	0		
105	Wind_05	24.9					Load	0		
106	Wind_06	24.9					Load	0		
107	Wind_07	24.9					Load	0		
108	Wind_08	24.9					Load	0		
109	Wind_09	24.9					Load	0		
110	Wind_10	24.9					Load	0		
111	Wind_11	24.9					Load	0		
112	Wind_12	24.9					Load	0		
113	Wind_13	24.9					Load	0		
114	Wind_14	24.9					Load	0		
115	Wind_15	24.9					Load	0		
116	Wind_16	24.9					Load	0		
117	Wind_17	24.9					Load	0		
118	Wind_18	24.9					Load	0		
119	Wind_19	24.9					Load	0		
120	Wind_20	24.9					Load	0		

Table B3.1
Bus Description and Generator Characteristics
Plan A 2,500 - 25 kV
WindPACT Turbine Design Scaling Studies

	Machine Base						Data for Short Circuit Model		
			System Base =	100 MVA			Machine	System	
				Data for Power Flow Model			Base	Base	Isc
			pf =	-0.95	0.95				
	kVA	kV	Pgen	Qmax	Qmin	Vhold	X"d	X"d	Amps
Windmill Model	2778	0.69	2.5	0.82171	-0.82171	1.0000	0.107	3.8520	21,723
System Equivalent		115.00						0.0100	50,206

		Power Flow Model							SC Model	
		Base	Pgen	Qmax	Qmin		Bus Type			
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
201	Turbine_01	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
202	Turbine_02	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
203	Turbine_03	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
204	Turbine_04	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
205	Turbine_05	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
206	Turbine_06	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
207	Turbine_07	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
208	Turbine_08	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
209	Turbine_09	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
210	Turbine_10	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
211	Turbine_11	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
212	Turbine_12	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
213	Turbine_13	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
214	Turbine_14	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
215	Turbine_15	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
216	Turbine_16	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
217	Turbine_17	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
218	Turbine_18	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
219	Turbine_19	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
220	Turbine_20	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596

Table B3.2
Distribution Cable and Overhead Line Characteristics
Plan A 2,500 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0400	86	0.0077	0.0065	0.000201	490	0.158	0.04	0.025	0.006
4	OH-SC-795	795 ACSR		0.0242	0.1135	3.59	0.0039	0.0183	0.000008	907	0.126	0.529	0.020	0.085
5	OH-DC1-795	795 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	907	0.126	0.492	0.020	0.079
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	907	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	642	1	UG-1/0-25	Wind_01 - Wind_02	24.9	101	102	1	0.0220	0.0053	0.000078	9	0.057	0.027
2-3	642	1	UG-1/0-25	Wind_02 - Wind_03	24.9	102	103	1	0.0220	0.0053	0.000078	9	0.057	0.027
3-4	642	1	UG-1/0-25	Wind_03 - Wind_04	24.9	103	104	1	0.0220	0.0053	0.000078	9	0.057	0.027
4-5	642	2	UG-4/0-25	Wind_04 - Wind_05	24.9	104	105	1	0.0111	0.0048	0.000096	13	0.035	0.011
5-6	642	2	UG-4/0-25	Wind_05 - Wind_06	24.9	105	106	1	0.0111	0.0048	0.000096	13	0.035	0.011
6-A	642	3	UG-500-25	Wind_06 - Riser_A	24.9	106	10	1	0.0050	0.0041	0.000129	21	0.016	0.004
7-A	642	2	UG-4/0-25	Wind_07 - Riser_A	24.9	107	10	1	0.0111	0.0048	0.000096	13	0.035	0.011
7-8	642	2	UG-4/0-25	Wind_07 - Wind_08	24.9	107	108	1	0.0111	0.0048	0.000096	13	0.035	0.011
8-9	642	1	UG-1/0-25	Wind_08 - Wind_09	24.9	108	109	1	0.0220	0.0053	0.000078	9	0.057	0.027
9-10	642	1	UG-1/0-25	Wind_09 - Wind_10	24.9	109	110	1	0.0220	0.0053	0.000078	9	0.057	0.027
10-11	642	1	UG-1/0-25	Wind_10 - Wind_11	24.9	110	111	1	0.0220	0.0053	0.000078	9	0.057	0.027
12-B	642	2	UG-4/0-25	Wind_12 - Riser_B	24.9	112	15	1	0.0111	0.0048	0.000096	13	0.035	0.011
12-13	642	2	UG-4/0-25	Wind_12 - Wind_13	24.9	112	113	1	0.0111	0.0048	0.000096	13	0.035	0.011
13-14	642	1	UG-1/0-25	Wind_13 - Wind_14	24.9	113	114	1	0.0220	0.0053	0.000078	9	0.057	0.027
14-15	642	1	UG-1/0-25	Wind_14 - Wind_15	24.9	114	115	1	0.0220	0.0053	0.000078	9	0.057	0.027
15-16	642	1	UG-1/0-25	Wind_15 - Wind_16	24.9	115	116	1	0.0220	0.0053	0.000078	9	0.057	0.027
17-B	3,852	2	UG-4/0-25	Wind_17 - Riser_B	24.9	117	15	1	0.0665	0.0286	0.000576	13	0.208	0.068
17-18	642	1	UG-1/0-25	Wind_17 - Wind_18	24.9	117	118	1	0.0220	0.0053	0.000078	9	0.057	0.027
18-19	642	1	UG-1/0-25	Wind_18 - Wind_19	24.9	118	119	1	0.0220	0.0053	0.000078	9	0.057	0.027
19-20	642	1	UG-1/0-25	Wind_19 - Wind_20	24.9	119	120	1	0.0220	0.0053	0.000078	9	0.057	0.027

Distribution Cable and Overhead Line Characteristics
Plan A 2,500 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0400	86	0.0077	0.0065	0.000201	490	0.158	0.04	0.025	0.006
4	OH-SC-795	795 ACSR		0.0242	0.1135	3.59	0.0039	0.0183	0.000008	907	0.126	0.529	0.020	0.085
5	OH-DC1-795	795 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	907	0.126	0.492	0.020	0.079
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	907	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet	Construction Type		Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
A-B	4,100	4	OH-SC-795	Riser_A - Riser_B	24.9	10	15	1	0.0160	0.0750	0.000034	39	0.083	0.350
B-F	1,600	4	OH-SC-795	Riser_B - Mission_25	24.9	15	2	1	0.0062	0.0293	0.000013	39	0.032	0.136

Table B3.3
Transformer Characteristics
Plan A 2500 - 25 kV
WindPACT Turbine Design Scaling Studies

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	Voltage kV	MVA	Rating	Z%	X/R	R(pu)	X(pu)
Station Transformer	115/24.9	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	24.90/.690	3	3	5.50%	9	0.2037	1.8333

		Rating	Tap	To	Ckt.	Imped. (Syst. Base)		
Transformer Name	Voltage kV	MVA	No.	No.	Id.	R(pu)	X(pu)	Tap
Mission_115 - Mission_25	115/13.8	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	24.90/.690	3	101	201	1	0.2037	1.8333	1.000
Wind_02 - Turbine_02	24.90/.690	3	102	202	1	0.2037	1.8333	1.000
Wind_03 - Turbine_03	24.90/.690	3	103	203	1	0.2037	1.8333	1.000
Wind_04 - Turbine_04	24.90/.690	3	104	204	1	0.2037	1.8333	1.000
Wind_05 - Turbine_05	24.90/.690	3	105	205	1	0.2037	1.8333	1.000
Wind_06 - Turbine_06	24.90/.690	3	106	206	1	0.2037	1.8333	1.000
Wind_07 - Turbine_07	24.90/.690	3	107	207	1	0.2037	1.8333	1.000
Wind_08 - Turbine_08	24.90/.690	3	108	208	1	0.2037	1.8333	1.000
Wind_09 - Turbine_09	24.90/.690	3	109	209	1	0.2037	1.8333	1.000
Wind_10 - Turbine_10	24.90/.690	3	110	210	1	0.2037	1.8333	1.000
Wind_11 - Turbine_11	24.90/.690	3	111	211	1	0.2037	1.8333	1.000
Wind_12 - Turbine_12	24.90/.690	3	112	212	1	0.2037	1.8333	1.000
Wind_13 - Turbine_13	24.90/.690	3	113	213	1	0.2037	1.8333	1.000
Wind_14 - Turbine_14	24.90/.690	3	114	214	1	0.2037	1.8333	1.000
Wind_15 - Turbine_15	24.90/.690	3	115	215	1	0.2037	1.8333	1.000
Wind_16 - Turbine_16	24.90/.690	3	116	216	1	0.2037	1.8333	1.000
Wind_17 - Turbine_17	24.90/.690	3	117	217	1	0.2037	1.8333	1.000
Wind_18 - Turbine_18	24.90/.690	3	118	218	1	0.2037	1.8333	1.000
Wind_19 - Turbine_19	24.90/.690	3	119	219	1	0.2037	1.8333	1.000
Wind_20 - Turbine_20	24.90/.690	3	120	220	1	0.2037	1.8333	1.000

Table B4.1
Bus Description and Generator Characteristics
Plan B 2,500 - 35 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			34.5			Power Flow Model				
		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_35	34.5					Load	0		
10	Riser_A	34.5					Load	0		
15	Riser_B	34.5					Load	0		
101	Wind_01	34.5					Load	0		
102	Wind_02	34.5					Load	0		
103	Wind_03	34.5					Load	0		
104	Wind_04	34.5					Load	0		
105	Wind_05	34.5					Load	0		
106	Wind_06	34.5					Load	0		
107	Wind_07	34.5					Load	0		
108	Wind_08	34.5					Load	0		
109	Wind_09	34.5					Load	0		
110	Wind_10	34.5					Load	0		
111	Wind_11	34.5					Load	0		
112	Wind_12	34.5					Load	0		
113	Wind_13	34.5					Load	0		
114	Wind_14	34.5					Load	0		
115	Wind_15	34.5					Load	0		
116	Wind_16	34.5					Load	0		
117	Wind_17	34.5					Load	0		
118	Wind_18	34.5					Load	0		
119	Wind_19	34.5					Load	0		
120	Wind_20	34.5					Load	0		

Table B4.1
Bus Description and Generator Characteristics
Plan B 2,500 - 35 kV
WindPACT Turbine Design Scaling Studies

				System Base =	100 **MVA**			**Data for Short Circuit Model**		
				Data for Power Flow Model						
								Machine	**System**	
	Machine Base		**pf =**	-0.95	0.95			**Base**	**Base**	**Isc**
	kVA	**kV**	**Pgen**	**Qmax**	**Qmin**	**Vhold**		**X"d**	**X"d**	**Amps**
Windmill Model	2778	0.69	2.5	0.82171	-0.82171	1.0000		0.107	3.8520	21,723
System Equivalent		115.00							0.0100	50,206

Power Flow Model

		Base	**Pgen**	**Qmax**	**Qmin**		**Bus Type**		**SC Model**	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
201	Turbine_01	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
202	Turbine_02	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
203	Turbine_03	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
204	Turbine_04	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
205	Turbine_05	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
206	Turbine_06	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
207	Turbine_07	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
208	Turbine_08	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
209	Turbine_09	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
210	Turbine_10	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
211	Turbine_11	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
212	Turbine_12	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
213	Turbine_13	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
214	Turbine_14	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
215	Turbine_15	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
216	Turbine_16	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
217	Turbine_17	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
218	Turbine_18	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
219	Turbine_19	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596
220	Turbine_20	0.69	2.5	0.82171	-0.82171	1.0000	V-Control	2	3.8520	0.2596

Table B4.2
Distribution Cable and Overhead Line Characteristics
Plan B 2,500 - 35 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 34.50
Z Base= 11.903

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-35	1/0 Al	34.50	0.2120	0.0550	37	0.0178	0.0046	0.000166	212	0.545	0.267	0.046	0.022
2	UG-4/0-35	4/0 Al	34.50	0.1070	0.0490	45	0.0090	0.0041	0.000202	312	0.333	0.113	0.028	0.009
3	UG-500-35	500 Al	34.50	0.0470	0.0420	60	0.0039	0.0035	0.000269	490	0.158	0.044	0.013	0.004
4	OH-SC-795	795 ACSR		0.0242	0.1135	3.59	0.0020	0.0095	0.000016	907	0.126	0.529	0.011	0.044
5	OH-DC1-795	795 ACSR		0.0242	0.1056	3.86	0.0020	0.0089	0.000017	907	0.126	0.492	0.011	0.041
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0020	0.0089	0.000017	907	0.126	0.492	0.011	0.041

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	642	1	UG-1/0-35	Wind_01 - Wind_02	34.5	101	102	1	0.0114	0.0030	0.000107	13	0.029	0.014
2-3	642	1	UG-1/0-35	Wind_02 - Wind_03	34.5	102	103	1	0.0114	0.0030	0.000107	13	0.029	0.014
3-4	642	1	UG-1/0-35	Wind_03 - Wind_04	34.5	103	104	1	0.0114	0.0030	0.000107	13	0.029	0.014
4-5	642	1	UG-1/0-35	Wind_04 - Wind_05	34.5	104	105	1	0.0114	0.0030	0.000107	13	0.029	0.014
5-6	642	1	UG-1/0-35	Wind_05 - Wind_06	34.5	105	106	1	0.0114	0.0030	0.000107	13	0.029	0.014
6-A	642	2	UG-4/0-35	Wind_06 - Riser_A	34.5	106	10	1	0.0058	0.0026	0.000130	19	0.018	0.006
7-A	642	1	UG-1/0-35	Wind_07 - Riser_A	34.5	107	10	1	0.0114	0.0030	0.000107	13	0.029	0.014
7-8	642	1	UG-1/0-35	Wind_07 - Wind_08	34.5	107	108	1	0.0114	0.0030	0.000107	13	0.029	0.014
8-9	642	1	UG-1/0-35	Wind_08 - Wind_09	34.5	108	109	1	0.0114	0.0030	0.000107	13	0.029	0.014
9-10	642	1	UG-1/0-35	Wind_09 - Wind_10	34.5	109	110	1	0.0114	0.0030	0.000107	13	0.029	0.014
10-11	642	1	UG-1/0-35	Wind_10 - Wind_11	34.5	110	111	1	0.0114	0.0030	0.000107	13	0.029	0.014
12-B	642	3	UG-500-35	Wind_12 - Riser_A	34.5	112	10	1	0.0025	0.0023	0.000173	29	0.009	0.002
12-13	642	3	UG-500-35	Wind_12 - Wind_13	34.5	112	113	1	0.0025	0.0023	0.000173	29	0.009	0.002
13-14	642	2	UG-4/0-35	Wind_13 - Wind_14	34.5	113	114	1	0.0058	0.0026	0.000130	19	0.018	0.006
14-15	642	2	UG-4/0-35	Wind_14 - Wind_15	34.5	114	115	1	0.0058	0.0026	0.000130	19	0.018	0.006
15-16	642	1	UG-1/0-35	Wind_15 - Wind_16	34.5	115	116	1	0.0114	0.0030	0.000107	13	0.029	0.014
16-17	642	1	UG-1/0-35	Wind_16 - Wind_17	34.5	116	117	1	0.0114	0.0030	0.000107	13	0.029	0.014

Table B4.2
Distribution Cable and Overhead Line Characteristics
Plan B 2,500 - 35 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 34.50
Z Base= 11.903

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-35	1/0 Al	34.50	0.2120	0.0550	37	0.0178	0.0046	0.000166	212	0.545	0.267	0.046	0.022
2	UG-4/0-35	4/0 Al	34.50	0.1070	0.0490	45	0.0090	0.0041	0.000202	312	0.333	0.113	0.028	0.009
3	UG-500-35	500 Al	34.50	0.0470	0.0420	60	0.0039	0.0035	0.000269	490	0.158	0.044	0.013	0.004
4	OH-SC-795	795 ACSR		0.0242	0.1135	3.59	0.0020	0.0095	0.000016	907	0.126	0.529	0.011	0.044
5	OH-DC1-795	795 ACSR		0.0242	0.1056	3.86	0.0020	0.0089	0.000017	907	0.126	0.492	0.011	0.041
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0020	0.0089	0.000017	907	0.126	0.492	0.011	0.041

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
17-18	642	1	UG-1/0-35	Wind_17 - Wind_18	34.5	117	118	1	0.0114	0.0030	0.000107	13	0.029	0.014
18-19	642	1	UG-1/0-35	Wind_18 - Wind_19	34.5	118	119	1	0.0114	0.0030	0.000107	13	0.029	0.014
19-20	642	1	UG-1/0-35	Wind_19 - Wind_20	34.5	119	120	1	0.0114	0.0030	0.000107	13	0.029	0.014
A-B	4,100	4	OH-SC-795	Riser_A - Riser_B	34.5	10	15	1	0.0083	0.0391	0.000066	54	0.043	0.182
B-F	1,600	4	OH-SC-795	Riser_B - Mission_35	34.5	15	2	1	0.0033	0.0153	0.000026	54	0.017	0.071

Table B4.3
Transformer Characteristics
Plan B 2,500 - 35 kV
WindPACT Turbine Design Scaling Studies

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	**Voltage kV**	**MVA**	**Rating**	**Z%**	**X/R**	**R(pu)**	**X(pu)**
Station Transformer	115/34.5	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	34.50/.690	3	3	7.00%	9	0.2593	2.3333

		Rating	Tap	To	Ckt.	Imped. (Syst. Base)		
Transformer Name	**Voltage kV**	**MVA**	**No.**	**No.**	**Id.**	**R(pu)**	**X(pu)**	**Tap**
Mission_115 - Mission_35	115/13.8	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	34.50/.690	3	101	201	1	0.2593	2.3333	1.000
Wind_02 - Turbine_02	34.50/.690	3	102	202	1	0.2593	2.3333	1.000
Wind_03 - Turbine_03	34.50/.690	3	103	203	1	0.2593	2.3333	1.000
Wind_04 - Turbine_04	34.50/.690	3	104	204	1	0.2593	2.3333	1.000
Wind_05 - Turbine_05	34.50/.690	3	105	205	1	0.2593	2.3333	1.000
Wind_06 - Turbine_06	34.50/.690	3	106	206	1	0.2593	2.3333	1.000
Wind_07 - Turbine_07	34.50/.690	3	107	207	1	0.2593	2.3333	1.000
Wind_08 - Turbine_08	34.50/.690	3	108	208	1	0.2593	2.3333	1.000
Wind_09 - Turbine_09	34.50/.690	3	109	209	1	0.2593	2.3333	1.000
Wind_10 - Turbine_10	34.50/.690	3	110	210	1	0.2593	2.3333	1.000
Wind_11 - Turbine_11	34.50/.690	3	111	211	1	0.2593	2.3333	1.000
Wind_12 - Turbine_12	34.50/.690	3	112	212	1	0.2593	2.3333	1.000
Wind_13 - Turbine_13	34.50/.690	3	113	213	1	0.2593	2.3333	1.000
Wind_14 - Turbine_14	34.50/.690	3	114	214	1	0.2593	2.3333	1.000
Wind_15 - Turbine_15	34.50/.690	3	115	215	1	0.2593	2.3333	1.000
Wind_16 - Turbine_16	34.50/.690	3	116	216	1	0.2593	2.3333	1.000
Wind_17 - Turbine_17	34.50/.690	3	117	217	1	0.2593	2.3333	1.000
Wind_18 - Turbine_18	34.50/.690	3	118	218	1	0.2593	2.3333	1.000
Wind_19 - Turbine_19	34.50/.690	3	119	219	1	0.2593	2.3333	1.000
Wind_20 - Turbine_20	34.50/.690	3	120	220	1	0.2593	2.3333	1.000

Table B5.1
Bus Description and Generator Characteristics
Plan A 5,000 - 25 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			24.9			Power Flow Model				
		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_25	24.9					Load	0		
10	Riser_A	24.9					Load	0		
15	Riser_B	24.9					Load	0		
101	Wind_01	24.9					Load	0		
102	Wind_02	24.9					Load	0		
103	Wind_03	24.9					Load	0		
104	Wind_04	24.9					Load	0		
105	Wind_05	24.9					Load	0		
106	Wind_06	24.9					Load	0		
107	Wind_07	24.9					Load	0		
108	Wind_08	24.9					Load	0		
109	Wind_09	24.9					Load	0		
110	Wind_10	24.9					Load	0		

Table B5.1
Bus Description and Generator Characteristics
Plan A 5,000 - 25 kV
WindPACT Turbine Design Scaling Studies

	Machine Base							Data for Short Circuit Model		
			System Base =	100 MVA	Data for Power Flow Model			Machine Base	System Base	Isc
			pf =	-0.95	0.95					
	kVA	kV	Pgen	Qmax	Qmin	Vhold		X"d	X"d	Amps
Windmill Model	7500	2.4	5	1.643421	-1.643421	1.0000		0.107	1.4267	16,862
System Equivalent		115.00							0.0100	50,206

		Power Flow Model					Bus Type		SC Model	
Bus No.	Name	Base kV	Pgen MW	Qmax MVAR	Qmin MVAR	Vhold	BType	BT	X"d	B(pu)
201	Turbine_01	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
202	Turbine_02	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
203	Turbine_03	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
204	Turbine_04	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
205	Turbine_05	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
206	Turbine_06	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
207	Turbine_07	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
208	Turbine_08	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
209	Turbine_09	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
210	Turbine_10	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009

Table B5.2
Distribution Cable and Overhead Line Characteristics
Plan A 5,000 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 24.90
Z Base= 6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	0.00	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	0.00	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	0.00	0.0480	0.0400	86	0.0077	0.0065	0.000201	490	0.158	0.04	0.025	0.006
4	OH-SC-715	715 ACSR		0.0268	0.1146	3.55	0.0043	0.0185	0.000008	849	0.082	0.556	0.013	0.090
5	OH-SC-477	477 ACSR		0.0406	0.1214	3.37	0.0065	0.0196	0.000008	646	0.096	0.563	0.015	0.091
6	OH-SC-4/0	4/0 ACSR		0.1085	0.1426	3.14	0.0175	0.0230	0.000007	360	0.165	0.585	0.027	0.094
7	OH-SC-2/0	2/0 ACSR		0.1597	0.1496	3.01	0.0258	0.0241	0.000007	276	0.217	0.592	0.035	0.095

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	906	1	UG-1/0-25	Wind_01 - Wind_02	24.9	101	102	1	0.0310	0.0075	0.000110	9	0.080	0.038
2-3	906	2	UG-4/0-25	Wind_02 - Wind_03	24.9	102	103	1	0.0156	0.0067	0.000136	13	0.049	0.016
3-A	906	3	UG-500-25	Wind_03 - Riser_A	24.9	103	10	1	0.0070	0.0058	0.000182	21	0.023	0.006
4-A	906	3	UG-500-25	Wind_04 - Riser_A	24.9	104	10	1	0.0070	0.0058	0.000182	21	0.023	0.006
4-5	906	3	UG-500-25	Wind_04 - Wind_05	24.9	104	105	1	0.0070	0.0058	0.000182	21	0.023	0.006
5-6	906	2	UG-4/0-25	Wind_05 - Wind_06	24.9	105	106	1	0.0156	0.0067	0.000136	13	0.049	0.016
6-7	906	1	UG-1/0-25	Wind_06 - Wind_07	24.9	106	107	1	0.0310	0.0075	0.000110	9	0.080	0.038
8-B	906	3	UG-500-25	Wind_08 - Riser_B	24.9	108	15	1	0.0070	0.0058	0.000182	21	0.023	0.006
8-9	906	2	UG-4/0-25	Wind_08 - Wind_09	24.9	108	109	1	0.0156	0.0067	0.000136	13	0.049	0.016
9-10	906	1	UG-1/0-25	Wind_09 - Wind_10	24.9	109	110	1	0.0310	0.0075	0.000110	9	0.080	0.038
A-F	10,740	4	OH-SC-715	Riser_A - Mission_25	24.9	10	2	1	0.0465	0.1985	0.000089	37	0.142	0.963
B-F	3,970	6	OH-SC-4/0	Riser_B - Mission_25	24.9	15	2	1	0.0695	0.0913	0.000029	16	0.106	0.375

Table B5.3
Transformer Characteristics
Plan A 5,000 - 25 kV
WindPACT Turbine Design Scaling Studies

	Transformer Characteristics					Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	Voltage kV	MVA	Rating	Z%	X/R	R(pu)	X(pu)
Station Transformer	115/24.9	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	24.90/2.40	7.5	7.5	5.75%	9	0.0852	0.7667

		Rating	Tap	To	Ckt.	Imped. (Syst. Base)		
Transformer Name	Voltage kV	MVA	No.	No.	Id.	R(pu)	X(pu)	Tap
Mission_115 - Mission_25	115/24.9	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	24.90/2.40	7.5	101	201	1	0.0852	0.7667	1.000
Wind_02 - Turbine_02	24.90/2.40	7.5	102	202	1	0.0852	0.7667	1.000
Wind_03 - Turbine_03	24.90/2.40	7.5	103	203	1	0.0852	0.7667	1.000
Wind_04 - Turbine_04	24.90/2.40	7.5	104	204	1	0.0852	0.7667	1.000
Wind_05 - Turbine_05	24.90/2.40	7.5	105	205	1	0.0852	0.7667	1.000
Wind_06 - Turbine_06	24.90/2.40	7.5	106	206	1	0.0852	0.7667	1.000
Wind_07 - Turbine_07	24.90/2.40	7.5	107	207	1	0.0852	0.7667	1.000
Wind_08 - Turbine_08	24.90/2.40	7.5	108	208	1	0.0852	0.7667	1.000
Wind_09 - Turbine_09	24.90/2.40	7.5	109	209	1	0.0852	0.7667	1.000
Wind_10 - Turbine_10	24.90/2.40	7.5	110	210	1	0.0852	0.7667	1.000

Table B6.1
Bus Description and Generator Characteristics
Plan A 5,000 - 35 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage =			34.5			Power Flow Model				
		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	**Name**	**kV**	**MW**	**MVAR**	**MVAR**	**Vhold**	**BType**	**BT**	**X"d**	**B(pu)**
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_35	34.5					Load	0		
10	Riser_A	34.5					Load	0		
15	Riser_B	34.5					Load	0		
101	Wind_01	34.5					Load	0		
102	Wind_02	34.5					Load	0		
103	Wind_03	34.5					Load	0		
104	Wind_04	34.5					Load	0		
105	Wind_05	34.5					Load	0		
106	Wind_06	34.5					Load	0		
107	Wind_07	34.5					Load	0		
108	Wind_08	34.5					Load	0		
109	Wind_09	34.5					Load	0		
110	Wind_10	34.5					Load	0		

Table B6.1
Bus Description and Generator Characteristics
Plan A 5,000 - 35 kV
WindPACT Turbine Design Scaling Studies

			System Base =	100 MVA			Data for Short Circuit Model			
				Data for Power Flow Model						
	Machine Base		pf =	-0.95	0.95		Machine Base	System Base	Isc
	kVA	kV	Pgen	Qmax	Qmin	Vhold	X"d	X"d	Amps
Windmill Model	7500	2.4	5	1.643421	-1.643421	1.0000	0.107	1.4267	16,862
System Equivalent		115.00						0.0100	50,206

Power Flow Model

Bus No.	Name	Base kV	Pgen MW	Qmax MVAR	Qmin MVAR	Vhold	Bus Type BType	BT	SC Model X"d	B(pu)
201	Turbine_01	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
202	Turbine_02	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
203	Turbine_03	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
204	Turbine_04	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
205	Turbine_05	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
206	Turbine_06	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
207	Turbine_07	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
208	Turbine_08	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
209	Turbine_09	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009
210	Turbine_10	2.4	5	1.64342	-1.643421	1.0000	V-Control	2	1.4267	0.7009

Table B6.2
Distribution Cable and Overhead Line Characteristics
Plan A 5,000 - 35 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 34.50
Z Base= 11.903

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	34.50	0.2120	0.0550	52	0.0178	0.0046	0.000233	212	0.545	0.267	0.046	0.022
2	UG-4/0-25	4/0 Al	34.50	0.1070	0.0490	64	0.0090	0.0041	0.000287	312	0.333	0.113	0.028	0.009
3	UG-500-25	500 Al	34.50	0.0480	0.0400	86	0.0040	0.0034	0.000386	490	0.158	0.044	0.013	0.004
4	OH-SC-715	715 ACSR		0.0268	0.1146	3.55	0.0023	0.0096	0.000016	849	0.082	0.556	0.007	0.047
5	OH-SC-477	477 ACSR		0.0406	0.1214	3.37	0.0034	0.0102	0.000015	646	0.096	0.563	0.008	0.047
6	OH-SC-2/0	2/0 ACSR		0.1597	0.1496	3.01	0.0134	0.0126	0.000014	276	0.217	0.592	0.018	0.050

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	906	1	UG-1/0-25	Wind_01 - Wind_02	34.5	101	102	1	0.0161	0.0042	0.000211	13	0.041	0.020
2-3	906	1	UG-1/0-25	Wind_02 - Wind_03	34.5	102	103	1	0.0161	0.0042	0.000211	13	0.041	0.020
3-A	906	2	UG-4/0-25	Wind_03 - Riser_A	34.5	103	10	1	0.0081	0.0037	0.000260	19	0.025	0.009
4-A	906	3	UG-500-25	Wind_04 - Riser_A	34.5	104	10	1	0.0037	0.0030	0.000350	29	0.012	0.003
4-5	906	2	UG-4/0-25	Wind_04 - Wind_05	34.5	104	105	1	0.0081	0.0037	0.000260	19	0.025	0.009
5-6	906	1	UG-1/0-25	Wind_05 - Wind_06	34.5	105	106	1	0.0161	0.0042	0.000211	13	0.041	0.020
6-7	906	1	UG-1/0-25	Wind_06 - Wind_07	34.5	106	107	1	0.0161	0.0042	0.000211	13	0.041	0.020
8-B	906	2	UG-4/0-25	Wind_08 - Riser_B	34.5	108	15	1	0.0081	0.0037	0.000260	19	0.025	0.009
8-9	906	1	UG-1/0-25	Wind_08 - Wind_09	34.5	108	109	1	0.0161	0.0042	0.000211	13	0.041	0.020
9-10	906	1	UG-1/0-25	Wind_09 - Wind_10	34.5	109	110	1	0.0161	0.0042	0.000211	13	0.041	0.020
A-F	10,740	5	OH-SC-477	Riser_A - Mission_35	34.5	10	2	1	0.0366	0.1096	0.000162	39	0.087	0.508
B-F	3,970	6	OH-SC-2/0	Riser_B - Mission_35	34.5	15	2	1	0.0533	0.0499	0.000054	16	0.072	0.197

Table B6.3
Transformer Characteristics
Plan A 5,000 - 35 kV
WindPACT Turbine Design Scaling Studies

Transformer	Voltage kV	Base MVA	Top Rating	Z%	X/R	Transf. Model Data (System Base MVA= 100) Imped. (Syst. Base) R(pu)	X(pu)
Station Transformer	115/34.5	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	34.50/2.40	7.5	7.5	5.75%	9	0.0852	0.7667

Transformer Name	Voltage kV	Rating MVA	Tap No.	To No.	Ckt. Id.	Imped. (Syst. Base) R(pu)	X(pu)	Tap
Mission_115 - Mission_35	115/34.5	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	34.50/2.40	7.5	101	201	1	0.0852	0.7667	1.000
Wind_02 - Turbine_02	34.50/2.40	7.5	102	202	1	0.0852	0.7667	1.000
Wind_03 - Turbine_03	34.50/2.40	7.5	103	203	1	0.0852	0.7667	1.000
Wind_04 - Turbine_04	34.50/2.40	7.5	104	204	1	0.0852	0.7667	1.000
Wind_05 - Turbine_05	34.50/2.40	7.5	105	205	1	0.0852	0.7667	1.000
Wind_06 - Turbine_06	34.50/2.40	7.5	106	206	1	0.0852	0.7667	1.000
Wind_07 - Turbine_07	34.50/2.40	7.5	107	207	1	0.0852	0.7667	1.000
Wind_08 - Turbine_08	34.50/2.40	7.5	108	208	1	0.0852	0.7667	1.000
Wind_09 - Turbine_09	34.50/2.40	7.5	109	209	1	0.0852	0.7667	1.000
Wind_10 - Turbine_10	34.50/2.40	7.5	110	210	1	0.0852	0.7667	1.000

Table B7.1
Plan A 10,000 - 25 kV
Bus Description and Generator Characteristics
WindPACT Turbine Design Scaling Studies

Collector System Voltage = 24.9

						Power Flow Model				
		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_25	24.9					Load	0		
10	Riser_A	24.9					Load	0		
101	Wind_01	24.9					Load	0		
102	Wind_02	24.9					Load	0		
103	Wind_03	24.9					Load	0		
104	Wind_04	24.9					Load	0		
105	Wind_05	24.9					Load	0		

System Base = 100 **MVA**

	Data for Power Flow Model						Data for Short Circuit Model		
	Machine Base		pf =	-0.95	0.95		Machine Base	System Base	Isc
	kVA	kV	Pgen	Qmax	Qmin	Vhold	X"d	X"d	Amps
Windmill Model	11111	4.16	10	3.286841	-3.286841	1.0000	0.107	0.9630	14,412
System Equivalent		115.00						0.0100	50,206

				Power Flow Model						
		Base	Pgen	Qmax	Qmin		Bus Type		SC Model	
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
201	Turbine_01	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
202	Turbine_02	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
203	Turbine_03	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
204	Turbine_04	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
205	Turbine_05	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384

Table B7.2
Distribution Cable and Overhead Line Characteristics
Plan A 10,000 - 25 kV
WindPACT Turbine Design Scaling Studies

Base MVA=	100
Volt Base=	24.90
Z Base=	6.200

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-25	1/0 Al	24.90	0.2120	0.0510	52	0.0342	0.0082	0.000122	212	0.549	0.263	0.089	0.042
2	UG-4/0-25	4/0 Al	24.90	0.1070	0.0460	64	0.0173	0.0074	0.000150	312	0.334	0.11	0.054	0.018
3	UG-500-25	500 Al	24.90	0.0480	0.0400	86	0.0077	0.0065	0.000201	490	0.158	0.04	0.025	0.006
4	OH-SC-795	795 ACSR		0.0242	0.1135	3.59	0.0039	0.0183	0.000008	907	0.126	0.529	0.020	0.085
5	OH-DC1-795	795 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	907	0.126	0.492	0.020	0.079
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0039	0.0170	0.000009	907	0.126	0.492	0.020	0.079

Map Code = 2

Sec Id	Dist. feet		Construction Type	Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	1,283	2	UG-4/0-25	Wind_01 - Wind_02	24.9	101	102	1	0.0221	0.0095	0.000156	13	0.069	0.023
2-A	1,283	3	UG-500-25	Wind_02 - Riser_A	24.9	102	10	1	0.0099	0.0083	0.000156	21	0.033	0.008
3-A	800	2	UG-4/0-25	Wind_03 - Riser_A	24.9	103	10	1	0.0138	0.0059	0.000097	13	0.043	0.014
4-A	1,500	3	UG-500-25	Wind_04 - Riser_A	24.9	104	10	1	0.0116	0.0097	0.000182	21	0.038	0.010
4-5	1,283	2	UG-4/0-25	Wind_04 - Wind_05	24.9	104	105	1	0.0221	0.0095	0.000156	13	0.069	0.023
A-F	4,500	4	OH-SC-795	Riser_A - Mission_25	24.9	10	2	1	0.0176	0.0824	0.000038	39	0.091	0.384

Table B7.3
Transformer Characteristics
Plan A 10,000 - 25
WindPACT Turbine Scaling Studies

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	**Voltage kV**	**MVA**	**Rating**	**Z%**	**X/R**	**R(pu)**	**X(pu)**
Station Transformer	115/24.9	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	24.90/4.160	11.1	11.1	6.50%	9	0.0651	0.5856

Transformer Name	Voltage kV	Rating MVA	Tap No.	To No.	Ckt. Id.	Imped. (Syst. Base) R(pu)	Imped. (Syst. Base) X(pu)	Tap
Mission_115 - Mission_25	115/24.9	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	24.90/4.160	11.1	101	201	1	0.0651	0.5856	1.000
Wind_02 - Turbine_02	24.90/4.160	11.1	102	202	1	0.0651	0.5856	1.000
Wind_03 - Turbine_03	24.90/4.160	11.1	103	203	1	0.0651	0.5856	1.000
Wind_04 - Turbine_04	24.90/4.160	11.1	104	204	1	0.0651	0.5856	1.000
Wind_05 - Turbine_05	24.90/4.160	11.1	105	205	1	0.0651	0.5856	1.000

Table B8.1
Bus Description and Generator Characteristics
Plan B 10,000 - 35 kV
WindPACT Turbine Design Scaling Studies

Collector System Voltage = 34.5

					Power Flow Model				SC Model	
		Base	Pgen	Qmax	Qmin		Bus Type			
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
1	Mission_115	115.00				1.0000	Reference	3	0.0100	100.0000
2	Mission_35	34.5					Load	0		
10	Riser_A	34.5					Load	0		
101	Wind_01	34.5					Load	0		
102	Wind_02	34.5					Load	0		
103	Wind_03	34.5					Load	0		
104	Wind_04	34.5					Load	0		
105	Wind_05	34.5					Load	0		

System Base = 100 **MVA**

				Data for Power Flow Model			Data for Short Circuit Model		
							Machine	System	
	Machine Base		pf =	-0.95	0.95		Base	Base	Isc
	kVA	kV	Pgen	Qmax	Qmin	Vhold	X"d	X"d	Amps
Windmill Model	11111	4.16	10	3.286841	-3.286841	1.0000	0.107	0.9630	14,412
System Equivalent		115.00						0.0100	50,206

				Power Flow Model					SC Model	
		Base	Pgen	Qmax	Qmin		Bus Type			
Bus No.	Name	kV	MW	MVAR	MVAR	Vhold	BType	BT	X"d	B(pu)
201	Turbine_01	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
202	Turbine_02	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
203	Turbine_03	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
204	Turbine_04	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384
205	Turbine_05	4.16	10	3.28684	-3.286841	1.0000	V-Control	2	0.9630	1.0384

Table B8.2
Distribution Cable and Overhead Line Characteristics
Plan B 10,000 - 35 kV
WindPACT Turbine Design Scaling Studies

Base MVA= 100
Volt Base= 34.50
Z Base= 11.903

	Construction Type	Conductor Size AWG or kcmil	Rated kV	ohms/1000 ft. R	ohms/1000 ft. X	pf/ft	PU/1000 ft. R	PU/1000 ft. X	PU/1000 ft. B	Rating Amps	ohms/1000 ft. R0	ohms/1000 ft. X0	PU/1000 ft. R0	PU/1000 ft. X0
1	UG-1/0-35	1/0 Al	34.50	0.2120	0.0550	37	0.0178	0.0046	0.000166	212	0.545	0.267	0.046	0.022
2	UG-4/0-35	4/0 Al	34.50	0.1070	0.0490	45	0.0090	0.0041	0.000202	312	0.333	0.113	0.028	0.009
3	UG-500-35	500 Al	34.50	0.0470	0.0420	60	0.0039	0.0035	0.000269	490	0.158	0.044	0.013	0.004
4	OH-SC-795	795 ACSR		0.0242	0.1135	3.59	0.0020	0.0095	0.000016	907	0.126	0.529	0.011	0.044
5	OH-DC1-795	795 ACSR		0.0242	0.1056	3.86	0.0020	0.0089	0.000017	907	0.126	0.492	0.011	0.041
6	OH-DC2-795	796 ACSR		0.0242	0.1056	3.86	0.0020	0.0089	0.000017	907	0.126	0.492	0.011	0.041

Map Code = 2

Sec Id	Dist. feet	Construction Type		Section Name	Voltage kV	From No.	To No.	Ckt. No.	Section Impedance Rpu	Section Impedance Xpu	Section Impedance Bpu	Rating MVA	Per Unit R0	Per Unit X0
1-2	1,283	1	UG-1/0-35	Wind_01 - Wind_02	34.5	101	102	1	0.0229	0.0059	0.000213	13	0.059	0.029
2-A	1,283	3	UG-500-35	Wind_02 - Riser_A	34.5	102	10	1	0.0051	0.0045	0.000213	29	0.017	0.005
3-A	800	1	UG-1/0-35	Wind_03 - Riser_A	34.5	103	10	1	0.0142	0.0037	0.000133	13	0.037	0.018
4-A	1,500	3	UG-500-35	Wind_04 - Riser_A	34.5	104	10	1	0.0059	0.0053	0.000249	29	0.020	0.006
4-5	1,283	1	UG-1/0-35	Wind_04 - Wind_05	34.5	104	105	1	0.0229	0.0059	0.000213	13	0.059	0.029
A-F	4,500	4	OH-SC-795	Riser_A - Mission_35	34.5	10	2	1	0.0091	0.0429	0.000072	54	0.048	0.200

Table B8.3
Transformer Characteristics
Plan B 10,000 - 35 kV
WindPACT Turbine Scaling Studies

Transformer Characteristics						Transf. Model Data	
					System Base MVA=		100
		Base	Top			Imped. (Syst. Base)	
Transformer	**Voltage kV**	**MVA**	**Rating**	**Z%**	**X/R**	**R(pu)**	**X(pu)**
Station Transformer	115/34.5	30	50	8.5%	19	0.0149	0.2833
Wind Mill Transformer	34.50/4.160	11.1	11.1	7.00%	9	0.0701	0.6306

		Rating	Tap	To	Ckt.	Imped. (Syst. Base)		
Transformer Name	**Voltage kV**	**MVA**	**No.**	**No.**	**Id.**	**R(pu)**	**X(pu)**	**Tap**
Mission_115 - Mission_35	115/34.5	50	1	2	1	0.0149	0.2833	1.000
Wind_01 - Turbine_01	34.50/4.160	11.1	101	201	1	0.0701	0.6306	1.000
Wind_02 - Turbine_02	34.50/4.160	11.1	102	202	1	0.0701	0.6306	1.000
Wind_03 - Turbine_03	34.50/4.160	11.1	103	203	1	0.0701	0.6306	1.000
Wind_04 - Turbine_04	34.50/4.160	11.1	104	204	1	0.0701	0.6306	1.000
Wind_05 - Turbine_05	34.50/4.160	11.1	105	205	1	0.0701	0.6306	1.000

APPENDIX C
POWER FLOW STUDY RESULTS

APPENDIX C
POWER FLOW STUDY RESULTS

The power flow analysis provides the following calculations:

1. Computes the power flow on each cable, overhead line, and transformer and compares it with the ratings of these facilities.

2. Computes the voltage drop across the system.

3. Computes the watt and VAR losses.

To evaluate ratings and voltage drop, the power flow analysis is typically made for peak generating conditions.

The power flow analysis in this report evaluated only the collector system. Therefore, the utility 115-kV connection was assumed to be an infinite bus with constant 100% voltage. A separate power flow study would be required to evaluate the impact of the wind farm on the utility 115-kV transmission system. CAI made a quick review of the 115-kV line serving Mission and also reviewed a report prepared by WAPA. The 115-kV line is capable of accepting the 50-MW generation.

Based on an infinite bus at the utility connection, the voltage drop across the proposed 13.8-kV collector system for the 750-kW plan is only 1.6% at peak generation. This system demonstrates good voltage regulation and indicates that other voltage regulating equipment, such as load-tap-changing (LTC) transformers or voltage regulators, is not required. For the remaining plans, the voltage drop across the 34.5- and 24.9-kV systems is less than 1.5%. The addition of generation (MW and MVAR) to the utility 115-kV system will impact voltage regulation on the utility 115-kV bus. The proposed system includes capacitive compensation to provide the generation to the utility at unity power factor.

For the 750-kW plan at 13.8 kV, losses at peak generation of 49.5 MW are 1.4 MW, or 2.9% of generation. These are the I^2R losses on the collector system. Thus, the power delivered to the utility 115-kV bus is approximately 48.1 MW. At 24.9 kV, losses are 1.20 MW, or 2.4%. Approximately 48.3 MW is delivered. Table C1 summarizes the power delivery for the remaining plans. No analysis has been made with regard to economic optimization of the collector system for losses. This can be done as an additional design effort. We do not expect it would have a significant impact on the costs.

The power flow studies were conducted on the basis of holding one-per-unit voltage at the generators, assuming that each wind generator can regulate VARs between lagging and leading 95% power factor. The power flow calculation confirmed that this was a valid assumption.

With each generator providing VARs to regulate its own terminal voltage, the overall collector system VAR requirement was determined. At full generation, the VAR losses on the collector system were approximately 10 MVAR. Thus, as the wind generation varies from 0 MW to 50 MW, the VAR losses on the collector system vary from 0 to 10 MVAR. If this were not corrected, it would be supplied by the utility. A fluctuating VAR load of 0 to 10 MVAR may cause voltage-regulating problems on the utility 115-kV system. We assumed that the utility would require that the net generation to the utility be near unity power factor. We believe the best method for meeting this requirement would be to install a power electronically switched capacitor bank. We included the cost for this device in our substation cost estimate.

Notwithstanding the need to further optimize the design, the studies demonstrate that a 15-kV class collector system is a viable concept for a wind farm comprising 750-kW generators. However, based on the cost estimates we assembled, a 25-kV system will cost less than a 15-kV system. Furthermore, as can be seen from Table E1 in Appendix E, for the remaining turbine sizes, the 25-kV plans were determined to be less costly than the 35-kV plans.

Table C1
WindPACT Turbine Design Scaling Studies
Plan Comparisons

Plant Sizes		Generation System			System Losses		Power Delivered @ 115 kV		
kW	**kV**	**MW**	**MVar**	**pf**	**Loss(MW)**	**MVar**	**MW**	**MVar**	**pf**
750	15	49.50	-0.41	100.0%	1.41	11.01	48.09	-11.42	97.3%
	25	49.50	-1.70	99.9%	1.20	9.06	48.30	-10.76	97.6%
2500	25	50.00	0.01	100.0%	1.15	10.54	48.86	-10.53	97.8%
	35	50.00	0.48	100.0%	1.17	11.19	48.83	-10.71	97.7%
5000	25	50.00	2.02	99.9%	1.46	13.99	48.54	-11.97	97.1%
	35	50.00	-0.89	100.0%	1.29	10.25	48.72	-11.14	97.5%
10000	25	50.00	0.83	100.0%	1.28	12.09	48.72	-11.26	97.4%
	35	50.00	1.01	100.0%	1.06	11.26	48.94	-10.25	97.9%

Table C2.1
Mission Wind Farm - 750 kW / 15 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

Bus		Base	Voltage	Generation	
Number	Name	kV	P.U.	P(MW)	Q(MVAr)
1	Mission_115	115	1.0000	-48.087	11.4232
201	Turbine_01	0.48	1.0000	0.75	-0.1062
202	Turbine_02	0.48	1.0000	0.75	-0.1010
203	Turbine_03	0.48	1.0000	0.75	-0.0906
204	Turbine_04	0.48	1.0000	0.75	-0.0750
205	Turbine_05	0.48	1.0000	0.75	-0.0542
206	Turbine_06	0.48	1.0000	0.75	-0.0280
207	Turbine_07	0.48	1.0000	0.75	-0.0126
208	Turbine_08	0.48	1.0000	0.75	0.0056
209	Turbine_09	0.48	1.0000	0.75	0.0264
210	Turbine_10	0.48	1.0000	0.75	0.0500
211	Turbine_11	0.48	1.0000	0.75	0.0614
212	Turbine_12	0.48	1.0000	0.75	0.0606
213	Turbine_13	0.48	1.0000	0.75	0.0485
214	Turbine_14	0.48	1.0000	0.75	0.0227
215	Turbine_15	0.48	1.0000	0.75	-0.0003
216	Turbine_16	0.48	1.0000	0.75	-0.0207
217	Turbine_17	0.48	1.0000	0.75	-0.0384
218	Turbine_18	0.48	1.0000	0.75	-0.0693
219	Turbine_19	0.48	1.0000	0.75	-0.0951
220	Turbine_20	0.48	1.0000	0.75	-0.1156
221	Turbine_21	0.48	1.0000	0.75	-0.1309
222	Turbine_22	0.48	1.0000	0.75	-0.1411
223	Turbine_23	0.48	1.0000	0.75	-0.1463
224	Turbine_24	0.48	1.0000	0.75	0.0166
225	Turbine_25	0.48	1.0000	0.75	0.0220
226	Turbine_26	0.48	1.0000	0.75	0.0329
227	Turbine_27	0.48	1.0000	0.75	0.0492
228	Turbine_28	0.48	1.0000	0.75	0.0710
229	Turbine_29	0.48	1.0000	0.75	0.0984
230	Turbine_30	0.48	1.0000	0.75	0.1055
231	Turbine_31	0.48	1.0000	0.75	0.0882
232	Turbine_32	0.48	1.0000	0.75	0.0723
233	Turbine_33	0.48	1.0000	0.75	0.0577
234	Turbine_34	0.48	1.0000	0.75	0.0443
235	Turbine_35	0.48	1.0000	0.75	0.0322
236	Turbine_36	0.48	1.0000	0.75	0.0213
237	Turbine_37	0.48	1.0000	0.75	-0.0017
238	Turbine_38	0.48	1.0000	0.75	-0.0221
239	Turbine_39	0.48	1.0000	0.75	-0.0398
240	Turbine_40	0.48	1.0000	0.75	-0.0707
241	Turbine_41	0.48	1.0000	0.75	-0.0964
242	Turbine_42	0.48	1.0000	0.75	-0.1169
243	Turbine_43	0.48	1.0000	0.75	-0.1323
244	Turbine_44	0.48	1.0000	0.75	-0.1425

Table C2.1
Mission Wind Farm - 750 kW / 15 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

Bus		Base	Voltage	Generation		
Number	Name	kV	P.U.	P(MW)	Q(MVAr)	
245	Turbine_45	0.48	1.0000	0.75	-0.1476	
246	Turbine_46	0.48	1.0000	0.75	0.1386	
247	Turbine_47	0.48	1.0000	0.75	0.1443	
248	Turbine_48	0.48	1.0000	0.75	0.1556	
249	Turbine_49	0.48	1.0000	0.75	0.1472	
250	Turbine_50	0.48	1.0000	0.75	0.1331	
251	Turbine_51	0.48	1.0000	0.75	0.1199	
252	Turbine_52	0.48	1.0000	0.75	0.1077	
253	Turbine_53	0.48	1.0000	0.75	0.0916	
254	Turbine_54	0.48	1.0000	0.75	0.0767	
255	Turbine_55	0.48	1.0000	0.75	0.0631	
256	Turbine_56	0.48	1.0000	0.75	0.0508	
257	Turbine_57	0.48	1.0000	0.75	0.0287	
258	Turbine_58	0.48	1.0000	0.75	0.0055	
259	Turbine_59	0.48	1.0000	0.75	-0.0151	
260	Turbine_60	0.48	1.0000	0.75	-0.0329	
261	Turbine_61	0.48	1.0000	0.75	-0.0481	
262	Turbine_62	0.48	1.0000	0.75	-0.0739	
263	Turbine_63	0.48	1.0000	0.75	-0.0945	
264	Turbine_64	0.48	1.0000	0.75	-0.1253	
265	Turbine_65	0.48	1.0000	0.75	-0.1356	
266	Turbine_66	0.48	1.0000	0.75	-0.1407	
				49.50	-0.4120	Total Wind Generation
				1.41	11.01	Total Losses
2	Mission_13.8	13.8	0.9845			
10	Riser_A	13.8	0.9919			
15	Riser_B	13.8	0.9895			
20	Riser_C	13.8	0.9890			
25	Riser_D	13.8	0.9862			
30	Riser_E	13.8	0.9868			
101	Wind_01	13.8	1.0023			
102	Wind_02	13.8	1.0020			
103	Wind_03	13.8	1.0014			
104	Wind_04	13.8	1.0005			
105	Wind_05	13.8	0.9993			
106	Wind_06	13.8	0.9978			
107	Wind_07	13.8	0.9969			
108	Wind_08	13.8	0.9958			
109	Wind_09	13.8	0.9946			
110	Wind_10	13.8	0.9933			
111	Wind_11	13.8	0.9926			
112	Wind_12	13.8	0.9926			
113	Wind_13	13.8	0.9933			
114	Wind_14	13.8	0.9948			
115	Wind_15	13.8	0.9962			
116	Wind_16	13.8	0.9973			
117	Wind_17	13.8	0.9984			
118	Wind_18	13.8	1.0001			

Table C2.1
Mission Wind Farm - 750 kW / 15 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

Bus		Base	Voltage	Generation	
Number	Name	kV	P.U.	P(MW)	Q(MVAr)
119	Wind_19	13.8	1.0016		
120	Wind_20	13.8	1.0028		
121	Wind_21	13.8	1.0037		
122	Wind_22	13.8	1.0043		
123	Wind_23	13.8	1.0046		
124	Wind_24	13.8	0.9952		
125	Wind_25	13.8	0.9949		
126	Wind_26	13.8	0.9942		
127	Wind_27	13.8	0.9933		
128	Wind_28	13.8	0.9920		
129	Wind_29	13.8	0.9905		
130	Wind_30	13.8	0.9901		
131	Wind_31	13.8	0.9910		
132	Wind_32	13.8	0.9920		
133	Wind_33	13.8	0.9928		
134	Wind_34	13.8	0.9936		
135	Wind_35	13.8	0.9943		
136	Wind_36	13.8	0.9949		
137	Wind_37	13.8	0.9962		
138	Wind_38	13.8	0.9974		
139	Wind_39	13.8	0.9984		
140	Wind_40	13.8	1.0002		
141	Wind_41	13.8	1.0017		
142	Wind_42	13.8	1.0029		
143	Wind_43	13.8	1.0038		
144	Wind_44	13.8	1.0044		
145	Wind_45	13.8	1.0047		
146	Wind_46	13.8	0.9881		
147	Wind_47	13.8	0.9878		
148	Wind_48	13.8	0.9872		
149	Wind_49	13.8	0.9876		
150	Wind_50	13.8	0.9885		
151	Wind_51	13.8	0.9892		
152	Wind_52	13.8	0.9899		
153	Wind_53	13.8	0.9909		
154	Wind_54	13.8	0.9917		
155	Wind_55	13.8	0.9925		
156	Wind_56	13.8	0.9932		
157	Wind_57	13.8	0.9945		
158	Wind_58	13.8	0.9958		
159	Wind_59	13.8	0.9970		
160	Wind_60	13.8	0.9980		
161	Wind_61	13.8	0.9989		
162	Wind_62	13.8	1.0004		
163	Wind_63	13.8	1.0016		
164	Wind_64	13.8	1.0034		
165	Wind_65	13.8	1.0040		
166	Wind_66	13.8	1.0043		

Table C2.2
Mission Wind Farm - 750 kW / 15 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
130 Wind_30	20 Riser_C	1	12.07	-0.78	12.09	511	12	100.8
1 Mission_115	2 Mission_13.8	1	-48.09	11.43	49.43	2068	50	98.9
149 Wind_49	150 Wind_50	1	-13.25	0.03	13.25	561	14	94.7
113 Wind_13	114 Wind_14	1	-7.48	1.07	7.55	318	8	94.4
30 Riser_E	2 Mission_13.8	1	25.10	-1.47	25.15	1066	27	93.1
139 Wind_39	140 Wind_40	1	-4.50	0.93	4.60	192	5	91.9
149 Wind_49	30 Riser_E	1	12.77	-1.00	12.81	543	14	91.5
131 Wind_31	132 Wind_32	1	-10.92	0.62	10.94	461	12	91.1
152 Wind_52	153 Wind_53	1	-10.82	0.50	10.83	457	12	90.2
130 Wind_30	131 Wind_31	1	-10.51	1.46	10.61	448	12	88.4
25 Riser_D	2 Mission_13.8	1	23.52	-2.20	23.62	1002	27	87.5
114 Wind_14	115 Wind_15	1	-6.94	0.89	7.00	294	8	87.5
117 Wind_17	118 Wind_18	1	-4.27	0.95	4.37	183	5	87.4
136 Wind_36	137 Wind_37	1	-6.56	1.12	6.66	280	8	83.2
157 Wind_57	158 Wind_58	1	-6.51	0.98	6.58	276	8	82.2
150 Wind_50	151 Wind_51	1	-11.33	1.01	11.38	481	14	81.3
109 Wind_09	110 Wind_10	1	6.44	-0.83	6.49	273	8	81.2
15 Riser_B	25 Riser_D	1	21.42	-2.04	21.51	910	27	79.7
151 Wind_51	152 Wind_52	1	-11.09	0.77	11.12	470	14	79.4
132 Wind_32	133 Wind_33	1	-9.36	1.29	9.45	398	12	78.7
153 Wind_53	154 Wind_54	1	-9.26	1.17	9.33	394	12	77.8
118 Wind_18	119 Wind_19	1	-3.76	0.82	3.85	161	5	77
145 Wind_45	245 Turbine_45	1	-0.75	0.18	0.77	920	1	76.8
123 Wind_23	223 Turbine_23	1	-0.75	0.18	0.77	919	1	76.8
137 Wind_37	138 Wind_38	1	-6.06	1.01	6.14	258	8	76.7
140 Wind_40	141 Wind_41	1	-3.76	0.78	3.84	160	5	76.7
144 Wind_44	244 Turbine_44	1	-0.75	0.18	0.77	918	1	76.7
122 Wind_22	222 Turbine_22	1	-0.75	0.17	0.77	918	1	76.7
166 Wind_66	266 Turbine_66	1	-0.75	0.17	0.77	918	1	76.7
148 Wind_48	248 Turbine_48	1	-0.75	-0.15	0.77	921	1	76.6
165 Wind_65	265 Turbine_65	1	-0.75	0.17	0.77	917	1	76.5
149 Wind_49	249 Turbine_49	1	-0.75	-0.15	0.76	920	1	76.5
121 Wind_21	221 Turbine_21	1	-0.75	0.16	0.76	916	1	76.4
143 Wind_43	243 Turbine_43	1	-0.75	0.17	0.76	916	1	76.4
147 Wind_47	247 Turbine_47	1	-0.75	-0.14	0.76	919	1	76.4
164 Wind_64	264 Turbine_64	1	-0.75	0.16	0.76	915	1	76.3
146 Wind_46	246 Turbine_46	1	-0.75	-0.14	0.76	918	1	76.3
158 Wind_58	159 Wind_59	1	-6.02	0.93	6.10	256	8	76.2
142 Wind_42	242 Turbine_42	1	-0.75	0.15	0.76	913	1	76.2
150 Wind_50	250 Turbine_50	1	-0.75	-0.13	0.76	916	1	76.1
120 Wind_20	220 Turbine_20	1	-0.75	0.15	0.76	913	1	76.1
151 Wind_51	251 Turbine_51	1	-0.75	-0.12	0.76	914	1	76
161 Wind_61	162 Wind_62	1	-3.73	0.69	3.80	159	5	75.9
101 Wind_01	201 Turbine_01	1	-0.75	0.14	0.76	911	1	75.9
102 Wind_02	202 Turbine_02	1	-0.75	0.13	0.76	910	1	75.8
152 Wind_52	252 Turbine_52	1	-0.75	-0.11	0.76	911	1	75.8
141 Wind_41	241 Turbine_41	1	-0.75	0.13	0.76	910	1	75.8

Table C2.2
Mission Wind Farm - 750 kW / 15 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
130 Wind_30	230 Turbine_30	1	-0.75	-0.10	0.76	911	1	75.7
163 Wind_63	263 Turbine_63	1	-0.75	0.13	0.76	909	1	75.7
119 Wind_19	219 Turbine_19	1	-0.75	0.13	0.76	909	1	75.7
103 Wind_03	203 Turbine_03	1	-0.75	0.12	0.76	909	1	75.7
129 Wind_29	229 Turbine_29	1	-0.75	-0.10	0.76	910	1	75.6
153 Wind_53	253 Turbine_53	1	-0.75	-0.09	0.76	909	1	75.6
133 Wind_33	134 Wind_34	1	-9.02	0.85	9.06	381	12	75.5
131 Wind_31	231 Turbine_31	1	-0.75	-0.09	0.76	908	1	75.5
154 Wind_54	155 Wind_55	1	-9.00	0.84	9.04	381	12	75.4
162 Wind_62	262 Turbine_62	1	-0.75	0.11	0.75	907	1	75.4
154 Wind_54	254 Turbine_54	1	-0.75	-0.08	0.75	907	1	75.4
104 Wind_04	204 Turbine_04	1	-0.75	0.11	0.75	906	1	75.4
128 Wind_28	228 Turbine_28	1	-0.75	-0.07	0.75	907	1	75.4
140 Wind_40	240 Turbine_40	1	-0.75	0.10	0.75	906	1	75.3
132 Wind_32	232 Turbine_32	1	-0.75	-0.07	0.75	906	1	75.3
118 Wind_18	218 Turbine_18	1	-0.75	0.10	0.75	906	1	75.3
112 Wind_12	212 Turbine_12	1	-0.75	-0.06	0.75	905	1	75.3
111 Wind_11	211 Turbine_11	1	-0.75	-0.06	0.75	905	1	75.3
155 Wind_55	255 Turbine_55	1	-0.75	-0.06	0.75	905	1	75.3
133 Wind_33	233 Turbine_33	1	-0.75	-0.06	0.75	905	1	75.2
105 Wind_05	205 Turbine_05	1	-0.75	0.05	0.75	905	1	75.2
156 Wind_56	256 Turbine_56	1	-0.75	-0.05	0.75	904	1	75.2
127 Wind_27	227 Turbine_27	1	-0.75	-0.05	0.75	904	1	75.2
113 Wind_13	213 Turbine_13	1	-0.75	-0.05	0.75	904	1	75.2
110 Wind_10	210 Turbine_10	1	-0.75	-0.05	0.75	904	1	75.2
134 Wind_34	234 Turbine_34	1	-0.75	-0.04	0.75	904	1	75.1
139 Wind_39	239 Turbine_39	1	-0.75	0.04	0.75	904	1	75.1
161 Wind_61	261 Turbine_61	1	-0.75	0.05	0.75	904	1	75.1
117 Wind_17	217 Turbine_17	1	-0.75	0.04	0.75	903	1	75.1
126 Wind_26	226 Turbine_26	1	-0.75	-0.03	0.75	903	1	75.1
135 Wind_35	235 Turbine_35	1	-0.75	-0.03	0.75	903	1	75.1
160 Wind_60	260 Turbine_60	1	-0.75	0.03	0.75	903	1	75.1
136 Wind_36	236 Turbine_36	1	-0.75	-0.02	0.75	903	1	75
109 Wind_09	209 Turbine_09	1	-0.75	-0.03	0.75	903	1	75
114 Wind_14	214 Turbine_14	1	-0.75	-0.02	0.75	903	1	75
106 Wind_06	206 Turbine_06	1	-0.75	0.03	0.75	903	1	75
116 Wind_16	216 Turbine_16	1	-0.75	0.02	0.75	903	1	75
157 Wind_57	257 Turbine_57	1	-0.75	-0.03	0.75	902	1	75
138 Wind_38	238 Turbine_38	1	-0.75	0.02	0.75	902	1	75
125 Wind_25	225 Turbine_25	1	-0.75	-0.02	0.75	902	1	75
137 Wind_37	237 Turbine_37	1	-0.75	0.00	0.75	902	1	75
115 Wind_15	215 Turbine_15	1	-0.75	0.00	0.75	902	1	75
107 Wind_07	207 Turbine_07	1	-0.75	0.01	0.75	902	1	75
158 Wind_58	258 Turbine_58	1	-0.75	-0.01	0.75	902	1	75
108 Wind_08	208 Turbine_08	1	-0.75	-0.01	0.75	902	1	75
124 Wind_24	224 Turbine_24	1	-0.75	-0.02	0.75	902	1	75
159 Wind_59	259 Turbine_59	1	-0.75	0.01	0.75	902	1	75
105 Wind_05	106 Wind_06	1	3.70	-0.57	3.75	157	5	74.9

Table C2.2
Mission Wind Farm - 750 kW / 15 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
108 Wind_08	109 Wind_09	1	5.93	-0.72	5.97	251	8	74.7
115 Wind_15	116 Wind_16	1	-5.65	1.17	5.77	242	8	72.1
128 Wind_28	129 Wind_29	1	3.54	0.02	3.54	149	5	70.8
112 Wind_12	10 Riser_A	1	8.35	-1.35	8.46	356	12	70.5
116 Wind_16	117 Wind_17	1	-5.52	0.82	5.58	234	8	69.7
134 Wind_34	135 Wind_35	1	-8.20	1.13	8.27	348	12	68.9
112 Wind_12	113 Wind_13	1	-8.18	1.12	8.26	348	12	68.8
107 Wind_07	108 Wind_08	1	5.42	-0.60	5.45	229	8	68.2
155 Wind_55	156 Wind_56	1	-8.09	1.01	8.16	344	12	68
111 Wind_11	10 Riser_A	1	7.91	-0.78	7.95	335	12	66.3
138 Wind_38	139 Wind_39	1	-5.11	0.98	5.20	218	8	65
110 Wind_10	111 Wind_11	1	7.75	-0.55	7.77	327	12	64.7
159 Wind_59	160 Wind_60	1	-5.08	0.91	5.16	216	8	64.5
10 Riser_A	15 Riser_B	1	17.05	-1.69	17.13	723	27	63.4
156 Wind_56	157 Wind_57	1	-7.52	0.92	7.57	319	12	63.1
141 Wind_41	142 Wind_42	1	-3.02	0.66	3.09	129	5	61.7
119 Wind_19	120 Wind_20	1	-3.02	0.65	3.09	129	5	61.7
162 Wind_62	163 Wind_63	1	-3.01	0.65	3.08	129	5	61.6
127 Wind_27	128 Wind_28	1	3.08	0.00	3.08	130	5	61.5
135 Wind_35	136 Wind_36	1	-7.19	1.18	7.29	307	12	60.8
104 Wind_04	105 Wind_05	1	2.98	-0.53	3.03	127	5	60.6
160 Wind_60	161 Wind_61	1	-4.56	0.80	4.63	194	8	57.9
129 Wind_29	15 Riser_B	1	4.61	0.16	4.62	195	8	57.7
106 Wind_06	107 Wind_07	1	4.50	-0.65	4.55	191	8	56.9
142 Wind_42	143 Wind_43	1	-2.27	0.53	2.34	97	5	46.7
120 Wind_20	121 Wind_21	1	-2.26	0.49	2.32	97	5	46.3
163 Wind_63	164 Wind_64	1	-2.26	0.49	2.32	97	5	46.3
148 Wind_48	25 Riser_D	1	2.27	0.35	2.30	97	5	46
103 Wind_03	104 Wind_04	1	2.23	-0.37	2.26	95	5	45.2
20 Riser_C	30 Riser_E	1	11.82	-0.91	11.86	502	27	43.9
126 Wind_26	127 Wind_27	1	2.14	-0.05	2.14	90	5	42.9
125 Wind_25	126 Wind_26	1	1.66	0.00	1.66	70	5	33.2
121 Wind_21	122 Wind_22	1	-1.52	0.37	1.56	65	5	31.3
143 Wind_43	144 Wind_44	1	-1.51	0.33	1.55	64	5	30.9
164 Wind_64	165 Wind_65	1	-1.51	0.33	1.55	64	5	30.9
102 Wind_02	103 Wind_03	1	1.50	-0.29	1.52	64	5	30.5
147 Wind_47	148 Wind_48	1	1.37	0.19	1.38	59	5	27.6
144 Wind_44	145 Wind_45	1	-0.76	0.21	0.79	33	5	15.8
165 Wind_65	166 Wind_66	1	-0.76	0.17	0.77	32	5	15.5
122 Wind_22	123 Wind_23	1	-0.76	0.16	0.77	32	5	15.5
101 Wind_01	102 Wind_02	1	0.74	-0.12	0.76	32	5	15.1
124 Wind_24	125 Wind_25	1	0.71	0.00	0.71	30	5	14.2
146 Wind_46	147 Wind_47	1	0.69	0.07	0.69	29	5	13.9

Table C3.1
Mission Wind Farm - 750 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

Bus		Base	Voltage	Generation	
Number	Name	kV	P.U.	P(MW)	Q(MVAr)
1	Mission_115	115	1.0000	-48.298	10.7626
201	Turbine_01	0.48	1.0000	0.75	-0.0852
202	Turbine_02	0.48	1.0000	0.75	-0.0836
203	Turbine_03	0.48	1.0000	0.75	-0.0803
204	Turbine_04	0.48	1.0000	0.75	-0.0755
205	Turbine_05	0.48	1.0000	0.75	-0.0691
206	Turbine_06	0.48	1.0000	0.75	-0.0611
207	Turbine_07	0.48	1.0000	0.75	-0.0514
208	Turbine_08	0.48	1.0000	0.75	-0.0401
209	Turbine_09	0.48	1.0000	0.75	-0.0272
210	Turbine_10	0.48	1.0000	0.75	-0.0127
211	Turbine_11	0.48	1.0000	0.75	0.0035
212	Turbine_12	0.48	1.0000	0.75	0.0020
213	Turbine_13	0.48	1.0000	0.75	-0.0157
214	Turbine_14	0.48	1.0000	0.75	-0.0318
215	Turbine_15	0.48	1.0000	0.75	-0.0462
216	Turbine_16	0.48	1.0000	0.75	-0.0590
217	Turbine_17	0.48	1.0000	0.75	-0.0702
218	Turbine_18	0.48	1.0000	0.75	-0.0798
219	Turbine_19	0.48	1.0000	0.75	-0.0878
220	Turbine_20	0.48	1.0000	0.75	-0.0942
221	Turbine_21	0.48	1.0000	0.75	-0.0990
222	Turbine_22	0.48	1.0000	0.75	-0.1021
223	Turbine_23	0.48	1.0000	0.75	-0.1037
224	Turbine_24	0.48	1.0000	0.75	0.0067
225	Turbine_25	0.48	1.0000	0.75	0.0084
226	Turbine_26	0.48	1.0000	0.75	0.0117
227	Turbine_27	0.48	1.0000	0.75	0.0167
228	Turbine_28	0.48	1.0000	0.75	0.0233
229	Turbine_29	0.48	1.0000	0.75	0.0317
230	Turbine_30	0.48	1.0000	0.75	0.0417
231	Turbine_31	0.48	1.0000	0.75	0.0476
232	Turbine_32	0.48	1.0000	0.75	0.0408
233	Turbine_33	0.48	1.0000	0.75	0.0281
234	Turbine_34	0.48	1.0000	0.75	0.0162
235	Turbine_35	0.48	1.0000	0.75	0.0052
236	Turbine_36	0.48	1.0000	0.75	-0.0051
237	Turbine_37	0.48	1.0000	0.75	-0.0242
238	Turbine_38	0.48	1.0000	0.75	-0.0418
239	Turbine_39	0.48	1.0000	0.75	-0.0577
240	Turbine_40	0.48	1.0000	0.75	-0.0720
241	Turbine_41	0.48	1.0000	0.75	-0.0847
242	Turbine_42	0.48	1.0000	0.75	-0.0958
243	Turbine_43	0.48	1.0000	0.75	-0.1053
244	Turbine_44	0.48	1.0000	0.75	-0.1132
245	Turbine_45	0.48	1.0000	0.75	-0.1195
246	Turbine_46	0.48	1.0000	0.75	-0.1242
247	Turbine_47	0.48	1.0000	0.75	-0.1274
248	Turbine_48	0.48	1.0000	0.75	-0.1289
249	Turbine_49	0.48	1.0000	0.75	0.1190
250	Turbine_50	0.48	1.0000	0.75	0.1199
251	Turbine_51	0.48	1.0000	0.75	0.1217
252	Turbine_52	0.48	1.0000	0.75	0.1119

Table C3.1
Mission Wind Farm - 750 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

Bus		Base	Voltage	Generation		
Number	**Name**	**kV**	**P.U.**	**P(MW)**	**Q(MVAr)**	
253	Turbine_53	0.48	1.0000	0.75	0.1002	
254	Turbine_54	0.48	1.0000	0.75	0.0895	
255	Turbine_55	0.48	1.0000	0.75	0.0697	
256	Turbine_56	0.48	1.0000	0.75	0.0516	
257	Turbine_57	0.48	1.0000	0.75	0.0188	
258	Turbine_58	0.48	1.0000	0.75	0.0041	
259	Turbine_59	0.48	1.0000	0.75	-0.0090	
260	Turbine_60	0.48	1.0000	0.75	-0.0204	
261	Turbine_61	0.48	1.0000	0.75	-0.0301	
262	Turbine_62	0.48	1.0000	0.75	-0.0383	
263	Turbine_63	0.48	1.0000	0.75	-0.0448	
264	Turbine_64	0.48	1.0000	0.75	-0.0545	
265	Turbine_65	0.48	1.0000	0.75	-0.0577	
266	Turbine_66	0.48	1.0000	0.75	-0.0594	
				49.5	-1.6994	Total Wind Generation
				1.2024	9.0632	Total Losses
2	Mission_25	24.9	0.9865			
10	Riser_A	24.9	0.9949			
15	Riser_B	24.9	0.9930			
20	Riser_C	24.9	0.9890			
101	Wind_01	24.9	1.0011			
102	Wind_02	24.9	1.0010			
103	Wind_03	24.9	1.0008			
104	Wind_04	24.9	1.0005			
105	Wind_05	24.9	1.0001			
106	Wind_06	24.9	0.9997			
107	Wind_07	24.9	0.9991			
108	Wind_08	24.9	0.9985			
109	Wind_09	24.9	0.9977			
110	Wind_10	24.9	0.9969			
111	Wind_11	24.9	0.9959			
112	Wind_12	24.9	0.9960			
113	Wind_13	24.9	0.9970			
114	Wind_14	24.9	0.9980			
115	Wind_15	24.9	0.9988			
116	Wind_16	24.9	0.9996			
117	Wind_17	24.9	1.0002			
118	Wind_18	24.9	1.0007			
119	Wind_19	24.9	1.0012			
120	Wind_20	24.9	1.0016			
121	Wind_21	24.9	1.0019			
122	Wind_22	24.9	1.0020			
123	Wind_23	24.9	1.0021			
124	Wind_24	24.9	0.9958			
125	Wind_25	24.9	0.9957			
126	Wind_26	24.9	0.9955			
127	Wind_27	24.9	0.9952			
128	Wind_28	24.9	0.9948			
129	Wind_29	24.9	0.9943			
130	Wind_30	24.9	0.9937			
131	Wind_31	24.9	0.9934			
132	Wind_32	24.9	0.9938			
133	Wind_33	24.9	0.9945			
134	Wind_34	24.9	0.9952			

Table C3.1
Mission Wind Farm - 750 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

Bus		Base	Voltage	Generation	
Number	**Name**	**kV**	**P.U.**	**P(MW)**	**Q(MVAr)**
135	Wind_35	24.9	0.9958		
136	Wind_36	24.9	0.9964		
137	Wind_37	24.9	0.9975		
138	Wind_38	24.9	0.9986		
139	Wind_39	24.9	0.9995		
140	Wind_40	24.9	1.0003		
141	Wind_41	24.9	1.0010		
142	Wind_42	24.9	1.0017		
143	Wind_43	24.9	1.0022		
144	Wind_44	24.9	1.0027		
145	Wind_45	24.9	1.0030		
146	Wind_46	24.9	1.0033		
147	Wind_47	24.9	1.0035		
148	Wind_48	24.9	1.0036		
149	Wind_49	24.9	0.9893		
150	Wind_50	24.9	0.9892		
151	Wind_51	24.9	0.9891		
152	Wind_52	24.9	0.9897		
153	Wind_53	24.9	0.9904		
154	Wind_54	24.9	0.9910		
155	Wind_55	24.9	0.9921		
156	Wind_56	24.9	0.9932		
157	Wind_57	24.9	0.9951		
158	Wind_58	24.9	0.9959		
159	Wind_59	24.9	0.9967		
160	Wind_60	24.9	0.9973		
161	Wind_61	24.9	0.9979		
162	Wind_62	24.9	0.9984		
163	Wind_63	24.9	0.9987		
164	Wind_64	24.9	0.9993		
165	Wind_65	24.9	0.9995		
166	Wind_66	24.9	0.9996		

Table C3.2
Mission Wind Farm - 750 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
136 Wind_36	137 Wind_37	1	-8.919	1.448	9.036	210	9	100.4
112 Wind_12	10 Riser_A	1	8.919	-1.143	8.992	209	9	99.9
154 Wind_54	155 Wind_55	1	-8.912	0.511	8.927	209	9	99.2
1 Mission_115	2 Mission_25	1	-48.298	10.763	49.482	1147	50	99.0
20 Riser_C	2 Mission_25	1	48.797	-3.710	48.938	1147	50	97.9
132 Wind_32	15 Riser_B	1	12.609	-1.514	12.700	296	13	97.7
137 Wind_37	138 Wind_38	1	-8.181	1.393	8.299	193	9	92.2
132 Wind_32	133 Wind_33	1	-11.872	1.523	11.969	279	13	92.1
112 Wind_12	113 Wind_13	1	-8.182	1.115	8.257	192	9	91.7
111 Wind_11	10 Riser_A	1	8.182	-0.902	8.232	192	9	91.5
155 Wind_55	156 Wind_56	1	-8.175	0.550	8.193	191	9	91.0
133 Wind_33	134 Wind_34	1	-11.134	1.521	11.237	262	13	86.4
152 Wind_52	20 Riser_C	1	11.127	-0.300	11.131	261	13	85.6
138 Wind_38	139 Wind_39	1	-7.442	1.322	7.559	175	9	84.0
113 Wind_13	114 Wind_14	1	-7.443	1.069	7.519	175	9	83.5
110 Wind_10	111 Wind_11	1	7.443	-0.876	7.494	174	9	83.3
156 Wind_56	157 Wind_57	1	-7.443	0.575	7.465	174	9	82.9
134 Wind_34	135 Wind_35	1	-10.395	1.507	10.503	245	13	80.8
152 Wind_52	153 Wind_53	1	-10.388	0.382	10.395	243	13	80.0
148 Wind_48	248 Turbine_48	1	-0.746	0.162	0.764	915	1	76.4
147 Wind_47	247 Turbine_47	1	-0.746	0.161	0.763	915	1	76.3
146 Wind_46	246 Turbine_46	1	-0.746	0.157	0.763	914	1	76.3
145 Wind_45	245 Turbine_45	1	-0.746	0.153	0.762	913	1	76.2
144 Wind_44	244 Turbine_44	1	-0.746	0.146	0.761	912	1	76.1
151 Wind_51	251 Turbine_51	1	-0.750	-0.122	0.760	914	1	76.0
150 Wind_50	250 Turbine_50	1	-0.750	-0.120	0.760	914	1	76.0
149 Wind_49	249 Turbine_49	1	-0.750	-0.119	0.759	913	1	75.9
143 Wind_43	243 Turbine_43	1	-0.746	0.138	0.759	911	1	75.9
123 Wind_23	223 Turbine_23	1	-0.746	0.137	0.759	911	1	75.9
122 Wind_22	222 Turbine_22	1	-0.746	0.135	0.758	910	1	75.8
152 Wind_52	252 Turbine_52	1	-0.750	-0.112	0.758	912	1	75.8
121 Wind_21	221 Turbine_21	1	-0.746	0.132	0.758	910	1	75.8
139 Wind_39	140 Wind_40	1	-6.702	1.235	6.815	158	9	75.7
142 Wind_42	242 Turbine_42	1	-0.746	0.129	0.757	909	1	75.7
120 Wind_20	220 Turbine_20	1	-0.746	0.127	0.757	909	1	75.7
153 Wind_53	253 Turbine_53	1	-0.750	-0.100	0.757	910	1	75.7
119 Wind_19	219 Turbine_19	1	-0.746	0.121	0.756	908	1	75.6
101 Wind_01	201 Turbine_01	1	-0.746	0.118	0.756	908	1	75.6
141 Wind_41	241 Turbine_41	1	-0.746	0.117	0.756	908	1	75.6
102 Wind_02	202 Turbine_02	1	-0.746	0.116	0.755	908	1	75.5
154 Wind_54	254 Turbine_54	1	-0.750	-0.089	0.755	909	1	75.5
103 Wind_03	203 Turbine_03	1	-0.746	0.113	0.755	907	1	75.5
118 Wind_18	218 Turbine_18	1	-0.746	0.113	0.755	907	1	75.5
104 Wind_04	204 Turbine_04	1	-0.746	0.108	0.754	907	1	75.4
140 Wind_40	240 Turbine_40	1	-0.746	0.105	0.754	906	1	75.4
114 Wind_14	115 Wind_15	1	-6.702	1.008	6.778	157	9	75.3
117 Wind_17	217 Turbine_17	1	-0.746	0.103	0.753	906	1	75.3
105 Wind_05	205 Turbine_05	1	-0.746	0.102	0.753	906	1	75.3
155 Wind_55	255 Turbine_55	1	-0.750	-0.070	0.753	906	1	75.3
106 Wind_06	206 Turbine_06	1	-0.750	0.061	0.752	905	1	75.2
166 Wind_66	266 Turbine_66	1	-0.750	0.059	0.752	905	1	75.2
116 Wind_16	216 Turbine_16	1	-0.750	0.059	0.752	905	1	75.2
165 Wind_65	265 Turbine_65	1	-0.750	0.058	0.752	905	1	75.2
139 Wind_39	239 Turbine_39	1	-0.750	0.058	0.752	905	1	75.2
164 Wind_64	264 Turbine_64	1	-0.750	0.054	0.752	904	1	75.2

Table C3.2
Mission Wind Farm - 750 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
156 Wind_56	256 Turbine_56	1	-0.750	-0.052	0.752	904	1	75.2
107 Wind_07	207 Turbine_07	1	-0.750	0.051	0.752	904	1	75.2
131 Wind_31	231 Turbine_31	1	-0.750	-0.048	0.752	904	1	75.2
135 Wind_35	136 Wind_36	1	-9.655	1.483	9.768	227	13	75.1
115 Wind_15	215 Turbine_15	1	-0.750	0.046	0.751	904	1	75.1
163 Wind_63	263 Turbine_63	1	-0.750	0.045	0.751	904	1	75.1
138 Wind_38	238 Turbine_38	1	-0.750	0.042	0.751	904	1	75.1
130 Wind_30	230 Turbine_30	1	-0.750	-0.042	0.751	904	1	75.1
132 Wind_32	232 Turbine_32	1	-0.750	-0.041	0.751	903	1	75.1
108 Wind_08	208 Turbine_08	1	-0.750	0.040	0.751	903	1	75.1
162 Wind_62	262 Turbine_62	1	-0.750	0.038	0.751	903	1	75.1
114 Wind_14	214 Turbine_14	1	-0.750	0.032	0.751	903	1	75.1
129 Wind_29	229 Turbine_29	1	-0.750	-0.032	0.751	903	1	75.1
161 Wind_61	261 Turbine_61	1	-0.750	0.030	0.751	903	1	75.1
133 Wind_33	233 Turbine_33	1	-0.750	-0.028	0.751	903	1	75.1
109 Wind_09	110 Wind_10	1	6.702	-0.834	6.754	157	9	75.0
109 Wind_09	209 Turbine_09	1	-0.750	0.027	0.750	903	1	75.0
137 Wind_37	237 Turbine_37	1	-0.750	0.024	0.750	903	1	75.0
128 Wind_28	228 Turbine_28	1	-0.750	-0.023	0.750	903	1	75.0
160 Wind_60	260 Turbine_60	1	-0.750	0.020	0.750	902	1	75.0
157 Wind_57	257 Turbine_57	1	-0.750	-0.019	0.750	902	1	75.0
127 Wind_27	227 Turbine_27	1	-0.750	-0.017	0.750	902	1	75.0
134 Wind_34	234 Turbine_34	1	-0.750	-0.016	0.750	902	1	75.0
113 Wind_13	213 Turbine_13	1	-0.750	0.016	0.750	902	1	75.0
110 Wind_10	210 Turbine_10	1	-0.750	0.013	0.750	902	1	75.0
126 Wind_26	226 Turbine_26	1	-0.750	-0.012	0.750	902	1	75.0
159 Wind_59	259 Turbine_59	1	-0.750	0.009	0.750	902	1	75.0
125 Wind_25	225 Turbine_25	1	-0.750	-0.008	0.750	902	1	75.0
124 Wind_24	224 Turbine_24	1	-0.750	-0.007	0.750	902	1	75.0
135 Wind_35	235 Turbine_35	1	-0.750	-0.005	0.750	902	1	75.0
136 Wind_36	236 Turbine_36	1	-0.750	0.005	0.750	902	1	75.0
158 Wind_58	258 Turbine_58	1	-0.750	-0.004	0.750	902	1	75.0
111 Wind_11	211 Turbine_11	1	-0.750	-0.004	0.750	902	1	75.0
112 Wind_12	212 Turbine_12	1	-0.750	-0.002	0.750	902	1	75.0
157 Wind_57	158 Wind_58	1	-6.702	0.564	6.726	157	9	74.7
153 Wind_53	154 Wind_54	1	-9.648	0.452	9.659	226	13	74.3
15 Riser_B	20 Riser_C	1	35.603	-3.574	35.782	836	50	71.6
140 Wind_40	141 Wind_41	1	-5.960	1.134	6.067	141	9	67.4
115 Wind_15	116 Wind_16	1	-5.961	0.933	6.033	140	9	67.0
108 Wind_08	109 Wind_09	1	5.961	-0.778	6.011	140	9	66.8
158 Wind_58	159 Wind_59	1	-5.960	0.540	5.985	139	9	66.5
141 Wind_41	142 Wind_42	1	-5.217	1.020	5.316	123	9	59.1
116 Wind_16	117 Wind_17	1	-5.218	0.845	5.286	123	9	58.7
107 Wind_07	108 Wind_08	1	5.218	-0.709	5.266	122	9	58.5
159 Wind_59	160 Wind_60	1	-5.217	0.502	5.242	122	9	58.2
142 Wind_42	143 Wind_43	1	-4.474	0.895	4.562	106	9	50.7
117 Wind_17	118 Wind_18	1	-4.474	0.746	4.536	105	9	50.4
106 Wind_06	107 Wind_07	1	4.474	-0.629	4.518	105	9	50.2
160 Wind_60	161 Wind_61	1	-4.474	0.453	4.497	104	9	50.0
129 Wind_29	130 Wind_30	1	4.474	-0.074	4.475	104	9	49.7
131 Wind_31	15 Riser_B	1	5.963	-0.041	5.963	139	13	45.9
143 Wind_43	144 Wind_44	1	-3.729	0.761	3.806	88	9	42.3
118 Wind_18	119 Wind_19	1	-3.730	0.638	3.784	88	9	42.0
105 Wind_05	106 Wind_06	1	3.730	-0.539	3.768	87	9	41.9
161 Wind_61	162 Wind_62	1	-3.729	0.395	3.750	87	9	41.7

Table C3.2
Mission Wind Farm - 750 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 49.5 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
128 Wind_28	129 Wind_29	1	3.730	-0.077	3.731	87	9	41.5
130 Wind_30	131 Wind_31	1	5.218	-0.061	5.219	122	13	40.1
10 Riser_A	15 Riser_B	1	17.082	-2.040	17.204	401	50	34.4
144 Wind_44	145 Wind_45	1	-2.984	0.619	3.048	70	9	33.9
119 Wind_19	120 Wind_20	1	-2.984	0.522	3.030	70	9	33.7
104 Wind_04	105 Wind_05	1	2.984	-0.442	3.017	70	9	33.5
162 Wind_62	163 Wind_63	1	-2.984	0.328	3.002	70	9	33.4
127 Wind_27	128 Wind_28	1	2.985	-0.072	2.985	70	9	33.2
145 Wind_45	146 Wind_46	1	-2.239	0.471	2.288	53	9	25.4
120 Wind_20	121 Wind_21	1	-2.239	0.399	2.274	53	9	25.3
103 Wind_03	104 Wind_04	1	2.239	-0.338	2.264	52	9	25.2
163 Wind_63	164 Wind_64	1	-2.239	0.260	2.254	52	9	25.0
126 Wind_26	127 Wind_27	1	2.239	-0.061	2.240	52	9	24.9
151 Wind_51	20 Riser_C	1	2.238	0.277	2.256	53	13	17.4
146 Wind_46	147 Wind_47	1	-1.493	0.318	1.526	35	9	17.0
121 Wind_21	122 Wind_22	1	-1.493	0.272	1.517	35	9	16.9
102 Wind_02	103 Wind_03	1	1.493	-0.230	1.510	35	9	16.8
164 Wind_64	165 Wind_65	1	-1.493	0.178	1.503	35	9	16.7
125 Wind_25	126 Wind_26	1	1.493	-0.045	1.493	35	9	16.6
150 Wind_50	151 Wind_51	1	1.492	0.184	1.504	35	13	11.6
147 Wind_47	148 Wind_48	1	-0.746	0.162	0.764	18	9	8.5
122 Wind_22	123 Wind_23	1	-0.746	0.137	0.759	18	9	8.4
101 Wind_01	102 Wind_02	1	0.746	-0.118	0.756	18	9	8.4
165 Wind_65	166 Wind_66	1	-0.746	0.092	0.752	17	9	8.4
124 Wind_24	125 Wind_25	1	0.746	-0.026	0.747	17	9	8.3
149 Wind_49	150 Wind_50	1	0.746	0.091	0.752	18	13	5.8

Table C4.1
Mission Wind Farm - 2500 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

Bus		Base	Voltage	Generation		
Number	Name	kV	P.U.	P(MW)	Q(MVAr)	
1	Mission_115	115	1	-48.855	10.5349	
201	Turbine_01	0.69	1	2.5	-0.1641	
202	Turbine_02	0.69	1	2.5	-0.1353	
203	Turbine_03	0.69	1	2.5	-0.0774	
204	Turbine_04	0.69	1	2.5	0.0098	
205	Turbine_05	0.69	1	2.5	0.0677	
206	Turbine_06	0.69	1	2.5	0.1405	
207	Turbine_07	0.69	1	2.5	0.1057	
208	Turbine_08	0.69	1	2.5	0.0474	
209	Turbine_09	0.69	1	2.5	-0.0401	
210	Turbine_10	0.69	1	2.5	-0.0983	
211	Turbine_11	0.69	1	2.5	-0.1273	
212	Turbine_12	0.69	1	2.5	0.2695	
213	Turbine_13	0.69	1	2.5	0.2093	
214	Turbine_14	0.69	1	2.5	0.1201	
215	Turbine_15	0.69	1	2.5	0.0609	
216	Turbine_16	0.69	1	2.5	0.0313	
217	Turbine_17	0.69	1	2.5	-0.0017	
218	Turbine_18	0.69	1	2.5	-0.0887	
219	Turbine_19	0.69	1	2.5	-0.1465	
220	Turbine_20	0.69	1	2.5	-0.1754	
				50	0.0073	Total Wind Generation
				1.145	10.5422	Total Losses
2	Mission_25	24.9	0.9874			
10	Riser_A	24.9	0.9927			
15	Riser_B	24.9	0.9896			
101	Wind_01	24.9	0.999			
102	Wind_02	24.9	0.9985			
103	Wind_03	24.9	0.9974			
104	Wind_04	24.9	0.9958			
105	Wind_05	24.9	0.9947			
106	Wind_06	24.9	0.9934			
107	Wind_07	24.9	0.994			
108	Wind_08	24.9	0.9951			
109	Wind_09	24.9	0.9967			
110	Wind_10	24.9	0.9978			
111	Wind_11	24.9	0.9983			
112	Wind_12	24.9	0.991			
113	Wind_13	24.9	0.9921			
114	Wind_14	24.9	0.9938			
115	Wind_15	24.9	0.9948			
116	Wind_16	24.9	0.9954			
117	Wind_17	24.9	0.996			
118	Wind_18	24.9	0.9976			
119	Wind_19	24.9	0.9987			
120	Wind_20	24.9	0.9992			

Table C4.2
Mission Wind Farm - 2500 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
1 Mission_115	2 Mission_25	1	-48.856	10.539	49.980	1159	50	100.0
15 Riser_B	2 Mission_25	1	49.391	-2.726	49.466	1159	50	98.9
112 Wind_12	15 Riser_B	1	12.422	0.234	12.424	291	13	95.6
105 Wind_05	106 Wind_06	1	12.113	-1.027	12.156	283	13	93.5
107 Wind_07	10 Riser_A	1	12.047	-0.891	12.080	282	13	92.9
113 Wind_13	114 Wind_14	1	-7.704	0.032	7.704	180	9	85.6
112 Wind_12	212 Turbine_12	1	-2.500	-0.270	2.514	2104	3	83.8
113 Wind_13	213 Turbine_13	1	-2.500	-0.210	2.509	2099	3	83.6
120 Wind_20	220 Turbine_20	1	-2.499	0.176	2.506	2097	3	83.5
101 Wind_01	201 Turbine_01	1	-2.500	0.165	2.506	2096	3	83.5
119 Wind_19	219 Turbine_19	1	-2.500	0.149	2.505	2096	3	83.5
106 Wind_06	206 Turbine_06	1	-2.500	-0.139	2.504	2095	3	83.5
102 Wind_02	202 Turbine_02	1	-2.500	0.138	2.504	2095	3	83.5
114 Wind_14	214 Turbine_14	1	-2.500	-0.117	2.503	2095	3	83.4
111 Wind_11	211 Turbine_11	1	-2.500	0.127	2.503	2094	3	83.4
110 Wind_10	210 Turbine_10	1	-2.501	0.100	2.503	2094	3	83.4
107 Wind_07	207 Turbine_07	1	-2.500	-0.107	2.502	2094	3	83.4
118 Wind_18	218 Turbine_18	1	-2.500	0.089	2.502	2093	3	83.4
103 Wind_03	203 Turbine_03	1	-2.500	0.078	2.501	2093	3	83.4
105 Wind_05	205 Turbine_05	1	-2.500	-0.069	2.501	2093	3	83.4
108 Wind_08	208 Turbine_08	1	-2.501	-0.047	2.501	2093	3	83.4
115 Wind_15	215 Turbine_15	1	-2.500	-0.063	2.501	2092	3	83.4
117 Wind_17	217 Turbine_17	1	-2.500	0.002	2.500	2092	3	83.3
104 Wind_04	204 Turbine_04	1	-2.500	-0.009	2.500	2092	3	83.3
109 Wind_09	209 Turbine_09	1	-2.500	0.040	2.500	2092	3	83.3
116 Wind_16	216 Turbine_16	1	-2.500	-0.031	2.500	2092	3	83.3
117 Wind_17	118 Wind_18	1	-7.449	0.740	7.486	174	9	83.2
103 Wind_03	104 Wind_04	1	7.429	-0.665	7.459	173	9	82.9
108 Wind_08	109 Wind_09	1	-7.424	0.663	7.453	173	9	82.8
104 Wind_04	105 Wind_05	1	10.215	-0.765	10.244	239	13	78.8
107 Wind_07	108 Wind_08	1	-10.094	0.499	10.106	235	13	77.7
117 Wind_17	15 Riser_B	1	9.941	-0.827	9.975	232	13	76.7
112 Wind_12	113 Wind_13	1	-9.889	0.093	9.890	231	13	76.1
106 Wind_06	10 Riser_A	1	14.735	-0.892	14.762	345	21	70.3
118 Wind_18	119 Wind_19	1	-5.127	0.513	5.153	120	9	57.3
102 Wind_02	103 Wind_03	1	5.126	-0.513	5.152	120	9	57.2
109 Wind_09	110 Wind_10	1	-5.087	0.362	5.099	118	9	56.7
10 Riser_A	15 Riser_B	1	27.251	-1.422	27.288	637	50	54.6
114 Wind_14	115 Wind_15	1	-4.588	0.237	4.594	107	9	51.0
115 Wind_15	116 Wind_16	1	-2.733	0.055	2.734	64	9	30.4
119 Wind_19	120 Wind_20	1	-2.368	0.386	2.399	56	9	26.7
101 Wind_01	102 Wind_02	1	2.349	-0.311	2.370	55	9	26.3
110 Wind_10	111 Wind_11	1	-2.347	0.310	2.368	55	9	26.3

Table C5.1
Mission Wind Farm - 2500 kW / 35 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

Bus		Base	Voltage	Generation		
Number	**Name**	**kV**	**P.U.**	**P(MW)**	**Q(MVAr)**	
1	Mission_115	115	1.0000	-48.83	10.7086	
201	Turbine_01	0.69	1.0000	2.5	-0.0385	
202	Turbine_02	0.69	1.0000	2.5	-0.0266	
203	Turbine_03	0.69	1.0000	2.5	-0.0027	
204	Turbine_04	0.69	1.0000	2.5	0.0332	
205	Turbine_05	0.69	1.0000	2.5	0.0812	
206	Turbine_06	0.69	1.0000	2.5	0.1412	
207	Turbine_07	0.69	1.0000	2.5	0.1170	
208	Turbine_08	0.69	1.0000	2.5	0.0689	
209	Turbine_09	0.69	1.0000	2.5	0.0328	
210	Turbine_10	0.69	1.0000	2.5	0.0088	
211	Turbine_11	0.69	1.0000	2.5	-0.0032	
212	Turbine_12	0.69	1.0000	2.5	0.1542	
213	Turbine_13	0.69	1.0000	2.5	0.1338	
214	Turbine_14	0.69	1.0000	2.5	0.0922	
215	Turbine_15	0.69	1.0000	2.5	0.0567	
216	Turbine_16	0.69	1.0000	2.5	-0.0027	
217	Turbine_17	0.69	1.0000	2.5	-0.0501	
218	Turbine_18	0.69	1.0000	2.5	-0.0856	
219	Turbine_19	0.69	1.0000	2.5	-0.1093	
220	Turbine_20	0.69	1.0000	2.5	-0.1211	
				50	0.48021	Total Wind Generation
				1.17	11.19	Total Losses
2	Mission_35	34.5	0.9869			
10	Riser_A	34.5	0.9911			
15	Riser_B	34.5	0.9880			
101	Wind_01	34.5	0.9961			
102	Wind_02	34.5	0.9959			
103	Wind_03	34.5	0.9953			
104	Wind_04	34.5	0.9945			
105	Wind_05	34.5	0.9933			
106	Wind_06	34.5	0.9919			
107	Wind_07	34.5	0.9925			
108	Wind_08	34.5	0.9936			
109	Wind_09	34.5	0.9945			
110	Wind_10	34.5	0.9950			
111	Wind_11	34.5	0.9953			
112	Wind_12	34.5	0.9916			
113	Wind_13	34.5	0.9921			
114	Wind_14	34.5	0.9931			
115	Wind_15	34.5	0.9939			
116	Wind_16	34.5	0.9953			
117	Wind_17	34.5	0.9964			
118	Wind_18	34.5	0.9972			
119	Wind_19	34.5	0.9978			
120	Wind_20	34.5	0.9981			

Table C5.2
Mission Wind Farm - 2500 kW / 35 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
1 Mission_115	2 Mission_35	1	-48.828	10.713	49.990	837	50	100.0
115 Wind_15	116 Wind_16	1	-12.482	1.142	12.534	211	13	96.4
105 Wind_05	106 Wind_06	1	12.345	-0.709	12.365	208	13	95.1
107 Wind_07	10 Riser_A	1	12.297	-0.565	12.310	208	13	94.7
113 Wind_13	114 Wind_14	1	-17.728	1.134	17.764	299	19	93.5
10 Riser_A	15 Riser_B	1	49.501	-2.201	49.550	837	54	91.8
15 Riser_B	2 Mission_35	1	49.311	-3.198	49.415	837	54	91.5
112 Wind_12	212 Turbine_12	1	-2.501	-0.155	2.505	2096	3	83.5
106 Wind_06	206 Turbine_06	1	-2.500	-0.142	2.504	2095	3	83.5
113 Wind_13	213 Turbine_13	1	-2.500	-0.133	2.504	2095	3	83.5
120 Wind_20	220 Turbine_20	1	-2.500	0.122	2.503	2094	3	83.4
119 Wind_19	219 Turbine_19	1	-2.500	0.110	2.502	2094	3	83.4
107 Wind_07	207 Turbine_07	1	-2.499	-0.116	2.502	2094	3	83.4
118 Wind_18	218 Turbine_18	1	-2.500	0.084	2.501	2093	3	83.4
115 Wind_15	215 Turbine_15	1	-2.501	-0.057	2.501	2093	3	83.4
114 Wind_14	214 Turbine_14	1	-2.499	-0.091	2.501	2093	3	83.4
105 Wind_05	205 Turbine_05	1	-2.500	-0.082	2.501	2093	3	83.4
108 Wind_08	208 Turbine_08	1	-2.500	-0.070	2.501	2092	3	83.4
111 Wind_11	211 Turbine_11	1	-2.500	0.003	2.500	2092	3	83.3
101 Wind_01	201 Turbine_01	1	-2.500	0.037	2.500	2092	3	83.3
110 Wind_10	210 Turbine_10	1	-2.500	-0.010	2.500	2092	3	83.3
109 Wind_09	209 Turbine_09	1	-2.500	-0.031	2.500	2092	3	83.3
104 Wind_04	204 Turbine_04	1	-2.500	-0.031	2.500	2092	3	83.3
102 Wind_02	202 Turbine_02	1	-2.500	0.029	2.500	2092	3	83.3
117 Wind_17	217 Turbine_17	1	-2.499	0.050	2.500	2092	3	83.3
103 Wind_03	203 Turbine_03	1	-2.500	0.003	2.500	2092	3	83.3
116 Wind_16	216 Turbine_16	1	-2.500	0.003	2.500	2092	3	83.3
104 Wind_04	105 Wind_05	1	10.548	-0.432	10.557	178	13	81.2
116 Wind_16	117 Wind_17	1	-9.827	0.934	9.871	166	13	75.9
114 Wind_14	115 Wind_15	1	-14.330	1.212	14.382	242	19	75.7
106 Wind_06	10 Riser_A	1	14.183	-0.951	14.215	240	19	74.8
107 Wind_07	108 Wind_08	1	-9.687	0.500	9.700	163	13	74.6
112 Wind_12	10 Riser_A	1	21.281	-1.927	21.368	361	29	73.7
112 Wind_12	113 Wind_13	1	-20.288	0.807	20.304	342	29	70.0
108 Wind_08	109 Wind_09	1	-7.884	0.220	7.887	133	13	60.7
117 Wind_17	118 Wind_18	1	-7.163	0.723	7.200	121	13	55.4
103 Wind_03	104 Wind_04	1	7.111	-0.576	7.134	120	13	54.9
118 Wind_18	119 Wind_19	1	-5.349	0.438	5.366	90	13	41.3
102 Wind_02	103 Wind_03	1	5.263	-0.151	5.266	88	13	40.5
109 Wind_09	110 Wind_10	1	-4.443	0.362	4.458	75	13	34.3
119 Wind_19	120 Wind_20	1	-2.675	0.223	2.684	45	13	20.6
110 Wind_10	111 Wind_11	1	-2.630	0.078	2.631	44	13	20.2
101 Wind_01	102 Wind_02	1	1.853	-0.432	1.903	32	13	14.6

Table C6.1
Mission Wind Farm - 5000 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

Bus Number	Bus Name	Base kV	Voltage P.U.	Generation P(MW)	Generation Q(MVAr)	
1	Mission_115	115	1	-48.539	11.9682	
201	Turbine_01	2.4	1	5	1.28398	
202	Turbine_02	2.4	1	5	0.11956	
203	Turbine_03	2.4	1	5	0.31049	
204	Turbine_04	2.4	1	5	0.26069	
205	Turbine_05	2.4	1	5	0.12992	
206	Turbine_06	2.4	1	5	-0.0667	
207	Turbine_07	2.4	1	5	-0.2631	
208	Turbine_08	2.4	1	5	0.2806	
209	Turbine_09	2.4	1	5	0.08116	
210	Turbine_10	2.4	1	5	-0.1169	
				50	2.0197	Total Wind Generation
				1.461	13.9879	Total Losses
2	Mission_25	24.9	0.9832			
10	Riser_A	24.9	0.9931			
15	Riser_B	24.9	0.9933			
101	Wind_01	24.9	0.9866			
102	Wind_02	24.9	0.9956			
103	Wind_03	24.9	0.9941			
104	Wind_04	24.9	0.9945			
105	Wind_05	24.9	0.9955			
106	Wind_06	24.9	0.9970			
107	Wind_07	24.9	0.9985			
108	Wind_08	24.9	0.9943			
109	Wind_09	24.9	0.9959			
110	Wind_10	24.9	0.9974			

Table C6.2
Mission Wind Farm - 5000 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

From Bus		To Bus		Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
1	Mission_115	2	Mission_25	1	-48.539	11.968	49.993	1159	50	100.0
104	Wind_04	10	Riser_A	1	19.877	-0.688	19.889	464	21	94.7
10	Riser_A	2	Mission_25	1	34.742	-1.946	34.796	812	37	94.0
15	Riser_B	2	Mission_25	1	14.897	-0.310	14.900	348	16	93.1
102	Wind_02	103	Wind_03	1	9.948	-1.384	10.044	234	13	77.3
105	Wind_05	106	Wind_06	1	-9.950	0.705	9.974	232	13	76.7
108	Wind_08	109	Wind_09	1	-9.951	0.413	9.960	232	13	76.6
103	Wind_03	10	Riser_A	1	14.911	-1.259	14.964	349	21	71.3
104	Wind_04	105	Wind_05	1	-14.913	0.760	14.932	348	21	71.1
108	Wind_08	15	Riser_B	1	14.912	-0.314	14.915	348	21	71.0
101	Wind_01	201	Turbine_01	1	-5.000	-1.284	5.162	1242	8	64.5
103	Wind_03	203	Turbine_03	1	-5.000	-0.311	5.010	1205	8	62.6
108	Wind_08	208	Turbine_08	1	-5.000	-0.281	5.008	1205	8	62.6
107	Wind_07	207	Turbine_07	1	-5.000	0.263	5.007	1204	8	62.6
104	Wind_04	204	Turbine_04	1	-5.000	-0.261	5.007	1204	8	62.6
105	Wind_05	205	Turbine_05	1	-5.000	-0.130	5.002	1203	8	62.5
102	Wind_02	202	Turbine_02	1	-5.000	-0.120	5.001	1203	8	62.5
110	Wind_10	210	Turbine_10	1	-5.000	0.117	5.001	1203	8	62.5
109	Wind_09	209	Turbine_09	1	-5.000	-0.081	5.001	1203	8	62.5
106	Wind_06	206	Turbine_06	1	-5.000	0.067	5.000	1203	8	62.5
101	Wind_01	102	Wind_02	1	4.969	-1.311	5.139	120	9	57.5
106	Wind_06	107	Wind_07	1	-4.979	0.455	4.999	116	9	55.5
109	Wind_09	110	Wind_10	1	-4.979	0.308	4.988	116	9	55.4

Table C7.1
Mission Wind Farm - 5000 kW / 35 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

Bus		Base	Voltage	Generation		
Number	**Name**	**kV**	**P.U.**	**P(MW)**	**Q(MVAr)**	
1	Mission_115	115	1	-48.715	11.1361	
201	Turbine_01	2.4	1	5	-0.2869	
202	Turbine_02	2.4	1	5	-0.1849	
203	Turbine_03	2.4	1	5	0.0197	
204	Turbine_04	2.4	1	5	0.0839	
205	Turbine_05	2.4	1	5	-0.0684	
206	Turbine_06	2.4	1	5	-0.2720	
207	Turbine_07	2.4	1	5	-0.3734	
208	Turbine_08	2.4	1	5	0.2365	
209	Turbine_09	2.4	1	5	0.0291	
210	Turbine_10	2.4	1	5	-0.0742	
				50	-0.8905	Total Wind Generation
				1.285	10.2456	Total Losses
2	Mission_35	34.5	0.9857			
10	Riser_A	34.5	0.9951			
15	Riser_B	34.5	0.9935			
101	Wind_01	34.5	0.9987			
102	Wind_02	34.5	0.9979			
103	Wind_03	34.5	0.9963			
104	Wind_04	34.5	0.9958			
105	Wind_05	34.5	0.9970			
106	Wind_06	34.5	0.9986			
107	Wind_07	34.5	0.9994			
108	Wind_08	34.5	0.9947			
109	Wind_09	34.5	0.9963			
110	Wind_10	34.5	0.9971			

Table C7.2
Mission Wind Farm - 5000 kW / 35 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
1 Mission_115	2 Mission_35	1	-48.717	11.122	49.970	836	50	99.9
15 Riser_B	2 Mission_35	1	14.919	-0.335	14.923	251	16	93.3
10 Riser_A	2 Mission_35	1	34.736	-2.366	34.816	586	39	89.3
104 Wind_04	105 Wind_05	1	-15.205	1.134	15.247	256	19	80.2
103 Wind_03	10 Riser_A	1	15.111	-0.953	15.141	254	19	79.7
105 Wind_05	106 Wind_06	1	-10.141	0.931	10.184	171	13	78.3
102 Wind_02	103 Wind_03	1	10.107	-0.827	10.141	170	13	78.0
108 Wind_08	15 Riser_B	1	14.761	-0.241	14.763	248	19	77.7
108 Wind_08	109 Wind_09	1	-9.985	0.419	9.994	168	13	76.9
104 Wind_04	10 Riser_A	1	20.120	-1.264	20.159	339	29	69.5
107 Wind_07	207 Turbine_07	1	-5.001	0.380	5.015	1206	8	62.7
101 Wind_01	201 Turbine_01	1	-5.000	0.289	5.009	1205	8	62.6
106 Wind_06	206 Turbine_06	1	-4.999	0.276	5.007	1204	8	62.6
108 Wind_08	208 Turbine_08	1	-4.999	-0.231	5.005	1204	8	62.6
102 Wind_02	202 Turbine_02	1	-4.999	0.185	5.002	1203	8	62.5
104 Wind_04	204 Turbine_04	1	-5.000	-0.088	5.001	1203	8	62.5
105 Wind_05	205 Turbine_05	1	-5.000	0.068	5.001	1203	8	62.5
109 Wind_09	209 Turbine_09	1	-5.000	-0.023	5.000	1203	8	62.5
103 Wind_03	203 Turbine_03	1	-5.000	-0.023	5.000	1203	8	62.5
110 Wind_10	210 Turbine_10	1	-4.999	0.081	5.000	1203	8	62.5
106 Wind_06	107 Wind_07	1	-5.088	0.524	5.115	86	13	39.3
101 Wind_01	102 Wind_02	1	5.058	-0.422	5.076	85	13	39.0
109 Wind_09	110 Wind_10	1	-5.024	0.318	5.034	84	13	38.7

Table C8.1
Mission Wind Farm - 10000 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

Bus		Base	Voltage	Generation		
Number	**Name**	**kV**	**P.U.**	**P(MW)**	**Q(MVAr)**	
1	Mission_115	115	1	-48.718	11.2604	
201	Turbine_01	4.16	1	10	-0.05	
202	Turbine_02	4.16	1	10	0.31523	
203	Turbine_03	4.16	1	10	0.40656	
204	Turbine_04	4.16	1	10	0.26225	
205	Turbine_05	4.16	1	10	-0.1021	
				50	0.8319	Total Wind Generation
				1.282	12.0923	Total Losses
2	Mission_25	24.9	0.9853			
10	Riser_A	24.9	0.9915			
101	Wind_01	24.9	0.9955			
102	Wind_02	24.9	0.9934			
103	Wind_03	24.9	0.9928			
104	Wind_04	24.9	0.9937			
105	Wind_05	24.9	0.9958			

Table C8.2
Mission Wind Farm - 10000 kW / 25 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

From Bus		To Bus		Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
1	Mission_115	2	Mission_25	1	-48.72	11.26	50.0	1159	50	100.0
10	Riser_A	2	Mission_25	1	49.53	-2.12	49.6	1159	50	99.2
104	Wind_04	10	Riser_A	1	19.85	-1.01	19.9	464	21	94.6
102	Wind_02	10	Riser_A	1	19.85	-0.90	19.9	464	21	94.6
103	Wind_03	203	Turbine_03	1	-10.00	-0.41	10.0	1389	11	91.0
102	Wind_02	202	Turbine_02	1	-10.00	-0.32	10.0	1389	11	91.0
104	Wind_04	204	Turbine_04	1	-10.00	-0.26	10.0	1388	11	90.9
105	Wind_05	205	Turbine_05	1	-10.00	0.10	10.0	1388	11	90.9
101	Wind_01	201	Turbine_01	1	-10.00	0.05	10.0	1388	11	90.9
104	Wind_04	105	Wind_05	1	-9.93	0.69	10.0	232	13	76.6
101	Wind_01	102	Wind_02	1	9.93	-0.63	10.0	232	13	76.6
103	Wind_03	10	Riser_A	1	9.93	-0.17	9.9	232	13	76.4

Table C9.1
Mission Wind Farm - 10000 kW / 35 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

Bus		Base	Voltage	Generation		
Number	**Name**	**kV**	**P.U.**	**P(MW)**	**Q(MVAr)**	
1	Mission_115	115	1	-48.944	10.2475	
201	Turbine_01	4.16	1	10	0.01402	
202	Turbine_02	4.16	1	10	0.36814	
203	Turbine_03	4.16	1	10	0.29878	
204	Turbine_04	4.16	1	10	0.34261	
205	Turbine_05	4.16	1	10	-0.0112	
				50	1.0124	Total Wind Generation
				1.056	11.2599	Total Losses
2	Mission_35	34.5	0.9883			
10	Riser_A	34.5	0.9917			
101	Wind_01	34.5	0.9949			
102	Wind_02	34.5	0.9927			
103	Wind_03	34.5	0.9931			
104	Wind_04	34.5	0.9928			
105	Wind_05	34.5	0.9951			

Table C9.2
Mission Wind Farm - 10000 kW / 35 kV
WindPACT Turbine Design Scaling Studies
Power Flow Bus Report (100% Generation, 50 MW)

From Bus	To Bus	Ckt	MW	MVar	MVA	AMPS	Norm	%Norm
1 Mission_115	2 Mission_35	1	-48.94	10.25	50.01	837	50	100.0
10 Riser_A	2 Mission_35	1	49.55	-2.10	49.59	837	50	98.9
102 Wind_02	202 Turbine_02	1	-10.00	-0.37	10.01	1389	29	91.1
104 Wind_04	204 Turbine_04	1	-10.00	-0.34	10.01	1389	29	91.0
103 Wind_03	203 Turbine_03	1	-10.00	-0.30	10.00	1388	11	90.9
101 Wind_01	201 Turbine_01	1	-10.00	-0.01	10.00	1388	11	90.9
105 Wind_05	205 Turbine_05	1	-10.00	0.01	10.00	1388	11	90.9
104 Wind_04	105 Wind_05	1	-9.93	0.64	9.95	167	11	76.7
101 Wind_01	102 Wind_02	1	9.93	-0.62	9.95	167	11	76.6
103 Wind_03	10 Riser_A	1	9.93	-0.33	9.94	167	13	76.4
104 Wind_04	10 Riser_A	1	19.84	-0.92	19.86	335	13	68.6
102 Wind_02	10 Riser_A	1	19.84	-0.86	19.86	335	13	68.5

APPENDIX D
SHORT-CIRCUIT STUDY RESULTS

APPENDIX D
SHORT-CIRCUIT STUDY RESULTS

CAI made a short-circuit calculation to determine whether standard equipment ratings were applicable and to provide short-circuit contributions to the utility system. For this analysis, we assumed the utility 115-kV system equivalent provided a three-phase fault level of 50,000 amps. If required, the utility can provide a more accurate short-circuit equivalent for its system, though this was not necessary for this study.

The primary short-circuit concern is whether the 15-kV–35-kV reclosers will have sufficient interrupting capability when applied to a generating system. The symmetrical interrupting rating of a standard VWE recloser is 12,000 amps. Table D1 summarizes the fault currents at various locations for the 750-kW 15-kV plan. In general, fault currents on the 15-kV system exceed the 12,000-amp level at all riser locations. The fault-current contribution from the 115-kV system is high, primarily due to its proximity (approximately 1,000 feet). The fault currents at the riser locations for the 25-kV and 35-kV plans, while less than those for the 15-kV plan, were also higher than 12,000 amps.

Modifications to lower fault currents could be made to the substation if a wind farm were to be located very close to a transmission line. Solutions could include: installation of either a high-impedance distribution transformer, installation of a reactor, or purchase of higher-rated switching devices.

A second short-circuit study with a slightly modified electrical system was conducted to show the effect of fault currents of a wind farm located 10,000 feet, rather than 1,000 feet, from a 115/15-kV substation. The results from this study are also tabulated in Table D1. In the modified electrical system, all of the fault currents on the 15-kV system are less than the maximum standard-equipment ratings.

Additional fine-tuning of the short-circuit analysis should be performed once an actual wind farm site has been determined. In addition, the utility to which the wind farm will be connected will need to know the additional fault contribution from the farm.

Table D1

WindPACT Turbine Design Scaling Studies
Short Circuit Fault Current Evaluation
750 kW - 15 kV Plan

			Fault Current (kA)			
			Plan As In Figure 1		Alternative Plan with 10,000 ft. extra OH Distribution Line	
Bus Number	Bus Name	kV	Three-Phase	Line-to-Ground	Three-Phase	Line-to-Ground
2	Mission 13.8	13.8	25.8	20.7	15.0	15.0
10	Riser A	13.8	14.1	5.8	9.9	5.2
15	Riser B	13.8	17.5	9.0	10.1	7.2
20	Riser C	13.8	15.5	7.4	10.0	6.3
25	Riser D	13.8	21.8	13.5	10.3	9.2
30	Riser E	13.8	22.3	13.6	11.3	9.8
149	Wind 49	13.8	19.3	9.8	10.9	7.8
249	Turbine 49	0.69	29.4	25.8	28.8	25.5
166	Wind 66	13.8	7.8	4.1	6.6	4.0
266	Turbine 66	0.69	28.7	25.5	27.7	25.2

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "1 Mission_115"
---------------------------------------------------------------------------
Substation UNDEFINED
Bus       1 Mission_115    Area   1 Mission        Zone   1 Phase1
        Ref  115.00 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                   SINGLE-LINE
X/R                     INFINITE                      INFINITE
FAULT CURRENT(Amps)     50981.                         .0082

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                      (Phase A)
                       ------------------------  ------------------------
Shunt Currents (Amps) >
System Equiv        49  50204.4      780.178         .00803       .00012

Branch Currents (Amps) from >
2      Mission_13.8  1  780.176      50204.4         .00007       .00810

---------------------------------------------------------------------------
Substation UNDEFINED
Bus       2 Mission_13.8   Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                   SINGLE-LINE
X/R                     14.803                        16.523
FAULT CURRENT(Amps)     25834.                        20661.

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                      (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
1      Mission_115   1  14260.4      11598.6        14487.3      6184.05
25     Riser_D       1  5332.03      20505.9        2842.89      17820.0
30     Riser_E       1  6267.50      19581.6        3341.65      17326.5
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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "10 Riser_A"
-------------------------------------------------------------------------
Substation UNDEFINED
Bus      10 Riser_A        Area   1 Mission         Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
X/R                     7.7349                         4.7423
FAULT CURRENT(Amps)     14183.                         5786.4

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
15      Riser_B       1  9174.58      5028.95        4423.35      1367.84
111     Wind_11       1  2411.83      11780.0        655.999      5132.71
112     Wind_12       1  2617.21      11572.8        711.861      5076.38

-------------------------------------------------------------------------
Substation UNDEFINED
Bus      15 Riser_B        Area   1 Mission         Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
X/R                     7.4133                         4.8327
FAULT CURRENT(Amps)     17537.                         8963.1

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
10      Riser_A       1  4306.86      13246.3        1467.48      7500.60
25      Riser_D       1  9482.99      8674.00        5133.11      4174.08
129     Wind_29       1  4858.23      13744.7        2862.67      6584.19

-------------------------------------------------------------------------
Substation UNDEFINED
Bus      20 Riser_C        Area   1 Mission         Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
X/R                     7.4203                         5.4757
FAULT CURRENT(Amps)     15462.                         7384.9

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
30      Riser_E       1  12029.5      3433.90        6291.93      1093.40
130     Wind_30       1  3433.90      12029.5        1093.40      6291.94
```

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "25 Riser_D"
-------------------------------------------------------------------------
Substation UNDEFINED
Bus     25 Riser_D        Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                  SINGLE-LINE
X/R                     10.647                       7.9007
FAULT CURRENT(Amps)     21807.                       13483.

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                      (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
2       Mission_13.8  1  16060.2      5746.82        11114.2      2368.78
15      Riser_B       1  3517.29      18359.1        1449.79      12060.0
148     Wind_48       1  2380.94      19530.3        981.398      12542.9

-------------------------------------------------------------------------
Substation UNDEFINED
Bus     30 Riser_E        Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                  SINGLE-LINE
X/R                     9.8456                       7.6935
FAULT CURRENT(Amps)     22338.                       13616.

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                      (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
2       Mission_13.8  1  15491.8      6850.04        10833.8      2783.63
20      Riser_C       1  3102.45      19235.8        1260.73      12355.5
149     Wind_49       1  3748.09      18593.3        1523.10      12094.3

-------------------------------------------------------------------------
Substation UNDEFINED
Bus     149 Wind_49       Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                  SINGLE-LINE
X/R                     4.8041                       2.5422
FAULT CURRENT(Amps)     19294.                       9776.8

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                      (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
30      Riser_E       1  15554.8      3869.77        8510.27      1307.27
150     Wind_50       1  3645.12      15766.6        1231.40      8582.34
249     Turbine_49    1  224.955      19078.5        75.9937      9703.96
```

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "249 Turbine_49"
-------------------------------------------------------------------------
Substation UNDEFINED
Bus    249 Turbine_49     Area   1 Mission        Zone   1 Phase1
        Ref     .48 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
X/R                     INFINITE                       INFINITE
FAULT CURRENT(Amps)     29373.                         25823.

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                       (Phase A)
                       ------------------------  ------------------------
Shunt Currents (Amps) >
750kW Gen            49  9369.91      20047.7       5491.77      20354.3

Branch Currents (Amps) from >
149    Wind_49       1  20047.7      9369.91       20354.3      5491.77

-------------------------------------------------------------------------
Substation UNDEFINED
Bus    166 Wind_66        Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
X/R                     2.1836                         1.0051
FAULT CURRENT(Amps)     7765.4                         4162.0

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                       (Phase A)
                       ------------------------  ------------------------
Branch Currents (Amps) from >
165    Wind_65       1  7610.21      224.938       4106.40      80.3824
266    Turbine_66    1  224.955      7610.19       80.3803      4106.40
```

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "266 Turbine_66"
-------------------------------------------------------------------------
Substation UNDEFINED
Bus    266 Turbine_66     Area   1 Mission        Zone   1 Phase1
        Ref     .48 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                  SINGLE-LINE
X/R                     INFINITE                     INFINITE
FAULT CURRENT(Amps)     28675.                       25457.

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                    (Phase A)
                       ------------------------  ------------------------
Shunt Currents (Amps) >
750kW Gen          49  9369.91      19396.9        5545.73      19958.7

Branch Currents (Amps) from >
166    Wind_66      1  19396.9      9369.92        19958.7      5545.74
```

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 NREL WindPACT Study Mission South Dakota
 Fault Study for 750kW Generators and 15kV Distribution  10,000 kft.of
Distribution
 SINGLE_LINE  at bus(es)   "1 Mission_115"
 --------------------------------------------------------------------------
-
 Substation UNDEFINED
 Bus      1 Mission_115    Area   1 Mission        Zone   1 Phase1
         Ref  115.00 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
 X/R                    4.0406                         INFINITE
 FAULT CURRENT(Amps)    2728.1                          .0114

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       ------------------------  ------------------------
 Branch Currents (Amps) from >
 2      Mission_13.8  1  560.128      2175.39       .00232         .00922
 3      Easteq_115    1  693.779      2034.37       .00284         .00867
 4      Westeq_115    1  700.039      2028.15       .00286         .00863
 5      Southeq_115   1  784.035      1949.54       .00384         .00806

 --------------------------------------------------------------------------
 Substation UNDEFINED
 Bus      2 Mission_13.8   Area   1 Mission        Zone   1 Phase1
         Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
 X/R                    6.0048                         7.8352
 FAULT CURRENT(Amps)    15034.                         14961.

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       ------------------------  ------------------------
 Branch Currents (Amps) from >
 1      Mission_115   1  8256.55      6777.15       10465.1      4496.39
 25     Riser_D       1  3229.37      11804.5       2142.57      12819.0
 30     Riser_E       1  3548.07      11485.8       2354.01      12607.6
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 NREL WindPACT Study Mission South Dakota
 Fault Study for 750kW Generators and 15kV Distribution
 SINGLE_LINE  at bus(es)   "3 Easteq_115"
 --------------------------------------------------------------------------
 Substation UNDEFINED
 Bus      3 Easteq_115     Area   1 Mission        Zone   1 Phase1
         Ref  115.00 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
 X/R                    INFINITE                       INFINITE
 FAULT CURRENT(Amps)    50707.                          .0046

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       ------------------------   -----------------------
 Shunt Currents (Amps) >
 System Equiv        49  50204.4      522.533        .00659        .00195

 Branch Currents (Amps) from >
 1      Mission_115   1  522.532      50204.4        .00217        .00672

 --------------------------------------------------------------------------
 Substation UNDEFINED
 Bus      4 Westeq_115     Area   1 Mission        Zone   1 Phase1
         Ref  115.00 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                    SINGLE-LINE
 X/R                    INFINITE                       INFINITE
 FAULT CURRENT(Amps)    50708.                          .0281

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
```

```
                                 -----------------------   ----------------------
Shunt Currents (Amps) >
System Equiv         49  50204.4      525.645         .02470       .00627

Branch Currents (Amps) from >
1      Mission_115   1  525.646      50204.4         .00644       .02486

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "5 Southeq_115"
-----------------------------------------------------------------------------
Substation UNDEFINED
Bus       5 Southeq_115    Area   1 Mission        Zone   1 Phase1
        Ref  115.00 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                   SINGLE-LINE
X/R                     INFINITE                      INFINITE
FAULT CURRENT(Amps)     50738.                         .0153

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       -----------------------   ----------------------
Shunt Currents (Amps) >
System Equiv         49  50204.4      566.231         .01510       .00019

Branch Currents (Amps) from >
1      Mission_115   1  566.230      50204.4         .00021       .01510

-----------------------------------------------------------------------------
Substation UNDEFINED
Bus      10 Riser_A        Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                   SINGLE-LINE
X/R                     9.3832                        5.1646
FAULT CURRENT(Amps)     9922.3                        5185.4

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       -----------------------  -----------------------
Branch Currents (Amps) from >
15     Riser_B       1  4905.23      5028.95        3436.37      1752.07
111    Wind_11       1  2411.84      7515.17        840.273      4346.56
112    Wind_12       1  2617.22      7308.33        911.828      4274.54

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "15 Riser_B"
-----------------------------------------------------------------------------
Substation UNDEFINED
Bus      15 Riser_B        Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                   SINGLE-LINE
X/R                     8.9545                        5.5491
FAULT CURRENT(Amps)     10169.                        7196.4

                        BRANCH       CLOSE-IN       BRANCH       CLOSE-IN
                                (+ seq)                     (Phase A)
                       -----------------------  -----------------------
Branch Currents (Amps) from >
10     Riser_A       1  4306.86      5869.89        2031.97      5167.47
25     Riser_D       1  3846.37      6527.36        3341.64      4043.23
129    Wind_29       1  2456.76      8106.79        2136.24      5347.58

-----------------------------------------------------------------------------
Substation UNDEFINED
Bus      20 Riser_C        Area   1 Mission        Zone   1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                        THREE-PHASE                   SINGLE-LINE
X/R                     7.0027                        5.5897
```

```
 FAULT CURRENT(Amps)      9974.2                          6283.3

                          BRANCH      CLOSE-IN       BRANCH      CLOSE-IN
                                  (+ seq)                      (Phase A)
                         ------------------------  ------------------------
 Branch Currents (Amps) from >
 30      Riser_E        1  6545.81      3433.90       4843.10      1442.12
 130     Wind_30        1  3433.90      6545.81       1442.12      4843.10

 ------------------------------------------------------------------------
----
 Substation UNDEFINED
 Bus       25 Riser_D       Area   1 Mission        Zone   1 Phase1
           Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                          THREE-PHASE                     SINGLE-LINE
 X/R                      8.8561                          7.8310
 FAULT CURRENT(Amps)      10267.                          9213.4

                          BRANCH      CLOSE-IN       BRANCH      CLOSE-IN
                                  (+ seq)                      (Phase A)
                         ------------------------    ----------------------
 Branch Currents (Amps) from >
 2       Mission_13.8  1  4530.26      5746.82       5779.54      3437.97
 15      Riser_B        1  3517.29      6883.50       2104.18      7177.62
 148     Wind_48        1  2380.94      7973.07       1424.38      7836.29

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 NREL WindPACT Study Mission South Dakota
 Fault Study for 750kW Generators and 15kV Distribution
 SINGLE_LINE  at bus(es)   "30 Riser_E"
 ------------------------------------------------------------------------
 Substation UNDEFINED
 Bus       30 Riser_E       Area   1 Mission        Zone   1 Phase1
           Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                          THREE-PHASE                     SINGLE-LINE
 X/R                      6.7501                          6.7251
 FAULT CURRENT(Amps)      11328.                          9760.5

                          BRANCH      CLOSE-IN       BRANCH      CLOSE-IN
                                  (+ seq)                      (Phase A)
                         ------------------------  ------------------------
 Branch Currents (Amps) from >
 2       Mission_13.8  1  4482.85      6850.00       5827.61      3934.75
 20      Riser_C        1  3102.45      8228.53       1782.10      7979.93
 149     Wind_49        1  3748.06      7580.44       2152.95      7607.81

 ------------------------------------------------------------------------
 Substation UNDEFINED
 Bus      149 Wind_49       Area   1 Mission        Zone   1 Phase1
           Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @     .00
                          THREE-PHASE                     SINGLE-LINE
 X/R                      7.3417                          3.1619
 FAULT CURRENT(Amps)      10853.                          7784.4

                          BRANCH      CLOSE-IN       BRANCH      CLOSE-IN
                                  (+ seq)                      (Phase A)
                         ------------------------  ------------------------
 Branch Currents (Amps) from >
 30      Riser_E        1  7034.22      3869.73       5954.59      1850.38
 150     Wind_50        1  3645.11      7252.01       1742.99      6059.45
 249     Turbine_49    1  224.955      10632.1       107.566      7678.70

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 NREL WindPACT Study Mission South Dakota
 Fault Study for 750kW Generators and 15kV Distribution
 SINGLE_LINE  at bus(es)   "249 Turbine_49"
 ------------------------------------------------------------------------
 Substation UNDEFINED
 Bus      249 Turbine_49    Area   1 Mission        Zone   1 Phase1
           Ref     .48 kV @0     Prefault 1.000 V (p.u.) @     .00
```

```
                              THREE-PHASE                         SINGLE-LINE
X/R                           INFINITE                            INFINITE
FAULT CURRENT(Amps)           28800.                              25526.

                              BRANCH        CLOSE-IN        BRANCH        CLOSE-IN
                                      (+ seq)                          (Phase A)
                             ------------------------  ------------------------
Shunt Currents (Amps) >
750kW Gen              49     9369.91       19474.0         5536.51       20011.9

Branch Currents (Amps) from >
149    Wind_49          1     19474.0       9369.92         20011.9       5536.51

-------------------------------------------------------------------------------
Substation UNDEFINED
Bus    166 Wind_66        Area    1 Mission        Zone    1 Phase1
        Ref   13.80 kV @0     Prefault 1.000 V (p.u.) @       .00
                              THREE-PHASE                         SINGLE-LINE
X/R                           3.1766                              1.1671
FAULT CURRENT(Amps)           6615.2                              3951.1

                              BRANCH        CLOSE-IN        BRANCH        CLOSE-IN
                                      (+ seq)                          (Phase A)
                             ------------------------   -----------------------
Branch Currents (Amps) from >
165    Wind_65          1     6431.30       224.955         3877.72       89.5796
266    Turbine_66       1     224.955       6431.30         89.5738       3877.72

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NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
SINGLE_LINE  at bus(es)   "266 Turbine_66"
-------------------------------------------------------------------------------
Substation UNDEFINED
```

```
MISCELLANEOUS DATA
NREL WindPACT Study Mission South Dakota
Fault Study for 750kW Generators and 15kV Distribution
BOOLEAN PARAMETERS FOLLOW
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
INTEGER PARAMETERS FOLLOW
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0
REAL PARAMETERS FOLLOW
   1.0E-12     100.0   0.000011000000.00       1.0   0.00001       0.0
0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0

AREA CODES AND NAMES
   1 Mission      Mission Area

ZONE NAMES
   1 Phase1

SHUNT CODES
   1 System Equiv
   2 750kW Gen
BUS DATA FOLLOWS
      1 Mission_115    1   1 115.000 1.00000  0.000000    0
S  49   1 A      0.0       0.0 0.0      -100.0000
      2 Mission_13.8   1   1  13.800 0.97400  8.021000    0
     10 Riser_A        1   1  13.800 0.98320 11.856000    0
     15 Riser_B        1   1  13.800 0.98080 10.452000    0
     20 Riser_C        1   1  13.800 0.97410  9.814000    0
     25 Riser_D        1   1  13.800 0.97640  8.809000    0
     30 Riser_E        1   1  13.800 0.97340  8.886000    0
    101 Wind_01        1   1  13.800 1.00320 12.284000    0
    102 Wind_02        1   1  13.800 1.00290 12.277000    0
    103 Wind_03        1   1  13.800 1.00230 12.261000    0
    104 Wind_04        1   1  13.800 1.00140 12.239000    0
    105 Wind_05        1   1  13.800 1.00020 12.209000    0
    106 Wind_06        1   1  13.800 0.99870 12.173000    0
    107 Wind_07        1   1  13.800 0.99690 12.130000    0
    108 Wind_08        1   1  13.800 0.99480 12.082000    0
    109 Wind_09        1   1  13.800 0.99240 12.030000    0
    110 Wind_10        1   1  13.800 0.98960 11.974000    0
    111 Wind_11        1   1  13.800 0.98660 11.916000    0
    112 Wind_12        1   1  13.800 0.98680 11.933000    0
    113 Wind_13        1   1  13.800 0.99010 12.008000    0
    114 Wind_14        1   1  13.800 0.99320 12.080000    0
    115 Wind_15        1   1  13.800 0.99580 12.148000    0
    116 Wind_16        1   1  13.800 0.99820 12.211000    0
    117 Wind_17        1   1  13.800 1.00030 12.268000    0
    118 Wind_18        1   1  13.800 1.00200 12.319000    0
    119 Wind_19        1   1  13.800 1.00350 12.362000    0
    120 Wind_20        1   1  13.800 1.00470 12.397000    0
    121 Wind_21        1   1  13.800 1.00560 12.423000    0
    122 Wind_22        1   1  13.800 1.00610 12.441000    0
    123 Wind_23        1   1  13.800 1.00640 12.450000    0
    124 Wind_24        1   1  13.800 0.98770 10.471000    0
    125 Wind_25        1   1  13.800 0.98740 10.469000    0
    126 Wind_26        1   1  13.800 0.98670 10.467000    0
    127 Wind_27        1   1  13.800 0.98570 10.463000    0
    128 Wind_28        1   1  13.800 0.98440 10.459000    0
    129 Wind_29        1   1  13.800 0.98280 10.455000    0
    130 Wind_30        1   1  13.800 0.97890  9.931000    0
    131 Wind_31        1   1  13.800 0.98330 10.050000    0
    132 Wind_32        1   1  13.800 0.98740 10.169000    0
    133 Wind_33        1   1  13.800 0.99120 10.285000    0
    134 Wind_34        1   1  13.800 0.99470 10.397000    0
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     135 Wind_35         1    1   13.800 0.99780 10.505000     0
     136 Wind_36         1    1   13.800 1.00070 10.606000     0
     137 Wind_37         1    1   13.800 1.00320 10.700000     0
     138 Wind_38         1    1   13.800 1.00550 10.786000     0
     139 Wind_39         1    1   13.800 1.00750 10.863000     0
     140 Wind_40         1    1   13.800 1.00920 10.930000     0
     141 Wind_41         1    1   13.800 1.01060 10.987000     0
     142 Wind_42         1    1   13.800 1.01170 11.033000     0
     143 Wind_43         1    1   13.800 1.01250 11.068000     0
     144 Wind_44         1    1   13.800 1.01310 11.092000     0
     145 Wind_45         1    1   13.800 1.01330 11.103000     0
     146 Wind_46         1    1   13.800 0.97850  8.793000     0
     147 Wind_47         1    1   13.800 0.97810  8.795000     0
     148 Wind_48         1    1   13.800 0.97740  8.800000     0
     149 Wind_49         1    1   13.800 0.97850  9.066000     0
     150 Wind_50         1    1   13.800 0.98330  9.246000     0
     151 Wind_51         1    1   13.800 0.98780  9.426000     0
     152 Wind_52         1    1   13.800 0.99190  9.602000     0
     153 Wind_53         1    1   13.800 0.99570  9.774000     0
     154 Wind_54         1    1   13.800 0.99920  9.940000     0
     155 Wind_55         1    1   13.800 1.00250 10.098000     0
     156 Wind_56         1    1   13.800 1.00540 10.249000     0
     157 Wind_57         1    1   13.800 1.01070 10.530000     0
     158 Wind_58         1    1   13.800 1.01310 10.659000     0
     159 Wind_59         1    1   13.800 1.01520 10.775000     0
     160 Wind_60         1    1   13.800 1.01700 10.879000     0
     161 Wind_61         1    1   13.800 1.01860 10.969000     0
     162 Wind_62         1    1   13.800 1.01990 11.045000     0
     163 Wind_63         1    1   13.800 1.02090 11.107000     0
     164 Wind_64         1    1   13.800 1.02250 11.200000     0
     165 Wind_65         1    1   13.800 1.02300 11.231000     0
     166 Wind_66         1    1   13.800 1.02320 11.247000     0
     201 Turbine_01      1    1    0.480 1.00000 14.793000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     202 Turbine_02      1    1    0.480 1.00000 14.784000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     203 Turbine_03      1    1    0.480 1.00000 14.766000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     204 Turbine_04      1    1    0.480 1.00000 14.740000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     205 Turbine_05      1    1    0.480 1.00000 14.706000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     206 Turbine_06      1    1    0.480 1.00000 14.664000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     207 Turbine_07      1    1    0.480 1.00000 14.614000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     208 Turbine_08      1    1    0.480 1.00000 14.558000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     209 Turbine_09      1    1    0.480 1.00000 14.497000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     210 Turbine_10      1    1    0.480 1.00000 14.430000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     211 Turbine_11      1    1    0.480 1.00000 14.360000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     212 Turbine_12      1    1    0.480 1.00000 14.378000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     213 Turbine_13      1    1    0.480 1.00000 14.466000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     214 Turbine_14      1    1    0.480 1.00000 14.550000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     215 Turbine_15      1    1    0.480 1.00000 14.628000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     216 Turbine_16      1    1    0.480 1.00000 14.700000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     217 Turbine_17      1    1    0.480 1.00000 14.766000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     218 Turbine_18      1    1    0.480 1.00000 14.823000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
     219 Turbine_19      1    1    0.480 1.00000 14.871000     0
S   49   2 A       0.0        0.0 0.0        -0.077900
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    220 Turbine_20      1    1   0.480 1.00000 14.911000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    221 Turbine_21      1    1   0.480 1.00000 14.941000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    222 Turbine_22      1    1   0.480 1.00000 14.961000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    223 Turbine_23      1    1   0.480 1.00000 14.971000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    224 Turbine_24      1    1   0.480 1.00000 12.919000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    225 Turbine_25      1    1   0.480 1.00000 12.916000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    226 Turbine_26      1    1   0.480 1.00000 12.911000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    227 Turbine_27      1    1   0.480 1.00000 12.904000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    228 Turbine_28      1    1   0.480 1.00000 12.894000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    229 Turbine_29      1    1   0.480 1.00000 12.884000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    230 Turbine_30      1    1   0.480 1.00000 12.344000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    231 Turbine_31      1    1   0.480 1.00000 12.481000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    232 Turbine_32      1    1   0.480 1.00000 12.616000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    233 Turbine_33      1    1   0.480 1.00000 12.747000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    234 Turbine_34      1    1   0.480 1.00000 12.873000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    235 Turbine_35      1    1   0.480 1.00000 12.993000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    236 Turbine_36      1    1   0.480 1.00000 13.105000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    237 Turbine_37      1    1   0.480 1.00000 13.209000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    238 Turbine_38      1    1   0.480 1.00000 13.303000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    239 Turbine_39      1    1   0.480 1.00000 13.388000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    240 Turbine_40      1    1   0.480 1.00000 13.461000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    241 Turbine_41      1    1   0.480 1.00000 13.524000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    242 Turbine_42      1    1   0.480 1.00000 13.574000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    243 Turbine_43      1    1   0.480 1.00000 13.612000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    244 Turbine_44      1    1   0.480 1.00000 13.637000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    245 Turbine_45      1    1   0.480 1.00000 13.650000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    246 Turbine_46      1    1   0.480 1.00000 11.204000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    247 Turbine_47      1    1   0.480 1.00000 11.205000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    248 Turbine_48      1    1   0.480 1.00000 11.208000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    249 Turbine_49      1    1   0.480 1.00000 11.478000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    250 Turbine_50      1    1   0.480 1.00000 11.677000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    251 Turbine_51      1    1   0.480 1.00000 11.874000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    252 Turbine_52      1    1   0.480 1.00000 12.067000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    253 Turbine_53      1    1   0.480 1.00000 12.253000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
    254 Turbine_54      1    1   0.480 1.00000 12.433000    0
S  49   2 A       0.0        0.0 0.0        -0.077900
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    255 Turbine_55     1    1    0.480 1.00000 12.604000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    256 Turbine_56     1    1    0.480 1.00000 12.766000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    257 Turbine_57     1    1    0.480 1.00000 13.067000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    258 Turbine_58     1    1    0.480 1.00000 13.205000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    259 Turbine_59     1    1    0.480 1.00000 13.329000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    260 Turbine_60     1    1    0.480 1.00000 13.439000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    261 Turbine_61     1    1    0.480 1.00000 13.535000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    262 Turbine_62     1    1    0.480 1.00000 13.616000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    263 Turbine_63     1    1    0.480 1.00000 13.682000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    264 Turbine_64     1    1    0.480 1.00000 13.781000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    265 Turbine_65     1    1    0.480 1.00000 13.814000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
    266 Turbine_66     1    1    0.480 1.00000 13.830000    0
S  49   2 A       0.0       0.0 0.0       -0.077900
SUBSTATION DATA FOLLOWS

TIES DATA FOLLOWS

BRANCH DATA FOLLOWS
      1       2  1   1   1      0 XFMR
P   0.01490     0.2833     0.0       0.0                    0.0       0.0
N   0.01490     0.2833     0.0       0.0                    0.0       0.0
Z INFINITE                 0.0       0.0                    .185   -3.520
      2      25  1   1   1      0 LINE
P    0.0127   0.0555     0.0         0.0                    0.0       0.0
N    0.0555   0.0555     0.0         0.0                    0.0       0.0
Z     0.066    0.258      0.0        0.0
     15      25  1   1   1      0 LINE
P    0.0292   0.1275     0.0         0.0                    0.0       0.0
N    0.0292   0.1275     0.0         0.0                    0.0       0.0
Z     0.152    0.594      0.0        0.0
     10      15  1   1   1      0 LINE
P    0.0292   0.1371      0.0        0.0                    0.0       0.0
N    0.0292   0.1371      0.0        0.0                    0.0       0.0
Z     0.152    0.639      0.0        0.0
      2      30  1   1   1      0 LINE
P    0.0127   0.0555     0.0         0.0                    0.0       0.0
N    0.0127   0.0555     0.0         0.0                    0.0       0.0
Z     0.066    0.258      0.0        0.0
     30      20  1   1   1      0 LINE
P    0.0292   0.1275      0.0        0.0                    0.0       0.0
N    0.0292   0.1275      0.0        0.0                    0.0       0.0
Z     0.152    0.594      0.0        0.0
     10     111  1   1   1      0 LINE
P    0.0420   0.0095      0.0        0.0                    0.0       0.0
N    0.0420   0.0095      0.0        0.0                    0.0       0.0
Z     0.107    0.047      0.0        0.0
     10     112  1   1   1      0 LINE
P    0.0420   0.0095     0.0         0.0                    0.0       0.0
N    0.0420   0.0095     0.0         0.0                    0.0       0.0
Z     0.107    0.047      0.0        0.0
     15     129  1   1   1      0 LINE
P    0.0420   0.0095      0.0        0.0                    0.0       0.0
N    0.0420   0.0095      0.0        0.0                    0.0       0.0
Z     0.107    0.047      0.0        0.0
     20     130  1   1   1      0 LINE
P     0.0420  0.0095     0.0         0.0                    0.0       0.0
N     0.0420  0.0095     0.0         0.0                    0.0       0.0
Z     0.107   0.047      0.0        0.0
     25     148  1   1   2      0 LINE
```

```
P    0.0156    0.073      0.0       0.0                    0.0       0.0
N    0.0156    0.073      0.0       0.0                    0.0       0.0
Z     0.081     0.34      0.0       0.0
     30    149  1   1   2      0 LINE
P    0.0757    0.026     0.0        0.0                    0.0       0.0
N    0.0757    0.026     0.0        0.0                    0.0       0.0
Z     0.295    0.224      0.0       0.0
    101    102  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    101    102  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    102    103  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    103    104  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    104    105  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    105    106  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    117    118  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    118    119  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    119    120  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    120    121  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    121    122  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    122    123  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    124    125  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    125    126  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    126    127  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
Z     0.107    0.047      0.0       0.0
    127    128  1   1   1      0 LINE
P    0.0420   0.0095      0.0       0.0                    0.0       0.0
N    0.0420   0.0095      0.0       0.0                    0.0       0.0
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Z     0.107    0.047        0.0       0.0
    128    129  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    139    140  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    140    141  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    141    142  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    142    143  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    143    144  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    144    145  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    146    147  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    147    148  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    148    125  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    161    162  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    162    163  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    164    165  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    165    166  1   1   1      0 LINE
P    0.0420   0.0095        0.0       0.0                              0.0       0.0
N    0.0420   0.0095        0.0       0.0                              0.0       0.0
Z     0.107    0.047        0.0       0.0
    106    107  1   1   1      0 LINE
P    0.0212   0.0085        0.0       0.0                              0.0       0.0
N    0.0212   0.0085        0.0       0.0                              0.0       0.0
Z     0.066    0.021        0.0       0.0
    107    108  1   1   1      0 LINE
P    0.0212   0.0085        0.0       0.0                              0.0       0.0
N    0.0212   0.0085        0.0       0.0                              0.0       0.0
Z     0.066    0.021        0.0       0.0
    108    109  1   1   1      0 LINE
P    0.0212   0.0085        0.0       0.0                              0.0       0.0
N    0.0212   0.0085        0.0       0.0                              0.0       0.0
Z     0.066    0.021        0.0       0.0
    109    110  1   1   1      0 LINE
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P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   113    114  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   114    115  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   115    116  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   116    117  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   136    137  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   137    138  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   138    139  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   157    158  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   158    159  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   159    160  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   160    161  1   1   1      0 LINE
P    0.0212   0.0085      0.0      0.0                    0.0       0.0
N    0.0212   0.0085      0.0      0.0                    0.0       0.0
Z     0.066    0.021      0.0      0.0
   110    111  1   1   1      0 LINE
P    0.0095   0.0073      0.0      0.0                    0.0       0.0
N    0.0095   0.0073      0.0      0.0                    0.0       0.0
Z     0.031    0.007      0.0      0.0
   111     10  1   1   1      0 LINE
P    0.0095   0.0073      0.0      0.0                    0.0       0.0
N    0.0095   0.0073      0.0      0.0                    0.0       0.0
Z     0.031    0.007      0.0      0.0
   112     10  1   1   1      0 LINE
P    0.0095   0.0073      0.0      0.0                    0.0       0.0
N    0.0095   0.0073      0.0      0.0                    0.0       0.0
Z     0.031    0.007      0.0      0.0
   112    113  1   1   1      0 LINE
P    0.0095   0.0073      0.0      0.0                    0.0       0.0
N    0.0095   0.0073      0.0      0.0                    0.0       0.0
Z     0.031    0.007      0.0      0.0
   130     20  1   1   1      0 LINE
P    0.0095   0.0073      0.0      0.0                    0.0       0.0
N    0.0095   0.0073      0.0      0.0                    0.0       0.0
Z     0.031    0.007      0.0      0.0
   130    131  1   1   1      0 LINE
P    0.0095   0.0073      0.0      0.0                    0.0       0.0
N    0.0095   0.0073      0.0      0.0                    0.0       0.0
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Z     0.031    0.007       0.0      0.0
    131    132  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    132    133  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    133    134  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    134    135  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    135    136  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    152    153  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    153    154  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    154    155  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    155    156  1   1   1      0 LINE
P    0.0095   0.0073       0.0      0.0                     0.0        0.0
N    0.0095   0.0073       0.0      0.0                     0.0        0.0
Z     0.031    0.007       0.0      0.0
    149      30  1   1   1      0 LINE
P    0.0067   0.0069       0.0      0.0                     0.0        0.0
N    0.0067   0.0069       0.0      0.0                     0.0        0.0
Z     0.021    0.005       0.0      0.0
    149      150 1   1   1      0 LINE
P    0.0067   0.0069       0.0      0.0                     0.0        0.0
N    0.0067   0.0069       0.0      0.0                     0.0        0.0
Z     0.021    0.005       0.0      0.0
    150      151 1   1   1      0 LINE
P    0.0067   0.0069       0.0      0.0                     0.0        0.0
N    0.0067   0.0069       0.0      0.0                     0.0        0.0
Z     0.021    0.005       0.0      0.0
    151      152 1   1   1      0 LINE
P    0.0067   0.0069       0.0      0.0                     0.0        0.0
N    0.0067   0.0069       0.0      0.0                     0.0        0.0
Z     0.021    0.005       0.0      0.0
    156      157  1   1   1      0 LINE
P    0.0190   0.0146       0.0      0.0                     0.0        0.0
N    0.0190   0.0146       0.0      0.0                     0.0        0.0
Z     0.063    0.015       0.0      0.0
    163      164 1   1   1      0 LINE
P    0.0839   0.0190       0.0      0.0                     0.0        0.0
N    0.0839   0.0190       0.0      0.0                     0.0        0.0
Z     0.215    0.094       0.0      0.0
    101    201  1   1   1      0 XFMR
P   0.6389   5.75000       0.0      0.0
N   0.6389   5.75000       0.0      0.0
Z  INFINITE                0.0      0.0                  0.0191    -0.1718
    102    202  1   1   1      0 XFMR
P   0.6389   5.75000       0.0      0.0
N   0.6389   5.75000       0.0      0.0
Z  INFINITE                0.0      0.0                  0.0191    -0.1718
    103    203  1   1   1      0 XFMR
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P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    104     204  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    105     205  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    106     206  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    107     207  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    108     208  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    109     209  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    110     210  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    111     211  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    112     212  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    113     213  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    114     214  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    115     215  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    116     216  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    117     217  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    118     218  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    119     219  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                   0.0191   -0.1718
    120     220  1   1   1      0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
```

```
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    121    221  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    122    222  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    123    223  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    124    224  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    125    225  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    126    226  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    127    227  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    128    228  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    129    229  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    130    230  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    131    231  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    132    232  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    133    233  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    134    234  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    135    235  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    136    236  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    137    237  1   1   1       0 XFMR
P   0.6389   5.75000              0.0         0.0
N   0.6389   5.75000              0.0         0.0
Z INFINITE                        0.0         0.0                  0.0191   -0.1718
    138    238  1   1   1       0 XFMR
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P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    139     239  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    140     240  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    141     241  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    142     242  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    143     243  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    144     244  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    145     245  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    146     246  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    147     247  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    148     248  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    149     249  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    150     250  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    151     251  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    152     252  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    153     253  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    154     254  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
Z INFINITE                 0.0       0.0                  0.0191   -0.1718
    155     255  1   1   1       0 XFMR
P   0.6389   5.75000       0.0       0.0
N   0.6389   5.75000       0.0       0.0
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Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    156    256  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    157    257  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    158    258  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    159    259  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    160    260  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    161    261  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    162    262  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    163    263  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    164    264  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    165    265  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718
    166    266  1   1   1          0 XFMR
P   0.6389   5.75000             0.0        0.0
N   0.6389   5.75000             0.0        0.0
Z INFINITE                       0.0        0.0                   0.0191    -0.1718

MUTUAL DATA FOLLOWS

END
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APPENDIX E
COST ESTIMATES

APPENDIX E
COST ESTIMATES

Table E1 provides a summary of the balance-of-station cost for all plans studied. Tables E2.1A through E2.4B provide the detailed estimate for each plan. The cost estimates are subtotaled by electrical, civil, communications, miscellaneous infrastructure, land, clearing, and project overhead costs. Also, average unit costs are provided where the cost can be related to either a number or length. For example, a generator step-up transformer is required for each wind turbine, so the unit cost for generator step-up transformers relates to the number of wind turbines installed. Cable and road unit costs are related to the length of these items. All costs are provided in present-day dollars.

CAI developed the cost estimates using internal data, manufacturers' equipment quotes, MEANS 2000 Electrical Cost Data, and MEANS 2000 Building Construction Cost Data. Details are provided in Tables E3 through E11. Table E12 summarizes manufacturer cost data for the major electrical equipment.

Additional assumptions are listed below:

1. The cost estimates do not include a low-voltage main circuit breaker on the secondary of the generator step-up transformers. It is assumed that this breaker is part of the wind turbine electrical system. Some coordination will be required to ensure that this main breaker can be tripped for a transformer fault. It might be necessary to add more relaying to the transformer to ensure this protection is adequately designed.

2. The underground costs are based on direct-buried cable installed in a trench. The trenching costs were taken from MEANS. This cost is based on trench in standard earth. We also assumed that any excess soil would be disposed of on-site at no cost. If there is considerable rock, then the trenching cost should be increased, perhaps doubled. Also, it may be necessary to haul and dispose of rocks that are brought to the surface. The cost for this would need to be added to the estimate.

3. No costs for line clearing were included. It is assumed that no clearing will be necessary at the Mission site.

4. Costs for land and right-of-way were included for the substation, maintenance building, and overhead line only. It is assumed that costs for the land rights for the underground cable and the access roadways will be negotiated as part of the land rights negotiated for the wind turbines.

5. The substation cost is based on installing a Power Delivery System (PDS) at a new substation site, as described in Appendix A. Rather than using this packaged system as assumed, a lower-cost substation may be possible by purchasing a stand-alone transformer and distribution breakers. This would be especially true if the existing

substation site is already developed for a second transformer and if the utility would allow for the wind farm transformer to be located at that site.

6. The substation cost estimates include a cost for a power electronic switched capacitor that would provide for delivery of 0 to 50 MW at a near-unity power factor.

7. Three options were considered for the access roads. The access roads are located only between wind turbines. Option 1 is based on a minimal 20-foot-wide gravel road. Option 2 is based on a paved 26-foot-wide road for the 750- and 2,500-kW plans and 32-foot-wide roads for the 5-MW and 10-MW plans. Option 2 road widths provide enough space to move a maintenance crane between towers but would not be wide enough to move the construction crane from site to site without disassembly. Option 3 road widths are 30 feet for the 750- and 2,500-kW plans and 40 feet for the 5-MW and 10-MW plans. These road widths would allow the construction crane to move from site to site. The gentleness of the Mission site terrain minimized the need for cut-and-fill of the roadbed. A steeper terrain would increase the road costs.

8. We have not included any costs to upgrade county or township roads.

TABLE E1
WindPACT Turbine Design Scaling Study
Technical Area 4 Balance of Station Cost
Cost Estimate ($ x 1,000)
SUMMARY SHEET

System Component		750 kW Plan		2500 kW Plan		5000 kW Plan		10000 kW Plan	
		15 kV	25 kV	25 kV	35 kV	25 kV	35 kV	25 kV	35 kV
Generator Step-up Transformers		1,147	1,153	676	710	1,177	1,196	819	870
Underground Cable		643	610	334	356	221	237	154	174
Risers and Reclosers		126	129	103	83	77	83	77	83
Overhead Line		188	123	121	121	333	301	98	98
Substation		2,612	2,528	2,528	2,729	2,528	2,729	2,528	2,729
Subtotal Electrical		4,716	4,543	3,762	3,999	4,337	4,545	3,677	3,954
Generator Foundations		5,148	5,148	7,000	7,000	8,300	8,300	8,000	8,000
Service Roads (Option 2)		2,310	2,310	1,156	1,156	1,000	1,000	680	680
Crane Pads		1,386	1,386	1,200	1,200	1,900	1,900	1,585	1,585
Subtotal Civil		8,844	8,844	9,356	9,356	11,200	11,200	10,265	10,265
Communications		823	823	380	372	335	335	209	209
Tower Lighting		660	660	200	200	100	100	50	50
Meteorological Towers		74	74	88	88	106	106	160	160
Maintenance Building		156	156	156	156	156	156	156	156
Subtotal Misc. Infrastructure		1,713	1,713	824	816	697	697	575	575
Land and Right-of-Way		47	47	47	47	76	76	44	44
Clearing and Site Preparation		5	5	5	5	5	5	5	5
Project Overheads		1,280	1,268	1,161	1,177	1,334	1,348	1,186	1,205
Subtotal (RW, Clearing & Overhead)		1,332	1,319	1,213	1,229	1,414	1,429	1,234	1,254
Project Subtotal		16,604	16,419	15,155	15,400	17,648	17,872	15,751	16,048
Contingency	20%	3,321	3,284	3,031	3,080	3,530	3,574	3,150	3,210
Plan Totals:		19,920	19,700	18,190	18,480	21,180	21,450	18,900	19,260

Table E2.1A
750kW - 15 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	66						
1000 kVA Padmount Transformers	66	ea.	$ 17,379	$ 1,147,000			
Underground Cables 1/0,4/0,500,750Al	28,300	feet	$ 22.72	$ 643,000		$ -	
Reclosers and Risers	5	ea	$ 25,100	$ 125,500			
Overhead 15 kV Line -3 x 795 ACSR	5,600	feet	$ 33.57	$ 188,000	$ 16,800	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,612,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 4,715,500	$ 31,800	$ 2,400	$ 4,749,700
Generator Foundations	66	ea.	$ 78,000	$ 5,148,000			
Service Roads (Option 2)	25,600	feet	$ 90	$ 2,310,000			
Crane Pads	66	ea.	$ 21,000	$ 1,386,000			
Subtotal Civil				$ 8,844,000			$ 8,844,000
Communications RTUs	73	ea.	$ 8,050	$ 588,000			
Fiber Communications Lines	33,900	feet	$ 4.96	$ 168,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 822,700			$ 822,700
Tower Lighting	66	ea.	$ 10,000	$ 660,000			$ 660,000
54m Meteorological Towers	2	ea.	$ 37,000	$ 74,000			$ 74,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Misc. Infrastructure				$ 1,712,700	$ 15,000	$ 2,400	$ 1,730,100
Subtotal Construction				$ 15,272,200	$ 46,800	$ 4,800	$ 15,323,800
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 1,069,100
Surveying	31,200	feet	$ 2.00				$ 62,400
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,279,900
Project Subtotal							$ 16,603,700
Contingency	20.0%						$ 3,320,740
Project Total							$ 19,924,440
						Rounded	**$ 19,920,000**

Table E2.1B
750kW - 25 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	66						
1000 kVA Padmount Transformers	66	ea.	$ 17,470	$ 1,153,000			
Underground Cables 1/0,4/0,500,750Al	28,300	feet	$ 21.55	$ 610,000		$ -	
Reclosers and Risers	5	ea	$ 25,860	$ 129,300			
Overhead 25 kV Line -3 x 795 ACSR	5,600	feet	$ 21.91	$ 122,700	$ 16,800	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,528,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 4,543,000	$ 31,800	$ 2,400	$ 4,577,200
Generator Foundations	66	ea.	$ 78,000	$ 5,148,000			
Service Roads (Option 2)	25,600	feet	$ 90	$ 2,310,000			
Crane Pads	66	ea.	$ 21,000	$ 1,386,000			
Subtotal Civil				$ 8,844,000			$ 8,844,000
Communications RTUs	73	ea.	$ 8,050	$ 588,000			
Fiber Communications Lines	33,900	feet	$ 4.96	$ 168,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 822,700			$ 822,700
Tower Lighting	66	ea.	$ 10,000	$ 660,000			$ 660,000
54m Meteorological Towers	2	ea.	$ 37,000	$ 74,000			$ 74,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Misc. Infrastructure				$ 1,712,700	$ 15,000	$ 2,400	$ 1,730,100
Subtotal Construction				$ 15,099,700	$ 46,800	$ 4,800	$ 15,151,300
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 1,057,000
Surveying	31,200	feet	$ 2.00				$ 62,400
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,267,800
Project Subtotal							$ 16,419,100
Contingency	20.0%						$ 3,283,820
Project Total							$ 19,702,920
						Rounded	**$ 19,700,000**

Table E2.2A

2500kW - 25 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	20						
3000 kVA Padmount Transformers	20	ea.	$ 33,800	$ 676,000			
Underground Cables 1/0,4/0,500,750Al	17,300	feet	$ 19.31	$ 334,000		$ -	
Reclosers and Risers	4	ea	$ 25,650	$ 102,600			
Overhead 25 kV Line -3 x 795 ACSR	5,700	feet	$ 21.26	$ 121,200	$ 17,100	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,528,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 3,761,800	$ 32,100	$ 2,400	$ 3,796,300
Generator Foundations	20	ea.	$ 350,000	$ 7,000,000			
Service Roads (Option 2)	12,800	feet	$ 90	$ 1,156,000			
Crane Pads	20	ea.	$ 60,000	$ 1,200,000			
Subtotal Civil				$ 9,356,000			$ 9,356,000
Communications RTUs	26	ea.	$ 8,050	$ 209,300			
Fiber Communications Lines	19,600	feet	$ 5.31	$ 104,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 380,000			$ 380,000
Tower Lighting	20	ea.	$ 10,000	$ 200,000			$ 200,000
92m Meteorological Towers	2	ea.	$ 44,000	$ 88,000			$ 88,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Misc. Infrastructure				$ 824,000	$ 15,000	$ 2,400	$ 841,400
Subtotal Construction				$ 13,941,800	$ 47,100	$ 4,800	$ 13,993,700
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 975,900
Surveying	18,500	feet	$ 2.00				$ 37,000
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,161,300
Project Subtotal							$ 15,155,000
Contingency	20.0%						$ 3,031,000
Project Total							$ 18,186,000
						Rounded	**$ 18,190,000**

Table E2.2B
2500kW - 35 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	20						
3000 kVA Padmount Transformers	20	ea.	$ 35,500	$ 710,000			
Underground Cables 1/0,4/0,500,750Al	13,900	feet	$ 25.61	$ 356,000		$ -	
Reclosers and Risers	3	ea	$ 27,633	$ 82,900			
Overhead 35 kV Line -3 x 795 ACSR	5,700	feet	$ 21.26	$ 121,200	$ 17,100	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,729,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 3,999,100	$ 32,100	$ 2,400	$ 4,033,600
Generator Foundations	20	ea.	$ 350,000	$ 7,000,000			
Service Roads (Option 2)	12,800	feet	$ 90	$ 1,156,000			
Crane Pads	20	ea.	$ 60,000	$ 1,200,000			
Subtotal Civil				$ 9,356,000			$ 9,356,000
Communications RTUs	25	ea.	$ 8,050	$ 201,250			
Fiber Communications Lines	19,600	feet	$ 5.31	$ 104,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 371,950			$ 371,950
Tower Lighting	20	ea.	$ 10,000	$ 200,000			$ 200,000
92m Meteorological Towers	2	ea.	$ 44,000	$ 88,000			$ 88,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Infrastructure				$ 815,950	$ 15,000	$ 2,400	$ 833,350
Subtotal Construction				$ 14,171,050	$ 47,100	$ 4,800	$ 14,222,950
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 992,000
Surveying	18,500	feet	$ 2.00				$ 37,000
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,177,400
Project Subtotal							$ 15,400,350
Contingency	20.0%						$ 3,080,070
Project Total							$ 18,480,420
						Rounded	**$ 18,480,000**

Table E2.3A
5000kW - 25 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	10						
7500 kVA Padmount Transformers	10	ea.	$ 117,700	$ 1,177,000			
Underground Cables 1/0,4/0,500,750Al	9,700	feet	$ 22.78	$ 221,000		$ -	
Reclosers and Risers	3	ea	$ 25,800	$ 77,400			
Overhead 25 kV Line -3 x 795 ACSR	15,300	feet	$ 21.78	$ 333,300	$ 45,900	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,528,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 4,336,700	$ 60,900	$ 2,400	$ 4,400,000
Generator Foundations	10	ea.	$ 830,000	$ 8,300,000			
Service Road (Option 2)	9,100	feet	$ 110	$ 1,000,000			
Crane Pads	10	ea.	$ 190,000	$ 1,900,000			
Subtotal Civil				$ 11,200,000			$ 11,200,000
Communications RTUs	15	ea.	$ 8,050	$ 120,750			
Fiber Communications Lines	25,000	feet	$ 5.92	$ 148,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 335,450			$ 335,450
Tower Lighting	10	ea.	$ 10,000	$ 100,000			$ 100,000
130m Meteorological Towers	2	ea.	$ 53,000	$ 106,000			$ 106,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Misc. Infrastructure				$ 697,450	$ 15,000	$ 2,400	$ 714,850
Subtotal Construction				$ 16,234,150	$ 75,900	$ 4,800	$ 16,314,850
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 1,136,400
Surveying	24,400	feet	$ 2.00				$ 48,800
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,333,600
Project Subtotal							$ 17,648,450
Contingency	20.0%						$ 3,529,690
Project Total							$ 21,178,140
						Rounded	**$ 21,180,000**

Table E2.3B
5000kW - 35 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	10						
7500 kVA Padmount Transformers	10	ea.	$ 119,600	$ 1,196,000			
Underground Cables 1/0,4/0,500,750Al	9,700	feet	$ 24.43	$ 237,000		$ -	
Reclosers and Risers	3	ea	$ 27,600	$ 82,800			
Overhead 35 kV Line -3 x 477 ACSR	15,300	feet	$ 19.65	$ 300,600	$ 45,900	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,729,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 4,545,400	$ 60,900	$ 2,400	$ 4,608,700
Generator Foundations	10	ea.	$ 830,000	$ 8,300,000			
20' Service Roads	9,060	feet	$ 110	$ 1,000,000			
Crane Pads	10	ea.	$ 190,000	$ 1,900,000			
Subtotal Civil				$ 11,200,000			$ 11,200,000
Communications RTUs	15	ea.	$ 8,050	$ 120,750			
Fiber Communications Lines	25,000	feet	$ 5.92	$ 148,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 335,450			$ 335,450
Tower Lighting	10	ea.	$ 10,000	$ 100,000			$ 100,000
130m Meteorological Towers	2	ea.	$ 53,000	$ 106,000			$ 106,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Misc. Infrastructure				$ 697,450	$ 15,000	$ 2,400	$ 714,850
Subtotal Construction				$ 16,442,850	$ 75,900	$ 4,800	$ 16,523,550
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 1,151,000
Surveying	24,360	feet	$ 2.00				$ 48,720
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,348,120
Project Subtotal							$ 17,871,670
Contingency	20.0%						$ 3,574,334
Project Total							$ 21,446,004
						Rounded	**$ 21,450,000**

Table E2.4A
10000kW - 25 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	5						
10/12.5/14 MVA Transformers	5	ea.	$ 163,800	$ 819,000			
Underground Cables 1/0,4/0,500,750Al	6,600	feet	$ 23.33	$ 154,000		$ -	
Reclosers and Risers	3	ea	$ 25,733	$ 77,200			
Overhead 25 kV Line -3 x 795 ACSR	4,500	feet	$ 21.84	$ 98,300	$ 13,500	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,528,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 3,676,500	$ 28,500	$ 2,400	$ 3,707,400
Generator Foundations	5	ea.	$ 1,600,000	$ 8,000,000			
Service Roads (Option 2)	6,150	feet	$ 111	$ 680,000			
Crane Pads	5	ea.	$ 317,000	$ 1,585,000			
Subtotal Civil				$ 10,265,000			$ 10,265,000
Communications RTUs	10	ea.	$ 8,050	$ 80,500			
Fiber Communications Lines	11,100	feet	$ 5.59	$ 62,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 209,200			$ 209,200
Tower Lighting	5	ea.	$ 10,000	$ 50,000			$ 50,000
184m Meteorological Towers	2	ea.	$ 80,000	$ 160,000			$ 160,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Infrastructure				$ 575,200	$ 15,000	$ 2,400	$ 592,600
Subtotal Construction				$ 14,516,700	$ 43,500	$ 4,800	$ 14,565,000
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 1,016,200
Surveying	10,650	feet	$ 2.00				$ 21,300
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,185,900
Project Subtotal							$ 15,750,900
Contingency	20.0%						$ 3,150,180
Project Total							$ 18,901,080
						Rounded	**$ 18,900,000**

Table E2.4B
10000kW - 35 kV Plan Cost Summary

	No.	Units	Avg. Cost Per Unit	Labor & Material Costs	Land & R/W	Clearing & Site Prep	Project Totals
No. Wind Turbines	5						
10/12.5/14 MVA Transformers	5	ea.	$ 174,000	$ 870,000			
Underground Cables 1/0,4/0,500,750Al	6,600	feet	$ 26.36	$ 174,000		$ -	
Reclosers and Risers	3	ea	$ 27,700	$ 83,100			
Overhead 35 kV Line -3 x 795 ACSR	4,500	feet	$ 21.84	$ 98,300	$ 13,500	$ -	
Substation - 30/40/50 MVA PDS	1	ea.		$ 2,729,000	$ 15,000	$ 2,400	
Subtotal Electrical				$ 3,954,400	$ 28,500	$ 2,400	$ 3,985,300
Generator Foundations	5	ea.	$ 1,600,000	$ 8,000,000			
Service Roads (Option 2)	6,150	feet	$ 111	$ 680,000			
Crane Pads	5	ea.	$ 317,000	$ 1,585,000			
Subtotal Civil				$ 10,265,000			$ 10,265,000
Communications RTUs	10	ea.	$ 8,050	$ 80,500			
Fiber Communications Lines	11,100	feet	$ 5.59	$ 62,000			
Communications Master Station	1	ea.	$ 66,700	$ 66,700			
Subtotal Communications				$ 209,200			$ 209,200
Tower Lighting	5	ea.	$ 10,000	$ 50,000			$ 50,000
184m Meteorological Towers	2	ea.	$ 80,000	$ 160,000			$ 160,000
40' x 60' Maintenance Building	1	ea.		$ 156,000	$ 15,000	$ 2,400	$ 173,400
Subtotal Infrastructure				$ 575,200	$ 15,000	$ 2,400	$ 592,600
Subtotal Construction				$ 14,794,600	$ 43,500	$ 4,800	$ 14,842,900
Project Overhead Costs							
Licensing & Permits							$ 5,000
Right-of-way Procurement	50.0%	of Land Costs					$ 23,400
Engineering	7.0%	of Labor & Material					$ 1,035,600
Surveying	10,650	feet	$ 2.00				$ 21,300
Construction Inspection	6	months	$ 10,000				$ 60,000
Owners Admin. Costs	6	months	$ 10,000				$ 60,000
Subtotal Project Overhead Costs							$ 1,205,300
Project Subtotal							$ 16,048,200
Contingency	20.0%						$ 3,209,640
Project Total							$ 19,257,840
						Rounded	**$ 19,260,000**

Table E3.1A
750 kW - 15 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100

Xfmr Id		Description	Rating kVA	Xfmr Costs
1	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100
2	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
3	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
4	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
5	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
6	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
7	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
8	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
9	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
10	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
11	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
12	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
13	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
14	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
15	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
16	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
17	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
18	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
19	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
20	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
21	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
22	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100
23	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100
24	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
25	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
26	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
27	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
28	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
29	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
30	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
31	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
32	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
33	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
34	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
35	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
36	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
37	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
38	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
39	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
40	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
41	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300

Table E3.1A
750 kW - 15 kV Plan Padmount Transformer Cost Detail

		Description	Rating	Cost
	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100

Xfmr Id		Description	Rating kVA	Xfmr Costs
42	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
43	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
44	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
45	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100
46	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100
47	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
48	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
49	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
50	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
51	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
52	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
53	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
54	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
55	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
56	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
57	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
58	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
59	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
60	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
61	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
62	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
63	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
64	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
65	1	1000 kVA, 13.8 kV - 480v, loop	1000	17,300
66	2	1000 kVA, 13.8 kV - 480v, end w/arresters	1000	18,100
Count	**66**		**Total**	1,146,600
			Rounded	**1,147,000**

Table E3.1B
750 kW - 25 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100

Xfmr Id		Description	Rating kVA	Xfmr Costs
1	2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100
2	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
3	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
4	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
5	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
6	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
7	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
8	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
9	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
10	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
11	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
12	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
13	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
14	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
15	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
16	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
17	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
18	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
19	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
20	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
21	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
22	2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100
23	2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100
24	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
25	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
26	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
27	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
28	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
29	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
30	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
31	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
32	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
33	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
34	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
35	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
36	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
37	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
38	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
39	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
40	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
41	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400

Table E3.1B
750 kW - 25 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100

Xfmr Id		Description	Rating kVA	Xfmr Costs
42	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
43	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
44	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
45	2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100
46	2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100
47	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
48	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
49	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
50	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
51	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
52	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
53	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
54	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
55	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
56	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
57	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
58	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
59	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
60	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
61	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
62	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
63	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
64	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
65	1	1000 kVA, 24.9 kV - 480v, loop	1000	17,400
66	2	1000 kVA, 24.9 kV - 480v, end w/arresters	1000	18,100
Count	**66**		**Total**	1,152,600
			Rounded	**1,153,000**

Table E3.2A
2500 kW - 25 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
2	3000 kVA, 24.9 kV - 690v, end w/arresters	3000	34,800

Xfmr Id		**Description**	**Rating kVA**	**Xfmr Costs**
1	2	3000 kVA, 24.9 kV - 690v, end w/arresters	3000	34,800
2	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
3	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
4	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
5	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
6	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
7	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
8	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
9	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
10	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
11	2	3000 kVA, 24.9 kV - 690v, end w/arresters	3000	34,800
12	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
13	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
14	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
15	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
16	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
17	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
18	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
19	1	3000 kVA, 24.9 kV - 690v, loop	3000	33,600
20	2	3000 kVA, 24.9 kV - 690v, end w/arresters	3000	34,800
Count	**20**		**Total**	675,600
			Rounded	**676,000**

Table E3.2B
2500 kW - 35 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
2	3000 kVA, 34.5 kV - 690v, end w/arresters	3000	36,500

Xfmr Id		Description	Rating kVA	Xfmr Costs
1	2	3000 kVA, 34.5 kV - 690v, end w/arresters	3000	36,500
2	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
3	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
4	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
5	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
6	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
7	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
8	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
9	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
10	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
11	2	3000 kVA, 34.5 kV - 690v, end w/arresters	3000	36,500
12	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
13	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
14	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
15	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
16	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
17	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
18	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
19	1	3000 kVA, 34.5 kV - 690v, loop	3000	35,300
20	2	3000 kVA, 34.5 kV - 690v, end w/arresters	3000	36,500
Count	**20**		**Total**	709,600
			Rounded	**710,000**

Table E3.3A
5000 kW - 25 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
2	7500 kVA, 24.9 kV - 2400v, end w/arresters	7500	118,600

Xfmr Id		Description	Rating kVA	Xfmr Costs
1	2	7500 kVA, 24.9 kV - 2400v, end w/arresters	7500	118,600
2	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
3	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
4	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
5	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
6	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
7	2	7500 kVA, 24.9 kV - 2400v, end w/arresters	7500	118,600
8	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
9	1	7500 kVA, 24.9 kV - 2400v, loop	7500	117,300
10	2	7500 kVA, 24.9 kV - 2400v, end w/arresters	7500	118,600
Count	**10**		**Total**	1,176,900
			Rounded	**1,177,000**

Table E3.3B
5000 kW - 35 kV Plan Padmount Transformer Cost Detail

	Description	Rating	Cost
1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
2	7500 kVA, 34.5 kV - 2400v, end w/arresters	7500	121,100

Xfmr Id		Description	Rating kVA	Xfmr Costs
1	2	7500 kVA, 34.5 kV - 2400v, end w/arresters	7500	121,100
2	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
3	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
4	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
5	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
6	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
7	2	7500 kVA, 34.5 kV - 2400v, end w/arresters	7500	121,100
8	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
9	1	7500 kVA, 34.5 kV - 2400v, loop	7500	118,900
10	2	7500 kVA, 34.5 kV - 2400v, end w/arresters	7500	121,100
Count	**10**		**Total**	1,195,600
			Rounded	**1,196,000**

Table E3.4A
10000 kW - 25 kV Plan Padmount Transformer Cost Detail

		Description	Rating	Cost
	1	10/12.5 MVA, 24.9 kV -4160V, loop	10/12.5/14	161,700
	2	10/12.5 MVA, 24.9 kV - 4160v, end w/arresters	10/12.5/14	165,300
Xfmr Id		**Description**	**Rating kVA**	**Xfmr Costs**
1	2	10/12.5 MVA, 24.9 kV - 4160v, end w/arresters	10/12.5/14	165,300
2	1	10/12.5 MVA, 24.9 kV -4160V, loop	10/12.5/14	161,700
3	2	10/12.5 MVA, 24.9 kV - 4160v, end w/arresters	10/12.5/14	165,300
4	1	10/12.5 MVA, 24.9 kV -4160V, loop	10/12.5/14	161,700
5	2	10/12.5 MVA, 24.9 kV - 4160v, end w/arresters	10/12.5/14	165,300
Count	**5**		**Total**	819,300
			Rounded	**819,000**

Table E3.4B
10000 kW - 35 kV Plan Padmount Transformer Cost Detail

		Description	Rating	Cost
	1	10/12.5 MVA, 34.5 kV -4160V, loop	10/12.5/14	171,800
	2	10/12.5 MVA, 34.5 kV - 4160v, end w/arresters	10/12.5/14	175,400
Xfmr Id		**Description**	**Rating kVA**	**Xfmr Costs**
1	2	10/12.5 MVA, 34.5 kV - 4160v, end w/arresters	10/12.5/14	175,400
2	1	10/12.5 MVA, 34.5 kV -4160V, loop	10/12.5/14	171,800
3	2	10/12.5 MVA, 34.5 kV - 4160v, end w/arresters	10/12.5/14	175,400
4	1	10/12.5 MVA, 34.5 kV -4160V, loop	10/12.5/14	171,800
5	2	10/12.5 MVA, 34.5 kV - 4160v, end w/arresters	10/12.5/14	175,400
Count	**5**		**Total**	869,800
			Rounded	**870,000**

Table E4.1A
750 kW - 15 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	12.03	3,110
2	3-1c 4/0 Al Cable	318	15.82	3,110
3	3-1c 500 Al Cable	502	24.66	3,110
4	3-1c 750 Al Cable	604	30.74	3,110

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs Cable Costs	Terminal Costs	Total Costs
1-2	377	416	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	13.8	1	216	4,535	3,110	7,645
2-3	377	416	1	3-1c 1/0 Al Cable	Wind_02 - Wind_03	13.8	1	216	4,535	3,110	7,645
3-4	377	416	1	3-1c 1/0 Al Cable	Wind_03 - Wind_04	13.8	1	216	4,535	3,110	7,645
4-5	377	416	1	3-1c 1/0 Al Cable	Wind_04 - Wind_05	13.8	1	216	4,535	3,110	7,645
5-6	377	416	1	3-1c 1/0 Al Cable	Wind_05 - Wind_06	13.8	1	216	4,535	3,110	7,645
6-7	377	416	2	3-1c 4/0 Al Cable	Wind_06 - Wind_07	13.8	1	318	5,964	3,110	9,074
7-8	377	416	2	3-1c 4/0 Al Cable	Wind_07 - Wind_08	13.8	1	318	5,964	3,110	9,074
8-9	377	416	2	3-1c 4/0 Al Cable	Wind_08 - Wind_09	13.8	1	318	5,964	3,110	9,074
9-10	377	416	2	3-1c 4/0 Al Cable	Wind_09 - Wind_10	13.8	1	318	5,964	3,110	9,074
10-11	377	416	3	3-1c 500 Al Cable	Wind_10 - Wind_11	13.8	1	502	9,297	3,110	12,407
11-A	377	416	3	3-1c 500 Al Cable	Wind_11 - Riser_A	13.8	1	502	9,297	3,110	12,407
12-A	377	416	3	3-1c 500 Al Cable	Wind_12 - Riser_A	13.8	1	502	9,297	3,110	12,407
12-13	377	416	3	3-1c 500 Al Cable	Wind_12 - Wind_13	13.8	1	502	9,297	3,110	12,407
13-14	377	416	2	3-1c 4/0 Al Cable	Wind_13 - Wind_14	13.8	1	318	5,964	3,110	9,074
14-15	377	416	2	3-1c 4/0 Al Cable	Wind_14 - Wind_15	13.8	1	318	5,964	3,110	9,074
15-16	377	416	2	3-1c 4/0 Al Cable	Wind_15 - Wind_16	13.8	1	318	5,964	3,110	9,074
16-17	377	416	1	3-1c 1/0 Al Cable	Wind_16 - Wind_17	13.8	1	216	4,535	3,110	7,645
17-18	377	416	1	3-1c 1/0 Al Cable	Wind_17 - Wind_18	13.8	1	216	4,535	3,110	7,645
18-19	377	416	1	3-1c 1/0 Al Cable	Wind_18 - Wind_19	13.8	1	216	4,535	3,110	7,645
19-20	377	416	1	3-1c 1/0 Al Cable	Wind_19 - Wind_20	13.8	1	216	4,535	3,110	7,645
20-21	377	416	1	3-1c 1/0 Al Cable	Wind_20 - Wind_21	13.8	1	216	4,535	3,110	7,645
21-22	377	416	1	3-1c 1/0 Al Cable	Wind_21 - Wind_22	13.8	1	216	4,535	3,110	7,645
23-24	377	416	1	3-1c 1/0 Al Cable	Wind_23 - Wind_24	13.8	2	216	4,535	3,110	7,645
24-25	377	416	1	3-1c 1/0 Al Cable	Wind_24 - Wind_25	13.8	1	216	4,535	3,110	7,645
25-26	377	416	1	3-1c 1/0 Al Cable	Wind_25 - Wind_26	13.8	1	216	4,535	3,110	7,645
26-27	377	416	1	3-1c 1/0 Al Cable	Wind_26 - Wind_27	13.8	1	216	4,535	3,110	7,645
27-28	377	416	1	3-1c 1/0 Al Cable	Wind_27 - Wind_28	13.8	1	216	4,535	3,110	7,645
28-29	377	416	1	3-1c 1/0 Al Cable	Wind_28 - Wind_29	13.8	1	216	4,535	3,110	7,645
29-B	377	416	2	3-1c 4/0 Al Cable	Wind_29 - Riser_B	13.8	1	318	5,964	3,110	9,074
30-C	377	416	3	3-1c 500 Al Cable	Wind_30 - Riser_C	13.8	1	502	9,297	3,110	12,407

Table E4.1A
750 kW - 15 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	12.03	3,110
2	3-1c 4/0 Al Cable	318	15.82	3,110
3	3-1c 500 Al Cable	502	24.66	3,110
4	3-1c 750 Al Cable	604	30.74	3,110

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
30-31	377	416	3	3-1c 500 Al Cable	Wind_30 - Wind_31	13.8	1	502	9,297	3,110	12,407
31-32	377	416	3	3-1c 500 Al Cable	Wind_31 - Wind_32	13.8	1	502	9,297	3,110	12,407
32-33	377	416	3	3-1c 500 Al Cable	Wind_32 - Wind_33	13.8	1	502	9,297	3,110	12,407
33-34	377	416	3	3-1c 500 Al Cable	Wind_33 - Wind_34	13.8	1	502	9,297	3,110	12,407
34-35	377	416	3	3-1c 500 Al Cable	Wind_34 - Wind_35	13.8	1	502	9,297	3,110	12,407
35-36	377	416	3	3-1c 500 Al Cable	Wind_35 - Wind_36	13.8	1	502	9,297	3,110	12,407
36-37	377	416	2	3-1c 4/0 Al Cable	Wind_36 - Wind_37	13.8	1	318	5,964	3,110	9,074
37-38	377	416	2	3-1c 4/0 Al Cable	Wind_37 - Wind_38	13.8	1	318	5,964	3,110	9,074
38-39	377	416	2	3-1c 4/0 Al Cable	Wind_38 - Wind_39	13.8	1	318	5,964	3,110	9,074
39-40	377	416	1	3-1c 1/0 Al Cable	Wind_39 - Wind_40	13.8	1	216	4,535	3,110	7,645
40-41	377	416	1	3-1c 1/0 Al Cable	Wind_40 - Wind_41	13.8	1	216	4,535	3,110	7,645
41-42	377	416	1	3-1c 1/0 Al Cable	Wind_41 - Wind_42	13.8	1	216	4,535	3,110	7,645
42-43	377	416	1	3-1c 1/0 Al Cable	Wind_42 - Wind_43	13.8	1	216	4,535	3,110	7,645
43-44	377	416	1	3-1c 1/0 Al Cable	Wind_43 - Wind_44	13.8	1	216	4,535	3,110	7,645
44-45	377	416	1	3-1c 1/0 Al Cable	Wind_44 - Wind_45	13.8	1	216	4,535	3,110	7,645
46-47	377	416	1	3-1c 1/0 Al Cable	Wind_46 - Wind_47	13.8	1	216	4,535	3,110	7,645
47-48	377	416	1	3-1c 1/0 Al Cable	Wind_47 - Wind_48	13.8	1	216	4,535	3,110	7,645
48-D	377	416	1	3-1c 1/0 Al Cable	Wind_48 - Riser_D	13.8	1	216	4,535	3,110	7,645
49-E	377	416	4	3-1c 750 Al Cable	Wind_49 - Riser_E	13.8	1	604	11,589	3,110	14,699
49-50	377	416	4	3-1c 750 Al Cable	Wind_49 - Wind_50	13.8	1	604	11,589	3,110	14,699
50-51	377	416	4	3-1c 750 Al Cable	Wind_50 - Wind_51	13.8	1	604	11,589	3,110	14,699
51-52	377	416	4	3-1c 750 Al Cable	Wind_51 - Wind_52	13.8	1	604	11,589	3,110	14,699
52-53	377	416	3	3-1c 500 Al Cable	Wind_52 - Wind_53	13.8	1	502	9,297	3,110	12,407
53-54	377	416	3	3-1c 500 Al Cable	Wind_53 - Wind_54	13.8	1	502	9,297	3,110	12,407
54-55	377	416	3	3-1c 500 Al Cable	Wind_54 - Wind_55	13.8	1	502	9,297	3,110	12,407
55-56	377	416	3	3-1c 500 Al Cable	Wind_55 - Wind_56	13.8	1	502	9,297	3,110	12,407
56-57	754	812	3	3-1c 500 Al Cable	Wind_56 - Wind_57	13.8	1	502	18,594	3,110	21,704
57-58	377	416	2	3-1c 4/0 Al Cable	Wind_57 - Wind_58	13.8	1	318	5,964	3,110	9,074
58-59	377	416	2	3-1c 4/0 Al Cable	Wind_58 - Wind_59	13.8	1	318	5,964	3,110	9,074

Table E4.1A

750 kW - 15 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	12.03	3,110
2	3-1c 4/0 Al Cable	318	15.82	3,110
3	3-1c 500 Al Cable	502	24.66	3,110
4	3-1c 750 Al Cable	604	30.74	3,110

1.05 extra

20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
59-60	377	416	2	3-1c 4/0 Al Cable	Wind_59 - Wind_60	13.8	1	318	5,964	3,110	9,074
60-61	377	416	1	3-1c 1/0 Al Cable	Wind_60 - Wind_61	13.8	1	216	4,535	3,110	7,645
61-62	377	416	1	3-1c 1/0 Al Cable	Wind_61 - Wind_62	13.8	1	216	4,535	3,110	7,645
62-63	377	416	1	3-1c 1/0 Al Cable	Wind_62 - Wind_63	13.8	1	216	4,535	3,110	7,645
63-64	754	812	1	3-1c 1/0 Al Cable	Wind_63 - Wind_64	13.8	1	216	9,071	3,110	12,181
64-65	377	416	1	3-1c 1/0 Al Cable	Wind_64 - Wind_65	13.8	1	216	4,535	3,110	7,645
65-66	377	416	1	3-1c 1/0 Al Cable	Wind_65 - Wind_66	13.8	1	216	4,535	3,110	7,645
Totals	25,636	28,280								Total Cost	$642,825
										Total Cost (Rounded)	$643,000
Rounded		28,300						**Average cost per mile**			$132,400
Miles	4.86										

Table E4.1B

750kW - 25 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	13.98	3,535
2	3-1c 4/0 Al Cable	318	17.70	3,535
3	3-1c 500 Al Cable	502	27.42	3,535
4	3-1c 4/0 Al w/Splice	318	17.70	4,750

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	377	416	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	24.9	1	216	5,270	3,535	8,805
2-3	377	416	1	3-1c 1/0 Al Cable	Wind_02 - Wind_03	24.9	1	216	5,270	3,535	8,805
3-4	377	416	1	3-1c 1/0 Al Cable	Wind_03 - Wind_04	24.9	1	216	5,270	3,535	8,805
4-5	377	416	1	3-1c 1/0 Al Cable	Wind_04 - Wind_05	24.9	1	216	5,270	3,535	8,805
5-6	377	416	1	3-1c 1/0 Al Cable	Wind_05 - Wind_06	24.9	1	216	5,270	3,535	8,805
6-7	377	416	1	3-1c 1/0 Al Cable	Wind_06 - Wind_07	24.9	1	216	5,270	3,535	8,805
7-8	377	416	1	3-1c 1/0 Al Cable	Wind_07 - Wind_08	24.9	1	216	5,270	3,535	8,805
8-9	377	416	1	3-1c 1/0 Al Cable	Wind_08 - Wind_09	24.9	1	216	5,270	3,535	8,805
9-10	377	416	1	3-1c 1/0 Al Cable	Wind_09 - Wind_10	24.9	1	216	5,270	3,535	8,805
10-11	377	416	1	3-1c 1/0 Al Cable	Wind_10 - Wind_11	24.9	1	216	5,270	3,535	8,805
11-A	377	416	1	3-1c 1/0 Al Cable	Wind_11 - Riser_A	24.9	1	216	5,270	3,535	8,805
12-A	377	416	1	3-1c 1/0 Al Cable	Wind_12 - Riser_A	24.9	1	216	5,270	3,535	8,805
12-13	377	416	1	3-1c 1/0 Al Cable	Wind_12 - Wind_13	24.9	1	216	5,270	3,535	8,805
13-14	377	416	1	3-1c 1/0 Al Cable	Wind_13 - Wind_14	24.9	1	216	5,270	3,535	8,805
14-15	377	416	1	3-1c 1/0 Al Cable	Wind_14 - Wind_15	24.9	1	216	5,270	3,535	8,805
15-16	377	416	1	3-1c 1/0 Al Cable	Wind_15 - Wind_16	24.9	1	216	5,270	3,535	8,805
16-17	377	416	1	3-1c 1/0 Al Cable	Wind_16 - Wind_17	24.9	1	216	5,270	3,535	8,805
17-18	377	416	1	3-1c 1/0 Al Cable	Wind_17 - Wind_18	24.9	1	216	5,270	3,535	8,805
18-19	377	416	1	3-1c 1/0 Al Cable	Wind_18 - Wind_19	24.9	1	216	5,270	3,535	8,805
19-20	377	416	1	3-1c 1/0 Al Cable	Wind_19 - Wind_20	24.9	1	216	5,270	3,535	8,805
20-21	377	416	1	3-1c 1/0 Al Cable	Wind_20 - Wind_21	24.9	1	216	5,270	3,535	8,805
21-22	377	416	1	3-1c 1/0 Al Cable	Wind_21 - Wind_22	24.9	1	216	5,270	3,535	8,805
23-24	377	416	1	3-1c 1/0 Al Cable	Wind_23 - Wind_24	24.9	2	216	5,270	3,535	8,805
24-25	377	416	1	3-1c 1/0 Al Cable	Wind_24 - Wind_25	24.9	1	216	5,270	3,535	8,805
25-26	377	416	1	3-1c 1/0 Al Cable	Wind_25 - Wind_26	24.9	1	216	5,270	3,535	8,805
26-27	377	416	1	3-1c 1/0 Al Cable	Wind_26 - Wind_27	24.9	1	216	5,270	3,535	8,805
27-28	377	416	1	3-1c 1/0 Al Cable	Wind_27 - Wind_28	24.9	1	216	5,270	3,535	8,805
28-29	377	416	1	3-1c 1/0 Al Cable	Wind_28 - Wind_29	24.9	1	216	5,270	3,535	8,805
29-B	377	416	1	3-1c 1/0 Al Cable	Wind_29 - Riser_B	24.9	1	216	5,270	3,535	8,805
30-C	377	416	2	3-1c 4/0 Al Cable	Wind_30 - Riser_C	24.9	1	318	6,673	3,535	10,208
30-31	377	416	2	3-1c 4/0 Al Cable	Wind_30 - Wind_31	24.9	1	318	6,673	3,535	10,208

Table E4.1B
750kW - 25 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	13.98	3,535
2	3-1c 4/0 Al Cable	318	17.70	3,535
3	3-1c 500 Al Cable	502	27.42	3,535
4	3-1c 4/0 Al w/Splice	318	17.70	4,750

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
31-32	377	416	2	3-1c 4/0 Al Cable	Wind_31 - Wind_32	24.9	1	318	6,673	3,535	10,208
32-33	377	416	2	3-1c 4/0 Al Cable	Wind_32 - Wind_33	24.9	1	318	6,673	3,535	10,208
33-34	377	416	2	3-1c 4/0 Al Cable	Wind_33 - Wind_34	24.9	1	318	6,673	3,535	10,208
34-35	377	416	2	3-1c 4/0 Al Cable	Wind_34 - Wind_35	24.9	1	318	6,673	3,535	10,208
35-36	377	416	2	3-1c 4/0 Al Cable	Wind_35 - Wind_36	24.9	1	318	6,673	3,535	10,208
36-37	377	416	1	3-1c 1/0 Al Cable	Wind_36 - Wind_37	24.9	1	216	5,270	3,535	8,805
37-38	377	416	1	3-1c 1/0 Al Cable	Wind_37 - Wind_38	24.9	1	216	5,270	3,535	8,805
38-39	377	416	1	3-1c 1/0 Al Cable	Wind_38 - Wind_39	24.9	1	216	5,270	3,535	8,805
39-40	377	416	1	3-1c 1/0 Al Cable	Wind_39 - Wind_40	24.9	1	216	5,270	3,535	8,805
40-41	377	416	1	3-1c 1/0 Al Cable	Wind_40 - Wind_41	24.9	1	216	5,270	3,535	8,805
41-42	377	416	1	3-1c 1/0 Al Cable	Wind_41 - Wind_42	24.9	1	216	5,270	3,535	8,805
42-43	377	416	1	3-1c 1/0 Al Cable	Wind_42 - Wind_43	24.9	1	216	5,270	3,535	8,805
43-44	377	416	1	3-1c 1/0 Al Cable	Wind_43 - Wind_44	24.9	1	216	5,270	3,535	8,805
44-45	377	416	1	3-1c 1/0 Al Cable	Wind_44 - Wind_45	24.9	1	216	5,270	3,535	8,805
46-47	377	416	1	3-1c 1/0 Al Cable	Wind_46 - Wind_47	24.9	1	216	5,270	3,535	8,805
47-48	377	416	1	3-1c 1/0 Al Cable	Wind_47 - Wind_48	24.9	1	216	5,270	3,535	8,805
48-D	377	416	1	3-1c 1/0 Al Cable	Wind_48 - Riser_D	24.9	1	216	5,270	3,535	8,805
49-E	377	416	2	3-1c 4/0 Al Cable	Wind_49 - Riser_E	24.9	1	318	6,673	3,535	10,208
49-50	377	416	2	3-1c 4/0 Al Cable	Wind_49 - Wind_50	24.9	1	318	6,673	3,535	10,208
50-51	377	416	2	3-1c 4/0 Al Cable	Wind_50 - Wind_51	24.9	1	318	6,673	3,535	10,208
51-52	377	416	2	3-1c 4/0 Al Cable	Wind_51 - Wind_52	24.9	1	318	6,673	3,535	10,208
52-53	377	416	2	3-1c 4/0 Al Cable	Wind_52 - Wind_53	24.9	1	318	6,673	3,535	10,208
53-54	377	416	2	3-1c 4/0 Al Cable	Wind_53 - Wind_54	24.9	1	318	6,673	3,535	10,208
54-55	377	416	1	3-1c 1/0 Al Cable	Wind_54 - Wind_55	24.9	1	216	5,270	3,535	8,805
55-56	377	416	1	3-1c 1/0 Al Cable	Wind_55 - Wind_56	24.9	1	216	5,270	3,535	8,805
56-57	754	812	1	3-1c 1/0 Al Cable	Wind_56 - Wind_57	24.9	1	216	10,541	3,535	14,076
57-58	377	416	1	3-1c 1/0 Al Cable	Wind_57 - Wind_58	24.9	1	216	5,270	3,535	8,805
58-59	377	416	1	3-1c 1/0 Al Cable	Wind_58 - Wind_59	24.9	1	216	5,270	3,535	8,805
59-60	377	416	1	3-1c 1/0 Al Cable	Wind_59 - Wind_60	24.9	1	216	5,270	3,535	8,805

Table E4.1B
750kW - 25 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	13.98	3,535
2	3-1c 4/0 Al Cable	318	17.70	3,535
3	3-1c 500 Al Cable	502	27.42	3,535
4	3-1c 4/0 Al w/Splice	318	17.70	4,750

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
60-61	377	416	1	3-1c 1/0 Al Cable	Wind_60 - Wind_61	24.9	1	216	5,270	3,535	8,805
61-62	377	416	1	3-1c 1/0 Al Cable	Wind_61 - Wind_62	24.9	1	216	5,270	3,535	8,805
62-63	377	416	1	3-1c 1/0 Al Cable	Wind_62 - Wind_63	24.9	1	216	5,270	3,535	8,805
63-64	754	812	1	3-1c 1/0 Al Cable	Wind_63 - Wind_64	24.9	1	216	10,541	3,535	14,076
64-65	377	416	1	3-1c 1/0 Al Cable	Wind_64 - Wind_65	24.9	1	216	5,270	3,535	8,805
65-66	377	416	1	3-1c 1/0 Al Cable	Wind_65 - Wind_66	24.9	1	216	5,270	3,535	8,805
Totals	25,636	28,280									$609,933
Rounded		28,300							Total Cost (Rounded)		$610,000
Miles	4.86								**Average cost per mile**		$125,600

Table E4.2A
2500kW - 25 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	13.98	3,535
2	3-1c 4/0 Al Cable	318	17.70	3,535
3	3-1c 500 Al Cable	502	27.42	3,535
4	3-1c 4/0 Al w/Splice	318	17.70	4,750

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	642	694	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	24.9	1	216	8,975	3,535	12,510
2-3	642	694	1	3-1c 1/0 Al Cable	Wind_02 - Wind_03	24.9	1	216	8,975	3,535	12,510
3-4	642	694	1	3-1c 1/0 Al Cable	Wind_03 - Wind_04	24.9	1	216	8,975	3,535	12,510
4-5	642	694	2	3-1c 4/0 Al Cable	Wind_04 - Wind_05	24.9	1	318	11,363	3,535	14,898
5-6	642	694	2	3-1c 4/0 Al Cable	Wind_05 - Wind_06	24.9	1	318	11,363	3,535	14,898
6-A	642	694	3	3-1c 500 Al Cable	Wind_06 - Wind_07	24.9	1	502	17,604	3,535	21,139
7-A	642	694	2	3-1c 4/0 Al Cable	Wind_07 - Wind_08	24.9	1	318	11,363	3,535	14,898
7-8	642	694	2	3-1c 4/0 Al Cable	Wind_08 - Wind_09	24.9	1	318	11,363	3,535	14,898
8-9	642	694	1	3-1c 1/0 Al Cable	Wind_09 - Wind_10	24.9	1	216	8,975	3,535	12,510
9-10	642	694	1	3-1c 1/0 Al Cable	Wind_10 - Wind_11	24.9	1	216	8,975	3,535	12,510
10-11	642	694	1	3-1c 1/0 Al Cable	Wind_11 - Riser_A	24.9	1	216	8,975	3,535	12,510
12-B	642	694	2	3-1c 4/0 Al Cable	Wind_12 - Riser_A	24.9	1	318	11,363	3,535	14,898
12-13	642	694	2	3-1c 4/0 Al Cable	Wind_12 - Wind_13	24.9	1	318	11,363	3,535	14,898
13-14	642	694	1	3-1c 1/0 Al Cable	Wind_13 - Wind_14	24.9	1	216	8,975	3,535	12,510
14-15	642	694	1	3-1c 1/0 Al Cable	Wind_14 - Wind_15	24.9	1	216	8,975	3,535	12,510
15-16	642	694	1	3-1c 1/0 Al Cable	Wind_15 - Wind_16	24.9	1	216	8,975	3,535	12,510
17-B	3,852	4065	4	3-1c 750 Al Cable	Wind_16 - Wind_17	24.9	1	318	68,180	4,750	72,930
17-18	642	694	1	3-1c 1/0 Al Cable	Wind_17 - Wind_18	24.9	1	216	8,975	3,535	12,510
18-19	642	694	1	3-1c 1/0 Al Cable	Wind_18 - Wind_19	24.9	1	216	8,975	3,535	12,510
19-20	642	694	1	3-1c 1/0 Al Cable	Wind_19 - Wind_20	24.9	1	216	8,975	3,535	12,510
Totals	16,050	17,253									$333,581
Rounded		17,300							Total Cost (Rounded)		$334,000
Miles	3.04								**Average cost per mile**		$109,700

Table E4.2B
2500kW - 35 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	16.66	5,479
2	3-1c 4/0 Al Cable	318	22.91	5,479
3	3-1c 500 Al Cable	502	32.39	5,479

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	642	694	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	13.8	1	216	10,696	5,479	16,175
2-3	642	694	1	3-1c 1/0 Al Cable	Wind_02 - Wind_03	13.8	1	216	10,696	5,479	16,175
3-4	642	694	1	3-1c 1/0 Al Cable	Wind_03 - Wind_04	13.8	1	216	10,696	5,479	16,175
4-5	642	694	1	3-1c 1/0 Al Cable	Wind_04 - Wind_05	13.8	1	216	10,696	5,479	16,175
5-6	642	694	1	3-1c 1/0 Al Cable	Wind_05 - Wind_06	13.8	1	216	10,696	5,479	16,175
6-A	642	694	2	3-1c 4/0 Al Cable	Wind_06 - Wind_07	13.8	1	318	14,708	5,479	20,187
7-A	642	694	1	3-1c 1/0 Al Cable	Wind_07 - Wind_08	13.8	1	216	10,696	5,479	16,175
7-8	642	694	1	3-1c 1/0 Al Cable	Wind_08 - Wind_09	13.8	1	216	10,696	5,479	16,175
8-9	642	694	1	3-1c 1/0 Al Cable	Wind_09 - Wind_10	13.8	1	216	10,696	5,479	16,175
9-10	642	694	1	3-1c 1/0 Al Cable	Wind_10 - Wind_11	13.8	1	216	10,696	5,479	16,175
10-11	642	694	1	3-1c 1/0 Al Cable	Wind_11 - Riser_A	13.8	1	216	10,696	5,479	16,175
12-B	642	694	3	3-1c 500 Al Cable	Wind_12 - Riser_A	13.8	1	502	20,794	5,479	26,273
12-13	642	694	3	3-1c 500 Al Cable	Wind_12 - Wind_13	13.8	1	502	20,794	5,479	26,273
13-14	642	694	2	3-1c 4/0 Al Cable	Wind_13 - Wind_14	13.8	1	318	14,708	5,479	20,187
14-15	642	694	2	3-1c 4/0 Al Cable	Wind_14 - Wind_15	13.8	1	318	14,708	5,479	20,187
15-16	642	694	1	3-1c 1/0 Al Cable	Wind_15 - Wind_16	13.8	1	216	10,696	5,479	16,175
16-17	642	694	1	3-1c 1/0 Al Cable	Wind_16 - Wind_17	13.8	1	216	10,696	5,479	16,175
17-18	642	694	1	3-1c 1/0 Al Cable	Wind_17 - Wind_18	13.8	1	216	10,696	5,479	16,175
18-19	642	694	1	3-1c 1/0 Al Cable	Wind_18 - Wind_19	13.8	1	216	10,696	5,479	16,175
19-20	642	694	1	3-1c 1/0 Al Cable	Wind_19 - Wind_20	13.8	1	216	10,696	5,479	16,175
Totals	12,840	13,882									$355,729
Rounded		13,900							Total Cost (Rounded)		$356,000
Miles	2.43								**Average cost per mile**		$146,300

Table E4.3A
5000kW - 25 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	13.98	3,535
2	3-1c 4/0 Al Cable	318	17.70	3,535
3	3-1c 500 Al Cable	502	27.42	3,535

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	906	971	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	13.8	1	216	12,666	3,535	16,201
2-3	906	971	2	3-1c 4/0 Al Cable	Wind_02 - Wind_03	13.8	1	318	16,036	3,535	19,571
3-A	906	971	3	3-1c 500 Al Cable	Wind_03 - Wind_04	13.8	1	502	24,843	3,535	28,378
4-A	906	971	3	3-1c 500 Al Cable	Wind_04 - Wind_05	13.8	1	502	24,843	3,535	28,378
4-5	906	971	3	3-1c 500 Al Cable	Wind_05 - Wind_06	13.8	1	502	24,843	3,535	28,378
5-6	906	971	2	3-1c 4/0 Al Cable	Wind_06 - Wind_07	13.8	1	318	16,036	3,535	19,571
6-7	906	971	1	3-1c 1/0 Al Cable	Wind_07 - Wind_08	13.8	1	216	12,666	3,535	16,201
8-B	906	971	3	3-1c 500 Al Cable	Wind_08 - Wind_09	13.8	1	502	24,843	3,535	28,378
8-9	906	971	2	3-1c 4/0 Al Cable	Wind_09 - Wind_10	13.8	1	318	16,036	3,535	19,571
9-10	906	971	1	3-1c 1/0 Al Cable	Wind_10 - Wind_11	13.8	1	216	12,666	3,535	16,201
Totals	9,060	9,713									$220,826
Rounded		9,700							Total Cost (Rounded)		$221,000
Miles	1.72							**Average cost per mile**			$128,700

Table E4.3B
5000kW - 35 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	16.66	5,479
2	3-1c 4/0 Al Cable	318	22.91	5,479
3	3-1c 500 Al Cable	502	32.39	5,479

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	906	971	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	13.8	1	216	15,094	5,479	20,573
2-3	906	971	1	3-1c 1/0 Al Cable	Wind_02 - Wind_03	13.8	1	216	15,094	5,479	20,573
3-A	906	971	2	3-1c 4/0 Al Cable	Wind_03 - Wind_04	13.8	1	318	20,756	5,479	26,235
4-A	906	971	3	3-1c 500 Al Cable	Wind_04 - Wind_05	13.8	1	502	29,345	5,479	34,824
4-5	906	971	2	3-1c 4/0 Al Cable	Wind_05 - Wind_06	13.8	1	318	20,756	5,479	26,235
5-6	906	971	1	3-1c 1/0 Al Cable	Wind_06 - Wind_07	13.8	1	216	15,094	5,479	20,573
6-7	906	971	1	3-1c 1/0 Al Cable	Wind_07 - Wind_08	13.8	1	216	15,094	5,479	20,573
8-B	906	971	2	3-1c 4/0 Al Cable	Wind_08 - Wind_09	13.8	1	318	20,756	5,479	26,235
8-9	906	971	1	3-1c 1/0 Al Cable	Wind_09 - Wind_10	13.8	1	216	15,094	5,479	20,573
9-10	906	971	1	3-1c 1/0 Al Cable	Wind_10 - Wind_11	13.8	1	216	15,094	5,479	20,573
Totals	9,060	9,713									$236,968
Rounded		9,700							Total Cost (Rounded)		$237,000
Miles	1.72								**Average cost per mile**		$138,100

Table E4.4A
10000kW - 25 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	13.98	3,535
2	3-1c 4/0 Al Cable	318	17.70	3,535
3	3-1c 500 Al Cable	502	27.42	3,535

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	1,283	1367	2	3-1c 4/0 Al Cable	Wind_01 - Wind_02	13.8	1	318	22,709	3,535	26,244
2-A	1,283	1367	3	3-1c 500 Al Cable	Wind_02 - Wind_03	13.8	1	502	35,180	3,535	38,715
3-A	800	860	2	3-1c 4/0 Al Cable	Wind_03 - Wind_04	13.8	1	318	14,160	3,535	17,695
4-A	1,500	1595	3	3-1c 500 Al Cable	Wind_04 - Wind_05	13.8	1	502	41,130	3,535	44,665
4-5	1,283	1367	2	3-1c 4/0 Al Cable	Wind_05 - Wind_06	13.8	1	318	22,709	3,535	26,244
Totals	6,149	6,578									$153,563
Rounded		6,600							Total Cost (Rounded)		$154,000
Miles	1.16								**Average cost per mile**		$131,900

Table E4.4B
10000kW - 35 kV Plan Underground Cable Cost Detail

	Description	Rating	Cost	Term.
1	3-1c 1/0 Al Cable	216	16.66	5,479
2	3-1c 4/0 Al Cable	318	22.91	5,479
3	3-1c 500 Al Cable	502	32.39	5,479

1.05 extra
20 ft

Sec Id	Dist. feet	Cable Req'd		Construction Type	Section Name	Voltage kV	Ckt. No.	Rating Amps	Underground Cable Costs: Cable Costs	Terminal Costs	Total Costs
1-2	1,283	1367	1	3-1c 1/0 Al Cable	Wind_01 - Wind_02	13.8	1	216	21,375	5,479	26,854
2-A	1,283	1367	3	3-1c 500 Al Cable	Wind_02 - Wind_03	13.8	1	502	41,556	5,479	47,035
3-A	800	860	1	3-1c 1/0 Al Cable	Wind_03 - Wind_04	13.8	1	216	13,328	5,479	18,807
4-A	1,500	1595	3	3-1c 500 Al Cable	Wind_04 - Wind_05	13.8	1	502	48,585	5,479	54,064
4-5	1,283	1367	1	3-1c 1/0 Al Cable	Wind_05 - Wind_06	13.8	1	216	21,375	5,479	26,854
Totals	6,149	6,578									$173,614
Rounded		6,600							Total Cost (Rounded)		$174,000
Miles	1.16								**Average cost per mile**		$149,100

Table E5.1A
750 kW - 15 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 15 kV Recloser with 1/0 Al Riser Cable	560	24,500
2	VWE 15 kV Recloser with 4/0 Al Riser Cable	560	24,600
3	VWE 15 kV Recloser with 500 Al Riser Cable	560	24,800
4	VWE 15 kV Recloser with 750 Al Riser Cable	560	25,000
5	VWE 15 kV Recl. W/(1) 750 and (1) 1/0 Riser	560	26,500

Riser	Type	Description	Amps	Costs
Riser A1	3	VWE 15 kV Recloser with 500 Al Riser Cable	560	24,800
Riser A2	3	VWE 15 kV Recloser with 500 Al Riser Cable	560	24,800
Riser B	2	VWE 15 kV Recloser with 4/0 Al Riser Cable	560	24,600
Riser C	3	VWE 15 kV Recloser with 500 Al Riser Cable	560	24,800
Riser E	5	VWE 15 kV Recl. W/(1) 750 and (1) 1/0 Riser	560	26,500
Count	**5**		**Total**	125,500
			Rounded	**125,500**

Table E5.1B
750 kW - 25 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 25 kV Recloser with 1/0 Riser Cable	560	25,500
2	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
3	VWE 25 kV Recl. W/(1) 4/0 and (1) 1/0 Riser	560	27,200

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	1	VWE 25 kV Recloser with 1/0 Riser Cable	560	25,500
Riser A2	1	VWE 25 kV Recloser with 1/0 Riser Cable	560	25,500
Riser B	1	VWE 25 kV Recloser with 1/0 Riser Cable	560	25,500
Riser C	2	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
Riser E	3	VWE 25 kV Recl. W/(1) 4/0 and (1) 1/0 Riser	560	27,200
Count	**5**		**Total**	129,300
			Rounded	**129,300**

Table E5.2A
2500 kW - 25 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800
Riser A2	1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
Riser B1	1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
Riser B2	1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
Count	**4**		**Total**	102,600
			Rounded	**102,600**

Table E5.2B
2500 kW - 35 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 35 kV Recloser with 1/0 Riser Cable	560	27,500
2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
3	VWE 35 kV Recloser with 500 Riser Cable	560	27,800

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
Riser A2	1	VWE 35 kV Recloser with 1/0 Riser Cable	560	27,500
Riser B	3	VWE 35 kV Recloser with 500 Riser Cable	560	27,800
Count	**3**		**Total**	82,900
			Rounded	**82,900**

Table E5.3A
5000 kW - 25 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800
Riser A2	2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800
Riser B	2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800
Count	**3**		**Total**	77,400
			Rounded	**77,400**

Table E5.3B
5000 kW - 35 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 35 kV Recloser with 1/0 Riser Cable	560	27,500
2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
3	VWE 35 kV Recloser with 500 Riser Cable	560	27,800

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
Riser A2	2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
Riser B	2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
Count	**3**		**Total**	82,800
			Rounded	**82,800**

Table E5.4A
10000 kW - 25 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800
Riser A2	1	VWE 25 kV Recloser with 4/0 Riser Cable	560	25,600
Riser A3	2	VWE 25 kV Recloser with 500 Riser Cable	560	25,800
Count	**3**		**Total**	77,200
			Rounded	**77,200**

Table E5.4B
10000 kW - 35 kV Plan Recloser and Riser Cost Detail

	Description	Rating	Cost
1	VWE 35 kV Recloser with 1/0 Riser Cable	560	27,500
2	VWE 35 kV Recloser with 4/0 Riser Cable	560	27,600
3	VWE 35 kV Recloser with 500 Riser Cable	560	27,800

Riser	Type	Description	Rating Amps	Recloser Costs
Riser A1	3	VWE 35 kV Recloser with 500 Riser Cable	560	27,800
Riser A2	1	VWE 35 kV Recloser with 1/0 Riser Cable	560	27,500
Riser A3	3	VWE 35 kV Recloser with 500 Riser Cable	560	27,800
Count	**3**		**Total**	83,100
			Rounded	**83,100**

Table E6.1A
750 kW - 15 kV Plan Overhead Line Cost Detail

	Construction Type		Cost of Poles Tan.	Cost of Poles Ang.	Cost of Poles DE	Cost Conductors 3-795	Cost Conductors 1 - 4/0	Total
1	S/C	Single Circuit	2,670	4,110	5,300	9.92	1.54	11.46
2	D/C	Double Circuit	3,350	6,410	10,970	9.92	1.54	11.46

Sec Id	Section Description	Length Feet	Const.	Type	Number of Poles Tan.	Ang.	DE	Cost of Poles Tan.	Ang.	DE	Total Poles	Cond.	Total
A-B	Riser_A - Riser_B	2,300	1	S/C	5		1	13,350	-	5,300	18,650	26,358	45,008
B-D	Riser_B - Riser_D	2,300	2	D/C	5		1	16,750	-	10,970	27,720	26,358	54,078
C-E	Riser_C - Riser_E	2,300	2	D/C				-	-	-	-	26,358	26,358
D-F	Riser_D - Mission_13	1,000	2	D/C	2		3	6,700	-	32,910	39,610	11,460	51,070
E-F	Riser_E - Mission_13	1,000	2	D/C				-	-	-	-	11,460	11,460
	Total New Line Length	5,600	feet					**Total Labor and Material**			**85,980**	**101,994**	**187,974**
	Line Length in Miles	1.06	miles					**Total Cost (Rounded)**					**188,000**
								Average Cost per Mile (Rounded)					**177,200**

Table E6.1B
750 kW - 25 kV Plan Overhead Line Cost Detail

			Cost of Poles			Cost Conductors		
		Construction Type	**Tan.**	**Ang.**	**DE**	**3-795**	**1 - 4/0**	**Total**
1	S/C	Single Circuit	2,670	4,110	5,300	9.92	1.54	11.46
2	D/C	Double Circuit	3,350	6,410	10,970	9.92	1.54	11.46

Sec Id	Section Description	Length Feet	Const. Type		Number of Poles Tan.	Ang.	DE	Cost of Poles Tan.	Ang.	DE	Total Poles	Cond.	Total
A-B	Riser_A - Riser_B	2,300	1	S/C	5		1	13,350	-	5,300	18,650	26,358	45,008
B-C	Riser_B - Riser_C	2,300	1	S/C	5		1	13,350	-	5,300	18,650	26,358	45,008
C-D	Riser_C - Mission_13	1,000	1	S/C	2		3	5,340	-	15,900	21,240	11,460	32,700
	Total New Line Length	5,600	feet					**Total Labor and Material**			**58,540**	**64,176**	**122,716**
	Line Length in Miles	1.06	miles					**Total Cost (Rounded)**					**122,700**
								Average Cost per Mile (Rounded)					**115,700**

Table E6.2A
2500 kW - 25 kV Plan Overhead Line Cost Detail

	Construction Type		Cost of Poles Tan.	Cost of Poles Ang.	Cost of Poles DE	Cost Conductors 3-795	Cost Conductors 1 - 4/0	Total
1	S/C	Single Circuit	2,670	4,110	5,300	9.92	1.54	11.46
2	D/C	Double Circuit	3,350	6,410	10,970	9.92	1.54	11.46

Sec Id	Section Description	Length Feet	Const.	Type	Number of Poles Tan.	Number of Poles Ang.	Number of Poles DE	Cost of Poles Tan.	Cost of Poles Ang.	Cost of Poles DE	Total Poles	Cond.	Total
A-B	Riser_A - Riser_B	4,100	1	S/C	10		1	26,700	-	5,300	32,000	46,986	78,986
B-C	Riser_B - Mission_13	1,600	1	S/C	3		3	8,010	-	15,900	23,910	18,336	42,246
	Total New Line Length	5,700	feet					**Total Labor and Material**			**55,910**	**65,322**	**121,232**
	Line Length in Miles	1.08	miles					**Total Cost (Rounded)**					**121,200**
								Average Cost per Mile (Rounded)					**112,300**

Table E6.2B
2500 kW - 35 kV Plan Overhead Line Cost Detail

			Cost of Poles			Cost Conductors		
		Construction Type	**Tan.**	**Ang.**	**DE**	**3-795**	**1 - 4/0**	**Total**
1	S/C	Single Circuit	2,670	4,110	5,300	9.92	1.54	11.46
2	D/C	Double Circuit	3,350	6,410	10,970	9.92	1.54	11.46

Sec Id	**Section Description**	**Length Feet**	**Const.**	**Type**	**Number of Poles Tan.**	**Ang.**	**DE**	**Cost of Poles Tan.**	**Ang.**	**DE**	**Total Poles**	**Cond.**	**Total**
A-B	Riser_A - Riser_B	4,100	1	S/C	10		1	26,700	-	5,300	32,000	46,986	78,986
B-C	Riser_B - Mission_13	1,600	1	S/C	3		3	8,010	-	15,900	23,910	18,336	42,246
	Total New Line Length	5,700	feet					**Total Labor and Material**			**55,910**	**65,322**	**121,232**
	Line Length in Miles	1.08	miles					**Total Cost (Rounded)**					**121,200**
								Average Cost per Mile (Rounded)					**112,300**

Table E6.3A
5000 kW - 25 kV Plan Overhead Line Cost Detail

				Cost of Poles		Cost Conductors		
	Construction Type		Tan.	Ang.	DE	Phase	Neutral	Total
1	S/C	795-4/0 ACSR	2,670	4,110	5,300	9.92	1.54	11.46
2	S/C	4/0-2/0 ACSR	2,670	4,110	5,300	4.62	1.17	5.79

Sec Id	Section Description	Length Feet	Const.	Type	Number of Poles Tan.	Ang.	DE	Cost of Poles Tan.	Ang.	DE	Total Poles	Cond.	Total
A-B	Riser_A - Mission_13	5,600	1	795	14		2	37,380	-	10,600	47,980	64,176	112,156
B-C	Riser_B - Mission_13	9,700	2	4/0	23		3	77,050	-	32,910	109,960	111,162	221,122

Total New Line Length	15,300	feet	**Total Labor and Material**	**157,940**	**175,338**	**333,278**
Line Length in Miles	2.90	miles	**Total Cost (Rounded)**			**333,300**
Total Rounded	15,300		**Average Cost per Mile (Rounded)**			**115,000**

Table E6.3B
5000 kW - 35 kV Plan Overhead Line Cost Detail

	Construction Type			Cost of Poles Tan.	Cost of Poles Ang.	Cost of Poles DE	Cost Conductors Phase	Cost Conductors Neutral	Cost Conductors Total
	1	S/C	477-4/0 ACSR	2,670	4,110	5,300	7.00	1.54	8.54
	2	S/C	2/0-2/0 ACSR	2,670	4,110	5,300	3.50	1.17	4.67

Sec Id	Section Description	Length Feet	Const.	Type	Number of Poles Tan.	Number of Poles Ang.	Number of Poles DE	Cost of Poles Tan.	Cost of Poles Ang.	Cost of Poles DE	Total Poles	Cond.	Total
A-B	Riser_A - Mission_13	5,600	1	S/C	14		2	37,380	-	10,600	47,980	64,176	112,156
B-C	Riser_B - Mission_13	9,700	1	S/C	23		3	61,410	-	15,900	77,310	111,162	188,472
	Total New Line Length	15,300	feet					**Total Labor and Material**			**125,290**	**175,338**	**300,628**
	Line Length in Miles	2.90	miles					**Total Cost (Rounded)**					**300,600**
								Average Cost per Mile (Rounded)					**103,700**

Table E6.4A
10000 kW - 25 kV Plan Overhead Line Cost Detail

			Construction Type	Cost of Poles Tan.	Cost of Poles Ang.	Cost of Poles DE	Cost Conductors 3-795	Cost Conductors 1 - 4/0	Total
	1	S/C	Single Circuit	2,670	4,110	5,300	9.92	1.54	11.46
	2	D/C	Double Circuit	3,350	6,410	10,970	9.92	1.54	11.46

Sec Id	Section Description	Length Feet	Const. Type		Number of Poles Tan.	Ang.	DE	Cost of Poles Tan.	Ang.	DE	Total Poles	Cond.	Total
A-B	Riser_A - Mission_13	4,500	1	S/C	10	1	3	26,700	4,110	15,900	46,710	51,570	98,280
	Total New Line Length	4,500 feet						**Total Labor and Material**			**46,710**	**51,570**	**98,280**
	Line Length in Miles	0.85 miles						**Total Cost (Rounded)**					**98,300**
								Average Cost per Mile (Rounded)					**115,300**

Table E6.4B
10000 kW - 35 kV Plan Overhead Line Cost Detail

			Construction Type	Cost of Poles Tan.	Ang.	DE	Cost Conductors 3-795	1 - 4/0	Total
1	S/C	Single Circuit		2,670	4,110	5,300	9.92	1.54	11.46
2	D/C	Double Circuit		3,350	6,410	10,970	9.92	1.54	11.46

Sec Id	Section Description	Length Feet	Const. Type		Number of Poles Tan.	Ang.	DE	Cost of Poles Tan.	Ang.	DE	Total Poles	Cond.	Total
A-B	Riser_A - Mission_13	4,500	1	S/C	10	1	3	26,700	4,110	15,900	46,710	51,570	98,280

Total New Line Length	4,500 feet	**Total Labor and Material**	**46,710**	**51,570**	**98,280**
Line Length in Miles	0.85 miles	**Total Cost (Rounded)**			**98,300**
		Average Cost per Mile (Rounded)			**115,300**

Table E7.1
New 15 kV PDS Substation Installed Adjacent Existing 115kV Line

Description	Material	Labor Equipm	Total	Total Incl O&P
115 kV Bus & Foundations	950,000	320,000	1,270,000	1,422,400
30/40/50 PDS Substation, 115-13.8 kV	697,000	21,200	718,200	804,384
Foundation & Oil Containment	3,900	7,800	11,700	15,210
13.8 Feeder Connection	30,000	10,000	40,000	44,800
Power Factor Correction	100,000	20,000	120,000	134,400
115 kV Metering	150,000	20,000	170,000	190,400
Total Substation	1,930,900	399,000	2,329,900	2,611,594
Total Substation (Rounded)				**2,612,000**
Land (3 acres at $5,000/acre) All Plans			$15,000	

Table E7.2
New 25 kV PDS Substation Installed Adjacent Existing 115kV Line

Description	Material	Labor Equipm	Total	Total Incl O&P
115 kV Bus & Foundations	950,000	320,000	1,270,000	1,422,400
30/40/50 PDS Substation, 115-24.9 kV	642,000	21,200	663,200	742,784
Foundation & Oil Containment	3,900	7,800	11,700	15,210
24.9 Feeder Connection	15,000	5,000	20,000	22,400
Power Factor Correction	100,000	20,000	120,000	134,400
115 kV Metering	150,000	20,000	170,000	190,400
Total Substation	1,860,900	394,000	2,254,900	2,527,594
Total Substation (Rounded)				**$ 2,528,000**

Table E7.3
New 35 kV PDS Substation Installed Adjacent Existing 115kV Line

Description	Material	Labor Equipm	Total		Total Incl O&P
115 kV Bus & Foundations	950,000	320,000	1,270,000		1,422,400
30/40/50 PDS Substation, 115-34.5 kV	662,000	21,200	683,200		765,184
Foundation & Oil Containment	3,900	7,800	11,700		15,210
34.5 Feeder Connection	15,000	5,000	20,000		22,400
Power Factor Correction	246,000	33,550	279,550		313,096
115 kV Metering	150,000	20,000	170,000		190,400
Total Substation	2,026,900	407,550	2,434,450		2,728,690
Total Substation (Rounded)				**$**	**2,729,000**

Table E8.1
20' STONE SERVICE ROAD FOR 750 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	4147	0.8	50		400	207,350
Riser-22	4147	0.8				207,350
23-Riser	2639	0.5				131,950
Riser-45	6032	1.1		2		302,400
46-Riser	1131	0.2				56,550
Riser-66	7540	1.4		2		377,800
Totals	25636	4.9		4		1,283,400
				Total Rounded		1,290,000

Table E8.2
20' STONE SERVICE ROAD FOR 2,500 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	3852	0.7	50		400	192,600
Riser-11	3210	0.6				160,500
Riser-20	5778	1.1		1		289,300
Totals	12840	2.4		1		642,400
				Total Rounded		643,000

Table E8.3
20' STONE SERVICE ROAD FOR 5,000 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	2718	0.5	50		400	135,900
Riser-7	3624	0.7				181,200
Riser-10	2718	0.5				135,900
Totals	9060	1.7		0		453,000
				Total Rounded		460,000

Table E8.4
20' STONE SERVICE ROAD FOR 10,000 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
Riser-1	2566	0.5	50		400	128,300
Riser-3	800	0.2				40,000
Riser-5	2783	0.5				139,150
Totals	6149	1.2		0		307,450
				Total Rounded		310,000

Table E8.1a
26' Paved SERVICE ROAD FOR 750 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	4147	0.8	90		400	373,230
Riser-22	4147	0.8				373,230
23-Riser	2639	0.5				237,510
Riser-45	6032	1.1		2		543,680
46-Riser	1131	0.2				101,790
Riser-66	7540	1.4		2		679,400
Totals	25636	4.9		4		2,308,840
	25600			Total Rounded		2,310,000

Table E8.2a
26' Paved SERVICE ROAD FOR 2,500 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	3852	0.7	90		400	346,680
Riser-11	3210	0.6				288,900
Riser-20	5778	1.1		1		520,420
Totals	12840	2.4		1		1,156,000
	12800			Total Rounded		1,156,000

Table E8.3a
32' Paved SERVICE ROAD FOR 5,000 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	2718	0.5	110		400	298,980
Riser-7	3624	0.7				398,640
Riser-10	2718	0.5				298,980
Totals	9060	1.7		0		996,600
	9100			Total Rounded		1,000,000

Table E8.4a
32' Paved SERVICE ROAD FOR 10,000 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
Riser-1	2566	0.5	110		400	282,260
Riser-3	800	0.2				88,000
Riser-5	2783	0.5				306,130
Totals	6149	1.2		0		676,390
	6150			Total Rounded		680,000

Table E8.1b
30' Paved SERVICE ROAD FOR 750 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	4147	0.8	110		400	456,170
Riser-22	4147	0.8				456,170
23-Riser	2639	0.5				290,290
Riser-45	6032	1.1		2		664,320
46-Riser	1131	0.2				124,410
Riser-66	7540	1.4		2		830,200
Totals	25636	4.9		4		2,821,560
				Total Rounded		2,830,000

Table E8.2b
30' Paved SERVICE ROAD FOR 2,500 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	3852	0.7	110		400	423,720
Riser-11	3210	0.6				353,100
Riser-20	5778	1.1		1		635,980
Totals	12840	2.4		1		1,412,800
				Total Rounded		1,413,000

Table E8.3b
40' Paved SERVICE ROAD FOR 5,000 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
1-Riser	2718	0.5	140		400	380,520
Riser-7	3624	0.7				507,360
Riser-10	2718	0.5				380,520
Totals	9060	1.7		0		1,268,400
				Total Rounded		1,270,000

Table E8.4b
40' Paved SERVICE ROAD FOR 10,000 KW PLAN

Road Section	Road Length (feet)	Road Length (miles)	Unit Cost (per foot)	Number Stream Crossings	Unit Cost (Ea.)	Road Cost
Riser-1	2566	0.5	140		400	359,240
Riser-3	800	0.2				112,000
Riser-5	2783	0.5				389,620
Totals	6149	1.2		0		860,860
				Total Rounded		870,000

Table E9
Maintenance Building All Plans

Description	Qty	Units	Unit Cost		Total
2,400 Square Foot Service Building	1	ea	100200		100,200
Water	1	ea	5000		5,000
Septic	1	ea	10000		10,000
Driveway/Parking	1800	sq ft	3		5,400
Security Fence	1440	ft	22.5		32,400
Gate	2	ea	1450		2,900
			Total		155,900
			Total Rounded	**$**	**156,000**
Land (Acres)	3		5000		15,000
Site Clearing	0		0		0
Site Preparation	3		800		2,400
			Total incl Land	**$**	**173,400**

Table E10
Communications Cost Detail

Item	Description	Unit	Unit Cost
1	Scada Master Station	Ea.	66,700
2	Scada RTU with Modem	Ea.	8,050
3	Underground Fiber Optic Installed in Open Utility Trench	Ft.	4.56
4	Overhead Fiber Optic	Ft.	7.09

Table E10.1
750 kW - Communications Cost Detail

Item	Description	Qty	Unit Cost	Total Cost		
1	Scada Master Station	1	66,700	66,700		
2	Scada RTU with Modem	73	8,050	587,650		**Rounded**
			Subtotal SCADA		654,350	654,000
3	Underground Fiber Optic	28,200	4.56	128,592		
4	Overhead Fiber Optic	5,600	7.09	39,704		
			Subtotal Fiber Optics		168,296	168,000
				Total Cost	822,646	823,000

Table E10.2
2500 kW - Communications Cost Detail

Item	Description	Qty	Unit Cost	Total Cost		
1	Scada Master Station	1	66,700	66,700		
2	Scada RTU with Modem	25	8,050	201,250		**Rounded**
			Subtotal SCADA		267,950	268,000
3	Underground Fiber Optic	13,900	4.56	63,384		
4	Overhead Fiber Optic	5,700	7.09	40,413		
			Subtotal Fiber Optics		103,797	104,000
				Total Cost	371,747	372,000

Table E10.3
5000 kW - Communications Cost Detail

Item	Description	Qty	Unit Cost	Total Cost		
1	Scada Master Station	1	66,700	66,700		
2	Scada RTU with Modem	15	8,050	120,750		**Rounded**
				Subtotal SCADA	187,450	187,000
3	Underground Fiber Optic	9,700	4.56	44,232		
4	Overhead Fiber Optic	14,700	7.09	104,223		
				Subtotal Fiber Optics	148,455	148,000
				Total Cost	335,905	336,000

Table E10.4
10000 kW - Communications Cost Detail

Item	Description	Qty	Unit Cost	Total Cost		
1	Scada Master Station	1	66,700	66,700		
2	Scada RTU with Modem	10	8,050	80,500		**Rounded**
				Subtotal SCADA	147,200	147,000
3	Underground Fiber Optic	6,600	4.56	30,096		
4	Overhead Fiber Optic	4,500	7.09	31,905		
				Subtotal Fiber Optics	62,001	62,000
				Total Cost	209,201	209,000

Table E11
Crane Pad Cost Detail

	Reference	Description	Unit	Mat.	Labor Equipment	Total	Total Incl O&P	
Means	03300-240-4000	Foundation Mat > 20 CY		103	54	157	199	1.27
		m^3	**C.Y.**					
750 kW	10mx11mx0.2286m=	25.15	32.88971	3,388	1,760	5,147	6,545	1.27
	9mx27mx0.2286m=	55.55	72.65636	7,484	3,887	11,371	14,459	1.27
		80.70	105.5461	10,871	5,647	16,518	21,004	
						Rounded	21,000	
2500 kW	1000sq.mx0.2286m=	228.60	298.9974	30,797	15,996	46,793	59,500	1.27
						Rounded	60,000	
5000 kW	2400sq.mx0.3048m=	731.52	956.7916	98,550	51,188	149,738	190,402	1.27
						Rounded	190,000	
10000 kW	4000sq.mx0.3048m=	1,219.20	1594.653	164,249	85,314	249,563	317,336	1.27
						Rounded	317,000	

Table E12
Vendor Quote for the Major Electrical Equipment

Item	Description		Manufacturer	Quote	Unit
PDS Substation		15kV	Waukesha	$697,000	Ea.
PDS Substation		25kV	Waukesha	$642,000	Ea.
PDS Substation		35kV	Waukesha	$662,000	Ea.
Power Factor Correction	IntelliVAr		PQS	$100,000	Ea.
Padmount Transformer	1000 kVA	15kV	Cooper	$11,375	Ea.
Padmount Transformer	1000 kVA	25kV	Cooper	$11,400	Ea.
Padmount Transformer	3000 kVA	25kV	Cooper	$23,500	Ea.
Padmount Transformer	3000 kVA	35kV	Cooper	$25,000	Ea.
Padmount Transformer	7500 kVA	25kV	Cooper	$81,800	Ea.
Padmount Transformer	7500 kVA	35kV	Cooper	$83,200	Ea.
Substation Transformer	10,000 kVA	25kV	Cooper	$90,000	Ea.
Substation Transformer	10,000 kVA	35kV	Cooper	$92,000	Ea.
Switchgear		25kV	Cooper	$17,620	Ea.
Switchgear		35kV	Cooper	$24,380	Ea.
Recloser		15kV	Cooper	$15,750	Ea.
Recloser		25kV	Cooper	$16,700	Ea.
Recloser		35kV	Cooper	$18,400	Ea.
Underground Cable	1/0	15kV	Okonite	$1.118	Ft.
Underground Cable	4/0	15kV	Okonite	$2.003	Ft.
Underground Cable	500	15kV	Okonite	$3.646	Ft.
Underground Cable	750	15kV	Okonite	$4.991	Ft.
Underground Cable	1/0	25kV	Okonite	$1.395	Ft.
Underground Cable	4/0	25kV	Okonite	$1.542	Ft.
Underground Cable	500	25kV	Okonite	$1.932	Ft.
Underground Cable	1/0	35kV	Okonite	$2.134	Ft.
Underground Cable	4/0	35kV	Okonite	$1.812	Ft.
Underground Cable	500	35kV	Okonite	$2.174	Ft.
Overhead ACSR	795		Southwire	$1.21	lb.
Overhead ACSR	477		Southwire	$1.38	lb.
Overhead ACSR	4/0		Southwire	$1.16	lb.
Overhead ACSR	2/0		Southwire	$1.17	lb.
SCADA Master Station	Model 9200		Ilex	$55,000	
SCADA RTU	Model 9300		Ilex	$5,000	

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13. ABSTRACT *(Maximum 200 words)*
DOE's Wind Partnerships for Advanced Component Technologies (WindPACT) program explores the most advanced wind-generating technologies for improving reliability and decreasing energy costs. The first step in the WindPact program is a scaling study to bound the optimum sizes for wind turbines, to define size limits for certain technologies, and to scale new technologies. The program is divided into four projects: Composite Blades for 80–120-meter Rotors; Turbine, Rotor, and Blade Logistics; Self-Erecting Tower and Nacelle Feasibility; and Balance-of-Station Cost. This report discusses balance-of-station costs, which includes the electrical power collector system, wind turbine foundations, communications and controls, meteorological equipment, access roadways, crane pads, and the maintenance building. The report is based on a conceptual 50-megawatt (MW) wind farm site near Mission, South Dakota. Cost comparisons are provided for four sizes of wind turbines: 750 kilowatt (kW), 2.5 MW, 5.0 MW, and 10.0 MW.

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