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Laboratory Tests of IEC DER Object Models for Grid Applications

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Laboratory Tests of IEC DER Object Models for Grid Applications

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Abstract

This report describes a Cooperative Research and Development Agreement (CRADA) between Salt River Project Agricultural Improvement and Power District (SRP) and Sandia National Laboratories to jointly develop advanced methods of controlling distributed energy resources (DERs) that may be located within SRP distribution systems. The controls must provide a standardized interface to allow plug-and-play capability and should allow utilities to take advantage of advanced capabilities of DERs to provide a value beyond offsetting load power. To do this, Sandia and SRP field-tested the IEC 61850-7-420 DER object model (OM) in a grid environment, with the goal of validating whether the model is robust enough to be used in common utility applications. The diesel generator OM tested was successfully used to accomplish basic genset control and monitoring. However, as presently constituted it does not enable plug-and-play functionality. Suggestions are made of aspects of the standard that need further development and testing. These problems are far from insurmountable and do not imply anything fundamentally unsound or unworkable in the standard.

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NOMENCLATURE

CHP	combined heat and power
CRADA	Cooperative Research and Development Agreement
DER	distributed energy resource
DETL	Distributed Energy Technologies Laboratory
DG	distributed generation
EPRI	Electric Power Research Institute
IEC	International Electrotechnical Commission
MCC	motor control center
OM	object model
PV	photovoltaic
SRP	Salt River Project Agricultural Improvement and Power District

1. INTRODUCTION

The purpose of this Cooperative Research and Development Agreement (CRADA) was for Salt River Project Agricultural Improvement and Power District (SRP) and Sandia National Laboratories (Sandia) to jointly develop advanced methods of controlling distributed energy resources (DERs) that may be located within SRP distribution systems. The two key requirements for these controls are that they (1) provide a standardized control interface so that equipment from a variety of manufacturers can be interconnected and controlled in a "plug-and-play" manner; and (2) allow utilities such as SRP to take advantage of advanced capabilities of DERs to provide a value beyond offsetting load power.

To achieve this purpose, Sandia and SRP field-tested a specific DER object model (OM) in a grid environment, with a goal of producing a model that is robust enough to be used in common utility applications. DER OMs are common software representations that allow similar types of generators to be addressed and controlled more readily. This could significantly improve the operation and efficiency of DERs that are operating in either a stand-alone or grid-tied mode. It could also permit utilities to take advantage of advanced capabilities of DER in distribution systems operations.

The OM tested was developed by the IntelliGrid Consortium (IntelliGrid) [1]. This initiative is managed by the Electric Power Research Institute (EPRI), a nonprofit scientific research organization [2].

IntelliGrid began the development of DER OMs with the goal of having them adopted as standards, and therefore worked closely with the International Electrotechnical Commission (IEC). The IEC, specifically Technical Committee 57, Working Group 17, "Communications for Distributed Energy Resources," is the international standards organization overseeing the development of the OMs [3]. The DER OMs were written as extensions of IEC 61850, an accepted standard that developed object models for substation equipment. IEC plans to use this common platform for advanced communication and control among all elements of power systems. During the course of this CRADA, IEC actually assumed ownership of this OM development project from IntelliGrid.

The OM tested in this project was that of a diesel generator and is presently titled IEC 61850-7-420. IntelliGrid and IEC developed models for a diesel generator and a fuel cell in their first round of activities, based largely on the participation of equipment vendors Cummins and Plug Power. IEC plans to continue this activity by developing OMs for combined heat and power (CHP) systems, photovoltaic (PV) systems, microturbines, and other DER. Wind generators are addressed in a separate IEC activity, but IEC plans to harmonize their control with that of other types of DER.

2. TECHNICAL BACKGROUND

At the time that this CRADA was initiated, EPRI CEIDS (later renamed "IntelliGrid") was planning laboratory developmental tests of DER OMs. The stated purpose of the tests was to determine whether the draft DER OMs were *correct* and *complete* by testing them under the most stringent conditions of future power system operations when DER devices are expected to have significant penetration in the distribution networks. These future conditions were captured in the functionality that was defined and documented by CEIDS (IntelliGrid) as "Advanced Distribution Automation (ADA)." Cleveland et al. performed the primary work to define the DER [4]. Markushevich et al. defined ADA and the testing required to validate the OM [5].

Figure 1 illustrates the plan suggested by Markushevich et al. in block diagram form [5]. This plan involved simulation of the utility power system as directed by the extensive set of ADA applications. On the order of 4,000 different test points were suggested. Because the resources that were available for this CRADA were not sufficient to perform this test, a meaningful subset was required.

Figure 2 is a block diagram showing the simplified test configuration that was implemented at Sandia's Distributed Energy Technologies Laboratory (DETL).

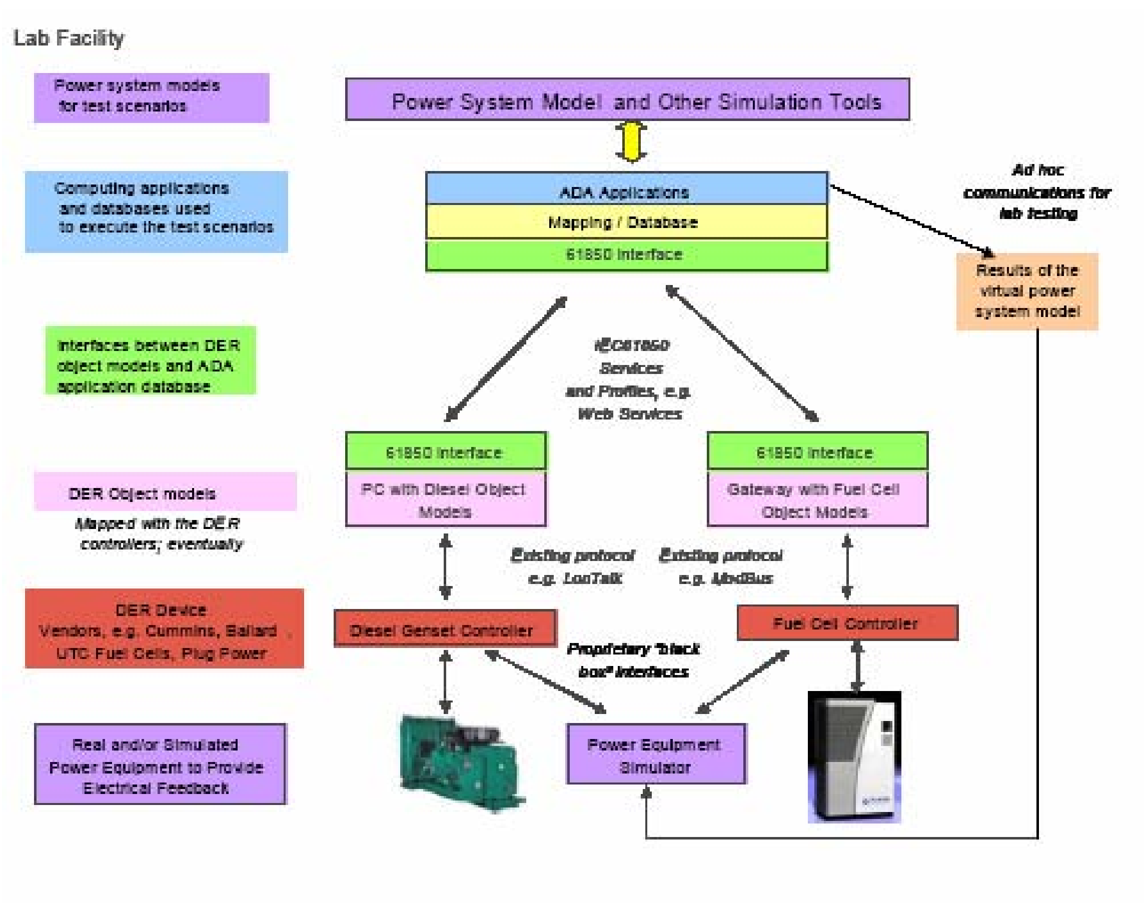

Figure 1. Block diagram of suggested laboratory test setup [1].

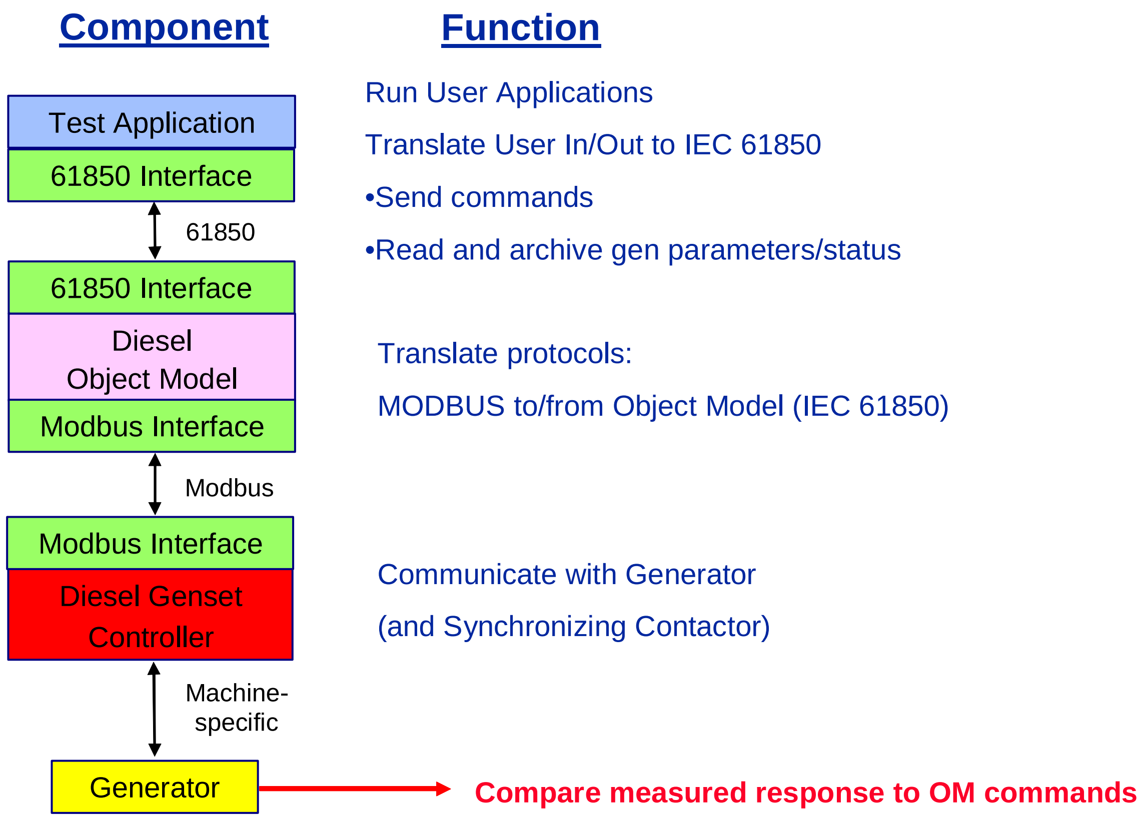

Figure 2. Block diagram of DETL test setup.

3. TEST PLAN

The test plan that was developed contained three basic sets of activities:

1. Determining the capability of the particular engine-generator under test.

   Grid voltage was selected as being a parameter with first-order impact that can vary in the field. Therefore, a transformer was installed having taps capable of providing the generator with +10%, nominal, or -10% values of ac voltage. Figure 3 is a hypothetical set of capability curves that might be expected from a generator feeding real and reactive power into a grid at three different grid voltages. Such “capability curves” were envisioned as information that would be critical to advanced distribution automation.

   The values of real and reactive power described by the test matrix of Table 1 were requested from the Caterpillar genset assuming the nameplate rating of 93 kVA. The genset was operated in grid-tied mode, and commands were sent using the front panel of the Woodward controller. To observe the effect of ambient air temperature, data were taken during early morning and again during mid-afternoon. (The altitude and low humidity of Albuquerque create differences on the order of 25 degrees F). Multiple points were taken at each test condition.

2. Evaluating how effectively the available set of OM parameters can be “mapped” into the native control protocol of the particular engine-generator controller under test.

   The key activity required to implement IEC 61850 communications and controls into a system not originally designed with it is mapping. In the present case, the MODBUS protocol used by the Woodward controller for remote communication had to be “mapped” into the IEC 61850-7-420 diesel generator object model. This mapping activity was performed by Enernex under the direction of Eric Gunther, as indicated in the diagram of Figure 4.

   This activity provides information as to the completeness of the draft OM. It identifies:

   a) OM attributes that the standard classifies as “mandatory” that are not present in the native controller.
   b) Native controller parameters that are not represented in the OM.
   c) Ambiguities in OM attribute definitions.

3. Comparing traditional measurements to OM measurements taken under various system conditions.

   The OM communication system must accurately command a variety of possible operating points encountered during normal operation. Because the ability to source or sink reactive power is a distinguishing capability of synchronous generators, different power factors were included in the matrix of test points. Because ambient temperature is another parameter that affects the capability of combustion-based generators, testing was planned for “hot” and “cold” ambient temperatures. The planned test matrix is shown in Table 1.

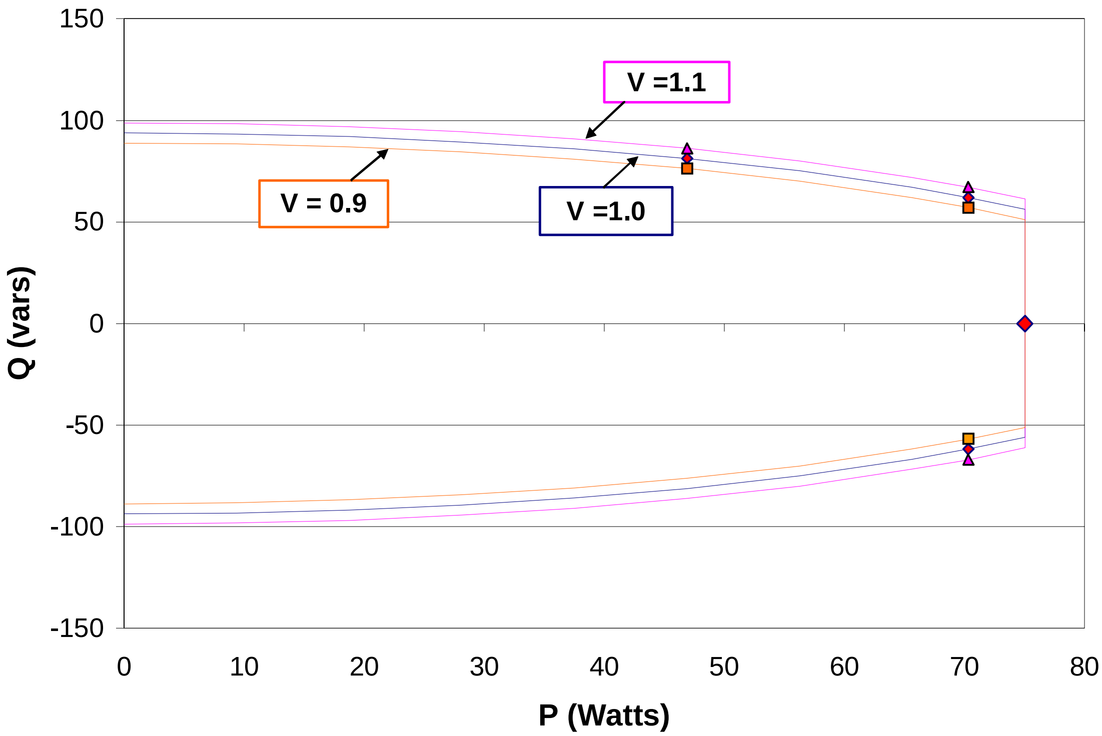

Figure 3. Generic hypothetical machine capability curves.

Table 1. Original matrix for normal-operation tests.

	Cold S_{rated}	Cold 75% S	Hot S_{rated}	Hot 75% S
Manual	Vnom	Vnom	Vnom	Vnom
	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0
	Vmin	Vmin	Vmin	Vmin
	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0
	Vmax	Vmax	Vmax	Vmax
	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0
	Cold S_{rated}	Cold 75% S	Hot S_{rated}	Hot 75% S
Auto via Object Model	Vnom	Vnom	Vnom	Vnom
	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0
	Vmin	Vmin	Vmin	Vmin
	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0
	Vmax	Vmax	Vmax	Vmax
	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0	-0.75, 0.5, 0.75, 1.0

Hot & Cold ***Ambient*** temperatures

For testing, each setpoint was commanded using the Woodward front panel controls ("manual") and then repeated using the IEC 61850 test platform of Figure 4 ("automatic").

At each test point, the genset output was reported in two ways:

a) The measurements made internally by the Caterpillar/Woodward control system were reported back to the client application via the IEC 61850 interface. Referring to the test platform implementation shown in Figure 4, these data were passed from the machine "up" to the test application and were recorded. These are referred to as "OM" measurements in Table 3.

b) The machine output was measured independently by the transducers and data acquisition system at DETL. These are referred to as "PS" measurements in Table 3.

Finally, tests cases were subdivided into two categories: normal and abnormal conditions.

Normal conditions represent the set of test cases were the unit is operating within its capability and operational limits. Table 1 describes the test cases used for normal conditions.

Abnormal conditions represent the set of test cases were the machine is given invalid operational setpoints. It is important to note that these "abnormal" conditions did not test the operation of the OM under abnormal power system conditions (fault, overcurrent, sag, etc.).

Two types of abnormal operational commands were envisioned. In one, the genset controller would be given a command just beyond the capability of the machine (such as 100 kW requested of a 60-kW generator). In the other, a physically impossible command could be issued due to operator error (requesting a power factor greater than unity). These two types of conditions were tested by using four cases:

1. Real power (P) slightly greater than the machine rating – To accomplish this, a 50-kW limit was set in the Woodward controller and then 60 kW was requested from the unit.
2. Power factor outside allowable bounds – To accomplish this test a 0.5-pf limit was set in the Woodward controller and then a request was made for operation at 0.1 pf.
3. Physically meaningless power factor – For this test, a request was made for operation at 2.0 pf.
4. Real power (P) outside the bounds of engine-generator capability – For this test, request was made for operation at 1,000 kW.

3.1 Laboratory Test Configuration

Figure 4 shows a block diagram of the test platform implemented. The Caterpillar engine combined with a Kato generator had a nameplate rating of 93 kVA, 75 kW at 0.8 power factor. The grid-paralleling controller was a Woodward EGCP-2 using MODBUS as its communication protocol.

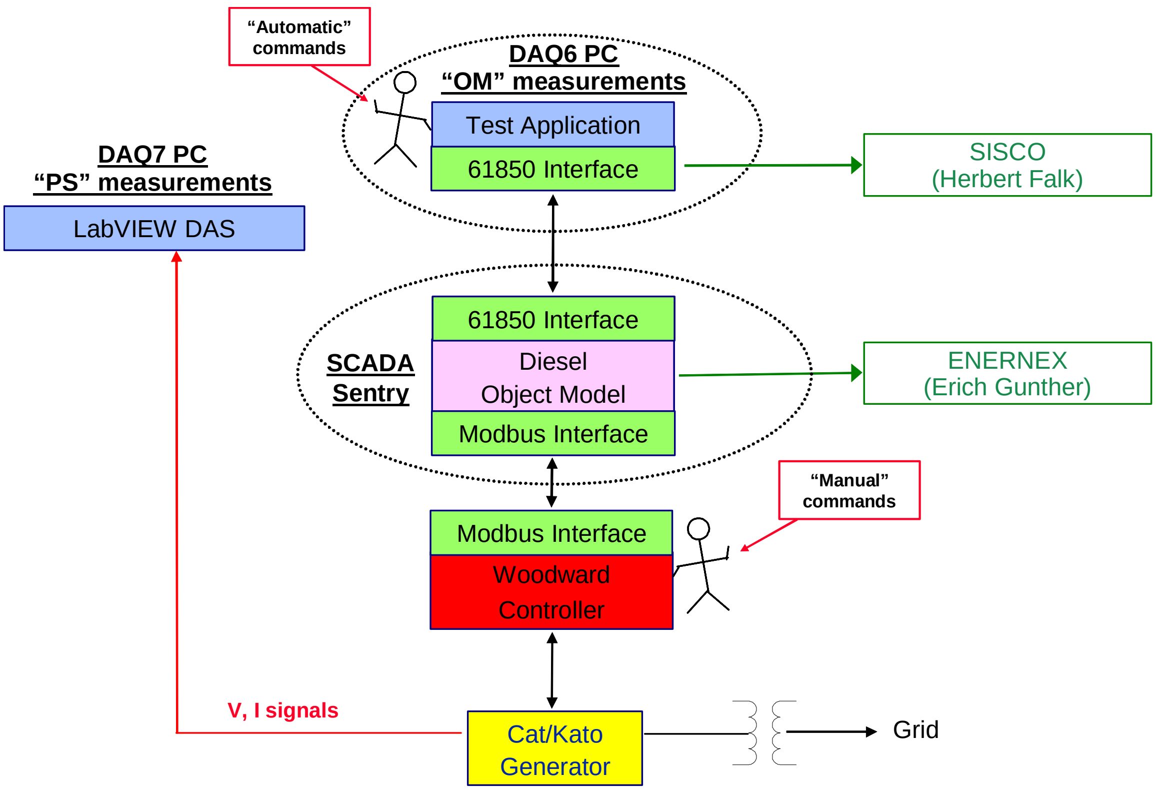

Figure 4. Test platform implemented at DETL.

4. TEST RESULTS

4.1 Machine Capability

Appendix A describes the results of these tests.

In a stand-alone operation where the load is appropriately matched to the diesel genset's rated capability, it can provide 90 kVA and 75 kW. The object model tests were conducted in a grid-tied mode. The machine was tested to test its capability in this grid-tied environment. As illustrated by the plot in Figure 5, it was determined that the genset was capable of 61 kVA at unity power factor (61 kW) (see the red curve in the figure). This placed a bound on the power that the machine could provide in a repeatable manner. These tests showed that the capability of the genset in grid-tied operation was significantly lower from that in stand-alone (off-grid) operation.

Because of this limitation, the "normal operation" of the machine was evaluated using a reduced rating of 60 kVA. It was decided that this derating was appropriate so that the machine's responses to manual commands could be compared to those given via the OM interface without uncertainty as to variations in machine capability.

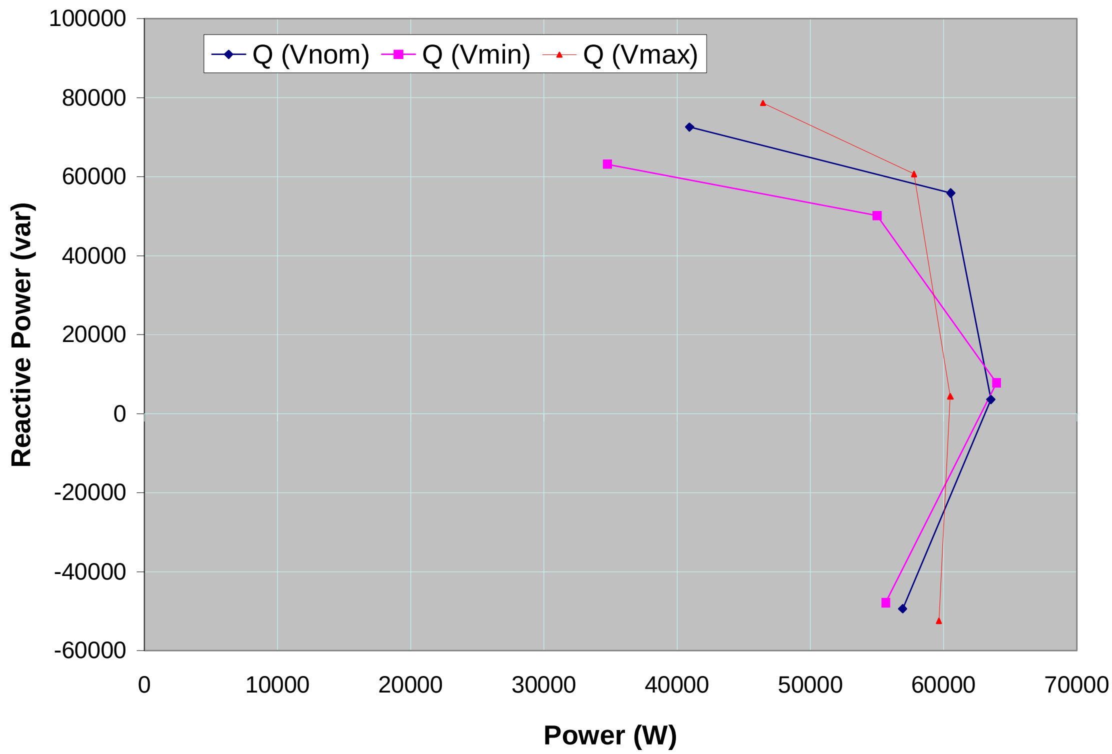

Figure 5. Genset response to requests for nameplate output of 92 kVA (grid-tied).

4.2 Object Model Mapping

Specific differences between the version of MODBUS used by Woodward and some other MODBUS variations led to some delays and additional programming work. This was exacerbated by the fact that EnerNex did not physically have the Woodward controller at their site for preliminary mapping work. A meeting was held at Sandia to determine the exact set of Woodward MODBUS attributes needed for the test implementation. The entire set as described in the Woodward EGCP-2 operations manual contains a number of parameters that were not relevant to this activity or necessary to prove the operational adequacy of the OM [6].

The goal of this activity was to identify "mandatory" OM attributes that could not be associated with a Woodward MODBUS attribute and, conversely, to identify Woodward MODBUS attributes that did not map directly into the OM without special custom programming. Appendix B contains the final mapping report from EnerNex. These findings were reported directly to the appropriate IEC committee as they were discovered.

4.3 Comparison of System Measurements

4.3.1 Normal Operations

Because the machine was being operated well within its nameplate capability, no difference between hot and cold ambient temperatures would have been observed. The test matrix of Table 1 could therefore be reduced to that of Table 2.

Table 2. Actual matrix for normal operation tests (S_{rated} = 60 kVA).

	S_{rated}	75% of S_{rated}
Manual	Vnom pf = -0.75, 0.5, 0.75, 1.0	Vnom pf = -0.75, 0.5, 0.75, 1.0
	Vmin pf = -0.75, 0.5, 0.75, 1.0	Vmin pf = -0.75, 0.5, 0.75, 1.0
	Vmax pf = -0.75, 0.5, 0.75, 1.0	Vmax pf = -0.75, 0.5, 0.75, 1.0
Auto via Object Model	Vnom -0.75, 0.5, 0.75, 1.0	Vnom pf = -0.75, 0.5, 0.75, 1.0
	Vmin -0.75, 0.5, 0.75, 1.0	Vmin pf = -0.75, 0.5, 0.75, 1.0
	Vmax -0.75, 0.5, 0.75, 1.0	Vmax pf = -0.75, 0.5, 0.75, 1.0

Test Condition 1of 6 (Vnom, Srated)

Table 3 lists the results from the first test condition, in which the machine was operated at nominal ac voltage and rated apparent power (60 kVA). Each value in Table 3 is an average of ten readings at that test condition. These data are plotted in Figure 6 for comparison purposes.

The two measurements agreed very closely, indicating that the machine was reporting accurate values via the 61850 interface. It also responded appropriately to commands, indicating that the 61850 interface was translating the commands properly.

Table 3. Results for normal-tests test condition #1 ($V_{nominal}$, S_{rated}).

commands		corresponding values			P (kW) meas		S (kVA) meas		Q (kvar) meas		Vrms meas		Irms meas		pf meas	
pf	P(kW)	S (kVA)	Q (kvar)	I (Arms) @ 480V	OM	PS	OM	PS	OM	PS	OM	PS	OM	PS	OM	PS
-0.75	45.0	60.0	39.7	72.2	44.9	46.2	60.4	60.4	-40.3	39.0	484	487	71.7	71.6	-0.74	0.74
1.00	60.0	60.0	0.0	72.2	59.9	60.3	60.6	60.8	-0.3	8.4	493	496	71.0	70.7	0.99	0.99
0.75	45.0	60.0	39.7	72.2	44.5	44.9	60.1	60.5	40.4	40.5	494	498	70.1	70.1	0.74	0.74
0.51	30.6	60.0	51.6	72.2	30.4	30.9	59.4	59.6	51.0	51.0	495	499	69.3	69.0	0.51	0.52

Man Test 1 Vnom, Srated

-0.75	45.0	60.0	39.7	72.2	44.7	45.0	59.5	58.8	-39.3	37.8	481	484	71.2	70.1	-0.75	-0.75
1.00	60.0	60.0	0.0	72.2	59.9	60.0	60.0	60.2	-4.1	8.1	487	490	70.7	71.0	1.00	1.00
0.75	45.0	60.0	39.7	72.2	45.1	45.3	60.3	60.4	40.0	40.0	492	495	71.3	70.4	0.75	0.75
0.51	30.6	60.0	51.6	72.2	30.6	31.0	61.0	61.3	52.8	52.9	493	496	71.4	71.4	0.50	0.51

Auto Test 1 Vnom, Srated

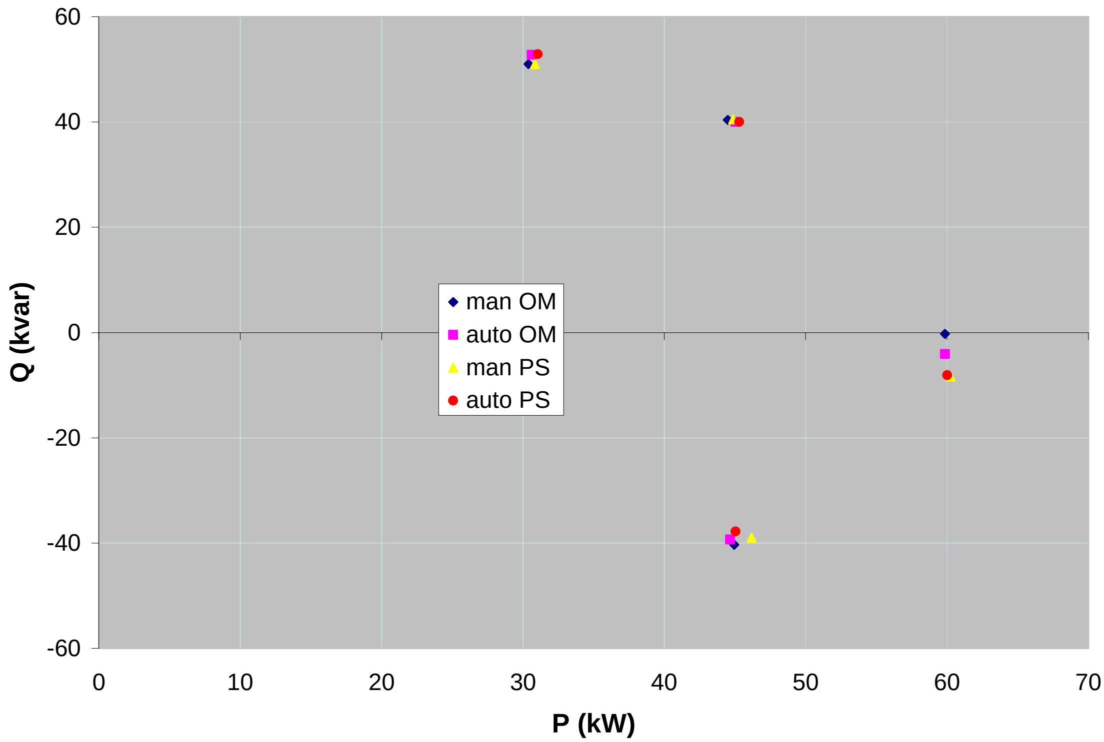

Figure 6. Measured real and reactive power for test condition #1 (V_{nom}, S_{rated}).

4.3.2 Abnormal Operations

The results of these tests, shown in Table 4, were observations indicating the importance of careful coordination between the native controller (the Woodward, in this case) and the IEC 61850 commands.

Table 4. Results for abnormal test conditions.

pf set	P(kW) set	S (kVA) calc	Q (kvar) calc	I (Arms) calc @480V	Observations: Response, alarms, ec.
1.00	60.0	60.0	0.0	72.2	P ramps to 50 kW and alarms, "kW High Limit Alarm"
1.00	40.0	40.0	0.0	48.1	Toggle down to 40kW, able to clear alarm
Man Test 1		Plimit = 50 kW			
1.00	60.0	60.0	0.0	72.2	P ramps to 50kW and alarms, "kW High Limit Alarm"
1.00	40.0				Unable to clear alarm or change power level
Auto Test 1		Plimit = 50 kW			
0.10	40.0	60.0	44.7	72.2	Used toggle switch to incrementally reduce pf. Would not go below limit of 0.5
1.00	40.0	41.8	7.1	49.1	No alarms. Toggle back to pf = 1.0 without issue
Man Test 2					
0.10	40.0	60.0	44.7	72.2	Entered pf = 0.1 to test application. Machine goes to 0.51
1.00	40.0	40.0	0.0	48.1	Succesfully responded to commands of .9, .8, .7, .6, but didn't respond to .5
Auto Test 2					
2.00	40.0	60.0	44.7	72.2	PF can only be changed from .5 to 1 to -.5
1.00	40.0	60.0	44.7	72.2	there isn't a means of entering a incorrect number
Man Test 3					
2.00	40.0	60.0	44.7	72.2	Entered PF setting in GUI for PF=2, dialog box pops up
1.00	40.0	60.0	44.7	72.2	Please enter a value between -1.00 and 1.00
Auto Test 3					
1.00	1000.0	60.0	#NUM!	72.2	utilizing toggle switches, the real power only increases to ~65kW, even if toggle still active
1.00	40.0	60.0	44.7	72.2	able to go back done to 40kW
Man Test 4					
1.00	1000.0	60.0	#NUM!	72.2	power goes up to 50kW alarms, "kW High Limit Alarm"
1.00	40.0	60.0	44.7	72.2	clear alarm but goes right back, not able to go to 40kW or change anything
Auto Test 4					

In abnormal test #1, the power output was limited to its preset "rating" of 50 kW with no issues when using manual controls. However, in automatic mode (using the IEC 61850 interface) it was not possible either to clear the alarm "kW high limit" or to change the power level while this alarm was present. A manual intervention was required.

In abnormal test #2, the machine responded to a request for a power factor of 0.1 by operating at its lower limit of 0.5. No problems were encountered in recovering from this limit either manually or automatically. One anomaly was that the "automatic" test interface would not respond to a request for 0.5, but would respond to a request for 0.51. Since the machine was capable of responding to manual P and Q commands corresponding to a power factor of 0.5, this inability to accept a direct power factor command of 0.5 through the OM interface was believed to be due to limitations in the Modbus interface.

In abnormal test #3, the goal was to request a power factor of 2. In manual mode, the controls on the front panel of the EGCP-2 do not allow the user to specify a power factor greater than one. The limit of 1.0 was reached and maintained without issue. In automatic mode, the value of 2.0

was rejected by the test application, which displayed a prompt stating the acceptable range of power factors. Obviously, these tests reflect the capabilities of the two user interfaces rather than the underlying communications protocols.

In abnormal test #4, a value of 1,000 kW was requested. The results were identical to those for the request of 60 kW in test #1. The limit of 50 kW was reached, and a “kW high limit” alarm was displayed. No issues were present in manual mode. In automatic mode, once the alarm was set there was no way to recover from the condition.

5. CONCLUSIONS AND RECOMMENDATIONS

The diesel generator OM tested was successfully used to accomplish basic genset control and monitoring. However, as presently constituted it is not adequate at the desired stage of routine "plug-and-play." Because variations among vendors in control structure and implementation are likely, custom programming will be required for each new generator vendor beyond simple direct mapping. The standard is flexible enough to accommodate such customization, and in the near term it will be required in order to successfully demonstrate and to continue to refine OM functionality. This complexity should be relieved when the standard is accepted and there is a motivation for vendors to write native controls using IEC 61850.

The fact that a mapping or translation step is required also introduces other limitations. The DER OM may be very capable, but its functionality is ultimately limited by that of the native protocol it is translated to (in this case Modbus). This was shown during the abnormal tests.

Moreover, in the present transitional period adoption of the IEC 61850-based OMs is hampered by the fact that limited tools are available to implement this new technology. Limitations exist in mapping, client software, and the number, quality, and availability of consulting vendors.

The DER OM standard IEC 61850-7-420 requires some revision based on these results. The mapping results summary was already communicated to the appropriate IEC committee.

More testing is clearly needed to define and categorize vendor-specific issues (MODBUS, other serial limitations – resolution, update rate) and response to a more exhaustive set of abnormal conditions.

These problems are far from insurmountable and do not imply anything fundamentally unsound or unworkable in the standard.

6. FUTURE WORK

This activity has highlighted the need for additional testing in the following categories:

1. Diesel genset controllers by different vendors.
2. Other types of DER (CHP, PV, energy storage, microturbines, etc.).
3. Systems-level tests of multiple DER configured as a microgrid connected to the main grid at a single point of common coupling.
4. Systems-level tests of simultaneous operation of multiple sources, either individually or configured as a microgrid, under the control of an energy management system or systems capable of prioritizing generators.
5. Systems-level tests including separation of such a combination of sources from the main utility and operating them autonomously (stand-alone), including operation of IEC 61850 switchgear, monitoring equipment, and load-shedding equipment.

In addition to discovering differences in protocols for communications and control, such testing – particularly at the systems level – could provide a valuable demonstration of the potential of the technology and thereby accelerate its adoption.

Figure 7 illustrates the IEC family of communications standards that are presently in various stages of development. The vision, when both the standards and the necessary harmonizing work has been completed, is to the enable the power grid of the future to operate so as to optimize not just costs, but emissions, energy surety, or other metrics that can be defined and codified in software. Menicucci describes one such application where OMs enable dynamically-reconfigurable systems [7].

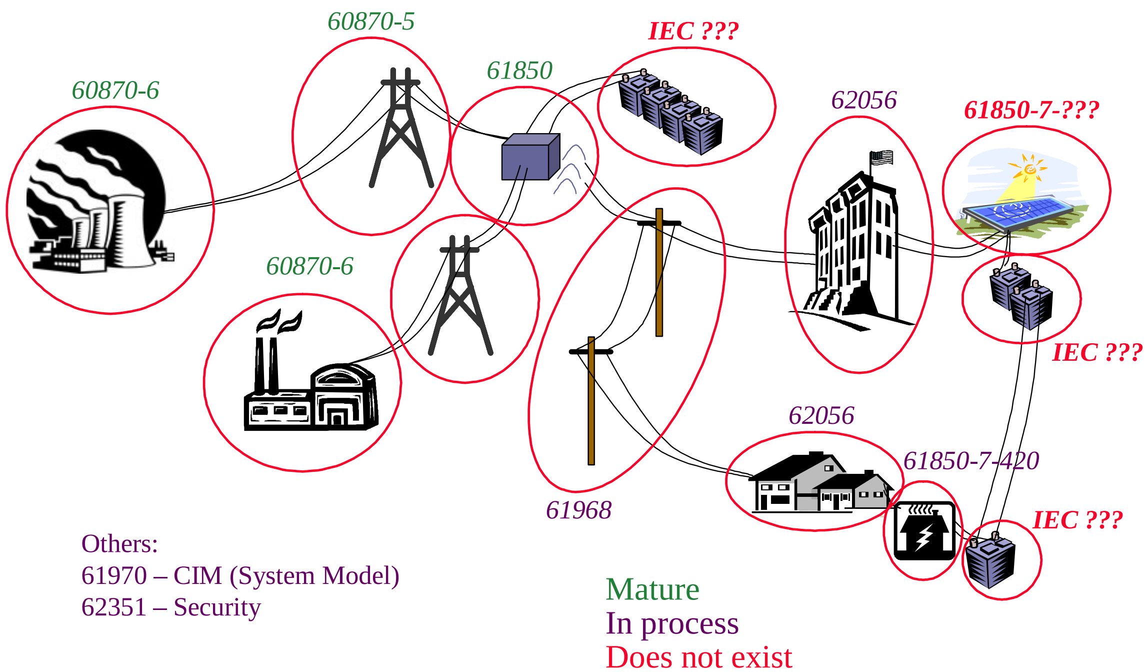

Figure 7. IEC information standards for automating power grid operations.

An outcome of this future grid is that the oft-quoted concept of “plug-and-play” could actually be realized. This is illustrated in Figure 8. Note that the microgrid is depicted with its four primary constituents: source, load, line (e.g., wires), and connectors (e.g., switches). An object model, such as one like IEC 61850, would facilitate the removal of one source and replacement with another. In this example a PV system and a diesel generator (both controlled via IEC 61850) could be interchanged with no need for custom engineering of the communication and control software.

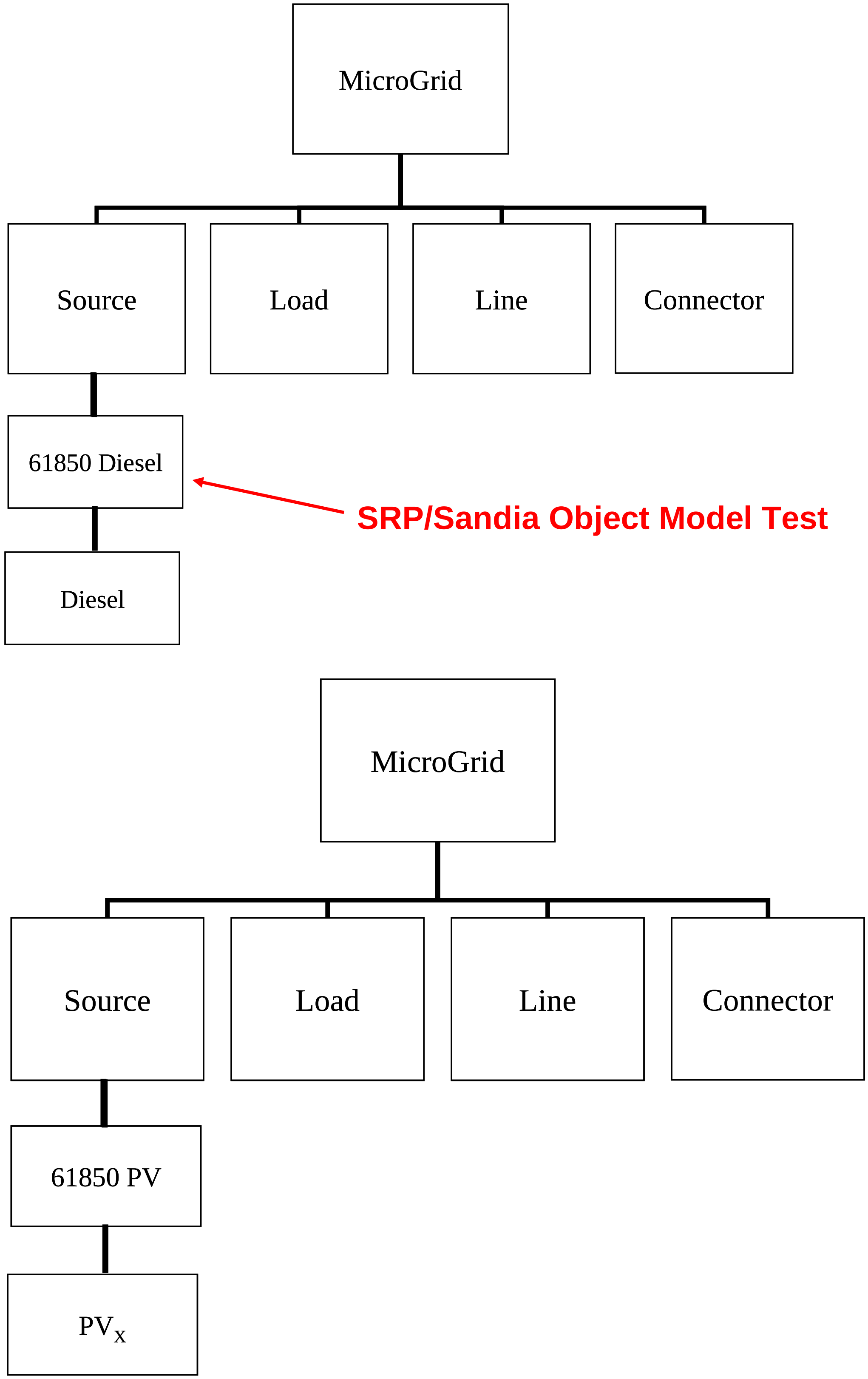

Figure 8. Using the DER OM standards to enable “plug-and-play” functionality.

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APPENDIX A: Caterpillar Generator Characteristics

The implementation of distributed generation (DG) for grid stability and peak shaving has been gaining momentum in the past decade and knowing the full capability of each of the utility-interconnected DG resources, a power system operator can dispatch the desired power, either it be real or reactive. Critical information on each DG and how the information is made available to the system operator is the focus of this exercise. The DG undergoing characteristic evaluations is a Caterpillar Synchronous 75-kW/92-kVA 480-V generator that has been fitted with a Woodward EGCP II, which enables the generator to run in isochronous mode and be utility interconnected. The generator is connected to a motor control center (MCC) and utilizes a utility service entrance that connects the generator to the main 480-V_{ac} bus that has a 100-amp limit. This places a limit on the amount of available power (real and reactive) during our low-power factor evaluations. Figure A-1 shows a one-line diagram showing how the generator is configured.

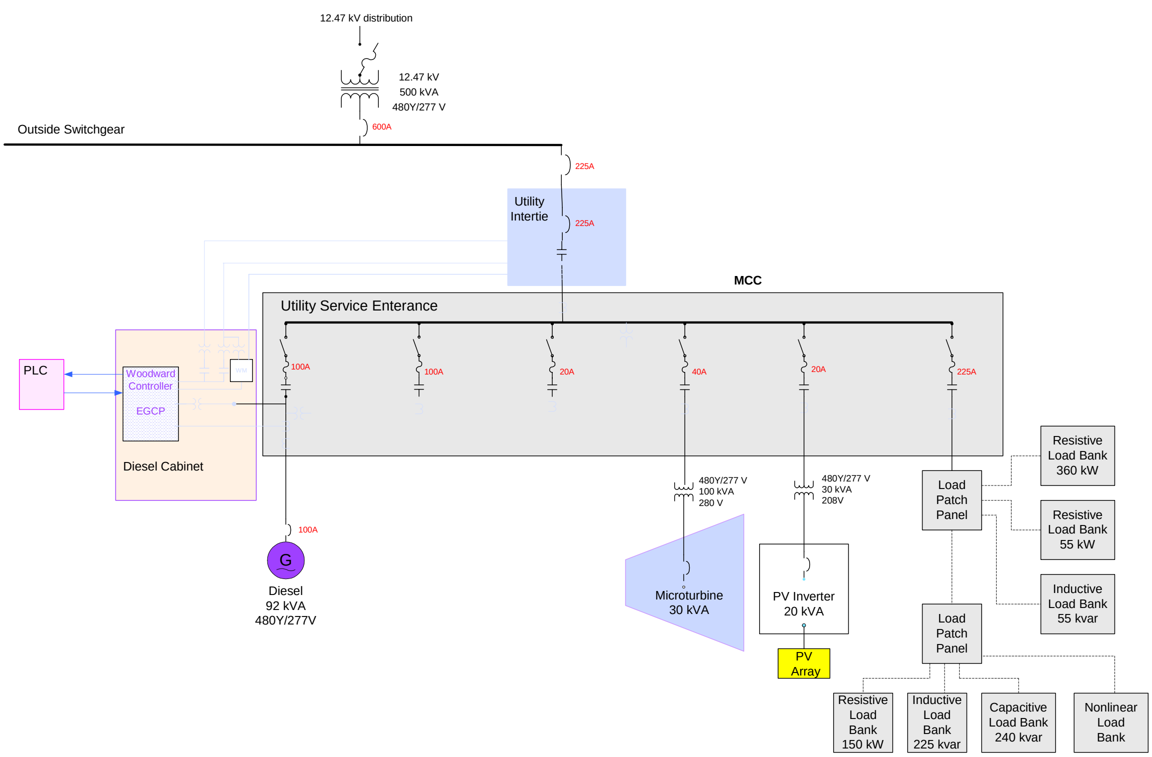

Figure A-1. Generator one-line diagram.

Objective

The objective of this exercise is to determine the capability of the Caterpillar 75-kW/92-kVA generator characteristics in utility interconnected mode. However, to determine its capability, the generator was initially configured for stand-alone mode operation and a baseline capability curve was generated. In stand-alone mode, load switch closed and utility switch open, our generator was able to deliver 75 kW of power to a resistive load and 92 kVA when connected to a resistive/inductive load up to a power factor of .5. Figures A-2 and A-3 show the data when the generator is supplying power to a resistive load used to determine real power capability, and a resistive/inductive load used to determine if it can supply the power to load that is adjusted for a power factor of ~ .5. The generator was then configured for utility interconnection mode using the Woodward EGCP II controller, which synchronizes the generator to the utility and enables it to deliver the programmed power to the utility.

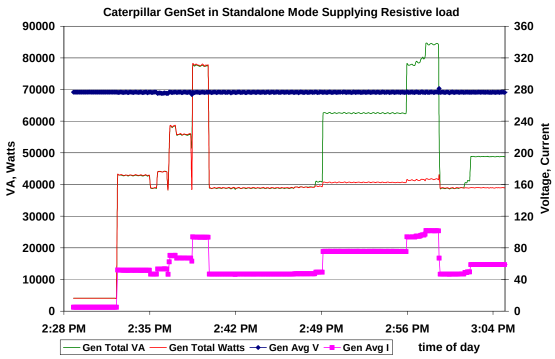

Figure A-2. Stand-alone characteristics.

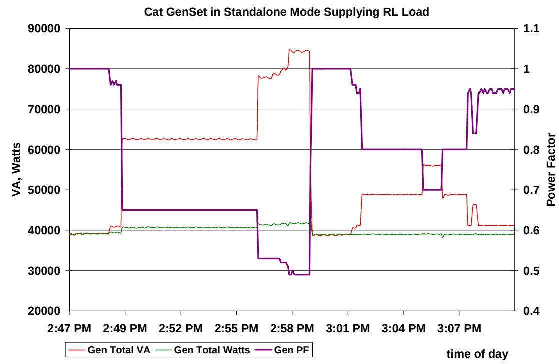

Figure A-3. Additional stand-alone data.

Characteristics

Utilizing a test bed comprised of different test conditions, shown in Table A-1, the generator's capability has been determined and is presented in the tables below. Since the test bed requires the utility voltage to be varied by ± 10% of nominal 480 V_{ac} a 150-kVA multi-tap transformer was implemented to achieve the desired voltage ranges. This voltage varies slightly since the DG is connected to the utility, and as the substation goes through its tap changes the voltage varies. The values presented in the following tables are average values from the data collected at the desired power and power factor levels.

Table 1. Caterpillar 75-kW/92-kVA capability test conditions.

Cold S Rated	Cold 75% S	Hot S_{rated}	Hot 75% S
Vnom (**Test 1**) -0.75, 0.5, 0.75, 1.0	Vnom (**Test 2**) -0.75, 0.5, 0.75, 1.0	Vnom (**Test 3**) -0.75, 0.5, 0.75, 1.0	Vnom (**Test 4**) -0.75, 0.5, 0.75, 1.0
Vmin (**Test 5**) -0.75, 0.5, 0.75, 1.0	Vmin (**Test 6**) -0.75, 0.5, 0.75, 1.0	Vmin (**Test 7**) -0.75, 0.5, 0.75, 1.0	Vmin (**Test 8**) -0.75, 0.5, 0.75, 1.0
Vmax (**Test 9**) -0.75, 0.5, 0.75, 1.0	Vmax (**Test 10**) -0.75, 0.5, 0.75, 1.0	Vmax (**Test 11**) -0.75, 0.5, 0.75, 1.0	Vmax (**Test 12**) -0.75, 0.5, 0.75, 1.0

Following are the pertinent characteristics for each of the test conditions listed previously. Since the generator is tied to our utility, the voltage may slightly fluctuate, which will affect the current and ultimately the output power.

Test 1 (Vnom, S Rated, Cold)						Test 2 (Vnom, 75% of S Rated, Cold)					
PF	**Voltage**	**Current**	**VA**	**Watts**	**PF**	**PF**	**Voltage**	**Current**	**VA**	**Watts**	**PF**
-0.75	480	91	75368	56915	0.76	-0.75	486	76	64049	48589	0.76
1	492	75	63656	63552	1.00	1	490	73	61695	61610	1.00
0.75	499	95	82376	60543	0.73	0.75	495	76	65130	48036	0.74
0.5	502	96	83299	40938	0.49	0.5	499	76	65600	31986	0.49

Test 3 (Vnom, S Rated, Hot)						Test 4 (Vnom, 75% of S Rated, Hot)					
PF	**Voltage**	**Current**	**VA**	**Watts**	**PF**	**PF**	**Voltage**	**Current**	**VA**	**Watts**	**PF**
-0.75	482	91	76322	57866	0.76	-0.75	479	75	62185	46465	0.75
1	490	71	60367	59889	0.99	1	485	70	58420	58152	1.00
0.75	496	89	76330	56788	0.74	0.75	492	72	61536	45550	0.74
0.5	499	103	88950	44184	0.50	0.5	495	78	67175	32776	0.49

Test 5 (Vmin, S Rated, Cold)						Test 6 (Vmin, 75% of S Rated, Cold)					
PF	**Voltage**	**Current**	**VA**	**Watts**	**PF**	**PF**	**Voltage**	**Current**	**VA**	**Watts**	**PF**
-0.75	441	96	73349	55646	0.76	-0.75	438	68	51710	44743	0.86
1	441	84	64445	63965	0.99	1	443	74	56443	56006	0.99
0.75	449	96	74451	55001	0.74	0.75	445	70	53793	40802	0.76
0.5	455	92	72112	34778	0.48	0.5	446	71	54658	26651	0.49

Test 7 (Vmin, S Rated, Hot)						Test 8 (Vmin, 75% of S Rated, Hot)					
PF	**Voltage**	**Current**	**VA**	**Watts**	**PF**	**PF**	**Voltage**	**Current**	**VA**	**Watts**	**PF**
-0.75	439	95	72338	54985	0.76	-0.75	438	68	51710	44743	0.86
1	441	78	59258	59144	1.00	1	443	74	56443	56006	0.99
0.75	449	94	73357	54709	0.75	0.75	445	70	53793	40802	0.76
0.5	451	93	72978	35987	0.49	0.5	446	70	54231	29095	0.54

Test 9 (Vmax, S Rated, Cold)						Test 10 (Vmax, 75% of S Rated, Cold)					
PF	**Voltage**	**Current**	**VA**	**Watts**	**PF**	**PF**	**Voltage**	**Current**	**VA**	**Watts**	**PF**
-0.75	529	87	79427	59646	0.75	-0.75	528	72	66138	49953	0.76
1	539	65	60652	60490	1.00	1	537	65	60230	59723	0.99
0.75	545	89	83818	57769	0.69	0.75	544	75	70636	52908	0.75
0.5	547	96	91378	46453	0.51	0.5	544	75	70225	48730	0.69

Test 11 (Vmax, S Rated, Hot)						Test 12 (Vmax, 75% of S Rated, Hot)					
PF	**Voltage**	**Current**	**VA**	**Watts**	**PF**	**PF**	**Voltage**	**Current**	**VA**	**Watts**	**PF**
-0.75	525	77	69702	57121	0.82	-0.75	527	74	67586	51248	0.76
1	528	66	60306	60352	1.00	1	534	62	56993	56761	1.00
0.75	536	83	77322	57421	0.74	0.75	541	74	69292	51271	0.74
0.5	544	99	92796	46574	0.50	0.5	542	79	74220	37285	0.50

These are the average values for each of the test conditions, which include additional power levels and power factor levels and offer a more detailed picture of the DG's capability characteristics.

Cat GenSet Test 1 Characteristics (Vnom, Rated, Cold)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
6:23:32 AM	491	25	21145	20967	0.99
6:30:23 AM	489	7	6172	5460	0.88
6:31:49 AM	489	13	10599	10257	0.97
6:33:05 AM	490	19	16494	16079	0.97
6:34:13 AM	490	24	20423	20091	0.98
6:35:22 AM	490	30	25839	25568	0.99
6:36:16 AM	490	36	30577	30409	0.99
6:37:17 AM	490	42	35440	35118	0.99
6:38:22 AM	490	48	40699	40422	0.99
6:39:29 AM	491	53	45134	45035	1.00
6:40:35 AM	491	59	50008	49841	1.00
6:41:37 AM	492	64	54368	54476	1.00
6:42:38 AM	492	69	59069	59039	1.00
6:45:08 AM	492	75	63656	63552	1.00
6:48:13 AM	495	78	66763	63290	0.95
6:50:07 AM	497	81	69852	62267	0.89
6:51:29 AM	498	85	73648	61936	0.84
6:53:34 AM	499	90	77625	61142	0.79
6:56:48 AM	499	95	82376	60543	0.73
7:10:01 AM	497	94	81297	56345	0.69
7:11:51 AM	496	96	82936	52677	0.64
7:13:55 AM	501	98	85383	50567	0.59
7:15:20 AM	501	95	82596	44161	0.53
7:17:42 AM	502	96	83299	40938	0.49
7:23:17 AM	491	73	62032	61605	0.99
7:24:39 AM	486	77	64840	61622	0.95
7:25:39 AM	485	81	67906	61643	0.91
7:27:05 AM	483	85	71100	61717	0.87
7:28:00 AM	482	91	76016	61107	0.80
7:39:20 AM	480	91	75368	56915	0.76

Cat GenSet Test 2 Characteristics (Vnom, 75% of Rated, Cold)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
8:11:35 AM	488	7	6114	5390	0.88
8:13:38 AM	488	13	11325	10997	0.97
8:14:35 AM	488	18	15625	15368	0.98
8:15:35 AM	488	24	20705	20447	0.99
8:16:31 AM	489	30	25222	25112	1.00
8:17:35 AM	489	36	30216	30215	1.00
8:18:38 AM	489	41	34953	34925	1.00
8:19:35 AM	489	47	39677	39582	1.00
8:20:34 AM	489	53	45077	44686	0.99
8:21:38 AM	489	59	50100	49760	0.99
8:22:34 AM	490	65	54910	54639	1.00
8:23:38 AM	490	70	59288	59116	1.00
8:24:45 AM	490	73	61695	61610	1.00
8:26:06 AM	494	76	64912	61412	0.95
8:33:31 AM	495	76	65457	58014	0.89
8:35:11 AM	495	77	65658	55234	0.84
8:36:36 AM	495	74	63675	50558	0.79
8:37:43 AM	495	76	65130	48036	0.74
8:39:31 AM	494	74	63308	43737	0.69
8:41:30 AM	494	74	63160	41031	0.65
8:43:26 AM	497	77	65928	38823	0.59
8:44:45 AM	500	76	65858	35411	0.54
8:47:15 AM	499	76	65600	31986	0.49
8:50:51 AM	493	72	61080	61101	1.00
8:52:16 AM	491	75	63708	60819	0.95
8:54:32 AM	489	77	65660	59745	0.91
8:57:15 AM	488	77	65010	55602	0.86
8:58:55 AM	487	77	64690	52225	0.81
9:00:41 AM	486	76	64049	48589	0.76

Cat GenSet Test 3 Characteristics (Vnom, S Rated, Hot)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
11:35:03 AM	489	11	9339	5189	0.56
11:38:31 AM	488	13	11081	10778	0.97
11:39:56 AM	488	19	15889	15593	0.98
11:41:07 AM	487	25	20952	20818	0.99
11:42:30 AM	487	30	25447	25173	0.99
11:43:45 AM	488	36	30243	30005	0.99
11:44:59 AM	488	42	35110	34869	0.99
11:46:30 AM	488	48	40143	39926	1.00
11:48:10 AM	488	54	45256	44818	0.99
11:49:32 AM	488	59	49640	49183	0.99
11:51:05 AM	489	65	55335	54759	0.99
11:52:43 AM	489	71	59774	59277	0.99
11:54:30 AM	490	71	60367	59889	0.99
11:55:56 AM	488	74	62768	59863	0.95
11:57:20 AM	486	78	65981	59407	0.90
11:59:24 AM	485	82	68871	59299	0.86
12:02:24 PM	484	86	72334	58592	0.81
12:05:47 PM	482	91	76322	57866	0.76
12:07:48 PM	489	70	59226	58632	0.99
12:09:04 PM	493	72	61602	58185	0.94
12:10:27 PM	494	76	64849	57913	0.89
12:11:49 PM	495	79	67449	57499	0.85
12:13:35 PM	496	84	72132	57085	0.79
12:14:54 PM	496	89	76330	56788	0.74
12:17:29 PM	496	94	80833	55743	0.69
12:19:21 PM	497	99	85304	55141	0.65
12:22:58 PM	498	107	92112	54012	0.59
12:27:31 PM	496	92	79436	42627	0.54
12:29:45 PM	499	103	88950	44184	0.50

Cat GenSet Test 4 Characteristics (Vnom, 75% of Rated, Hot)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
3:42:17 PM	483	7	6104	5591	0.92
3:43:36 PM	483	13	10746	10397	0.97
3:44:31 PM	483	19	15989	15731	0.98
3:45:38 PM	483	24	20293	20190	0.99
3:46:41 PM	484	30	25222	24987	0.99
3:47:38 PM	483	36	30302	30003	0.99
3:48:33 PM	484	42	35075	34800	0.99
3:49:36 PM	484	48	40149	39860	0.99
3:50:49 PM	485	53	44780	44628	1.00
3:52:10 PM	485	59	49564	49316	1.00
3:53:09 PM	485	65	54229	54131	1.00
3:55:01 PM	485	70	58420	58152	1.00
4:00:46 PM	489	71	60441	57120	0.95
4:05:49 PM	490	72	61318	54994	0.90
4:06:56 PM	491	75	64125	53504	0.83
4:08:30 PM	492	76	64462	51190	0.79
4:11:04 PM	492	72	61536	45550	0.74
4:12:24 PM	493	74	63347	43414	0.69
4:13:59 PM	494	74	63458	41072	0.65
4:15:57 PM	495	76	65066	38198	0.59
4:17:33 PM	494	75	63991	34448	0.54
4:18:52 PM	495	78	67175	32776	0.49
4:21:53 PM	488	45	38061	37873	1.00
4:26:20 PM	487	71	60130	56766	0.94
4:29:09 PM	486	75	62699	56875	0.91
4:37:52 PM	481	75	62567	53044	0.85
4:38:50 PM	480	73	60916	49457	0.81
4:39:41 PM	479	75	62185	46465	0.75

Cat Gen Test 5 Characteristics (Vmin, S Rated, Cold)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
6:11:27 AM	438	8	6098	5508	0.90
6:12:36 AM	439	14	10782	10450	0.97
6:13:40 AM	439	20	15465	15314	0.99
6:14:42 AM	439	27	20474	20301	0.99
6:15:40 AM	439	33	25401	25288	0.99
6:16:44 AM	440	41	30879	30643	0.99
6:17:43 AM	440	46	35344	35173	1.00
6:18:39 AM	440	53	40146	39915	0.99
6:19:43 AM	440	59	44737	44553	1.00
6:20:39 AM	440	65	49471	49269	1.00
6:21:43 AM	440	71	54216	54055	1.00
6:22:50 AM	440	78	59733	59464	1.00
6:24:15 AM	441	84	64445	63965	0.99
6:25:54 AM	446	87	67001	62944	0.94
6:26:48 AM	447	91	70602	62830	0.89
6:28:04 AM	448	95	73820	61897	0.84
6:29:49 AM	448	94	73095	58216	0.80
6:30:50 AM	449	96	74451	55001	0.74
6:31:54 AM	450	98	75965	52554	0.69
6:33:36 AM	455	92	72220	46625	0.65
6:34:33 AM	456	96	76007	44630	0.59
6:35:45 AM	456	94	74289	39866	0.54
6:37:13 AM	455	92	72112	34778	0.48
6:40:11 AM	447	79	61217	60898	1.00
6:41:12 AM	445	83	64294	61012	0.95
6:42:18 AM	444	86	66544	60807	0.91
6:43:24 AM	443	91	69926	60491	0.87
6:46:15 AM	441	97	74037	59717	0.81
6:49:06 AM	441	96	73349	55646	0.76

Cat Gen Test 6 Characteristics (Vmin, 75% of Rated, ~Cold)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF
11:41:35 AM	443	74	56443	56006	0.99
11:43:10 AM	444	72	55560	52150	0.94
11:44:14 AM	444	71	54505	49262	0.90
11:45:30 AM	445	71	54786	46372	0.85
11:46:38 AM	445	70	53559	43074	0.80
11:47:53 AM	445	70	53793	40802	0.76
11:49:06 AM	446	70	54367	38386	0.71
11:50:14 AM	446	72	55304	35629	0.65
11:51:22 AM	446	70	53874	32309	0.60
11:53:07 AM	446	70	54231	29095	0.54
11:55:37 AM	446	71	54658	26651	0.49
11:58:40 AM	442	73	56146	56099	1.00
11:59:54 AM	440	72	54763	52965	0.97
12:01:06 PM	439	72	54699	50039	0.91
12:02:21 PM	438	71	54016	47534	0.88
12:03:30 PM	438	68	51710	44743	0.86
12:05:39 PM	438	62	46678	41409	0.89

Cat Gen Test 7 Characteristics: (Vmin, Rated Power, Hot)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
2:10:53 PM	434	9	6421	6123	0.95
2:12:49 PM	434	14	10606	10425	0.98
2:13:54 PM	435	21	16066	15997	1.00
2:14:58 PM	435	27	20547	20520	1.00
2:16:29 PM	437	33	25369	25216	0.99
2:17:59 PM	440	39	30004	29970	1.00
2:19:04 PM	440	46	35174	35133	1.00
2:20:07 PM	440	52	39799	39704	1.00
2:21:18 PM	441	58	44557	44598	1.00
2:22:36 PM	441	65	49631	49433	1.00
2:23:46 PM	441	71	53872	53917	1.00
2:25:30 PM	441	78	59258	59144	1.00
2:27:32 PM	445	81	62244	58697	0.94
2:28:42 PM	446	84	64859	57992	0.89
2:29:58 PM	447	89	68544	57778	0.84
2:31:38 PM	448	93	72076	57074	0.79
2:40:18 PM	449	94	73357	54709	0.75
2:43:14 PM	450	93	72825	50810	0.70
2:45:46 PM	451	95	74162	47524	0.64
2:47:44 PM	451	96	75078	42557	0.57
2:49:08 PM	451	97	75800	40360	0.53
2:51:26 PM	451	93	72978	35987	0.49
2:57:37 PM	447	72	56010	55831	1.00
3:03:35 PM	443	77	58781	56130	0.96
3:05:18 PM	442	80	61382	55801	0.91
3:07:19 PM	440	88	66984	55214	0.82
3:09:34 PM	439	95	72338	54985	0.76

Cat GenSet Test 8 Characteristics (Vmin, 75% of S Rated, Hot)

time (avg)	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF
11:41:35 AM	443	74	56443	56006	0.99
11:43:10 AM	444	72	55560	52150	0.94
11:44:14 AM	444	71	54505	49262	0.90
11:45:30 AM	445	71	54786	46372	0.85
11:46:38 AM	445	70	53559	43074	0.80
11:47:53 AM	445	70	53793	40802	0.76
11:49:06 AM	446	70	54367	38386	0.71
11:50:14 AM	446	72	55304	35629	0.65
11:51:22 AM	446	70	53874	32309	0.60
11:53:07 AM	446	70	54231	29095	0.54
11:55:37 AM	445	66	50767	26790	0.55
11:58:40 AM	442	73	56146	56099	1.00
11:59:54 AM	440	72	54763	52965	0.97
12:01:06 PM	439	72	54699	50039	0.91
12:02:21 PM	438	71	54016	47534	0.88
12:03:30 PM	438	68	51710	44743	0.86

Cat GenSet Tetst 9 Characteristics (Vmax, S Rated, Cold)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
7:19:19 AM	534	7	6376	5303	0.83
7:20:43 AM	534	12	11310	10677	0.94
7:21:55 AM	536	18	16418	15753	0.96
7:22:53 AM	535	22	20505	20238	0.99
7:23:57 AM	535	27	25425	25090	0.99
7:24:58 AM	535	33	30566	30331	0.99
7:25:55 AM	535	39	35861	35608	0.99
7:26:54 AM	535	43	40132	39770	0.99
7:27:54 AM	536	49	45136	44648	0.99
7:28:56 AM	536	54	50085	49843	1.00
7:29:58 AM	536	59	54651	54147	0.99
7:31:18 AM	538	65	60220	59697	0.99
7:32:59 AM	539	65	60652	60490	1.00
7:37:42 AM	541	67	63196	59967	0.95
7:38:30 AM	542	71	66846	59470	0.89
7:40:44 AM	542	75	70473	59346	0.84
7:42:14 AM	543	79	74241	58881	0.79
7:45:22 AM	545	89	83818	57769	0.69
7:46:31 AM	546	95	89652	57081	0.64
7:49:40 AM	547	100	94815	55950	0.59
7:53:12 AM	547	97	92240	49749	0.54
7:54:37 AM	547	96	91378	46453	0.51
7:56:55 AM	538	64	59992	59978	1.00
7:59:47 AM	535	68	63234	60194	0.95
8:06:05 AM	533	71	65895	60195	0.91
8:07:02 AM	531	76	69708	60019	0.86
8:08:09 AM	531	80	73790	59799	0.81
8:09:09 AM	529	87	79427	59646	0.75

Cat GenSet Test 10 Characteristics (Vmax, 75% of Rated, Cold)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
8:55:17 AM	537	65	60230	59723	0.99
8:56:22 AM	541	67	62803	59088	0.94
8:57:37 AM	541	71	66352	58928	0.89
9:00:04 AM	542	74	69213	58239	0.84
9:03:05 AM	543	74	69565	55508	0.80
9:04:17 AM	544	75	70636	52908	0.75
9:05:27 AM	544	75	70225	48730	0.69
9:08:53 AM	536	63	58215	57296	0.99
9:09:54 AM	535	67	62274	59683	0.96
9:11:28 AM	533	71	65724	59654	0.91
9:13:59 AM	531	72	65786	56080	0.85
9:15:23 AM	530	71	65407	52890	0.81
9:16:36 AM	528	72	66138	49953	0.76

Cat GenSet Test 11 Characteristics (Vmax, S Rated, Hot)

time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
2:23:28 PM	524	8	6885	5731	0.83
2:24:39 PM	524	12	11200	10661	0.95
2:25:39 PM	524	18	16124	15592	0.97
2:26:45 PM	524	23	20967	20548	0.98
2:27:51 PM	524	28	25627	25502	0.99
2:28:43 PM	525	34	30776	30407	0.99
2:29:45 PM	525	39	35904	35681	1.00
2:30:46 PM	525	44	40145	39934	1.00
2:31:44 PM	525	50	45119	44766	0.99
2:32:44 PM	526	55	49678	49540	1.00
2:33:49 PM	527	60	54410	54405	1.00
2:35:49 PM	528	66	60306	60352	1.00
2:38:03 PM	531	69	63272	59690	0.94
2:39:06 PM	532	71	65303	59269	0.91
2:40:15 PM	533	75	69457	58655	0.84
2:41:06 PM	535	79	73153	58162	0.79
2:42:02 PM	536	83	77322	57421	0.74
2:43:05 PM	537	88	82254	56727	0.69
2:45:26 PM	538	94	88056	55888	0.63
2:48:21 PM	538	94	87960	51599	0.59
2:50:19 PM	543	96	90234	49024	0.54
2:51:34 PM	544	99	92796	46574	0.50
2:56:17 PM	533	62	57564	57198	0.99
2:57:57 PM	530	66	60615	57571	0.95
2:59:39 PM	528	70	63578	57484	0.90
3:00:51 PM	526	74	67073	57351	0.85
3:01:58 PM	525	77	69702	57121	0.82

Cat GenSet Test 12 Characteristics (Vmax, 75% of Rated, Hot)

Time	Gen V (avg)	Gen I (avg)	Gen VA (avg)	Gen Watts (avg)	Gen PF (avg)
3:26:59 PM	536	7	6627	5571	0.84
3:28:19 PM	536	12	11153	10517	0.94
3:29:42 PM	536	18	16604	16046	0.97
3:30:38 PM	536	23	21399	21153	0.99
3:31:38 PM	537	27	25386	24992	0.99
3:32:42 PM	534	34	31679	30563	0.97
3:33:45 PM	532	38	35081	34999	1.00
3:34:42 PM	532	44	40275	39911	0.99
3:35:41 PM	533	49	45282	44812	0.99
3:36:45 PM	533	55	50392	49967	0.99
3:37:48 PM	533	59	54754	54159	0.99
3:39:07 PM	534	62	56993	56761	1.00
3:40:40 PM	537	64	59754	56482	0.94
3:41:50 PM	539	68	63700	56090	0.88
3:42:40 PM	540	72	67135	55522	0.83
3:45:00 PM	540	74	69535	54885	0.79
3:47:34 PM	541	74	69292	51271	0.74
3:48:42 PM	541	76	71058	48969	0.69
3:49:52 PM	541	76	71206	45864	0.64
3:50:22 PM	542	81	75874	46232	0.61
3:50:37 PM	542	79	74220	37285	0.50
3:52:08 PM	536	60	55822	55771	1.00
3:53:26 PM	534	64	59476	56201	0.95
3:54:40 PM	533	67	61992	56081	0.90
3:56:00 PM	530	71	65375	55746	0.85
3:57:33 PM	530	75	68434	55922	0.82
4:00:58 PM	527	74	67586	51248	0.76

APPENDIX B. Distributed Energy Resources IEC 61850 Object Modeling Woodward EGCP-2 Generator Control and Engine Maintenance Systems

DISTRIBUTED ENERGY RESOURCES IEC 61850 OBJECT MODELING WOODWARD EGCP-2 GENERATOR CONTROL & ENGINE MAINTENANCE SYSTEM

DRAFT

Prepared For:
Sandia National Laboratories

Prepared By:
EnerNex Corporation

EnerNex CORPORATION

Version0.3
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TABLE OF CONTENTS

1 Introduction

This interim report describes the proposed mapping process for the Woodward EGCP-2 into IEC 61850 object models. The process will use the mapping principles in the present draft of the IEC DER object models document to derive the mapping.

This report will describe the top-level model (Logical Device/Logical Node level) and detailed mapping to those models. A discussion of unmapped points (both Modbus device points and required IEC 61850 points) will then explain reasons for the mapping “holes.” Annexes are presented with the mapping/nonmapping details.

2 References

The following documents were used for this report.

IEC 61850-7-420 (57/818/CDV dated April 2006)

IEC 61850-7-3 Ed1 (2003-05)

IEC 61850-7-4 Ed1 (2003-05)

IEC 61850-8-1 Ed1 (2004-05)

Woodward EGCP-2 Communication Manual (26181, Revision A)

Woodward EGCP-2 Application Manual (26175)

Woodward EGCP-2 Installation and Operation Manual (26174, Revision B)

3 Mapping Hierarchy

IEC 61850 defines a communications hierarchy for data servers. The hierarchy consists of

- Logical Devices (LD)
- Logical Nodes (LN)
- Functional Constraints (FC)
- Data Objects (DO)
- Data (object) Attributes (DA)
- Data (object) (sub-)Attrbutes (DA)

Each of LD and LN and FC and DO has exactly one level whereas there can be up to four DA levels. For example, a portion of a IEC 61850 server could be named as follows:

MyDevice/MMXU1MXPPV$phsAB$cValmagf

This indicates that the information resides within the Logical Device named "MyDevice," which resides within the first instantiated Logical Node MMXU, which contains a group of measurements (MX), one of which is the three phase line-to-line voltages. This is further specified as the AB phases-to-phase voltage, which has a complex (polar coordinate) data value, a portion which is the magnitude. Finally, this object represents a floating-point version (SI engineering units) of that voltage.

The purpose of the DER mapping is to "find a home for the Modbus objects which relate to the 61850 standard."

3.1 Top-Level Hierarchy

The first level of mapping is to define Logical Devices for the generator controller:

- ECP0 maps the Electrical Connection Point (ECP) between the plant and the utility grid;
- ECP1 maps the ECP between the first generator and the plant (others are ECP2, etc.);
- DERC maps the overall DER controller "farm";
- DERG maps one DER (electrical) generator (which is mechanically linked to the engine); and
- DRCP maps one reciprocating engine (which is mechanically linked to the generator).

Each of these Logical Devices contains Logical Nodes.

3.2 Logical Node Mapping

Logical Node ECP0

- LLN0 – Common issues for a Logical Device
- LPHD1 – Common issues for a Logical Device
- DPST1 – Status of utility lines and breaker contact
- CSWI1 – Status of utility breaker controller
- MMXU1 – Voltage measurement of utility line (single phase)

Logical Node ECP1

- LLN0 – Commons issue for a Logical Device
- LPHD1 – Commons issue for a Logical Device
- DPST1 – Status of generator breaker
- CSWI1 – Status of generator breaker controller
- MMXU1 – Measurements of generator output

Logical Node DERC

- LLN0 – Common issues for a Logical Device and (overall) alarm reset
- LPHD1 – Common issues for a Logical Device
- DRCT1 – Unit Controller characteristics and setpoints
- MMXU1 – Plant/Generator bus frequency measurement
- CALH1 – (overall) Alarm Status
- GGIO1 – Process control mode/setpoint, load control state, synchronizer state

Logical Node DERG

- LLN0 – Common issues for a Logical Device
- LPHD1 – Common issues for a Logical Device
- DGEN1 – Generator operations
- DRAT1 – Generator ratings
- GGIO1 – Generator stable indicator

Logical Node DRCP

- LLN0 – Common issues for a Logical Device
- LPHD1 – Common issues for a Logical Device
- DCIP1 – Reciprocating engine
- ZBAT1 – Starter battery voltage
- MPRS1 – Oil pressure
- MTMP1 – Coolant temperature
- GGIO1 – Cooldown override control, rated RPM

3.3 Data Object and Attribute Mapping

Annex A contains the present mapping for all mappable objects. The following attribute list illustrates the simplest (by far) Logical Device, ECP0. The logical device name has been omitted for clarity.

LLN0STMod$stVal – ECP0 logical device control mode commands

LLN0STMod$q – Operating mode commands (read value) quality

LLN0STMod$t – Operating mode commands (last change) timestamp

LLN0DCMod$d – Description of the "Mod" object

LLN0CFMod$ctlModel – Control models used with stVal (is fixed at "Status-only")

LLN0STBeh$stVal – ECP0 logical device behavior (on/test/blocked, etc.)

LLN0STBeh$q – quality of above

LLN0STBeh$t – timestamp of above

LLN0DCBeh$d – Description of the "Beh" object

LLN0STHealth$stVal – ECP0 self-test status

LLN0ST Health$q – quality of above

LLN0ST Health$t – timestamp of above

LLN0DCHealth$d – Description of the "Health" object

LLN0DCNameplt$vendor –vendor name of ECP0

LLN0DCNameplt$swRev – firmware revision of ECP0

LLN0DCNameplt$d – description of ECP0

LLN0DCNameplt$configRev – configuration version identifier for ECP0

LPHD1DCPhyNam$vendor – name of device vendor ("EnerNex/Woodward")

LPHD1STPhyHealth$stVal – physical device health (1=OK)

LPHD1STPhyHealth$ q – quality of above

LPHD1STPhyHealth$ t – timestamp of above

LPHD1DCPhyHealth$d – Description of the "PhyHealth" object

LPHD1STProxy$stVal – Is this a proxy device? (FALSE=NO)

LPHD1STProxy$ q – quality of above

LPHD1STProxy$ t – timestamp of above

LPHD1DCProxy$d – Description of the "Proxy" object

LPHD1DCPhyName$vendor – name of device vendor ("Woodward")

DPST1STMod$stVal – DPST1 logical device control mode commands

DPST1STMod$q – Operating mode commands (read value) quality

DPST1STMod$t – Operating mode commands (last change) timestamp

DPST1DCMod$d – Description of the "Mod" object

DPST1CFMod$ctlModel – Control models used with stVal (is fixed at "Status-only")

DPST1STBeh$stVal – ECP0 logical device behavior (on/test/blocked, etc.)

DPST1STBeh$q – quality of above

DPST1DCBeh$d – Description of the "Beh" object

DPST1STBeh$t – timestamp of above

DPST1STHealth$stVal – ECP0 self-test status

DPST1ST Health$q – quality of above

DPST1ST Health$t – timestamp of above

DPST1DCHealth$d – Description of the "Health" object

DPST1DCNameplt$vendor –vendor name of ECP0

DPST1DCNameplt$swRev – firmware revision of ECP0

DPST1DCNameplt$d – description of ECP0

DPST1DCNameplt$configRev – configuration version identifier for ECP0

DPST1STECPConn$stVal – last commanded position of utility/plant breaker

DPST1STECPConn$q – quality of above

DPST1STECPConn$t – timestamp of above

DPST1DCECPConn$d – Description of the "ECPConn" object

CSWI1STMod$stVal – CSWI1 logical device control mode commands

CSWI1STMod$q – Operating mode commands (read value) quality

CSWI1STMod$t – Operating mode commands (last change) timestamp

CSWI1DCMod$d – Description of the "Mod" object

CSWI1CFMod$ctlModel – Control models used with stVal (is fixed at "Status-only")

CSWI1STBeh$stVal – ECP0 logical device behavior (on/test/blocked, etc.)

CSWI1STBeh$q – quality of above

CSWI1STBeh$t – timestamp of above

CSWI1DCBehd$d – Description of the "Beh" object

CSWI1STHealth$stVal – ECP0 self-test status

CSWI1ST Health$q – quality of above

CSWI1ST Health$t – timestamp of above

CSWI1DCHealth$d – Description of the "Health" object

CSWI1DCNameplt$vendor –vendor name of ECP0

CSWI1DCNameplt$swRev – firmware revision of ECP0

CSWI1DCNameplt$d – description of ECP0

CSWI1DCNameplt$configRev – configuration version identifier for ECP0

CSWI1STPos$stVal – present position of utility/plant breaker

CSWI1STPos$q – quality of above

CSWI1STPos$t – timestamp of above

MMXU1STMod$stVal – MMXU1 logical device control mode commands

MMXU1STMod$q – Operating mode commands (read value) quality

MMXU1STMod$t – Operating mode commands (last change) timestamp

MMXU1DCMod$d – Description of the "Mod" object

MMXU1CFMod$ctlModel – Control models used with stVal (is fixed at "Status-only")

MMXU1STBeh$stVal – ECP0 logical device behavior (on/test/blocked, etc.)

MMXU1STBeh$q – quality of above

MMXU1STBeh$t – timestamp of above

MMXU1DCBeh$d – Description of the "Beh" object

MMXU1STHealth$stVal – ECP0 self-test status

MMXU1ST Health$q – quality of above

MMXU1ST Health$t – timestamp of above

MMXU1DCHealth$d – Description of the "Health" object

MMXU1DCNameplt$vendor –vendor name of ECP0

MMXU1DCNameplt$swRev – firmware revision of ECP0

MMXU1DCNameplt$d – description of ECP0

MMXU1DCNameplt$configRev – configuration version identifier for ECP0

MMXU1$ MXPhVPhsA$cVal$mag$f – utility phase A-N RMS measurement

MMXU1$ MXPhVPhsA$cVal$q – quality of above

MMXU1MXPhV$PhsA$cVal$t – timestamp of above

MMXU1DCPhV$d – Description of the "Mod" object

4 Comments on the mappings

Annex A contains the IEC 61850 data models and their associated mappings to the Modbus registers. All 61850 objects in this mapping have a description component named "d" in the functional constraint area named DC (description). All of the objects with functional constraint MX (measurements) and ST (status) have associated quality ("q") and timestamp ("t") components as well. These common components are not shown in the table for brevity's sake.

Note that the column "DO Class" contains the name of the specialization of the common data class name as specified in the SCL file in the "DOType" section. The first few letters (up to the first underscore) is the name of the generic common data class (CDC) from IEC 61850-7-3. This information will be helpful in case the object dictionary is redesigned.

It should be obvious from the list of attributes above and in Annex A that the 61850 mapping contains a large number of objects, some of which map to Modbus and some to the gateway itself. However, not all of the Modbus points in the controller are mapped. In addition, some of the important points in the controller have been mapped to logical nodes that contain object and attributes that do not exist in the controller. Annex B contains the complete list of Modbus objects in the controller along with a note as to whether the point has been mapped. Annex C contains IEC 61850 objects without any apparent mappings to the Modbus register set.

4.1 Modbus Register Without 61850 Mapping

Many of the registers within the controller have no appropriate IEC 61850 mapping. There are several categories of this type of data:

- **Vague definitions** – The register definition is too vague for mapping. For example, register 00009 is named "Remote Fault Input #1." This has no concrete meaning and is therefore not mappable.
- **Controller-specific data** – The register has "uncommon" data. 61850 maps only to most used data objects. For example, register 10001 "Bus/Mains PT Switch in Transition" is special to this brand (and possibly model) of engine controller.
- **No specific mapping** – Alarm status values have been purposely left out of the mapping because they have no specific mappings into the DER object model. If Sandia desires, these can be mapped to "generic" inputs (GGIO) Logical Nodes within the appropriate Logical Device. These data objects can have descriptors ("d" attributes) that contain both the original Modbus register number and the Modbus description. The gateway can synthesize the appropriate timestamp and quality flags for these values. For example, register 10049 "Generator Undervoltage Alarm Status," could be mapped as DERG/GGIO1MXAnIn1 with attributes mag and q and t and d.

4.2 IEC 61850 Mandatory Objects Without Mappings

During the mapping phase, it became apparent that some controller information should be modeled even if all mandatory components of the logical node were not present. These are shown in Annex C. Note that this list will expand if more Modbus registers are mapped because many 61850 Logical Nodes contain mode mandatory elements that do not exist within the engine controller. In some cases, mistakes have been found in the 61850 object models that prohibit mappings. Classes of these mistakes include:

- **Obvious cut and paste errors** – For example, LN DERG has an object "GnAlm" of non-existent class ALM. Further refinement of the standard will surely eliminate this mistake.
- **Mapping errors** – For example, LN DRAT has an object "DERId" of class MRID. However, MRID is explained as a shorthand for an integer. The problem is that this lacks a definition of the Functional Constraint, without which a mapping cannot be made.
- **Unclear mapping** – For example, there are many references to "self-service" throughout the proposed standard without any indication of what this means.

5 Comments on the Proposed DER Mappings

The report is based upon IEC 57/818/CDV with the current title of IEC 62350 and a comment that it will be tentatively renumbered as IEC 61850-7-420. The document is a product of IEC Technical Committee 57 Working Group 17, which is chaired by Frank Goodman of EPRI. The author of this report has already worked closely with Mr. Goodman on this standard as an IEC TC57 member and has also participated in two modeling workshops that prepared this current report. This allows the report author to submit official IEC comments on specific perceived shortcoming of the proposed standard. These submissions are submitted on a standard IEC form ("Form 8c"). A copy of the submitted comment form can be found in Annex D.

6 Sandia Deliverables

Sandia has received a ScadaSentry device that implements a configurable IEC 61850-to-Modbus gateway. This gateway is configured using two loadable files: SCL.XML and datamap.CFG. The SCL file defines the IEC 61850 model of the device while the datamap file defines the Modbus mappings of the model's objects. Additionally, EnerNex has delivered a functional IEC 61850 client program (front panel) based upon a simple Microsoft Excel spreadsheet. Sandia personnel have been trained on adaption of these files for their future needs.

7 Future Work Items

The IEC 61850 gateway delivered to Sandia implements only a subset of the full capabilities of the Woodward controller and the client program implements only a subset of functionality inside the gateway. Sandia personnel need to exercise the delivered system to expose any missing "required" functionality.

One example of missing Woodward functionality is the ability to access both sets of engine controller watt/Power Factor/VAr setpoints (the "engine stopped" version as well as the implemented "engine running" values). One simple way to accomplish this would be to add a second Logical Node named "DERC/DRCT2" with objects [SP]OutWSet and OutPFSet and OutVArSet. This would be a simple matter of cutting and pasting of the existing delivered SCL and datamap files. The changes to the SCL files are outlined below:

Change:

```
<LDevice inst="DERC">
      <LN0 lnClass="LLN0" inst="" lnType="LN0_plus_LEDRs"/>
      <LN lnClass="LPHD" inst="1" lnType="LPHD_com"/>
      <LN lnClass="DRCT" inst="1" lnType="DRCT_DERC"/>
      <LN lnClass="MMXU" inst="1" lnType="MMXU_DERC"/>
      <LN lnClass="CALH" inst="1" lnType="CALH_DERC"/>
      <LN lnClass="GGIO" inst="1" lnType="GGIO_DERC"/>
</LDevice>
```

To:

```
<LDevice inst="DERC">
      <LN0 lnClass="LLN0" inst="" lnType="LN0_plus_LEDRs"/>
      <LN lnClass="LPHD" inst="1" lnType="LPHD_com"/>
      <LN lnClass="DRCT" inst="1" lnType="DRCT_DERC"/>
      <LN lnClass="DRCT" inst="2" lnType="DRCT2_DERC"/>
      <LN lnClass="MMXU" inst="1" lnType="MMXU_DERC"/>
      <LN lnClass="CALH" inst="1" lnType="CALH_DERC"/>
      <LN lnClass="GGIO" inst="1" lnType="GGIO_DERC"/>
</LDevice>
```

Duplicate the following section, but change "DRCT_DERC" to "DRCT2_DERC" and remove the object "AutoManCtl":

```
<LNodeType id="DRCT_DERC" lnClass="DRCT">
      <DO name="Mod" type="INC_com"/>
      <DO name="Beh" type="INS_com"/>
      <DO name="Health" type="INS_com"/>
      <DO name="NamPlt" type="LPL_com"/>
      <DO name="AutoManCtl" type="SPC_com"/>
      <DO name="OutWSet" type="ASG_com"/>
      <DO name="OutVArSet" type="ASG_com"/>
      <DO name="OutPFSet" type="ASG_com"/>
</LNodeType>
```

The changes to the datamap files follow directly from this change. Simply locate the lines with DRCT1 and duplicate these as DRCT2 with appropriate remappings of the Modbus registers.

8 Conclusions

The report defines a draft mapping proposal for many of the points within the diesel generator controller. Sandia National Laboratories must now decide whether the proposed mapping should be implemented in a 61850 server or whether some alternative mapping should be implemented in the server.

Specifically, Sandia should review Annex B for registers that must be mapped in order for the server to be useful. Also, Sandia should review Annex C to decide whether mandatory objects in 61850 are truly mandatory for any reasonable implementation. If they are mandatory, then the server will need to "somehow" derive this information (for example, by serving constant data).

Any additional mapping would likely be to nonstandard Logical Nodes and/or nonstandard objects. These would not be interoperable with all IEC 61850-compliant clients. The additions of GGIO objects would not hinder interoperability, but it would add additional manual steps to the client configuration task (manually entering the object identification).

One particular example of an additional mapping would be the "second" grouping of the generator setpoints. The proposed model in 61850-6-420 has a single set of setpoints (named "Control" in the proposed model) in the DRCT Logical Node for watt and VAr and Power factor. However, the Woodward controller implements both "engine stopped" and "engine running" versions of these variables. The Widget controller mapping delivered to Sandia implements only the "engine running" version of these variables.

The result of this study was presented at the International Electrotechnical Commission (IEC) Technical Committee 57 (TC57), Working Group 17 (WG17) meeting held the week of October 16, 2006, in Arnhem, Netherlands. This group is focused upon IEC 61850-based models of DER equipment. The intent of this meeting was to move the draft standard (tentatively titled 61850-7-420) toward a Final Draft International Standard (FDIS), which would have allowed a vote of approval/disapproval by member countries without further opportunity to change the standard.

The group discussed the overall standard and specifically the reciprocating engine model at length. The committee members were very surprised that many critical aspects of some DER systems (specifically the Woodward controller) were missing. Based upon the level of demonstrated inadequacies of the Reciprocating-Engine-based models and further work of Working Group 18 (Hydro Power models), it was decided to stop forward movement on the draft standard. All of the existing models in the standards will be reviewed for complete revision and harmonization with the Hydro models.

As an example of the restructuring, the DER models of a electrical generator start had specific cases for each type of prime mover (example: fuel cell or micro-turbine or photovoltaic) whereas the Hydro model specified a generic "sequencer" for all types of generators. WG17 sees value in this type of generic approach, which can vastly simplify the modeling process.

Annex A Mappings

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
ALL	LPHD1	DC	PhyNam	DPL_com	vendor	VSTR255	Vendor name		M				
		ST	PhyHealth	INS_com			Health of Woodward contrlr		M				
					stVal	INT32			M	GW			Can be fixed at 1=GOOD
					q	Quality			M	GW			can be fixed at 0
					t	Timestamp			M	GW			can be fixed at power-up time
					d	VSTR255	Description of object		O	GW			
			Proxy	SPS_com			Is this proxied?		M				
					stVal	BOOLEAN				GW			Can be fixed at FALSE
					q	Quality				GW			can be fixed at 0
					t	Timestamp				GW			can be fixed at power-up time
					d	VSTR255	Description of object		O	GW			
ALL	LLN0		Mod,Beh,Health,NamePlt (including configRev)						M	GW			See Logical Node "EVERY"
	ALL		Mod	INC_com			Operating mode commands		M				
		ST	Mod		stVal	INT32	1=on,2=blocked,3=test,4=test/blocked,5=off		M	GW			can be fixed at 1
		ST	Mod		q	Quality			M	GW			can be fixed at 0
		ST	Mod		t	Timestamp			M	GW			can be fixed at power-up time
		CF	Mod		ctlModel	ENUM	0=status only,1=DO,2=SBO,etc		M	GW			can be fixed at 0
					d	VSTR255	Description of object		O	GW			

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
	ALL		Beh	INS_com			Current operating behavior		M				
		ST	Beh		stVal	INT32	1=on,2=blocked,3=test,4=test/blocked,5=off		M	GW			can be fixed at 1
		ST	Beh		q	Quality			M	GW			can be fixed at 0
		ST	Beh		t	Timestamp			M	GW			can be fixed at power-up time
					d	VSTR255	Description of object		O	GW			
	ALL		Health	INS_com			Health of Logical Node		M				
		ST	Health		stVal	INT32	1=OK,2=warning,3=alarm		M	GW			can be fixed at 1
		ST	Health		q	Quality			M	GW			can be fixed at 0
		ST	Health		t	Timestamp			M	GW			can be fixed at power-up time
					d	VSTR255	Description of object		O	GW			
	ALL		Nameplt	LPL_LN0, LPL_com									LPL_LN0 is used in LN0 logical nores, LPL_com is used in all other logical nodes
		DC	Nameplt		Vendor	VSTR255	Vendor name		M	GW			Can be fixed at "Woodward"
		DC	Nameplt		swRev	VSTR255	Logical Node version		M	GW			Can be fixed at "1"
		DC	Nameplt		D	VSTR255	Logical Node description		M	GW			Can be fixed at "(Name of Logical Node)"
		DC	Nameplt		configRev	VSTR255	Configuration revision ident		M	GW			For LLN0 only, where it can be fixed at "Rev 0"
ECP0							Electrical Connection Point : Utility to Plant/Generator Bus						

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
	DPST1	ST	ECPConn	SPS_com	stVal	BOOLEAN	DER plant connected to utility		M	MB	10026		
	CSWI1	ST	Pos	DPC_com	stVal	coded enum	main breaker commanded state	int,off,on,bad	M	MB	10006	F->1,T->2	Component CF ctlModel is 0 (status only)
	MMXU1		PhV	WYE_voltA_only	phsA	*Info only*	Mains phase A volts		O				Only one phase (A) is measured
	MMXU1	MX	PhV	(CMV_com)	phsA. cVal.mag.f	FLOAT32	Mains phase A volts	volts	M	MB	30058		If phsA present, mag/q/t are mandatory
ECP1							Electrical Connection Point : Plant/Generator Bus to Generator						
	DPST1	ST	ECPConn	SPS_com	stVal	BOOLEAN	Generator connected to plant bus?		M	MB	10025		
	CSWI1	ST	Pos	DPC_com	stVal	coded enum	Gen breaker commanded state	int,off,on,bad	M	MB	10007	F->1,T->2	
	MMXU1	MX	PPV	DE_comL	phsAB.cVal.mag.f	FLOAT32	Gen Line-to-line Volts A-B	volts	O	MB	30007		
	MMXU1	MX	PPV	DEL_com	phsBC.cVal.mag.f	FLOAT32	Gen Line-to-line Volts B-C	volts	O	MB	30008		
	MMXU1	MX	PPV	DEL_com	phsCA.cVal.mag.f	FLOAT32	Gen Line-to-line Volts C-A	volts	O	MB	30009		
	MMXU1	MX	PhV	WYE_com	phsA.cVal.mag.f	FLOAT32	Gen phase A volts	volts	M	MB	30055		
	MMXU1	MX	PhV	WYE_com	phsB.cVal.mag.f	FLOAT32	Gen phase B volts	volts	M	MB	30056		
	MMXU1	MX	PhV	WYE_com	phsC.cVal.mag.f	FLOAT32	Gen phase C volts	volts	M	MB	30057		
	MMXU1	MX	A	WYE_com	phsA.cVal.mag.f	FLOAT32	Gen Amperes A	amps	O	MB	30059		
	MMXU1	MX	A	WYE_com	phsB.cVal.mag.f	FLOAT32	Gen Amperes B	amps	O	MB	30060		
	MMXU1	MX	A	WYE	phsC.cVal.mag.f	FLOAT32	Gen Amperes C	amps	O	MB	30061		

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
				_com									
	MMXU1	MX	VAr	WYE _com	phsA. cVal.mag.f	FLOAT32	Gen VArs A	watts	O	MB	30013	MB*100 0	
	MMXU1	MX	VAr	WYE _com	phsB.cVal.mag.f	FLOAT32	Gen VArs B	watts	O	MB	30014	MB*100 0	
	MMXU1	MX	VAr	WYE _com	phsC.cVal.mag.f	FLOAT32	Gen VArs C	watts	O	MB	30015	MB*100 0	
	MMXU1	MX	VA	WYE _com	phsA.cVal.mag.f	FLOAT32	Gen VAs A	watts	O	MB	30062	MB*100 0	
	MMXU1	MX	VA	WYE _com	phsB.cVal.mag.f	FLOAT32	Gen VAs B	watts	O	MB	30063	MB*100 0	
	MMXU1	MX	VA	WYE _com	phsC.cVal.mag.f	FLOAT32	Gen VAs C	watts	O	MB	30064	MB*100 0	
	MMXU1	MX	TotW	MV_ com	mag.f	FLOAT32	Generator KW (should be > 0)	watts	O	MB	30010	MB*100 0	MB value is in kiloWatts, 61850 is watts
	MMXU1	MX	TotVAr	MV_ com	mag.f	FLOAT32	Generator Vars (either sign)	watts	O	MB	30016	MB*100 0	MB value is in kiloWatts, 61850 is watts
	MMXU1	MX	TotVA	MV_ com	mag.f	FLOAT32	Generator VAs (must be > 0)	watts	O	MB	30011	MB*100 0	MB value is in kiloWatts, 61850 is watts
	MMXU1	MX	TotPF	MV_ com	mag.f	FLOAT32	Generator power factor	- 1.00...+1.00	O	MB	30012	MB*0.01	if (MB[10071]==1) then invert sign
	MMXU1	MX	Hz	MV_ com	mag.f	FLOAT32	Generator Frequency	0…70.0	O	MB	30018	MB*0.1	
DERC							DER (overall) controller						
	LLN0	CO	LEDRs	SPC_ com	Oper.ctlVal	BOOLEAN	Reset all alarms		O	MB	00016		Status is in CALH1.ST.GrAlm.stVal
	DRCT1	SP	OutWSet	ASG _com	Oper.setMag.f	FLOAT32	Watt setpoint		O	MB	30215 40003		Readback and write values
	DRCT1	SP	OutVArSet	ASG _com	Oper.setMag.f	FLOAT32	VAr setpoint		O	MB	30230 40007		Readback and write values
	DRCT1	SP	OutPFSet	ASG	Oper.setMag.f	FLOAT32	Power Factor setpoint		O	MB	30229		Readback and write values

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
				_com							40005		
	DRCT1	CO	AutoManCtl	SPC	Oper.ctlVal	BOOLEAN	Set AutoMan		M	MB	00024		boolean might be inverted (CDV is unclear), ctlModel = 1 (direct operate)
	MMXU1	MX	Hz	MV	mag.f	FLOAT32	Bus Frequency	0…70.0	O	MB	30017	MB*0.1	
	CALH1	ST	GrAlm	SPS_com	stVal	BOOLEAN	Any alarm active?		M	MB	10004		
	GGIO1	CO	SPCSO1	SPC_com	Oper.cltVal	BOOLEAN	Change "using Process Control Mode"		O	MB	00008		ctlVal component always 1 (direct operate only)
	GGIO	ST	SPCSO1	SPC_com	stVal	BOOLEAN	Status of "using Process Control Mode"		O	MB	10027		
	GGIO1	CO	ISCSO1	INC_plus_control	Oper.ctlVal	INTEGER	Overall control mode		O	MB	00001 00002 00003	3 modbus registers packed into integer	0=OFF, 5=Auto Run
	GGIO1	ST	ISCS01	INC_plus_control	stVal	INTEGER	Present value of Overall control mode		O	MB	10018 10019 10020	3 modbus registers packed into integer	0=OFF, 5=Auto Run
	GGIO1	ST	IntIn1	INS_com	stVal	INTEGER	Load control state		O	MB	30067		0=Off … 4=Process
	GGIO1	ST	IntIn2	INS_com	stVal	INTEGER	Synchronizer state		O	MB	30068		0=off … 9=Mains sync
	GGIO1	SP	ASGSO1	ASG_com	Oper.setMag.f	FLOAT32	Process reference setpoint		O	MB	30216 40002		Readback and write values, Scaling is defined by the process input
DERG							DER individual (electrical) generator						
	LLN0	ST	EEHealth	INS_com	.stVal	INTEGER	Controller Health		M	GW			Hardwired to 1=Healthy
	LLN0	DC	EEName	DPL_com	Vendor	VSTR256	Controller Name		M	GW			Hardwired to "EnerNex/Woodward"
	DGEN1	MX	TotWh	MV_com	mag.f	FLOAT32	Total watt-hours delivered		O	MB	30005	MB*1E6	
	DRAT1	ST	ConnTyp	INS_	stVal	INT32	Delta vs Wye	CDV is	M	MB	10070		MB:0=Wye,1=Delta

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
				com			vs single-phase	unclear					
	DRAT1	MX	HzRtg	MV_ com	mag.f	FLOAT32	Nominal frequency		O	MB	30253	see note	0->50.0,1=60.0
	DRAT1	MX	VARtg	MV_ com	mag.f	FLOAT32	max volt-amp		O	MB	30256		
	DRAT1	MX	WRtg	MV_ com	mag.f	FLOAT32	Max watts		O	MB	30255		
	DRAT1	MX	VAVArRtg	MV_ com	mag.f	FLOAT32	Max VArs		O	MB	30257		
DRCP							DER Reciprocating engine (shaft/engine group)						
	DCIP1	ST	EEHealth	INS_ com	stVal	INT32	Engine health, 1=OK,2=warning,3=alarm		M	GW			Hard wire 1=OK
	DCIP1	DC	EEName	DPL_ com	Vendor	VSTR255	Vendor name		M	GW			Hard wire "Woodward"
	DCIP1	ST	OpTmh	INS_ com	stVal	INT32	Engine run time		O	MB	30004		
	DCIP1	MX	EngRPM	MV_ com	???	FLOAT32?	Engine speed		O	MB	30006		CDCis wrong, probably should be class MV
	ZBAT1	MX	Vol	MV_ com	mag.f	FLOAT32?	Starter battery voltage		M	MB	30001		Could use BATT but then have many mandatory unmapped objects
	MPRS1	MX	PresVal	MV_ com	mag.f	FLOAT32	Engine oil pressure		O	MB	30002		
	MTMP1	MX	TmpVal	MV_ com	mag.f	FLOAT32	Engine coolant temperature		O	MB	30003		
	GGIO1	CO	SPCSO1	SPC_ com	Oper.ctlVal	BOOLEAN	Cooldown override control			MB	00036		ctlModel=1 (direct operate)
	GGIO1	MX	AnIn1	MV_ com	Mag.f	FLOAT32	Rated Speed (RPM)			MB	30254		

The following items are desirable if the utility treats the generator as it's own asset

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
ECP0	DCRP		PlntOwn	DOO	Owner	VSTR255	Owner of plant		M	GW	(not MB)		is LN needed?
ECP0	DCRP		PlntOwn	DOO	Owner		Operator of plant		M	GW			is LN needed?
ECP0	DPST	MX	PintDERConn	LIST	ListLength	INT16U	List Length	0..1	M	?			This identifes # der plant connected to utility
ECP0	DPST	MX	PintDERConn	LIST	Id0	INT32U	Unique #	0..8	M	GW			
ECP0	DPST	MX	PintDERConn	LIST	q0	Quality	Quality (fixed?)	0..8	M	GW			
ECP0	DPST	MX	PintDERConn	LIST	t0	Timestamp	Timestamp (upon change)	0..8	M	GW			
ECP1	DPST	MX	PintDERConn	LIST	ListLength	INT16U	List Length	0..1	M	?			This identified generators on local bus
ECP1	DPST	MX	PintDERConn	LIST	Id0	INT32U	Unique #	0..8	M	GW			
ECP1	DPST	MX	PintDERConn	LIST	q0	Quality	Quality (fixed?)	0..8	M	GW			
ECP1	DPST	MX	PintDERConn	LIST	t0	Timestamp	Timestamp (upon change)	0..8	M	GW			
ECP1	DPST	MX	PintDERConn	LIST	Id1	INT32U	Unique #	0..8	M	GW			
ECP1	DPST	MX	PintDERConn	LIST	q1	Quality	Quality (fixed?)	0..8	M	GW			
ECP1	DPST	MX	PintDERConn	LIST	t1	Timestamp	Timestamp (upon change)	0..8	M	GW			
DERC1	DRCT	MX	OpModOnConn	SPS			On and Connected		M				Cannot find
DERC1	DRCT	MX	OpModOnAvail	SPS			On and available		M				Cannot find
DERC1	DRCT	MX	OpModOnUnav	SPS			On but not unavailable		O				Cannot find
DERC1	DRCT	MX	OpModOffAvail	SPS			Off but avail to start		O				Cannot find
DERC1	DRCT	MX	OpModOffUnav	SPS			Uff but not avail to start		M				Cannot find

Log. Device	Log Node	Func Con-str	Data Object	DO Class	Attribute	Attrib Type	Description	Units/Enum-erations	M/O	Src Dev-ice	Modbus Reg-ister	Scaling & Offsets	Notes
DERC1	DRCT	MX	OpModTest	SPS			Test mode		O				Cannot find
DERC1	DRCT	MX	OpModStr	SPS			Starting up		O				Cannot find
DERC1	DRCT	MX	OpModStop	SPS			Stopping/shutting down		O				Cannot find

Annex B Modbus Object Table

?

"Coil" Objects (0xxxx) read via FC=1, written via FC=5+15)

Mapped?	Modbus Address	Type	Item	Semantics
YES	00001	BW	Automatic	0 = False, 1 = True
YES	00002	BW	Test	0 = False, 1 = True
YES	00003	BW	Run with Load	0 = False, 1 = True
	00004	BW	Voltage/PF/VAR Raise Command	0 = False, 1 = True
	00005	BW	Voltage/PF/VAR Lower Command	0 = False, 1 = True
	00006	BW	Load/Speed Raise Command	0 = False, 1 = True
	00007	BW	Load/Speed Lower Command	0 = False, 1 = True
YES	00008	BW	Process Control Switch	0 = False, 1 = True
	00009	BW	Remote Fault Input #1	0 = False, 1 = True
	00010	BW	Remote Fault Input #2	0 = False, 1 = True
	00011	BW	Remote Fault Input #3	0 = False, 1 = True
	00012	BW	Remote Fault Input #4	0 = False, 1 = True
	00013	BW	Remote Fault Input #5	0 = False, 1 = True
	00014	BW	Remote Fault Input #6	0 = False, 1 = True

Mapped?	Modbus Address	Type	Item	Semantics
N/A	00015	BW	Not Used	
YES	00016	BW	Reset All Alarms	Resets control, but does not clear alarm log
YES	00024	BW	Auto Sequence	0 = Disabled, 1 = Enabled
YES	00036	BW	Cooldown Override	0 = Disabled, 1 = Enabled

"Contact" Objects (1xxxx) read via FC=2

Mapped?	Modbus Address	Type	Item	Semantics
	10001	BR	Bus/Mains PT Switch in Transition	0 = Not Active, 1 = Active
	10002	BR	Mains Stable Indication	0 = Not stable (waiting for timeout), 1 = Stable
	10003	BR	Bus Stable Indication	0 = Not Stable (waiting for timeout), 1 = Stable
YES	10004	BR	Alarm Status	0 = No Alarms, 1 = Active Alarm
	10005	BR	Loss of Mains Alarm Status	0 = Mains OK, 1 = LOM detected
YES	10006	BR	Mains Breaker Close DO Status	0 = Open, 1 = Closed
YES	10007	BR	Gen Breaker Close DO Status	0 = Open, 1 = Closed
	10008	BR	Engine Preglow DO Status	0 = Open, 1 = Closed
	10009	BR	Fuel Solenoid DO Status	0 = Open, 1 = Closed
	10010	BR	Engine Crank DO Status (Starter)	0 = Open, 1 = Closed

Mapped?	Modbus Address	Type	Item	Semantics
	10011	BR	Visual Alarm DO Status	0 = Open, 1 = Closed
	10012	BR	Bus PT Connect DO Status	0 = Open, 1 = Closed
	10013	BR	Mains PT Disconnect DO Status	0 = Open, 1 = Closed
	10014	BR	Mains Breaker Shunt Trip DO Status	0 = Open, 1 = Closed
	10015	BR	Gen Breaker Shunt Trip DO Status	0 = Open, 1 = Closed
	10016	BR	Audible Alarm Status DO Status	0 = Open, 1 = Closed
	10017	BR	Relay #12 Idle/Rated - KVA Switch DO Status	0 = Open, 1 = Closed
YES	10018	BR	Auto DI Status	0 = Open, 1 = Closed
YES	10019	BR	Test DI Status	0 = Open, 1 = Closed
YES	10020	BR	Run DI Status	0 = Open, 1 = Closed
	10021	BR	Voltage Raise DI Status	0 = Open, 1 = Closed
	10022	BR	Voltage Lower DI Status	0 = Open, 1 = Closed
	10023	BR	Speed Raise DI Status	0 = Open, 1 = Closed
	10024	BR	Speed Lower DI Status	0 = Open, 1 = Closed
YES	10025	BR	Gen Breaker Aux. DI Status	0 = Open, 1 = Closed
YES	10026	BR	Mains Breaker Aux. DI Status	0 = Open, 1 = Closed
YES	10027	BR	Process Control DI Status	0 = Open, 1 = Closed

Mapped?	Modbus Address	Type	Item	Semantics
	10028	BR	Remote Fault #1 DI Status	0 = Open, 1 = Closed
	10029	BR	Remote Fault #2 DI Status	0 = Open, 1 = Closed
	10030	BR	Remote Fault #3 DI Status	0 = Open, 1 = Closed
	10031	BR	Remote Fault #4 DI Status	0 = Open, 1 = Closed
	10032	BR	Remote Fault #5 DI Status	0 = Open, 1 = Closed
	10033	BR	Remote Fault #6 DI Status	0 = Open, 1 = Closed
	10034	BR	Sync Timeout Alarm Status	0 = No Alarm, 1 = Active Alarm
	10035	BR	Sync Reclose Alarm Status	0 = No Alarm, 1 = Active Alarm
	10036	BR	Crank Fail Alarm Status	0 = No Alarm, 1 = Active Alarm
	10037	BR	Voltage Range Alarm Status	0 = No Alarm, 1 = Active Alarm
	10038	BR	Over Speed Alarm Status	0 = No Alarm, 1 = Active Alarm
	10039	BR	Gen Phase Over Current Alarm Status	0 = No Alarm, 1 = Active Alarm
	10040	BR	Gen Reverse Power Alarm Status	0 = No Alarm, 1 = Active Alarm
	10041	BR	Gen Reverse VAR Alarm Status	0 = No Alarm, 1 = Active Alarm
	10042	BR	Speed/Freq Mismatch Alarm Status	0 = No Alarm, 1 = Active Alarm
	10043	BR	Coolant Temp. High Alarm Status	0 = No Alarm, 1 = Active Alarm
	10044	BR	Coolant Temp. Low Alarm Status	0 = No Alarm, 1 = Active Alarm

Mapped?	Modbus Address	Type	Item	Semantics
	10045	BR	Rated Oil Press High Alarm Status	0 = No Alarm, 1 = Active Alarm
	10046	BR	Rated Oil Press Low Alarm Status	0 = No Alarm, 1 = Active Alarm
	10047	BR	Battery Volt Low Alarm Status	0 = No Alarm, 1 = Active Alarm
	10048	BR	Battery Volt High Alarm Status	0 = No Alarm, 1 = Active Alarm
	10049	BR	Gen Under Volt Alarm Status	0 = No Alarm, 1 = Active Alarm
	10050	BR	Gen Over Volt Alarm Status	0 = No Alarm, 1 = Active Alarm
	10051	BR	Gen Over Freq Alarm Status	0 = No Alarm, 1 = Active Alarm
	10052	BR	Gen Under Freq Alarm Status	0 = No Alarm, 1 = Active Alarm
	10053	BR	Load High Limit Alarm Status	0 = No Alarm, 1 = Active Alarm
	10054	BR	Load Low Limit Alarm Status	0 = No Alarm, 1 = Active Alarm
	10055	BR	Process High Limit Alarm Status	0 = No Alarm, 1 = Active Alarm
	10056	BR	Process Low Limit Alarm Status	0 = No Alarm, 1 = Active Alarm
	10057	BR	Remote Fault1 Alarm Status	0 = No Alarm, 1 = Active Alarm
	10058	BR	Remote Fault2 Alarm Status	0 = No Alarm, 1 = Active Alarm
	10059	BR	Remote Fault3 Alarm Status	0 = No Alarm, 1 = Active Alarm
	10060	BR	Remote Fault4 Alarm Status	0 = No Alarm, 1 = Active Alarm
	10061	BR	Remote Fault5 Alarm Status	0 = No Alarm, 1 = Active Alarm

Mapped?	Modbus Address	Type	Item	Semantics
	10062	BR	Remote Fault6 Alarm Status	0 = No Alarm, 1 = Active Alarm
	10063	BR	Load Surge Alarm Status	0 = No Alarm, 1 = Active Alarm
	10064	BR	Mains Under Volt Alarm Status	0 = No Alarm, 1 = Active Alarm
	10065	BR	Mains Over Volt Alarm Status	0 = No Alarm, 1 = Active Alarm
	10066	BR	Mains Over Freq Alarm Status	0 = No Alarm, 1 = Active Alarm
	10067	BR	Mains Under Freq Alarm Status	0 = No Alarm, 1 = Active Alarm
N/A	10068	BR	Not Used	
YES	10069	BR	Generator Stable Indication	0 = Not Stable (wait for timeout), 1 = Stable
YES	10070	BR	Generator Sense Configuration	0 = Wye (L-N), 1 = Delta (L-L)
	10071	BR	PF Leading/Lagging Indicator	0 = Lag, 1 = Lead
	10073	BR	Coolant Temp High Pre-Alarm Status	0 = No Alarm, 1 = Active Alarm
	10075	BR	Low Oil Press Pre-Alarm Status	0 = No Alarm, 1 = Active Alarm

"Input" Objects (3xxxx) read via FC=4

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
YES	30001	AR	Battery Voltage	Vdc	0	500	10
YES	30002	AR	Engine Oil Pressure	Units per configuration bar or psi	0	1000	10

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
YES	30003	AR	Engine Coolant Temperature	Units per configuration deg C or deg F	-100	300	
YES	30004	AR	Engine Run Time	Hours	0	32767	
YES	30005	AR	Generator MW-Hours	Mega Watt hours	0	32767	
YES	30006	AR	Engine RPM	RPM	0	5000	
YES	30007	AR	Gen Phase A L-L Volts	Volts	0	32767	
YES	30008	AR	Gen Phase B L-L Volts	Volts	0	32767	
YES	30009	AR	Gen Phase C L-L Volts	Volts	0	32767	
YES	30010	AR	Gen Total KW	kW	-32768	32767	
YES	30011	AR	Gen Total KVA	kVA	-32768	32767	
YES	30012	AR	Generator Power Factor	Always a positive number (see BR 10071 for Leading or Lagging status)	0	100	100
YES	30013	AR	Gen Phase A kVAR	kVAR	-32768	32767	
YES	30014	AR	Gen Phase B kVAR	kVAR	-32768	32767	
YES	30015	AR	Gen Phase C kVAR	kVAR	-32768	32767	
YES	30016	AR	Gen Total kVAR	kVAR	-32768	32767	

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
YES	30017	AR	Bus Frequency	Hz	0	700	10
YES	30018	AR	Generator Frequency	Hz	0	700	10
	30019	AR	Network Address		1	8	
	30020	AR	Sync Timeout Action	See Analog Read Address information	1	3	
	30021	AR	Sync Reclose Action	See Analog Read Address information	1	3	
	30022	AR	Crank Fail Action	See Analog Read Address information	1	3	
	30023	AR	Voltage Range Action	See Analog Read Address information	0	3	
	30024	AR	Overspeed Action	See Analog Read Address information	0	5	
	30025	AR	Overcurrent Action	See Analog Read Address information	0	5	
	30026	AR	Gen Reverse Power Alarm Action	See Analog Read Address information	0	5	
	30027	AR	Gen Reverse VAR Alarm Action	See Analog Read Address information	0	5	
	30028	AR	Speed Freq Mismatch Action	See Analog Read Address information	0	5	
	30029	AR	Coolant Temp. High Alarm Action	See Analog Read Address information	0	5	
	30030	AR	Coolant Temp. Low Alarm Action	See Analog Read Address information	0	5	
	30031	AR	Oil Press High Alarm Action	See Analog Read Address information	0	5	
	30032	AR	Oil Press Low Alarm Action	See Analog Read Address information	0	5	

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
	30033	AR	Battery Volt Low Alarm Action	See Analog Read Address information	0	5	
	30034	AR	Battery Volt High Alarm Action	See Analog Read Address information	0	5	
	30035	AR	Gen Under Volt Alarm Action	See Analog Read Address information	0	5	
	30036	AR	Gen Over Volt Alarm Action	See Analog Read Address information	0	5	
	30037	AR	Gen Over Freq Alarm Action	See Analog Read Address information	0	5	
	30038	AR	Gen Under Freq Alarm Action	See Analog Read Address information	0	5	
	30039	AR	Load High Limit Action	See Analog Read Address information	0	5	
	30040	AR	Load Low Limit Action	See Analog Read Address information	0	5	
	30041	AR	Process High Limit Action	See Analog Read Address information	0	5	
	30042	AR	Process Low Limit Action	See Analog Read Address information	0	5	
	30043	AR	Remote Fault 1 Action	See Analog Read Address information	0	7	
	30044	AR	Remote Fault 2 Action	See Analog Read Address information	0	7	
	30045	AR	Remote Fault 3 Action	See Analog Read Address information	0	7	
	30046	AR	Remote Fault 4 Action	See Analog Read Address information	0	7	
	30047	AR	Remote Fault 5 Action	See Analog Read Address information	0	7	
	30048	AR	Remote Fault 6 Action	See Analog Read Address information	0	7	

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
	30049	AR	Load Surge Action	See Analog Read Address information	0	3	
	30050	AR	Mains Under Volt Alarm Action	See Analog Read Address information	0	3	
	30051	AR	Mains Over Volt Alarm Action	See Analog Read Address information	0	3	
	30052	AR	Mains Over Freq Alarm Action	See Analog Read Address information	0	3	
	30053	AR	Mains Under Freq Alarm Action	See Analog Read Address information	0	3	
N/A	30054	AR	Not Used				
YES	30055	AR	Generator Phase A-N Volts	Always Line-Neutral	0	32767	
YES	30056	AR	Generator Phase B-N Volts	Always Line-Neutral	0	32767	
YES	30057	AR	Generator Phase C-N Volts	Always Line-Neutral	0	32767	
YES	30058	AR	Mains Phase A-N Volts	Always Line-Neutral	0	32767	
YES	30059	AR	Gen Phase A current	Amps	-32768	32767	
YES	30060	AR	Gen Phase B current	Amps	-32768	32767	
YES	30061	AR	Gen Phase C current	Amps	-32768	32767	
YES	30062	AR	Gen Phase A KVA	KVA	-32768	32767	
YES	30063	AR	Gen Phase B KVA	KVA	-32768	32767	

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
YES	30064	AR	Gen Phase C KVA	KVA	-32768	32767	
	30065	AR	Voltage Bias Analog Output	% output: 0 = 0 bias 100 = 100% raise -100 = 100% lower	0	100	
	30066	AR	Speed Bias Analog Output	% output 0 = 0 bias 100 = 100% raise -100 = 100% lower	0	100	
YES	30067	AR	Load Control State	See Analog Read Address information	0	4	
YES	30068	AR	Synchronizer State	See Analog Read Address information	0	9	
	30069	AR	Number of Unacknowledged Alarms		0	99	
	30070	AR	Unit Network Priority		1	8	
	30071	AR	Address of Master Unit		1	8	
	30072	AR	Engine State	See Analog Read Address information	0	7	
	30073	AR	Synchroscope	See Analog Read Address information	-180	180	
	30215	AR	Actual Baseload Reference	See Analog Read Address information	0	30000	
	30216	AR	Actual Process Reference	See Analog Read Address information	-32767	32767	
	30229	AR	Actual PF Reference	–800 = 0.8 Lag 800 = 0.8 Lead 1000 = unity PF	-1000 to -500	500 to 1000	1000
	30230	AR	Actual VAR Reference	See Analog Read Address information	-20000	20000	

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
	30250	AR	Network Address	*	1	8	
YES	30253	AR	AC Frequency	0 = 50Hz 1 = 60Hz *	0	1	
YES	30254	AR	Rated RPM	RPM *	100	5000	
YES	30255	AR	Rated Power	*	1	30,000	
YES	30256	AR	Rated Volt-Amps	*	1	30,000	
YES	30257	AR	Rated Volt-Amps Reactive	*	1	30,000	
	30267	AR	Operating Mode	0 = No Parallel 1 = Mains Parallel *	0	1	
	30268	AR	Number of Units	0 = Single 1 = Multiple *	0	1	
	30269	AR	Preglow Time	seconds	0	1200	
	30270	AR	Crank Time	seconds	0	240	
	30271	AR	Crank Cutout	RPM	5	1000	
	30272	AR	Crank Delay	seconds	1	240	
	30273	AR	Crank Repeats		0	20	
	30276	AR	Idle Time	seconds	1	240	
	30277	AR	Cooldown Time	seconds	0	2400	
	30280	AR	Sync Mode	0 = Check 1 = Permissive 2 = Run	0	2	

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
	30291	AR	Sync Timeout	seconds	0	1200	
	30294	AR	Load Control Mode	0 = Normal, 1 = Soft Transfer, 2 = kW Droop *	0	2	
	30300	AR	Base Load Reference Setpoint	*	0	30,000	
	30303	AR	Load Time	seconds	1	7,200	
	30304	AR	Unload Time	seconds	1	7,200	
	30305	AR	Raise Load Rate	% / sec X 100	0.01	100.00	100
	30306	AR	Lower Load Rate	% / sec X 100	0.01	100.00	100
	30311	AR	KVA Switch Low		0	30,000	
	30312	AR	KVA Switch High		0	30,000	
	30315	AR	Voltage Ramp Time	seconds	0	1,000	
	30318	AR	KVAR Reference Setpoint	*	-20,000	20,000	
	30319	AR	PF Reference Setpoint	–800 = 0.8 Lag, 800 = 0.8 Lead,1000 = unity PF *	-1000 to –500	500 to 1000	1000
	30321	AR	Process Action	0 = Direct, 1 = Indirect *	0	1	
	30328	AR	Process Reference		-32,768	32767	
	30329	AR	Process Raise Rate	% / sec X 10	0.0	100.0	10

Mapped?	Modbus Address	Type	Item	Semantics	Min	Max	Scale
	30330	AR	Process Lower Rate	% / sec X 10	0.0	100.0	10
	30334	AR	Fast Transfer Delay	Seconds X 10	0.1	30.0	10
	30335	AR	Mains Stable Delay	seconds	1	30,000	
	30336	AR	Gen Stable Delay	seconds	1	30,000	
	30342	AR	LOM Action Delay	seconds X 10	0.1	30.0	10
	30344	AR	Min Gen Load	% of rated load	1	100	
	30345	AR	Next Genset Delay	seconds	1	1200	
	30346	AR	Rated Load Delay	seconds	1	1200	
	30347	AR	Max Start Time	seconds	1	1200	
	30348	AR	Max Gen Load	% of rated load	1	100	
	30349	AR	Reduced Load Delay	seconds	1	1200	
	30350	AR	Max Stop Time	seconds	1	1200	

"Holding Register" Objects (4xxxx) read via FC=3, written via FC=6+16)

Mapped?	Modbus Address	Type	Function	Semantics	Min	Max	Scale
	40001	AW	Priority Change Address		1	8	
YES	40002	AW	Process Control Actual Reference	See Analog Write Address information	-32767	32767	
YES	40003	AW	Base Load Actual Reference	See Analog Write Address information	0	30,000	
	40004	AW	Not Used				
YES	40005	AW	PF Actual Reference	–500 = 0.5 Lag 500 = 0.5 Lead 1000 = unity PF	-1000 to-500	500 to 1000	1000
	40006	AW	Not Used				
YES	40007	AW	Remote VAR Actual Reference	See Analog Write Address information	-20000	20,000	
	40250	AW	Network Address	*	1	8	
	40253	AW	AC Frequency	0 = 50Hz 1 = 60Hz *	0	1	
	40254	AW	Rated RPM	RPM *	100	5000	
	40255	AW	Rated Power	*	1	30,000	
	40256	AW	Rated Volt-Amps	*	1	30,000	
	40257	AW	Rated Volt-Amps Reactive	*	1	30,000	
	40267	AW	Operating Mode	0 = No Parallel 1 = Mains Parallel *	0	1	
	40268	AW	Number of Units	0 = Single 1 = Multiple *	0	1	

Mapped?	Modbus Address	Type	Function	Semantics	Min	Max	Scale
	40269	AW	Preglow Time	Seconds	0	1200	
	40270	AW	Crank Time	Seconds	0	240	
	40271	AW	Crank Cutout	RPM	5	1000	
	40272	AW	Crank Delay	Seconds	1	240	
	40273	AW	Crank Repeats		0	20	
	40276	AW	Idle Time	Seconds	1	240	
	40277	AW	Cooldown Time	Seconds	0	2400	
	40280	AW	Sync Mode	0 = Check 1 = Permissive 2 = Run	0	2	
	40291	AW	Sync Timeout	Seconds	0	1200	
	40294	AW	Load Control Mode	0 = Normal 1 = Soft Transfer 2 = kW Droop *	0	2	
	40300	AW	Base Load Reference Setpoint	*	0	30,000	
	40303	AW	Load Time	seconds	1	7,200	
	40304	AW	Unload Time	seconds	1	7,200	
	40305	AW	Raise Load Rate	% / sec X 100	0.01	100	100
	40306	AW	Lower Load Rate	% / sec X 100	0.01	100	100
	40311	AW	KVA Switch Low		0	30,000	

Mapped?	Modbus Address	Type	Function	Semantics	Min	Max	Scale
	40312	AW	KVA Switch High		0	30,000	
	40315	AW	Voltage Ramp Time	Seconds	0	1,000	
	40318	AW	KVAR Reference Setpoint	*	-20,000	20,000	
	40319	AW	PF Reference Setpoint	–800 = 0.8 Lag 800 = 0.8 Lead 1000 = unity PF *	-1000 to –500	500 to 1000	1000
	40321	AW	Process Action	0 = Direct 1 = Indirect *	0	1	
	40328	AW	Process Reference Setpoint	In configured units *	-32,768	32767	
	40329	AW	Process Raise Rate	% / sec X 10	0.0	100.0	10
	40330	AW	Process Lower Rate	% / sec X 10	0.0	100.0	10
	40334	AW	Fast Transfer Delay	Seconds X 10	0.1	30.0	10
	40335	AW	Mains Stable Delay	Seconds	1	30,000	
	40336	AW	Gen Stable Delay	Seconds	1	30,000	
	40342	AW	LOM Action Delay	Seconds X 10	0.1	30.0	10
	40344	AW	Min Gen Load	% of rated load	1	100	
	40345	AW	Next Genset Delay	Seconds	1	1200	
	40346	AW	Rated Load Delay	Seconds	1	1200	

Mapped?	Modbus Address	Type	Function	Semantics	Min	Max	Scale
	40347	AW	Max Start Time	Seconds	1	1200	
	40348	AW	Max Gen Load	% of rated load	1	100	
	40349	AW	Reduced Load Delay	Seconds	1	1200	
	40350	AW	Max Stop Time	Seconds	1	1200	

Annex C 61850 Objects Without Any Mapping

Logical Device	Logical Node	Func Constr	Data Object	DO Class	Attrib Lev1	Attrib Type	Description	M/O	Source Device	Notes
ECP0	DCRP		PlntOwn	DOO	Owner	VSTR255	Owner of plant	M	GW	is LN needed, no DCRP objects mapped!
ECP0	DCRP		PlntOwn	DOO	Owner		Operator of plant	M	GW	is LN needed, no DCRP objects mapped!
ECP0	DPST1	MX	PintDERConn	LIST	ListLength	INT16U	List Length	M	?	This identifes # Der plant connected to utility
ECP0	DPST1	MX	PintDERConn	LIST	Id0	INT32U	Unique #	M	GW	
ECP0	DPST1	MX	PintDERConn	LIST	q0	Quality	Quality (fixed?)	M	GW	
ECP0	DPST1	MX	PintDERConn	LIST	t0	Timestamp	Timestamp (upon change)	M	GW	
ECP1	DPST	MX	PintDERConn	LIST	ListLength	INT16U	List Length	M	?	This identified generators on local bus
ECP1	DPST	MX	PintDERConn	LIST	Id0	INT32U	Unique #	M	GW	
ECP1	DPST	MX	PintDERConn	LIST	q0	Quality	Quality (fixed?)	M	GW	
ECP1	DPST	MX	PintDERConn	LIST	t0	Timestamp	Timestamp (upon change)	M	GW	
ECP1	DPST	MX	PintDERConn	LIST	Id1	INT32U	Unique #	M	GW	
ECP1	DPST	MX	PintDERConn	LIST	q1	Quality	Quality (fixed?)	M	GW	
DERC	DRCT	ST	OpModOnConn	SPS			On and Connected	M		Cannot find
DERC	DRCT	ST	OpModOnAvail	SPS			On and available	M		Cannot find

Logical Device	Logical Node	Func Constr	Data Object	DO Class	Attrib Lev1	Attrib Type	Description	M/O	Source Device	Notes
DERC	DRCT	ST	OpModOnUnav	SPS			On but not unavailable	O		Cannot find
DERC	DRCT	ST	OpModOffAvail	SPS			Off but avail to start	O		Cannot find
DERC	DRCT	ST	OpModOffUnav	SPS			Off but not avail to start	M		Cannot find
DERC	DRCT	ST	OpModTest	SPS			Test mode	O		Cannot find
DERC	DRCT	ST	OpModStr	SPS			Starting up	O		Cannot find
DERC	DRCT	ST	OpModStop	SPS			Stopping/shutting down	O		Cannot find
DERC	DRCT	ST	OpModAvailCtl	SPC			Is DER resource available?	M		
DERC	DRAT1	??	DERId	MRID			Master resource ID of DER device	M		CDV does not spec FC nor proper CDV for this obj
DERG	DGEN1	??	GnAlm	ALM			Generator alarms	M		CDV ALM does not exist
DERG	DRAT1	??	DERId	MRID			Master resource ID of DER device	M		CDV does not spec FC nor proper CDV for this obj
DERG	DRAT1	MX	VRtg	MV	Mag.f	FLOAT32	Voltage level rating	M		Cannot find
DERG	DRAT1	MX	Artg	MV	Mag.f	FLOAT32	Current level rating	M		Cannot find
DRCP	DCIP1	ST	EngOnOFF	SPS	stVal	BOOLEAN	Engine running?	M		Cannot find
	DCIP1	CO	EngCtl	DPC	ctlVal	BOOLEAN	Start/Stop engine	M		Cannot find
	DCIP1	??	DERId	MRID			Identity of reciprocating engine	M		CDV does not spec FC nor proper CDV for this obj

Annex D IEC Comments on DER Draft Document

Comment Author	Clause/ Subclause	Paragraph Figure/ Table	Type of comment (General/ Technical/Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE EDITOR on each comment submitted
Muschlitz	5.2.1	DPST	E	ECP Logical device summary states LN DPST contains alarm objects but LN table in clause 5.2.6 has no alarms	Either change LN summary description or add alarms to LN DPST	
Muschlitz	5.2.2	DCRP LN	E	PlntOwn and PlntOpr are irrelevant for customer-owned peak shaving without utility control. These should be optional and not mandatory.	Change to optional	
Muschlitz	5.2.2	DCRP LN	E	It is unclear why PlntOblXXX are Boolean status values. This allows the possibility to be in two modes at the same time.	Replace all Boolean values that cannot be simultaneously true with PlntObl type INS (with enumeration values). Note that some PlntOblXXX values might not be included in this grouping.	
Muschlitz	5.2.4	DOPR LN	E	CktID needs ENUM list	Define values for CktID	
Muschlitz	5.2.5	DOPM LN	E	It is unclear why OpModXXX are Boolean status values. This allows the possibility to be in two modes at the same time.	Replace all Boolean values which cannot be simultaneously true with OpMod type INS (with enumeration values). Note that some OpModXXX values such as OModTest might not be in this grouping.	
Muschlitz	5.2.6	DPST LN	E	ECPConn and PlntDERConn is mandatory but is irrelevant in some situations (such as a generator farm where only aggregate output is important)	Change to optional	
Muschlitz	5.2.7	DCCT LN	E	CntctAncil should be series of Booleans rather than an enumerated value (it can have more than one capability at the same time)	Change to series of CntctAncil SPG values	

Comment Author	Clause/ Subclause	Paragraph Figure/ Table	Type of comment (General/ Technical/Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE EDITOR on each comment submitted
Muschlitz	5.3.2	DRCT LN	E	AutoMan definition does not specify if TRUE is automatic or manual. It is also unclear which portion of the controller is specified in automatic with this mode.	Rename to "AutoMod" so that it is obvious that TRUE means automatic. Clarify definition as to which portion automatic is referring to.	
Muschlitz	5.3.2	DRCT LN	E	It is unclear why OpModXXX are Boolean status values. This allows the possibility to be in two modes at the same time.	Replace all Boolean values which cannot be simultaneously true with OpMod type INS (with enumeration values). Note that some OpModXXX values such as OModTest are NOT included in this grouping (however, test is insufficiently defined to be useful).	
Muschlitz	5.3.2	DRCT LN	E	SeqSt is missing enumeration values	Add values	
Muschlitz	5.3.2	DRCT LN	E	SeqPos is missing enumeration values	Add values	
Muschlitz	5.3.2	DRCT LN	E	LodModXX should be enumeration since it be in only one state at a time	Change from series of SPS to a single INS and define the enumeration values	
Muschlitz	5.3.2	DRCT LN	E	The explanation SelfSrvWh as "Actual self service watt-hours" does not explain the term self-service.	Clarify term "self service." Is this the energy used to operate the DER controller, operate the DER generator, or operate the DER load (not served by the utility)?	
Muschlitz	5.3.2	DRCT LN	E	AutoManCtl definition does not specify if TRUE is automatic or manual (see AutoMan for similar issue)	Rename to "AutoModCtl" so that it is obvious that TRUE means automatic	
Muschlitz	5.3.2	DRCT LN	E	OpModXX should be enumeration since can be in only 1 state at a time	Change from series of SPC to an enumerated INC value (and specify the enumerations)	
Muschlitz	5.3.2	DRCT LN	E	Definition of DCPowStatCtl is unclear	Clarify	
Muschlitz	5.3.2	DRCT LN	E	Definition of DeRteTarg is unclear	Clarify	

Comment Author	Clause/ Subclause	Paragraph Figure/ Table	Type of comment (General/ Technical/Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE EDITOR on each comment submitted
Muschlitz	5.3.2	DRCT LN	E	ImExSet explanation is unclear. Is it watts or vars? How does it interact with OutWSet and OutVArSet?	Clarify	
Muschlitz	5.3.2	DRCT LN	T	DERId specifies a CDC of MRID. However, MRID is not a CDC but a common data attribute type. This type of definition has no specification for the FC type. The mistake is repeated in clauses 6.4.3 and maybe 5.2.2.	Create a CDC with a single attribute with a specified FC and a attribute type of MRID. Refer to this in clauses 5.3.2, 6.4.3 and 5.2.2.	
Muschlitz	5.3.2	DRCT LN	T	DERId is irrelevant in many cases, it should not be mandatory	Make optional	
Muschlitz	5.4.2	DGEN LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	5.4.2	DGEN LN	E	GnSync explanation is as a Boolean but the CDC is for enumeration	Change CDC of GnSync to SPS	
Muschlitz	5.4.2	DGEN LN	E	GnAlm CDC is 'ALM' but that CDCdoes not exist. Note that more than one alarm can be simultaneously active.	Either define a new CDC 'ALM' of change the CDC to INS	
Muschlitz	5.4.2	DGEN LN	E	Unclear if DroopV is true when enabled	Rename as DroopVEn	
Muschlitz	5.4.2	DGEN LN	E	RampLodSw does not specify M/O value	Assign as M or O	
Muschlitz	5.4.2	DGEN LN	E	TotWh and PerWh are counter types but are specified as CDC MV. MV types are not suitable for energy values (integers roil over at 2000 MWh and floats lose precision as values get larger).	Change type to BCR	
Muschlitz	5.4.2	DGEN LN	E	PerWh does not specify M/O value	Assign as M or O	

Comment Author	Clause/ Subclause	Paragraph Figure/ Table	Type of comment (General/ Technical/Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE EDITOR on each comment submitted
Muschlitz	5.4.2	DGEN LN	E	GnOpTmms definition is unclear	Define as "time from beginning of cranking until engine speed exceeds cranking limit" (if this is correct definition). Consider renaming to GnCrankTmms because Op is too vague.	
Muschlitz	5.4.2	DGEN LN	E	There is no correct type for GnRL. It needs to be similar to BSC but with a float value for a present value and step size. This same type is needed for Hydro use to control the PID setpoints.	Define new CDC similarly to BSC but with FLOAT32 replacing all INT quantities	
Muschlitz	5.4.3	DRAT LN	E	None of the mandatory attributes are universally used. All attributes should be optional.	Change all to optional	
Muschlitz	5.4.3	DRAT LN	E	Attribute DERId has CDC of MRID. MRID is not a CDC but is a common data attribute (it has no FC).	Change CDC to INS	
Muschlitz	5.4.3	DRAT LN	E	Attribute DERTyp is CDC INS but there is no enumeration for this	Add text indicating enumeration values	
Muschlitz	5.4.3	DRAT LN	E	Attribute ConnType is CDCINS but there is no enumeration for this	Add text indicating enumeration values	
Muschlitz	5.4.3	DRAT LN	E	Attribute WRtg is listed twice with slightly different explanations	Remove one of WRtg	
Muschlitz	5.4.3	DRAT LN	E	VAVArRtg seems to be misnamed	Rename as VArRtg	
Muschlitz	5.4.3	DRAT LN	E	MaxLodRampRtg, and MaxUnlodRampRtg, and EmgRampRtg should be in same units as watts	Change from CDC INS to CDC MV	

Comment Author	Clause/ Subclause	Paragraph Figure/ Table	Type of comment (General/ Technical/Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE EDITOR on each comment submitted
Muschlitz	5.4.3	DRAT LN	E	It is unclear how WRtg differs from MaxWOut	Clarify	
Muschlitz	5.4.3	DRAT LN	E	RotDir is irrelevant. If it is needed it belongs in a non-DER LN.	Remove	
Muschlitz	5.4.3	DRAT LN	E	PowStab explanation is as a Boolean but the CDC is for enumeration	Change CDC of PowStab to SPS	
Muschlitz	5.4.3	DRAT LN	E	TGD is of CDC THD. That CDC is not defined.	Define CDC THD	
Muschlitz	5.4.4	DRAZ LN	E	TGD is of CDC THD. That CDC is not defined.	Define CDC THD	
Muschlitz	5.4.5	DCST LN	E	CostRamp is not clearly defined, it would seem to be always zero	Clarify	
Muschlitz	5.5.2	DREX LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	5.5.2	DREX LN	E	ExtForc is described as Boolean but classed as integer	Change from CDC ING to INS	
Muschlitz	5.6.2	YRCT LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	5.6.2	YRCT LN	E	CmutTyp has only 2 values but is CDC ING	Rename as CmutTypSelf and change to CDC SPC	
Muschlitz	5.6.3	YINV LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	6.1.3	DCIP LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	

Comment Author	Clause/ Subclause	Paragraph Figure/ Table	Type of comment (General/ Technical/Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE EDITOR on each comment submitted
Muschlitz	6.1.3	DCIP LN	E	EngOnOff is (I think) the status of the fuel solenoid. If so, it should be renamed. It needs renaming in any case to remove ambiguity as to ON=TRUE or FALSE	Rename EngFuelOn.	
Muschlitz	6.1.3	DCIP LN	E	EngRPM is CDC ANV but ANV does not exist	Change to CDC MV	
Muschlitz	6.1.3	DFCL LN	E	CrankCtl should be removed as a dangerous control. If the connection is lost, the engine will crank forever with obvious damage. Only a start sequencer is practical for an engine and this is handled with EngCtl.	Remove CrankCtl	
Muschlitz	6.2.3	DFCL LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	6.3.3	DPVE LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	6.3.4	DPVC LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	6.3.5	DTRC LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	7.1.2	MITV LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	7.2.2	FUEL LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	7.2.3	FULP LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	

Comment Author	**Clause/ Subclause**	**Paragraph Figure/ Table**	**Type of comment** (General/ Technical/Editorial)	**COMMENTS**	**Proposed change**	**OBSERVATIONS OF THE EDITOR** on each comment submitted
Muschlitz	7.3.2	BATT LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	7.3.3	BATC LN	E	It is unclear why EEHealth and EEName are mandatory for this LN	Clarify	
Muschlitz	7.4.5	MFLW LN	E	FlwHorDir and FlwVerDir explanations are unclear (are these the horizontal and vertical components of FlwSpd?)	Clarify	
Muschlitz	8.2.1	Table 8-2	E	The FC column is missing from the definition of ARY	Add column with all entries FC=MX	
Muschlitz	8.2.2	Table 8-3	T	It is unclear whether the zero-eth array element exists. In any case, elements 0 through N inclusive contains N+1 elements, not N.	Change "Id[0-n]" to Id[1-n]. Change "q" and "t" attributes similarly.	
Muschlitz	8.2.4	Table 8-5	E	Rows with attribute type ARY specify FC=MX. But ARY is not a "low-level" CDC and therefore the FC specification should not be present (compare to definition of 'WYE" in part 7-3).	Remove the FC entry for attributes IntvDmd and CumDmd and ContCumDmd and Pks	

Annex E Revision History

Rev 02 – BAM 11-July-2006

Add LPHD1 to mapping example

Add Mod, Beh, Health, Namplt to ECP0 mapping in all logical devices

Rev 03 – BAM 28-August-2006

Revise footer

Add changes requested after meeting at Sandia

Insert Annex D with IEC comments

Rev 04 – BAM 8-December-2006

Revise mapping to add read values for all setpoints (DERC/DRTC1.OutWSet, DERC/DRTC1.OutWSet, DERC/DRTC1.OutPFSet, DERC/GGIO1.ASGSO1)

Add sections: Sandia Deliverables and Future Work items

Rewrite conclusions, add results of IEC TC57/WG17 meeting in Arnhem

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