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Implementation of Parallel Synchronization Method of Generators for Power & Cost Saving in University of Gujrat

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Abstract

In the current economic and political scenario of Pakistan where new projects of Electrical generation seems impossible, one should adopt such means so as to minimize the power consumption via load management. In this paper a relatively better Electrical power system is proposed for University of Gujrat (UOG) power system. UOG runs its all generators whether it is full load or merely a load of 20 percent as a standby power. It is suggested that if generators system is synchronized and connected in parallel, it can not only minimize the cost, number of personnel required but also increase the reliability of the system. ETAP software is used for simulation and results show that by adopting this method generation cost can be reduced up to 30 percent which is indeed a huge figure. Losses and cable parameters were calculated using this software and found this proposal quite feasible.

Keywords

Synchronization, Load Management, Reliability, Cable, Transformer

1. Introduction

Today Pakistan is facing disastrous power crises. The demand is much higher than supply so energy supplied to consumers is not continuous and load shedding of 12 - 16 hours badly affects the consumers. The University of Gujrat (UOG) is also affected by this load shedding, to carry on educational activities without any interruption; University of Gujrat has its own standby power system. In UOG for every one or two blocks there is a separate generator. These generators run on almost 30% or less load in 10 months of the year and run on almost 50% load in remaining two months *i.e.* May and June. In case if any of the generators becomes out of order, the relevant

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block faces total black out. So to provide continuous supply to all of the blocks, it is better to operate generators in parallel (synchronized generators operation). In this way if any of the generators goes out of order, the blocks will still avail electricity supply from parallel connected generators. This is the main idea of this research work.

UOG is facing financial losses in aspect of standby power system. These losses comprise of fuel cost, higher maintenance cost and lubrication oil cost. Therefore by implementing this method, these losses can be reduced to a great extent. Furthermore UOG can also avail many advantages of this configuration like a lot of savings in terms of diesel cost. For example in synchronized operation of generators, there may be a need to run only two generators instead of three or four, hence fuel and maintenance cost is reduced.

Heavy load of blocks for example machinery, medical lab equipment, and other such sort of massive loads can be operated easily by parallel synchronization method because all the generators are synchronized and bulk load can be managed. But in existing system to operate such load, a separate generator has to install as it is done in Medical Block in recent months. Synchronized generators method also has the ability to meet future expansion of the load. For example, if all the blocks have to build a new computer lab in future then to meet this demand, there is a need to install a single generator in parallel. But if generators are not synchronized, we have to install a generator for all of the blocks instead of one. In parallel operation of generators efficiency of the system will be improved. Less number of personnel is required [1].

2. Power System of UOG

2.1. Transformers

The power entering into the UOG power system is distributed using distribution transformers of different KVA ratings. These transformers step down the voltage from 11 kV to 400 volts line to line. There are a total of about 36 transformers of total 4700 kVA. Their number and kVA ratings, the location of each transformer with the load it is serving, the current output of each transformer and the voltage at each of them given in **Table 1**.

Table 1. Transformers location and rating.

Sr #	Location	KVA rating
1	E Block	200
2	M Block	200
3	A Block	200
4	B Block	200
5	S Block	200
6	P Block	200
7	BS Block	200
8	Guest House	200
9	Admin Block	200
10	Durbar	100
11	Water Turbine	200
12	Girls Hostel 1	200
12	Girls Hostel 2	200
14	Mosque	200
15	Lane 1 Residences	200
16	Lane 2 Residences	200
17	Lane 3 Residences	200
18	Main Gate	200
19	Boys Hostel 1	200
20	Boys Hostel 2	200
21	SSIC	200
22	IR	200
23	IHRM	200
24	SSC	200
	TOTAL	**4700**

2.2. Generators

The power input source of UOG is behind the main gate of the university, which is provided by WAPDA. It also has thirteen mobile diesel operated generator sets of different capacity. All these generator sets are made by SMJ company. The generation voltage of these generators sets is 380 V, which is directly fed to the different department of UOG. Location and kVA rating of these generators is shown in Table 2.

3. What Is Synchronization

In today's world of technology, a separate generator is found very rare supplying the load independently. Very often on small places where the emergency power is required for a short while the synchronous generator is used independently. As in any Electrical system, the loads are not constant load is varying with time, Electrical systems are interconnection of large number of alternators operating in parallel and supplying large number of loads. During the process of synchronization of generators the magnitude of voltage, frequency and phase angle is kept constant this process of paralleling of one alternator to another or to the bus bar is called the synchronization. Figure 1 shows the block diagram of the synchronized system, where three generators are connected to the same load and any time these can be used together to address the load demand [2].

3.1. Need of Synchronization

In any power system it is preferred that instead of supplying power with one big unit, use one or more units at

Table 2. Generators location and rating.

Sr #	Location	KVA rating
1	E + M Block	200
2	A + B Block	200
3	S Block	150
4	P + BS Block	200
5	Guest House	20
6	Admin Block	100
7	Water Turbine	100
8	Girls Hostel 1 + Female Faculty	50
9	Girls Hostel 2 + Mosque	30
10	VC House	20
11	Residence	100
11	Movable (1)	110
12	Movable (2)	20
13	Boys Hostel	50
14	SSIC	100
15	IHRM & SSC	50
	TOTAL	1500

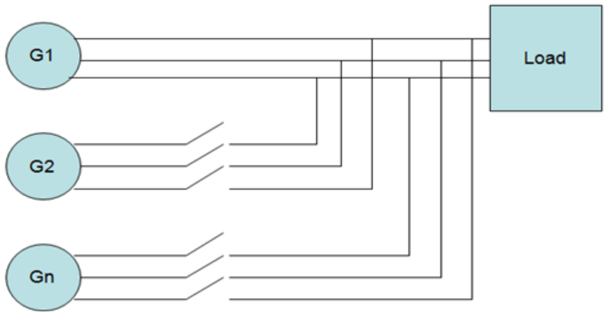

Figure 1. Synchronization.

different load conditions, there are number of benefits that are given below when we run alternators in parallel.

1) As we know the efficiency of any machine is maximum at its full load and we can run any machine when it is required and doing this efficiency can be increased.

2) Using several generators can supply a bigger load.

3) Reliability of the system is increased since if one generator is failed than the other is used for the operation and whole system will not be shut down.

4) Having many generators that are working in parallel we can remove one or more generator for the maintenance purpose.

5) If load demand increases than more generators can be connected.

6) Instead of placing generators at different locations it is better to place all of them at one place it will ease the maintenance.

7) Standby losses and per unit price is reduced because our generation is according to our demand [3].

3.2. Conditions for Synchronization

The conditions for the generators to be paralleled are given below:

1) The RMS value new coming generator voltage should be equal to the bus bar voltage.

2) The phase sequence of new coming generator should be same to that of bus bar. The phase angle must be the same.

3) The frequency of new generator called the incoming frequency of the generator should be slightly higher than that of running frequency of the bus bar.

The first condition can be found by using the volt meter and the second and 3rd can be found by using lamp method or Synchroscope [4].

3.3. Techniques for Synchronization

Different techniques are being used for the synchronization of the alternators, the purpose is to check the all four conditions listed above and then different schemes are used to connect the generators to the system. These methods are given below:

1) The bright lamp method.

2) The dark lamp method.

3) The Synchroscope method.

These methods are not preferred today due to less accuracy and manual operation; these methods required a very experienced person and also reliability and security of these methods is not enough. So, Synchroscope method is used now a day and microprocessor based systems are used for the automatic synchronization of the alternators, these methods are reliable and easier to manage [5].

3.4. Synchronization Using Synchroscope

As it is already being explained that for synchronization the lamp method is not applicable because it depends on operator decision and experience. And although the three lamp method is cheap but it cannot tell us that either the frequency of incoming generator is higher or lower, in order to parallel alternators in right way a device named Synchroscope is used. In larger systems lamp method is not applicable so Synchroscope method is used. It consists of three coils and one moving vane. A pointer is connected to moving vane. The coils are connected to the bus bar and the alternator which is to be synchronized. The potential transformer is used to measure the voltage difference, the pointer move in clockwise and antic clockwise manner and when speed of incoming machine is same to that of bus bar then pointer will stop at vertical point and relays are closed that connect the alternator to the bus bar as shown below in **Figure 2**. Assume the voltage difference, the pointer move in clockwise or anti clockwise manner and when speed of incoming machine is same to that of bus.

If the phase angle between the two voltages is different than the pointer of Synchroscope will move, it will move to slower point when the incoming machine is slower and move towards the faster point if then incoming machine is faster and pointer will stop when the incoming generator frequency is same to that of bus bar if this situation is attained then the switch is closed [5].

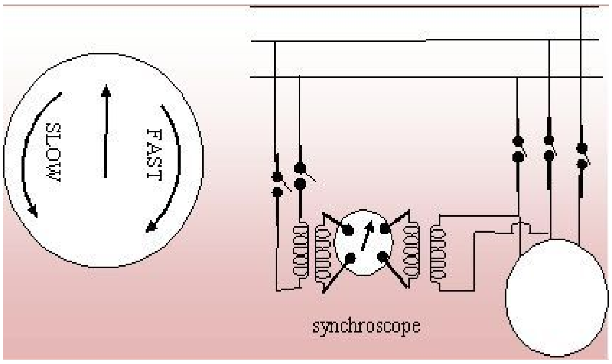

Figure 2. Schematic diagram of Synchroscope.

4. Existing System of UOG and Its Drawbacks

4.1. Power Requirement of UOG

Annual power required for UOG is increasing day by day; energy requirement for UOG from year 2009 to 2013 and expected increase in energy demand after 2013 is given in **Table 3**.

4.2. Prime Power

As the energy crisis in Pakistan is almost at its peak, approximately there is 12 - 16 hours of load shedding per day. So that's why the prime power supplied by the electric company is almost 30% - 40%. Due to this severe problem, UOG requires a lot of stand by energy to fulfill out electricity requirements. In the compensation of this problem UOG is using generators to accomplish their stand by power. The per unit cost of electricity is given below:

Present cost of WAPDA/Kwhr (Unit) = 13 Rs./Kwhr [6].

4.3. Standby Power

In order to fulfill the standby power requirements, UOG is using number of generators at different locations. Per unit cost of stand by generators are: Cost of unit produced by diesel generator/Kwh (Unit) = 33 Rs./Kwhr. The total generation capacity of these generators is 1500 KVA.

5. Drawbacks of Existing System

5.1. No Reliability

For every system reliability is one the most important factor. It means supply of energy should be consistently available at any time. The current system is not reliable as it should be. For example academic blocks are fed by separate generators and in case of maintenance issue or if any generator is out of order for a time, the respected block is black out, and the minimum maintenance time for a generator is at least one day, it means the respected block should remain without electricity for a long time.

One another example is of the generator which is installed for water pump is of 100 kVA, if this generator is out of order the water supply for the entire university is disturbed, on the same time all the generators are running properly and generating extra electricity which is not entertained. According to current system there are blocks which are fed by a generator of high kVA rating which is large enough to entertain two blocks at once. In case one generator for a block is out of order and at the same time the generator of adjacent block generates enough electricity which could entertain both the blocks, but the current system does not allow doing so.

5.2. Higher Cost

For any engineering system lower cost and maximum output is always preferred, so first and foremost priority for an engineer is to reduce the cost of the system. As in existing case numbers of circumstances are available when load requirement is less to an extent that one or two generators are enough to meet the demand of aca-

Table 3. Power requirement of UOG.

Year	Power requirement
2008	300 KVA
2009	600 KVA
2010	800 KVA
2011	1000 KVA
2012	1150 KVA
2013	1200 - 1250 KVA
2014	1300 - 1400 KVA (Expected)

demic blocks. For example in winter season and after 4 PM. the total demand of the academic blocks is reduced to 25% of the peak demand, it could be fed by one generator and separate generator for each block is not required. But use of all generators as in the case of existing system to provide the electricity increases the cost in terms of diesel and maintenance requirement.

5.3. Less Efficiency

Efficiency is one of the most important factor of the system. Smaller input and greater output is the first preference. A more efficient system provides more stability and reduces cost and losses. In UOG all of the generators are running at 25% - 50% of the maximum load. The optimal operational point for synchronous generator is 75% - 80% load of its rated value. At this optimal point the synchronous generator will be at its maximum efficiency. At evening the generators are operated at 25% of the load in order to reduce diesel cost, its mean generators are operating at lower efficiency that is not good for the life of the generator. Using one generator running at 80% of the load will increase the efficiency of the system and reduces the fuel and maintenance cost as well [7] [8].

5.4. No Future Extension

An Electrical system is designed in such a manner to provide electricity for the loads introducing in future. This increases the reliability of that system. If a system is designed according to the prescribed condition it will be long lasting. It is noticed that electricity demand is increasing annually in UOG so in case of future expansion same generators will not be able to feed the system. For this compensation there is requirement to install new generators or replace the existing one by a higher kVA value, but both of the things are difficult to evaluate.

5.5. Annual Diesel Cost of Existing Generators

Annual costs of diesel generators have been calculated. Calculations were shown in **Table 4**.

Total diesel cost per year is Rs. 3,780,100/—excluding lubrication cost.

6. Fuel Cost Comparison for Existing & Proposed System

In this section calculations were done for the fuel cost of various months and the savings obtained by connecting the generators in parallel combination (Synchronization). For these calculations an average of 5 - 6 hour load shading is taken into account. Fuel cost and savings in the month of March is given below in **Tables 5-7**.

Fuel Cost Comparison in Month of March

Avg load at Generator 1 per day = 42.66 kVA.

Avg load at Generator 2 per day = 41.86 kVA.

Avg load at Generator 3 per day = 26.91 kVA.

Avg load at Generator 4 per day = 40.70 kVA.

So savings in the month of March is = Rs. 441,575.

Similarly calculations were done for the months of April, May, June and July. Saving for these months are rupees respectively.

Table 4. Diesel cost of existing generators.

Location	Capacity	Fuel consumption Ltr/hr	Average running hours/month	Diesel drawn/month	Cost Rs./month
E + M Block	200	26	80 - 90	2210	221,000
A + B Block	200	26	80 - 90	2210	221,000
S Block	150	19	80 - 90	1615	161,500
P + BS Block	200	26	80 - 90	2210	221,000
Admin Block	100	15	150 - 160	2325	232,500
SSIC	100	15	80 - 90	1275	127,500
Water Turbine	100	15	70 - 75	1050	105,000
Mosque Girls Hostel	30	05	150 - 260	900	90,000
VC House	20	04	190 - 200	760	76,000
Boys Hostel	50	12	150 - 160	1800	180,000
Girls + Faculty Hostel	50	12	150 - 160	1800	180,000
Residences	100	15	140 - 150	2250	225,000
Guest House	20	04	130 - 140	520	52,000
Moveable 1	110	16	50 - 60	880	88,000
Moveable 2	20	04	50 - 60	200	20,000
IHRM & SSC	50	12	40 - 50	540	54,000
TOTAL	1400				3,708,100

Table 5. Generators operating at 25% load.

Generator	Avg load/day (KVA)	Fuel drew (Ltr/hr)	Running hours in a month	Fuel consumed (Ltr)	Cost per month (Rs.)
G1	42.66	12.5	85	1079.5	107,900
G2	41.86	12.5	85	1079.5	107,900
G3	26.91	09	85	765.5	76,500
G4	40.70	12.5	85	1079.5	107,900
Total	152.3	45.5	340	4003.5	400,200

Table 6. Generators operating at 50% load.

Generator	Avg load/day (KVA)	Fuel drew (Ltr/hr)	Running hours in a month	Fuel consumed (Ltr)	Cost per month (Rs.)
G1	42.66	25	85	2125	212,500
G2	41.86	25	85	2125	212,500
G3	26.91	17	85	1445	122,825
G4	40.70	25	85	2125	212,500
Total	152.3	92	340	7820	760,325

Table 7. Generators operating at 80% load.

Generator	Avg load/day (KVA)	Fuel drew (Ltr/hr)	Running hours In a month	Fuel consumed (Ltr)	Cost per month (Rs.)
200 KVA	152. 3	37.5	85	3187.5	318750

7. Real Time Reading of Generators

Generators Reading in Different Months

Several real time readings were taken from the Generators in different months at different times using clamp meter and load of each generator is calculated. The readings of all four generators at different times are given in **Tables 8-11** at different times and days.

Table 8. Generators reading in March.

Date: 15-03-2013 Time: 04:50 PM							
	E Block	M Block	A Block	B Block	S Block	P Block	BS Block
R (Phase)	19	10	14	04	20	09	20
Y (Phase)	08	06	16	06	11	10	08
B (Phase)	32	22	17	16	19	08	14
S (KVA)	13.62	8.77	10.85	6.00	11.54	6.23	9.69
ST (KVA)				66.74			

Table 9. Generators reading in April.

Date: 10-04-2013 Time: 2:00 PM							
	E Block	M Block	A Block	B Block	S Block	P Block	BS Block
R (Phase)	59.7	23	46	22.8	22	41	82
Y (Phase)	25	25	55	36.3	19	26	40
B (Phase)	71	22	42	43.8	56	28	58
S (KVA)	35.95	16.19	33.02	23.76	22.40	21.93	41.56
ST (KVA)				194.82			

Table 10. Generators reading in May.

Date: 17-05-2013 Time: 11:00 AM							
	E Block	M Block	A Block	B Block	S Block	P Block	BS Block
R (Phase)	60	91	82	60	61	108	53
Y (Phase)	73	56	80	90	42	90	51
B (Phase)	54	79	86.3	71.7	95	96	85
S (KVA)	43.18	52.19	57.34	51.19	45.72	67.89	43.64
ST (KVA)				361.19			

Table 11. Generators reading in June.

Date: 13-06-2013 Time: 02:00 PM							
	E Block	M Block	A Block	B Block	S Block	P Block	BS Block
R (Phase)	51	76	41	53	93	95	85
Y (Phase)	49	51	43	104	89	75	65
B (Phase)	78	69	42	95	129	98	62
S (KVA)	41.10	45.26	29.09	58.19	71.82	61.89	48.95
ST (KVA)				356.33			

8. E-Tap Simulations

Using previous mentioned readings of loads two E-Tap models one for synchronized system and for un-synchronized system were made for the power system of UOG. In these models real time values of load were used. The ETAP Load Flow Analysis module calculates the bus voltages, branch power factors, currents, and power flows, throughout the Electrical system. Newton Raphson method is adopted to find the optimum results and five iterations were required for this method. Following are the equations used in Newton Raphson calculations.

$$V_\rho = |V_\rho| < \delta_\rho = e_\rho + jf_\rho \tag{1}$$

e_ρ and jf_ρ are real and imaginary parts of voltage in Equation (1).

$$P_i = U_1(e, f) \tag{2}$$

$$Q_i = U_2(e, f) \tag{3}$$

δ is the phase angle and P_i and Q_i denotes the real and active power in Equations (1), (2) and (3) respectively.

$$\Delta P_i = \sum_{p=2}^{n} \frac{\partial P_i}{\partial e_p} \Delta e_p + \sum_{p=2}^{n} \frac{\partial P_i}{\partial f_p} \Delta f_p \tag{4}$$

$$\Delta Q_i = \sum_{p=2}^{n} \frac{\partial Q_i}{\partial e_p} \Delta e_p + \sum_{p=2}^{n} \frac{\partial Q_i}{\partial f_p} \Delta f_p \tag{5}$$

Active and reactive power mismatch can be calculated from Equations (4) and (5) respectively.

$$\left[\frac{\Delta P}{\Delta Q}\right] = \left[\frac{J_1 | J_2}{J_3 | J_4}\right] \cdot \left[\frac{\Delta e}{\Delta f}\right] \tag{6}$$

$$|V_i|^2 = e_i^2 + f_i^2 \tag{7}$$

Voltage is the sum of square of real and imaginary parts of voltage and can be calculated using Equation (7).

$$\Delta |V_i|^2 = \frac{\partial |V_i|^2}{\partial e_i} \Delta e_i + \frac{\partial |V_i|^2}{\partial f_i} \Delta f_i \tag{8}$$

Voltage mismatch can be calculated using Equation (8).

8.1. Un-Synchronized System Simulation

In un-synchronized system all the generators are working separately at different locations in UOG. There are four generators for seven academic blocks. First generator feds Engineering and Medical Block, second generator feds Academic and Business Blocks, third generator feds Science Block, while the fourth generator feds P and BS Blocks. Real time readings of load in E-Tap were used to take the load flow calculation. E-Tap model for un-synchronized system and load flow report shown in **Figure 3** and **Figure 4** respectively.

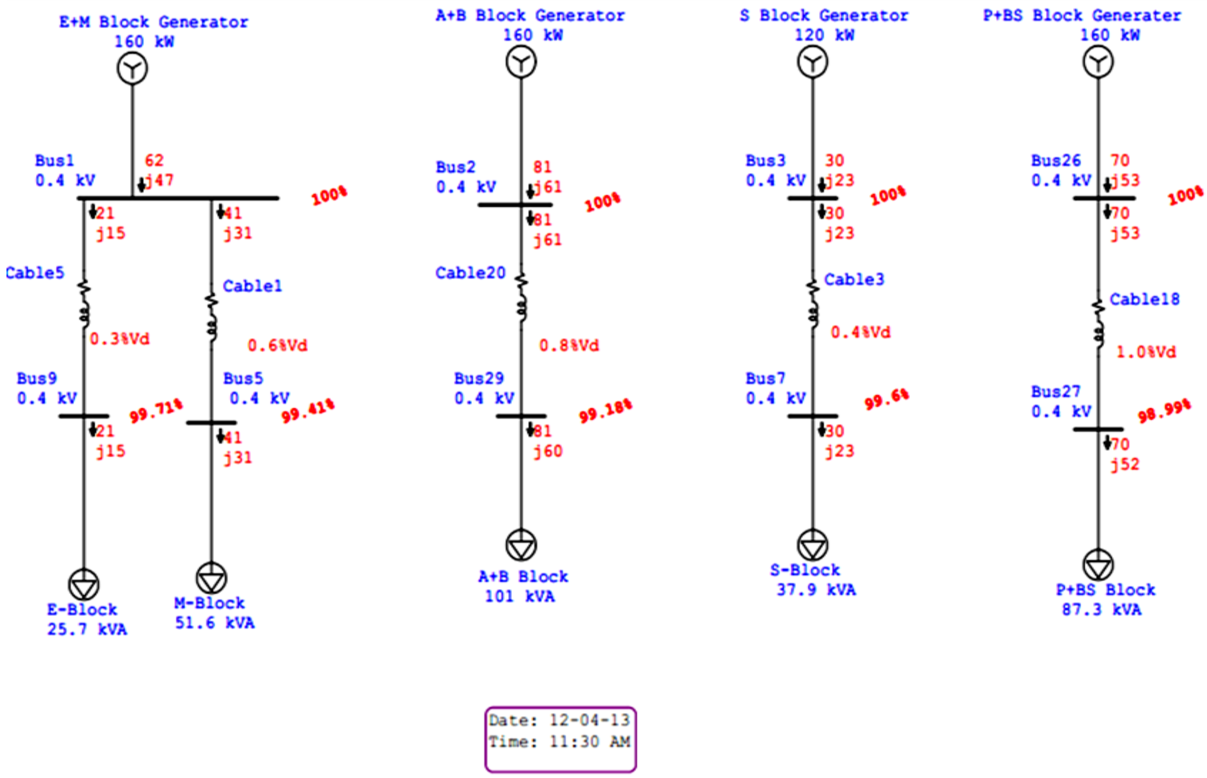

Figure 3. Un synchronized generator operation.

Project:		ETAP	Page:	1
Location:		6.0.0	Date:	05-29-2013
Contract:			SN:	12345678
Engineer:		StudyCase: LF	Revision:	Base
Filename:	project		Config.:	Normal

Existing System (Unsynchronized) Date: 12-04-13 Time: 11:30 AM

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
*Bus1	0.400	100.000	0.0	0.062	0.047	0	0	Bus5	0.041	0.031	74.7	80.0	
								Bus9	0.021	0.015	37.2	80.0	
*Bus2	0.400	100.000	0.0	0.081	0.061	0	0	Bus29	0.081	0.061	146.5	80.0	
*Bus3	0.400	100.000	0.0	0.030	0.023	0	0	Bus7	0.030	0.023	54.8	80.0	
Bus5	0.400	99.410	0.0	0	0	0.041	0.031	Bus1	-0.041	-0.031	74.7	80.0	
Bus7	0.400	99.601	0.0	0	0	0.030	0.023	Bus3	-0.030	-0.023	54.8	80.0	
Bus9	0.400	99.707	0.0	0	0	0.021	0.015	Bus1	-0.021	-0.015	37.2	80.0	
*Bus26	0.400	100.000	0.0	0.070	0.053	0	0	Bus27	0.070	0.053	126.8	80.0	
Bus27	0.400	98.990	0.0	0	0	0.070	0.052	Bus26	-0.070	-0.052	126.8	80.0	
Bus29	0.400	99.184	0.0	0	0	0.081	0.060	Bus2	-0.081	-0.060	146.5	80.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# Indicates a bus with a load mismatch of more than 0.1 MVA

Figure 4. Load flow report.

8.2. Synchronized System Simulation

In synchronized system which is the proposed solution, all the generators are connected in parallel and then load flow calculations are performed on this system. In this system all the generators give supply to a main bus bar, and then different cables execute from this bus bar and reach the academic blocks. The E-Tap models include two different schemes, *i.e.* once using aluminum conductor and once using copper conductor. E-Tap model & load flow report for aluminum and copper conductor have been shown in **Figures 5-8**.

9. Synchronized Generator Operation

For this solution all the generators for the academic blocks have to be placed on one place then they will be synchronized through a synchronization panel. In this manner all the generators will supply power on a bus bar. Academic blocks will get supply from this common bus bar through cables of different gauge depending upon the respective load. Generators will get start according to the load demand, for example if load of all the blocks is 300 KVA, then only two generators of 200 KVA and 150 KVA will run to meet this demand. In this manner only two generators are required for the total demand instead of four generators as present. In winter season for reduced load only one generator is enough to meet the load demand. This solution will result in minimum cost.

The diagrammatic representation of our proposed solution is given in **Figure 9**. In this figure the cables which are shown in bold are pre-installed, while the cables shown in light lines are to be installed. The length and gauge of all the cables have been shown. Cable of gauge 400 mm^2 which is to be installed has a length of 200 meters, while the cable of gauge 240 mm^2 has a length of 135 meters.

9.1. Existing Equipments

1) Four Generators (200 kVA * 3 + 150 kVA * 1) = 750 KVA.
2) ATS switches.
3) Bus bars.

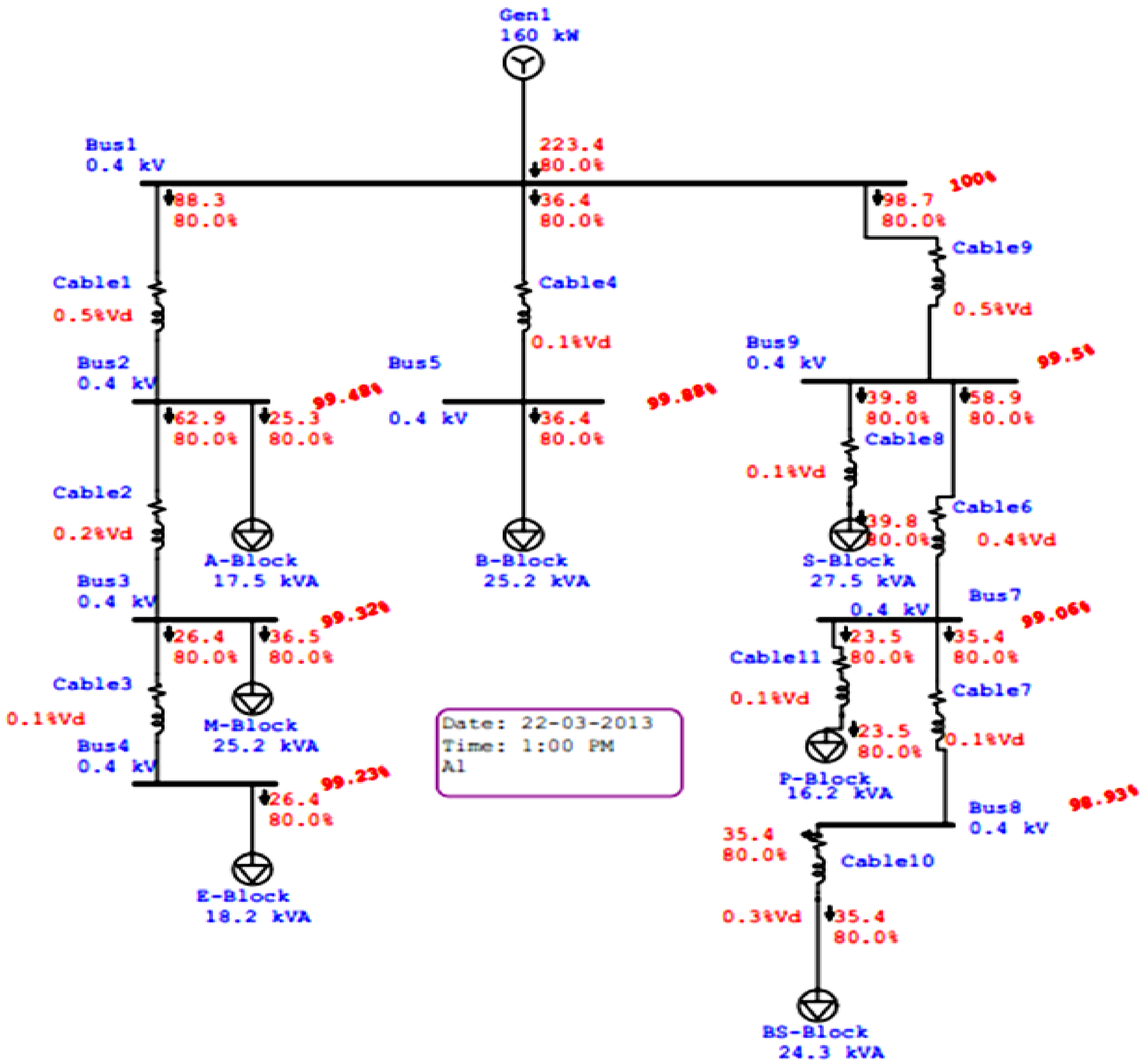

Figure 5. E-TAP model with aluminum conductor.

9.2. Equipment Required for Proposed Solution

1) Synchronization panel.
2) Cables of gauge 240 mm^2 and 400 mm^2 to be installed.
3) ATS switches.
4) Generators to be synchronized.
5) Main bus bar.
6) Circuit breakers.

9.3. Synchronization Panel

Synchronization panel is automatic Electrical device which synchronizes various generators. It is better to use a synchronization panel which must have properties like automatic and manual synchronization, load sharing at generators according to the power; it should automatically start and stop generators according to the load, automatically balance work hours (co-aging) etc. For this proposed solution refer synchronization panel is TEKSAN. Generators made by company which produces generators and synchronization panels. Model: TJPS10 Synchro-

Synchronized system with all new Cables of Aluminum Date: 22-03-2013 Time: 1:00 PM

LOAD FLOW REPORT

Bus	Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
*Bus1	0.400	100.000	0.0	0.124	0.093	0	0	Bus2	0.049	0.037	88.3	80.0	
								Bus5	0.020	0.015	36.4	80.0	
								Bus9	0.055	0.041	98.7	80.0	
Bus2	0.400	99.477	0.0	0	0	0.014	0.010	Bus1	-0.049	-0.036	88.3	80.0	
								Bus3	0.035	0.026	62.9	80.0	
Bus3	0.400	99.317	0.0	0	0	0.020	0.015	Bus2	-0.035	-0.026	62.9	80.0	
								Bus4	0.015	0.011	26.4	80.0	
Bus4	0.400	99.227	0.0	0	0	0.015	0.011	Bus3	-0.015	-0.011	26.4	80.0	
Bus5	0.400	99.877	0.0	0	0	0.020	0.015	Bus1	-0.020	-0.015	36.4	80.0	
Bus7	0.400	99.063	0.0	0	0	0	0	Bus9	-0.032	-0.024	58.9	80.0	
								Bus8	0.019	0.015	35.4	80.0	
								Bus12	0.013	0.010	23.5	80.0	
Bus8	0.400	98.934	0.0	0	0	0	0	Bus7	-0.019	-0.015	35.4	80.0	
								Bus11	0.019	0.015	35.4	80.0	
Bus9	0.400	99.499	0.0	0	0	0	0	Bus7	0.032	0.024	58.9	80.0	
								Bus10	0.022	0.016	39.8	80.0	
								Bus1	-0.054	-0.041	98.7	80.0	
Bus10	0.400	99.364	0.0	0	0	0.022	0.016	Bus9	-0.022	-0.016	39.8	80.0	
Bus11	0.400	98.658	0.0	0	0	0.019	0.015	Bus8	-0.019	-0.015	35.4	80.0	
Bus12	0.400	98.975	0.0	0	0	0.013	0.010	Bus7	-0.013	-0.010	23.5	80.0	

Figure 6. Load flow report with aluminum conductor.

nization Panel.

9.4. Cables Price & Length Calculation

For this solution proposed, there is requirement to install some new cables of different gauge at different locations as shown in the **Figure 9**. Cables at some locations are already installed. The length, gauge and location for the new cables are shown in the **Table 12**.

For this solution, cables of two different gauges *i.e.* 240 mm^2 and 400 mm^2 have to be installed. The total length of 240 mm^2 is 125 meters, which includes 33 meters from A Block to M Block and 92 meters from S Block to P Block. The total length of 400 mm^2 is 195 meters which includes 105 meters from B Block to A Block and 90 meters from B Block to S Block. The cost comparison for these lengths of 3 & half core non-armored copper, aluminum and copper aluminum conductor given below in **Tables 13-15**.

9.5. Total Cost for the Solution

For the proposed solution we have to put all the generators at one place and then synchronize them through a synchronization panel. Then we have to install some cables that are mentioned above. The total cost comparison for this solution including panel and cable cost is given below in the **Table 16**.

Hence the total cost for this solution is **Rs. 4.13 million Rs**.

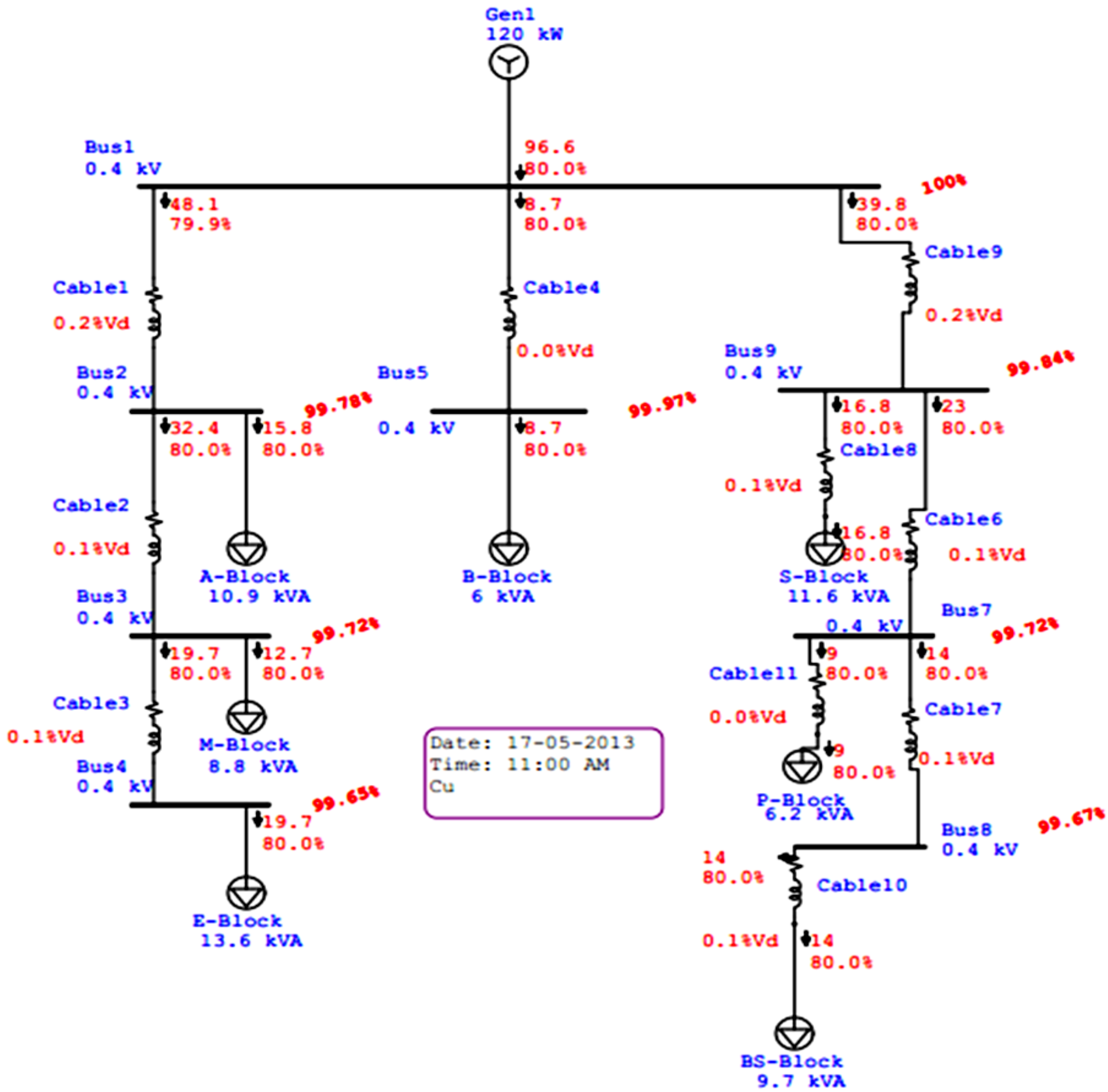

Figure 7. E-TAP model with copper conductor.

Table 12. Cable length required.

Cable	Gauge	Location	Length
1	400 mm^2	From B to A Block	105 m
2	240 mm^2	From A to M Block	33 m
3	400 mm^2	From B to S Block	90 m
4	240 mm^2	From S to P Block	92 m

Table 13. Price for copper conductor.

Cable	Specification	Current rating	Length required	Price/meter (Rs.)	Total price (Rs.)
240 mm^2	3 & half core cable	410	125	9000	1,125,000
400 mm^2	3 & half core cable	545	195	14,540	2,835,300
Grand total			Rs. 3.96 million		

Synchronized system with all new Cables of copper Date: 22-03-2013 Time: 1:00 PM

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
*Bus1	0.400	100.000	0.0	0.124	0.093	0	0	Bus2	0.049	0.037	88.2	79.9	
								Bus5	0.020	0.015	36.4	80.0	
								Bus9	0.055	0.041	98.6	79.9	
Bus2	0.400	99.596	-0.1	0	0	0.014	0.010	Bus1	-0.049	-0.037	88.2	80.0	
								Bus3	0.035	0.026	62.9	80.0	
Bus3	0.400	99.479	-0.1	0	0	0.020	0.015	Bus2	-0.035	-0.026	62.9	80.0	
								Bus4	0.015	0.011	26.4	80.0	
Bus4	0.400	99.389	-0.1	0	0	0.015	0.011	Bus3	-0.015	-0.011	26.4	80.0	
Bus5	0.400	99.877	0.0	0	0	0.020	0.015	Bus1	-0.020	-0.015	36.4	80.0	
Bus7	0.400	99.294	-0.1	0	0	0	0	Bus9	-0.032	-0.024	58.8	80.0	
								Bus8	0.019	0.015	35.3	80.0	
								Bus12	0.013	0.010	23.5	80.0	
Bus8	0.400	99.165	-0.1	0	0	0	0	Bus7	-0.019	-0.015	35.3	80.0	
								Bus11	0.019	0.015	35.3	80.0	
Bus9	0.400	99.612	-0.1	0	0	0	0	Bus7	0.032	0.024	58.8	80.0	
								Bus10	0.022	0.016	39.8	80.0	
								Bus1	-0.054	-0.041	98.6	80.0	
Bus10	0.400	99.478	-0.1	0	0	0.022	0.016	Bus9	-0.022	-0.016	39.8	80.0	
Bus11	0.400	98.890	-0.1	0	0	0.019	0.015	Bus8	-0.019	-0.015	35.3	80.0	
Bus12	0.400	99.206	-0.1	0	0	0.013	0.010	Bus7	-0.013	-0.010	23.5	80.0	

Figure 8. Load flow report with copper conductor.

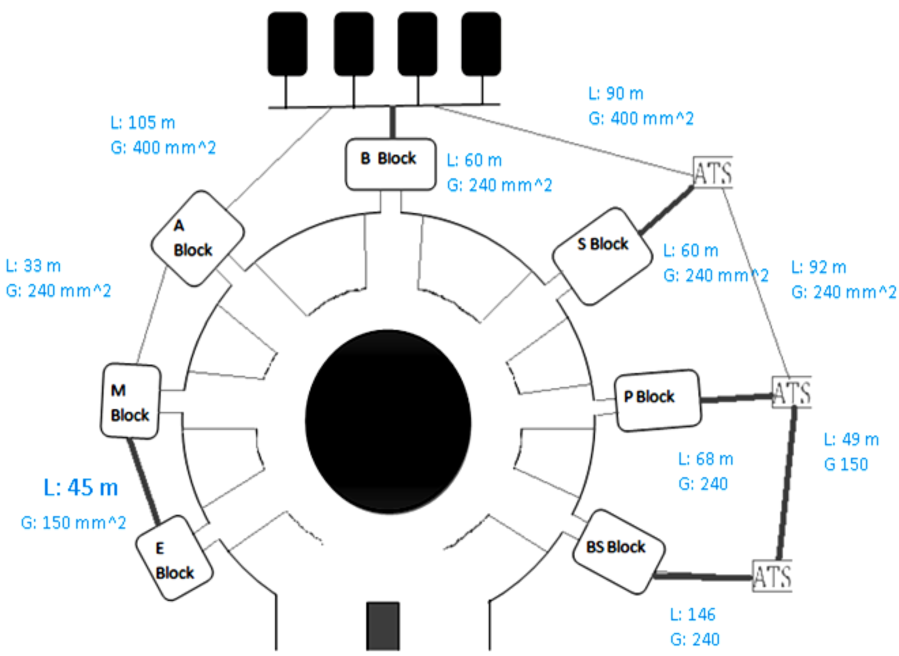

Figure 9. Proposed model for synchronized operation.

9.6. Pay Back Period

As have been seen from the real time calculations that diesel cost can be save every month in a good manner. Adding all the diesel savings and approximated savings for coming months can be helpful to obtain the payback period. Total saving in current year have been shown in **Table 17**.

The approximated savings in the up-coming months are estimated below in **Table 18**.

It is clear from calculations that 18 months are required to compensate these costs. So if Synchronized net

Table 14. Price for aluminum conductor.

Cable	Specification	Current rating	Length required	Price/meter (Rs.)	Total price (Rs.)
240 mm^2	3 & half core cable	361	125	1470	183,750
400 mm^2	3 and half core cable	490	195	2400	468,000
Grand total			Rs. 6.51 Lac		

Table 15. Price for copper aluminum conductor.

Cable	Conductor type	Length required	Cost/meter (Rs.)	Total price (Rs.)
400 mm^2	Aluminum	125	2400	300,000
400 mm^2	Copper	195	14,540	2,835,300
Grand total		3.13 million Rs.		

Table 16. Total cost.

Cable	Equipment	Equipment price (Rs.)	Grand total (Rs.)
1	Synchronization panel	1,000,000	Rs. 4.13 million
2	Cables	3,135,300	

Table 17. Estimated savings.

Sr. #	Saving in this month	Grand total
March	441,575	
April	104,075	
May	239,400	Rs. 1.2 million
June	199,500	
July	252,000	

Table 18. Approximated savings.

Sr. #	Savings	Grand total
August (2013)	200,000	
September (2013)	250,000	
October (2013)	300,000	
November (2013)	300,000	
December (2013)	300,000	
January (2014)	300,000	
February (2014)	300,000	Rs. 3 million
March (2014)	300,000	
April (2014)	100,000	
May (2014)	200,000	
June (2014)	100,000	
July (2014)	200,000	
August (2014)	150,000	

work is being installed in **December 2013**, the amount can be getting back in **June 2015**. Hence the payback period is approximately **18 months**.

10. Conclusion

From the preceding analysis one can conclude that implementing parallel Synchronization technique can bring advantages in the form of power and cost saving. Total cost of the solution is 4.13 million and total annual expenses of old system is 3708100 Rs. Total approximated cost saving in 18 months is 4236550 Rs. with average monthly saving is 235363.9 Rs. Hence payback period of this solution is 18 months.

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