COST BENEFIT ANALYSIS OF A DG INTEGRATED SYSTEM: CASE STUDY

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ABSTRACT

Distributed Generation is capable of meeting the load of the consumers partially or completely. Depending on the type of DG involved it can be operated in interconnected mode and islanded mode. The availability of numerous alternatives present for the DG technologies and large initial investments necessitates a detailed cost benefit analysis for the implementation of DG technologies. In this work an attempt has been made to study the costs involved in implementing the DG technologies. A practical system having two kinds of distributed generation i.e., Diesel Generator and solar photovoltaic system for its back up purpose is considered. A detailed cost analysis of the two DG technologies is carried out.

Keywords: *Diesel Generator, Solar Photovoltaic System (SPV), utility grid, Energy Costs*

1. INTRODUCTION

Distributed generation is electricity production that is on site or close to the load center and is interconnected to the utility distribution system. Distributed generation can allow utilities to defer transmission and distribution upgrades [1]. By placing these alternative energy sources, and other smaller traditional energy sources, on the distribution power system, will lead to the development of a new model related to distributed generation (DG). Micro-turbines, wind and solar energy, fuel cells, small gas turbines are a few among the different DG technologies. DG can be used in an isolated way, supplying the consumer's local demand, or in an integrated way, supplying energy to the remaining of the electric system. This local generation reduces the need for large-scale utility projects [1]. DG can overcome the deficiencies in the transmission system and therefore prove beneficial for both consumers and utilities especially where central generation is not practicable. DG can provide many benefits such as voltage support, improved utility system, reliability, loss reduction, transmission and distribution capacity release and better power quality [2]. Accomplishing these positive effects require large investments in terms of cost of DG, installation and maintance costs. In this paper a practical distribution system of Vasavi College of Engineering is considered for cost effective evaluation of DG integration. Vasavi college of Engineering has utility supply of connected load 650 kVA to meet its load requirement. Prior to the installation of solar power generation, the scheduled and forced outages are met by Diesel Generators set of one 625 kVA, one 500 kVA and one 125 kVA. In addition to the capital cost of Diesel generators, the maintenance cost of Diesel Generator was high. Diesel Generators were operated whenever there is an interruption in the utility supply. The maximum demand of the load cannot be decreased as the load is met by the diesel generator in the event of interruptions only. With the installation of Solar power the maximum demand agreement with the utility is reduced and the diesel requirement also reduced. In this work a detailed cost analysis of these two ways of meeting the load requirement of the selected network is presented. The technical details and the single line diagram of the selected network is given in Section 2, the diesel requirement and the cost evaluation details in meeting the load using diesel generator are presented in Section 3. Section 4 discusses the cost and technical details of the solar power installed. The comparison of the two methodologies is specified in Section 5 and the conclusions are presented in Section 6.

2. TEST SYSTEM AND SINGLE LINE DIAGRAM

The distribution system of Vasavi college of Engineering is selected for comparing the cost of different DG technologies. The college was established 1981 and is one of the top engineering colleges in the state of Telangana. There are seven engineering departments which have major laboratories. It has a total maximum demand of 650 kVA and a power factor of 0.9 is maintained with the help of a capacitor bank of 170 kVAR (1X50 kVAR, 4X25 kVAR and 2X10 kVAR). The single line diagram of the system is shown in Fig. 1.

The power requirement of the college is met through a 650 kVA, 11/0.415 kV transformer. To meet the load in the event of scheduled and forced outages, three DG sets of capacities 625 kVA, 500 kVA and 125 kVA are installed.

3. COST EVALUATION FOR DIESEL GENERATOR

Diesel Generators of capacities 625 kVA, 500 kVA and 125 kVA are installed for providing back up to the college in the event scheduled and forced outages. 625 kVA Diesel Generotor is connected to Ramanujan block, C.V.Raman Block and J.C.Bose Block for backup requirements. 500 kVA diesel generator set is connected Viswesrayya block, Sarvepally Radha Krishnan Block, Mechanical, Civil, Laboratories and Canteen. A bus coupler transfers the entire load to either 625 kVA DG set or to 500 kVA DG set. The 125 kVA is used during

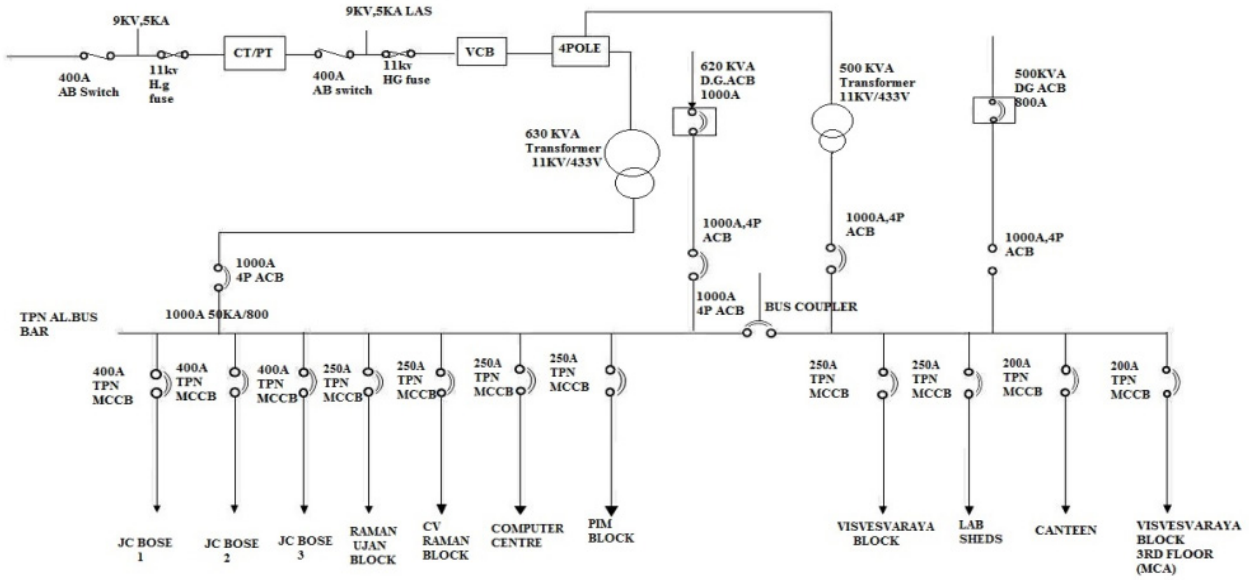

Fig. 1 Single Line diagram of Vasavi College of Engineering

holidays and after working hours of the college for illumination (Street Lighting).

The number of units generated, quantity and cost of diesel consumed in an year i.e, from October 2013 to September 2014 is given in Table 1.

Table 1 Diesel Consumption and cost in an year

S. No	Month	Diesel Consumption (liter)	Total Number of Diesel Units (kWh)	Total Cost of Diesel (Rs)
1	October	2003	5624	112168
2	November	796	2013	46056
3	December	1060	2722	62084
4	January	295	491	17278
5	February	1435	3639	85827
6	March	1820	5354	109964
7	April	1797	5530	108593
8	May	1183	3505	73074
9	June	1273	3544	78663
10	July	1340	2708	84447
11	August	2197	5455	139795
12	September	871	2154	55422

The total number of units produced by the diesel generators in the period considered from the above table are 42,739. Diesel unit refers to the kilo-watt-hours produced by the Diesel generator. Total number of diesel units is the output of the Diesel Generator in kWh during its period of operation. The quantity of diesel consumed in this period was 16,070 liters. The total expenditure on diesel during this period is Rs.9,73,341/-. (Rs refers to Rupees in INR and 1 Rupee is equal to 0.02 USD ₹1.00=US $0.02)

4. COST EVALUATION FOR PHOTOVOLTAIC SYSTEM

The Vasavi college of Engineering has five buildings namely Viswesrayya block, Ramanujam block, C.V. Raman block, Sarvepalli Radha Krishnan block and Jagdish Chandra Bose block. The rooftop solar PV plant was erected on J.C.Bose block and Viswesrayya block. 125 kWp SPV is installed on J.C.Bose block in the available 41.53 Sq.mt area and an area of 25 Sq.mt is available on Viswesrayya block on which 75 kWp SPV is installed. The grid interactive roof top solar PV system generally comprises the following equipment.

- Solar PV Modules
- Inverter Mounting Structure
- AC and DC Cables
- Earthing equipment /material
- Junction Boxes
- Lightning protection equipment

4.1. Scheme of Grid Interactive Roof top Solar PV system

The single line diagrams of the SPV installed on JC Bose block is shown in Fig. 2 and that of the Viswerayya block is given in Fig. 3. The installed SPV has no battery backup and it requires reference voltage for synchronization with the grid. Thus the SPV is operated in unification of either grid supply or Diesel generator supply. Therefore the output of the inverters is connected to the common bus to which the utility supply and diesel generators are interconnected.

It was estimated that there will be an annual energy generation of 300-360 MWh .The PV Modules produce 1000 watts per sq.mt on a standard sunny conditions this is called a peak sun. Less than one peak sun reduces the module current proportionately. The monthly energy generation from the SPV power plant has been presented in Table 2 and is represented graphically in Fig. 4. It can be observed from the figure there is a large variation in the number of units being generated as the generation of solar energy is dependent on solar radiation at an optimum temperature of 25°C.

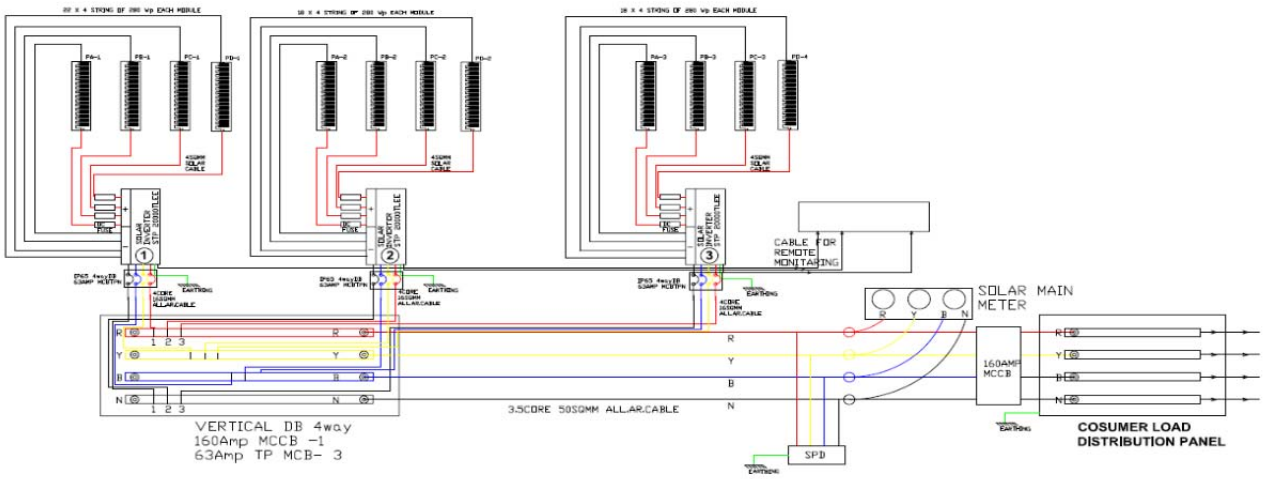

Fig. 2 Single Line diagram of SPV on JC Bose Block

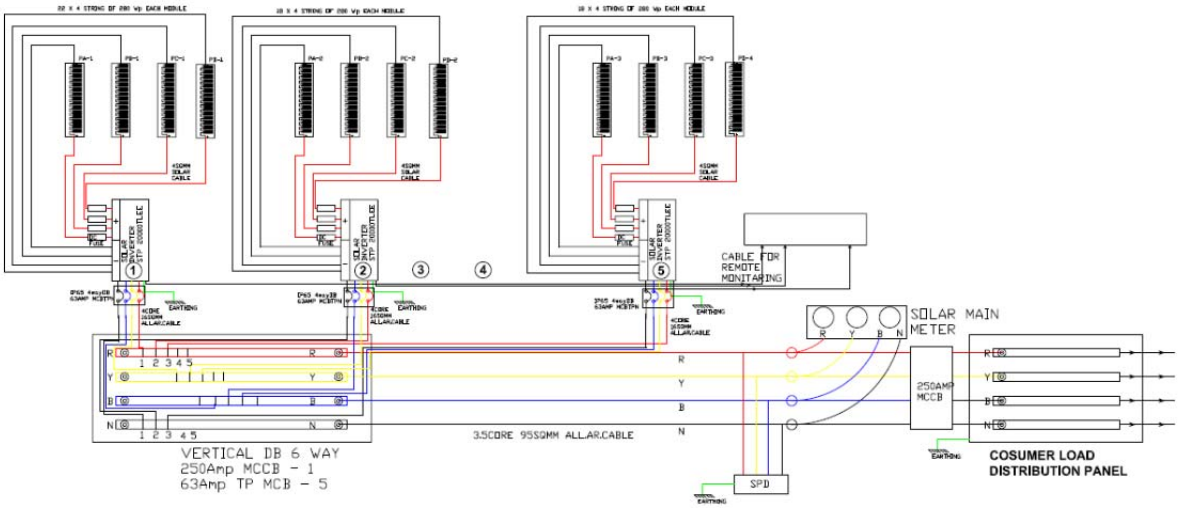

Fig. 3 Single line Diagram of SPV on Viswesrayya Block

Table 2 Solar Power Generation

S. No	Month	Number of units generated
1	November	23723
2	December	21100
3	January	24385
4	February	28582
5	March	23604
6	April	26090
7	May	27872
8	June	25811
9	July	6770
10	August	8240
11	September	12890
12	October	23630

With the addition of Solar Photovolatic System, the amount of diesel consumed is decreasd considerably. Diesel Genearators are operated when there are outages on the grid. The pattern of diesel consumption and the utility bill after the SPV integration is shown in Table 3.

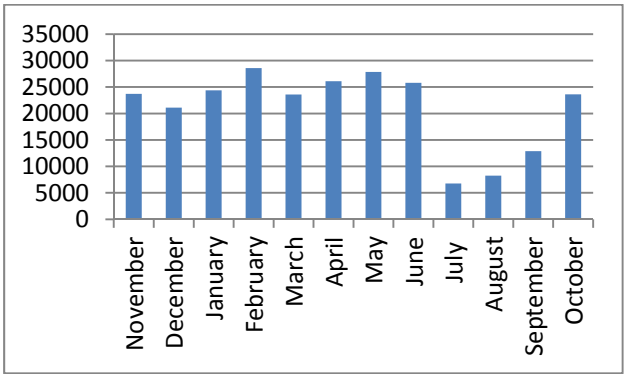

Fig. 4 Monthly Solar Power Generation

Table 3 Diesel Consumption after the SPV integration

S. No	Month	Diesel Consumption (liter)	Total Number of Diesel Units	Total Cost of Diesel (Rs)
1	October	2349	6358	150899
2	November	381	765	23081
3	December	387	592	23444
4	January	326	521	19749
5	February	401	651	24293
6	March	375	780	22718
7	April	888	2446	48786
8	May	569	975	31261
9	June	507	1131	27854
10	July	440	835	23883
11	August	464	752	25186
12	September	569	1318	30885

The total number of units produced by the diesel generators in the period considered from the above table is 17,124. The quantity of diesel consumed in this period was 7656 liters. The total expenditure on diesel during this period is Rs.4, 52,039/-.

5. DIESEL VS SOLAR POWER GENERATION

The considered system has two alternative power supplying means namely Diesel Generator and Solar Photo Voltaic System in addition to the state electricity board supply. Diesel Generators can be operated in an islanded mode to meet the entire load in the event of forced/Scheduled outages. SPV can take only a percentage of the total load along with either Diesel Generator or utility. The load requirements are met by the SPV and utility under normal conditions and by the SPV and diesel generators in the event of scheduled/forced outages. Thus load on utility and diesel generators are reduced after the installation of SPV.

This results in a reduction of diesel bill and utility bill. Utility bill and Diesel bill before and after SPV installation are presented in Table 4. Fig. 5 shows the reduction in utility bill and Diesel bill before and after the installation of SPV and Fig. 6 represents the reduction in the number of Diesel Generator units generated before and after SPV.

Table 4 Diesel and Utility Bill before and after SPV

Month	Utility Bill (Rs)		Diesel Cost (Rs)	
	Before SPV	After SPV	Before SPV	After SPV
October	437499	131562	112168	150899
November	432066	217117	46056	23081
December	389218	134731	62084	23444
January	372490	129121	17278	19749
February	434770	135455	85827	24293
March	422080	190943	109964	22718
April	422472	247391	108593	48786
May	458305	258353	73074	31261
June	429125	209259	78633	27854
July	339837	173195	84447	23883
August	368024	340609	139795	25186
September	286433	321678	55422	30885

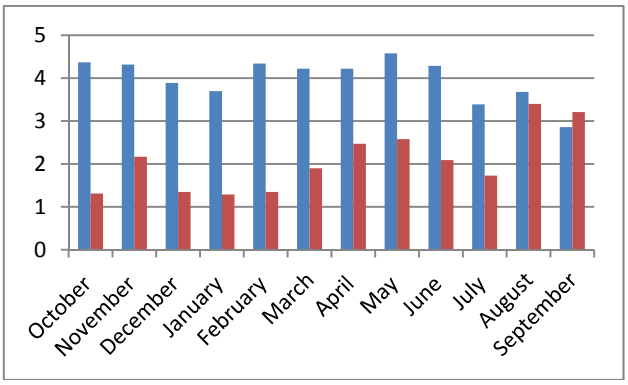

Fig. 5 Utility bill before and after SPV

The first column of the figure represents the utility bill before the installation of SPV and the second column is the utility bill after the installation of SPV.

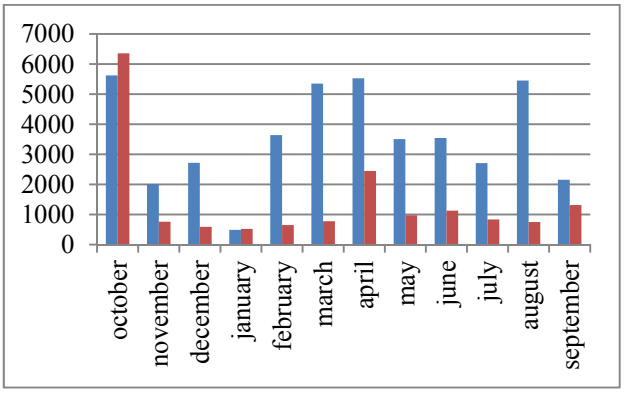

Fig. 6 Number of Diesel Units Generated before and after SPV

The first column of the figure represents the Diesel units (kWh) before the installation of SPV and the second column is the Diesel units (kWh) after the installation of SPV.

Diesel Generator has can take the total load of the college alone and its generation is independent but it suffers from the disadvantage that its operation cost is very high and its operation is not free form pollution. The Solar Photovoltaic system can take only a partial load of the system and it has to be operated in integrated mode with the utility and in the absence of the load the generated units are fed to the grid generating revenue. Reduction in the maximum demand agreement and the clean energy production were the additional benefits.

Diesel Generators have high capital costs and running cost. No reduction in the connected load can be obtained as diesel generators operated in the event grid unavailability. Before the installation of SPV the diesel generators were used to meet the load and thus energy charges over a year include diesel consumption charges and utility bill. After the installation of SPV the diesel generators usage is considerably reduced. The energy charges before and after the installation of SPV are compared and the comparison of charges in the two cases is given in Table 5.

Table 5 Comparison of energy charges before and after SPV

S. No	Category	Before SPV(Rs)	After SPV(Rs)	Percentage Reduction
1	Connected Load/Maximum Demand Charges	1,68,000	84000	50.00
2	Utility Bill	42,92,319	24,89,413	42.00
3	Diesel Consumption Charges	9,73,341	4,52,039	53.55
4	Total Energy Bill	52,65,660	29,41,452	44.13

6. CONCLUSIONS

In this work the case study of a distribution system containing two types of distributed generation is considered and compared. When Diesel Generator is present as an alternate power supply the energy expenditure was Rs.52,65,660/-. When solar is added to the system as the second alternate power supply the fixed charges corresponding to maximum demand and the amount of diesel utilized are reduced. In addition the above two advantages, being a grid integrated SPV system in the absence of load demand, and the generated units were exported to the grid generating revenue. Thus the total energy charges considering the solar photo voltaic system were Rs.29,41,452/- resulting a reduction of 44% in the total energy bill. This work presents the advantage of SPV over Diesel generator in terms of operating cost and can be helpful in determining the size of SPVs for installation.

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