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Mitigating Load Shedding in Rural Areas Using Microgrid Based Renewable Energy Model

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Abstract: *Increase in use of energy, increase of load on utility grid, rise in crude oil rates, warming of globe and improvement in Renewable Energy technology with drop in prices inspire government for the deployment of productive, low cost use of energy sources for the Microgrid based Renewable Energy System. Load-shedding nowadays is one of the biggest concerns, especially in rural areas as rural areas are more prominent to load-shedding. This research paper mainly focuses the application of Microgrid based Renewable Energy System and its feasibility for a small village of Pakistan. The complete Microgrid based Renewable Energy System has been designed and analyzed using PV*Sol software tool. Simulation result indicates that the total cost of Microgrid System installed has been recovered as well as even generated revenue by selling surplus power to third party consumers.*

Keywords*: Solar Photovoltaic, Energy Consumption, Microgrid System Designing, Grid Connected, PV*SOL Premium 2019.*

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I. Introduction

Electrical Energy is one of the substantial parts of energy nowadays. Improvement in lifestyle of human being is vastly subject to prosper of Electrical Energy. The value of Electrical Energy is well known from the rise of prices and demands of electricity. Researchers are busy round the clock for discovery of energy resources which are cheaper, clean and environmental friendly for the generation of power. Generation units of Electrical Power must be build in such a location which are not nearer to residential buildings and energy resources are in vast quantity for the production of power. Viable, societal and financial prosperity rely on sufficient power production of any region and state [1]. Microgrid Based RE System linked with local grids through bidirectional meters is one of the best mechanisms in DG Systems to overcome load-shedding and supply uninterruptable power to the consumers [2]. As the deployment of Microgrid system has more benefits of using but still there is high expenditure in beginning of this system [3]. Therefore, government has concluded to motivate sponsors by starting different packages for the publicity of sustainable energy [4]. Microgrid Based Renewable Energy System connected with grid provide better elasticity in its operation by deciding either the system should be operated in islanded mode with Energy storage system or it should be operated in grid connected mode to use power from utility grid [5].

II. Load Profile of Selected Case Study

The load profiling is a basic step in developing, Microgrid Based RE System. This analysis is started from selection of several houses electricity bill of consumers of a small village Pirsai in rural area of Mardan City, Pakistan in year 2018-19. Four houses with separate loading behaviours have been picked following an extensive research. Selected loads have been multiplied with number of houses having same consumption throughout the year to investigate Microgrid Based RE System throughput. The consumers have been picked among various houses having different consumption status and are classified as Class A, Class B, Class C and Class D. After detailed analysis of electric bills, we found that the highest consumption of energy is in the month of July. Further, we have selected five number of Class A, 30 number of Class B, 35 number of Class C and 30 numbers of Class D consumers making total of hundred household consumers. The total monthly energy demand is as shown in Fig 1. July has the highest peak load of 42546 kWh. Monthly consumption for July is as shown in Table 1, while Yearly consumption of Total load for 24 hours is shown in Fig 1.

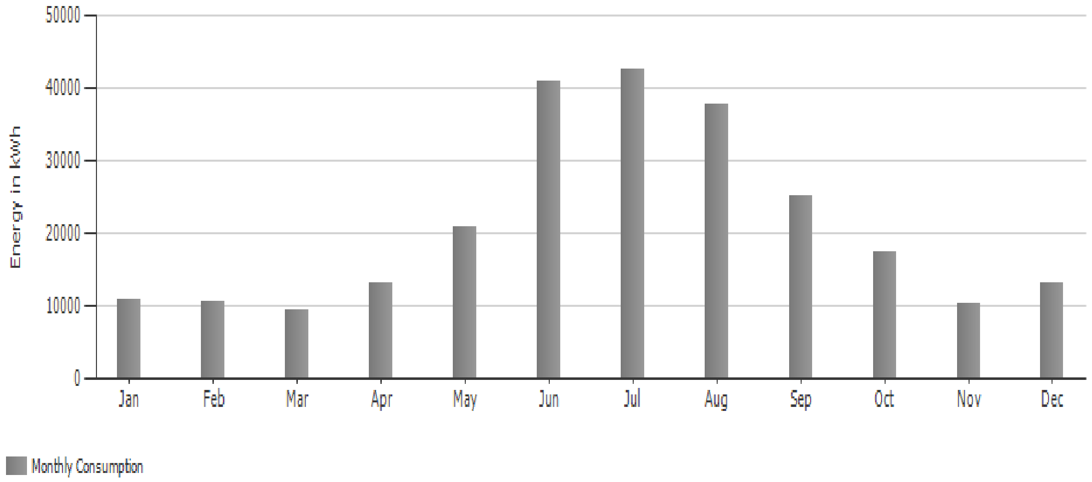


Figure no 1: Monthly Consumption of total load in a year 2018 - 19

Table no 1: Monthly Consumption of all Consumers for the month of July

Class	Monthly Consumption	Number of Homes	Total Consumption
Class A	766 KWh	5	3830 KWh
Class B	599 KWh	30	17970 KWh
Class C	234 KWh	35	8190 KWh
Class D	64 KWh	30	1920 KWh
Total		100	31910 KWh

III. Microgrid Design

As according to the given consumption, a high capacity Solar System needed to install for acquiring the energy demand. In this direction we have used a system designing tool called PV*SOL premium.

3.1 PV*SOL Premium 2019:

Simulation software is the ideal design tool, making accurate predictions easy. It gives customers the best return on their investment by visualizing systems and creating professional reports. PV*SOL® premium is the solar software design tool for simulating photovoltaic system performance. It is a fully featured program for those who do not wish to use 3D to model shading and visualize the landscape [15].

3.2 Solar Data:

In the development of PV network that accurately estimates production of power from photovoltaic infrastructure; solar asset details perform a vital function. In MetoSyn and Metronome server, this selected simulation tool has been developed for climate modeling and periodic location luminosity rates. Both of these have data about solar irradiance from multiple locations. However, fresh location luminosity details could be collected on monthly basis by overlaying between two closest sites. We want to evaluate the Microgrid based Renewable Energy system economic viability using PV*Sol in our research. Our selected case study used, mathematical model which utilizes climatic data from Village Pirsai, Rustam of Khyber Pakhtunkhwa.

3.3 PV Panels:

The photovoltaic panels transforms solar energy into DC electric power while inverter invert it into AC to meet the consumer own load as well as provides excess power to third party and connected to utility. Total generation of Microgrid structure relies upon the technological data variables including photovoltaic and inverters. In the design, the RNG-300D; 300W Monocrystalline Solar Panel is selected from PV*Sol Solar panels list for research. These scientific template developments consist of formulas, which derive its typical output of panel’s current-voltage curve with performance graphs that contained within software servers. Such parameters are chosen for field evaluation in actual Photovoltaic structures depending on manufacturing requirements. Functional specification of equipment used at Standard conditions including 1000w/m and 25 degree centigrade indicated in Table 2.

Table no 2: PV Module Specifications

Specifications	Value
Solar Cell Type	Monocrystalline (6.14 x 6.14 in)
Maximum Power at STC*	300 W
Optimum Operating Voltage (Vmp)	32.25 V
Optimum Operating Current (Imp)	9.33 A
Open Circuit Voltage (Voc)	39.82V
Short Circuit Current (Isc)	9.78 A
Module Efficiency	18.24%
Weight	6.5 kg

3.4 Inverter:

The output voltage produced from PV arrays are changed from Direct Current to Alternating Current through an inverter, therefore ABB inverter PVS-100/120-TL is used in this design from selected simulation software list of inverters. Efficiency measurements of commonly accessible inverter were evaluated by actual photovoltaic schemes installed under standard testing procedure depending upon vendor information collection and ground calculation details. Table 3 shows specifications of ABB PVS 100/120-TL.

Table no 3: Specifications of Inverter Selected

Inverter Model	Max Power Input	Max Power output	AC output Frequency	DC input Voltage	Efficiency
ABB PVS-100/120-TL	102 KW	100 KW	50Hz / 60Hz	1000 V	98.40%

3.5 Energy Storage Unit:

Backup unit also known as storage unit consists of battery packs. It is one of the important parts of Microgrid based RE Infrastructures, as key consumers are usually fed from backup units throughout load-shedding. Throughout the layout of Microgrid, top priority is suitable choice of backup unit potential. The German Off-grid Power (GOP) SUNSILO 10KWh battery system is selected for the design of Microgrid.The SUNSILO is a complete lithium storage system including charge controller and inverter for connection to a photovoltaic system or another power source (diesel generator, CHP, etc.).It can be used both as isolated network and mains connection. In an event of a power failure in the network, the GOP SUNSILO automatically takes over the emergency power supply. Seven number of battery system are used in the design of Microgrid for the coverage of load having two hours of backup capacity. Specification of the battery system used in this Microgrid design is shown in the Table 4.

Table no 4: Specifications of Battery System

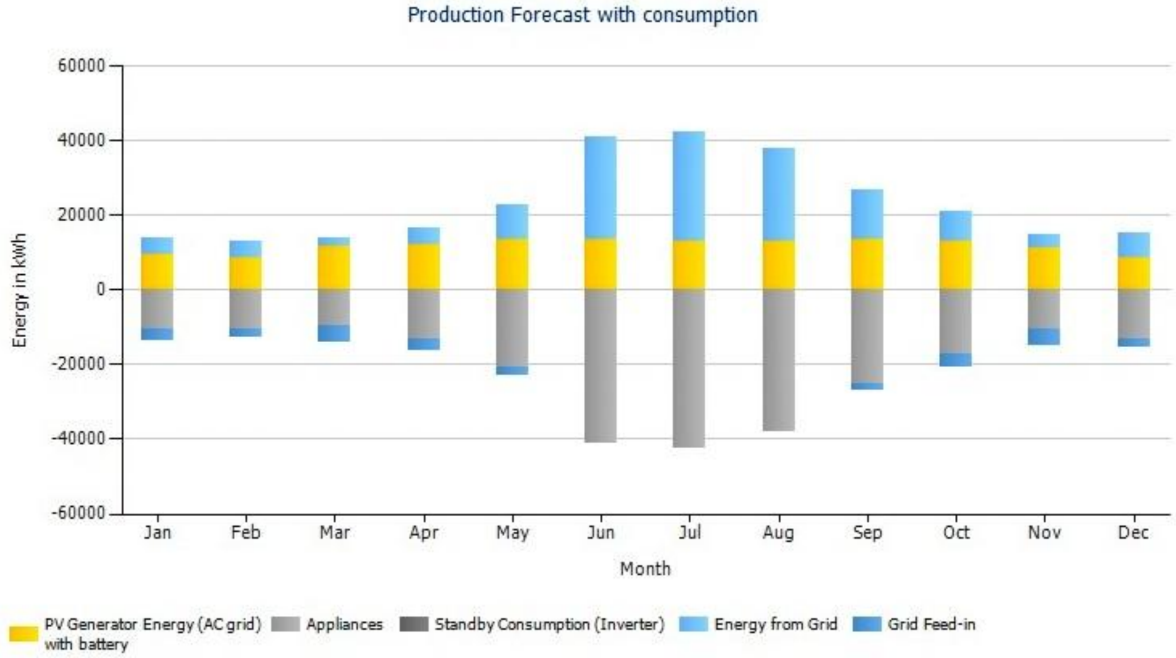
Battery System	Max Power Input	Max Charge and Discharge Power	Storage Capacity of Batteries	Battery Type	Nominal Voltage
GOP SUNSILO	10KW	9 KW	9 KW	Lithumionen	51.2 V

IV. Results and Discussion

Deriving simulation results of a Microgrid based Renewable Energy (PV) model for load-shedding mitigation, energy consumption and peak usage of energy at specific time etc. are some of the most important aspects which have been analyzed. The peak demand with hours of load-shedding are considered for designing the required Microgrid Based RE System. After entering these variables into the simulation software, an energy flow graph will be derived including incoming energy from the local grid, flow of energy into the grid or third party for selling as an extra power, energy generated from photovoltaic side and flow toward storage unit for storing.

4.1 Production Forecast with Consumption:

The analysis began with the collection of different consumers load previous annual electric bills. The overall consummation of energy from consumers has been determined as 251616 kilowatt hours annually having peak demand of 57.2 KW. As, load-shedding is considered for six hour a day, therefore PV system is designed for coverage of load for six hours a day with battery system in backup for two hours. The simulation results of Production Forecast with Consumption and Consumption Coverage are shown in Figure 2.



. **Figure no 2:** Energy Production Forecast with Consumption

4.2 Energy Flow Graph:

Energy Flow Graph indicates that if 93.6 KW of Microgrid-Based RE scheme is deployed with backup units, then it helped in covering of power requirement during load-shedding hours as well as feeding extra power to utility grid in off peak periods round the year thus reducing load on the National /Utility grid. Lump sum of electricity inflow to consumer side is 146386 kilowatt hours while outflow from Microgrid structure to third party or electricity companies is 47391 kWh annually, so the maximum purchasing from power companies remain 98995 kilowatts hour annually. It indicates that user have to buy approximately 40% of its demands from government energy supplying companies. The energy consumer uses from Microgrid is 105,230 Kwh. The total energy covered from PV system with batteries in backup is 152621 kWh as shown in Figure 3.

With incorporation of local-grid or power companies, Microgrid Based RE structure deployment at rural areas was derived to contribute approximately 60% of electricity demands, with covering load-shedding hours as well as feed surplus energy to utility grid as shown in Figure 3.

Figure 3 shows the viability of Microgrid Based Renewable Energy system and its feasibility in rural areas by showing that, the system installation will help in mitigating load-shedding as will feed in extra power generated from the system to National Grid or third party. The third party will payback for the amount of energy used from the Microgrid system.

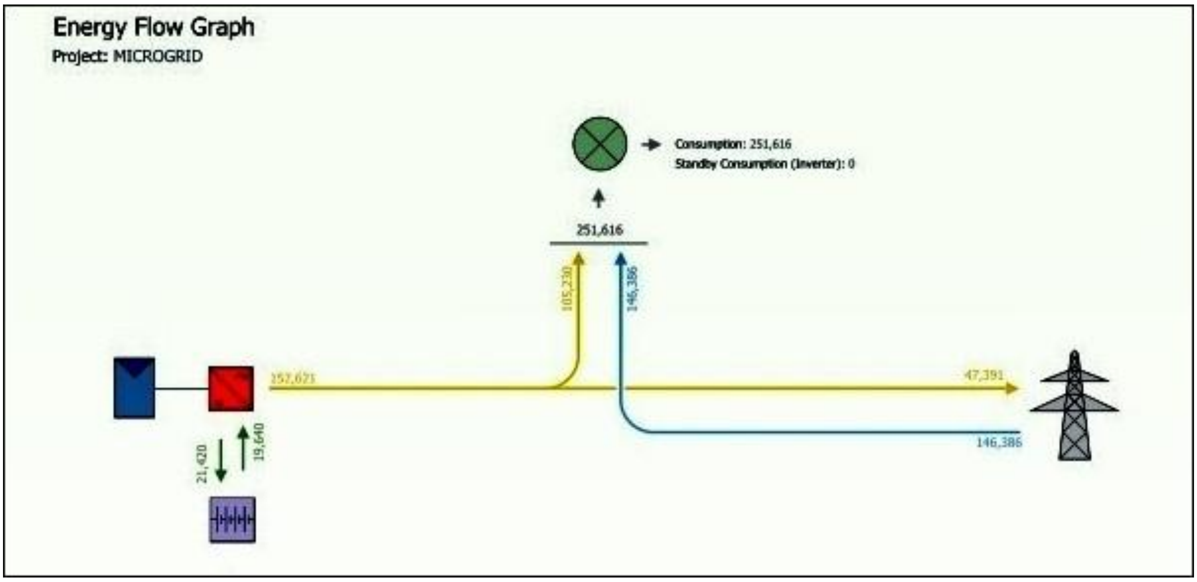


Figure no 3: Energy Flow Graph

4.3 Technical Analysis:

The simulation of Microgrid based Renewable Energy (PV) system employing PV*Sol software technology, was derived. This tool used is really sophisticated computing tool software with economics as well as FIT remix strategy features. Based on past consumer yearly consumption records, the Microgrid-Based RE System has been simulated. Technical analysis is illustrated in Table 5 which shows Positive effect of Microgrid networks on consumer as well as distribution. Around 1630 KW per kilowatt power of electricity is generated by Microgrid System. These types of Microgrid schemes not even achieves intake for power consumers as well as pours additional energy into network, thereby leading to exchange of demands between electricity grids. Microgrid networks are really effective in preventing global hazards gases and in stability of production prices.

Table no 5: Technical Analysis of Microgrid System

Size of system (KW)	PV energy generated (KWh/year)	Own consumption (Kwh)	Grid Feed in (Kwh)	Specific annual yield (KWh/KWp)	Consumption from Utility grid (KWh)
93.6	152621	105230	47391	1630.56	146386-47391= 98995

4.4 Financial Analysis:

Table 6 shows one time investment cost of 229027.92 $ for installation of 93.6 kWp Microgrid system , 2292.36$ Operational and Maintenance cost with 2% inflation rate per year and rate of Electricity provided to other consumers or feed back to utility grid with inflation rate of 2% per year is 0.110 USD.

Table no 6: Financial Analysis of Microgrid System

Size of system (KW)	Investment cost (USD)	Operation and Maintenance Cost /Year with inflation rate of 2%/ year (USD)	Price Of Electricity sold to Third party with 2% inflation/year (USD)
93.6	229027.92	2292.36	0.110

Figure 4 show the financial viability of Microgrid based Renewable Energy system in rural areas for load-shedding mitigation. It shows that even an initial significant investment expenses needed for deployment of Microgrid based RE System, and later on Return on Asset (ROA) is quite good by selling surplus power to third party which is decent indicator for local government department to install small Microgrid, to overcome energy availability crises at villages specially. It is evident in figure 4 that COE (Cost of Energy) of Microgrid scheme is reasonable, recoverable with the passage of time and gives good income after few years of its operation.

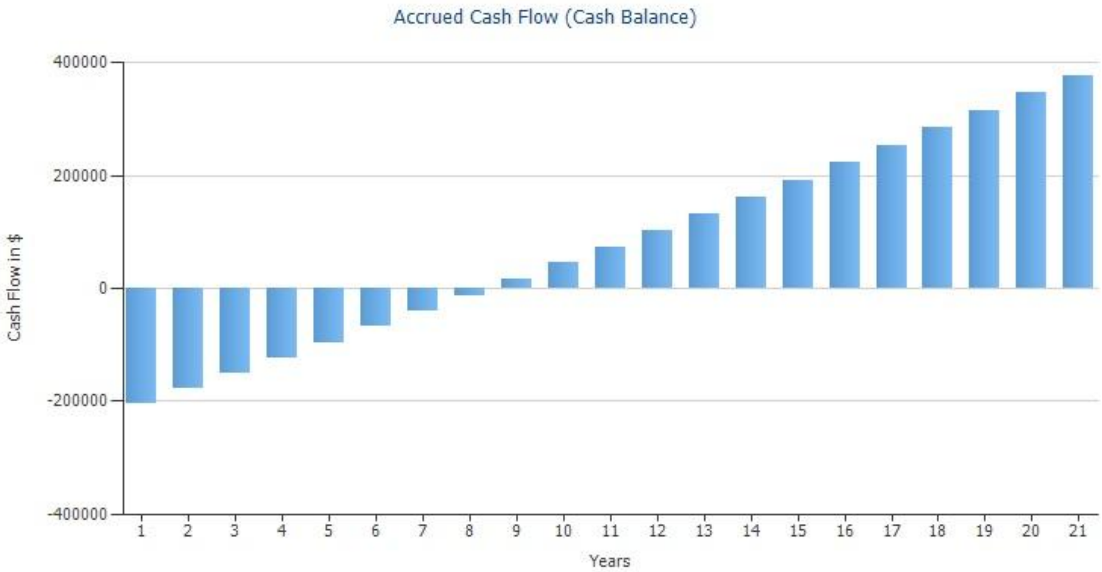


Figure no 4: Cash Flow Graph

V. Conclusion

Investigation of Microgrid Based Renewable Energy (PV) system for load-shedding mitigation in rural area of Pakistan deployment has been carried out in this research study. Our study shows that Microgrid based RE (Renewable Energy) system installation decreases consumer's reliance on local grid as well as lower consumer regular electricity charges. The consumer's demand exchange via Microgrid, relieves its pressure on energy supply companies as well as support, network during blackouts. Microgrid-Based RE Systems are easy to install and manage as compare to conventional-grid. It also helps as clean and green energy services without generating harmful gases hazards to human life and reduce crises of electricity. Furthermore rural areas are very suitable for installation of Renewable Energy (PV) Microgrid because in rural areas there are lots of open areas for installation renewable energy plants as well as there is high irradiance and less or no pollution in rural areas as compared to urban areas which limit the generation of electricity from PV (Photovoltaic) panels. Successful implementation of Microgrid based Renewable Energy shows the potentials to decrease the gas purchase expense, minimize its domestic utility's extra stress minimize dependency on governmental generating companies for power, and the main advantage is reduction of load-shedding in rural areas of Pakistan.

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