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Techno-Economic Analysis of a Hybrid Power System with Energy Storage

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A B S T R A C T

Due to fast urbanisation, intensive industrial expansion, and economic growth, load growth and energy consumption are rapidly rising in developing nations like India. The majority of this need is satisfied by using conventional energy sources, which have a negative impact on the environment. Renewable energy sources offer a fantastic alternative, but they also have significant limitations, such as intermittent generation, high initial costs, difficult regulation, conversion between AC and DC generation, grid integration, etc. A hybrid power system, which combines the advantages of different power sources, can be thought of as a preferable choice to create and deliver electricity in order to get beyond these drawbacks and effectively use the energy resources that are already accessible. In this project, techno-economic analysis of a hybrid power system for an educational facility will be carried out. The facility consists of traditional grid power supply, diesel generator, biogas plant and solar photovoltaic generation. To improve the reliability of supply, an energy storage system is proposed for augmenting the existing system. System will be simulated using HOMER PRO software and the results will be summarized. The summarised results include data on load assessment, simulation studies, and the economics of developing a hybrid power system

Keywords:Grid Integration, Renewable energy, Diesel Generator, Photovoltaic Generation, Grid Power Supply

1. Introduction

With the rising expense of energy, people have turned to fossil fuels, which have been in use for ages but are now in short supply due to human activity. Clean, affordable, reliable, & sustainable energy for all consumers worldwide is the ultimate aim of the alternative energy movement. The most realistic approach to lowering our dependency on fossil fuels is to increase our usage of renewable energy sources (RES). The term "renewable energy" refers to power that comes from renewable sources such the sun, wind, waves, and the earth's core. Since it is sometimes unfeasible to link the grid to these outlying places, RES could be used to bring electricity to these communities. Integrated Renewable Energy Systems (IRES), distributed generation, and hybrid power systems (HPS) may be created to supplement the electrification of single-family homes using renewable energy. A Hybrid Energy system is one in which many renewable energy sources are combined with traditional energy sources to maximise system efficiency. Knowledge of such limits as current technology, obtainable government rules, consumer needs, and available resources is necessary. Both the advantages and the challenges of coordinating the use of the primary grid are specific to each system. Due to its ability to draw from both RES and conventional sources, HPS was selected for this investigation. The heart of the HPS is a collection of energy generators and batteries that work in tandem to maximise efficiency. This means that greater efficiency can be attained by making the most of each energy source and/or gadget while overcoming their unique constraints. This study presents an effort to conduct a techno-economic analysis of a hybrid power system at a school, consisting of a combination of the traditional grid, a diesel generator, photovoltaic generation, and storage. Hybrid Optimization of Multiple Electric Renewables (HOMER) from the National Renewable Energy Laboratory is employed. Before installing a hybrid power system, designers can utilise HOMER Pro to figure out the best possible setup for the system in terms of stability, cost, size, and number of components. Since these findings shed light on the techno-economics of the current system's functioning, they can be used to develop more effective methods for operation and maintenance, ultimately resulting in less reliance on traditional energy sources and greater usage of renewable energy.

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2. Study Area

There is an engineering school in India called GMR Institute of Technology (GMRIT). It's in the Andhra Pradesh town of Rajam, in the Srikakulam district. The Jawaharlal Nehru Technological University in Kakinada is its parent institution. The GMR Varalakshmi foundation, the CSR arm of the GMR Group, founded GMRIT in 1997. The coordinates are 18.4556 degrees north and 83.6494 degrees east. GMRIT has a total connected load of 7760 kW. Hybrid Power System is the current power system in use at GMRIT (HPS). The Eastern Power Distribution Company of Andhra Pradesh Limited (APEPDCL) provides electricity by 11 kV bus connections, and this school is the only one in the Srikakulam district to use an HPS and the Net Metering system.

3. System Modelling

At 18.4556° N, 83.6494° E, NASA and NREL metrological data are used as inputs for proposed Hybrid power system models of varying configurations in order to evaluate system performance.

3.1. Load Profile

If you plot electrical demand against time, you get a load profile. The characteristics of a load profile will shift depending on factors such as the composition of the customer base (residential, commercial, industrial), the time of year, and any planned holidays. Here, we focused on a particular segment of consumers: businesspeople. Peak load in the study region is 750 kilowatts, and annual electricity usage is 17,18,214.58 kilowatt hours.

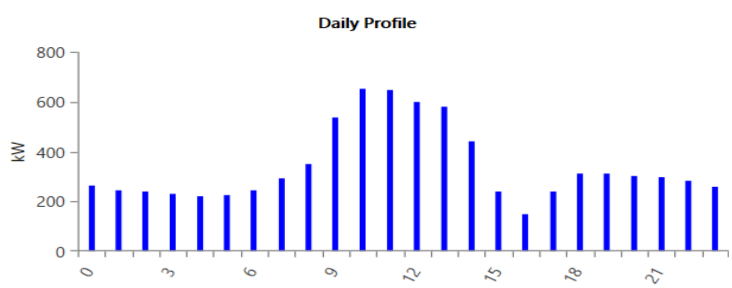

Fig. 1 –Daily Profile

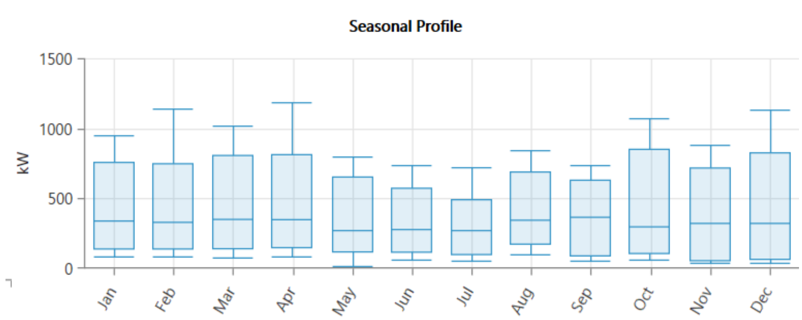

Fig. 2 – Seasonal Profile

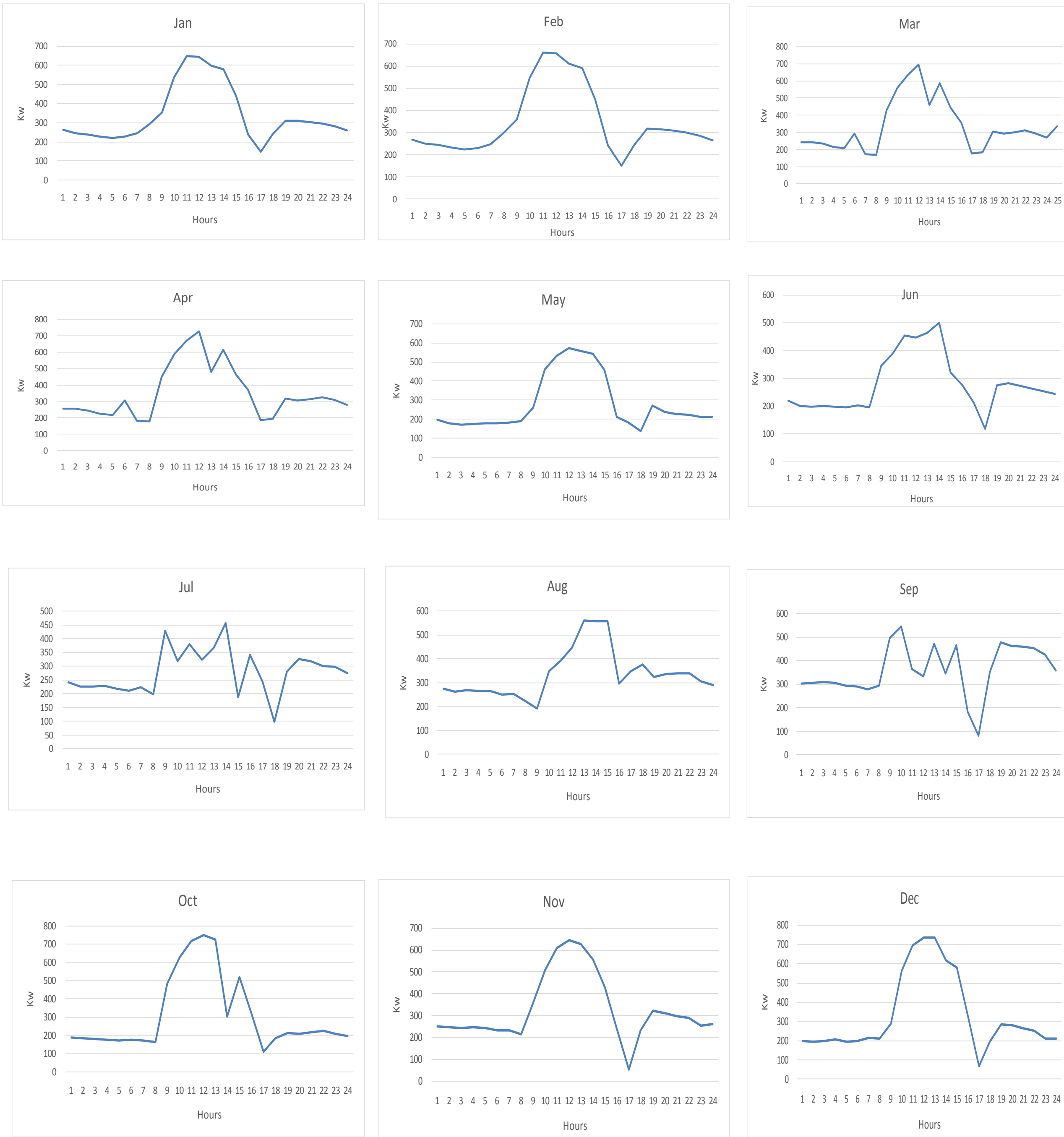

Fig. 3–Load Profile

3.2. Resource Assessment

Using HOMER Pro to model a hybrid energy system requires inputs such as technological choices, component costs, resource availability, and electric loads.

3.2.1. Solar Resource

The planned energy system uses HOMER's standard, flat-plate PV technology. A 700-kilowatt photovoltaic (PV) plant is estimated to have a capital cost of $2,625,000, a replacement cost of $2,625,000, and an annual operation and maintenance cost of $2,625,000. Without monitoring equipment, a 25-year lifespan was accounted for. The daily radiation and clear index of the earth's horizontal irradiation are displayed in Figure 2. In April, the world receives the most horizontal irradiation. Annual mean irradiance is calculated to be 6.02 kWh/m2/d. For this investigation, we will use a derating factor of 80% and a ground reflectance of 20%. Efficiency in standard test conditions is 16.42 percent, with a nominal operating cell temperature of 43 degrees Celsius. The degree of panel slant is 18.46 degrees Celsius.

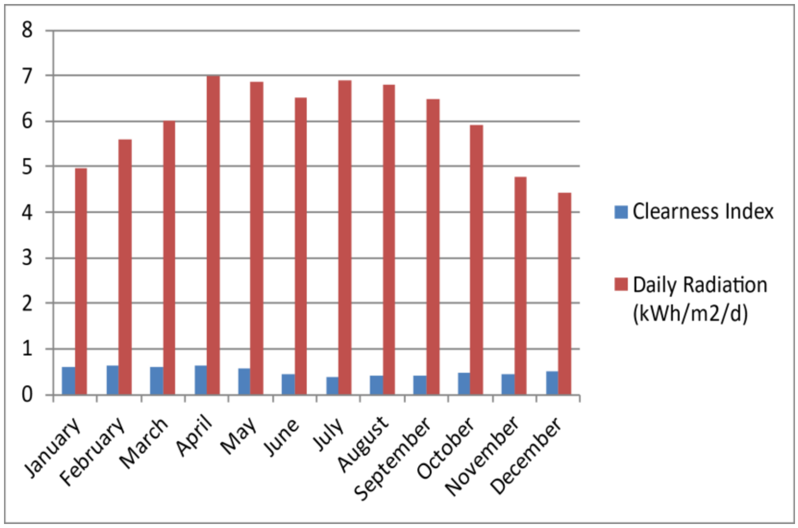

Fig. 4–Global Horizontal Irradiation

3.2.2. Converter

Power from solar photovoltaic panels (PV) must be converted from direct current (DC) to the alternating current (AC) required by the power grid. To keep the current flowing between the AC and DC components, a 750kW converter was constructed at a capital cost of $24,375. Together with the AC generator, it functions simultaneously. The estimated annual expenses of $2,467 for operations and replacement are $24,675 for the latter. The typical working lifespan is estimated to be 5 years. With an inverter, efficiency increases to 99%.

3.2.3. Battery

In order to provide power when it is needed, a battery stores energy. The battery is made to store enough juice to keep everything running in the event of a blackout. By minimising the capacity shortage factor, energy storage helps boost the efficiency of the system. The proposed model considers the cost effectiveness of using a Lithium-ion battery with a 100kWh, 167Ah capacity. The maximum power discharged from this 600V battery is 300kW. Less energy is lost during the charge/discharge process using lithium-ion batteries. In addition, they boast a deep discharge that lets you use every ounce of battery power. Lithium-ion batteries have a normal lifetime of 10 years or more. It doesn't need to be serviced frequently. Since a 600V battery is not commercially available, a boost converter is incorporated into the system to achieve the necessary voltage. As a result, the price of the converter is factored in as well. Four batteries are used as the system's input to ensure enough power for the workspace.

3.2.4. Grid

The Power Price of grid is taken as 0.15$/kWh. The Net Excess Price of Grid is taken as 0.029$/kWh. The net metering is considered monthly.

4. Configurations

PV/STORAGE/GRID HPS setup is taken into account during the course of this research. Cost of Energy (COE), Net Present Cost (NPC), Renewable Fraction (RF), and carbon emissions are just some of the technical, economic, and environmental parameters that are considered in analysing the findings of the models, which use a variety of different combinations of producing sources.

4.1. PV/Storage/Grid

Figure 3 illustrates the PV/STORAGE/GRID configuration. Lithium-ion batteries of 167Ah capacity are considered in this configuration. However, the scheduling of the batteries is done in such a way that it is required to operate only when PV system is unable to generate power. For analysis purposes 0 kW and 700 kW ratings are considered for PV system. Net metering method is functional in this configuration with other operational features of the grid remaining same as mentioned in Section 3.2.4. According to Andhra Pradesh State Electricity Regulatory Commission (APSERC), the sell back price/kWh of a system is $0.106818.

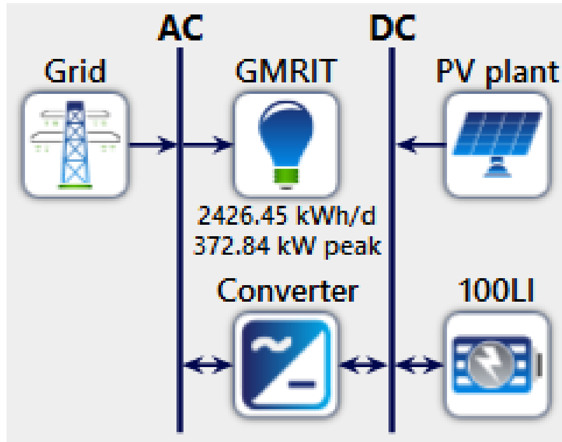

Fig. 5– PV/Storage/Grid

5. Results

In this section techno economic analysis has been done for the PV/STORAGE/GRID configuration. Techno economic evolution incorporates optimization studies taking into consideration various combinations of available energy generating resources and gives various parameters as output. The results of techno economic evaluation have been presented in following table.

Architecture				Cost				System	100LI			Grid	
PV plant (kW)	100LI	Grid (kW)	Converter (kW)	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Autonomy (hr)	Annual Throughput (kWh/yr)	Nominal Capacity (kWh)	Energy Purchased (kWh)	Energy Sold (kWh)
700	1	999999	500	600222	0.03315	24824.51	279303	71.0637	0.791282	90230.86	100.0002	405265.6	514890.1
700	1	999999	750	612063	0.03331	25111.96	287428	71.08574	0.791282	80.00016	100.0002	411010.7	535827.4
700	1	999999	750	617484	0.034	25531.29	287428	71.14894	0.791282	106090.4	100.0002	405296.9	519136.9
700	1	999999	250	870200	0.05763	46337	271178	64.90457	0.791282	38428.09	100.0002	409957.9	282470
		999999		2E+06	0.1503	133113.7	0	5.55E-14				885653.5	0
	1	999999	250	2E+06	0.15204	133983.7	8678	0.0084836	0.791282	80.00016	100.0002	885581	2.637982
	1	999999	250	2E+06	0.15205	133996.6	8678	0	0.791282	80.00016	100.0002	885667.1	2.637982
	1	999999	500	2E+06	0.15368	134808.8	16803	0.0084836	0.791282	80.00016	100.0002	885581	2.637982
	1	999999	500	2E+06	0.1537	134821.8	16803	0	0.791282	80.00016	100.0002	885667.1	2.637982
	1	999999	750	2E+06	0.15532	135634	24928	0.0084836	0.791282	80.00016	100.0002	885581	2.637982
	1	999999	750	2E+06	0.15534	135646.9	24928	0	0.791282	80.00016	100.0002	885667.1	2.637982

6. Conclusion

In this paper, the techno economic analysis of a HPS has been carried out by considering PV/STORAGE/GRID configuration. After simulation, it is observed that many combinations have obtained. From Table 1 it can be understood that out of all possible combination results, the result with one string of batteries and 999999 kW Grid, converter with 750kW is optimum. Considering the worst-case scenario of grid failure, one string of battery arrangement is sufficient to supply the required load demand. If further, load is increased storage system cannot meet the demand and load shedding has to be done for insignificant loads. But in this case charging of the battery can be done from only one source i.e., grid. Another combination that can be considered is battery arrangement with 999999kW Grid, 750kW converter and 700kW PV. During day time PV system is sufficient to meet the load. By minimizing the capacity shortage factor, energy storage helps boost the efficiency of the system.

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