Optimization and Techno-Economic Analysis of a Sustainable Microgrid Providing Back-up Power to a Hospital: A Case Study in Jammu & Kashmir

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***Abstract*—Electricity is central to modern economies. The concept of microgrids is highly advocated to achieve energy independence and ef- ficiency. Microgrids allow integration of renewable energy sources into the grid to promote regional reliability and to reduce the demand for grid expansion. Microgrids are cost-effective, environment-friendly and offer potential solutions to improve the resiliency and reliability of the grid. This paper investigates various techno-economic factors of a micro- grid supplying back-up power supply to a hospital where an interrupted power supply can prove critical. The main objective of the analysis is to determine the most optimal system configuration while minimizing the net present cost (NPC) of the system. The HOMER (Hybrid Opti- mization of Multiple Energy Resources) software is used to design the microgrid and study its performance. The solar irradiance and air tem- perature data is obtained from the National Renewable Energy Labora- tory (NREL) database. Finally, the ecological benefits of a microgrid in terms of reduced greenhouse gas emissions are also studied.**

Keywords: Microgrid · Renewable Energy · Pptimization· Distributed Energy Resources.

I. Introduction

Energy, economy and environment decide the sustainability of a country. The en- ergy demand is increasing at a very fast rate, especially in developing economies like India. In order to meet the demands, the dependence on fossil fuel-based products in also increasing [1, 2]. This has a derogatory impact on the environ ment. Renewable energy sources provide a sustainable and environment friendly solution to these problems. A microgrid integrates a renewable energy source into the system to increase its efficiency and reduce the the consumption of fossil fuels [3]. In India, renewable energy accounts for more than 20% of the total generation capacity [3, 4]. To promote energy security, India has been investing in distributed energy sources like wind, solar and biomass energy. Technological advancements and research have made the use of distributed energy sources economically viable [5]. Due to high solar irradiance received by almost all parts of India, solar energy provides a sustainable solution to meet the electrical load demands [6, 7]. The easy installation and cost-effectiveness make the implementation of a grid-connected PV system preferable over the off-grid PV system [8, 11]. The use renewable energy to meet electrical load demands is further sup- ported by the government through various subsidies and tax incentives [9].

The reliability of power supply determines the growth and productivity of an industry [10, 12]. The issue of intermittent grid service is more than mere an inconvenience for some industries, especially a hospital utility. Electricity is needed for the operation of medical equipment, ventilation, lighting and other auxiliary services. Microgrids can provide back-up power to hospitals to ensuring a functional energy infrastructure [13, 14]. Though the power sector in India is still evolving, it is highly diverse [15]. The frequency of grid outages is expected to reduce by incorporation of distributed energy sources into the utility grid.

II. Model Description

The microgrid system is designed depending on the renewable resource availability and present technology. The inflation rate and the discount rate are set at 7.13% and 15.5%, respectively. The project lifetime is taken to be 25 years. Fig. 1 shows the schematic diagram of the suggested microgrid model.

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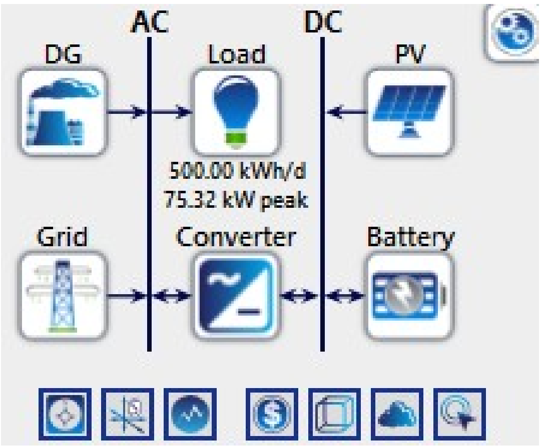

Fig. 1. Schematic Diagram of the Microgrid Model.

The prices of the components included in the simulation are real-time market prices provided by manufacturers and suppliers. The data requirements of the analysis are presented below:

A. Global Horizontal Irradiance (GHI) Data

As per the National Renewable Energy Laboratory (NREL) database, the daily solar radiation for Jammu & Kashmir ranges from 2.531 kWh/m2/day to 7.232 kWh/m2/day whereas the annual average is 5.03 kWh/m2/day. The clearness index varies between 0.52 and 0.669. Fig. 2 depicts the renewable energy availability data at the location.

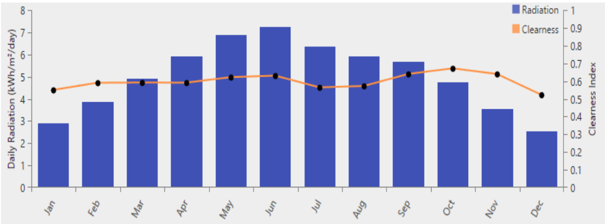

Fig. 2. Monthly Solar Global Horizontal Irradiance (GHI) Data.

B. Load Profile

The load profile is based on the monthly power consumption of a hospital located in the Pulwama region of Jammu & Kashmir. The annual average load value is 500 kWh/day and the peak load value is 75.32 kW. To account for random variabilities in the load demand, a day to day variability of 30% is considered in the simulation.

C. Utility Grid

The electricity tariff rate is considered to be 4.5 Rs/kWh. The grid is simulated to operate in off-grid mode from 10:00 AM to 11:00 AM and 3:00 PM to 4:00 PM to account for scheduled grid outages during a day. A mean outage frequency of 150 considers the random grid outages throughout the year.

D. Solar Photovoltaic System

For the proposed system, solar modules with the lifetime of 25 years are used. The PV derating factor is 80%. The capital cost of the the system, which includes the cost of modules, installation cost and the cost associated with wiring and mounting hardware is Rs.80,00,000 for a 250 kW system, as quoted by the local suppliers. The replacement cost is considered to be same.

E. Diesel Generator

To meet the load demand during power outages, diesel generators are widely used. The capital cost of a 50 kW diesel generator is Rs.450000 and the replacement cost is the same. The minimum load ratio is 25% and the lifetime is 15,000 hours. The fuel price is 83.56 Rs./L.

F. Converter

As the system contains both AC and DC elements, a converter is used to perform the required conversions. The lifetime of the converter used is 15 years with an efficiency of 95%. The capital cost and the replacement cost Rs.18,000. HOMER optimizer calculates the number of converters required to meet the load demand at all times throughout the lifetime of the project.

G. Battery

To store the surplus power, a lead-acid battery bank is used. Each battery has a nominal voltage of 12 V. The lifetime of each battery is 10 years. The capital and replacement cost of a single battery is Rs.8,500. The initial and minimum state of charge of the battery is 100% and 40% respectively.

III. Simulation Results

Based on the inputs and power constraints HOMER simulated 530 solutions. The results are presented in the following categories:

A. Optimum System Architecture

The following system configurations were found to be the most optimum by HOMER. The results are sorted according to the minimum value of net present cost (NPC). Table 1 depicts the optimized system configuration results obtained by HOMER.

The results show that the system with PV+DG+Battery+Grid configuration has the least value of both NPC and COE. The NPC and COE of the system is Rs.14.0M and Rs.7.09, respectively. On comparison with the grid only system, it can be observed that as the renewable fraction increases from 0% to 54.1% the COE decreases from Rs.9.14 to Rs.7.09. The internal rate of return (IRR) and the payback period is found out to be 14.5% and 5.91 years, respectively. The results show that the system is economically viable.

TABLE 1: OPTIMIZED SYSTEM CONFIGURATIONS SIMULATED BY HOMER.

Model	PV (kW)	DG (kW)	Battery	Grid (kW)	Conv. (kW)	NPC (Rs.)	COE (Rs.)	Ren. Fraction (%)
PV+DG+Battery +Grid+Converter	80	100	300	200	100	14.0M	7.09	54.1
PV+Battery +Grid+Converter	150	-	300	200	100	14.6M	7.4	61.7
PV+DG +Grid+Converter	70	100	-	200	100	17.6M	8.88	39.4
DG+Grid	-	100	-	200	-	18.1M	9.14	0
DG+Battery								
+Grid+Converter	-	100	300	200	100	23.9M	12.08	0

B. Environmental Benefits

To highlight the ecological importance of integrating renewable energy sources into the microgrid, the emission levels of the most optimum system configuration are compared with that of DG+Grid system. Table 2 compares the emission levels of both the systems.

TABLE 2: COMPARISON OF GREENHOUSE GAS EMISSION LEVELS.

Poisonous Emissions	PV+DG+Battery +Grid+Converter System (kg/yr)	Grid Only System (kg/yr)
Carbon Dioxide	53,181	124,523
Carbon Monoxide	4.29	187
Unburned Hydrocarbons	0.174	7.56
Particulate Matter	0.0172	0.748
Sulfur Dioxide	229	488
Nitrogen Oxides	112	221

The significant reduction in the level of pollutant gases like Carbon Dioxide from 124,523 kg/yr to 53,181 kg/yr proves that the system is environmentally viable as well.

IV. CONCLUSION

The study validates the significance of implementing renewable energy integra- tion into the microgrid system interms of reduced net present cost and green- house gas emission levels. The results obtained can be used to design a PV-based microgrid system at a preliminary stage to estimate the optimal size and eco- nomics of microgrid. The analysis in this paper highlights the importance of implementing a microgrid system to reduce the carbon footprint of the sytem.

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