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Optimization and Techno-Economic Analysis of a Microgrid for an Industry with Intermittent Grid Service using HOMER Software: A Case Study in Ladakh, India

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Abstract- The concept of integrating renewable energy sources into the grid is supported worldwide as it improves energy efficiency and regional reliability, reduces energy losses and the demand for grid expansion. Due to the increasing price of fossil fuel-based products and deteriorating environmental conditions, there seems to be increased prospects for distributed energy resources to address electricity generation. However, the economic aspect acts as a significant variable in the promotion of renewable energy. Hence, to configure and design a grid connected renewable energy system, system planning in terms of component design and system sizing is important. This work presents a detailed optimal sizing method and techno-economic analysis of a microgrid system for an industry running under grid outages in Ladakh, India. The system is simulated using Hybrid Optimization Model for Electric Renewables (HOMER) software. The objective function of the optimization problem is to reduce the Net Present Cost (NPC), Cost of Energy (COE) and greenhouse gases emission levels of the system. The results of the analysis aid in estimating the optimal size and economics of a renewable energy based microgrid at a preliminary design stage. Additionally, the environmental impact of integrating renewable energy into the grid is also highlighted.

Index Terms- renewable energy, solar energy, microgrid, cost of energy (COE), optimization

I. INTRODUCTION

About 80% of the worldwide primary energy demand is comprised of fossil fuels which accounts for approximately two-thirds of the total CO2 emission levels [1]. In 2019, fossil fuels accounted for 84 percent of global primary energy consumption. The related levels of pollution will have catastrophic temperature implications for the world. The desire to curb emissions does not rule out the use of fossil fuels, but it does necessitate a drastic shift of course. Renewable technology is the most feasible option for powering the world without damaging the ecosystem, and there is a growing global trend for a transformation that is endorsed by national and foreign policies [2]. Despite expanded deployment, renewables contribute marginally more than 30% of global power output [3]. One of the main reasons for this can be the intermittent nature of the renewable energy sources. The most visible and highly publicized hurdle to green energy is cost, specifically, capital costs, or the initial cost of constructing and installing solar and wind farms [4].

India suffers from energy shortages as a result of inadequate fuel supply for power generation and transmission capability, resulting in rolling blackouts [5]. Inadequate investment in transmission and delivery systems, industry inefficiencies, technological difficulties transporting energy between states, low electricity tariffs, and distribution company financial instability have all harmed grid stability [6]. This has a detrimental impact on the sectors requiring an uninterrupted grid supply for their functioning. The industrial sector has been India's largest energy user, accounting for the largest share of growth followed by the residential sector [7]. Frequent power outages may result in waste of resources, equipment failure, and lost productivity time [8].

This paper presents a software-based approach for the detailed analysis of a microgrid using HOMER software. The results help in determining the technical and economic viability of a microgrid system.

II. MODEL DESCRIPTION

The microgrid is designed depending upon 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.

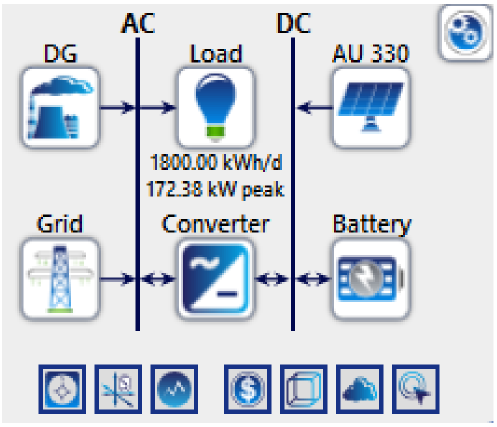

FIGURE 1: Schematic of the Microgrid Model

A. *Global Horizontal Irradiance (GHI) Data*

As per the National Renewable Energy Laboratory (NREL) database, the daily solar radiation for Ladakh ranges from 3.204 kWh/m2/day to 8.059 kWh/m2/day whereas the annual average is 5.84 kWh/m2/day. The clearness index varies between 0.654 and 0.755.

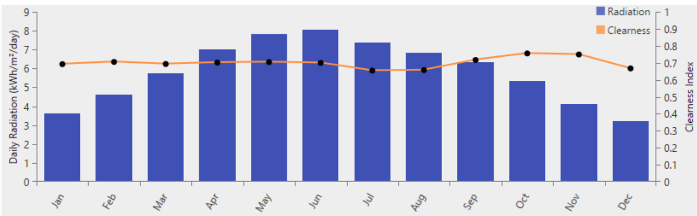

FIGURE 2: Monthly solar Global Horizontal Irradiance (GHI) Data

B. *Load Profile*

The annual average load of the industry is 1800 kWh/day and the peak load value is 172.38 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 0.04 $/kWh. The grid is simulated to operate in off-grid mode from 9:00 AM to 10:00 AM and 2:00 PM to 3:00 PM to account for scheduled grid outages during a day. A mean outage frequency of 160 considers the random grid outages throughout the year.

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*

After considering key economical factors like NPC, COE and renewable fraction, the details of different optimized configurations are shown in Table 1 and Table 2. The results show that Model 1, i.e. renewable energy based grid connected system with a diesel generator and energy storage, is the most feasible system configuration to meet the desired load.

The NPC, COE and the renewable fraction of the most optimal system is $373,264, $0.0524 and 39.4 % respectively. The Internal Rate of Return (IRR) of the system is 22.1 % and the payback period is 4.29 years. To analyze the benefits of integrating renewable energy into the grid, Model 3, i.e. standard grid system, is considered as a base case for comparison with Model 1. The results show that as the renewable fraction increases from 0 % to 39.4 %, the COE decreases from $0.0779 to $0.0524.

D. *Solar Photovoltaic System*

For the proposed system, solar modules with the lifetime of 25 years are used. The PV derating factor is 85%. 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 $109960 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 $6200 and the replacement cost is the same. The minimum load ratio is 25% and the lifetime is 15,000 hours. The fuel price is 1.15 $ /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 $3450. 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 $117. The initial and minimum state of charge of the battery is 100% and 40% respectively.

TABLE 1: DETAILS OF THE SYSTEM ARCHITECTURE OF THE MOST FEASIBLE CONFIGURATIONS

Model	PV (kW)	DG (kW)	Battery	Grid (kW)	Converter (kW)
1	200	100	400	200	150
2	200	150	0	200	100
3	0	150	0	200	0
4	0	150	200	200	100

TABLE 2: SIMULATION RESULTS BASED ON NPC, COE AND RENEWABLE FRACTION

Model	NPC ($)	COE ($)	Ren. Fraction (%)
1	373,264	0.0524	39.4
2	466,873	0.0655	33.4
3	555,016	0.0779	0
4	595,908	0.0836	0

B. Environmental Benefits

One of the key factors to choose the most optimum system configuration is to analyze its environmental impact. The environmental benefits can be observed by comparing the emission levels of Model 1 and Model 3 as shown in Table 3. The value of carbon dioxide emissions in Model 1 and Model 3 is 252,642 kg/yr and 428,157 kg/yr, respectively. From the results, it is evident that the renewable energy based grid connected system is environmentally feasible than the standard grid system.

TABLE 3: COMPARISON OF THE EMISSION LEVELS

Poisonous Emissions	Model 1 Value (kg/yr)	Model 3 Value (kg/yr)
Carbon Dioxide	252,642	428,157
Carbon Monoxide	28.8	398
Unburned Hydrocarbons	1.17	16.1
Particulate Matter	0.115	1.59
Sulfur Dioxide	1087	1746
Nitrogen Oxides	529	816

IV. CONCLUSION

The analysis presented in this paper confirms that for locations with substantial renewable energy availability, the shift from a completely fossil fuel-driven grid to a renewable energy based microgrid reduces the net present cost (NPC) and cost of energy (COE) of the system. Also, the emission levels of pollutant gases decrease significantly reducing the carbon footprint of the system.

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