Design and Simulation of Hybrid Solar PV-Fuel-Cell-Battery System to supply in the Nit Kurukshetra Campus and its effect on the Environment using Homer Software

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Abstract. The main objective of this paper is to design a hybrid power system for continuous power supply in the institute campus nit Kurukshetra in an economical way to replace the external grid power system. In this paper solar photovoltaic Fuel cell battery hybrid system has been studied. Costing, sizing, optimization, and simulation were done using the software homer pro. The Levelized Cost of electricity (COE) is Rs. 11.12 per KW is obtained and the system is based on renewable energy sources so it sustainably generates electricity.

Keywords: Homer, N.I.T Kurukshetra, fuel cell plant, solar power plant, hybrid energy system,

Introduction

Electricity is the most important part of a country. The supply of electrical energy has been directly impacted the national economy of that country. The demand for electrical energy is increasing very rapidly. At this time a major part of electrical generation is done using the thermal power plants run by using conventional fuel like coal, oil, and gas\textsuperscript{[1]}. The natural reserve of the fossil fuel in the earth is limited and may exhaust after a few decades \textsuperscript{[2]}if we continue to use fossil fuel resources at this rate. By the burning of fossil fuels emits many harmful gases that pollute our environment and cause many problems like the greenhouse effect, ozone layer depletion, acid rain\textsuperscript{[3, 4]}, etc. so, we need alternative energy sources to overcome such problems. The best alternative energy sources are renewable energy sources like solar photovoltaic, fuel cell, wind turbines, Biomass, geothermal, tidal energy, and small hydropower plant\textsuperscript{[5]}, etc. using renewable energy sources has the advantage that they are pollution-free, easily accessible, and inexhaustible. A single source of renewable energy is not sufficient for the continuous supply of electricity to the load. In such a situation hybrid energy system is needed for the continuous power supply to the load\textsuperscript{[6]}. The hybrid Power system is the combination of two or more energy sources\textsuperscript{[7]}. Renewable energy sources such as wind turbines, solar photovoltaic do not deliver continuous power but their hybrid combination can provide more continuous power output\textsuperscript{[8]}.
In this paper, we suggest the best alternative to replace the grid system with a renewable-based hybrid system[9]. Homer pro Software[10] has been used to perform different simulations and optimization to accessing the best reliable and economically feasible cost-effective system chosen by renewable technologies such as solar photovoltaic wind turbine, biomass, fuel cell, etc. To know the viability of continuous & uninterrupted power supply to the load.

**Area of study**

National Institute of Technology Kurukshetra, Haryana was chosen for the study. The Institute is situated in Haryana India. its latitude is 29°56.9′N and its longitude is 76°48.9′E shown in Fig 1.

![Fig.1 Location of nit Kurukshetra](image)

**Load profile of study area**

The per-day average energy consumption of the campus Nit Kurukshetra is about 11424.00 kWh/day and the daily peak is about 1130.08 kW annually. The monthly load data of the institute nit Kurukshetra is shown in fig.2.
Resources of study

The Solar radiation data and daily temperature data for the selected location have been obtained from NREL (National renewable energy lab) and NASA (national aeronautics and space administration) surface metrology[12]. All detail of annual average solar radiation and temperature is shown in fig.3 and fig.4 respectively. The daily irradiance solar radiation is 5.15 kWh/m²/day and the average clarity index is 0.593.
Component costing and lifetime

The lifetime of the hybrid system is 25 years. The cost associated with this hybrid system is as follows:

Net present cost (NPC) ₹536,795,500.00, Capital cost ₹408,373,000.00, Operating cost ₹11,089,760.00.

Table 1. The cost of the individual component and its lifetime

| Component   | Cost          | Lifetime |
|-------------|---------------|----------|
| Fuel cell   | ₹189,000,000.00 | 10 year  |
| Solar PV    | ₹175,000,000.00 | 25 year  |
| Battery     | ₹18,900,000.00  | 10 year  |
| Reformer    | ₹3,780,000.00   | 15 year  |
| Converter   | ₹21,525,000.00  | 10 year  |
Homer is the short name of the Hybrid optimization model for the electrical renewable[13] for simulation and optimization purpose, the capital cost of each of the components of the hybrid system, replacement cost, operation and maintenance cost of each component, sizes of the component, lifetime, fuel costing, project lifetime, coordinates of the selected location is given as the input in the homer software to perform the optimization and simulation. To perform sensitivity analysis in some particular cases, multiple numbers of input instructions were given. for an optimal and best hybrid solution, homer performs hundreds or even thousands of possible solutions. According to the result of homer, the best economical and optimal system consists of solar PV 900 kW, lead-acid battery 1025 kW, fuel cell generator 900 kw[14], converter 1025 kW, hydrogen tank capacity 300 kg[15], reformer 180 kg/hour, For the supply of continuous electrical power to the load. The schematic model of the solar PV-fuel cell-Battery hybrid system [16] is shown in fig.6
The total electrical power generated by the hybrid system is used to feed the ac load. The total electrical power generated annually by the hybrid system is 4,713,621 kWh/year all detail is shown in fig. 7. Annual electrical power generated by the fuel cell is 2,833,458 kWh/year and solar PV 1,880,163 kWh/year of which total electricity is stored in the battery is 9,851 kWh/year power supplied by the battery is 7,880 kWh/year and power is wasted during charging and discharging process is 1,970 kWh/year. all detailed analysis is shown in fig. 8. The total electricity consumption annually is 4,169,276 kWh/year and 322,939 kWh/year excess electrical power is generated by the system where the unmet electrical supply is almost 0 (0.0116 %).

Fig.6 Schematic model of the hybrid system

Fig.7 The monthly electric production by solar PV-fuel cell-battery system
Environmental impact and Comparison

When we burn fossil fuel for the generation of power that emits harmful gases [17] like unburned carbon, particulate matter, carbon dioxide, carbon mono oxide, etc that pollute our environment[18]. This harmful emission can be reduced with improvement in our power supply system and by using cleaner sources like renewable energy sources. The detail of emission in two different cases (Case-1 nit campus connected to the external grid, case-2. nit campus connected to solar PV-fuel cell-Battery hybrid system) is shown in table 2.

Table II. Emission in KG/YEAR

| Quantity               | Case: 1      | Case: 2      |
|------------------------|--------------|--------------|
| Carbon Dioxide         | 26,35,288    | 0            |
| Carbon Monoxide        | 0            | 0            |
| Unburned Hydrocarbon   | 0            | 0            |
| Particulates Matter    | 0            | 0            |
| Sulphur Dioxide        | 11,445       | 0            |
| Nitrogen oxide         | 5,587        | 0            |

Conclusion

In this research paper design and simulation of a Solar photovoltaic fuel cell battery hybrid power system for the continuous supply of electricity at nit Kurukshetra, Haryana had been carried out using homer software. The result shows that the external grid meets the monthly and yearly load demand at the cost of electricity (COE) ₹7.10 per kW and operating cost is ₹29,605,300 and cost of electricity (COE) of solar
A photovoltaic fuel cell battery hybrid system is found to be ₹11.12 per kW with the net present cost of the hybrid system is ₹536,795,500.00 and operating cost per year is ₹11,089,760.00, operating cost less when compared to external grid, grid also emits harmful gases. So the alternate option for replacing the external grid system for a greener future is Solar photovoltaic fuel cell battery hybrid system. The proposed system is based on Renewable energy sources so no emission of harmful gases and the main disadvantage of this hybrid power system is its high capital cost.

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