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COST OPTIMIZATION FOR INTEGRATING MICROGRID WITH ELECTRIC VEHICLES USING STOCHASTIC OPTIMIZATION TECHNIQUE

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Abstract: The prices of fossil fuels have been increasing, leading to a gap between power demand and supply. Energy consumption in residential areas is also increasing due to the use of appliances. The project aims to optimize power consumption by implementing a microgrid in a household. The microgrid will be more efficient and flexible than conventional grids and will involve customers in monitoring the smart grid. The project will focus on modeling and optimizing the microgrid, comparing technologies and simulating different energy sources. The project will have societal impacts by reducing energy consumption, lowering electricity bills, and decreasing CO2 emissions. The importance of optimization and modeling in managing energy generation, transmission, distribution, and storage will be emphasized. The financial feasibility will also be considered.

***Index Terms* -** Energy Cost Optimization, Microgrid Integration, Electric Vehicles, Stochastic optimization technique, Renewable Energy Sources.

I. INTRODUCTION

Prices of fossil fuels have been increasing, leading to a gap between power demand and supply. Energy consumption in residential areas is also increasing due to the use of various electrical appliances. optimize power consumption by implementing a microgrid in a household. The issues facing the modern energy landscape are growing expenses and greenhouse gas emissions, which have a special effect on cities because of increased urbanization and the widespread use of electric vehicles (EVs). EVs are essential to the development of distributed generation and transportation systems based on alternative fuels, which are increasingly needed to meet these challenges [1,2]. But as EVs become more widely used, the current distribution network may face technical difficulties that could result in grid infrastructure vulnerabilities and issues like overloading situations, harmonic disturbances, and higher power consumption [3]. Grid-to-vehicle (G2V) and vehicle-to-grid (V2G) technologies have garnered significant attention from researchers recently as a means of addressing the aforementioned problems and preserving power balance within the grid infrastructure [4-6]. A growing number of experts believe that microgrids are a practical technology for combining intermittent renewable energy sources with the conventional grid [7,10]. Microgrids powered by solar and wind are becoming more and more common [11-13], and there are continuous talks about how to optimize them [14- 16]. However, physical factors like investment, solar efficiency, and project area constraints also play a crucial role in microgrid capacity planning and day-to-day operations [17,18]. Improving the responsiveness of the power system in islanded hybrid microgrids by sizing components optimally is another area of intense research [19-23]. The process is optimized using Stochastic optimization techniques, which are designed to minimize the microgrid's overall cost while maintaining a consistent supply of energy. Additionally, this study takes into account the community's future demand as well as its long- term energy needs. This research explores the comparative analysis of various source combinations, including PV-Wind, PV-BESS, Wind-BESS, and more, in order to identify the most economical and environmentally friendly energy option for the changing energy landscape. In light of future energy demands, the research findings—which are presented in detail in this paper—offer important insights into the intricate and dynamic interactions that exist between microgrid energy management, cost optimization, and EV integration.

II. SYSTEM ARCHITECTURE DESCRIPTION

An area of 500 homes with hundred two-wheeler EVs and forty four-wheeler EVs makes up the suggested system model. The model is composed of a AC microgrid, which is further composed of an EV as a load, a backup diesel generator, a wind turbine, a PV solar panel, and a BESS. Fig. 1 shows the suggested system architecture.

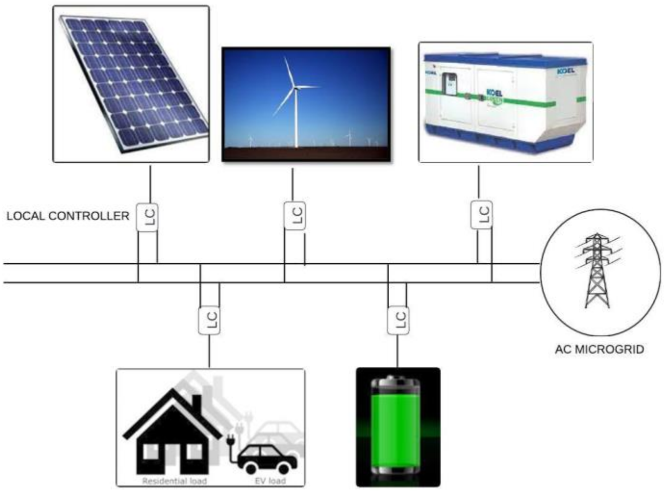


Fig.1 Proposed System Architecture

III. METHODOLOGY

3.1 Cost function

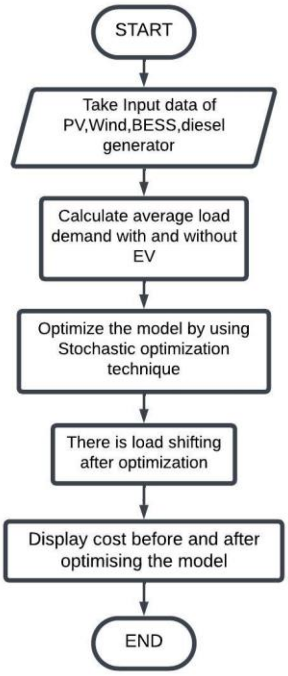
To minimize the energy cost a linear optimization problem is formulated by optimally scheduling all the available resources. The equations are given as:

$$\min \; f^T x$$
$$\text{subject to} \;\; A.x \leq b$$
$$A_{eq}.x = b_{eq}$$
$$lb \leq x \leq ub$$

Constraints considered:

- Battery Energy Storage System: Generation>Load(charging) Generation<load(discharging)
- Diesel Generator switched on only if:
  PV production + Wind production + Battery charging = 0
- EV Loads
  Two-wheeler EVs : 3KW per EV(charging time 3 hours)Four-wheeler EVs: 13KW per EV(charging time 6 hours)

3.2 Flow chart



Initial PV, wind, battery, and Diesel generator data input is obtained, and the average load demand of homes with and without EVs is computed. Using the Stochastic technique, the model is optimized, and the resultant individual cost of generation from each source and the profit are shown.

3.3 Optimization Technique

Stochastic optimization is a field of mathematical optimization that deals with optimization problems that in- volve random variables in data. This approach is effective in addressing uncertainty in optimization models and has been widely used in the energy system, specifically in the electrical power system. The uncertain factors in stochas tic optimization are described based on their probability distribution characteristics. The outcomes of stochastic optimization are scenario-specific, demonstrating the best strategy for each scenario. This study mainly applies this method to incorporate uncertainties in wind turbine output and electrical market price. By considering all sets of scenarios, the optimal solution is determined, improving the risk resilience of a microgrid's output operation strategy.

IV. RESULTS AND DISCUSSION

4.1 Case 1:

The understanding of the load demand variation is crucial for designing an efficient microgrid system that can meet the energy demands of both residential houses and electric vehicles (EVs). After accounting for five hundred households, hundred two-wheeler electric vehicles, and forty four-wheeler electric vehicles, average load demand data is considered for a day.

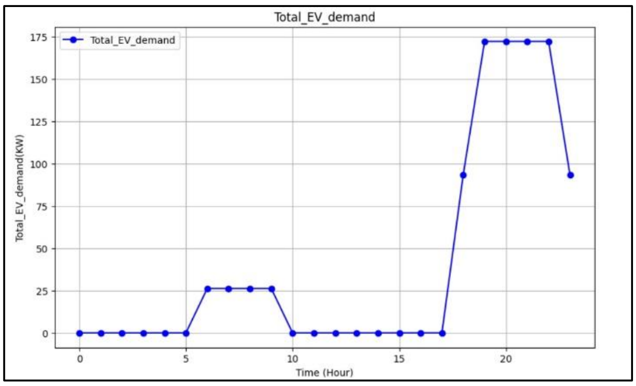


Fig.4.1: EV load demand

Figure 4.1, displays the average load demand of two-wheeler and four-wheeler electric vehicles. The charging pattern is shown considering the information collected from the individuals using electric vehicles.

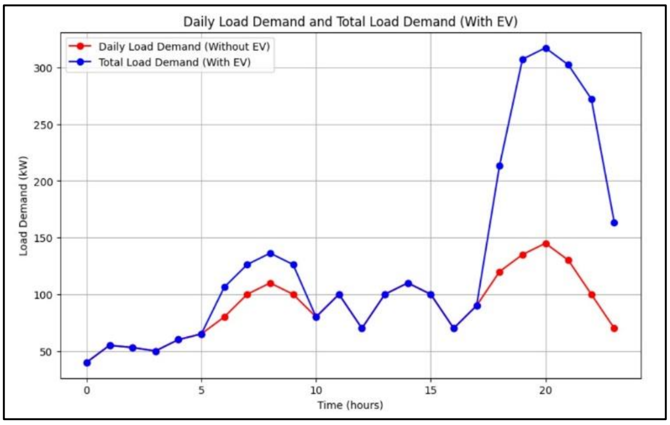


Fig. 4.2. Load demand of the locality.

Figure 4.2 illustrates the daily load demand of a locality. This graph provides essential insight into the electricity consumption patterns of the locality over the course of a day. It can be seen that consumption of electricity is maximum during the period from 12 am to 11 pm.

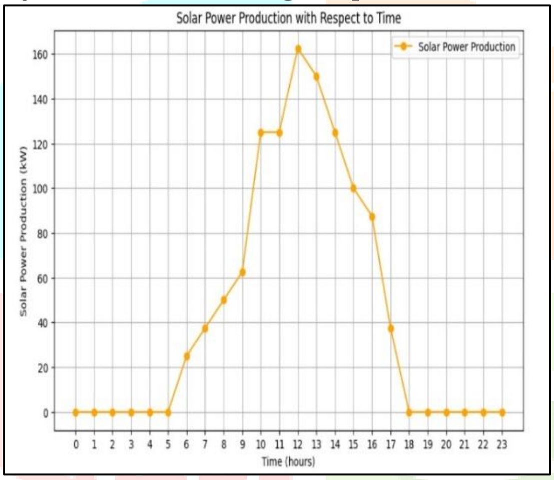


Fig. 4.3(a): Solar power production in a day

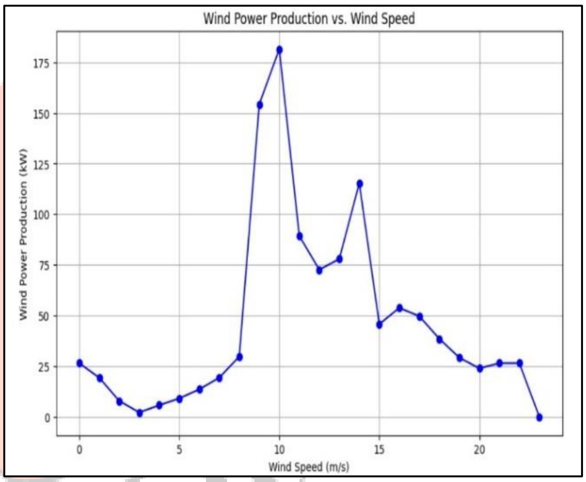


Fig 4.3(b): Wind power production in a day

Solar irradiation and wind speed data for a day is acquired from an existing power plant to capture realistic environmental conditions. Figure 4.3(a) illustrates the amount of electricity that can be produced by the microgrid utilizing solar radiation and figure 4.3(b) shows power produced by wind energy changes with respect to the wind speed.

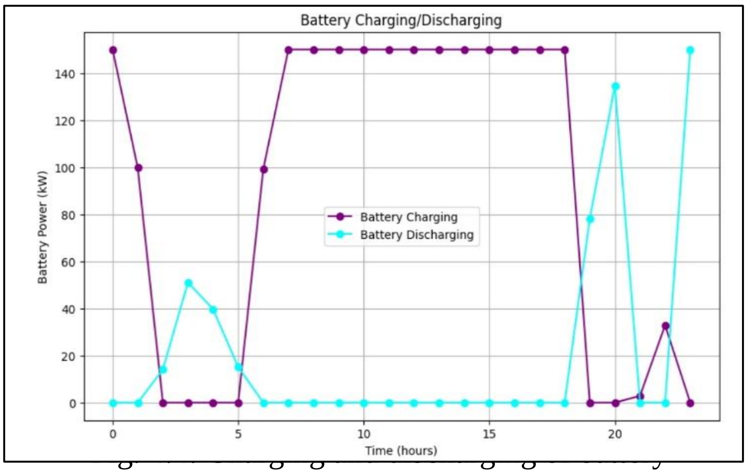


Figure 4.4 displays the charging and discharging patterns of the battery with respect to time. Overcharging and over-discharging of the battery is prevented by setting up the limits. It is seen that battery is charging

during the off-peak time when the power from solar and wind are sufficient to supply the load demand and discharging during the peak time.

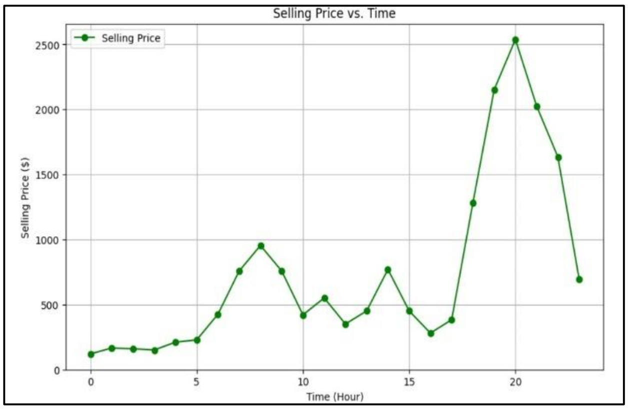
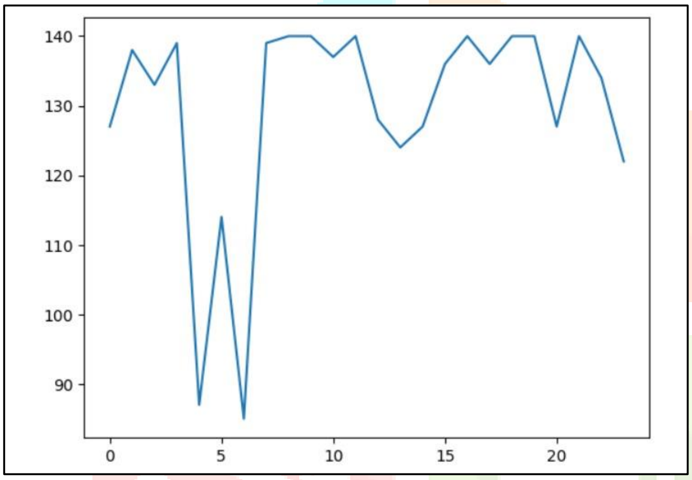


Fig. 4.5. Total selling price

The cost of power from wind, solar, battery, and diesel is estimated to be 2.01 INR/kWh, 2.93 INR/kWh, 2.66 INR/kWh, and 29.38 INR/kWh, respectively, and the total load demand with EV is 3583 kW. The entire installation cost is estimated to be 2.4 crore INR.



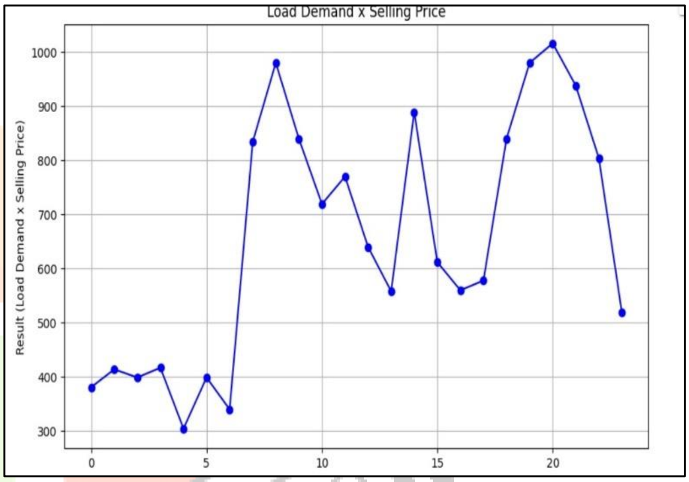


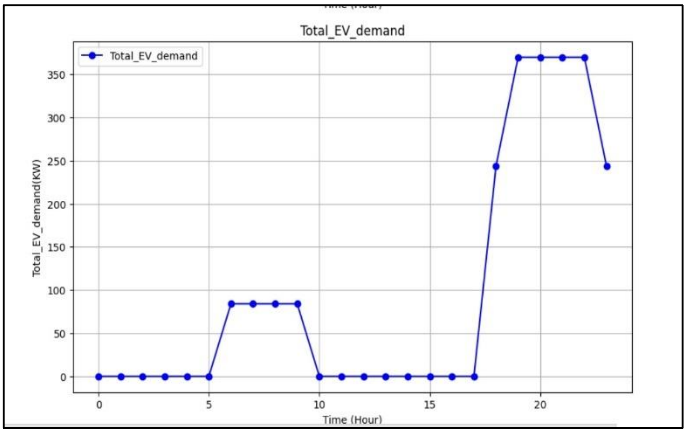
Fig.4.6: Total load demand after shifting

Fig.4.7: Optimized cost

The figure 4.6 and figure 4.7, shows the optimization algorithm, designed to minimize the overall energy bill, has proven to be successful by reducing the cost from 17,904 INR to 15,731 INR. This outcome is highly encouraging and signifies the potential for implementing load shifting and scheduling strategies in smart homes.

4.2 Case 2:

In this case, the system's load demand is analysed by considering constant number of houses and simultaneously increasing the number of EVs. In this case, 700 houses, 200 two-wheelers and 75 four-wheelers are taken into consideration.



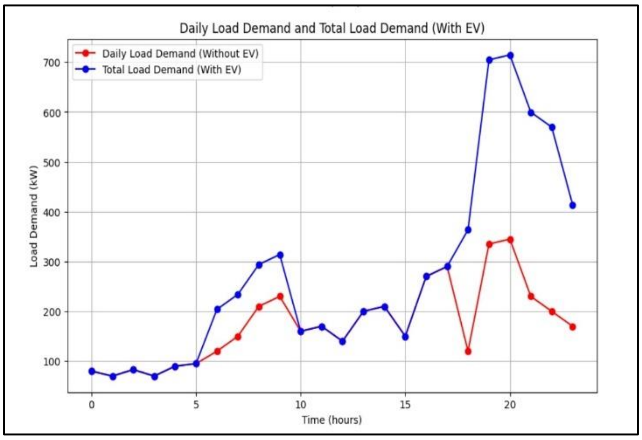
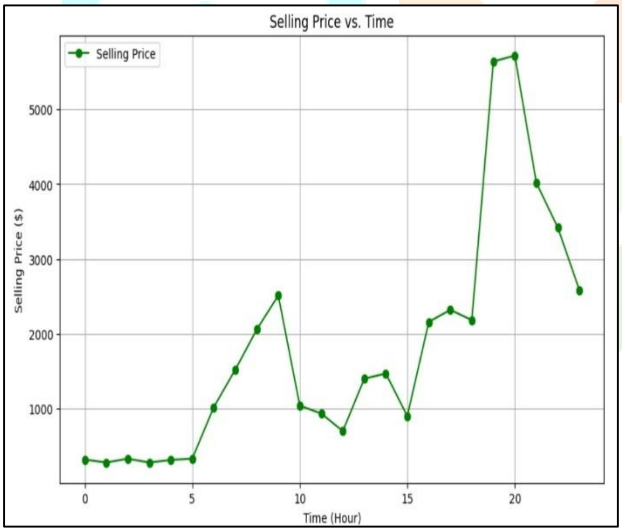


Fig. 4.9. Average load demand of EV Fig.4.10. Total load demand (With and without EV)

The figure 4.9 shows charging demand of electric vehicles for the considered scenario. The comparison between the load demand of the locality with and without EVs is done and is illustrated in figure 4.10. Variation occurs during the charging time of the EVs.



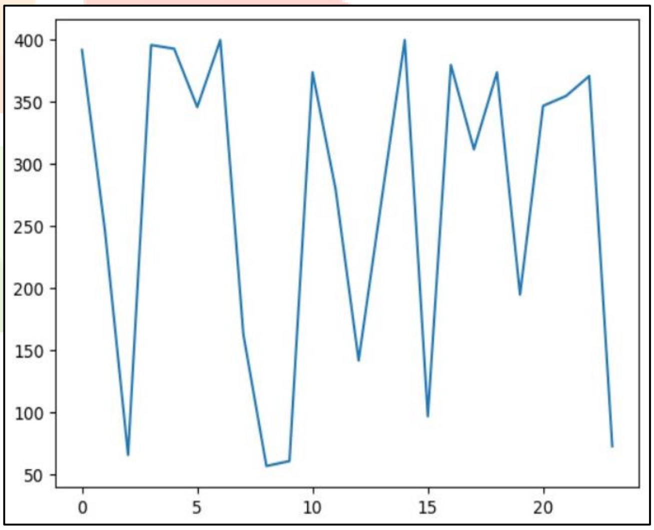


Fig.4.11. Total selling price Fig. 4.12: Total load demand after shifting

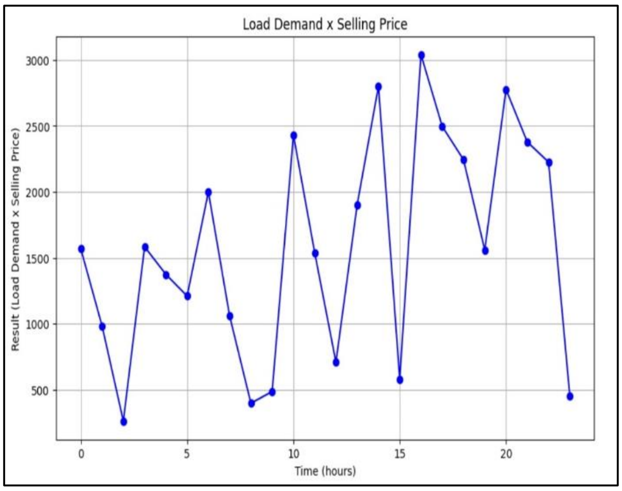


Fig. 4.13. Optimized cost

The figure 4.12 and figure 4.13 shows the optimization algorithm, designed to minimize the overall energy bill, has proven to be successful by reducing the cost from 43,456 INR to 38,076 INR. This outcome is highly encouraging and signifies the potential for implementing load shifting and scheduling strategies in smart homes.

V. CONCLUSION

The aim of this research is to enhance the cost effectiveness of microgrids by integrating electric vehicles (EVs) as part of the load alongside renewable resources such as solar and wind energy. Indeed, the synergy of these components can lead to a more economical and sustainable energy system, characterized by increased efficiency. The primary objectives of this system typically involve maximizing the utilization of renewable energy sources, minimizing energy expenses, implementing load shifting, and ensuring a consistent electricity supply. To achieve these goals and facilitate load shifting, a Stochastic optimization technique is employed. This approach takes into account variables such as battery energy storage, wind and solar energy production, EV charging schedules, and the overall operation of the microgrid. This strategy aligns with the broader trend of integrating electric vehicles and clean energy sources into the energy infrastructure, aiming to reduce carbon emissions, cut energy costs, and enhance energy resilience. It represents a promising direction for advancement in this field.

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