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Efficient Micro-grid connected Solar, Wind, Mini-Gas-turbine, Diesel Generator and Battery Storage Integrated Electrical Vehicle Charging Station with variable capacity

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Abstract

Micro-grid is connected with various energy resources, including wind, solar, micro gas turbine, energy storage system, and raw power form grid. This paper proposes an efficient integrated system to deliver the long term power demand with scheduled in the microgrid. The microgrid is supplying to the electric vehicle charging station works like vehicle to grid interface, which will control the charging time and charging rate. The proposed system should be a properly balanced charging station for flexible load and power generating systems. A variable-capacity plan using integrated microgrid is implemented with four different sources of energy. In the current scenario, the general electric Vehicle charging station needs to charge different cars at a different current rate based on their battery and charging system. Based on the charging rat, the cost of the charging should be collected from the car owner. For the same, this paper proposes an efficient plan for charging and generation units to use the maximum renewable energy and optimal utilization of non-renewable energy. The proposed system calculated that the overall charging station variable operation cost is reduced by 30%. The expansion cost is taken more on wind energy systems, about 140%. Still, the result of the wind energy power generation is far better than the other renewable energy generation unit in the Geographical region of Chennai, Tamilnadu, India. The overall cost optimization obtained by our proposed model is 52% compared to the existing general non-renewable energy-based charging station.

Keywords: *Electrical Vehicle Charging Station, Micro-grid, Variable capacity plan, Renewable energy Integration, Payment based charging system*

1. Introduction

Electrical Vehicle is gaining more attention in the current world in all the segments like a light vehicle, two-wheelers, and heavy vehicles. The principal issue in the electrical vehicle eco-system is charging station location and the charging speed based on its current rate. The ever-increasing load in the charging station is conventionally solved by increasing the network plan. This plan expansion is implemented on generation, transmission, and distribution on the electric grids. This plan expansion technique is one of the costly techniques, which will take at least 5 to 20 years ahead calculation as a long-term plan [1-4].

To expand the generation plan, the capacity available is calculated at the maximum load, if the existing load is not sufficient. The new generation unit will be installed, and this is going to be a very costly process. All the generation process is calculated based on the mathematically model of the system, and the optimization is derived with the help of linear and the non-linear optimization method [2]. To develop this system, it is mandatory to calculate and analyze location, size of the system, technology of power generation, operating pattern, and time take to install the setup all these parameters are included to investigate the investment cost, maintenance cost, operational cost, environmental cost, and reliability. Also, security is another major issue in the electric vehicle charging station, includes technical and economic constraints [3-6]. The main challenge in the power generation expansion is the integration of a new generation system with the existing generation system, transmission, power trade at peak time, renewable energy system integration, energy storage system integration [7]. Energy storage is one of the ideal solutions for peak performance and also storing renewable energy for all time use; the study on energy storage is performed in the research article for expansion plan [8-12]. The new expansion plan is calculated and predicted for the future power demand growth in the optimization method [13]. To reduce the initial investment cost, with security and reliability [14]. Integrating renewable energy systems, energy storage systems, and grid to reduce the cost in an optimal way for the electrical vehicle storage system [15-20].

Integrating the cost calculating for the EV charging usage is used in the proposed system with e-payment methods. A microgrid is a recent development in the field of EV charging stations [21]. The expansion of the charging system is developed and installed with very efficient in the large scale network [22, 23]. The electric vehicle is another energy storage device that is more sustainable in the short term and long term. Also, all the charging station and location of the charging station is mapped with the vehicle GPS and calculated the distance based on the energy available in the car. Every charging station has its level of charging rate. Also, the charging rate will vary on the climatic condition, which will affect the battery temperature. Also, renewable energy power generation will vary based on the climatic condition. In summer, solar energy will be in peak production. In winter, wind energy will be in the peak [24]. The best energy storage technologies are sodium-sulfur, lithium-ion, redox-flow.

This paper proposes an advance energy demand capacity expansion techniques with low cost for a different type of charging rate with several energy sources. The proposed system micro-grid is integrated with a Power grid, windmill, solar panel, diesel generator, mini gas turbine, and energy storage system. The Electrical Vehicle charging station is connected with the microgrid. The proposed system will learn the pattern of the battery recharging system, and it is more flexible for optimal charging in terms of power usage and cost utilization. In the end, all the EV, Microgrid, and available capacity are analyzed under one roof for optimal utilization. Every hour, the availability and the capacity is calculated and shared in the usual cloud so that the data is shared with all the vehicles for the optimal utilization. All the existing advanced technology is adopted, and a new way of analyzing and predicting the power demand is proposed in the system.

The highlights of the proposed system are used to calculate optimal power calculation on hourly basics, regulating the charging rate, charging time, and discharging time are optimized for the expansion cost. Also, the uncertainty of power load and the energy source is calculated based on the stochastic process with a linear model and also considered the operational cost.

2. General Microgrid Structure

Generated electricity through the source like solar, wind, diesel generator, and gas turbine. Also, the energy storage device is connected to the microgrid. A microgrid is a single controlled device that will integrate all the energy inputs and outputs [13]. The microgrid structure is shown in Figure 1. The microgrid model is a bidirectional system in the power network. Renewable and Non-renewable energy resources are connected, and also the energy storage system is integrated with the micro-grid. All the charging systems will be adequately maintained, and it will avoid overcharging and the power wastage. Charging time and the charging rate is adequately regulated and controlled for the best output to maintain the safety and reliability of the battery.

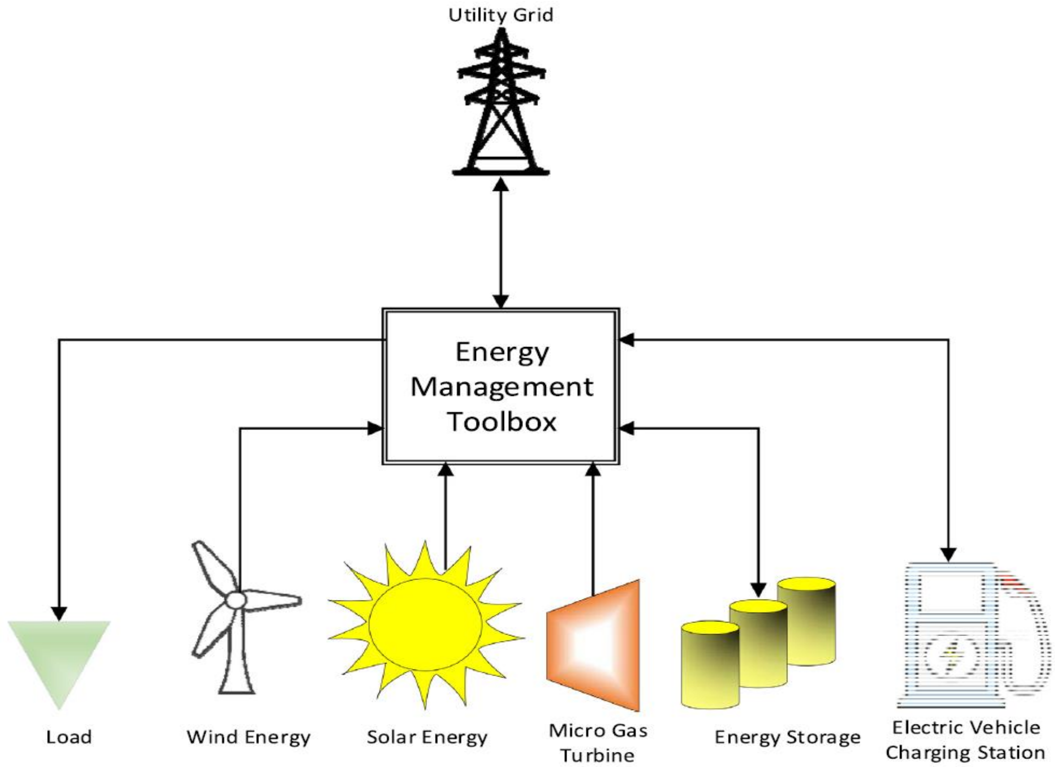

Figure 1: Proposed Structure of Microgrid.

2.1 Model to expand the Capacity:

The ever-growing power demand in the upcoming years will not be adequately supplied by the microgrid. So, it's mandatory to expand the power capacity. Capacity planning depends on the power demand growth rate, charging time, and the charging rate with its new technology. The proposed system with renewable and non-renewable energy resources is adequately calculated to meet the power demand growth of the future.

2.2 Microgrid short term and long term plan:

The proposed model comprises of two terms like short term model and long term model with very efficient optimization technique to avoid the power loss and operational cost. The proposed model is modeled as a flowchart, and the same is shown in Figure 2.

The long-term plan installs new capacity resources, where the short term plan installs new techniques to increase the power demand with proper optimization techniques. Long term plans need cost to implement the new source of energy. The existing resource will be calculated appropriately and utilized with the peak load. If the demand load exceeds the existing resource demand, the new resources will be installed. Based on the demand, the optimal power source is installed to optimize the use of implementation costs. Based on the hourly operation, it is appropriately estimated the power demand. Instant electrical vehicle recharge can be managed by short term plans, and if the demand was not sufficient, then we can manage to install a new long term plan for the proper utilization.

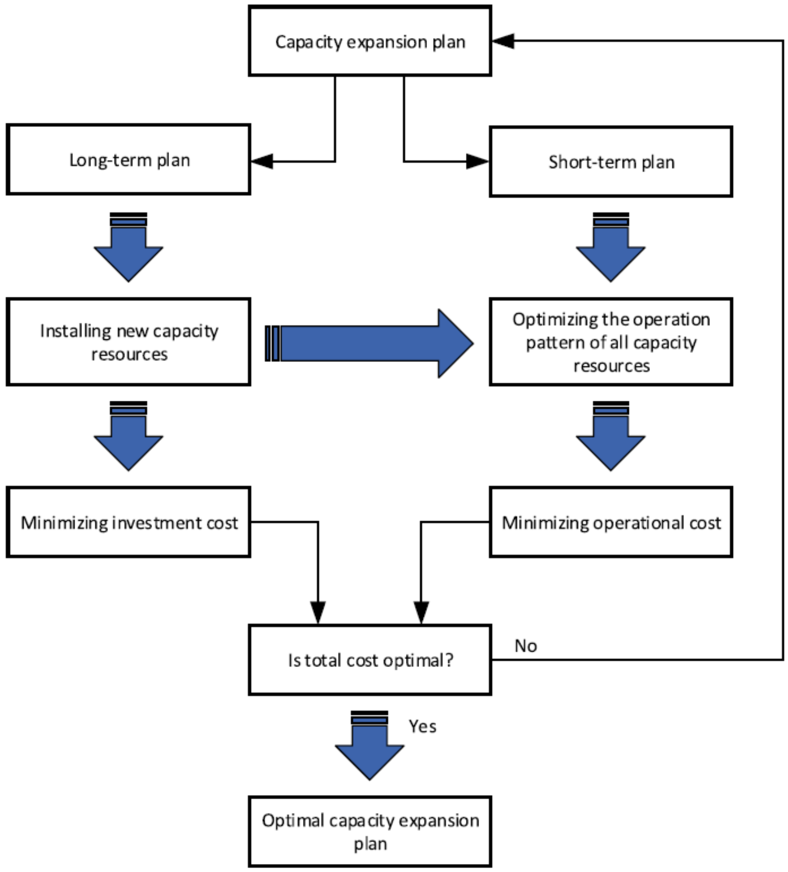

Figure 2: Capacity Expansion Plan Flowchart for Long Term and Short Term.

3. Mathematical model of the proposed system:

The proposed model of the system consists of all types of energy resources, and also it has an energy storage system in it. The cost of investment, operation, and maintenance are also included in the calculation. Total investment and operational cost of Solar panel costs are given in Eq .1 and 2 which is given below.

$$z_{inv}^{sol} = \sum_{y \in Y} (TS_{ins}^{y} \times P_{sol} \times I_{sol} \times A_1 \times A_2) \quad (1)$$

$$z_{ope}^{sol} = \sum_{y \in Y} (TST_{ins}^{y} \times P_{sol} \times O_{sol} \times A_2 \times 365) \quad (2)$$

Where TST is available solar power each year, P_{sol} is rated power of the solar system, O_{sol} is the operational cost of the solar system in $/kW, A_2 is the coefficient of net present value.

The investment and the operation cost of the wind system are given in equation 3 and 4, which is given below.

$$z_{inv}^{win} = \sum_{y \in Y} (TW_{ins}^{y} \times P_{win} \times I_{win} \times A_1 \times A_2) \quad (3)$$

$$z_{ope}^{win} = \sum_{y \in Y} (TWT_{ins}^{y} \times P_{win} \times O_{win} \times A_2 \times 365) \quad (4)$$

The investment and the operational cost of the mini turbine are given in equations 5 and 6.

$$z_{inv}^{mt} = \sum_{y \in Y} (TM_{ins}^{y} \times P_{rmt} \times I_{mt} \times A_1 \times A_2) \quad (5)$$

$$z_{ope}^{mt} = \sum_{y \in Y} \sum_{t \in T} (P_{mt}^{y,t} \times O_{mt}^{y,t} \times A_2 \times 365) \quad (6)$$

The investment cost and the operational cost of the energy storage system is given in equation 7 and 8.

$$z_{inv}^{pes} = \sum_{y \in Y} (TPE_{ins}^{y} \times P_{res} \times I_{pes} \times A_1 \times A_2) \quad (7)$$

$$z_{ope}^{pes} = \sum_{y \in Y} (TPET_{ins}^{y} \times P_{res} \times O_{pes} \times A_2 \times 365) \quad (8)$$

The overall cost of network expansion is given in equation 9.

$$Z_{plan} = z_{inv}^{sol} + z_{ope}^{sol} + z_{inv}^{win} + z_{ope}^{win} + z_{inv}^{mt} + z_{ope}^{mt} + z_{inv}^{pes} + z_{ope}^{pes} \quad (9)$$

In the expansion model, the long term plan installs all the new energy resources like a solar panel, windmill, mini-turbines, and energy storage systems. The short term plan optimizes the hourly uses of the EV charging is optimized with charging time and charging rate.

4. Simulation Results:

The simulation results of the proposed system with microgrid on long term plans are shown in Table 1. This model installs different needs at the different climatic conditions in the year. The hourly profile is shown here.

Table 1.Hourly Profile of Solar and Wind Energy and Load.

Hour	Electricity Price (Rs/kW)	Wind Power	Solar Power	Load Power
1	8	70	0	5
2	8	70	0	5
3	8	70	0	5
4	8	70	0	7
5	8	70	0	8
6	8	80	15	9
7	8	85	15	20
8	12	85	30	20
9	12	70	40	30
10	12	70	80	30
11	12	70	100	40
12	12	90	100	40
13	12	90	100	60

14	12	80	100	100
15	15	60	90	100
16	15	70	85	80
17	15	70	70	80
18	18	80	70	90
19	18	80	60	70
20	18	90	20	60
21	18	90	0	60
22	18	90	0	50
23	18	90	0	35
24	18	90	0	35

The annual cost of the proposed method is calculated correctly and evaluated based on the demand on the hourly based on the long term and short term plans. The power generation of the microturbines in the overall six-year plan and the one year plan is shown in Figure 3.

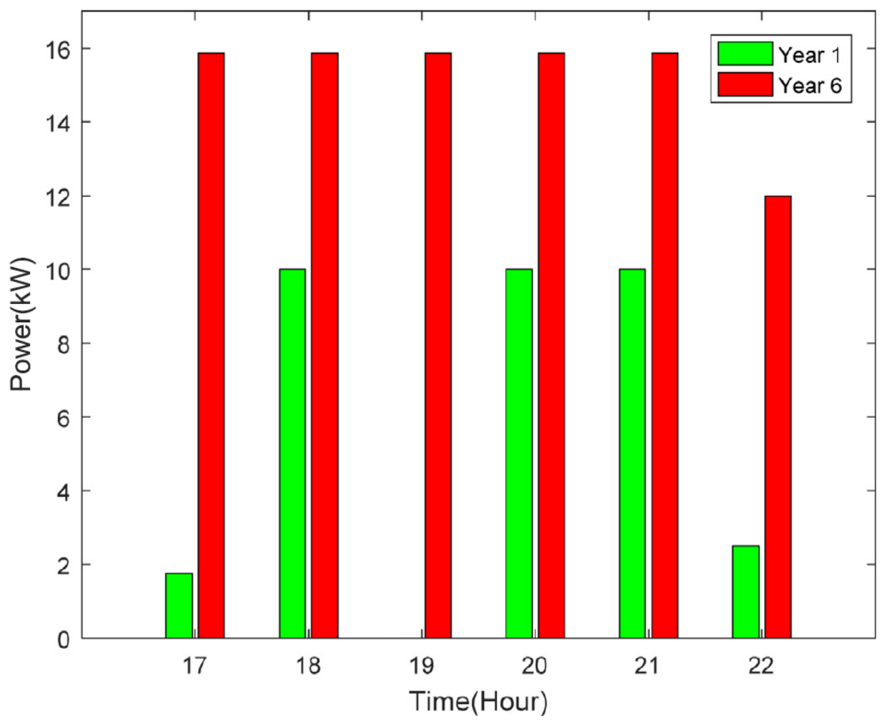

Figure 3: Operation of Microturbine at the beginning and the last year.

The power exchange between the microgrid upstream and the network is shown in Figure 4. Starting from the time of installation and the overall results from year 1 to year six have been observed, and the same is explicitly mentioned. The vehicle to grid-connected technology is shown in the critical component; there is a chance of generating power within the vehicle. At the same time, the brake is applied in the vehicle, and the generated energy is stored in the supercapacitor for boosting the car to accelerate in the necessary place. In this instance, the vehicle needs a huge amount of power. The enormous amount of power is extracted from the Supercapacitor. The overall system is used to generate the power for better optimization and better utilization of battery stored power in the electric vehicle.

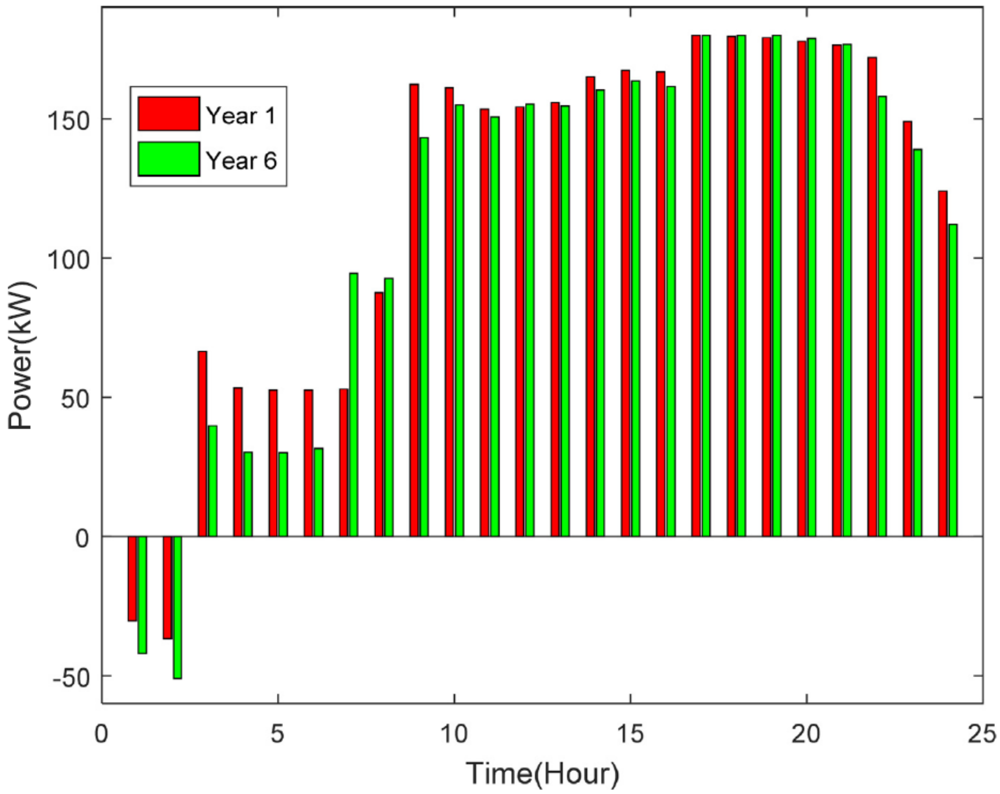

Figure 4: Exchanged power between microgrid and upstream network in different years.

5. Conclusion:

This paper addresses the most important research problem in the field of Electrical Vehicle Charging station load and the expansion capacity issue. All the renewable and non-renewable energy resources are connected with the microgrid, which is connected with network power. Based on the demand, the power generation units will respond by expanding the generation for utilization. A microgrid is connected to Network upstream when the locally generated power is more than the demand. The load growth was modeled for 1 to 6 years, and the same has been simulated and obtained an optimal power usage in the hourly basics. The principal objective is to minimize the investment cost, reduce the operational cost, and reduce the power wastage. According to the results, the expansion cost is major with wind energy, but the output of wind energy is the maximum. On average, the expansion of wind energy is 180% more than solar energy. As a result, the planning cost the EV Charging station cost is reduced by 28%, and the solar energy cost is reducing by 51%. Hence by using our technique, the optimal microgrid is installed and optimally utilized the power.

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