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ENERGY MANAGEMENT SYSTEM IN MICROGRID: A REVIEW

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Abstract - ***Nowadays, the number of consumers in the electricity market is getting increased, which results in an increasing electricity demand. High emissions of greenhouse gases from coal-based thermal power generation result in hazardous health concerns to society. To mitigate this emission, the conventional grid should be integrated with renewable energy resources. But this penetration has some drawbacks such as imbalance in power flow and the need an of energy storage system. This paper presents a literature review about the recent researches that are carried out in the field of Energy Management System (EMS) and Demand Response Management (DRM). This will help the prosumers to meet their demand at a lower energy cost. Further, this paper classifies the work based on the different approaches, strategies and methodologies that are adopted for improving energy efficiency and energy management in the microgrid. Besides, it reviews different optimization techniques that are adopted to address the energy management issues and encourages the customers to use their local generation and also provides the direction for future research at the end of this paper.***

Key Words **- Microgrid, smart grid, energy management system, demand response management, renewable energy resources, battery energy storage system, consumption price.**

1. INTRODUCTION

The demand for electricity in recent years is high due to the dramatic rise in population which results in high emission of greenhouse gases. Alternatively, this results in high demand for coal which becomes uneconomical in future. Researchers are trying to find the best solution to look out another way to meet the demand and also to reduce the emission which is hazardous.

Energy management is efficiently carried out with the help of controllers like Home Energy Management Controller (HEMC) and Energy Market Management Controller (EMMC) which is used to manage load forecasting, minimize the cost price and to manage energy transaction between source and load [1]. To ensure the escalate use of local generation or renewable energy resources and to mitigate the use of conventional fuel, battery sizing plays an important role. The charging/discharging power, exchange of power with the main network and State of Charge (SOC) of energy storage system should be analyzed and controlled in an efficient manner [2].

Electricity pricing is an important factor which is to be controlled and reduced for productive energy management. A stochastic framework for the demand based on which Time of Use (ToU) characteristics can be selected to minimize the electricity price paid by the customer for their demand is stated in [3]. The systematical planning of load scheduling will succour to minimize the energy cost. The central price based energy management and its modeling is formulated in [4] to improve the load scheduling accurately.

This review paper is categorized as section 2 deals with microgrid energy management system, section 3 reviews the control strategies for emission of greenhouse gases, section 4 suggests the control strategies for energy storage system, section 5 deals with the control strategies for energy cost, section 6 reviews the different approaches for demand response management and section 7 presents the conclusion of this energy management system of microgrid.

2. MICROGRID ENERGY MANAGEMENT SYSTEM (MGEMS)

Microgrid is a small-scale power grid that generates the electricity on its own where some of them are integrated with renewable energy resources and it supplies the power to their area or community located nearer to it. In microgrid, an energy management system mainly concentrates in some areas like renewable energy resources, SOC, ESS charging and discharging powers, greenhouse gas emission and load scheduling (demand response) for effective management as shown in Fig -1.

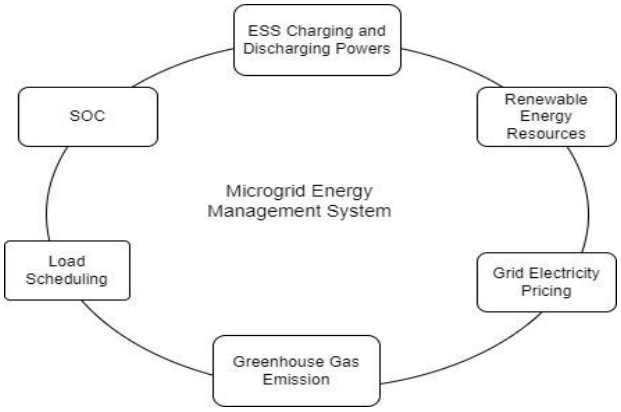

Fig -1: Microgrid Energy Management System (MGEMS)

Renewable energy resources can be utilized for the generation of electricity which reduces the emission of greenhouse gases. Due to the supplementary use of RER's, the battery energy storage system becomes the vital part of microgrid. Smart use of battery with the proper sizing will reduce the cost. For an optimal planning, demand response management (load scheduling) has to be included with an algorithm that gives fast convergence. The demand should be met by the local generation (RER's) so that the energy trading from microgrid will get reduced which in turn reduces the electricity cost.

3. CONTROL STATEGY FOR THE EMISSION OF GREENHOUSE GASES

The most important challenge the world facing is energy crisis which makes us to produce large amount of energy. While generating the electricity in traditional way, the air pollution and emission of greenhouse gases is getting increased. In thermal power plant fossil fuel is the main creator of air pollution. Usually energy accidents like pipeline leak, exploding drilling platforms and the dumping of millions of gallons of oil into the ocean are occurred due to fossil fuels. To reduce its emission, one of the finest way is the introduction of renewable energy resources [5]. In this section, the method to control the emission of greenhouse gases is discussed.

3.1. Mixed Integer Linear Programming

Mixed integer linear programming is formulated in [6] for the microgrid energy management system. In this method, hybrid power resources such as solar power, wind mill, distributed generator, fuel cell and battery energy storage system are used to produce a clean energy. Some of the details like cost of energy, fuel and total cost are given as an input to the system. The estimation of load for the algorithm and the difficulty for the management of energy will be increased by using energy storage system (ESS). The charging and discharging state of implementing DLC based DR program, the emission of CO_2 is reduced to 51.60% per year comparing with conventional grids.

4. CONTROL STRATEGY FOR ENERGY STORAGE SYSTEM (ESS)

Substantially the power that is generated in traditional method will be stable and balanced. When the renewable energy resources are integrated in the microgrid, it will create the imbalance in power flow. To produce a balanced power flow to the load, Energy Storage System (ESS) will be essential [7] in a microgrid. The important control strategies of ESS in microgrid for optimal planning are shown in Fig -2 [8].

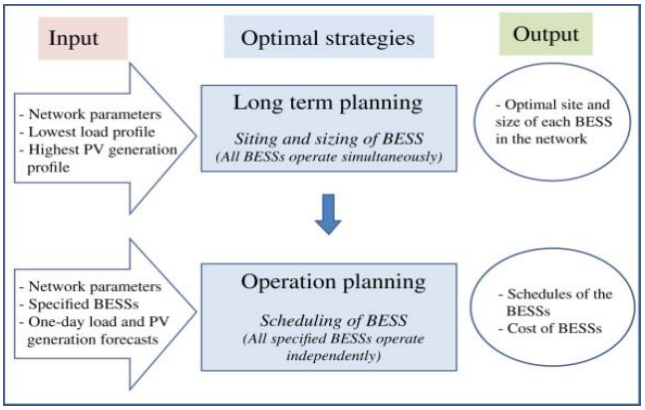

Fig -2: Control strategies for ESS [8]

4.1. Grey Wolf Optimization Technique

For the optimal use of renewable energy resources and to reduce the fuel usage, proper energy management and battery sizing is important. Grey wolf optimization is one of the optimization algorithm proposed in [9] for intelligent energy management. In this method, lithium battery is used and they implemented 24h monitoring method for microgrid operation to set the charging and discharging rules for storage devices. After monitoring, the signal will be generated according to the price factors (comparison of local generation price and utility market price). After comparison, grey wolf algorithm will make the charging decision. As per [9], by using GWO technique 33.185% of operational cost is reduced with the smart utilization of BES.

4.2. Mixed Integer Linear Programming

In microgrid, to improve energy efficiency and to minimize the energy cost the SOC of ESS should be predetermined. Mixed integer linear programming with fuzzy inference system [6] is used to decide at which rate ESS should be charged and discharged. The information of load demand, RER generations, electricity prices, characteristics of MG and SOC state of ESS are fed to fuzzy system and optimization algorithm to determine the amount of power exchange from RER or grid to the load. In the absence of fuzzy scheduling system of ESS, MGEM operates in dynamic programming method. In the presence of fuzzy system it goes out of dynamic programming method and is optimized for each hour of the scheduling period separately.

5. CONTROL STRATEGIES FOR ENERGY COST

In the modern day demands more electricity in traditional grid, the penetration of renewable energy resources in microgrid becomes essential. Hence, demand side management is essential for prosumers to reduce their electricity cost [10] and hence making the grid more efficient. The below sections deals with some of the methods to mitigate the electricity cost for the prosumers.

5.1. Multi Objective Grey Wolf Optimization Technique

An efficient energy management system called Multi Objective Grey Optimization Technique (MOGWO) is approached in [11] to mitigate the issues in microgrid. This algorithm is adopted with the help of two controllers: Home Energy Management Controller (HEMC) and Energy Market Management Controller (EMMC). The details of energy providers and load are given to these controllers. Then the decision will be made by the control agent and whether the energy should be traded from grid or RER. With the help of this algorithm, energy cost is reduced from 29.9% to 62.2%.

5.2. Novel Rule Base-Bat Algorithm

Novel rule base-bat algorithm is suggested in [12] for energy management in microgrid. The hourly values of P-Q of the DG's, SOC of ESS, energy cost, main grid power and OLTC tap position are predicted and fed into this algorithm. After that the charging and discharging state of ESS, the hourly price of DG's and price of ESS charging is compared by this algorithm and power flow analysis is conducted in MG using Newton-Raphson method. This method maximizes the profit of MG with shorter computation.

5.3. Affine Arithmetic (AA) Method

Most of the researches in EMS are done with assumed and predicted data. But [13] proposes Affine Arithmetic Unit Commitment (AAUC) method where the EMS is performed at the computational cost without any assumptions regarding the statistical characteristics of the uncertainties. This approach mainly focused to find the commitment status of dispatchable resources and the parameters of the affine form as in [14] which are then converted into random variable. Now AAUC will produce the dispatch set point using optimal power flow which generates balanced power at reduced cost.

5.4. Genetic Harmony Search Algorithm (GHSA)

One of the essential components of smart grid is the energy management system to meet the demand efficiently at lower cost. For this purpose, an efficient home energy management controller (EHEMC) based on genetic harmony search algorithm (GHSA) is proposed in [14]. In this real time electricity pricing, critical peak pricing and HEMC are considered and the appliances are classified based on their energy consumption. GHSA shows ON/OFF status of the appliances. The electricity cost will be calculated only at the ON status of the appliances so that the wastage of electricity will be reduced. With the help of GHSA, for single home the electricity expense is reduced upto 46.19%.

6. DEMAND RESPONSE MANAGEMENT

Demand response is considered to be economical in microgrid. The Demand Response Management (DRM) produces interaction between the energy providers and the customers to meet the energy requirements [15]. For this, the prediction of net load demand, load forecasting according to the penetration of renewable energy resources and the problems related to load scheduling should be well known for the efficacious energy management in microgrid [16].

6.1. Bayesian Optimal Algorithm

A data-driven energy management solution based on Bayesian-optimization-algorithm (BOA) is proposed in [17] for a single grid-connected home microgrid. To solve online optimization problem, a model free and data driven solution is designed in [17] where the flexibility and ability to achieve long term optimization is attained with time varying objective functions.

6.2. Co-Evolution Algorithm

For an optimization within and outside microgrid, a new energy management model is designed in [18] which suggested Lagrangian multiplier and Co-evolution algorithms. To reduce the number of energy purchase from external grid, it introduces a demand mechanism and optimized energy storage units in three different schemes. If the external microgrid cannot meet the demand, then it will give priority to the neighboring microgrid and then the public grid. By utilizing these schemes, the ToU electricity price and real time electricity price can be managed effectively.

6.3. Fuzzy Expert System

For demand side management, automatic decision making regarding energy management system is important. A Fuzzy Expert System is proposed in [19] for an optimized energy consumption to load. The electricity price, RER details, grid power and demand were given as an input to fuzzy system. Next fuzzification of input and defuzzification of output will be done. The output of fuzzy system will have three options to decide. The energy transactions to the load are mostly done with the renewable energy resources with the continuous adjustment of input data.

6.4. Artificial Neural Network

Inorder to achieve greater independence of microgrid, [20] developed a microgrid dynamic model through Artificial Neural Network (ANN) to predict the scheduling of programmable loads. On the basis of monthly load management maps, the scheduling of programmable loads known weather conditions relative to day and to one day before and the weather forecast for the day after was suggested.

7. CONCLUSION

Integration of renewable energy resources in microgrid has brought a dramatic change in the field of microgrid which mainly concerns about the reduced emission of greenhouse gases. But this penetration may affect the balanced power flow, reliability and stability of the system which needs an efficient energy management system. This paper reviews about the control strategies that had been adopted for the mitigation of greenhouse gases. It also provides information about the methods and techniques that were used to find the best sizing and designing of battery energy storage system. This article also discuss about the recent strategies that were formulated for the optimal planning of the load scheduling and the ideas to reduce the energy cost were also suggested which leads to future research directions to develop more advanced and robust EMS in microgrid.

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