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Review on Enhancement of Power System Demand Side Management and Forecasting of Grid Performance Using Machine Learning Approach

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Abstract- Renewable energies are being introduced in countries around the world to move away from the environmental impacts from fossil fuels. In the residential sector, smart buildings that utilize smart appliances, integrate information and communication technology and utilize a renewable energy source for in-house power generation are becoming popular. Accordingly, there is a need to understand what factors influence the accuracy of managing such smart buildings. Thus, this study reviews the application of machine learning prediction algorithms in Home Energy Management Systems. Various aspects are covered, such as load forecasting, household consumption prediction, rooftop solar energy generation, and price prediction. Also, a proposed Home Energy Management System framework is included based on the most accurate machine learning prediction algorithms of previous studies. This review supports research into the selection of an appropriate model for predicting energy consumption of smart buildings.

Index Terms- Home Energy Management System, Machine Learning algorithm, Prediction, Forecasting, Optimization

I. INTRODUCTION

In past couple of decades, existing power grid couldn't find any major changes and improvements when compared to the domains like automotive, biomedical instrumentation, nano science, aeronautics, space research and Information and Communication Technologies (ICT). At present, the power grid system is facing major challenges due to increase in population, industries, buildings and residential homes. In addition to that present power grid is intricate in nature and interconnected with different energy sources as well as different transmission voltages. If any failure occurs in a small region, then it will affect the entire region with cascading failure happening simultaneously. As a result, service providers would not be able to satiate the consumers power need and consumers will face major issues like brownout, blackout and power fluctuations. In the present power grid system, the power outages are common issues, moreover people are habituated to these power cognate issues.

These mentioned issues engender astronomically immense damage in the electrical appliances and it is very arduous task for the consumers to manage it. Consequently, there is a necessity to manage the entire energy system to operate at low cost and optimize the energy consumption.

Electrical appliances have been treated as a separate passive device which is connected to the power system in the distribution end. Moreover, the consumers are considered as a passive component because they consume the power and pay the bill blindly without any erudition of energy tariff models. However, there is an essential need to convert these passive components into active to make the energy system perspicacious and make the consumer as an active player to gain the erudition about tariff, billing and power incentives provided by the service providers.

The impeccable and timely approach solution is smart grid which provides a consummate solution to above mentioned power cognate issues with active consumer participation. Smart grid is solution for the aforementioned issues with greatest challenges in the implementation (Gungor et al. 2011). In order to utilize the smart grid technology in a better and efficient mode, there is a need to upgrade the electrical devices used (example, analog and digital meters into smart meters) and secure communication infrastructure (example, wired to latest wireless) of the exiting power grid system.

II. CONVENTIONAL POWER GRID

The existing electrical system is intricate in nature and it is distributed across the entire country. It can be broadly classified into three categories:

- Power generation
- Power transmission
- Power distribution

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1. Power Generation

Power is generated in the power generation plants which is either located at a remote location or local generation stations. The most of the common power generation techniques are based on the conversion from one form of energy to another. Also, the natural sources such as wind and sunlight can be used to generate electrical energy. The energy sources can be classified as renewable energy sources and nonrenewable energy sources.

The different energy generation sources are Hydro, thermal, solar, wind and nuclear. Energy generation from the energy sources like thermal, hydro and nuclear power plants are reliable and available most of the times. Solar and wind power are unpredictable in nature which is not reliable. Many countries are trying to increase the percentage of energy generation through renewable energy sources to reduce their energy bill.

2. Power Transmission

Transmission is the process of transferring the generated power from the generation station to substations. The low voltage current is converted into high voltage through transformers to reduce the transmission losses through the transmission lines.

Energy is generated and transferred at a frequency of 50 Hz or 60 Hz depending upon the individual country standard and power grids operates on maximum voltages of 110 kV, 230 kV and 400 kV in the transmission networks.

3. Power Distribution

Distribution is the process of converting high voltage into low voltage and distributing the electrical energy to the end users. In this distribution point, power is transferred at a frequency of 50 Hz or 60 Hz and less than 110 kV voltages i.e. low voltage 230 V, 440 V. Energy is transferred from transmission system to consumers through intermediate substations and transformers which reduce voltage levels to the required levels of consumers (the normal residential user has a supply voltage of 230 V).

The conventional electric grid consists of a huge network and transmission lines, aforementioned components like generation station, substation, transformers, feeders and measuring meters and other devices which can able supply the electricity from the generation station to residential homes, industries and commercial buildings.

The existing system is built in a couple of decades ago. The existing transmission faces huge loss during the transmission from generation station to distribution station (Zhao et al. 2008). There is a necessity to update the power grid into a smart grid to avoid the existing socioeconomic problems.

III. DEMAND SIDE MANAGEMENT

Demand Side Management (DSM) is the process to satisfy the consumer energy demand through various methods like financial incentives, demand response scheme, scheduling etc (Lopes et al. 2013). In the smart grid, with the help of the emerging DSM techniques, service provider can able to transmit and distribute the generated power to consumer with low operating cost. But in real time due to the issues which are discussed earlier is a complex task.

The DSM approach manages and controls the required end users energy without adding an additional generation unit. It manages the demand with the available energy sources by introducing the scheduling algorithms and energy prediction methodologies. A proper energy prediction and energy scheduling mechanism with the advanced ICT satisfies the residential home demand response. Demand response reduces the peak energy usage and it avoids the over utilization of power grid. Moreover, this will brings the cost benefit for consumer by applying the proper scheduling policies. Further, it makes the consumer a live player in the power market while they are entirely passive in the past decades. The proposed research focuses on the automatic adaptation of power consumption and pricing models that can support consumer to save their energy bills.

IV. LITERATURE REVIWE

Imrus Salehin et al. [1] The “BanE-16” dataset is a comprehensive repository integrating electricity grid dynamics with meteorological variables for machine learning-based energy forecasting. Featuring peak energy demand, environmental factors (temperature, wind speed, atmospheric pressure), and electricity generation statistics, this dataset enables intricate analysis of weather-energy correlations. Its multidimensional nature facilitates predictive modeling, exploring intricate dependencies, and optimizing energy infrastructure. Leveraging machine learning methodologies, this dataset stands as a catalyst for innovative forecasting models and informed decision-making in energy management.

Benedikt Nilges et al. [2] Demand-side management via load shifting allows synchronizing electricity demand with supply from fluctuating renewable energies. Synchronizing seems desirable so that electricity from renewables will not be curtailed and overall greenhouse gas (GHG) emissions can be reduced. However, the change in GHG emissions by utilizing load shifting in electric power systems depends on the prevailing electricity generation mix. Although some publications discuss the impact of load shifting on the GHG emissions of specific electric power systems, a systematic analysis on the GHG emissions due to load shifting in general is still missing.

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Shui Yu et al. [3] In view of the excessive energy consumption caused by building demand-side matching, it is very important to combine energy storage systems and renewable energy to improve equipment energy efficiency and building energy efficiency, and correctly match demand-side management (DSM). This paper combines the energy coupling system with demand-side management to get the best balance of energy production and power grid load pressure. A photovoltaic/thermal coupling system that can be combined with heat pumps and energy storage in a single building is proposed, and a dynamic simulation model is developed to describe its operating performance. The simulation results show that the coupling system has a good energy-saving effect in the heating and cooling seasons.

Xiangfeng Zhou et al. [4] To accommodate wind power as safely as possible and deal with the uncertainties of the output power of wind- driven generators, a min-max-min two-stage robust optimization model is presented, considering the unit commitment, source-network load collaboration, and control of the load demand response. After the constraint functions are linearized, the original problem is decomposed into the main problem and subproblem as a matrix using the strong dual method. The minimum-maximum of the original problem was continuously maximized using the iterative method, and the optimal solution was finally obtained.

Abdulrahman H. Ba-Alawi et al. [5] A reverse osmosis (RO) desalination plant powered by solar and wind energy resources is a promising sustainable solution to meet the increasing freshwater demand. However, the high energy consumption and complex management of systems present significant design and operational challenges.

Wei Yang et al. [6] Load management can improve the overall benefit of power system through peak cutting and valley filling, whose performance depends on the accuracy of load forecasting. However, how to efficiently utilize load data to uprate forecasting performance is urgent. Therefore, a peak cutting and valley filling forecasting algorithm based on load operation state is proposed. Firstly, adaptive data decomposition based quantile-long-short-term memory (QLSTM) probabilistic forecasting framework is proposed to reflect the future load information more comprehensively.

Abhishek Kumar et al. [7] This research work presents the tri-level optimization framework for the optimal scheduling of grid-connected and autonomous microgrids to diminish power losses and maximize loadability. Since the network's voltage profile depends on the loading level, the flexible load shaping-based demand-side management strategy is incorporated to investigate its impact on microgrid loadability. With the consideration of uncertain parameters related to renewable power generation, load demand, and power loss, voltage limit constraints, the resultant problem is formulated as a stochastic mixed-integer non-linear problem to enhance microgrid loadability and optimize daily operating costs.

Jing Wang et al. [8] This paper addresses microgrid energy management in the presence of distributed generation and active loads while accounting for operational, economic, environmental, and reliability factors. The objective is to minimize the cost of shutdown during N-1 contingencies, projected emission-related expenses, and the overall operational cost of microgrids integrated with distributed generations. A stochastic scheduling technique that optimizes short-term microgrid operation, reducing costs and pollution through renewable resources is introduced. Utilizing demand response programs among residential, commercial, and industrial participants is proposed to counter the uncertainty of renewable resource-generated power.

Mehdi Esmaeili et al. [9] In this paper, a robust power management system (RPMS) for a DC microgrid is proposed. A novel neural network-based scheme is proposed for the PV cells' generation prediction using ultraviolet (UV) index, temperature, and cloud coverage which gives a considerable improvement in the prediction error in comparison with the existing works. Moreover, another neural network predicts the demand for the microgrid. The proposed RPMS will make decisions under the uncertainties of these prediction errors such that the system stays robust and works near the optimal operating point. Besides, three different possible scenarios for operation of the microgrid are considered which represents all real operating conditions.

Firmansyah Nur Budiman et al. [10] Power quality (PQ) issues are direct consequences of integrating power electronics components and non-linear loads into microgrids. These issues can also be triggered by an unbalanced loading in the microgrid. Certainly, they affect the daily operation scheduling of the microgrid. This paper proposes an optimal harmonic power flow (OHPF) framework for the daily optimal scheduling of a grid-connected microgrid, which is constructed by combining the optimization formulation and harmonic power flow (HPF). Within the framework, PQ is evaluated by observing three indices including voltage magnitude, voltage total harmonic distortion (THD), and voltage unbalance factor (VUF). A non-iterative mitigation scheme based on demand side management (DSM) is proposed to avoid PQ indices violations and is integrated into the optimization formulation part of the OHPF as a set of load constraints.

V. CONCLUSION

Increasing energy demand puts pressure on the power grid to balance supply and demand. Smart grids can play an important role. In these systems, data related to energy use are regularly collected and analyzed to obtain energy

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consumption. The usage patterns obtained can be useful for demand and load forecasting. This is a challenging task in the context of smart environments, which is why researchers are putting special efforts into this.

To meet today's demand forecasting challenges, where smart grids generate large amounts of data, it is necessary to use modern data-driven techniques. Deep Learning based models are a good alternative. Traditionally, research has focused on forecasting customers' energy consumption using the small historical data sets available on their behavior. However, current research applying Deep Learning methods has demonstrated better performance than conventional forecasting methods.

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