ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 5, Issue 2, February 2018

Residential Energy Optimization in Smart Grid Perspective

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Abstract: - **Recently intensive efforts have been made on the transformation of the world's largest physical system, the power grid, into a "smart grid" by incorporating extensive information and communication infrastructures. Key features in such a "smart grid" include high penetration of renewable and distributed energy sources, large-scale energy storage, market-based online electricity pricing, and widespread demand response programs. From the perspective of residential customers, we can investigate how to minimize the expected electricity cost with real-time electricity pricing, which is the focus of this paper. By jointly considering energy storage, local distributed generation such as photovoltaic (PV) modules or small wind turbines, and inelastic or elastic energy demands, A salient feature of our proposed approach is that it can operate without any future knowledge on the related stochastic models (e.g., the distribution) and is easy to implement in real time. We have also evaluated our proposed solution with practical data sets and validated its effectiveness.**

Index Terms - **Smart grid, optimal power management, energy storage, renewable energy generation, real-time pricing.**

I. INTRODUCTION

Electrification, as made possible by the electric power grid, has been selected as the most significant engineering achievement of the 20th Century by the US National Academy of Engineering . However, not until recently has the imperative of revitalizing US electric infrastructures been realized and a lot of efforts are being put into the grid modernization, which transforms the century-old power grid to the "smart grid." This transformation has been motivated by the following notable drivers:

1) The physical infrastructure of the electric grid is aging and overburdened. The electricity demand continues to rise while the investments in the power transmission and distribution infrastructure have been dwindling.

2) Concerns over global climate change (e.g., global warming) and carbon emissions have forced us to aim at more aggressive goals of deep integration of large amounts of renewable generation, especially wind and solar, to meet our electric energy needs. As stated in , the smart grid would be the enabler for meeting environmental targets, accommodating a greater emphasis on demand response (DR), and supporting widespread plug-in hybrid electric vehicles (PHEVs) as well as distributed generation and storage capabilities. To realize such vision for the smart grid, we have to seek helps, from advanced communication, information, and control technologies in conjunction with advances in renewable energy generation, energy storage, materials, sensors, and power-electronics.

Although the smart grid is not a reality as yet, we can articulate how to design it to achieve the vision. We envision that the smart grid will consist of the following essential components in addition to the traditional power grid

1. Renewable energy generation: Given the significant concerns regarding climate change, green energy such as solar and wind energy has become critical for our future energy sustainability. Most states in the US have developed their own renewable portfolio standards (RPSs), which require a predetermined amount of a state's energy portfolio to come exclusively from renewable sources by the next decade. However, the intermittency and variability of wind and solar energy impose a significant challenge to the grid operation when the penetration level increases.

2. Energy storage: Energy storage can alleviate the need to generate power at the time when needed and can smooth out the variations of energy utility due to random power demand and uncertain energy supply, which is desirable due to economic con-sideration and incorporation of more intermittent renewable sources. Examples of utility-scale energy storage include compressed air, pumped hydro, ultra capacitors, flywheels, fuel cells as well as batteries. In residential areas, energy storage is practically synonymous with batteries. Due to the popularity of the emerging PHEVs, the batteries in them may be treated as temporary electricity storages for residential customers .

3. Demand side management: While traditional power system is designed for highly controllable supply to match a largely uncontrolled demand, a new energy balancing paradigm in the smart grid is needed in order to facilitate greater penetration of variable renewable energy sources. As noted in, over 10 percent daily energy consumption in the US is from the usage of appliances such as water heater, air conditioners, cloth dryers, and dish washers, which are envisaged to become "smart" and have the following distinct features: their energy demands are elastic and delay tolerant, i.e., as long as their energy demands are met within certain time limits, the customers would be satisfied. We call these appliances the energy consumers while other appli-ances, which should be powered whenever needed, are referred to as the power consumers. By utilizing the flexibility in the consumer side and providing appropriate incentives (such as real-time pricing), we can reduce the peak demand in the electric power grid and lower the need for expensive peak load generators. Within the smart grid, advanced dynamic control will be required for simultaneous management of real-time pricing, flexible loads, electric vehicle charge, solar, wind, and other distributed generation sources, many forms of energy storage as well as microgrid management. In the smart grid, we expect more and more renewable generators will be located at the side of residential customers due to environmental concerns.

Moreover, by generating power close to the premises where the energy is needed, we can greatly reduce the transmission line losses associated with power delivery from remote power plants and significantly relieve the congestion due to limited transmission capacity of power lines. For example, residential customers may be interested in rooftop photovoltaic (PV) system because of its least environmental impact, scalable capacity, as well as decreasing cost. A basic PV cell converts sunlight of certain wavelengths into direct current (DC) using the "photo-electric effect." Unfortunately, a basic PV cell typically generates only a small amount of power, which may not be enough to power a whole household. However, due to their modularity and portability, PV cells can be easily inter-connected to form a PV panel to meet any electrical requirement, no matter how large or small it is. Although the current cost on PV systems is still high (around $10 per watt installed), it is expected to reduce by two or three folds in the future. Therefore, in this paper, we select a PV system as the renewable energy source for our study. However, our model is quite flexible and can be easily adapted to other forms of renewable energy sources. A practical system model consisting of the aforementioned essential components in the smart grid for residential customers is shown in Figure.

Since solar energy cannot be dispatched and the fluctuations in solar irradiance may occur in a minute-to-minute time scale, the energy generating profile of a PV system does not coincide with residential energy demand profile for most of the time. There may be electricity spillage at daytime when the PV electricity generation is high and electricity shortage at nighttime when the PV electricity generation is low. To cope with this mismatch, energy storage may have to be used.

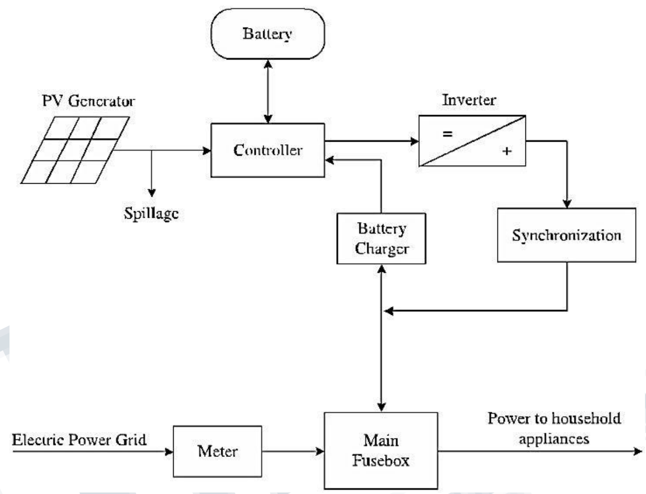

Fig.1 A PV-utility grid system with the energy storage for residential customers in the smart grid

By storing some excessive generated electricity at daytime, it can be released at nighttime to supplement the power usage for a household. Intuitively, through this method, the total amount of electricity drawn from the electric utility grid can be reduced. Unfortunately, battery charges and discharges will impact the operational life of a battery. In order to protect the battery from overcharge and over discharge, a controller is needed to regulate the charging and discharging process. Because of the finite capacity of energy storage, some PV generated electricity may still be spilled. As the power generated by PV panels is DC, an inverter is needed to convert DC into alternating current (AC) before it can be used by household appliances. Moreover, a synchronization device is required to adjust the voltage phase and magnitude of the output power from the inverter, so that the output power can be combined smoothly with the power drawn from the electric utility grid to supply electricity to household appliances together. This combination is usually completed at the main fusion box. In the smart grid, customers would be enrolled in a real-time electricity pricing environment, where the electricity price is time varying. The electricity drawn from the power grid can also be stored in the battery through the battery charger so that it can be reused later. Intuitively, the total electricity cost can be reduced by recharging the battery from the electric power grid when the electricity price is low while discharging it during the high electricity price period. Obviously, it is challenging to manage the use of both the traditional energy and the harvested renewable energy to overcome the variability in the energy supply from the renewable energy source and the energy demand from residential customers while minimizing the cost of traditional energy usage. In this paper, we take the first step to investigate the optimal power management for residential customers in the smart grid by utilizing the battery storage facilities so in this way we can able to save energy and can able to reduce our electricity price. The studies most relevant to ours are , in which short-term resource scheduling for an integrated thermal and renewable generations with battery is used to minimize the total thermal generation cost. These studies are from the perspective of power generators and assume that future renewable generation profiles are known beforehand or can be forecasted. However, we consider the long-term time-average expected electricity cost from the viewpoint of residential customers and assume that future knowledge of all related stochastic models are unknown. Therefore, our problem is more challenging. The ideas on using available energy storage to reduce electricity cost at a data center in real-time pricing environment is proposed

II. CONCLUSION

In this paper we have proposed renewable energy generation and optimal way of energy storage method for reducing electricity cost for residential Customer in smart grid. The intuition of our approach is to use storage energy and to harvest excessive renewable generation for later use and to charge the battery when the electricity price is low while dischargeing it when the electricity price is high.

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