Poster Abstract: Towards Developing a Large Energy Store using Small Scale Distributed Batteries

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ABSTRACT

Electricity is perhaps the only resource that has to be consumed at the moment it is produced. Due to expensive storage, large quantity of electricity cannot be stored for optimal operation of the grid. However, in recent times, large scale batteries are making inroads to the power sector. But, large scale batteries are still prohibitively expensive, thus cannot be readily used with reasonable return on investment. We propose to create a large virtual energy storage system (ESS) using myriad number of small scale batteries. Using a large central electricity storage suffers from disadvantages of capital, operational and maintenance cost and decrease of profit due to storage failure. Small scale ESSs are installed and managed by the end users who voluntarily connect their ESSs with the utility grid and provide it's control to the utility operator. In return, utility operator shares some percentage of arbitrage profit with the electricity users as an incentive.

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1 INTRODUCTION

The use of information and communication technologies enables smart grid to enforce controlled use of energy, incorporate distributed and renewable energy resources, and use of distributed energy storage such as G2V/V2G [1–3, 5]. There has been a huge shortfall of electricity in some of the developing countries since past decade. Many countries are taking serious steps to install renewable energy sources, such as wind and solar, to meet their energy demands. ESS is required to store excess electricity from renewable energy sources and use it during peak hours when renewable generation cannot fulfill the demand.

Installation of high capacity battery system at the utility amounts to hight operational cost. We present our current results as the bases to use consumer's installed batteries as a high capacity distributed virtual energy store for the utility. Using batteries of large number of consumers requires optimal charging/discharging schedule for all of the batteries that fulfill consumer's electricity demand, increase battery lifetime and reduce peak stress on the grid. Moreover, utility requires an incentive system for the consumers to keep their ESSs operational. To our knowledge, using large number of batteries as a distributed electricity store for the utility under distributed renewable generation has not been explored as yet. It is imperative to develop practical centralized control of ESS that is not only useful for the utility as well as for the consumers. Centralized control of ESS aims to schedule ESS's charging/discharging and aggregate a large number of small ESS's as a large virtual ESS for the utility.

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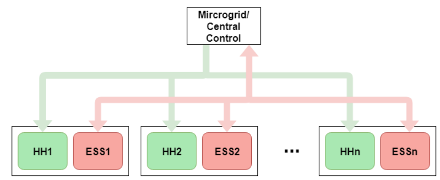

Figure 1: System model schematic diagram

Main objective of the proposed distributed storage model is the energy arbitrage and we also show in the results that a significant reduction in electricity generation cost can be achieved if we have a large electricity storage. Our model is different from G2V/V2G distributed storage models [1, 2]. In G2V/V2G the electricity charged/discharged from the vehicle batteries depends on vehicle owner travel requirements and the utility cannot always fully discharge vehicle batteries. However, in our model consumers provide electric utility with the full control of their batteries and the centralized controller can charge/discharge batteries as needed.

Table 1: Parameters of the ESS

	Grid Connected	**Individual**
Capacity (kWh)	C_i^{grid}	C_j^{ind}
Max. charge power (kW)	P_{ic}^{grid}	P_{jc}^{ind}
Max. discharge power (kW)	P_{id}^{grid}	P_{jd}^{ind}
Round trip efficiency	η_i^{grid}	η_i^{ind}

2 PROPOSED MODEL

Figure 1 shows system model. There are n households (HH) who have installed an ESS of a given capacity. Each of the ESS is connected with the microgrid. The microgrid can centrally control ESS charging and discharging. Green arrow indicates that electricity flows from microgrid to the household whereas red arrows indicate two way flow of electricity to charge and discharge the household ESSs.

Suppose there are N households connected with the microgrid. Let $\{d_{it} : t = 1, 2, 3, \ldots, T\}$ be the consumption profile of i_{th} household at time t with Δt hour resolution. We suppose that the consumption for the next T time steps of length Δt hour can estimated by the utility at midnight. Let N_1, N_2 and N_3 represent number of households with grid connected electricity storage, consumers with individually controlled electricity storage and the consumers without electricity storage, respectively. Parameters of the electricity storage of i_{th} $(i = 1, 2, 3, \ldots, N_1)$ grid connected ESS and j_{th} $(j = 1, 2, 3, \ldots, N_2)$ individually controlled ESS are given in the table 1.

We need to find overall charge/discharge power for each of the T times for large virtual electricity store aiming at increasing profit for the utility grid by charging the virtual store with low wholesale electricity price and selling it to the consumers at high retail price.

3 SIMULATION RESULTS

Figure 2 shows hourly demand of Pakistan on a randomly selected day. If we use 231 MW of power from the battery at 6 PM at the evening, the demand on the grid will be reduced from 11660 MW to 11429 MW. We need to store 289 MWh into the battery to account for battery losses (80% efficiency) in the off-peak time at 2 AM. The demand at 2 AM will be increased from 8030 MW to 8319 MW. This is shown in figure 3. Economic merit order of power plants is obtained from National Transmission and Dispatch Company (NTDC) Pakistan [4]. This merit order determines the order in which different power plants are turned on depending on power demand and thus determines the cost of electricity generation. We use this merit order to determine cost of electricity generation with and without shifting peak demand. In the box given below, it is shown that net profit of Rs. 0.63 millions can be achieved by shifting 231 MW of power from peak time to off-peak time using an ESS. This is achieved only by shifting demand at peak hour to off peak hour in an unoptimized way. Optimized balancing will mostly come up with higher profit. It is also important to note that this is just an example to show the potential benefits of using batteries on the overall demand of Pakistan. However, our proposal's scope does not cover energy arbitrage/power balancing at the country's demand level. But, we propose to use consumer's batteries for large electricity store at the level of a mircrogrid that is limited to localized area.

$$
\begin{aligned}
\text{Cost(8319 MW)} &= \text{Rs. 38.57 Millions} \\
\text{Cost(8030 MW)} &= \text{Rs. 36.70 Millions} \\
\text{Charging Cost} &= \text{Cost(8319 MW)} - \text{Cost(8030 MW)} \\
&= 38.57 - 36.70 \\
&= \text{Rs. 1.87 Millions} \\
\text{Cost(11660 MW)} &= \text{Rs. 66.74 Millions} \\
\text{Cost(11429 MW)} &= \text{Rs. 64.24 Millions} \\
\text{Discharging Profit} &= \text{2.50 Millions} \\
\text{Net Profit} &= \text{Discharging Profit} - \text{Charging Cost} \\
&= 2.50 - 1.87 \\
&= \text{0.63 Millions}
\end{aligned}
$$

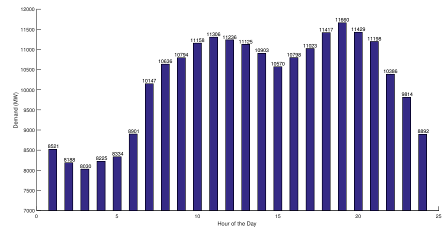

Figure 2: Pakistan power demand for a single day

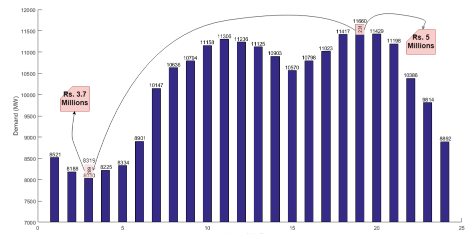

Figure 3: Pakistan power demand: profit using ESS

4 CONCLUSION

ESS can play a central role in matching demand and supply, especially in recent years with rapid expansion in renewable energy sources such as wind and solar. Using centralized large ESS managed by the utility suffers from certain disadvantages such as capital, maintenance and operational cost and degradation with single ESS failure. We propose to use consumer's installed small-scale ESSs as large-virtual ESS for the utility, as an uber like service. With the proposed scheme, the electric utility has no operational or maintenance cost as opposed to installing a single large storage. However, electricity consumers whose batteries constitute the large virtual electricity store do have an associated O&M cost which usually depends on the battery type and size. Our results show that electricity generation cost can be reduced greatly, even after considering all costs, if a large electricity storage is readily available. As there are large number of ESSs, there is flexibility to schedule charge/discharge in such a way that have minimal effect on the lifetime of the ESSs. In the future, we aim to develop practical centralized control schemes for optimal charge/discharge scheduling of large number of batteries not only to reduce generation cost but also to aid in grid stability such as frequency/voltage regulation and other ancillary services.

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