Exploitation of Reserve Services from Energy Storage Systems as Load Following Reserves

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***Abstract*—Utility-scale energy storage systems (ESSs) have a wide application in power systems. For example, they are mainly used for peak shaving and reducing the operational cost. Therefore, the application of ESSs as a provider of flexibility services is highly desirable for system operators. As the use of storage for reserve deployment at a certain hour is depending on its sequential dispatches, the ignorance of such dependency can cause power shortages at the real-time operation. On the other hand, the energy level of ESS has a typical range which is sufficient for performance outside the base schedule only for a few hours. In this regard, this paper intended to develop a mechanism for the application of storage to address load forecasting errors.**

The variable consumption pattern of the electricity subscribers leads to a non-uniform load curve over an operation horizon. The conventional thermal generators can be used but are costly and have negative environmental impacts. Hence, over-sizing the thermal units to supply the load during the peak period is not also effective economically. For this reason, the storage devices play an important role in peak-load shaving. In addition, the ESSs have fast response which enables them to be used as regulation reserve. This paper intends to provide load following reserves using the online generators along with regulation services of the ESSs.

Generally in the operation model, the ESSs are dispatched based on their available energy defined by the variable state of charge (SOC). The previous research works considering the regulation services of storage devices, use the storage to deal with the different scenarios of uncertainties in the system. However, the hourly SOC depends on its values at the previous time-step and the charging/discharging dispatches at the corresponding hour. However, common stochastic models are not time-dependent. For example, the first scenario at hour 1 is not followed by the same scenario at hour 2, and any combinations of scenarios between hours can be expected. Therefore, any regulation services deployed by the ESSs should be managed correctly based on the time dependence of SOC values.

This paper proposes a model with two categories of variables for the storage devices. The SOC of the ESSs of the first category checks the base schedule of storage during the horizon of operation to satisfy the time dependence of ESSs' energy level, and the second one will ensure the dispatches through any scenarios. The model links these two categories of variables to be matched at each time step. Hence, any large violations based on the occurrence of unexpected situations will be managed by the operators at real-time decisions.

Furthermore, this work considers load forecast errors as a source of uncertainty and considers a stochastic framework with scenarios. The scenario generation is performed using normal distribution function for around the forecasted values of the hourly loads. Then, a scenario reduction method based on probability distance is performed to reduce the computing effort. Other sources of uncertainty can be modeled in the same way.

More specifically, the reserves for uncertainty management will be deployed by the generators and ESSs. The cost function of the problem includes the generation cost as well as reserves capacity in the joint energy and reserve market.

The model is implemented using the CPLEX solver of the general algebraic modeling system (GAMS) software. The IEEE RTS-24 test system is used to evaluate the performance of the proposed model. In this test system, 12 generators and 5 ESSs with regulation reserves capability are considered. Numerical validation shows that the proposed model will successfully deploy the regulation reserves from both generators and ESSs. Also, the storage performance in different scenarios will be matched to the hourly base schedule, while the base values of ESSs dispatches participate in the peak-shaving performance. As expected, the application of ESSs reduce the operational costs by reducing the need for load following reserves from the conventional thermal units.

***Index Terms*--Load following reserves, storage devices, regulation reserve services, load forecasting errors, stochastic unit commitment.**