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Energy storage: quantification of needs and anticipated benefits

Approaches to quantify system storage needs

Baterry energy storage systems (BESS) are considered a prerequisite for power systems to achieve targets regarding RES penetration levels and reduction of CO_2 emissions. System operators (SOs) are challenged to identify the optimal battery storage requirements of a system, in terms of energy and power capacity, in order to reach such targets. In this context, two main approaches are adopted by SOs to determine storage optimal solutions: the capacity expansion modelling (CEM) approach and the day-ahead scheduling (DAS) simulation method. CEM approach optimizes system operation over a long time horizon, considering the investment in new generation and accounting for the full system cost to finally derive the optimum generation portfolio, including storage. These models provide a unique solution for generation system development depending on the predetermined targets which are set as constraints into the optimization problem of CEM. Capacity expansions models often resort to simplifications to reduce the number of variables and constraints of the problem, while they may over-simplify system management and operational constraints, trying to maintain a balance between detail and feasibility of solution. On the other hand, the DAS-based models follow a different approach, optimizing system operation over a limited look-ahead horizon. Their main target is to capture in detail the impact of storage on system operation, adopting a more realistic representation of actual unit commitment and economic dispatch (UC-ED) practices, especially as they relate to market conditions. In order for the optimal BESS solution to be identified under this approach, different scenarios regarding energy and power capacity of storage are investigated and the corresponding results are compared. This approach allows the direct comparison between the benefits attributed to different BESS configurations. It is noted that for the quantification of other services provided by BESS, such as voltage and frequency regulation, congestion management or contribution to black start, different type of models are used involving the dynamic analysis of system operation.

Anticipated benefits from storage integration and comparison of possible solutions

To quantify the benefits from BESS integration into a power system under the DAS-based approach, system operation is first simulated without storage (baseline scenario). Subsequently, the operation of system is simulated in presence of BESS and the improvement in system performance in terms of both operation and economics compared to the baseline scenario, is quantified. Various configurations of BESS are tested in order for the optimal solution to be determined. Such an analysis was conducted for the non-interconnected power system of Cyprus. The anticipated benefits from BESS introduction proved to be multifaceted.

- *Provision of active power reserves*: BESS enhance system security by providing all types of necessary reserves. Specifically, BESS due to their fast response characteristics can provide frequency containment reserves (FCR), a resource in scarcity in isolated power systems.
- *Thermal units' improved operation*: Thermal units operate in more efficient loading levels in presence of BESS, as they are significantly relieved of providing necessary active power reserves. Moreover, fewer thermal units are committed in the daily generation scheduling as a result of RES production increase, while fewer start-ups of thermal units take place.
- *Increase in RES penetration*: The RES curtailments are reduced compared with the baseline scenario without storage, as the system can accommodate more renewable energy due to the extra flexibility provided by BESS. Specifically, the BESS introduction has a twofold impact regarding RES uptake; first the technical limitations responsible for RES rejections imposed by online units are relaxed allowing the direct absorption of greater amounts of renewable energy; second the otherwise curtailed renewable energy during system congestion conditions now charges BESS and is later re-injected into the grid (energy arbitrage).
- *Reduction in CO_2 emissions*: The reduction of thermal production in conjunction with the more efficient loading of thermal units due to BESS introduction results in a significant reduction of CO_2 emissions.
- *Enhancement of system adequacy*: BESS contribute to capacity adequacy of the system. Specifically, BESS can significantly reduce critical from adequacy perspective system peak loads by executing load leveling. This service can also be monetized as the avoided cost of an investment in a new thermal capacity.
- *System cost reduction*: All the above mentioned benefits from BESS integration lead to a decrease in total system generation cost compared with the baseline scenario.

For the case of Cyprus, the optimal BESS configuration was decided based on the net annual economic benefit of the system taking into consideration the annual fixed cost of BESS investment. Indicatively, a 150MW/300MWh BESS is considered as optimal leading to a net annual system benefit of €7.3 million, ~30.8% RES penetration level, a ~72% reduction in RES curtailments and a ~5% reduction in CO_2 emissions.