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Improving the economics of battery storage

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Nations are increasingly committed towards carbon-neutrality in accordance with the Paris Climate Agreement. Emission cuts in the energy system play a key role to reach these targets. Variable renewable electricity such as solar and wind power is increasingly used to decarbonize power production, but their impact could also expand to other sectors such as mobility and heating/cooling through increasing electrification and sector coupling. Such a change from a fuel-based to weather-driven energy system will increase the volatility of supply and will have broad spatiotemporal impacts on several of the power system elements (Fig.1). There are a range of countermeasures available to mitigate these effects such as congestion management, increased flexibility and ancillary services. Energy storage and batteries fit to such purpose.[1]

The characteristics of energy storage technologies determine the services which they can provide in the power system (Fig. 2). Typically, batteries would best fit to power quality issues, though advanced battery chemistries may broaden their scope in the future.[2,3] For example, the Li-ion battery employed in the study of Englberger et al. [4] operates in a time range from some minutes to a few hours.

Energy storage is still dominated by hydro power-based solutions (99%), but the positive economic trend of Li-ion batteries makes them a promising future option, in particular in countries now mainly served by thermal power capacity. The IEA predicts that battery storage could more than 20-fold by 2040 from the present level.[5] Also, emerging second-life market of used batteries from electric vehicles (EVs) is expected to add to the battery use in stationary applications. IEA predicts 20-50 million EVs by 2030[5]. A decade later these could be potential second-life batteries adding several hundreds of GWhs of battery capacity.

Though the theoretical potential of batteries could be large, the extent to which they would be used in practice will be a trade-off between their cost and the value(s) storage can provide. The benefits from storage or a battery are system dependent and have different values in different situations[6]. Energy storage can add value to the electricity system in several ways, e.g. by contributing to balancing, network capacity, reserves, and generation adequacy.[2,6]

These multiple benefits are not necessarily captured by the present electricity market design which may not deliver the necessary price signals to encourage investments in batteries.[7] However, in thermal-dominated power systems, e.g. in India, battery storage could be lucrative both for integrating large amounts of photovoltaics into the power system and to maintain flexibility. In hydro-dominated systems such as in the Nordic region, the economic conditions for batteries are not that favourable.

Englberger et al.[4] provides a relevant study to capture on the different energy system values from a battery storage system to improve the competitiveness of a 1.34MWh/1.25 MW battery storage system in Germany, which represents a typical thermal-based power system. They basically optimized the battery use between the battery cost and wearing against four benefits: two in-front-of-the-meter (FTM) and two behind-the-meter (BTM). The former typically relates to the transmission system and the electricity market, e.g. providing frequency regulation, and the latter one to the end-use side and the distribution system, e.g. peak load shaving.

Through a comprehensive techno-economic optimization of the battery based on real-case data with high time resolution (5-min), Englberger et al.[4] compared different allocation strategies of the battery for four applications. They found out that using a stacking strategy of the battery capacity for multiple applications simultaneously, the annual profit could be 2-3-folded compared to allocating the battery to a single-use only. In this way, they were able to reach a break-even point (Net Present Value, NPV >0) in 4-6 years in spite of a rather high battery system cost (€380/MWh) assumed. For comparison, the best single-use application (spot market trading) would reach a positive NPV not until the 9th year of operation. The operating profit from the multi-use is slightly lower than the sum of the single-uses due to trade-offs in different power and energy capacity sharing.

As their analysis was limited to four revenue streams only (peak-shaving, self-consumption, frequency reserve, spot market trading), excluding e.g. supply capacity, power distribution, transmission, customer energy management applications, and other ancillary services, the above estimates may be conservative, though not all of these may be captured by the present Li-ion technology[3]. On the other hand, decreasing returns could be expected with a larger number of similar systems instead of one agent like in the present study.[8] The practical control of a battery for allocating dynamically its capacity to multiple uses may be challenging, though the authors show that a quite long switching time up to half of day could be allowed for reallocating without severely affecting the profitability. Whereas for a sequential allocation strategy, i.e. providing exclusive service of one application at a time, the profits start to drop when the switching time exceeds a few hours.

Though dynamic stacking of multiple applications could technically be feasible, the present regulatory framework prohibiting vertical bundling may inhibit using a battery storage cross the transmission and distribution system. This may require updating present electricity market legislation to allow distributed storage systems to be located in the intersection of the transmission and distribution system and serve the needs of both parts of the grid system. Shared storage between the Transmission and Distribution System Operator could be a solution to the allocation problem. Succeeding in releasing the full potential of battery storage would definitely help in decarbonizing the energy system.

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Figure captions

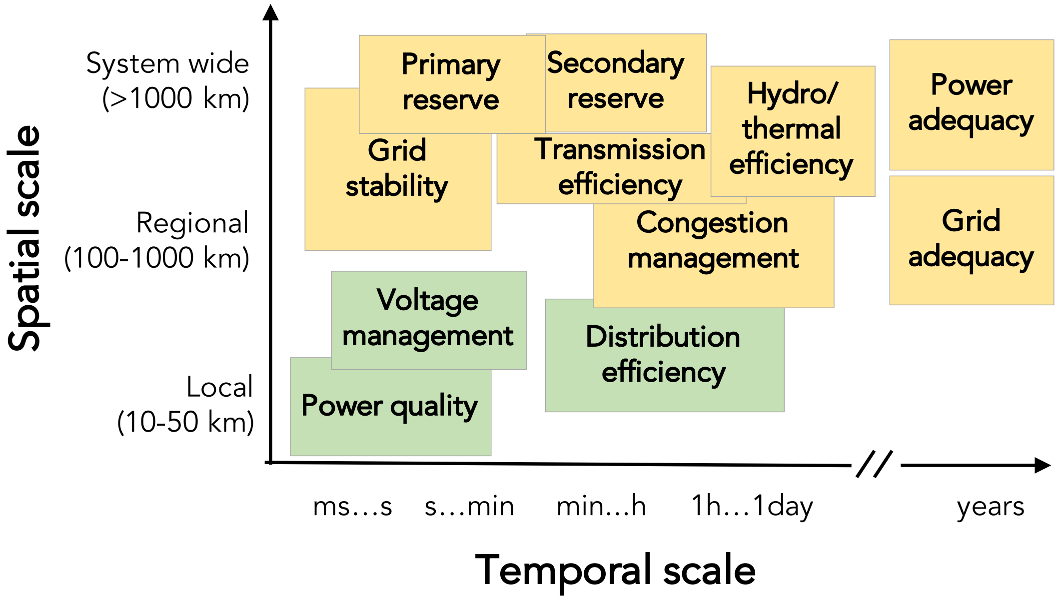

Figure 1. Spatiotemporal impacts on the electricity system on different scales from variable renewable electricity. (Adapted from Ref. 7)

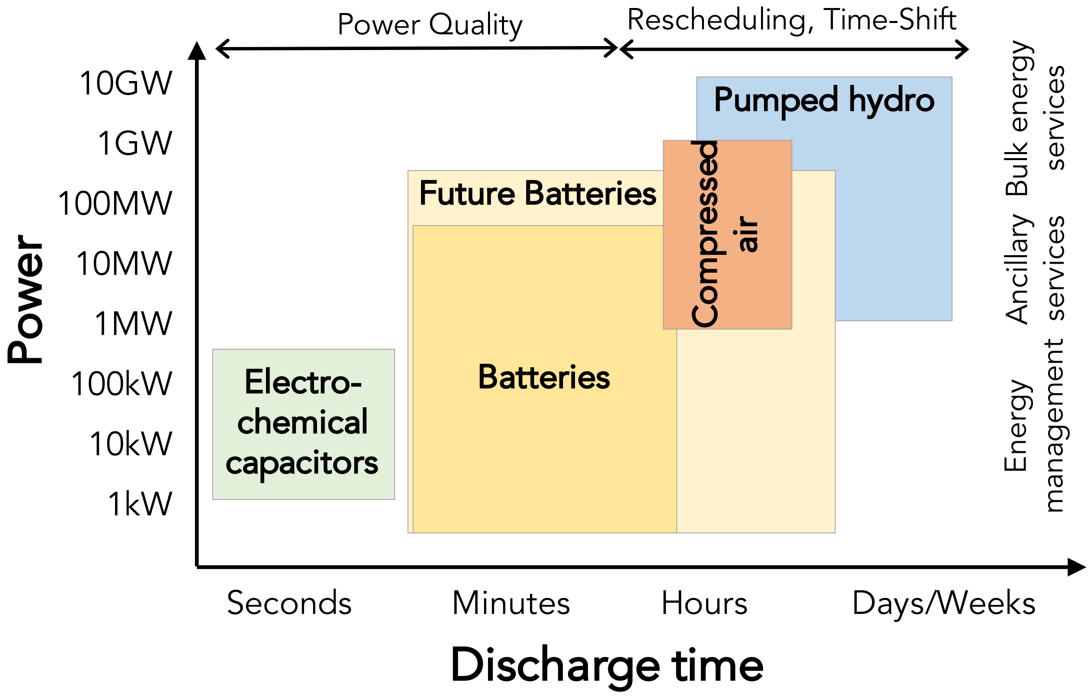

Figure 2. Characteristics of different energy storage technologies aligned with typical applications in the electricity system. (Adapted from Ref.3)