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Suitability of Electrochemical Energy Storage Technologies for Ramp-Rate Control of PV Power

Yu Jiang[1], John Fletcher[2], Patrick Burr[2], Charles Hall[1], Bowen Zheng[2], Da-Wei Wang[3], Zi Ouyang and Alison Lennon[1]

[1]*School of Photovoltaic and Renewable Engineering, UNSW Sydney, NSW 2052, Australia*

[2]*School of Electrical Engineering and Telecommunication, UNSW Sydney, NSW 2052, Australia*

[3]*Particles and Catalysis Research Group, School of Chemical Engineering, UNSW Sydney, NSW 2052, Australia*

Photovoltaic (PV) systems can exhibit rapid variances in their power output due to irradiance changes which can risk the stability of an electricity grid. One approach is to use energy storage systems (ESS) to buffer the variances in PV power output [1]. In this presentation, we report a quantitative comparison of the suitability of state-of-the-art electrochemical ESS technologies, based on their required 'power-normalised volumes (V_{ESS}/P_N)', to provide ramp-rate control of power in PV systems. This analysis is performed for a set of scenarios: i) two ramp-rate control strategies (i.e., at an array level or module level, Figure 1a and b); ii) three representative PV system sizes; and iii) different ramp-rate and/or compliance requirements.

Our modelling results show that (Figure 2), for system sizes typically of a residential rooftop or a commercial PV system, lithium ion battery (LIB) is the most suitable technology: high-power LIBs require the smallest V_{ESS}/P_N for higher ramp-rate limits (≥ 20% min^{-1}) or lower compliance (< 99.8%), whereas high-energy LIBs were found to be more suitable when stricter ramp-rate limits or compliance are necessary. As the system size increases, the required V_{ESS}/P_N values are substantially lower and the power capability of an ESS becomes more and more important. The large differences in the required V_{ESS}/P_N for the different ESS technologies highlight the importance of correctly selecting a suitable ESS for this application.

We also discuss an alternative ramp-rate control concept of power buffering at the PV module level, and the specific case of integrating an ESS with a micro-inverter located in the junction box of a PV module is explored (Figure 1b). Results suggest that the V_{ESS}/P_N requirements for this ESS configuration are similar to those for array-level ramp-rate control for a rooftop PV system. Again, among various ESS technologies LIBs are most suitable for this ramp-rate control strategy. However, as shown in Figure 1c, when a volume restriction of 0.1 L is applied then current commercially available LIBs can only achieve a 10% min^{-1} ramp-rate limit with ~ 99.5% compliance. Further reductions in ramp rates or increases in compliance will require more accessible volumes on a module to accommodate an ESS, or development of ESSs with energy densities > 400 Wh L^{-1} and power densities > 2300 W L^{-1}.

This study conclude that high energy and power density are both important characteristics for an ESS to be used for PV ramp-rate control applications. Requirements for state-of-the-art ESS technologies to meet the desirable power ramp-rate limits are found to be challenging, especially for buffering on a module level.

References

[1] Beaudin, M., Zareipour, H., Schellenberglabe, A., and Rosehart, W.: 'Energy storage for mitigating the variability of renewable electricity sources: An updated review', Energy for Sustainable Development, 2010, 14, (4), pp. 302-314

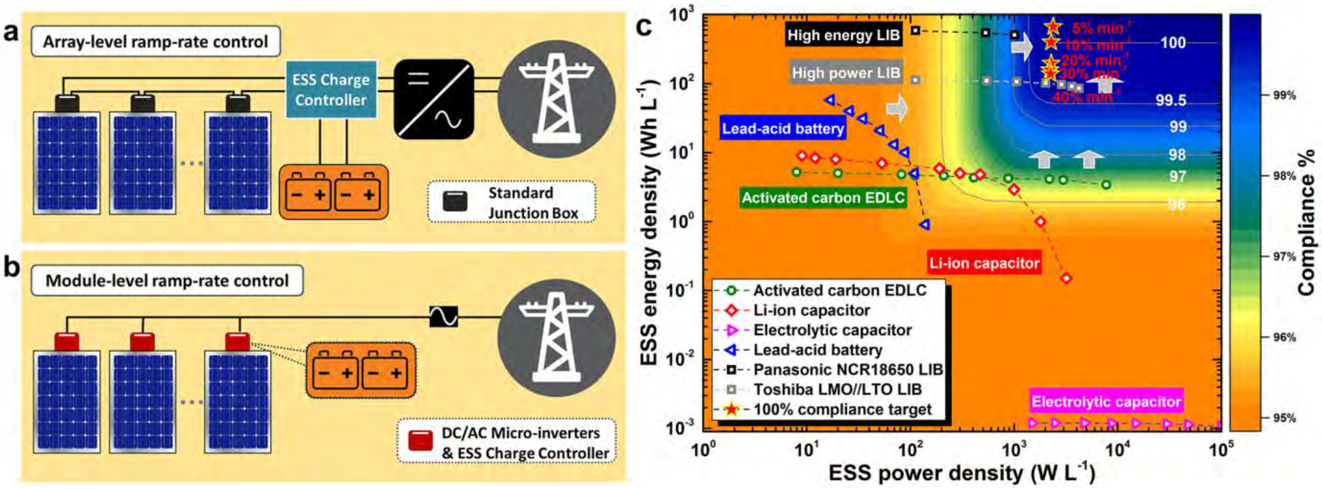

Figure 1. Configuration of a PV system with an ESS for ramp-rate control at the a) array level and b) module level. c) Achieved levels of compliance for a ramp-rate limit of 10% min^{-1} when the ESS volume is restricted to 0.1 L.

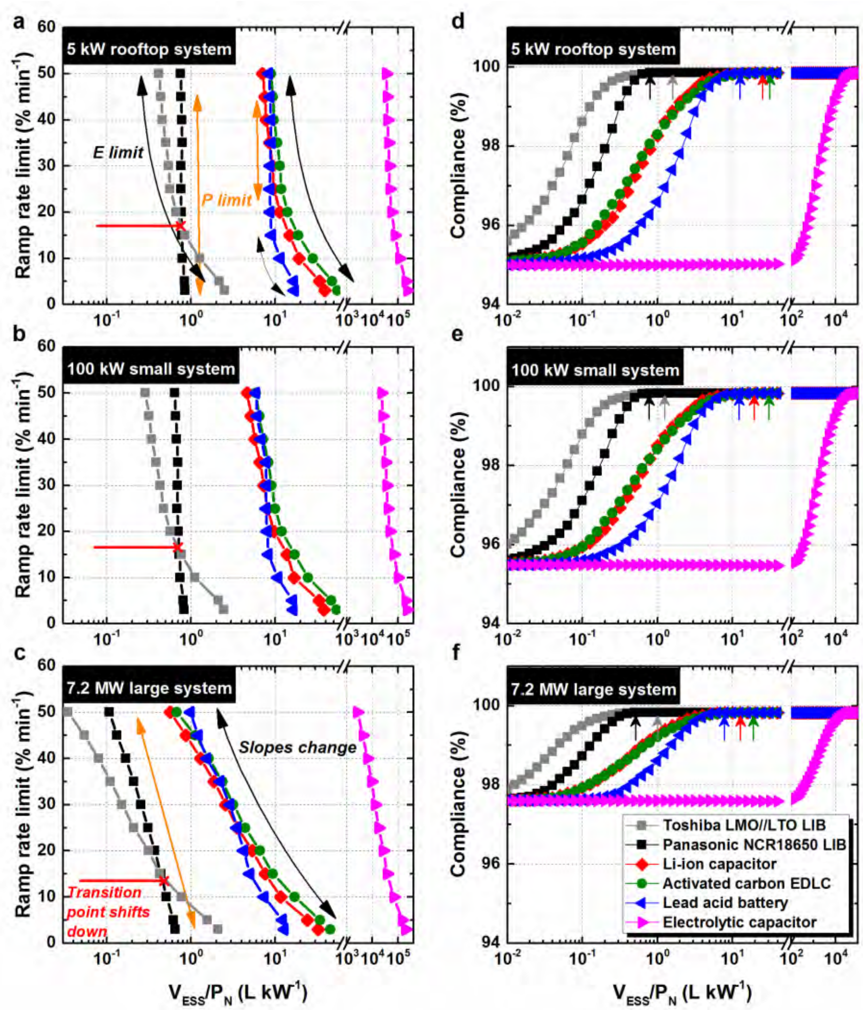

Figure 2. Calculated ESS V_{ESS}/P_N requirements for different allowable ramp-rate limits for three PV system sizes.