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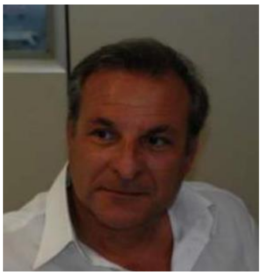

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Abstract

Title: Battery modeling and characterization: challenges and perspectives

Energy Storage Systems (ESS) play a vital role in the transition towards a clean and reliable energy future. Their benefits let them cover multiple areas, from grid-connected application to the industry and the automotive field. In particular, batteries are the most widely used technology for storing electricity, representing the key point on which much investment has been and continues to be focused. As for the grid-connected applications, ESS and batteries can increase the renewable energy integration, storing excess energy generated during peak production times (sunny days, strong winds) and release it when demand is high or when renewable generation is low. They can improve grid stability and reduce reliance in peak power plant. As for the automotive sector, batteries serve for different purposes of which the main one is to store the energy needed by the electric powertrain. From the analysis of these two sectors, it is possible to realize how wide the energy storage market is. Nowadays, research is focused on different aspects of them, such as new materials, Life Cycle Assessment (LCA), safety, applications, and modelling. The latter is a very complex and evolving field, as well as one of crucial importance, since reliable models allows for performance simulation under different operating conditions, design efficient and safe systems, design control algorithms for energy management and optimize storage systems for specific applications. The choice of the most suitable battery model depends on several factors: the specific application, the level of accuracy required, the computational resources available. The challenges in the field of battery modelling are related to different factors such as complexity of battery systems, lack of data and nonlinearities.

Based on the purpose of modelling, different types of models are available in the literature: thermal models, behaviour models, ageing models. For them, different approaches can be employed. An electrochemical approach provides a very accurate analysis of the system through equations describing chemical processes occurring inside a cell; analytical models, on the other hand, are simpler to implement, however, they suffer from low accuracy and often the equations employed do not have a physical match. Equivalent circuit modelling has the merit of being a trade-off between the previous ones, however, experimental tests are often needed for cell characterization, whereas the ones employing finite element analysis (FEA) are very accurate but require very high computational effort. All these approaches and methodologies can be a valid solution to predict the state of charge (SOC), the state of health (SOH), the thermal and electrical behaviour of the cell, or more generally to study the

battery behaviour from different points of view. The challenges for researchers are represented by balancing complexity and accuracy, describing multiscale phenomena and generalizing theory with respect to the wide literature.

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