SEA: Smart Energy Applications
Editorial

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***Abstract*—The topic of Smart Energy (SE) has become a top priority in several research programs, especially in the European Union (Horizon2020, ECSEL, EPoSS), as a natural follow-up of the 2015 Paris Agreement, which set an ambitious direction for investment into low-carbon innovation. A number of measures have been therefore proposed to achieve this goal, with emphasis being put on the "green" perspective of energy, such as the recent 'Clean Energy for all Europeans' package of measures of 2016 which pursues three main goals: (i) energy efficiency, (ii) leadership of Europe in renewables, and (iii) a fair deal to consumers [1].**

This Special Track will focus on topics related to Smart Energy Applications, while also including papers that deal with the technologies that enable those applications.

***Index Terms*—Smart Energy; Smart Grid; Battery Modeling; Electric Vehicles; Non-Intrusive Load Monitoring;**

I. INTRODUCTION

Adding smartness to energy systems relies on a set of enabling technologies to achieve an intelligent and efficient use of energy that enable a set of smart "services". These enabling technologies essentially include: new *materials and devices* for efficient generation, transportation and storage of energy; *fast and reliable connectivity* to enable interaction among different parts of a grid, possibly using an Internet-of-things (IoT) paradigm; efficient and accurate *simulation models and engines* to allow early prototyping of these systems, possibly allowing the concurrent simulation of devices, connectivity and software within the same framework.

Services enabled by these enabling technologies might include real-time monitoring of energy consumption (through smart meters), energy balancing and management in the grid at the building- or district-level, predictive identification of upcoming faults due to aging components, efficient integration of (possibly distributed) renewable sources, just to name a few.

According to the ECSEL 2020 SRA, research and innovation in the smart energy field should follow three main directions [2]:

- Ensuring sustainable power generation and energy conversion.
- Reducing energy consumption
- Achieving efficient community energy management;

where the former two are more related to the enabling technologies and the latter more oriented to the services dimension.

In this Special Track we feature two papers that are mainly focused on the enabling technologies, and a third one more oriented towards smart energy services.

II. SUBMISSIONS

The first paper of the track, titled *"The Importance of Accurate Battery Models for The Power Assessment in Smart Energy System"* [3] illustrates with two use cases that adopting an elaborate battery model in smart energy systems' power simulations can lead to more accurate power assessment results. As remarked by the authors, simulation is a critical step to evaluate the power flow in the early design phases of a smart energy system. The essential elements to enable an accurate simulation are precise models of all involved components. In particular, the authors of the paper classify smart energy systems components into four main categories: power sources, energy storage components, loads, and converters. Energy storage components, and in particular batteries, are among the most complex elements to model for simulation, due to their non-ideal discharge characteristics. Indeed, several literature works [4], [5] have shown that the battery's actual consumed energy depends on its state of charge (SOC), on the discharge current magnitude, and on the load current frequency.

The authors of this paper use SystemC-AMS to implement a simulation framework supporting multiple models of computations for all components in a smart energy system. In particular, the framework supports a circuit-equivalent battery model that accounts for the SOC, current magnitudes and load frequency dependencies in the simulation.

Two smart energy systems of different scales are simulated to demonstrate the effectiveness of this framework. A first simulation on a small-scale IoT multi-sensor node shows that only the advanced battery model can highlight the different energy consumption deriving from different schedules of the node operations (e.g. sensing, computation and transmission). Next, a large-scale case study illustrates that a simulation based on a simplistic battery model would underestimate the power consumption in a smart house, compared to the accurate circuit-equivalent one. In conclusion, both case studies demonstrate the importance of the battery model accuracy for smart energy systems power assessment.

The second paper, titled *"Powertrain Modeling and Range Estimation of The Electric Bus"* [6] addresses the problems of optimal route planning and battery sizing for electric buses. Electric buses are increasingly adopted in cities due to their emission free engines, low noise, small vibration, easy maintenance, etc. However, route planning and battery sizing are two relevant issues that influence the efficiency of electric buses in public transportation systems. As in the previous paper, accurate and computationally efficient modeling of the involved energy systems, in this case the bus powertrain, turns out to be a fundamental requirement for an effective optimization. The authors demonstrate a modeling method that incorporates:

- A powertrain parameters extraction for so-called "complex" vehicle simulation
- A vehicle driving simulator supporting various driving cycles
- An equation-based powertrain modeling based on coefficient extraction
- A fast driving power estimation with a traffic- and altitude-aware driving cycle

The so-called "complex" vehicle simulation is based on component models for the motor, vehicle chassis and battery. These are built combining vehicle specifications provided by vehicle manufacturers with experimental driving results (e.g. the energy consumption per 100 km). While accurate, the authors show that using such complex simulation to determine the optimal route or battery size of an electric bus is too time consuming, especially for real-time route planning, e.g. embedded in a GPS navigator app. Therefore, they propose a fast yet accurate alternative model based on mathematical equations of the vehicle dynamics and motor efficiency, whose key parameters are extracted from a set of reference simulations performed with the "complex" simulator. The effectiveness of the simulator is verified on two case studies, concerning: (i) fast energy consumption estimation along with route information and (ii) bus battery sizing considering driving efficiency and range.

The third paper, titled *"When Privacy Protection Meets Non-Intrusive Load Monitoring: Trade-off Analysis and Privacy Schemes via Residential Energy Storage"* [7], discusses privacy issues in the context of Non-Intrusive Load Monitoring (NILM) algorithms that are used to disaggregate the electricity usage of a whole household into the contribution of individual appliances. Residential energy storage (e.g., batteries) could be used to relieve such concerns by altering the monitored electricity profile. However, they are quite costly and hence assessing the financial overhead of privacy protection techniques is of uttermost importance.

The paper specifically focuses on the calculation of how much residential energy storage would be required to fool a state-ofthe-art NILM algorithm, and the relative economic assessment in order to provide recommendations on how to effectively use residential energy storage to protect the privacy of electricity users against NILM algorithms.

The authors identify a number of NILM masking options such as noise addition, removal of one appliance, or use of a battery to filter our variations, and do a systematic simulation-based analysis of the privacy/cost tradeoff. Results indicate that some intuitive methods do not necessarily lead to significant reduction in disaggregation performance of the NILM algorithm, even though they require significant battery capacity. This points towards further systematic research tailored to providing protection against NILM algorithms while minimizing the battery cost overhead that will be explored in future works.

III. CONCLUSION

Smart Energy encompasses a number of technologies that enable smart services. By optimizing energy management (generation, storage, distribution, consumption) at different scales, these services can contribute to the objectives of clean energy and sustainability. This Special Track features papers that deal with both aspects (technologies and services) as a sample of the wide scope of the research topics under the smart energy umbrella.

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