Technical University of Denmark

Popular science summary of the PhD thesis

PhD student	Guillaume Le Ray
Title of the PhD thesis	On the role of smart metering data analytics in the energy sector digitization process
PhD school/Department	Department of Electrical Engineering

Science summary

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The electrical grid is facing profound structural changes due to the increased share of renewable energy generation dictated by the need to limit climate change impact and dependencies on imports. However renewable energy generation is variable, uncertain and not controllable, as it depends on the weather conditions and thus it is not dispatchable like conventional power generation. In the current grid operation framework, generation adjusts to cover the needs of demand and to keep the system balanced. Hence, a system integrating a large share of renewable energy sources requires other sources of flexibility among which demand flexibility that is controllable thanks to smart grid technologies. Smart grids and digitization of the energy sector through the deployments of smart meters open up to new business models for the utilities. Metering data analytics provides insights to the operators to make informed decisions in a close to real-time manner. Indeed, the analysis of streams of data as they are collected by smart meters can provide detailed information on the characteristics of the demand that can be used to improve the grid operation and planning.

This thesis addresses the crucial role of metering data analysis in the context of the digitization of the energy sector. The focus is on the implementation of methodologies for load analysis (load profiling) and load management (assets detection and management, Demand Response (DR) analysis) that can be implemented in the real-world and have a substantial positive impact on the grid operation and planning.

As a disruptive communication technology with large scale deployment, smart meters have raised privacy concerns. Beyond privacy problems, we first discuss the ethical implementation of smart grids and how the relationships between utilities and customers could secure investments in smart grid technologies. Indeed, the future of smart grids relies on the capacity to keep customers involved. Hence, beyond the technical aspects of smart grids, ethics should be the driver for decision making concerning interactions with customers.

Load profiling has been used to understand when and how electricity is consumed and to represent the loads with a limited number of typical load profiles summarizing the load behaviors. We propose in this work to take advantage of the stream nature of metering data to create a novel dynamic approach to load profiling using an online adaptive clustering algorithm. The online adaptive clustering algorithm was benchmarked against state-of-the-art clustering algorithm on a real-world dataset provided by Radius (Danish DSO) with more than 10 000 customers.

Among the new business models of utilities, assets detection and management for demand flexibility is probably the most important. Hence, the extraction of information about large appliances, that could be used to provide services to the grid is needed. We propose to use Non-Intrusive Load Monitoring (NILM) to decompose the aggregated consumption signal into individual appliances consumption signals. An unsupervised NILM algorithm is implemented and benchmarked against state-of-the-art NILM algorithm on the UK-Dale dataset. An application of the algorithm to the detection of Heat Pump (HP) is also presented.

The demand flexibility can be harnessed using DR through dynamic pricing. In a price-based DR framework there is significant variability of the individual response of participants. Hence, the analysis of the load to evaluate the responsiveness, quantify and characterize the response is fundamental to understand how the aggregated response is formed. The EcoGrid EU project in Denmark regroups 1900 participants into a real-world application of DR. The data collected during the EcoGrid EU project are used to test a responsiveness evaluation protocol as well as quantification and characterization of the response without the support of a baseline.

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