Doctoral Program in Computer and Control Engineering (35thcycle)

Distributed platform for multi-model co-simulations in smart grids

Abstract of Doctoral Dissertation

By
Matteo Orlando
******
Supervisor(s):
Prof. Massimo Poncino, Supervisor

Nowadays legacy electric grids are facing a big challenge: the steady increase in energy demand is increasing the need for a renovation of the systems which requires the introduction of technologies that can facilitate monitoring and increase the automation capabilities. In addition to this, the raising necessity to shift from fossil-fuel is rapidly increasing the diffusion of renewable energy sources. These two challenges force us to rethink the way in which the grid is operated and require us to switch to the Smart Grid paradigm. This paradigm aims to redesign the old grid by introducing Information and Communication Technologies (ICT) that can support the monitoring and the automation mechanism, but also it allows us to take into account the various distributed renewable energy resources that will be more and more diffused.
This dissertation addresses these 2 challenges by using the Internet Of Things (IoT) to provide a possible solution to the first challenge, and by studying solutions for the new actors that will enter the energy market with their own distributed renewable energy systems.

Firstly the dissertation proposes an IoT architecture to enable communication among the different entities of the Smart grid to allow both an accurate monitoring of the grid and also to enable remote actuation and therefore increase the automation of the grid. This architecture makes use of well-known ICT tools to assess its capabilities and its resilience. Together with that, the dissertation introduces a design guideline for a 3-phase smart-meter and proposes a related prototype. This prototype realized with low-cost and open-source hardware, exploits the communication infrastructure to self-configure and auto-update itself, but also to achieve a self-healing grid.

Then the dissertation analyzes the characteristics of the new actor that will appear in the smart grid, in particular: i) the prosumers, i.e. those customers that can both consume or self-produce the energy they need, ii) the Energy Aggregator, i.e. a third party entity that aggregates the energy demand and request of multiple customers, iii) the Renewable Energy Community, i.e. a group of prosumers that join together to share a common renewable energy system which can at least partially satisfy their energy demand.
Nowadays the most common technology used by those actors are PhotoVoltaic (PV) for this reason, the dissertation proposes three different solutions to plan the deployment of PV system in three different contexts.

Each solution has its own implementation which takes into account the constraints and the opportunity of every single context. However, they share a common goal: to provide an optimization of the placement of the PV panels and to provide an economic analysis that can help those actors to evaluate the cost and the benefits of such a system.

The thread that runs along the dissertation is that all the proposed solutions have been developed to be used in a co-simulation environment. Co-simulation is a technique that allows studying the interaction among the simulation of different aspects of a complex system. This technique is particularly useful in the Smart Grid field, where there are a lot of different actors that are involved and interact with each other.

Therefore the solution proposed in this dissertation have various functionality for researchers: i) the proposed solutions can be used in complex cosimulation scenarios to provide a communication infrastructure for the Smart Grid ii) the proposed smart meter implementation can be used to test new technologies or policies, iii) the PV frameworks can be used to assess the impact of the new actors and their distributed energy plant on the electric network. However, also operators and customers can use the proposed solution as a standalone product to evaluate the cost and the benefits of monitoring the grid infrastructure or the deployment of PV systems.