POLITECNICO DI TORINO
Dipartimento di Automatica e Informatica

PhD in Computer and Control Engineering

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Supervisor

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Modelling and simulation infrastructure for smart energy and renewable technologies in urban districts

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1. Introduction

Many countries are investing in Energy efficiency, Smart energy and renewable technologies to reduce the impacts on climate changes. Information communication technologies has been recognized as a key player in the transition to a sustainable society. The objective of this research is to develop of a distributed infrastructure for simulation and modelling of **smart energy policies** and **renewable technologies** impacts in urban districts. The developed solution wants to provide a decision support systems on all levels (energetic, economic and political) by integrating **real-time data**, **user profiles, Geographic Information Systems** (GIS) and **distribution grid models**.

2. Methodology

The developed infrastructure, Figure 1, is implemented exploiting a mirco-services approach in order to ease the decoupling of the infrastructure and its maintenance. The communication between the different objects is enabled trough the adoption of Internet-of-Things (IoT) communication protocols such as REST and MQTT.

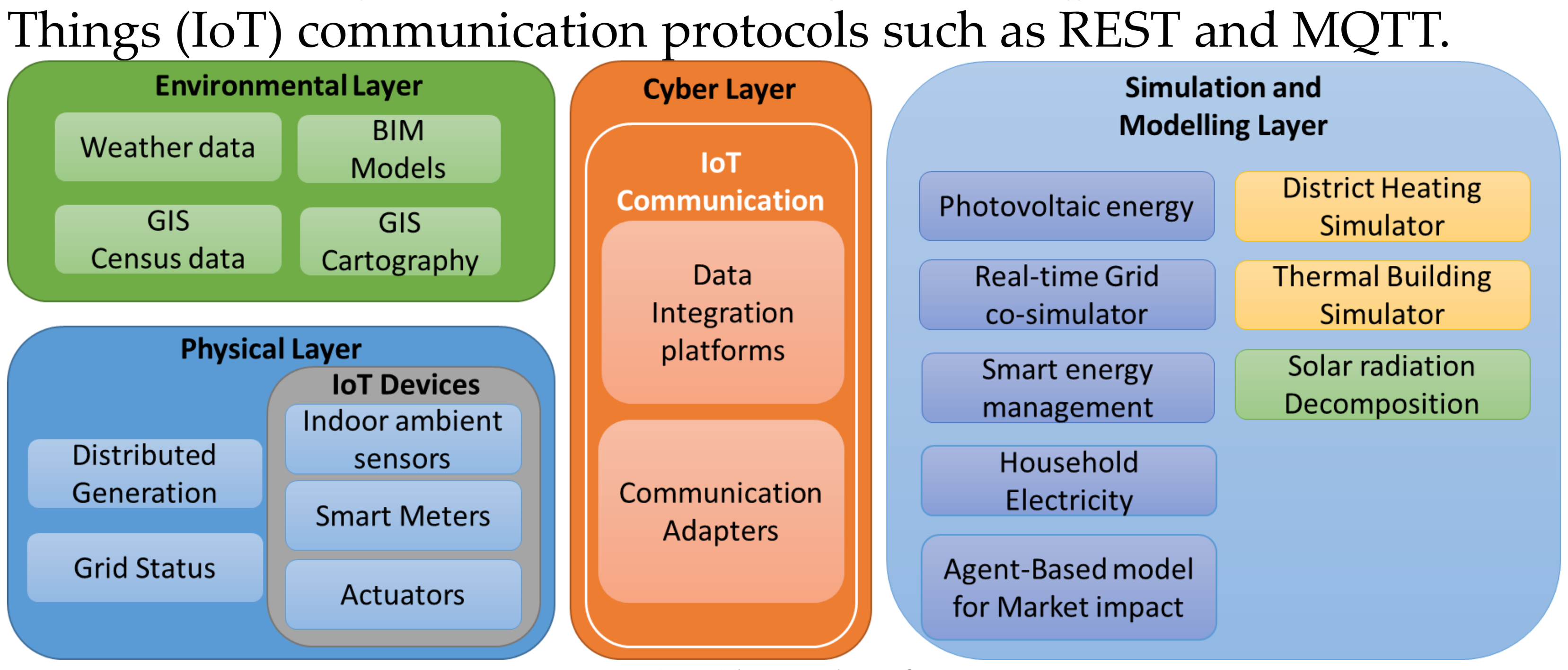

Figure 1 – Distributed Infrastructure

The proposed infrastructure is composed by four 4 layer:

- The **Environmental layer** integrates Open Weather Data (third party services), Building Information Models (BIM), GIS census data (e.g. population distribution) and GIS cartography (e.g. Cadastral maps, Digital Elevation Models).
- The **Physical layer** integrates data of installed Distributed Generation, Distribution Grid status and topology and data coming from IoT devices such as: Ambient sensors (Temperature and Humidity), Smart Meters (e.g. Gas, Electricity, Water) and Actuators (e.g. Battery Management).
- The **Cyber layer** uses IoT communication protocols and is in charge of: i) collecting the various data sources exploiting data integration platforms (e.g. Smart metering architectures), ii) providing the data to the simulation and modelling layer and iii) enabling the communication between the modules trough communication adapters.
- The **Simulation and Modelling layer** provides modules to simulate electrical energy, thermal energy and environmental conditions. The *Photovoltaic* (PV) *energy simulator* [1], by integrating GIS and weather data, identifies suitable area for PV deployment on rooftops and simulate energy production every 15-minutes considering real-sky condition. *The Real-time grid co-simulator module* [2] consists of Real-Time Simulators (e.g. Opal-RT) to simulate the power grid. It integrates: i) hardware components of the grid, ii) data coming from physical devices, novel control strategies and iii) external simulator for both generation and consumption loads.

The Real-time grid co-simulator module provides a simulation framework capable of co-simulating the impact of renewable sources and novel control policies on the distribution grid. The *Household electricity module* simulates realistic electric consumption of residential house using census and statistical data that provide information for each appliance at home. The *Agent based module* simulates the impact of PV and/or novel control policies on electricity markets. Both *District Heating and Thermal building simulation modules* [3-4] provide tool for analyze and simulate the thermal behavior of buildings integrating BIM and IoT data.

3. Results

The accuracy of the PV simulation has been tested exploiting the PoliTo PV system. Figure 2-E reports the simulated and measured generation loads for three different days (Sunny, cloudy and rainy) and shows how simulations (red dotted line) follow with good accuracy the measured production (blue sloid line).

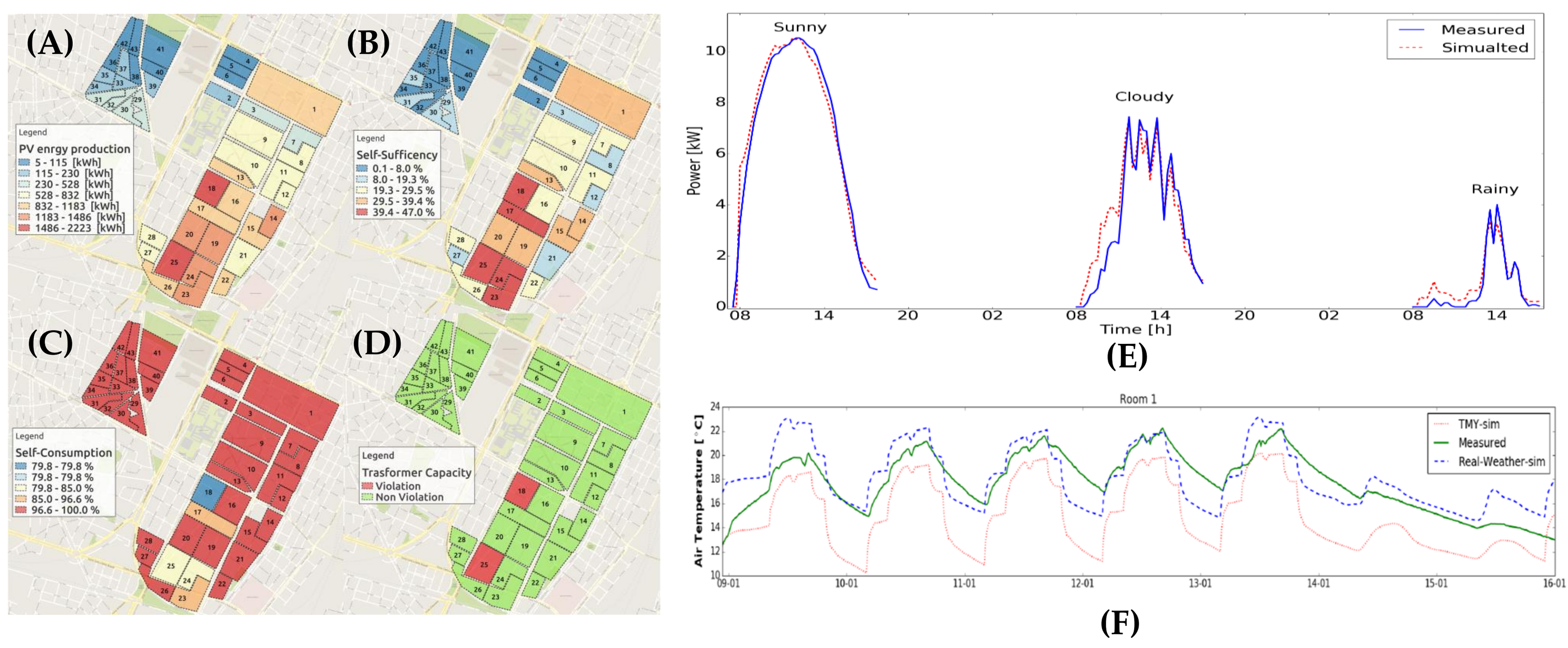

Figure 2 – Simulation results

Maps in Figure 2 report the results obtained with the Real-time co-simulator considering a full PV deployment of all available areas. Map: (A) shows the PV energy production of each Medium Voltage substation in a summer sunny day, (B) shows the level of maximum achievable self-sufficiency of each sub-station, (C) shows the amount of energy that is instantaneously absorbed by the load of the sub-station and (D) shows in which sub-station there is a violation of the transformer capacity. This last map shows that in the studied areas only in two substation there has been a violation of the capacity. In this case possible solutions are: i) reducing the amount of installed PV system or ii) refurbishing the MV transformers. Figure 2-F reports the results of the Thermal Building simulator. It highlights how the developed methodology increases the accuracy of the simulation by integrating real-weather conditions instead of using Test Meteorological Years.

4. References

1. Bottaccioli, L., Patti, E., Macii, E., & Acquaviva, A. (2017). GIS-based Software Infrastructure to Model PV Generation in Fine-grained Spatio-temporal Domain. IEEE Systems Journal.
2. Bottaccioli, L., Estebsari, A., Pons, E., Bompard, E., Macii, E., Patti, E., & Acquaviva, A. (2017). A Flexible Distributed Infrastructure for Real-Time Co-Simulations in Smart Grids. IEEE Transactions on Industrial Informatics.
3. Acquaviva, A., Apiletti, D., Attanasio, A., Baralis, E., Bottaccioli, L., Castagnetti, F. B., ... & Patti, E. (2015, June). Energy signature analysis: Knowledge at your fingertips. In Big Data (BigData Congress), 2015 IEEE International Congress on (pp. 543-550). IEEE.
4. Bottaccioli, L., Aliberti, A., Ugliotti, F., Patti, E., Osello, A., Macii, E., & Acquaviva, A. (2017, July). Building energy modelling and monitoring by integration of IoT devices and Building Information Models. In Computer Software and Applications Conference (COMPSAC), 2017 IEEE 41st Annual (Vol. 1, pp. 914-922). IEEE

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