MARTINE: Multi-Agent based Real-Time INfrastructure for Energy

Demonstration

Tiago Pinto[1], Luis Gomes[1], Pedro Faria[1], Filipe Sousa[1] and Zita Vale[2]
[1] GECAD - Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development - Polytechnic of Porto (IPP), R. Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal
{tcp, lufog, pnf, ffeso}@isep.ipp.pt
[2] Polytechnic of Porto (IPP), R. Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal
zav@isep.ipp.pt

ABSTRACT

This paper presents the Multi-Agent based Real-Time INfrastructure for Energy (MARTINE). MARTINE is a simulation and emulation infrastructure for the study of power and energy systems using a combination of artificial intelligence approaches. MARTINE combines real buildings with sensoring and actuation capabilities with real-time simulation, emulation of physical resources and the intelligent decision support to players actions. The infrastructure is managed and operated by means of several multi-agent systems, which connect to physical resources but also represent additional simulated players that are not present physically in the simulation and emulation environment.

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1 Introduction

The operation and management of power and energy systems are suffering several transformations. This is occurring mostly due to the increasing use of renewable energy sources. The growing complexity and unpredictability in this sector is increasing the difficulty of decision making, which is exacerbated by the increasing number of new player types and regulatory frameworks that are continuously being implemented to deal with the new challenges [1]. Therefore, the intervenient entities are forced to rethink their behaviour and market strategies to cope with such a dynamic sector [2].

So that these entities can deal with the new challenges, the use of decision support tools becomes crucial. However, decision support and simulation platforms are currently only addressing specific and focused problems in the field. Although this focus is essential to overcome specific problems; this approach is not enough, as the evolution of the power system is increasingly dependent on the interactions between entities at multiple levels. It becomes, therefore, essential to address the system a whole and develop decision support, simulation and emulation tools that enable studying the interactions between multiple types of players, markets and operation environments [3].

In order to provide such a complete simulation and emulation infrastructure for power and energy systems, the Multi-Agent based Real-Time INfrastruture for Energy (MARTINE) simulation and emulation infrastructure has been developed. MARTINE puts together advanced decision support, optimization and negotiation artificial intelligence-based approaches; with the actual control and operation of real buildings and micogrids. The entire infrastructure is managed and operated through a combination of multi-agent systems, which operate physical resources but also represent additional simulated players that are not present physically in the simulation and emulation environment. The multiple multi-agent systems are directed to specific problems in the field, and cooperate and interact with each other by means of ontologies, providing semantic meaning to the communications [4, 5]. Demonstration video available: https://www.youtube.com/watch?v=vELttqcNmHQ.

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2 MARTINE platform

This work presents an infrastructure to enable the study, simulation emulation of power and energy systems. This is achieved through the interoperability of heterogeneous multiagent systems directed to the study, simulation, analysis and management of electricity markets, smart grid [6], and buildings energy management [7]. The MARTINE platform is composed by four layers, as shown in Figure 1.

The bottom layer from Figure 1 represents the real-time simulation capabilities, which enable simulating the physical components of energy resources and emulating resources as well. The following layer refers to the actual real buildings that are managed and operated by MARTINE. These buildings are equipped with multiple sensors (e.g. energy consumption, luminosity, humidity, temperature, presence); and actuation devices, which enable the control of energy consumption devices. The second layer concerns the multi-agent systems, which control and operate the different specific systems within MARTINE (e.g. simulation of electricity markets, operation of smart grids, building energy management), besides enabling the communication with physical devices and also the simulation of additional players that are not part of the system (e.g. adding electric). Finally, the top layer is devoted to the decision support an intelligent behaviour of the entities that participate in the system; in this layer are included the advanced optimization algorithms for energy resource management, the automated negotiation approaches for electricity market participation, the machine learning for interaction with buildings, etc.

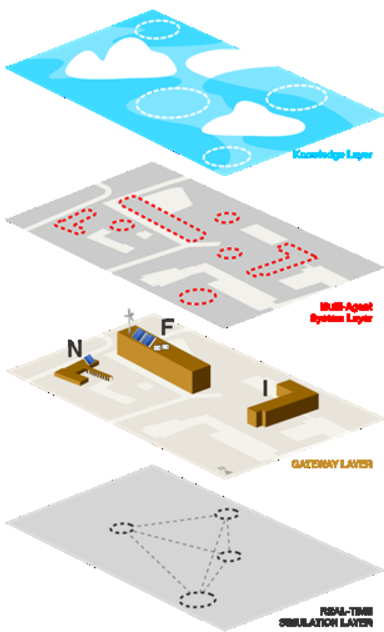

Figure 1. MARTINE architectural layers

In summary, the most relevant features of MARTINE are:

- multi-agent-based platform integrating several multi-agent systems;
- agents representing energy resources of 3 types (real buildings, other installations and equipment; physically emulated components; software agents) allowing to mix physical and simulated resources in real-time simulation;
- includes real-time data acquisition and historic data repository, storing measured real-time data, data obtained in measurement campaigns, and data from multiple sources;
- provides augmented reality by realistic simulation in real-time, enabled by artificial intelligence algorithms in conjunction with hardware-in-the-loop simulation;
- enables integration of external applications and physical installation (buildings, houses, labs); receives real-time data remotely, used in real-time management and simulation;
- integrates most of the GECAD models for smart grids (e.g. energy resource scheduling optimization, demand response, market simulation);
- provides effectiveness/efficiency to intelligent management (according to the time constraints to provide the solution) by the use of reinforcement learning.

The concepts necessary for the interactions between the various involved agents are represented by ontologies. The developed ontologies not only enable the interoperability between different multi-agent systems but also represent the concepts needed to understand and use real data, from different sources. These are acquired in real time through analyzers/sensors and databases available online. For that, ontologies allow the representation of knowledge in a common vocabulary, regardless of the source; thus facilitating interoperability between the various heterogeneous systems and data, information and knowledge sources.

The multi-agent systems society considers the use of the developed ontologies for the interoperability between the diverse systems and for the representation of the knowledge in a vocabulary common to all the participants, allowing them to communicate with external entities in the same language. For this purpose, multi-agent system servers for certain services are provided with the flexibility to communicate in different existing RDF languages. In this way, the interaction with further external systems and knowledge sources is facilitated, as these can use their own language. Through the alignment of the ontologies, any external system that complies with this can be easily integrated in MARTINE.

3 Conclusions

This paper presents and demonstrates MARTINE, a multi-agent simulation and emulation platform that enables the study of power and energy systems by coordinating and complementing real actuation environments with real-time simulation and physical emulation of energy resources.

The demonstration of this system includes the execution of its several components, namely through the demonstration of actuation actions on physical devices inside a real building, located in the GECAD buildings, at the Polytechnic of Porto campus. This control is coordinated by simulated agents with specific roles (e.g. market negotiating agents, system operators) using the intelligent decision support.

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