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# Dynamic Approach and Testbed for Small and Medium Players Simulation in Smart Grid Environments

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**Abstract:** The Smart Grid environment allows the integration of resources of small and medium players through the use of Demand Response programs. Despite the clear advantages for the grid, the integration of consumers must be carefully done. This paper proposes a system which simulates small and medium players. The system is essential to produce tests and studies about the active participation of small and medium players in the Smart Grid environment. When comparing to similar systems, the advantages comprise the capability to deal with three types of loads – virtual, contextual and real. It can have several loads optimization modules and it can run in real time. The use of modules and the dynamic configuration of the player results in a system which can represent different players in an easy and independent way. This paper describes the system and all its capabilities.

## 1. INTRODUCTION

The International Energy Agency recently concluded that smart grids could "coordinate the needs and capabilities of all generators, grid operators, end-users, and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability" (International Energy Agency, 2011). For these reasons, the concept of smart grids has gained attention of politicians around the world (Brandstatt et al., 2012).

One of the advantages of smart grids is the active participation of small and medium players. The consumers will become a part of the smart grid management, having bilateral connections with other players of the grid (Ye Yan et al., 2013). To achieve a feasible and fast integration of small and medium consumers, Demand Response (DR) programs that can be launch by several players inside the smart grid are used (Yunfei Wang, 2011).

The integration of DR to allow an active participation of small and medium players must be studied. The consumer's action determines the success of the DR program. To provide satisfactory answers, consumers can implement a Demand Side Management system (Yee Wei Law et al., 2012). Studies regarding DSM in facilities can be seen in (Barbato, 2012), (Quintero, 2012) and (Guo et al., 2008).

DR programs represents mainly the reduction of consumption by small and medium players, which leads to load optimization algorithms. In (Barbato, 2012) an optimization process capable of minimizing the overall consumption is shown. The simulator proposed in (Guo et al., 2008) has the ability of comparing more than one optimization process. This ability is an advantage for the study of DSM.

This paper will propose a dynamic system capable of simulating small and medium players in smart grid environments. The simulator proposed has the goal of representing the actions and reactions of small and medium players. To perform a realistic representation of real consumers, the simulator has got three different types of loads: two of them are simulations, and the third comprises real loads connected to the system. The capacity of integrating real loads separates this simulator from the simulators proposed by other authors. The communications between real loads and the simulator are made through the TCP/IP protocol, to communicate with PLC loads, and/or through ZigBee protocol, for real loads that are connected to a management and controller devices.

To allow the DSM in the system, this simulator can accommodate multiple optimization algorithms, such as the simulator proposed in (Guo et al., 2008). However, the simulator proposed in this paper can easily integrate any optimization algorithm implemented in MATLAB.

The simulator proposed in this paper has the particularity of dealing with real loads. For this reason, the simulator may gain the functionality of a unique real system for the DSM. To allow the control and management of this system, a mobile application was developed. The focus in this paper is the control of a refrigerator that contains a ZigBee device capable of communicating with the simulator.

After the introduction, this paper presents the system architecture in section 2, followed by the description of the type of loads in section 3. Section 4 presents the implemented mobile application and a practical implementation. A case study regarding the analysis of the consumptions of a real refrigerator in our lab is shown in section 5. Finally, section 6 presents the conclusions of the paper.

## 2. SYSTEM ARCHITECTURE

The proposed system simulates small and medium players that can be introduced in a smart grid environment. Smart grids are an important concept for the future of energy grids (Brandstatt et al., 2012). To achieve the complete implementation of smart grids it is necessary to test and analyse the integration of small and medium players, which represent most of the stakeholders in the grid.

The simulator described in this paper aims the creation of a testbed system which can realistically simulate small and medium players. For this purpose, the simulator has the possibility of integrating real loads. One can see the architecture of the simulator in Fig. 1.

The simulator is implemented in Java, yet it also uses MATLAB and GAMS. The use of MATLAB and GAMS was one requirement of the system, as these languages are essential for the execution of the system's optimization algorithms. The integration between MATLAB and Java was made by using MATLAB Builder JA, which allows the transformation of MATLAB functions into Java functions.

The optimization module is an essential part of the simulator. The simple management and control of loads are not enough to bring small and medium players into the smart grid environment. These players need to acquire some kind of intelligence, which has been introduced into the simulator by applying artificial intelligence techniques. Although being an important part of the simulator, the optimizations and the application of Artificial Neural Networks (ANN) in the simulator are not discussed in this paper. The focus is given to present the architecture of the simulator and the integration of real loads, namely the integration (in real time) of a real refrigerator into the simulator.

The optimizations modules and the optimization algorithms can be seen in (Gomes et al., 2013*a*); the use of ANN to achieve the user preferences according to the context can be seen in (Gomes et al., 2011); the combination of ANN and optimization allow a custom cut in the consumption, minimizing the negative impact for the users.

The intelligence of the system, provided mainly by the optimization algorithms, acts on the loads controlled by the simulator. The simulator supports three types of loads: Simulated Load; Contextual Load; and Real Load. The real loads are divided into two types: Programmable Logic Controller (PLC) Loads, and ZigBee Loads. The description of loads can be found in section 3.

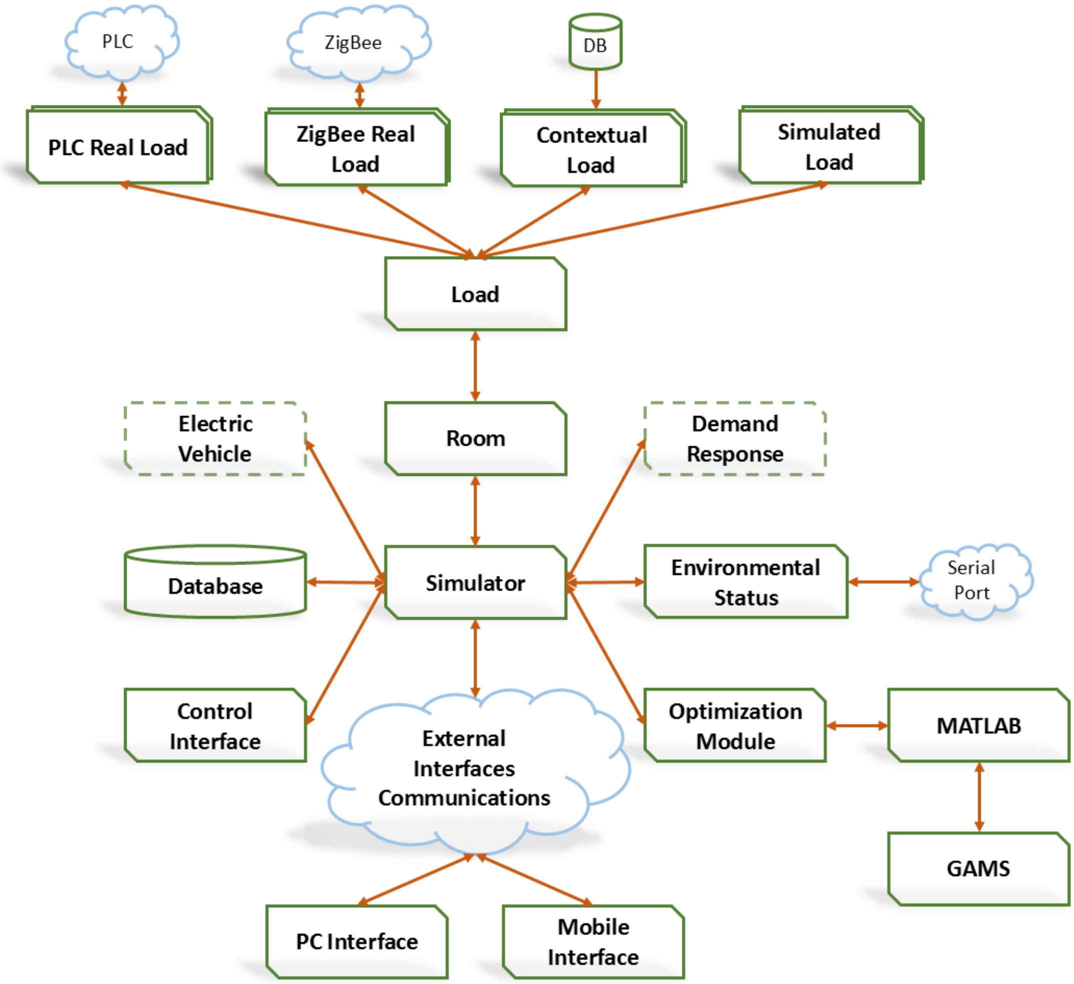


Fig. 1. Architecture of the simulator