A MAS-based simulator for the prototyping of Smart Grids

Gillian Basso[1], Vincent Hilaire[1], Fabrice Lauri[1], Robin Roche[1], and Massimo Cossentino[2]

[1]Laboratoire Systèmes et Transports (SeT)
Université de Technologie de Belfort-Montbéliard (UTBM)
90010 Belfort cedex, France
gillian.basso@utbm.fr
+33 384 58337 97
www.multiagent.fr
[2]Istituto di Calcolo e Reti ad Alte Prestazion
Consiglio Nazionale delle Ricerche
Palermo, Italy
cossentino@pa.icar.cnr.it

Abstract. Energy management is, nowadays, a subject of uttermost importance. Indeed, we are facing several problems like petroleum reserve depletion or earth global warming. Smart Grids, a new type of electrical grid which try to intelligently manage its components, are a possible answer to these issues. Multi-Agent Systems (MAS) are a good candidate for modelling and managing Smart Grids. In this context, one of the main issue is to design adapted MAS architectures that take into account the hardware infrastructure of the electrical grid. In order to ease the elaboration of the testing and validation phases of specific MAS architectures for Smart Grid management, we advocate the use of a reliable MAS-based simulator. The simulator proposed in this paper is analysed and designed according to a MAS methodological process, namely ASPECS. This simulator is planned to be implemented and used as a prototyping tool for managing Smart Grids without deploying real devices.

Key words: Multi-Agent Based Simulation, Organisational methodology, Smart Grids

1 Introduction

Energy management is, nowadays, a subject of uttermost importance. Indeed, we are facing several problems like petroleum reserve depletion or earth global warming. A system able to manage energy in an intelligent way is thus desirable. However, energy management is a complex problem. Each source has its specific characteristics such as production cost, environmental constraints, capacity, etc. The backbone to this renewed electrical grid is known as the smart grid. This

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. “A MAS-based simulator for the prototyping of Smart Grids.” In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

DRAFT COPY

concept covers a wide range of possible electrical grids in which a modernised electrical grid with large proportions of carbon-free energy resources interacts with a communication and control network [16]. The management of such an electrical grid includes many different objectives such as economic, environmental or quality of service, and also many different technologies to aim these objectives such as self-healing, sources & loads control, voltage or frequency management, etc..

Multi-Agent Systems (MAS) are a good candidate in order to model and manage such kind of systems. Indeed, smart grids are geographically distributed systems composed of autonomous and reactive entities among which some are pro-active and have social abilities. Moreover, smart grids are a good example of open and dynamic systems. Loads and sources can connect and/or disconnect and have a partially predictable behaviour.
In this context, one of the main issue is to design MAS for the management of Smart Grids, as for example [3]. These MAS must take into account the many different existing, and up to come, hardware infrastructures of the electrical grid. In order to test and validate specific MAS for smart grid management, we propose to build a simulator, based on MAS, that should avoid the deployment of real devices. We plan to use this simulator as a prototyping tool for MAS for Smart Grids management. Ideally, such a simulator should exhibit the following features: (1) reliable, it should reproduce the behaviour of real electrical devices and can be replaced by real devices without global change, (2) open, it should allow the connection/disconnection of devices, (3) generic, in the sense that it should not make hypothesis on the management part. In order to design such Multi-Agent Systems, we have chosen to follow the ASPECS methodological process [5].
This paper is structured as follows: section 2 discusses some approaches using agents for Smart Grids. Section 3 presents the methodological approach and platform used in this paper. Section 4 details the simulator architecture and section 5 gives concluding remarks and future research directions.

2 Related Works

Some works, coming from the electrical community have identified the interest of using MAS for designing and managing Smart Grids [12, 13, 16]. In this section is presented a brief overview of the software systems dedicated to Smart Grids.

Developed by Infotility, the GridAgents framework [4, 8] implements several types of agents:

– "Sense and Control" and "Resource" Agents which have analytic methods to calculate optimal response based on pricing signals.
– "Planning and Optimisation Agents manage Distributed energy resources (DER) devices under various operational scenarii such as optimal microgrid control strategies.

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

– "Blackboard" Agents can store databases (from several media, like Internet or the MAS).

GridAgents also offers human interactions and network protection. This Suite is developed for managing distributed energy resources and can be used for large-scale integration of distributed energy and renewable energy resources into real distribution systems.

Homebots [19, 1, 7] is a decentralised power load management at the customer side using MAS. Two types of agents are developed:

1. One intelligent agent representing the utility. If we consider a small residential area, this agent will reside somewhere in the low-voltage grid in a secondary substation area (transformer) supplying a collection of family homes.
2. For each customer, one or more agents acting as representative. Under each customer, we have a number of household appliances or industrial equipment.

In Homebots every controllable load in the system is represented by a load agent whose needs and preferences are modelled by a utility function which is different for every agent. They determine the interest, for an agent, the addition of a share of resources. The relation of the agents in the Homebots architecture is based on the concepts coming from the theory of competitive economic exchange markets.

IDAPS [15] is a distributed smart grid concept proposed by Advanced Research Institute of Virginia Tech. The agents in the IDAPS MAS work in collaboration to detect upstream outages and react accordingly to allow the microgrid to operate autonomously in an islanded mode. The proposed MAS consists of:

– a control agent that monitors the system voltage, detects problems and sends signals to the main circuit.
– a DER agent that is responsible for storing associated DER information and monitoring and controlling DER power levels.
– a user agent that acts as a customer (user or load) gateway
– a database agent that is responsible for storing system information

IDAPS is realized with Zeus [14] multi-agent system platform, which is FIPA-compliant. This work aims at demonstrating a practical implementation of multi-agent systems in a smart grid located at a distribution level. It also demonstrates that the agent's capability can be considered as a software alternative to a traditional hardware-based zonal protection system for isolating a microgrid. IDAPS separates the multi-agent system (developed with Zeus) and the microgrid hardware (developed with Matlab/Simulink).

The PowerMatcher [9, 11] MAS is designed according to specifications derived from the CRISP-project. It is a market-based control concept for supply

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

and demand matching in electricity networks with a high share of distributed generation.

In the PowerMatcher system each device is represented by a control agent, which tries to operate the process associated with the device in an economical optimal way. The electricity consumed or produced by the device is bought, respectively sold, by the device agent on an electronic exchange market.

All devices present in the PowerMatcher communicate with an SD-Matcher (for Supply/Demand Matcher) which manages demands and supplies of a cluster of devices directly below it. It implements various devices like dwellings or wind turbines (and wind turbines park) as well as residential heat production or emergency generators. Due to device reactions on price fluctuations, the simultaneousness between production and consumption of electricity in a sub-network is increased. As a result, the net import profile of the sub-network is smoothed and peak demand is reduced, which is desired from a distribution network operational viewpoint.

The simulator described in [10] is a Smart City Simulator that attempts to create the dynamic behaviour of a smart city developed with JADE [2]. Its architecture is composed of three layers:

1. The top layer: the enterprise application layer communicates with the simulator layer via web services. It offers the possibility to enterprises to influence the parameters and get results in the runtime.
2. The middle layer: this layer receives the action of the top layer and communicates with the third layer via local method invocations.
3. The bottom layer: the agent simulator layer.

The main purpose of this simulator is to depict the real world structure and behaviour considering the smart city and smart grid area. Thus it implements devices which can change its location in the grid such as Plug-in Hybrid Electric Vehicles (PHEV). But all the implemented devices have only two state (ON/OFF) with no variations between these states. Furthermore the PHEV are implemented as loads and cannot provide energy to the grid. In this work the authors focus exclusively on the heterogeneity of devices and their consumption and generation profiles, as the main interest is on creating a smart city and focus on the interactions and dynamics of the infrastructure.

All these simulators are developed and used for specific purposes. They were not analysed nor designed according to a MAS methodology in order to place emphasis on the realistic characteristic and the fact to be used as a prototyping tool. We propose to develop an Energy Simulator whose configurable components allow users to easily design, build and test any kind of electrical systems while respecting realistic characteristics of these systems.

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. “A MAS-based simulator for the prototyping of Smart Grids.” In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

3 Background

3.1 ASPECS

The ASPECS life cycle consists of three phases: (1) System requirements (2) agency and (3) implementation and deployment. Definitions of all ASPECS metamodels can be found in [5] and on the ASPECS website[1]. The figure 1 describes the concepts of the first phase, namely system requirements.

The System Requirements phase aims at identifying a hierarchy of organisations, whose global behaviour may fulfil the system requirements under the chosen perspective. Each organisation is responsible for exhibiting a behaviour that fulfils the requirements it is responsible for. The behaviour of each organisation is realised by a set of interacting roles whose goals consist in contributing to the fulfilment of (a part of) the requirements of the organisation within which they are defined. In order to design modular and reusable organisation models, roles are specified without making any assumptions on the structure of the agent that may play them. To meet this objective, the concept of capacity has been introduced. A capacity is an abstract description of a know-how, i.e., a competence of a role. Each role requires a set of skills to define its behaviour and these skills are modelled by means of a capacity. Besides, an entity that wants to play a role has to be able to provide a concrete realisation for all the capacities required by the role. Finally, the last step of the system requirements phase: the capacity identification activity, aims at determining the capacities required by each role.

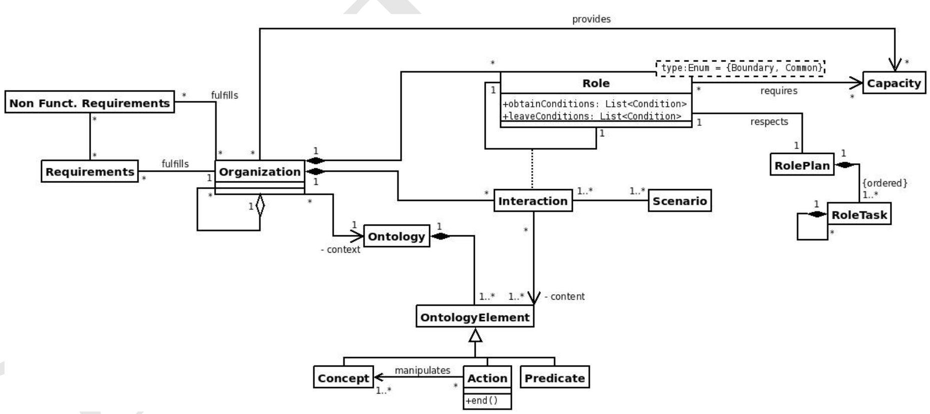

Fig. 1: Metamodel of the ASPECS problem domain

In our approach, a Role defines an expected behaviour as a set of role tasks ordered by a plan, and a set of rights and obligations in the organisation con-

[1] http://aspecs.org

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

text. The goal of each Role is to contribute to the fulfilment of (a part of) the requirements of the organisation within which it is defined.

Roles use their capacities for participating to organisational goals fulfilment; a Capacity is a specification of a transformation of a part of the designed system or its environment. This transformation guarantees resulting properties if the system satisfies a set of constraints before the transformation. It may be considered as a specification of the pre- and post-conditions of a goal achievement.

3.2 Janus

This section is dedicated to the presentation of the metamodel of the JANUS platform [6]. Its main concepts are described in the UML diagram, presented in Figure 2.

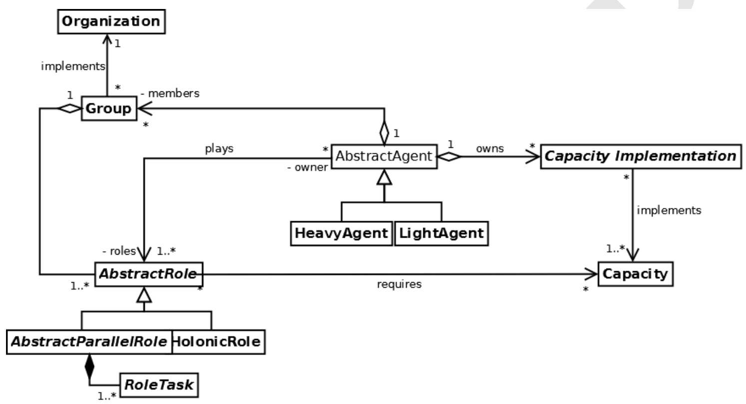

Fig. 2: Diagram of a part of the metamodel of the JANUS platform

JANUS was designed to facilitate the transition between design and implementation phase. So it provides a direct implementation of the five key concepts used in the design phase: organisation, group, role, agent and capacity.

The organisation is implemented as a first-class entity (a class in the object-oriented sense), which includes a set of role classes. An organisation can be instantiated in the form of groups. Each group contains a set of instances of different classes of roles associated with the organisation which it implements. The number of authorised instances for each role is specified in the organisation. A role is local to a group, and provides agents playing the role and the means to communicate with other group members. One of the most interesting aspects of JANUS covers the implementation of roles as first class entity. A role is seen as a full-fledged class, and the roles are implemented independently of the entities that play them. Such an implementation facilitates the reuse of organisations in other solutions, but also allows a wide dynamic for roles.

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

An agent can play simultaneously multiple roles in several groups. It can dynamically access new roles and leave the ones that are no longer in use. When an agent assumes a role, it obtains an instance of the class of this role that it stores in its roles container. Respectively, when it leaves a role, the corresponding instance is removed.

The notion of capacity enables the representation of agent skills. Each agent has, since its creation, a set of basic skills, including the ability to play roles (and therefore communicate), to obtain information on existing organisations and groups within the platform, create other agents, and obtain new capacities. The capacity concept is an interface between the agent and the roles it plays. The role requires some capacities to define its behaviour, which can then be invoked in one of the tasks that make up the behaviour of the role. The set of capacities required by a role are specified in the role access conditions. A capacity can be implemented in various ways, and each of these implementation is modelled by the notion of *Capacity Implementation*. This concept is the operational representation of the concept of service defined in the Agency domain.

In addition to these concepts, JANUS provides a range of tools to facilitate the work of the developer which are not described here.

4 Power grid simulator

This section presents the principles of the MAS based simulator for Electrical Grids. This simulator avoids the deployment of real electrical devices in order to test intelligent, MAS based, systems for Smart Grids management. To do so the simulator must be as reliable as possible and accurately represents a physical process for a deployment from the simulator to real grids as smooth as possible. To ensure this transition, electrical devices should satisfy some strong principles that are described in the next subsection. After the presentation of these principles, a part of the modelling of the simulator, following the ASPECS methodology, is presented in the other subsections.

4.1 Principles for interfacing external systems

The Energy Simulator is a MAS that respects the weak notions defined in [18]. Each agent representing an electrical device has the following properties:

autonomy : the devices operate without being directly controlled by humans or other agents, and have some kind of control over their actions and internal states,

social ability : the devices interact with other agents (and possibly humans),

reactivity : the devices perceive their environment (which may be the physical world), and respond in a timely fashion to changes that occur in it,

pro-activeness : the devices do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking initiatives.

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

In order to introduce a mechanism that ensures a smooth transition from the MAS based simulator to real electrical grids and ensure openness, we define the concepts of sensors and actuators. These concepts specify behaviours which consist of: (1) an Input part, namely sensors, that extracts data (2) an Output part, namely actuators, that send data to devices in order to modify their behaviours as illustrated in figure 3.

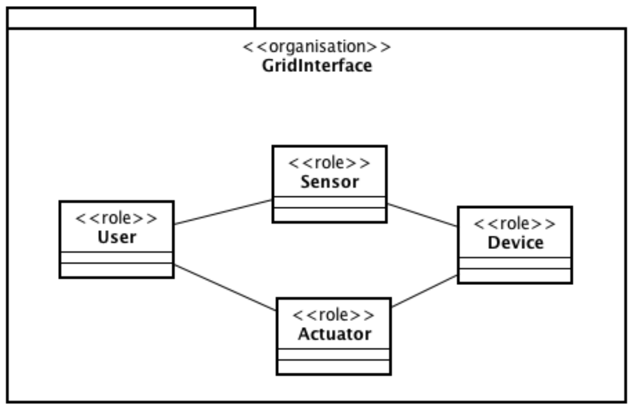

Fig. 3: Organisation for interfacing the different grid types and MAS

The Sensor role monitors data present in a (real or virtual) device represented by the role Device. This information will be stored and formalised to be sent to external users represented by the User role. No assumptions are made on these external users. An external user can be a supervisory control and data acquisition (SCADA) system, an intelligent system or every kind of software or hardware that wants to monitor internal data of a specific device of the Energy Simulator.

The Actuator role gives behavioural instructions to a Device. The Device will take into account this information and will apply it as soon as possible (if no other conflicting information is received). Actuators cannot influence directly a production or consumption of a Device. It only changes its parameters and the production or consumption will change automatically according to the physical constraints of the Device.

4.2 Simulator organisation

The Organisation of the Energy Simulator defines three roles.

the energy producer i.e, sources, which offer energy to other devices. The energy is distributed through a transmitter. Each source, has specific characteristics and constraints. The capacity required to play this role is Pro-

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

DRAFT COPY

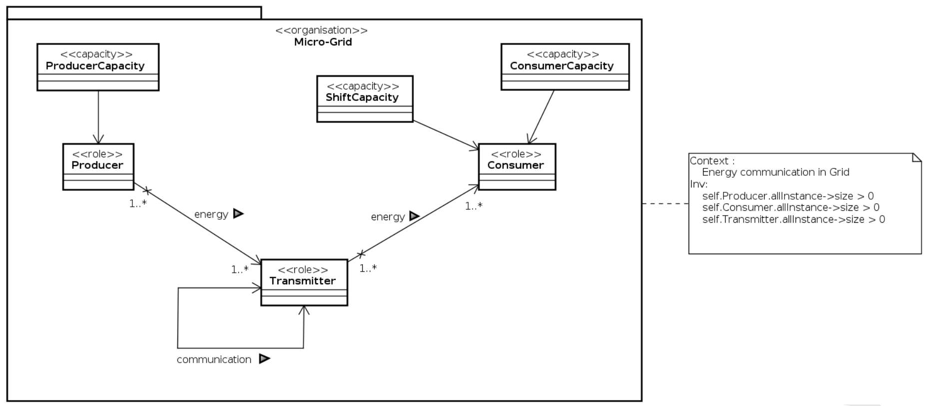

Fig. 4: The Grid Organisation in the Energy Simulator

ducerCapacity. This capacity determines the amount of energy that can be distributed.

the energy consumer i.e, loads, which use energy present in the grid by taking it from the transmitters. The Consumer role requires, at least, the ConsumerCapacity. This capacity allows the Consumer to take energy from the transmitter and specifically what amount of energy is taken. Moreover, some Consumer can exhibit the ShiftCapacity. This capacity enables the Consumers to delay their consumption of energy and specify the constraints concerning this delay.

the energy transmitter where the energy can circulate (with or without loss of energy).

The basic constraints imposed to this organisation are the following. A coherent grid needs at least one producer, one consumer and one transmitter. These constraints are expressed in OCL[2] in the right part of the figure 4.

To be as realist as possible, some other constraints must be respected. These constraints must be respected in the Organisation. First of all, the amount of energy distributed to the transmitter must equal the sum of the amount of energy exiting and the energy lost in the transmitter. A transmitter must be linked to, at least, two other devices. If a transmitter has zero or one link, it will be inactive until new devices are added (and previous constraint true). A device not linked to a transmitter is also inactive. The producers provide energy to its linked transmitters while the consumers remove energy from its linked transmitters. The transmitters will manage the distribution. It is impossible for other devices to know where and how much energy is provided or removed. All these constraints are invariant: they must be always true during the simulation. There exist other constraints that offer modularity to the system in the meanwhile respecting the reliability of the grid. A device may be dynamically added or removed during

[2] see http://www.omg.org/spec/OCL/

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

the simulation. For example, if an empty storage system has been added, the linked transmitter should automatically yield energy to fill it, but the amount of the power provided should never exceed the maximum allowed input/output power of the storage system. This Organisation is sketched in figure 4.

4.3 Role description

Several types of energy producers are present in the simulator. For example, the predictable sources, like fuel cells or nuclear power plants, and the non-predictable sources, like photovoltaic panels or wind turbines. This difference is specified by a Capacity to externalise this feature. The *ProducerCapacity* determines the amount of energy delivered by a producer. In this Capacity, the production of a predictable source needs a parameter which is the curve of the energy production.

The energy consumers, as energy sources, can have many different profiles. To represent this fact we have defined a Capacity, equivalent to the *ProducerCapacity*, the *ConsumerCapacity*. This capacity allows the externalisation of the consuming profile. Another Capacity is defined for consumers. This Capacity (called *ShiftCapacity*) offers the possibility to a load to delay its need of energy. This capacity may be provided by certain consumers.

The energy transmitters play a crucial Role in the Grid Organisation, because all communications must go through this Role. But they also have another important Role: the simulation of the distribution of energy.

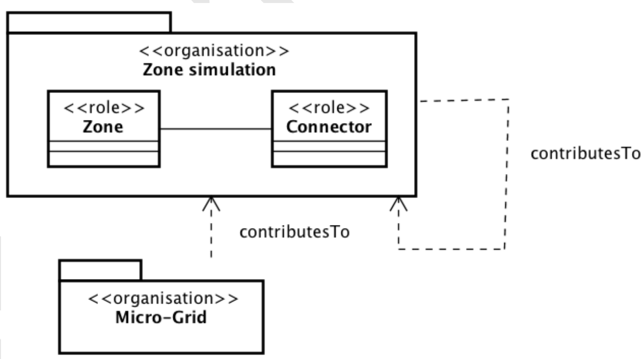

Fig. 5: Relationships between different simulation levels

The relation of a micro-grid with an external grid is specified by the figure 5. In this figure the micro-grid organisation is linked to an upper-level organisation named Zone simulation. The principle is based on the connectivity of the electrical devices. Each micro-grid, if not islanded, is connected to other micro-grids or more important grids by mean of devices represented by the Connector role.

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

The Zone role then represents a micro-grid, for level 1, or a geographically bigger grid if at upper levels.

To have an overview of the simulation, a scenario of simulation of a micro-grid instance single step is discussed and sketched in figure 6. No assumption is made about the number of players of *ProducerRoles* and *ConsumerRoles* in this instance of *Organisation*. The only assumption is that at least two transmitters are present.

4.4 A Simulation Step

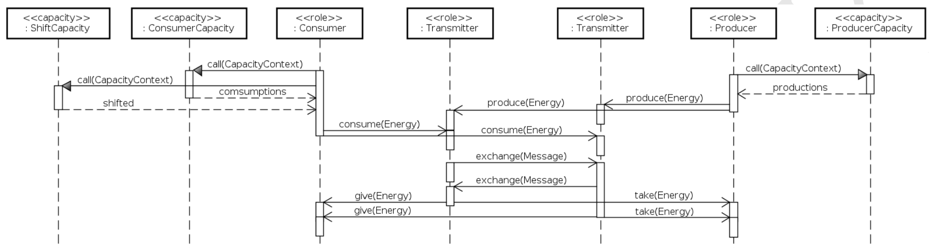

Fig. 6: A simple example of communications between Roles

A *ProducerRole* has to request the *ProducerCapacity* of its player Agent. This Capacity gives the amount of energy produced by this source to the *ProducerRole* and it forwards the data to its linked instance of *TransmitterRole*.

In parallel, the same sequence is made for the *ConsumerRole*, the *Consumer-Capacity* and the *ShiftCapacity* of the Agent playing the Consumer role gives the related information. This information is then given to the linked player of *TransmitterRole*.

When this information is received, the players of *TransmitterRole* begin the communications between themselves. When all *TransmitterRoles* agree with the amount of transmitted energy, they take energy from *ProducerRoles* and offers the energy to the *ConsumerRoles*. If no agreement is reached, a part of the network can be disconnected from the whole network. This disconnection can be made after a change in voltage or frequency below a given threshold. The devices in charge of disconnecting micro-grid are circuit breakers. In the Micro-Grid Organisation, the circuit breakers have to play the *TransmitterRole* and in the Zone Simulation organisation they have to play a *ConnectorRole* (see Fig. 5).

4.5 Agentification

An example of agentification, following the organisations defined above, is given in figure 7. Two examples of agent are detailed. The first agent is a fuel cell agent and the second agent is a battery agent.

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

A fuel cell is a source device that converts chemical energy into electricity. The power $P_s(I)$ produced by the fuel cell can be determined by the voltage $V_s(I)$ and the current I (equation 1).

$$P_s(I) = V_s(I) \cdot I \tag{1}$$

To be as realist as possible, the model has to take into account losses due to the auxiliaries of the fuel cell [17]. Let η_a be the share of P_s consumed by the auxiliaries and P_a the constant power consumed by others, the energy offers from the fuel cell to the grid in Δt seconds is determined by equation 2.

$$E_f = [(1 - \eta_a)P_s(I) - P_a]\Delta t \tag{2}$$

The fuel cell agent uses equation 2 to simulate the energy production in the smart grid organisation (see 4.2). It has to play a source role and the producer capacity (see 4.2), which has to calculate the energy production of this agent, implements the model.

A battery consists of electrochemical cells that convert chemical energy into electrical energy (distribution) or electrical energy into chemical energy (storage). The model of the battery defined in [17] represents a battery but could also be used with other types of storage due to its generic nature. Its characteristics are its capacity C_b, its charge (positive) and discharge (negative) efficiency η_b, its state of charge SoC. The SoC is updated using equation 3, where P_b is the set point and Δt the duration between two set points.

$$SoC_t = SoC_{t-1} + \eta_b \frac{P_b \cdot \Delta t}{C_b} \tag{3}$$

The battery agent is a complex agent which has to play several roles. When charging, the battery agent has to play the consumer role (see 4.2) thus it must implement the capacities needed by this role (*i.e.* the ConsumerCapacity and the ShiftCapacity, see 4.2) but when it is discharging, the battery agent has to play the producer role (see 4.2) and must also implement the needed capacity (*i.e.* the ProducerCapacity, see 4.2). The implementation of the three capacities must take into account the model defined by equation 3, two variables have to be adapted to manage the state of charge :

η_b : its value decrease over the time of simulation to simulate the wear of the battery. The sign of this variable can change, it is positive when charging (*i.e.* in the ConsumerCapacity) and negative when discharging (*i.e.* in the ProducerCapacity).

P_b : this variable can determine the bottleneck of the battery. It must be calculated by the agent and should be zero when the battery cannot receive or send energy (e.g. when the ShiftCapacity decide to delay the consumption of the battery).

Moreover, due to the analysis and specifically to the structure of the organisations of figure 5 and their inherent self-inclusion, the system is scalable

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

and open. Indeed, as illustrated by figure 7, a zone can be composed by smaller zones linked by a connector. The Connector role is played by a circuit breaker. This Connector ensures that if one of the two Micro-grid organisation instance crashes, the other can continue. This architecture may be pre-defined to represent a real electrical grid or it can evolves during simulation to satisfy openness or computation constraints such as memory or CPU usage. These different organisations can be distributed over a computer network or a computing grid using the Janus platform.

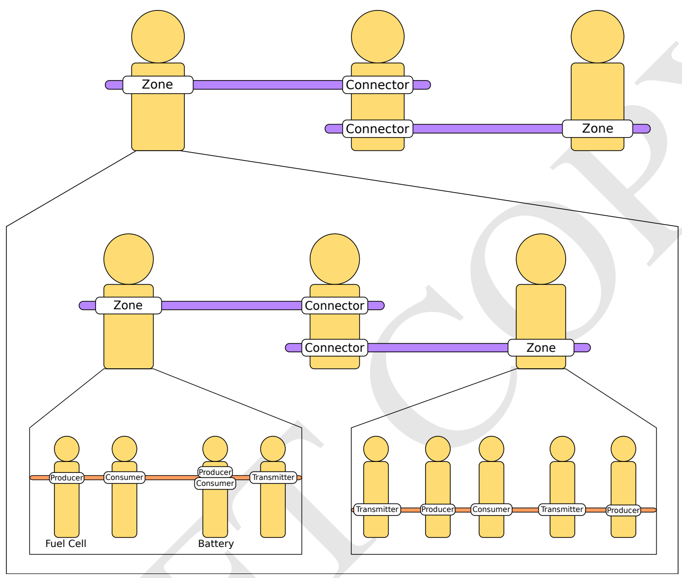

Fig. 7: An example of groups

5 Conclusions and future works

In this paper we have presented a subject of importance for the Smart Grids community. The proposition consists of a simulator capable of reproducing the behaviours of electrical devices in order to test MAS for Smart Grids management. Moreover, the presented principles allow to replace the simulator with real devices without changing the Smart Grids management part. One of the aim of this simulator is to enable a prototyping approach for MAS dedicated to Smart Grids management.

The simulator has been designed according to a specific MAS methodology, namely ASPECS [5]. This methodology is based on organisational concepts and is supported by a development platform that implements the methodology metamodels elements, JANUS [6].

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. “A MAS-based simulator for the prototyping of Smart Grids.” In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

In the future, we plan to evaluate different MAS for Smart Grids in order to identify efficient approaches. These MAS will be tested within the proposed simulator and on real grids.

References

1. J.M. Akkermans, F. Ygge, and Gustavsson R. Homebots: Intelligent decentralized services for energy management. In *Fourth International Symposium on the Management of Industrial and Corporate Knowledge, ISMICK '96, Rotterdam*, pages 128–142. Ergon Verlag, 1996.
2. Fabio Bellifemine, Agostino Poggi, and Giovanni Rimassa. Jade: a fipa2000 compliant agent development environment. In *Proceedings of the fifth international conference on Autonomous agents*, AGENTS '01, pages 216–217, New York, NY, USA, 2001. ACM.
3. M. Cirrincione, M. Cossentino, S. Gaglio, V. Hilaire, A. Koukam, M. Pucci, L. Sabatucci, and G. Vitale. Intelligent energy management system. In *Proceedings of the IEEE indin conference*, 2009.
4. D.A. Cohen. Gridagents : Intelligent agent applications for integration of distributed energy resources within distribution systems. In *Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE*, pages 1 –5, july 2008.
5. Massimo Cossentino, Nicolas Gaud, Vincent Hilaire, Stéphane Galland, and Abderrafiaa Koukam. ASPECS: an agent-oriented software process for engineering complex systems. *Autonomous Agents and Multi-Agent Systems*, 20(2):260–304, 2010.
6. Nicolas Gaud, Stéphane Galland, Vincent Hilaire, and Abderrafiâa Koukam. An organisational platform for holonic and multiagent systems. In Koen Hindriks, Alexander Pokahr, and Sebastian Sardina, editors, *Programming Multi-Agent Systems*, volume 5442 of *Lecture Notes in Computer Science*, pages 104–119. Springer Berlin / Heidelberg, 2009.
7. Rune Gustavsson. Agents with power. *Commun. ACM*, 42:41–47, March 1999.
8. Geoff James, Dave Cohen, Robert Dodier, Glenn Platt, and Doug Palmer. A deployed multi-agent framework for distributed energy applications. In *Proceedings of the fifth international joint conference on Autonomous agents and multiagent systems*, AAMAS '06, pages 676–678, New York, NY, USA, 2006. ACM.
9. Rene Kamphuis, Cor Warmer, Maarten Hommelberg, and Koen Kok. Massive coordination of dispersed generation using powermatcher based software agents. *CIRED*, May 2007.
10. S. Karnouskos and T.N. de Holanda. Simulation of a smart grid city with software agents. In *Computer Modeling and Simulation, 2009. EMS '09. Third UKSim European Symposium on*, pages 424 –429, nov. 2009.
11. J. K. Kok, C. J. Warmer, and I. G. Kamphuis. Powermatcher: multiagent control in the electricity infrastructure. In *Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems*, AAMAS '05, pages 75–82, New York, NY, USA, 2005. ACM.
12. S.D.J McArthur, E.M. Davidson, V.M. Catterson, A.L. Dimeas, N.D. Hatziargyriou, F. Ponci, and T. Funabashi. Multi-agent systems for power engineering application - part I: Concepts, approaches, and technical challenges. *IEEE Transactions on Power Systems*, 22(4):1743–1752, 2007.

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS

13. S.D.J McArthur, E.M. Davidson, V.M. Catterson, A.L. Dimeas, N.D. Hatziargyriou, F. Ponci, and T. Funabashi. Multi-agent systems for power engineering application - part II: Technologies, standards, and tools for building multi-agent systems. *IEEE Transactions on Power Systems*, 22(4):1753–1759, 2007.
14. Hyacinth S. Nwana, Divine T. Ndumu, Lyndon C. Lee, and Jaron C. Collis. Zeus: A toolkit for building distributed multiagent systems. *Applied Artificial Intelligence*, 13(1-2):129–185, 1999.
15. M. Pipattanasomporn, H. Feroze, and S. Rahman. Multi-agent systems in a distributed smart grid: Design and implementation. In *Power Systems Conference and Exposition, 2009. PSCE '09. IEEE/PES*, pages 1 –8, march 2009.
16. R. Roche, B. Blunier, A. Miraoui, V. Hilaire, and A. Koukam. Multi-agent systems for grid energy management: A short review. In *IECON 2010 - 36th Annual Conference on IEEE Industrial Electronics Society*, pages 3341 –3346, 2010.
17. R. Roche, L. Idoumghar, B. Blunier, and A. Miraoui. Optimized fuel cell array energy management using multi-agent systems. *46th IEEE Industry Applications Annual Meeting (IAS 2011)*, 2011.
18. Michael Wooldridge and Nicholas R. Jennings. Intelligent agents: theory and practice. *The Knowledge Engineering Review*, 10(02):115–152, 1995.
19. Fredrik Ygge, Rune Gustavsson, and Hans Akkermans. Homebots: Intelligent agents for decentralized load management. *DA/DSM 96 Europe Distribution Automation & Demand Side Management Vienna, Austria,*, (8-10), October 1996.

DRAFT COPY

Draft for Gillian Basso, Vincent Hilaire, Fabrice Lauri, Robin Roche, and Massimo Cossentino. "A MAS-based simulator for the prototyping of Smart Grids." In Proc. of the 9th European Workshop on Multiagent Systems (EUMAS11), Maastricht, Netherlands, Paper 43.
2011 © EUMAS