Management Approach for Microgrid Operation Using Multi Agent System (MAS) Technique

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***Abstract*— The integration of renewable energies in the electrical grid and the shift to a distributed structure of the grid had made the control operation extremely complicated. This complexity has prompted researchers to take an interest in the conception of smart interfaces in order to manage the operation of microgrids. This paper proposes an approach of microgrid management using the Multi Agent System (MAS) technique. Based on the distributed nature of MAS and their ability to communicate heterogeneous entities with each other's, the studied approach consists in ensuring the adequate interactions between the concerned agents in order to perform two microgrid operation modes: the first one is the operation of the microgrid without connection with the main grid. In this case, the balance between supply and demand of energy must be achieved. The second operation mode consists on the sale and the purchase of electricity to/from the neighbors' microgrids and the main grid.**

Keywords-Smart Interface; management; Multi Agent System (MAS; microgrid; operation mode.

I. INTRODUCTION

Because of the increase of environmental conscience, renewable energy has invaded electrical grid. As a result the concept of smart grid was created. With the implantation of renewable generators in dispersed locations, the electrical production passed from centralized to a distributed structure. In fact, the grid has been converted into an array of "smaller" grids, which can work in a connected or islanded operation mode. It is the concept of microgrid. This concept increased the complexity of electricity management and control. In fact, when the microgrid works in connected mode, the direct connection with the main grid doesn't ensure the energy optimization for the system. When the microgrid works in islanded mode, the electric interface is not sufficient to stabilize the microgrid operation. Hence the requirement for a software smart management interfaces, which must ensure the microgrid operation in islanded and connected mode, as well as in the moment of switch between these two operation modes. In the literature, the management of the microgrid operation had been performed using different Energy management frameworks [1][2], but, artificial intelligence techniques have proven their performances in the management of complex systems particularly the systems with behaviors similar to those of microgrids (Network management, intelligent platform management interface, database management, etc.) [3]. Assuming that the microgrid consists of a set of heterogeneous entities, which interact with each other's in a distributed way, these characteristics match with the MAS working. In fact, the MAS is a software level based on a distributed operation. Therefore, it was used in several microgrid applications, such as spot market mechanism and economic dispatch [4], smart grid control [5], demand response [6], service restoration mechanism [7], and Virtual Power Plant (VPP) control [8].

The disadvantage of the most of previous researches is that, they considered the agent as all the element of the microgrid. Then, they turned the physical aspect of the microgrid into a purely software aspect, based on the communication between agents, in the same computer or in a different computers by a TCP-IP protocols [9]. However, it is not the case of real systems. Therefore, in our research, it is assumed that each agent is implemented in a computing system, associated to each microgrid element. The exchange of information between agents is ensured by a communication system. Besides this system, each agent exchanges information with its associated physical microgrid element. The aim of our research is to ensure the microgrid operation using the above described MAS. The proposed approach is to build a smart management system, which must ensure the balance between supply and demand of energy in the two operation modes (connected and islanded). In islanded mode, the MAS predicts the energy to be produced and that to be consumed in real time in order to supply all local loads. However, in connected mode the mission of MAS is to ensure two tasks: the sale and the purchase of electricity to/from the neighbors' microgrids and the main grid using an optimization algorithm.

The paper was organized as follows. In Section 2, the microgrid will be defined. In Section 3, the MAS will be presented by defining Agent and its classification. Then, Section 4 will present the reasons of the MAS choice. Section 5 will focus on the proposed approach and the description of the different scenarios. Finally, Section 6 will conclud the paper.

II. MICROGRIDS

A. *Definition and structure of microgrid*

With the integration of renewable energy sources in the electrical grid, the electricity production has become intermittent. This situation requires the integration of storage facilities and units of computing and control to supply the demand of consumers in energy. At this level, the electrical grid passed to a smart grid. In order to maintain the consumption – production balance in all circumstances, and to enable the final consumer to better control his demand, the production of electricity has become decentralized. For example, a consumer can install his own Photovoltaic panel and wind turbine on the roof of his house. This is the concept of microgrid.

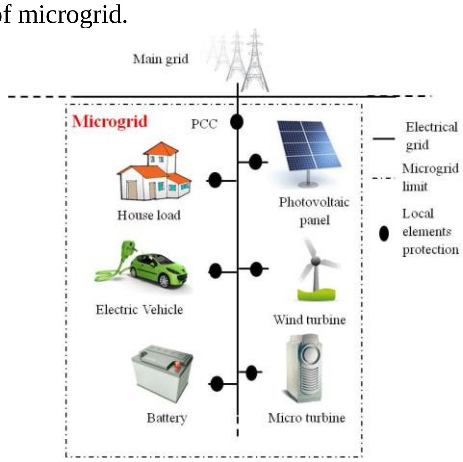

Figure 1. Example of Microgrid structure

The structure of microgid varies from one microgrid to another. But, as shown in Figure 1, three necessary elements must exist to obtain the microgrid: generators (photovoltaic panel, wind turbine, micro turbine), storage systems (battery, electric vehicle) and loads (house load, electric vehicle). The distributed generators are the producers of energy. The distributed storage systems are the components which store the energy and provide it depending on the situation of microgrid. However, the loads are the consumers of energy.

B. *Operation modes of microgrid*

Microgrids have two operations modes: the connected and the islanded mode. In connected mode, the microgrid is connected to the main grid, which is the superimposed grid. Therefore, in the connected mode the energy balance between supply and demand is ensured through the exchange of energy with the main grid or the microgrids neighbors, which are connected to the main grid. In islanded mode the microgrid is electrically isolated from the main grid. There are no energy exchange between grids. As a result, maintaining the energy balance in islanded mode becomes a challenging task.

III. MULTI AGENT SYSTEMS (MAS)

A Multi Agent System is a system consisting of several interacting agents with each other's and with the elements of their environment.

A. *Agent definition*

An agent is an autonomous entity (software or hardware), which acts on itself and on its environment. In the Multi Agent context, an agent is able to communicate with the other agents. Its behavior is the result of its observations, its knowledge, and its interactions with the other agents and the entities of its environment.

B. *Properties of Agents*

In MAS, agents are characterized by several properties, where the most importants are:

- Autonomy: An agent is able to act without the direct intervention of another entity (agent or human). It can also control its actions and its state.
- Reactivity: An agent perceives its environment and responds to the changes occurring there.
- Communication: An agent can communicate with another agents and entities (Software, Hardware or human).
- Sociability: An agent can interact with the other agents in a collaborative or a competitive way in order to achieve its objectives.
- Pro-activity: An agent is able, on its own initiative, to set goals to reach its objectives [10].

C. *Classification of Agents*

Based on the evocated properties, researchers proposed several classifications of agents. According to Grislin et al. [3], agents can be classified according to the degree of autonomy, of cooperation and adaptation. These properties are generally seen as main characteristics in distributed artificial intelligence [11]. Three types of agents were distinguished in the MAS [12]:

- Reactive agent: This agent has limited ability for communication, has little or not a model on itself, on other agents or on the environment. Its behavior is of type "stimulus-response", then it operates based on receiving messages.
- Cognitive agent: This agent has a more "thoughtful" behavior, resulting from a choice among a set of possible actions. This choice is a result of reasoning.
- Hybrid agent: The hybrid agent is neither reactive nor cognitive. In fact, it has some level of every agent property. Therefore hybrid agent behavior can be placed between reactive agent and cognitive agent.

IV. MAS IN MICROGRIDS

Based on their size, their heterogeneity and their evolving nature, microgrids are considered complex systems. The choice of MAS technique for the microgrid control is justified by several reasons. In fact, microgrids are characterized by their distributed nature and the interaction of heterogeneous elements between each other's and with their environment. Microgrid elements have only a local view of the grid and do not have access to the global behavior of the system. Only the operators of the grid have a global view of the system macroscopic behavior. In addition, the microgrid has a history; its size and its structure vary over time, so its past is at least partially responsible for its current situation. Besides, in connected mode, the microgrid accomplishes interactions based on the market mechanism, which is one of the basic tasks of MAS. In fact, to supply local load, the microgrid performs a negotiation phase with main grid and neighbors' microgrids to purchase energy. In the same way, to supply external load, the microgrid negotiates to sell its production of energy.

V. PROPOSED APPROACH

Several propositions were performed to control microgrids using MAS [3]-[10][13]. The main principle is to develop a representative agent for each element of the microgrid, and one additional agent, which controls and represents the microgrid in its external environment (Main grid and neighbors' microgrids). The proposed approach of this paper is based on the capacity of information exchange between each agent and its associated microgrid element. This exchange is bidirectional. In fact, the agent is able to perform two functions: it recovers measures (current, voltage, temperature, etc.) and it acts on the physical part of the microgrid, in order to perform different operations as connection/de-connection, and change of operation point. Thus, the MAS presents the smart interface of the microgrid, when each agent is embedded in a system set up with the associated microgrid element.

As described in Figure 2, our first microgrid prototype consists of photovoltaic (PV) panels, batteries, and loads. The main grid is represented by a "global supervisor agent" and the microgrid by a "local supervisor agent". Each element of the microgrid is represented by a local agent: load agent, battery agent and PV agent. "Interface agent" was added in order to detect the connection and disconnection of microgrid elements and to ensure the interaction with the user platform. The interaction between agents is presented in Figure 3.

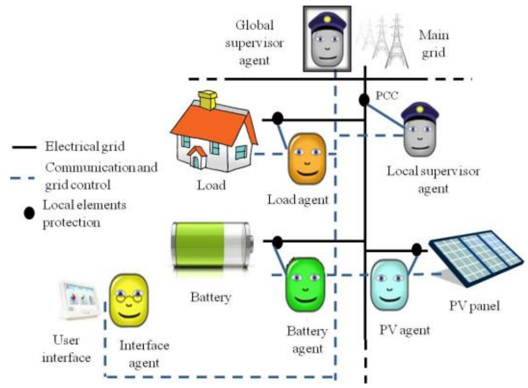

Figure 2. MAS for the proposed Microgrid management approach

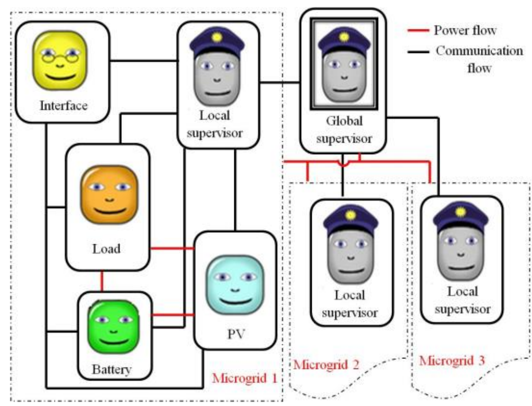

Figure 3. Interaction between agents in the proposed approach

The principle of the proposed management approach is based on sending and receiving of messages between agents in order to exchange information and to take decisions. Local agents communicate with their local supervisor agent and if the operation mode is connected, the local supervisor agent communicates with the global supervisor and the local supervisor agents of the neighbors' microgrids.

The proposed algorithm for the operation management is presented in Figure 4. It is important to note that drawn diagram describes both the progress of management program and the interaction between agents.

The used variables in the following paragraph and Figure 4 are as follows:

P_c: The power quantity to be consumed.
P_p: The power quantity to be produced.
P_{bat}: The available power of the battery.
SOC: The battery state of charge.

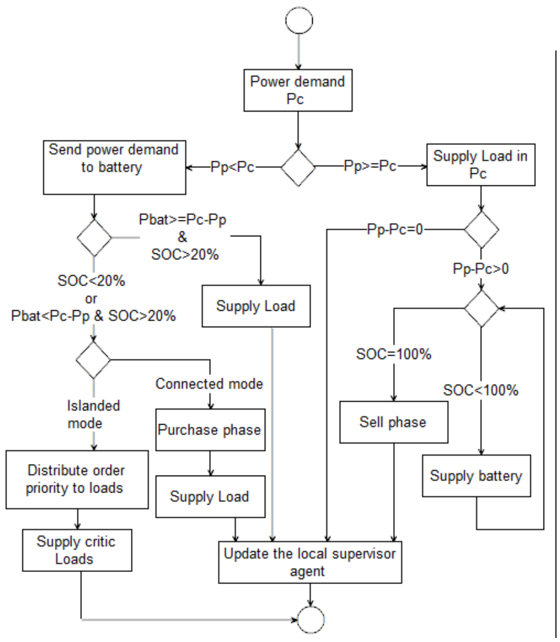

Figure 4. Proposed management algorithm for microgrid operation

It is supposed that in the starting state the demand and the supply are balanced. The MAS must be able to manage events, such as power demand in Figure 4. As a result of this event, three cases are possible:

1/ If the amount of produced power Pp is greater than or equal to the requested power Pc, loads are supplied and the local supervisor agent proposes to supply battery by Pp- Pc. If the SOC is less than 100% the battery is supplied. And after this, if there is an excess of power and the operation mode is connected, the local supervisor agent initiates a communication phase with the global supervisor agent and the neighbors' supervisor agents in order to perform a power sales phase.

2/ If the produced power summed with the available battery power is greater than or equal to the requested power Pc, loads are supplied by PV and battery.

3/ If the produced power summed with the available battery power is not enough to supply all loads, the management of this event depends on the operation mode. In connected mode, the local supervisor agent starts a power purchase phase with the global supervisor agent and the neighbors' supervisor agents, and it takes decisions based on an optimization algorithm identifying the minimal cost of the energy. Therefore, in islanded mode, the microgrid is no more able to supply all loads, so some loads can be disconnected. As a result, the local supervisor agent must distribute a priority order to all loads. The loads with the highest priority order are the critic loads. They must be supplied before other loads.

VI. Conclusion and Future Work

This paper proposed a management approach of microgrid using MAS technique. Based on the distributed nature of microgrid and the heterogeneity of its elements, the MAS presents an adequate smart management interface for the microgrid. This interface had the mission of ensuring energy balance between demand and supply in the connected and the islanded mode. The next step of this work is the implementation of agents in order to validate results.

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