Contribution to Energy Management in Hybrid Energy Systems Based on Agents Coordination

Djamel Saba, Fatima Zohra Laallam, Brahim Berbaoui

Abstract—This paper presents a contribution to the design of a multi-agent for the energy management system in a hybrid energy system (SEH). The multi-agent-based energy-coordination management system (MA-ECMS) is based mainly on coordination between agents. The agents share the tasks and exchange information through communications protocols to achieve the main goal. This intelligent system can fully manage the consumption and production or simply to make proposals for action he thinks is best. The initial step is to give a presentation for the system that we want to model in order to understand all the details as much as possible. In our case, it is to implement a system for simulating a process control of energy management.

Keywords—Multi agents system, hybrid energy system, communications protocols, modelization, simulation, control process, energy management

I. INTRODUCTION

IN the early 20th century, the environmental impacts associated with human energy consumption began to appear: inadequacies of primary energy sources, climate change, pollution, acid rain, etc. [1]. To remedy this, we have to invent a way to develop sustainably. In addition to reducing energy consumption, many tracks related to the way we consume must be explored. A consumer may still draw energy at any time of the day. Until now, energy suppliers are equipped to handle all the requests of people, without considering the environmental impact and the automated management aspect of energy. The importance of these problems is growing with the demands of users that increase more and more.

The energy management should improve energy efficiency by reducing losses from primary energy, that is to say, the energy "potential" contained in natural resources and the energy that will be consumed. This management should be thinking in terms of production, distribution and end-use of energy.

We are interested in this research on energy management to develop a system able to dynamically find a production and energy consumption policy, while taking into account the criteria set by the user and the availability of the sources energy.

The development of the exploitation of clean energy has prompted many experts to study wind, photovoltaic, energy storage and control systems based on coordination between various units of the system. Different countries have worked on some projects that show improvements in the power of a controlled energy storage system [2]-[6].

Classically the energy management of electrical systems (photovoltaic, wind...) is based on an intelligent and centralized algorithm. This method shows their performance but, as it is characterized by certain defects such as difficulty in the extensibility of the system, shown by [7]-[9].

Also, if an event not taken into consideration by the system, the system is unable to respond properly and the control program must be completely redesigned [10]-[13]. In the same context, [14] offers work that includes an energy control strategy based on coordination between MAS agents to establish optimal planning methodology that reduces operating costs and NOx emissions. With the same approaches to artificial intelligence, [15] adopts the bottom-up approach to design a management system for distributed power generation based on MAS and verified by simulations that this system is more effective in treating problems better than the centralized energy management systems. However, [16] uses a high energy density to design an effective and robust energy plan for a hybrid system based on coordination between the MAS agents. In the same context, [17] proposes a solution for managing a hybrid system based on coordination between agents.

The hybrid system concerned with the study includes two energy sources (photovoltaic, wind) accompanied by energy storage, the main objective of this work is to create a balance between production and consumption of energy to improve the effectiveness of overall functioning and reduce costs of consumption. In the same context, [18] presents a comparison between centralized control and decentralized on the basis of their cost and the life cycle. The storage system optimization was also treated. The objective of this study was to determine the economic benefit that could be drawn from the centralized management of energy storage systems. Analysis of the life cycle costs was discussed. They determined that the centralized control of the storage system is more reliable.

Based on the existing research results, we presented a design for an energy control system based on multi-agent coordination. The system stimulates the tendering system using communication protocols. The system solves the

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optimal distribution plan for the global energy system and optimizes solar wind energy storage performance for large-scale power generation units based on the following steps:

1) Design an architecture of multi-agent system based on the physical structure of the hybrid system (solar, wind) and energy storage batteries;
2) Propose appropriate control strategies based on the output characteristics of the various elements of the hybrid system.

II. THE ENERGY MANAGEMENT: CENTRALIZED OR DECENTRALIZED?

We distinguish two approaches to energy management, which are being examined in various research projects aimed to know the energy capacity of each.

A. The Centralized Energy Management

In this type of power management, we have various energy generators in combination with storage, where it can be controlled in a centralized manner. The disadvantage of this approach is the difficulty of controlling the system with increasing elements of the system, as the complexity of the centralized optimization increases exponentially with the number of generators and loads. Therefore, technically, it is only sensible to implement centralized management for a small number of generators and loads.

B. The Decentralized Energy Management

This type of management is less complex and decisions are taken by the decentralized energy management systems that optimize power generation and consumption (load).

C. Centralized Production to Decentralized Production

Until the 1990s, the electrical energy is produced exclusively centrally and consumed in a decentralized way, which requires the establishment of a network capable of transporting the energy produced in a few production plants to the millions of consumers spread over the entire territory.

For economic and ecological reasons for the growing interest in the environment, producers are encouraged to develop means of decentralized electricity production based on the use of renewable energy sources and cogeneration in order to increase the energy efficiency of production facilities.

III. GENERAL ORGANIZATION OF A CONTROL SYSTEM

A control system comprises software and hardware components. The main components are as follows (see Fig. 1):

A. The Sensors

These are the technological components that ensure the measurement interface, they are very different types and using the most varied physical phenomena for measuring physical parameters of the process transforming them into usable electrical quantities by digital computers.

B. The Actuators

They are used to convert a control signal generated by the control system in an effective action at the level of the controlled physical system.

C. The Software

Operation of the system is ensured by a set of software for processing the particular applications of the controlled system.

D. The Communications Equipment

These tools ensure the transmission and exchange of information safely and reliably to ensure the proper functioning of the system and the coordination of its various elements. Communications tend to be organized around local networks that are designed to connect in a simple way all the automated system stakeholders.

E. The Interfaces

They liaise between the sensors and the computer equipment on one side and between the computer equipment and actuators of another.
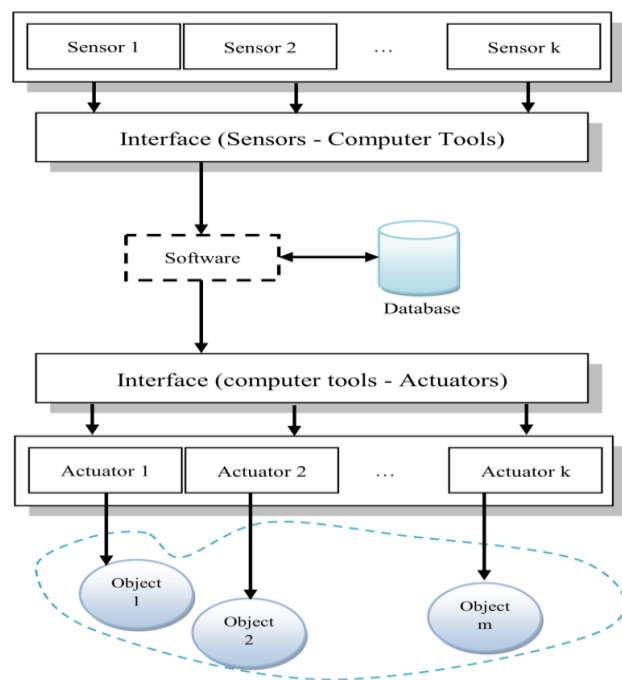

Fig. 1 The main control system components

IV. PRESENTATION OF HYBRID ENERGY SYSTEM AND ENVIRONMENT

The hybrid system and environment consists of four parts: power generation, energy storage, energy consumption, and the impact part (see Fig. 2).

A. The Production of Energy

This part concerns the sources of energy; generally, we select one as the main source and the other as secondary or alternative source. This classification based on a

meteorological study of the installation site. In our work we are interested in solar-photovoltaic and wind power.

B. Energy Storage

The battery is used to store the energy produced by the energy sources. There is a need of storage every time of energy demand is shifted in time a result of external energy supply. The volume of the battery bank is attached with the number of days of autonomy (the total absence of electricity generation by sources). A good study based on a good optimization of these systems.

C. Energy Consumption

It is also called the load, which is related to consumers' electrical energy needs and is measured in watts. In the new generation of energy management, designers give importance to the economy of energy and expenses are classified according to their priority.

D. Influences

It concerns the elements of the external environment that influence the production of energy, either positively or negatively, in our study we distinguish three elements, which are temperature, radiation and wind speed.
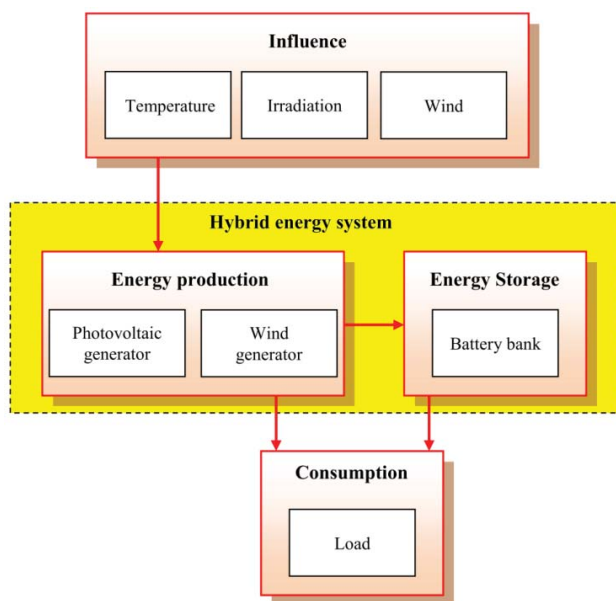

Fig. 2 The essential elements of the hybrid energy system and environment

Electrically, the SEH includes two energy sources (see Fig. 3), photovoltaic for producing direct current and wind for production alternative current. The diversity in the production of two generators requires the presence of specific equipment, such as converters [19], [20].
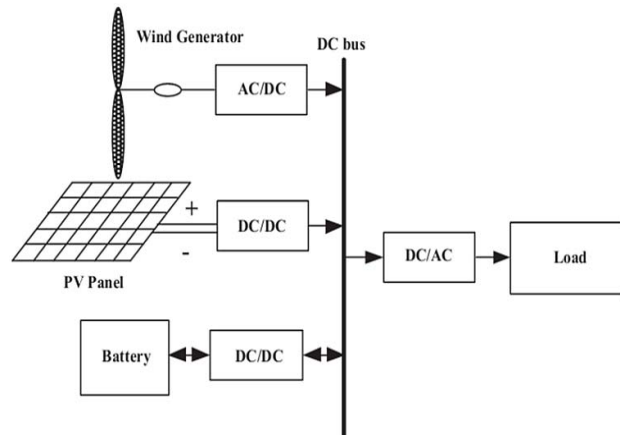

Fig. 3 Electrical configuration of system [21]

V. DISTRIBUTED ARTIFICIAL INTELLIGENCE, AGENT, MULTI AGENT SYSTEM

A. Distributed Artificial Intelligence

The distributed artificial intelligence (DAI) is a sub-field of artificial intelligence that deals with situations where multiple systems interact to solve a common problem [22]. The DAI is divided into two main branches:
1) The resolution distributed of problems (RDP);
2) The simulation of complex systems (CSS).

B. Agent

An agent is an encapsulated system located in a computer environment in which it is capable of performing a flexible and autonomous action, consistent with the design objectives (see Fig. 4).
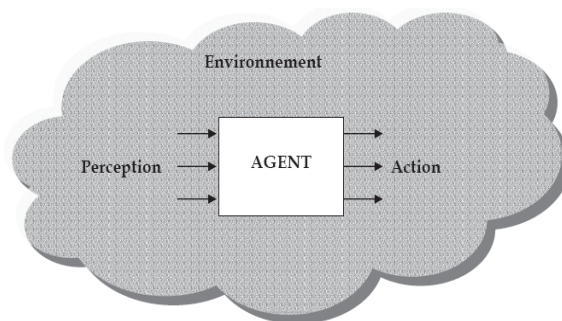

Fig. 4 External preview of agent

We distinguish two types of agents [23]: cognitive agents, reactive agents. Depending on the type of agents that can be found in the SMA, we speak of cognitive systems or reactive systems. However, it is possible to combine the two types of agents to obtain hybrid agents enjoying the benefits of each type.
1) Cognitive agent is characterized by a reasoning ability of a knowledge base and ability to process information including those relating to the management of interactions with other agents and its environment, allowing it to perform only operations complex. This type of agent is

said to have a high degree of granularity [23]. The main functions of a cognitive agent are: to perceive, decide, act. Can add other functions such as: conflict detection, belief revision (knowledge), cooperation (negotiation, coordination), learning ... etc.

2) Reactive agent: follow the principle "Stimulus/Action". These are low granularity agents. This type of agents has only a protocol and a reduced communication language to enable them to perceive stimuli from their environment and respond to them by actions [23]. It receives events from its environment thanks to its capacity of perception. This knowledge is represented by a set of "Condition-Action" relationships, where a condition is an event. Then, the reagent is based on this knowledge by taking the decision of an action and then performs that action.

3) Hybrid agents: in general, the difference between reactive agents and cognitive agents can be explained by the compromise efficiency/complexity. The complexity of reactive systems requires the development of new theories in the field of cooperation, communication and understanding of new phenomena such as the emergence. However, it is now possible to design heterogeneous systems with both types of behaviors (cognitive and reactive) is then made to hybrid agents.

C. Multi-Agent Systems (MAS)

Is a distributed system to implement homogeneous and heterogeneous agents with common or distinct purposes, it consists of a set of dynamic agents that interact most often, according to modes of cooperation, competition or coexistence [24], [25].

The characteristics of MAS are:

- Each agent information or problem-solving abilities, and each agent in a partial view;
- No overall control of the multi-agent system;
- Data is decentralized;
- The calculation is asynchronous.

Otherwise, a text message is composed of the elements: Environment (E), Objects ensemble (O), Agents ensemble (A), Relationship ensemble (R), Operation ensemble (OP).

Addressing the problem of interaction in the field of SMA, it is to provide the means to analyze and design the different forms of interaction that agents can use to perform their duties and fulfilling their objectives. Thus, the solutions are to ensure interaction protocols. Indeed, the interaction with the organization is one of the basic concepts of multi-agent systems. According to [26], "for an agent to interact with each other is both the source of his power and the source of his problems." Indeed, it is the cooperation of agents that provides a kind of intelligence or the ability to solve fairly complex problems, but also because of the numerous conflicts that arise.

Interactions come from the dynamic binding of several agents through a series of interactions. There are several types of interactions that depend on three parameters: objectives, resources and skills.

VI. AGENT MODELING AND CHARACTERISTIC ANALYSIS

A. Basic Structure of Agent

From the perspective of the internal architecture of the agent, various types of MA-ECMS agents are distinguished by the nature of the internal modules that compose them and by the manner in which these modules are interleaved with each other. Indeed, in our conception of SMA, we opted for the decomposition of the internal architecture of agents in several modules. Each module is dedicated to a specific function required for the fulfillment of the mission of the [27] agent. This modular decomposition of the internal architecture of agents promotes the improvement, adding and reuse of the main modules.

In the case of our multi-agent platform, the internal architecture of agents includes seven modules. Fig. 5 illustrates the internal structure of our agents, and the imbrication of the modules used. These main modules are:

1) Individual and social knowledge module: This is in two parts: individual knowledge and social knowledge. Individual knowledge reflects the agent itself, including name, address, individual goals, decision protocols and different states. Social skills reflect the representation that the agent and the social environment in which it operates. This special knowledge includes all information necessary for the proper functioning of the agents. Indeed, they allow the agent to select the most appropriate agents who will be able to help him to achieve his goal or improve its utility function. Each agent has appropriate information modeling and knowledge associated with it.

2) A collective knowledge module: It allows establishing communications with a shared ontology between agents of the MA-ECMS, this ontology includes all concepts and informational details on the hybrid energy system.

3) Treatment/planning module: This is based on a body of knowledge acquired by the agent and messages from other agents. At this module, the decision-making process allows the agent to choose the solution or the appropriate response, based either on the performance criteria encapsulated by a utility function or a set of goals.

4) A module of expertise: This describes the basic actions that the agent can perform, as well as their skills. It reflects the business capabilities and cognitive organizational entity encapsulated by the modeler agent. Indeed, this module details the behavior of the agent which will enable it to improve its utility function or achieve his goal and that, through a series of basic actions.

5) A module for the management of communications: With other agents. On the one hand, this module receives from the "processing module/planning" message transmission requests to one or more agents; on the other, he relays his messages from other agents.

6) An interface module: With the external environment elements in SMA. This module provides basic methods to support the interaction of the human type/agent in the mode input/output. In particular, it offers the results

display methods, parameter values input and perception of external disturbances.

7) Cooperation module: This allows it to engage in a process of negotiation with other agents of the same type, and to form coalitions that will allow it to improve its scheduling plan. This module is a library of procedures and rules establishing mechanisms for cooperation and conflict resolution.
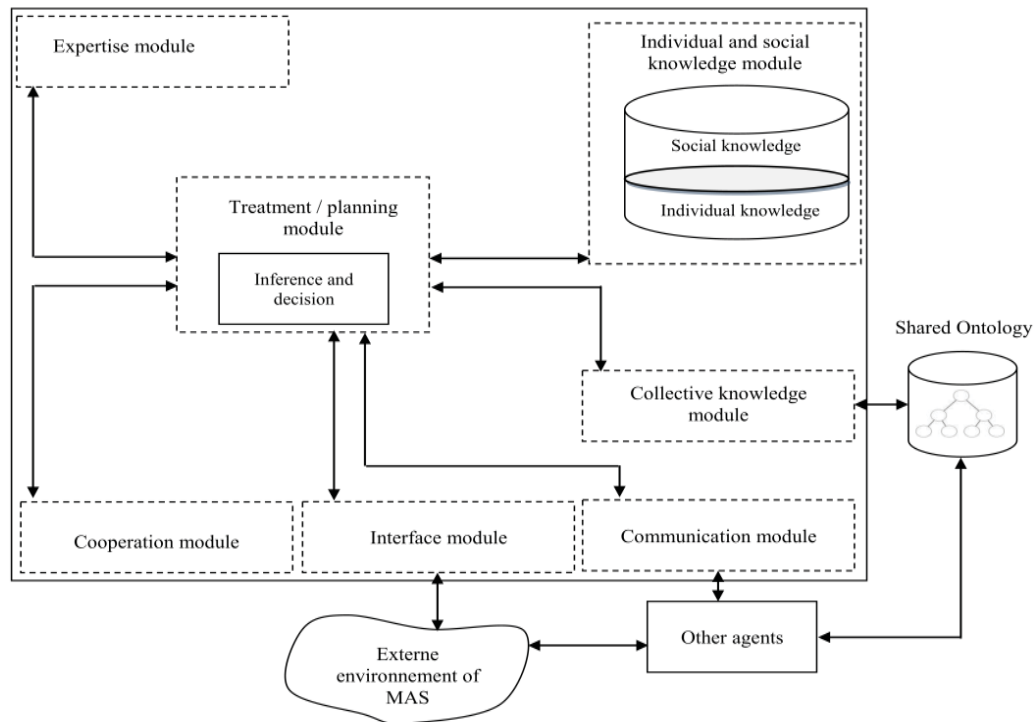

Fig. 5 Basic structure of agent

B. The MA-ECMS Structure

Four agents are designed to our MAS, including wind agent (WT Agent), photovoltaic agent (PV Agent), battery agent (BAT Agent) and load Agent (LD Agent). Each agent can control multiple units of the same type following the information received from each device. The hybrid system includes two buses, one for direct current (DC) and the second for the alternating current (AC). All it requires is the integration of equipment, like the inverter, which is necessary for the proper operation of the hybrid system. The structure of the MA-ECMS is shown in Fig. 6.

The system adopts the multi-agent, client-server mechanism of cooperation, following the changes of the load and weather data.

After receiving the request of the load, the agent of the main energy source begins the process of supply of energy (to avoid conflicts caused by multiple initiators on the coordination of energy tasks at the same time, a priority between energy sources (Agent) are stored in the knowledge base associated with the MA-ECMS). Other officers determine how to participate in the coordination of energy according to their own characters and control objectives.

WT Agent: represents the wind control units. Each wind generator is characterized by a power curve which depends on the operating speed. The principle of maximizing the use of renewable energy, the characteristics of the WT are designed to be participating in the call for tenders actively until all available equipment operates at maximum output power. At the same time, they can initiate the energy coordinator task when changing the output power.

1) PV Agent and WT Agent: Represent respectively, the control units of the PV array and wind generator. Both generators are characterized by a power curve that depends on the meteorological data of the site concerned by the installation of the hybrid system. The principle of maximizing the use of renewable energy, the characteristics of generators are designed to participate in the bidding actively until all available equipment operates at maximum output power. At the same time, they can initiate task of coordination of energy when changing the output power.

2) BAT Agent: their role is to monitor the state of charge (SOC) of the battery and manage the operation of the charge/discharge. On the basis of information, coordination with other agents determines the energy value to load or unload.
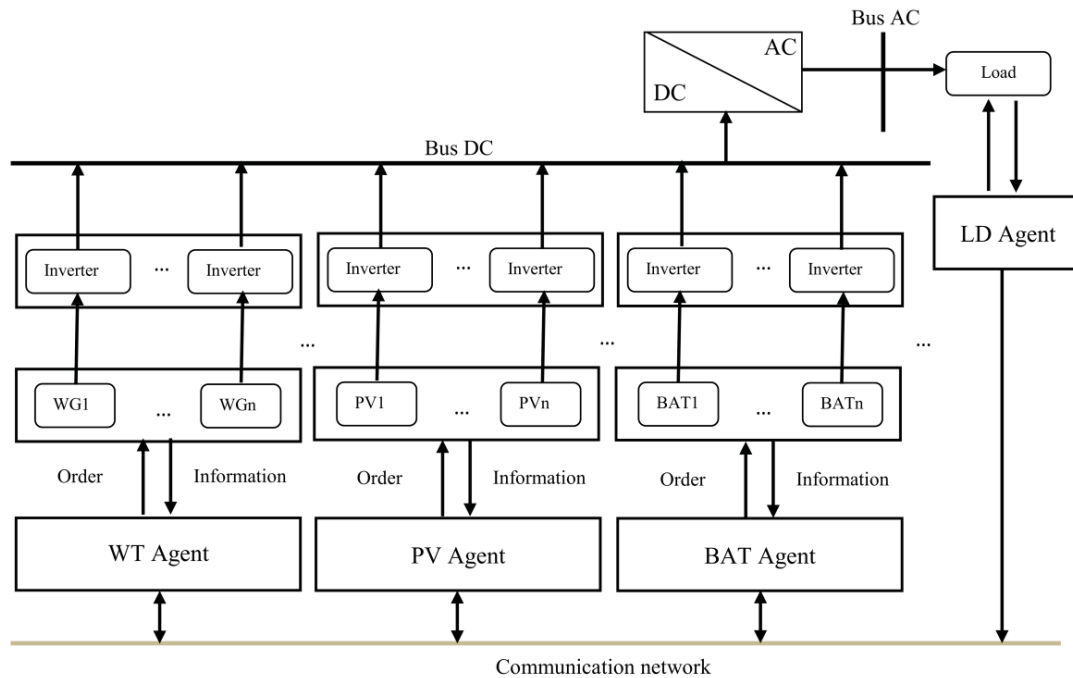
Fig. 6 The general structure of MA-ECMS

VII. CONCLUSION

The growth of the field of systems management energy, the need to provide designers with a quality work and traditional modeling techniques are static and can consider the hybrid energy system as an evolving system, this has led us to seek to model the energy management in these systems by multi-agent technology that led to very interesting results in many other areas.

We have tried, through this initiation, to present the future SMA for power management in a hybrid system and give a description of each agent (missions, internal architecture). The external environment was also presented in details, such as climate data influencing the hybrid system and the necessary sensors, to data acquisition and smooth operation of the MAS.

The next step is the implementation of the proposed solution to visualize the simulation results for energy management. In this part, we choose a model and a platform most suitable for our application.

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