Market-Oriented Operation in Microgrids Using Multi-Agent Systems

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***Abstract*- The transition from conventional power systems to smart grids is leading to a new generation of power networks which, among others characteristics, allows a more flexible demand consumption, and the efficient integration of renewable resources. MicroGrids (MGs) are a clear example of this trend. In this paper, a Multi-Agent Systems (MAS) implementation is proposed to address a decentralized operation of MGs. This Multi-Agent System is used to model the interaction among agents considering a market-oriented operation inside a MG. Agent's behavior is driven by specific optimization problems interacting among them through an original auction. Test results are presented for an illustrative MG and compared against those obtained within a centralized operation.**

Index terms- microgrids, distributed energy resources, renewable energies, market-oriented operation, optimization, price responsive demand, Multi-Agent Systems

NOTATION

A. Indexes

t	time periods (hours), $t = 1,2,\ldots,24$;
i	battery and generators, $i = 1,2,3$;
j	agents, $j = 1,2,\ldots,6$.

B. Parameters

k	maximum periods of time for demand shifting;
η_C	battery charge efficiency;
η_D	battery discharge efficiency;
λ_t^s	main grid hourly selling price to the microgrid (€/MWh);
λ_t^b	main grid hourly buying price to the microgrid (€/MWh);
λ_g	minimum price at which generators are willing to sell their energy (€/MWh);
$t_0/\,t_f$	current/final period of time;
$d_{j,t}^{ne}$	fixed demand for the agent *j*, at period t (kWh);
$d_{j,t}^{e}$	initial price responsive demand for the agent *j* during time period *t* (kWh);
$d_{d,j}^{max}$	maximum price responsive demand for agent *j* in a period (kWh);
$d_{dv,j}^{max}$	maximum price responsive demand change for agent *j* between two consecutive periods (kWh);
$P_{g,i,j}^{max}$	upper limit for the power output of generator *i*, belonging to agent *j* (kW);
$P_{g,i,j}^{min}$	lower limit for the power output of generator *i*, belonging to agent *j* (kW);
$S_{i,j}^{max}$	upper limit for the energy level of battery *i*, belonging to agent *j* (kWh);
$P_{b,i,k}^{max}$	upper limit for the power flow battery *i*, belonging to agent *j* (kW);
$P_{b,i,j}^{min}$	lower limit for the power flow battery *i*, belonging to agent *j* (kW);
vc_i	variable cost for generator *i* (cents of €/kW);
fc_i	hourly fixed cost for generator *i* (cents of €/h);
yc_i	start-up cost for generator *i* (cents of €);
sc_i	stop cost for generator *i* (cents of €).

C. Positive variables

$D_{j,t}^{u}$	total demand for agent *j* in period *t* (kWh);
$D_{j,t}^{e}$	price responsive demand for agent *j* in period *t* (kWh);
$P_{t,j}^{B}$	energy that agent *j* is willing to buy in period *t* (kWh);
$P_{t,j}^{S}$	energy that agent *j* is willing to sell in period *t* (kWh);
$P_{t,i,j}^{G}$	power output for generator *i* belonging to agent *j* in period *t* (kW);
$P_{t,i,j}^{c}$	charge power for battery *i* belonging to agent *j* in period *t* (kW);
$P_{t,i,j}^{d}$	discharge power for battery *i* belonging to agent *j* in period *t* (kW);
$S_{t,i,j}^{b}$	energy level for battery *i* belonging to agent *j* in period *t* (kWh).

D. Binary variables

$v_{t,i,j}^{G}$	commitment state for generator *i* belonging to agent *j* in period *t*;
$y_{t,i,j}^{G}$	start-up variable for generator *i* belonging to agent *j* in period *t*;
$s_{t,i,j}^{G}$	shut-down variable for generator *i* belonging to agent *j* in period *t*.

I. INTRODUCTION

Nowadays, the increasing interest in achieving a quality electric energy supply, which is also reliable, sustainable, and has lower environmental impact, along with advances in communication and control, are driving the development of MicroGrids (MGs) in the electric energy industry.

MGs are electric power networks containing small distributed energy resources, different end users and storage devices connected to each other by electric lines. A MG can work in islanded mode, supplying energy to critical loads or relying on the main distribution or transmission grid. It is expected that MGs improve energy use, reduce losses in transport, provide reliability in the whole system and enable the integration of renewable resources [1], [2].

Depending on the particular characteristics of the MG and the market strategies, we can encounter a variety of control and operational issues. The main control issues are related to voltage and frequency control and active/reactive power control. Some MG tasks are power and energy management when disturbances or faults occur, economic dispatch for output power control of dispatchable generators, load sharing and renewable resources management. The whole set of tasks can be carried out through either a centralized or a decentralized control [2]. Because of generators, loads and storage units have usually different owners and there are several decisions to be taken locally, centralized control, although possible, becomes difficult. Local operators have autonomy, intelligence and can communicate between them in order to achieve an overall objective in the MG. That is why Multi-Agent Systems (MAS) are suitable for decentralized MG control [1].

S.D.J. McArthur et al. [3], [4] were among the first authors in studying MAS applied to power engineering, in particular, distributed control in MGs. They establish the basis of agent theory. There is plenty of research about MAS applied to MGs. D. Hatziargyriou and A. Dimeas worked to solve operation and control issues in MGs with MAS [5]−[7]. In [1], the implementation of distributed controls for a typical energy market operation is presented using intelligent agents via an evolutionary approach. A hierarchical coordinated control using MAS [8] is applied to a MG under the premise of voltage stability and power balance trying to maximize the efficiency of renewable resources.

In this paper agent collaboration is presented to decide how much energy is bought from the main grid and how much is sold to it, depending on the results of a specific auction and taking into account different optimization problems related to the agents. The agent architecture considered here allows for the existence of agents with demands, generation (renewable or conventional), batteries or any combination of them. Each agent has the internal data that allows it to make a decision. We make the assumption that renewable energy generators will produce energy whenever the primary resource is available, regardless of other considerations. In the results section it is shown that agent interaction yields higher costs than centralized operation.

This paper is organized as follows: in section II, agents are described and the auction used in this paper is presented in detail. The mathematical formulation of the optimization problems is developed in section III. Finally, in section IV, the case study is presented and in section V conclusions for centralized and decentralized systems are drawn.

II. MULTI-AGENT SYSTEMS AND MICROGRIDS

A. Introduction

An agent is an entity (software or hardware) that is situated in some environment and is able to autonomously react to changes in that environment. Agents in most of engineering applications have a certain degree of intelligence. An intelligent agent has three main characteristics: reactivity, pro-activeness and social ability [9].

An agent encapsulates complete knowledge about its own status and partial knowledge about the environment in which is placed. The interaction among the different agents and their behavior enable the system to carry out its main objectives. Depending on the grade of intelligence of the agent, it can be more or less autonomous; it can be free to decide what to do in a situation or it can give in to another agent. Agent architecture defines a more centralized or decentralized framework.

Jade [10] has turned to be a suitable middleware to implement MAS in power engineering applications and that is, together with conformity to FIPA standards, why it has been selected for the simulations in this paper [11].

B. Agents, goals and behaviors

In this paper we have defined three types of agents:

- Demand agents: they own loads that consume electric energy but they have no energy sources.
- Generation agents: they own loads and non-renewable energy sources.
- Renewable agents: they own loads, renewable energy sources and batteries.

Each agent solves a particular optimization problem to decide how much energy it is willing to use, buy or sell. A price responsive demand, which represents a portion of the demand, has been considered. This demand can be shifted to other periods of time, like for example the energy required for a washing-machine or an electric heater.

A particular agent called auctioneer handles all the information from the agents and carries out an auction to distribute energy according to a specified set of rules. Electrical energy demand which is not supplied in the auction is bought ultimately from the grid.

Although agents have different particular goals, there are global objectives:

- To get a more autonomous MG that resorts to clean energies and stores or sells energy if necessary.

- To take advantage of energy produced by renewable generators and counting with the support from other ones.
- To incentivize the use distributed generators, trying to reduce the dependence on the main grid, using an auction internal to the MG.

C. Auction description

A MG is composed of several entities which have electrical energy necessities and/or own different kinds of assets. In a real situation, it can be assumed that these entities all have electrical energy demand but they may or may not have generation or storage devices. Owners have to decide where to get electric energy from and what to do if they have a surplus.

Demand agents solve an optimization problem and send the necessary data to the auctioneer in each period of time. These data are the following: amount of electrical energy to buy and auction strategy. From the auctioneer's point of view generation agents and renewable agents may behave as demands or as generators. If they have an energy surplus, the data that they must send to the auctioneer are: amount of electrical energy to sell and auction strategy. The amounts of electrical energy bought or sold in the auction are the result from the internal optimization problem. The auction strategy is a private issue for each agent and it is determined considering its expectations on the auction.

Before the auction takes place, the auctioneer determines how many agents that demand energy and how many agents that sell energy are available. All the energy will be bought from the main grid if all agents act as demands; otherwise the auction begins.

The auction is carried out through rounds so it finishes when either there is no generation available or there is no demand to be satisfied. In the first round, the generation price is set to selling market price from the main grid and demand price is set to the buying market price.

In this paper it is proposed that the auction bid is determined by a third-grade polynomial function whose value is decreased every round for each generator:

$$f(x) = a \cdot x^3 + b \cdot x^2 + c \cdot x + d \tag{1}$$

where x is the number of rounds. The coefficients are determined by four conditions:

$$f(1) = \lambda_t^s\,;\ f(n_a) = \lambda_t^b\,; \\ f\left(\frac{n_a}{2}\right) = i_p;\ f'\left(\frac{n_a}{2}\right) = \alpha_a; \tag{2}$$

where: n_a is the maximum number of rounds foreseen; α_a is the slope of the function for $x = n_a/2$; and i_P is an intermediate price, which is determined as follows:

$$i_P = \frac{\lambda_t^s + \lambda_t^b}{2};\ if\ \lambda_g \le \lambda_t^b \tag{3}$$

$$i_P = \lambda_t^b + \frac{\lambda_t^s - \lambda_g}{2};\ if\ \lambda_g > \lambda_t^b \tag{4}$$

The values above are set by an agent and show its willingness to buy/sell energy. For demands, a similar function with increasing values has been implemented.

Supply and demand are matched when the price at which a generator is willing to sell is lower or equal to the price at which a demand is willing to buy. Other specific rules were established to solve match situation between multiple generators and demands as well as the energy assignment in case a draw occurs. For the sake of simplicity, these rules are not described in detail in the paper.

When the auction ends either generators have sold all their available energy or buyers have satisfied all their demand. Unmatched quantities are then sent to the main grid. The idea is to get a better price for buyers and sellers in relation to what they would get from the main grid, whenever possible.

The flow chart of the auction is shown in Fig. 1. In the chart, P_d stands for the amount of energy to buy, P_g is the amount of energy to sell, n_d is the number of buyers and n_g the number of sellers.

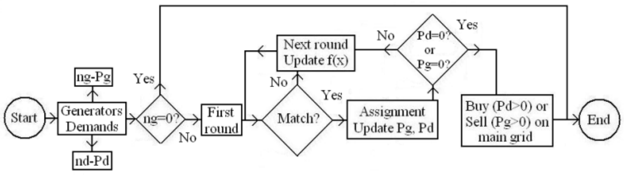

Fig.1. Flow chart describing the auction

III. MODEL DESCRIPTION

This section provides the mathematical formulation of the optimization problems that are solved by each agent in the MG. It is assumed that generation cost functions are known. Main grid buying and selling market prices are known as well. Each optimization problem is either linear or mixed integer lineal programming. The optimization problems for the different types of agents are presented next.

1) Demand agents: Demand agents try to shift their price sensitive demand, if possible, to time periods for which a better market price is expected. In that way, if their demand is not satisfied at the auction, then they can get a good price from the main grid. The objective function is expressed as follows:

$$\text{minimize} \sum_{t=t_0}^{t_0+k} \lambda_t^s \cdot D_{j,t}^u \tag{5}$$

Subject to the following constraints:

a) Total demand: the total demand can be divided into the sum of a fixed demand and a price sensitive demand.

$$D_{j,t}^u = d_{j,t}^{ne} + D_{j,t}^e \tag{6}$$

b) Price responsive demand: the initial flexible demand in period t cannot be shifted more than k periods forward. This constraint is implemented with (7) and (8)

$$\sum_{t=1}^{t^*} D_{j,t}^{e} \leq \sum_{t=1}^{t^*} d_{j,t}^{e}\,;\ t^* = 1,\ldots,24 \tag{7}$$

$$\sum_{t=1}^{t_f} D_{j,t}^{e} \geq \sum_{t=1}^{t^*} d_{j,t}^{e}\,;\ t^* = 1,\ldots,24 \tag{8}$$

where: $t_f = \min\{t^* + k, 24\}$

In this context, price responsive demand is electric energy demand that is flexible and can be moved to a different time period for which the market price or other conditions are more advantageous. On the other hand, inflexible demand is electric energy demand which has to be consumed in a particular period of time. Other restrictions related to the price responsive demand configuration are expressed as follows:

$$D_{j,t}^{e} \leq \left|d_{d,j}^{max}\right| \tag{9}$$

$$-\left|d_{dv,j,t}^{max}\right| \leq D_{j,t+1}^{e} - D_{j,t}^{e} \leq \left|d_{dv,j}^{max}\right| \tag{10}$$

2) Generation agents: Generation agents try to shift its demand, if possible, where a less cost is expected. Because they have dispatchable generators they can adjust their production for own consumption and decide to buy or sell energy at the auction or the main grid. The objective function is formulated as follows:

$$\text{maximize}\left\{\sum_{t=t_0}^{t_f}(\lambda_t^b \cdot P_{t,j}^S - \lambda_t^s \cdot P_{t,j}^B) - \sum_{t=t_0}^{t_f} C_{t,i,j}^G\right\} \tag{11}$$

The generation cost, for generator i belonging to agent j, is decomposed into variable, fixed, start-up and stop cost in the following way:

$$\begin{aligned} C_{t,i,j}^G = {} & vc_i \cdot P_{t,i,j}^G + fc_i \cdot v_{t,i,j}^G + \\ & yc_i \cdot y_{t,i,j}^G + sc_i \cdot s_{t,i,j}^G \end{aligned} \tag{12}$$

In order to ensure the fulfillment of technical requirements, it is needed to take into account the following restrictions:

a) Power output limits: the power output of generators cannot be higher than a fixed quantity due to technical reasons; also, it cannot be under a certain technical limit:

$$P_{g,i,j}^{min} \leq P_{t,i,j}^G \leq P_{g,i,j}^{max} \tag{13}$$

b) Start-stop logic: the relationship between binary variables which represent start, stop and operation for generator i and agent j can be written as [12]:

$$y_{t,i,j}^G - s_{t,i,j}^G = v_{t,i,j}^G - v_{t-1,i,j}^G \tag{14}$$

c) Power market balance: there has to be a balance between the power produced by generators, the power bought, the power sold and total demand:

$$P_{t,j}^S - P_{t,j}^B = \sum_{i=1}^{n_{g,j}} P_{t,i,j}^G - D_{j,t}^u \tag{15}$$

where $n_{g,j}$ is the number of generators belonging to agent j.

From (15) it can be seen that a generator sells energy surplus once its own demand is satisfied. An agent cannot sell and buy at the same time. The constraints described for an agent demand are also applicable for a generator agent.

3) Renewable agents: A renewable agent always has its generators connected to the grid regardless of costs. Like generator agents, renewable agents can decide what to do with their energy production although they have the support of batteries.

Power output for wind turbines is considered using scenarios obtained from a Weibull distribution, while solar array power is obtained from realistic solar radiation data. Both renewable energies are modeled using scenarios to take into account the amount of power produced by them. At this point, the superscript associated with the scenarios is dropped for the sake of clarity. The objective function in this case is written as:

$$\text{maximize} \sum_{e} W^e \cdot \left(\sum_{t=t_0}^{t_f}(\lambda_t^b \cdot P_{t,j}^S - \lambda_t^S \cdot P_{t,j}^B)\right) \tag{16}$$

The restrictions for battery operation are described below:

a) Battery energy storage restriction: battery storage level has a superior limit because of its design:

$$S_{t,i,j}^b \leq S_{i,j}^{max} \tag{17}$$

b) Battery power flow restriction: the hourly amount of energy flowing into the battery or from the battery is limited:

$$-\left|P_{b,i,j}^{min}\right| \leq P_{t,i,j}^d - P_{t,i,j}^c \leq \left|P_{b,i,j}^{max}\right| \tag{18}$$

c) Battery charge/discharge equation: there is a relationship between the storage energy in a hour and the storage energy in an previous hour via an efficiency charge coefficient and power flow through the battery:

$$S_{t,i,j}^b - S_{t-1,i,j}^b = \eta_C \cdot P_{t,i,j}^c - (1/\eta_D) \cdot P_{t,i,j}^d \tag{19}$$

A battery cannot charge and discharge at the same time.

The constraints described for a demand agent are also applicable for a renewable agent. The power balance equation for a generation agent is applicable as well, taking into account the energy from renewable resources and the power due to batteries.

In order to establish a reference, one centralized optimization problem was formulated. For this centralized optimization, the control of the whole system is assumed to be in the hands of a central operator which maximizes the social welfare over the MG; this formulation includes most of the constraints described above.

IV. CASE STUDY

The case study is based on the microgrid presented in [1], [7] and [13]. However, the microgrid is modeled as a single node system connected to a main grid. Hourly energy demand for each agent is also taken from [13] and market selling prices were adapted from the realistic spot prices taken from the Spanish Market Operator (OMEL) [14].

Energy resources and demands have been grouped into six different agents. Agent 1 is a renewable generation agent that operates all renewable resources including micro wind turbines (WT), photovoltaic panels (PV) and a battery. Agents 2 and 3 are conventional generation agents and they operate the microturbine (MT) and the fuel cell (FC), respectively. Agents 4, 5 and 6 are demand agents. Technical data related to energy resources and the battery are given in Tables I-III.

TABLE I
COST PARAMETERS FOR ENERGY RESOURCES

Type	Variable cost (c€/kWh)	Hourly fixed cost (c€/h)	Start-up cost (c€)
MT	4.37	85.06	9
FC	2.84	255.06	16
WT	10.63	0	–
PV	54.84	0	–

TABLE II
TECHNICAL LIMITS FOR ENERGY RESOURCES

Type	Min power output (kW)	Max power output (kW)
MT	6	30
FC	3	50
WT	0	10
PV 1	0	3
PV 2,3,4,5	0	2.5

TABLE III
TECHNICAL DATA FOR THE BATTERY

S^{ij}_{min} (kWh)	S^{ij}_{max} (kWh)	P^{bij}_{max} (kW)	P^{bij}_{max} (kW)
0	30	-10	10
Overall efficiency $\eta = \eta_c \cdot \eta_d = 0.95$			

According to the problem of an agent with generation resources, this agent is willing to sell energy once its internal demand has completely been satisfied. If its demand in a given period of time is higher than its generation capacity, it will buy energy from the market.

In Fig 2, we show the behavior of the price responsive demand within the designed decentralized approach (DA). The results are compared against those obtained within a centralized approach (CA). Input data from initial power demand are also given in Fig. 2. Although selling market prices are not displayed, it can be noticed from Fig. 4 that price responsive demand is moved from those time periods where a high selling market price is present.

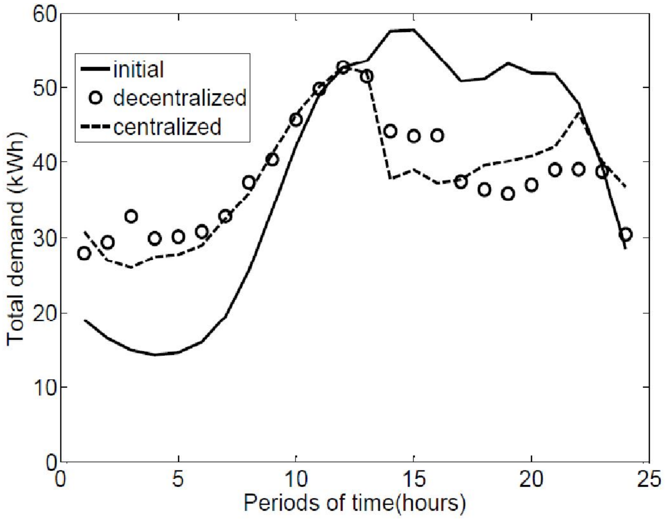

Fig. 2 Price responsive demand in centralized and decentralized situation

Actually, price responsive demand tends to be shifted to those periods of time for which a better selling market price is expected.

The energy output for non-renewable resources and energy level of the battery are shown in Fig. 3. MT is generating intermittently while FC is generating from period 19 to 21 at maximum power. Energy levels under CA and DA show different profiles but with a similar trend. In both cases, the battery charges when selling market price is going to increase and discharges when the opposite occurs.

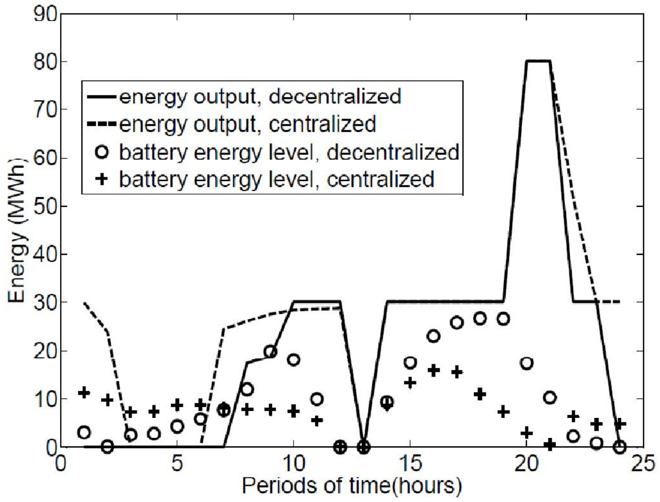

Fig. 3 Hourly energy output for non-renewable resources

In Fig. 4 and Table-IV some results are given regarding the auction, overall clearing prices and energy transactions. Note that the auction only takes place at certain periods and the resulting price ranges between the buying and selling prices from main grid which are input data. The overall number of rounds for the auctions lies between 4 and 10.

The demand agents buy a considerable fraction of its demand from the auction with respect to the amount bought from grid. The renewable agent sells in almost every period of time while conventional generation agents buy energy in some periods where it is not economical to produce with its own generators.

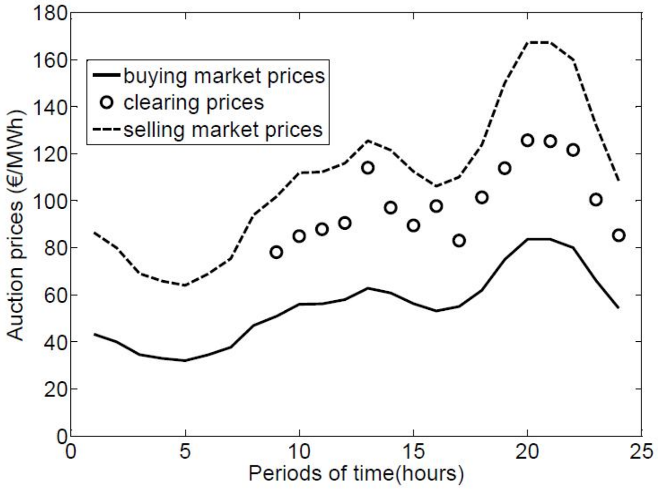

Fig. 4 Overall clearing prices in auction in respect to selling and buying prices from main grid

Under the CA energy bought and sold from the main grid are 120.77 kWh and 98.73 kWh, respectively. In addition, energy satisfied from own generators are 787.30 kWh and 395.00 kWh in CA and DA, respectively. These results show that CA tries to satisfy its demand from its own resources rather than main grid unlike DA.

TABLE IV
DAILY ENERGY TRANSACTIONS IN AUCTION AND MAIN GRID IN DECENTRALIZED SYSTEM

Agent	Auction		Main grid	
	Buy (kWh)	Sell (kWh)	Buy (kWh)	Sell (kWh)
1	−	82.55	0.99	18.29
2	19.11	−	39.81	90.38
3	14.53	138.76	89.05	24.84
4	113.62	−	81.66	−
5	23.49	−	32.97	−
6	50.56	−	55.32	−
All	221.31	221.31	299.80	133.51

Another interesting result comes from the value taken by the objective function and the overall cost necessary to satisfy the demand. These results are given in Table-V.

TABLE V
OBJECTIVE FUNCTION AND OVERALL COST IN CS AND DCS

Objective function (€)		Overall cost (€/MWh)	
CS	DCS	CS	DCS
−53.02	−55.46	59.05	72.43

The negative value of the objective function means that for the microgrid the cost for buying energy plus generation costs are bigger than incomes from the energy sold. Overall costs are calculated as the ratio of global cost necessary to satisfy the total demand in € and the amount of total demand in MWh. Overall cost for CA turns out to be smaller than overall cost for DA.

V. CONCLUSION

A decentralized approach for a market-operation of a microgrid using Multi-Agent Systems has been proposed. The approach explicitly considers an efficient integration of renewable generation and the operation of price response demand.

Under the decentralized proposed approach, the independent operation of involved agents is preserved and obtained results are pretty close to those obtained within a centralized approach.

REFERENCES

[1] R. Bhuvaneswari, S.K. Srivastava, C.S. Edrington, D.A. Cartes and S.Subramanian, “Intelligent based auction by economic generation scheduling for microgrid operation,” in *Innovative Smart Grid Technologies (ISGT)*, Gaithersburg, Maryland. Jan. 19-21 2010, pp 1-5.

[2] F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, “Microgrids management,” *IEEE power & energy magazine*, pp. 54- 65, May./Jun. 2008.

[3] S.D.J. McArthur, E.M. Davidson, V.M. Catterson, A. Dimeas, N. Hatziargyriou, F. Ponci and T. Funabashi, “Multi-agent systems for power engineering applications−part I: concepts, approaches, and technical challenges,” *IEEE Transactions on Power Systems*, vol. 22, pp. 1743-1752, Nov. 2007.

[4] S.D.J. McArthur, E.M. Davidson,V.M. Catterson, A. Dimeas, N. Hatziargyriou, F. Ponci and T. Funabashi, “Multi-agent systems for power engineering applications−part II: technologies, standards, and tools for building multi-agents systems,” *IEEE Transactions on Power Systems*, vol. 22, pp. 1753-1759, Nov. 2007.

[5] A. Dimeas and N. Hatziargyriou, “A multi-agent system for microgrids,” in *IEEE Power Engineering Society General Meeting,* pp. 55-58, Jun. 2004.

[6] A. Dimeas and N, Hatziargyriou, “Operation of a multiagent system for microgrid control” *IEEE Transactions on Power Systems*, vol. 20, no 3, pp. 1447-1455, Aug. 2005.

[7] A.G. Tsikalakis and N. Hatziargyriou, “Centralized control for optimizing microgrids operation,” *IEEE Transactions on Energy Conversion*, vol. 23, no 1, pp. 241-248, Mar. 2008.

[8] Zhang Jian, Ai Qian, Jiang Chuanwen, Wang Xingang, Zheng Zhanghua, Gu Chenghong, “The application of multi agent system in microgrid coordination control,” in *International Conference on Sustainable Power Generation and Supply,* China, Nanjing, Apr. 2009, pp 1-6.

[9] M. Wooldridge and G. Weiss, “Intelligent Agents,” in *Multi-agent Systems*, Cambridge, MA: The MIT Press, Apr. 1999, pp. 3-51.

[10] *Java Agent Development Framework (JADE)* [Online]. Available: http://jade.tilab.com/

[11] *Foundation for Intelligent Physical Agents (FIPA)* [Online]. Avalaible: http://www.fipa.org/

[12] A.J. Conejo, J. Contreras, J.M. Arroyo, S. de la Torre, “Optimal Response of an Oligopolistic Generating Company to a Competitive Pool-Based Electric Power Market”, *IEEE Transactions on Power Systems*, vol. 17, pp 424-430, May 2002.

[13] S. Papathanassiou, N. Hatziargyriou, K. Strunz, “A benchmark low voltage microgrid network,” *Proc of the CIGRE Symposium: Power Systems with Dispersed Generation*, Athens, Greece, Apr. 2005.

[14] *Operador del Mercado Ibérico de la Energía (OMEL)* [Online]. Avalaible: http://www.omel.es/files/flash/ResultadosMercado.swf