Model for smart appliances toward smart grid into smart city

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Model for Smart Appliances toward Smart Grid into Smart City

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Abstract— **In addition to the lowering of consumption, the smart grid of the future will be able to reduce the peak levels of demand through a more efficient allocation of consumption over the day. For this purpose, end users need to rely on energy monitoring and control systems that provide detailed information about how and when to use and indicate how actively to contribute to the reduction of peak demand. Although the technology is already available, it remains to understand how this type of two-way communication. With this paper is to propose a model for the management, control and optimization of electrical loads through two-way communication between smart appliances and smart grid, through smart metering, in order to obtain an energy management developed in accordance with the planning and programming used, so as to create an appropriate programming model for different optimization goals.**

Keywords—Smart city; smart grid; smart appliances; ICT, smart control; HEMS, Multi Agent System.

I. Introduction

The smart grid is to be used in new ways which include not only the use of advanced materials in order for the equipment such as transformers and switches to improve efficiency, safety and performance but also the spread of electronic devices to optimize resources existing and improve the flexibility of the network in case of interruption, even through intelligent monitoring and control systems in real time; the use of storage technologies at all levels to mitigate peak demand and extend the use of energy produced from renewable sources; communication technologies able to afford more than that of energy exchange of data flows between the intelligent distributed devices in the electrical system.

The main objective of the smart grid of the future, therefore remains more efficient use of energy, with the implementation of technologies also aimed at energy savings to the end user in the industrial, commercial and domestic. In addition to the lowering of consumption, the smart grid of the future will be able to reduce the peak levels of demand through a more efficient allocation of consumption over the day. A system of this kind requires substantial changes in terms of management of supply and demand, but the energy demand largely escapes out of control while in a smart grid to manage proactively, enabling operators to balance it better with the procurement.

For this purpose, end users need to rely on energy monitoring and control systems that provide detailed information about how and when to use and indicate how actively to contribute to the reduction of peak demand. A real-time communication between suppliers and consumers will allow users to respond directly to changes in conditions and prices, sometimes while allowing the system to limit consumption by excluding certain equipment to ensure that the application does not exceed the amount of available electricity. In the area of electricity supply this process is known as "demand-response" and aims to bring down the peaks causing consumers to lead non-essential consumption over periods when demand is lower.

Although the technology is already available, it remains to understand how this type of two-way communication will be used and to what extent it can contribute to the reduction of peak demands.

The aim of this paper is to propose a model Hems (Home Energy Management System) for the management, control and optimization of electrical loads by means two-way communication between the smart grid and smart appliances through smart meters in order to obtain an energy management developed according to the design and programming used, in order to create an appropriate programming model for different goals.

II. ICT For Smart Grid To Smart Appliances

Through the Smart Grid (SG) and the latest ICT technologies for the processing of detailed data in real time on the conditions of networks of thousands of grid points, it gives consumers the opportunity to play an active role, enabling them to adopt informed decisions on how and when electricity usage times and even helping them to generate their own energy, redirecting surplus on the net Without these technologies would be impossible to allow the large-scale integration of renewable resources, in fact, more and more users will also become producers, by installing small solar panels or wind turbines on the roofs of their homes. Currently, the only users able to participate equally significant in the electricity market are the intensive industrial plants which own electric power generation systems of considerable size.

The goal is to go from one concept in which the network of distribution spreads the energy from power production to end-users to one in which the energy production is through sources spread all over the distribution network, where end users may also be producers of energy, and the management of the energy flows is regulated in most effective way to respond in real time to the change in demand and offer also due to the generation of energy from new and less predictive renewable sources.

The smart grid should focus on the high automation and the growing understanding of the electrical distribution networks to ensure a high quality service, efficient and reliable waste reduction in energy delivery to the users.[1]

Micro-grid is a fundamental and most effective technology to deal the growing challenges of modern power systems such as environmental sustainability, high power quality and reliability, and increasing social sector needs, and the aging of infrastructure of the current power grid.

A micro-grid system is typically composed of distributed generators (DGs), distributed storages (DSS) and controllable loads. Since generators and storage devices geographically locate near to the controllable loads, a series of advantages can be achieved including improved reliability and reduced transmission losses. In addition, micro-grid using renewable resources such as energy supply, satisfying the requirement of respect for the environment

The microgrid system can be connected and disconnected from the upstream utility grid according to the current condition in order to minimize the disruption to the loads [2]-[5].

III.

IV. QBUILDING SMART ACTIVE

The buildings represent about 38% of global energy needs of the end users and their consumption can be reduced thanks to energy-saving technologies, such as intelligent control systems (temperature control, lighting, handling loads) as needed real. Currently, systems for intelligent buildings are independent from the smart grid, and in the future, they must interact to give consumers more control over the amount of energy used and the period of use. For example, customers can configure the automation systems of its buildings in order to lower heating during peak periods or may delegate this task. This solution would allow customers to reduce the energy bill, and improve the overall efficiency of the system. To be fully integrated into the electrical supply network, the buildings must be equipped with measurement systems (smart metering) able to collect more accurate data on power consumption and communicate with the automation systems of the distribution or management of network, (see fig.1).

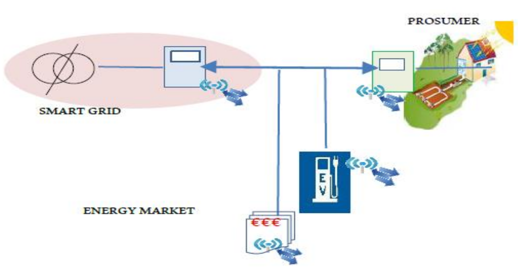

Fig. 1: SG and SA connected into Smart City

V. HOME ENERGY MANAGEMENT SYSTEM TOWARDS SMART CITY

The Managament System to control the energy of the home, is based on smart appliances that can manage themselves by adjusting the power consumed, avoiding overloads, peaks in consumption and in relation to production (renewable for example) and the price of energy, avoiding disconnection from the grid due to an excessive load and automatically balancing consumption still ensuring reliable operation of the appliance.[6]

Every smart appliances can be managed in relation to the power flow, to get the best use of renewable sources, energy consumption at the best price in this way will be obtained a management and control system within each district, for the end user and at the same time the optimal control of the smart grid.

VI. MODEL FOR OPTIMIZATION FLOW ENERGY INTO SMART CITY

It proposes a mathematical model for home energy management system to optimize the planning of activities in view of the real-time pricing and customer demand. The purpose is to provide an innovative tool for users of the electrical system in such a way as to make the same active part of future smart grid and support them in the use of energy.

Smart Appliances (SA) using ICT to make functions faster, cheaper and more efficient; with the following characteristics:

- energy

SA must be able to be powered by the SG to optimize energy use at suitable times of the day;

- bidirectional communication

SA have the ability to communicate with other devices in the district of a dedicated SG to adjust and optimize the use of community-based energy;

- connectivity

SA must be connected to the web, via wireless, to be managed, monitored and controlled remotely.

Also to establish a model it must be considered that the appliances can be divided into two categories:

1) Programmable appliances:

this type of devices can operate automatically without manual control and divided into two categories according to their operational characteristics: time and temperature displaceable. The use of variable time devices (eg washing machines, dishwashers, plug-in hybrid electric vehicle (PHEV), dryer) may be delayed or anticpato into time slots, with no impact on consumer comfort. In this manner the loads mentioned above can adapt delayed in their operation to a certain degree and this tolerance varies for each device.

2) Appliances not programmable:

this devices are manually operated, the basic loads and real-time devices that all these names indicate the intrinsic nature of their mode operation. The energy consumption of these devices (for example, lighting, TV, vacuum cleaner) must be provided immediately at any time, at the request of a resident, and it is impossible to provide a predetermined program for them. [7]

Furthermore, the programming must be carried out taking into account that the devices must be of two types ie that can be interrupted and can not be interrupted: the first interruptible types of electrical devices, such as heaters, air conditioners, and household appliances such as refrigerators with continuous operation. [6]
In our model we have made an optimization program for a designated building (a house, a school, an office), we selected some types of electrical devices that can be programmed into the building, denoted by A (i),
The definition of each of the average electric power is indicated by W(i), for the optimization programming period will be divided in 24 hours per day, indicated by T (i), the working time for each appliances is indicated with N (i), as shown in (1), where the working time varies between 1 and 0, referred to as S [i, j] matrix, with a boundary condition:

$$\sum_{j=1}^{n} S_{ij} * X_{ij} = N_i \tag{1}$$

where Xij is a matrix that each index is 1 or 0. One day before the user from the power company informed that the date of a time, denoted by P (j), based on the principle of less electricity can be drawn from this programming system, a linear programming model based as follows (2):

$$\min \sum_{j=1}^{24} P_j \bullet \sum_{i=1}^{6} W_i \cdot S_{ij} \cdot X_{ij} \tag{2}$$

where Pj Hourly Spot Price, in fig.2 it outlines the trends in prices in real time, (of a specific company of electricity supply in Italy, taken as reference) and Wi average power of the appliance.

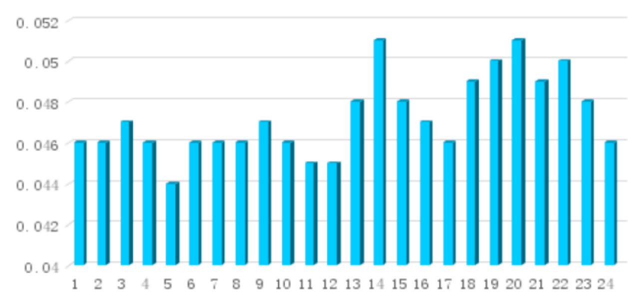

Fig.2: the price in real time in the 24 hour

5.1.model and simulation with the goal of minimizing cost

In this case, it is assumed that the data of several common appliances, do not exceed the 3kWh, as in most of electric energy supply contracts. Since the refrigerator is a device that is running 24 hours a 24, estimated 0.5KWh, the other appliances present in the home for now should not exceed 2.5Kwh. This restriction is given by (3):

$$\sum_{i=1}^{n} W_i * S_{ij} * X_{ij} \le 3 - 0.5 \tag{3}$$

is obtained so the following table 1, in which it was assumed a number of devices, with a certain Kwh consumption, with a functioning assumed for a given number of hours per day:

Appliances	***Time slot [a,b]***	***N (number)***	***W (Kwh)***
Wash machine	14-20	2	0,8
Water heater 1	16-20	1	1,5
Microwave oven 1	5-9	1	1,2
Electric Kettle	14-17	1	1,8
Air conditioning	16-23	2	1,5
Water heater 2	5-10	1	1,5
Microwave oven 2	19-21	1	1,2
Refrigerator	0-24	1	0,5

Table 1: The data used in the case of family

The simulation for household results are summarized as follows in Table 2:

Appliances	***Xij***
Wash machine	16-17
Water heater 1	17-18
Microwave oven 1	8-9
Electric Kettle	15-16
Air conditioning	16-17 23-24
Water heater 2	05-06
Microwave oven 2	21-22

Table 2: A Planning result in case household

in this manner is obtained so the trend of electricity required in the case household assumed, as shown in figure 3:

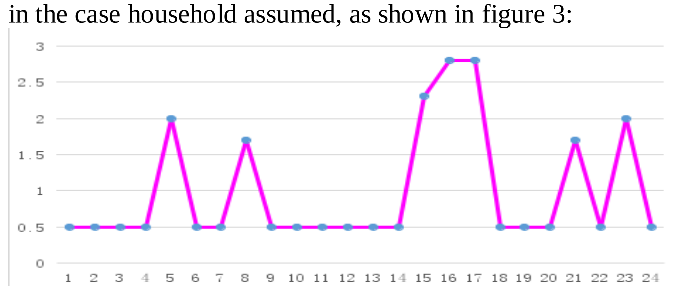

Fig.3: trends in electricity consumption in case household

Thus achieves price performance that will pay for every single hour, according to the estimated consumption (see figure 3) and the trend in the cost (see figure 2), the results are summarized in figure 4:

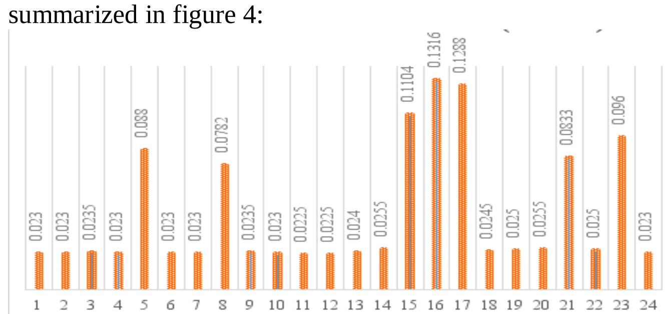

Fig. 4: price performance without customer satisfaction

choosing as objective function the lower cost of energy is obtained a specific consumption per hour and an average daily cost of Cprice = 0.5523 euro / day.[8]

5.2. Model and simulation with the goal of customer satisfaction

In the previous model, "the user wishes that the appliances work in a time interval [a, b], defined by the lower cost and not from their needs, this presupposes that, if there are no electrical devices that work between the needs of users [a, b], user satisfaction will be zero.
Assuming that the user want the operations of household appliances both within a specified time interval (for example the washing machine runs out of washing clothes within the time period chosen), it has that, when a device is operated at time a, if time not exceed the range a + N and therefore, it will be completed the work cycle, it will have the highest user satisfaction, equal to the value 1.
Therefore, customer satisfaction is a function of a time segment linked to the execution of the task F, where F is related to the time of end of the work, see (4):

$$s(F) = \begin{cases} \dfrac{F-b}{a+N-b} \times 100\% \\ 0 \end{cases} \qquad (4)$$

with

$a+N \leq F < b$

Moreover users inside the same home, there can be various degrees of priority for the different electrical equipment for the satisfaction of a working cycle,.
Here we represent γ as satisfaction factor in relation to the operation of appliances and γ is an integer not less than 0.
When γi = 0, we have that the running time of the device is independent of satisfaction.
Thus, the satisfaction factor (weighted satisfaction) can be expressed as a function of dsi(Fi), see (5):

$$ds_i(F_i) = \begin{cases} \gamma_i \times \dfrac{F_i - b_i}{a_i + N_i - b_i} \\ 0 \end{cases} \qquad (5)$$

with

$F_i > b_i$

At the same time, the entire planning process for the total weighted satisfaction Sod can be defined as in (6):

$$sod = \sum_{i=1}^{n} ds_i(F_i) \qquad (6)$$

To enter the satisfaction in programming model, in which the satisfaction items are added in the objective function optimization, using α(αϵ(0,1)), necessary to identify the degree of satisfaction in the specific weight of the whole scheduling. The products containing Satisfaction and proportion α are added to the programming model of the formula (3), thus obtaining the following (7):

$$\min \sum_{j=1}^{n} W_i * S_{ij} * X_{ij} - \alpha * sod \qquad (7)$$

It carries out the simulation in the case of a family, in which the optimization function is also based on the satisfaction criteria. Since as previously defined are obtained by the data summarized in table 3:

Appliances	***Time slot [a,b]***	***N (number)***	***W (Kwh)***	***γ***
Wash machine	14-20	2	0,8	5
Water heater 1	16-20	1	1,5	6
Microwave oven 1	5-9	1	1,2	3
Electric Kettle	14-17	1	1,8	1
Air conditioning	16-23	2	1,5	4
Water heater 2	5-10	1	1,5	6
Microwave oven 2	19-21	1	1,2	3

Tab. 3 : specific data with the goal satisfaction (Sod)

where the goal is user satisfaction, the development of consumption will be the one shown in Figure 5:

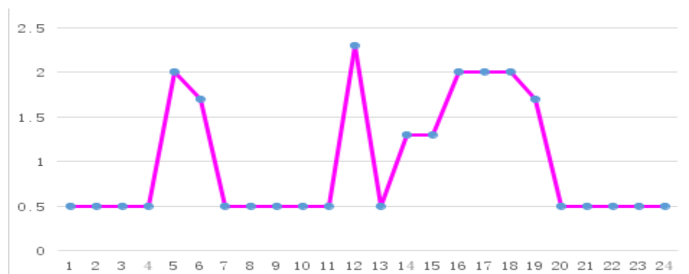

Fig.5: trend in electricity consumption with the goal satisfaction (Sod)

in Figure 6 are summarized payment hour by hour of electricity consumed, taking into account the cost of energy given in Fig. 2, with the goal higher user satisfaction:

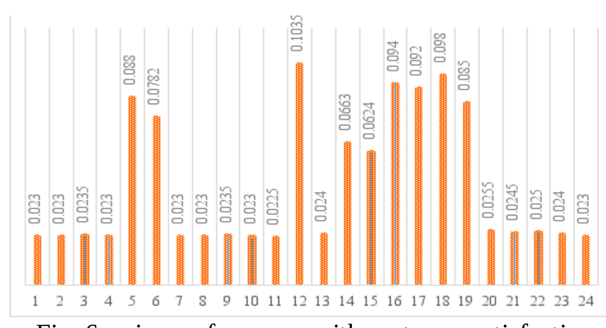

Fig. 6: price performance with customer satisfaction

In this case, the average cost of electricity, having as its goal the satisfaction of the customer is highest and is equal to: Csod=1.1201euro/giorno.
It seems obvious that if programming is performed according to just the satisfaction and needs of the user, without the

evaluation of the cost per hour, the final payment will be higher, Cprice <Csod. [9]
In figure 7 shows the comparison between the different hourly consumption of electricity in the case of greater customer satisfaction and the trend of the lower cost of energy in real time, where it is clear that the energy requirement does not coincide with the cheap energy . The trend, however, may be helpful for a targeted program, run by the control systems and smart appliances in the home, but also help the user can choose whether to start, however, the appliance or to postpone the starting at the time of greater economic benefit.

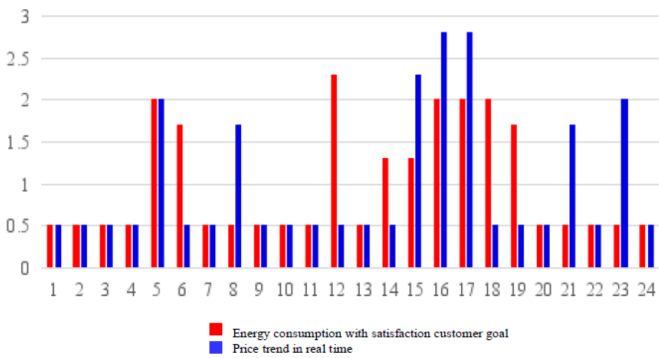

Fig. 7: electricity consumption 'with the goal customer satisfaction in relation to electricity prices in real time

The control can also be remotely managed, through specific app from their smartphones or tablet, in order to handle the energy flows in line with the trend of prices or of any changes in their needs. Through smart metering related to the smart grid and microgrid, it can optimize the energy flows, in real time, for each residential customer,
This behavior by the user, may be determined by the energy manager's reward for virtuous conduct.The control objectives for a smart home are to maintain the high comfort and satisfaction level, while reducing total energy consumption by developing a smart energy control and home energy management system. [10]

VII. MULTI-AGENT CONTROL FOR SMART APPLIANCES

The integrated smart home with smart appliances and micro-grid systems have some salient advantages such as environmental friendliness. However, the major challenge is to reduce the energy consumption and to maintain the high level of satisfaction of user.
To meet this challenge, a home control system, reactive and flexible, it must be developed. This paper aims to integrate the energy management model, illustrated in the previous paragraphs, with a multi-agent system to integrated micro-grid and utility grid system.
The proposed multi-agent system can be integrated with the Home Energy Management System (HEMS) and the required hardware such as sensors, microprocessors, actuators, and communication devices that should be installed in the home as well as smart appliances that can be autonomous and reagent.
The higher customer satisfaction and power efficiency (in term of cost) should be obtained by developing an effective home energy management system for smart home integrated with smart appliances and micro-smart grid systems.
For this purpose, the Multi-Agent System (MAS) is applied to develop the control system for the energy consumption (in term of cost) and satisfaction of the household ,trough smart appliances in smart home and micro utility-grid systems.
Multi-agent control system technology has been successfully utilized in various fields and the fundamental element is the agent, which can be a software or physical entity.
The objective of the control system is to meet the user's need for energy in the low price of electricity moments within the technical constraints of the distribution network. The control system's ability to work successfully when the distribution network is operated within its load limits. Several techniques are used for decision making of the agents.
Although different agents exhibit distinct behaviors, they share some common properties and all agents cooperate with one another to achieve the overall control goals [11]-[15]:

- Agents have a reliable degree of autonomy enabling them to function properly without human intervention;
- Agents are able to communicate with each other through a dedicated language called “agent communication language” (ACL);
- Agents are able to perceive and reacte to changes in the environment as well as determining the proper behaviors to achieve the final goal

Agents can be divided into multiple layers according to their several functions, and the correct cooperation of different agents reach successful control, which is to reduce energy consumption without compromising customer satisfaction.
Types of agents used are illustrated in figure 8 and are:
the switch agent with trading capability, for micro grid and utility grid; the customer satisfaction agent with load agent, for smart appliances, cooperate with each other to achieve the overall control goals.

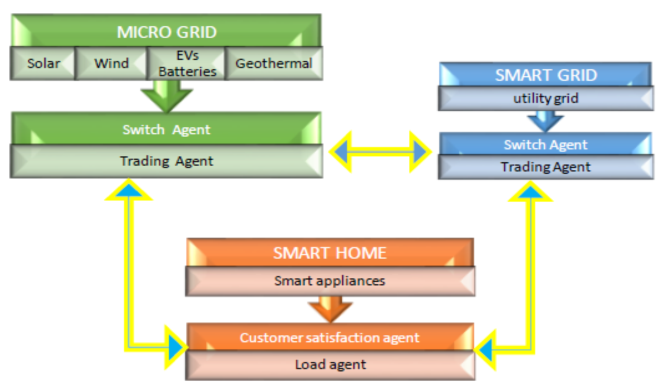

Fig.8: Multi Agent System model

The smart home is integrated into the micro-grid system and it can be seen as the controllable load. The operation mode for the smart building includes grid-connected mode and islanded mode and distributed renewable energy resources are considered as the primary energy supply and the utility grid is the backup energy supply.

All appliances in the smart home prefer consumption of renewable energy over utility power. The utility grid can be connected to the smart home in order to supply power When the available renewable energy can not Satisfy the home demands [16] and this operation is managed in an autonomous way from the agents switch.

The switch agent including negotiation agent, is used to determine and monitor the energy exchange between the utility grid and the smart appliances according to customer preferences and cheap energy.

The load agent, which controls all the interruptible loads and plug-in loads. In this case, interruptible loads are those noncritical appliances that have direct connection with the satisfaction of users, while plug-in loads are the non-comfort-related and uninterruptible appliances. The load agent decides the amount and the order of the interruptible load shedding according to the customer preference to maintain the high-level satisfaction with cheap energy.

Through the cooperation of these multi-layered agents, the control goal, which is to maximize the customer satisfaction and minimize the energy consumption and price simultaneously, can be achieved [17].

Two communication modes in terms of direct communication and indirect communication are used for facilitating the communications between various agents in the proposed control framework. Direct communication mode can be utilized for the inter-agent communications in the same layer. This is accomplished through a direct information exchange between agents based on the ACL, Agent Comunication Language. A database is needed for storing the incoming information from agents including the switch agent, and the load agent. After the data are manipulated, processed data or the resulting decisions will be sent back to the corresponding agents. Using these modes of communication, each agent in the proposed control system will have real-time enough information to make correct decisions and therefore exhibit desired behaviors [18].

VIII. CONCLUSION

Smart home and smart appliances are becoming a trend for the next-generation and micro-grids are a promising technology in the future power sector. Thus, it is beneficial to combine these emerging technologies for home integrated smart appliances and micro-grid systems. Advantages of these micro-grid-enabled smart home include the improvements of indoor comfort, power efficiency, and reduction of emission. Renewable energy resources are utilized as the primary power supply of smart home to meet the requirements on environmental sustainability.[19]

In this paper we proposed some optimization models of energy consumption in smart home. This model uses an integer linear programming method, according to different users needs. Can be achieved programming optimization for minimum energy consumption and user satisfaction. This program can be used as a working model for smart agent, so that they can independently decide which is the condition to be implemented according to the maximization of customer satisfaction with cheap energy.

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