A Smart Home model to Demand Side Management

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ABSTRACT

In order to address the challenges of greener energy generation, new techniques need to be developed both to generate electricity with lower emissions and to optimize energy distribution and consumption. Smart grid techniques have been developed specifically to tackle this latter challenge. This paper aims to contribute in improving the efficiency of energy use within a single household by modeling appliances within it as a multiagent system (MAS). We model this system as a virtual organization that seeks to minimize energy consumption while reaching a tradeoff between user comfort, energy cost and limiting peak energy usage.

General Terms

Algorithms, Management, Reliability

Keywords

Demand Side-Management, Smart grid, Smart Home

1. INTRODUCTION

Electricity is the most versatile and widely used form of energy, as such, global demand is growing continuously. However, electricity generation is currently the largest single source of greenhouse gas emissions, making a significant contribution to climate change.

There are approaches within the developed world to reduce reliance on fossil fuels and move to a low-carbon economy to guarantee energy security and mitigate the impact of energy use on the environment. To mitigate the consequences of climate change, the current electrical system needs to undergo adjustments. The solution to these problems is not only in generating electricity more cleanly, but also in optimizing the use of the available generating capacity. To achieve such optimization, the *Smart Grid* comes into play. A *Smart Grid* is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. [10]. The Smart Grid has come to describe a next-generation electrical power system that is typified by the increased use of communications and information technology in the generation, delivery and consumption of electrical energy. Smart Grid initiatives can provide more electricity to meet rising demand and quality of power supplies, integrating low carbon energy sources into power networks. It possesses demand response capacity to help balance electrical consumption with supply, as well as the potential to integrate new technologies to enable energy storage devices and the large-scale use of electric vehicles.

Demand for electricity should be made more adaptive to supply conditions, avoiding peaks of demand, resulting in a more efficient grid with lower prices for consumers. As a result, the new electrical grid intends to get an economic balance and increase the efficiency of the current the electrical supply. Energy efficient technologies such as intelligent controls systems that adjust the heating temperature, lighting can help with the management of consumption in buildings and houses. This intelligent control system can give consumers control over the amount of electricity they use. Furthermore, the intelligent control system can integrated into the power grid through equipment capable of collecting data about electricity consumption and of communicating with others entities in the power grid. A key element that allows all of the emerging smart grid technologies to function together is the interactive relationship between the grid operators, utilities, and the user. Controls in the household and appliances can be set up to respond to signals from the energy grid to minimize the energy use at times when the power grid is under stress from high demand, or even to shift some of their power use to times when power is available at a lower cost. This intelligent control system inside a household introduce the concept of *Smart Home*.

Within the smart grid, a smart home is a household that has highly advanced automatic systems responsible for manager and control the smart appliances. Our main contribution is an agent-based smart home model whereby individual autonomous agents are deployed to control each household energy consuming device, as well as an agent coordinating them all through the energy meter. This model should allow a smart home to become more collaborative with the electric grid by balancing energy demand, increasing the resilience of the household as well as optimizing user comfort. The rest of this paper is structured as follows: Section 2 reviews the background required for our definition of a smart home model; Section 3 presents the Smart Home model itself; Section 4 evaluate how the appliances are managed using the

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model proposed; and finally, Section 5 concludes this paper and presents future work.

2. BACKGROUND

In this section, we briefly explain the organization of the electric power industry and its three major sectors. Moreover, we introduce key concepts relating to the smart grid, and some of its associated technologies.

2.1 Electric Power Industry

The power industry is divided into three major sectors: generation, transmission and distribution.

Electricity *generation* is the large-scale process of generating electric power for industrial, residential, and rural use, generally in stationary plants designed for that purpose. Steam turbine generators, gas turbine generators, diesel engine generators, alternate energy systems (with exception of photovoltaic power cells), even nuclear power plants all operate on the same principle - magnets plus copper wire plus motion equals electric current. The electricity produced is the same, regardless of source. A power station (also referred as power plant) is an industrial facility for the generation of electric power. At the center of nearly all power stations is a generator, a rotating machine that converts mechanical power into electrical power by creating relative motion between a magnetic field and a conductor [6].

Electric power *transmission* is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers. Substations transform voltage from high to low, or the reverse, between the generating station and consumer, electric power may flow through several substations at different voltage levels. Transmission lines, when interconnected with each other, become transmission networks [4].

Electricity *distribution* is the final stage in the delivery of electricity to end users. A distribution system's network carries electricity from the high-voltage transmission system and delivers it to consumers. Substations are needed to step up and down the voltage, since long range transmission is more efficient at very high voltages. Typically, the network would include medium-voltage (less than 50 kV) power lines, substations and pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and sometimes meters. At a distribution substation, a substation transformer takers the incoming transmission-level voltage (35 to 230 kV) and steps it down to several distribution primary circuits. The distribution infrastructure is extensive, after all, electricity has to be delivered to customers concentrated in cities, suburbs and very remote regions [17].

2.2 Smart Grid

Smart Grid generally refers to a class of technologies using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries [10]. Murphy et al. [11] define the term Smart Grid as a modern electricity system that uses uses sensors, monitors, communication, automation and computers to improve the flexibility, security, reliability, efficiency and safety of the electricity system.

The benefits of the smart grid are substantial. These benefits will result from improvements in the following six key value areas [8]:

- **Reliability**: by reducing the cost of interruptions and power quality disturbances and reducing the probability and consequences of widespread blackouts;

- **Economics**: by keeping downward prices on electricity prices, reducing the amount paid by consumers;

- **Efficiency**: by reducing the cost to produce, deliver, and consume electricity, however providing the same or better level of quality service;

- **Environmental**: by reducing emissions by enabling a larger penetration of renewables and improving efficiency of generation, delivery, and consumption;

- **Security**: by reducing the probability and consequences of manmade attacks and natural disasters; and

- **Safety**: by reducing injuries and loss of life from grid-related events.

Ramchurn et al. [13] argue that the Smart Grid provides significant new challenges for research in AI since Smart Grid technologies will require algorithms and mechanisms that can solve problems involving a large number of highly heterogeneous actors. Demand-Side Management, electric vehicles, virtual power plants, energy prosumers and self-healing networks are some of the key components that deserve attention in smart grid research.

A safe and efficient electricity grid should be in perfect balance. Schweppe et al. highlight reasons why demand for electricity should be made more adaptive to supply conditions [16]. They note that if peaks of demand were flattened, it would result in longer term and cheaper production contracts, resulting in a more efficient grid with lower prices for consumers.

Demand-side management (DSM) is used to describe the actions of a utility, with the objective of altering the end-use of electricity, whether it be to increase demand, decrease it, shift it between high and low peak periods, or manage it when there are intermittent load demands. In other words DSM is the implementation of measures that can help the customers to use electricity more efficiency. Existing approaches to reduce demand have been limited to either directly controlling the devices used by the consumers (e.g., automatically switching off high load devices such as air conditioners at peak times), or to providing customers with tariffs that deter peak time use of electricity. With the deployment of smart meters, it is possible to make real-time measurements of consumption, providing every home and every commercial and industrial consumer with the ability to automatically reduce load in response to signals from the grid. An important AI challenge in demand-side management is designing automation technologies for heterogeneous devices that learn to adapt their energy consumption against real-time price signals when faced with uncertainty in predictions of future demand and supply.

The "Model City Mannheim" (moma) project is an example of smart grid initiative; the project focuses on researching the implications of innovative IT for the energy grid. The project is part of the E-Energy project framework initiated and partly funded by the German federal ministries for economics and environment [15].

2.3 Smart Home

Smart Home is the term commonly used to define a residence that has appliances, lighting, heating, air conditioning, TVs, computers, entertainment audio and video systems, security, and camera systems, etc, that are capable of communicating with one another and can be operated remotely by a control system. This control system allows the definition schedules for operation or remote operation by phone or over the internet.

Within a smart home, a smart meter is responsible to provide the interface between household and the energy provider. Replacing the old electromechanical meter, these meters operate digitally, and allow for automated and complex transfers of information between the household and the energy provider. For instance, smart meters can receive signals from the energy provider to help the household balance demand and reduce energy costs. Smart meters also provide utilities with more information about how much electricity is being used.

Smart appliance is a device that allows access and operation through an automated management system. Smart appliances can also be able to respond to signals from the smart meter to avoid using energy during times of peak demand.

This new generation of household devices can be distinguished by three characteristics [1]:

- Instrumented: devices provide increasingly detailed information about and control over their own operation and also provide information about the environment in which they operate.

- Interconnected: devices can communicate and interact, with people, systems and other devices. It supports the aggregation of information and control of devices throughout the network.

- Intelligent: devices can make decisions based on data, leading to better outcomes, supporting the optimization of their use, both for the individual consumer and for the service provider.

Current smart appliances and their communications technology are very heterogenous among different vendors, with standardization in its early phases. In this scenario of heterogeneous devices and protocols, it is necessary to adopt an abstract, standards-based view of the new smart grid system as early as possible. In an ideal smart grid environment, all smart grid appliance functions, device connectivity, and device protocols are be standardized in order to avoid multiplied maintenance effort and vendor lock-in for proprietary components [15].

One challenge to the realization of the smart home vision is the need to integrate a large number of entity interfaces, networking protocols and technologies and a variety of applications and services already deployed in the home today. Two types of communication protocols may be considered. The first one is LAN-like protocols to enable appliances to communicate with each other inside of the household. The second type of communication protocol is a WAN-like, this protocol allow a wider communication with other elements of the power grid. For example, each household appliance can take advantage of the household router to connect directly to service in the network [1].

Quanto a citação das redes: alí eu modifiquei muito pouco, no paper que fala sobre isso, eles citam a necessidade de protocolos de comunicação Lan-like e Wan-like, esses termos foram propostos pelos autores, pelo o que entendi, lan-like seria uma comunicação interna entre os elementos da casa, ficando restrito aos limites da casa, uma intranet, por isso "like", e o wan-like seria a comunicação mais ampla entre os demais elementos, por isso algo parecido com a abrangencia que eu posso obter com a Internet, onde consigo acessar qualquer ponto desde que ligado na rede wan.

The deployment of a smart home goes beyond the improvement of a household, for example, if a set of smart homes work together it is possible avoid peak of demand in the whole power grid. For instance, a smart air conditioner might extend its work time slightly to reduce its load on the grid; while not noticeable to the user, millions of air conditioners acting the same way could significantly reduce the load on the power grid. Likewise, a smart refrigerator could defer its defrost cycle until off-peak hours, or a smart dishwasher might defer running until off-peak hours.

A smart home can use micro generation system to supply the household demand. Rooftop solar electric systems, small wind turbines and small hydropower are examples of micro generation system. Moreover, smart homes with their controls system can help to effectively connect all micro generating systems to the grid. For instance, a community of smart homes with photovoltaic panels can use their solar array to keep the lights on even when there is no power coming from the grid.

3. SMART HOME MODEL

The estimated average monthly consumption of appliances presented in this work comes from a company which operates in the areas of generation, transmission and distribution of electricity. Table 1 shows a group of appliances for a household used by a family of three. In this table we have the list of appliances, the power each one consume per hour, the amount of each type of appliance that exists in the household, the time that each appliance is switched on daily and the daily consumption of each appliance.

Table 1: Consumption of a household

Appliance	Power (W)	Quantity	Hours per day	kwh
Air condicioner	950	1	2	57
Vacuum	1000	1	0,10	3
Laptop	200	2	0,25	3
Clothes Iron	1000	1	0,10	3
Fluorescent bulb	32	6	3	17,28
LED bulb	13	5	3	5,85
Washing machine	600	1	0,25	4,50
Microwave	1400	1	0,05	2,10
Refrigerator	50	1	24	36
Television	150	1	2	9
Roof fan	200	1	3	18

3.1 Domestic Appliances

Within the domestic energy domain, it is common to characterize domestic appliances under specific categories: wet and cold appliances, water heating, space heating, cooking and lighting appliances, periodic load and miscellaneous appliances [7] [12]. Table 2 illustrates the types of domestic electrical appliances.

Table 2: Domestic device groups

Type	Examples
Wet	Washing machine, tumble dryers, dishwashers
Cold	Refrigerators, fridge-freezers
Lighting	Incandescent light bulbs, led lamps, fluorescent light bulbs.
Cooking	Electric ovens, microwaves, grill, coffee and tea makers, etc.
Temperature Controller	heat pumps, radiators, air conditioners
Periodic Load	laptop computers, cell phones, tablet computers, electric bicycles, battery chargers
Entertainment	television, home theater, radio, etc
Personal Care	hair dryers, electric toothbrushes, electric razors
Miscellaneous	sewing machines, clothes irons, vacuum cleaners, garden equipment, electric blankets, computer printers, slide projectors, etc.

The different categories imply different behaviors. Wet appliances typically involve set periods of time, programmed by the user or a device controller. Cold appliances have continuous demand, however, this demand is associated to weather variation, e.g. in the summer cold appliances such as a refrigerator need more energy to keep the temperature compared to the energy needed in winter. Temperature controllers have power consumption related to their usage and user routine, when there are users at home, temperature controllers and water heating have power consumption, otherwise when there is nobody at home they should be off or in a standby state. Lighting, cooking appliances, entertainment, periodic load and miscellaneous are much more dependent on the user lifestyle and preferences.

3.2 Appliances Description

All devices considered in this model have only two possible states, ON and OFF, and change between these states via their internal schedule or an external command. Moreover, we assume that all appliances have similar energy consumption distribution during all the days of the year. Future studies can consider additional states, such as a standby state. Another future study can expand energy consumption profiles within the year e.g. different consumption for workdays and weekends as well as different consumption during summer and winter. For this model we consider a typical domestic profile with fixed time intervals consisting of single days, divided in periods of half-hour. Each time slot $t \epsilon$ T where T = 1,...,48 [18] [12].

Each appliance is responsible to request the power required for each cycle, and cannot demand more power than needed to operate in one cycle, even if there is energy left. An exception to this rule is related to the appliances that must operate continuously, such as a refrigerator, in this case the appliance must request all necessary power to operate in the operation window. Each appliance must execute within its predefined operation window.

The attributes defined for each appliance are: power, the number of cycles that the appliance needs to operate per day, category and operation window. Each appliance is described using the following notation:

$$appliance(Pow, Cycles_number, Categ, Window[Start, End])$$

3.2.1 Wet appliances

Devices in this category usually work in well-defined periods of time, e.g. washing machines work one to two hours per use. The user has three different periods of time to schedule wet appliances, e.g. 8:01 AM to 4:00 PM, 4:01 PM to 00:00 AM and 00:01 AM to 8:00 AM. Once the appliance starts working, the state switches from OFF to ON and during the defined period of time, the device must remain in the ON state, switching to OFF after finishing its work.

3.2.2 Cold appliances

Cold appliances work to satisfy certain configuration constraints, e.g. if a refrigerator is programmed to keep its temperature at 5 degrees celsius, it should request power in order to maintain this temperature. For this type of device, power demand variation is associated to weather changes instead of user lifestyle, routine and preferences. So, for example, in summer the device might require a little less power, otherwise, in winter the device requires more power to keep the programmed temperature.

3.2.3 Temperature Controllers

Temperature controllers typically demand power according users needs, e.g. the air conditioner should work to make the user comfortable. For example, summer temperatures in certain countries can easily reach 35 celsius degrees and the user wants to get home and get cooler temperature, so the air conditioner should start working some time before the user arrives home.

3.2.4 Lifestyle appliances

This last category includes lighting, cooking appliances, entertainment, periodic load and miscellaneous appliances. All household appliances from these categories are strongly related to user routines, preferences and lifestyle, e.g. users who likes cooking, users who have the lifestyle focused on mobile technologies probably charge their mobile devices periodically. Assuming that this kind of users does not yield in their preferences, they will use the appliances from this category, without taking into consideration the cost involved.

4. EXPERIMENTS AND EVALUATION

In this section we describe the setup used in our experiments. This set up includes the environment used in the simulations that contains the daily shift configuration, the appliances profile and the group of appliances used in the simulation. We follow with a description of the implementation of our simulation, including the appliances setup, the local allocation protocol used to coordinate the simulation and three different scenarios used during the simulations.

4.1 Experiment Setup

Based on average household consumption within a developing country, we assume that a household consumes during summer time 173 kWh per month or 5.77 kwh per day.

Each day is divided in 48 cycles of 30 minutes, the first cycle starts at 0:00 AM and ends at 00:29 AM. Each appliance can be classified according their daily execution shift, there are 6 different options for which each appliance can be scheduled to operate, in this simulation we define that just one option can be chosen and the appliance is now allowed to operate out of its daily execution shift. Table 3 illustrates the daily shifts.

Table 3: Day shift execution

Day Shift	Begin	End	Initial Cycle	Final Cycle
Dawn	00:00	05:59	1	12
Morning	06:00	11:59	13	24
Afternoon	12:00	17:59	25	36
Night	18:00	23:59	37	48
All	00:00	23:59	1	48
Any	–	–	–	–

If an appliance has its day shift as "Morning", it can can operate between 06:00 AM and 11:59, however if an appliance is scheduled to operate during the entire day, its day shift must be "All", meaning that this appliance wants operate in all cycles. Moreover if an appliance has the value "Any" in its day shift, it means there is no priority to this appliance, and it can operate in any cycle. Appliance are also classified in category described in Section 3.1. Finally, each appliance has an operating window, the interval on which the appliance must operate. The appliance must operate within its operating window, it is not allowed the operate outside the cycles defined in the operating window.

4.2 Implementation

Our simulation was implemented using JaCaMo[1], a framework for Multi-Agent Programming that combines three separate technologies. Each of the three independent platforms composing the JaCaMo framework has its own set of programming abstractions and its reference programming model and meta-model. JaCaMo combines the use of three technologies, Jason[2] [3] for the development of autonomous agents, Cartago[3] [14] for development of virtual environments and Moise[4] [9] for developing the organizational model for multi agents based on concepts as roles, groups, mission and schemes.

The implementation of the model was organized in order to respect the proposal of JaCaMo framework. The organization with the roles, objectives and schemes are implemented at the Moise level. The environment artifacts that define he limit of power per day and limit of power per cycle are implemented at the Cartago level. Finally the implementation of agents is done at the Jason level.

4.2.1 Moise *Level*

The roles defined at the Moise level are: the smart meter and appliances that are divided according to the categories described in Section 3.1 The groups defined in this layer represent the power consumption described in Section 3.2

We defined one scheme to coordinate the power consumption. This scheme covers four goals. The first goal is set to control peak of demands, this goal is achieved through mission control peak demand, only the *SmartMeter* can assume this mission. The three other goals are energy demanded, energy received and executed in operation window; these three goals are achieved through the missions: demand energy, receive energy and execute in operation window; all appliances must commit to these three missions.

4.2.2 Cartago *Level*

Two artifacts are defined in the environment implemented at Cartago level, the first artifact control the cycles: when the cycles start, the cycle progress and a routine to stop the cycle progress. All agents in the simulation have knowledge of this artifact.

The second artifact control the power load: the limit of power to each cycle, the limit of power per day and control the appliances consumption. This artifact is known only by the controller (*SmartMeter*).

4.2.3 Jason *Level*

This level includes the agents implementation, the agents can assume the roles defined at Moise level, some roles may be assumed by more than one agent, for example, the role 'temperature controller' can be assumed by the air conditioner or the ceiling fan. Each objective defined in the functional specification at Moise level is met by plans implemented in the agents.

Each agent represents an appliance, and their individual behaviour takes into consideration the appliance types from 3.1. Consequently, we implemented a generic appliance-agent that includes initial beliefs common to all appliances, as well as a common plan library. At runtime, each appliance-agent commits to the same missions over time, depending on the appliance it controls.

4.3 Setup

As described in Section 3.2 the attributes defined for each appliance in this simulation are: power, the quantity of cycles it wants operate per day, category and operating window. The group of appliances used in the simulation is described in Table 4. This table describe the appliances used in the simulations, for each appliance we have: the power required for operation, the number of cycles they operate per day, the day shift, the category and the operating window.

4.4 Load Allocation Protocol

The Smart Meter has the responsibility of releasing load for each appliance; monitoring the set of appliances so they do not operate out of their operating window; control the peak of demand per cycle and control the limit of load per day; and prioritizing the order that the appliances demand power, for example: the appliances that need operate during all day should demand power first, after that coming the morning appliances, afternoon, appliances, night appliances, dawn appliances and just after those appliances the "Any" appliances can demand load.

The appliances have to monitor their operating window, request the necessary load from the Smart Meter at the start of an operating window and in each cycle, negotiate with the

[1]http://jacamo.sourceforge.net/
[2]http://jason.sourceforge.net/
[3]http://cartago.sourceforge.net/
[4]http://moise.sourceforge.net/

Table 4: Appliances used in the simulation

Appliance	Power (W)	Cycles/day	Daily Demand	Day Shift	Category	Operating Window
Air conditioner	950	4	1900	afternoon	Temperature Controller	27 to 34
Washing machines	600	0.5	150	any	Wet	1 to 48
Coffee maker	500	0.2	50	morning	Cooking	13 to 13
Fridge	50	48	1200	all	Cold	1 to 48
Television System	430	5	1075	afternoon	Entertainment	28 to 36
Cellphone charger	15	2	15	dawn	Periodic Load	1 to 12
Ceiling fan	120	6	360	night	Temperature Controller	41 to 48
2 Living room Fluorescent light bulbs	40	4	80	night	Lighting	37 to 42
Bathroon Fluorescent light bulbs	20	4	40	night	Lighting	40 to 44
Kitchen Fluorescent light bulbs	20	4	40	night	Lighting	37 to 42
Bedroom Fluorescent light bulbs	20	4	40	night	Lighting	40 to 48
2 Living roon LED bulbs	10	6	30	night	Lighting	37 to 42
2 Living roon LED bulbs	5	6	15	night	Lighting	37 to 42
3 Dining roon LED bulbs	15	2	15	night	Lighting	39 to 43

Smart Meter if can operate or should wait until next cycle.

When the device is in the first cycle of their operating window, it should negotiate with the smart meter all the power necessary to operate in the current operating window. Get the quantity of power necessary does not guarantee that the appliance will operate in all cycles that it intends, the appliance still must negotiate with the smart meter if it can or cannot operate in each cycle.

The smart meter sends power to the appliance after verifying there is capacity remaining in the current cycle. If an appliance demands 100 watts and there is 90 watts remaining, the smart meter will not release any load. In this scenario the smart meter just controls if the limit of load per cycle and limit of load per day is not violated, the first appliance that demand, will be served.

4.5 Runs

Three difference scenarios were considered in order to compare the results. The first one focus in an average consumption during all day, after analyze the average of demand required for a household where 3 people live together [5], we assumed that the peak of demand allowed in each cycle should be 10% of the daily load. The second scenario focus in the user economy, the peak of demand per cycle allowed is 3.33% of the daily load (one third of the peak allowed in the first scenario), in this scenario the priority is save energy and the user comfort steps aside, the appliances may fail to operate because the competition for power is high.

In the third scenario the user comfort is top priority, this scenario allows a peak of demand per cycle of 60% of the daily load, the appliances operating window are distributed in the 48 cycles because we assume that the group of appliances defined here does not operate together, however the peak of demand defined in this scenario allows all appliances to operate at the same time.

4.6 Results

To empirically evaluate these scenarios, we executed each of them 100 times. We extracted and compared the total load demanded in each cycle, the total load received in each cycle and the total load consumed in each cycle.

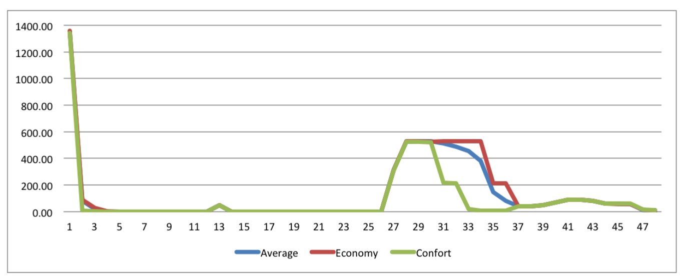

Figure 1: Load demanded in each scenario

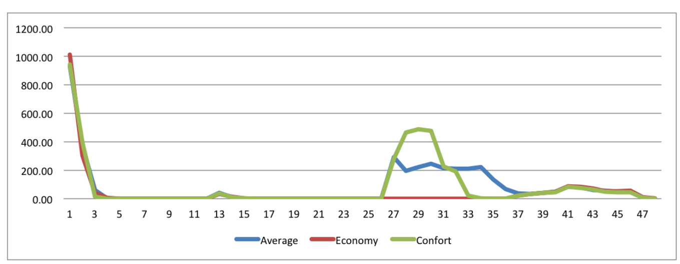

Figure 2: Load received in each scenario

Figure 1 shows a chart of the load demanded in each of three scenario. Figure 2 shows a chart of the load received in each of three scenario. Figure 3 shows a chart of the load consumed in each of three scenario.

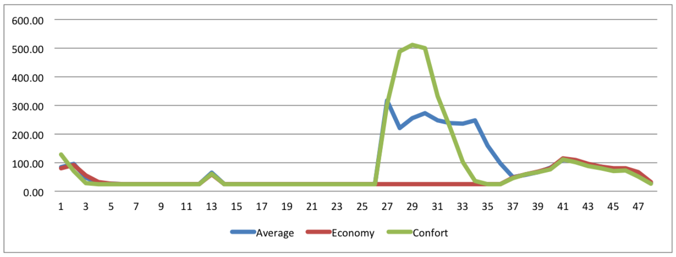

Figure 3: Load consumed in each scenario

As can be seen in the Figure 1, there is a peak of demand in the first cycle, this peak occurs because of the energy demanded from the fridge, as the fridge must operate in all cycles, it is allowed that the fridge demand all necessary power in the first cycle. In addition, the fridge sent a power request to the smartMeter in the cycle 1 in 100% of the cases, besides the fridge received the power demanded during the first cycle in 73% of the cases and received during the second cycle in 27% of the cases.

The air conditioner is programed to begin the operating window over the 27th cycle and the television system operating windows begins at 28th cycle, together they need more than 500 watts to operate, this causes a peak of demand between cycles 26 and 36. In the economic scenario (red line), both the air conditioner and the television system demands more power than the limit allowed per cycle, the cycle limit is 200 watts that represent 3.33% from the available daily load and the air conditioner and television system demand 314 watts and 215 watts per cycle respectively. As a result, there is a peak of demand during the operating windows of these appliances (Figure 1), however the smart meter does not release any power during the cycles 26 and 32 (Figure 2).

In the average scenario (blue line) the behavior of the air conditioner and the television system are different. The cycle limit allows the just one of then receive energy per cycle resulting that the power usage is distributed along the cycles, avoiding peaks of demand, in cycles that both appliances could demand power together (cycles 28 and 33) sometimes the air conditioner receives power and the television system does not and sometimes the opposite.

In the comfort scenario we can see that the air conditioner and the television system get energy in the firsts cycles of their operating window, it is possible because the cycle limit is higher than their demand.

After cycle 37 the light system begins operates, as the sum of all lights is smaller than all cycle limits configured in all three scenarios it is not possible observe any kind of variation in the light appliances. It is necessary to modificate the light appliances profile to observe the behavior of the lights being affected in the different scenarios.

5. CONCLUSIONS AND FUTURE WORK

The electrical power system is now one of the most critical components of the infrastructure on which modern society depends. It delivers electrical energy to industrial, commercial and residential consumers, meeting an ever-growing demand. To satisfy both the increasing demand for power and the need to reduce carbon emissions, we need an electric system that can handle these challenges in a sustainable, reliable and economic way.

Development of Smart Grid technologies is accelerating, however the potential of the Smart Grid opportunity for solution providers is still unclear. Smart meters are often the first application deployed in the implementation of a Smart Grid, consequently, it is expected that in 2014 the numbers of Smart meters deployed reach 30 million. Furthermore, it is estimated that the global market potential for Smart Grid solution providers and equipment manufacturers will total somewhere between $15 billion and $3 billion annually by 2014, splitting the value along three main business segments: grid applications, advanced metering infrastructure and customers applications [2]. Based on analysis of the literature, we presented a possible application of software agents in the Smart Grid. By extending the Smart Home model to the level of an entire neighborhood, it should be possible to implement an agent-controlled Microgrid.

As future work we will further develop the model presented in this paper by aggregating to the Smart Home model the micro generation system and the evolve the control system and the communication protocol between smart entities. The daily execution shift will be explored in future work, in a reward and penalty approach the appliance can be encouraged to operate in the daily execution shift in exchange of receive a reward, otherwise, the appliance can be free to choose operate in other daily shift however a penalty will be applied. We intend to study the different users' profiles to understand the kind of customization that the smart system should perform to balance the demand considering the energy variation in the grid, also study the household configuration profiles (cost versus comfort) to enable the users to configure their houses balancing cost and comfort in different levels.

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