Intelligent Energy Management using CBR: Brazilian Residential Consumption Scenario

Filipe Fernandes[1], Douglas Alves[2], Tiago Pinto[1], Fabrício Takigawa[2],
Rubipiara Fernandes[2], Hugo Morais[1], Zita Vale[1], Nelson Kagan[3]
[1]GECAD/IPP – Polytechnic of Porto, Portugal
{fijgf, tmcfp, hugvm, zav}@isep.ipp.pt
[2]IFSC – Federal Institute of Santa Catarina – Electrotechnical Academic Department, Florianópolis, Brazil
{douglasalves, takigawa, piara}@ifsc.edu.br
[3]USP - University of São Paulo - Department of Electrical Engineering, Polytechnic School, São Paulo, Brazil
nelsonk@pea.usp.br

Abstract—**This paper proposes a novel case-based reasoning (CBR) approach to support the intelligent management of energy resources in a residential context. The proposed approach analyzes previous cases of consumption reduction in houses, and determines the amount that should be reduced in each moment and in each context, in order to meet the users' needs in terms of comfort while minimizing the energy bill. The actual energy resources management is executed using the SCADA House Intelligent Management (SHIM) system, which schedules the use of the different resources, taking into account the suggested reduction amount. A case study is presented, using data from Brazilian consumers. Several scenarios are considered, representing different combinations concerning the type of house/inhabitants, the season, the type of used energy tariff, the use of Photovoltaic system (PV) generation, and the maximum amount of allowed reduction. Results show that the proposed CBR approach is able to suggest appropriate amounts of energy reduction, which result in significant reductions of the energy bill, while, with the use of SHIM, minimizing the reduction of users' comfort.**

Keywords—Brazilian residential scenario; case based reasoning; energy resources management; intelligent house management

I. INTRODUCTION

The world has increased the consumption of energy and in particular, the consumption of electricity. For example, the European reports in 2010 mentioned the increase of global consumption in EU-27 and the domestic consumers represent about 29.70% of the total electricity [1]. On the other hand, the domestic consumers of the United States are responsible for 22.00% of electricity consumption for the year 2011 [2]. Lastly, a study in 2012 about electricity consumption in Brazil shows the domestic consumers responsible for 24.92% of total electricity consumption [3]. Brazil being a country with special conditions, namely, the large territorial extension and the climate differences, the electricity consumption depends directly on the Brazilian regions. Summarized in three regions, the highest percentage of consumption in northern region is for Heating, Ventilating and Air Conditioning (HVAC) and cold domestic equipments. In central-west region, the electric shower is the load with highest impact, the second load is the cold equipment and the third is the HVAC systems. Finally, in the Southern Region, which is discussed in this paper, the highest load consumption is the HVAC systems, followed by electric shower and cold domestic equipment [3].

The consumer is an active resource in context of smart grids [4]. Thereby, management systems should include new characteristics and advanced functions, namely the management of electric vehicles, the interface with external operators, and others. In this sense, these management systems are defined as a smart home system. The smart home represents a house with network communication between all devices allowing the control, monitoring and remote access of the management system [5]-[6]. Several works deal with the smart home as a house management system to effectively manage consumption, storage, distributed generation and the participation in Demand Response (DR) events [7].

With automatic participation in DR events the house management system can reduce the electricity consumption based on the interaction with an external entity. This interaction is performed by smart meters, which enable bidirectional communications between the house and the grid, with measurements in small time intervals, the energy costs information in real time and the remote control of the electricity demand management [8]-[9].

This paper proposes a novel case-based reasoning (CBR) approach [10] to determine the amount of energy consumption that should be reduced in each moment and in each context, in order to guarantee users' comfort while minimizing the energy bill. The SCADA House Intelligent Management (SHIM) system [11] is used to schedule the use of the different resources, taking into account the reduction amount provided by the CBR method. A case study using data from Brazilian consumers is presented, considering different scenarios of residential consumption, generation, tariffs use, and contextual information.

After this introductory section, a review of the Brazilian electricity market is presented in Section II. Section III

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describes the SHIM house management system, including the presentation of the proposed CBR methodology. The input data used to define the residential scenarios is presented in Section IV and the analysis of the main results, and discussion of the advantages of the proposed method are presented in Section V. Section VI includes the main conclusions and contributions of the presented work.

II. Brazilian Electricity Market

In Decree No. 5163/04 two contracting environments were instituted for the Brazilian energy market, the Regulated Contracting Environment (ACR) and the Free Contracting Environment (ACL). In ACR, utilities must purchase their energy by the Federal Government through energy auctions; and in ACL, freely negotiated transactions between buyers and sellers of energy can occur, as can be seen in Figure 1.

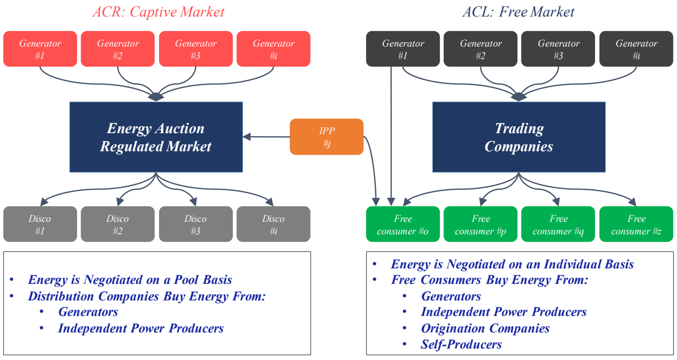

Figure 1 - Brazilian wholesale entity market with two regulated markets: ACR and ACL.

The sellers of energy can strategically sell in both contracting environments, stimulating the competition on the generation side. On the demand side, the competition takes place only in the ACL, where negotiation among agents is free. In ACR, the consumers (captive) do not choose their energy supplier, they can only buy energy from the utilities which are connected and pay tariffs regulated by the Brazilian Electricity Regulatory Agency (ANEEL) [12].

Captive consumers using the standard tariff have no immediate incentives to change consumption habits, since tariffs are regulated and the time of use is not measured by utilities. Thus, the Federal Government decided to strategically encourage residential consumers to adopt a complementary energy generation. The ANEEL's Normative Resolution 482/2012 [13]-[14] encourages generation from renewable sources to consumers, for their own consumption.

The ANEEL defined micro and mini Distributed Generation (DG) as a generating plant, connected to the utilities network:

- micro DG: generating plant with less than or equal to 75 kW installed power;
- mini DG: generating with installed capacity greater than 75 kW and less than or equal to 5 MW plant (except for central hydropower generation, that the limit is 3 MW).

For a generation unit to be classified as micro or mini DG their primary energy source must be renewable (based on hydropower, solar, wind, biomass or qualified cogeneration).

The DG, besides being a clean source of energy and contribute to the diversification of the Brazilian energy matrix can provide a surplus of energy to the consumers. This surplus, injected to the distribution of low voltage electricity network, will provide energy credits to the consumer unit (Net Metering), valid for 60 months [14].

Allied to the encouragement of micro and mini DG for the consumer, the Federal Government also recently inserted the white tariff, with the intention that consumers respond to an economic signal. The white tariff is offered to residential consumers (a type of captive consumers) and different values are applied in intermediate hours (5 pm to 6 pm and 9 pm to 10 pm), in peak hours (6 pm to 9 pm) and during the day (off-peak). The Government's purpose, by means of the white tariff, is that consumers respond to an economic demand signal (when the cost of operating the system is high). Critical demand peaks usually occur between 6 pm to 9 pm and the white tariff encourages consumers to shift their load to other time periods of the day.

In [15] is presented a general discussion of regulatory and commercial aspects to the entrance of mini and micro DG in the Brazilian energy market after the first regulation of micro and mini DG [13]. Also, some impacts of this alternative tariff are studied in [16]-[17].

The Brazilian consumer can manage their energy consumption, according to their priority, the different tariff values and the ability to meet part of their consumption through micro or mini DG, like as the Photovoltaic system (PV) generation [18]-[19]. Regarding [19], an analysis of the energy management in the consumer with PV generation is made and a linear optimization problem is proposed. However, the proposed problem in [19], does not consider priority and curtailment loads.

III. Intelligent House Management

The SHIM platform to optimize the power consumption and the learning model application are presented in this section. One of the advanced functions of the SHIM system is the learning algorithms to adapt the system's behavior to the user and context profiles. A new learning model is developed to support this function of the SHIM platform in moments when it is needed to optimize the use of the energy.

A. *SHIM platform*

SHIM is part of a large simulation platform based on multi-agents systems: Multi-Agent Smart Grid Simulation Platform (MASGriP) is a test platform that simulates a competitive environment in future power systems [20]. The SHIM testbed platform, presented in Figure 2, has been developed in the Institute of Engineering – Polytechnic of Porto (ISEP/IPP).

The main goal of SHIM is testing, simulating, and validating new algorithms and methodologies to apply in house/buildings' management. In order to obtain a realistic simulation, the platform comprises real equipment such as several types of loads, mini and micro DG (photovoltaic panels, wind generator), and storage systems that allow the simulation of the electric vehicles behavior.

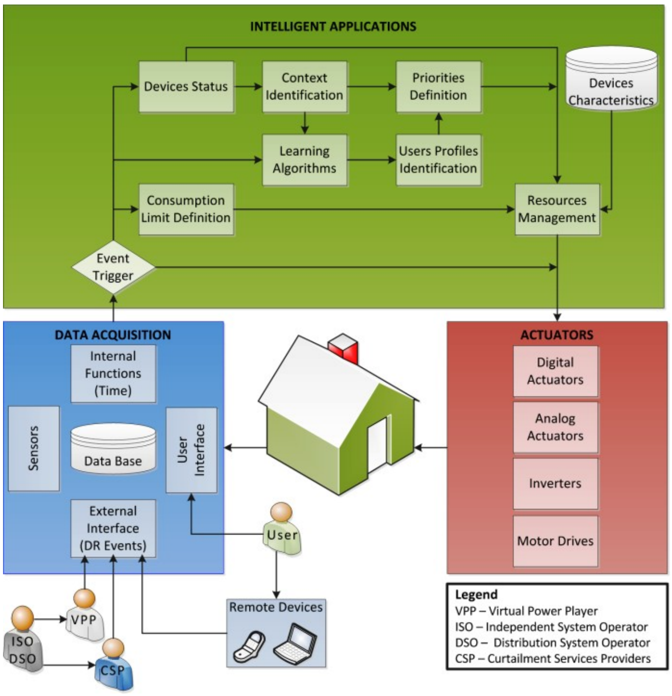

Figure 2 – SHIM simulation platform [11].

To ensure the simulation of complex scenarios, SHIM is able to control real loads and virtual loads simulating the characteristics of the real ones. The system is composed of different modules that are grouped into three different parts: the Data acquisition, the Actuators, and the Intelligent Applications where is included the learning algorithms. The detailed information of the structure can be found in [11].

B. *Optimization algorithm*

In order to minimize the impact of the curtailments in the users' comfort, an optimization algorithm was developed. The algorithm includes two regulation variables (regulation up and down) to guarantee the optimization feasibility. If the regulation down value is equal to 0, it means that the optimization has obtained a good solution. On the other hand, if the regulation down value was higher than 0, it means the optimization algorithm has obtained a solution with higher power consumption than power limit.

SHIM considers different types of events, comfort levels, and the user's interaction. The main goal of the optimization algorithm is to guarantee the power consumption limit (P_{Limit}). All the aspects of the house management influence the values of resource priority factors (λ_{Load}). The priority factors change between 0 (lower priority resources) and 10 (highest priority resources). The objective function to determine the resources that should continue in service is presented below. The detailed problem formulation and the respective nomenclature applied in the optimization process for every minute is presented in [21].

$$Minimize\ f = min \left\{ \begin{array}{l} \sum_{Load=1}^{nLoad} \lambda_{Load} \times P_{Load} + \lambda_{Grid} \times P_{Grid} + \lambda_{Down} \times Reg_{Down} \\ -\sum_{DG=1}^{nDG} \lambda_{DG} \times P_{DG} - \lambda_{UP} \times Reg_{Up} \end{array} \right\} \quad (1)$$

where

λ_{DG}	DG priority
λ_{Down}	Regulation down priority
λ_{Grid}	Grid priority
λ_{Load}	Load priority
λ_{Up}	Regulation up priority
DG	DG index (ID)
nDG	Maximum number of DG
$Load$	Load index (ID)
$nLoad$	Maximum number of loads
P_{DG}	Power generation of DG [W]
P_{Grid}	Power injection in the grid [W]
P_{Load}	Power consumption of load [W]
Reg_{Down}	Power regulation down [W]
Reg_{Up}	Power regulation up [W]

C. *Case-Based Reasoning model*

SHIM is able to reach an optimal scheduling of the available resources taking into account the target level of consumption in the house at each moment. However, determining the target consumption that most benefits the users at each time, considering the balance between their comfort and the minimization of the energy bill is by itself a challenging problem.

In order to reach a solution for this problem in an adaptive and intelligent way, a CBR approach is proposed. CBR is a prominent kind of analogy making, which considers the analysis of previous similar cases, and extrapolates and adapts the results of these cases in order to meet the demands of the new similar case [10]. Each case consists of a problem and its solution. In the proposed approach, each problem is characterized by the following information:

- Contextual information, namely:
  - ✓ Instant of the day (hour or minute);
  - ✓ Day of the week;
  - ✓ Season of the year.
- Absolute power consumption in the corresponding instant;
- Absolute generation in the house in the instant;

- Energy tariff price in the concerned instant;
- Complementary information, which may or not be present, namely:
  - ✓ Temperature;
  - ✓ Luminosity;
  - ✓ Humidity.

Each case, characterized by such information, is associated to an output:

- The consumption reduction applied in the instant.

The proposed approach considers the 4 typical phases of CBR [22] as follows.

1) Retrieve

This phase concerns the identification and retrieval of similar cases from the historic case-base log. This is done by using a clustering algorithm, namely the K-Means [23], to group the cases according to their similarity, thus identifying those that are most similar to the current case.

The clustering methodology considers a set of cases ($x_1, x_2, \ldots, x_n$), where each case is a d-dimensional real vector, and n is the number of considered cases. The clustering process aims at partitioning the n cases into k ($\leq n$) clusters $C = \{C_1, C_2, \ldots, C_k\}$ so that the Within-Cluster Sum of Squares (WCSS) is minimized (2).

$$\min \sum_{i=1}^{k} \sum_{x \in C_i} ||x - \mu_i||^2 \quad (2)$$

where μ_i is the mean of points in C_i, *i.e.* the cluster *centroid.*

The dimension of the vector that characterizes each case x_p, $p \in \{1, \ldots, n\}$ is equal to the sum of the individual dimensions of n vectors, where each of these n vectors contains the data that is referent to a different data variable, e.g. consumption, generation, tariff price, etc.

With the objective of minimizing equation (2), the clustering process executes an iterative process between two steps: (i) the assignment step, where each observation x_p is assigned to the cluster $C^{(t)}$ whose mean value yields the minimum WCSS in iteration t, as presented in (3); and (ii) the update step, where the new means of each cluster are calculated, considering the newly assigned cases, determining the new *centroid* μ_i of each cluster, as in (4).

$$C_i^{(t)} = \{x_p : ||x_p - \mu_i^{(t)}||^2 \leq ||x_p - \mu_j^{(t)}||^2 \; \forall j, 1 \leq j \leq k\} \quad (3)$$

$$\mu_i^{(t+1)} = \frac{1}{|C_i^{(t)}|} \sum_{x_j \in C_i^{(t)}} x_j \quad (4)$$

The execution of the algorithm stops when the convergence process is completed, *i.e.* when the assignments of cases to different clusters no longer change. By minimizing the WCSS objective, in equation (2), the K-Means clustering methodology assigns cases to the nearest cluster by distance. This means that each case will be grouped in the same cluster as the ones that are more similar. These are the cases that are retrieved by the CBR process.

2) Reuse:

In this phase, the solutions from the similar retrieved cases are mapped to the target problem. This involves adapting the solutions of the previous cases to fit the new situation. This is achieved by combining the solutions of the similar cases in order to create a novel solution, adapted to the new case. The solution of each similar case is used with a weight proportional to its similarity to the new case, i.e. the distance between the new case and each case considered similar by the clustering process is calculated, so that the solutions of the closest cases have a larger influence on the newly creates solution, and the most distanced cases have a lighter contribution to this solution. The distance between two cases x_i and x_j is calculated as defined in (5).

$$d(xi, xj) = \sqrt{\frac{1}{H} \times \sum_{h=1}^{H} (xi(h) - xj(h))^2} \quad (5)$$

where H represents the size of the vector that contains all elements that represent each observation.

Once all distances are calculated, they are normalized so that their sum is equal to 1. These normalized distances represent the weights that will be used for a weighted sum of the corresponding outputs (consumption reduction applied in each similar case), thus creating a novel amount of suggested consumption reduction.

3) Revise:

In order to adapt the amount of suggested consumption reduction achieved from the *Reuse* phase to the reality of the new case, this amount is revised, taking into account the actual consumption of the several devices of the house that are expected to be in use in the considered instant. All devices are ordered by their usage priority (assigned by SHIM), and the equipment with the least priority for the system are excluded, until the value of reduction from phase 2) is achieved. The device, in which this process stops, is then analysed.

If this device's consumption can be reduced, than the suggested reduction is kept the same, since this device's consumption can be adapted to meet the exact reduction amount. On the other hand, if the device can only assume states on or off, the reduction amount will be increased or decreased in order to meet the limit that is closer to the suggested reduction amount (i.e. if letting the device on represents a smaller change in the reduction amount, or if the smaller change is achieved by turning the device off). This revision of the reduction values enables adapting the outputs to the actual reality of the new case in the considered instant.

4) Retain:

Once the new case output is defined, it can be stored in the case-base, so that this new experience can be used as input for future cases. However, if the new case is too similar to an already existing one, then it will not bring added value by being stored, rather only bringing extra useless information to be processed. For this reason, the new case is only stored if there is no other case that has a similarity of more than 95%.

IV. CASE STUDY

This section describes the data considered to create the set of scenarios used to manage the energy of the different domestic consumers of the south of Brazil. The data considers the typical consumption and generation of Brazil. This case study allows obtaining results under the European project Electricity Consumption Analysis to Promote Energy Efficiency Considering Demand Response and Non-technical Losses (ELECON).

A. *Input data*

This sub-section describes the typical houses from the south of Brazil to be simulated in the SHIM system in the context of the house management tools. For the case study is considered three typical houses with different characteristics which depend of the user type and the consumption profiles changing with the context of the day. Also, a mini DG corresponding to a profile generation of a PV system from Brazil is considered.

The three types of houses were developed: the first house refers to a residence with two student rooms (for two persons); the second house is a middle-class residence with three bedrooms (for a family of four persons); and finally an upper-class house with four bedrooms (for a family of four persons and employees). The consumption data of household appliances were developed using [24]-[26].

The technical specification and used time is shown in Table 1. The consumption due to operation in the standby mode, with less than 1W, was not considering [27].

Table 1 – Description of the electrical appliances used.

Electrical Appliances	Power (W)	Minutes ON	Electrical Appliances	Power (W)	Minutes ON
Heat accumulator	1500	240	Washing machine	900	120
HVAC 1	1500	141	Dryer machine	2000	140
HVAC 2	1500	88	Dishwasher	1900	61
HVAC 3	1500	55	TV 1	138	244
HVAC 4	2500	143	TV 2	138	227
Vacuum cleaner	800	84	TV 3	138	87
Electric shower 1	3000	22	Internet modem	1	361
Electric shower 2	3000	29	Videogame	300	99
Electric shower 3	3000	22	Telephone	2	717
PC	350	317	Electric gate	350	40
Notebook 1	90	360	Pool motor	800	120
Notebook 2	90	360	Radio and clock	1	58
Extractor	300	120	Hair dryer	1000	38
Clothes iron	1200	64	Table fan	60	180
Oven	1500	60	Ceiling fan	90	180
Toaster	800	12	Light 1	120	393
Electric faucet	3000	83	Light 2	60	329
Microwave	1200	30	Light 3	100	389
Freezer	100	287	Light 4	60	66
Refrigerator	150	299	Light 5	60	355

* The detailed information about the used loads can be consulted in http://www.gecad.isep.ipp.pt/elecon/paper/input_data.pdf

A seasonal load exists when it is very difficult to forecast the use of specific load. In a residential consumer, these loads are hair dryers, toasters, blenders, among others. To the three consumers simulated, the loads least used were not considered and the most used (ex. hair dryer) were consider an average consumption for a daily consumption profile.

The PV generation data was acquired from the Smart Grid and Power Quality Laboratory, at the Polytechnic School - University of São Paulo (ENERQ/Brazil) and also used in [21]. The PV system is composed by ten photovoltaic panels each one with 200 Wp and it has the profile generation illustrated in Figure 3 for a summer and a winter day.

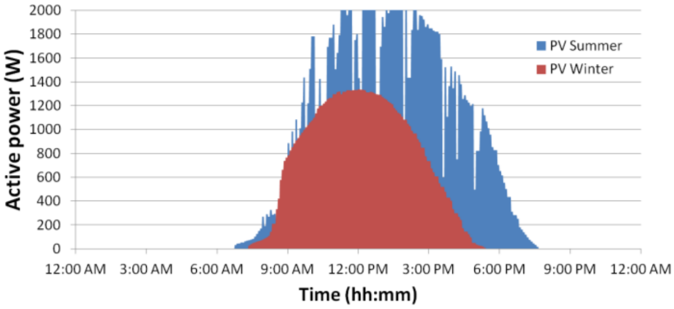

Figure 3 – Power generation for a PV system in a summer and winter day

B. *Scenarios description*

A set of 60 distinct scenarios have been simulated in this case study, considering different combinations regarding the three considered houses, the PV generation, the Brazilian tariffs, the season, and considered levels of allowed consumption reduction. The 60 considered scenarios are divided into 12 base scenarios, and 48 scenarios that consider intelligent management. The 12 base scenarios are described as follows:

- 6 base scenarios, regarding the two considered days (in winter and summer) of the three houses, without any generation or consumption reduction;
- 6 scenarios concerning the base scenarios plus PV generation (considering the winter or summer generation profile depending on the day).

The 48 scenarios with intelligent management refer to the combination between:

- 12 base scenarios (with and without generation);
- 2 energy tariffs - Standard and White, illustrated in Table 2;
- 2 potential consumption reduction limits, namely of 10% and 30%.

Table 2 – Brazilian tariff values.

Tariff	Off-peak (R$/kWh)	Intermediate (R$/kWh)	Peak (R$/kWh)
Standard		0.3448	
White	0.29033	0.40979	0.63011

This case study considers the application of the proposed intelligent method for energy management to the latter 48 scenarios. From these results a suggested amount of potential reduction of consumption for each instant of the considered day.

Additionally, considering this indicated target consumption, SHIM schedules the consumption of the different devices of each house. Both tariffs are also applied to the consumption profile of the 60 scenarios, in order to compare the potential monetary benefit of each scenario when using each tariff.

V. Results Analysis

The case study was tested on a computer compatible with 2 processors Intel® Xeon® W3565 3.20GHz, each one with 4 Cores, 6GB of RAM and the operating system Windows Server 2007 64bits. The optimization module of the SHIM system is implemented by a deterministic approach based on Mixed-Integer Non-Linear programming (MINLP) implemented on the *General Algebraic Modelling System (GAMS)* platform, interfaced with the computing tool MATLAB® R2009 64bits.

After executing the proposed intelligent energy management methodology, an amount of suggested consumption reduction is proposed for each of the 48 scenarios (all but the base ones), for each instant of the considered day. Figure 4 shows the average hourly consumption reduction allocated to each scenario (where 1, 2 and 3 refer to the 3 houses, and *s* and *w* refer to the season summer and winter, respectively).

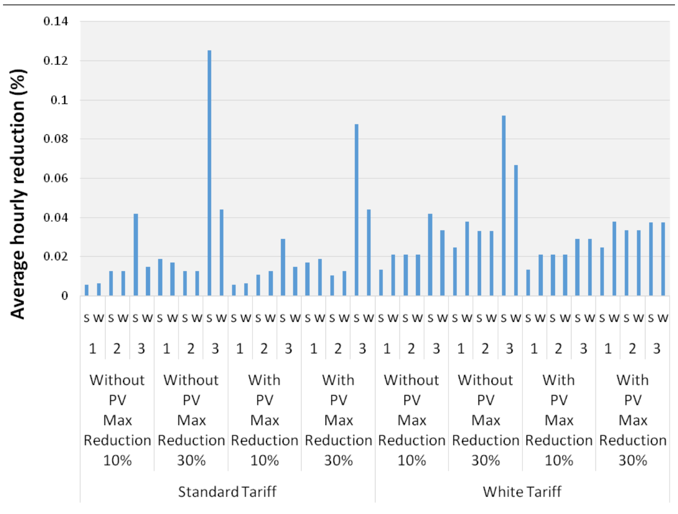

Figure 4 – Average hourly consumption reduction proposed for each scenario.

From Figure 4 it is visible that the proposed reduction is generally higher when using the white tariff. This is verified due to the high price that this tariff imposes during the hours of greater consumption. The need to reduce the energy bill thereby obligates to reduce the consumption during the peak hours of consumption. Figure 4 also shows that the house with the larger amount of allocated reduction is house 3.

Figure 5 shows the percentage amount of consumption reduction suggested in each simulation scenario for each hour. Since the figure includes 48 scenarios is improper to present the legend of all cases.

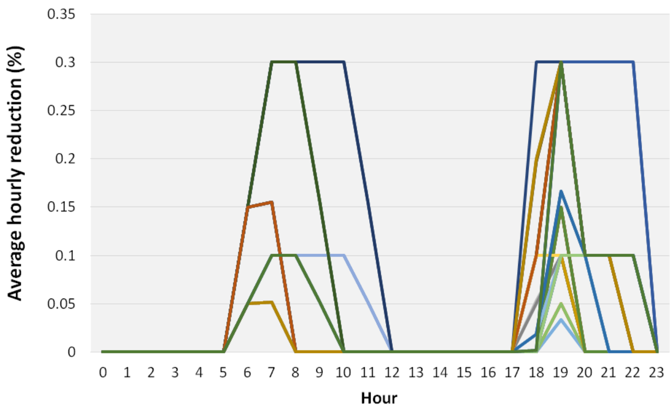

Figure 5 – Average consumption reduction proposed for each scenario for each hour.

Taking into account the results presented in Figure 5, it is important analyze that the generally of the simulated scenarios tend to allocate the larger amount of reduction to the peak hours of consumption, especially between hours 18 and 22, and also some reduction is allocated to hours 7 to 10. This amount of suggested reduction thereby coincides with the times of the day when the consumption assumes larger values, especially in the peak hour of consumption in late-afternoon and evening, in which the prices are much higher with the Brazilian white tariff.

A summary of the monetary expenses (in R$) in the total of the considered day, regarding all scenarios, considering both tariffs, is presented in Table 3.

Table 3 – Energy cost (in R$) in the total of the considered day, for all considered scenarios, using each of the two tariffs.

DG	House	Season	Maximum Reduction					
			Standard Tariff			White Tariff		
			Base	10%	30%	Base	10%	30%
No PV	1	S	3.106	3.013	2.809	3.753	3.520	3.291
		W	5.648	5.456	5.188	6.620	6.175	5.655
	2	S	6.570	6.317	6.317	7.635	7.165	7.634
		W	8.433	8.083	8.083	9.892	9.270	8.598
	3	S	14.492	13.439	11.331	16.300	15.017	13.599
		W	13.558	13.073	12.103	15.015	13.976	12.799
PV	1	S	-1.815	-1.907	-2.091	-0.649	-0.875	-1.101
		W	2.878	2.686	2.301	4.287	3.842	3.322
	2	S	1.649	1.431	1.430	3.232	2.791	2.296
		W	5.663	5.313	5.313	7.558	6.936	6.264
	3	S	9.571	8.823	7.328	11.898	10.993	10.399
		W	10.788	10.332	9.420	12.682	11.843	11.324

From Table 3 it is possible to extract several relevant conclusions. Probably the most important is to verify that, in all scenarios, the energy bill using the white tariff is higher than using the standard bill. This means that, in spite of helping to smooth the consumption diagram throughout the day, and lower the peak consumption hours, thereby bringing clear advantages to the system, the white tariff does not reflect into monetary gains for the consumer.

In fact, in most cases, even when applying a consumption reduction of up to 30% in some periods of the day, when using the white tariff, the cost in the end of the day is still superior to the cost without any reduction when using the standard tariff. Other, more obvious conclusions that can be taken are that the energy bill during the winter is more than in the summer, for all scenarios; and that the cost using PV is, evidently, inferior to scenarios where there is no installed generation. In fact, the scenario of House 1 in the summer, with PV, results in a global profit in the end of the day, due to the large amount of PV generation, which exceeds the consumption in several hours of the day, as can be seen by the negative values of cost, i.e. income.

Taking one particular scenario as illustrative example of the intelligent management made by SHIM, Figure 6 presents the comparison between the total expected consumption per minute, and the consumption for a suggested reduction of up to 30%, for the scenario considering House 3, in the winter day, without PV, using the white tariff.

From Figure 6 it is visible that the main suggested reductions for this scenario are located during the peak periods of consumption, namely during the morning period and during the late afternoon hours. The results of the loads scheduling in SHIM system are presented in these periods: morning period between 6:00 and 10:00 hours; late afternoon hours between 18:00 and 22:00 hours.

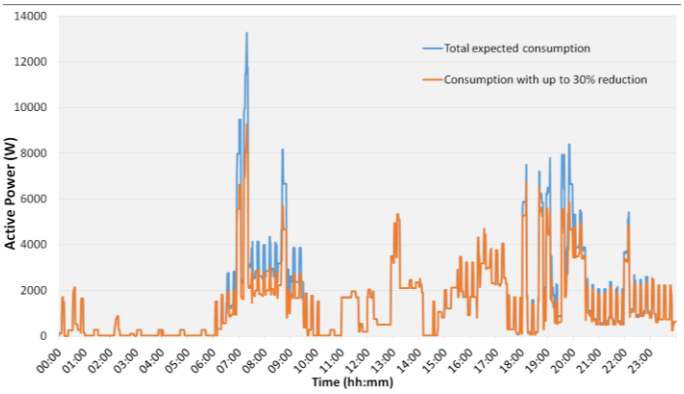

Figure 6 – Total expected consumption for each minute, and consumption with a suggested reduction of up to 30%, for the scenario considering House 3, in the winter day, without PV, using the white tariff.

In Figure 7 the desegregated consumption of the electric appliances of the House 3 is presented between two peak periods mentioned above. These scheduling results consider the reduction presented in Figure 6. The results show that SHIM system keeps the suggested power reduction. The loads with lower priority are turned off and the priority value of some of them is changed to allow a dynamic energy management between different types of loads (electric appliances).

To better specify these dynamic results between the loads, Figure 8 illustrates some loads results for the last period of the day, comparing the priority value with the power consumption for each load.

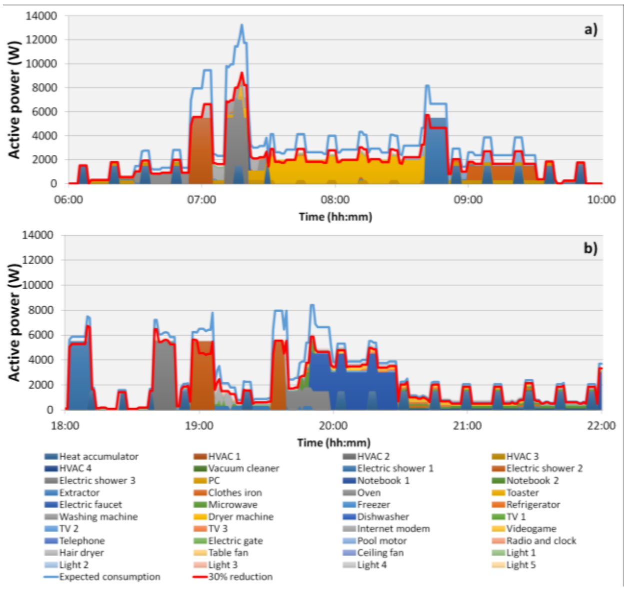

Figure 7 – Loads scheduling results in House 3 for winter scenario: a) between 6h-10h; b) between 18h-22h.

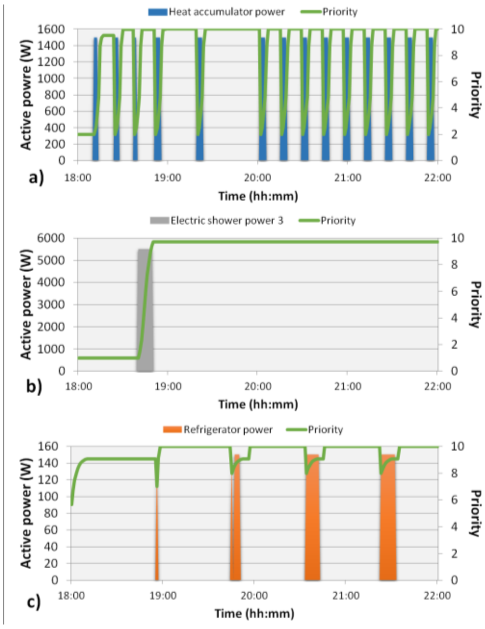

Figure 8 – Results of the loads priorities in House 3 for winter scenario for heat accumulator (a), electric shower (b) and refrigerator (c).

The analysis of the three loads in House 3 is as follows:

- Heat accumulator: presented in Figure 8 a), the priority is between 2 and 10. When the priority is 2, the load is turned on and when the priority is 10, the load is turned off. The heat accumulator is used for small periods, but between 19:00 and 20:00 it was used only one time;
- Electric shower 3: presented in Figure 8 b), the priority is between 1 and 10. When the user takes a shower, the priority value increases from 1 to 10, which corresponds to the end of the shower. This value is kept because the user does not take a shower again;
- Refrigerator: presented in Figure 8 c), the priority is between 6 and 10 with some changes over the time.

The refrigerator is turned on four times, being the first time only for one or two minutes. In the other three times, the refrigerator is on during 5 more minutes and the priority changes between 8 (turn on), 9 (turn off) and 10 (keeping turned off).

One of the main conclusions for Brazil context is the capability to allow the use of electric shower. However, to use the electric shower it is needed to turn off or reduce power in some other loads to keep the power reduction. The user maintains its comfort because some loads like heat accumulators, HVACs or pool motor can be turned off by 10 minutes, which corresponds to the use time of the electric shower, without much influence. It means that the loads with higher nominal power can be divided over the time instead of being used simultaneously. In other words, when a power limit occurs, this type of load should be used at different times, e.g., as presented in Figure 8, when the electric shower is turned on, at 18:40, the heat accumulator is turned off. The heat accumulator can be turned on again after the electric shower is turned off at 18:49; which really occurs at 18:52.

VI. CONCLUSIONS

This paper proposed a CBR approach to enable the intelligent management of energy resources in a residential context. The actual energy resources management is executed using SHIM. A case study using data from Brazilian consumers has been presented with relevant conclusions. The use of the CBR approach brings significant reductions of the energy bill, by choosing the right moments to reduce some consumption, especially when considering tariffs with variable prices throughout the day. These tariffs, e.g. the considered white tariff, tend to result in higher energy bills, even when applying significant reductions of consumption during the most expensive hours. The particular context of Brazil enables reaching interesting results, for instance by dealing with the specific characteristics of the widely used electrical shower.

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