Demand Side Management of Electricity Aiming to Minimize Cost of Residential Consumers

Rubipiara Cavalcante Fernandes, Ricardo de Avila Geisler, Daniel Tenfen, Samuel Luna Abreu, Fabricio Y. K. Takigawa, and Edison A. C. Aranha Neto

***Abstract*—The main objective of this study is to analyze the photovoltaic generation of electric energy by the consumer and to show possible energy management of his consumption. Different kinds of tariffs depending on the hour of use and system capacity are analyzed. In addition, it is intended to show the benefits of the renewable energy of micro photovoltaic plants in residences, combined with practices of a better energy use through equipment/materials more intelligent/efficient, in other words, the possibility of a demand side management. In this way, initially it was listed the chances to promote the energy-efficiency by the analyses of the technology availability and a more efficient use of equipment. This study aims the development of residential projects that contemplate energetic optimization since its creation and enable the consumer to manage his consumption according with his priority in energy use. It is also taken into consideration the possibility to attend part of the consume using photovoltaic solar generation and the different values of energy tariff. For this, it was conducted a comparative study that verified the photovoltaic solar microgeneration technical-economic viability in residential dwellings considering the option of "Time-of-use Tariffs", that can provide to the residential consumer a better management on the use of electric energy and implies changes in consumption habits.**

***Index Terms*—Microgeneration, conventional tariff, time-of-use tariff.**

I. Introduction

Better energy use and alternatives that reduce its usage are extremely important. The energy consumption grows worldwide, as well as the environment and sustainability concerns, so combine new technologies, change habits, and techniques that enable a more efficient use of energy are current needs.

In 2006, the International Energy Agency (IEA), on the World Energy Outlook 2006 (WEA), released an estimative of the World's energy consumption. They proposed two world scenarios, one as a reference, where efficiency policies already proposed are not considered but only that already in use. In a second scenario, it was considered the policies, actions and new technologies of efficiency expected to be implemented until 2030. As result, the estimative showed that the demand of the reference scenario in 2030 would be 12% bigger than the other scenario, which represents a 3421 TWh difference [1].

One of the challenges to the adoption of initiatives that promote energy efficiency is its costs. Conventional technologies are cheaper and easy to access. Awareness in relation to the change of habits and the idea of the return of investment could be of a hard understanding inside society.

The adoption of efficient practices is possible in all sectors of the electric system, but the current work has its focus on the residential sector, where the consumer, through possible habit changes affects the system and contributes for its efficiency (demand side management). Different actions, as new appliances and changing habits can promote a residential efficiency, with benefits for both the consumer and the electric system in general.

In residences, appliances can represent a great change on energy consumption, through the use of more efficient technologies. Within the possible changes, the highlights are: illumination, air conditioning, electric shower, refrigeration, computers, and stand-by lights (present in many devices). However, incentives and more information are necessary to promote these changes and raise awareness about the financial benefits.

Besides the consumption reduction through more efficient technologies, to control the time of use is also interesting, taking into account the peak-load present in Brazilian load curve as an example. Having a mostly hydraulic generation, the use of thermal sources, more expensive and pollutant, is only made during the peak hours, from 6 PM to 9 PM. During this time period, people arrive at home from work; and public and commercial illuminations are turned on simultaneously. Therefore, reducing residential consumption during this time, could avoid the use of thermal sources. Measures that stimulate this reduction have been already taken, and there are some more that will be taken in the future.

With the advance of technology and the reduction of costs of the new sources of energy, as an example, the energy generated from photovoltaic solar panels, today is possible to generate electric energy from small generator units with low installed power. In the world, the use of generator units in residences is normal and is being established gradually. The Distributed Generation has become an option for countries that are in need of resources for generating energy. In Brazil,

Manuscript received March 19, 2015; revised September 9, 2015. This work was supported in part by the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under project ELECON - Electricity Consumption Analysis to Promote Energy Efficiency Considering Demand Response and Non-technical Losses, REA grant agreement No 318912.

Rubipiara Cavalcante Fernandes, Ricardo de Avila Geisler, Fabricio Y. K. Takigawa, and Edison A. C. Aranha Neto are with the Federal Institute of Santa Catarina, IFSC, DAE / Centro, Florianopolis, SC, Brazil, CEP 88020-300 (fax: +55 48 3221.0570; e-mail: {piara, takigawa, earanha}@ifsc.edu.br, ricgeisler@hotmail.com).

Daniel Tenfen is with the Federal University of Santa Catarina, UFSC; Florianopolis, 88040-900, Brazil (e-mail: tenfendaniel@gmail.com).

Samuel Luna Abreu is with the Federal Institute of Santa Catarina, IFSC, São José, 88103-310, Brazil (e-mail: abreu@ifsc.edu.br).

doi: 10.18178/jocet.2016.4.5.305

this model of generation of energy is still in its initial stage, being introduced as a way of cutting costs for the residential consumption and for a better security of energy supply.

During the last years, it has been searched more and more the use of distributed generation, reducing the costs of transport from the source to the load. Also new proposes of energy tariffs with the objective of finding the better use of energy from a consumer point of view are being discussed.

The search for this alternatives are found in the Normative Resolution n °482, 17/04/2012 [2] and in the Technical Note n °311/2011 [3] that establish the rules for use of distributed micro and minigeneration for the electric energy distribution systems and the proposal of tariffs with different prices for low voltage consumers according the period of use, based on the load of the system (time-of-use tariff).

In this context, this paper has the goal of analyze the payback for a consumer supplied in low voltage, using a new tariff for the residential consumer established by ANEEL (Brazilian Electricity Regulatory Agency) together with photovoltaic solar energy microgeneration for residential consumer units.

II. Methodology

In the current paper, it was taken as reference the current Brazilian regulatory framework referent to microgeneration and tariffs types. Measured data provided by the company SMA Solar Technology [4] is used to simulate the performance of the solar generator. These data was collected by the Federal University of Santa Catarina – UFSC in a solar generator unit with installed capacity of 2 kWp during a ten years period. Details can be obtained in [5].

In the beginning, it was made a wide literature review concerning the rules, resolutions, decrees, laws, and other documents related to: Time-Of-Use Tariff (called “Tarifa Branca” in Brazil); Microgeneration; Regulatory policies; and other important themes for the understanding of everything that covers the addressed issue. Then, a collection of data referent to: a) load curves of residential consumers class B1; b) costs of energy generation from the photovoltaic panel; c) tariff values applied by CELESC (utility of Santa Catarina State) according to Aneel Homologatory Resolution n °1322 of 31/07/2012; and d) to the technical and economic values related to the installation of a microgeneration systems. All these information were used together with a mathematical model to estimate some economic figures and an analysis of the results was made.

III. Case Study

A. Residential Consumption Demand

Based on the information given in [6] a graphic of load curves of two typical energy consumers in the range of 300 to 500 kWh per month (range of the time-of-use tariff) were plotted (See Table I and Fig. 1).

B. Energy Tariff for Residential Consumer

After obtaining the load curves, it was necessary to find data about the energy tariff for the B1 Group (Residential Consumer). For this objective, were used data from CELESC - Distributor of Santa Catarina, Brazil [7].

TABLE I: Demand Data for Two Typical Consumers

Hora	Consumo (kWh)					
	Consumidor 1			Consumidor 2		
	Dia Útil	Sábado	Domingo	Dia Útil	Sábado	Domingo
1	0.42	0.35	0.4	0.42	0.42	0.37
2	0.4	0.33	0.37	0.4	0.45	0.31
3	0.33	0.3	0.37	0.38	0.41	0.32
4	0.28	0.3	0.3	0.39	0.41	0.33
5	0.33	0.29	0.35	0.4	0.39	0.33
6	0.38	0.29	0.36	0.4	0.39	0.33
7	0.45	0.31	0.37	0.41	0.33	0.25
8	0.49	0.4	0.33	0.64	0.55	0.29
9	0.4	0.55	0.36	0.85	0.62	0.36
10	0.45	0.42	0.4	0.88	0.68	0.35
11	0.44	0.45	0.42	0.9	0.66	0.35
12	0.47	0.38	0.42	0.72	0.55	0.35
13	0.45	0.41	0.4	0.78	0.51	0.32
14	0.47	0.5	0.41	0.85	0.5	0.32
15	0.49	0.51	0.42	0.85	0.49	0.33
16	0.49	0.52	0.4	0.84	0.48	0.34
17	0.48	0.6	0.42	0.82	0.42	0.34
18	1.1	1	0.55	0.6	0.38	0.28
19	1.17	1.02	1	0.42	0.35	0.29
20	0.9	1.02	0.95	0.42	0.37	0.31
21	1.55	1.18	1.18	0.4	0.38	0.32
22	0.85	0.75	0.8	0.48	0.39	0.33
23	0.6	0.65	0.6	0.5	0.39	0.31
24	0.45	0.55	0.42	0.48	0.37	0.29

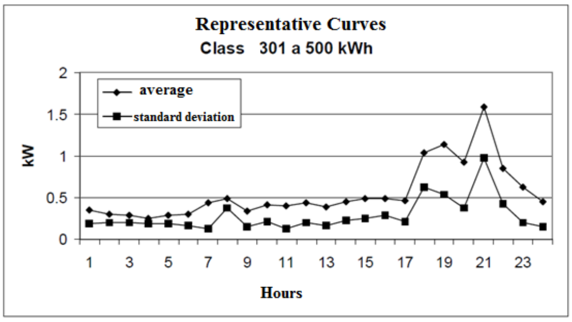

Fig. 1. Typical load curve of the residential consumers in workdays. Source: [6].

C. Microgeneration System

As a source of microgeneration, it was used as reference data from a photovoltaic system with capacity of 2 kWp, installed at UFSC. This was the first system in Brazil connected to the public electric grid, with 68 photovoltaic amorphous silicon modules, being 55 opaque modules (32 Wp) and 13 semi-transparent modules (27 Wp) [5].

The values used are averages obtained from SMA SOLARES TECHNOLOGY AG (2014) available in their website. Fig. 2 shows the average generation of photovoltaic energy of the 2 kWp module. It is necessary to highlight that the output of this system was used as a reference for the present study, and the values can be different considering the particularities of each residence. The goal here is to promote a base of evaluation of the payback of a working system in low voltage with conventional tariff and time-of-use tariff.

IV. Results

A. Graphic Analysis

It is possible to notice, as showed in Fig. 2 and Fig. 3, that the photovoltaic generation has its larger scale production during 9 AM and 3 PM. It is important to emphasize that these data are an average of generation of the modules during 2012/2013, therefore, the peak of generation in some periods of the year are bigger than the showed in this study, and can be equal or higher to the maximum production of 2 kWp or to the energy demand peak.

Fig. 2 and Fig. 3 present the energy demand of consumer 1 and consumer 2 respectively, together with the average photovoltaic generation for 2 kWp system.

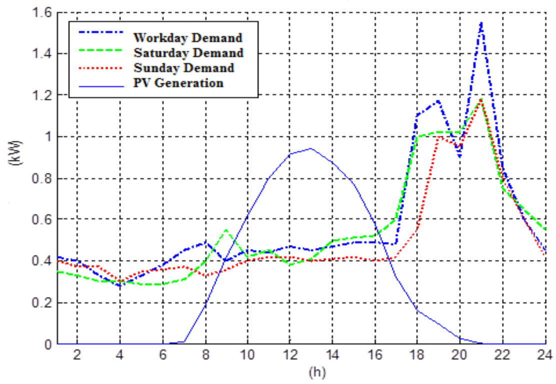

Fig. 2. Demand of Consumer 1 and photovoltaic generation.

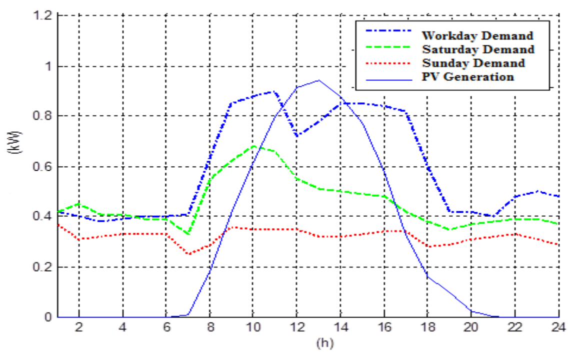

Fig. 3. Demand of Consumer 2 and photovoltaic generation.

Doing the balance between demand and generation for both consumers, the net energy imported from or exported to the grid is given in Fig. 4 and Fig. 5.

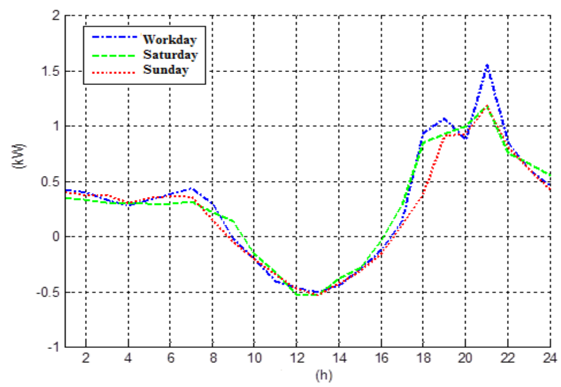

Fig. 4. Difference between demand and photovoltaic generation for Consumer 1.

It can be noticed that for these two cases the peak exported power to the distribution system is not greater than the peak imported because an average value of production and consumption of solar energy was used. However, as module solar power generation is 2 kWp there will be times when the energy delivered to the grid will be close to this value. If the distribution system is not dimensioned to receive this value, an increase in system capacity will be needed.

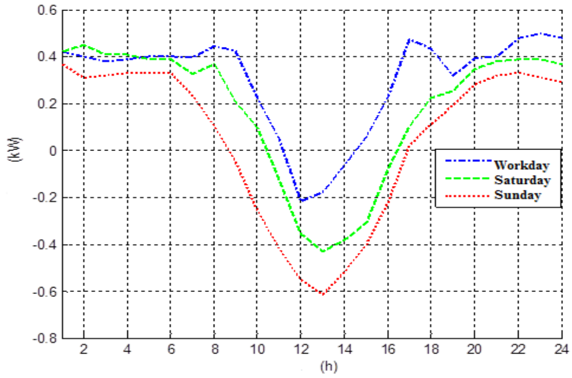

Fig. 5. Difference between demand and photovoltaic generation for Consumer 2.

B. *Costs of PV Generation System*

Considering that the total costs of installing a 2kWp system, using as reference value of 5 euro/Wp, costs decrease of 5% per year, and interest rate of 8% per year, it results in value of euro €7500.00. Adding the maintenance, it results in €8300.00.

With consumption demand and generation established, the evaluation impact resulting in the price of energy in that month using or not solar energy was estimated. Table II presents the result for consumers 1 and 2, with and without photovoltaic generation for both conventional and time-of-use tariffs.

TABLE II: MONTHLY TARIFF — SIMULATION

	Monthly electricity bill (€)	
	with photovoltaics	**without photovoltaics**
Consumer 1 - Conventional Tariff	21.11	43.22
Consumer 1 – time-of-use Tariff	28.46	48.34
Consumer 2 - Conventional Tariff	19.14	41.15
Consumer 2 – time-of-use Tariff	20.23	40.11

The net-metering model (compensation energy system) used in Brazil, is a mechanism in which the energy is absorbed or transported to the grid instantly. The energy peak of the residential consumer 1 is within 6 PM and 9 PM, and it is in these hours that the time-of-use tariff has its higher price. Once the photovoltaic generation has its peak during the afternoon, the price paid by the time-of-use tariff is the lowest possible, it is more profitable the use of conventional tariff for both consumers when they have a photovoltaic system. An alternative would be the change of habits related to energy use, so the reduction on the energy bill with time-of-use tariff would be higher in comparison to conventional tariff. This observation also leads to the need of a more intelligent control of generation/consumption and a more detailed analysis of the consumption since depending on the consumption habits different alternatives for a demand side management can be implemented.

V. CONCLUSIONS

The objective of this work was to do some considerations about the way that a consumer could manage his energetic consumption, with a potential application of intelligent/efficient equipment together with the possibility of photovoltaic microgeneration considering the actual tariff policies

The usage of photovoltaic generators in combination with a good system design can bring good economic results, but with these new tariff policies this time could be drastically reduced, making this technology economically feasible. With the time-of-use tariff and the possibility of "selling" energy in watts, it is possible to export energy to the system during the day, and getting it back during the night, with price adjustment already made, but still bringing economy.

However, it was possible to check that the investment in the installation of a photovoltaic microgeneration system is not attractive yet with the actual costs and regulation, because the payback time was calculated in more than 30 years, and that the life cycle of the panels is around 25 years.

The distributed generation is an important alternative for cleaner energy production. It also could assure a stronger and with lower risks of interruption and faults energy production, promoting a robust system in all senses. Therefore, the incentives for the scope of microgeneration through regulatory policies or new tariffs, as the time-of-use tariff, should remain to promote a more correct and sustainable energy use by the consumers.

Following the conclusion of this work, it is suggested that a deeper analysis to check what would be the change on the bill if the consumer choose to change his consumption profile using energy out of the peak time.

ACKNOWLEDGMENT

The authors acknowledge financial support from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under project ELECON - Electricity Consumption Analysis to Promote Energy Efficiency Considering Demand Response and Non-technical Losses, REA grant agreement No 318912.

REFERENCES

[1] C. W. Gellings, *The Smart Grid: Enabling Energy Efficiency and Demand Response*, The Fairmont Press Inc., Lilburn, USA, 2009.

[2] Aneel — Brazilian Electricity Regulatory Agency. (April 2012). Normative Resolution n º 482. [Online]. Available: http://www.aneel.gov.br/cedoc/bren2012482.pdf

[3] Aneel — Brazilian Electricity Regulatory Agency. (November 2011). Technical Note n º 311/2011-SRE-SRD/ANEEL, Brasília. [Online]. Available: http://www.aneel.gov.br/cedoc/nren2011464.pdf

[4] SMA Solar Technology AG. Fotovoltaica — UFSC-2kW. [Online]. Available: http://www.sunnyportal.com/Templates/PublicPageOverview.aspx?page=7d255403-457d-4472-9438-7d7b59bbc1e7&plant=9e74494f-8850-4508-a49a-3e10dc6e3d96&splang=pt-pt

[5] L. R. Nascimento, "Long-term evaluation of a building integrated grid-connected photovoltaic system (in Portuguese)," Master thesis, UFSC, Brazil, 2014.

[6] A. A. Francisquini, "Estimation of consumers and distribution transformers load curves (in Portuguese)," Master thesis, UNESP- Ilha Solteira, 2006.

[7] Aneel — Brazilian Electricity Regulatory Agency. Homologatory Resolution n º 1322. [Online]. Available: http://www.aneel.gov.br/cedoc/reh20121322.pdf

Rubipiara Cavalcante Fernandes received the graduate Eng., master Eng. and Ph.D. Eng degrees in electrical engineering from Federal University of Santa Catarina, UFSC, Florianopolis, SC, Brazil, in 1985, 1995 and 2006, respectively. Since 1991 he has been developing his teaching/research activities at Federal Institute of Santa Catarina, IFSC, Florianopolis, Brazil. He has been working with the Brazilian Electric Energy Sector restructuring process and his main fields of interest are power market simulation and regulation, power system planning, power system optimization and mini and microgeneration.