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AN OVERVIEW OF THE HOME ENERGY MANAGEMENT SYSTEM

BY

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Abstract. This paper focuses on modelling of the flexible loads of a residential area, based on a classification of eligible appliances. Thus, in order to use the photovoltaic energy with a higher efficiency, the methods of traditional load management are involved in residential sector in order to ensure an optimal balance between demanded load and photovoltaic generated power. The concept of Home Energy Management System is an action taken by the consumer and it is part of the concept for Demand Load Management. The most important thing in implementation of this algorithm is to perform a classification of the electrical appliances. Using the Matlab simulation, in this paper has been generated a consumption load profile based on a list of appliances specific to residential area. Based on generated load profile, in the paper has been extracted in several graphs, the power of the equipment that supports and does not support changes in the operating program. Previously, a classification of these appliances has been conducted, the most important aspect taken into account in their classification being the minimum impact on the user's comfort.

Keywords: home energy management system (HEMS); photovoltaic sources; load management; demand side management; demand response.

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1. Introduction

The most used sources with a high energy potential are photovoltaic sources, main objective of using them is to maximize the consumption percentage of the energy produced. To achieve this goal, we have a number of traditional methods of managing the load in the residential sector, used to ensure a balance between the required load and the power generated by the photovoltaic system. The idea referred to in this paper, namely Home Energy Management System is used by the household consumer and is part of the concept Demand Load Management, concept that refers to the process of balancing the power supplied by the grid with the electrical load, by adjusting or controlling the electrical load (Mohammad Shakeria, 2017).

With this concept of HEMS, this paper improves the self-consumption and self-sufficiency indices of residential prosumers. In order to increase the self-consumption indices, HEMS has been proposed to be integrated into low-voltage utility grid in order to manage the deficit and excess of power from photovoltaic panels. In the utility grids, without a HEMS, the profile of the demanded load curve does not fully match with the profile of the power curve generated by the photovoltaic panels. If the consumption is higher than the generated power by the photovoltaic system, the deficit of power and energy will be drawn from the electrical grid, whilst in the case of local consumption lower than the photovoltaic output power, the excess of power and energy will be injected into the electrical grid.

This paper focuses to model the flexible loads of a residential consumer, based on a classification of eligible appliances and to use the flexible loads for balancing the generated power curve. The most important thing in implementation of this algorithm is to perform a classification of the electrical appliances in order to minimally affect the user's comfort.

2. Home Energy Management System

Home Energy Management System (HEMS) is a concept developed for monitoring and managing the energy requirements of the electrical appliances of residential consumers and is considered the most popular technique for Demand Side Management in residential sector (Boynuegri, 2013). Demand Side Management is a method for planning and monitoring the customer use of electricity. This method typically encourages the use of limitation energy during peak periods or moving them to intervals where there has greater availability (Gelazanskas, 2014).

HEMS methods are important solutions to save the electricity bills, reduction of peak demand and meeting the demand side requirements. This system can be called efficient when it provide load shifting and shedding ability when is needed with a minimally effect on the user's comfort (Pipattanasomporn, 2012).

The Fig. 1 presents the specific methods of the Demand Side Management concept. With these six objectives this concept can be summarised in two major directions, the first one is Load Management and second one is Energy Efficiency.

For the Load Management direction, the main methods are the peak clipping, valley filling and load shifting. Energy efficiency implies a reduction in the overall use of energy and is sometimes referred as a conserving energy method (Ţigănaşu, 2019).

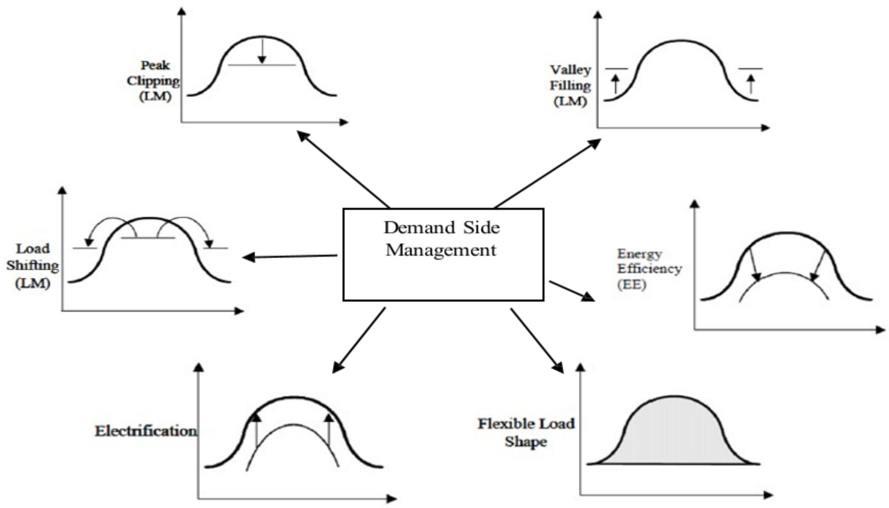

Fig. 1 – Demand Side Management load objectives (Gelazanskas, 2014).

One of the main advantages of using DSM is the reduction of the peak consumption, which leads to the reduction of the investments in additional energy capacities on the system (Singh, 2015).

The HEMS algorithm is also part of Demand Response (DR) method, is an important way to save energy cost. The DR assumes a lowering power consumption during the peak periods and move in a period when is a greater availability of power. The DR programs have some specific characteristics presented in Table 1.

Direct load involves a series of procedures that allow controlling the load, to remotely turn on or off in case it is necessary (Gelazanskas, 2014).

Interruptible load implies an agreement between the grid operator and the customer, that for a lower price, the operator can change the load curve in accordance with needs of the grid operator.

Table 1
Specific Characteristic of Demand Response Program

<table>
<tr><td rowspan="6">Demand Response</td><td rowspan="2">Technical control</td><td>Direct load control</td></tr>
<tr><td>Interruptible Load</td></tr>
<tr><td rowspan="4">Economical control</td><td>Critical Peak Pricing</td></tr>
<tr><td>Time of use tariff</td></tr>
<tr><td>Real time pricing</td></tr>
<tr><td>Extreme day pricing</td></tr>
</table>

The critical peak tariff assumes to be a three or five times higher than usual, and it is present for a few days in a year. Time of use tariff involves supplier involvement, there is a price set for a peak period and off-peak period. One of the first advantages of this type of tariffs is their stability. Real time pricing represents these tariffs that are announced with a day ahead, or at least a few hours before. Extreme day pricing it is a category that includes a tariff for that the customer gets a price discount for load reduction in a critical period (Singh, 2015).

3. Classification of the Residential Appliances

In the residential sector exists a multitude of electrical appliances that can be classified based on a multitude of criteria (Ayan, 2018).

Before implementing a HEMS algorithm, most important thing is to set a priority of loads that have not affect the user comfort. Thus, a series of appliances can be classified as shiftable or non-shiftable, which means that those may accept or not a delay in their operation, as is depicted in Fig. 2. In the HEMS program the essential appliances are flexible ones or those shiftable. The non-shiftable appliances refer to those that cannot be shifted or interrupted in the functional program.

In other studies (Ayan, 2018), the appliances that are classified as shiftable or non-shiftable are defined as flexible and non-flexible loads. In (Costanzo, 2012), this classification can be found in the terms of Brust load and Regular load. Brust load refers to those appliances that have an effective operating interval, with the start and stop moments and cannot be stopped from operating once they are started. Thus, these appliances can be switched on different time interval where there is higher energy availability and the load curve is flattened.

Regular load can be defined by those appliances that are in continuous operation for a longer period of time, their functioning being intermittent. Their operation can only be interrupted for certain periods of time, so that the comfort of the user is not influenced by these actions.

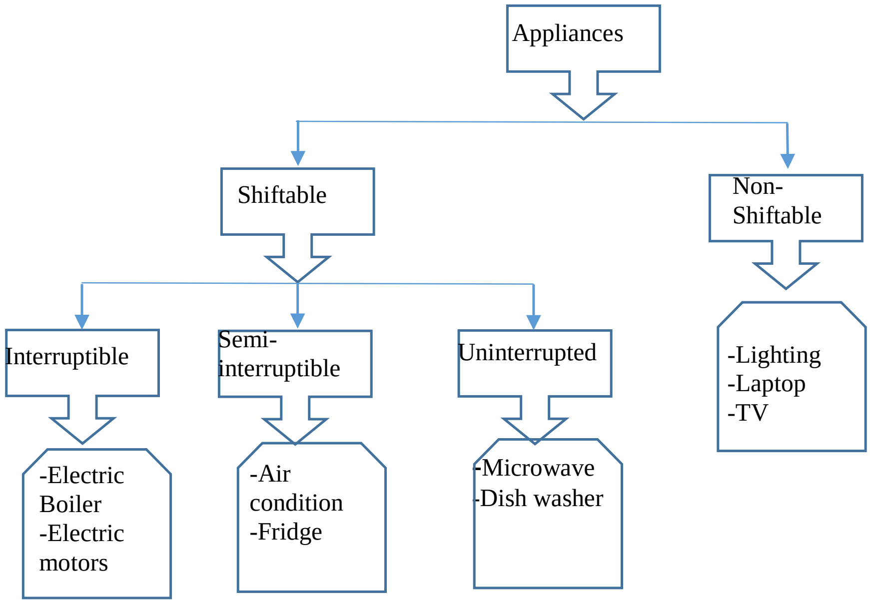

Fig. 2 – Classification of residential appliances (Huang, 2015).

Another important element that can characterize the load curve of a residential consumer is the operating time of each consumer. By this feature, the consumption curve can be modified, depending on the availability of energy in the electrical grid. Taking into account an appliances prioritization, the power exchanged with the electrical grid can be reduced to a minimum value.

4. Implementation of the Home Energy Management System

Considering the ability of some appliances to change their operating range in other periods of time, it is necessary to realize a clear prioritization of them (Pipattanasomporn, 2012).

Based on operating regime of each appliance, present to a residential customer, in Table 2 are summarised the operating times for these appliances. Using the Matlab program, a simulation of operating program with the appliances described in Table 2 has been created. The appliances have been classified having in view the operating regimes.

Within a 24-hour operating range, the consumption of a number of 12 appliances of a residential user has been generated in accordance with the operating period. Thus, based on these operating regimes, the consumption curve specific to this consumer has been generated and presented in Fig. 3.

Table 2
Appliances and Power Consumption Base on Fig. 2

Type of function	Appliance	Power [W]	Operating period	Chart name of appliances
Non shiftable	TV	100	7 AM -10 AM; 16 PM -22 PM;	Apps1
	Lighting	200	7 AM - 8 AM; 19 PM – 23 PM;	Apps2
	PC	500	17 PM- 22 PM;	Apps3
Interruptible	Electrical boiler	2000	6 AM – 7 AM; 21 PM – 22 PM;	Apps4
	Electrical motors	2500	13 PM – 15 PM;	Apps5
	Submersible pump	2000	9 AM – 10 AM; 18 PM – 19 PM;	Apps6
Semi-interruptible	Air condition	1100	11 AM – 16 PM;	Apps7
	Fridge	500	1 AM -24 PM;	Apps8
	Fan	200	11 AM – 16 PM;	Apps9
Uninterrupted	Dish washer	1500	10 AM; 16 PM; 20 PM;	Apps10
	Microwave oven	2000	7 AM; 12 PM; 20 PM;	Apps11
	Electric hood	1000	10 AM – 11 AM; 20 PM – 21 PM;	Apps12

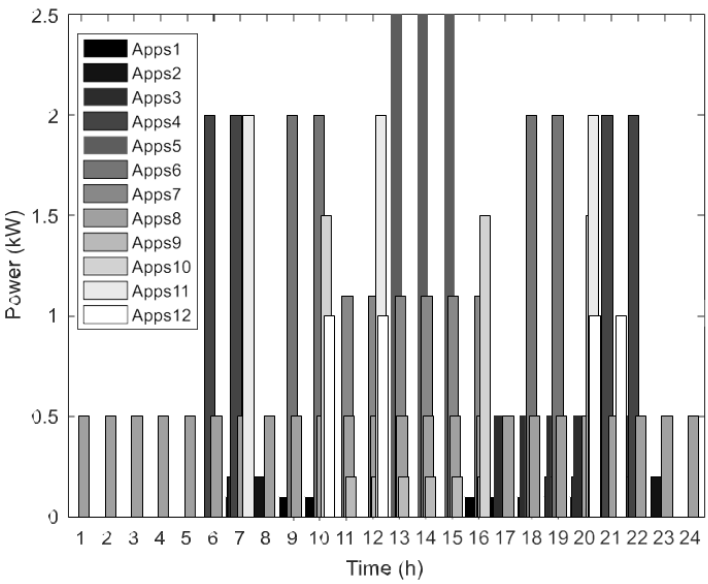

Fig. 3 – Power consumption scheduled.

In Fig. 4 is presented the cumulated power of appliances sampled over the 24 hours period. This figure represents the specific consumption curve, which can be used in the method of Home Energy Management System.

As can be seen in Fig. 4, the peak of consumption power has two maximal values, reached in the morning and evening hours. Thus, in the morning hours, the maximum power, around 5 kW, is reached at 10 o'clock and in the evening hours, the maximum value, around 6 kW, is reached at 21 o'clock respectively. It can be seen that in the morning and evening times, generated power from photovoltaic system cannot cover the required power of the consumer.

The system can be customized according to the behaviour of the consumer, so that the operating intervals which are not covered by the photovoltaic power are moved during periods of time when have a higher availability of energy.

The classification of the equipment's that are presented in Table 2 can be addressed as being in two categories of devices, namely the interruptible and the non-interruptible. The operation time of the first category is not conditioned by anything so changes can be made in the operating mode while the second category is conditioned, so it does not support changes.

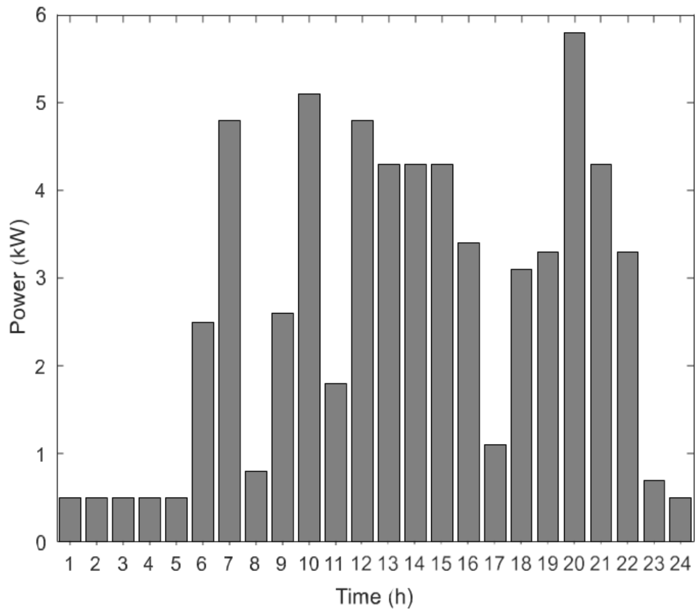

Fig. 4 – Cumulated power of appliances.

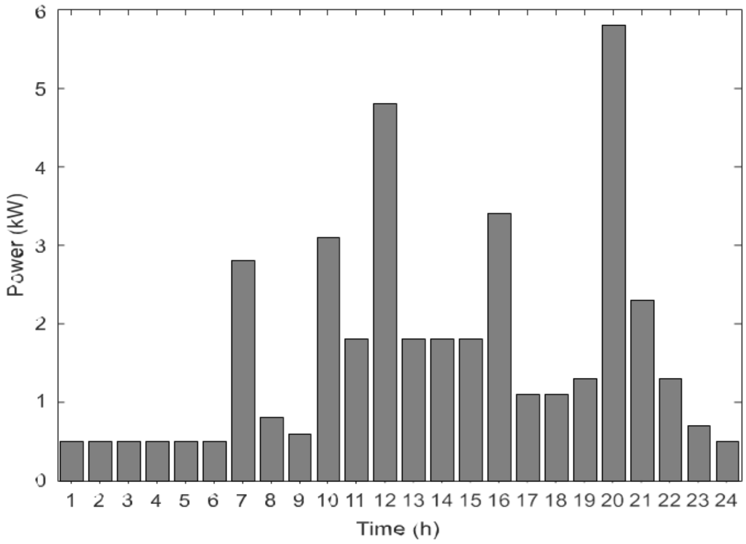

Fig. 5 – Hourly power consumption for non-shiftable appliances.

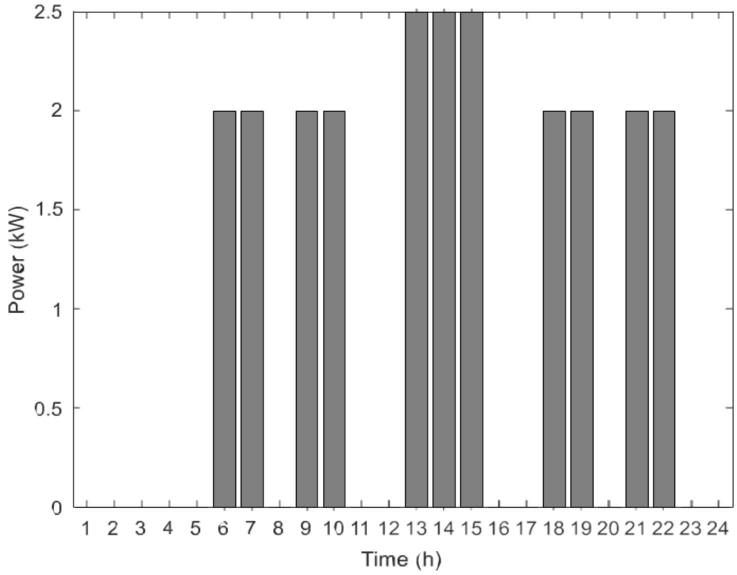

Fig. 6 – Hourly power consumption for shiftable appliances.

In Fig. 5 it is presented a graph in which are sampled for a period of 24 hours all appliances that cannot be changed during the operating period. With this diagram it can generate the consumption curve specific to these appliances.

In Fig. 6 are represented all the consumers that belong to the category of the changeable ones, those can be changed during the operating program, thus, with this appliances a Home Energy Management Program can be be applied.

In order for this management program to have a higher efficiency, is necessary a larger number of appliances with the availability to be moved in other intervals of time, where we have greater availability of energy produced in photovoltaic regime. Thus, the self-consumption is higher and at the same time energy exchange with the electrical grid will decrease.

5. Conclusions

In this paper, an introduction on the concept of HEMS has been presented, with its implementation for a residential consumer witch has a photovoltaic system installed. A very important component that must be taken into account when using a load management method is the classification of all appliances of the customer's electrical installation.

This method is a way to encourage the self-consumption, that means to use the energy generated in the photovoltaic regime in a percentage as large as possible, thus diminishing the exchange of energy with the electrical grid. Using the Matlab simulation program, in the paper a specific load curve of a residential consumer has been generated, creating thus a consumption load profile.

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O PRIVIRE DE ANSAMBLU ASUPRA SISTEMULUI DE MANAGEMENT A SARCINILOR

(Rezumat)

Această lucrare se concentrează pe modelarea sarcinilor flexibile dintr-o zonă rezidenţială, bazată pe o clasificare a aparatelor eligibile. Astfel, pentru a utiliza energia fotovoltaică cu o eficienţă mai mare, în sectorul rezidenţial sunt implicate metode tradiţionale de gestionare a sarcinii, pentru a asigura un echilibru optim între încărcarea cerută şi energia generată de instalaţia fotovoltaică. Conceptul de sistem de management al energiei la domiciliu (HEMS) este o acţiune întreprinsă de consumator şi face parte din conceptul de management al sarcinii. Cel mai important lucru în implementarea acestui algoritm este efectuarea unei clasificări a aparatelor electrice.