

Energy Optimization and Management in a Building Using Clean Energy

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Abstract: - To lower the production of greenhouse gases while covering energy needs, it is necessary to exploit renewable energies in the urban environment and manage energy production and consumption as well.

In this work, we interested in the study of a house using renewable energy sources such as photovoltaic (PV) panels, thermal panels and wind turbines (WT). The energy consumption happens through electrical charges like the refrigerator, the heat pump, the lighting...

The main objective of this work is to change the operating time of secondary loads and to propose an energy management algorithm.

Firstly, we will model the consumption of electrical charges and move the operation of secondary charges to moderate the consumed energy. Finally, we suggested an algorithm to manage and optimize energy production and consumption.

The results show that the displacement of secondary loads reduces over 8.5% of the energy bill and the suggested algorithm optimizes the operation of the energy production equipment while covering the energy needs of the inhabitants.

Key-Words: - Electrical charges, Modeling, Optimization, Algorithm, Energy Management, Wind Turbine, Photovoltaic Panel.

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1 Introduction

Buildings generate about 25-40% of greenhouse gas emissions, which are the main determinant of climate change [1]. The energy consumption of a building represents up to 40% of the total energy consumption, especially in developed countries [2]. To control energy consumption in building and reduce of greenhouse gas, there are several solutions:

- Using of low consumption electrical loads.
- Integration of renewable energies in the buildings.
- Implementation of a smart load management [3].

In order to manage energy as well as possible while ensuring the desired comfort, Ky LE (2008) proposed a real-time load management method based on load shedding according to the power curve authorized [3].

In this work, a real-time load management method is proposed based on load shedding according to the availability of hot water supplied by a solar water heater. In order to reduce the total power consumed in the building, we can shift the operating time of the washing machine and dishwasher to periods when there is the availability of hot water from solar water heaters, which will moderate the power consumed.

The displacement can be done according to several criteria such as the price of kWh, the security or the availability of energy. In this case, the displacement depends on the availability of hot water and solar energy.

On the other hand, to ensure better use of renewable energy resources such as wind and solar energy. Elsieid et al (2014) have developed a model using genetic algorithms [4].

In this way, M. Abarkan (2013) proposed a control algorithm developed with the state flow. The switching control system seeks to optimize resources in terms of consumption and storage [5].

For our case, we managed the production and consumption of energy in the studied building and we proposed an algorithm that uses an approach that uses the State-flow library of Matlab / Simulink. Our algorithm is compared with the results of M. Abarkan (2013).

In our work, we combined the displacement of secondary loads consumption and the energy management algorithm.

The diagram in Figure 1 below summarizes the objective of our work:

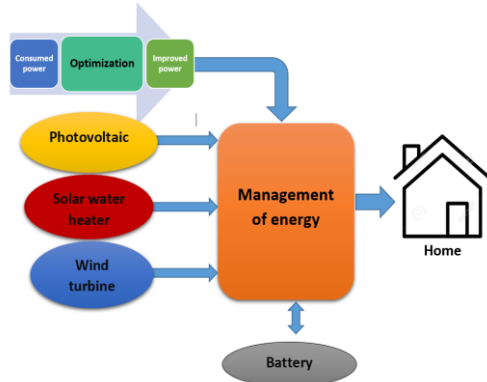


Fig .1. Energy optimization and management

2. Modeling the Energy Consumption of a House

2.1 Equipments

The studied building is equipped with the following electrical charges:

Table1. Power of electric charges

Electric charges	Power (W)
Refrigerator	150
Washing machine	2400 - 80 -150
Dishwasher	1600-80-1600
Heat pump	14823
Electric cooker	1000
Lighting	120
Refrigerator	150

To model the consumption of the electrical loads of the studied building using the Matlab/Simulink software, we used the power and operating time of each load.

2.2 Method

The objective of this part is the modeling of the consumption of the electrical loads using the Matlab/Simulink software.

Let's take the example of the washing machine: The model of the washing machine is shown in Figure 2

with a washing and rinsing power of 80W, a spinning power of 150W and a washing heating power of 2400W [3].

In the same way as the washing machine, we modelled all electric charges and we obtained the following schema:

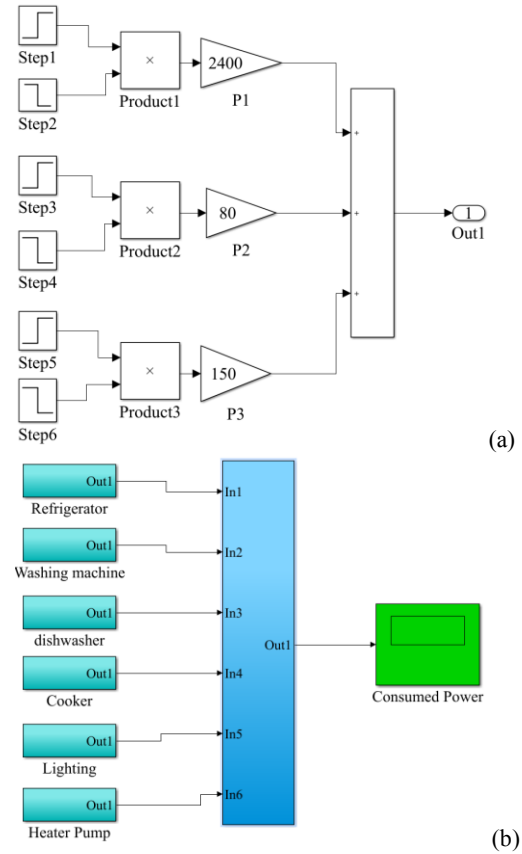
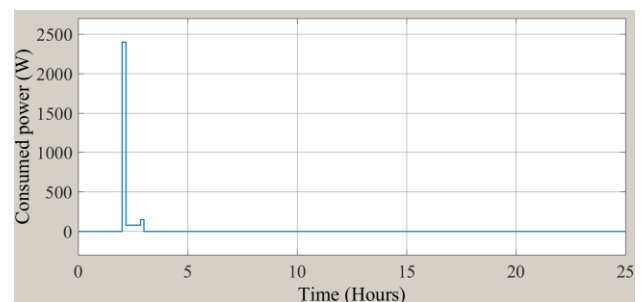
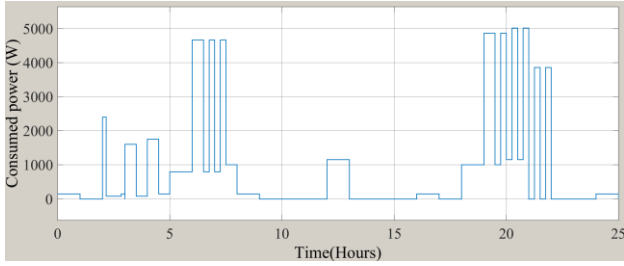


Fig. 2: (a) Washing machine modeling (b) Modeling of electric charges

2.3 Results and Discussion



(a) Washing machine modeling



(b) Electric charges modeling
Fig.3: Evolution of the consumed power

For figure .3 (a), we notice that the washing machine consumes a significant power in the first phase (water heating) compared to the other phases. The same goes for Dishwasher.

For figure .3 (b), we notice that there is a significant energy consumed by the heat pump to heat the house.

In the middle of the day, the energy consumption within the house is low, however, PV can produce significant energy. To do this, consider moving the operation of certain electrical charges to optimize the energy consumed.

3 Optimization of the Energy Consumed in the Building

3.1 Equipment and Method

To optimize the energy consumed in the building under study, the solar water heater is used as a renewable energy source that supplies the washing machine and dishwasher with hot water.

Electric loads can be classified into two main categories:

- ✓ Exclusive loads: They cover the essential needs of the inhabitants and cannot be delayed. Generally, they consume a lot of energy (lighting, heating, cooling).
- ✓ Secondary loads: They correspond to specific needs or to auxiliary functions such as the use of the washing machine, the dishwasher... [7].

In general the shift of operation of the loads (of the washing machine and dishwasher) can be done according to several criteria such as the price per kWh, safety, availability of energy, availability of hot water. In this work, the load shedding is done according to the availability of hot water supplied by a solar water heater.

The accumulation of the consumed energy at time t_n is calculated using the following relation:

$$E_n = \sum_{i=1}^n P_i(t_i - t_{i-1}) \quad (1)$$

P_i : Electric power consumed during the interval $[t_i ; t_{i-1}]$.

After the displacement, the energy consumed at time t_n becomes:

$$E_n^* = \sum_{i=1}^n (1 - \varepsilon_i) \cdot P_i \cdot (t_i - t_{i-1}) \quad (2)$$

ε_i : Power reduction coefficient of phase i, it depends on the machine operating phase and the operating period.

The operating period of each device can be divided into three phases and each phase is characterized by a power, an operating time and a reduction coefficient. These characteristics are grouped in the table below:

Table2. Characteristics of Washing machine and Dishwasher

Machine		Operating phases		
		Phase 1	Phase 2	Phase 3
Washing machine	Power (W)	2400	80	150
	Duration (min)	10	30	10
	$\varepsilon_i(\%)$	80	0	0
Dishwasher	Power (W)	1600	80	1600
	Duration (min)	30	30	30
	$\varepsilon_i(\%)$	80	0	0

For washing (laundry or dishes), it has an essential thermal function since **80%** of the energy consumed during a washing cycle is used to heat the water [3]. The study building is equipped with a solar water heater that is capable to providing domestic hot water and also provides hot water to the washing machine and dishwasher.

3.2 Results and Discussion

From the evolution of the power consumption Fig.3 and equation (2) we found the evolution of the energy consumed by the electrical loads before and after the displacement is given in figure 4:

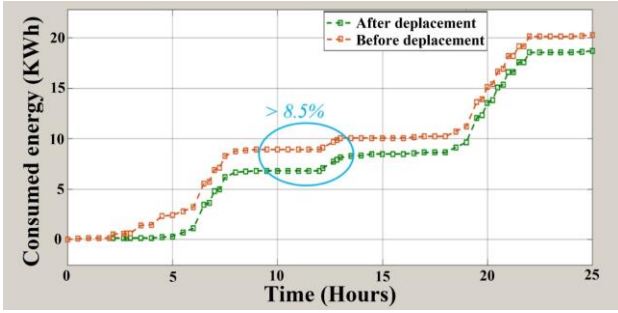


Fig. 4: Evolution of the energy consumed before and after displacement

It is observed that there is a difference in the energy consumption before and after the shift of the operation of the washing machine and the dishwasher. On average, energy consumption can be reduced by 8.5% by the effect of secondary load displacement and the free availability of hot water. With this action, the energy consumed in the house becomes moderate and has a positive effect on the cost of investment in clean energy equipment.

4 Energy Management Algorithm

4.1 Algorithm

We used the State-flow tool which allows us to manage constraints. Indeed, State-flow plays the role of supervision unit and instructions generation. This tool presents a user-friendly graphical interface and allows a good interaction with the models used in the global simulations of the bench test [8], [9].

The strategy of switching and controlling the production of PV and wind turbines as well as the management of charge and discharge of the battery is summarized in the following flowchart:

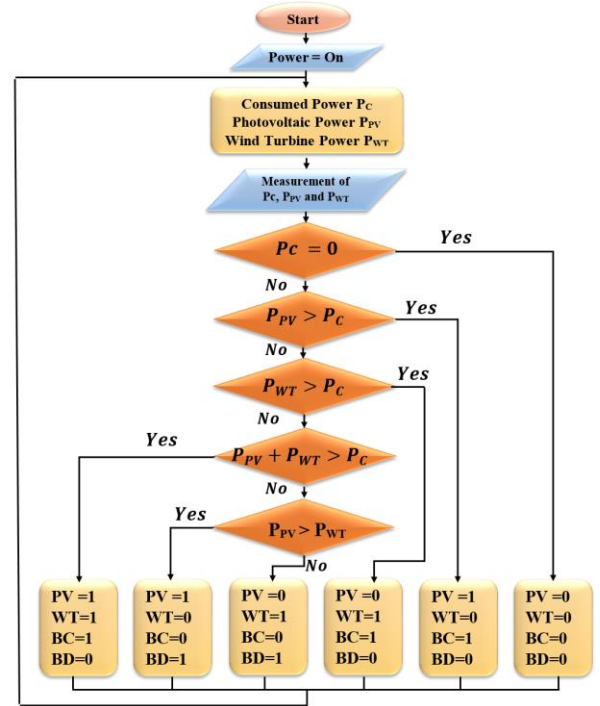


Fig.5: Suggested organization chart

The management of the system complies with the following rules, with the status equal to 1 if activated, and 0 if deactivated. We used the State-flow tool available on Matlab/Simulink which allows to deal with the constraints of the energy management algorithm. Here is the produced program diagram:

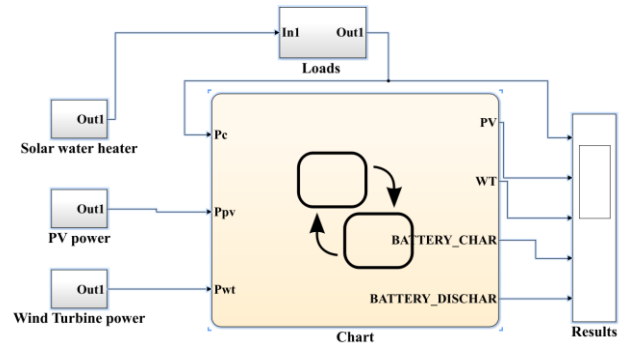


Fig.6: State-flow algorithm diagram

4.2 Results and Discussion

Our proposed algorithm is valid for all solar and wind energy profiles, but just to test it, we propose the following two complementary profiles:

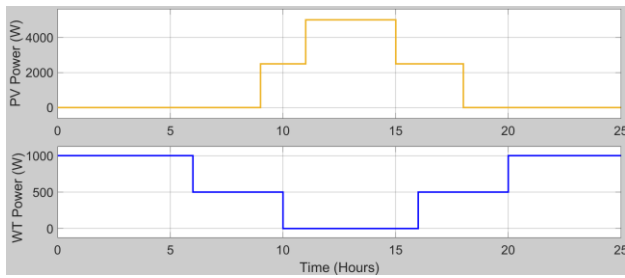


Fig. 7: Proposed profile of the power produced by PV and WT

We executed the last program in figure 6 and obtained the evolution of the P_C power consumption in the studied building and the operating status of PV, WT, battery charge and discharge.

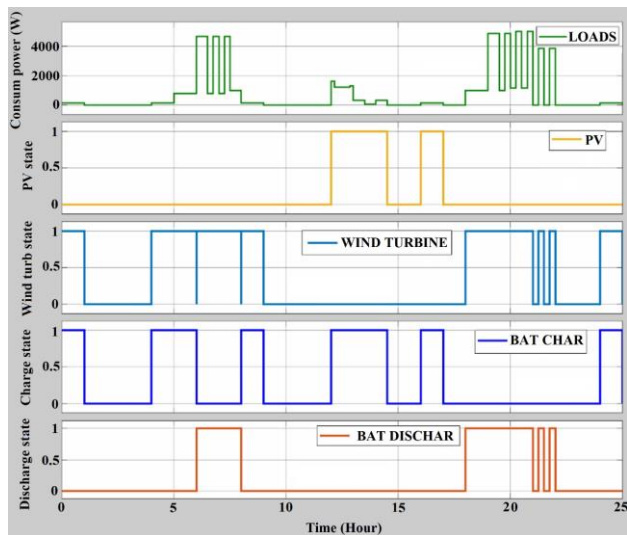


Fig.8: Results of the energy management algorithm

If $P_c = 0$, you must deactivate all the equipment. When P_c is small than P_{PV} we activate the PV and the rest of the energy is stored in the battery, if P_c is big than P_{PV} and smaller than P_{WT} we deactivate the PV and activate the wind turbine and the battery is charged but if P_c is big than P_{PV} and P_{WT} on PV is activated, the wind turbine and the battery are discharged etc.

This energy management technique, for a hybrid system, is implemented under State-flow. Even with a simple set of rules, this control method has proven effective in managing the energy produced by the hybrid system with multiple uses. Because it can manage all of the energy flows in the building, of satisfying the loads.

5 Conclusion

Energy efficiency is a set of gestures that optimize energy while keeping the same comfort for the occupants. In this work, we combined the displacement of secondary charges and the suggestion of an energy management algorithm:

By moving the secondary loads, energy consumption can be reduced by 8.5% of the energy consumed. The proposed algorithm capable of optimizing the operation of energy production and storage equipment while covering the energy needs of the occupants.

The advantage of shifting the consumption in our work is based on the availability of hot water due to solar radiation (renewable energy), whereas for Ky LE [3] the shift is based on the power curve authorized.

The advantage of our algorithm compared to the algorithm of M. Abarkan [5] is that we have added two other cases such as one where there is no energy consumption in the building ($P_c = 0$) and a second case where the energy produced by the PV and the WT exceeds the required power ($P_{PV} + P_{WT} > P_c$), which allows us to optimize the energy consumption...

The results show that energy management is capable of reducing primary energy consumption, extending the life of energy production equipment, especially the battery (which is too expensive and does not exceed 5 years [10], [11]) and reducing the production of greenhouse gases while covering energy needs and meeting demand.

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