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Optimizing the Performance of Smart Grids in Relation with Residential Energy Centers Equipping with Solar Power Units (PV)

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Abstract: In this study, the performance of smart grids is optimized in relation with residential energy centers equipping with solar power units or PV. In this regard, two optimization algorithms are used to reduce energy costs and the results of the two methods are compared with each other. The results obtained from this study can be used by 3 groups of external consumers, environmental experts and energy suppliers. Big home appliances consume large part of household energies. Now, there is a smart control tool that makes consumers enable to program home appliances daily or weekly that in addition to use them, they can pay less in non-peak load time. Hub energy is a concept that has been considered in energy systems mixed with multiple energy carriers. Hub is determined as the locus of activity of system. Certainly, hub is core energy, in which all activities associated with a system including generation, storage and consumption of energy in applied equipment are determined. In this research, YALMIP toolbox in MATLAB software is used for optimization of energy consumption with the objective of reduction of costs created by fossil fuels with regarding generation ability of a PV generation unit. Using this toolbox, right time to turn each appliance on is specified due to the practical limitations of the appliances and the maximum possible application of PV unit as clean energy generation is done.
Keywords: optimizing, smart grids, solar power, photovoltaic

INTRODUCTION

Due to lack of energy resources and high costs of production and distribution of energy, people have been always tended to optimize energy consumption, so that they could pay lowest cost at the same time by using all needed instruments consuming energy. Consumption optimization is in benefit of consumer not only economically, but also it is useful for production units and the environment. Smart grids could be a solution to this problem and implementing these grids can be costly at the first; although it can reduce lots of economic costs and environmental pollution in long-term.

Smart grids can use local renewable energies like wind and solar energy to solve environmental problems, increase reliability of equipment and system and reduce the costs of infrastructure. The smart grids connected to household grids allow the consumer of electric products, grids and services to act in integrated way as much as possible. Development of smart grids can play key role in reduction of costs related to energy. In this regard, the way of matching the consumptive equipment has become too important. There is no doubt that one of the most important challenges of the current century across the world is the issue of energy. In general, there are various methods for energy resource conservation. The most common method is saving energy, which can be realized by culture making. The most novel idea to conserve energy is use of modern systems and equipment considered for this purpose. Building energy management systems are in this group. Smart building is such a building that encompasses a dynamic and affordable environment by means of integrating 4 main elements including systems, structure, services and management and their correlation. A smart building can provide these advantages through smart control systems. Another discussion that plays key role in field of return on investment is optimal use of facilities, which can lead to increased lifecycle of facilities: for example, in mechanical facility system, through dividing function times among all members of a complex, the working pressure would be divided among all members. Moreover, it can also prevent inactivity of a part of the complex constantly and this can improve performance of whole complex.

Today, the concept of microgrid is being used for purpose of helping the environment through using several renewable and available resources such as wind and solar energy, along with other energy generators such as fuel cells and micro-turbines to reduce generation costs and reduce environmental pollutions. The resources are not only interrelated, but also the interaction continues in higher levels such as distribution networks. Restriction of fossil fuels and increasing growth of demand for energy, enhanced living standards, global warming and environmental problems have led to increasing advancements in technology and use of modern energies. Growth and development of human societies has been always parallel to energy generation and consumption. According to the recorded statistics, over the 30 years, energy needs of the world have been increased considerably. Nowadays, use of modern energies for supplying grid load has been changed into one of the most important issues. Use of modern energies is considered, especially in cases like remote areas, at which the load connection to national power network is problematic. In this study, a multipurpose energy management system is used to optimize energy hub performance to reduce costs during a day.

Smart grids of electric power distribution can be considered as one of the most modern technologies of the world and the fruit of efforts of experts to modernize distribution networks and to enter to digital century. The main purpose is supplying reliable electricity and meeting increasing needs of customers with lowest rate of damages of the environment. The aim of designers by using smart technology is associated with 3 main axes of subscribers, equipment and communications. Smart technology has the ability to make fundamental changes in generation, transmission, distribution and use of electric energy, along with economic and environmental interests, which can finally result in meeting needs of customers and access to reliable and sustainable power. On the other hand, the system can use the collected data in critical conditions and make decision and prevent unplanned outages [1].

PV (photovoltaic) refers to conversion of the sunlight to electricity. These systems are composed of assembled modules in array form that can be installed inside or near the building. Power invertor can generate direct current (DC) generated by system to grid with alternative current (AC) quality. Traditional single-crystal solar cells are made of silicon like flat plate and in general, the most efficient multi-crustal solar cells with similar technologies but slightly more efficient. Thin-film solar cells are made of silicon or non-silicon amorphous like cadmium telluride [2].

Solar radiation is the greatest renewable energy resource on the earth and if just 1% of deserts of the world are used by solar thermal plants, same value is enough for generation of annual electricity demanded by the world [3].

However, use of this energy has also special limitations and the main limitations are related to effect of altitude, cloudy days and reduced power of solar radiation on the earth. If a country wants to supply required energy by sun, it needs required area to install solar equipment. Moreover, depending on realization of this issue, supplying this amount of energy needs large warehouses and facilities for purpose of transmission. All mentioned factors can increase the cost of supplying this type of energy two times more than fossil fuels [4].

In a simple definition, smart grid could be considered as community of power grid infrastructures with wide area telecommunication network. This type of network provides the condition for two-way communication and use of advanced sensors to improve efficiency and reliability of system, security of transmission and consumption of power. As another definition, smart grid could be defined as community of communicative networks with power system to create suitable route for electric power and information. This set has the ability to monitor its accuracy in all times and also, in case of emergence of errors, it can inform higher levels and take some reforming measures automatically and prevent changing a local event to command-and-control exit [5].

The idea of smart grid was begun with idea of Advanced Metering Infrastructure (AMI) to develop demand management, increase energy efficiency and a self-repair electric grid, so that it could improve reliability and responding to natural disasters or deliberate sabotage. However; later developments could improve initial aspects desired for smart grid and helped formation of new vision of power industry. In this study, two methods are used to optimize performance of smart grids in relation with residential energy centers of PV units.

Simulation

Optimization using YALMIP toolbox

YALMIP toolbox of MATLAB software is introduced in this section and also, this issue is investigated that how YALMIP can be used for purpose of modeling and to solve optimization problems usually in systems and theory of control. Two important cases of mathematical tools in theory of control and systems over the decade include semidefinite programming (SDP) and Linear matrix inequalities (LMI). SDP considers integration of large number of problems of control including old 100-year theory of Lyapunov for linear systems and modern control theory since 60s decade based on Riccati equation and recent evolutions such as $H\infty$ control in 80s decade. More importantly, LMI and SDP have given new results on stability and synthesis for indefinite system, model prediction control, controlling repetitive systems and identification of power system to mention definite applied plans. It is known that control program is solvable, if the program is summarized in Riccati equation as second degree linear control.

Description of decision making variables

Decision making variables can be considered as the main component of an optimization problem. Decision making variables in YALMIP are presented by SDPVAR objects. Using matrix P is described as follows:

```
>> P = sdpvar(n,n,'symmetric' , 'real' )
```

Square matrixes with the presumption that they are asymmetric and in real time, the common variable could be just defined using dimensional arguments.

```
>> P = sdpvar(n,n);
```

A set of standard parameters are predefined and can create absolute parametric matrixes and different types of matrixes with mixed variables.

```
>> Y = sdpvar (n,n,'full')
>> X = sdpvar (n,n,'hermitian','complex')
```

Most standard instructions of MATLAB and operators can be used for sdpvar variables and hence, following instruction is important:

```
>> X = [ P P(:,1) ; ones(1,n) sum(sum (P))]
```

Optimization problem solving

When all variables and limitations are defined, the optimization problem can be solved. In other words, assume that matrixes a, b and c are provided and the trend is minimization depending on limitations of Ax<b. Using YALMIP to solve the problem could be regarded as a novel innovation and basically, it can be a trace of mathematical descriptions. The order solvesdp3 is used for all optimization problems and includes usually 2 arguments including 1) as set of limitations and 2) target function.

```
>> x = sdpvar ( length(C), 1);
>> F = set (A*x<b) + set (sum(x)==1);
>> solvesdp(F, c' ,1);
```

YALMIP is automatically responsible for classification of linear programming problem and a suitable solution. Optimal solution could be extracted by double(x) order.

The second argument is used to conduct YALMIP to select the solution with specific choices.

```
>> ops = sdpsettings('solver','glpk');
>> ops = sdpsettings(ops,'glpk.dual',0);
>> ops = sdpsettings(ops,'verbose',1);
>> solvesdp(F,c'*x,ops);
```

MODELING

Modeling method

Hub energy is a concept that has been recently presented in mixed energy systems with multiple energy carriers. Hub is determined as system activity center. Certainly, hub energy is a center, in which all activities related to a system including generation, storage and consumption of energy in applied equipment are determined.

Big home appliances consume large part of household energies and just some of them can have less effect on increasing costs and generation of greenhouse gases for the consumers with programming. Now, there is a smart control tool that makes consumers enable to program home appliances daily or weekly that in addition to use them, they can pay less in non-peak load time. Moreover, using home appliances can be controlled by use of household network systems and remote control could be used to activate them. These systems have usually several specific controls, which are turned on and off through connecting the appliances to electrical socket and home control center. As a result, the users can control different programs and events and implementation of rule-based decision making in field of controlling central household appliances. In this field, a smart decision making core is considered here, which can plan use of home appliances optimally, so that energy costs could be declined as much as possible. The smart core is inseparable part of EMSs, which is modeled based on mathematical equations. In figure 1, full view of using hub energy in presence of different home appliances including energy saver system (e.g. battery), energy generation systems (e.g. PV solar energy and wind power) and two-way communicative links among the components could be observed.

Demand of user (consumer)

Executive models of household hub energy should be prior for the demand and need of user and the executive orders should be sufficiently simple and executable for the consumer. The model should include common behavior of user (e.g. regulating the room temperature or time of using the appliances). Even at the time that user tends to have most changes for a component of appliances; the model should be able to implement this order.

The proposed mathematical model and also the controlling method of using appliances are existed in central hub controller. The controller using mathematical model of each element in hub, setting of the parameters and other external information like users' needs in consuming time try to obtain optimal time of using appliances. This issue is illustrated in figure 2. Database of the device includes all technical information of components (e.g. power rate, storage and generation rate) and external information include information of cost, weather prediction, solar radiation and prediction of greenhouse gas CO generation.

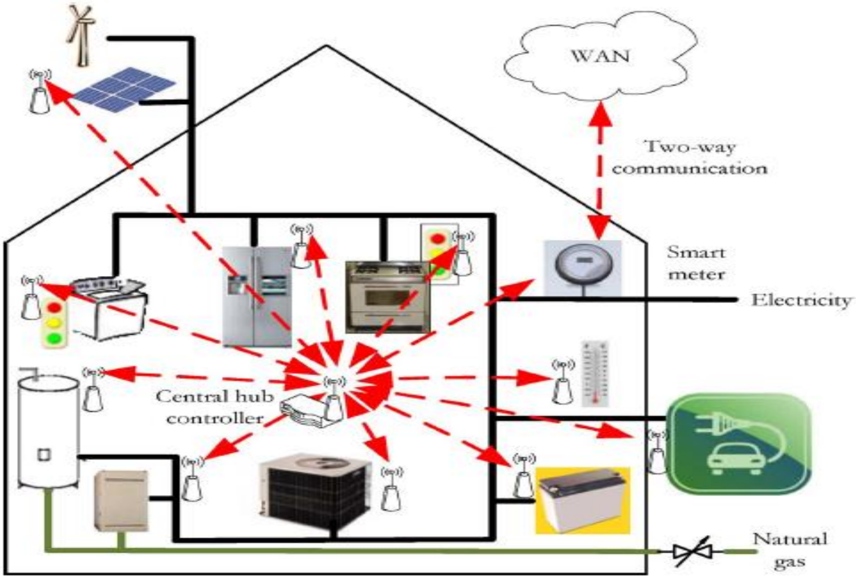

Figure 1: household hub energy structure

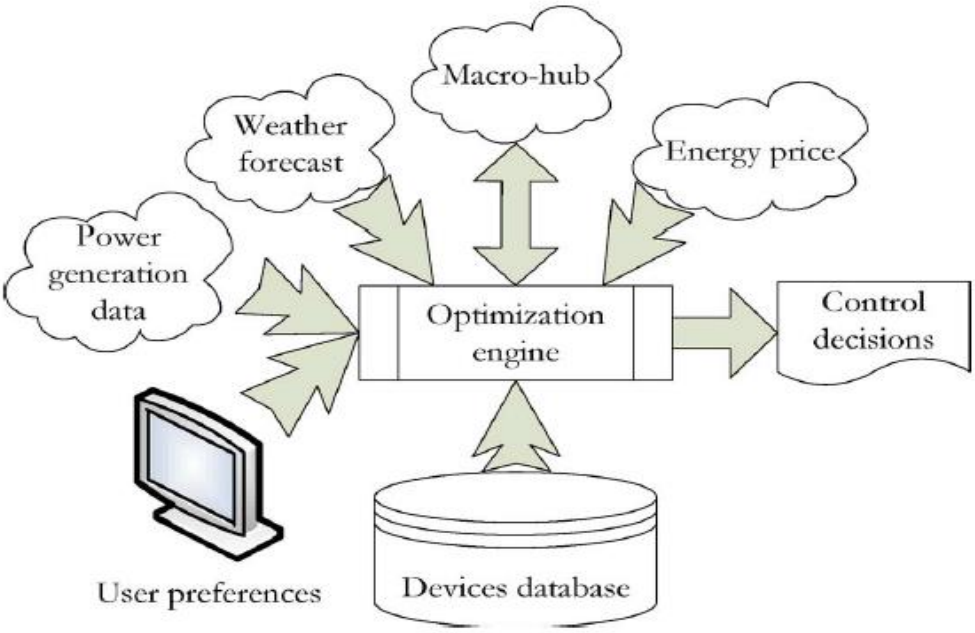

Figure 2: a view of central hub controller

The horizon of programming and duration of each time period in optimization models could be different depending on type of hub and energy activities in the locus of control.
Now, the study tends to present short description of each determinant factor to implement optimization:

Activity level

In residential places, presence of individuals at home has significant effect on energy consumption pattern. Moreover, the consumption pattern in every house varies due to season and days of week and weekend holidays. In order to consider effect of occupation of house on energy consumption pattern, the term "activity level" is introduced. This term shows the hourly activity of energy consumption in a programmable area. To determine a reasonable value of residential level of energy center, the historical data of energy consumption presented by smart measurement instrument embedded in each house could be used. Hence, the previous measurement data of weeks and months and years can be used to predict energy consumption in special day and as a result of producing residential load profile. The load profile can be used to obtain an option for activity level of a house hourly. For example, an example of this activity level is illustrated in figure 3.

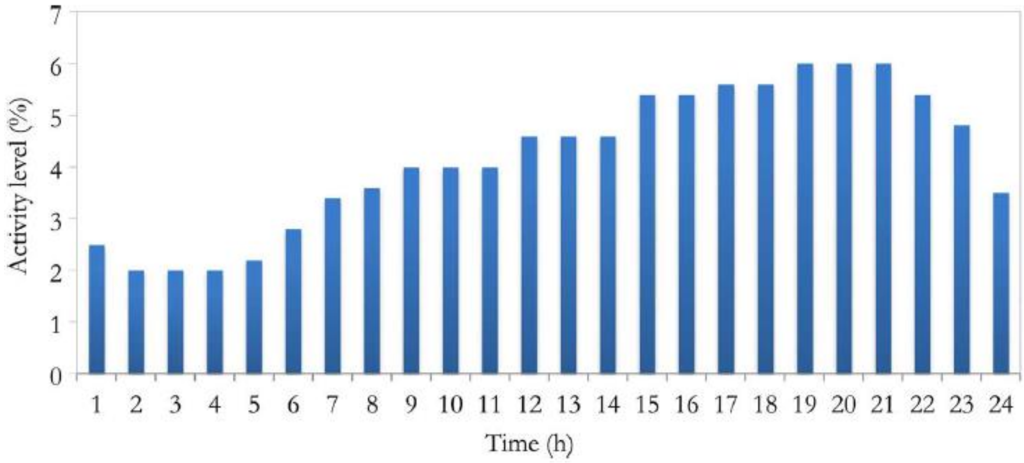

Figure 3: percent of activity level per day

Energy cost

The main aim by dynamic pricing is to encourage reduction of energy consumption during peak time of consumption. Fixed rate design, application time and real time pricing are 3 possible types of pricing for customers, which are supplied by the government. Currently, for household uses, two early cases are mostly used.

Mathematical model

Form of overall optimization model used in this study for a household energy hub is as follows: optimization includes minimization of overall cost functions as introduced here.

Min j=objective function

$$s.t \sum_{i \in A} P_i S_i(t) \leq P^{\max}(t), \forall t \in \mathrm{T}$$

Where; i refers to one household appliance. Limitation in second phrase shows that in every moment of day and night, maximum consumed power can be higher than determined limit P^{max}.

Modeling results

In this study, YALMIP optimization software is used for purpose of programming energy hub with the aim of reducing costs. At the first, the power related to devices is defined in binary form. It means that each device can be only in two modes of on or off and to calculate their consumed power in "on" mode, they are only multiplied in their nominal power.

P=binvar (5, 48)

Here, the value 5 refers to 5 devices, for which optimized "on" mode is going to be calculated and the value 48 shows that the time interval considered to calculate the power rate is equal to 30min.

(30min * 48 = 28hrs)

To show the difference in peak consumption time compared to other rimes, cost coefficients are used as follows:

```
cost=zeros(1,48);
cost(1,1:12)=1;
cost(1,13:24)=2;
cost(1,25:36)=5;
cost(1,36:48)=2;
```

To determine unit power consumed by each device, power coefficient is used.

```
power(1,1:48)=450;
power(2,1:48)=500;
power(3,1:48)=600;
power(4,1:48)=400;
power(5,1:48)=500;
```

After implementing the power program, the relevant outputs of each device and storage and supplier are illustrated as follows (figures 4-10).

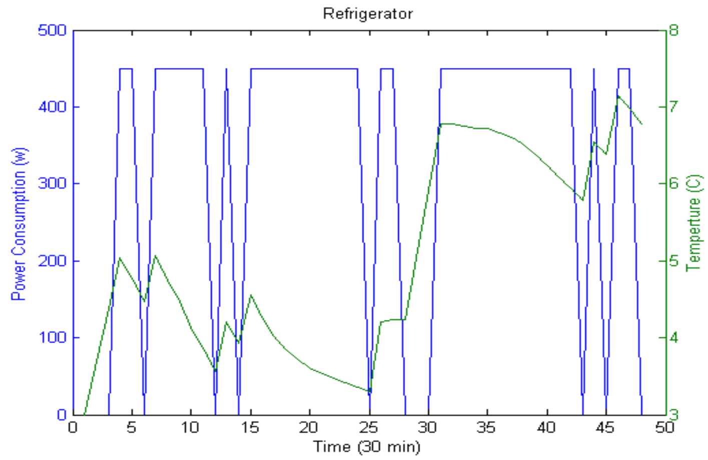

Figure 4: temp and power of refrigerator

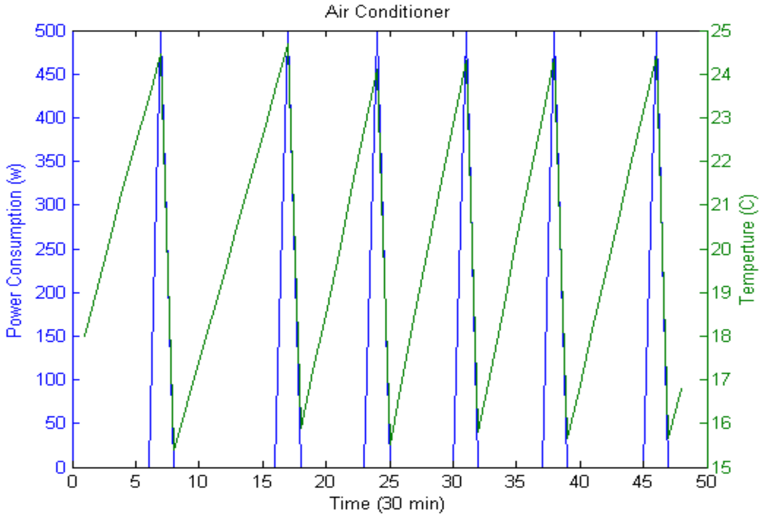

Figure 5: cooler temp and power

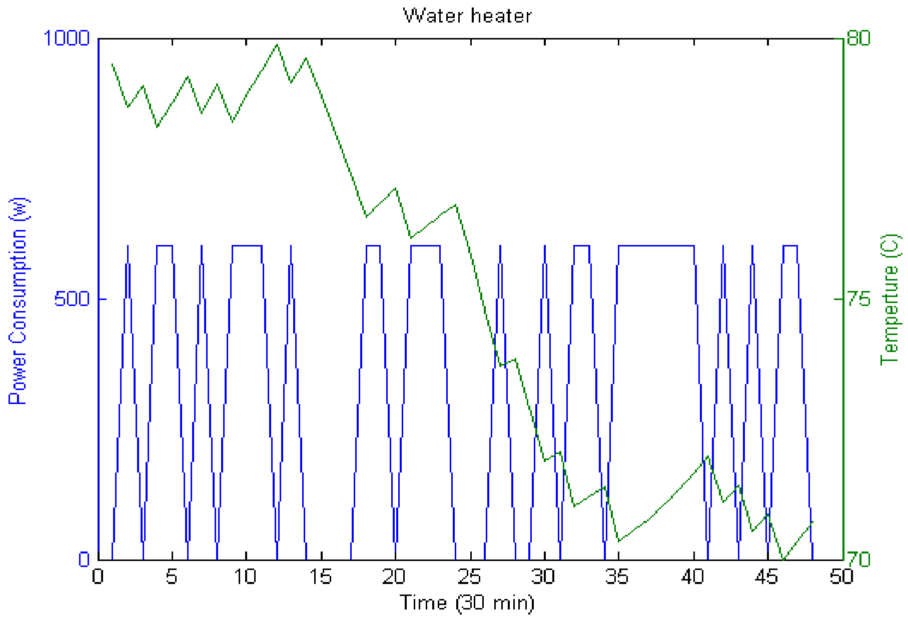

Figure 6: water heater temp and power

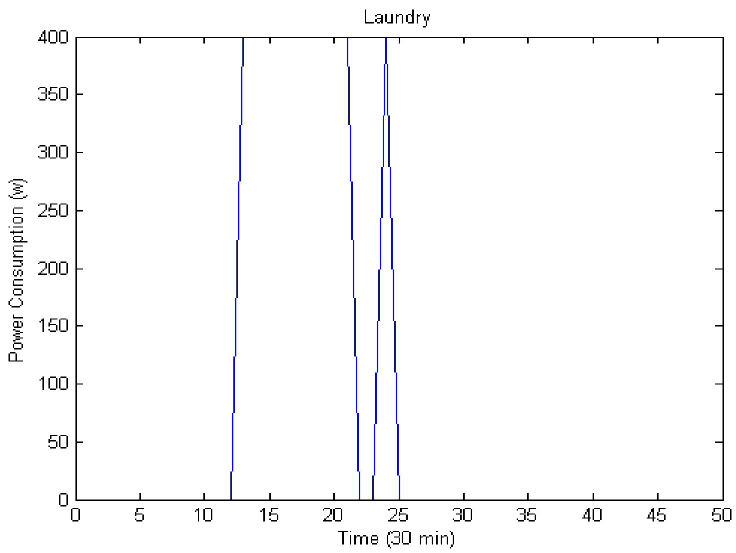

Figure 7: washing machine temp and power

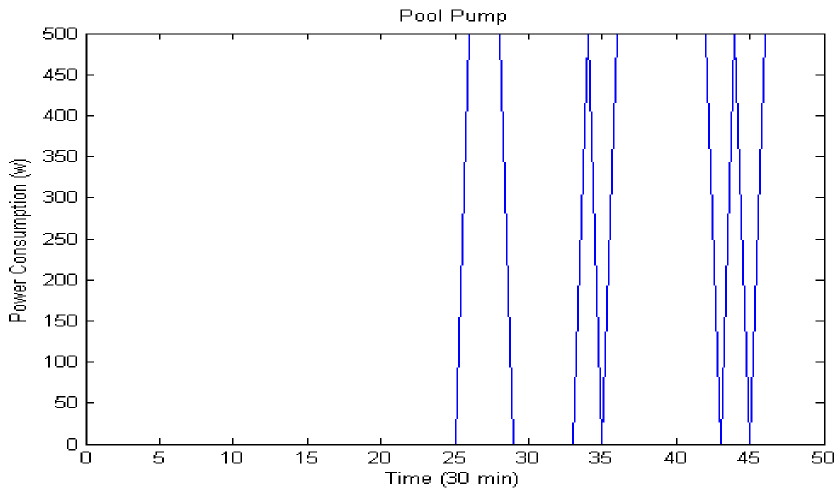

Figure 8: pool pump power

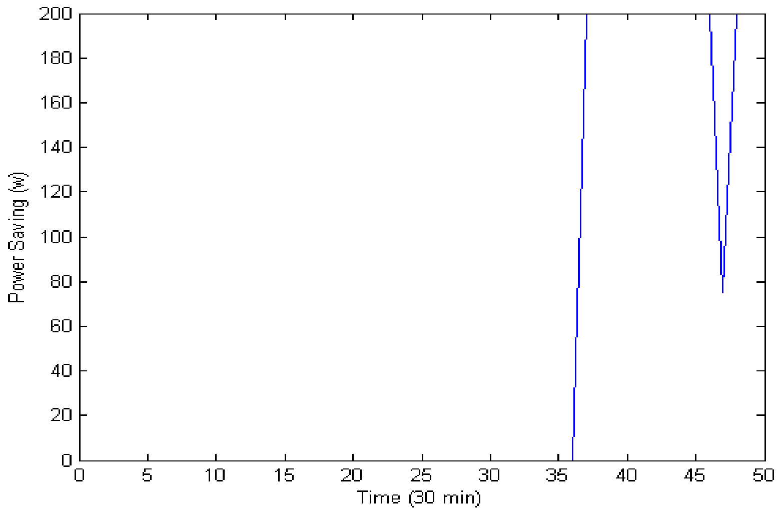

Figure 9: power stored by battery

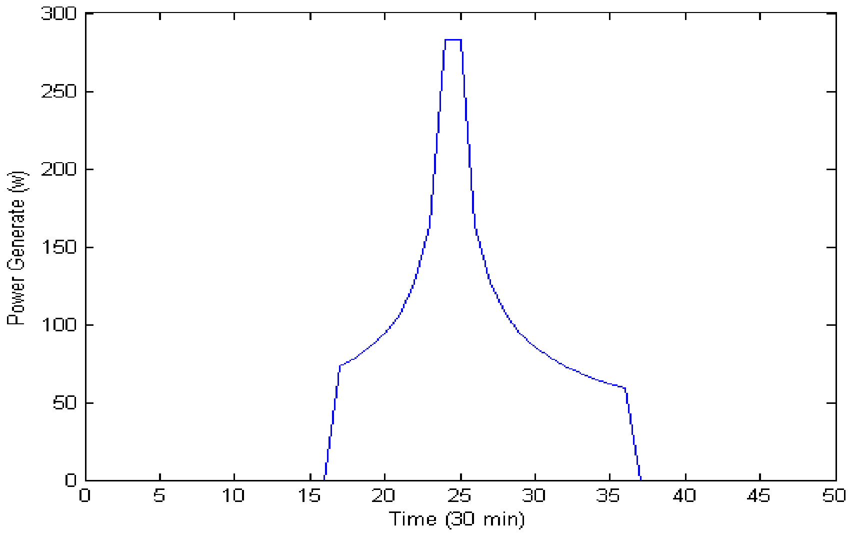

Figure 10: generation power of solar panel

In this section, the study tends to determine the success rate of using yalmip optimization method to reduce consumption costs and peak declining according to the results and the diagrams. For example, the consumptive power diagram of one of the high energy consuming devices like refrigerator is given in figure 4. As it is obvious, the consumed power showing the "on" times of fridge engine is illustrated by blue lines and the temperature inside the refrigerator is shown on the other side. As it is clear, one of the limitations considered here is temperature of refrigerator that is assumed to 3-8°C. The refrigerator consumed 450w power when in on mode. Formulation of function of refrigerator is in such manner that when fridge engine is started, the temperature inside the fridge is decreased. Yalmip optimization software tends to use lowest "on" mode of fridge to reduce fuel consumption generally.

However, figure 4 is traced for the cases that the optimization is just done for one day; although it would be better to organize the limitations in optimization in such manner that the purpose of reducing fuel consumption is followed for longer time. For this purpose, the limitation that can be added to optimization program is ≤ level of end temp compared to initial temp of the fridge during the day. This can provide conditions that there would be no need to give high energy level to the devices to achieve user's desires. The results obtained by applying this limitation could be observe din figure 11.

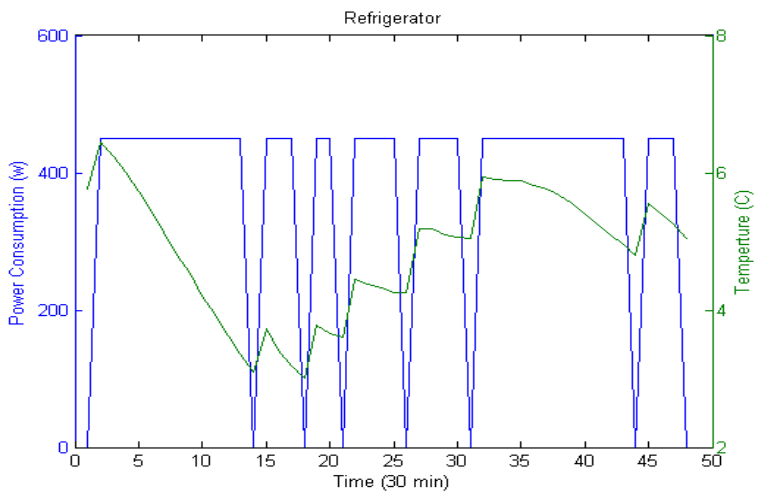

Figure 11: fridge temp and power

As it is observed, the initial and end temp of fridge is about 5°C during day and night. The limitation could be also considered for other devices working with temperature regulation. All optimization processes for household appliances are done due to the generation power that is supplied by PV system during the day hours. All devices attempt to get their energy from solar panel, so that this action can lead to reduced energy consumption and costs and reduction of pollutions caused by consumption of fossil fuels. In this optimization process, limitation of maximum power consumption is considered. It means that total power consumption of household appliances can't be higher than certain level in certain time.

As it is clear in the diagrams, YALMIP software has been properly able to optimize the power consumed for high consumption household devices and has shown also good time for turning the devices on and as a result, this approach could lead to reduction of costs and economic saving.

CONCLUSION

Nowadays, the concept of "microgrid" is being used in cases that the intention is to help reduction of generation costs and environmental pollutions using several renewable and available resources such as wind and solar energy, along with other traditional energy generators like fuel cells and micro-turbines. The resources are not only interrelated, nut also the interaction is also continued in higher levels like distribution networks. Limitation of fossil fuels and increasing growth of demand for energy, enhanced living standards, global warming and finally, environmental problems have led to great advancements in field of technology and use of new energies. Growth and development of human societies has been in line with energy generation and consumption. According to the recorded statistics, over the 30 years, energy needs of the world have been increased considerably. Nowadays, use of modern energies for supplying grid load has been changed into one of the most important issues. Use of modern energies is considered, especially in cases like remote areas, at which the load connection to national power network is problematic. In this study, a multipurpose energy management system is used to optimize energy hub performance to reduce costs during a day. In this algorithm, optimization is performed according to limitations of main energy consuming machines like fridge, cooler, washing machine and pool pump. Here, due to recursivity of thermal limitations of resources and the standby time desired by user for each of them, nonlinear optimization of YALMIP software is used. Using YALMIP toolbox in MATLAB software in energy consumption optimization with the purpose of reduction of costs of using fossil fuels is done with regard to generation power of a PV generation unit. Using this toolbox, this study has been able to specify favorable time for turning on each household appliance due to practical limitations of them and to use PV unit as generator of clean energy as much as possible. This method in wide range can lead to reduction of electric power generation costs.

REFERENCES

Bahmanyar, Sanaz, Sedaghat, Amin (2012), economic and environmental assessment of renewable energy in Iran, National Congress modified the pattern of consumer products.

Bahmanyar, Sanaz, Sedaghat, Amin, (2011), economic and environmental assessment of renewable energy in Iran, National Congress modified the pattern of consumer products.

Chehreghani Bozchalui,M.(2012). Optimal Operation of Residential Energy Hubs inSmart Grids. IEEE TRANSACTIONS ON SMART GRID, VOL. 3, NO. 4,.

Dehghani, G, M, Dehghani, (2013), Introduction to solar energy and its applications, the first national conference on new energies and clean.

Lofberg, John " YALMIP : A toolbox for modeling and optimization in MATLAB" , IEEE International Symposium on Computer Aided Control Systems Design, Taiwan , 2004.

Michael Angelo A. Pedrasa, Student Member, IEEE, Ted D. Spooner, an Iain F. MacGill.(2010) Coordinated Scheduling of Residential Distributed Energy Resources to Optimize Smart Home Energy Services. IEEE TRANSACTIONS ON SMART GRID, VOL. 1, NO. 2.

NREL (2011). Kandt, Walker, Hotchkiss. Implementing Solar PV Projects on Historic Buildings and in Historic Districts. NREL. Draft Technical Report. NREL / TP-7A40-51297.

Yoza, A., Yona, A., Senjyu, T., & Funabashi, T. (2014). Optimal capacity and expansion planning methodology of PV and battery in smart house. Renewable Energy, 69, 25-33.

Zakaria zadeh, A., smart grid and demand response where, (2010), modeling and energy management in smart metering systems Iran, the Iranian energy efficiency (Saba).