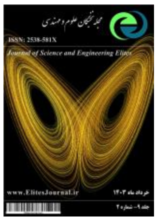
مجله نخبگان علوم و مهندسی
Journal of Science and Engineering Elites
جلد ۹- شماره ۲ - سال ۱۴۰۳
www.ElitesJournal.ir



An Overview of Home Energy Management Considering Energy Systems

Farhad Zishan[1]*, Reza Pourmand [2]

1-Department of Electrical Engineering, Worker's House University of Applied Science and Technology, Ardabil Branch, Ardabil, Iran

2-Department of Agriculture Engineering, University of Mohaghegh Ardabili, Ardabil, Iran

* f_zishan99@sut.ac.ir

Received: March 2024 Accepted: June 2024

Abstract

Home energy management (HEM) plans convince residential customers to actively participate in price-based demand response (DR) programs. In these price-based HEM methods, the controller scheduling for energy consumption of household devices in response to the electricity price signal has many priorities among customers. Although various methods have recently been proposed to use HEM, prioritizing the performance of controllable devices from the customer's point of view in price-oriented HEM has not been determined. For this purpose, the load reduction value of each device is defined in such a way that it raises the implementation priority of that device from the customer's point of view. Taking into consideration the load reduction value of the devices, electricity tariffs and the implementation limitations of the devices, the optimization problem is proposed to reduce the energy consumption and reliability prices.

Keywords: Home Energy Management, Demand Response, Energy systems.

1- Introduction

Load management is the distribution of load throughout the day and the seasons of the year, and its main goal is to improve the load factor of the distribution network [1-3]. Improving the load factor first reduces production costs and then reduces the need to invest in new capacities in the field of electric power generation and transmission. By increasing the load factor of the system, the amount of energy produced per kilowatt of installed capacity increases, which results in a reduction in production costs. Demand side management is one of the main success tools of any industry and is of particular importance. Consumption management is the planning, execution and monitoring of that part of electricity-related activities that affect electricity consumption and cause favorable changes in the load pattern, time pattern of consumption and the amount of energy consumption [4-5]. Energy consumption management includes a series of interconnected activities between the electricity industry and its subscribers in order to reduce the peak load of the network and common energy consumption, as well as leveling the curve of the network consumption load so that it can meet the needs of consumers with more efficiency and less cost. In the beginning, consumption management was proposed in order to reduce the amount of peak consumption and actually under the title of load management, and gradually reduction of production costs in industries, optimal allocation of resources, reduction of environmental pollution and other motivations of consumption management were proposed by adopting Consumption management policies do not reduce the standard of living of the consumer, but by maintaining their standard of living and welfare level, less energy is consumed.

In general, the goals of load management on the consumption side for the electricity industry can be mentioned as follows:

• Reducing the cost of production by increasing the load factor and optimizing electricity consumption and reduce line loading [6]

• Freeing the funds of the electricity industry in order to increase the efficiency and improve the quality of the existing facilities [7]

• Reducing environmental pollution by reducing the production of electrical energy [8]

• Reducing investment costs in the development of the power network by reducing the peak load of the network [9]

Consumption management solutions and some energy saving opportunities in the domestic, commercial and industrial sector are expressed.

In smart grids, supply- DR programs play an important role in enabling end users to distribute system performance. In these programs, the plans of the distribution system are operational in such a way that the electricity tariff or an index of the consumers regarding the voluntary change in the consumption pattern is created. Since residential demand is a significant portion of the total system load, residential DR programs are important from a system active perspective.

One of the obstacles in the use of residential DR programs is the lack of sufficient customer information to respond to pricing and stimulus signals [10-13]. One of the proposed solutions is a control system that automatically responds to the received signals by solving the optimal problem and is generally called Home Energy Management (HEM) systems [14]. The HEM program reduces the costs of the customers and is a factor to encourage them to participate in the rejection of DR programs. The output of solving the HEM optimization problem is scheduling the energy consumption of controllable devices. Several articles cost on HEM modeling and structure [15-16]. The proposed methods in these articles reduce the energy price for the customer along with the maximum household load.

Therefore, the priority of controllable devices is aligned with the temperature and operational ranges in [23, 24] to determine which devices can be turned off if DR is used. Although the concept of instrumental priority is in line with this research, DR plans include the antecedents of price-oriented DR plans.

The objectives of the research are as follows:

• Determining the impact of considering customer preferences in home energy management programs.

• Determining the impact of considering energy tariffs in home energy management programs.

2- Daily Load Curve

The daily load curve is obtained by drawing the amount of electric load consumption during 24 hours. This curve characterizes the amount of consumption during a day and night and is widely used in planning and operation for power companies. Figure (1) shows an example of a daily load curve.

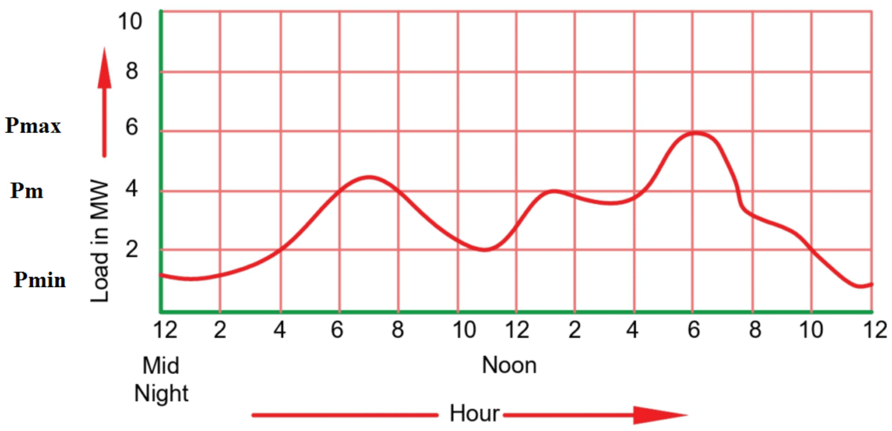


Figure 1: An example of a daily load curve

Each day of the week has its own load curve. Load consumption curves on holidays and non-holidays are different from each other. In different seasons of the year, according to the factors specific to each season, such as the length of the day, the load curve changes. Over time, due to the population growth and the economic growth of the society, the average amount of load consumption gradually increases or vice versa due to the optimization of electrical tools or economical measures of major electricity consumers. Changing consumer habits due to load management by electric energy producers or changing the economic structure (agricultural, industrial, residential and commercial) of the power supply and short-term load factors such as television programs are also effective on the structure of the load curve. By having the load curve, the amount of values such as maximum load consumption (Pmax), minimum load consumption (Pmin), average load consumption (Pm) and the amount of energy consumption can be easily extracted as the level under the load curve. The ratio of the average load consumption Pm during the year (or day) to the maximum load (peak consumption) of that year (or day) is called the load coefficient m.

This coefficient is considered one of the important parameters in power systems and is mainly expressed as a percentage. The closer this coefficient is to one, it indicates the better quality of energy consumption from an economic point of view for the energy supplier company. If this coefficient increases, the investments made by the company will be used more optimally. By taking measures, it is possible to improve the load factor by transferring load consumption from peak hours to non-peak hours.

3-Consumption management

Since the domestic sector of the country pays only the cost of the active energy consumed in the case of electricity consumption, that too in the form of a single tariff, so from the point of view of the time of electricity consumption, the electricity costs of this sector can be saved [17]. Multi-tariffing of electricity consumption costs in this sector is necessary to create motivation in rationalizing electricity consumption by these subscribers. Below are solutions to reduce the consumption of electrical energy in home use.

One of the ways to reduce electricity consumption in the home sector is to replace your old and high-consumption devices with new and low-consumption devices. In Iran, electricity consumption per capita in refrigerators and freezers is about 30% higher than international standards. Most washing machines made in the country use the cold water system. If these machines are replaced with machines that use heated water outside the system, a lot of energy is saved. Lighting devices are considered to be one of the major consumers of electrical energy in residential use, therefore, the use of lighting can be reduced to a large extent by using energy-saving lamps. The cooling system of buildings in Iran is mostly water coolers, gas coolers or air conditioners. According to the technology obtained in recent years, by taking measures, it is possible to increase the efficiency of these coolers and save a considerable amount of electrical energy.Considering that public, office, commercial, and domestic buildings are among the major energy consumers, therefore, the issue of developing scientific principles to reduce energy consumption through reducing thermal losses and maximum use of natural light has been considered for a long time. Many countries in the world have made it mandatory to create energy consumption standards in buildings and to implement them in new buildings, so that in new buildings, the use of suitable insulation, adaptation to weather conditions, the use of nature (trees and water features) and equipment Having proper control devices has greatly reduced the amount of energy consumption in general and the consumption of electrical energy in particular, and has made it possible to use energy optimally in buildings. In countries such as Iran, where the peak consumption is strongly affected by the increase in electricity consumption in lighting purposes, the prevalence of using energy-saving lamps is the best tool for load management, considering that the electricity consumption of compact fluorescent lamps is about 20% of incandescent lamps with the same light output. The complete replacement of such energy-saving lamps is suggested. The main problem of these lamps is that they cannot be replaced in some of the uses of the current lamps and if they are widely used, the current high consumption lamps will still maintain a part of their consumption market. Another form of these lamps is creating harmonics, which Installation of suitable filters can be fixed. Considering the high initial price of these types of lamps compared to incandescent lamps, it is very important to create an efficient subsidy system in this field.

Installing suitable meters in sync with efficient tariff system is one of the most important load management methods in the whole world, which is widely welcomed by customers. With the installation of multi-tariff meters, the electricity consumer is given the opportunity to apply appropriate load management policies and coordinate his consumption with the actual cost of production, which is announced in the form of different tariffs by the electricity companies. In different tariffs, it depends on the state of production and the balance of production and consumption of electricity, so that when the amount of production in the peak does not meet the consumption, the amount of the peak tariff can be declared very high, and on the contrary, when the production facilities are suitable, it can be The announcement of low tariffs encouraged consumers to consume. From the point of view of the priority of installation of multi-tariff meters, industrial, commercial, and high consumption domestic uses are placed respectively.

4-Systems Used in Home Management

An example of these smart buildings is shown in Figure 2. It also has a grid connection to obtain electricity during hours of peak power demand or to sell electricity to the grid when there is excess electricity generation. Every house has a number of household appliances, such as dishwashers, washing machines, etc. The building is assumed to be an energy management system, and communication systems are for the distribution of energy consumption plan. Since the model presented in this work only provides optimal planning for 1 day, the selection of equipment capacity is not considered here, and all equipment capacity is given. The real-time electricity price profile is known from the network and changes in one day. The maximum load demand for excess electricity consumption is given from the network. It is also assumed that the weather forecast can provide 24 hours of wind speed information. The heat demand is given from the whole building while the electricity demand depends on the performance of the household appliances.

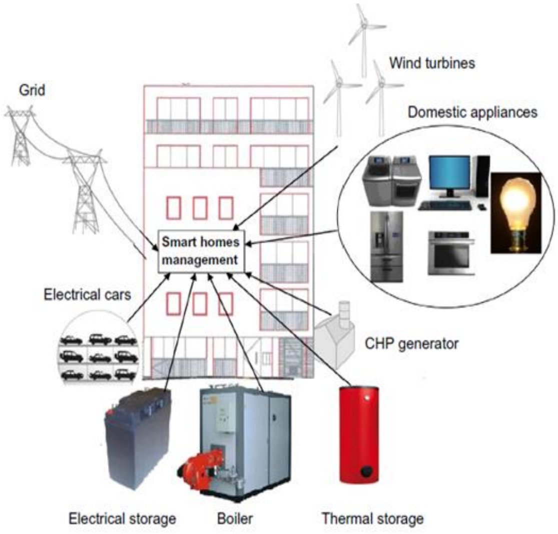


Figure 2- Systems used in household management

Renewable energy sources [18-29] can play a new way to solve this natural problem. Despite unlimited access to wind and solar energy, a self-sufficient wind or photovoltaic generator system cannot provide a 24-hour load. In other words, because the production of power in wind power plants is highly dependent on the presence of wind, they cannot be classified in the group of conventional generators. This fluctuating nature has caused challenges in the power grid so that most of the time the changes in wind and solar energy cannot fully provide the distributed load. In fact, the frequency changes created in power systems due to fluctuations in wind power production are one of the key factors in limiting the penetration level of wind energy.

With the development of distribution networks and the concept of microgrid, the use of renewable energy units in distribution networks is increasing. The concern that exists in the use of these production units is the intermittent nature of primary energy (wind and sun) in these units. Considering that wind speed changes are uncontrollable, the production power of wind turbines fluctuates, which can cause power quality phenomena such as frequency changes or voltage drop or voltage flicker. One of the ways to overcome this problem is to use energy storage systems or BESS. The use of these systems not only increases the reliability of the system, but also guarantees the stability of the transient state with their fast response. For example, if the power consumption of the network consisting of wind turbines is greater than the production power of the wind farm in a short period of time, in this situation the system faces a frequency drop and to prevent damage to consumers sensitive to this phenomenon, such as Inductive loads, the energy storage system comes into action with its high dynamic speed and compensates for the lack of power for this short period and returns the frequency to the nominal value to restore the balance between supply and demand. Another advantage of using the energy storage system next to the wind power plant is from an economic point of view. In other words, considering that the price of electricity and the production capacity of wind turbines change during the day, storing energy during periods when the price of electricity is low and then selling electricity during periods of high price is an economic idea. The purpose of the proposed idea is to use the changes in the price of electricity during the day and earn an income in this way, which requires a precise schedule for charging and discharging the energy storage unit. The profit from the sale of electricity in this strategy is related to the optimal use of the energy storage system.

A smart grid has the potential to change the operation of the power system, and this change occurs when renewable energy has the most interference with the traditional system. Managing renewable resources like traditional resources causes problems in system performance. By using the smart grid, it is possible to improve the connection of the traditional grid with renewable energies. During different times, production and load must match. Conventional

production can be controlled to a large extent, but the load and production of renewable energy must be predicted. The ability of the smart grid to process such information leads to significant improvements in the performance of renewable energy sources. In the smart grid, data must be available, however, these are future hourly forecasts that are useful for estimating the production and load of the power system and are obtained in most global networks. Usually, hourly forecasts are based on the use of statistical methods. Recent observations are used.
Although the implementation of the building management system increases the cost of building construction, the amount of savings in current building costs due to the implementation of this system can compensate the initial costs in a short period of time and also provide a higher level of comfort for the residents. To be accompanied intelligent control systems have a high level of flexibility that can be easily adapted to different needs. Also, during operation, it is possible to easily change and optimize operations for better management and reducing energy costs and reducing maintenance costs. Gave Also, building management systems have high controllability, and with the implementation of a suitable structure, it is possible to control its various components from all over the world. By defining different access levels, the controllability of different components can be leveled so that it is possible to make some changes only for authorized users and if the defined password is entered.
The intelligent building management system tries to manage the resources and resources of a building depending on its type of use (residential, office, commercial, etc.) by using control technologies. Smarting reduces the impact of factors such as human error, the rate of out-of-control events and accidents, and increases the reliability of the correct operation of building facilities and equipment and improves the general safety of the building. The functionality of various side systems or modern systems, such as condensing boilers, solar systems, cogeneration systems of electricity and heat (CHP), etc., which themselves have a separate control system through communicating the desired system with the management system There is a center and it can be defined in the system.
As a result, it can be concluded that with the proper use and careful management of the installed renewable resources, the cost of fuel and the amount of produced pollutants and the final cost will be reduced. Of course, this amount of reduction is if the goal is long-term exploitation. Because in the short term, due to the high cost of installing renewable sources, it will not be economical.
Considering the instability and lack of resources and the energy consumption situation in Iran and that a large percentage of this energy is wasted in the building due to incorrect design in the style of urban development as well as the design of the building. First, there should be a general revision in the constructions, then by means of the intelligent management system, we should reduce the energy consumption in the buildings to the minimum possible, and the buildings, through proper management and the use of smart equipment, will become buildings with maximum efficiency, comfort and Make it permanent. In this regard, it should be mentioned that since our country, Iran, is very suitable and prone to the use of renewable energy sources, especially the sun, therefore, the use of this source in the energy consumption basket of homes in residential areas due to having a flat roof and the possibility of installing the system These are very useful. On the other hand, using this source as a solar water heater and injecting produced hot water in the existing installation system helps a lot to reduce the energy consumption for heating water in the motor house. Also, the use of intelligent lighting energy supply systems in residential and office buildings that are intelligently lit when there is no light is another thing that has an effective role in energy consumption, on the other hand, automatic temperature regulation in the water supply and heating system of homes with Adjusting the temperature in different seasons and installing suitable sensors is another effective way to reduce the waste of energy resources, which is generally introduced as the application of automatic and intelligent energy supply systems and can be used in urban areas.

5- Conclusion

Load management that leads to the control of load growth and the proper shape of the load curve. It pursues various goals, these activities may be in order to reduce investment costs, eliminate limitations in the capacity of supplying electrical energy, create an optimal and economical energy supply, reduce service costs, improve the load factor, improve the efficiency and effectiveness of the system and The improvement of the reliability coefficient of the system has been established and implemented.

6- References

1. Luis Fernando Grisales-Noreña, Oscar Danilo Montoya, B. Cortés-Caicedo, Farhad Zishan, and J. Rosero, “Optimal Power Dispatch of PV Generators in AC Distribution Networks by Considering Solar, Environmental, and Power Demand Conditions from Colombia,” Mathematics, vol. 11, no. 2, pp. 484–484, Jan. 2023.
2. M. A. Judge, A. Manzoor, C. Maple, J. J. P. C. Rodrigues, and S. ul Islam, “Price-based demand response for household load management with interval uncertainty,” Energy Reports, vol. 7, pp. 8493–8504, Nov. 2021.
3. E. Akbari, A. R. Sheikholeslami, and F. Zishan, “Participation of Renewable Energy in Providing Demand Response in Presence of Energy Storage,” Renewable Energy Research and Applications, vol. 4, no. 2, pp. 225–234, Jul. 2023.
4. N. Ganjei et al., “Designing and Sensitivity Analysis of an Off-Grid Hybrid Wind-Solar Power Plant with Diesel Generator and Battery Backup for the Rural Area in Iran,” Journal of Engineering, vol. 2022, pp. 1–14, Feb. 2022.
5. P. Ma, S. Cui, M. Chen, S. Zhou, and K. Wang, “Review of Family-Level Short-Term Load Forecasting and Its Application in Household Energy Management System,” Energies, vol. 16, no. 15, p. 5809, Jan. 2023.
6. F. Zishan, E. Akbari, A. R. Sheikholeslami, and N. Shafaghatian, “Optimization and Placement of DG Resources in the Network to Reduce Line Loading,” International Journal of Industrial Electronics Control and Optimization, vol. 6, no. 2, pp. 89–100, Jun. 2023.
7. A. Barwińska-Małajowicz, R. Pyrek, K. Szczotka, Jakub Szymiczek, and T. Piecuch, “Improving the Energy Efficiency of Public Utility Buildings in Poland through Thermomodernization and Renewable Energy Sources—A Case Study,” Energies, vol. 16, no. 10, pp. 4021–4021, May 2023.
8. B. Bose, “Global Warming: Energy, Environmental Pollution, and the Impact of Power Electronics,” IEEE Industrial Electronics Magazine, vol. 4, no. 1, pp. 6–17, Mar. 2010.
9. Pudjianto et al., “Smart control for minimizing distribution network reinforcement cost due to electrification,” Energy Policy, vol. 52, pp. 76–84, Jan. 2013.
10. F. Zishan, E. Akbari, O. D. Montoya, D. A. Giral-Ramírez, and A. M. Nivia-Vargas, “Electricity retail market and accountability-based strategic bidding model with short-term energy storage considering the uncertainty of consumer demand response,” Results in Engineering, vol. 16, p. 100679, Dec. 2022.
11. O′ConnellN. P. Pinson, H. Madsen, and O′MalleyM. “Benefits and challenges of electrical demand response: A critical review,” Renewable and Sustainable Energy Reviews, vol. 39, pp. 686–699, Nov. 2014.
12. F. Zishan, S. Mansouri, F. Abdollahpour, L. F. Grisales-Noreña, and O. D. Montoya, “Allocation of Renewable Energy Resources in Distribution Systems While considering the Uncertainty of Wind and Solar Resources via the Multi-Objective Salp Swarm Algorithm,” Energies, vol. 16, no. 1, p. 474, Jan. 2023.
13. A. J. Conejo, J. M. Morales, and L. Baringo, “Real-Time Demand Response Model,” IEEE Transactions on Smart Grid, vol. 1, no. 3, pp. 236–242, Dec. 2010.
14. B. Zhou et al., “Smart Home Energy Management systems: Concept, configurations, and Scheduling Strategies,” Renewable and Sustainable Energy Reviews, vol. 61, no. 61, pp. 30–40, Aug. 2016.
15. S. Mansouri, t al., “Using an intelligent method for microgrid generation and operation planning while considering load uncertainty,” Results in Engineering, p. 100978, Feb. 2023.
16. A. Monge Vega, Santamaria F, and E. Rivas, “Modeling for home electric energy management: A review,” vol. 52, pp. 948–959, Dec. 2015.
17. A. Q. H. Badar and A. Anvari-Moghaddam, “Smart home energy management system – a review,” Advances in Building Energy Research, vol. 16, no. 1, pp. 1–26, Aug. 2020.
18. R. Alayi, F. Zishan, M. Mohkam, S. Hoseinzadeh, S. Memon, and D. A. Garcia, “A Sustainable Energy Distribution Configuration for Microgrids Integrated to the National Grid Using Back-to-Back Converters in a Renewable Power System,” Electronics, vol. 10, no. 15, p. 1826, Jan. 2021.
19. R. Alayi, F. Zishan, S. R. Seyednouri, R. Kumar, M. H. Ahmadi, and M. Sharifpur, “Optimal Load Frequency Control of Island Microgrids via a PID Controller in the Presence of Wind Turbine and PV,” Sustainability, vol. 13, no. 19, p. 10728, Sep. 2021.
20. B. Sadeghi, N. Shafaghatian, R. Alayi, M. El Haj Assad, F. Zishan, and H. Hosseinzadeh, “Optimization of synchronized frequency and voltage control for a distributed generation system using the Black Widow Optimization algorithm,” Clean Energy, vol. 6, no. 1, pp. 105–118, Dec. 2021.

21. L. Tightiz, S. Mansouri, Farhad Zishan, J. Yoo, and Nima Shafaghatian, “Maximum Power Point Tracking for Photovoltaic Systems Operating under Partially Shaded Conditions Using SALP Swarm Algorithm,” Energies, vol. 15, no. 21, pp. 8210–8210, Nov. 2022.
22. E. Akbari, Nima Shafaghatian, Farhad Zishan, Oscar Danilo Montoya, and D. Ramírez, “Optimized Two-Level Control of Islanded Microgrids to Reduce Fluctuations,” IEEE Access, vol. 10, pp. 95824–95838, Jan. 2022.
23. F. Zishan, E. Akbari, O. D. Montoya, D. A. Giral-Ramírez, and A. Molina-Cabrera, “Efficient PID Control Design for Frequency Regulation in an Independent Microgrid Based on the Hybrid PSO-GSA Algorithm,” Electronics, vol. 11, no. 23, p. 3886, Jan. 2022.
24. O. D. Montoya, F. Zishan, and D. A. Giral-Ramírez, “Recursive Convex Model for Optimal Power Flow Solution in Monopolar DC Networks,” Mathematics, vol. 10, no. 19, p. 3649, Jan. 2022.
25. F. Zishan, L. Tightiz, J. Yoo, and N. Shafaghatian, “Sustainability of the Permanent Magnet Synchronous Generator Wind Turbine Control Strategy in On-Grid Operating Modes,” Energies, vol. 16, no. 10, p. 4108, Jan. 2023.
26. F. Zishan, O. D. Montoya, and D. A. Giral-Ramírez, “New Design and Study of the Transient State and Maximum Power Point Tracking of Solid Oxide Fuel Cells Using Fuzzy Control,” Energies, vol. 16, no. 6, p. 2572, Jan. 2023.
27. A. Azari, A. S. Noghabi, F. Zishan, O. D. Montoya, and A. Molina-Cabrera, “Evaluating the Effect of the Communication Link of the Relays on the Operation Time of the Protection System,” Energies, vol. 16, no. 6, p. 2692, Jan. 2023.
28. Farhad Zishan, E. Akbari, and Oscar Danilo Montoya, “Analysis of probabilistic optimal power flow in the power system with the presence of microgrid correlation coefficients,” Cogent engineering, vol. 11, no. 1, Dec. 2023.
29. E. Akbari and Farhad Zishan, “Modified Topology and Modulation Technique for Z-Source Neutral-Point Clamped Inverter,” Power Electronics and Drives, vol. 7, no. 1, pp. 210–226, Jan. 2022.