KHAZAR UNİVERSİTY

Faculty: **Graduate School of Science, Art, and Technology**

Department: **Physics and Electronics**

Specialty: **Electronics and Automation**

MASTER'S THESIS

SUBJECT: Management with fuzzy logic of electrical energy obtained from solar panels and application in intelligent home systems.

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MAGİSTR TEZİSİ

Mövzu: Günəş panellərindən əldə edilən elektrik enerjisinin qeyri-səlis məntiq ilə idarə edilməsi və ağıllı ev sistemlərində tətbiqi.

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ABSTRACT

In this thesis, application of Fuzzy Logic controller to the building energy management system using solar power system energy as a renewable energy source has been put into practice in smart home automation buildings. Solar panels with 2 photovoltaic system with 150 Watt force value and 2 accumulators with 12 V 200 Ah values were used in this hybride power system. The aim of this study is to provide the created system both work autonomous and grid connected. According to this purpose, including the grid connection failure providing energy permanence on managed loads is aimed. This process done by Fuzzy logic controllable building energy managament system. Energy which is produced by hybrid system, firstly charges accumulators and then is transfered to grid or loads. If the hybrid system doesn’t produce energy and batteries are empty, continuity of autonomous loads are compensated from city grid. Additionally before the connecting to the city grid, the controller can analyze home distribution system for supply to the life safety and most importance loads such as , fire alarm control system, access door system, wifi network and extar low voltage power supply. The most important factor here is to ensure the stability of the energy supply of important loads. Second issueis that, energy saving by opening unnecessary loads and also reducing unnecessary energy consumption in smart home systems through specially applied lighting, brightness, movement and precense sensors has been studied.

Keywords: Smart home, photovoltaic panel (PV), renewable energy, DC/DC converter, DC/AC inverter, fuzzy logic controller

XÜLASƏ

Bu tezisdə günəş panellərindən alınan elektrik enerjisinin bərpa olunan enerji mənbəyi kimi istifadə edərək binanın enerji idarəetməsini qeyri-səlis məntiqin tətbiqi ilə idarə olunması tədqiq edilmişdir. Bu hibrid enerji sistemində 150 Vatt gücündə 2 fotovoltaik sistemli günəş panelləri və 12 V 200 Ah gücündə 2 akkumulyator istifadə edilmişdir. Bu tədqiqatın məqsədi yaradılmış sistemin həm avtonom işləməsini, həm də şəbəkəyə qoşulmasını təmin etməkdir. Bu məqsədlə, idarə olunan yüklər üzərində enerji davamlılığını təmin edən şəbəkə bağlantısının kəsilməsi hədəflənir. Bu proses qeyri-səlis məntiqlə idarə oluna bilən bina enerjisinin idarə edilməsi sistemi tərəfindən həyata keçirilir. Hibrid sistemlə istehsal olunan enerji əvvəlcə akkumulyatorları doldurur, sonra isə şəbəkəyə və ya yüklərə ötürülür. Hibrid sistem enerji istehsal etmirsə və batareyalar boşdursa, həyati vacib və binanın idarəetməsi üçün lazım olan yüklərin davamlılığı şəhər şəbəkəsindən kompensasiya edilir. Bundan əlavə, şəhər şəbəkəsinə qoşulmazdan əvvəl nəzarətçi evin paylama sistemini həyat təhlükəsizliyi və yanğın siqnalizasiyasına nəzarət sistemi, giriş qapısı sistemi, WiFi şəbəkəsi və zəif axın enerji təchizatı kimi ən vacib yükləri təhlil edə bilər. Burada ən mühüm amil mühüm yüklərin enerji təchizatının sabitliyini təmin etməkdir. İkinci məsələ ondan ibarətdir ki, xüsusi tətbiq olunan işıqlandırma, parlaqlıq, hərəkət və dəqiqlik sensorları vasitəsilə ağıllı ev sistemlərində lazımsız yüklərin açılması yolu ilə enerjiyə qənaət, həmçinin lazımsız enerji sərfiyyatının azaldılması tədqiq olunub.

Açar sözlər: Ağıllı ev, günəş panelləri, bərpaolunan enerji, DC/DC çevirici, DC/AC inverter, qeyri-səlis məntiqli kontroller

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INTRODUCTION

Relevance of the topic. Energy is not the only factor that causes economic growth, but it is a critical factor. Energy is considered a factor that indirectly affects the growth of monetary investments. This proves the importance of energy for sustainable development. With energy in our life, it is possible to run a factory, produce products, travel, send goods and services from the producers to the clients, etc. Because energy is so essential, industrialized nations compete with each other to control energy resources. Today, the events taking place in the region and in the world, which have the strategic importance of oil and gas, once again show how important energy is.

In modern times, the decrease in energy reserves, the fluctuating prices, and the conflict of interests of the world's countries for political, economic, and energy sources make it necessary for each country to define a strong strategy to ensure energy security.

In ensuring the country's energy security, the reliable supply of energy carriers to the population and the economy, diversification of fuel and energy types, the use of renovable energy fuentes, and the efficient and effective use of energy resources are particularly important. Efficient use of energy resources is defined as one of the main directions of sustainable energy policy. Energy efficiency is important for countries that want to have a strong and sustainable economy.

Energy efficiency is the reduction of the amount of energy consumed without reducing the quantity and quality of production, without creating an obstacle to the improvement of the level of financial development and well-being. In a broad sense, energy efficiency and energy saving mean reducing the losses of energy resources (electricity and heat energy, natural gas, gasoline, diesel, etc.), ensuring the recovery and evaluation of waste and energy, meeting the energy demand without affecting production through the application of modern technologies and scientific and technical achievements. Includes measures such as reducing and increasing the use of alternative and renewable energy sources. Energy efficiency is not only aimed at saving resources but also creates conditions for sustainable economic development, the transition to a green economy and ensuring environmental safety, the production of competitive and cheap industrial and agricultural products, increasing the supply of consumers with energy carriers, and reducing wastage and excess costs in communal services. If energy efficiency is not ensured, the country's excess funds spent on energy resources will remain a major problem in the face of economic development and social welfare.

Ensuring energy efficiency is one of the main components of the energy security policy of our country. Energy resources should be used efficiently and effectively to ensure the stability of our country's energy security, reduce the energy capacity of the gross domestic product, strengthen the competitiveness of the country's economy, protect the environment, and reduce wastage and excess costs in communal services.

Effective use of energy resources and ensuring the energy efficiency of end users simultaneously creates conditions for achieving sustainable development of the country's economy, increasing export potential, increasing the supply of energy resources to consumers, and protecting the environment and energy resources. It is a more effective and efficient management method of electric energy obtained from solar panels from alternative energy sources by applying fuzzy logic.

The purpose of the thesis. The main purpose of the dissertation is to provide a control system for fuzzy logic management of electricity from solar panels.

The research object of the thesis.The processes related to the problem arising during the operation of the electric energy received from the solar panels, and the subject of the research is managing the electrical energy from solar panels with fuzzy logic and its application in smart home systems.

The scientific innovations of the work. At present, the use of solar panels for energy supply in newly built buildings in the territory of Karabakh and Zangezur economic regions, which have been freed from occupation, is becoming widespread in our country. The application of fuzzy logic in this energy management also improves the energy consumption of the controllers used in the management of smart homes. It also ensures proper management of energy received from solar panels.

The structure of the work. The presented dissertation was compiled as a result of the observations made in the research facility and the collected theoretical data.The dissertation consists of an introduction, literacy review, three chapters, a conclusion, and a bibliography.

The dissertation consists of 73 pages and 38 figures and 7 data tables. The list of used literature includes 53 titles of literature.

CHAPTER 1

1. PRİNCİPLES OF BUİLDİNG SOLAR PANELS USİNG SOLAR ENERGY

1.1. Literacy Review

Since the birth of fuzzy set and the first application in the process control domain this set theory has become broad, deep, and systematic and has found many applications in laboratories and industries. Extensive fuzzy logical control algorithms have been proposed and many of them implemented successfully. (Zadeh, 1965; Mamdani, 1977)

The self-organizing FLC and some other run time adaptive approaches to automated fine-tuning of FLCs have been proposed (Bartolini, 1985). These adaptive schemes reduce the time and effort required of the controller designer to finetune the system. These adaptive methods base their modifications to the fuzzy logic controller on a local evaluation of the system's performance and the resulting global performance of the controller are somehow improved at the same time. Fuzzy set theory, which was first defined mathematically by Zadeh in 1965, started to enter electronics and automation applications only in the second half of the 1980s. In 1993, Christos Douligeris classified home automation products. (Christos, 1993)

Lan Zhang, Henry Leung and Keith Chan carried out the study and application of combining the smart home control system with basic knowledge in their studies. Here, information is checked and collected with internet access. In the network inside the house, it is connected to radio waves via bluetooth and the user's requests are calculated with fuzzy logic and sent to the device unit inside the house. From here, it is sent to the peripheral devices. (Zhang et al., 2008)

Zhang, McClean Scottney, Hong; Nugent and Mulvenna carried out an important study in 2008. They have designed a healthy home environment project for elderly and disabled people and Alzheimer's patients who need help. In the designed system, basic information such as people's resumes are sent to smart sensors and evaluated there. In this way, both ease of movement and 24-hour health control can be provided for these people. It is known that 18 million people worldwide have Alzheimer's disease. When this is taken into consideration, it is understood how important but still insufficient studies are. (Zhang et al., 2008)

Today, smart home technology provides home and environmental security, and many processes such as heating and cooling of the house, automatic control of the garage and garden door, supervision of the children at home from the office, automatic irrigation of the garden are carried out. Each newly built smart house brings a different perspective to automation by revealing its superiority over the previous one.

H.Işık and A.A.Altun controlled a system created in a home environment using a microcontroller and the devices connected to this system using a mobile phone in their work that they designed and implemented in 2005. Before the system was designed, the circuit that decodes the key codes sent from the person's mobile phone, that is, DTMF (Dual Tone Multi Frequency) tones, was designed. After decoding the DTMF tones coming to the mobile phone connected to the system, the decoded code was processed with the help of the programmed PIC 16F84 microcontroller. This implemented system is open to development. In addition, the number of controlled devices connected to the system can be increased depending on this improvement. (Işık et al., 2005)

Infrastructure in smart homes needs to be flawless. If not, the smart home is nothing more than a nightmare. The smart home managed by the mainframe has a complex technological infrastructure. Apart from the fact that all devices in the house understand the user's language, the devices must understand each other. In other words, there is a need not only for smart products in the house, but also for the service that will perform the installation and, more importantly, the maintenance of the technology in the house.

Despite all the convenience that smart homes add to our lives, the concept of smart home can sometimes cause negative consequences. Health problems such as dizziness, nausea, and difficulty in adaptation, which occur as a result of improper regulation of air conditioning systems, are among the most common problems especially in office environments.

Another problem encountered in smart homes is; The issue of “accessibility” in such houses with fully electronic equipment. In case of any disruption in the network system, since there is no manual intervention by the user, the living space can become open to every corner over the internet. With this; programming a computer system so that when one plan fails, another one kicks in, setting it up securely and by ensuring that the system is operated by experts, can be remedied. There isn't a widely agreed-upon definition of the Internet of Things in general. Although the term's initial use has been credited to Kevin Ashton, a specialist in digital innovation, there are really many other groups of people who have defined it. (Yuejun et al.,2005).

The unifying theme among these definitions is that the first iteration of the Internet was about data produced by humans, whereas the second, known as the Internet of Things, was about data produced by things. The unifying theme among these definitions is that the first iteration of the Internet was about data produced by humans, whereas the second, known as the Internet of Things, was about data produced by things. The Internet of Things is defined in a variety of ways. Listed below are a few definitions: In general, the Internet of Things (IoT) was described as "dynamic global network infrastructure with self-configuring capabilities based on standards and interoperable communication protocols; physical and virtual 'things' in an IoT have identities and attributes and are capable of using intelligent interfaces and being integrated as an information network". (Ashton, 2009) IoT aims to enhance the functionality of the original Internet and make it more practical. Users can share information provided by items in the actual world as well as information provided by humans and stored in databases using the Internet of items (IoT). (Li et al., 2015)

The Internet of Things (IoT) is an intelligent ecosystem of pervasive computing that connects physical objects to the Internet and to one another for a variety of practical reasons. Incorporated intelligence that is capable of detecting changes in an object's physical condition can also be used to describe it. We can say that the Internet of Things (IoT) is a new technology system that combines a lot of information technologies because the general definition of IoT is that it involves computers, sensors, and things interacting with each other and processing data. Different technologies are combined into the semi-autonomous Internet of Things. It establishes connections between individual devices and the network. In the network, there are also controller systems (software and services) that serve as the system's brains for processing data by analyzing and interpreting the information gathered by the connected devices to decide what to do and how to do it from the same or different devices. (Zhong, 2015)

The main goal of IoT is to provide us the ability to use the internet to uniquely identify, signify, access, and control anything at any time and from any location. Numerous intelligent and autonomous apps and services that have considerable advantages for one's personal, professional, and financial well-being may emerge as a result of the interconnected device networks. (Miller, 2015)

When we conduct this literature review, we see that most of the above-given literature on smart homes mainly focuses on possible energy security problems that can happen to smart homes. A lot security issues are repeated by different authors in different years and some differ. I can't see any paper that covers the entire architecture of smart homes, from home to remote server, and focuses only on some parts of the system, and in my thesis I will close this research gap by conducting a comprehensive energy security risk assessment for the entire system. Also, these documents are not about possible solutions or countermeasures for every mentioned threat. Neither the implications nor recommendations were presented in their article. to investigate this gap, research questions were defined.

1.2 Alternative energy sources and solar panels

One hundred thirty years ago, when Thomas Edison demonstrated the invention of the incandescent lamp, he said: "We can make power so reasonably priced that simplest the wealthy will mild candles". Unfortunately, the non-rich still burns candles, and electricity costs still represent a significant portion of the total operating costs of buildings. With the increase in the use of electricity for lighting, some measures should be taken to reduce costs. With the rapid development of automation systems in structures called smart buildings, ventilation, heating, cooling, energy control, and security systems can be controlled from a central location. Large enterprises generally prefer these systems, such as large shopping malls, hotels, hospitals, museums and libraries, airports, cultural centers, bank offices, and high-rise buildings in general (Lin et al., 2021). Households accounted for 43. Three percent of final energy consumption, industry and construction for 20.2 percent, transport for 23.2 percent, and other sectors of the economy for 13.3 percent. This rate is around 40% on average in all countries. 60% of the electricity consumed in the housing and service sector is intended only for lighting purposes, equal to 21% of the energy consumed in Azerbaijan. Therefore, unnecessary and uncontrolled lighting in the building consumes energy and increases the facility's operating costs. Efficient energy use in lighting will significantly contribute to the country's economy. As in other developing countries, the demand for energy in our country is increasing day by day due to reasons such as the continuation of industrialization and rapid population growth. Between 2009 and 2020, primary energy consumption increased by 32%.

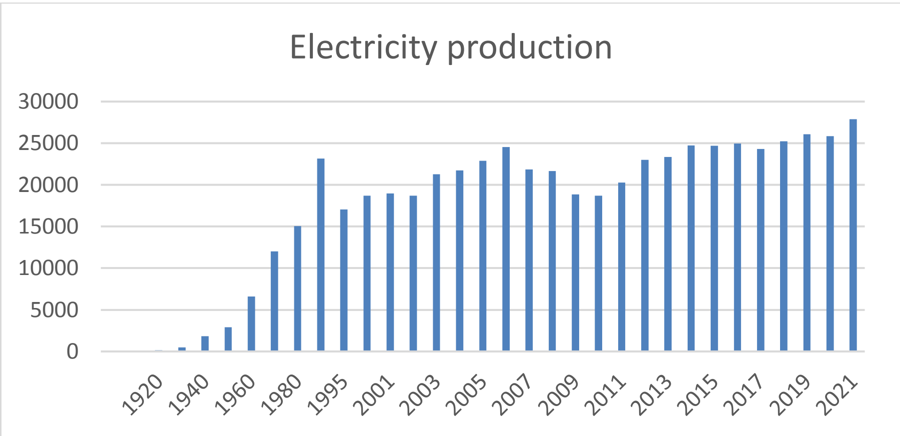

Figure 1.1. Total electrical energy production chart in Azerbaijan

According to the information of the countries that are members of the Organization for Economic Cooperation and Development, our country is at the forefront due to the increased demand for electricity between 1913 and 2021. This increase is visible in Figure 1.1. It is known that for non-traditional, renewable energy sources, the possibilities are enormous. These sources include the Sun, the planet, geothermal waters, wind, swells and drafts, rivers, biogas, hydrogen, biomass, and fuel cell energy can be cited as an example.

Table 1.1. Electrical energy production by the types in Azerbaijan (www.stat.gov.az)

5.4 Elektrik enerjisinin istehsalı, milyon kVt·st

İllər	Elektrik enerjisinin istehsalı	o cümlədən:							
		yanacaqla işləyən ES və İES-lər	SES-lər	müəssisələrin daxili ehtiyaclarının ödənilməsinə xidmət edən stansiyalar (yanacaqla işləyən)	generatorlar vasitəsilə	külək elektrik stansiyaları	günəş elektrik stansiyaları	tullantıların yandırılmasından alınan elektrik enerjisi	biokütlənin yandırılmasından alınan elektrik enerjisi
1913	110.8	...	...	...	...	-	-	-	-
1920	122.0	...	...	...	...	-	-	-	-
1930	503.9	...	...	...	...	-	-	-	-
1940	1,826.3	1,802.0	24.3	...	...	-	-	-	-
1950	2,923.5	2,894.0	29.5	...	...	-	-	-	-
1960	6,589.0	4,626.0	1,963.0	...	...	-	-	-	-
1970	12,026.7	10,893.0	1,022.0	111.7	...	-	-	-	-
1980	15,045.2	13,825.0	1,098.0	122.2	...	-	-	-	-
1990	23,152.6	21,399.0	1,658.0	95.6	...	-	-	-	-
1995	17,043.6	15,401.0	1,556.0	86.6	...	-	-	-	-
2000	18,699.1	17,069.0	1,534.0	83.1	13.0	-	-	-	-
2001	18,969.1	17,521.0	1,301.0	131.2	15.9	-	-	-	-
2002	18,700.6	16,558.0	2,020.0	103.8	18.8	-	-	-	-
2003	21,286.3	18,681.0	2,470.0	104.9	30.4	-	-	-	-
2004	21,743.2	18,589.0	2,755.0	365.4	33.8	-	-	-	-
2005	22,871.5	19,344.0	3,009.0	430.5	88.0	-	-	-	-
2006	24,542.7	21,407.0	2,518.0	475.9	141.8	-	-	-	-
2007	21,847.0	19,051.0	2,364.0	432.0	-	-	-	-	-
2008	21,641.6	19,090.0	2,232.0	319.6	-	-	-	-	-
2009	18,868.3	16,289.0	2,308.0	269.2	-	2.1	-	-	-
2010	18,709.2	15,003.0	3,446.0	259.7	-	0.5	-	-	-
2011	20,294.0	17,317.0	2,676.0	301.0	-	-	-	-	-
2012	22,988.0	19,537.0	1,821.0	1,630.0	-	-	-	-	-
2013	23,354.4	20,065.6	1,489.1	1,664.0	-	0.8	0.8	134.1	-
2014	24,727.7	21,401.2	1,299.7	1,848.1	-	2.3	2.9	173.5	-
2015	24,688.4	20,904.6	1,637.5	1,955.3	-	4.6	4.6	181.8	0.0
2016	24,952.9	20,699.0	1,959.3	2,062.0	-	22.8	35.3	174.5	0.0
2017	24,320.9	20,445.4	1,746.4	1,899.5	-	22.1	37.2	170.3	0.0
2018	25,229.2	21,242.9	1,768.0	1,934.1	-	82.7	39.3	162.2	0.0
2019	26,072.9	22,289.7	1,564.8	1,872.9	-	105.4	44.2	195.9	0.0
2020	25,839.1	22,471.3	1,069.5	1,954.6	-	96.1	47.0	200.6	0.0
2021	27,887.8	24,308.8	1,277.3	1,961.9	-	91.4	55.2	193.2	-

The importance of these energies in people's living conditions even more so in the recent period when it has improved and the energy demand has increased sharply is multiplying. Among the types of renewable energy, the most expensive are the ones are three:

- Solar energy;
- the planet's (gravitational) energy;
- geothermal energy.

The annual amount of solar energy falling on the Earth is $3{,}9 \cdot 10^{24}$ C or $1{,}08 \cdot 10^{18}$ kWh.

(In some sources, It is shown to be $1.57 \cdot 10^{18}$ kWh.) This is another user on the ground about 10,000 times of primary energy types, energy reserves, and many times more than the sum of all the types available to people it's a lot. However, the density of this type of energy falling on the ground is generally very small compared to its value. The energy of the SunSun falling on the Earth exceeds all energy reserves and annual energy consumption. Solar energy can be used in different ways. It mainly depends on the form of solar energy and how it is used. The following picture Figure 1.2 shows the forms of solar energy and the possibilities of using it.

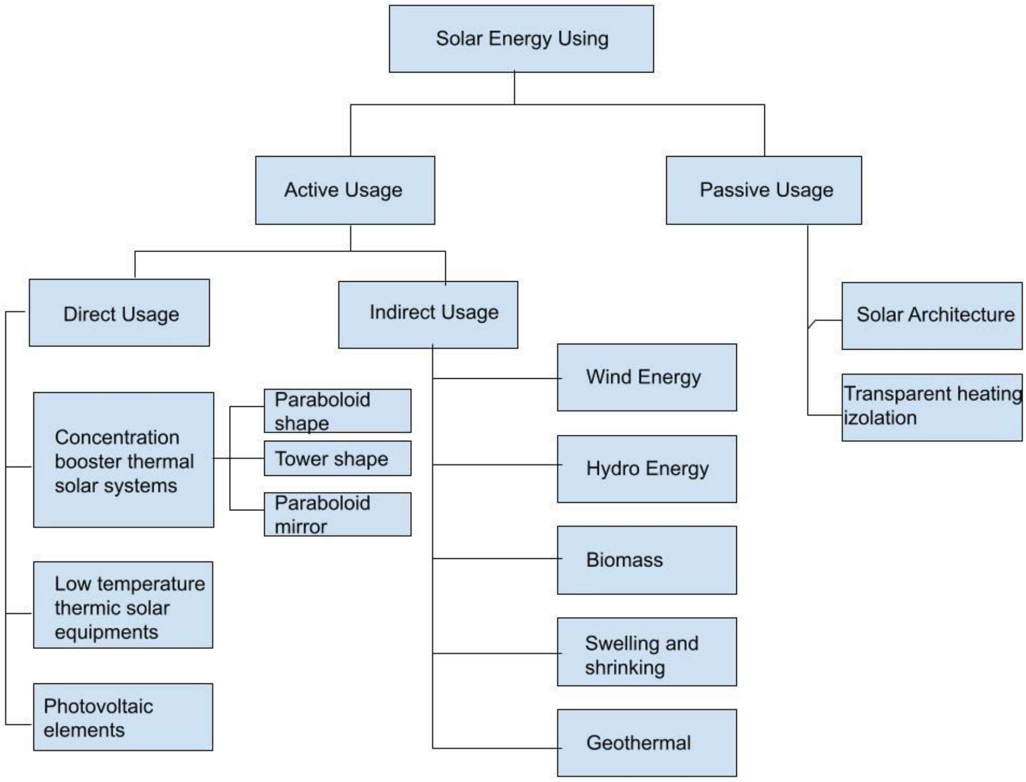

Figure 1.2. Solar energy usage diagram

It can be seen from here that solar energy is used actively and passively. Active resignation is possible in direct and indirect ways. Examples of devices that increase the concentration of solar energy for direct use are low-temperature thermal solar devices and photovoltaic elements. Low-temperature thermal solar installations are usually of houses applied for heating or hot water supply. The role of photovoltaic elements is great in the direct conversion of solar energy into electricity. These photovoltaic elements are Solar energy directly without being converted into another form of energy converted into electricity.

The Sun is an inexhaustible source of energy and heat. The possible production capacity of the energy it gives to the Earth is estimated at 20 billion kW. Considering that the Sun sends $68.8.10^{16}$ kW of energy to the Earth daily, its use is almost zero. The amount of solar energy falling on the surface of the Earth is $1.2x10^{14}$ T conventional fuel. Solar energy is considered the most environmentally friendly and cost-effective. The process of converting this energy into electrical energy in the ecological environment, living and non-living, does not harm the world; it does not cause any changes in the evolution of the energy balance for a long time. Now in many countries of the world, solar energy is used through cooling devices. At present, special facilities are used for the processing, drying, etc., of agricultural products from the sweetened sea and ocean waters. used for purposes. It has been estimated that supplying water heated by a solar battery to a building with an area of 1,000 km2 saves electricity by 45-50 percent. Back in the 1960s, according to the "Sunrises" program developed by Japan, solar devices were used for heating and cooling buildings, and more than 250 thousand such devices were in operation.

Since solar energy is sparsely distributed on the Earth's surface, it is difficult to obtain electricity from it. One of the reasons for this difficulty is that to collect solar energy, solar cells are required to be installed in very large areas. On the one hand, the occupation of large areas of land; on the other hand, the high cost of batteries does not allow the use of this energy to be economically and ecologically efficient. The most convenient way to use solar energy is to operate space power plants powered by solar cells. It is believed that even though the SES operating at a distance close to the Earth's orbit occupies a large area, it can become the most profitable production area in the future. At a distance close to the Earth's orbit, the solar energy converted into electrical energy is transmitted to the planet by special devices and creates an electric current.

In modern times, the limitation of traditional fuel resources and the lack of these resources in many countries suggest the use of solar energy on a large scale. For example, in the "Sun Village" located on a plateau 200 km from the capital of Algeria, the 2500 inhabitants of the village get their heat, steam, fuel, and electricity entirely from the Sun is paid at the expense of heat. "Solar basins" created in Israel, on the coast of the Dead Sea, in Australia, in the USA, and in Algeria drive 5-50 kW GES. In our country also appling solar system in the villages for building new villages in Karabagh region , another mountain villages and also lot of industrial regions.

As we know, using electricity is more affordable, convenient, and efficient than other types of energy. Therefore, learning the principles of obtaining electricity from solar energy and using it is currently one of the most critical issues. According to the information provided by the International Energy Agency (IEA), 66% of the energy used in the world comes from organic fuel, of which coal is the central part. The share of renewable energy sources is only 2.8%. Solar modules share 0.6% of this share. The progress of solar technologies from year to year increases the demand for the participation of this field in the energy industry. The advantages of solar energy can be classified as follows:

- Lack of dependence on external influences;
- Being a cheap source of energy, excluding the cost of production and installation;
- Absence of transportation, transportation, and transmission problems;
- Being an inexhaustible and ecologically clean source of energy;
- Storage of solar power in a special way when energy is not used;
- Giving concessions by the government and organizations to houses or areas that use solar energy for their participation in environmental protection;
- The possibility of selling surplus energy from the SunSun- to the electricity grid. In addition to all this, we can say that by using solar energy, we support greening; we also maintain a favorable position of business, efficient development, and energy reliability at all times. Solar energy can be converted into thermal, mechanical, and electrical energy and can be used in chemical and biological processes. Electricity from solar energy is mainly obtained in two ways: The first method is the traditional method of obtaining electricity from solar energy. An example of this is to feed steam to a steam turbine and their electricity energy can be produced. The second method is the purchase of electricity with the help of solar cells. With their help, the thermal energy of the Sun's rays can be directly converted into electrical energy. Solar elements are used for this. The thermal energy of the Sun'sSun's rays is converted into electrical energy in these elements, resulting in a constant electric current. This process is based on the famous photo effect. It is the transformation of this energy. A typical solar cell produces a voltage of 0.5 to 1V and can produce about 0.7W of electricity. A solar panel consists of many solar cells. The electricity requirements of many households in remote areas are fulfilled by using solar panels. Streetlights and traffic lights are also powered by solar energy.

PV cells are produced using semiconductor materials. They are typically obtained by combining two thin semiconductor materials, p-type and n-type. Electron transfer takes place between these two semiconductor materials. Although many semiconductor materials can be used in PV cell construction, crystalline silicon is commonly used. The crystalline silicon cell is divided into groups such as single crystal silicon (sc-Si) and polycrystalline silicon (mc-Si), depending on the production technology of the silicon used in its construction. In 2010, 87% of the PV panels sold worldwide were produced with crystalline silicon technology. The yields of crystalline silicon materials vary between 14% and 19%. Another material used in PV cell construction is Amorphous silicon (a-Si). Amorphous silicon is a material used in thin film technology. The efficiency of panels using amorphous silicon varies between 4% and 8%. In the laboratory environment, their efficiency can reach up to 12%. Some companies produce panels using a-Si for use in curved areas such as roofs and facades. Another material used in thin film technology is Cadmium Telluride (CdTe). Cadmium Telluride thin film technology is cheaper and has higher cell efficiency (16.7%) compared to other thin film technologies. Cadmium telluride contains cadmium, a by-product of zinc mining, and telluride, a by-product of copper mining. The most important problem of this material is that telluride is produced less than cadmium and its production is dependent on the copper sector for many years. Another material used in thin film technology is Copper Indium Selenide (CIS). Of all thin-film PV technologies, CIS PV technology provides the highest efficiency. Today, the panel efficiencies vary between 7% and 16% today, the level of 20.3% has been reached in the laboratory environment. Although not as widely used as the technologies described above, there are two other types of production technologies: concentrator PV cell technology and organic PV cell technology. In concentrator cell technology, daylight is concentrated by means such as lenses. The downside to these types of cells, however, is their requirement to receive light at a constant right angle. Organic PV cells are made using organic or polymer materials. Although not very expensive, their efficiency is between 4-5% in commercial PV panels and 6-8% in laboratory environment. Therefore, their use is not widespread. Photovoltaic is the process of producing electric current by photons of light. Semiconductors such as silicon, gallium arsenic, cadmium telluride or copper indium diselenide are used as materials to absorb light photons. They are similar in structure to diodes consisting of p and n junctions. In order for these semiconductor materials to be used in PV cells, they must be doped in p or n type. By adding the necessary additives into the p or n type base material, p-n junction surfaces are formed. The oppositely charged majority carriers in the Combination Zone merge and disappear in a short time. However, due to the "crippled atoms" they leave behind, a negative charge density occurs in the p region and a positive charge density in the n region. Thus, a potential difference occurs between the two sides of the joint surface. This potential difference, which occurs at the depth of the junction zone, prevents the charge carriers outside this zone from being destroyed as a result of their merger by passing to the opposite side; in other words, it creates a force equivalent to the force with which opposite charges attract each other, keeping the crystal in balance. In order for the silicon crystal to produce a measurable voltage or power, an external energy flow in the form of a luminous flux is needed. In this case, the newly generated charge carriers (majority carriers) shift to the opposite polar regions with the effect of the Diffusion Voltage and cause the polarization of the crystal by polarizing the regions they leave in opposite signs. This voltage is called the "Open Circuit Voltage Uoc" of the crystal. With this polarization, which results in a very short time, a measurable voltage difference occurs between the outer surfaces of the crystal. If a load is connected to the cell output, an electric current is generated. The PV cell structure is similar to the diode as described above. In order to prepare the simulation models of the PV cell, it is necessary to obtain its mathematical equations. In order to derive these equations, the electrical equivalent circuit of the PV cell must be known. The PV cell is expressed as a current generator. ISC in the equivalent circuit represents the photon current, the diode p-n semiconductor junction surface, and the losses in series and parallel resistors. In the equivalent circuit, using Kirchhoff's law of currents and voltages, the output current (I_{PV}) and voltage (V_{PV}) of the PV cell can be calculated.

$$Ipv = Isc - Id\text{-}Vd/Rp \tag{1}$$

$$V_{PV} = V_D - R_s I_{PV} \tag{2}$$

Since the parallel resistance seen in the equivalent circuit is much larger than the series resistance, the series resistance can be neglected for ease of calculation and modelling. Thus, the diode current can be expressed by equation 2

$$I_D = I_O \ \hat{}e^{\frac{Vd}{Vt} - 1} \tag{3}$$

$$V_T = k{*}T / q \tag{4}$$

Where

I_{SC}: Short circuit current,

I_D: Diode current,

V_D: Diode voltage,

R_S: Series resistance,

R_P: Parallel resistance,

I_0: Diode saturation current,

V_T: Thermal voltage,

k: Boltzman constant (1.381x10-23J/K), and

T: Absolute temperature.

The decrease in panel power depending on the temperature or the amount of radiation causes the already low panel efficiency to decrease further. In order to prevent a decrease in efficiency, it is necessary to obtain maximum power from the PV panels under all conditions.

For this, maximum power point tracking (MPPT) is applied. By following the maximum power point, the panel power can be increased between 10% and 30% depending on the changing working conditions. There are many algorithms developed for maximum power point tracking. The most used of these algorithms are; mix and observe method, incremental transmission method, disruptive capacity method, constant voltage method. Among the aforementioned methods, the most widely used one is the mix and observe method due to its easy applicability. This method regulates the operating voltage and current until maximum power is obtained from the PV panel. PV power systems are generally classified according to the way the produced energy is used, the type of voltage produced, the size of the PV system in terms of power and its connection with other energy sources. The PV power system can be operated to produce direct current (DC) and/or alternating current (AC), autonomous or grid-connected, or in conjunction with other energy sources and/or storage elements. PV systems are also classified as small power (up to 10 kW), medium power (10 kW to 500 kW) and large power (greater than 500 kW).

The solar power plant is classified into two types according to the way the load is connected- Standalone and Grid connected. The standalone system operates as a separate power source. It is not wired into a grid. It has a direct connection to the load. When a grid is not available, such as in a forest or hilly location, this sort of plant is employed. This kind of plant is used to provide the load when the grid's electricity is unavailable. It can also be utilized as a backup power source. The system can be used without a battery and charge controller. However, to boost reliability, this method is typically used in conjunction with a battery and charge controller. DC loads can connect directly to this plant. For an AC load, however, an inverter is necessary to convert DC electricity into AC.

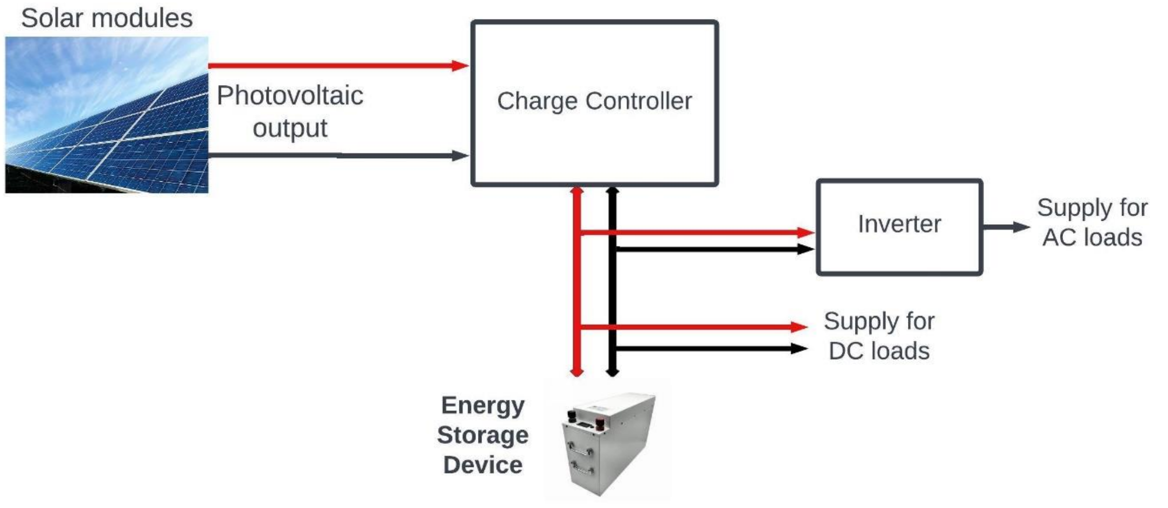

Figure 1.3. Standalone system connection diagram

The standalone system falls into the categories listed below.

-Direct-coupled standalone system

-Standalone system with battery storage

-Standalone system with batteries and charge controller

-Standalone system with AC and DC loads

-Hybrid standalone system

Direct-coupled standalone system. The solar panels and loads are connected directly in this kind of system. Due to the lack of an inverter, this system is not appropriate for an AC load. So, the solar panel provides direct power to DC loads. When there is no sunshine or at night, this mechanism cannot function. Typically, this kind of system is employed in agriculture to run pump sets and other agricultural auxiliary equipment. The picture in Figure 1.4 depicts the system's block diagram.

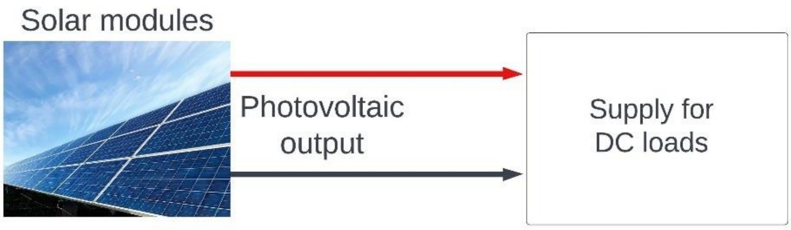

Figure 1.4. Direct coupled standalone system.

Battery-Powered Stand-alone System is possible to use this kind of device when there is no sunlight. The solar panel is utilized to recharge the battery during the daylight hours when sunshine is present. Additionally, the battery is utilized to provide electricity at night. Because it does not use a charge controller, this technology is inexpensive. But under this arrangement, the battery could be overcharged or entirely discharged, which shortens the battery's lifespan. The picture in Figure 1.5 depicts the system's block diagram.

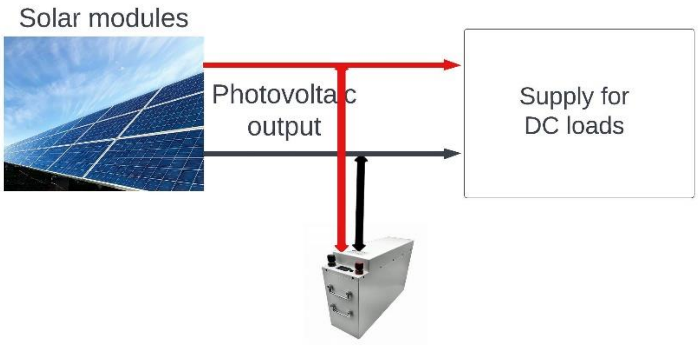

Figure 1.5. Battery supplied standalone system.

Independent System with Battery and Charger - The battery's charging and discharging are managed by the charge controller. This system has a hefty price. However, this system has a long lifespan. In comparison to a standalone system without a charge controller, the battery operates more effectively because of the charge controller. The picture in Figure 1.6 depicts the system's block diagram.

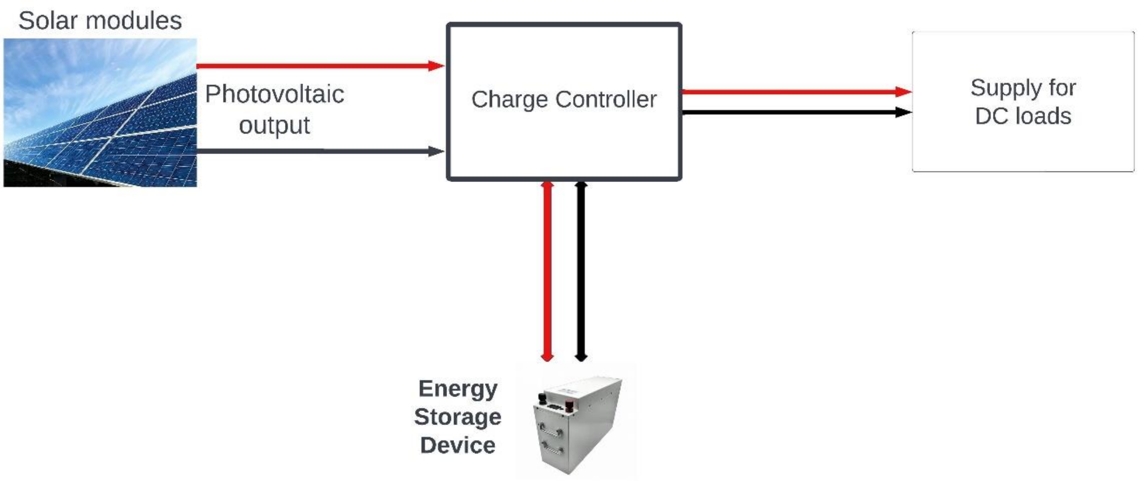

Figure 1.6. Charge controller and Battery supplied standalone system.

Independent system with loads (AC and DC) The solar panel produces DC power as its output. Therefore, a DC load can be connected to a solar system directly. However, the inverter is required to transform the DC power into AC power if you need to connect an AC load. This plant typically has connections to other AC sources as well. And when sunshine is not there, this source is used to charge batteries. The picture in Figure 1.7 depicts the system's block diagram.

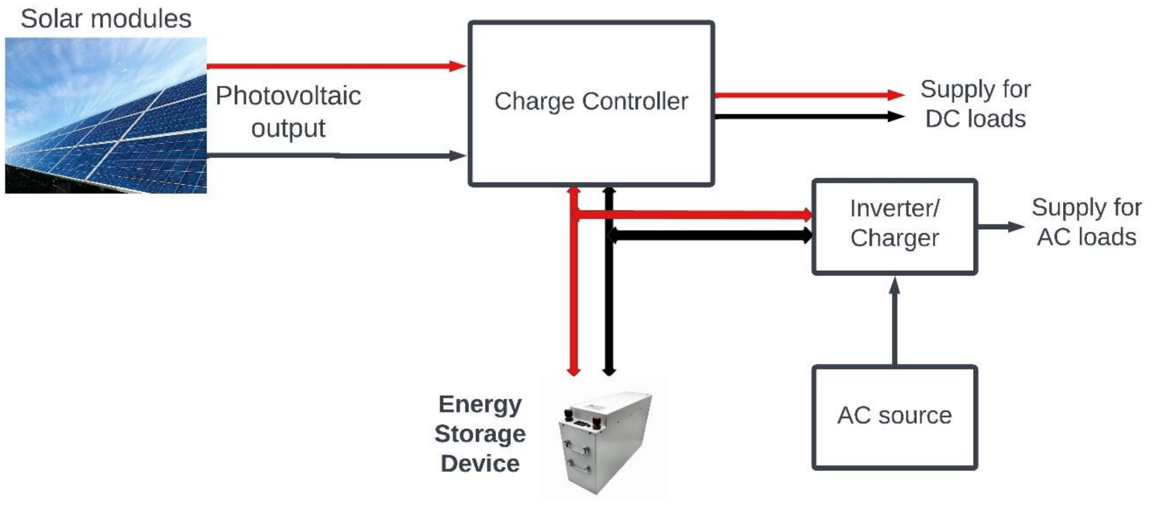

Figure 1.7. AC and DC load standalone system.

System connected to a grid . This kind of system is used to produce large amounts of power and send it via a grid to the load. This plant is hence referred to as a grid-connected power plant. In this technique, more solar panels are utilized to produce more power. A power plant also needs a lot of space to be constructed. The picture in Figure 1.8 depicts the system's block diagram.

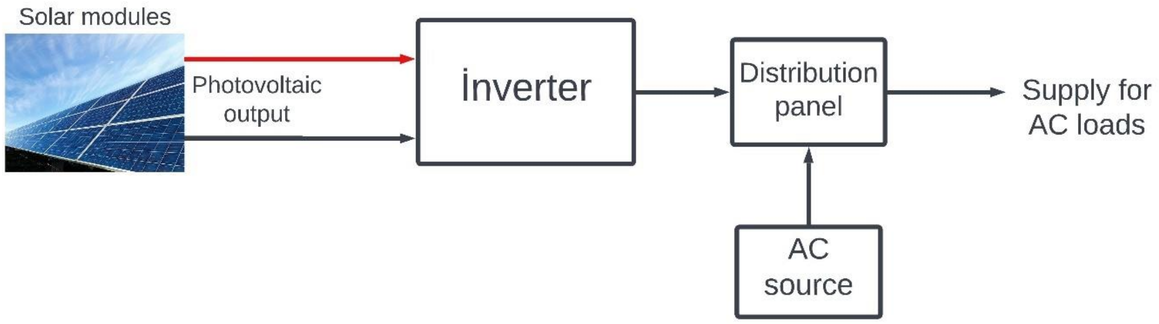

Figure 1.8. Grid connected system.

The grid power is available as AC in order to power the grid, we need solar power plants to provide an equivalent amount of power. The output frequency and voltage must match the grid's frequency and voltage, which is the most crucial requirement for this system. Additionally, the grid standard is maintained by the power quality. The schematic block diagram of this system is shown in the figure below.

In energy production systems, the amount of energy generated and the amount of energy used must always be in balance. In case of imbalance, some loads may be de-energized, or systems may be damaged in case of excess energy. For this reason, these systems must be constantly checked and inspected. It is important to know when the wind will blow and what its intensity will be, especially in WPPs. But these values are always changing, unstable. This instability can cause the network to be unstable as well. In order to eliminate this situation, it is customary to estimate the wind speed using different techniques. Determining this situation is important for understanding when energy production will occur or not and its amount.

Numerical weather forecasting or statistical methods are commonly used to determine wind speed. Forecasting methods are short-term forecasting and long-term forecasting. Especially short-term forecasts are important for determining the amount of power produced instantly. Long-term forecasts are important, for example, in determining the amount of energy that can be obtained from wind farms periodically in a year. Estimation is of great importance here is gaining. A high degree of accuracy is important for the economic gain to be obtained from both the network and the farm. Advanced control techniques are commonly used for wind forecasting. Among them, artificial neural networks it is tried to determine the wind speed by using The fact that this technique depends on learning with statistical methods seems to be the biggest benefit of this type of estimation system.

Looking at the data from prior years is one of the estimating approaches employed in this regard. By averaging the data collected in prior years, wind speed is attempted to be predicted. The wind speed intensity distribution fits the Weibull and Rayleigh distributions, according to another statistical method. The Weibull distribution function gives the probability that the wind speed will be less than or equal to a given speed value. The Rayleigh distribution's ability to be determined using merely the average wind speed is its greatest advantage. The Weibull and Rayleigh distributions' parameters can be found using several techniques.For example, using the least squares method, these functions try to estimate the wind speed. In addition, values such as mean wind power density, standard deviation, energy density, and average speed are found with the Weibull and Rayleigh distribution functions .

One of the estimation techniques used in this case is to look at the data from previous years. Wind speed is projected using an average of the data gathered in earlier years. Another statistical method shows that the distribution of the wind speed intensity fits the Weibull and Rayleigh distributions. The Weibull distribution function gives the probability that the wind speed will be less than or equal to a given speed value. The main advantage of the Rayleigh distribution is that it can be determined from the average wind speed alone. There are numerous methods to find the parameters of the Weibull and Rayleigh distributions.For instance, these functions attempt to predict the wind speed using the least squares method. Additionally, metrics like mean wind power density and standard deviation, energy density, and average speed are found with the Weibull and Rayleigh distribution functions .

Just as wind speed is important in RES, the amount of sunlight is important in PV solar panels. It is especially important to determine the number of sunny days in a year and to reach information such as the power that can be obtained from PV solar panels in a region and the return on investment. In addition, the high intensity of sunlight is another factor that will increase the amount of energy to be produced.

The fact that renewable energy sources such as solar energy are affected by environmental conditions and the energy obtained from these sources is not continuous causes problems in the load part. In the absence of the SunSun or on a rainy day, the amount of energy to be obtained from solar energy changes. Similarly, the wind is always, it does not blow at a constant speed; it is intermittent. Therefore, the amount of energy to be obtained from these sources is variable. Especially in low-power applications, for example, if a house's energy needs are provided by these sources, cutting off the energy while watching television is a troublesome problem in the case. To prevent such situations, energy resources must be managed effectively. Guaranteed power technique is a method developed to prevent problems such as voltage drop in sudden changes on the load side. A part of the energy produced in this technique is separated in the system under the name of guarantee power. Therefore, as long as this amount of energy allocated is not exceeded, sudden load changes are not felt on the load side. Figure 2.11 shows a block diagram of such a technique. Here, the guaranteed power value may vary depending on the size of the system used. The sum of the power produced and the guaranteed power is always more than the power consumed. In case of deficiency, if there is another energy generation unit installed in the system, this is activated.

1.3. Solar Photovoltaic system description

Off-grid solar photovoltaic (PV) systems are also known as standalone solar PV power systems. These store electrical energy generated by solar PV modules in storage devices such as batteries. Energy stored in batteries can be used when there is a demand for power supply or at night when there is no sunshine. More precisely, these systems are used in areas with no electricity supply, a shortage of energy, or remote locations/islands where there is no accessibility to a grid. The following are some examples of various types of standalone or off-grid solar PV power systems:

(a) Solar PV-powered water pumping system.

(b) Solar PV-powered home power system.

(c) Solar PV-powered cathodic protection system.

(d) Solar PV-powered telecom systems.

An off-grid solar PV system provides electricity in situations where utility power is not available. Solar PV modules are connected in series to form strings, and these strings are combined together in a string combiner box (array junction box), which is located near the array. The generated DC electricity from the PV panels flows through the string combiner box and from there to a controller in the inverter system. The controller regulates the DC power to the batteries. The inverter converts the DC power from the battery to AC electricity, and the AC electricity goes to the main electrical panel. From the main electrical panel, the electricity is used by the loads connected to the main panel. These systems allow the solar power to be stored in batteries; then, power can be supplied to the loads during the grid outage or whenever required. Figure1.3 gives the schematic of an off-grid solar PV system. The broad solar system components of a typical solar PV standalone or an off-grid solar PV system are as follows:

Solar PV module.

Solar charge controller.

Battery.

Solar PV modules are available in various sizes with different technologies, different wattages, and different voltages of operation. The solar modules are available with a nominal voltage of 12, 24, and 30 V. Solar PV modules with high conversion efficiency and voltage from different suppliers with advanced technology are available.

The current and voltage values of the module vary depending on the solar irradiance incident on the module and the operating temperature of the module. The current-voltage and

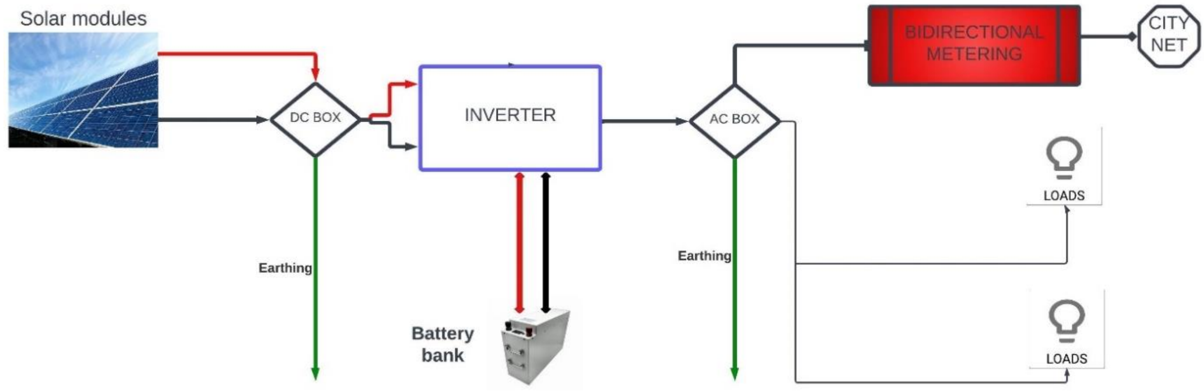

Figure 1.9. Schematic of an off-grid solar PV system.

power-voltage curves for different irradiance conditions for a 405 W module maintained at 25°C. A module of 405 W gives power of 324 W at 800 W/cm2 intensity at 25°C. This is because the Isc of the solar module varies proportionally according to the intensity of the radiation falling on the module. The Voc logarithmically depends on the incident radiation. So, the Voc of the module is slightly reduced with the decrease of the intensity of the radiation.

1.4.PWM (Pulse Width Modulation) type solar charge controller

The topology of PWM's solar charge controller is less expensive. The solar charge controller is mostly used for solar house lighting or home electricity systems, and it is directly connected to batteries and solar PV modules/arrays. The higher solar PV array voltage is lowered to the level of the battery terminal voltage by constantly connecting the solar PV module/array to the battery. The battery voltage rises as the solar PV array charges it, and the charge controller makes sure that the output voltage of the solar array is greater than the battery voltage. Considering the solar PV module's nominal voltage, a 12 V solar PV module is appropriately made to provide an output of about 18 V. Considering the solar PV module output voltage variation owing to temperature rise and cable voltage loss, a solar PV module with a nominal voltage of 12 V is appropriately built to generate an output of about 18 V, which may charge the battery to 14.4 V (the maximum charge for a flooded lead-acid battery). It should be clear that charging a battery using a solar PV module is impossible if the two components have the same voltage. As a result, the solar PV module must be built at a higher voltage than the battery. Two solar PV modules with a V_{mp} of 18 volts each must be connected in order to charge a 24 volt battery bank, and a 48 volt battery bank must be charged similarly. The capacity of two solar PV modules (V_{mp} 14-18 V) used in line to charge a 12 V battery would be wasted, which is not the best use of solar PV module capacity. Similar to the last example, it would be impossible to charge a 24V battery bank using a single solar PV module (V_{mp} 14- 18 V), and the battery would instead discharge. Figures 1.4 and 1.5 show the energy lost when a 12V module is linked to a 12V battery and a 24V module is connected to a 12V battery, respectively.

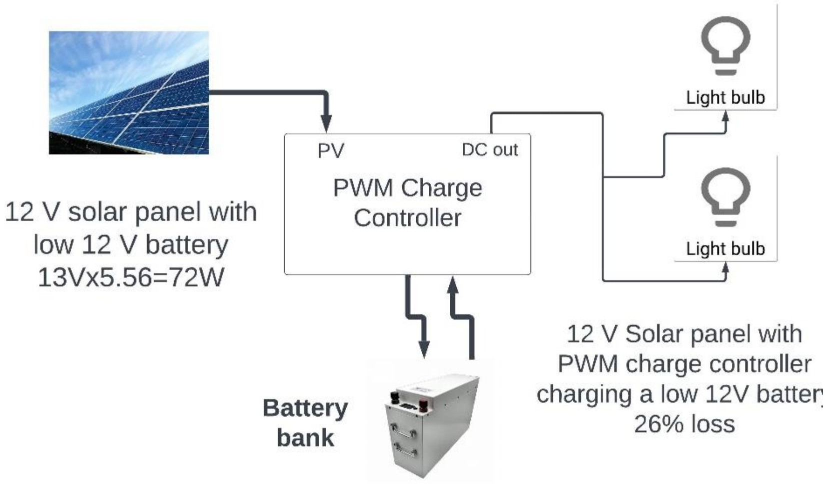

Figure 1.10. Energy loss occurs when a PWM charge controller is used to link a 12 V module to a 12 V battery.

Constant voltage controllers with two stages of regulation are PWM solar charge controllers. In the initial charging stage, the controller will use a higher voltage to fully charge the battery. In the second stage, the battery will be trickle-charged to maintain a 100% charge level once it has been fully charged by lowering the voltage from the solar array. This method of charging keeps the battery's charge level at 100% while reducing water loss and overcharging.

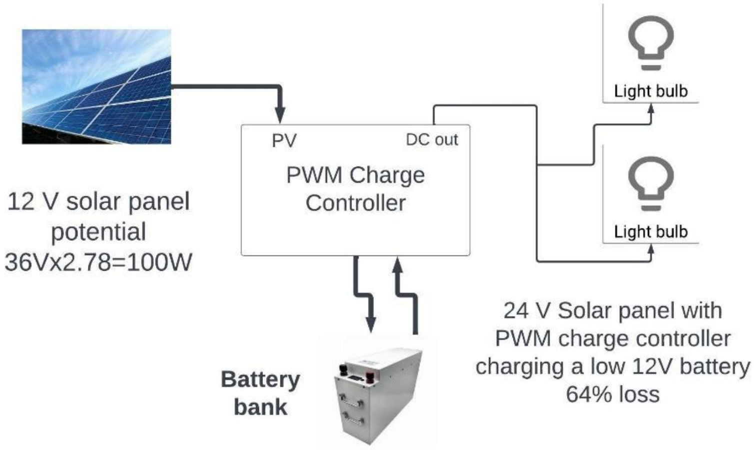

Figure 1.11. Energy loss while using a PWM charge controller to connect a 24 V module to a 12 V battery.

1.5. MPPT (Maximum Power Point Tracking) type solar charge controllers

PWM controllers use older, less sophisticated technology than MPPT (Maximum Power Point Tracking) charge controllers. The solar array controls may run at its "maximum power point," which is the perfect current and voltage. While MPPT controllers can transform extra solar energy into more power for the batteries, other charge controllers will lose extra energy produced by the solar panels.

Although MPPT technology has been around for a while, it has only lately become accessible to the average homeowner due to falling costs. MPPT charge controllers are used in the majority of cutting-edge residential solar power systems. According to some estimations, an MPPT controller can boost a solar system's efficiency by about 30%. By turning extra voltage into more amperage for the battery, MPPTs increase efficiency.

For residential solar installations, MPPT controllers are invariably the best option. The improved efficiency of an MPPT controller will be extremely advantageous for any system that makes use of many panels. This holds true in every system where the PV array working at a higher operating voltage than the battery storage bank. This extra power would be wasted by other controller kinds. MPPT charge controllers are more expensive than PWM charge controllers. However, because the controller can generate more power from the same number of solar panels over time, the higher initial purchase price results in cost savings. Batteries function at a lower voltage and typically charge at a slower rate when they are almost empty. In this case, an MPPT is useful since it can transform the additional voltage into higher amps for the low battery. There are also all-in-one bundles that make the installation procedure simpler if building your own solar system piece by piece seems intimidating.

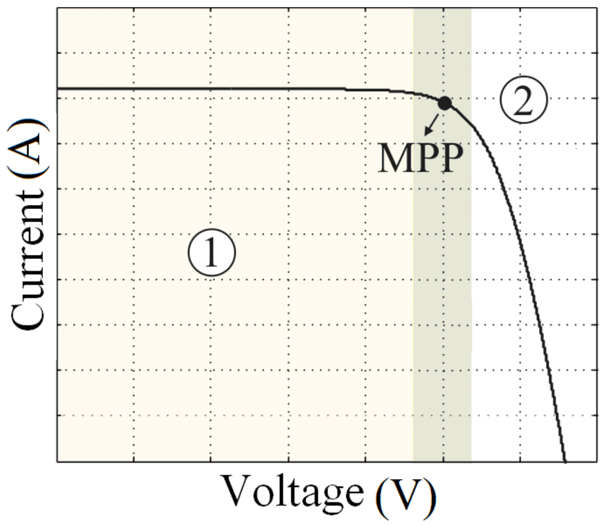

Figure 1.12. Photovoltaic Current and Voltage characteristics curve of MPP

Photovoltaic modules are semiconductors devices able to directly convert the incident solar radiation into electric energy. On the I-V photovoltaic plot, presented on Figure1.7, two different regions are identified: (1) current source and (2) voltage source. The point called MPP will always occur on the knee of the curve, where the generated PV power is maximized.

In most applications it is desired to optimize the power flow from the photovoltaic device to the load. When this condition is required, the operation point of the system must be established at the MPP. Nevertheless, as the maximum power point depends on solar radiation (S) and temperature (T), and these environmental conditions varies randomly, the MPP position is constantly changed. In order to always ensure the operation point on the maximum power point, or close to it, specific circuits, called Maximum Power Point Trackers (MPPT), are employed. Typically, the MPPT is achieved by interposing a DC-DC converter between the PV generator and the load, thus, from the voltage and/or current measurements, the MPPT algorithm calculates the optimal duty cycle (D) in order to maximize the power flow. Figure1.8 presents the whole scheme. Obviously, as the radiation and temperature are dynamic variables, the MPPT algorithm must work practically in real time, updating D constantly and keeping the accuracy and speed of tracking.

The most cited MPPT algorithms on the literature are: Constant Voltage, Perturb and Observe (P&O), Incremental Conductance (IncCond), Short-circuit Pulsed-base and Openvoltage Pulsed-based.

Constant Voltage - this method only a voltage sensor is necessary and the DC-DC converter duty cycle is changed in order to provide a constant PV output voltage.

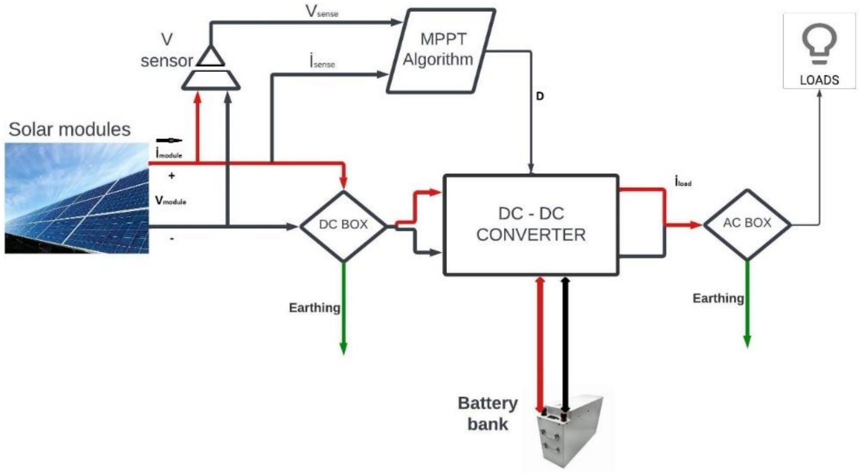

Figure 1.13. Implementation of MPPT system using voltage and current sensors.

The main aspects related to this algorithm are:

1) Single sensor.

2) Ease of implementation.

3) Tracking accuracy dependent on the PV surface temperature.

Perturb and Observe (P&O) is one of the most used MPPT algorithms. The main advantage of this technique is that the search for the MPP will be done independently on the environmental conditions, however its implementation requires a voltage and a current sensor. When in operation, the P&O algorithm calculates the PV output power $P_{n-1}=I_{n-1} V_{n-1}$ and causes a perturbation on the duty cycle D. If after the perturbation the power $P_n = I_n V_n$ increases, i.e., $p_n > p_{n-1}$, the perturbation is kept at the same direction. On the other hand, if after the perturbation the power $p_n = I_n V_n$ decreases, $p_n < p_{n-1}$, the direction of the duty cycle is nverted. Obviously, the step-size will determine the velocity in which the MPP will be search and the oscillations around it: small steps imply in reduced tracking speed and low oscillations around the MPP in steady state and large steps imply in high tracking speed and large oscillations around the MPP in steady state, presents below Figure 1.14

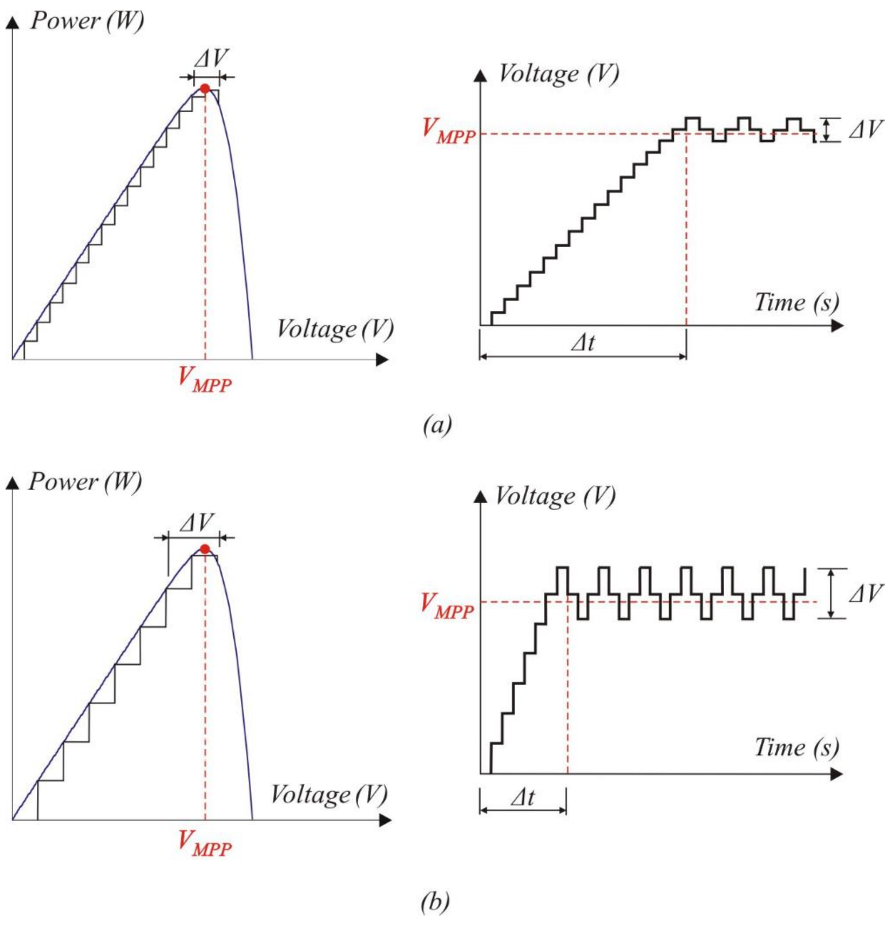

Figure 1.14. MPPT based on Perturb and Observe: a) small steps b) large steps

Incremental Conductance method is the most suitable MPP algorithm, once it combines tracking speed and accuracy. From the voltage V and current I measurements, the algorithm calculates the photovoltaic output power P and its derivative in function of the voltage dP/dV. Usually the IncCond method is implemented digitally and the derivative is represented by (1):

$$\frac{dP}{dV} = I + \frac{dI}{dV} = I_n + \frac{In-1+In}{Vn-1+Vn} \qquad (1)$$

Short-current Pulsed-base - This algorithm is based on the I-V photovoltaic characteristic, where it is verified that the maximum power point current I_{mpp} is directly proportional to the short-circuit current I_{sc} through a factor k_{sc} :

$$I_{mpp} = k_{sc} \text{ x } I_{sc} \qquad (2)$$

A disadvantage of this method comes from the fact of the measurement of the I_{sc} must be done periodically, however, during the short-circuit time interval, there is no power being transferred to the load.

Open-voltage Pulsed-base This algorithm is also based on the I-V photovoltaic curve, from where is noted that the maximum power point voltage V_{mpp} is directly proportional to the open-circuit voltage V_{oc} by a factor k_{oc}:

$$V_{mpp} = k_{oc} \text{ x } V_{oc} \qquad (3)$$

Again, oc k keeps itself constant under a wide range of temperature and irradiance conditions, and it value depends on the employed photovoltaic module. For modern photovoltaic modules this constant may be set in $k_{oc} = 0.76$. The problem with this algorithm comes from the time interval needed to measure the open voltage, since the energy is wasted when the load is disconnected from the photovoltaic device.

Advantages and disadvantages of MPPT type solar charge controller:

- Efficiency: This sort of Controllers can convert excess voltage into more useful current, making them superior for large systems with fluctuating voltages.
- Works in both warm and cold weather situations in regular operating mode.
- Costlier than PWM controllers is a drawback.

1.6. Methods of increasing the efficiency of the solar panel

Solar panel cleaning

1) Natural Cleansing

2) Mechanical cleaning

3) Electrostatic cleaning

4) Cleaning the panel with human presence

Natural cleaning

Dust accumulated on the upper surface of solar panels has a negative effect on the efficiency of the panel. Natural ways such as wind or rainwater can be used to remove these dusts from the panel surface. However, these methods are not effective in completely cleaning the dust accumulated on the panel surface. The process of cleaning the panel surface by natural methods is especially effective when the solar panel is in an upright or inclined position, as well as on rainy and windy days. (Arun et al., 2020)

Mechanical cleaning

Among the solar panel cleaning methods, one of the most used methods is mechanical cleaning systems. These systems use brushes or compressed air to clean the panel surface. There is a possibility of damaging the glass on the surface of the panel by scratching during cleaning with the brushing mechanism of the brush. High energy consumption is achieved by using fans during cleaning with compressed air. Therefore, in terms of energy efficiency, this method is widely used in solar panel cleaning systems. Mechanical cleaning of solar panels can also be done through remote control receiver and transmitter circuits.

Electrostatic cleaning

Solar power plants built today are built on inefficient soils, and environmental factors such as dust and sand in these soils negatively affect the output power of the panel. Although natural factors such as rain and wind clean these negative factors on the surface of the panel, they cannot completely remove them from the surface of the panel. In this case, another method of cleaning solar panels - electrostatic cleaning method is used. This system consists of parallel electrodes placed under the glass of the solar panel. This electroplating panel is a layer that protects against sand. As a result of gravity, a flip-flop movement occurs in the device, and as a result, dust particles are cleaned from the surface of the panel. This cleaning method is carried out with the participation of a person. It is the most commonly used method for cleaning solar panels. Using this method, solar panels are cleaned with clean water at least once a month. Panel degradations

Exposure to Light - There are various forms of mechanical and chemical degradation caused by panel exposure to light, including:

Light-induced degradation (LID). Interaction of crystalline silicon cells in the panel with the external environment. (Məmmədov, 2011)

Direct Light Induced Degradation (DLID). Direct exposure to sunlight during the initial installation period can cause the electronics inside the photovoltaic cells to warp or warp from heat.

UV light induced degradation (UVID). Initial exposure to sunlight causes a boron dioxide layer to form on the surface of the panel, reducing the efficiency of the crystalline silica.

Potential Induced Degradation (PID)- Unlike LID, PID does not necessarily affect every solar panel, but can occur if photovoltaic cells and components are operated at different voltages. This breakdown causes voltage leakage, reducing the amount of electricity the panel can send to the inverter.

CHAPTER 2

2. FUZZY LOGİC ENERGY MANAGEMENT

2.1. Fuzzy Logic Theory

Lutfy A. Zadeh published his ideas as The Theory of Fuzzy Logic and Fuzzy Sets. The word "fuzzy logic" in the theory immediately attracted attention, but in the sense of an adverse mass reaction. When Zadeh uses the phrase "fuzzy logic" to explain his theory fully and clearly, "Does your logic also have a fuzzy one!" objections began to rise. The most important reason for these debates was the difficulty of associating the word "fuzzy" with logic. Because many logicians and practitioners of logic were cynically criticizing the word "fuzzy" without asking L. Zadeh what the logic he developed was. For this reason, fuzzy logic theory has found an application area in another country. Because in America, there was already a set of values that cared about "precision." The Japanese have succeeded very well in adopting and developing this original idea while the debates are still going on in the USA. First, they looked for a way to avoid the cold reaction to the fuzzy term. They didn't translate "fuzzy" as "aimai" [fuzzy/vague] in their language but took it exactly as "faaji." "Faaji" has been used to connote "intelligent".

To implement a linguistic control strategy based on human knowledge, Fuzzy Theory is used. While designing control systems, respectively, fuzzy control rules that make up the target and knowledge base are determined, and blurring and defuzzification. Fuzzy Logic is shown in below block diagram.

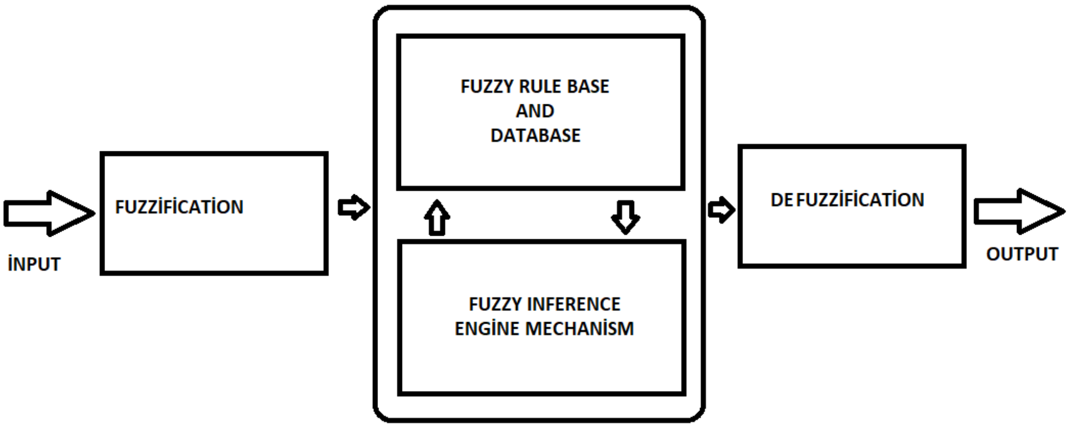

Figure 2.1. Fuzzy Logic block diagram

The most effective theory of fuzzy sets and Fuzzy Logic. The application area is control systems. Fuzzy systems based on knowledge or rule-based systems. To control a system,

The mathematical model that makes up the system should be chosen well. Some Mathematical models of systems are very difficult to obtain. For this, The best way is to use fuzzy sets. fuzzy sets traditional concept of the set used in set theory, is that an object is part of a set. It combines two options, such as "1" to have an element or "0" to not have an element. is based on logic. "0" or "1" in traditional set theory, there is no in-between. A problem with uncertainty is difficult to solve. A person is possible to put a controller that acts like it can happen. We can call this controller system Fuzzy Logic. Conventional control systems, with the help of fuzzy sets, Fuzzy Logic, are converted into systems. The using of Fuzzy Logic in the control management system, before making a decision is necessary to examine the system well. Then it is necessary to decide whether a fuzzy system will be used. After the decision to design a fuzzy system, the first work to be done is IF YOU EVER get the set of fuzzy rules is to. These rules are made with the help of experts.
Fuzzy Logıc Controller - Due to qualities like its durability, simplicity, and adaptability, fuzzy logic has been seen as an appealing solution for a variety of technical issues. To create this kind of control system, three conditions must be met: fuzzification, inference rules, and defuzzification. This system's primary goal is to regulate the greenhouse's internal climate and increase its efficiency.

2.2. Fuzzification

Input values are converted to fuzzy values to be used in the Fuzzy Logic system.

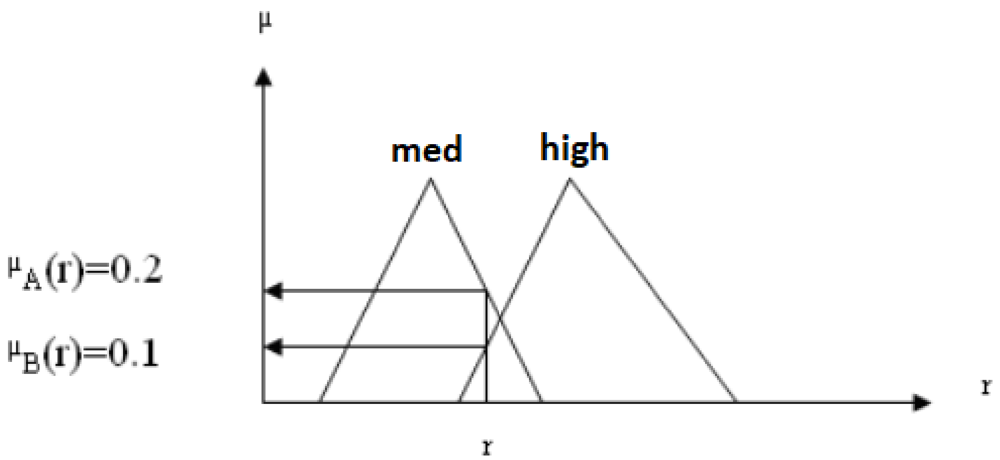

Figure 2.2. Fuzzification Process

The input values are converted into fuzzy values according to the membership functions they belong to, and these fuzzy values obtained correspond to the membership degrees in the membership functions they belong to. Figure 2.2 shows the conversion of a real value to a fuzzy value.

2.3. Fuzzy Rule Base and Database

After deciding to design a fuzzy system, the first thing to do is to obtain the IF-THEN rules table. These rules are generally created by utilizing an expert. It contains all the rules that can be written as a logical IF-THEN type that binds inputs to output variables in the database. In writing these rules, only all possible interval (fuzzy set) connections between input data and outputs are considered.

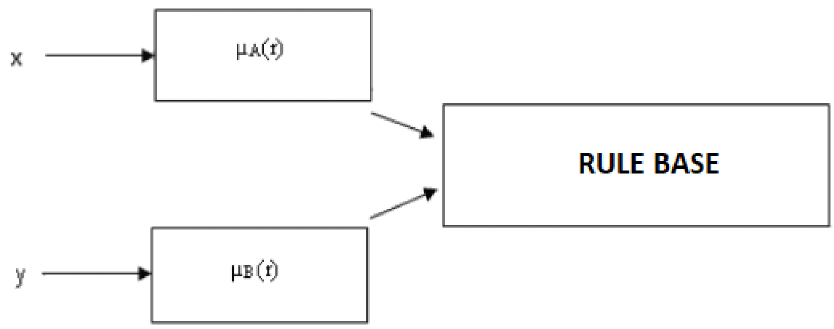

Figure 2.3. IF – THEN concept

Thus, each rule logically connects a part of the input space to the output space. All of these contexts make up the rule base. Figure 2.3 below shows the IF – THEN concept schematically.

2.4. Fuzzy Inference Engine Mechanism

Between input and output, fuzzy sets in fuzzy rule base by gathering all the established relationships together; it is a mechanism that includes a collection of transactions that ensure that it behaves with output. This engine collects the implications of each rule and determines what kind of output the whole system will give under the inputs. The decision-making unit is also called the Fuzzy Engine. It is the core part of Fuzzy Logic control. This part processes fuzzy concepts in a way similar to human decision-making and inference ability and determines the necessary control by making inferences. The basis of a fuzzy controller is a rule-based system consisting of a rule analyzer, database, and rule base. Here, as in expert systems, the rules created in the IF-THEN structure are kept in the rule base, and the types and limit values of the membership functions used in the database are kept. The internal structure of a rule-based inference system used in a fuzzy controller is seen in more detail in Figure 2.4.

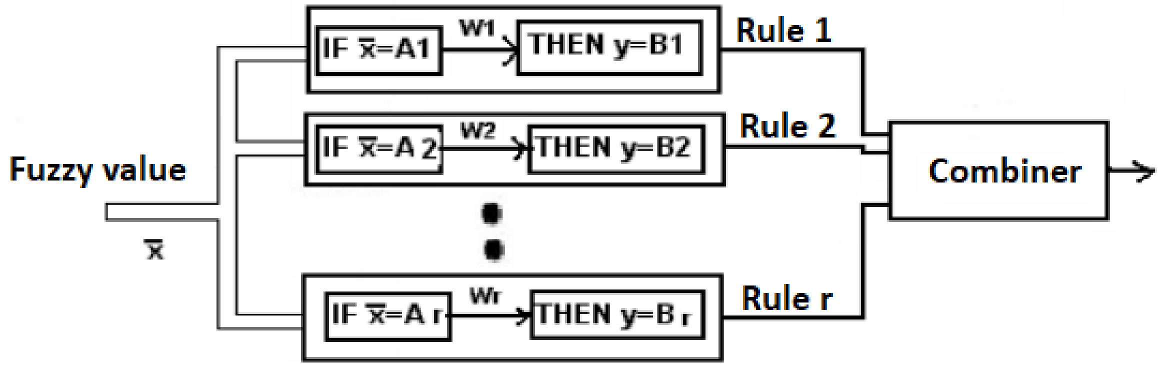

Figure 2.4. Fuzzy Rule-Based Inference System Structure

Different analysis methods can be applied in a fuzzy rule-based system. The most important of them are; It is the Mamdani and Sugano model. In addition, there are different inference methods applied in the relations to be created between more than one rule in the combiner.

2.5. Defuzzification

The result of the inference operation is a fuzzy set. Since fuzzy expressions or fuzzy sets do not make sense in the real world, the fuzzy information obtained at the end of the inference must be transformed into real-world information. This process is done in the defuzzification part. Defuzzification methods are below:

1. Maximum method
2. Maximum mid-method
3. Left edge method
4. Right edge method
5. Center of gravity method

In the mid-maximum method, only the rule with the largest saturation degree is sent to the output to obtain the sharp value of the output. That is, the result with the largest height (with the largest membership degree) among the processed rules is fuzzy set processing. As can be seen in Figure 2.5, where two rules are processed simultaneously, the value to be obtained with this method corresponds to the [y_1 y_2] interval. In the [y_1 y_2] interval, the result represents the large membership degree of the fuzzy set. In the range [y_1 y_2], the result fuzzy set represents the largest membership degree. There are three different uses for this method in different applications.

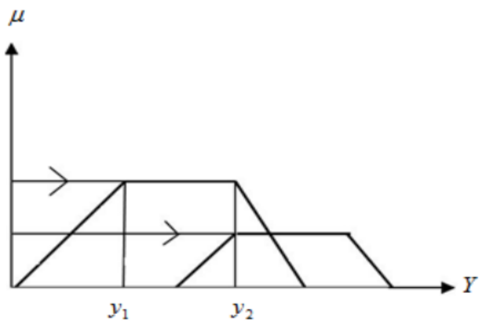

Figure 2.5. Schematic Representation of the Inference Process

Maximum Middle Method .In the fuzzy output set with the highest height, the average of the limit value [y_1 y_2], which determines the limits of the maximum height, is taken. The representation of the maximum mean subtraction method is shown in Figure 2.6. In the literature, when "clarification according to maximum height" is mentioned, the average value is meaning.

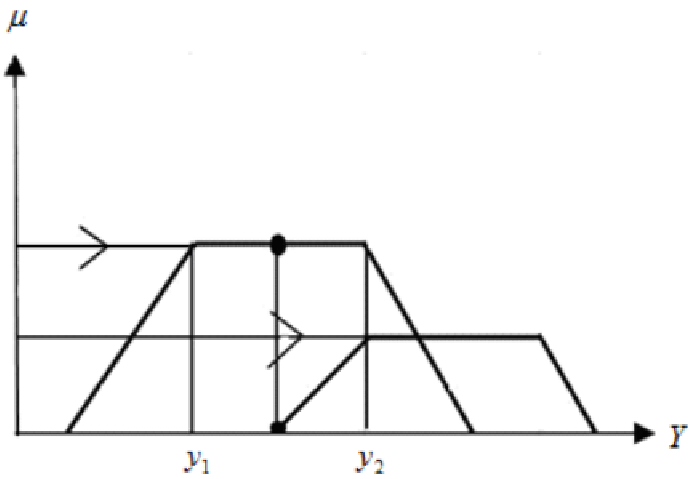

Figure 2.6. Representation of Maximum Middle Method.

Left edge method

In this type of application, the lower range limit value is selected as the result sharp value. The representation of the left edge point method is expressed in Figure 2.7

$$y' = y_1$$

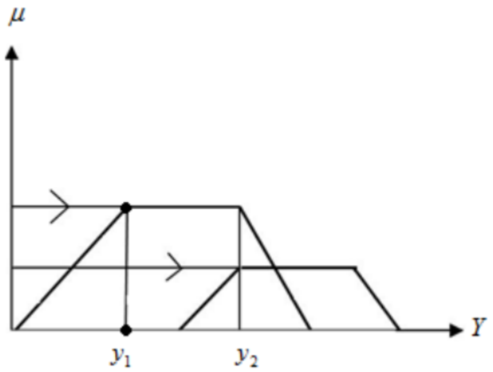

Figure 2.7. Display of Maximum Left Edge Point Method

Right edge method

In this type of application, the upper range limit value is selected as a result sharp value. The representation of the right edge point method is shown in Figure 2.8

$$y' = y_2$$

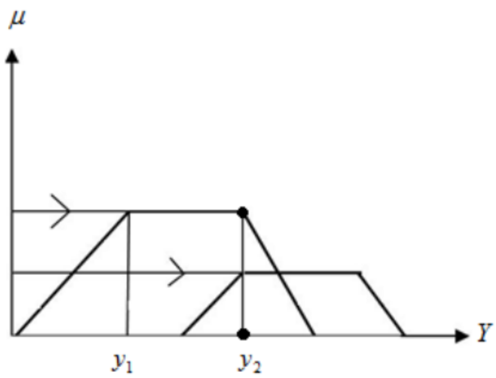

Figure 2.8. Representation of Maximum Right Side Point Method.

Center of gravity method

The sharp output value of the result is considered the horizontal axis value of the center of gravity of the area formed by the sum of the fields under the compensation values of the fuzzy sets. This method is one of the most used clarification methods.

$$y' = \frac{\int y * u(y) * dy}{\int u(y) * dy} \quad (1)$$

Technically, this calculation is performed by the numerical integral y at the fundamental discrete support points. The result is more precise. Increases calculation time.

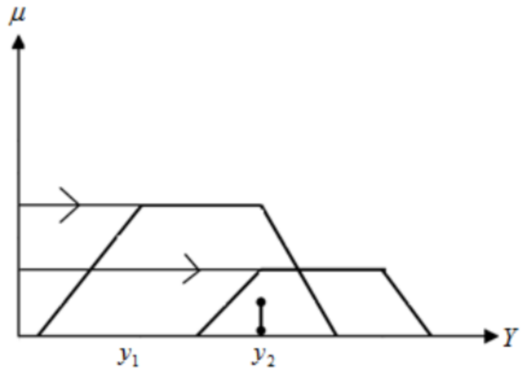

Figure 2.9. Representation of the Center of Gravity Method

The representation of the center of gravity method is expressed in Figure 2.9. All fuzzy output sets obtained by the rules processed in the maximum method versus the center of gravity method are included in the calculation. Therefore, many active rules are averaged by their degree of fulfillment.

2.6. Application fuzzy logic in energy management obtained from solar panels

The fuzzy expert system for efficient energy smart house management for renewable energy sources is proposed in this research. The membership functions and histogram of the electricity cost are supplied for the proposed fuzzy expert system to show how the membership functions relate to actual data. A concise computational description of the full knowledgebase can be created by combining numerous rules. A set of rules describes the complete knowledge base. The rules can be changed to achieve the user's desired profit maximization, energy cost reduction, or other objective. Rules for minimizing CO2 emissions can be created in conjunction with utilities. The following and final phase is defuzzification. Device inference is transformed into an output signal by defuzzification. It is a process that needs the aggregated output, which is essentially a cross-section surface, to transform into a signal in order to be recognized by the process. The controller output must have a distinct value, a true one that denotes a choice. The type and size of the customer can alter these values. The mentioned input ranges are covered by modifications to all membership characteristics. The values of the number and membership functions are the best representations of the input data histogram. Before the PV solar panel energy generation systems are practically installed, it should be tried to understand how the PV solar panels system will behave by simulating separately. For this reason, different simulation studies related to PV solar panels have been made, and the behavior of these systems has been tried to be better understood. MATLAB software was utilized to determine the ideal configuration for the PV system that would provide energy to the house. This was done by considering the actual irradiance and temperature data of the location, a one-day autonomy, and the home's energy consumption pattern. The energy demand of the house influences this, the PV energy generated, the battery bank's state of charge, and the energy imported from the grid. To optimize the balance between energy production and consumption, a fuzzy logic energy management system was developed.

When the temperature of the environment where the PV solar panel is located and the solar radiation level change, the operating temperature of the PV solar cells in the panel also changes, creating a new photocurrent and a new output voltage. The operating temperature of PV solar cells varies depending on the solar radiation level and the ambient temperature. Variable ambient temperature affects the output voltage and photocurrent of the T_X battery.

It affects the photocurrent and operating temperature of the PV battery and, therefore, the output voltage. If the solar radiation level changes from a value such as S_{C1} to a value such as S_{C2}, the operating temperature changes from T_{C1} to T_{C2}, and the photocurrent changes from I_{FV1} to I_{FV2}. Thus, solar radiation effects of the change in level on the battery photocurrent and output voltage are expressed with two separate correction coefficients. These correction coefficients are given by C_{SV} for output voltage and C_{SI} for photocurrent.

$$C_{sv} = 1+\beta_T \times \alpha_s (S_x - S_{bat}) \tag{1}$$

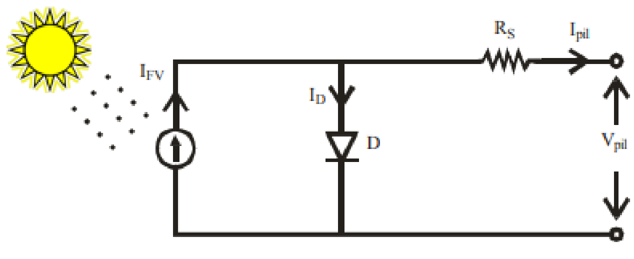

Figure 2.10. PV equivalent circuit

Solar panels consist of a p-n type semiconductor. N-type is at the top of the panel and p-type is at the bottom of the panel. Electrons are located in the n junction, and holes are located in the p junction. A part of the electrons in the N junction goes to the p junction, and a part of the holes located in the P junction goes to the n junction, and thus a p-n junction is formed. When the sun's rays fall on the panel, the photons give their energy to the negatively charged electrons in the p junction. Energized electrons move and cross the barrier to leave the n-layer, thus creating an electric current. A photovoltaic panel is modeled using a diode and a current source. The current source creates the I_L- photocurrent. This current is proportional to the parameter-G, denoted as light intensity.

$$I_g = I_L - I_d = I_L - I_0\left(exp\left(\frac{qV}{nkT}\right) - 1\right) \quad (2)$$

Electrical characteristics of solar panels - In order to receive high value current in the solar panel, the panels work in short-circuit mode. Because in this mode the current gets the maximum value. Iqq - the short-circuit current is directly proportional to the light intensity, and the voltage is directly proportional to the logarithm of the light intensity

Iq-short-circuit current and Vad-open circuit voltage are used to determine the percentage of solar panel's electricity generation. To measure Iq, close the outputs and set the max illumination. At the values of maximum current and maximum voltage, maximum power is generated in the solar panel. The maximum current is denoted by Im, the maximum voltage by Vm, and the maximum power by Pm.

$$\eta_{\text{Persuasive precedent}} = \frac{I_m V_m}{I_q V_{ad}} \quad (3)$$

The PV solar panels and the battery pack are interconnected by a device that also includes a regulator and a maximum power monitor. In this way, when the desired power cannot be obtained from the Sun, the batteries come into play and transfer the needed energy to the loads. Maximum power can be obtained from the SunSun in the current ambient conditions with the tracker. The aim is to make the best use of the available power. The regulator used also has a charge control unit. The regulator is a 12/24/36/48V, 30A device. Four 80W PV solar panels are used in the system. The total amount of power is 320W at the maximum level. They are connected 2 in series and 2 in parallel. The batteries are 2 pieces of water-type 12V batteries, and their voltage values are brought to 24V by connecting them in series. This value is fixed by passing it through a chopper and bringing it to 48V. This value is then applied to the input of the inverter. The power produced by the PV panels, the stored power according to the battery's

SOC (State of Charge), and the consumed power are the three key inputs that determine how the management system operates.

The Fuzzy energy management will decide which loads will be powered based on the previous parameters (Pp, Pc, and SOC) while taking into account the following predefined priorities.

1. The category of non-disconnectable appliances (refrigerators and Wi-Fi) has priority 01.
2. The category of movable appliances (washing machines, dishwashers) is priority 02.
3. The category of non-essential appliances, which may go unused if the batteries run out and there isn't enough PV generation, is priority 03.

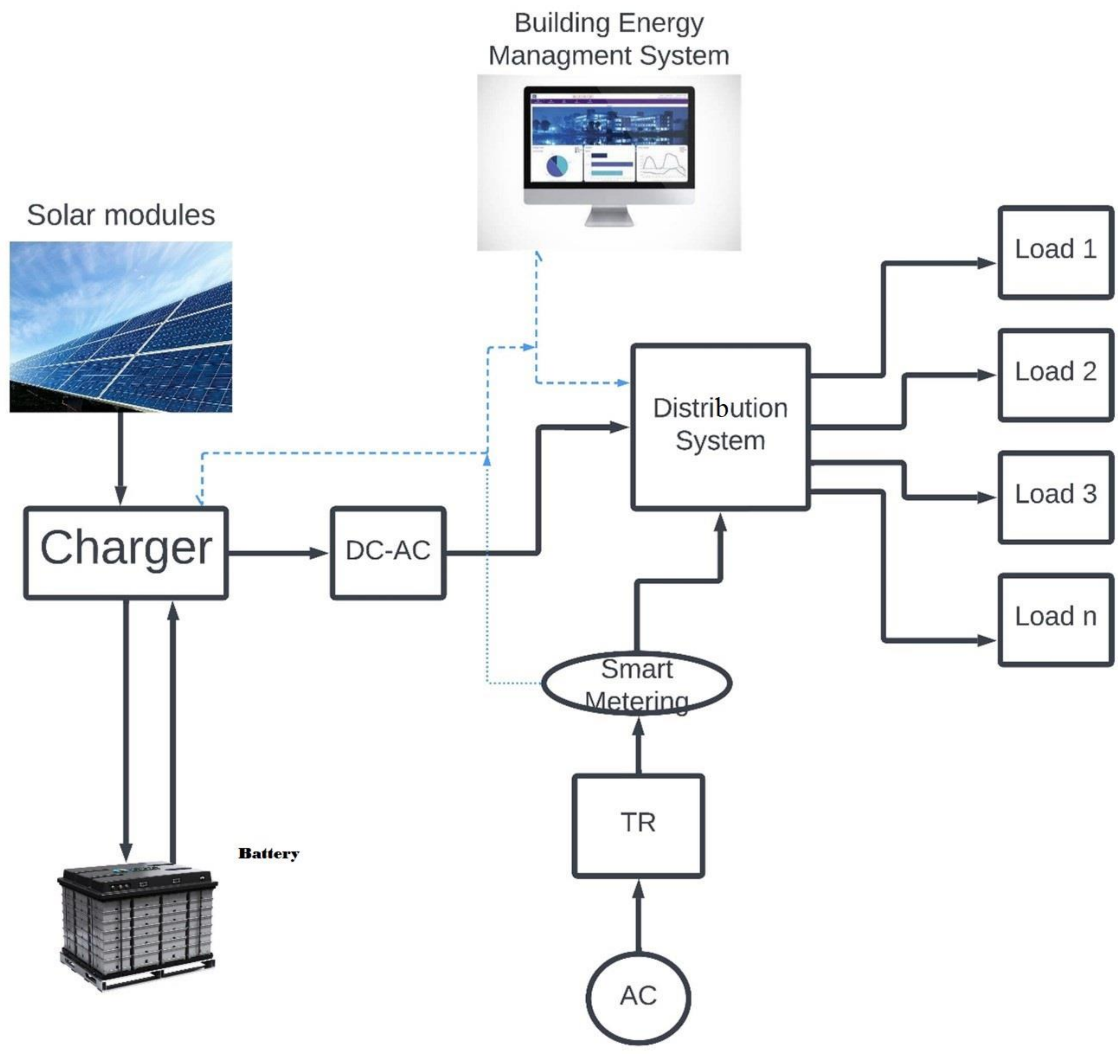

Figure 2.11. Description of Building energy management Grid-connected PV system with battery storage for the solar energy applied on smart home.

The inverter is a device whose input voltage value is 42-60V direct current, and it converts this value to 220V/50Hz alternating voltage. Here, the current and voltage information on the loads and the input voltage and output current of the chopper are measured, and these values are transferred to the computer. In the system, PV solar panels charge the batteries. When the SunSun is high, both the batteries are charged, and the loads are fed. In case of no load, the batteries are charged until they are fully charged. After it is fully charged, the charging unit automatically deactivates the PV solar panels and ensures the longevity of the batteries. The energy obtained from the PV solar panels is used economically with the maximum power tracking device in the system.

2.7. Matlab Model Experimental Results

Using a MATLAB model, the proposed fuzzy logic-based energy management strategy's efficacy was evaluated. In this study, Mamdani type fuzzy logic controller with two inputs and one output is used. One of the inputs is the error in the current or voltage in the supervised system, and the other is the derivative of the error (the amount of change in the error). The fuzzy logic controller generates a controlled output signal based on the input values and rules. The controlled output is used as the switching ratio of the transistors. The input to the fuzzy logic controller is made by multiplying the input variables with certain gain values. While determining these gain values, the system mathematical model and values suggested by Ziegler-Nichols are used. Determining the membership functions of the input and output variables in the fuzzification unit is one of the most important steps in fuzzy logic controller design. In this study, current and voltage error (e), derivative of error (amount of change) (ce) for fuzzy logic controllers are determined as input variables. Seven triangular membership functions were chosen for the input variables. Membership functions determined for power consumption and energy balance are shown in Figure 2.12. A model of the PV solar cell is created.The created model is designed to include changes in ambient temperature and changes in solar light intensity. As a result of the given equation, PV solar cell current and voltage values are calculated. This expression is shown in Equation (1). PV panel current should be a function of PV battery temperature and ambient light level, and the Matlab model in Figure 2.12 is designed to include these effects.

$$V_{bat}=f\ (I_a, S_x, T_x) \quad (1)$$

When the temperature of the environment where the PV solar panel is located and the solar radiation level change, the operating temperature of the PV solar cells in the panel also changes, creating a new photocurrent and a new output voltage.

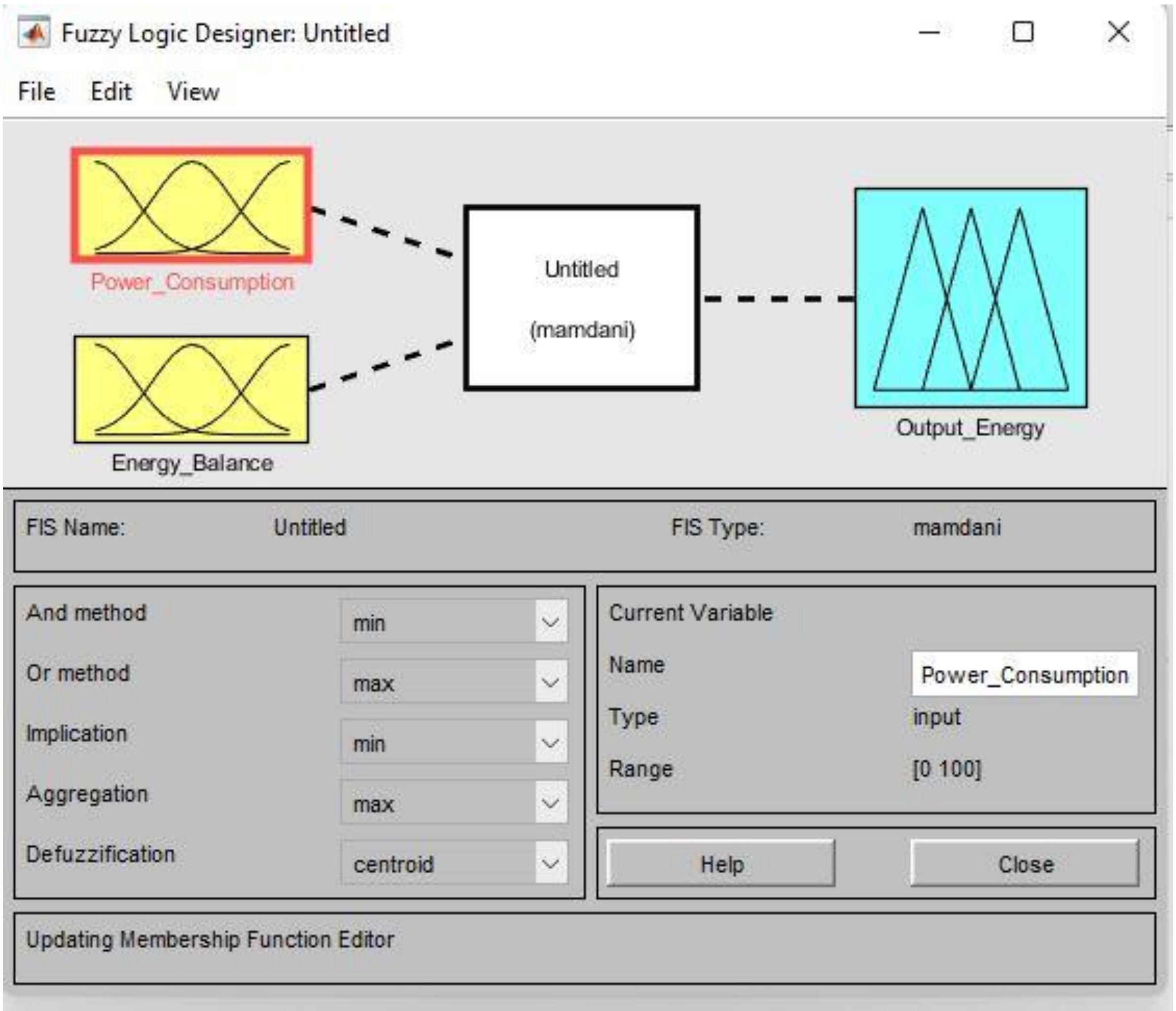

Fıgure 2.12. Developed Energy Control Module using Fuzzy Logic

The operating temperature of PV solar cells varies depending on the solar radiation level and the ambient temperature. Variable ambient temperature affects the output voltage and photocurrent of the T_X battery. These effects are seen in Equation (2) and Equation (3) with temperature, voltage, and current coefficients C_{TV} and C_{TI}, respectively, in the battery model.

$$C_{TV} = 1+\beta_T (T_a - T_x) \quad (2)$$

$$C_{TI} = 1 + \frac{\gamma_T}{S_{pil}} (T_x - T_a) \quad (3)$$

The fuzzy logic approach requires that input and output values be allocated to one of three levels: low, medium, or high.

Table 2.1. Fuzzy Logic rules

	Electrical requirements			
		Low	Med	High
Battery	Low	battery	battery	Network
	Med	battery	battery	Network
	High	battery	battery	battery

The internal structure of Matlab subsystems where membership functions energy consupmtion and energy balance are calculated on base of input data from Table 2.1 and Table 2.2 is shown in Figure 2.13 and Figure 2.14. As also reported in Table 2.2, with a maximum value for the power of the load is 40- 60 W, 20-40 W is associated to the medium level. In the same way, will be 21-20 affected to low levels. The output signals adhere to the same fuzzy logic assignment using the same justification, with the values of the instant levels around 0, 0.5, and 1 affecting the low, medium, and high levels, respectively. But it's clear that the immediate values match the indexed variables.

Table 2.2. Limit values of Fuzzy Logic function

	Power of electrical load	**Level of Battery Voltage**
Low	1-20 watt	15-16 V
Medium	20-40watt	16-17 V
High	40-60 watt	17-18 V

The experimental findings show that the proposed fuzzy expert system for efficient energy smart home management systems is superior to existing FEMAN, MANFIS, FLSHEMS, FLEMS, and FLEMA methods in terms of efficiency, cost-effectiveness, low error rate. When we look at the results signals in Figure 2.13 series, we can see that the fuzzy expert system for efficient energy smart home management systems controller's power management technique enables it to fully coordinate the power flows between solar energy sources, the electric grid, the storage system, and the load. It should be mentioned that the chosen hybrid power system and its deliberate strategy, i.e., the best possible use of solar energy sources and within the support of the grid, the load will be always powered. Inference unit; It is the part of the human brain where the decision-making process is modeled. In this part, there are fuzzy rules that provide the relationship between the fuzzy input variables and the output variables. Therefore, the knowledge base and the inference unit are in constant interaction. By putting the fuzzy input values in the rule base, first the active rules are determined, then the rules are combined with one of the fuzzy reasoning methods. In this study, the commonly used Min-Max method was used. "The defuzzification unit does the reverse of the blurring operation. In the defuzzification unit, the fuzzy values produced by the inference unit are converted into numerical values that can be applied to the system. Different methods such as center of gravity method, maximum membership method, weight average method and mean-max membership method are used in the clarification process.

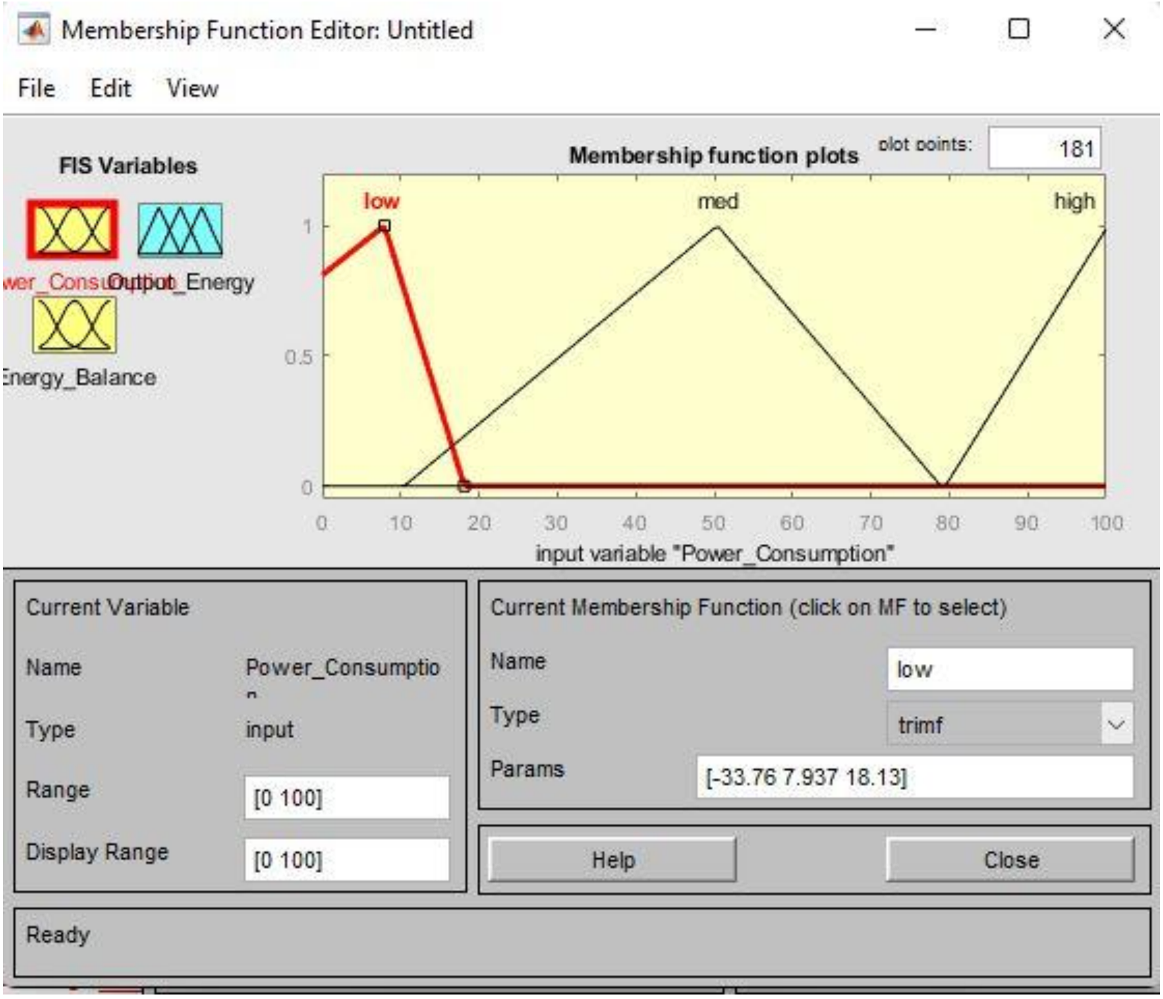

Figure 2.13. Membership Functions

By applying data power profiles such as solar energy and battery storage to the system throughout a typical May Day using MATLAB tools, the developed Fuzzy Logic Energy management controller's dependability was ensured. Each month's load requirements are different. The warmest months are associated with summer in the eastern hemisphere in Baku.

As a result, the load demand for those months would be reduced, and for the three other seasons, more overcast days with cooler temperatures are anticipated. Because of the potential need for heating and more lighting during these months, there would be a greater demand for power. The morning hours (6:00–8:00) and the middle of the day see an increase in energy demand highest during night between 17:00 and 23:00, when most of the electrical equipment is turned on. Solar energy is produced by solar panels while the sun is out from 8:00 am to 7:00 pm. Solar energy production is interrupted by passing clouds between 2:00 and 4:00 pm. The batteries' level of charge, or SOC, which ranges from 20% to 80% when charged by the grid, solar panels, and drained by a load, makes up the fourth power profile.

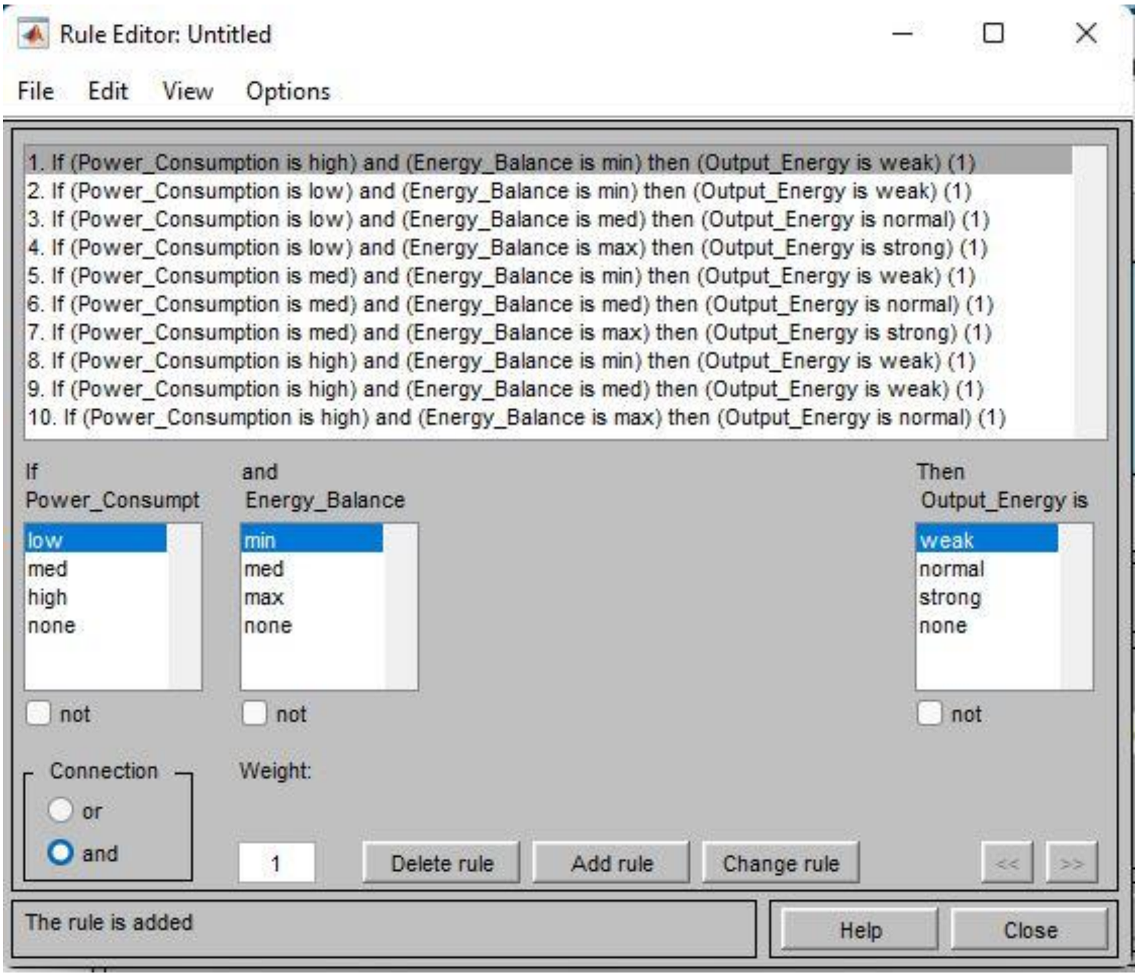

Figure 2.14. Verbose format of rule in Fuzzy Logic Rule Matlab database

To increase the home's fuel efficiency as much as feasible, an appropriate fuzzy logic rule can be designed for the power generation of the solar energy system and the current SOC of the battery. For instance, when the home device's load demand is high, it is preferable to use the power produced by the renewable energy system and it should be maximized to cut down on the power supply of city network; when the home's load demand is low, it is preferable to take into account the efficiency of city network. City network particular power consumption may rise under light loads, hence it is advisable to feed as much renewable energy system electricity into the power grid as feasible. In this situation, it's important to keep the renewable energy system's output power within a tolerable range. The following 10 fuzzy rules are constructed and described in fuzzy language based on the aforementioned premises.

Residential consumption is a crucial component of grid improvements because it is the most energy-intensive sector, along with tertiary enterprises. With local photovoltaic energy production, it is intended to comfortably meet home energy demand. This requires an effective home energy management system which integrates home energy management control to regulate appliances to lower the customer's power bill in response to dynamic pricing signals, reducing energy use, and taking user comfort into account. Utilizing efficient scheduling from renewable energy sources- here solar panels, the suggested FES-EESHM approach reduces the energy usage in a smart house.

Table 2.3. Energy consumption rate %.

Number of datasets	without energy management	with load management	with Fuzzy Logic energy management
5	15	33	13
10	60	57	32
15	52	56	40
20	49	28	30
25	45	52	32
30	67	60	22
35	57	72	15
40	42	63	7

The system operates the devices in order of priority of use, either P1, P1 + P2, or P1 + P2 + P3, for a certain irradiance and temperature. It also takes into account the produced energy and the consumed energy at time t.

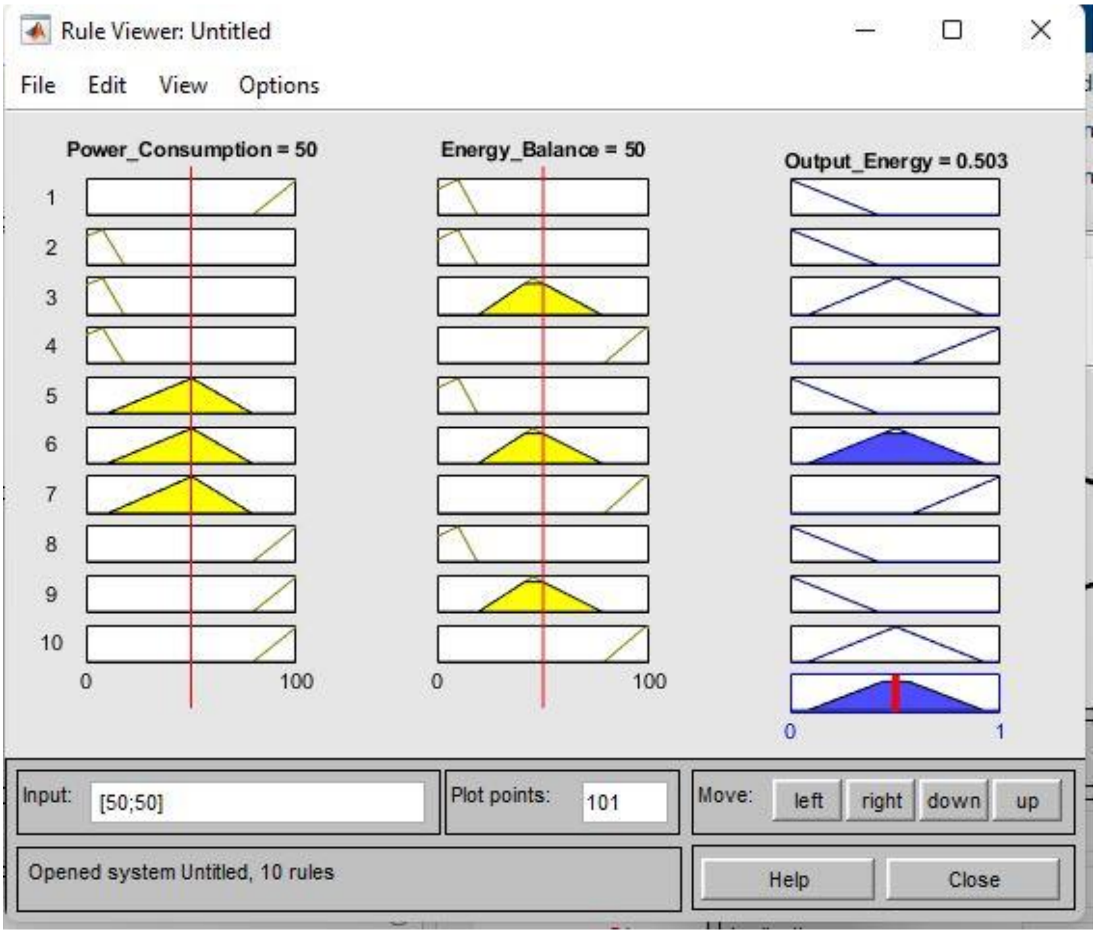

Figure 2.15. Result screenshot for the rules shown in Figure 2.14

Figure 2.16 displays the suggested FES-EESHM method's energy consumption rate with the defuzzification outcomes of the Fuzzy Logic energy management controllers utilizing the related membership functions. The electric grid and the loads are connected in series by the proposed smart controlled hybrid energy system. When the weather is bad and storage is inadequate, the grid is the only source used. Otherwise, the grid will appear to be continuously connected to the load as long as fuzzy membership function shapes, PWM coefficient for electrical switches (instead of classic crisp logic), and fuzzy logic sets (instead of classic crisp logic) are used. In fact, especially when the computation steps are carried out thigh frequency, the rated contribution of the grid and all the resources to supply the load and the batteries is frequently between 5% and 95% (duty-cycle of the PWM) at maximum.

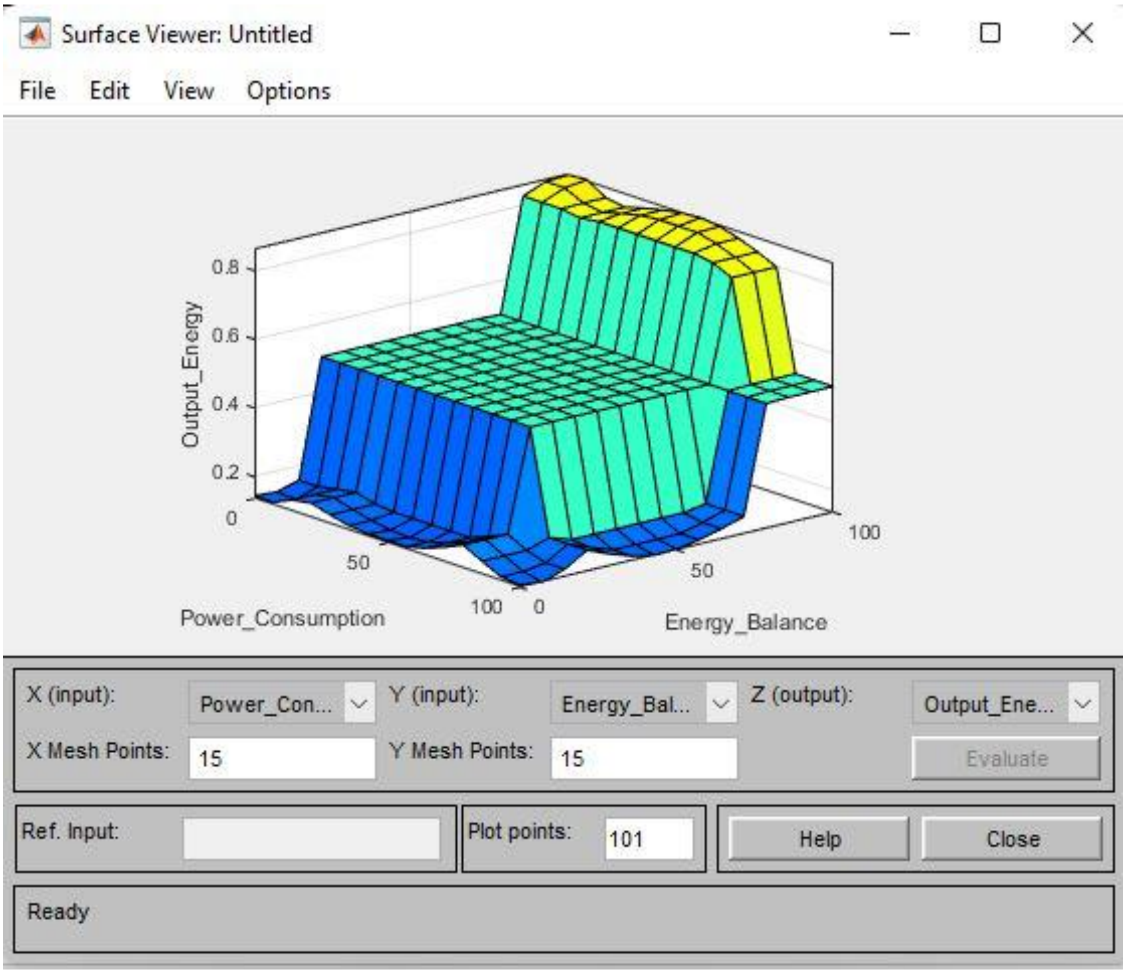

Figure 2.16. Load profile with surface viewer

After have been defined the fuzzy variables and the membership functions, the next step concerns the definition of the If-Then logic inference. In order to understand the membership functions, an example for each priority will be given below: IF ΔP is Big negative AND SOC is Big, THEN the probability to start the appliances of the priority P1 only is High. IF ΔP is Big negative AND SOC is Small, THEN the probability to start the appliance P1+P2 is Very low. IF ΔP is Big Positive AND SOC is Big, THEN the probability to start the appliance P1+P2+P3 is Very High.

CHAPTER 3

3. INTELLECTUAL BUILDING SYSTEM THEORY-CONCEPTUAL BASIS

3.1. Management systems of "Intellectual buildings"

Home automation is a process or system integration that allows a person to improve their lifestyle and make the home more comfortable, safe, and convenient. With home automation, lighting, heating, air conditioning, security, telecommunications, audio, and video systems can all be connected to a single control mechanism and all controlled from a single point inside or outside the home or controlled according to a predetermined program.

Kitchen appliances and food processors, TVs, stereos, DVD players, VCRs, refrigerators, washing machines and dishwashers, automatic garage doors, dimmable light bulbs, cordless phones, vacuum cleaners and more. It has become an integral part of human life with the introduction of technologies designed for everyday life.

Later, these devices underwent many changes to make human life easier with advancing technology; Remotes for televisions, stereos, and even garage doors, timers for coffee machines, washing machines, and dishwashers; refrigerators have been developed to offer the user many options. Now, as the next stage of this process, home automation technologies that allow controlling the whole house from a single point and automatically provide this control with programming capabilities are presented to the consumer. What a smart home can do depends on imagination and personal needs. The greatest convenience in this regard is the "scenario" option, in which home automation systems execute multiple commands one after the other. Normal time-wasting operations such as closing all the curtains, dimming the lights, setting off the alarm downstairs, and turning off the TV after an hour can all be done with a single command. Starting the coffee machine at a certain time in the morning, adjusting the water and the temperature of the house, turning on the stereo or TV, turning off the alarm system and turning off all devices when you leave the house, and calling you at work can be achieved by setting scenarios when you leave the house. (Harper, 2003)

Today, technology is increasingly used to make home and work life easier and to make everyday tasks easier. Depending on the developing technology, the execution time of work has also shortened, and the execution of operations has become easier. Today, there are many important applications in the field of automation, and systems designed to control devices used in homes have given rise to intelligent building automation systems. (Bushby et al., 2008)

Home automation systems can generally be explored under the following headings.

The most important point in the concept of a smart home can be considered as the formation of the automation system applied in your home in the way you want. For example, with a remote control or a touch panel, all your wishes will be realized, from the lighting system of your home to security cameras or from the control of curtains and blinds to the control of the home theater. In fact, all these functions will be under the control of residents through the phone or the Internet.

In our world, where it has become almost impossible to keep up with the evolving technology since the computer entered our lives, homes have also taken their share of this evolving technology. Smart homes, which were considered a dream until a short time ago, have become a reality today.

One of the main factors taken into account when developing smart home systems is that these systems can work in full compatibility with personal computers. The next step in smart home technology is that these computers will also change home life. This change will happen by controlling appliances and lights in a home through computers.

The most important reason for the transition to automation in industry is to improve efficiency and save energy. The same goes for home automation. The biggest factors that increase the energy costs of a normal family and lead to unnecessary energy consumption are the unnecessary turning on of lights, the high level of operation of heating and cooling systems, the heating of unused parts of the house, and the inability to take advantage of daylight. as necessary; devices left open and similar cases.

Another great security advantage of smart homes is that they can call not only alarm stations but also predefined phone numbers. Outside of such scenarios, the astrological clock and travel apps in some smart home systems provide a little more security and convenience to their users. An astrological time clock is a feature where the sunrise and sunset are programmed for 365 days, and the system takes these times into account. Features such as blinds control, heating systems, and scenarios in buildings are controlled according to the sunrise and sunset at different times in each season. (Abd El-Shafy, 2009)

Travel programs are based on the principle that the system works as if there is someone at home when there is no one in the building. The smart home system continuously records in its memory the actions of the homeowner during the last week. In this recording, there are processes such as how the owner turns the light on and off, how many hours he listens to music and watches TV, and when to water his garden. When the travel program is activated when leaving the building for a long time, the smart home system applies these programs as if the user were at home.

With all these features, smart homes bring convenience to people's lives and save time, especially for the elderly and the disabled. Not forgetting things with a button when leaving the house, turning on the lighting and alarm system with a single button in the moment of danger, automatic phone calls come to the fore as vital factors. Smart homes bring security, convenience, and prestige to people's lives with ever-increasing capabilities and capabilities.

Smart home systems are gaining popularity day by day and continue to be integrated into our lives day by day. Smart home systems are technology systems that are planned to provide various services to the daily life of human life in the future, bring comfort to our lives, and give us various advantages in our homes in terms of security and remote control.

3.2. Analysis of home appliances control methods

The palm-sized Smart Home Controller was squeezed with the Energy Manager. To intelligently and automatically distribute solar power throughout the smart house, it interfaces with the photovoltaic system. Domestic appliances come first. Energy flows to the heat pump after they have all the power they require, with any excess flowing to the battery for storage after that. It is essential to ascertain how to increase the use of the lighting system in advance the main factors that characterize the interior lighting in terms of performing the functions of turning on and off the lighting, changing the brightness, and changing the color temperature of the lighting. Such a factor should include the forms of lighting characteristic of the activity performed and the comfortable color temperature of the lighting, which will help to accumulate the productivity of the end-user and, at the same time, help to maintain his biological processes.

Table 3.1 Lighting standards for different types of buildings parts

Room types	**Lighting level, lux**
Cabinet, Library	300
Coridor halls	50
Bedroom	200
Kitchen	150
Living rooms	150

Indoor lighting methods can be classified as general lighting methods and local lighting methods. The general lighting method can improve interior lighting by creating uniform lighting throughout the space of the room while minimizing the lighting imbalance in its different parts. On the other hand, the local lighting method allows you to set the desired lighting on the work surface, thereby increasing the lighting efficiency compared to the general lighting method. However, this method can reduce the comfort of being in such a space due to uneven lighting. In this regard, it considers the number of humans in that area, the status of their current situation, the lighting in the room, and the control of the brightness of the general lighting using the technology to determine the time of day, thereby saving lighting energy.

Indoor artificial lighting control methods can be divided into lighting on/off control, sensor-based lighting control, dimming lighting control, and mixed lighting control, as shown in Table 3.2. On-off lighting control is inexpensive and easy to install, controlled by a simple switch, while sensor-based lighting control provides automatic control by detecting passenger movement as well as interior and exterior lighting. Dark-based lighting control provides step-by-step lighting control that improves visual comfort for passengers and provides efficient energy savings. Finally, mixed lighting control is a method to improve lighting efficiency by combining the previous three methods. The lighting control method proposed in this paper is a hybrid lighting control method because it is a combination of sensor-based lighting control and dimming-based lighting control.

Table 3.2. Artificial lighting control methods

Lighting control systems	**Management format**	**Details**
On and off	Manual	Lowest-cost lighting control, easy to install and change
Sensor (Presence, Brightness, Motion)	Automatically	Lighting control based on people’s movement
Dimming	Manual / Automatically	Lighting control by determining optimal lighting and, thus, energy consumption
Multi-functional (Dim, sensors)	Manual / Automatically	Using the sensors for dimming the outputs

When choosing the architecture of a smart lighting system without using a light sensor, it is necessary that the system takes into account the time of sunrise and sunset.

3.3. Energy saving in residencial and commercial buildings

Electricity bills have a significant share in the costs of commercial buildings. In general, electricity is used for heating, cooling, ventilation, space conditioning, hot water supply, office equipment, elevators, escalators, and lighting. According to research conducted by the North American Energy Agency, 46% of the electricity consumed in commercial buildings is used for lighting, 19% for ventilation, 13% for appliances, 9% for miscellaneous work, 7% for refrigeration, 4% for for heating, and 2% for hot water needs. (Bushby et al., 2008)

Apparently, the most important reason for turning to lighting automation is to save energy in large buildings. In this regard, its simultaneous operation with other HVAC (heating, ventilation, and cooling) security systems is important in terms of lighting automation features. Thus, energy saving becomes more efficient at the same time.

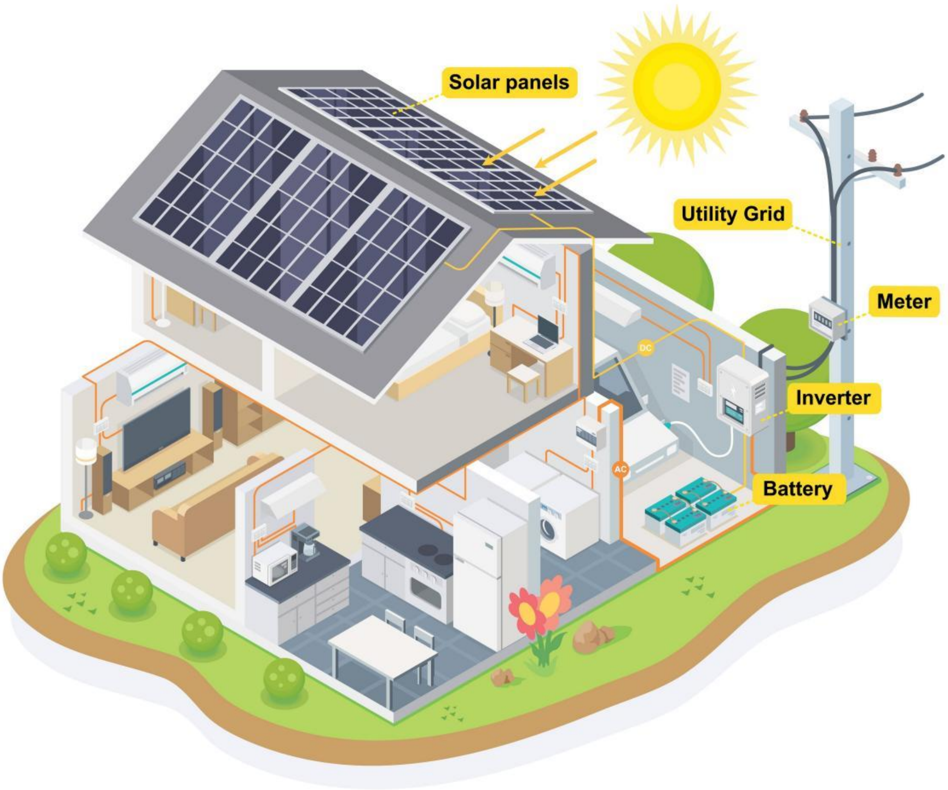

Figure 3.1 Fuzzy logic-based energy management system.

A large share of electricity is used for lighting in our country. For example, 35% of the total electricity consumed is consumed in residential houses and the service sector. 60% of the electricity consumed in the residential and service sector is intended only for lighting purposes, which is equal to 21% of the energy consumed in Azerbaijan. For example, a 20% saving represents 4% of all energy consumption; that is, it will correspond to about 60% of the total electricity imported from some neighboring countries in recent years. For this reason, effective and efficient use of energy in lighting will make great contributions to the country's economy. A study was carried out to determine the lighting characteristics of commercial buildings. The comparison of the area of use led to and the annual consumption of lighting energy of 10 different buildings, certain results were obtained.

In order to determine the share of lighting in the consumed electricity, all lamps, ballast types, power, and quantities used in the buildings were determined. During the survey studies, the usage periods of the volumes were also determined. From the total power of all lighting devices, the installed power of lighting of buildings (W) and the annual electric energy consumed for lighting purposes (kW/year) according to the period of use were calculated and shown in Table 3.3.

Table 3.3. Electricity consumed for lighting purposes

Building	Room	Area (m2)	Lighting power	Power consumption per year (kWh/il)	Lighting level
1	Office	9924	121858	275529	21,2
2	Office	12997	145523	341425	23,9
3	Office	10200	122100	997764	16,7
4	Office	3332	8872	24662	7,1
5	Conference room	52000	182780	391645	27,2
6	Office	18000	260239	654409	21,0
7	Office	17022	181483	710518	10,0
8	Office	35295	255535	3668964	13,0
9	Office	25000	244071	775392	27,1
10	Office	11000	392819	124618	7,3

The information presented above demonstrates that the amount of electricity used for lighting purposes in buildings varies according to the purpose of use. While the share of lighting in the total electricity consumption in hotel buildings is about 7%, it rises to an average of 19% in office buildings. The electricity consumed for lighting purposes in a building can be expressed in the simplest way by the following equation.

$$W=\sum_{i=1}^{m} N_{arm,i} \cdot P_{arm,i} \cdot T_i \quad (1)$$

Here;

W : Electrical energy consumed (Wh)

Narm,i : number of lamps of type i

Parm,i: Mains power (W) of each type I lamp, including ballast and transformer losses

Ti : annual lifetime of lamp of type i (h)

m : the number of types of lamps in the building

As can be seen from equation (9.1), there are three ways to reduce the electricity used for lighting purposes.

• Following the latest technological innovations, efficient lamps and auxiliary elements (ballast, transformer, etc.) can be used to reduce the power drawn by the lamps from the mains.

• The total number of lamps can be reduced with lighting designs made using high-quality, high-efficiency lamps that emit light in any way.

• Control systems can ensure that lighting is used at the required hours and in the required amount.

Lighting automation systems are very important to maximize this energy saving in workplaces with dimmers. Light sensors to make the most of daylight, motion detectors to prevent energy consumption in unoccupied areas, time clocks to adjust lighting control according to working hours, and astrological time clocks to economically program ambient lighting; maximum energy savings are achieved by integrating it into the lighting automation system. In addition, it is possible to save energy by automatically activating different lighting programs for times when electricity is expensive or cheap.

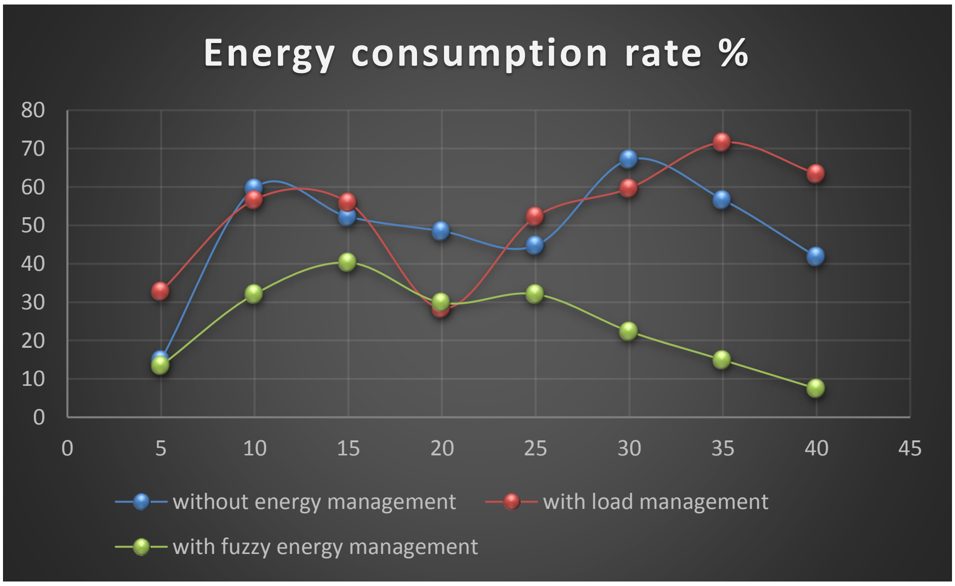

Figure 3.2. Energy consumption rate

The biggest feature of DALI systems is that they can provide active energy management in energy saving. Since each dimmable ballast has its own address, it allows us to direct the energy as we wish. Therefore, the result of the following study shows that the amount of energy savings achieved in one day in an open office floor with only 80 ballasts of 58 W is negligible.

First, the calculations were made by taking measurement results from a system without lighting automation. Since these types of systems do not have a dimmer system, you can either turn the lamps on or off, which does not give us the opportunity to save energy while the workers do not turn off the lamps.

It is then seen that energy savings of up to 50% can be achieved when a DALI lighting system is installed, including traffic and daylighting systems, provided that the behavior of the people working in the same location and the environmental conditions remain unchanged.

It is seen how much it can contribute to the country's economy as a result of lighting automation, which is not very attractive at first in terms of investment cost.

At the same time, thanks to DALI automation systems, Changes to office space over time (creation of new office space, creation of new walls or partitions, etc.), changes to the lighting system, major changes to the electrical installation for new controls or ballast additions, and sometimes a complete redesign is required is not done. These problems are eliminated with simple and minor installation changes. The upgrade cost is limited only by the investment cost of the equipment to be used. Incorporating the group, scenario, and new equipment in the new system can be done easily with a computer program. Thus, changes in the system are kept as flexib le, practical, and cost-effective as possible. For example, if the need arises in the future, it is quite easy to add a remote control module to the system.

Considering all these points, it is possible that the system can cover the investment costs in a shorter period of time. The achievement of energy efficiency and long-term sustainability in buildings depends on building control systems. standard Building Energy Management System have made substantial use of a few standard load monitoring control methods, including thermostats, proportional-integral (PI), and proportional-integral- derived (PID). Additionally, these control systems have been applied to a range of applications and disruptive environmental conditions, and they have consistently performed badly and have not offered an effective control strategy.

3.4. Equipment for intelligent control system

The equipment used in intelligent building management systems works on the basis of many protocols. Examples of these protocols include KNX, Lutron, Cresnet, AMX and others. The cresnet protocol of the Crestron company was used in the practical work of this thesis. The building's central control processor is the 3rd generation CP3 device; in addition, DIN-8SW8, DIN-1DIM4, DIN-DALI2 actuators for lighting control, DIN-2MC2 actuators for controlling the curtain motor system, climate it is possible to integrate the control system over several protocols. Specifically, a centralized VRV climate control system is used here. The core of this VRV system is integrated into the CPU through a Coolmaster device. To implement the lighting control system, it is necessary to take into account the composition of the equipment, which includes a video control device, an infrared motion sensor, a data storage and collection device, a data processing device, a light sensor, and a wireless data transmission device. An 8-channel switching and non-dimmable lighting control module is called the DIN-8SW8-I. Eight isolated digital inputs are also included in the DIN-8SW8-I, enabling standard momentary switches to initiate events with or without a control system. Applications using 120 and 220-240 Volts are supported by the same model. Incandescent loads up to 10 Amperes, fluorescent loads up to 5 Amperes, and 1/2 HP motor loads are all supported by each channel. This table switch is fitted, with 4 inputs connected to push buttons and 8 channels connected to lamps. A third series DIN AP3 processor is also present for programming, and its first input is linked to the 0-1 button. The C2NI-CB keypad and TSW-760 touch panel are additional third-party devices that can be used to control the system. A lighting control module for the DIN rail that has four dimming channels is called the DIN-1DIM4. Incandescent non -dimming lighting fixtures, neon/cold cathode type lights, 2-wire dimmable fluorescent type lights, and non-dimmable lighting loads up to 5 Amperes per channel, a maximum of 10 Amperes, are supported by a single model at both 120 and 220-277 Volts. A tabletop dimmer is fitted, and two of its channels are wired to lamps. A third series DIN AP3 processor is also present for programming, and its first input is linked to the 0-1 button. The C2NI-CB keypad and TSW-760 touch panel are additional third-party devices that can be used to control the system. A DALI® interface for Crestron® systems, the DIN-DALI-2 allows for the control of up to two separate DALI loops. The DIN-DALI-2 is a fantastic low-profile Cresnet® or Ethernet companion for the DIN-AP3 processor or any 3-Series® control system and is housed in a DIN-rail box. It has a built-in DALI power supply in addition to regulating the DALI data bus. Single-wire connectivity makes new and retrofit installations simpler, and Power-over-Ethernet

(PoE) flexibility helps when working with CAT5 infrastructure that already exists. This table has a DALI interface installed, with two loops that are connected to ballasts, and lamps that are connected to these ballasts, one of which was made by Crestron and the other by Tridonic. A third series DIN AP3 processor is also present for programming, and its first input is linked to the 0-1 button. The C2NI-CB keypad and TSW-760 touch panel are additional third-party devices that can be used to control the system.

The automatic control of a light bulb's output can greatly cut energy consumption. Two techniques are frequently employed to control lighting. The first method employs an individual lighting control system, in which each light bulb's output is independently adjusted in accordance with the level of light output of its neighboring bulbs. The second method employs a networked lighting control system, which is more effective than the first because all bulbs intelligently communicate with one another to achieve the required level for the room light intensity. DLCS (distributed lighting control system) for the first approach in Figure 3.2 and CLCS (centralized lighting control system) for the second method in Figure 3.3 are two different types of networked lighting management systems. The controller in DLC systems receives the sensor data from each light bulb, and the neighbors can communicate to alter their output levels in response to one another's states. But in the central unit CLCS, which gets the state of every node based on data from the sensors, actuators are used to carry out control activities. In this system, the central unit uses data from sensors to determine each light bulb's output level. The central unit in CLCS does a variety of duties, including gathering sensor input from each node and calculating the ideal condition at which each light bulb will provide the space with the necessary amount of light.

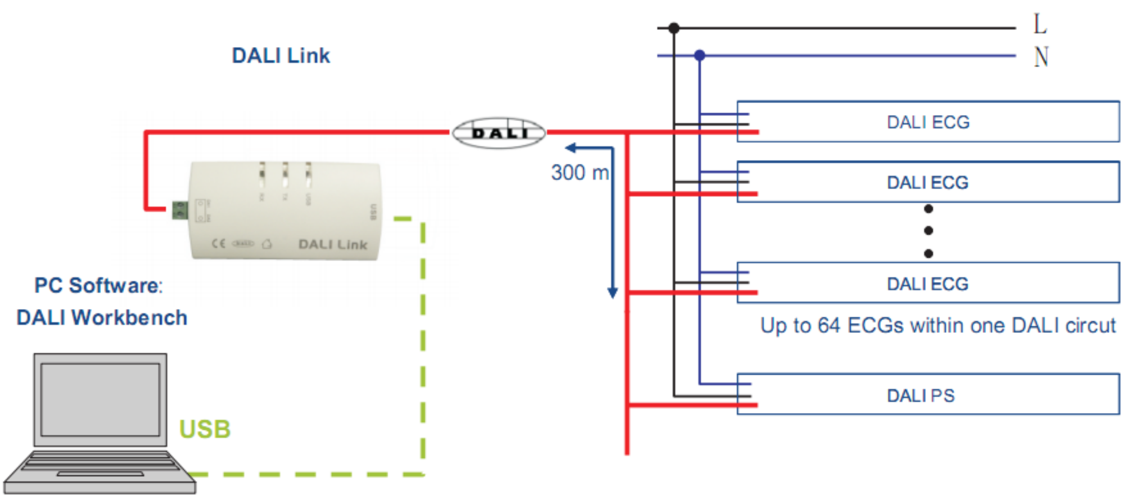

Figure 3.3 Connection diagram of lighting fixtures as distributed lighting control system.

DALI lighting control system wiring must be less than 300 meter and maximum quantity of ballasts is 64 pcs within one circuit.

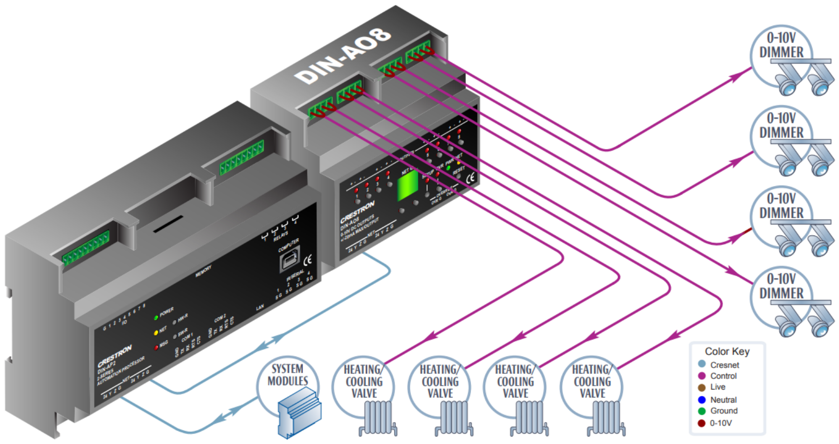

Figure 3.4 Connection diagram of centralized lighting fixtures and shade control motors.

Using a PIR (passive infrared) sensor, one may detect occupancy in a room or office. When a PIR sensor senses occupancy, it sends instructions to the controller to turn on or off the lights. The controller receives the necessary da-ta from one or more light intensity sensors. The control device delivers instructions to the light dimmer(s) to dim the LED light bulbs to the predetermined Lux level needed for the room taking daylight into account. A second regular fluorescent light bulb is utilized to replicate outside daylight. This method starts by looking for occupancy. If there is no occupancy, the Crestron Home Automation controller instructs the AC light dimmer to turn off the lights by adjusting the intensity of the light bulbs. PIR sensor detects occupancy within the room and activates the Crestron Home Automation controller if someone is present. As a result, depending on the input from the light intensity sensor(s), the controller sends a signal to the dimmer(s) to turn on the light and adjust the room's lux to reach the preset number. This control is based on the principle of feedback control. One of the most basic and affordable types of occupancy sensors is the PIR sensor, which is extensively used throughout the world. It has the ability to measure the room's various air temperatures. Sensors deliver signals to turn on or off lights when someone enters the room. PIR sensors measure the infrared light that an object emits as it moves into the field of view of the sensor. In addition to radiating thermal energy, persons have a temperature that is higher than absolute zero. The wavelength of radiation is roughly 9 to 10 micrometers throughout the day. PIR sensors are able to pick up wavelengths of radiation that only appear when a person enters their field of vision. Since it is emitted at infrared wavelengths, the radiation given out by any things with temperatures greater than absolute zero cannot be seen by the human eye. However, electronic devices, such as PIR sensors, can detect it. This type of sensor relies solely on the energy that objects release to function. The sensor turns on the controller when the quantity of heat alters in intensity or position. This Intelligent Lighting System's IR sensor has a pyroelectric sensor module that is intended to detect human body heat. This sensor's lens angle is roughly 140 degrees, and its sensing range is between 3 and 4 meters. PIR sensors have several benefits over other occupancy sensor types, including simplicity of installation, tiny size and lack of complexity. Additionally, it can function in temperatures between 15 and 70 degrees, uses very little power, and is highly sensitive. The fact that it can penetrate walls where motion may be foreseen and that it is less expensive than other sensors make it significantly superior to other sensors. The PIR sensor is sensitive to temperature, but it cannot detect a constant or little motion. The fact that this sensor's field of view is less than that of other kinds of occupancy sensors is another drawback. Additionally, this sensor cannot be placed close to areas where temperature varies often. But this senior is suitable for usage in an indoor industrial building. There is no need to use an interface transducer to convert the observed value to lux when using this sensor because it can measure lux directly. The Cresnet protocol is used by this sensor to interact with the controller. It is simple to utilize with a controller to this protocol. With several advantages over fluorescent lights and incandescent bulbs, LED bulbs are the greatest option for use in energy-efficient lighting systems. These days, LED bulb technology has advanced and offers light bulbs that may be utilized in a variety of situations. Additionally, this kind of light bulb has non-dimmable and dimmable alternatives, opening up the possibility for usage with intelligent lighting systems. Since no mercury is used, LED lights are incredibly durable. Despite having a higher upfront cost than other types of bulbs, over the course of their lifespan, LED bulbs are less expensive to operate than fluorescent or incandescent lights.. Using led bulbs in Intelligent Lighting Systems rather than other types of bulbs can be advantageous for all the aforementioned reasons. The light intensity can be changed by using an AC light dimmer to dim the lamp's lightbulb. However, when variable resistance is utilized to alter the brightness of a lamp, resistance turns some of the energy into waste heat. Regularly shutting off the AC power while only giving the light a fraction of the complete wave is an efficient dimming technique. If the periodic light switches and the phase of the AC power are locked, it will produce flicker, but it won't be visible to the human eye. This may seem unusual at first. Two circuits, a zero-crossing detector and a pulse-controlled switch, are needed to achieve the dimming. This is used to keep switching while keeping the power supply in phase. To cope with 220 V AC, safety measures should be put in place. Because of this, the circuit needs to be mechanically and electrically separated from the outside using a metal box and appropriate optoisolators. A full wave rectifier with high power resistors is utilized as the zero-crossing detector to lower voltage (Figure 3.3). A Diac or Triac is also present in the pulse-controlled switch.

Over half of an intelligent home's annual energy expenditure is made up of heating and cooling costs. The statistics show that about 75% of sunlight is converted into heat. It can make up to 40% of the annual energy budget that would otherwise be lost to poorly controlled home heating. As a result, a window transforms into a noticeable vulnerable intersection in a structure that, if neglected, can result in significant energy loss. Using motorized controllable blinds will help to stop energy waste during any season. Intelligent and traditional home heats up during the hot summer, necessitating an additional cooling system to maintain a suitable temperature. High-quality window coverings may efficiently block out heat and light. In the winter, a heater's warmth may dissipate if no blind mechanism is there to stop it. How effectively window blinds can regulate heat is determined by two elements. To start, it's important to understand how a blind can modify sun irradiation to change the temperature in a certain location. The second factor is related to how the homeowners use the space, and how consistently they do so affect the overall cooling or heating requirements of the property. So how do we evaluate an energy-efficient blind's performance? To do this, we require a variable known as the "R-value," which is connected to window materials and measures heat resistance. More thermal resistance equates to higher performance. A single-pane window typically has an R-value of 0.9, which is significantly less efficient than a plywood window's R-value of 1.25. The better the material is, the higher the R-value, the more energy-efficient it is. An R-value of 2.2 solid hardwood structure is the best option for windows. To achieve the greatest energy savings, the approach should be to choose materials with a higher R-value.

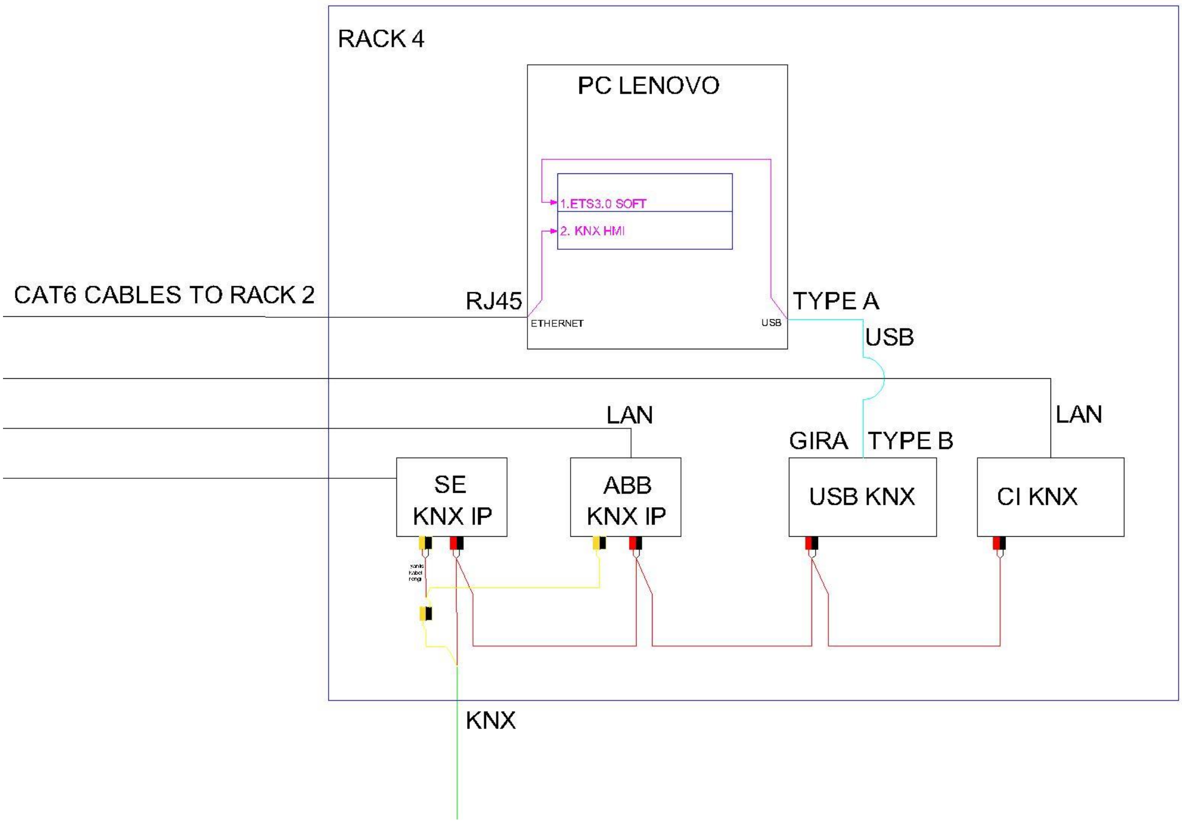

Figure 3.5. Main Control System and interface connectivity to the KNX bus

A Crestron RMC3 microprocessor is used by the fuzzy logic climate controller to do calculations. The microprocessor includes 256MB of DDR3 SDRAM and Flash 4 GB. With an 8 megahertz clock, it can cycle through instructions in 500 ns. The CPU features an eight channel inbuilt analog to digital converter. The control system's inputs, including ambient (outside) temperature, engine coolant temperature, interior temperature, and sun load, are all measured using four of the system's eight channels. The set point temperature is another input to the system that may be changed by the occupants of the car using buttons on the control unit's front face.

The system outputs include blower speed, blend door position, discharge air mode (fresh air or recirculate), and intake air mode. The first two outputs are discrete, but the last two have continuous values. The first two outputs are discrete, but the last two have continuous values. Scaled input values are used in the fuzzy logic control computation to provide a single relative output value. There are four rule sets since there are four system outputs. Fuzzy logic output values for continuous outputs are scaled and used directly; for discrete outputs, output values are compared against thresholds to produce certain system modes or states.

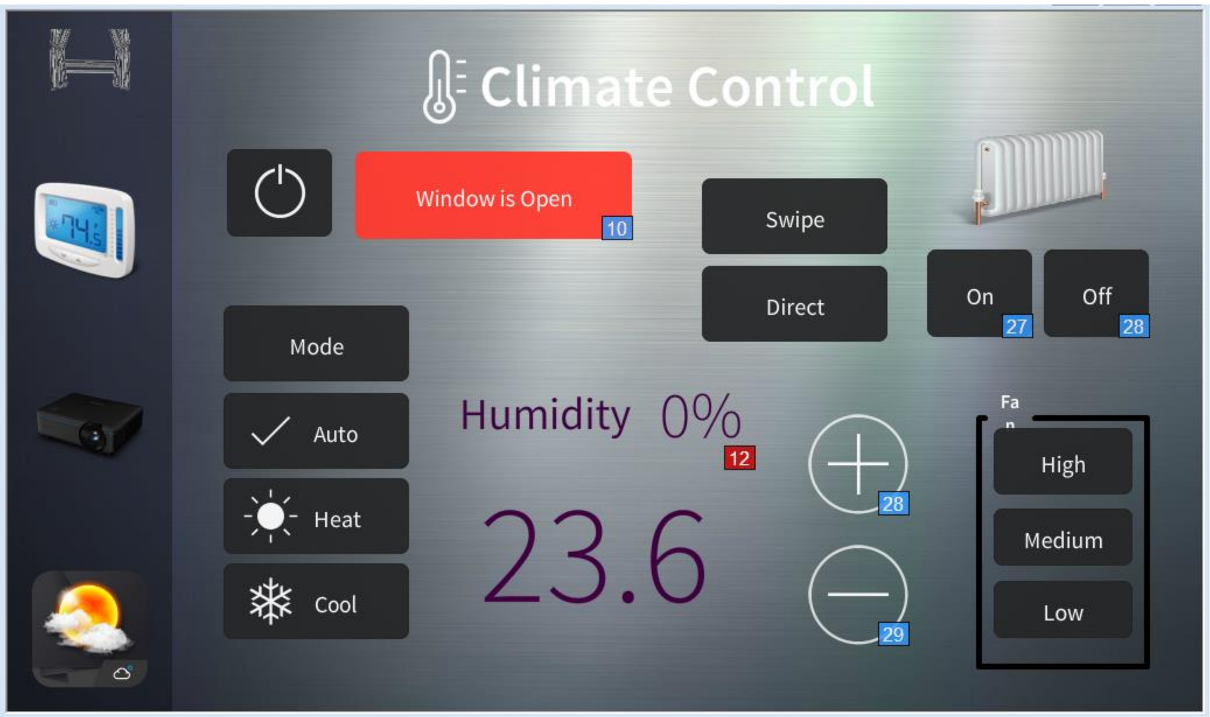

Figure 3.6. HVAC control system user interface

The control unit is mostly programmed in SIMPL++ and has cross-assembled instructions for microprocessors. Each collection of fuzzy rules is integrated into the fuzzy engine as a set of tables that have been transformed into a run-time calculation-efficient format. In the main loop, which runs once every 30 milliseconds, the fuzzy logic control function is invoked. During ita execution, the fuzzy logic engine requires 12 bytes of RAM and about 600 bytes of ROM. The supplementary table uses 900 bytes of RAM. A fuzzy calculation normally takes 2 milliseconds to complete. The Fuzyy Logic Climate Control System processor's input variables for temperature and humidity are represented by the symbols T for outside temperature and H for outside humidity knowing that:

$$\Delta T = T_{desired} - T_{indoor} \in (NB,NM,Z,PM,PB) \quad (1)$$

$$\Delta H = H_{desired} - H_{indoor} \in (NB,NM,Z,PM,PB) \quad (2)$$

where outside temperature ∈(PM, Z, PG),

NB – negative big

NM – negative medium

Z – Zero

PM – Positive medium

PB – Positive big

The exterior environmental factors (outside temperature and outside humidity) were considered during the control. The heating rate (Heating), ventilation rate (Ventilation), and humidifying rate (Humidifying) are the output variables.

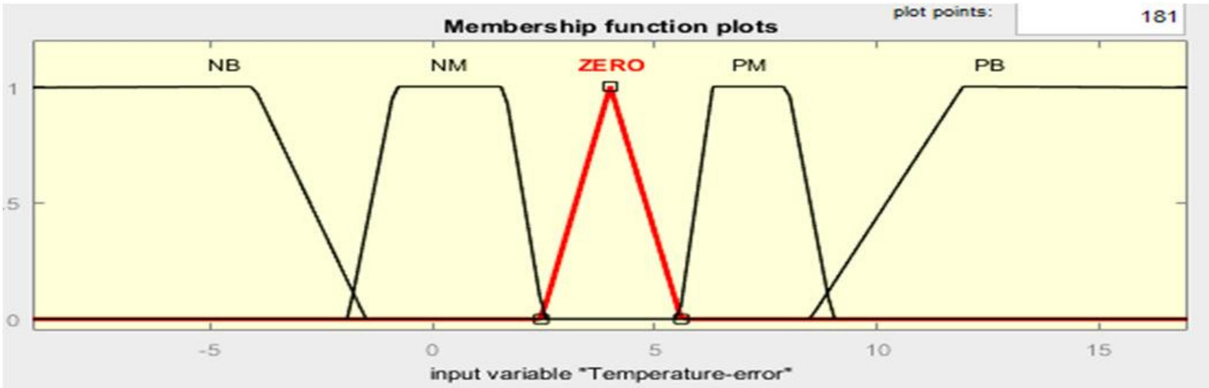

Figure 3.7 Membership functions of temperature

Fuzzy logic controller decoupling - The input variables for temperature and outside temperature are shown in Figures 3.7, respectively, while the input variables for humidity and outside humidity are shown in Figure 3.8. The output variables for heating, ventilation, and humidifying rates are shown in Figure 3.9.

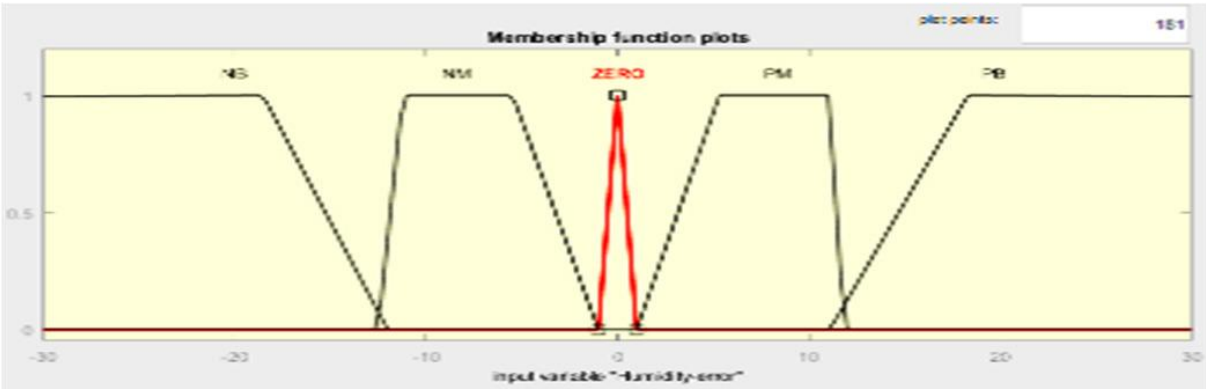

Figure 3.8 Membership functions of humidity

The primary goal of control is to smoothly adjust the greenhouse's interior air temperature and humidity to the desired levels ($T_{desired}$, $H_{desired}$). In order to conserve energy, we managed the actuators by lowering their rates. The ideal temperature is 15°C at night and 28°C during the day. 70% relative humidity is ideal.

There are pros and cons of solar cells for applications in smart home system.

• Panels are easy to maintain, and maintenance costs are very low.

• No fuel purchase and transportation costs as it uses solar energy as fuel. In addition, it is not affected by price changes because it is independent of the fuel market.

• They leave no harmful waste to the environment and work silently.

• Most system components are portable.

• Can be applied in a wide power range from 1 Watt to several Kilowatts

• It causes less breakdowns than a generator as it has no moving parts.

In a medium-sized system, if a module or battery fails, the entire system is unaffected and continues to operate.

• Although the initial investment cost is high compared to generators, it costs less in the long run due to fuel and maintenance costs.

• Produced electricity is stored in batteries, so it can be used at any time and in any amount. When generators are compared, it takes the generator to run to even light 1 bulb.

• The number of losses that may occur during the conveyance of energy is extremely modest because there is not a great distance between where it is created and where it is used.

Despite having many advantages, solar systems have the following disadvantages compared to other electricity generating systems:

Initial investment cost is high. It is not economical for high power engines and heating systems. The rate of conversion of solar energy into electricity is low.

The production potential of the system is affected by seasonal and daily weather changes. A battery is required when there is no mains connection. Because they produce direct current, electricity needs to be converted to alternating current to make it usable.

More expensive than mains electricity.

CONCLUSION

In this thesis we first present a tutorial solar energy obtaining, Intelligent Energy Management System (IEMS) on fuzzy logic and fuzzy sets as they relate to control system design. The concept of a fuzzy set and operations on a fuzzy set are presented in comparison to conventional sets to help understand the concept more easily. People are turning to renewable energy sources today as a result of the world's fast growing energy needs, rising energy prices, and environmental pollution. Numerous organizations support the research on this topic because these resources are ongoing and do not harm the environment. They are therefore being explored more closely and being tested out.In order to test the suggested IEMS, a RES made up of photovoltaic (PV) solar panels is created. A management system is needed to fulfill the load power requirement because solar sources cannot be relied upon for sustainability or high-quality power. The section can be summarized by pointing out that most locations have excessive lighting since background light is not taken into account during the design process. Additionally, lights are turned on in places that are empty, wasting electricity. In order to effectively regulate the amount of illumination, Intellect Lighting System is absolutely necessary to solve this issue. It controls indoor lighting intensity while taking into account occupancy status and background light entering the space. Therefore, it is important to emphasize that Intelligent Lighting Systems that use well chosen LED bulbs reduce power consumption as well as maintenance costs, pollution from power plants, and the potential for gas sales. The development of intelligent blinds and curtains is one of the most prominent instances of a breakthrough development in home automation. These cutting-edge home accessories provide many benefits, including energy efficiency, improved privacy, and unparalleled ease. The correct motor, electronic controller, and control system can significantly impact how effectively your automated home system integrates with your smart curtains.. For anyone wishing to upgrade their lifestyle and experience the future of home automation, smart curtains and blinds are undoubtedly a wise purchase. Comfort levels for users of climate control systems may be increased thanks to the use of fuzzy logic controls. The design of the method can address several problems that have not always been handled graciously thanks to the flexibility to construct progressive, nonlinear responses. By making effective use of the extra flexibility that fuzzy logic offers, issues like blower speed initiation during warmup in cold weather and ambient temperature correction can be lessened.

The amount of time available to design new automatic temperature control strategies is decreasing due to new vehicle projects and the demands of simultaneous engineering. The control engineer must create the control strategy concurrently with the design of the HVAC system. The evolution of fuzzy logic is organized and adaptable. Current linear controllers cannot compete with fuzzy logic climate control systems in several performance facets.

The comfort of the occupants might be preserved more consistently across a wider range of circumstances. To increase the effectiveness of the installed components the suggested intelligent IEMS is also utilized to track and determine the maximum solar power from PV that is generated and available. The fuzzy reasoning-based IEMS creates the necessary operating sequences to control the overall system power with the least amount of utility input using the generated and required power information from the wind/PV and load sides. The energy control is made to manage renewable energy systems as a component of an electric utility. Therefore, in the suggested smart home energy management application, the integrated energy management system may also be regarded as a smart grid operator. Distributed power systems can use the proposed integrated energy management system to make quick judgments about power management during crucial peak power periods.

LİTERATURE

1. A. Abd El-Shafy, Nafeh design and economic analysis of a standalone PV system to electrify a remote area household in Egypt, Open Renew. Energy. J. 2 (2009) 33–37.
2. Almaraashi, M. (2017). Short-term prediction of solar energy in Saudi Arabia using automated-design fuzzy logic systems. PLoS One, 12(8), e0182429.
3. Arun et al., 2020 Arun K.K., Mydhili S.K., Baskar S., Shakeel P.M. Fuzzy rule-based environment-aware autonomous mobile robots for actuated touring.
4. Ashton, K. (2009). That ‘internet of things’ thing. RFiD Journal, 22(7), 97-114.
5. Bushby, S.T.; Butler, J.F. BACnet® for Utilities and Metering. Ashrae J. 2008.
6. Coelho, R.F; Concer, F.M. and Martins, D. “A Study of the Basic DC-DC converters Applied in Maximum Power Point Tracking”. 10th Brazilian Power Electronics Conference, 2009, pp. 673-678.
7. C. Douligeris - Intelligent home systems IEEE Communications Magazine, 1993
8. Coşkun, İ., Ardam, H., “A remote controller for home and office appliances by telephone”, IEEE Transactions on Consumer Electronics, 44 (4): 1291-1297 (2008).
9. Di Giorgio A, Pimpinella L. An event driven smart home controller enabling consumer economic saving and automated demand side management. Appl Energ 2012; 96:92–103
10. Ebrahim Mamdani (1977). “Application of Fuzzy Logic to Approximate Reasoning Using Linguistic Synthesis”, IEEE Transactions on Computers, C-26, no. 12, pp. 1182-1191.
11. F. Chekired, A. Mahrane, M. Chikh, Z. Smara, Optimization of energy management of a photovoltaic system by the fuzzy logic technique, Energy Procedia 6 (2011) 513–521
12. He Zhanga, Arnaud Davigny, Frédéric Colasa, Yvan Poste, Benoit RobynsaFuzzy logic based energy management strategy for commercial buildings integrating photovoltaic and storage systems, Energy and Buildings 54 (2012) 196–206.
13. Jahangir Hossain, Aida. F. A. Kadir, Ainain. N. Hanafi, Hussain Shareef, Tamer Khatib,Kyairul., A. Baharin and Mohamad. F. Sulaima A Review on Optimal Energy Management in Commercial Buildings.
14. Jiang, L., Liu, D. Y.,Yang, B., “Smart home research” , Proceedings of the Third International Conference on Machine Learning and Cybernetics, Shanghai , 659-663 (2004).
15. G. Bartolini. etc. "Development of Performance Adaptive Fuzzy Controllers with Application to Continuous Casting Plants,"Industrial Applications ofFuzzy Control, pp. 73-87, 1985.
16. Koyuncu, B., “PC remote kontrol of appliances by using telephone lines”, IEEE

Transactions on Consumer Electronics, 41 (1): 201-209 (1995).

17. Lin et al., 2021 Lin X., Sun X., Manoharan G., Rawal B.S. Advanced energy consumption system for smart farm based on reactive energy utilization technologies. Environ. Impact Assess. Rev., 86 (2021), Article 106496.

18. L. A. Zadeh, "Fuzzy Sets", Information and Control 8, p. 338 - 353,1965.

19. L.A. Zadeh, Fuzzy logic and approximate reasoning, Syntheses 30 (1975) 407-428.

20. L.A. Zadeh, A theory of approximate reasonin in (J.E. Hayes et a1 eds.) Machine Intelligence (John &ey and Sons, New York, 1979), 149-194.

21. L. I. Davis, Jr., T. F. Sieja, R. W. Matteson, G. A. Dage, and R. Ames Ford Motor Company, P. 0. Box 2053, Room 3135, SRL Dearborn, Michigan 4812116.

22. Li, J., Huang, Z., & Wang, X. (2011, May). Notice of Retraction Countermeasure research about developing Internet of Things economy: A case of Hangzhou city. 2011 International Conference on E-Business and E-Government (ICEE).

23. Li, S., Da Xu, L., & Zhao, S. (2015). The internet of things: a survey. Information Systems Frontiers, 17(2), 243-259.

24. Miller, M. (2015). The internet of things: How smart TVs, smart cars, smart homes, and smart cities are changing the world. Pearson Education.

25. N. K. Suryadevara and S. C. Mukhopadhyay, Smart Homes: Design, Implementation and Issues, vol. 14. Springer, 2015.

26. O.C. Otumdi, C. Kalu, I. Markson, Determination of loss of load probability for standalone photovoltaic power.

27. Pedersen H., Strauss, J., Selj J. (2016). Effect of soiling on photovoltaic modules in Norway. Energy Procedia.

28. Rabindra Satpathy and Venkateswarlu Pamuru, Solar PV Power, Off-grid solar photovoltaic systems. # 2021 Elsevier Inc., Chapter 7, pages 267-273.

29. R. Harper, Inside the Smart Home. Springer, 2003.

30. Roberto F. Coelho, Filipe M. Concer, Denizar C. Martins. A MPPT Approach Based on Temperature Measurements Applied in PV Systems, Electrical Engineering Department, Power Electronics Institute, Federal University of Santa Catarina, P.O. 5119 -Florianópolis, SC 88040-970, Brazil.

31. Saizmaa,T.,Kim H.C.,"Smart Home Desing:Home or House", International on Convergence and Hybrid Information Technology, Korea , 621-749 (2008).

32. S. A. Shinde. Home Energy Management System for Demand Response Applications. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol

4 Issue 06, June-2015.
33. S. Onaygil, Ö. Güler, E. Erkin, H. Saygın, “Energy Saving by Using Compact Fluorescent Lamps at the Residences”, XII National Conference LIGHT’2004, pp. 101-104, Varna, July 2004.
34. Tascikaraoglu A, Boynuegri A.R, Uzunoglu M. A demand side management strategy based on forecasting of residential renewable sources: A smart home system in Turkey. Energ Buildings 2014; 80:309–320.
35. Weston, H.C. ve Taylor, S.K. (1926). The relation between illumination and efficiency in fine work (typesetting by hand), Final Report of the Industrial Fatigue Research Board and the Illumination Research Committee, London.
36. Yuejun, Z., Mingguang, W., “Design of wireless remote module in X-10 intelligent home”, IEEE Transactions on Consumer Electronics, 1349-1353 (2005).
37. Zhang, L., Leung, H., Chan, K.C.C., “Information Fusion Based Smart Home Control System and Its Application”, L. Zhang et al: Information Fusion Based Smart Home Control System and Its Application (2008).
38. Zhang,S., McClean,S., Scotney, B., HongX., Nugent,C., Mulvenna, M., “Decision Support for Alzheimer’s Patients in Smart Homes” , 21 st IEEE International Symposium on Computer –Based Medical Systems (2008).
39. Zhong, Y. (2015). I2oT: Advanced Direction of the Internet of Things. ZTECOMMUNICATIONS, 3.
40. Беллиа Л. Освещение внутренней среды: визуальные и невизуальные источники света с разной спектральной мощностью // Новизна. 2017. 254 с.
41. F.F. Məmmədov “Azərbaycanda günəş enerjisindən istifadə və müasir günəş energetik qurğuları”.Dərs vəsaiti .Bakı- 2011.
42. M.F. Cəlılov., Alternatıv regeneratıv enerjı sıstemlərı, Milli Kitabxana. Bakı, 2009, səh.82-94.
43. R.Ə. Balayev, M.N. Əlizadə, İ.K. Musayev “İntellektual sistemlər və texnologiyalar” Dərs vəsaiti, BAKI 2016.
44. R.Ə.Əliyev, R.R.Əliyev “Soft kompütinq” (nəzəriyyə, texnologiya və praktika) Çaşıoğlu, Bakı-2003.
45. S.Q.Kərimov “İnformasiya sistemləri” Bakı «Elm» 2008
46. Abdurrahim E., Atatürk Üniversiteti “İqtisadiyyat ve İdarəetmə elmləri” Jurnalı, Cild: 23, 3, 2009.

47. Işık, H., Altun, A.A., “Mikrodenetleyici Kullanarak Cep Telefonu Kontrollü Akıllı Ev Uygulaması”, Selçuk Üniversitesi Teknik Bilimler Meslek Yüksek Okulu,Teknik-Online Dergi , 4(1):1-8 (2005).

48. Göktaş, İ., Akıllı ev teknolojisi, Yüksek Lisans Tezi, Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Elektrik-Elektronik Mühendisliği, Ankara,1-5 (2006).

49. Onaygil, S. ve Demir, N., (1996), “Ofis Aydınlatmasında Enerji Tasarrufu”, Kaynak Dergisi, Ocak Sayısı.

50. Energetika | Azərbaycan Respublikasının Dövlət Statistika Komitəsi www.stat.gov.az

51. https://minenergy.gov.az/az/alternativ-ve-berpa-olunan-enerji/azerbaycanda-berpa-olunan-enerji-menbelerinden-istifade

52. Control Systems for Home Automation, Campus & Building Control by Crestron Electronics [Crestron Electronics, Inc.]

53. White Paper Controls DALI Comparison between DALI & DALI-2 (2022).