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A Smart Lighting Control System Using Solar Energy in The Scope of Internet of Things

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Abstract – Artificial lighting is an important part of global electricity consumption. At office buildings, the energy consumed by artificial lighting can reach up to 40% of total energy consumption. This work is being done to find solutions to such problems with energy saving and lighting control. It is necessary to adjust the illumination level with a system to save energy. This system is the smart lighting control system. Smart lighting is a part of Internet of Things concept. Thanks to advances in the technologies of Internet of Things, devices become smart. These smart devices contain sensors. These sensors collect the necessary data. By using these data and various inputs, it is aimed to make a decision of the system and control the lighting. In addition, it is planned to save a great amount of money by using solar energy.

Keywords – *Smart Lighting, Lighting Control, Internet of Things, IoT, Energy Saving, Solar Energy, LED, Renewable Energy*

I. INTRODUCTION

Rapid advances in detection, computing and communication technologies ensure that objects in lighting systems are intelligent and communicate with each other, so that each luminaire in the system has these functions. These technologies have made the system more intelligent by allowing a lighting system to be flexibly adapted to its environment. The energy consumed by artificial lighting reaches to very large dimensions. Control of the artificial lighting is an important way to reduce the energy consumption of artificial lighting while maintaining the comfort of lighting, thereby reducing building operating costs. The approaches established for energy efficient lighting control are realized with the adaptation of artificial lighting to occupancy and change in daylight. A smart lighting system with occupancy and light sensors in the luminaires provides spatial information about occupancy and light distribution in a closed area. Each luminaire provides information on a occupancy sensor; user presence and rough location. This occupancy information can be used to activate the luminaires. Thus, lighting is provided when necessary. In addition, the light sensors in the luminaires can be used to adapt the amount of artificial light to match the amount of daylight available for providing the required amount of illumination and the required total illumination. Adjusting the illumination level using such sensing information to provide localized illumination makes it possible to save energy effectively. Especially in the occupied areas, high average lighting levels are provided and the luminaires are closed when empty.

In addition to smart lighting systems, renewable energy sources such as solar and wind can be used to provide energy saving in indoor lighting. For example, solar panels can be used to generate energy. Thus, energy can be saved by using a continuous energy source. In addition, high-energy savings can be achieved by using appropriate control strategies developed specifically for lighting systems. This control can also be performed using fuzzy logic. An important aspect for lighting systems is to consider saving when using energy systems and lighting systems. The design of a lighting system with reduced energy consumption should include light sources with energy saving characteristics and a control unit to obtain information about daylight to incorporate in the operating cycle. The approaches reported with energy-efficient control units and lighting systems often refer to changes in ambient occupancy and daylight. Lighting control can contribute to energy savings, especially in large, common interiors. The dimmable LED luminaires have great advantages for energy efficient lighting systems as a luminaire's degree of illumination is related to its strength. It is possible to control the light output of the luminaire easily and accurately in LED luminaires. Some studies show that the energy consumed by the lighting is saved by controlling the lighting degree and the design of the indoor lighting. LEDs compared to traditional lighting sources; It has many advantages such as higher energy efficiency, long life, good light colour, smaller size, good electro-optical efficiency, colour rendering index, dynamic light effects, more flexible design and fast switching. In addition, LEDs can be used in general applications both indoor and outdoor lighting. A new smart lighting control system should be designed to:

- Maximize the use of LEDs.
- Have ability to communicate.
- Control lighting with motion detection capability.
- Ensure both energy efficiency and consumer satisfaction.

When the appropriate luminaire, solar panel, charging system and battery are assembled, the lighting system can operate at maximum efficiency.

The energy used in the illumination, the majority of the overall energy consumption, is a problem today. Energy should be saved as a solution to this problem. A lighting control system should be designed for this. In most studies in the literature, only systems using sensors are available. But these are not enough. In addition, it is important that the energy source is a sustainable, renewable resource. In this study, this source is determined as solar energy. Unlike other studies, it is intended to use weather data as input other than sensors. In this way, we can decide addiction to the future weather and also contribute to the control of the lighting. As a result of this system, we can save energy.

In the second part of this study, the studies in the literature are mentioned. The methods and materials used in the third chapter are explained and the results are given in the fourth chapter.

II. REVIEWING LITERATURE

J. Mix et al. have developed a device to adjust the light level in the study and patent they have received. This device includes a sensor that detects whether the room is full, a sensor that senses ambient light and a circuit that controls the light in the room. If the room occupancy is determined, the amount of light is increased or decreased according to the ambient light. If there is no movement in the room, the light is turned off. The invention relates to a device for controlling electrical power. There are motion sensors for detecting the occupancy of the room or sensors for sensing body temperature. The motion is determined by ultrasonic transceivers and transmitters. This is ensured by the ultrasonic transmitter transmitting an audio signal that reflects objects in the room and being detected by the ultrasonic receiver. Body temperature is determined by an infrared sensor that senses the heat given by a person or senses the movement or changes in a heat source. Although these sensors are designed for energy efficiency, before this invention none of the occupancy sensors can adjust the brightness of the lights in a room according to the level of ambient light in the room. The present invention solves problems with prior sensors by detecting whether a room is occupied and having a sensor, which detects the ambient light level in a room. The present invention adjusts the lighting of a room to maximize energy savings [1].

A. Pandharipande et al. deal with luminaire based smart lighting control systems for indoor lighting applications such as offices. Each luminaire has a occupancy sensor and a light sensor. Lighting information is used to control the lighting level according to occupancy and daylight changes. The design goal of the lighting control system is to provide the required lighting conditions with low energy consumption. Two different basic architecture, central and distributed, are studied for illumination. The most recent control methods are reviewed and several methods are reviewed. This study summarizes various technical challenges in the future design of lighting systems. Luminaires, sensors and controller are located on the ceiling. The occupancy and light sensors inform the controller of the status and lighting values, respectively, on a periodic basis or on an event change based on local detection according to their field of view. Periodic sensor processing is useful to support data analysis services in these lighting systems. However, it is sufficient to transmit event changes to most control applications. In the case of an occupancy sensor, an event change refers to a change in occupancy status. In the case of the light sensor, the event change may correspond to the difference between the last transmitted and the current light sensor measurement exceeding a certain threshold. The communication link between the sensors and the controller or between the controller and the luminaires can be either wired or wireless. Wired systems offer higher communication reliability, but generally have higher installation costs. On the other hand, wireless lighting systems are easier to install, offering “plug and run” solutions. However, lower connectivity reliability resulting from wireless channels should be considered in the system design to provide a reliable system solution [2].

Two main architectural concepts are used for lighting control systems with luminaire based occupancy and light sensors. In central architecture, a central lighting control system is shown. Therefore, the occupancy and light sensors send the corresponding occupancy and illumination values to the central control. The central control calculates the dimming levels for the various luminaires based on the sensing inputs and sends the dimming values to the respective luminaires. However, a central control can be limited by the number of communication inputs / outputs it can use, and there may be a congestion for large-scale lighting systems. A distributed lighting control system is shown in the distributed architecture. Here, each luminaire has a local control, with interfaces for occupancy and light sensors. Occupancy and light sensors send relevant occupancy and light values to the local controller; where the dimming value is determined for the respective luminaire. Each controller in a distributed system has a lower processing requirement because the number of inputs / outputs of the controller is limited. Compared to central lighting control systems, distributed control systems provide better modularity and scalability. Local controllers can operate independently, in which case no control information is exchanged between the multiple controllers or the control information is changed in a coordinated manner and in this case some control information is exchanged between multiple controllers. In the case of stand-alone control, a local controller determines the dimming level of the luminaire based on inputs from its luminaire and light sensors. In the case of coordinated controls, additional control information, such as the local occupancy of adjacent sensors, and the dimming levels of adjacent fixtures, can be used by a local control unit to determine the dimming level of the luminaire. They also point out that a hybrid of centralized and distributed control architectures can be used. It may have a distributed lighting control system with control functionality on local controllers; however, in addition to the gateway there is a central controller control functional element. The role of the central controller may be to transmit non-real-time information (for example, changes in controller parameters) or external inputs from a building management system (e.g., demand response signals) to local control devices [2].

I. Kıyak et al. designed an LED luminaire using Osram Coinstar W4 brand power LED module. The LED driver board, a feature of the luminaire; It is designed to provide ideal operating conditions and to be used as a power supply for LEDs. A communication card is designed to exchange information between LED lighting fixtures, motion detectors and light sensors; Each RS485 communication line has been installed to connect the system. Under the control of the luminaire, the lighting has been tested by a fuzzy expert system. A system that can be used indoors with this project design and testing has been developed [3].

In order to obtain the required light intensity and optimize the dim levels of multiple LED sources, the locations of the motion detectors are provided by an illumination control algorithm. Thus, the adoption of scenarios based on different occupancy states contributed to the design of the energy-saving system. Based on the data measured by light and motion sensors, the fuzzy logic controller is manufactured with an LED luminaire considering the luxury requirements and user preferences for lighting. Four photovoltaic batteries, each with a capacity of 125 W, were established in the direction of 42° south, which is the best position for Istanbul to obtain energy from the sun. The generated energy is accumulated in the battery bank (400 Ah). A series of four modules were formed and a 24V system was obtained by parallel connection of the groups. These two 24V discharge leads are placed in a 40A solar charge controller connected to a 24V battery pack. On the roof of Marmara University Technology Faculty, a parallel-wing vertical-axis wind turbine type has been established. After the turbine assembly, a three-phase 42V AC output is connected to charge the control module. The charge controller has converted the voltage to 24V DC. The output of the control unit is connected to a 24V battery pack. A total of 42 Osram Coinstar W4 power LED modules are used in LED luminaires designed for lighting system. Technical specifications of Osram Coinstar W4 series power LEDs were analysed as lighting units and the working current was measured as 0.5A. This is a relatively high operating current for LEDs. At catalogue values, 450 cd luminous flux gives 5400 K colour temperature and 0.5A operating current at 25°C. Under normal conditions, the operation time of the power LEDs is 50,000 hours. Light efficiency and operating time may vary inversely with the operating temperature. The cooling of the LEDs in the design of the LED luminaires is crucial to improve the working life and performance. Osram Coinstar brand cooler was used in this study. When the power LED's internal temperature exceeds the critical level, the fans are activated. In this way, power LEDs are aimed at active cooling in addition to passive cooling and an increase in energy efficiency is observed. In the smart lighting system, a control circuit is designed to control the luminaire containing an LED with six control cards. A total of seven luminaires were used and all luminaires communicated with a daisy chain RS485-type half-duplex communication infrastructure. The brightness level of each LED bulb can be adjusted between 0 and 10V DC. The control circuit includes two digital, six analogue outputs (8 bits) and one (4-20 mA) two analogue inputs. Also there is active cooling and a fan in the thermostat. The thermostat was set at 55°C. When the LED PCB(Printed Circuit Board) temperature is higher than 55°C, the luminaire is subjected to active cooling. As the control circuit supply, the voltage level must be +5 to +12 V. A smart control system is designed in the laboratory for LED luminaires based on the fuzzy expert system. Fuzzy logic, by using a concept called fuzzy membership, offers an approach based on modelling the way a person thinks. Fuzzy controllers work very effectively, especially in systems where the analysis of information sources in numerical, specific or non-ambiguous systems is very complex. During the operation, energy was generated using the wind-solar hybrid energy system and then the energy produced was stored in the batteries for use in the lighting system. A data logger and measuring system has been designed to instantly monitor and record the energy generated by wind turbine and photovoltaic batteries. The power of the three-phase synchronous generator, the voltage and current data of the photovoltaic batteries were recorded in the data logger at 5-minute intervals. Thus, using only LED bulbs, 30% energy savings are achieved compared to the conventional system [3].

M. I. Zaidy, in his study of the United Arab Emirates (UAE), says that energy consumption has doubled in a few years and there is still an increase. Lighting is the majority of this consumption. This study aims to apply solar energy for the production of energy. It also focuses on reducing energy consumption by utilizing daylight and appropriate controls with led lighting technology. Solar energy is renewable, clean, and environmentally friendly and has no harmful gas emissions. Solar energy can be used here all year long, making a big difference. An experimental prototype of the 20 Watt solar lighting system using LEDs is installed with a solar charge controller and a light sensor. Daylight saving, led light planning and an energy efficient building architecture have been created and the results have shown that this system has a satisfactory performance. The main objective of the project is to demonstrate the adequacy of the renewable energy lighting systems that can be used for use in residential and commercial buildings in the UAE. The system is designed using the light planning program called Dialux Evo. This planning is used to create a suitable prototype. The system design requires the installation of a solar panel on the outside of the building. The output of the solar panel is connected to a solar charge controller that goes to the battery, regulating the incoming voltage / current. 12V DC batteries are used to power the lighting. Led lighting is used due to maximum efficiency. A light sensing sensor that detects light and darkness is integrated into this circuit. When the light level is bright enough, the light turns off or the light is turned on when it is dark [4].

A small scale prototype of the system is designed and tested to see its performance. The general system is prepared using the following main components:

1. Solar PV Panel;
2. Solar Charge controller;
3. DC Battery;
4. Each 10W 2 LED light
5. Sensor Circuit

The components are selected according to the following load calculations:

• Load(Lighting): 20 watts

The Watt Hour of Illumination is an energy unit equivalent to 1W used for 1 hour:

• Watt clock = illumination power ratio (20 watts) * operating time (5 hours) = 100 watt hours = voltage * current * hours

Battery rate:

• Battery voltage required for a 12 V system

• Battery capacity = load / voltage = 100/12 = 8.33 Ah

80% efficient battery =

• 0,8 * 8,33 = 6,66 Ah

For this reason, a 10Ah deep loop lead acid battery was selected for some margins.

The nominal power from the sunlight changes depending on the number of hours of effective sunlight in that area. The UAE assumes 5 hours of effective sunlight under all weather conditions:

• Total power output of the panel = 12V x 10Ah = 120Wh

• Power to be produced per hour = 120/5 = 24W

For this reason, 50W / 12V solar panel was selected to protect the margin.

• For a 12 V system, the charge regulator rating = 12V

• Current rating = Solar panel / Voltage output power = 50/12 = 4.16A

Therefore, a charge controller of 12 V and a value higher than 4.16 A, 10A were selected [4].

The renewable solar energy lighting system is designed and manufactured to deliver excellent performance in the UAE as well as with its abundant renewable energy source. Solar energy, LED lighting, light sensors and daylight saving not only save energy when applied in buildings with accurate and intelligent architecture, but also protect future generations from non-reproducible sources that cannot last long as fossil fuels and oil. Using different photo sensor controls and unique building architecture, new techniques for daylight utilization are intended to provide maximum power savings. Successful results were obtained using the lighting software. In addition, when the solar panel outputs are operated with DC power and LEDs with DC power, there is no need to use an inverter in the system. Therefore, the system is cost effective and environmentally friendly as well as performing well [4].

I. Çolak et al. used solar energy to charge a battery system and designed a lighting system that uses LEDs from this system by using two different lenses. Two different types of lenses are used in the luminaires and these luminaires are supported by the power generated from the solar panels. Energy is produced from renewable sources and elements with low power consumption are used. In order to prolong the life of the lighting elements used, a cooler is also added to the system and it is preferred that they be used with drives that can operate at constant current. Here, the voltage obtained in the solar panel feeds the 12 V, 18 Ah batteries used in the system through a charging unit. The voltage obtained from the batteries is applied to the driver circuits and the LEDs are operated with the help of drivers. In addition, if the application is made without drivers, the LEDs can be operated with the voltage at the output of the battery charger by replacing the drives with a front resistor. The experimental studies show that this system, which is formed by LEDs with lens and high luminous power, is convenient and efficient. The results obtained with the different lenses used show that when a 45 ° lens is used, a larger area is illuminated with less light intensity than a 15 ° lens, but the light intensity decreases. This showed that the angle of the lens used was effective on the illumination surface. It is known that the initial installation cost of the systems created by using LED is quite high. However, a LED luminaire, which lasts about 10 times longer than a normal luminaire meets the cost of installation [5].

S. Işcan et al. conducted a prototype system application with photovoltaic solar cell, battery groups, charge control unit and led lighting equipment which are independent from the grid and carried out an evaluation on the daily electrical energy production and consumption data of the system. In the evaluation, the production data of the photovoltaic panel and the battery were compared with the current data obtained during the operation by means of the energy analyser. In the prototype system, the average depreciation period is calculated by comparing the installation cost and the amount of energy production. In this study, a photovoltaic solar panel in the daytime between 06: 00-17: 00, 2 parallel-connected 12 V 28 Ah battery charge control unit by charging; from the moment of darkening, an astronomical time relay was used to illuminate the environment with 2 x 12 Volt 10 W LED projectors between 18: 00-06: 00. All the devices used in the system are selected in such a way that they can operate in accordance with 12 V DC voltage and system installation is provided. The electricity generated by the sunlight falling on the photovoltaic solar panel at different times of the day was transferred to the charge control unit. The charge controller is provided using a DC-DC microcontroller controlled converter, which increases or decreases the voltage level required for charging the battery pack. If the battery charge drops below 30%, the system automatically protects the batteries in the system. The energy control of the solar panel and LED lighting equipment installed in the external environment was carried out via a panel in the indoor environment. For protection purposes, 10 A fuse was installed on the battery pole and short circuit conditions of the batteries were prevented. In addition, an astronomical time clock and a relay that can switch with latitude and longitude information are working together. It is aimed to prevent unnecessary energy consumption with time clock. The charge control unit, which was supplied as a prototype from the 60 W photovoltaic solar panel, also carried out the battery charge and load relationship. During the day, depending on the light intensity of the 12-17 V solar panel manufacturing as a variable, the charge of the battery with the help of charge regulator different currents and voltages carried out during the day. In this study, it is aimed to prevent extra power losses by the absence of DC-AC power conversion [6].

Table 1. Comparison of studies

Literature / Features	LED	Cooling	Solar Energy	Wind Energy	PIR sensor	LDR sensor	Fuzzy Logic	Indoor
J. MİX et al.					YES	YES		YES
A. PANDHARİPANDE et al.	YES				YES	YES		YES
İ. KIYAK et al.	YES	YES	YES	YES	YES	YES	YES	YES
M. I. ZAİDY et al.	YES		YES			YES		YES
İ. ÇOLAK et al.	YES	YES	YES					
S. İŞCAN et al.	YES		YES					

The common goal in all of the studies examined above is energy savings. The energy saving is realized by adjusting the lighting level. To do this, they use devices such as ambient light sensor, motion detection sensor and a control circuit. In most of the studies, LED technology is used because of its benefits. In some studies, solar energy is used as a renewable energy source. Thus, continuous energy is provided to the system. With these technologies, they aim to save energy by making lighting smart.

III. Materials and Method

A. *Internet of Things*

The technologies to be used within the scope of the study are related to internet of things concept. First of all, it is necessary to explain this concept. The term "Internet of Things (IoT)" was first described by British technology pioneer Kevin Ashton in 1999 to describe a system in which physical things can be connected to the internet [7]. International Telecommunication Union (ITU) defines "Internet of Things" as a global infrastructure for the information society, which enables advanced services by linking things based on existing and developing, interoperable, information and communication technologies [8]. Things work individually or in conjunction with other things and have unique IDs. IoT technological change has far-reaching implications and has the potential to affect more. Today, there are about 1.5 billion computers accessed to internet and more than 1 billion internet supported mobile phones. It is estimated that there will be between 50 and 100 billion devices connected to the internet in 2020. Since these smart devices contain sensors, it is obvious that many sensors will be deployed around us in the future. Internet of things foresees billions of smart devices to connect to the internet. Internet of things provides a networked infrastructure that allows you to connect to any thing, anywhere, ideally using any network and any service. By adding "everything" dimension to information and communication technologies that have 'always' and 'anywhere' functionality with IoT, so it makes traditional things smart forms. A number of different activation technologies are used to implement the internet of things. These; radio frequency identification systems, wireless sensor networks, machine-to-machine (M2M) systems, big data, cloud services and smart applications. Internet of things encompasses industries and areas such as intelligent health, intelligent transportation, intelligent living, intelligent building, intelligent food, intelligent energy, intelligent industry and even smart cities [9,10,11]. Internet of things will bring innovations that will make human life easier and provide technological advances.

B. Fuzzy Logic

The fuzzy set theory, which uses fuzzy logic and logic rules, was developed by Lotfi A. Zadeh and published in the original article of 1965 and the analysis of uncertainty systems gained a new dimension. Just as a human being uses the data bank in his head while solving a problem that he / she is facing, and a conclusion is made in the light of this information, a system dealing with fuzzy logic principles also reaches a conclusion about the new situation by using the information that was previously taught to it. Fuzzy logic; it aims to model logical reasoning with ambiguous or inaccurate expressions that may include linguistic limits. The main element of fuzzy logic is the fuzzy set. Fuzzy sets provide a mathematical approach to situations with ambiguity that are frequently encountered in daily life. Classical clusters and mathematical logic divide the world into two; yes and no, black and white, right and wrong. Fuzzy sets and fuzzy logic rate events. In fact; many, quite and lightly as many limits, can be used simultaneously to express different emphasis levels. Therefore, it is necessary to expand fuzzy logic systems with multiple limits. Using fuzzy logic brings many facilities, especially in the case of complex situations where classic clusters cannot answer easily. Fuzzy sets have taken place in every branch of logic science and engineering. Fuzzy logic control is also found in our daily lives with household appliances such as vacuum cleaners, washing machines [12-14].

C. Solar Energy and Solar Panel

C.1. Renewable Energy Sources: Solar Energy

Solar energy is a kind of renewable energy source that is accessible, free and abundant for all countries. Solar energy is an energy that can be converted into electrical and thermal energy. In general, there are two main categories that can convert solar energy into electrical energy [15,16]. The first is Concentrating Solar Power (CSP) systems that produce heat or electricity with hundreds of mirrors that concentrate sunlight to a temperature between 400 and 1000°C. "CSP" as a solar energy technology can work either by storing heat or by combining power with fossil fuel power plants such as natural gas and oil power plants, make the power uninterrupted in times when the solar energy is not enough [17]. CSP is a large-scale and commercially available and applicable way to generate electricity. The second application of solar energy is photovoltaic (PV) power. Electricity is produced by solar energy systems such as photovoltaics. PV cells convert radiant energy from the sun to direct electricity. There are several different PV technologies and installed system types. Today, photovoltaic (PV) modules in the market are monocrystalline silicon solar cells, polycrystalline silicon (or multi-crystalline), micro-crystalline silicon as well as cadmium telluride and copper-indium-gallium-diselenide solar cells [18,19]. These systems provide clean energy for small or large-scale use. This energy is produced worldwide for use in commercial buildings, residences, offices and public buildings [20]. Although fossil fuel sources still control the energy balance of the global economy, there are still several reasons for the use of solar energy technologies. Sustainability is one of the safest sources of energy available for any nation, compared to other renewable energy sources. At the same time, it produces little or no pollution to global warming emissions. In addition to other renewable energies, it may reduce energy-related greenhouse gas emissions over the next few decades to mitigate the effects of climate change. Solar energy is endless and sustainable. The demand for reliable power and energy is numerous. Because most activities are cost-effective and it provides sufficient energy [21]. Solar energy can compete with traditional energy sources with its technologies such as non-network electricity generation and solar water heating applications [22]. Due to global energy shortages and the control of adverse environmental impacts, the use of solar energy has attracted worldwide attention. Solar energy technologies can bring many benefits to society in many ways [23].

Renewable energy (RE) plays an important role in meeting the needs of a country in terms of sustainable development. The development and proper use of renewable energy should be a priority issue. Increased interest in renewable energy sources (RES) can be attributed to a number of factors beyond climate change. The recent concerns about the volatility in oil prices and dependence on foreign energy sources are factors contributing to the current interest in RES [24]. The use of RES, encouraged by this increased importance, has undergone a remarkable global growth profile in recent years [25]. Considering this important role of RES in the discussion of a reliable and sustainable energy future, it is important to understand the key determinants and determine conclusions for the energy policy. Marques et al. [26] take attention to important determinants in the distribution of renewable resources, including political, socioeconomic and country-specific factors [27].

The sun is a great source of renewable energy for our world. At present, new technologies are used to generate electricity from solar energy. These approaches have already been proven and are widely practiced around the world. Theoretically, it has the potential to adequately meet the energy demands of the world, if technologies are available to exploit solar energy [28]. As a result, solar energy is considered a non-polluting, reliable and clean energy source [29].

C.2. Solar Panel

Photovoltaic is derived from the words ‘photo’, which means light or ray and ‘volt’, the unit of voltage. The photovoltaic battery, which is used in our study that converts the sun rays into electric current, is an increasing energy technology. Solar cells (photovoltaic cells) are semiconductor materials that convert sunlight directly into electrical energy. The N-type semiconductor, usually consisting of charge carriers electrons, and the P-type semiconductor consisting mostly of load-bearing cavities, are brought together. When the light energy falls to this junction, the current passes through the external circuit. In the solar cell model P-N semiconductor combination; The electrons will pass through the P-type region and the spaces near the junction surface will complete the electron deficiency in the charge carrier and create negative ions, while the N-type region will have a positive ion wall. If there is no external influence, this energy wall will prevent the current from passing. If the beam falls into this region, since the charge-bearing electrons are in very small proportions, a valence will probably release energy from the electron and push it towards the P-type region. The external circuit current will be from P to N. In this way, solar cells produce a certain current and voltage per unit area under certain sunbathing conditions. It is necessary to connect several batteries in series and parallel for the desired energy. Thus, solar panels are created. A large number of solar cells can be connected to each other in parallel or in series to mount them on a surface to obtain a solar cell module or a photovoltaic module, thereby increasing the power output. The most important advantages of solar cells; the fact that they do not have any moving parts, they can be used for 25-30 years without any problems with low maintenance and they do not leave any pollutant wastes to the environment during their working period [30].

The transformation of solar radiation into electricity is first caused by the photovoltaic effect observed by Becquerel in 1839. This effect occurs in materials known as semiconductors that offer two energy bands, one of which is allowed to have electrons in it (bad value), and in others there is no presence, i.e. the band is completely empty(transmission band). The more commonly used semiconductor material is silicon, the second most abundant element in the world. The atoms are characterized by the presence of four electrons connected to their neighbors and forming a crystal network. The function of sunlight on the photovoltaic effect is to provide some energy to the outermost electron to enable it to pass through the strip of tape in the material to the conductor band and thereby generate electricity. Nearly all photovoltaic devices include a PN joint in a semiconductor developed through a photo voltage. These devices are also known as solar cells or photovoltaic cells [31-40].

When the solar cell is exposed to light from the sun, the negative layer of the PV cell absorbs photons. In this way, the electrons are released from the layer and a potential difference is occurred to generate the electric current. This system requires easy installation and low maintenance. Solar cells (photovoltaic batteries) are semiconductor materials that convert sunlight into their electricity. The areas of the solar cells that are shaped as square, rectangular and circular surfaces are generally around 100 cm^2 and their thickness is between 0.2-0.4 mm. Solar cells are made of semiconductor materials such as transistors, rectifier diodes. Among the many substances which exhibit semi-conductive properties, the most suitable for making solar cells are silicon, gallium arsenide, cadmium telluride. When these materials are specially prepared for solar cells, when the solar energy comes into the PN joint, the charge of electrons in the photons creates a potential difference between the PN substances. This voltage is around 0.15-0.5 volts [4,6].

D. LED Technology

LED is the abbreviation of Light Emitting Diode. When applying the correct polarity to the LED; with the cavities in the substance P, the electrons in substance N are neutralized on the joint surface. The energy that emerged at the time of this merger is the light energy. In order to visualize this light, “gallium arsenide” was added to the compound surface of P and N substances [30].

The LED, called the light emitting diode, is a semiconductor circuit element that converts electrical energy into light. The most important part of the LED consists of a semiconductor material and a light emitting LED chip. The LED chip is a point light source and the reflective element placed in the sheath allows the light to spread in a certain direction [41]. LEDs are released as an indispensable element in the opto-electronics sector and nowadays show a great revolution in the field of lighting. Thanks to advances in lighting technology in recent years, LED lighting systems provide innovative and contemporary solutions [42]. LEDs have advantages such as low energy consumption, long life, robustness, small size, fast switching, high durability and reliability compared to conventional lighting systems. Since the LEDs entered the electronic market in 1962, it has made great progress [43,44].

The LED is a p-n connection semiconductor that emits light directly from an external electric field [45]. Recent studies have shown that energy-efficient smart LED lighting systems provide a better visual comfort-work environment with less energy consumption than existing lighting systems [46].

Cooling of luminaires consisting of LEDs is also an important issue in order for the LEDs to be used for longer life and better performance. Some devices may be installed to provide this. In addition, lighting design program such as DIALUX may be used to design indoor lighting.

E. Battery, Charge Control Unit

Devices that convert chemical energy into electrical energy and stored it are called batteries. If the chemical-electric energy conversion is one way, the battery is primary (single use) structure. The conversion is in both directions, so the electric energy can be converted back into chemical energy and thus energy use can be achieved for a long time, the battery is a secondary structure or, in other words, a rechargeable system. When a charge is connected to the battery, chemical energy is converted into electrical energy. All batteries are structurally similar and consist of a group of electrochemical cells. Each cell consists of one positive, one negative electrode and one separator. Batteries with the same chemical structure, different dimensions and electrical capacities can be assembled individually to create battery groups. Batteries are used in somewhere like lighting systems, mobile phone, computer, electric vehicles and storage energy production systems. In the case of large power storage systems, the battery block is used. Charge control in batteries; controlled by DC-DC converters. DC-DC converters are used in a wide range of voltage and current control purposes. The current and voltage information of the electrical energy produced by the solar panel changes within the day. With the charge controller and regulator, it is limited by PWM control technique in order not to reflect the voltage change to the batteries. In addition, the battery charge drops below 30%, it protects the battery and shows the ability to cut the electrical energy to the load [6].

F. Arduino, PIR and LDR Sensors

F.1. Arduino

Microcontroller; It is a microprocessor that can process the data received from the input ports with the commands given to it, forward it to the output ports and be programmed many times. Arduino is also a type of microcontroller. Arduino microcontroller platform is an easy to use and has open source software and hardware. Arduino UNO model is used in this study. Different connection ports, such as digital input / output, PWM output, UART TTL (5V) serial communication and analogue input, make the Arduino Uno card a powerful and cost effective hardware for data collection. Arduino UNO has 14 digital inputs / outputs, 6 out of these outputs are used as PWM outputs. In addition, there are 6 analogue inputs. The Arduino Uno board includes an integrated development environment (IDE) and an Atmel ATmega328 microprocessor that can be programmed in C / C ++. Arduino IDE platform is used to activate Arduino. Arduino also has a large online community that accelerates the development process and provides rapid prototyping and debugging. In addition, numerous high-quality sensors and devices have active Arduino libraries and active support from manufacturers for the platform. The supply voltage 5 V and 3.3 V outputs can be edited to use specific sensors from the Arduino board [47-49].

F.2. LDR (Light Dependent Resistor)

The first sensor used is the Light Dependent Resistor (LDR) sensor. When the light falls on, the resistance decreases and in the dark the resistance-increasing element is called the photo-resistor (LDR). Some substances such as calcium sulphate and cadmium selenide exhibit resistance changes inversely with the light that falls on them. The resistance of the LDR is very high (10 Mohm) unless it receives any light on it. This resistance value decreases as the applied light intensity increases (75-300 Ohm). The LDR sensor works on sensing light and darkness. It also calculates the light intensity when LDR is the light source [50, 30].

In this study, daylight is detected with LDR. If daylight enters the environment, LDR calculates the intensity of this light and the intensity of the LED luminaires is determined accordingly. It gives LED light inversely with daylight. If the environment is too bright, the LED will not light. If there is a medium or low intensity daylight, a light intensity is given according to this. Maximum illumination is provided if the weather is completely cloudy.

F.3. PIR (Passive Infrared Sensor)

PIR sensors are commonly used to detect things' movements. Motion sensors are sensors that are used to detect live motion in an environment. The module with digital output gives logic 0 when there is no movement in the environment and logic 1 when there is motion. Infrared radiation is present in the electromagnetic spectrum at a longer wavelength than visible light. Heat generating things also produce infrared radiation, which includes animals and the human body. PIR sensors are made of pyroelectric sensors that are capable of detecting infrared radiation levels and thus commercially used for the automation of electrical devices and home surveillance systems. The basic function of the differential PIR sensor is to measure the difference in the infrared radiation intensity of the two pyro-electric elements in the sensor. Normal changes in the temperature caused by the air are invalidated by two parallel-connected elements. If the elements measure the same amount of infrared radiation, the sensor generates zero output. Most commercially available PIR motion sensor circuits produce digital output. However, analogue signal output can also be obtained from PIR sensors. [51,52].

In this study, it is aimed to detect environment occupancy by motion sensor. If there is any movement in the environment with the motion sensor, this is detected and feedback is provided. Thus, the lighting is activated as long as there is movement in the environment. There is no need to use illumination if there is no movement in the environment.

G. Taking Weather Forecast Information

The feature that will differentiate this study from other studies is to reduce the consuming energy to be used in illumination by using weather forecasts. For example, if the weather is cloudy for a few days, the environment will be dark and solar energy will not be loaded. Therefore, the energy in the battery will need to be used efficiently. If the lighting intensity is reduced accordingly, the energy consumption will be reduced. Thus, the energy stored in the battery will be used longer and energy savings will be ensured.

H. Designed System

The created system uses components like solar panel, charge controller, battery, LED, PIR, LDR sensors and microcontroller. In this system, it is aimed to obtain solar energy by using solar panels and to use this energy in lighting system. The energy obtained by solar panels is stored in the DC battery. The charge controller is used to prevent the circuit elements from being affected by the energy changes. The battery charge rate is also controlled by the microcontroller. In addition, the motion status detected by the motion sensor and the ambient light detected by the LDR sensor are also used for lighting control. Unlike other studies, the weather information is also processed by the microcontroller. These four input information will be interpreted to determine the intensity of illumination and to illuminate the LED luminaires. Lighting will not be used if there is no movement in the environment; if motion is detected, the lighting system will be activated. The daylight level measured by LDR will also be an important factor in determining the intensity of illumination. If the ambient light is too high, the LED does not light; if it has moderately light, LED's light is moderate. If the ambient light is low, the led will be full performance. If the battery is empty, LED will not light and if it is in the middle level, the light intensity will be medium or if the battery is fully charged, this means that the light intensity may be very high. Moreover, if the future weather information is cloudy, LED's light will be at low power or the light intensity can be high if the weather is clear. Using these four input information together, the luminous intensity of the LEDs must be determined. Thus, the desired performance will be achieved and energy saving will be ensured.

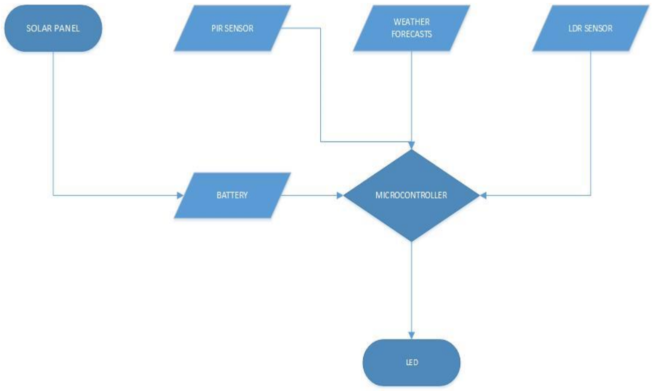

Fig 1. Smart Lighting System Design

IV. DISCUSSION AND CONCLUSION

As mentioned in this study, it has become necessary to provide energy saving with lighting control systems. As in the studies in the literature, using sensors such as motion sensor, LDR sensor, we can control the lighting by taking into account the battery charge. However, this is not enough. In addition, the source should be sustainable. Therefore, renewable energy such as solar energy should be used. In some studies, this has been noticed and added. Future weather information can be added as input to the system as an additional innovation that cannot be found in other studies. Thus, energy saving can be realized more efficiently.

ABBREVIATIONS

LED: Light Emitting Diode
PCB: Printed Circuit Board
DC: Direct Current
A: Amper
C: Centigrade
K: Kelvin
cd: Kandela
V: Volt
UAE: United Arab Emirates
PV: Photovoltaic
W: Watt
DC: Direct Current
AC: Alternative Current
p: Proton
n: Neutron
PWM: Pulse Width Modulation
IDE: Integrated Development Environment
LDR: Light Dependent Resistor
PIR: Passive Infrared Sensor
RE: Renewable Energy
RES: Renewable Energy Sources
CSP: Concentrating Solar Power

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