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244. Solar Powered Building Automation System by Using Passive Infrared Sensor and Lead Acid Battery Backup

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Abstract

Commercial offices and Buildings are major consumer of electrical power and therefore require special effort to achieve power saving operation. One of the most overlooked energy-saving tools in the work place is the light switch. Lighting accounts for 30 to 50% of a building's energy use. Reducing lighting electricity usage reduces your energy cost and their environmental impacts associated with electricity generation. This paper is about the implementation of Passive Infrared sensor to the management and switching of the various electrical load. Passive Infrared sensor has been selected due to its passive nature of detection and high accuracy. It will detect the occupant by the Infrared rays emitted by the human body. A solar input power has been equipped with a 12 V solar charger and a lead acid battery back-up to maintain the continuity of supply. The input signal is then amplified by electronic circuitry and used for the triggering of relay. The electronic circuitry is modified and has less components, thus consume minimum power. Lighting load is luminous dependent and a general purpose 555 timer IC has been used in its monostable mode for that logical operation.

Keywords: *Smart Buildings; Energy Management System; Automation System; Passive Infrared Sensor; Lead Acid Battery; Solar Charger*

1. Introduction

Buildings are responsible for the consuming a large amount of electrical power. The main reason behind this consumption is inefficient habits and poor behaviour of staff. One of the negative impact of these inefficient habits are rapid environment changes and global warming. Buildings also contribute towards the production of CO2 and other greenhouse gases. Inefficient design of lighting systems and Heating, Ventilation and Air-conditioning system also add towards increased energy consumption.

Studies have shown that this consumption can be reduce by adapting energy management system for lighting and Heating Ventilation and Air conditioning. By implementing such system devices can be control on individual basis depending on the occupancy status per space. By using such system electrical power can be saved only by monitoring dynamic changes in the occupant's behaviours. Another way of reducing the energy consumption is retrofitting of all the lighting and HVAC system but that method would be highly expensive.

For Office lighting system, motion detection occupancy sensor reduces the consumption of electrical power up to a significant level. For that reason, one of the most accurate sensor is Passive Infrared. Passive Infrared sensor is a device that sense infrared lighting radiation from humans. Whenever Passive Infrared sensor observe any change regarding infrared radiation in the environment it produces an electrical signal which can be used to trigger the electronic circuitry of occupancy sensor.

In this paper, an occupancy detection system based on passive infrared sensor has been presented. The aim is to determine the occupancy in the specific space and control the lighting and HVAC system of that particular workspace. A general purpose 555 timer integrated circuit has been used in coordination with LDR for monitoring the outside light so that light can be made on according to the need. The whole system is solar powered for that purpose a poly silicon technology based solar panel is used which is followed by solar charge controller with inherent short circuit and overcharging protection. The whole system is provided with a V.R.L.A lead acid battery backup.

2. Problem Statement

Lighting system is one of the most electrical energy consuming system in the commercial buildings all over the world. Lighting system consumes about 31% to 52% of the building energy consumption. In US only lighting system consumes about 17 to 18% of annual electrical consumption. By using occupancy sensor system which can only turn off the lighting system when not needed electrical energy consumption can be reduce by huge amount. Studies have shown that by using such type of sensors electrical energy consumption can be reduce by 45%. As electrical energy is quite valuable thing and most of it is coming from non-renewable resources so if we are saving electrical energy, we are decreasing environmental effect that are linked with the generation of electrical power.
Electrical energy contributes most towards the operating cost of commercial buildings, and to reduce electrical energy cost is a major concern for building owners. Thus optimizing electrical power for commercial use is extremely important without hurting the comfort zone of the people. One way of reducing electrical energy consumption is the retrofitting of lighting equipment. Another possible way is to use occupancy sensor system for optimizing electrical energy without hurting the comfort zone.

3. Literature Review

An occupancy sensor is luminous control device that sense the occupancy of people and turns the lights on/off automatically, using passive infrared (PIR), ultrasonic (US) or microwave sensing technology. These sensors are used with a suitable assembly of circuit which provides the control over electrical equipment's such as lamps, heaters, air conditioner, HVAC system and other devices. The aim of using this device is to save energy, provide automation, and comply with building codes [1]. The work which is already done on this device the recent past years is given as follows:

3.1 Measuring Building Occupancy Using Existing Network Infrastructure

Green IT is focusing on the reduction of energy consumption in IT infrastructural buildings. Energy saving methods is applied in both IT and non-IT infrastructural buildings and results are obtained in saving energy. This technique is based on an idea of implicit occupancy sensing in buildings that are largely based on controlling, monitoring and directing MAC and IP addresses in routers and wireless access points, and then interfacing these addresses to the occupancy of a room, corridor, buildings, car parking, elevator zone and many other zones where occupancy is to be measured for some control purposes. This occupancy measurement data is then used for controlling lighting, heating, ventilation, elevator operation, AC controlling, HVAC, and other building equipment's, to improve building operations and to minimize power consumption. These control actions given a complete automatic and smart building concept. This also increases system working functionality in reliable manner. To assess the efficiency of implicit sensing and the feasibility of the dual-use of IT infrastructure, they practically analyse the data and their measurements [2].

3.2 POEM: Power-efficient Occupancy-based Energy Management System

To reduce the energy consumption an efficient way is used. As buildings are great consumer of electrical energy namely for heating, lighting, cooling, ventilation, elevators and in other equipment's, more energy efficient devices are used for reducing energy wastage, new building materials are used in construction and new technologies are adopted to use the nearby energy in efficient way. Energy saving problems needs a lot of attention so a system capable of reducing energy consumption and using the energy in a suitable way is achieved by a system. It is a complete feedback control system for handling HVAC systems that is being installed on existing occupancy levels in buildings. It consists of OPT Net (wireless network cameras) that operates as an optical turnstile to determine particular area occupancies. It also contains PIR sensor based wireless network cameras called BONet that functions alongside OPT Net [3].

3.3 An Integrated Approach to Occupancy Modelling and Estimation in Commercial Buildings

They had developed a model to analyze the activities of all the individuals of a building for measuring the occupancy in their predefined zone of detection in commercial buildings and to determine the low-ordered graphical models from Monte-Carlo simulations of the model. Building with such integrated approach to occupancy modelling achieves high energy efficiency through feedback control. This system is modified with sensing data especially for the case of one occupant and one room. With the help of graphical model predictions, noisy measurements are fused by using the classical LMV estimator. This

device is used to estimate occupancy of a room in the building [4].

3.4 A Design Model for Building Occupancy Detection Using Sensor Fusion

Sensor fusion techniques are used to control and direct the occupancy, by using non-identical indoor climatic ranges of variables for useful energy consumption and to control the building services such as heating, lighting, air conditioning, ventilation and other equipment's by maintaining a comfort level. As complete reliable occupancy is difficult due to number of issues as unreliable data, maintaining privacy, change of use, sensor drift and other financial pressures such as quality and economy that's why fusion technique offers reliable occupancy measuring. In recent past years, artificial intelligence (AI) systems are used for control of buildings, and can also be adopted for occupancy analysis. This method for controlling and detecting the occupancy of buildings based on sensor fusion model through Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm [5].

3.5 Occupancy Monitoring using Passive RFID Technology for Efficient Building Lighting Control

This method proposed a technique of controlling artificial lighting other parameters of buildings for saving energy and observing the occupancy, based on PIR and data fusion approach of passive RFID. This provides efficient need based control to user buildings parameters as lighting, heating, air conditioning and so many others. It gives an approximately of 13% of power energy savings for public building and also saves cost in office buildings. Practically, real-world occupancy profiling data to be utilized with PIR sensing which is reliable and a well-established approach, provide by RFID gateways for the analysis and enhancement of building lighting usage. This RFID provides better monitoring and helps in saving more energy. [6].

3.6 Dual-Input Dual-Output RF Sensor for Indoor Human Occupancy and Position Monitoring

This method is based on RF sensor proposed as concurrent dual band occupancy sensor, based on Doppler principle, for monitoring and controlling the occupancy of human in a room, corridor, car parking, or in any zone of building where this sensor is used. It operates simultaneously at 2.44-GHz and 5.25-GHz frequency bands. By using the sensor prototype and off-the-shelf laboratory equipment an estimating setup has been developed. From the analysis of signals correlation spectrum, received at individual frequency bands and from the estimated directed arrival of received signals, the human presence in a prescribed range can been predicted. This can benefit the proposed sensor lies in the reduction of the false alarms due to its well-designed operation, power consumption, and size [7].

3.7 Cost-effective Air Conditioning Control Considering Comfort Level and User Location

For the general purpose conventional control systems, use of expensive motion, temperature and humidity sensors to collect data of, both the area and the comfort of users and to provide area-based control to users but this will increase the system overall costs. In order to reduce cost of sensors, the proposed system use low-cost pressure sensors and provide energy efficient personal behaviour that will increase the efficiency of overall functions proving energy saving. To obtain occupancy data and its locations, low-cost pressure sensors and low-power communication nodes are used which are fixed to the chairs and they transmit seating data continuously to the database which store the information through PLC of a server in the database [8].

4. Methodology

The Methodology of Energy Management System is as shown in figure. This system is equipped with solar input and lead acid battery back-up to maintain the continuity of the system. The 12 V solar panel attached with a solar charger having a voltage regulator, gives an approximate output of 13.56 V. This voltage is being maintained with a voltage regulator integrated circuit. LM317 AH has been used with a proper selection of resistor and a capacitor to maintain our desired output. To prevent excess flow of heat within the circuit, a heat sink integrated circuit has been used to maintain flow of heat absorption. TIP122 is used to maintain the level of heat flow inside the circuit. The LED indicates the charging process with its light illumination. This output can charge the battery when charge potential on solar panel exceeds the potential of the battery, usually during day time. As the potential of the battery rises from solar charge potential, the overall system energized through battery supply until solar charge potential exceeds again.

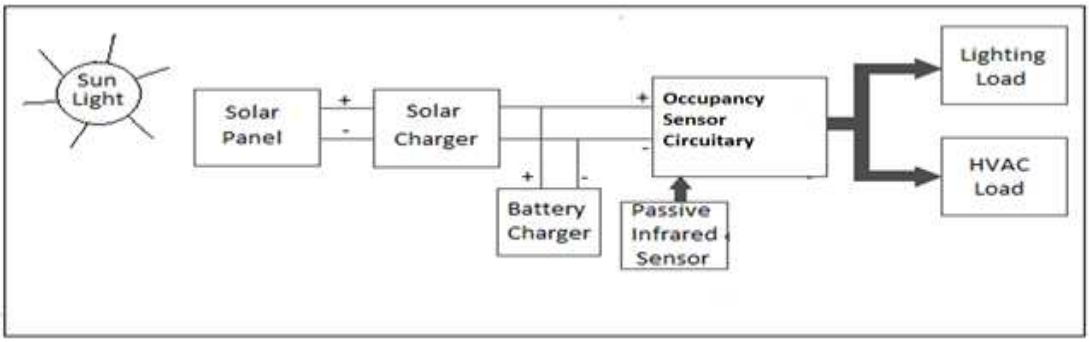

Fig. 1. Illustration of The Methodology of the System

4.1 Solar Battery Charger

Solar panel is the main component in solar system it takes energy from the Solar source, i.e. (Sun) and convert it into the electrical energy. The process of converting light energy of the photons into electrical energy is known as photovoltaic effect. To convert light energy into electrical energy semiconductor materials are used. When semiconductor materials are provided with light, photons transfer their energy to electrons due to which they become highly energized electron

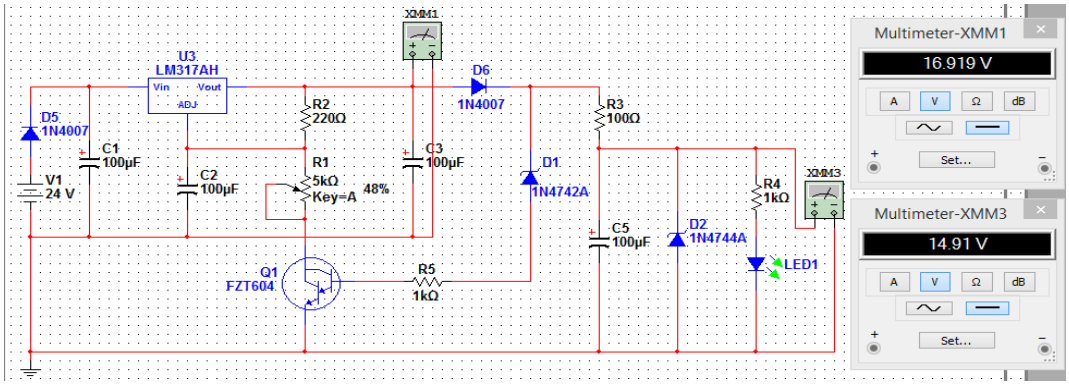

Fig 2. Illustration of Solar Battery Charger

4.2 Working of PIR Sensor

Infrared radiations are the type of electromagnetic radiations which are larger in wavelength than visible light but shorter than microwave radiations. These type of radiation cannot be seen by humans, but they can be detected by some animals. Snake's nostrils have the ability to detect infrared rays. Any sensitive thermometric element can, in principle, be used as a thermal infrared detector. When the pyroelectric detector absorbs radiation, its temperature rises, changing its surface charge.

Pyroelectric medium produces a potential difference when they are heated or cooled, thus if any pyroelectric medium will absorb IR radiations a potential difference will be developed if provided a suitable path due to potential difference an electric current will flow for a short duration of time in the form of electrical pulse. Pyroelectric material can be obtained from pits of viper but now a day's artificial pyroelectric materials are more popular.

The PIR sensor is made from pyroelectric medium, one property of pyroelectric medium is that it produces potential difference whenever there is temperature change detected. PIR sensor detect a person by comparing the infrared emission of the person and the background. PIR sensors have a direct line of sight therefore operators can easily define their limits. Normally PIR sensors have two or more input slots for absorbing infrared radiations and when there is change in the intensity of infrared radiation in any of the slot a minute voltage is developed which cause differential change between the slots and due to potential difference an electrical pulse is generated. It is designed in such a way that it is most sensitive towards the wavelength which is emitted by the human body as infrared rays as shown in fig 5.

4.3 Working Principle of Electronic Circuitry

As the motion (IR Radiation) is detected by PIR Sensor it will convert those radiations into electrical signals which will be applied to the base of Q1. The Base current will be very less but as it will trigger

Q1 due to which collector current of Q1 will start flowing that will be applied into the base of Q2 due to which Q2 will enter into the saturation region and emitter current of Q2 will amplified version of the signal, and the amplified signal is applied across the Zener diode.
When Q2 will be triggered the emitter current of Q2 will cause Zener breakdown which will energize the relay. Zener diode is used to maintain a constant voltage level across relay and it will also act as freewheeling diode, which will provide protection from high transient currents at the time of switching. The relay remains energize even after the IR source has disappeared from the premises due to the introduction of C1. The time for which the relay remains energize is determined by the product of R4 and C1, which is directly proportional to the time period of the circuit.
A portion of output from Q2 is given to 555 timer IC which has been used in the mono-stable mode. This circuit detects light falling on the Photo-cell (Light Dependent Resistor) to turn on the 555 timer IC. As long as there's enough light over the LDR, this keeps the output of 555 timer IC low until the ambient light falls below a predetermined value. A voltage-divider has been made up of the LDR and 5K resistor, as the resistivity of LDR will increase circuit will be activated.

4.4 Circuit (Multisim Simulation)

For Simulation purpose the whole electronic circuitry is developed in multisim. As passive infrared sensor detects any human, it will generate an output of almost 3 volts. In multisim simulation the output of passive Infrared sensor has been shown with electrical an electrical battery of 3 volts. The circuit is shown in fig 5.

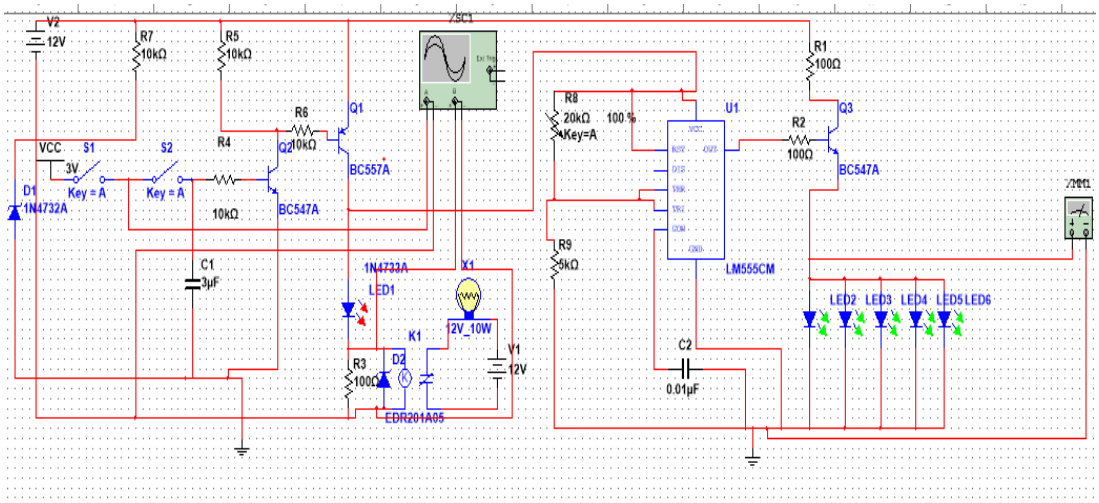

Fig 5. Illustration of the Circuitry of Passive Infrared Sensor with 555 Timer Integrated Circuit

5. Results

5.1 Results of Simulation with different RC Time Constant

It is shown from the simulations result that we can control the RC time constant according to the need of application. For the analysis of the data an appropriate summary of the results from the test should be provided to the user to assist them in understanding the project were carried out to test the components, this chapter will explain end the results of the tests that were carried out to verify different component of the project. The results with different component ratings are shown in fig 6.

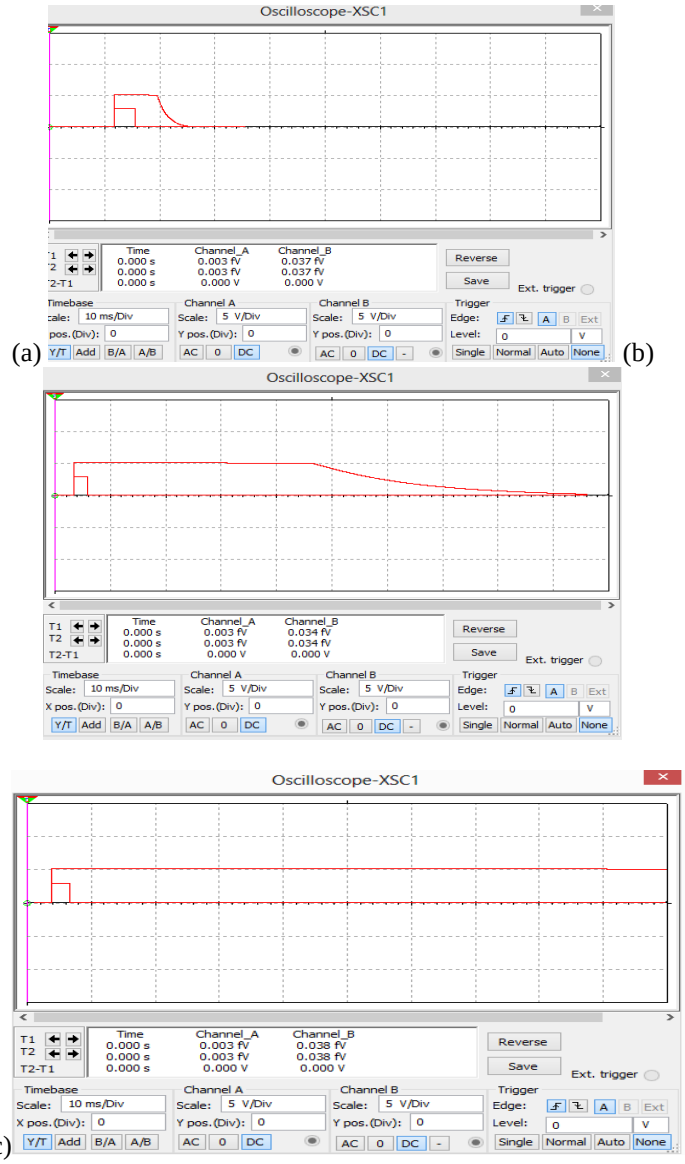

Fig 6. Illustration of the working electronics circuitry (a) with R_4 = 10K ohm and C = 0.09uf (b) with R_4=10K Ohm and C=0.9uf
(c) with R_4=10K Ohm and C=3uf

5.2 Results from Power Supply Circuit

As the main source of power of our project is the main power supply of 220 AC which is stepped down to 12v AC by using the transformer, but this alone will not work for the distribution of power different components as some components need 5Vto operate and some need 12v to operate. We have used a vole regulator IC to convert our 12V AC into 5V DC.
As the main source of power of our project is 12-volt solar panel. It does not have a stable output so a charge controller has been connected with it to charge the battery. As solar charger also has overcharging protection it will prolong battery life. Different results were taken under direct and indirect sunlight. The output was stable and can be easily controlled by voltage divider network that is connected with regulator IC 317.

5.3 Result from Connectivity Test

As the electric components are fixed on the board with the help of soldering iron and wire, therefore after soldering it is very important to check soldering. As during soldering you might leave a component UN intentionally loose, so this will result in errors in the future tasks and also the joints must also be verified because sometimes two joints are joined and this result in short circuit and may destroy your circuit. This

test s verified through multi-meter and every joint was checked and results were precise.

5.4 Result of PIR Sensor's Accuracy

An experiment has been conducted to find out the accuracy of PIR sensor. Accuracy can be defined as sensor detected the occupancy when the prescribed place was occupied, while vacancy can be defined as sensor didn't detect the occupancy when the prescribed place wasn't occupied. PIR sensor is extremely accurate sensor for the detection as it has overall efficiency of 90% and has a detection range of up to 20 feet, due to its passive nature of detection. It detects occupancy with the confidence interval of 95% and vacancy with a confidence interval of 85%. The graph is shown in fig 7.

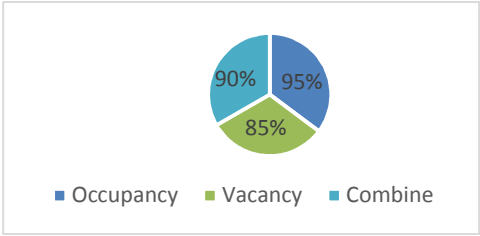

Fig 7. Illustration of passive infrared sensor accuracy

6. Conclusion

Occupancy sensor system has diverse application at different work places. With little change in programming and parameters it can be used at almost every place. This concept not only insures that our work will be useable in the future but also provides the flexibility to adapt and extend, as needs change
Though Occupancy sensor system is not much complicated but it will be very helpful for saving electricity by monitoring and controlling the unwanted flow of electricity. Usually in public places like hospitals, schools, colleges, hostels etc. the lights, fans and other appliances are still ON when they are not in use or the street lights are on even the day time, so we can save good amount of electricity by avoiding this misuse.
In this project Arduino mega microcontroller has been implemented for occupancy sensor system, and different kinds of sensor has been integrated for getting better results regarding occupancy information. We have learned about different sensors and their interfacing with microcontroller and different signals flowing across circuit. There are different ways in which the Energy management system can be developed. For example, in case of university or college classes the timetable can be made. When the students are present in the class the appliances are on and when they go for attending the practical the appliances are off. Another application of occupancy sensor system in case of universities are personal offices and practical laboratories. We have implemented the occupancy sensor system by employing motion detector circuitry with the help of passive Infrared sensor as it will detect only humans, moreover motion and position of occupant is confirmed by ultrasonic sensor because there are problems that can occur in the occupancy sensor system if only one sensor is interfaced.

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