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A REVIEW OF IoT BASED PHOTOVOLTAIC MONITORING SYSTEM APPLICATIONS

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Abstract

We are becoming more and more aware of the lack of electricity problem. In order to make the energy crisis bearable, it is necessary to invest in alternative energy sources and use energy more effectively. Solar energy can generate electricity directly from the sun's energy using PV panels. PV systems are used in households, industries, agricultural facilities, and others. In order to significantly improve the reliability, energy efficiency, safety, and quality of the electricity supply, it is necessary to build a smart grid that will include the activities of all users-producers, consumers, and those who are both. The Internet of Things (IoT) offers a new solution to overcome these problems. IoT is a network of physical objects embedded in electronics, software, and sensors that enables remote sensing and management of things through the existing network. IoT enables quick and easy interaction with everyday objects such as personal computers, smartphones, sensors, and microcontrollers. This paper gives detailed description of four very different innovative applications of PV system and IoT coupling used to increase energy efficiency of widely used devices.

Keywords: Photovoltaic, IoT, Monitoring system application

INTRODUCTION

Millions of small photovoltaic systems are operational, providing energy, for example, for lighting and telecommunications. Solar energy systems can be integrated very well in the built environment and are contributing substantially to the impressive growth of the utilisation of solar energy that we see today. In order to significantly improve the reliability, energy efficiency, security, and quality of the electricity supply, it is necessary to build a smart electricity grid (smart grid) that will include the activities of all user-producers, consumers, and those who are both. A smart grid applies information technologies, tools, and techniques that make the network more efficient and flexible.

The conventional method of system monitoring mainly involves manual testing and remote monitoring. These methods have some disadvantages, such as time consuming and problems with complex wiring. The Internet of Things (IoT) offers a new solution to overcome these problems. IoT is a network of physical objects embedded in electronics, software and sensors that enables remote observation and management of objects through the existing network. [1,2] IoT enables fast and easy interaction with everyday objects such as personal computers, smartphones, sensors, microcontrollers, transceivers, etc. [3,4]. Thus, a communication network with IoT can enable the monitoring and control of PV systems located in remote locations.

The term IoT refers to a system of interconnected devices used in everyday life that aims to automate a certain domain (from home devices, through manufacturing to military applications). These devices are equipped with different types of sensors, cameras, and positioning modules that generate different types of data. They can also be equipped with actuators to control the environment. [4]

It can be noted that IoT has great potential for application in smart grids. Smart grids require measuring and actuating devices to be distributed throughout residential and industrial areas to collect the necessary data and provide adequate responses to emerging changes. IoT systems are perfectly suited for that purpose, given that internet connectivity is widely available today. [1,4]

The paper gives four detailed descriptions of IoT-based photovoltaic system applications used to increase with intent of energy efficiency increase of used devices.

IOT BASED PHOTOVOLTAIC MONITORING SYSTEM APPLICATION

The authors in [5] designed a system for measuring the voltage, current, and temperature of a solar PV panel, as well as the intensity of sunlight received by the panel. All data was captured by an Arduino ATMega2560 microcontroller and uploaded to the internet using a NodeMCU ESP8266 wireless transceiver.

The authors used Thinkpeak to store all the data from the sensors, so the user can monitor the data remotely as long as an internet connection is available. Monitoring was done through the Thinkspeak website and also through a smartphone app designed using MIT App Inventor. The system diagram is shown in Figure 1.

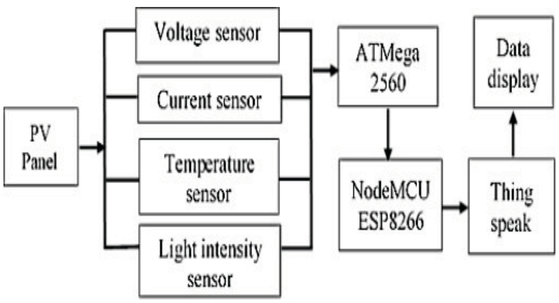

Figure 1. *Diagram of the PV panel monitoring system [5]*

A current sensor based on the Hall effect was used to measure the current in the circuit. The Hall effect is the creation of a potential difference across a current conductor in a vertical magnetic field. Current sensor had an overall output error of ± 1.5% with an optimized accuracy range of ± 30 A. The board temperature was measured using an LM35 temperature sensor. Temperature sensor gives a very accurate reading in the range of 0-100 °C. Light intensity sensor GI-49 MAKS44009 was used to measure the intensity of sunlight to which the panel is exposed. To ensure the accuracy of data collection, authors firstly calibrated all sensors to an appropriate standard.

The performance of the PV system was measured on three consecutive days for eight hours a day (8 a.m. to 4 p.m.). The PV system was placed on top of a building that is exposed to direct sunlight without much shadowing from surrounding objects. The system was placed at a fixed angle of 30^0 facing the South. Tracking of the movement of the Sun was not used. Arduino Mega based on ATMega2560 acted as the microcontroller that collects and processes all the data from the sensors. The data was then sent via WiFi module NodeMCU ESP8266 via a serial communication protocol.

Figure 2. shows the hardware that authors designed for a solar photovoltaic system consisting of all the above mentioned components. [5]

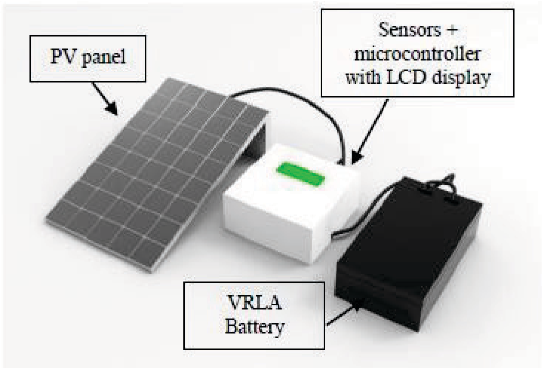

Figure 2. *The hardware of the solar photovoltaic system [5]*

SMART SOLAR LED STREET LIGHT

Authors in paper [6] propose an energy-efficient smart street lighting system using an Arduino-based microcontroller. The main objective of their work was to design energy-efficient smart street lighting for energy conservation in existing street lighting in rural areas, urban areas as well as in smart cities.

Smart Solar LED Street Light system consisted of LED bulbs, Solar panels, a light sensor (Light Dependent Resistor-LDR), a motion sensor (Passive Infrared Sensor-PIR), Battery, a Charge controller, an LED driver, MOSFET (Metal oxide semiconductor field effect transistor) and Arduino microcontroller.

Figure 3. shows a diagram of the Smart Solar LED Street Light system designed by authors in [6].

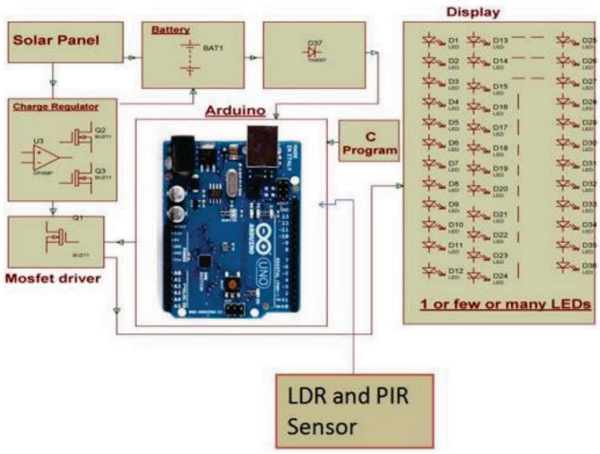

Figure 3. *Diagram of the Smart Solar LED Street Light system [6]*

Authors programmed system to automatically turn off during daylight hours and only operate at night and during heavy rain or bad weather.

The battery for powering the LED bulb was charged during the day by the PV solar panel. With the help of LDR, at dusk, the street light automatically turned on at 30% intensity and the battery starts to discharge. For each movement of a vehicle or a person, the PIR motion sensor sent a command to the microcontroller to increase the light intensity from 30% to 100% for a preset period of time. After a certain time and if no motion was detected the light gradually decreases to 30%. This ensured optimal lighting as well as energy savings. In the morning, LDR sent a command to Arduino and the street light turned off. The power supply of the street lighting was connected to the battery, and if the battery was not sufficiently charged due to cloudy weather, the street lighting automatically switched to power from the electrical distribution network.

Arduino the microcontroller received the command signal from the LDR light sensor, motion sensor, and charge controller and controlled the street lighting according to the program loaded into it. Authors gave following working diagram of system (Figure 4).

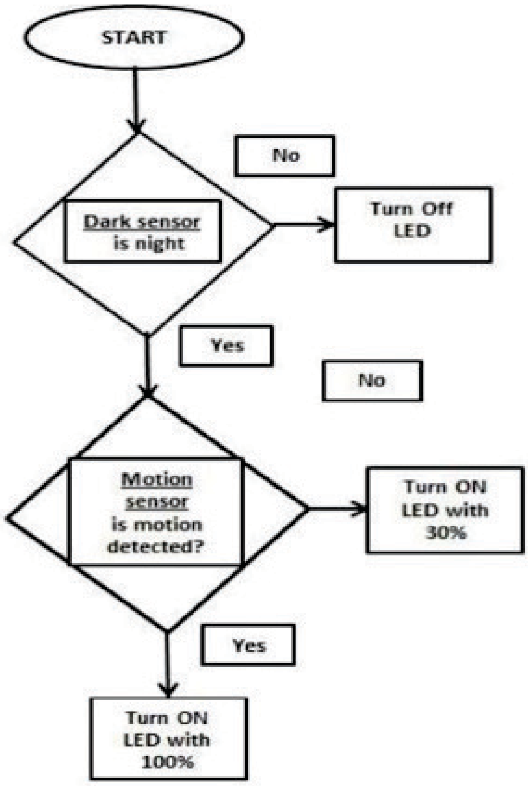

Figure 4. *Operation diagram of the Smart Solar LED Street Light system [6]*

The system can be integrated as an IoT application using a low-cost ESP Wi-Fi module, so the brightness of the LED lighting can be set to any required value. Various street lighting parameters can be monitored online, such as battery charge percentage, power consumption, on/off status, etc. In the coming years, all cities will have access to the Internet, so IoT control of street lighting will be able to be used. [6]

SMART SHOWER

Authors in [7] designed a smart shower that is an example of an autonomous photovoltaic system. Using a microcomputer and microcontroller, the shower monitors the operation of all its parts. It has sensors, relays, and other electronic components that enable it to distribute energy properly. It uses only solar energy and no additional energy source is needed. The power of the solar system was 60 W, which was enough for the operation of all components of the shower. Figure 5. shows a smart shower presented in [7].

Figure 5. *Smart shower[7]*

Each shower was connected to a base station that enabled remote control. In this way, constant monitoring of all components and timely updating of the system and elimination of potential malfunctions were carried out.

The shower included the ability to connect to the Internet and had ambient RGB LED lighting for users to access the shower at night, which was connected to the motion sensors. It had a screen that showed weather forecast data, the intensity of UV radiation, and the temperature of the sea. The scheme of the smart shower given [7] is shown in Figure 6.

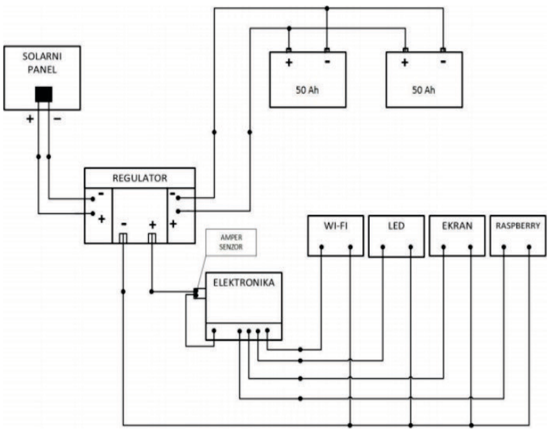

Figure 6. *Scheme of a smart shower [7]*

The smart shower consisted of PV modules, rechargeable batteries, charge controllers, and consumers.

Photovoltaic modules were an integral part of the system. The shower had rechargeable batteries to store energy in sunny weather (called the charging period). The discharge period occurred when the battery was the source of energy because the PV module did not produced enough energy for various reasons (time, age, etc.). An electrolytic lead battery was used in the shower.

A charge controller or voltage regulator was used for regulating the battery charge by stabilizing the AC voltage coming from the PV module. In this way, authors stabilized the voltage and the battery was maintained. The controller also ensured that the battery does not discharge too deeply.

The smart shower used all the necessary electrical energy for its work (parts such as sensors, info screens) from the solar radiation, while the ability to connect to the Internet made this device smart [7].

SOLAR POWERED SMART IRRIGATION SYSTEM

Authors in [8] used solar energy from solar panels to power the pumps that filled the tank with water. The water from the tank was used to water the crops and the tank had a valve that controlled the flow of water coming out of it. The valve was connected to a moisture sensor that detects the amount of moisture present in the soil, and depending on the moisture level, the valve opens and closes. Figure 7. shows the layout of the system that authors designed.

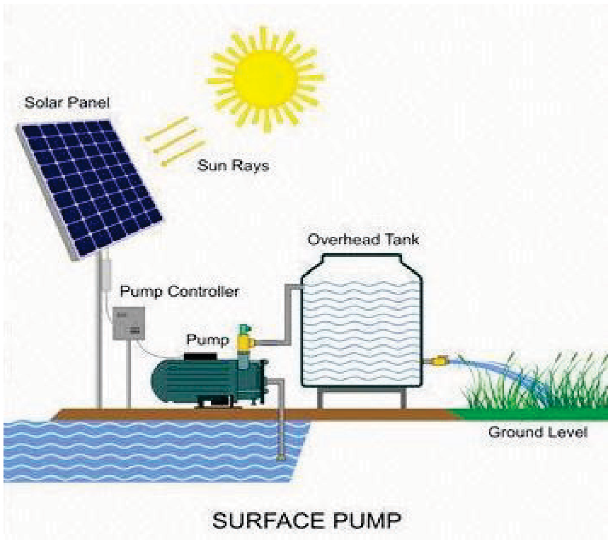

Figure 7. *Scheme of the irrigation system[8]*

The irrigation system presented in [8] consisted of two modules:

1. module for solar power supply of the pump,
2. module for automatic irrigation.

In the solar pump module, the solar panel of the required specifications was mounted near the pump. The batteries were charged by the solar modules, after which the electricity from them passed through the inverter and powered the pump.

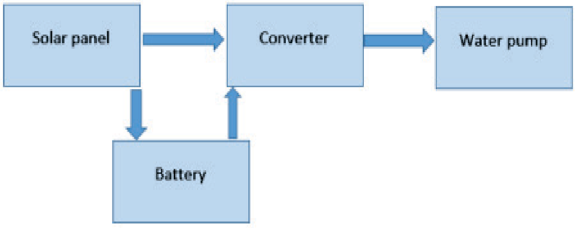

Figure 8. *Solar pumping module diagram [8]*

The water was then pumped into a temporary water storage tank before releasing the water into the field, (Figure 8.). In the automatic irrigation module, the tank's water outlet valve was electronically controlled by a system connected to a soil moisture sensor. The sensor converted the soil moisture content into an equivalent voltage.

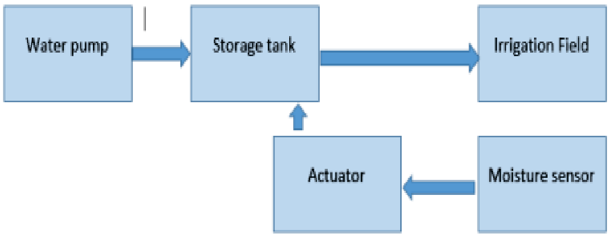

Figure 9. *Diagram of the automatic irrigation module[8]*

The sensor had a module for detecting the reference level of humidity that was pre-selected. The humidity sensor used in [8] is shown in Figure 10.

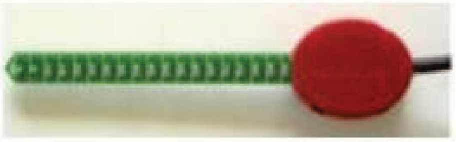

Figure 10. *Moisture sensor VG400[8]*

By using an automatic irrigation system authors made possible watering the crops without flooding. Another advantage of presented irrigation system was that the irrigation was controlled by one person [8].

CONCLUSION

Systems for photovoltaic conversion of solar radiation are used for the operation of audiovisual and cooling devices, the operation of signaling devices on roads, tunnels, airports, and lighthouses, for powering buildings, ships, airplanes, space stations, as well as in households, agriculture, the auto industry, etc. Applications such as lighting, telecommunications as well as providing electricity to entire settlements, especially in remote areas, have proven to be competitive and profitable compared to already existing technologies.

This paper gives an overview of four examples of innovative application of power smart systems (solar energy, smart sensors and microcontrollers as the main elements), which enabled energy efficiency increase and electrical energy saving. All four examples considered PV systems that can be integrated as an IoT application that enables real-time monitoring of system parameters.

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