Energy Management of Solar Power Generation Using IOT

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Abstract

This paper presents a prototype for the energy management of a solar panel system, which efficiently controls the load in different ways. The prototype consists of a 10-watt solar panel, a 12V 8Ah battery, charge controllers, relays, and sensors for detecting various parameters. The IoT platform used in this system is Adafruit, which receives all the required parameters and controlling options. The necessary parameters that are monitored in real-time include the solar panel output voltage, battery voltage, battery current, and the status of the main power supply. The controlling options include the main supply and the pump for panel cleaning.

By monitoring the data in real-time, the operator can evaluate the current state of the system and make immediate decisions if necessary. This system can be improved further by learning from the recorded data. The system's efficiency can be enhanced by analyzing the recorded data and making necessary adjustments to the system. This prototype demonstrates the potential for using solar energy and IoT technologies in managing energy systems more efficiently.

Keywords: Solar panel, Solar charge controller, Battery, Inverter, ESP8266 Wifi module, Relay, Mobile charger, Current sensor.

Introduction

The significance of renewable energy sources, particularly solar power, in meeting the increasing energy demand. The author notes that the domestic usage of solar power is not efficient, leading to the wastage of power stored in the battery and unnecessary discharge. The author suggests that managing the system efficiently can be achieved by finding the voltage of the battery, solar panel, and current draws from the battery, using suitable sensors and voltage divider technique. The author also highlights the problem of dust settling on domestic solar panels, which can be solved by using a pump suitable for the panel size.

The passage discusses the increasing use of photovoltaic methods for generating electricity and the importance of monitoring system stability and performance. The author notes that data collection and processing are crucial but expensive, as cables are required to transmit the data to a processing station. The author also highlights the problem of dust settling on solar panels in windy areas and suggests using specialized robots to clean them. The manual switching between battery and mains is also noted as a labor-intensive process. To address these issues, the author proposes collecting and remotely accessing data on panel and battery voltage and current. They also suggest implementing a water cleaning method that can be controlled locally using software, and automatic switching between battery and mains. This would help to maintain battery life and efficiency.

The author [1] has carried out a review on solar panel monitoring system using IoT which is used to compute the voltage and current generate from the solar module using Arduino UNO

The author [2] IoT was used to monitor and operate solar power plants, which is a critical step since renewable energy sources are rapidly being incorporated into utility systems. Monitoring and management of solar power plants has become more intellectualised, which has enhanced decision-making for large-scale solar power plants and grid integration. Remote monitoring powered by IoT improves system energy efficiency by leveraging new wireless modules that use less power.

Microcontroller (Node MCU), a PV panel, sensors (INA219 current module, digital temperature sensor, and LDR), a battery charger module, and a battery were all successfully constructed into an IoT-based real-time solar power monitoring system in their work [3]. The system could gather real-time data from places far from the control centre and monitor the environmental conditions of PV panels in real-time, including voltage, current, temperature, and light intensity, using a GUI. Through the usage of IoT, real-time data is continuously recorded and monitored. The collected data is then analyzed to predict and estimate future power generation possibilities, income output, and other factors. The implementation of this IoT-based system would consequently facilitate and improve recorded data analysis, decrease intervention and supervision time, streamline network management, and do away with the requirement for routine PV system maintenance. Since the sun's radiation range is not constant and can change with place and time. In order to make the most effective use of the maximum quantity of solar radiation and get the highest output, author has carried out management of the PV panel by setting up a Solar Power Tracking System. If any component of the system develops a defect, the developed Solar Power Monitoring system will also be advantageous

The developed prototype with current, voltage and temperature measurement devices fed to Arduino Atmega 2560 which is allied to wifi module for purpose of data acquisition for plant monitoring system through cyber physical system. The author[5] compared two different approaches to predict the solar radiation through Artificial Neural Network (ANN) and Multiple Linear Regression. However, ANN model founds to be more accurate for non-linear forecasting technique.

The author [6] developed a GUI to alert the user whenever there is dust found on the solar panel and the power output goes down. The various electrical parameters are stored in the Thinks speak cloud network. The author [7] has done a literature survey on the monitoring system of solar panel. Also the concern of damage in the solar cell is also concentrated by many researchers.

The author [8] developed a PV monitoring system through interactive GUI. THE GUI gives alert to the user when the power output goes below the certain limit. With the use of Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE), the accuracy of a prediction is calculated by [9]. The author have developed a prediction and monitoring system for solar PV system where two models were used for prediction and the error from the proposed model was found to be less than the linear regression model.

2.Proposed Methodology

In the proposed system, we can find the sunlight intensity, voltage of battery and solar panel, current of battery and also able to control the load, water pump for cleaning solar panel. In this system, we find out the voltage of the solar panel output and battery using the voltage divider/nbnbtechnique. All of those parameters and controls can be monitored and controlled in real time over the IOT platform named Adafruit. In addition to that, all those values can be monitored locally in the LCD placed next to the system. Arduino UNO is used to read those values and ESP8266 Node MCU is used to provide the values over the internet. The switching operation of the pump and the load is done with the two channel relay. In this system, we made the main load to consume power from the main supply and in the absence of main supply, it automatically draws power from the battery stored by solar power. With those values of voltage and current, we can conclude for using the system in an efficient way.

3. Hardware components

Solar panel

Photovoltaic cells convert sunshine energy into direct current electricity. PV is a technology that converts sunlight energy, which is made up of energy particles known as "photons," into electricity that may be utilised to power electrical components. PV panels are the combination of PV modules, unless they are unavoidable in the title or heads.

Solar Charge Controller

The charge controller controls the amount of current is added to or removed from an electric battery. Overcharging may be avoided using a charge controller, and the battery can be protected from overvoltage or total draining. A charge controller's principal duty in a stand-alone photovoltaic (PV) system is to safeguard the battery against overcharge and overdischarge. A charge controller and/or a low-voltage load disconnect are required for any system with unpredictable loads, human interaction, optimised or inadequate battery storage (to minimise initial cost), or any other features that may cause severe battery overcharging or overdischarge. Charging can be controlled in two ways: shunt and series regulation.

Battery

A battery uses a chemical process to turn chemical energy into electrical energy. The chemicals are stored within the battery. It is used to power other components in circuits. A battery generates direct current (DC) power (current that goes in one direction and does not reverse).Using energy from a building outlet is less expensive and more efficient, but a battery can provide electricity in locations without electric power delivery. It is also beneficial for moving objects like electric automobiles and mobile phones.

NodeMCU ESP8266

It is an open source Internet of Things platform. It comprises firmware that works on Espressif Systems' ESP8266 Wi-Fi SoC and hardware that is based on the ESP-12 module. The name "NodeMCU" refers to firmware rather than development kits. It is also a free and open-source platform. There are two available versions of NodeMCU as version 0.9 & 1.0 where the version 0.9 contains ESP-12 and version 1.0 contains ESP-12E where E stands for "Enhanced”. It initially included firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which was based on the ESP-12 module. Later, support for the ESP32 32-bit MCU was added. NodeMCU is an open-source firmware for which open-source prototyping board designs are available.

Relay

The relay is an electrically operated switch that may be switched on or off to allow or halt current flow.They are intended to be controlled by low voltages such as 3.3v.The function relay module is an electromagnet-controlled electrical switch. When engaged by a separate low power signal from the microprocessor, the electromagnet pulls to either open or close an electrical circuit

Single Channel Relay

The Single Channel Relay Module is a handy board that may be used to regulate high current loads including motors, solenoid valves, lights, and AC loads, as well as high voltage. It can interact with microcontrollers such as Arduino, PIC, and others. To open or close a switch, the relay employs an electric current. It is often accomplished with the assistance of a coil, which attracts the contacts of a switch and draws them together when engaged, and the coil is deactivated when the spring pushes them apart.

Dual Channel Relay

The dual-channel relay module is nearly identical to the single-channel relay module, however it has certain additional characteristics such as optical isolation. The dual-channel relay module is mostly used to switch mains-powered loads from a microcontroller's pins. The Dual Channel Relay Module is often used to control a circuit with a single signal or to control many circuits with a single signal. As a result, it is largely a switching device. The primary distinction between single channel relay and dual channel relay is that a single channel relay board can only switch one load at a time, but a dual channel relay board can switch two loads at the same time.

Phone Charger

A phone charger is a device that uses an electric current to store energy in a mobile battery. Mobile phone chargers are merely power adapters that supply power to the charging circuitry, which is nearly invariably housed within the mobile phone. Making a cell phone charger consists of four main processes. The first step is to reduce the 220 volt AC supply to a low voltage. The second step is to convert AC to DC using a full wave bridge rectifier. Because the DC voltage obtained in the second step contains AC ripple, the filtration process is used to remove it.

Arduino Nano

The Arduino Nano includes a crystal oscillator with a frequency of 16 MHz. Using a constant voltage, Arduino Nano can generate a clock with a precise frequency. The Arduino Nano has a restriction in that it lacks a DC power connector, which means that an external power source cannot be supplied through a battery. Arduino Nano is a kind of microcontroller board created by Arduino.cc. It may be made using microcontrollers such as the Atmega328. Because Arduino Nano has a flash memory of 32kB with a pre-installed bootloader and Uno has 32kB without a bootloader, using Arduino Nano is preferable to Uno. In Arduino systems, static random-access memory is also employed. There are several types of Arduino Nano has facilities for communicating with a computer, with another Arduino, or other microcontrollers.

Pump

It's a kind of submersible pump. A motor that can be powered by a 3 6V power supply. It has a capacity of 120 litres per hour and a relatively low current consumption of 220mA. Simply connect the tube pipe to the motor outlet, immerse it in water, and turn it on. Maintain a water level that is constantly higher than the motor. This pump has a restriction in that a dry run may cause the motor to overheat and emit noise.

Light Emitting Diode

A light-emitting diode (LED) is a semiconductor light source that generates light when current runs through it. Electron holes in the semiconductor recombine with electrons, producing energy in the form of photons. The colour of light (equivalent to photon energy) is determined by the energy required for electrons to pass the semiconductor's band gap.

Light Dependent Resistor

A light detection sensor can be used to detect light. It features variable resistance that changes based on the amount of light that strikes it. As a result, they are suitable for use as light sensor circuits. The resistance range and sensitivity of an LDR can vary greatly between devices.Furthermore, unique photoresistors can react significantly differently to photons within specific wavelength bands. A LDR can have a resistance as high as several megaohms (M) in the dark and a resistance as low as a few hundred ohms in the light. They operate on the basis of light waves, and the infrared light reflected from the item to the sensor will be utilised to calculate the distance between the object and the sensor. As a result, range plays a significant role in object detection. It has a transmitter that produces infrared radiations (also known as IR-LRDs), followed by IR receivers that receive the radiation from the IR transmitters.

Cleaning Process using Pump

Solar power plants require little maintenance and have no moving components. Panel cleaning to boost efficiency is an important part of solar panel maintenance that should not be overlooked. Solar panels generate power by converting sunlight that falls on them. The more light that strikes the panel, the more electricity it generates. When dust and other materials fall on the panel surface during this time. It lowers the quantity of light striking the solar panel, resulting in a lower output. When solar panels are cleaned, the efficiency of the solar panels increases, which corresponds to an increase in the number of units of electricity produced by the panels. Cleaning solar panels on a regular basis has the potential to boost electricity production. During low light conditions during production, the recommended time for solar cleaning modules is the shortest. During the day, the panels heat up, and cleaning them with cold water in the evening may result in thermal shock, which can cause permanent damage to the solar panel. The optimum time to clean the solar panels is early in the morning, when the plant is not in operation. The electrical shock threat is reduced and the temperature of the panels is not high.

In this we have used 4 relays. The solar panel is our main component and source of power. The solar panel is used to convert photons into electrical energy. The charge controller is use to manage the charge which is store in the battery from the solar panel.The main supply is connected to a dual channel relay which is connected to the Arduino Nano. There are two voltmeters which are connected to the solar panel and the battery to check the voltage. Then it is connected to the Arduino Nano. That completes the first half of the block diagram. Next, the Arduino Nano is connected to a LCD and Node MCU microcontroller which is used to monitor the data obtained. Then it is followed by the relay and a pump. Node MCU is linked to a relay and the relay is connected from the relay which is connected to the battery and resultant relay is related to the load. That's it about the connections. Regarding working the solar panel produces the energy and the energy is controlled by the controller and stored in the battery. The voltmeters will give the voltage of the solar panel and the battery. The reason we are using the dual channel relay which is connected to the main supply is because whenever the main supply is shutdown the current will be taken from the battery. Pump is used to clean the solar panel to increase the intensity of the light and thereby increasing the efficiency

4. Detection of sunlight intensity and main supply

We are detecting the sunlight intensity with the help of an analog LDR sensor type. Then the detection of the main supply is done by the power adapter as mentioned in this work. Those live statuses can be viewed over the Iot platform anywhere from the world. The crop of the sensor is given to the microcontroller and values are analyzed over the Iot platform.

Sunlight Intensity sensing

To detect the intensity of light from the sun, we are using the LDR sensor. We calibrated the maximum intensity of sun as 100 and minimum value as 0. Those values can be altered while programming. Since we measure the sun intensity falling on the solar panel, this sensor is made to fit over the panel. This makes us receive the most accurate value. The output of this LDR is given to the microcontroller and with the help of wifi-module, the live value can be visible on the Iot.

Main Supply Sensing

The sensor is connected to the main supply 220 volts by converting 220 volts AC to (5 or 6 KVA) transformer and DC (rectifier) before attaching it to a microcontroller input. Another simple method is to connect the discarded phone charger to a power supply; the output is 5-volt DC, which is more than enough to power up the relay coil. When the switch is closed, the input is a microcontroller. As a result, we can validate the presence of the main supply in the surrounding region. Furthermore, the Iot platform allows you to check the live status.

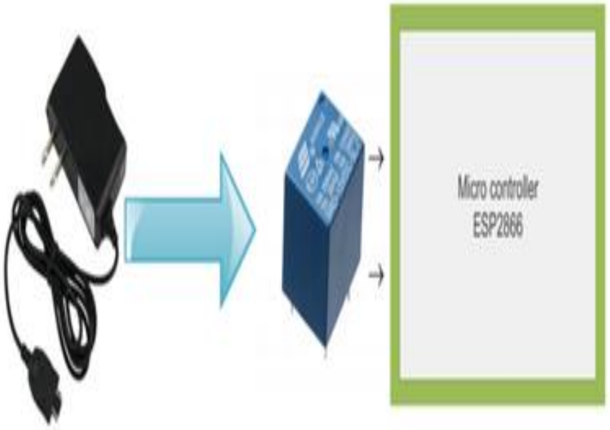

Fig: 1.Main Supply Detection

5. Modes of operation

Here the conventional switches are connected between the input and microcontroller and also in parallel with the microcontroller which results in output. As the name manual suggests here the operation is done manually by switching ON and OFF conservative switches to control the process. It is always placed next to the load we are using.

Relay switch

This operation is similar to the physical switch operation but instead of using conventional switches relays are used. Here the relays are connected between the main supply and Arduino Nano, Node MCU and pump and the final one is between the supply and load. This operation is accepted out by the IOT platform and to turn ON and OFF the relay coils and the operation can also be monitored.

Automatic Mode

In this mode the operation is carried out automatically depending upon the availability of the main power supply i.e., whenever the power from the main supply is shutdown it automatically takes the power from the battery which was supplied to it by the solar panel by converting photons into electrical energy. With the assist of the webpage we can monitor the status of the operation. It helps us to discharge the power from the battery in an efficient way.

6. Controlling of parameters

The important parameter of this project is to find the voltage of solar panel output and the battery. Here we find those voltages by the voltage divider technique which is explained below.

Voltage Divider

A voltage divider is a basic series resistor circuit. The output voltage is a constant proportion of the input voltage. The divide-down ratio is determined by the two resistors. Voltage divider is a highly popular and useful series resistor circuit. It is termed a voltage divider because it divides voltage with regard to a common point or ground, generally 0V, or it can split voltage between two supplies, such as 5V or 12V. Voltage dividers are also known as potential dividers since the "Volt" unit of voltage determines the amount of potential difference between two places. is If the output wire current is zero, the input voltage is Vin and the output voltage is Vout.

$V_{out} = Z2/(Z1+Z2)*V_{in}$

Then the Sunlight intensity parameter is found with the Analog LDR sensor connecting to the microcontroller. Finally the status of the main supply voltage is found by connecting the power adapter like phone charger to the relay, whose output is related to the microcontroller. So the microcontroller is programmed in such a waythat, when the relay is turned ON the main supply voltage is available and vice versa.

When looking at the controlling feature, the IOT platform called Adafruit is used. Here we control the main load and the pump to clean the solar panel. To control both the parameters, we use the two-channel relay. It can be controlled by the switches available in the Adafruit platform. Moreover, the main supply status can be monitored lively and turned on or off over there.

7. Results and discussion

The below picture depicts the hardware output of this project. As you can see the solar panel is allied to the battery through the charge controller. The microcontroller is soldered to the dot matrix board, where all the sensors and relays are connected to it. The LCD placed over there, helps to receive all the parameters locally of the system. The below diagram shows the main dashboard, where we can get all the parameters including the controlling option. It is the IOT platform named as Adafruit and it is absolutely free to use for all. Make sure, the password and ssid programmed in the Wifi-module is the same as the local network. Note that, there is availability of internet to the microcontroller and the device which you use for operating the system. The Adafruit platform is extremely easy to modify, even if you have uploaded code to the microcontroller. It has the edit option on the right side, with that you can create multiple blocks. Once added, the dashboard is customizable over the screen. Just drag and drop the blocks wherever you want.

The below graph is drawn for the sunlight intensity using the LDR sensor and the solar panel voltage by the voltage divider technique. You can clearly see with the purpose of the voltage is produced from the solar panel. only when the sunlight intensity is available or high. Since a 10watts 12volts panel is used here, the maximum voltage is referred to as 12 volt. Then the maximum sunlight intensity is programmed as 100 and the least intensity can be considered as less then 30 from the LDR sensor. Moreover, for every parameter we received in the Adafruit, we can produce the graph and analyze it.

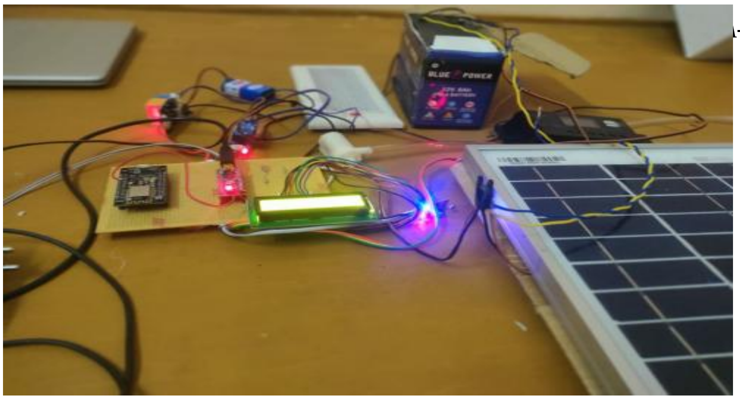

Fig 2 .Hardware Output

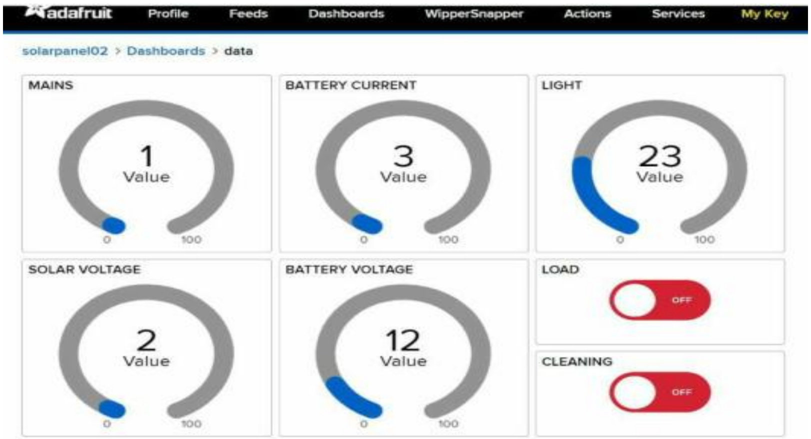

Fig 3. Controlling and Monitoring Dashboard

Fig 4. Graph. Sunlight intensity Vs Solar voltage

8.Conclusion

These approaches feature weekly, monthly, and daily tracking of solar energy. The analysis became easier, more convenient, and economically beneficial. Process can enjoy non-conventional energy indefinitely. The solar array voltage generation is one of the most advanced options for clean energy production. By observing and managing the voltage created by our intended system, we may be able to overcome the disadvantage of the previously described system. This technology has a cheap operating cost and may be used in remote places while also reducing manpower.One of the possibilities is to use a current sensor (hall effect sensor) to measure the current and then display the status of the electricity used to construct the Solar Panel.

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