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Cost-Effective Solar PV Based Energy Monitoring System using IoT

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ABSTRACT

Energy monitoring of solar water heater system and DC fan can be a useful task for residential home owners. The effective management of home appliances is dependent on accurate data regarding the usage and measurable parameters of the specific installed system. This project aimed to develop a non-complex and cost-effective solar based energy monitoring for water heater system and DC fan that is connected to the internet of things for data collection. Data collected by the system includes the power consumed by the system, power produced by solar panel, status of the battery, current consumed by water heater and DC fan as well as the time of occurrence. The designed system is non-complex in the sense that it can easily be installed by the home owner without disturbing the existing electrical wiring of the residential house. Furthermore, data is collected via an internet server, called Thing Speak, using an existing Wi-Fi connection at the residence. The system is cost effective regarding affordable hardware and free software that is used in the operation of the system..

KEYWORDS:Water Heater, DC-Direct Current, IOT-Internet of Things

1. INTRODUCTION

Energy monitoring of water heater system and DC fan load is solar based system which optimizes the renewable energy and also the data collected is observed via an internet server. It is a cost-effective system where affordable hardware and free software is used. The effective management of home appliance is dependent on accurate data regarding the usage and measurable parameters of the specific installed system. Data collected by the system includes the power consumed by the system, the outside temperature, as well as the time of occurrence. The designed system is non-complex in the sense that it can easily be installed by the home owner without disturbing the existing electrical wiring of the residential house. Furthermore, data is collected via an internet server, called Thing Speak, using an existing Wi-Fi connection at the residence. The system is cost effective regarding affordable hardware and free software that is used in the operation of the system. With data that is obtained from the system regarding warm water usage and power consumption, the home owner can make informed decisions to optimize the solar home appliance installation, easily be accessed by the home owner for monitoring, optimization, and maintenance of the system.

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure, important terms, objectives and overall description. In Section 2 we discuss the existing methods. In Section 3 we have the complete information about the proposed system.. Section 4 shares information about the design methodology. Section 5 tells us about the technical design methodology adopted. In Section 6 the system flowchart and In Section 7 result analysis are discussed. Section 8 tells us about the concludes the paper with acknowledgement and references.

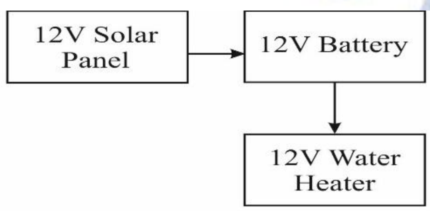
OBJECTIVES

The aim of this project is thus to describe the designed system. In the designed system, current and temperature sensors are used as inputs to the analog to digital converters of an Arduino microprocessor.

The microprocessor then communicates the sensor data to an ESP8266 Wi-Fi module. The Wi-Fi module connects to the Internet of Things (IoT) cloud server named Thing Speak, where the data is stored and displayed. The structure of this project is as follows. Firstly, the Wi-Fi Module, the ThingSpeak server, and the Microprocessor is introduced. After that, the specific water heater ystem and DC fan that was monitored.

2. EXISTING SYSTEM

Water heater is powered by solar energy using solar cells that convert solar energy (sunlight) directly to electricity. The electricity is stored in batteries and used for the purpose of lighting whenever required. The Solar Water heater system is a fixed installation designed for domestic application. The system comprises of Solar PV Module (Solar Cells), charge controller, battery and heater. The solar module is installed in the open on roof/terrace -exposed to sunlight and the charge controller and battery are kept inside a protected place in the house. The solar module requires periodic dusting for effective performance. The figure 2.1 shows the existing system.



*With Tank, Gate Valve, &12V Water Heater.J.

Fig 1 Existing System

3. PROPOSED SYSTEM

During the partially shaded condition of the PV panel, the output voltage of the panel is reduced. In the proposed method string current diverter is used which maintains the output voltage of the PV panel during the partially shaded conditions. The proposed consists of PV panels. The output voltage of the PV is given to the SEPIC converter. The SEPIC converter steps up the voltage. The dc voltage measurement used solar output, SEPIC converter output, battery output voltage monitoring for this system. The outputs of the three SEPIC converters are given to battery. Then temperature sensor used water temperature level monitoring and fan load current measuring. The battery voltage used for water heater and fan. The all information sends to web server in help of WI-FI IoT device. The below figure 2.2 shows the block diagram.

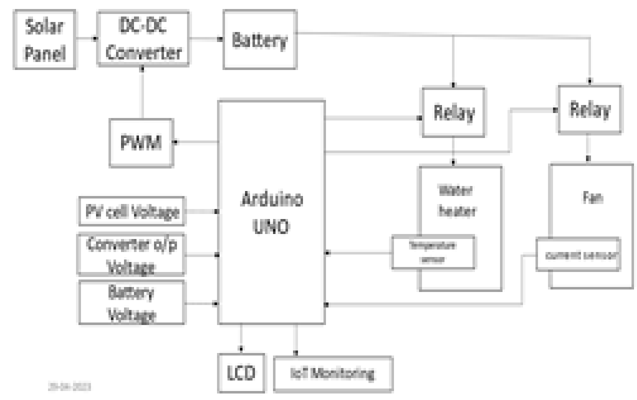


Fig. 2 Block Diagram

4. DESIGN METHODOLOGY

The Proposed System components are as follows

- o Solar Panel
- o Arduino UNO
- o Battery
- o SEPIC Converter
- o Relay
- o DC Fan
- o DC Water Heater
- o Power supply
- o Display
- o Internet of Things

A. Solar Panel

The solar panel (photovoltaic module or photovoltaic panel) is a packaged interconnected assembly of solar cells, also known as photovoltaic cells. The solar panel is used as a component in a larger photovoltaic system to offer electricity for commercial and residential applications. Because a single solar panel can only produce a limited amount of power, many installations contain several panels. This is known as a photovoltaic array. A photovoltaic installation typically includes an array of solar panels, an inverter, batteries and interconnection wiring.

B. Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. An Arduino UNO microcontroller (based on ATmega328p) is used in this project, which has lots of libraries developed and available online for free.

C.Battery

Battery is use for storing the energy produced from the solar power. The battery used is a lead-acid type and has a capacity of 12v; 2.5A.the most inexpensive secondary cell is the lead acid cell and is widely used for commercial purposes. A lead acid cell when ready for use contains two plates immersed in a dilute sulphuric acid (H_2SO_4) of specific gravity about 1.28.the positive plate (anode) is of lead –peroxide (PbO_2) which has chocolate brown color and the negative plate (cathode) is lead (Pb) which is of grey color.

D. SEPIC Converter

DC-DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input; the output of the SEPIC is controlled by the duty cycle of the control transistor. A SEPIC is essentially a boost converter followed by a buck-boost converter; therefore, it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown.

E. Relay

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example, a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical.

F.DC Fan

A mechanical fan is an electrically powered device used to produce an airflow for the purpose of creature comfort (particularly in the heat), ventilation, exhaust, cooling or any other gaseous transport.

G.DC Water heater

The DC water heater used in this project is a 70 watts heater (12V) used to heat the water obtaining power from solar panel. The heater works on the principle, when an electrical current flows through a resistive element, heat is produced and the element becomes red hot.

H. Power Supply

The ac voltage, typically 220V rms, is connected to a transformer, which steps that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation.

I. Display

The calculated power parameters current power factor, mains voltage, mains current, real and apparent power are continuously displayed on a 16x2 Liquid Crystal Display monitor.

J. IOT

The Internet of things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect, collect and exchange data.

The following figure shows the completely implemented design of the project.

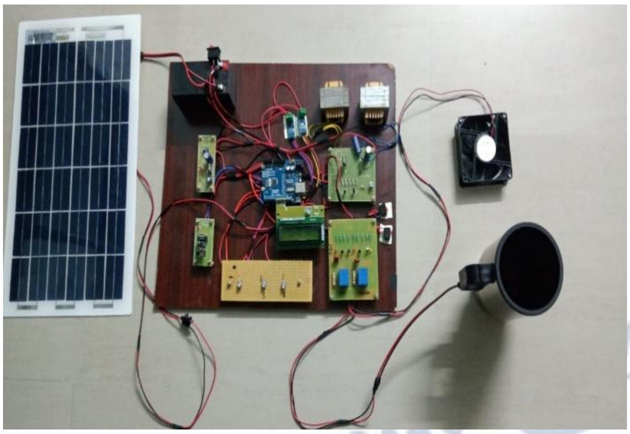


Fig. 3 Working model

5. TECHNICAL DESIGNS

A. Circuit Diagram

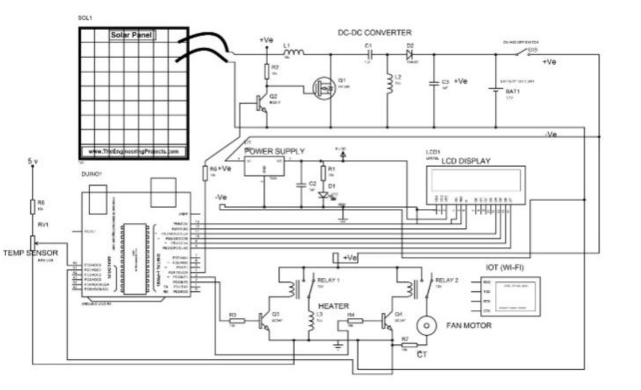


Fig.4 Circuit Diagram

B. System Flowchart

The following figure shows the functional flowchart of the system

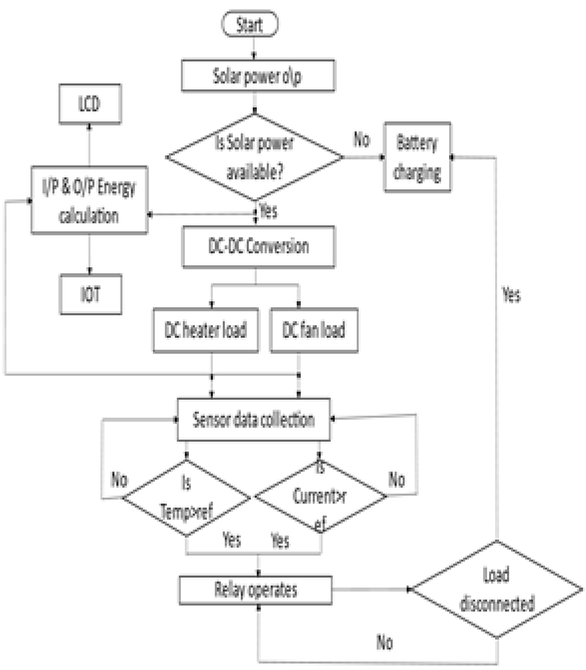


Fig.5Flowchart

C. Required calculation

DC WATER HEATER LOAD

Power rating of DC Water Heater = 600 watts

The usage of water heater is considered to be 4 hours a day approximately

4 hours per day = 600*4

= 2400wh

= 2.4Kwh power is consumed per day

DC FAN LOAD

Power rating of DC fan = 12 watts

The usage of fan is considered to be 10 hours a day approximately

10 hours per day = 12*10

= 120 wh

= 0.12 kwh power is consumed per day

CONSIDERING BOTH LOADS

DC water heater + DC fan = 2.4 + 0.12

= 2.52 Kwh power is consumed when both loads are connected

Average solar panel power = 400 watts

Let's consider solar panels for 8 hours = 400*8

= 3200 wh

= 3.2 Kwh

$$\text{Efficiency} = \frac{\text{Output power}}{\text{Input power}} = \frac{2.52}{3.2} = 80\%$$

INITIAL COST:

Let's consider 400 watts solar panel

Solar panel price = 16,000 rupees

Battery size = Solar panel power / Battery watts

= 3200 / 12

= 267 ah (Approximately 300 ah battery is used)

Battery price for 300 ah battery = 19000 rupees

Initial cost = Solar panel price + Battery price

= 16,000 + 19,000

= 35,000 rupees

COST SAVING

From the energy calculation the DC water heater and DC fan consumes 2.52 Kwh per day, the cost for one unit of electricity is 10 rupees

Cost saved per day = 2.52*10

= 25.2 rupees

Cost saved per month = 25.2*30

= 756 rupees

Cost saved per year = 25.2*365

= 9198 rupees

6. RESULTS ANALYSIS

The result of this project is the demo of the cost-effective energy monitoring system. A solar panel collects the solar energy and it is boosted with boost converter. The energy is stored in the battery. A temperature sensor is used to sense the room temperature and current sensor used to sense the current of DC fan. An Android app is created to see the energy levels in our mobile using IoT. The energy levels are displayed in the LCD display as well. By using solar power and IoT technology, the system can be self-sustaining and provide real-time data that can be used to optimize energy efficiency and reduce costs.

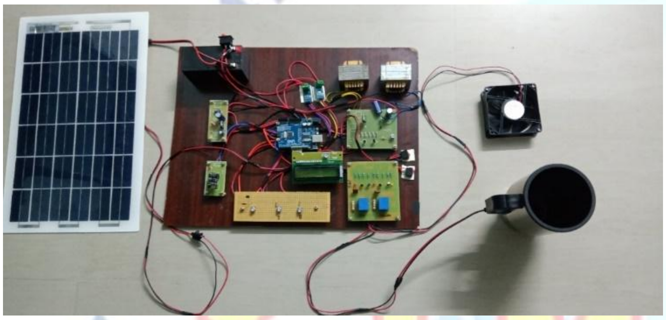


Fig 6 Before supply is ON

Fig.7 Initial ratings before supply is ON

Initially, by switching on the supply the current ratings for fan and heater will be at initial 0. The solar, converter and battery ratings will also be at initial 0 as shown in the LCD display

CASE STUDY 1: FAN LOAD

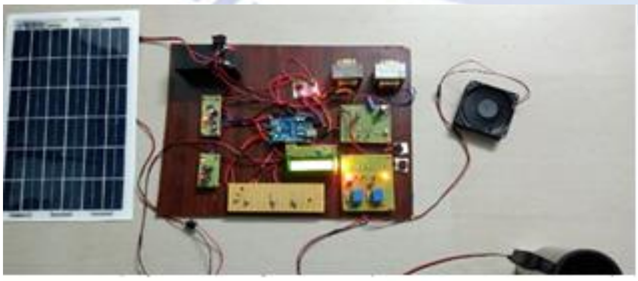


Fig 8 When Fan Load is ON

Fig.9 Ratings when fan load is ON

Now, when the supply for fan is ON, the current ratings will be varied, as shown in the display. This can be seen in our mobile using the software.

CASE STUDY 2: WATER HEATER LOAD

Fig.10 When water heater load is ON

Fig.11 Ratings when water heater load is ON

And when the supply for water heater is ON the current ratings varied. This also can be seen in the mobile.

CASE STUDY 3: BOTH LOADS

Fig.12 Screenshot in our mobile.

7. CONCLUSION

The purpose of this paper was to describe the design and development of a non-complex and cost-effective solar energy monitoring system that is connected to the IoT for data collection. This non-complex system only requires a CT sensor, temperature sensor, Arduino microprocessor, ESP8266 Wi-Fi module and internet connectivity. The system is also cost-effective, in the sense that it costs less than R1000 to build. The designed system collected data regarding electrical energy consumption as well as air temperature. The collected data were recorded on a cloud server, called ThingSpeak, where the user can access the data from any internet connection. Valuable information regarding hot water usage, power consumption and air temperature is now accessible and can be used for SWH system and DC Fan optimization and maintenance. As indicated in literature an optimized SWH can reduce the hot water requirements of a residential home by UP to 70%. With the use of this cost-effective energy monitoring system, this target is within reach of the residential home owner. Future research may entail the use of the collected data to optimize and to verify optimization of the installed system.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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