IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Comprehensive Solar Power Measurement System For Grid Integration

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Abstract

The proposed paper is designed to measure various parameters of a solar cell, such as light intensity, voltage, current, and temperature, through multiple sensor-based data acquisition methods. A solar panel is employed to track sunlight, with a PIC microcontroller serving as the central processing unit. The system utilizes an LDR (Light Dependent Resistor) sensor to measure light intensity, a voltage divider circuit for voltage measurement, a current sensor for current detection, and a temperature sensor to monitor temperature levels. These parameters are then processed by the microcontroller and displayed on a 16x2 LCD screen. The light intensity is measured via the LDR sensor, voltage is determined using the voltage divider principle, current is sensed by the current sensor, and temperature is tracked by the temperature sensor.

The power supply consists of a 230V/12V step-down transformer, which reduces the voltage to 12V AC. This AC voltage is converted to DC using a bridge rectifier, with ripple smoothing provided by a capacitive filter. The output is then regulated to 5V using a 7805 voltage regulator, which is required for the operation of the microcontroller and other associated circuits.

Keywords: Solar Panel, Arduino Uno, Temperature Sensor, Current Sensor, Light Intensity Sensor

Introduction

The solar energy market is one of the fastest-growing renewable energy sectors globally. Recently, there has been a noticeable increase in demand for equipment to measure solar energy in various applications. This study aims to measure solar energy using multiple sensor data acquisition techniques. A solar panel is employed to continuously track sunlight, with different parameters of the panel—such as light intensity, voltage, current, and temperature—being measured. The collected data is then sent to an Arduino, which displays the information on an LCD screen.

In today's world, the Internet of Things (IoT) is rapidly evolving, offering the ability to connect devices through communication protocols and cloud platforms, thus making them smarter and more user-friendly. Factors such as current, voltage, irradiance, and temperature play a crucial role in determining the efficiency of solar panels. Therefore, a real-time solar monitoring system is necessary to enhance panel performance by comparing it to experimental data and enabling preventive actions.

The rising prices of fossil fuels, global warming, and extreme weather conditions have pushed governments worldwide to explore alternative energy sources to reduce reliance on fossil fuels. Among these, solar energy stands out as one of the most promising renewable sources to meet the growing global electricity demand. After wind energy, solar energy is the fastest-growing renewable energy source for power generation. Solar energy is converted into electricity through solar cells, which absorb sunlight directly, while concentrated solar energy captures it indirectly. Photovoltaic (PV) solar systems utilize solar cells to convert photon energy from the sun into electricity. The energy from photons knocks electrons out of semiconductors in the solar cells, enabling electric current. Solar panels are typically made of two types of cells: monocrystalline and polycrystalline. Monocrystalline cells, made from a single silicon crystal, are more efficient than polycrystalline cells, which are composed of multiple silicon crystals. The amount of energy produced by a solar cell is significantly influenced by environmental conditions, particularly solar irradiance and temperature.

Recent advancements in the energy sector have highlighted the rapid growth of the solar energy industry. The demand for remote monitoring and control systems for solar energy applications has also increased. Technological innovations have led to the development of smarter solar cells, which are more efficient, flexible, and lightweight. These cells now include embedded electronics such as power optimizers, micro DC-DC converters, and condition monitoring devices. Monitoring solar PV parameters and environmental conditions is crucial for assessing the performance of existing systems, enabling advanced monitoring, forecasting future energy production, and improving system maintenance. Reliable data collection methods are essential for evaluating system performance and ensuring effective condition monitoring. Although collecting such data can be costly, especially when implementing cutting-edge technology in the field, it is necessary for accurate assessment. Concerns have also been raised about the reliability of using satellite data in place of locally gathered data.

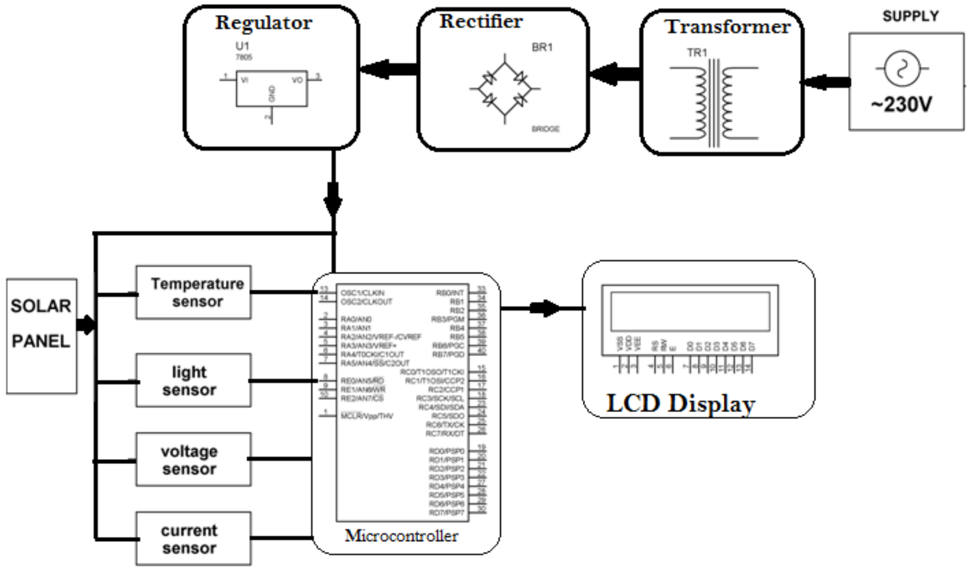

Figure 1: System Model

Literature Review

Data loggers are frequently employed in all systems relating to technology, not just in the electronic realm. It is frequently used to collect data for a system that pertains to electrical and climatic factors due to its ability to store information for a long time. Data loggers have been utilized extensively in monitoring both parameters, particularly in the field of photovoltaic (PV) systems. It's ideal for PV systems since it can store a wide range of data for a prolonged period of time without requiring complete user scrutiny. In an Off-Grid PV system, a data logger is critical for logging all data because the system is placed in a remote area that is typically far from the utility grid. As a result, a user's constant supervision is not worthwhile solely to collect data for observation reasons.

The capacity of data loggers to store data over time without constant supervision has made PV systems with data recorders an excellent pair. PV systems are now being acknowledged by Malaysia's higher authorities, as well as a few environmental and industrial organizations. Its technology has the potential to meet the world's energy needs in an environmentally friendly and renewable manner. As a result, the PV system requires a reliable data logging technique to save all electrical and meteorological data for monitoring and observation; a data logger appears to be required in this field.

Methodology

The 5V power supply is connected to the Arduino's power input port, while the 3.3V supply is provided to the Wi-Fi module. Pin A1 of the Arduino is connected to the current sensor, Pin A2 to the voltage sensor, Pin A3 to the LDR sensor, and Pin A4 to the temperature sensor module. The data from these sensors is displayed on a 16x2 LCD display. Since this paper also requires remote functionality, the Wi-Fi module is connected to the Arduino through Pins D2 and D1, allowing communication with ThingSpeak, where the data is displayed in graphical form.

The solar panel, voltage sensor, current sensor, MOSFET, and ESP8266 Wi-Fi module are all interfaced with the Arduino. The inputs from the 12V solar panel are sent to both the current and voltage sensors. The current sensor measures the current, and the MOSFET is used to display the maximum power point tracking (MPPT) value. The voltage sensor is also connected to the Arduino.

The Arduino communicates with the user interface, such as a laptop or circuit board, via the Arduino Software (IDE) through a USB connection. The code is uploaded to the Arduino through the IDE. With the Wi-Fi module connected, the system provides real-time data in the form of graphs on the ThingSpeak IoT platform. ThingSpeak is an open-source IoT platform that enables us to visualize and analyze live-stream data in the cloud.

Hardware Specifications

- 8051 series MC
- Diodes
- LCD
- LED
- Solar Panel
- Transformer
- Voltage Regulator

Software Specifications

- Keil compiler
- Language: Embedded C or Assembly

Result and Analysis

In this paper, solar parameters are measured using various sensor acquisition methods, facilitated by an IoT-based system designed to optimize the power output from solar panels. The system accounts for changes that may affect the solar panels, such as dust accumulation or environmental factors encountered during data collection. A monitoring system is implemented to alert users if the solar panels fail, displaying the failure on the screen. It also collects data about the solar system to which the connected loads are attached. When the output falls below specified thresholds, these parameters are presented to the user through an intuitive graphical interface (GUI), as shown in the figures below.

This approach operates effectively under certain conditions, enabling the solar panel to track sunlight. Using IoT technology, metrics like light intensity, voltage, current, and temperature are displayed on an LCD. Currently, we are able to view this information in real time on the cloud, but in the future, the entire system will be controllable remotely through IoT, offering a more convenient and distant method of operation.

Figure 2: Proposed Model

Conclusion

The Arduino-based solar energy parameter measurement system was designed and constructed using optimized simulated parameters in Proteus. The system was employed to collect data on solar current, voltage, temperature, and light intensity. This setup allows for the measurement of solar panel data, which can be used to evaluate the performance of the solar energy generated and predict future energy production. Based on the collected data, it was observed that photovoltaic (PV) output is directly influenced by solar irradiance and temperature.

Future Scope

The use of solar energy can help reduce the reliance on firewood and dung cakes in rural areas, which do not produce harmful emissions that contribute to global warming. Since a significant portion of the population resides in rural regions, there is great potential for solar energy adoption in these areas. This paper can be particularly beneficial in areas with low population density and limited rainfall. The solar energy system with Maximum Power Point Tracking (MPPT) can help monitor and prevent excessive electricity usage, while also tracking the times and duration of peak solar energy generation throughout the day. The live data feed can be utilized for both domestic and commercial purposes, allowing users to monitor available solar energy and track the energy consumption of appliances and connected loads.

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