JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Node MCU Based Solar Panel Management System Integrated With Security Features

Prakash N
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, India
prakash.n.eee@kct.ac.in

Haridha T
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, India
haridha.21ee@kct.ac.in

Vibin Pon Xavier M
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, India
vibinponxavier.21ee@kct.ac.in

Sivapriyan S
Dept. of Electrical and Electronics Engineering
Kumaraguru College of Technology
Coimbatore, India
sivapriyan.21ee@kct.ac.in

Abstract **- This research work presents an efficient solar panel monitoring and management system based on Node MCU microcontroller which aims two main issues. These concerns are how to attain maximum output of solar installations especially in far flung unattended areas and how to secure the solar installations. The system employs integrated sensors to monitor such critical parameters as voltage, current, power output and assesses the performance of the panel in real time. Maximum Power Point Tracking (MPPT) system is incorporated to automatically vary energy within the solar panel's output to enable efficiency as external factors change. In addition, a dust sensor detects the level of dust on the panels and sets off a self-cleaning system that activates water sprinklers and DC motors to clean the panels to enable optimal energy production.**

The system is equipped with a strong security module in addition to the performance enhancement, for the purpose of curbing theft or tampering of installations. Any physical movement that takes place within the vicinity of the solar panels is monitored and unauthorized movements are stopped with the use of motion sensors and vibration sensors. This is also supplemented with a GPS system that indicates the position of the panel fitted onto the controller unit of the panel itself. In the event of any suspicious movement being registered, the Node MCU sends a message via the GSM module which pings the owner or the guards within the shortest time possible for necessary action, in this way, safeguarding the system from any energy loss as well as ensuring the system's availability especially in remote and less supervised places. The system also focuses on the use of renewable energy and safety management of the installations which in turn is an advantage for the existing solar energy systems.

Keywords: solar panel monitoring, MPPT, Solar management, theft prevention, GPS tracking, Node MCU

I. INTRODUCTION

As the energy needs of the world escalate, the importance of clean energy sources such as solar energy in shifting away from fossil fuels and in environmental management cannot be overemphasized. Solar energy is harnessed via solar panels which are devices that convert sunlight to electricity and they are becoming more popular in the households, businesses, and industries. Nevertheless, the challenge of ensuring that the installations are operated with maximum efficiency and security particularly in remote or unattended areas is another issue that has to be addressed. For instance, effective monitoring and protection are necessary in such a way that the solar panels will not be tampered with, which may lead to degraded operational levels due to environmental factors such as dust or situations of theft and vandalism.In this light, the Node MCU Based Solar Panel Management System aims to resolve this by integrating the process in real-time for monitoring, cleaning and security. The system employs Node MCU microcontroller which manages data acquisition, communication and control over components assembled within the system. Key performance indicators like voltage, current and power outputs are constantly monitored with the aim of enabling Maximum Power Point Tracking (MPPT) control to increase the efficiency of the panel under different sunlight intensities. A dust sensor is used to clean the panel once the surface has been soiled – this includes spraying water through DC motors and sprinklers so as to don't lose efficiency.

Furthermore, the system has a security feature that is necessary when such systems are used in extreme or remote sites. Motion and shock sensors pick up any movement of the panels, or any vandalism intent, while a GPS antenna indicates the position of the panels. In the event of any suspicious behaviour or interference, Node MCU prompts the alarm system utilizing a GSM module that alert the owner or appropriate person in charge.

II. BACKGROUND OF THE PROJECT

The worldwide tilt towards the use of renewable energy has emphasized the significance of solar power in the reduction of greenhouse gas emissions as well as the sustenance of energy. Solar panels, which generate electricity with the help of the sun, provide a clean and renewable source of energy that can be harnessed in different ways. However, in light of the increasing use of solar PV systems, newer and more complicated issues have arisen concerning the maintenance and safety of these solar systems. For instance, solar panels are often in great danger of climatic conditions or even dust build-up, as well as being subject to threats such as theft and destruction, particularly in remote or insecure locations. Such problems may greatly compromise the effectiveness and dependability of solar energy systems. In the typical arrangement, the maintenance and security of the solar installations also involve some periodic manual inspections that are expensive and laborious. Over a period of time, dust and dirt particles will build up on the solar panels resulting in interference with sunlight absorption and thus lowering the solar panel efficiency. There are many studies on the effects of the dust on solar panels and they all point to a very drastic fall in the power outputs of the solar when these panels are not cleaned on a regular basis. In addition, in most cases, these solar panels are exposed in far-off places for long periods of time without any protective measures, which poses a risk of theft. All these raise the costs in the operation of the energy systems and affect the output of energy thus making utilization of solar energy systems less efficient.

The problems above have been only superficially addressed by existing solar management systems in terms of their basic monitoring attempts and energy management systems. Most of them, however, do not present a system that integrates advanced surveillance and control of entire section with monitoring of energy consumption and its management system

III. SOLAR PANEL AND ITS IMPORTANCE

Solar energy panels are increasingly becoming one of the key technologies that will help the world overcome the energy crisis. Solar power systems consist of elements called solar panels that take in sunlight and produce electricity. In course of time, such a solution proves to be a clean source of power which is sustainable and requires little to no effort to harness and avail. The role of solar energy technologies goes above and beyond the benefits to the environment and the economy. There is also a huge social impact making solar energy one of the basic needs for the world's energy consumption

1. Environmental Advantages: Use of solar energy is one such cleaner fuel helping mankind to go easy on use of fossil fuels which contribute a large share of greenhouse gases to the atmosphere. In this regard there are few, if any, technologies as solar panels, which produce electricity without any harmful emissions. A shift in energy dependence from coal, oil or gas to solar energy also helps in reducing the carbon footprint hence aids in the health of the planet and the organisms inhabiting it. As countries try to play catch up with climate goals, solar power presents a cut where such goals are possible with some equanimity.

2. Financial Benefits: Limitations of electricity costs are economic advantages of the solar panels to the individual, businesses and government. Looking at the very beginning, one may see that installation solar energy systems is expensive however looking at the durations where solar energy will be in use, there are no costs incurred in operations and this helps to cut down bills in the long run due to less or no power consumption. Local manufacturing plants have been established, which due to technological innovation and mass production trends, have come down in the price of solar roof panels. Concisely defined, in some contexts made easier through the use of external benefits such as tax credits, rebates and feed in tariffs among other benefits, adoption is made easier. Also, it helps reduced depreciation on foreign source of fuels by converting some of it to solar energy, this solar energy enhances energy security and stability of energy prices.

Node Mcu in solar panel:

The Node MCU is an open source, low-cost microcontroller board developed around the ESP8266 Wi-Fi Chip. This controller platform is selected for this project due to its abilities to process data in real time, control many elements and include IoT operability which makes it very effective for applications related to the management and monitoring of solar panels.

Key Features of Node MCU (ESP8266)

1. Wi-Fi Connectivity

The ESP8266 chips which come with the Node MCU are Wi-Fi enabled hence no external Wi-Fi modules are needed for communication. This capability is very critical since it enables the project to be remotely monitored as the system can send information and receive commands via the internet. The Node Mcu can further access the cloud or any user interface over the Wi-Fi connected allowing the access of the performance metrics of the solar panels and the security in real time.

2. Processing Power

The Node MCU is equipped with 32 bit microprocessor (Tensilica L106) which optimally runs at 80 MHz, this is enough processing capacity for multitasking for instance data gathering, real time data processing and running control strategies such as Maximum Power Management.

IV.CHALLENGES IN SOLAR PANEL MANAGEMENT SYSTEM

Creating an all-in-one system for the management of solar panels comprising of optimal performance, and outbreak maintenance with security presents with a few technical issues and operational challenges. A few of the key challenges faced in this project includes:

1. Real Time Monitoring and Data Accuracy

Accurate real-time monitoring of solar panels parameters such as voltage, current, and power output, among many others, is essential on a bid to enhance efficiency. The challenge is thus on what sensor and how best it will be integrated within the Node MCU unit to achieve the shortest possible data transmission duel without data distortion. Incorrect data readings may result in undesirable performance correction leading to poor energy generation and loss of faith in the system with respect to its operations.

Positive Attitude Maximum Power Point Tracking (MPPT)

MPPT stands for maximum power point tracking and it aims an important role in improving the efficiency of the system by changing the operating point of the panel in response to the changes in sunlight intensity. The challenge with implementing MPPT on small priced devices such as the Node MCU is the little processing power its controller possesses. The challenge is to optimize the algorithm so that it does real-time optimization but not jeopardizing the system and over using the power.

Designed Automatic Cleaning System

Cleaning is needed to the surfaces of solar panels, more so, at regions where there is a lot of dust or pollution, as still moisture is able to trap dust on the surface of the solar panels causing dirt and mud to accumulate on them. The development of a cleaning system that is both fully automated and operates on inconsequential amounts of energy is in itself a design problem. The system must be designed to work only on demand, to preserve energy; however, it must also work efficiently enough to dislodge any deposits while being gentle enough not to scratch the panels. In addition to this, maintaining low water consumption and its integration with low energy consuming motors is paramount for an effective cleaning system.

V. POWER MANAGEMENT AND EFFICIENCY

1. Low-Power Modes in Node MCU

There are several power management protocols in the Node MCU (of ESP8266 architecture) enhancing its efficiency:

Deep Sleep Mode: In this mode, the Node MCU's power consumption can be lowered as much as 10 µA, which is expedient for battery usage during non-active operation of the device. For instance, a system may be required to monitor the performance of its solar panel system at certain intervals. However, at night there may be no need to check performance (intently) and so system will go into deep sleep with only wake up circuits operational.

Light Sleep Mode: This mode saves energy while the system is still able to perform some other operation and so the Node MCU can return to full operation almost instantly. Light sleep mode is helpful for devices that need to be updated often but are not active all the time for example, security sensors that must be poised for an intruder at all times.

These sleep modes are profitably employed to idle turning off the power resources without losing any crucial operation especially aimed at surveillance or security systems that are likely to be idle.

2. Sensor Power Management

The sensors used in this project (e.g. voltage, current, dust motion and vibration sensors) have different power consumption levels and therefore effective power management is very important.

VI. METHODOLOGY

The primary objective of the project is to analyze the feasibility of creating a smart solar panel management system which controls the energy output, performs self-cleaning and provides protection for the solar panels. A Node MCU forms the central processing unit in this project, controlling data processing, control actions and communication within the system. Various components and functions are combined and integrated to create a solar panel management system that is operational, efficient, and most importantly secure.

1. System Design and Component Selection

In the beginning, the project chooses correct hardware components to complete the specified tasks:

Node MCU: This microcontroller is appropriate since it is easy to incorporate into the devices that are to implement the Internet of Things as well as carry out data processing in real time. This enables better management of the system's sensors, communication devices, and motors.

Sensing: Current and Voltage sensors are used in measuring how much power output is made by the solar panel; dust sensors are for monitoring the cleaning status of solar panels. Security is incorporated through the use of motion and vibration sensors, where any such movements or changes lost surveillance will trigger an alarm.

Cleaning Mechanism: Installation of DC motors and water sprinklers which clean the panels when dust is detected.

Communication Modules: Wi-Fi and gsm modules transmit the operational and security alert performance information to the far located user devices or servers.

2. Resilient Power Generation Control and MPPT

The voltage and current sensor modules installed on the Node MCU microcontroller are used to monitor the power unit of the solar panel in real time. To control the energy in the output of the system, a Maximum Power Point Tracking (MPPT) has to be work in the system that shifts the operating point of the panel according to the level of light received by the panel.

3. Automated Cleaning System

Rehabilitation of the operational state of the solar panels comprises of an automated cleaning system, which is designed to take action when the amount of dirt on the surface of the panels reach a predetermined level. This subsystem consists of:

Dust Detection: A dust sensor is placed on the panel surface in a continuous mode. When the dust concentration exceeds a limit established beforehand, the cleaning unit is activated by the Node MCU.

Cleaning Mechanism Activation: Water sprinkler connected DC motors are switched on to clean the panel dust and dirt. This function is programmed in a way that minimal water is used to clean the panel with no damages occurring due to excess water on the panel.

4. Security and Theft Prevention

With the increasing threat this poses, particularly in off-grid provisions, the system has mechanisms in place to safeguard the solar panel from vandalism or even worse tampering:

Motion and Vibration Sensors: Any movements or vibrations of the solar panel are detected by these sensors, which may lead to unauthorized handling of the solar panel or even damage of the equipment.

GPS and GSM Module: In the advent that dangerous movement is sensed, the Node MCU turns on GPRS and sends a message to the owner or security personnel through the phones they are carrying. This message includes a GPS location of the panel so that action can be taken if need arises.

BLOCKDIAGRAM:

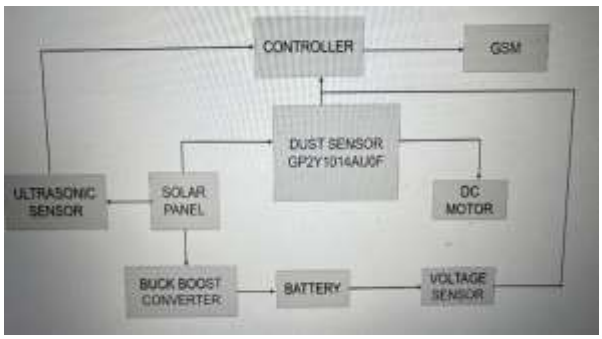

Figure 1. Block diagram

MATLAB Simulation:

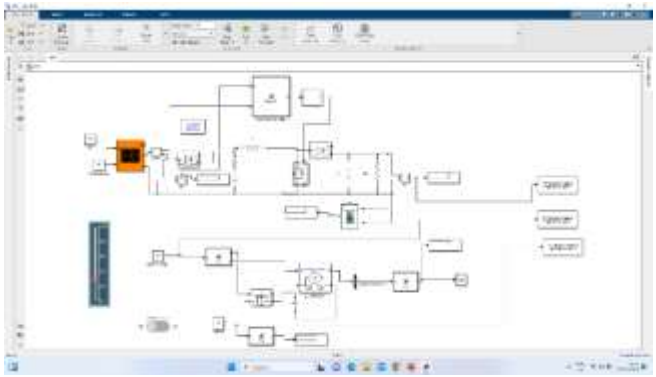

Figure 2. MATLAB Simulink model of solar panel dual management system using node MCU

MATHEMATICAL CALCULATION:

Power calculation:
P=V*I
V=voltage across solar panel
I=current generated along solar panel
MPPT algorithm:
P=Pnew-Pold
V=Vnew-Vold
Power consumption and efficiency
Pdevice=Vdevice*Idevice
Ptotal=Pnodemcu+Psensor+Pmotor+Pgsm

VII. CLOUD BASED INFORMATION

Data baking: Thing Speak has a mechanism that is able to allow devices communicate to the clouds through either HTTP requests or through MQTT protocols. Communication is possible in two ways either at regular intervals or on the occurrence of certain conditions aiding ease in data acquisition.)
Data Presentation: In addition to the wide array of data analysis tools, the other less complex, yet useful aspect of the software is the line, bar and histogram charts for presentation of data and for analyzing changes in data and identifying any anomalous events.
Analysis Topics: These built-in analytics are not confined to metrics of the usage but also allow input of MATLAB code on the available data and manipulation of the data using filters which allows for direct analysis of real time data.
Alarms and other indications: Along with event triggers, it also allows any alerts to be generated automatically in other cases. For instance, when there is a fall in the solar collector performance below a level

Figure 3. Output solar panel data

Simulation Results:

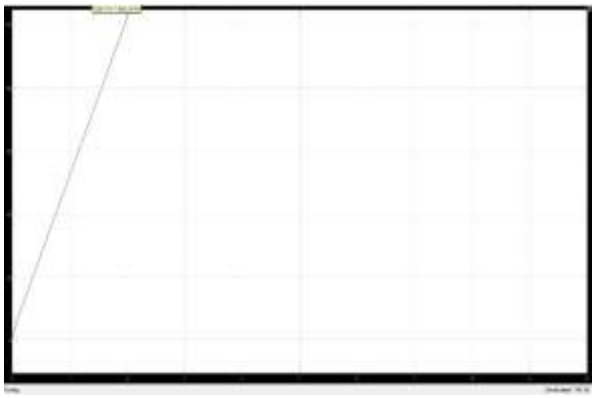

Figure 4. Motor output speed

VIII. CONCLUSION

All these factors are integral to the development of an efficient theft prevention and maintenance solution for solar panels that will safeguard investments into the utilization of solar energy. This setup addresses two major challenges: security and operational efficiency, making the reliability of solar systems more significant. With the wireless capabilities of Node MCU, users can monitor not only their solar panels but also the surroundings in which they exist and contribute to taking proactive measures against theft and periodic maintenance. This system will discourage the theft too because in risky cases, there will be an alert from the system; this makes maintenance periodic through remote monitoring of the solar plant, even during no activity. This has even reduced loss through intrusion detection systems since a response can be provided immediately before the danger becomes emergencies.
It maximizes the use of energy while making sure that maintenance is carried out efficiently and in time. It reduces the downtime and the lifespan of the system increased. The dual management feature encourages the adoption of solar energy as it ensures the security of assets and ensures systems' longevity.

IX. REFERENCE

[1] Thopate, K., Shilaskar, S., & Bhatlawande, S. (2023). An internet of things based solar power monitoring system using node MCU. Int. J. Recent Innov. Trends Comput. Commun, 11, 708-714.
[2] Shahed, M. T., Haque, M. M., Akter, S., Mian, S., & Shil, R. C. (2023). IoT-Enabled Smart Solar Energy Management System for Enhancing Smart Grid Power Quality and Reliability. SN Computer Science, 4(6), 805.
[3] Crăciunescu, M., Mocanu, Ș., Merezeanu, D., & Dobrescu, R. (2019). Integration of a Solar Panel in Power Microgrid via Internet of Things. In Service Orientation in Holonic and Multi-Agent Manufacturing: Proceedings of SOHOMA 2018 (pp. 86-96). Springer International Publishing.
[4] Khasanov, D., Khujamatov, K., Fayzullaev, B., & Reypnazarov, E. (2021). WSN-BASED MONITORING SYSTEMS FOR THE SOLAR POWER STATIONS OF THE TELECOMMUNICATION DEVICES. IIUM Engineering Journal, 22(2), 98-118.
[5] Aghenta, L. O., & Iqbal, M. T. (2019, May). Development of an IoT based open source SCADA system for PV system monitoring. In 2019 IEEE Canadian Conference of Electrical and Computer Engineering (CCECE) (pp. 1-4). IEEE.
[6] Samuel, J., & Rajagopal, B. (2021). IoT Based Solar Panel Monitoring and Control. NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| NVEO, 7609-7618.

[7] Edeoghon, A. I., Okocha, J. C., Ebu, J. S., Ohiocheoya, R. E., Chukwunweike, O. V., Ebikade, G., ... & Nicholas, O. (2022). Design and Implementation of an IoT-Based Solar-Powered Inverter Control System. GSJ, 10(8)

[8] Samuel, J., & Rajagopal, B. (2021). IoT Based Solar Panel Monitoring and Control. NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| NVEO, 7609-7618.

[9] Lopez, M. E. A., Mantinan, F. J. G., & Molina, M. G. (2012, September). Implementation of wireless remote monitoring and control of solar photovoltaic (PV) system. In 2012 Sixth IEEE/PES Transmission and Distribution: Latin America Conference and Exposition (T&D-LA) (pp. 1-6). IEEE