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Real Time Date Monitoring of PV Solar Cell

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Abstract: The peak demand load is rising globally, but the load factor is steadily declining. Since fossil fuels are thought to be insufficient, solar energy systems are becoming more and more beneficial. This is true not only in terms of installation but also in terms of monitoring, which is extremely important. The importance of monitoring increases as the quantity of solar panels increases. The effectiveness of solar panels and monitoring of solar panel producing systems are issues that frequently arise in the usage of solar panels. To evaluate a solar panel's performance and efficiency under actual climatic circumstances, monitoring its output characteristics is crucial. In order to make it simpler to obtain direct and real-time information on the output parameter data of the solar panels, a monitoring system based on a wireless sensor network was developed. Monitoring photovoltaic (PV) characteristics is crucial for the deployment and best use of solar energy as a source of power. A driving program is added to a low-cost, low-consumption wireless PV monitoring system to capture the PV system's characteristics. Four different types of sensors are used in the circuit to handle four characteristics that are crucial for real-time monitoring and prediction of PV performance. Sensors, LabVIEW software, and National Instruments (NI) data collecting modules are all used to measure the data. Then, all of the real-time data gathering for the voltage and current of the PV plant's electrical output parameters are shown and recorded in the PC drive. With all the measurements, the I-V and P-V curve computation for a particular time period may be done.

Keywords: Real Time Date, Monitoring, Photovoltaic, Solar Cell

INTRODUCTION

To the most fundamental need that everyone has in life, electricity is added. The energy consumption graph is rising daily while the available energy is declining concurrently. Different sources are employed to create power in order to offset its shortage. There are two methods for producing electricity: one is traditional, and the other is unconventional. Although some energy sources, such as fossil and nuclear fuels, are employed, they are not considered conventional since they are not renewable resources. In the broadest sense, harnessing solar power as a source allows for the creation of a sustainable energy supply. [1] The use of alternate and greener energy sources is a major global concern. The PV is more widely used among clean energy due to its low environmental impact, extended lifespan, and wide availability. By employing a PV module in an outdoor application in accordance with the manufacturer specification provided problems and may lead to a system failure later on, the maximum reliability is regarded to be an extra problem in this technology. For a PV system to become more dependable, affordable, and efficient, monitoring PV parameters under actual conditions is crucial.[2] Any solar electric system's dependable operation and maximum production depend on the monitoring and management of the photovoltaic system. In addition to values like PV array power, AC grid power, and PV array current that are often accessible, environmental data like module temperature, ambient temperature, and solar irradiance should also be monitored for a more detailed analysis. This is due to the fact that a photovoltaic system's investment cost is now relatively expensive, and the investor frequently needs information on the system's performance to determine if their investment has paid off. [3] Solar energy, which has one of the lowest environmental impacts of all the renewable & sustainable energy sources, is now drawing researchers from all over the world. It is crucial to be prepared as solar energy grows to account for an increasing portion of the world's overall electricity production. Only an intelligent method of generation, monitoring, and distribution will allow us to provide such insights. Every solar energy system should have reliable performance monitoring. [4] a solar power facility where the parameters need to be carefully watched and managed. The data collection system needs a lot of measured data, and in order to save time and remove the possibility of human mistake, highly frequent records must be automated. Additionally, the data must be able to be shown graphically for easy monitoring and analysis as opposed to being displayed numerically to reach desired performance.[4]

Traditional electronics or data-acquisition systems (DAQS) powered by microprocessors are used in current monitoring systems. They gather and keep track of weather information as well as the electrical properties of PV systems. These parameters are monitored because the major climatic factors impacting a PV panel are panel temperature and sun irradiation. I-V characteristics, PV array output, power converter output, and power converter performance are the electrical statistics that are frequently examined.[5] The same is true for solar PV plants, whose parameters need to be carefully regulated and monitored, necessitating a suitable data collecting system. To reduce the possibility of human mistake and save time, the data gathering system, which requires a lot of measured data and frequent recordings, must be automated. For usage in a wide range of applications, several data collection systems have been created, it is also necessary that the data can be represented in graphical form for straightforward monitoring and analysis in comparison to having the data in numerical format. These tasks include measuring, acquiring, and processing environmental variables; monitoring and evaluating the performance of PV systems; and monitoring the status of batteries for water pumping PV systems. Therefore, it is highly desirable to design a virtual measuring system that can be used to track the performance of solar PV systems.[6]

LITERATUR REVIEW

Monika P. Tellawar et al. (2019) For a PV solar energy system to operate effectively, reliably, and smoothly, data logger and monitoring systems are very essential. The effective operation of the system is made possible by the data logger and monitoring system, which also helps to spot system issues before they become serious. This thesis focuses on constructing a pico solar home system for a rural location of a developing country that is low-cost, user-friendly, and dependable. All monitoring parameters are stored on a micro-SD card by an ESP 32 microcontroller-based data logger, which is shown on a Blynk App. Direct data download from the website are available for system analysis and verification. The hardware prototype for the created data recorder employs just four sensors to sense humidity, temperature, voltage, and current. A previously created Android app is used for mobile devices to display all metrics on a real-time basis for effective monitoring. This app may also be used to provide maintenance staff with crucial information on any problems with battery charging. To complete the mission, we created hardware that implements the Internet of Things-based photovoltaic systems' remote data collecting architecture. This prototype is reasonably priced overall.[1]

Krismadinata Krismadinata et al. (2021) The generating characteristics of solar power plants are dynamic and subject to change. The degree of sunlight intensity and surrounding temperature have an impact on these qualities. The design and production of wireless monitoring systems to measure the amount of current and voltage produced by a solar module are covered in this article. A current and voltage sensor is used to measure the constantly changing current and voltage of the solar module. By using Short Message Services (SMS), it is possible to obtain the current and voltage data for this solar module at any time. The ATmega328 microcontroller serves as the main controller for the monitoring system, along with the ACS712 current sensor, a voltage divider circuit for measuring voltage, and a SIM900A wireless communication module, which is an electronic circuit module that can communicate between a processor and the Global System for Mobile (GSM). Supporting software is employed, and the Arduino-IDE interface supports the C programming language. A wireless monitoring system for solar power plants has been created as a prototype, and it can capture voltage and current data produced by solar modules with minimal physical labor on the part of the user. The quantity of power generated information may be quick, exact, and accurate thanks to the prototype's ability to reduce time and maintenance expenses.[7]

Makbul Anwari et al. (2011) Installing a photovoltaic system is an expensive endeavor. Because of this, the user generally needs useful information from the system, such as the efficiency, performance, and energy produced. Therefore, creating a small-scale PV monitoring system provides the customer with essential information on the installation's return on investment. In this design, a small-scale photovoltaic monitoring system is created utilizing LabVIEW and a PIC16F877a microcontroller. The PIC microcontroller was chosen because of its affordability. Research is being done on how to monitor data utilizing the microcontroller's analog to digital conversion as well as data transfer and storage using LabVIEW. The created system is capable of simulating and tracking the voltage and ampere drawn from the solar array. It also simulates and monitors additional environmental variables, such as ambient temperature and sun irradiance data. Utilizing LabVIEW, the monitoring program was created.[3]

Tarun Sinsh et al. (2019) A contemporary measuring and instrumentation system must include data logging. Data logging is necessary for almost all industrial processes. Today, finding an affordable and practical solution for data logging in industrial and scientific processes is challenging with proprietary data loggers. In this research study, we presented the design and development of a two-channel data logger that offers a cheap and workable method for tracking and logging the voltage, current, power, and energy of two PV solar panels. The developed prototype data logger is based on the Arduino UNO and enabled data logging on an SD card or on the memory of an Android smartphone using Bluetooth. With this data logger, data may be remotely monitored and recorded. Instead of using proprietary hardware and commercial software, the design of this data logger is entirely based on open-source software and hardware. Two PV solar panels' voltage, current, power, and energy may be measured and monitored, and their data can be recorded on an appropriate electronic media.[8]

Benabed Khadidja et al. (2019) One of the main issues is energy consumption since it is rising and has a significant effect on the environment. A potential solution to the problems posed by the coming energy shift is photovoltaic energy. The solar photovoltaic system requires strict monitoring of its electrical and physical characteristics for efficient functioning. One of the cornerstones of solar maintenance engineering is monitoring. The design and construction of a solar monitor for ensuring the proper operation of a small photovoltaic power plant are described in this article.[9]

Hamdani et al (2021) Based on the results of the trials, it can be said that the system for real-time monitoring of solar panels has been created to be able to record and read information about the current, voltage, power, light intensity, and location of the solar panels. The system can operate effectively and send measurement data to the database successfully. The precision of the current and voltage sensors employed in the solar panel performance monitoring system heavily influences the reading of the output parameters of the solar panel. The disparity in readings from the employed current and voltage sensors is within typical bounds.[10]

Srilakshmi Madadi et al (2021) The continuous supply imbalance in the electricity sector may be effectively closed with the help of renewable energy sources. Solar energy is the most advantageous of all renewable energy sources due to its universal availability, unlike other resources that are limited by geography. For this huge scale of solar system implementation, sophisticated frameworks for remote monitoring of the plant utilizing a web-based interface are needed. Since the majority of them are located in remote locations, it is impossible to monitor them from one precise spot. The Internet of Things (IoT) opens up opportunities for the pure physical environment integration into computer-based frameworks by allowing things to be identified and remotely controlled by a network's-built infrastructure. [11]

Omar Henni et al. (2017) One of the crucial steps in ensuring the quality and compliance with requirements of this equipment is to test photovoltaic (PV) modules. One needs a data collecting system to carry out some of the PV module testing. A data gathering system for solar systems is designed and implemented in this study. A cheap board built on a microcontroller serves as the defining feature of the designed system. Both a hardware description and a performance testing application are provided. The created system is capable of reading, storing, and analyzing data from a variety of solar systems. To support the best qualities of the designed data acquisition board, experimental results are provided. [12]

CALCULATION OF THE SOLAR POSITION

First, one must be able to forecast the sun's position with respect to the energy-harvesting apparatus in order to comprehend how to harness solar energy. This section uses a special vector technique to explain the essential equations. The equations for the location of the sun in relation to a tracking solar collector will be developed in this paper using this method.[13]

Assuming that there are around 10 hours of sunlight per day in the tropical region, where solar panels are most effective. [13]

Angles to be covered in total=180-150º

The amount of time it takes the sun to move from sunrise to dusk= 10 hours= 10 X 60= 600mins

$$\text{Minutes of travel per degree} = \frac{180}{600}\ \text{min}$$

$$= 0.3^{\circ}/\text{min}$$

As a result, we choose a minimum angle of at least 5 degrees for each pulse that will be used to cause the steeper motor to revolve since this angle is too little to be taken into account.

$$\text{the interval of time between each pulse-taking} = 5 \div 0.3$$

$$= 16.777\ \text{min}$$

The solar panels must thus be pulsed every 17 minutes in order for them to monitor the sun correctly. To improve the tracker's accuracy, we must adjust the programming such that, depending on when the device is set up, an addition or subtraction of 20 minutes from the total number of sunshine hours is made to the program every 14 days. In order to allow for additional tracking, the next day, the panels must be returned to their starting position when the sun sets.[13]

3.1 REAL TIME MONITORING

The LDRs are linked to the DAQ card's analog input channels, with the other side grounded. The LabVIEW DAQ helper obtains the resultant value. An LDR's resistance will decrease when the greatest quantity of sunshine hits it, according to the operating principle. This value is contrasted with all the other LDRs' values. Given that the LDR with the lowest resistance is also the one that faces the sun the most, the matching LED on the front panel will illuminate.[14] produced LabVIEW code for monitoring purposes. The DAQ assistant's signal is provided to an array that is indexed in the following step. NI USB 6221 is the DAQ in use. It features 16 channels for analog input. Six of them have been utilized. They must be set up for a +/- 10K range at most. The maximum and minimum function is then applied to the array, and the LDR with the lowest resistance is to be taken into account. The needed position is provided by the index option. This number, which is an integer, is sent to a switch case structure, which in turn, depending on the location of the sun, turns ON the appropriate LED. Real-time power monitoring is also possible if the value is lower than what is required for the DAQ card to operate safely.[13]

3.2 MAXIMUM POINT TRACKING TECHNIQUE

There are three types of solar radiation that are absorbed by the earth's atmosphere: global, diffuse, and beam (direct) radiation. Different equipment can be used to measure each radiation. The measurement of diffuse and global radiation may be done with pyranometers. Similarly, beam (direct) radiation may be measured with pyrheliometers. The duration of brilliant sunlight that is present each day at a site is measured using a different tool called a sunshine recorder.[14]

Photo diodes and temperature sensors are used in pyranometers and pyrheliometers to provide signals proportional to the incoming light intensity falling on the sensor. The glass sphere used in the housing of the sunlight recorder is solid. The amount of sunshine in a day is recorded on a light-sensitive standard trace recorder paper. These devices are extremely costly and intricate. These sensors use sun light across a broad spectral range to measure things. Regular calibration of these devices is necessary, but it is also expensive. To precisely estimate the irradiance received on a surface, a complicated yet low-cost alternative method is needed.[14]

3.3 MEASUREMENTS OF THE I-V CURVE FOR THE SCELLS MODEL

A one-diode equivalent model often serves as a representation of a solar cell. The model includes a current source Iph and a series resistance Rs that stand in for the resistance found within each cell and at the points where cells are connected to one another. [15]

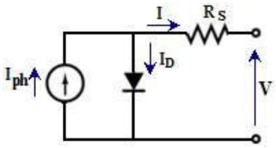


Figure 1- Solar cell model [15]

3.4 SYSTEM OBJECTIVE

A PV solar cell, module, or system can be measured and monitored using the system. features of the cell, module, or system's dark I-V range. Determine the electric cell characteristics as well as the I-V and P-V curves of the PV cell, module, and/or system under STC or any situation. The user can view graphs of the I-Vs-V and P vs-V curves as well as the instantaneous values of any of the aforementioned parameters on a computer screen. [15]

PHOTOVOLTAIC MEASUREMENTS

The sensor circuitry and software code have an impact on how accurately PV measurements are made. Irradiances and temperatures are the PV characteristics that are often tracked and recorded for weather, whereas voltage and current are used for electrical measurements. The PV output voltages have been shown using a low-cost XBee Pro S1 module that acts as a voltage sensor and features a voltage divider. In order to lower the input voltage by ten times from its original value, this sensor module relies on the idea of resistance points. The 10-bit analog to digital converter on the XBee module chip can translate values between 0 and 1023, hence the resolution is 0.003226 V (3.3V/1023). The voltage at the module's Vref pin, which is set at 3.3 in our example, determines the maximum input voltage range for the XBee.[2]

$$V_{PVout} = \left(\frac{3.3}{1023}\right) V_{XBee}.\ 1/\ Ratio \qquad (1)$$

Where V_{XBee} is the analogue signal (0-1023)

$$Ratio = 1/10 \qquad (2)$$

The PV current may also be measured using an ACS712 current sensor, which offers an accurate and cost-effective solution for such applications. A suitable voltage value is generated from the current value using the ACS712 current sensor. In order to benefit from a wider range, the design recommends supplying a power of 5V rather than 3.3V. The middle sensing voltage is set by default to 2.5V when no current is being sensed. After that, equation (2) was used to determine the PV current.

$$I_{PVout} = \left(\frac{5}{1023}\right).\ V_{XBee2} - 2.5/0.185 \qquad (3)$$

4.1 COMMUNICATION PROTOCOL

The term "serial interface protocol" refers to the method of data access through communications over a serial bus. The default setting for XBees setup is translucent mode. However, one of the two XBee modes used in this study was the Application Programming Interface API. Data is transmitted across the serial interface in structured packets when using the API mode, which offers a structured interface. Without having to define the protocol, this will make it possible to construct complicated communication between an XBee base module and an XBee end device or remote module. The first step of the algorithm is to develop a frame-based API to raise the bar for how a host application may communicate with a module's networking capabilities. Data from the USB serial input is queued up for radio transmission, after which wireless data is transmitted directly to the serial output without any further information. When API mode is enabled (AP = 1), a frame structure is present in the UART data. [2]

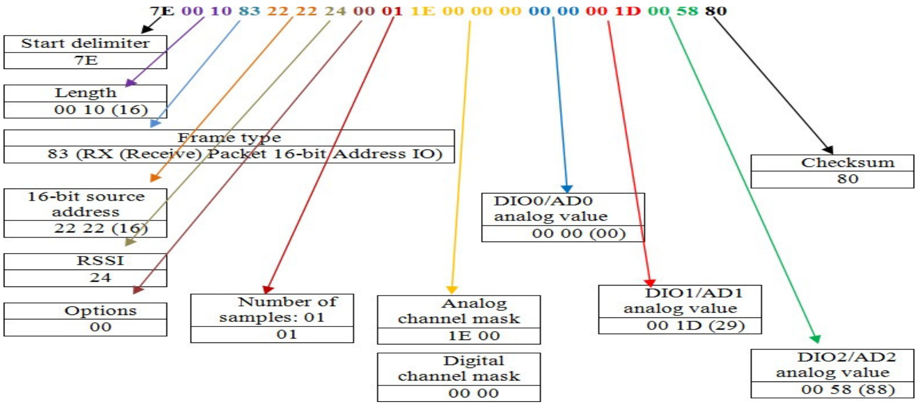


Figure 2. Frame structure when API mode is enabled. [2]

4.2 XBEES INITIAL CONFIGURATION

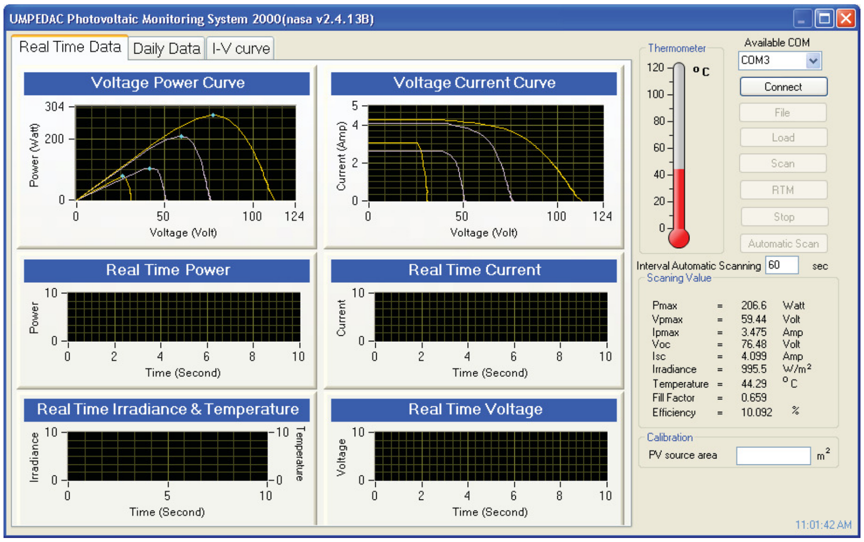
The Xbees (base and remote) were first set up with the correct settings to enable communication between them. XCTU is used to load the basic settings in both XBee radios. As a transceiver in the construction of such a wireless network, the XBee RF node can fall into one of three categories: coordinator, end node, or router. All incoming data packets from the end device or router one are received by a coordinator XBee, which also serves as an access point. The end device node XBee, in contrast, gathers, processes, and sends data packets to a coordinator sensor. The data packets from two neighboring end device nodes or routers may be sent using an XBee router that serves as both a transmitter and a receiver. The remote RF module is configured by the XBees to use AD0, AD1, AD2, and AD3 as analogue inputs that are sampled once every 20 ms. transmitting to the RF base module next. Accordingly, a 24-Byte transmission must be received by the base every 20 ms.[2]

TRACKING SYSTEM DEVELOPMENT

The entire system is primarily split into two stages: a tracking system and a monitoring system. The tracker model was made up of an Arduino Uno R3, a solar panel, a solar charge controller, a battery, a direct current (DC) motor, and a motor driver. When developing hardware, the solar charge controller was connected to the solar array. This solar charge controller controls the flow of power from the array into the battery bank to prevent overcharging the batteries and nighttime power flow back to the solar panels. The energy in the battery is partly stored by solar panels. In order to follow the movement of the panel as it turns up and down, the Arduino is used to regulate the solar voltage and LDR sensor. This DC geared motor is used to power the solar tracking device. Using a motor driver circuit board, the on-board switches and speed potentiometer may be used to easily regulate the motor. Upward and downward movement of the solar panel is controlled by limit switches located at the box casing.[16]

5.1 THE GRAPHICAL USER INTERFACE (GUI) DESIGN

PV monitoring system GUI The curves are controlled via a tab on the left. Real Time Data is available on three of the controller's tabs. The voltage-power curve and voltage-current curve are also presented simultaneously; for Daily Data, this displays long-term data, and for I-V Curve, this displays the I-V and P-V curves. A combo box on the right upper side allows you to choose the serial port that the PV monitoring system will utilize. A serial-to-USB converter can be used in its place if the computer lacks a serial port. There are a few controls for the PV monitoring system behind the combo box. Before scanning the PV array, the text box for the PV source region must be entered into the calibration box on the right bottom. The calibration form is called using the text field in the calibration box. In order to calibrate the PV monitoring system, the user must enter the actual value of each measurement and save it. If the text box is empty or has the word "calibration" in it, the GUI invokes the calibration form, which will provide the ADC reading of each sensor.[17]



Available COM: COM3

Interval Automatic Scanning 60 sec

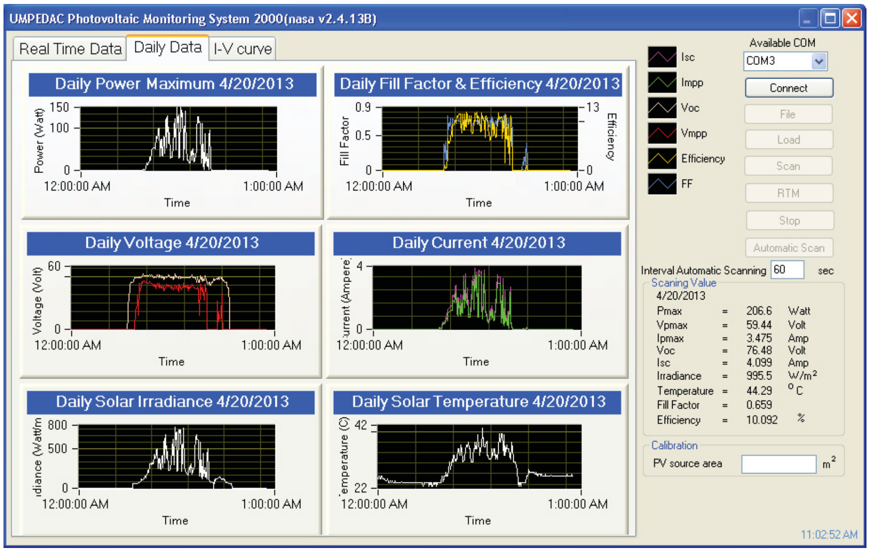
Scaning Value

Pmax = 206.6 Watt
Vpmax = 59.44 Volt
Ipmax = 3.475 Amp
Voc = 76.48 Volt
Isc = 4.099 Amp
Irradiance = 995.5 W/m²
Temperature = 44.29 °C
Fill Factor = 0.659
Efficiency = 10.092 %

Calibration

PV source area m²

Figure 3. I-V Curve tab [17]



Available COM: COM3

Interval Automatic Scanning 60 sec

Scaning Value

4/20/2013

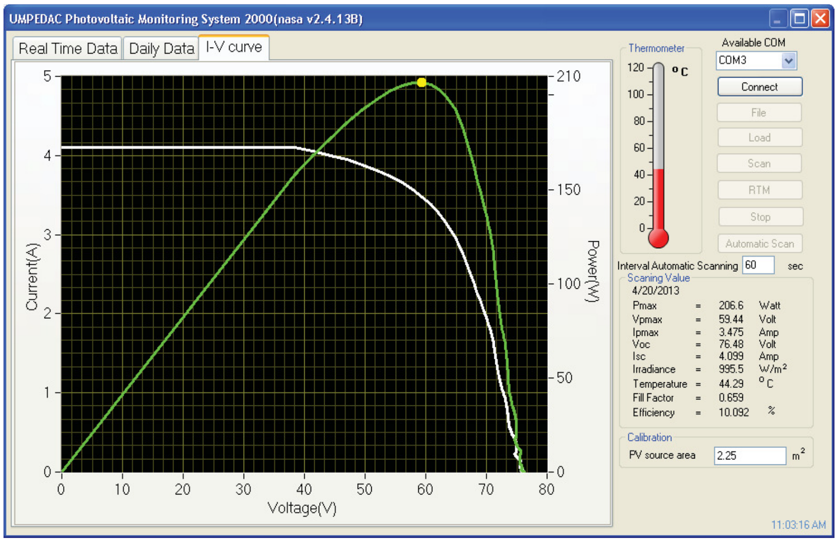
Pmax = 206.6 Watt
Vpmax = 59.44 Volt
Ipmax = 3.475 Amp
Voc = 76.48 Volt
Isc = 4.099 Amp
Irradiance = 995.5 W/m²
Temperature = 44.29 °C
Fill Factor = 0.659
Efficiency = 10.092 %

Calibration

PV source area m²

Figure 4: Daily-data tab [17]

For long-term monitoring, an automatic scan mode is available; the scanning interval is user-specified. The Real Time Data Tab displays the I-V curve each period. The Daily Data tab displays a graphic of solar temperature. The graphs depict the relationship between short-circuit current, open-circuit voltage, and peak power and temperature and sun irradiation.[17]



Interval Automatic Scanning 60 sec

4/20/2013

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Voc = 76.48 Volt
Isc = 4.099 Amp
Irradiance = 995.5 W/m^2
Temperature = 44.29 °C
Fill Factor = 0.659
Efficiency = 10.092 %

PV source area 2.25 m^2

Figure 5: Daily-data tab [17]

AN ARCHITECTURE OF THE SYSTEM

6.1 AN OVERVIEW OF THE SYSTEM

We are working on two items with various uses and jobs: 1) For simplicity of repair and maintenance, SEMD enables the user to spin the output gear shafts at a predefined angle. 2) A Solar Energy Module (SEM): A SEM is a device that efficiently collects, stores, converts solar energy into electrical power, and distributes it. The software system, which is used to monitor and manage both products, is built on a client-server design. A specialist and an operator will play separate roles in the system. While an expert will be in charge of monitoring and running the panel through the software system, an operator will be able to access information. Specialists can upgrade the software in SEM and SEMD thanks to the software system.[4]

6.2 THE OPERATION OF THE SYSTEM

SPM, an accumulator, and a converter are all components of SEM. SPM is required for fixing the placement of solar panels. A solar panel's accumulator collects energy (a DC current) and stores it before sending it to the converter for conversion. A expert or operator in charge of maintaining solar panels may identify and correct faults in the operation of the solar module thanks to the converter, which converts direct current to alternating current. This information about flaws in the operation of the SEM is given to hardware for servicing.[4]

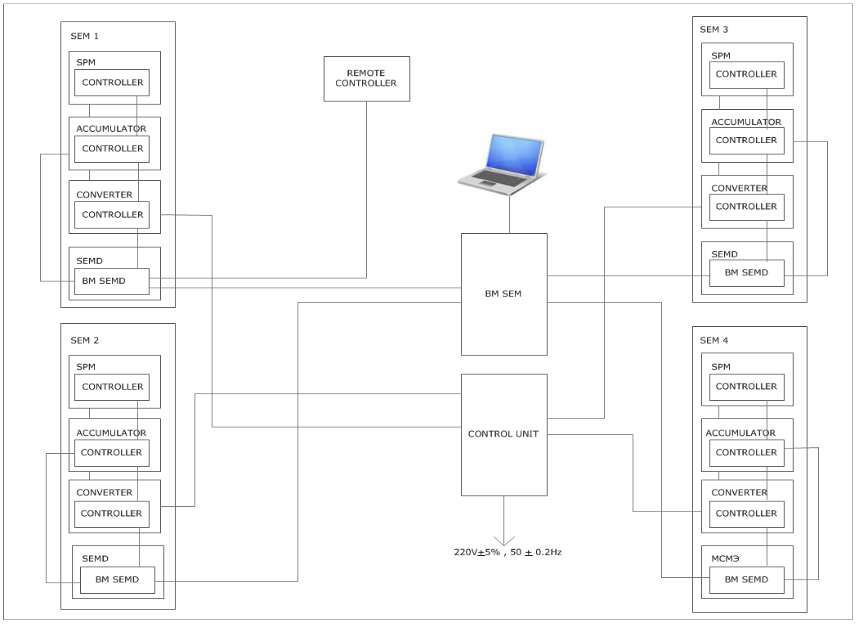

Figure 6. The SEM (Solar Energy Module) Block Diagram [4]

Two key parts of SEMD are a mechatronic module with an elevation sensor and a mechatronic module with an azimuth sensor. Both modules have an engine, a brake, an encoder, and an engine controller, all of which are managed by the same remote controller that moves the solar panel in orbit.

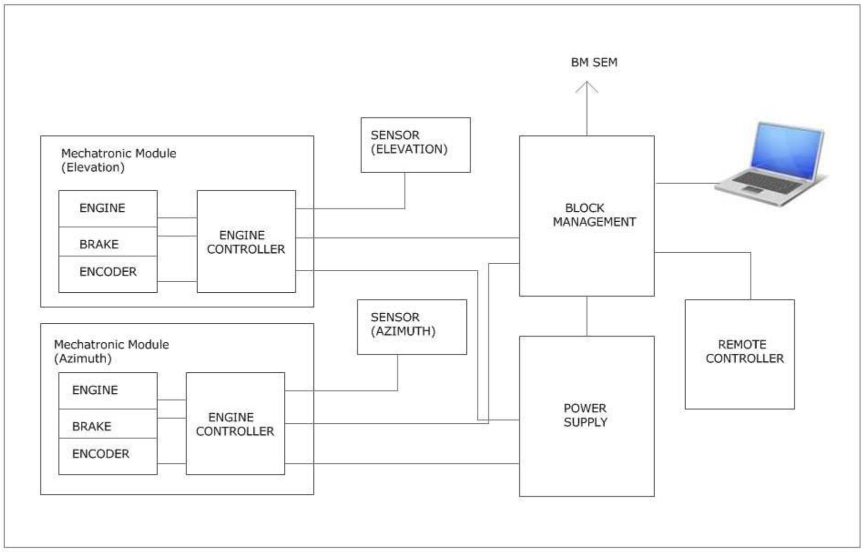

Figure 7. Scalable Energy Efficient Mechatronic Device[4]

DESIGN OF THE DATA ACCESS SYSTEM

7.1 MODEL OF THE DATA ACQUISITION SYSTEM

Software for the data gathering system was created in embedded C. Keil C51 compiler and a block diagram of the system software are the tools used to build this code. Initialization of the entire system by transmitting control or data bits, processing data collection by accessing data, and forwarding data to the host system or storage media using any communication modules like RS-232 and Zigbee. A data acquisition system is a method for gathering data that may be analyzed and stored by a computer to study a particular event. The transmission type (serial or parallel) and information exchange mechanism between system elements are the two key components that make up this system.[18] When a system starts, continuous analog data is first sent to an analog-to-digital converter, which receives data through the VIN (+) pin and produces data in digital form from the DO pin. This produced data is now being sent to any controller pin so that the controller may take action in accordance with the incoming value. Following processing, data is sent to the host system via the serial RS-232 and Zigbee wireless communication modules. Currently, data is gathered at the host system and stored in a database. A graph was then developed in Visual Basic to visualize changes.[18]

7.2 THE INTERFACES OF DATA COLLECTION AND PROCESSING

NI DAQ cards with high accuracy and LabVIEW GUI software are used to create the automated monitoring system. All the metrics, including PV voltage and current, may be gathered and monitored simultaneously by creating the automated monitoring system utilizing LabVIEW and NI DAQ. The NI small DAQ can accommodate up to 8C series I/O modules for this system, providing 256 analog input, 32 analog output, and 64 digital I/O. The NI 9219 24-Bit Universal Analog Input is used in conjunction with the NI small DAQ to gather all the data. The voltage, current, and temperature may all be measured using the module's four analog input channels. It features a maximum sampling rate of 100S/s and an ADC resolution of 24 bits.[18]

CONCUSION

The notion of monitoring a PV system's parameters is suggested in this study, which is characterized by reduced costs and efficiency for smart grid applications. The suggested prototype advocates for highly functional monitoring tools that can assess system performance with more energy savings. This study makes significant contributions to the attempt to choose a smart grid monitoring system that is both more effective and simpler to use. But giving such affordable technologies that are suited to user profiles is a good place to start if you want to provide real-time feedback in a simple manner. It should be mentioned that the amount of overall power generated during the day has significantly increased as a result of the work that has been done. The major objective of this work is to build and implement a novel real-time system for monitoring, measuring variables, and making decisions for the photovoltaic power system in order to improve decision efficacy in PV power stations. The suggested system is created, modeled, put into practice, and empirically evaluated. The automated intelligent monitoring system's user is capable of automatically detecting problems and monitoring, which may unquestionably increase the PV system's efficiency and lower maintenance costs. The technology offers flexibility in the case of adding more panels to the plant, and it also demonstrates data collecting over extended periods of time without interruption from users. Remote monitoring through the Internet is another option. A prototype of an autonomous adaptable solar PV module with a monitoring system has been successfully created via this study. Real-time parameter measurements are supported by the data analytics platform.Real-time data are quickly and easily recorded, and they may be retrieved from a distance. The outcome shows that the static solar panel collects less energy. Future study on Solar PV can be conducted using the data gathered thus far.

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