

DESIGN AND IMPLEMENTATION OF AN IOT-BASED SOLAR POWER MONITORING AND DATA LOGGER SYSTEM

by

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**BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC
ENGINEERING**



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A thesis

submitted as partial fulfilment of the requirement for the degree of

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CERTIFICATE OF APPROVAL

The project entitled as “**Design and Implementation of an IoT Based Solar Power Monitoring and Data Logger System**” submitted by **Musrin Sultana Shompa**, bearing Matric ID. **ET-173208** and **Alina Hoque**, bearing Matric ID. **ET-171206** of session **Autumn 2022**, to the Department of Electrical and Electronic Engineering, International Islamic University Chittagong, has been accepted as satisfactory in partial fulfilment of the requirements for the degree of Bachelor of Science in Engineering and approved for the examination held on 22nd **July, 2022**.

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DECLARATION

It is hereby declared that this work has been done by us and no portion of the work contained in this project has been submitted elsewhere for the award of any degree or diploma.

Musrin Sultana Shompa

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Authors

ABSTRACT

When it comes to PV solar energy systems, having reliable data recorders and monitoring systems is a must. In order to detect problems early on, it is necessary to utilize a data logger and monitoring system to assure proper operation. Efforts have been made to build low-cost data logging and monitoring systems for small solar household systems in rural parts of developing countries. A solar power monitoring and data logging system based on the Internet of Things (IoT) has been developed. Sensor data is stored in EEPROM memory. In contrast, data is being continuously uploaded to the Thingspeak cloud server for analysis. It is possible to obtain the server's data directly for the purpose of analysis and verification. The prototype data recorder uses only four sensors to measure temperature, humidity, voltage and current. The LCD panel provide the parameter values in real time, allowing technicians to see any issues with battery charging in real time.

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LIST OF ABBREVIATIONS

IoT	Internet of Things
EPROM	Erasable Programmable Read-Only Memory
PV	Photovoltaic
SCC	Solar Charger Controller
PWM	Pulse Width Modulation
MCU	Microcontroller Unit
RTOS	Real Time Operating System
LCD	Liquid Crystal Display
API	Application Program Interface
RMII	Reduced Media-Independent Interface
I2S	Integrated Inter-IC Sound
I2C	Intergrated Inter Circuit
UART	Universal Asynchronous Receiver/Transmitter
RTC	Real Time Clock
ROM	Read Only Memory
CAN	Controller Area Network
SPI	Serial Peripheral Interface
RNG	Random Number Generator
GPIO	General Purpose Input Output

CHAPTER 1

INTRODUCTION

This section presented the solar power monitoring and data logger, which is one of the key motives for this study. It then goes on to explain the particular research challenges and research areas. It then covers the research's objectives and goals before specifying its scope. Consequently, the significance and originality of contributions are discussed. Finally, the chapter concludes by providing an outline of this study.

1.1 Introduction

Energy, or electrical power, plays a vital part in modern civilisation, and the availability of energy for industries and human civilization is critical to the proper development of a nation. As a result, energy or power is a critical component of a country's socioeconomic development. The world's energy consumption is rapidly increasing as a result of rapid urbanization and technological advancement. Global energy consumption is expected to rise by 28% between 2015 and 2040, according to the US Energy Information Administration (EIA). It will rise from 575 quadrillion British thermal units (Btu) in 2015 to 663 quadrillion Btu in 2030 and 736 quadrillion Btu in 2040 [5]. **Fig 1.1** depicts world energy consumption from the year 1990 to 2040.

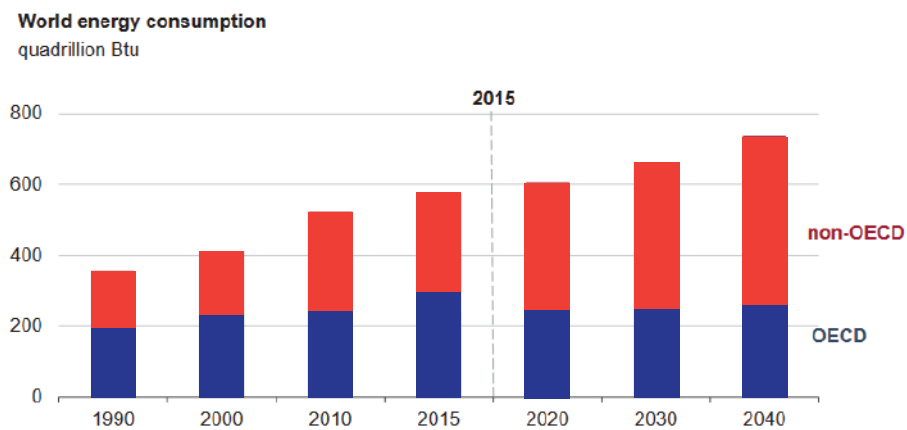


Fig. 1.1 World Energy Consumption [5]

Oil and other fossil fuels make up the majority of the world's energy resources. The whole global resource of this fossil fuel will be used up over the next two or three decades at the latest. Reduced reliance on fossil fuels as the sole source of energy for society is essential to ensuring its continued viability.

In addition, the combustion of these fuels results in the production of greenhouse gases and a sizeable amount of carbon dioxide. Therefore, in order for the human world to continue to exist, it is necessary to find an alternate source of energy that is both dependable and cost-effective. It is also essential to make certain that everyone in the world has access to a reliable source of electrical power. People in every region of the world have a constant need for power or electricity in order for their societies and economies to advance.

At the present time, more than 20% of the world's population does not have access to electricity, and many more people have access to a limited amount of electrical power at best. People who reside in rural parts of poor nations, in particular, do not have access to contemporary energy services. This lack of access results in a bad quality of life as well as a lack of access to vital services such as healthcare and education. They get stuck in a cycle of having insufficient access to energy. They are unable to improve their standard of living since they do not have access to power, which also prevents them from making any changes to the way they live. A bar chart illustrating the number of individuals around the world who do not have access to electricity is shown in **Fig 1.2**

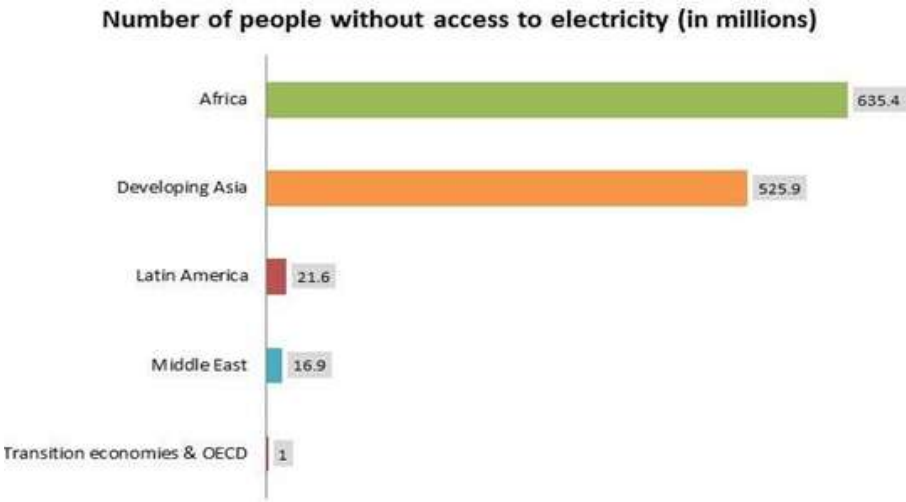


Fig. 1.2 In 2016, the number of people in the globe without power [6]

In the future, it is much more likely that a solution that is efficient, cost-effective, and environmentally friendly will be developed in order to satisfy this enormous demand for energy and provide electricity to everyone. The primary energy sources will not be adequate to satisfy the significant upward trend in demand. As a consequence of this, renewable energy has the potential to contribute to the reduction of the deficit by serving as a source of energy that is not only clean but also affordable and easily accessible.

Renewable sources of power have a huge potential to satisfy the ever-increasing need for energy while also producing less carbon than conventional sources. According to forecasts, by the year 2050, renewable sources of energy will be able to satisfy one hundred percent of the demand for energy worldwide.

Renewable energy use has expanded dramatically in both industrialized and developing countries during the last 10-20 years. Renewable energy accounts for over 71 percent of total energy generation in European countries. Renewable energy has sparked a lot of interest as a way to fulfill the growing energy demand because it is a clean, economical, and readily available option. Solar, wind, biomass, geothermal, tidal, and hydro energy are the most common renewable energy sources. Renewable energy sources are becoming more important as a means of addressing the global energy constraint and future demand. Different countries' policymakers and governments are conducting various projects and plans to offer power to all citizens. Several rural electrification schemes based on the utilization of small-scale renewable energy systems have been launched in recent decades, but the rate of progress is still insufficient to give electricity to everyone. The number of rural electrification schemes that are implemented, as well as their magnitude, will need to be considerably enhanced. Solar is one of the most important renewable energy sources, with the greatest potential of all. Solar energy has a potential of 1.73×10^{16} kW, which is enough to supply a thousand times the world's total energy consumption. Solar power currently generates 301 GW of energy globally. In rural parts of developing countries, solar home systems (SHS) have had a significant influence as a rural electrification program. A tiny solar PV (Photovoltaic) generator (usually one PV module), a battery charge controller, and a battery make up a Solar Home System.

Small solar panels, such as the ones used in pico-solar systems, are called pico-solar systems. Pico-solar systems are smaller, whereas traditional SHS systems are much larger. The primary purpose of this technology is to provide power to a remote consumer who does not have access to the on-grid distribution lines. Electric illumination, phone charging, and small DC fans are all commonly powered by pico-solar systems out in the country. With the exception of a separate charge controller unit, pico-solar systems function in the same way as normal SHS. They come in a range of shapes and sizes, and are designed to be portable. **Fig 1.3** depicts a solar home system that includes a Pico-Solar Panel.

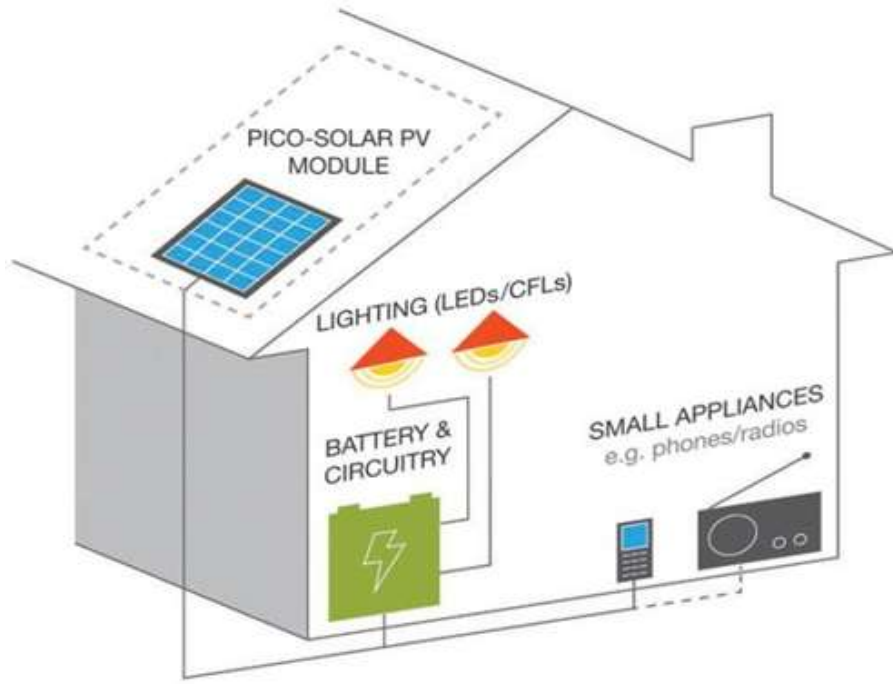


Fig. 1.3 PICO- Solar PV based Solar Home System [7]

1.2 Motivation

At present Bangladesh is 100% electrified country. But power loss is a big issue for our country. To solve the loss of power we need proper planning and system. For the reason, we have developed a solar power monitoring and data logger system for off grid. It can be possible for both off grid and on grid just change of some functionality. Primarily we're proposing off grid IoT Based Solar Power Monitoring and Data Logger System.

1.3 Problem Statement

In our developing country like Bangladesh, system fault is a big problem in the power sector. People suffer from load-shedding.

Providing a simple power tracking solution which helps to solve the problem in generating and distributing of power. In our project, initially we developed based on solar panel as source. Our system is capable of providing real time data monitor and logging the data. Whenever we want, can download the log from the server and publicly accessible the server.

1.4 Objectives

The details objectives of this project are given below:

- To design a low cost solar PV monitoring and data logger system for small scale.
- To track the real time data and save from power loss
- To design of a prototype PCB for data monitoring, analysis and production.

1.5 Chapter Outline

After this chapter, the dissertation is put together in the following way:

Chapter 1: This chapter contains the "Introduction" including introductory discussion about motivation, problem statement and objectives.

Chapter 2: This chapter contains "Literature Review" Previous work which is related on this project has been discussed in this chapter.

Chapter 3: This chapter contains "Methodology" including the methodology of the project, block diagram, hardware development, component list, circuit diagram and the algorithm of the system.

Chapter 4: This chapter contains "Result and discussion" where the result of our project has been discussed.

Chapter 5: This chapter contains "Conclusion" where conclusion and future work has been discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Global energy consumption has increased as a result of rising population and technological improvements. The government and universities are placing more emphasis on alternative or renewable energy sources. Solar power is the most promising and dependable form of renewable energy. In order to verify that a PV (photovoltaic) system functions consistently, it is required to develop a monitoring system. Big plants have access to a wide range of expensive and time-consuming data collection and monitoring devices. Even with a basic plant like a pico-solar system, there was no data collection and control mechanism for rural house electricity prior to the game. As a result of this difficulty, researchers are attempting to find a low-cost and reliable pico-solar system solution. It's critical to understand why and how a new low-cost data logger and control system is being built in rural developing countries, so the following ideas are explored.

2.2 Non-Commercial Systems

Ranhotigamage et al. [9], suggests the design and development of a monitoring system to gather information on the defective solar panels in order to perform repairs and maintenance in a timely manner. It has been suggested that the planning, development, and testing of a performance monitoring system for distributed solar panels, complete with automatic data recording that is based on a low-cost wireless sensor network, would assist the present situation. This system is capable of being utilized with solar cell systems with up to 146 V and 15.5 A, and it has an automated selection of the optimal resolutions. The whole price of their system comes to around \$175.

In this article, a LabVIEW-based real-time interface system [10] is used to characterize the performance and dynamic behavior of solar systems in detail. Several devices were combined into a single system to allow for live measurements of all data sources and real-time comparisons between simulated and observed data. As a result of making the PV system database ready, the suggested technique delivers an efficient, secure and reliable system. Studies on PV system defect diagnosis may make advantage of the real-time integration approach of robust simulation and monitoring data.

Table 2.1 Characteristics of Previous Monitoring Systems [1]

Work was done by	Data Transfer Mechanism	Parameters	Monitoring method	Software/ Programming Language
Mukaro and Carelse (1999)	Wired: RS232	None	PC	Turbo C++, ASSEMBLY
Pietruszko and Gradzki (2003)	Wired	Vpv, Vac, Ipv, Iac, Pac, Eac, Z, f	PC	Not mentioned
Koutroulis and Kalaitzakis (2003)	Wired: PCI bus	Vpv, Ipv, Vb, Ib, W/Gv, W/Gc	PC	LabVIEW
Kalaitzakis, Koutroulis, and Vlachos (2003)	Wireless: RF	Vpv, Ipv, W/Gv, W/Gc, W/Gs, Vb, Ib	Web	Java
Krauter (2004)	Wireless: Satellite	Ppv, Vb, Pb, Pac	Web	Not mentioned
Papadakis, Koutroulis, and Kalaitzakis (2005)	Wireless: RF	W/Gv, W/Gc, W/Gs, Vpv, Ipv, Vb, Ib	Web	VB, SQL server 2000
Forero, Hernández, and Gordillo (2000)	Wired: RS232	Vpv, Ipv, Epv, Ppv, Voc, Isc, FF, $\hat{u}$, Pmax	PC	LabVIEW
Soler-Bientz, Ricalde-Cab, and Solis-Rodriguez (2006)	Wired: RS232	Vpv, Ipv, Ppv, Vb, Ib	PC	LabVIEW
Benghanem (2009a)	Wireless	Vpv, Ipv	PC	Matlab
Carullo and Vallan (2012)	Wired	Vpv, Ipv, Vac, Iac, Ppv, Pac, Epv, Eac	PC	LabVIEW

In order to address the current problem of monitoring PV systems in remote or poor regions, an Arduino-based data logger was developed. This data logger [11] meets the requirements of the International Electrotechnical Commission since it has an 18-bit resolution and eight analog inputs for monitoring up to eight PV modules (IEC). They claim that this data logger, which retails for roughly \$90, can be simply and economically customized to match the specific needs of each project.

While working on their photovoltaic (PV) power generation remote monitoring system, Jihua et al. [12] colleagues used TinyOS. It was possible to remotely monitor and administer this system using the host computer, ARM gateways, wireless sensor networks, and other components.

Researchers at Gad et al [13] have created a simple sensor-based microcontroller data gathering system for monitoring solar installation temperature data. When a power outage or other error occurs, the system handles it correctly. With 16 sensors, a four-button LCD screen, and storage devices like flash memory or SD cards, the suggested data acquisition system doesn't need an external computer to store the sensor data. Any mathematical software, such as Excel or MATLAB, may simply manage and evaluate the data stored in this system's SD card, which is automatically created each day and saves data. The internet is used to monitor the sensors remotely.

Using IOT, Shrihariprasath et al. [14] have developed a smart remote monitoring system that can keep track of the performance of a solar PV power control unit (PCU) while also storing the collected data in a cloud database for later retrieval. The Solar PV Power Conditioning Unit and the Remote Server are connected via GPRS technology, giving the system a degree of adaptability.

Another that was designed with the assistance of LabVIEW and a DAQ card may be found in [15]. After being connected to the battery, the solar panel is subsequently connected to the sensors. The data acquisition process for the suggested system is handled by four separate sensors that are connected to LabVIEW and DAQ hardware. LabVIEW has demonstrated excellent performance in terms of communicating with several devices at the same time and excellent capacity in terms of presenting the behavior of multiple variables all at once.

An android-based design of an electronic system for the measurement and control of the physical parameters such as water temperature, solar collector's fluid temperature, solar radiation level, etc. is presented in to monitor and, as a result, optimize the functioning of a thermal-solar plant [16]. These parameters include water temperature, solar collector's fluid temperature, and solar radiation level. To check or correct operation and quickly reveal any fault, to manage and view locally the functioning of the plant by serial connection to PC with terminal role, and also remotely viewing and monitoring actions, by Android-based mobile devices, through RS485/Ethernet adapter and modem/router device connected to internet network, the control unit that was designed can monitor and program the device's functionality using a touch-screen graphical display. This allows for remote viewing and monitoring of actions.

An Operation and Maintenance (OM) system has been developed by Begum et al. [17] using predictive analytics and supervisory control and data acquisition (SCADA) with the assistance of the internet cloud and Internet of Things (IoT) devices. The ARM processor is used to acquire the sensor data and then converted to the required format to transfer over the internet. As the cloud end, Google Compute Engine is utilized, and it is tasked with the responsibility of connecting to all of the data.

source nodes that use the MQTT protocol, which is a lightweight sensor messaging system (MQ Telemetry Transport).

A conceptual system was presented by Soham et al. [18] in to monitor the state of a photovoltaic system using an Internet of Things-based network in order to control it remotely. The information collected by the sensors is sent out into the world through the mobile radio network. For the purpose of transmitting data to the remote server, a GPRS module is utilized. The IoT application schematic is composed of three layers, beginning with the sensing layer at the bottom, which is comprised of current sensors, voltage sensors, a pyranometer for irradiance measurement, and other sensors. Additionally, this layer includes microcontroller-based data processing of data acquired from the sensors. The microcontroller initiates and maintains communication with a wireless module so that data can be sent to the server. According to the current proposal, Layer 2 will be the network layer. This will be the layer where data will be logged from the plant for real-time processing. This layer will also include a database for storage.

The data that has been processed and saved is then utilized in the application layer, which comes after the network layer. At this level, complex web-based services are conceived and developed on the basis of the data that has been gathered, processed, and saved. Graphical user interfaces will be able to assist in monitoring the operation of the plant, and the console will also counsel the administrator with decision-making based on previous data, which will considerably minimize the amount of time spent deciding what to do.

Pereira et al. [8] came up with the idea for a new system called the Renewable Energy Monitoring System (REMS), which is a novel concept for an open source and low-cost data collecting and transmission system.

Decentralized renewable energy plants can benefit from Raspberry Pi, multi-user cloud remote monitoring, and Internet of Things applications. REMS architecture is composed of three primary components: a SanUSB microcontroller, a Raspberry Pi (Rpi) Embedded Linux System (ELS), and an Online Web Monitor for real-time cloud monitoring. These components are organized according to the principles of the Internet of Things (IoT) and cloud computing. The information shown in **Table 1.1** is a summary of the non-commercial monitoring systems that have been created up to this point [53]-[84].

2.3 Commercial Systems

A commercial photovoltaic (PV) monitoring system [3] called the Geo Solo II PV monitoring system is available from Green Energy Options Ltd.



Fig. 2.1 Geo Solo II PV monitoring system [8]

The Solo II PV is a sleek and sophisticated In-Home Display that is web-enabled. It offers real-time information that piques the user's interest and gives an indication to turn on high-load appliances like washing machines and dishwashers when more than 750W is being generated, which allows us to get the most out of our PV system. You can access our online service, which is known as Energynote, using the internet bridge that we supply when we use the online service named Energynote. Energynote delivers comprehensive and real-time generation statistics, as well as recommendations and tips for your microgeneration, as well as analysis of all historical data. It shows the total generation in kW, the amount of money earned through the Feed-In Tariff, as well as the quantity of CO₂ emissions that were avoided. A Geo Solo II photovoltaic (PV) monitoring system is depicted in **Fig 2.1**.



Fig. 2.2 SMA Data Manager M powered by ennexOS [20]

A smart energy monitor is an essential piece of equipment for photovoltaic or microgeneration installations. Eco-eye has created a monitoring system that they call Eco Eye Smart PV [19], and it is a smart energy monitor. The Smart PV system has comprehensive display and monitoring capabilities thanks to the presence of sensors on both the generated and demand cables. These sensors indicate power generated, power utilized, and net power. Through the use of a memory card, smart PV has the capability to record both the amount of electricity it generates and the amount of electricity that is required for analysis on a Windows or Mac computer. The Intuition-PV Solar PV Monitoring system, which was developed by OWL and enables for monitoring of the PV generation, export, and overall consumption of a property that is equipped with solar panels [20]. Access to the Intuition online dashboard is granted to the user regardless of their location, provided they have access to the internet. Apps for Android and iPhone provide users with the ability to access this system while they are on the move. It displays live readings down to intervals of 12 seconds and a historical record of the information mentioned above. Additionally, it notifies the user when their consumption habits have changed or when

their solar panels are functioning better.

The unit is able to compute the total amount that the user has spent on a daily, weekly, and monthly basis thanks to tariff settings that may be customized by the user. You are able to observe the real influence that your solar panels are having on your costs by adjusting the FITS settings. **Fig 2.2.**

This is a representation of the Intuition-PV Solar PV monitoring system in SMA **Fig 2.4** depicts SMA Solar Technology AG's Data Manager M powered by ennexOS [4], a monitoring and controller system that comes equipped with sunny portal. The communication, monitoring, and control of photovoltaic (PV) systems with as many as 25 SMA components can be optimized with the help of this data manager. The SMA Data Manager M is the appropriate professional system interface for electric utility companies, direct marketers, service personnel, and operators of PV systems. It is based on SMA's brand-new IoT platform for energy management, ennexOS. The fact that it features a user interface that is both forward-thinking and extremely effective, and that this interface has been standardized for both Data Manager M and the new Sunny Portal powered by ennexOS, is particularly amazing. The amount of time required for commissioning and parameterization is greatly cut down thanks to a variety of intuitive help capabilities that are driven by ennexOS and are available for the Data Manager M, inverters, and the Sunny Portal. The fundamental range of capabilities and interfaces provided by the new Data Manager M is synchronized with the relevant features found in the Sunny Portal powered by ennexOS and may be adjusted to meet the needs of upcoming projects in a step-by-step manner. Systems can be expanded to include additional components such as I/O systems or energy meters, from either SMA or other suppliers, thanks to its modular design and systematic support of industry standards such as Modbus/TCP. This is made possible by the modular design of the system as well as the systematic support of industry standards. Swart et al. represent a comparison of advantages and disadvantages for some datalogger systems available in South Africa in [2]. **Table 2.2** shows the comparison represented in their paper.

Table 2.2 Some Commercial Data logger Available in South Africa [2]

Data Logger	Advantages	Disadvantage
PICOLOG 1012	1. Relatively cheap(\$210) 2. Very user friendly interface 3. Repetitive unlimited samples with unique file name 4. Real time mathematical calculations 5. 12 input analog/digital channels 6. 2 output digital channels 7. Remote download	1. Time stamp per sample missing. 2. Must be permanently connected to PC
DAQPro 5300	1. User friendly interface 2. Onboard memory for medium data storage	1. Modestly prices(\$800) 2. 8 input analogue channels 3. Limited number of samples 4. Mathematical calculation after data collection 5. One alarm output reduces input channels by 1 6. No remote download
CAMPBELL Scientific CRS800	1. User friendly interface 2. Onboard memory for medium data storage 3. Remote download 4. 4 output digital channels 5. Resistance measurements 6. Pulse counter	1. Very expensive(\$1000) 2. 6 single-ended analogue input channels 3. Mathematical calculations after data collection

A comparison of the costs of several commercially available monitoring and data logging systems for photovoltaic cells is presented in **Table 2.2**. Here, we showed the advantages and disadvantages of the data logger device available in South Africa.

Table 2.3 Price Comparison of Commercial PV Monitoring System [3] [4]

SL No	Name	Manufacturer	Price (BDT)
1	Geo Solo II PV	GEO	9053
2	Eco Eye Smart PV	Eco Eye	9340
3	Owl Intution PV	OWL	9700
4	Solar Cache Wi-Link Kit Comprehensive Energy Monitoring	DSM Energy Control Ltd.	44477
5	SMA Data Manager M powered by ennexOS	SMA Solar Technology AG	Not found
6	Solarfox Solar Display systems	SOLEDOS GmbH	41315

2.4 Findings of Literature Review

After reviewing the literature, it was found that the older monitoring systems were wired. They were reliable, but they had to use long cables to send data. In wired monitoring systems, RS232 or RS485 cables were used to send and receive data. The cost of setting up and maintaining this physical system was high. The wireless monitoring system is meant to make up for these problems with the wired system.

Satellite, GSM, Zigbee, and other RF devices have all been used to send and receive data for wireless data monitoring systems. People say that satellite data transmission is slow and that installation costs a lot. Compared to satellite, GSM-based systems are reliable and fast, but they have problems with low retransmission and data loss. On the other hand, the RF data transfer system is good for sending data without a wire transmission line. The main problems with RF systems are that they cost a lot to set up and need permission to do so. Wi-Fi, on the other hand, is another option. It is a good wireless data communication system with a faster rate of data transfer. Wi-Fi has become a popular way to send data, but the system is expensive and uses a lot of power.

Some people have also suggested a low-cost and open-source computer-based general data acquisition system that uses a dedicated PC with USB or Serial RS-232 for communication. A LabVIEWTM-based system for simulating and keeping an eye on PV is also suggested. Most of these data loggers and monitoring systems are based on microcontrollers and use a third-party server in the cloud. This microcontroller-based system is not cost-effective because it needs a PC and an internet connection to store and monitor data. Also, there is no information security and privacy policy for the cloud-based system.

After the new era of the internet, solutions based on IoT are also being proposed using Arduino, open source servers, and mobile apps like Blynk.

This kind of technology has become very popular, and scientists are working on making a system that is cheap and easy to use. However, this type of data logger and monitoring system needs an internet connection, which is not available in many rural areas.

This thesis proposes a low-cost data logger and control system for the pico-solar system that uses ESP 32 and a local HTTP web server to keep track of data and make it more cost-effective, secure, and easy to use. This data logger will show the charging current, battery voltage, and output power of the pico-solar system for a rural area in a developing country. The historical data for the PV system will be stored on an SD card so that it can be analyzed and fixed if something goes wrong. This data logger and monitoring system will also improve the overall efficiency of the system by showing the system parameters. It will also keep the batteries from getting damaged because it is easy to access through a local HTTP server and doesn't need to be connected to the internet. Any web browser, like Mozilla Firefox, Internet Explorer, etc., can be used to get data from a web server on a local computer. All of the PV parameters are also being tracked through an Android app.

CHAPTER 3

METHODOLOGY

3.1 Introduction

We have developed low cost an IoT based solar power monitoring and data logger system. In this chapter we will discuss about methodology of the project including the block diagram of the project, component list and their description, circuit diagram with its operation. Finally we will discuss about the algorithm development of the project.

3.2 Functional Block Diagram

This functional block diagram demonstrates that the primary source of energy is a solar panel. A battery was added after the solar panel and solar charge controller were installed. The battery, a voltage and current sensor, and the load are all connected. A sensor transmits its value to the MCU ESP32. It is published to a cloud server by the microcontroller. After that, it can observe in real time. Functional Block Diagram shows that the Solar

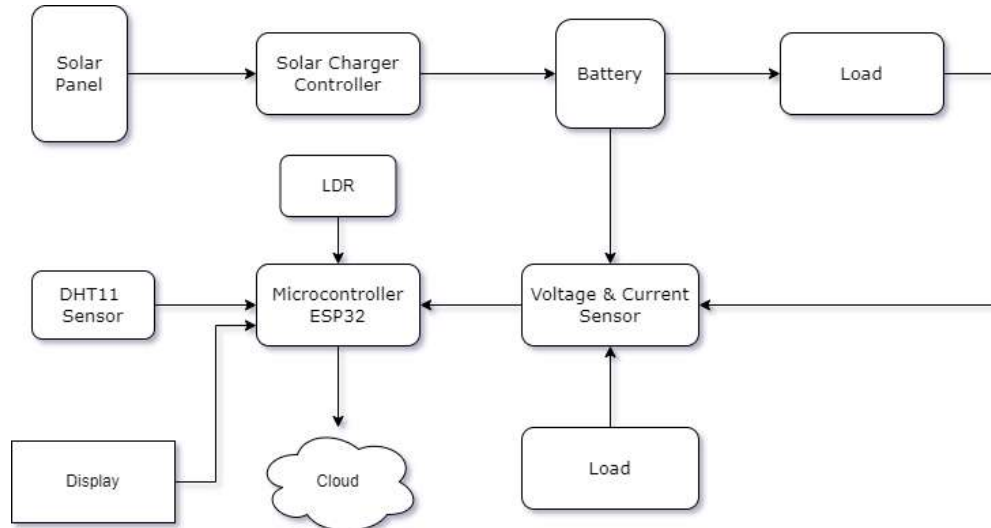


Fig. 3.1 Functional Block Diagram of the system

Panel provides power source, and its connected (PWM) solar charge controller. PWM distribute to battery, load and voltage & current sensor. Sensor connected with ESP32 Microcontroller, which receives reading from DHT11 sensor, LDR, MAX471 sensor. MCU receives and shows it to LCD monitor and send it to cloud server.

3.3.2 Circuit Design

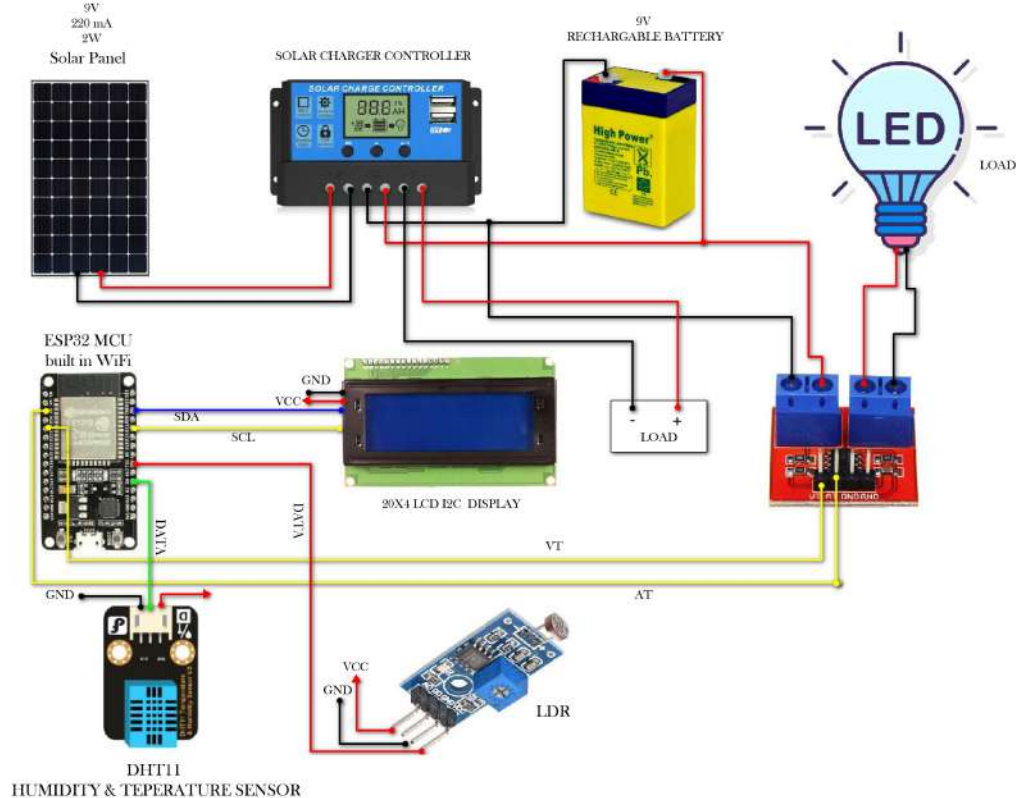


Fig. 3.3 Circuit Design of Solar Power Monitoring and Data Logger System

Fig 3.3 shows that the circuit design of the Solar Power Monitoring and Data Logger System. 9V 220mA Solar Panel connected to Solar Charger Controller (SCC). SCC manage the incoming and outgoing power. It receives solar power and supply it to battery. Then it supply power to load. ESP32 Microcontroller collect reading from max471 current & voltage sensor, temperature and humidity reading from DHT11 sensor, light intensity reading from LDR sensor. All the reading output shows in LCD display. Besides, it initialize WiFi connectivity and send the real time data to the thingspeak cloud server.

3.3.3 Algorithm Development

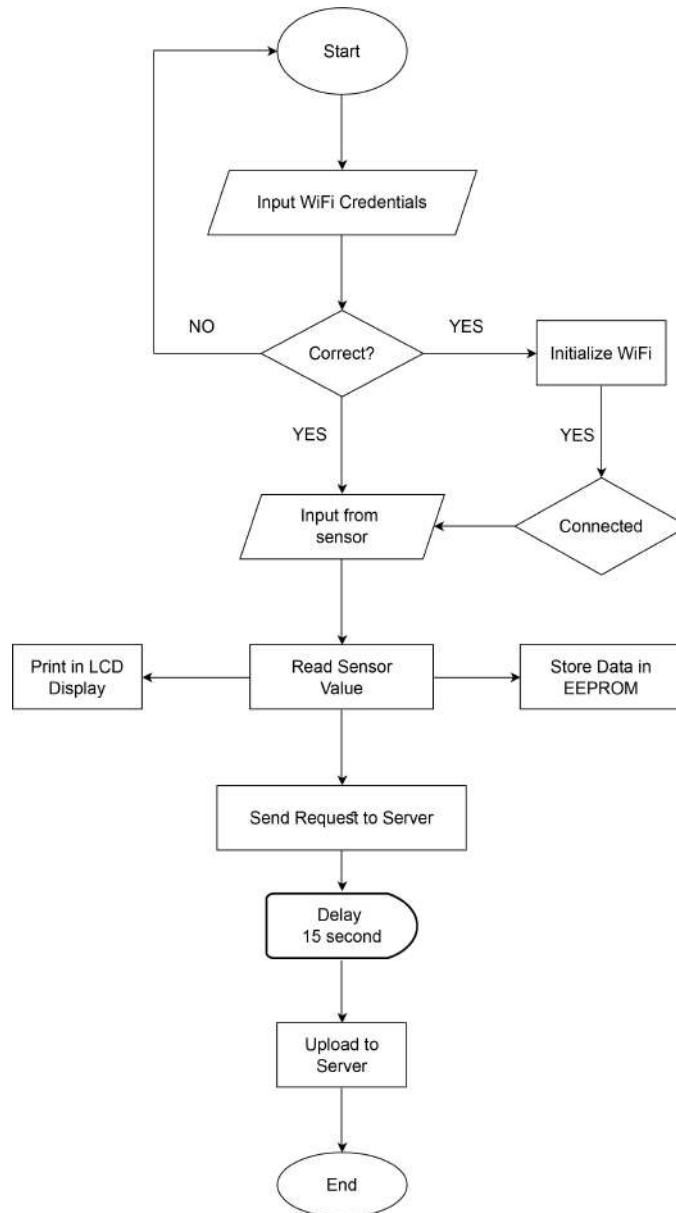


Fig. 3.4 System Algorithm Flowchart

In our project, this algorithm has been followed. After power on, this system will search for matching WiFi credentials. When WiFi credential will match it will go to the next procedure otherwise it will not go to the next and continuously searching for the credentials. If credentials match then it will execute to collect sensor data and process next step.

3.4 Hardware Description

This section contains different types of hardware and their description with figure whose are required in this project.

3.4.1 Hardware Components

- ESP32 Micro-controller Unit
- Solar PV Panel
- Solar Charger Controller
- Battery
- MAX471
- DHT11
- LDR(Light Dependent Resistor)
- 20x4 i2c LCD Display

3.4.2 ESP32 Micro-controller Unit

The ESP32 is a very versatile System On a Chip (SoC) that may be used as a general purpose microcontroller. It comes equipped with quite an extensive range of peripherals, including the ability to communicate wirelessly via WiFi and Bluetooth.

Espressif Systems, based in Shanghai, is the company that makes it, and it can be purchased for less than \$5. Even though the ESP32 is a system-on-a-chip (SoC), the vast majority of customers won't begin by employing simply the ESP32 chip by itself. Although the ESP32 System on a Chip (SoC) can be used in the development of a product, this strategy is not very prevalent. The vast majority of designs that are based on the ESP32 platform, on the other hand, make use of pre-made modules that include a genuine ESP-32 SoC, external flash memory, a crystal, and either a pre-tuned PCB antenna or an IPEX antenna connector. The fact that Espressif has already pre-loaded the low-level device drivers, the wireless protocol stacks for WiFi b, g, and n, Bluetooth and BLE, and FreeRTOS as the base operating system is one of the most significant advantages of utilizing this module as opposed to designing something from the ground up.

In addition, a bootloader has been installed, which enables user programs to be downloaded in a manner that is not overly complicated. Another type of module that is frequently referred to as an ESP32 is the ESP32 Development Module, which is the more accurate name for this component. This is essentially an ESP32 module that has been put on a board that also has other support circuitry including a voltage regulator and a serial to USB IC. It allows direct connection to a desktop PC that can then be used to

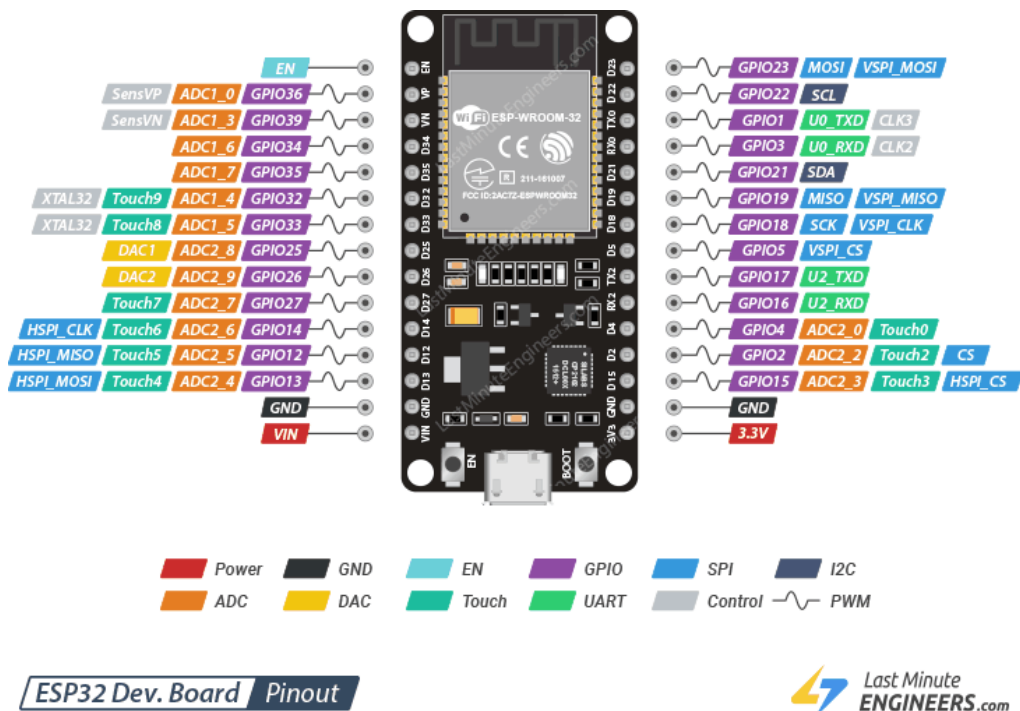


Fig. 3.5 Pin Diagram of ESP32

compile, download, and run programs directly on this module. Note that one has more of the pins of the ESP module available than the other one, and is slightly more expensive. Otherwise, they are very similar. They each allow a direct connection to a desktop development system through a USB cable.

Specifications and Features:

- Main processor: Tensilica Xtensa 32-bit LX6 microprocessor
- Cores: All versions of the ESP32 series are dual-core except for ESP32-S0WD, which is single-core.
- Clock frequency: up to 240 MHz
- Performance: up to 600 DMIPS

- Ultra low power co-processor: allows you to do ADC conversions, computation, and level thresholds while in deep sleep.
- Wi-Fi: 802.11 b/g/n/e/i (802.11n @ 2.4 GHz up to 150 Mbit/s)
- Bluetooth: v4.2 BR/EDR and Bluetooth Low Energy (BLE)
- ROM: 448 KB For booting and core functions
- SRAM: 520 KB For data and instruction
- RTC fast SRAM: 8 KB For data storage and main CPU during RTC Boot from the deep-sleep mode
- RTC slow SRAM: 8 KB For co-processor accessing during deep-sleep mode

Fuse: 1 KBit Of which 256 bits are used for the system (MAC address and chip configuration) and the remaining 768 bits are reserved for customer applications, including Flash-Encryption and Chip-ID.

- Embedded flash:

0 MB (ESP32-D0WDQ6, ESP32-D0WD, and ESP32-S0WD chips) 2 MB (ESP32-D2WD chip) 4 MB (ESP32-PICO-D4 SiP module) Flash memory is connected internally via IO16, IO17, SD_CMD, SD_CLK, SD_DATA_0 and SD_DATA_1 on ESP32-D2WD and ESP32-PICO-D4.

- External flash SRAM: ESP32 supports up to four 16 MB external QSPI flashes and SRAMs with hardware encryption based on AES to protect developers' programs and data. ESP32 can access the external QSPI flash and SRAM through high-speed caches.

Up to 16 MB of external flash are memory-mapped onto the CPU code space, supporting 8-bit, 16-bit and 32-bit access. Code execution from flash is supported. Up to 8 MB of external flash/SRAM memory are mapped onto the CPU data space, supporting 8-bit, 16-bit and 32-bit access. Data-read is supported on the flash and SRAM. Data-write is supported on the SRAM. Note that ESP32 chips with embedded flash do not support the address mapping between external flash and peripherals.

- Peripheral input/output: The ESP32 offers a rich peripheral interface with DMA that includes:

Capacitive touch ADCs (analog-to-digital converter) DACs (digital-to-analog converter) I²C (Inter-Integrated Circuit) UART (universal asynchronous receiver/transmitter) CAN 2.0 (Controller Area Network) SPI (Serial Peripheral Interface) I²S (Integrated Inter-IC Sound) RMII (Reduced Media-Independent Interface) PWM (pulse width modulation), and more.

- Security:

IEEE 802.11 standard security features all supported, including WPA, WPA/WPA2 and WAPI Secure boot

- Flash encryption 1024-bit OTP, up to 768-bit for customers Cryptographic hardware acceleration: AES, SHA-2, RSA, elliptic curve cryptography (ECC), random number generator (RNG)

3.4.3 Solar PV Panel

The term "Photovoltaic panel" is sometimes abbreviated to "PV panel." A PV panel can also be referred to as a solar panel. A photovoltaic (PV) panel or solar panel is an assembly that consists of a number of PV cells or solar cells arranged together. A photovoltaic cell, also known as a solar cell, is a type of electronic device that can directly convert the energy from light into electrical energy through the process known as the photoelectric effect.



Fig. 3.6 9V 220mA 2W Poly-crystalline PV Panel

This effect has both a physical and a chemical mechanism. It is common knowledge that the Sun is the primary source of energy for our planet. This photovoltaic (PV) or solar cell transforms the sun's rays into direct current (DC), and the mechanism by which it does so will be discussed more in the section on the operation of PV panels and solar panels. Solar panels are nothing more than silicon-based semiconductors, and solar cells are nothing more than p-n junctions. Solar cells are what make up solar panels. Connecting a large number of solar cells in a series-parallel arrangement results in an increase in both the current and voltage produced by the solar panel. Solar cells, just like batteries, are made up of two distinct layers. One layer with good energy and one layer with negative energy.

Table 3.1 Advantage and Disadvantage of Solar Panel

Type of Solar Panel	Advantages	Disadvantages
Monocrystalline	High efficiency	Expensive
Polycrystalline	Cost effective	Low efficiency
Thin-film	Portable and flexible	Low efficiency

When solar cells are placed in an environment where they are directly illuminated by sunlight during the day, both their positive and negative layers combine to produce an electric field. There are many different varieties of solar panels. There are monocrystalline solar panels, polycrystalline solar panels, and thin-film solar panels among those that are available. These three different panels each offer their own set of benefits and drawbacks in comparison to the others.

A table of advantages and disadvantages of different type of solar panel or PV panel is mentioned above

There is a difference in the amount of silicon that is contained in monocrystalline and polycrystalline solar panels, despite the fact that both types of panels contain silicon cells. In order to produce monocrystalline solar cells, a single crystal of pure silicon is utilized. In contrast, polycrystalline solar cells are made out of shards of silicon crystal that are melted together in a mold and then sliced into wafers for use. These solar cells are then utilized to generate electricity. Thin-film solar panels are so-called because they only include a single layer of photovoltaic material [6]. Below you will find some images of monocrystalline, polycrystalline, and thin-film products.

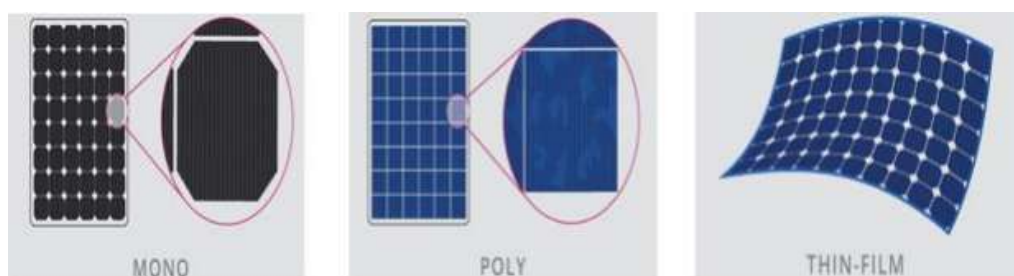


Fig. 3.7 Mono, Poly and Thin Film Crystalline PV Panel

3.4.4 Solar Charger Controller

A Solar Charge Controller is an electronic device that governs the flow of electricity from the solar array into the battery bank. It prevents the deep cycle batteries from being overcharged during the day and prevents the power from running back to the solar panels overnight, which would drain the batteries and cause an imbalance in the system. Although some charge controllers come with extra features such as lighting and load control, the fundamental responsibility of a charge controller is to manage the power supply. The acronym "PWM" refers to a solar charge controller that uses pulse width modulation. When these are turned on, they function by establishing a connection between the solar array and the battery bank. During the process of bulk charging, the output voltage of the array is "drawn down" to the voltage of the battery bank whenever there is a continuous connection between the array and the battery bank. The voltage of the battery increases as it charges, and because of this, the voltage output of the solar panel also increases. As a result, the battery makes greater use of the solar power as it charges.



Fig. 3.8 PWM Solar Charger Controller

THE KEY FEATURES OF A SOLAR CHARGE CONTROLLER ARE:

- Multistage charging of battery bank - changes the amount of power set to the batteries based on its charge level, for healthier batteries.
- Reverse current protection - stops the solar panels from draining the batteries at night when there is no power coming from the solar panels.
- Low voltage disconnect - turns off attached load when battery is low and turns it back on when the battery is charged back up.

- Lighting control - turns attached light on and off based on dusk and dawn. Many controllers are configurable, allowing settings for a few hours or all night, or somewhere in between.
- Display- may show voltage of battery bank, state of charge, amps coming in from solar panel.

3.4.5 Battery

We have used High Power DC Battery for our system. Product Details of Battery Rechargeable Sealed Lead-Acid Battery High Power 6v.4.5Ah: Sealed lead acid battery is a lead acid battery that has the sulfuric acid electrolyte coagulated (thickened) so it cannot spill out. They are partially sealed. They can be used for smaller applications where they are turned upside down. They are also safer. They use different chemicals than dry cells, so they are rechargeable.



Fig. 3.9 Rechargeable Liquid Acidic Battery

3.4.6 MAX471 Voltage and Current Sensor

The MAX471/MAX472 are highside current-sense amplifiers that are full, bidirectional, and designed for use in portable computers, telephones, and other systems where it is essential to monitor the battery or DC power line. Since it does not interfere with the ground routes of the battery chargers or monitors that are frequently found in "smart" batteries, high-side power-line monitoring is particularly helpful in battery-powered systems. This is because it is especially useful in battery-powered systems.

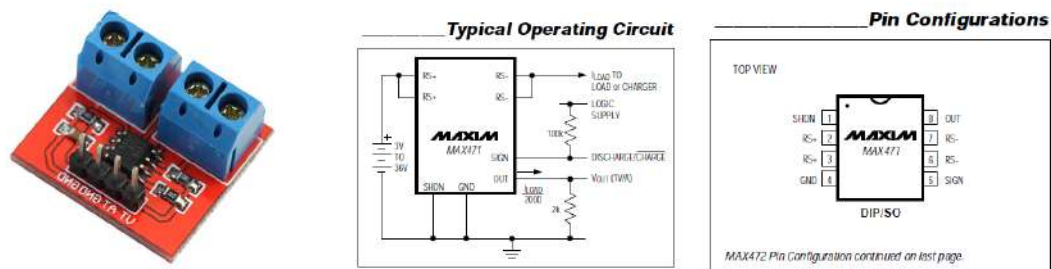


Fig. 3.10 MAX471 Voltage and Current Sensor

The MAX471 incorporates a current-sense resistor with an internal value of 35m and is capable of measuring battery currents of up to 3A. The MAX472 is capable of functioning with external sensing and gain-setting resistors, making it suitable for use in applications that require a larger current or increased flexibility. Both of these devices feature a current output that, with the addition of just one resistor, may be changed into a ground-referred voltage. This opens the door for a broad variety of battery voltages and currents. The direction in which current is flowing can be determined from an open-collector SIGN output, allowing the user to determine if a battery is being charged or drained. Both of these devices have an operating voltage range of 3V to 36V, an average current consumption of less than 100 μ A, and a maximum shutdown current of 5 μ A.

3.4.7 DHT11 Humidity and Temperature Sensor

The DHT11 is a commonly used Temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The sensor is also factory calibrated and hence easy to interface with other microcontrollers.

The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy. So if you are looking to measure in this range then this sensor might be the right choice for you.

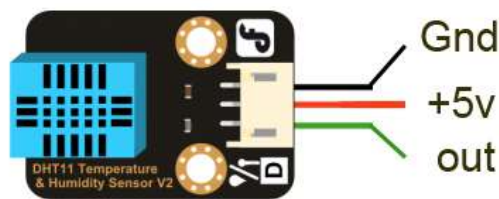


Fig. 3.11 Pin Diagram of DHT11

DHT11 Specifications:

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0° to 50°
- Humidity Range: 20% to 90%
- Resolution: Temperature and Humidity both are 16-bit

3.4.8 LDR Sensor

A Light Dependent Resistor, also called a photoresistor or LDR, is a device that changes its resistance based on the amount of electromagnetic radiation hitting it. So, they are devices that respond to light. They are also called photocells, photoconductors, and photoconductive cells.

They are made of high-resistance semiconductor materials. One of the most common ways to show that something is a photoresistor or LDR is with the symbol shown in the figure below.



Fig. 3.12 Light Dependent Resistor (LDR)

The arrow shows where light is hitting it. The idea of photoconductivity is what makes photoresistors work. Photoconductivity is an optical effect in which light is absorbed by a material, which makes the material more conductive. When light, or photons, hit the device, the photons cause the electrons in the valence band of the semiconductor material to jump to the conduction band. For the electrons to move from the valence band to the conduction band, the photons in the light that hit the material should have more energy than the gap between the bands.

So, when light with enough energy hits the device, more and more electrons move to the conduction band. This makes a lot of charge carriers. The result of this process is that when the circuit is closed, more and more current starts to flow through the device. This means that the resistance of the device has gone down. This is the most common way that LDR works.

Photoresistor LDRs are devices that depend on light. When light hits them, their resistance goes down, and when it gets dark, it goes up. A light-dependent resistor has a very high resistance when it is kept in the dark. The name for this kind of resistance is "dark resistance." It can be as high as 10^{12} , and if the device is allowed to soak up light, it will have a much lower resistance. If a constant voltage is put on it and the light gets brighter, the current will start to rise. LDRs and photocells are nonlinear devices. The length of the light wave that hits them changes how sensitive they are. Some photocells may not respond at all to a certain range of light wavelengths. Different cells have different spectral response curves based on the materials they are made of.

When light hits a photocell, it usually takes 8 to 12 ms for the resistance to change, and it can take a second or more for the resistance to rise back to its original level after the light is taken away. A resistance recovery rate is the name for this kind of thing. Compressors for sound use this property.

3.4.9 20x4 i2c LCD Display

A 20x4 LCD display is an extremely fundamental module that is utilized in a wide variety of different devices and circuits. In comparison to seven segments and other multi segment LEDs, these modules are the superior choice. The reasons for this are as follows: LCDs are inexpensive; they are easily programmable; they do not have any limitations when it comes to showing special or even custom characters (unlike seven segment displays); animations; etc.



Fig. 3.13 20x4 LCD DISPLAY

The term "20x4 LCD" refers to a screen that can display 20 characters across each of its lines and has a total of 4 lines. Each character in this LCD is displayed using a pixel matrix that is 5x7 in size. This LCD contains two registers, which are designated as Command and Data, respectively. The HD44780 controller LCD looks just like this. Standard LCDs measuring 16x2 or 20x4 do not have a change code for their interfaces.

1. 20 Characters x 4 Lines
2. Built-in HD44780 Equivalent LCD Controller
3. Works directly with ATMEGA, ARDUINO, PIC and many other microcontroller.
4. 4 or 8 bit data I/O interface
5. Low power consumption



Fig. 3.14 20x4 I2C LCD DISPLAY

This LCD Display Module uses an I2C communication interface, which only needs 2 wires to display information on any microcontroller-based project, including the Arduino. It is capable of displaying 4 lines of 20 white characters on a blue background. Moreover, it is compatible with either 3.3V or 5V logic systems, which is basically everything in programmable electronics.

3.5 Summary

This chapter covers the project's methodology, including the project's block diagram, component list, and descriptions of the most important components. Include a diagram of the circuit as well as a description of how it operates. Finally, this chapter focused on the project's algorithm development. It will be discussed in chapter 4 how this project turned out in terms of its overall output.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This section introduces with the individual hardware implementation pictures and other processes. The operations and achievement through the project work defines via the attached picture of the particular findings indeed.

4.2 Hardware Prototype

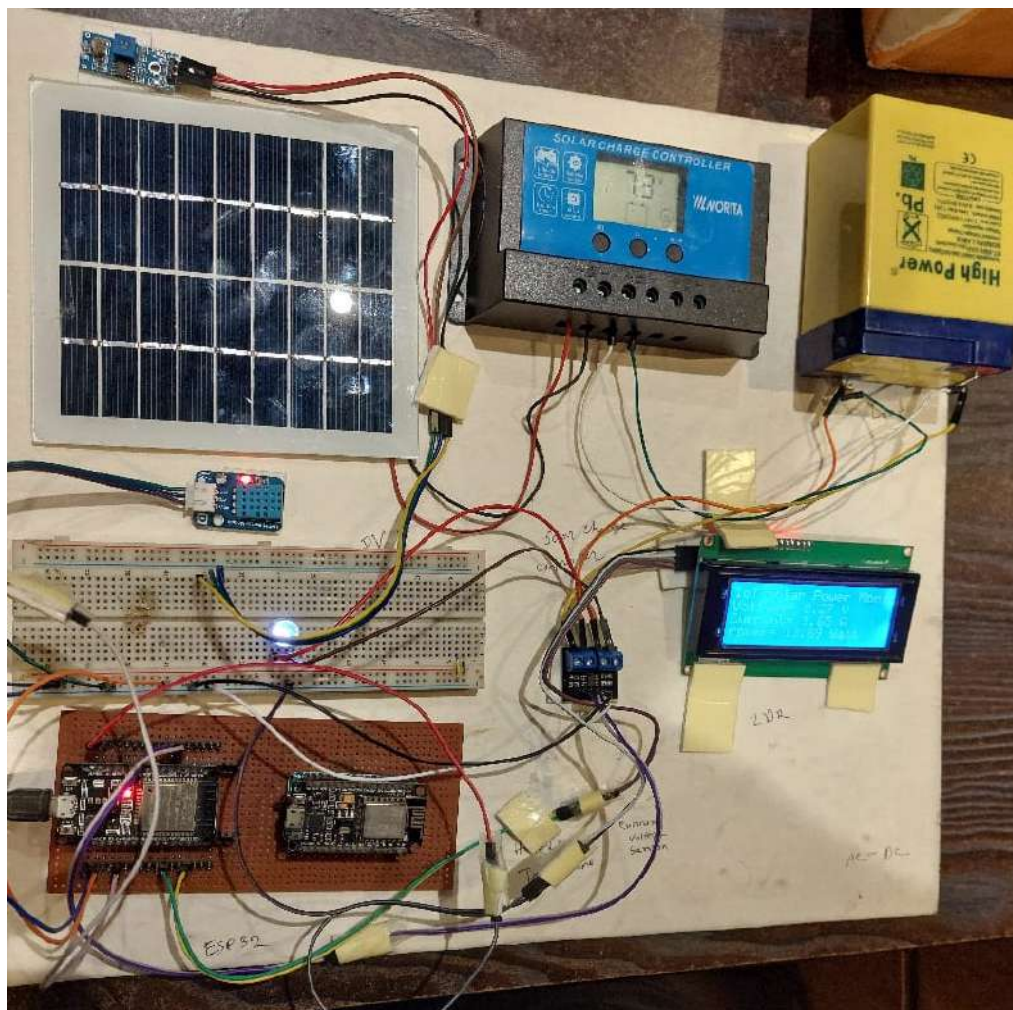


Fig. 4.1 Solar Power Monitoring and Data Logger Prototype Device

The **Fig 4.1** shows that the IoT Based Solar Power Monitoring and Data Logger System Prototype Device.

4.3 Hardware Connection

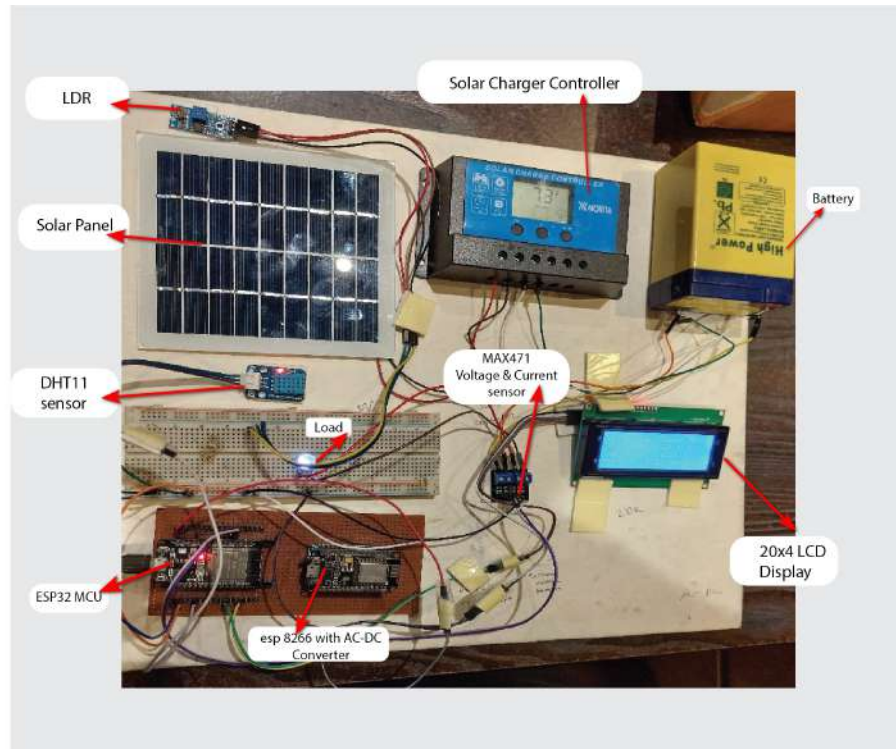


Fig. 4.2 Hardware Connection of the system.

In our development project, main control unit is ESP32 Microcontroller. Solar panel working here as power source.

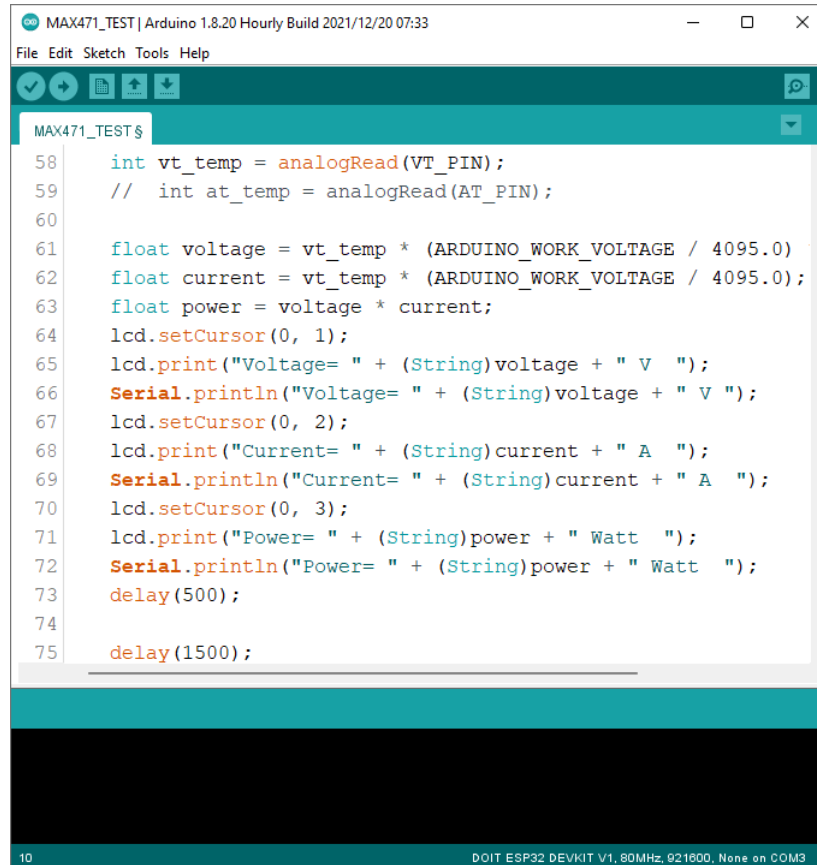
Pin connection between Microcontroller (ESP32) vs sensors are given below:

Table 4.1 Pin Description of the Circuit

Serial	Microcontroller Pin	Pin No	Component Name
1	GPIO 4	DATA	DHT11
2	GPIO 21	SDA	LCD
3	GPIO 22	SCL	LCD
4	GPIO 34	AT	MAX471
5	GPIO 35	VT	MAX471
6	GPIO 5	OUT	LDR
7	GND	GND	Sensor
8	VCC	VCC	Sensor

4.4 Software

We used Arduino IDE for compiling our program. ESP32 supports Arduino IDE for compiling & debugging. Arduino IDE based on C/C++ language.



```
MAX471_TEST | Arduino 1.8.20 Hourly Build 2021/12/20 07:33
File Edit Sketch Tools Help
MAX471_TEST$
58   int vt_temp = analogRead(VT_PIN);
59   // int at_temp = analogRead(AT_PIN);
60
61   float voltage = vt_temp * (ARDUINO_WORK_VOLTAGE / 4095.0);
62   float current = vt_temp * (ARDUINO_WORK_VOLTAGE / 4095.0);
63   float power = voltage * current;
64   lcd.setCursor(0, 1);
65   lcd.print("Voltage= " + (String)voltage + " V ");
66   Serial.println("Voltage= " + (String)voltage + " V ");
67   lcd.setCursor(0, 2);
68   lcd.print("Current= " + (String)current + " A ");
69   Serial.println("Current= " + (String)current + " A ");
70   lcd.setCursor(0, 3);
71   lcd.print("Power= " + (String)power + " Watt ");
72   Serial.println("Power= " + (String)power + " Watt ");
73   delay(500);
74
75   delay(1500);
10 DOIT ESP32 DEVKIT V1, 80MHz, 921600, None on COM3
```

Fig. 4.3 Arduino IDE editor & compiler of the program

4.5 Data Logger

ESP32 has builtin EEPROM memory. Where we can store the values. In our system we used EEPROM for storing data.

To read and write from the ESP32 flash memory using Arduino IDE, we'll be using the EEPROM library. Using this library with the ESP32 is very similar to using it with the Arduino.

We can use up to 512 bytes of the flash memory with the ESP32 and the EEPROM library. This means we have 512 different addresses, and each one can hold a number between 0 and 255.

We've used the EEPROM to write to the flash memory.

write() function that takes as arguments the location or address where we want to save the data and the value (a byte variable) we want to save:

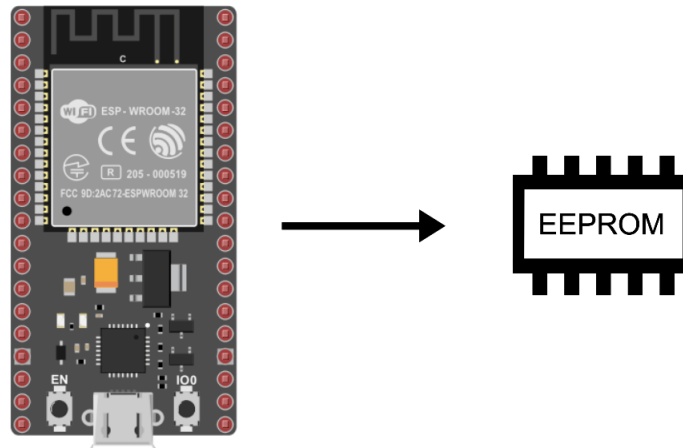


Fig. 4.4 EEPROM of ESP32 MCU

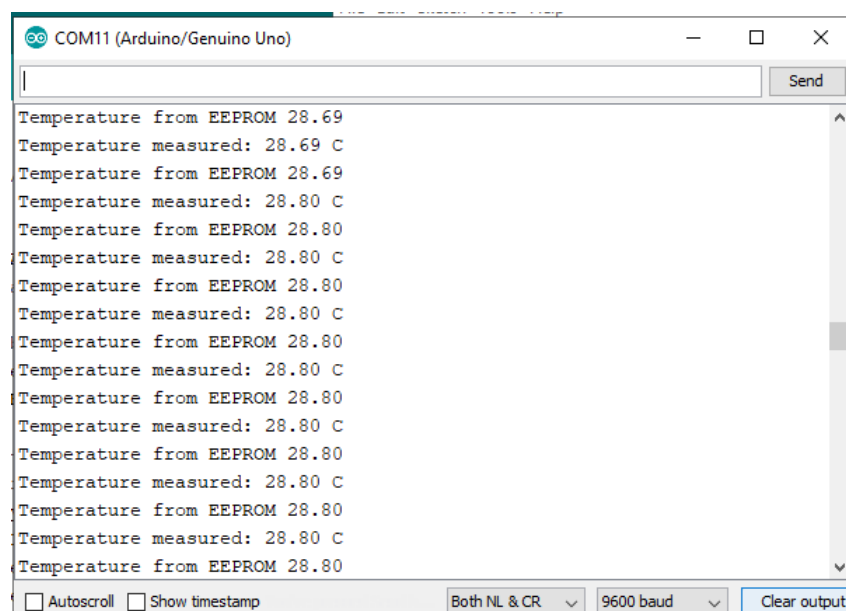


Fig. 4.5 EEPROM Reading

Use the `EEPROM.read()` function to read a byte from the flash memory. This function takes as an argument the address of the byte to read.

4.6 Cloud Setup

In our project, we have used Thingspeak cloud server which is SaaS(Software as a Service). Minimum 8 channel can be used in free of cost. ThingSpeak is an open-source software written in Ruby which allows users to communicate with internet enabled devices. It facilitates data access, retrieval and logging of data by providing an API to both the devices and social network websites. Free use of ThingSpeak's services is offered for non-profit organizations working on small projects (up to 3 million messages per year or 8,200 messages per day). Standard, Academic, Student, and Home licenses are the four main types of annual licenses that are available for use with larger projects or commercial applications.

Protocol: HTTPS

Channel ID : 1766006

Channel Link : <https://thingspeak.com/channels/1766006>

Channel Settings

Percentage complete 30%

Channel ID 1612283

Name IoT Based Solar Power Monitoring and Data Logger Sys

Description

Field 1 Current ☒

Field 2 Voltage ☒

Field 3 Watt ☒

Field 4 Temperature ☒

Field 5 Humidity ☒

Field 6 LDR ☒

Fig. 4.6 Channel configuration of thingspeak cloud server

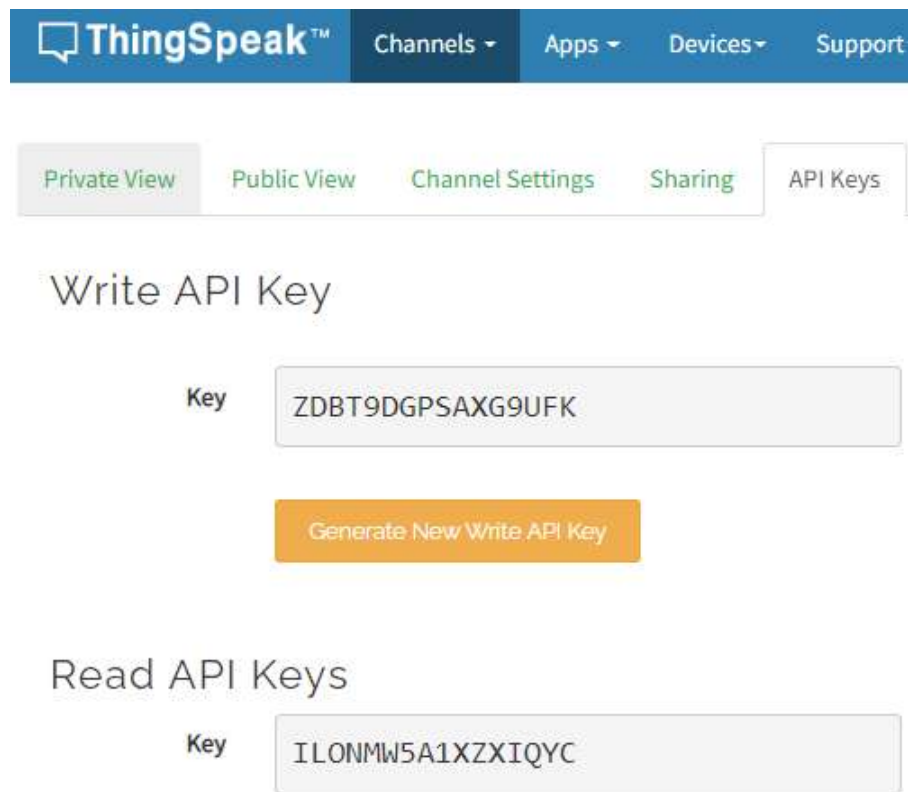


Fig. 4.7 API keys for thingspeak channel

After creating channel in thingspeak cloud server we get Write API Key and Read API Keys. These API credentials need to input in our microcontroller program.

4.7 Real Time Data Update to Thingspeak Cloud Server

Here, we can see the real time data uploading continuously to cloud server. It takes 15s for updating the value. Communication protocol is https. In thingspeak channel there 5 different field has been created. Individual field receive different sensors value and store it to cloud.

Field 1 Chart shows that the real time current value of the system across the connected load.

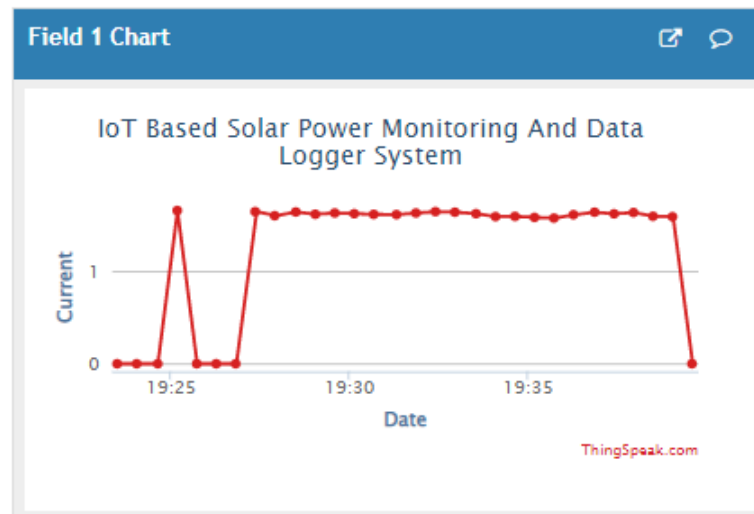


Fig. 4.8 Real Time Current Value[Min 0 Amp and Maximum 2 Amp]

Field 2 Chart shows that the real time current value of the system across the connected load.

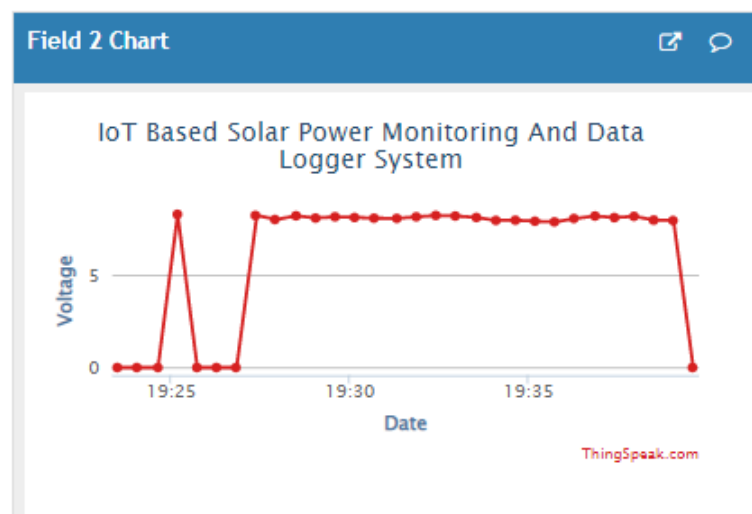


Fig. 4.9 Real Time Voltage Value[Min Voltage = 0V, Maximum Voltage = 8V]

Field 3 Chart shows that the real time power of the system across the connected load.

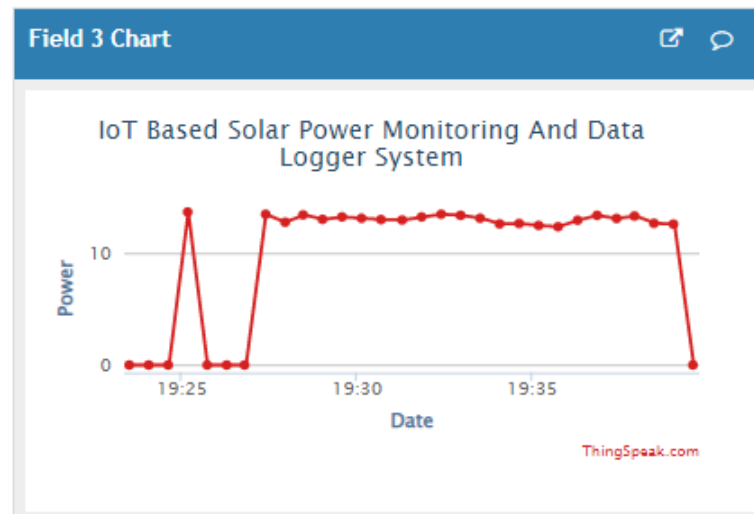


Fig. 4.10 Real Time Power Value

Field 4 Chart shows that the real time current value of the system across the connected load.

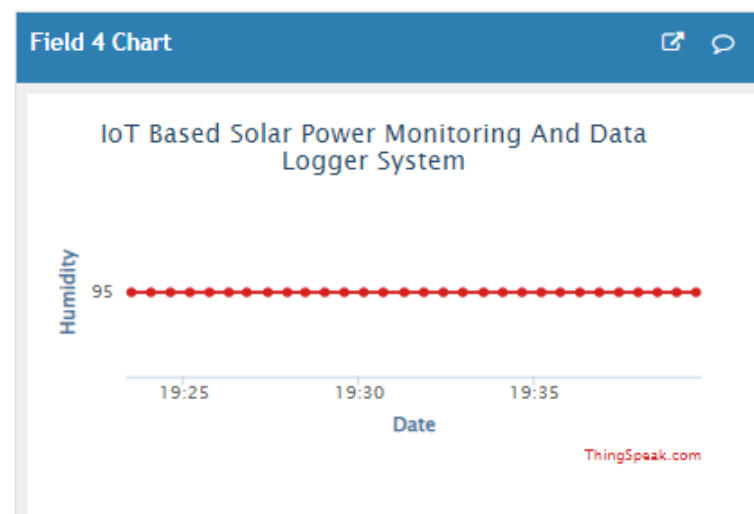


Fig. 4.11 Real Time Humidity value of the system

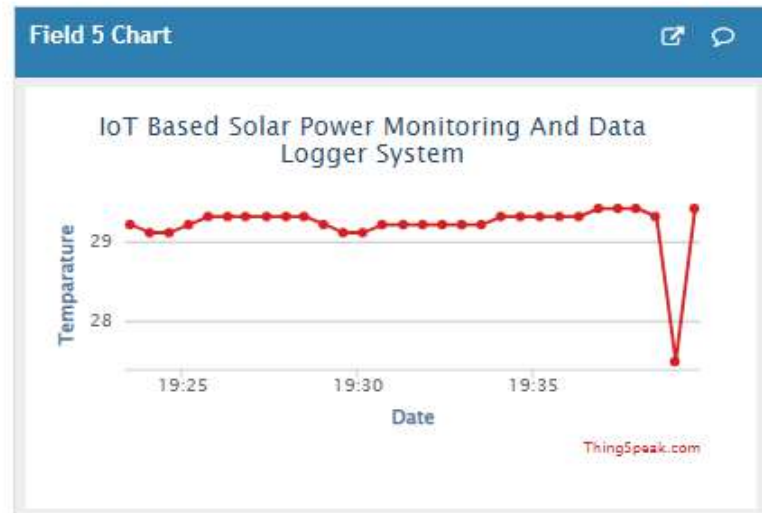


Fig. 4.12 Real Time Temperature value of the system

Field 5 Chart shows that the real time current value of the system across the connected load.

Current, Voltage & Power Figure shows that the real time value of the system across the connected load.

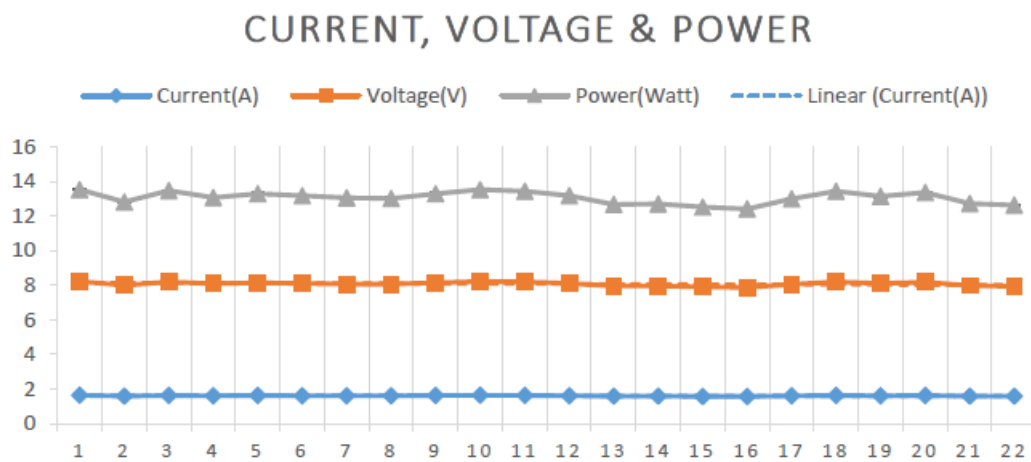


Fig. 4.13 Real Time Current, Voltage, Power Value



Fig. 4.14 Power Consumption From Solar Panel

Fig 4.14 Shows that the power consumption from solar panel, stand alone mode 24h backup.



Fig. 4.15 Solar Panel Produce 12.6V to load

Fig 4.15 Shows that the solar panel producing 12.6V to the connected load.



Fig. 4.16 Solar Panel Receiving Power

Fig 4.16 shows that the Power receiving via solar panel is 13.2V.



Fig. 4.17 Power stored in Battery

Fig 4.17 shows that the power stored in battery is 7.3V. From the stored battery power it can share with loads.



Fig. 4.18 When Load not Connected, value of Voltage, Current and Power

Fig 4.18 shows that the load is not connected & it shows 0 value. In our system, it's mandatory to load connected first. If there is no load connect then no value will show to display & it will not send to data server.



Fig. 4.19 When Load Connected, value of Voltage, Current and Power

Fig 4.19 shows that the load is connected with system. As a result, value is showing to the display. Besides, it sends the value to the cloud server. No function will execute if we do not connect load with our system.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

The project shows the real time power monitoring and data logging system using Internet of Things (IoT). The main objective of this study is developing a useable, low cost assistive solar power monitoring device. In this project we developed a solar power monitoring and data logger system with an in-built programmed ESP32 builtint WiFi microcontroller. Where data is continuously transferring to cloud server besides it will save its data to its EEPROM. From the public channel server power monitoring system can access anytime from anywhere in the world. As a result, anyone can observe the system configuration along with environment situation remotely. The entire processes of different methodology are accumulated. The codes are mentioned in the Appendix part.

5.2 Advantages and Application

IoT based solar power monitoring and data logger system will help to record real time data. It can be monitored from the far, we can track the power consumption. We can easily download the report whenever we want it.

We can use our system in power management, energy monitoring, home appliances monitoring and can be implemented in transmission line using high rating CT and PT.

5.3 Limitations

- WiFi connectivity varies from location. Sometimes it works so fast. And disconnects too. WiFi connectivity should more stable.
- Firmware Upgrade Over the Air is not implemented in this system. To upgrade firmware, need to connect system with computer.
- It is a prototype device, not for production.

5.4 Future Works

We are hopeful to make some future works that can be done with it to modify it with its best outcomes. Some suggestions of the possibilities of future works are given below:

- For production purpose design a Printed Circuit Board
- OTA feature enable in the system, as it can be firmware upgraded anytime.
- Real Time Operating System(RTOS) implementation in programming. For large scale system, without time management it cannot be handled. RTOS can be the best solution.
- Addition portable system both builtin WiFi and SIM Module. SIM module will enable where WiFi is not available.
- STM32 Microcontroller implementation in system. It is industrial grade Microcontroller and it has lots of good features.

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APPENDIX

Listing 6.1 Program of System Arduino (C/C++)

```
1 #include <WiFi.h>
  #include "ThingSpeak.h"
3 #include "DHT.h"

5 const char* ssid = " ";    // your network SSID (name)
  const char* password = " "; // your network password
7
  WiFiClient  client;
9

11 #include <Wire.h>
   #include <LiquidCrystal_I2C.h>
13 #define DHTPIN 4
   #define DHTTYPE DHT11
15 #define VT_PIN 35// connect VT
   #define AT_PIN A1 // connect AT
17
   DHT dht(DHTPIN, DHTTYPE);
19 #define ARDUINO_WORK_VOLTAGE 5

21 unsigned long myChannelNumber = 3;
   const char * myWriteAPIKey = "MR8SISLTZ6FBY828";
23
   unsigned long lastTime = 0;
25 unsigned long timerDelay = 30000;

27 LiquidCrystal_I2C lcd(0x27, 20, 4); // LCD2004

29 void storedata();

31 void setup()
  {
33   Serial.begin(9600);
     WiFi.mode(WIFI_STA);
35   ThingSpeak.begin(client);
     dht.begin();
37   lcd.init(); // initialize the lcd
     lcd.backlight();
39   lcd.print("IIUC EEE");

41   delay(1000);

43   lcd.clear();
  }
45
  void loop() {
```

```

47  if ((millis() - lastTime) > timerDelay) {
49      if (WiFi.status() != WL_CONNECTED) {
51          Serial.print("Attempting to connect");
52          while (WiFi.status() != WL_CONNECTED) {
53              WiFi.begin(ssid, password);
54              delay(5000);
55          }
56          Serial.println("\nConnected.");
57      }
58
59      lcd.setCursor(0, 0);
60      lcd.print("IoT Solar Power Monitor");
61
62      int vt_temp = analogRead(VT_PIN);
63      int at_temp = analogRead(AT_PIN);
64
65      float voltage = vt_temp * (ARDUINO_WORK_VOLTAGE / 4095.0) * 5;
66      float current = vt_temp * (ARDUINO_WORK_VOLTAGE / 4095.0);
67      float power = voltage * current;
68      lcd.setCursor(0, 1);
69      lcd.print("Voltage= " + (String)voltage + " V ");
70      Serial.println("Voltage= " + (String)voltage + " V ");
71      lcd.setCursor(0, 2);
72      lcd.print("Current= " + (String)current + " A ");
73      Serial.println("Current= " + (String)current + " A ");
74      lcd.setCursor(0, 3);
75      lcd.print("Power= " + (String)power + " Watt ");
76      Serial.println("Power= " + (String)power + " Watt ");
77      delay(500);
78
79      delay(1500);
80      float humidity = dht.readHumidity();
81      // Read temperature as Celsius (the default)
82      float temperature = dht.readTemperature();
83      // Read temperature as Fahrenheit (isFahrenheit = true)
84      float f = dht.readTemperature(true);
85
86      // Check if any reads failed and exit early (to try again).
87      if (isnan(humidity) || isnan(temperature) || isnan(f)) {
88          Serial.println(F("Failed to read from DHT sensor!"));
89          return;
90      }
91
92      // Compute heat index in Fahrenheit (the default)
93      float hif = dht.computeHeatIndex(f, humidity);
94      // Compute heat index in Celsius (isFahreheit = false)
95      float hic = dht.computeHeatIndex(temperature, humidity, false);
96
97      Serial.println(F("Humidity: "));

```

```

97     Serial.print(humidity);
    Serial.println(F("% Temperature: "));
99     Serial.print(temperature);
    Serial.print(F("°C "));
101    Serial.print(f);
    Serial.print(F("°F Heat index: "));
103    Serial.print(hic);
    Serial.print(F("°C "));
105    Serial.print(hif);
    Serial.println(F("°F"));
107    ThingSpeak.setField(1, current);
    ThingSpeak.setField(2, voltage);
109    ThingSpeak.setField(3, power);
    ThingSpeak.setField(4, humidity);
111    ThingSpeak.setField(5, temperature);
    int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
113
    if (x == 200) {
115        Serial.println("Channel update successful.");
    }
117    else {
        Serial.println("Problem updating channel. HTTP error code " +
            String(x));
119    }
    lastTime = millis();
121 }

123 }

125 void storedata()
{
127     EEPROM.write(0, current);
    EEPROM.write(0, voltage);
129     EEPROM.write(0, power);
    EEPROM.write(0, humidity);
131     EEPROM.write(0, temperature);
}

```