IOT BASED PORTABLE POWER STATION USING SOLAR ENERGY

By

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A Thesis

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Science

In

Electrical Engineering

Session 2019-2023

Department of Electrical Engineering

THE UNIVERSITY OF AZAD JAMMU AND KASHMIR

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بسم الله الرحمن الرحيم

"In the name of ALLAH, The Most Beneficent, The Most Merciful".

DEDICATION

We are thankful to Allah for his guidance and help throughout this project.

We dedicated this project to our respected teachers because without their efforts and guidelines it was difficult for us to complete this task.

We also dedicate this project to our beloved parents, brothers and, sisters because of their prayers and support due to which we were able to complete this task.

We devoted it to our families, Teachers, Friends and, all Engineers who are serving the worldwide local area.

ACKNOWLEDGMENT

In the name of ALLAH who is the Most Gracious and the Most Merciful.

All praises to ALLAH and His countless blessings for the completion of this thesis. We thank ALLAH for all the opportunities, trials, and strength that have been showered upon us to finish writing this thesis. We gained lots of experience during this process, not only from the academic aspect but also from the aspect of personality. Our humblest gratitude to the Holy Prophet Muhammad (SAW peace be upon Him) whose way of life has been continuous guidance for us.

Foremost, we would sincerely like to thank our supervisor Dr. Sheeraz Iqbal for his guidance, understanding, and patience. Most importantly, he has provided us positive encouragement and a warm spirit to finish this thesis. It has been a great pleasure and honor to have him as our supervisor.

We would also like to thank all our beloved friends who were with us and supported us through thick and thin. We also want to continue our thanks to the Admin staff in the faculty of engineering, University of Azad Jammu and, Kashmir for their help and support in the administrative works.

May ALLAH bless all of them with good health, prosperity, and honor in their life.

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ABSTRACT

The rapid growth of portable electronic devices and the increasing demand for sustainable energy solutions have led to the development of solar photovoltaic (PV) based portable charging stations. This thesis presents an overview of the design, functionality, and potential applications of such charging stations.

Solar PV portable stations capture solar energy with photovoltaic panels, storing it in batteries. They provide clean, renewable power, reducing reliance on fossil fuels. These stations conveniently charge devices like smartphones, laptops, electric bikes, and small appliances.

A solar PV charging station includes panels, controllers, storage, inverters, and multiple ports. It offers versatile charging and can be used as an emergency power source during outages or outdoor activities.

The thesis discusses the benefits of solar PV charging stations, including sustainability, versatility, and cost savings. It also addresses challenges like weather-dependent energy generation and the role of emerging technologies in overcoming them.

To conclude, solar PV-based portable charging stations offer a promising solution for sustainable and convenient on-the-go power generation. As technology progresses, they have the potential to significantly reduce carbon emissions and improve energy access across diverse settings, including urban areas and remote off-grid locations. This thesis provides insights into their design, functionality, and potential future advancements.

1 INTRODUCTION

1.1 Background

Recent research interests have been driven by concerns about the environment and the diminishing availability of fossil fuels in traditional power generation and transportation systems. This project focuses on the development of portable charging stations for various electronic devices, aiming to reduce greenhouse gas emissions and reliance on fossil fuels. Portable charging stations, which can be used for smartphones, laptops, and other devices, have the potential to contribute to a more sustainable energy landscape. These stations are designed to harness renewable energy sources, such as solar power, providing a clean and eco-friendly way to char devices.

In addition to their environmental benefits, portable charging stations offer several advantages, including increased energy efficiency, reduced maintenance requirements, and quieter operation. To ensure sustainability, it is crucial to power these stations with electricity generated from renewable sources rather than fossil fuels. A portable charging device based on solar PV technology consists of several essential components that collaborate to capture, store, and deliver renewable energy for charging various electronic devices. Its core elements encompass solar panels, an internal rechargeable battery, USB ports, charge controllers, and LED indicators. Solar panels are pivotal as they are responsible for converting sunlight into electrical power. The internal rechargeable battery acts as an energy reservoir, storing solar power for later use or when sunlight availability is limited, ensuring a consistent power supply. USB ports function as the connection point for electronic devices, providing adaptability and compatibility.

Charge controllers play a critical role in optimizing the charging process by preventing overcharging and voltage fluctuations. LED indicators offer valuable feedback to users, conveying information about the battery's status and charging progress. Collectively, these constituents render portable solar PV-based charging devices a dependable and environmentally friendly solution for energizing various gadgets while on the move, especially in outdoor or off-grid settings.

1.2 Problem Statement

The challenge posed by the development of a portable solar photovoltaic (PV) charging device stems from the growing global demand for cleaner and more sustainable energy solutions. In the face of an escalating dependence on portable electronic devices like smartphones, tablets, and laptops, there arises a critical requirement for convenient and environmentally conscious means of maintaining the power supply for these devices while on the move. Conventional energy sources often exhibit limitations, and the continued reliance on fossil fuels for charging exacerbates environmental harm. Consequently, the central issue to be addressed involves the creation of a cost-effective and efficient portable charging solution that leverages solar PV technology to swiftly and reliably power electronic devices. This endeavor encompasses overcoming challenges related to energy storage, device compatibility, and user convenience, all aimed at fostering a cleaner and more sustainable future. This study focuses on the following

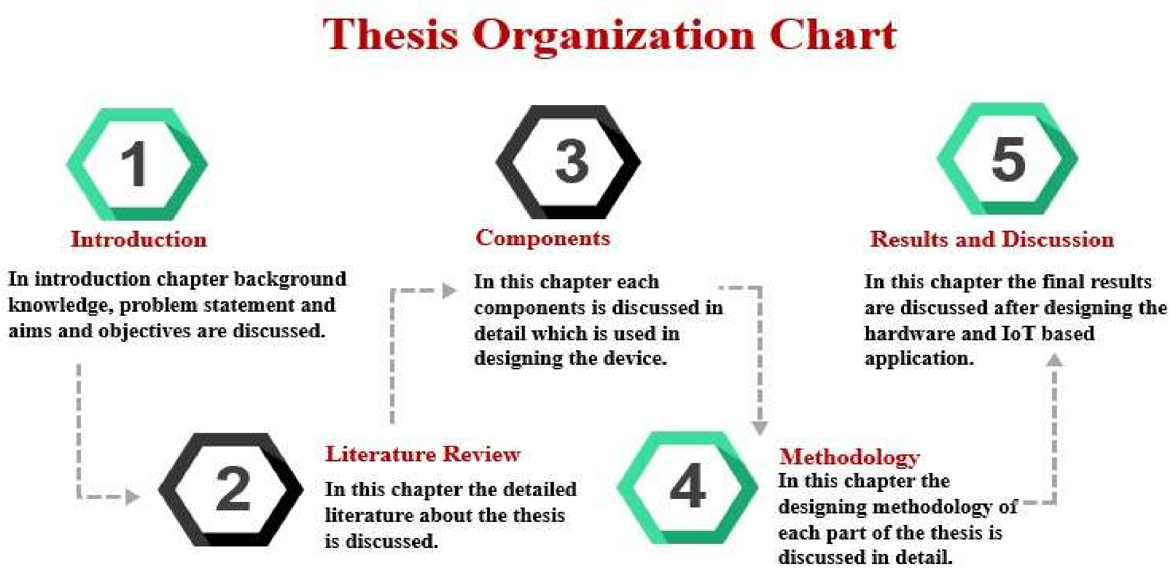
- Designing of the portable charging station using solar PV
- Smart IoT based real time monitoring of solar panel voltage generation.
- High voltage and low voltage chargers using different power converters.

1.3 Aims and Objectives

The aims and objectives of a solar PV-based portable charging device are multifaceted and pivot around addressing critical needs in today's energy landscape. First and foremost, the device aims to provide a clean and sustainable power source for a wide range of portable electronic devices, including smartphones, tablets, and laptops. It seeks to reduce our dependence on fossil fuels for charging, thus contributing to environmental preservation and reducing greenhouse gas emissions. Furthermore, the device aims to enhance energy accessibility in remote or off-grid areas, providing a reliable power solution for people who lack access to conventional electricity sources. To achieve these goals, the device's objectives include optimizing solar energy conversion efficiency, ensuring compatibility with various electronic gadgets, designing lightweight and user-friendly form factors, and maintaining affordability to make it accessible to a broad user base. Overall, the solar PV-based portable charging device aspires to promote clean energy adoption, convenience, and sustainability in a rapidly evolving technological landscape. The following is a list of the goals and objectives.

- Development of Solar PV based multipurpose portable Charging device.
- Design and development of High and Low voltage chargers using power converters.
- Designing of smart IoT-based circuitry for panel voltage generation monitoring.

1.4 Thesis organization



1.5 SDGs relevant to the thesis

1. **SDG 7 (Affordable and clean energy):** Sustainable Development Goal 7 (SDG 7) emphasizes the critical importance of affordable and clean energy for a sustainable future. It seeks to ensure access to modern energy services for all, particularly in underserved areas, while promoting the transition to renewable and efficient energy sources. By addressing energy access and environmental concerns, SDG 7 plays a pivotal role in mitigating climate change, fostering economic growth, and improving the quality of life worldwide.The thesis focuses on the development of solar PV based multipurpose charging device so the energy source is green and renewable and also it’s very cheap as compared to the other sources.
2. **SDG 9(Industry, innovation and infrastructure):** Sustainable Development Goal 9 (SDG 9) underscores the significance of industry, innovation, and infrastructure in achieving sustainable development. It aims to promote inclusive and sustainable industrialization, foster innovation, and upgrade infrastructure. By investing in these areas, countries can drive economic growth, enhance resilience, and facilitate access to

crucial services, ultimately contributing to a more prosperous and equitable global society. SDG 9 highlights the vital role of infrastructure and innovation as catalysts for progress in the modern world. This research work focuses on the innovation in the charging and battery industry of the electronic devices by using a sustainable infrastructure considering the environmental impacts of the energy sources.

2 LITERATURE REVIEW

Numerous techniques are suggested in the literature for determining the ideal charging schedule for portable solar PV-based charging devices. The centralized solution, however, is often impractical in some circumstances when operators of multiple solar PV charging stations handle dynamically changing data, such as the current state of the energy storage system and information about the devices being charged.

In this paper [1], author design, build, test, and analyses an electronic circuit that can be utilized as a solar portable charger for mobile phone devices that uses solar energy as a power source. A tiny solar cell panel that is easier to transport to regions away from city electric grids is chosen. The utilization of solar energy as a power source is useful in outdoor emergency circumstances since it avoids the typical method of waiting near electrical sockets or outlets for charging. We propose here a unique electronic design and construction with a significant advantage in managing battery charging currents.

In [2] author showcases a techno-economic evaluation of a sustainable, small-scale PV/Wind/Battery hybrid system designed for providing off-grid electricity to rural areas in Mbouda. The research employs HOMER Pro for optimizing and conducting sensitivity analysis on this hybrid system. The results from this investigation reveal that, in comparison to fixed solar panels, the dual-axis solar tracker system emerged as the most effective solution for maximizing power generation.

In [3] author designed a Smart Bag with a purpose-built design with wide-ranging utility for individuals across society. "Smart" denotes its intelligent capabilities, as the bag is engineered to perform a multitude of everyday functions. At its core, the microcontroller ATmega16 serves as the system's central controller, overseeing all its distinctive features. The bag incorporates a solar panel on its front, enabling it not only to charge electronic devices such as mobile phones and laptops but also to power the entire system. To address the issue of forgetfulness when packing essential items, RF-ID technology will be harnessed.

In [4] author proposes a solution (G. Dispenza a, 2017)for smart cities encompasses a diverse range of objectives, primarily aimed at reducing pollutant emissions, enhancing energy efficiency, and optimizing energy production and consumption. Complying with the latest European directives, alternative fuels are expected to play a pivotal role in the future of transportation. Within the scope of the Italian research project named i-NEXT (Innovation for Green Energy and Exchange in Transportation), CNR-ITAE has developed a microgrid capable of harnessing solar energy as its input source and providing hydrogen and electricity for both electric and hydrogen vehicles as its output. This system is powered by a 100 kW photovoltaic array situated on the roof of a vehicle recovery shed.

In [5] author discusses the integration of cutting-edge technologies has sparked a remarkable surge in automated appliances within the housing sector. The establishment of new infrastructures to cater to electrical demands has become increasingly vital to ensure the safety and functionality of residential devices. A significant approach in this regard is Demand Side Management (DSM), a fundamental element in both micro-grid and Smart Grid technology. DSM involves the strategic control of energy consumption while maintaining the trust and satisfaction of consumers. Much of the research on Demand Side Management has concentrated on assisting households in optimizing their electricity usage plans.

In [6] author proposes Vehicle-to-Home (V2H) is regarded as a promising and fertile area of research, owing to its potential to tackle various challenges associated with smart household electricity consumption and consumer energy needs. With the expanding population and evolving lifestyles, the demand for residential energy continues to rise, presenting increasingly complex electricity supply challenges. In response, the implementation of a Home Energy Management System (HEMS) is gaining traction to mitigate these issues. To optimize the use of various household appliances in accordance with energy demand and a predetermined schedule, we propose the deployment of a precise Home Centralized Photovoltaic (HOCP) System, incorporating V2H technology, Solar Photovoltaic (SPV) panels, and a Green Electric Vehicle (GEV).

In [7] The author explained that the global enthusiasm for renewable energy-driven power systems is spurred by their plentiful supply and eco-friendly characteristics. A recent advancement in this domain is the emergence of Islanded Hybrid Microgrid Systems (IHMS). These systems entail the fusion of two or more sustainable energy sources, including wind turbines, solar photovoltaic (PV) systems, and other renewables like ocean, wave, and geothermal energy. To ensure an uninterrupted power supply for the expanding community and industrial sector on Perhentian Island, Malaysia, it is imperative to effectively synchronize and regulate these alternative energy sources through a comprehensive energy management system.

In [8] author proposes a novel study for daily activities associated with farming and gardening, irrigation holds paramount importance. This is especially true in the context of rice cultivation, where substantial amounts of water are traditionally used. The conventional approach involves maintaining a continuous standing water level over the paddy fields throughout the entire growth cycle of the rice crop, even though it is not imperative to do so. An innovative technology known as Alternate Wetting and Drying (AWD) irrigation systems offers a contemporary solution that not only conserves water but also enhances crop yields.

In [9] author discusses the results achieved through the implementation of the EESAEO algorithm lead to a reduction in electricity costs, enhanced network performance, increased customer comfort, and a decrease in peak load formation. To gauge the effectiveness of the EESAEO algorithm, it is pitted against the original algorithm using simulated data. Various pricing strategies, including Time of Use (TOU), Critical Peak Pricing (CPP), and Real-Time Pricing (RTP), are employed to validate the efficiency of the system under investigation. The positive outcomes obtained demonstrate the viability of employing this method for scheduling household appliances.

In [10] The author provide a detailed introduction to the primary components and functions of renewable energy resources, encompassing solar, wind, geothermal, hydropower, ocean, and biofuels, within the context of smart cities. Furthermore, we delve into a thorough analysis of the integration of these renewable sources into the energy systems of smart cities, examining them through both technical and economic lenses. Finally, we address existing challenges and outline future scenarios, offering an in-depth discussion to shed light on the advancements and prospects of smart renewable energy systems in the context of smart cities.

With the continued demand for energy and concerns about environmental sustainability, portable solar PV-based charging devices have become essential for both personal device charging and powering various applications. Alongside this demand, there has been increasing awareness of the need to reduce reliance on non-renewable energy sources, lower emissions, and mitigate environmental risks associated with fossil fuel-based power generation [11].

Several countries, including the United States, the United Kingdom, Japan, and various European nations, have implemented regulations pertaining to transportation networks. These regulations are aimed at reducing emissions associated with the use of portable solar PV-based charging devices. Notably, since the adoption of stringent emission regulations in these regions, there has been a remarkable 99% reduction in the net percentage of "atmospheric aerosol particles" generated by the operation of these devices. Additionally, levels of carbon dioxide and nitrogen dioxide emissions have witnessed significant declines since the implementation of these regulations.[12]

Looking ahead, there are ambitious plans in Europe to further reduce carbon dioxide emissions from portable solar PV-based charging devices. By the year 2020, the target is to achieve reductions of 95 g/km for carbon dioxide emissions and 35 mg/km for nitrogen dioxide emissions. These efforts underscore a commitment to combat air pollution and promote sustainable energy solutions through the use of portable solar PV-based charging devices.

In [13] electric vehicles are pricing internal combustion engine automobiles out of the market as a result of this paradigm shift (ICEVs). A number of countries, including the United States, the United Kingdom, China, and European nations, are aware of how well EVs perform and have issued a number of resolutions and donated large sums of money to encourage the widespread use of EVs.

All EV fleets will be powered by RES by 2050, according to anticipated planning timeframes. Actually, what has boosted EV usage and popularity is the development of battery technology and the growth of battery charging infrastructure in an attempt to fulfil their energy demands. The overall design of the charging infrastructure is crucial for marketing EVs [14].The primary disadvantage of EV charging infrastructures is that they only pull power from the grid, which makes them environmentally unfriendly. Given that EV charging can be managed and that renewable energy sources are distributable and time-limited, it follows that RES and EVs work best together Electricity production and EV charging must be balanced in order to ensure and sustain secure continuous grid operation. One of the major issues that has to be resolved for the electrical system to function in the future is the unpredictable nature of RES production. When using a range of load operating modes, load fluctuation management and power control have historically not worked effectively together to balance the grid. Scheduling loads when RES output is controlled has generally been advocated as a workable solution because scheduling additional electricity production is critical for the efficient operation of the power system. Furthermore, EVs have demonstrated that they can assist the primary grid in maintaining a specific level of supply and demand equilibrium, increasing the likelihood of RES adoption.

Actually, this subject has been the subject of a lot of study articles, including those in [15]. Additionally, PV production can sustain EV use because the energy demands of EVs do not considerably increase the overall load [16]. But regardless of how EVs and PVs are incorporated into the grid—individually or in tandem—adequate planning is necessary to avoid jeopardizing system reliability.

According to electricity grid operators, the most critical issue in PV production is temporal unpredictability [17]. The issue with EVs is that they may disrupt claim and overload the grid, reducing power quality and system stability.

According to the authors of [18], EV and PV grid penetration needs to be managed and controlled; for instance, more EVs and PVs can be added by adopting the planned load technique. RES, particularly PV, WT, and biomass energy, may presently be utilized to scale up electricity output in the power grid. Due to their high energy density, inexpensive construction costs, ease of use, and increased power production efficiency, they are often used to swiftly charge EVs [19, 20]. Solar energy is currently commonly used because of the sun's intense radiation on Earth's surface and because it is silent and non-polluting. Since the amount of electricity a stand-alone PV system can produce depends on the weather and its surroundings, it is often unreliable.

Since the PV system can be quickly and easily constructed using different power sources, it is simple to utilize in private homes and/or public areas. The erratic character of PV power output can be considerably reduced by utilizing an energy storage device at the charging station [21, 22]. It is taken into account how the mismatch between energy supply and demand affects the charging system's design. Along with a study of EV users' daily travel patterns, complete modelling of climatic data, such as solar irradiation and temperature, is also necessary. The nominal power of the PV, grid, and BSS must be taken into account while building the EV charging system to estimate the necessary number of power conversion stages.. During periods of overproduction, the ESS stores energy to power the charging system during periods of low production, allowing it to handle changes in solar energy production or the electrical grid at the same time. To make the EV charging cycle follow changes in power source output, modern charging systems use intelligent charging strategies [23, 24].

Based on their mode of operation and comparative analysis, the study [25] provides a variety of traditional and complex battery charging techniques as well as power topologies. Based on their charging location, charging time, connection type, architectural portfolio, and comparative performance study of different power converters used in EV chargers, the various EV charging station levels are examined. In order to lessen the uncertainties brought on by transmission power networks, this article stresses the usage of integrated renewable energy (RE) together with an effective energy management algorithm and an architecture for charging electric cars. Just a few of the cutting-edge charging methods being investigated for electric cars include fast charging, smart charging, wireless charging, and battery swapping.

According to the study [26], installing EV charging stations on a large scale poses a number of challenges for the electricity system and public facilities. Due to the demand on power infrastructure and physical space constraints, the simple solution of installing additional charging stations to increase charging capacity to address the issue of lengthy charging periods does not work. Using modelling and optimization, researchers have focused on developing clever scheduling methods to control the demand for public charging. A growing number of people are interested in using data-driven methodologies to model EV charging. Researchers are looking for trends in consumer charging behaviours to find information and predictive analytics.

In a work [27], the charging problem is presented in a novel way that particularly considers discrete action sets for EVs. The three components of a day of the case make up the cost function being considered. The suggested distributed algorithm, which is examined with game-theoretic tools like ordinal potential games, determines charging start times. It is shown that convergence of the given approach is assured for a few critical particular circumstances. Surprisingly, the performance isn't significantly worse than with the centralized approach. Through simulations based on real-world, publicly available data, as well as explicit messages about the trade-offs associated with including the three components in the examined cost function, it is possible to gain a better understanding of the issues with convergence and optimality loss. Simulations show that, under ideal non-EV demand forecasting conditions, the proposed charging policy outperforms other (continuous) charging policies, such as valley-filling type solutions, but they also highlight an additional benefit of rectangular profiles.

In the paper [28] authors look at 7,979 Californians who own plug-in electric vehicles (PEVs) and their charging habits. The survey looks into how people charge their devices, including where they charge them—at home, at work, or in public settings—and what kind of charging they do—

level 1, level 2, or DC fast charging. Studies usually draw general conclusions on charging behaviour, even as PEV owners' charging behaviours vary depending on their travel choices, access to infrastructure, and other factors. The authors of this study assess differences in charging behaviour by looking at how various PEV owner categories use charging places and levels. The authors then list the elements that affect PEV owners' decisions on charging location and intensity. We found that the availability of workplace charging, car attributes, commute habit, and socio demographics (gender and age) were all significant factors influencing the choice of charging station.

The Adaptive Charging Network (ACN), which was originally employed on the Caltech campus in early 2016 and is currently used at over 100 more locations around the US, is described by the author in the publication [29]. The architecture allows extensive EV charging as well as real-time monitoring and management. The adaptive scheduling method used by the ACN, which permits significant over-subscription of electrical infrastructure, is based on model predictive control and convex optimization. We talk about several real-world problems with charging systems, such unbalanced three-phase wiring, inadequate battery charging, and quantized control signals. We use accurate system models and actual workloads from the Caltech ACN to show how the Adaptive Scheduling Algorithm addresses these issues. We also compare the algorithm's performance to other benchmark techniques from the deadline scheduling literature. When supplying energy to congested networks, our scheduling method frequently outperforms baseline algorithms, and in these real-world scenarios, it can increase operating profit by 3.4 times over uncontrolled charging.

In the research [30], Reinforcement Learning (RL) has been widely used to regulate EV charging. RL is based on maximizing the cumulative reward, unlike other machine learning algorithms. The literature review presented in this paper discusses the objectives, architecture, and RL-based framework for coordinating charging methods for electric cars in power systems. The review study also provides a thorough comparative examination of the strategies used to meet different constraints and achieve distinct charge coordination goals. This article focuses how to utilize RL to coordinate EV research and development, as well as the most advanced optimum energy management system (EMS) for EV charging.

The authors of the research presented a model for a fast electric car charging station that is linked to the grid, assures high power transfer quality, and has low harmonic currents [31]. Electric cars are linked to a DC bus at the charging station through battery chargers via a converter that links the grid to the DC bus. Decentralized charging is used for individual cars, and a different management system keeps an eye on the power being sent from the AC grid to the DC bus. To lessen the effect of rapid charging on the grid, an energy management strategy based on effective power flow is also advised. A solar PV generating system and a charging station are connected using this technique. By reducing both the net energy supplied by the grid and the power output of the EV fleet batteries placed at the charging station, the integrated solution lowers total grid load and conversion.

The adaptive utility-oriented scheduling (AUS) method was suggested by the study's authors [32] in order to optimize total value for the charging operator while attaining a low job dropping probability and a high profit. In order to lessen performance degradation brought on by a disparity between charging information and vehicle stochastic arrivals, the charging operator may additionally use the previous reservation technique. The authors then run thorough simulations with accurate EV charging parameters and TOU prices. Results from simulations show how the suggested AUS algorithm works better than current benchmark scheduling methods.

Researchers looking into this question are looking into whether solar energy can be utilized to recharge battery-powered cars at work in the Netherlands [33]. The direction from which PV panels in the Netherlands will generate the most power is determined using information from the Dutch Meteorological Institute. To ascertain the amount of energy available for EV charging and if a grid connection is necessary, the seasonal and diurnal fluctuation in solar insolation is evaluated. The power rating of the PV array may be 30% greater than the power rating of the converter due to the Netherlands' comparatively low solar insolation. To lessen dependency on the grid and maximize the use of solar power to directly charge the EV, several dynamic EV charging profiles are researched. There are two scenarios under consideration: one in which EVs can only be charged on weekends, and the other in which they can be charged every day of the week. A priority approach is suggested to allow many EVs to be charged from a single EV-PV charger. If local storage is added, it is determined if EV-PV chargers will become grid independent. What storage capacity will reduce grid dependence by 25%.

The paper's authors [34] proposed a scheduling algorithm based on a dual-objective optimization model that seeks to maximize user satisfaction while minimizing user cost while taking into account a variety of metrics such as charging and discharging entity location, waiting time, and EV driving speed, among others. To solve the optimization model, a superior Non-dominated Sorting Genetic Algorithm (NSGA) is proposed. The effectiveness of the suggested scheduling technique is evaluated through experiments using a real-world map of Beijing. The findings indicate that when compared to V2V-based and G2V-based algorithms, the suggested method performs better in terms of user happiness and user cost.

3 COMPONENTS

3.1 Solar Panel

Solar energy is harnessed from the sun, utilizing photovoltaic (PV) panels, often called solar panels, which capture the sun's radiant light consisting of tiny energy particles known as "photons" to generate power for various applications. Solar panels find utility in diverse settings, including remote cabin power systems, telecommunications equipment, remote sensing devices, and residential and commercial solar electric systems. These panels convert sunlight, a sustainable and clean energy source, into electricity, subsequently powering electrical devices and systems. Each solar cell within a panel consists of layers of silicon, phosphorous (inducing a negative charge), and boron (imparting a positive charge). Solar panels absorb photons, leading to the generation of an electric current. The electric field created by the cells launches electrons from their atomic orbits, guiding them into a controlled current. This entire process is known as the photovoltaic effect. Typically, the roof space of an average household can accommodate the necessary number of solar panels to potentially supply the entire home with solar energy, with any excess energy being fed back into the main power grid, thereby reducing nighttime electricity consumption. Well-balanced solar arrays connected to the grid generate daytime energy for immediate use and offer compensation opportunities for surplus energy generation through net metering programs.

Off-grid solar systems are essential components of energy autonomy, typically comprising battery banks, charge controllers, and often inverters. In this system, the solar array generates direct current (DC) power, which is directed to the battery bank through the charge controller. Before the energy is drawn from the battery bank, the inverter plays a pivotal role by converting DC into alternating current (AC), making it compatible with devices that operate on AC power. This transformation facilitated by the inverter enables the scalability of solar panel arrays, catering to a wide range of electrical load requirements. AC power generated in this manner can power a diverse array of applications, including telecommunications equipment, oil and gas flow monitoring systems, remote cabins, cottages, recreational vehicles, boats, residential properties, commercial establishments, Remote Terminal Units (RTUs), Supervisory Control and Data Acquisition (SCADA) systems, and various other electrical equipment.

Figure 3.1: Solar Panel

3.1.1 Uses

It is very practical to generate electricity from solar panels for a range of uses. Living off the grid would seem to be the most sensible choice. The term "off-grid living" refers to living apart from the main electrical grid. Solar power systems are a great addition to homes and cabins in isolated areas. From the closest main grid access point, installing an electric utility pole and cable is no longer unreasonably expensive. If properly maintained, a solar electric system has the potential to be less expensive and produce power for up to three decades.

Requirements

The requirements for a solar PV-based portable charging device are driven by the need for efficient, sustainable, and versatile power solutions in today's world. Firstly, it must possess high solar energy conversion efficiency to make the most of available sunlight, ensuring swift and reliable device charging. Compatibility with a wide range of electronic gadgets is crucial, accommodating various connectors and voltage requirements. Portability and user-friendliness are essential, with lightweight and compact designs, making it easy to carry and set up anywhere. Durability is paramount for outdoor use, ensuring the device can withstand environmental factors. Additionally, it should include effective energy storage mechanisms, such as integrated batteries, to provide power even when sunlight is limited. Affordability is key to making this technology accessible to a broader audience, while also contributing to sustainability goals by reducing reliance on traditional energy sources. Lastly, user education and support are essential to promote proper utilization and maintenance of these devices. In summary, a solar PV-based portable charging device must combine efficiency, compatibility, portability, durability, energy storage, affordability, and user engagement to meet the demands of a diverse and environmentally conscious user base.

3.2 Node MCU ESP 32

The SoC (System on Chip) microcontroller known as ESP32 has been quite popular recently. It is arguable as to whether the popularity of ESP32 increased as a result of the development of IoT or as a result of ESP32's launch. It's likely that 7–8 out of 10 persons you know who have contributed to IoT device firmware development have worked on the ESP32 at some time. Let's look at some of ESP32's key specs before getting into the real reasons for its popularity.

With the aforementioned features in front of you, it is fairly simple to understand why ESP32 is so popular. Think about what an IoT device's microcontroller (MC) would need to do. Sensing, processing, storing, and transmitting are the four main building parts of every IoT device, as you probably understood if you read the previous chapter. As a result, the MC should initially be able to communicate with a number of sensors. All standard communication protocols needed for the sensor interface, including UART, I2C, and SPI, should be supported. It should be able to count pulses and use ADC. All of these conditions are met by ESP32. Additionally, it has the ability to connect to capacitive touch sensors. As a result, ESP32 can smoothly communicate with the majority of standard sensors. Second, the C should have enough memory to retain the incoming sensor data and be able to conduct basic processing of it, often at rapid rates. The ESP32 can operate at a maximum frequency of 40 MHz, which is a sufficient frequency. Parallel computing is made possible by its two cores, which is an added benefit. Not to that, its 520 KB SRAM has ample capacity to process a variety of data onboard. Numerous well-known operations and transformations, including peak detection, Root Mean Square (RMS) computation, and Fast Fourier Transform (FFT), may be carried out on the ESP32. In terms of storage, ESP32 surpasses traditional microcontrollers by offering a file system inside the memory. The actual chip itself houses a mini-SD Card. SPIFFS not only lets you save data but also text files, images, HTML and

CSS files, and much more. People have utilized.WiFi servers developed with ESP32 to display beautiful Web sites by storing HTML files in SPIFFS.

The integration of WiFi and Bluetooth stacks into ESP32 for data transfer has been a game-changer. To test cloud communication, no additional module (such a GSM or LTE module) is necessary. You can get started with just the ESP32 board and an active WiFi network. You can utilize WiFi on an ESP32 device in Station and Access Point modes. It supports Hypertext Transfer Protocols (HTTPS) in addition to Transmission Control Protocol (TCP), Other common communication protocols include the Hypertext Transfer Protocol (HTTP), Message Queuing Telemetry Transport (MQTT), and others. Yes, what you heard is true. It is equipped with a crypto-accelerator, also known as a crypto-core, a unique piece of hardware whose main function is to accelerate the encryption process. As a result, you can furthermore safely connect to your web server. As a result, you can furthermore safely connect to your web server. Support for Bluetooth Low Energy (BLE) is essential for a number of applications. Of course, you may connect ESP32 to LTE, GSM, or LoRa modules. Therefore, ESP32 goes above and above expectations on the "transmitting data" front as well.

ESP32 must be quite expensive with all of its features, right? The finest thing is that. The average price of an ESP32 development module is $500. Additionally, the chip's modest size (25 mm x 18 mm, including the antenna area) enables its usage in products with extremely compact form factors. ESP32 may also be programmed using the Arduino IDE, which significantly reduces the learning curve. Isn't that wonderful? Are you eager to experiment with the ESP32? In the following chapter, let's begin by setting up the ESP32 board in the Arduino IDE.

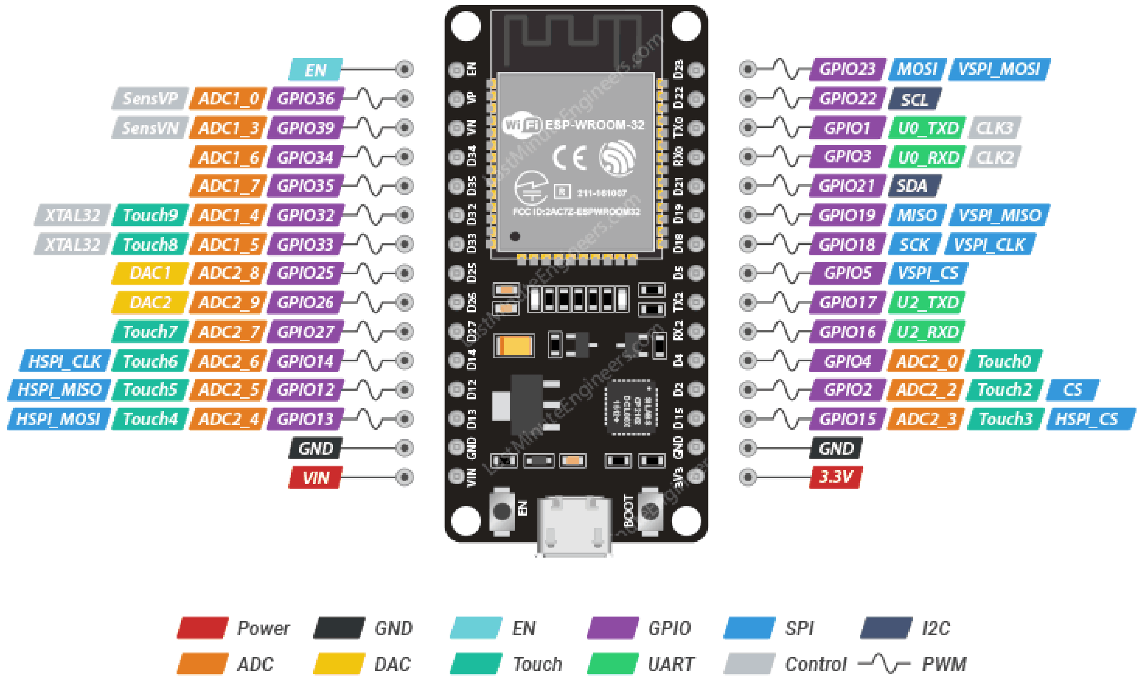


Figure 3.2: Parts of ESP-32

3.2.1 Applications

Now that you know a decent amount about ESP32, let's look at its use. In this chapter, I don't think I need to say anything. You would have developed thoughts in your brain after reading the tutorial's numerous parts. You would already have a list of potential uses for ESP32 in rough form. The majority of the applications you suggested are also possible, which is wonderful news.

For certain applications, ESP32 is more practical than for others. My main goal in this chapter is to help you understand the elements you should take into account when determining whether or not to utilize ESP32 for a certain application. Please be aware that this chapter focuses on manufacturing, that is, when thousands or lakhs of devices are being discussed. Simply utilize ESP32 without giving it a second thought if you only need a few devices and it can meet your needs. ESP32 can also be used without any reluctance for Proof of Concept (PoC) prototyping and establishment.

One of ESP32's key advantages is that WiFi and Bluetooth hardware and software stacks are already included. In static applications where dependable WiFi access is guaranteed, such as an environment monitoring application in, say, a laboratory, the ESP32 will therefore be the ideal microcontroller. Due to the fact that the WiFi stack is already included into the module, you will have saved money by not purchasing a separate networking module. However, you will need to rely on a GSM or LTE module if you utilize the ESP32 in an asset tracking application where the object is always moving. The ESP32's competitive advantage is gone in this situation, and you could be better off utilizing a less expensive microcontroller that can still accomplish your goals. In a similar vein, the ESP32 is the best choice for applications needing secure communication since it has a hardware accelerator for encrypting messages (HTTPS). So utilizing ESP32 is better than using other microcontrollers that don't enable encryption if you are working with sensitive data that you don't want to end up in the wrong hands. Industrial IoT in the military industry is one such use.

Once more, the ESP32 is your go-to microcontroller for processing-intensive applications like those that require separate cores for data processing and transmission and receive data at a very high baud rate due to the availability of two cores. The industrial IoT has a number of these applications. For a very light application where a secure connection is not even necessary, a microcontroller with basic specs might perform better. After all, why bother having (and effectively paying for) two cores if you can get away with only one.

The quantity of GPIOs and peripherals should be taken into account as well. The ESP32 features three UART channels. You might need to hunt for a different microcontroller if your application requires more than 3 UART channels. The ESP32 contains 34 programmable GPIOs, which are more than enough for the majority of applications. However, you might need to move to a different microcontroller if your application does require additional GPIOs.

You have more storage onboard the microcontroller with the ESP32's 1.5 MB of default SPIFFS than with most other microcontrollers. Your use of ESP32 eliminates the need for an external SD Card or Flash Chip if your storage needs are less than 1.5 MB. Wear-leveling inside SPIFFS is handled by ESP32 on its own, saving you a tone of work on development. The competitive advantage, however, vanishes if ESP32 is unable to meet your storage needs.

The 520 KB of Random Access Memory (RAM) on the ESP32 is likewise more than enough for the majority of applications. This only becomes a bottleneck in extremely demanding applications like image/video processing.

Last but not least, ESP32 features specifications that are suitable for the vast majority of your applications. Make sure the parameters aren't too demanding for you before raising production. In other words, you could be better off utilising a less costly microcontroller and saving money if you can provide the desired output with appropriate specifications. As your production numbers increase by orders of magnitude, these savings become considerable. The ESP32 is without a doubt the greatest microcontroller for producing proof of concept prototypes, regardless of whether it is produced.

3.3 Voltage Sensor

Wireless voltage sensors can be installed in a variety of equipment, machinery, and assets to enable continuous, round-the-clock monitoring for the detection of potential voltage anomalies. These sensors diligently collect voltage data, which may be a sign of deeper problems. Certain assets may be at risk from elevated voltage levels, while readings of low voltage may indicate possible issues. A central computer system receives notifications as soon as predetermined thresholds are breached. Magnetic, electromagnetic, and contact voltage fluctuations are all accurately detected by voltage sensors. They provide maintenance teams with useful information about the state of their assets and equipment, enabling proactive maintenance and problem solving.

Voltage sensors are used to monitor and communicate electric currents in devices such as tools, gadgets, batteries, and other sensors. This could help a maintenance team identify areas that need immediate attention or alert them to a potential problem.

3.4 Uses of Voltage Sensor

Voltage sensors is used to measure several parameters in a electric circuit.

Magnetic Fields

These sensors track magnetic flux as well as the strength and direction of a specific magnetic field that exists between two objects. They can be utilized in scientific measurement, industrial applications, and navigational equipment. Your computerized maintenance management system may receive a warning if a sensor notices a weak magnetic field (CMMS).

Electromagnetic Fields

The strength of these waves is monitored in vital assets by electromagnetic field sensors, which are able to spot speeding charged particles. These sensors, which are also employed in industrial, scientific, and navigational applications, can notify a company's CMMS when electromagnetic fields weaken.

Contact Voltage

Numerous applications and sectors can make use of sensors made to measure contact voltage. Battery monitoring is one such use. A battery could be inserted in a piece of equipment and then fall out of place after several months. When the contact voltage drops, this sensor will notice it and notify your CMMS. Then, a maintenance professional can investigate and make contact again.

The Three Main Types of Voltage Sensors

Voltage sensors are wireless devices used to monitor changes in various voltage types across a variety of assets. A facility's CMMS can get a notification when a disparity is found, and predictive maintenance can then be carried out.

AC Sensors

AC voltage is measured by these sensors. Power demand management, power breakdown detection, and load sensing are examples of typical uses. AC sensors can also be used to control motor overload and safety switching.

DC Sensors

These sensors can be used to monitor DC voltage if necessary. DC voltage sensors are useful for building control and energy management systems. Temperature control, data collecting, and defect detection are among additional typical applications.

Specialized Sensors

Other varieties of voltage sensors will be created for specialized applications as technology develops further. For instance, unique sensors may be needed for high-voltage applications, and many use fiber optic components to track voltage levels.

Popular Uses for Voltage Sensors

Facilities can monitor vital assets around-the-clock with the use of reasonably priced voltage detectors. Your equipment needs to be powered properly in order to run consistently. Here are a few frequent applications for voltage sensors.

Power Demand Monitor

The most power-hungry assets and pieces of equipment can be identified using sensors. Later, choices on energy conservation or efficiency can be taken.

Power Failure Monitoring

In a facility, a power outage can obviously have catastrophic results. Management can be informed by voltage sensors when there is a voltage drop that might indicate an upcoming power outage.

Load Sensing

In hydraulic systems, these sensors are typically employed to determine whether a specific pump is operating properly.

Fault Detection

They can be used to identify a specific issue with a piece of machinery or with the system as a whole.

Temperature Control

Temperature sensors, which are used to check whether a resource or location is within a safe temperature range, can break down. When this happens, they frequently release extra voltage, which a voltage sensor can detect.

Safety Switching

Your staff are more likely to receive an electric shock if there are faulty cables. A safety switching system that automatically shuts down or reroutes the voltage can be coupled to voltage sensors. It is also possible to send a warning so that the broken wires can be fixed.

Motor Overload Control

In hydraulic systems, these sensors are typically employed to determine whether a specific pump is operating properly.

Energy Management Controls

They can be used to identify a specific issue with a piece of machinery or with the system as a whole.

Building Control Systems

Temperature sensors, which are used to check whether a resource or location is within a safe temperature range, can break down. When this happens, they frequently release extra voltage, which a voltage sensor can detect.

Fault Detection

Your staff are more likely to receive an electric shock if there are faulty cables. A safety switching system that automatically shuts down or reroutes the voltage can be coupled to voltage sensors. It is also possible to send a warning so that the broken wires can be fixed.

Data Acquisition

They can significantly aid in the development of historical maintenance data in your CMMS. You may make better long-term judgments by gathering data on asset performance as well as maintenance frequency.

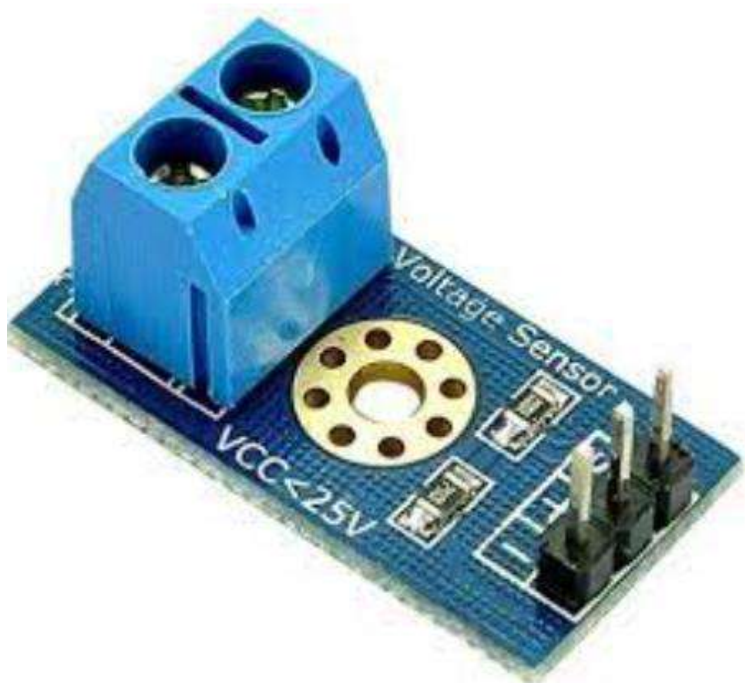


Figure 3.3: Voltage Sensor

3.5 Battery

One or more cells make constitute a battery. Each cell engages in chemical reactions to produce the flow of electrons in a circuit. The three main components of every battery are the anode (the "-" side), the cathode (the "+" side), and some type of electrolyte (a material that chemically reacts with the anode and cathode).

When the cathode and anode of a battery are connected to a circuit, a chemical reaction occurs between the anode and the electrolyte. Through this process, electrons return to the cathode and go through a second chemical change. The battery is unable to produce power when the cathode or anode material is exhausted or is not currently being utilized in the reaction.

Components

The anode, cathode, and electrolyte are a battery's three primary components. If the electrolyte is inadequate, a separator is often utilized to keep the anode and cathode from coming into contact. Batteries often have a kind of casing to house these parts. An electrode may be either a cathode or an anode. Electricity may flow into or out of a circuit element via conductors called electrodes.

Anode

The anode of an electrical device connected to a circuit emits electrons. This suggests that the well-known "current" enters an anode. In a battery, the chemical interaction between the anode and electrolyte builds up electrons. These electrons want to get to the cathode, but the electrolyte or separator blocks their path.

Cathode

In a piece of equipment that is linked to a circuit, electrons flow into the cathode. This demonstrates that a cathode generates steady "current." In batteries, the anode generates electrons that are utilized in the chemical process occurring at or near the cathode. The battery's external circuit is the sole path for the electrons to take in order to reach the cathode.

Electrolyte

The electrolyte may transport ions between the chemical processes taking place at the anode and cathode. It is commonly a liquid or gel. Additionally, the electrolyte allows electrons to move more freely across the external circuit between the anode and the cathode while preventing them from moving easily through the electrolyte itself.

The electrolyte is necessary for a battery to operate. Electrons are unable to pass through the anode, thus they must move through a circuit of electrical conductors that connects the anode to the cathode.

Separator

Separators, which are porous materials, prevent a short circuit in the battery by keeping the anode and cathode from coming into contact. A number of materials, including cardboard, cotton, nylon, polyester, and synthetic polymer films, may be used to create separators. Anodes, cathodes, and electrolytes do not chemically react with separators.

The electrolyte is made up of ions of different sizes and positive and negative charges. It is possible to create specialized separators that let certain ions through but not others.

Casing

Most batteries need a means of containing their chemical components. Casings, often referred to as "housings" or "shells," are essentially mechanical frames designed to house the battery's internal components. Almost any material, including plastic, steel, soft polymer laminate pouches, and others, may be used to create battery casings. A conducting steel shell and an electrode are connected electrically in certain batteries. The typical alkaline cell's cathode is linked to the steel shell.

Operation

In order to function, batteries often require a number of chemical reactions. The anode and its vicinity experience at least one reaction each, and the cathode and its vicinity experience one or more reactions. Every time, the cathode reaction uses the extra electrons that the anode reaction produces through a process known as reduction, and vice versa.

Every time, through a process known as reduction, the cathode reaction uses the excess electrons that the anode reaction generates, and vice versa. When electrons are moved between substances, redox reactions take place. To power our circuit, we can use the flow of electrons generated by this reaction as they leave the battery.

Anode Oxidation

Between the anode and the electrolyte, the redox reaction's initial step, oxidation, results in the production of electrons (marked as e-). Ions are created by some oxidation processes, like in a lithium-ion battery. In other chemistries, such as in the typical alkaline battery, the reaction consumes ions. In either instance, ions can readily move through the electrolyte but electrons are unable to do so.

Cathode Reduction

The second half of the redox process, reduction, takes place at or close to the cathode. During the reduction phase, the electrons generated by the oxidation event are used up. Other times, the reduction process uses the positively charged lithium ions created during the oxidation event, such in lithium-ion batteries. In some circumstances, such as with alkaline batteries, reduction results in positively charged ions.

Electron Flow

Most batteries permit some or all chemical reactions to occur even if they are not connected to a circuit. These answers may have an effect on a battery's longevity. The majority of the time, in order for the reactions to occur with the greatest amount of energy, an electrically conductive circuit must be established between the anode and the cathode. Chemical reactions can proceed more quickly when there is less resistance between the anode and cathode. We can direct these travelling electrons through a variety of electrical "loads"—or components—in order to do something helpful. We are using our moving electrons to ignite a fictitious light bulb in the motion graphic at the start of this section.

Dead Battery

The battery's chemical components will eventually achieve equilibrium. The chemicals won't have a tendency to react in this state, therefore the battery won't produce any additional electric current. The battery is now regarded as "dead."

The primary cells need to be thrown away once the battery is dead. By passing a reverse electric current through the battery, secondary cells can be recharged. Chemicals can be recharged by going through a fresh set of reactions to get back to their original condition.

Terminology

When discussing a battery's voltage, capacity, current sourcing capability, etc., people frequently utilize a standard set of words.

Cell

A cell is made up of a single anode and cathode separated by an electrolyte and used to generate voltage and current. One or more cells can be used to create a battery. One cell, for instance, is an AA battery. There are six 2.1 V cells in a car battery.

Primary

Chemistry of primary cells can never be changed. As a result, once the battery is dead, it must be discarded.

Secondary

Secondary cells have the ability to be recharged and have their chemistry changed back to what it was before. These cells, also referred to as "rechargeable batteries," have a long lifespan.

Nominal Voltage

The manufacturer has established the battery's nominal voltage. Alkaline AA batteries, for instance, are classified as having 1.5 V. According to this article from Mad Scientist Hut, the alkaline batteries they looked at start with a value of around 1.55 V and quickly fall voltage as they are depleted. The battery's maximum or starting voltage is shown by the "1.5 V" nominal voltage in this figure.

Capacity

The amount of electrical charge that a battery can generate at a given voltage is determined by its capacity. Milliamp hours and amp hours (Ah) are the most commonly used units for battery ratings (mAh). The majority of battery discharge graphs, like these Power Stream AA battery tests, show the voltage of the battery as a function of capacity. The mAh or Ah rating that corresponds to the lowest permitted voltage can help you assess whether a battery has adequate power to run your circuit.

C-Rate

To more accurately measure battery parameters, many batteries, most notably powerful lithium-ion batteries, express discharge current as "C-Rate". In proportion to the battery's maximum capacity, the C-Rate gauges the rate of drain. The battery might run out in an hour with 1C of energy. A 400 mAh battery, for instance, would be delivering 400 mA at 1 C of current. 5C would be 2 A for the same battery.

At greater current draws, the majority of batteries lose capacity. This product information graph from Charger, for instance, demonstrates that their LiPo cell has fewer mAh at higher C-Rates.

Figure 3.4: l2 volt battery

3.6 Power Converters

A DC-DC converter transforms the input source's DC voltage level into a different DC voltage level. You may utilise a direct conversion between DC and DC or another technique. An alternate approach is stepping up or stepping down the AC voltage using a step-up or step-down transformer before rectifying the AC back into DC. This method of changing the DC voltage level requires a lot of time and work. The fastest and easiest method is direct DC-DC conversion using a boost converter or buck converter. Boost converters operate to enhance input voltage while buck converters are used to reduce input voltage levels. Isolated and non-isolated DC converters are the two main topologies used in DC-DC converters. According to the concept of isolation, the AC component isolates the DC-DC converter's input and output. The rectifier, transformer, and inverter are the three essential components of an isolated DC-DC converter.

The apparatus that converts input voltage from DC to AC, Use a transformer to raise or reduce the AC voltage, and a rectifier to convert the voltage back to the desired level. A non-isolated DC converter, on the other hand, doesn't have an AC component separating the input from the output. A non-isolated DC converter just changes DC input into DC output as a consequence. The SEPIC converter, as well as the Cuk, Boost, Buck, and Buck-Boost, are examples of non-isolated DC-DC inverters. Push-pull, forward, flyback, half-bridge, and full-bridge converters are examples of isolated converters, in contrast to isolated converters. An essential part of a non-isolated converter that changes direct current to direct current is a regulated switch. However, when the switch is off, the load is devoid of power and the whole input voltage is visible across the switch. This is because when the switch is turned on, the input voltage may be felt throughout the load even when there isn't any.

The output pulses as a result of the switch's regular ON and OFF cycles. The output is then utilized to determine the DC average value of the pulsating output after passing through a filter. Since the input and output powers are identical, the ideal power loss is zero. A pure DC source, which is a DC current and voltage source devoid of any ripples or AC components, should preferably be used as the input side of a DC-DC converter. The DC-DC converter's output must meet the same criteria. The converter's output must be flawlessly converted with no AC components and no ripples. In reality, current ripples are present at the inputs of DC-DC converters whereas voltage ripples are present at the outputs. Filters are therefore needed at both the input and output ends. For the purpose of obtaining average voltage and eliminating ripples, the output filter is essential.

3.7 Buck Converter

By directly lowering the applied DC input voltage, buck converters. directly denotes a buck converter or other non-isolated DC converter. In any board-level circuit that requires local conversion, non-isolated converters should be used. Board-level circuits, such as those found in copiers, fax machines, and scanners, may necessitate conversion at any point in the circuit. A buck converter transforms the input voltage from DC to the other necessary levels as a consequence. Applications requiring low voltage and low power often employ buck converters. High current at low voltage may be produced using buck converters with many phases. This makes it feasible to use both low voltage and high power applications. This study will examine both low voltage low power converters and low voltage high power converters.

Through the use of synchronous and resonant versions, the converter's efficiency may be increased. The multiphase variant of buck converters is the alternate technique for increasing efficiency. The possible efficiency improvement that multiphase inverters might provide is examined in the article's conclusion. A controlled switch, a diode, a capacitor, and controlled driving circuitry make up the basic buck converter. The switch alternates between the ON and OFF states often to regulate the amount of input power that goes into the output. The duration of time the switch is on is known as the duty cycle.

Figure 3.5: Buck Converter

3.8 Boost Converter

When converting DC to DC power, a boost converter, also known as a step-up converter, lowers current while raising voltage from the input (supply) to the output (load). At least two semiconductors, a diode and a transistor, as well as at least one energy storage device are included in this switched-mode power supply (SMPS) (a capacitor, inductor, or both). Capacitor-based filters are often attached to the input (a load-side filter) and output (rarely in combination with inductors) to decrease voltage ripple (supply-side filter). Any acceptable DC source, such as batteries, solar panels, rectifiers, and DC generators, may be used to power the boost converter. The technique of converting one DC voltage to another DC voltage is known as DC to DC conversion. Any DC to DC converter with an output voltage greater than the source voltage is referred to as a boost converter. A boost converter is sometimes referred to as a step-up converter since it "steps up" the source voltage.

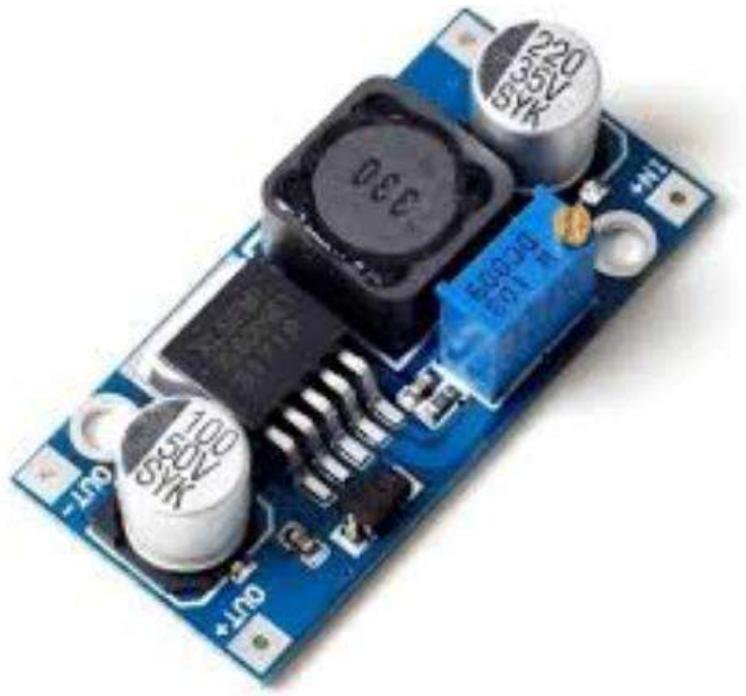


Figure 3.6: Boost Converter

4 METHODOLOGY

4.1 Circuit Simulation

To ensure optimal energy generation from solar power plants, consistent monitoring is essential. This monitoring helps detect issues like damaged solar panels, connectivity problems, the gradual accumulation of dust reducing output, and other factors that affect solar performance. Our advanced Internet of Things (IoT)-based automated solar power monitoring technology offers remote, automated monitoring of solar power systems from any location via the internet. Collecting and analyzing solar energy metrics through IoT allows us to predict system performance and maintain stable power generation.

The primary advantage of our solar panel monitoring system is its ability to identify optimal performance levels, enhancing the maintenance of photovoltaic (PV) systems. This system is constructed using a Wi-Fi-enabled ESP8266 microcontroller, which communicates with the Thingspeak platform to transmit data to the cloud. Implementing a wireless monitoring system not only enhances operational reliability but also incurs minimal additional costs.

As we are well aware, the battery is a critical component of any device, as it powers the entire apparatus. To prevent damage to the battery and avoid system failures, it is imperative to monitor the battery's voltage level, as improper or excessive charging and discharging can be detrimental. Most electrical and electronic equipment incorporate a Battery Management System (BMS), which monitors voltage, current, temperature, and includes an auto-off feature for the battery.

In our IoT-based battery monitoring system, we utilize the NodeMCU ESP8266 to transmit battery status data to ThingSpeak's cloud platform. This real-time monitoring allows us to track voltage levels both during battery charging and discharging processes, ensuring the battery's health and optimal performance.

In our device, we have ingeniously incorporated two distinct power output options to cater to a wide range of electronic devices and their varying power requirements. The first power output, operating at a standard 5 volts, is designed to efficiently charge common portable gadgets such as mobile phones, tablets, emergency lights, and even medical devices like blood pressure monitors. This versatile 5-volt plug ensures that users can conveniently charge their everyday devices without any compatibility issues.

For those with more substantial power needs, our device offers a second high-voltage output capable of delivering up to 18 volts. This higher voltage output is specifically tailored to charge larger devices, such as laptops and other electronics that demand a higher power input. Whether you're a professional on the go, a student working on a laptop, or anyone in need of a quick laptop charge, our high-voltage output has you covered.

To achieve these precisely calibrated power outputs, we've implemented power converters within both power output designs. These converters play a pivotal role in transforming the input energy from the solar panels into the desired output power for the connected load. This ensures not only efficient charging but also the utmost safety of your valuable electronic devices. Whether it's the convenience of charging your smartphone or the flexibility of charging your laptop, our device provides you with a reliable and adaptable power solution for all your needs.

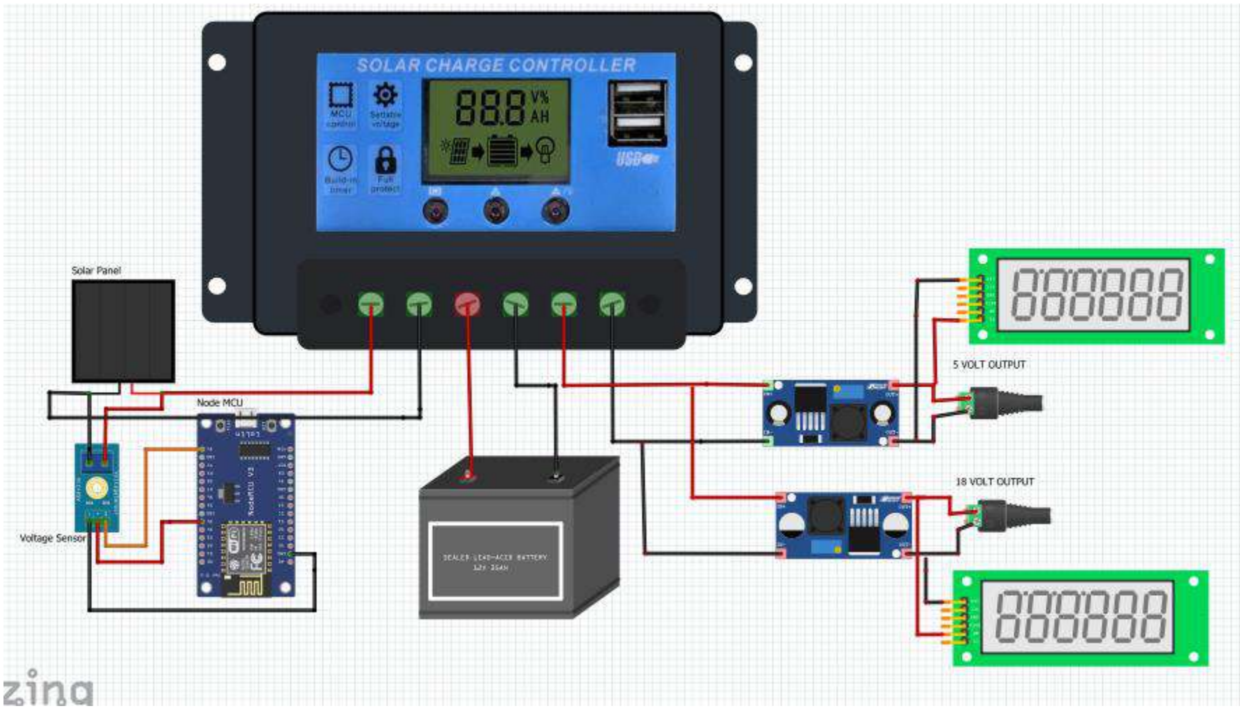
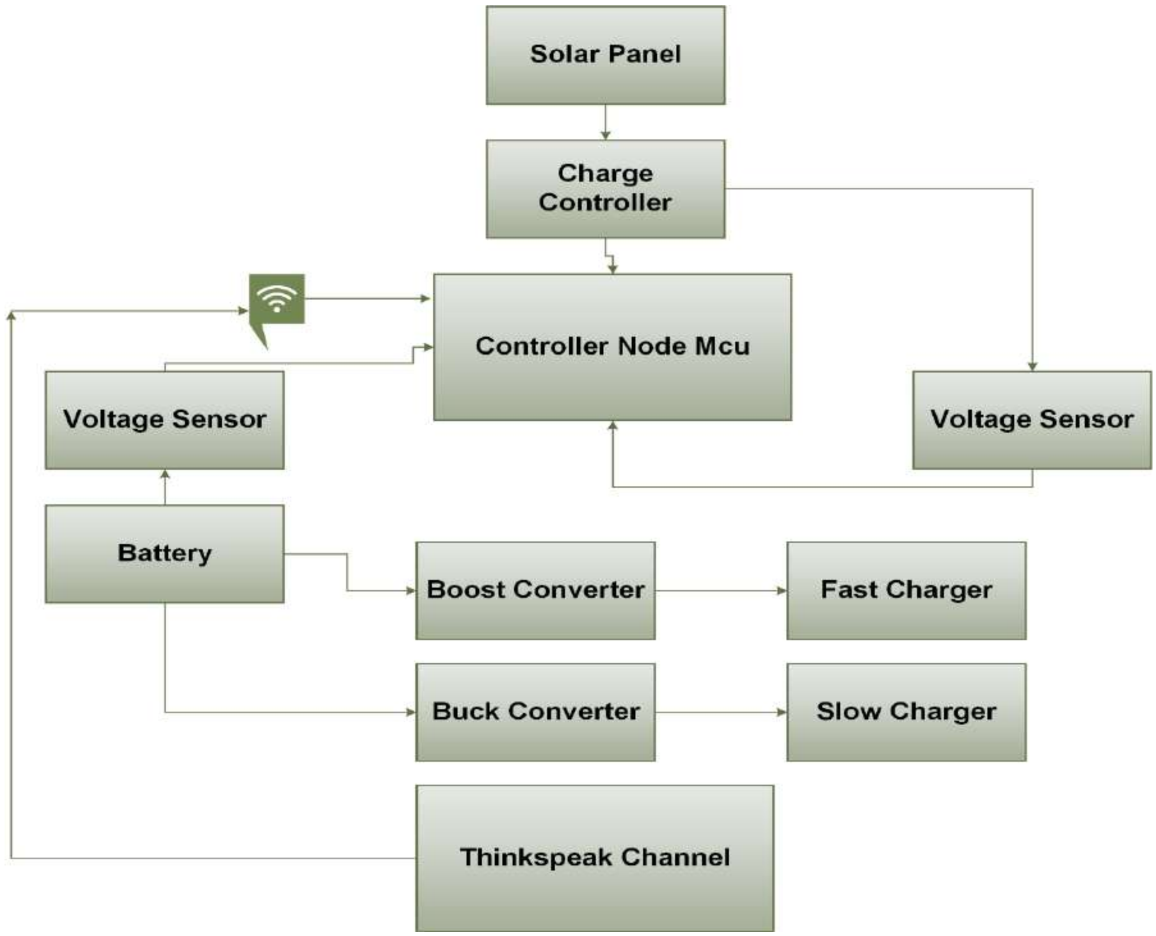


Figure 4.1: Schematic Diagram



4.2 Workflow Graph

The following graph depicts the step-by-step approach of the project workflow. To begin, a solar panel with an output voltage of 18 volts and a power capacity of 10 watts is placed to power the charging station. The charge controller charges the battery with the maximum voltage output feasible. In our configuration, an 18-volt battery and a boost converter are utilized to charge the 18-volt load, while a 7-volt battery and buck converter are used to charge the 5v output derives Voltage sensors are used in the Internet of Things to measure the voltage of solar panels. The solar panel is connected to the node mcu, which also monitors data from the Thingspeak channel. The buck and boost converter is used to build both slow and fast chargers. In the final phase, the load batteries are connected to slow and fast chargers.

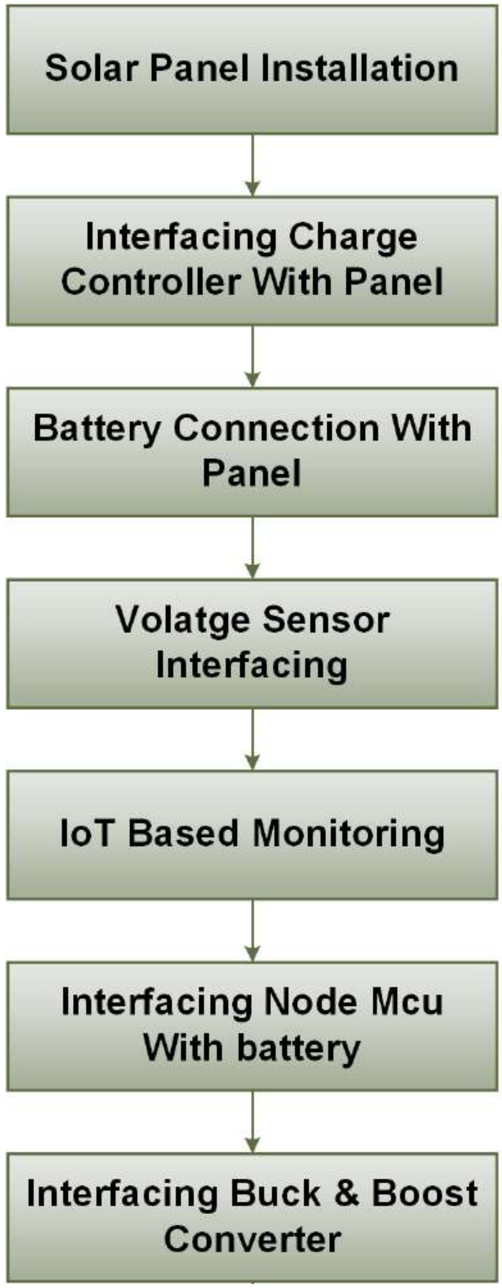


Figure 4.2: Workflow graph

4.3 Solar Panel Monitoring:

A battery charge controller, also known as a battery voltage regulator, is used in battery backup systems that are both grid-connected and off-grid. The charge controller regulates the solar panel's output voltage and current, which vary depending on the direction of the sun, and matches them to the needs of the batteries being charged. To do this, the charge controller provides a sufficiently consistent and controlled flow of current from the charging source to the battery. This inhibits both overcharging from the source and over discharging from the associated load, allowing the battery to remain fully charged. Because batteries prefer a constant charge within a specified range, variations in output voltage and current must be carefully managed. Because photovoltaic solar panels generate direct current (DC), the solar energy they generate is only usable in one direction. As a result, in order to charge a battery, a solar panel must be operating at a voltage greater than the battery. In order for a positive current to flow into the panel, its voltage must be greater than the voltage of the battery being charged. The output power of various energy sources, such as solar cells, wind turbines, or even hydro generators, will fluctuate. It is normal practise to position a charge controller between a battery bank and a charging equipment. It regulates the quantity of direct current energy that goes from the power supply to the batteries, a direct current motor, or a direct current pump by monitoring the incoming voltage from various charging devices. When the batteries are fully charged and their terminal voltage reaches a predefined threshold, typically 14.2 Volts for a 12 Volt battery, the charge controller switches off the circuit current. This protects the batteries from damage by preventing overcharging, which shortens the lifespan of pricey batteries. The regulator controls the battery's charge level to guarantee optimal battery charging (SoC). In our setup, we paired an 18-volt, 10-watt solar panel with a 12-volt charge controller for improved battery charging and protection. In this research project, we're using IoT to monitor the voltage of solar panels. The positive solar panel terminal is linked to the positive voltage sensor terminal while the negative solar panel terminal is not. The voltage sensor will have its ground linked to the NodeMCU module's ground and its OUT pin attached to the NodeMCU ESP8266's A0 pin. The tool from ThingSpeak might be quite helpful for IoT applications. By visiting the ThingSpeak website and using the Channels and web pages it offers, we can remotely administer and monitor our system. We constructed a channel to measure the voltage of solar panels for this study.

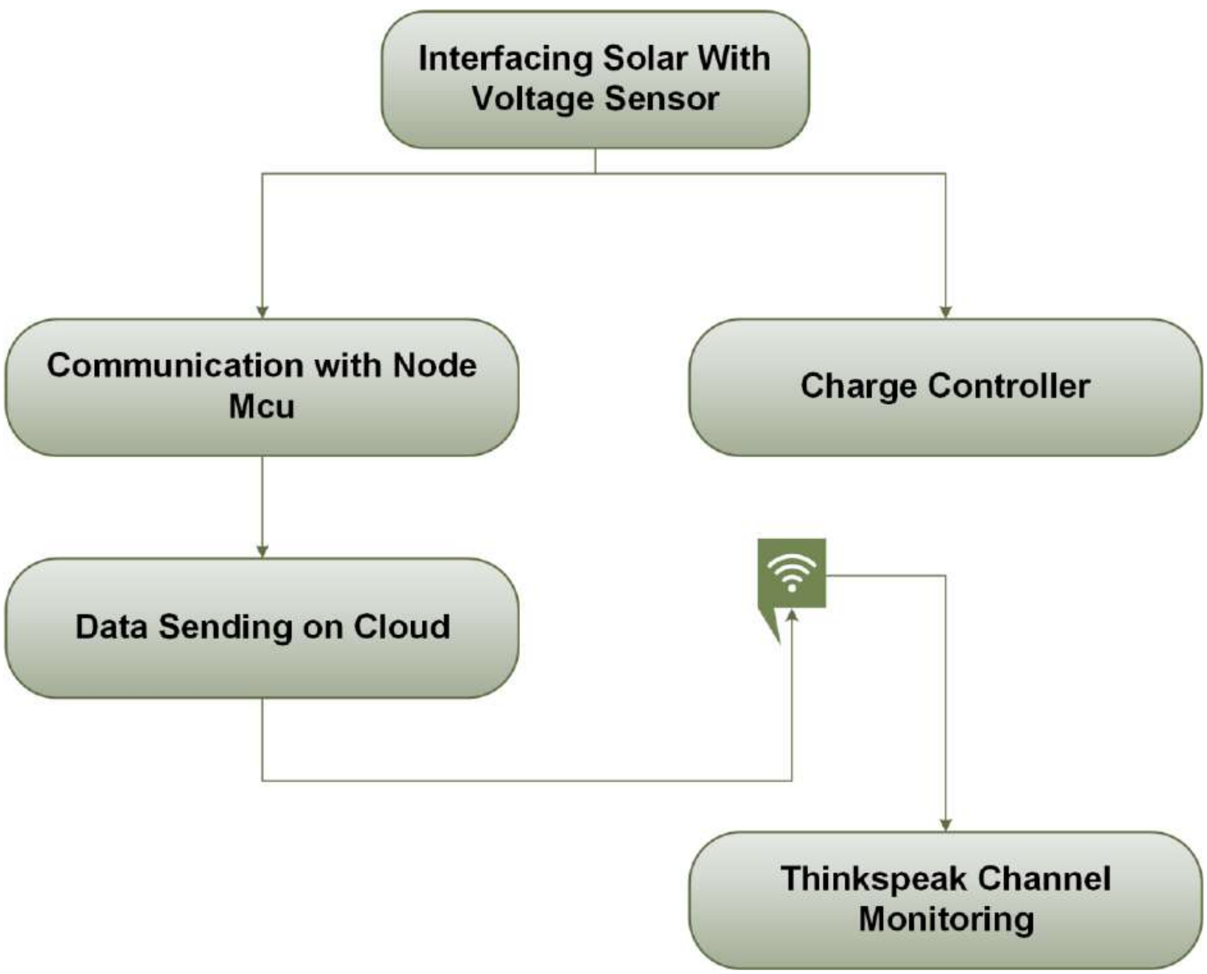


Figure 4.3: Solar panel monitoring diagram

4.4 Battery Status Monitoring

In today's tech-driven world, the integration of battery level monitoring via LCD (Liquid Crystal Display) has become a ubiquitous and indispensable feature in a wide range of electronic devices. This technology empowers users with real-time visual feedback, displaying a clear and easily comprehensible representation of their device's remaining battery capacity. Such insight is invaluable, allowing individuals to stay well-informed about their device's power status at a glance.

The significance of this functionality is particularly pronounced in portable gadgets like smartphones, laptops, and digital cameras. In these devices, where mobility and uninterrupted usage are paramount, battery level monitoring serves as a guardian against unexpected power depletion. Users can now plan their activities and recharging schedules with precision, ensuring that their devices remain operational precisely when needed and averting the frustration of abrupt shutdowns, especially during critical tasks or important calls.

Moreover, the inclusion of LCD-based battery monitoring enhances the overall user experience and convenience factor. It provides an intuitive and user-friendly interface for individuals of all tech-savviness levels to effortlessly track their device's battery levels. The straightforward visual representation eliminates the need for complex calculations or guesswork, streamlining the user's interaction with their device. This ease of use not only simplifies daily routines but also contributes to a sense of control and readiness, ensuring that devices are always powered and ready to meet the demands of our fast-paced, digitally connected lives.

5 RESULTS AND DISCUSSION

5.1 Hardware Model Design

This intricate model represents a fusion of advanced technologies and innovative design, carefully composed of several key components. At its core lies a highly efficient solar panel, harmoniously integrated with a charge controller, voltage sensors, a NodeMCU, and power converter modules. Together, these elements converge to form a solar-powered portable multipurpose charging device, equipped with cutting-edge Internet of Things (IoT) monitoring capabilities.

One of the central components, the voltage sensor, plays a pivotal role in this model's functionality. It diligently collects real-time data from the solar panel, ensuring that every ray of sunlight is optimally harnessed. After meticulous data processing, this valuable information is seamlessly transmitted to the NodeMCU, a sophisticated microcontroller equipped to handle the intricacies of IoT technology. From there, the NodeMCU takes charge, facilitating the transmission of this data to the cloud through the Thingspeak platform. This cloud connectivity opens up a world of possibilities for remote monitoring and data analysis, ensuring that the system operates at peak efficiency.

This model goes a step further by incorporating LCD screens for battery level monitoring, catering to both 5-volt and 18-volt power outputs. These LCDs provide users with clear, real-time information about the battery's status, enhancing their ability to manage power resources effectively. Whether it's charging a mobile phone, tablet, blood pressure machine, or powering up a laptop, this device offers versatile solutions to a wide range of power needs.

To bring it all together, the Thingspeak channel in the cloud serves as the nerve center for real-time battery level monitoring. It not only collects and stores data but also facilitates its transmission to ensure that users are always informed about their device's power status. In essence, this model represents the seamless integration of technology, sustainability, and user-centric design, offering a glimpse into the future of solar-powered, IoT-enabled charging solutions.

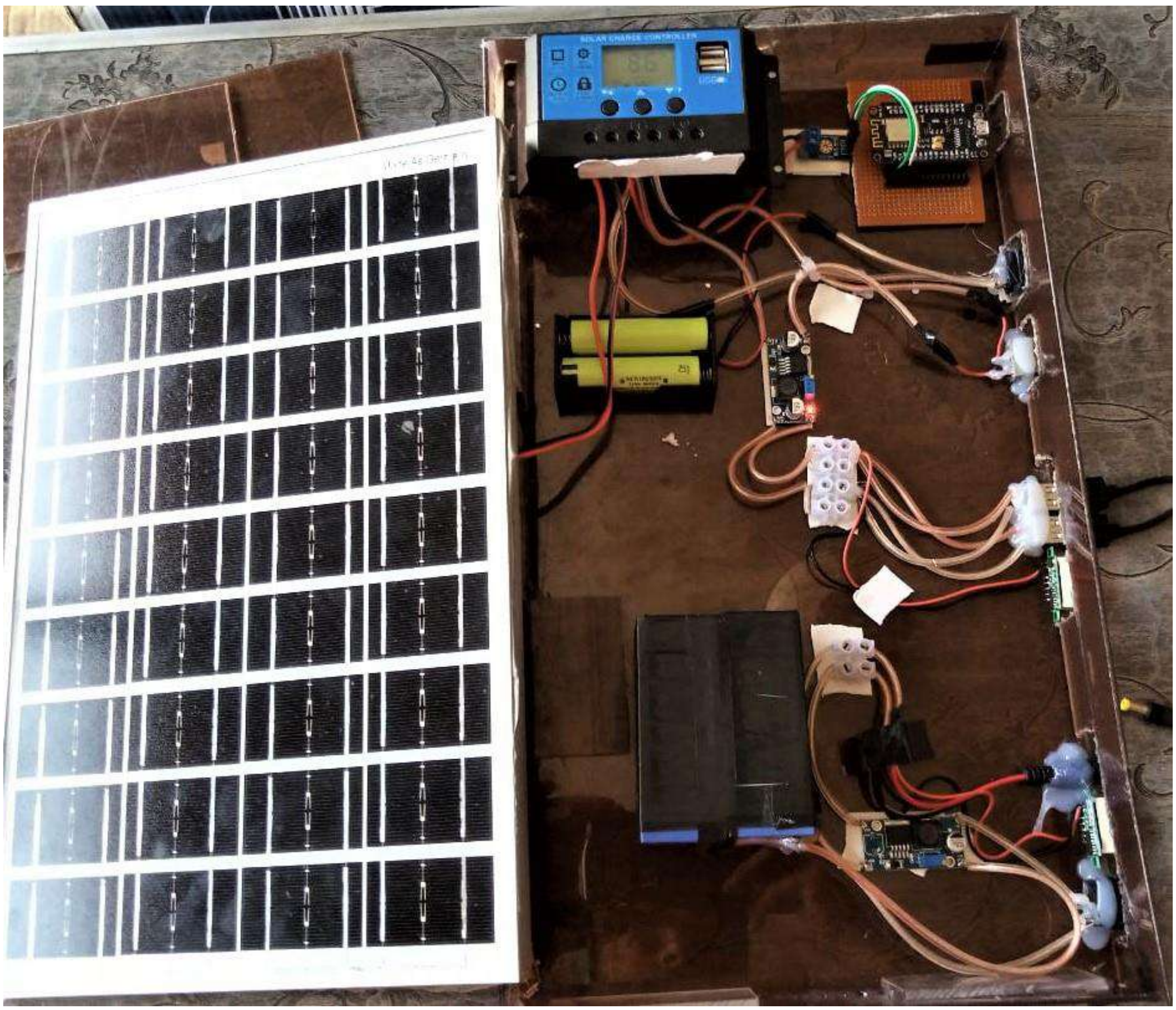


Figure 5.1: Hardware model design

5.2 Designing of 5 volt charger using Buck Converter

A DC-to-DC power converter known as a "buck converter" (sometimes referred to as a "step-down converter") increases current while reducing voltage from its input to its output (load). It is a type of switched-mode power supply (SMPS) that typically consists of at least two semiconductors, such as a diode and a transistor (although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification), as well as at least one energy storage device, such as a capacitor, inductor, or the two separately or together. To decrease voltage ripple, capacitor-based filters are usually linked to the input (load-side filter) and output (rarely in combination with inductors) (supply-side filter). On the other hand, the inductor "bucks," or opposes, the supply voltage. Switching converters (like buck converters) provide a far greater degree of power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that decrease voltages by dissipating power as heat but do not step up output current. Switching frequencies for buck converters typically range from 100 kHz to a few MHz. Smaller inductors and capacitors can be employed at greater switching frequencies, but efficiency is lost more frequently as a result of transistor switching. When building this model, we connected the buck converter to the 7 volt battery to create a slow charger. After stepping it down, the buck converter had a 7 volts input and a 5 volts output. As a result, we used a buck converter to reduce the input voltage level for the slow charger from 7 volts to 5 volts.

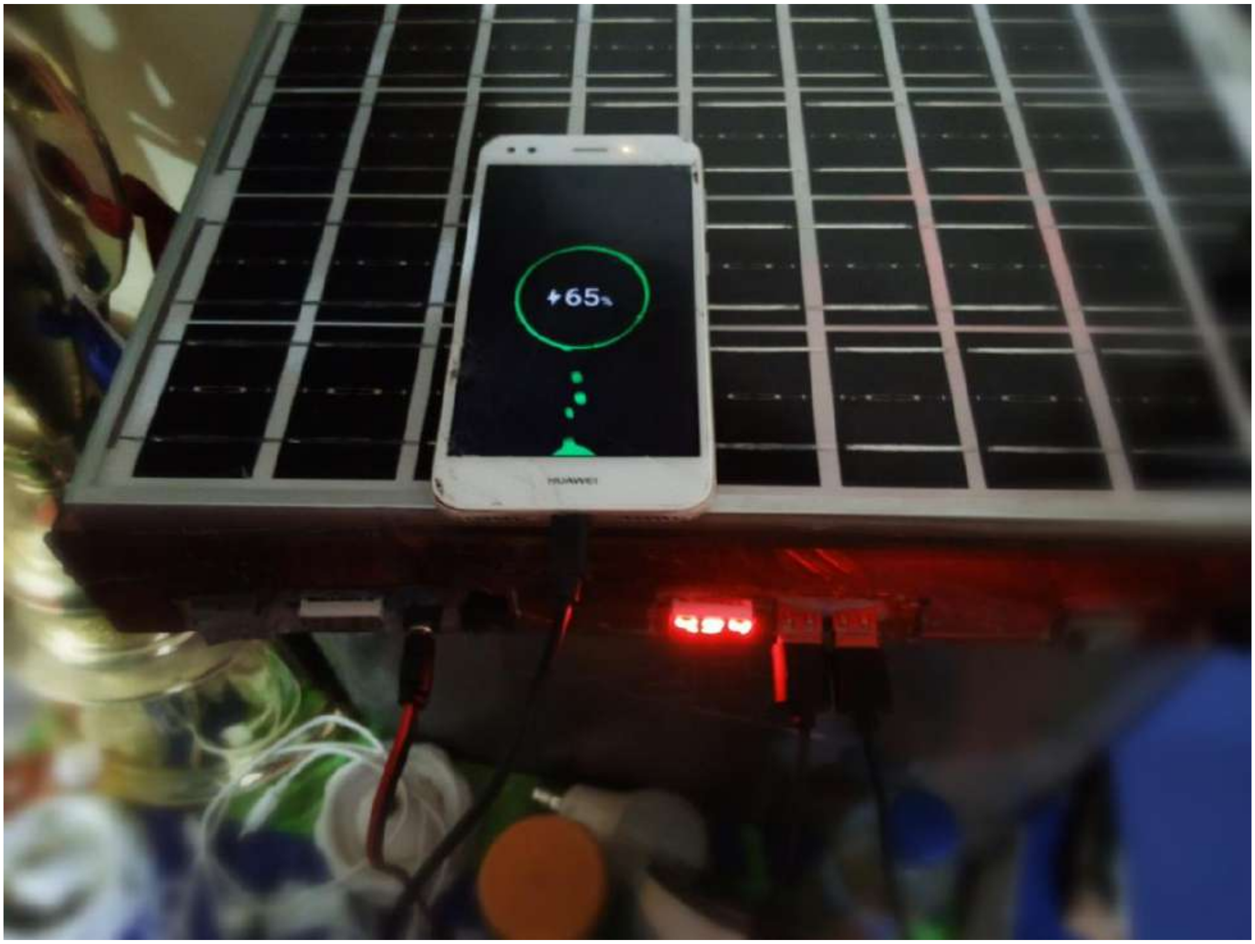


Figure 5.2: Buck converter testing

5.3 Designing of 18v charger using boost converter

When converting DC to DC power, a boost converter (also known as a step-up converter) lowers current while raising voltage from its input (supply) to its output (load). This SMPS has a diode, a transistor, at least two semiconductors, and an energy storage device (a capacitor, inductor, or both). To decrease voltage ripple, capacitor-based filters are usually linked to the input (load-side filter) and output (rarely in combination with inductors) (supply-side filter). The inductor's capacity to endure current changes by holding more or less energy in its magnetic field is the foundation of the boost converter. A boost converter's output voltage is always higher than its input voltage. The inductor creates a magnetic field when the switch is closed (in the "on" position), and current flows anticlockwise through it, enabling the inductor to store energy. On the left side of the inductor, positive polarization is evident. Current will be decreased because the switch's greater impedance in the open (or "off-state") state. The energy of the magnetic field that was previously created will be diminished in order to maintain the current moving in the proper direction toward the load. The polarity will change as a consequence (meaning the left side of the inductor will become negative). The two sources are connected in series, therefore a higher voltage will be delivered to diode D to charge the capacitor. The boost converter in our model is primarily used to build a quick charging facility. The input voltage of the boost converter is 12 volts, and we increased its output voltage to 18 volts by boosting it to a higher level. As a result, by accelerating it, we can quickly charge the load battery.

Figure 5.3: Boost converter testing

5.4 Solar Panel voltage monitoring on Thingspeak

The thingspeak channel monitors the solar panel voltage in real time using the internet of things. To monitor the solar panel, we'll use the Thingspeak platform and an ESP8266 Nodemcu.

We can use our channel to remotely check the voltage of the solar panel and other data by using the Nodemcu ESP8266 and Thingspeak platform.

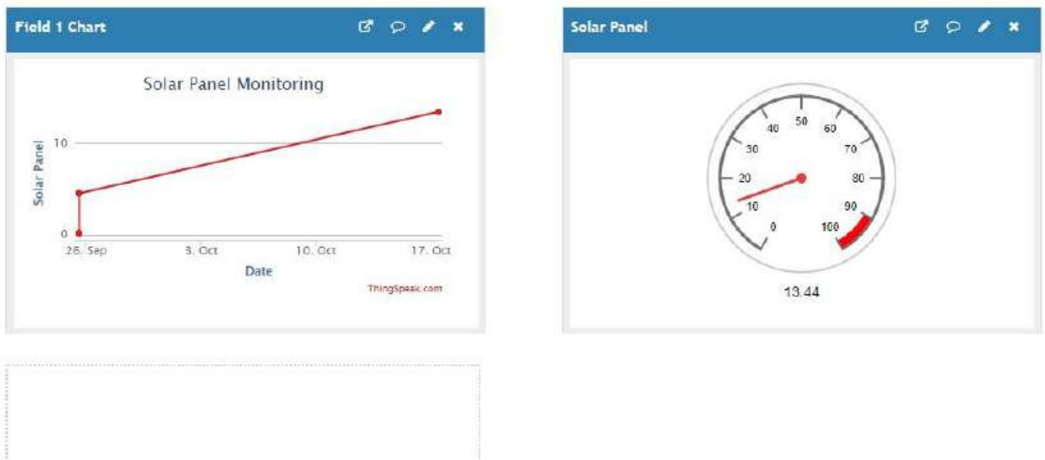


Figure 5.4: Solar Panel monitoring on Thingspeak

5.5 Battery Voltage monitoring on Lcd

The inclusion of an LCD display in this device significantly enhances its usability and utility. This LCD screen serves as a valuable tool for users to effortlessly monitor the battery voltage and gauge the remaining battery life during usage. This real-time feedback empowers users with essential information, ensuring they are well-informed about the power status of the device at any given moment.

What sets this device apart is its comprehensive approach to battery monitoring. Both the high-powered 18-volt power output and the versatile 5-volt power output are equipped with dedicated voltage monitoring LCDs. This thoughtful design choice caters to a wide range of device compatibility, making it an adaptable solution for various electronic gadgets. Whether users are charging a laptop with the 18-volt output or powering up their mobile phones, tablets, or other 5-

volt operated devices, they can rely on the intuitive LCD displays to provide precise, real-time information about the battery's voltage.

In essence, these dual voltage monitoring LCDs not only elevate the user experience but also exemplify the gadget's commitment to user convenience and empowerment. Users can enjoy the peace of mind that comes with being able to monitor their device's power status effortlessly, ensuring they can make informed decisions about recharging and usage, ultimately maximizing the efficiency and longevity of their electronic gadgets.

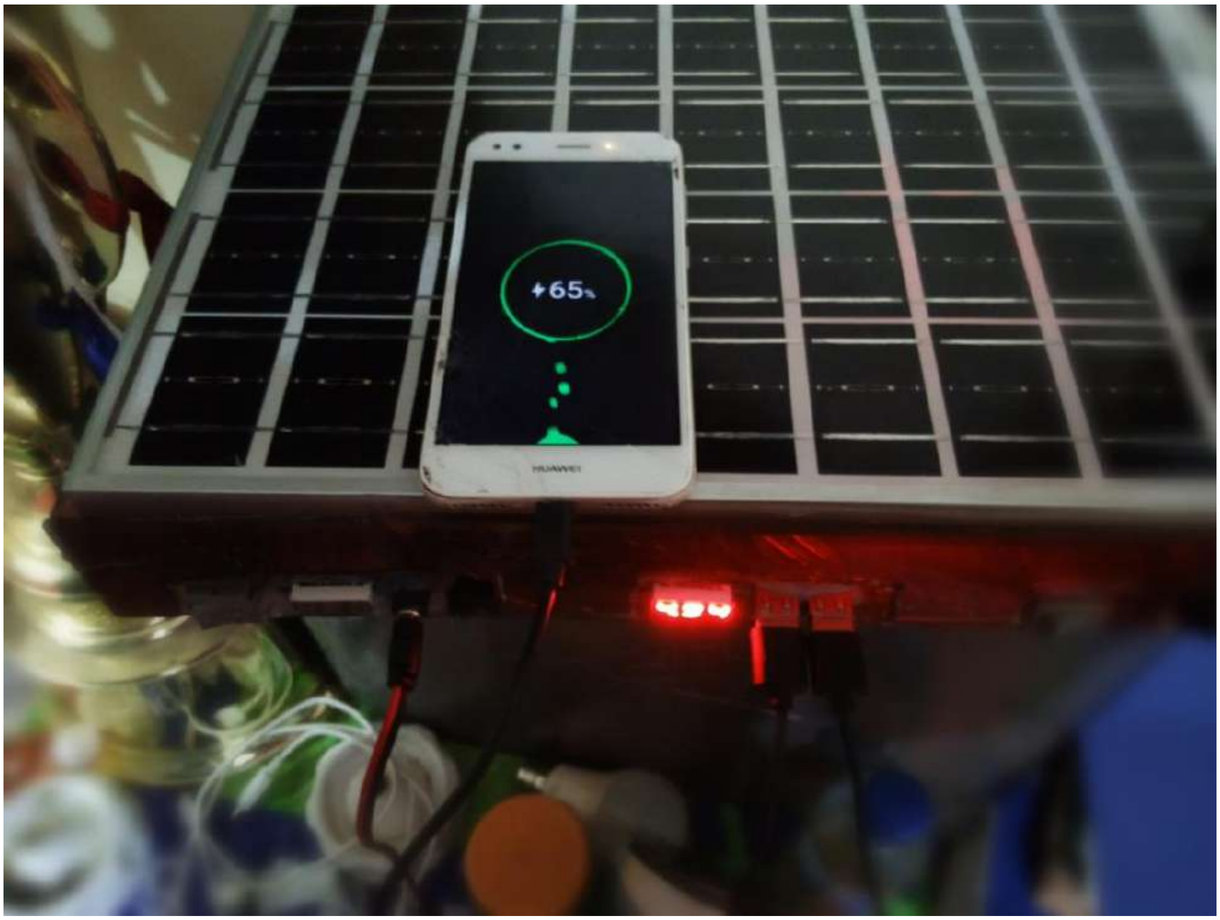


Figure 5.5: Battery voltage monitoring on LCD

CONCLUSION

In conclusion, the rapid evolution of portable electronic devices and the escalating demand for eco-friendly energy solutions have paved the way for the emergence of solar photovoltaic (PV) based portable charging stations. This thesis has offered a comprehensive overview, delving into the intricacies of these charging stations, their design, functionality, and diverse applications.

Solar PV based portable charging stations harness the inexhaustible power of the sun, channeling it through photovoltaic panels and storing it in energy storage systems like batteries. This approach not only champions environmental sustainability but also reduces our reliance on finite fossil fuels. The versatility of these stations shines as they cater to an array of devices, from the ubiquitous smartphones and laptops to the increasingly popular electric bikes and even small appliances.

At their core, these charging stations encompass a sophisticated ensemble of components, including photovoltaic panels, charge controllers, energy storage systems, inverters, and multiple output ports. Their flexibility allows users to either charge devices directly or store energy for future use, transforming them into valuable assets during power outages or remote outdoor adventures.

This thesis has illuminated the myriad advantages of solar PV based portable charging stations, from their eco-friendliness and versatility to their potential long-term cost savings. It has also underscored the challenges they face, such as weather-dependent energy generation and the quest for efficient energy storage solutions. Moreover, we have explored the promise held by emerging technologies, such as advanced solar panel designs and cutting-edge energy management systems, in addressing these challenges.

In summation, solar PV based portable charging stations represent a promising and sustainable solution for on-the-go power generation. As technology continues to advance, these stations are poised to make significant contributions to reducing carbon emissions and expanding energy access across diverse settings, from bustling urban environments to remote off-grid locations. This thesis has served as a beacon, shedding light on their design, functionality, and the exciting potential for future developments in this evolving field.

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