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Multi Terminal EV Charging Station with PV Support

COLLEGE OF
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COLLEGE OF ELECTRICAL AND MECHANICAL ENGINEERING

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PROJECT REPORT

<u>Multi Terminal EV Charging Station with PV Support</u>

Submitted to the Department of Electrical Engineering
in partial fulfillment of the requirements
for the degree of

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Sponsoring DS:

Submitted By:

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CERTIFICATE OF APPROVAL

It is to certify that the project **"MULTI TERMINAL EV CHARGING STATION WITH PV SUPPORT"** was done by **PC Ehtisham ul Haq**, **ASC Momin Adnan,** and **NC Muzammil Sohail** under the supervision of **Dr. Taosif Iqbal.**

This project is submitted to **Department of Electrical Engineering**, College of Electrical and Mechanical Engineering (Peshawar Road Rawalpindi), National University ofSciences and Technology, Pakistan in partial fulfilment of requirements for the degree of Bachelor of Electrical Engineering.

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DECLARATION

We affirm that the content presented in this Project Thesis is original and has not been submitted in support of any other degree or qualification at this or any other educational institution. We acknowledge that any act of plagiarism will result in full responsibility and may lead to disciplinary action, including the potential cancellation of our degree, based on theseverity of the offense.

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Regards
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ABSTRACT

Improvement and clean charging alternatives for electric vehicles (EVs) have continuously learned from their rapid growth recently, which is a big challenge. The idea of this project lies in designing and constructing a controllable solar-powered EV charging station that will tap into renewable solar capacity to power future road transport.

Design of a solar-powered EV charger that employs both solar and AC power and uses a lithium-ion battery to cheaply charge. The principal goal is not only to provide a means of electric vehicle charging but also to enhance flexibility and reliability through the introduction of an intermittent AC electric power backup. It uses a controller consisting of an Arduino-based switch and switches between the PV source and AC from the grid. It tracks the PV source and will charge from the AC grid only when surplus solar power is available. The controller only controls the AC grid when the battery is fully charged or when solar power is insufficient. The code is compiled on the Arduino platform, which includes both battery status monitoring and sourcing decision-making. The battery shutoff will be triggered when it reaches its full charge to protect it from being damaged.

A Sepic converter comes after the solar output; it is positioned in a strategic manner. It is an essential part of maintaining the output voltage constant even if the solar input fluctuates, which will consequently improve the life of the battery by protecting it from voltage fluctuations. Conversely, it is critical to be able to monitor the health condition of the lithium-ion battery so that it is not exposed to overcharging or excessive voltage to maximize its life span.

A wide range of functions can be performed by this project, and renewable energy is used for charging electric vehicles, thus showcasing its feasibility, and promoting it for sustainable development, which in turn can replace non-renewable sources. The option of solar installation implies some complications, including occasional solar availability and making charging work uninterrupted. This is achieved in the system by using a smart system structure and special equipment, such as Sepic converters and Arduino-based controls.

The project gives prominence to the fact that cutting-edge power generation technologies, which play a major role in meeting the growing energy needs of electric vehicles, can be incorporated with existing technologies to balance the mix. A V2G model emphasizes not only energy efficiency but also the reliability of the charger. This makes the technology more adaptable to natural circumstances. The implementation of this system would mean that the establishment of off-grid EV charging stations would be greatly increased, and this would be an important step towards having better access to electric vehicle infrastructure in areas where there is no grid. This advanced method is to be used as workable guidance for future advancement in sustainable vehicle technology using solar energy as a main source of energy supply for a revolutionary transformation of the transportation ecosystem.

SUSTAINABLE DEVELOPMENT GOALS

Goal 7: Affordable and Clean Energy – Promoting affordable and clean energy (solar) for transportation, reducing reliance on fossil fuels.

Goal 11: Sustainable Cities and Communities - Contribute to the development of smart and sustainable healthcare systems for urban areas, ensuring quality healthcare services are accessible to all.

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INTRODUCTION

Problem Statement

The sustainability of solar EV chargers has not been the only matter of concern due to some barriers they face. Solar energy usage is hampered by, for example, lack of sunlight availability, which usually occurs during cloudy weather or shaded days when demand for electricity is at its peak. This also affects the charging speed. And on top of that, there can be the expenses incurred in putting up these installations, and poor efficiency in converting the sunlight into usable energy is another thing that needs to be considered. The project seeks to design a solar-powered EV charging system with precision, which aids in the capture, storage, and conversion of solar energy to provide dependable and efficient charging services in variable climate conditions.

Objectives:

The aim of this design is to design and develop a high-performance and highly valued solar powered EV charging station that uses solar energy along with an AC power source when necessary for the efficient charging of a built-in lithium-ion battery. This project's goal is to increase efficiency and sustainability in electric vehicles by using renewable energy sources in a charging system that is built around them. Focused on the creation of an intelligent distributed system using an Arduino microcontroller unit that chooses solar energy over grid power whenever solar power is enough. This practice, besides saving non-renewable energy, also involves less pollution that occurs to natural resources when traditional energy is used. The Arduino features code that makes sure solar power is used everywhere by switching to an AC source only when solar power cannot sustain it, and this in so doing promotes the use of clean energy. A point worth mentioning is the importance of a Sepic converter in the design, as it helps to vary the intensity of sunlight without affecting the battery voltage levels. By leveraging this method of power control, one can prevent undesirable effects such as overvoltage or under voltage, which can cripple the battery's operation and drastically reduce its lifespan. While the initiative includes a relay system wherein the alternation between power sources and charging cycles takes place safely, this same system facilitates effective transferring between power sources and fast charging cycles. The Arduino controller is employed to specifically handle the charging process while setting it, so it turns off the power at 14 volts and then recharges when the battery voltage drops to 12 volts. Such a system, in turn, makes sure that the battery holds the proper parameters and prolongs its service life. At the end of the day, the project goal is to prove the feasibility of solar power for integration with EV chargers, creating a scalable model that can be used for mass applications. Despite the complexity of EV charging scenarios, the large-scale rollout of solar-powered EV charging technologies can dramatically change the paradigm of electric vehicles.

Significance of the Study:

The study is very crucial because electric vehicles are an upcoming and highly efficient means of sustainable electric transport. The project is targeting the two main obstacles, which are mining for any minimal minerals and the greenhouse gas releases because of wind generation, which are much bigger than those that result from charging electric cars. This to be flashlight comes with both solar and AC input options, which will allow you to charge anytime with no weather restrictions.

This initiative is aimed at the use of lithium-ion batteries, which have high energy density, fast charging abilities, and excellent lifespans. As such, it improves the management of the batteries and eventually prolongs their life cycle. Other than environmental benefits, the technology can boost grid management, improve power quality, and make renewable technologies scalable. Solar-powered EV including chargers, which involve AC backup made at different locations, reduces the overall peak grid demand and, as a result, promotes a more uniform energy distribution system.

To achieve such an approach, there must be a concrete organization to involve all stakeholders, including the relevant authorities, who are mandated with allocating a portion of land where charging stations are established nationwide to be operated within the reach of consumers and for convenience, thereby achieving energy independence and better public health status, which leads to reduced air pollution. Researchers who pay attention to components of these systems and the control algorithms enabling bi-directional communication both might achieve efficiency improvement and reduce cost, as well as federal integration into smart grids.

Chapter 2:

BACKGROUND AND LITERATURE REVIEW

I. Introduction:

A. Background of Traditional Vehicles

Since cars have had us hooked for a couple of decades now, most people do not even imagine anything else. Up to 80% of those are vehicles that have an internal combustion engine of a gasoline or diesel variety fuels that have a high carbon footprint as they contribute many greenhouse gases. Even though we have gone several feet ahead with the fuel efficiency of automobiles and the efficiency of exhaust emissions, they aren't sustainable reasons for the air pollution and global warming that we face presently. It is no surprise, thus, that a cleaner alternative gets into a lot of people's concerns.

B. Electric Vehicles; A new era of Eco-Friendly and Sustainable Transportation

Just like the old emissions-powered vehicles are gone with the bad gas emissions that the world is facing now, electric vehicles are giving the fight against climate change a new dimension. They are the most cleansed in the general car group, truly, as they aren't dependent on the use of fossil fuels and have lower emissions. This way, both the earth and us benefit, as they are great for the earth and effective. They have good potential to change the grid's energy into actual traveling distance on the roads. Also, they direct the energy sources in the earth, like wind and solar, to use more of the renewable energy and reduce carbon emissions.

C. EVs and How They Effect Transit

Electronic trucks are really the mavericks of transport. They're whisper-quiet; none of the pollution comes out of the tailpipes because they don't have them there. And it comes down to air compounds and less carbon dioxide being mixed in the atmosphere. If we want this change to happen, EVs should be the substituted ones at an early stage for reducing the overall emissions as set in the global agreements. With it, fuel costs are cut back and maintained over time, and traditional cars can be inferior to such a vehicle in terms of maintenance.

2.1 Battery Charging Technologies for EV

The transition from gasoline to electric cars will largely depend on the mechanism of how to keep them charged. Here are the main ways to do it.

1. Slow Charging (AC Charging): Additionally, this is the one-night-and-day type of charging that is great for the moments when you only want to use the car to work in your city. The device is operated using alternating current (AC) and is compatible with several types of plugs.
2. Fast Charging (DC Fast Charging): It's an ideal choice for long trips and can also be easily found at "free way" rest rooms and public charging points. Cases like the CCS and Tesla Supercharger can hardly even be compared to those with slow charging speeds.
3. Ultra-Fast Charging: Guess what? Fast charging is your best ally in a case of deficiency. They can charge your EV super-fast, getting you out of the recharging facilities infrequently to the extent of covering long distances.
4. Wireless Charging: Imagine yourself driving your own car over the charging pad, and all you would have to do is sit back and wait for the car to be charged without even the need for any plug or cable. That's wireless charging. It's quite convenient, in fact, for a self-driving car in the city center.

2.2 Solar Powered Battery Charging

Charging the EV battery is regarded as a pivotal technology that provides environmentally sound ways for electric vehicle battery charging. In essence, it has been compared to a miracle of nature that may assist in solving the problem of a standby auto electricity provision for electric vehicles. These are the solar panels under the term photovoltaic (PV) cells, or differently called PV cells. These PV cells, or photovoltaic roof panels, function by changing solar energy into direct current (DC). The generated DC by the solar is either stored in the battery pack or converted into AC by the inverter to allow the EV charging infrastructure to constantly maintain its compatibility with the AC grid.

This role is usually performed by the charger that sits at the charging station, which is responsible for functioning as a regulator, so that the power sent to the EV battery is broken down into numerous smaller flows (restricting the flow of the electricity to the batteries) with the goal of avoiding overcharging and maintaining the longevity of the batteries. The station of charging is often equipped with a charge controller, which gives the regulated gate for the lithium-ion battery of the EV, aiming to shield the battery from overcharging and extend its life lapses. The use of the charging station would serve to decrease both CO2 emissions from car manufacturing and electricity demand.

Due to this, we should upgrade our energy system to more sustainable solutions. Installation of solar panels takes the charge of electric vehicle chargers, and this shift is aligned with renewable resources, and the vehicles use can be charged only by the harvested resources instead of the electricity grid power from the power grid, which also carries on with reduced carbon footprints. Battery storage works as an effective backup in case of an energy blackout caused by insufficient solar power generation that is currently being developed as a secondary system, mainly to improve the network's residential installations to commercial and public charging stations, broadening the impact across various sectors. Investment in research and development continues to optimize the integration of solar panels with smart grid technology, paving the way for smarter energy management systems that dynamically balance power supply and demand, thereby maximizing the utilization of renewable resources and promoting a sustainable, eco-friendly transportation ecosystem. reliability.

Alongside it, these toolkits will build up momentum, so the transition towards low-carbon transport architecture itself may be driven more and more aggressively. Using wireless charging methods, which work with solar-powered energy sources, can enable charging systems to overcome all barriers. Commencing with the contraction of the fossil energy industry, it will result in a global decrease in greenhouse gases and overcome the climate change challenge.

The future of renewables lies in the upgrading of solar technology, and these distributed energy systems powering charging stations will be part of the shift towards e-vehicles, which in turn will add an extra level of freedom to the power systems when regenerating from disruptions. Along with these, the progress made in the manufacture of the manufacture of solar panels has resulted in an increase in efficiency, while the price of the equipment has gone down and is becoming more sensibly accessible and affordable for ordinary residents.

These systems could be scaled up from the ground up, from simple home installations to commercial and public systems, the meaning of which is that many sectors will eventually feel the impact of their implementation. Innovation never quits, and periodic solar panels feed through the smart grid design that can make supply and demand come backward and forward positively for renewable sake, giving the long transpiring lifespan of a sustainable transportation management system.

2.3 Limitations and Challenges in EV Battery Charging

Electric vehicle (EV) battery charging technology also has some troubles and restrictions. Introduced secondarily, this act contains sentiments that impact its effectiveness, expansibility, and revenue-generating. A major part of the problems is technical, as programmers and software engineers.

complex in form; they are rather concerned with the issue of how fast the spread of EV technology is.

Indeed, among the technical limitations that charge technology will face is the time it takes. Unlike the unrealizable gasoline that keeps conventional refueling.

Those vehicles that, in a few minutes, charge a battery, for example, with Level 1 and Level II, or even CCS in the case of DC, fast charging in much less time. Two chargers take hours. However, charging is even slower than charging a car using some DC fast charging technology; fast charging and instant charging that charge a car in a matter of hours are not yet commonplace. Charging for up to 80% in about 30 minutes, the fast-charging system stands out because it is much faster than traditional refueling techniques. This disparity might be down to lots of aspects, like the impediment on the part of the chemical capabilities and battery.

Thermal management can be a critical part of a fast-charging mode to prevent overheating while providing a high level of charging. The battery capacity and the depreciation of products are also complex issues. In most cases, Electric Cars have lithium-ion batteries, which could be a problem because they complicate the storage of electrical energy and in this way, there will be an extension of these occurrences manifested in efficiency in the life of the product. Nevertheless, thermal degradation of batteries is also a variable that can lead to faster degradation of the battery.

Given instances of severe temperature changes, such facilities will probably need to purchase sophisticated environmental control systems and prevent it from draining early and preserving the battery's state of health.

Currently, infrastructural issues are a major challenge, which includes the easy accessibility of various charging stations.

The installation of charging points is also accompanied by quite difficult technical and physical work, which is much more expensive than just drilling a hole. Although space could bring some advantages to the city, the settlements can struggle with this risk, deprived of population and related activities.

In this sense, updating the existing grid to an extent to take on the new load is also one of the most crucial steps that poses challenges. Standardization if charging systems were present; chargers might not have been compatible with one or the other technology, but rather than this, charging stations should have been installed all over the city, which would encourage the citizens to use EVs.

Even though it is a game changer as an alternative option for traditional vehicles, challenges in battery charging technology will also entail dealing with technical constraints like battery chemistry and hardships in the infrastructural setup, which will also include logistical issues. These elements underline how pertinent this development of electric cars is.

2.4 Integration of Renewable Energy in EV Charging

Renewable energy integration into EV charging infrastructure would be a very important step to achieve higher energy sustainability in the transport sector, which is currently associated with environmental issues. Utilization of alternative energies, especially solar ones, is a pivotal aspect that EV charging technology should concentrate on since nature provides a variety of clean and renewable power. The disaster is not only eco-protective, but the decoupling of the operation from the traditional power plant grid will also reduce grid overload during peak demand times. The central elements of the integration that are relevant to the current power grids are renewable technologies' ability to scale up and the overall economics of renewable-based systems, which intend to cover a wide area.

Equitable integration also demands an effort to overcome the intermittency factor that calls for strong energy management systems that allow for balancing of all the sources and demand sides so as to maintain the availability of all the power for EV charging. Additionally, the successful blending of renewables into EV charging infrastructure requires innovative policy programs and grants that can compel either the public or the private sector to invest. The support of the government in regulating heavily by providing subsidies, tax breaks, and grants may help boost the swift installation of renewable energy systems and necessary charging infrastructure. At the same time, utilities may be encouraged to build and upgrade their network infrastructure to cope with the growing expansion of renewable energy output.

Likewise, technology plays a significant role, such as in smart chargers that are designed to reduce electrical draw by setting function rates based on energy availability and grid demand in real-time. These intelligent systems are used to optimize the usage of renewable energy by facilitating EV charging, especially during times of high renewable energy generation, such as the solar energy time of day, which peaks at midday. This not only ensures optimal green energy use but also contributes to balancing the grid by softening up peak loads. This horde of approaches contributes to the stabilized integration of renewable energy, which is green, simple, and efficient for large-scale acceptance by electric vehicles in the notable electric transport movement.

2.5 Advancements and Innovations in Charge Controlling

In the past ten years, the progress made in charge management technologies is responsible for the growing impact they have on the stability of EV battery charge systems. The introduction of modern charge controllers with built-in smart algorithms that adjust charging rates with energy availability and battery condition is expected to have a positive impact on the performance of the system. Additionally, this increases the speed of charging while at the same time prolonging the life of the battery cells because of the elimination of the overcharge cycles and the deep discharge.

Also, new innovations are popping up, such as wireless charging and bidirectional charging, that can provide you with different options for charging, which makes it convenient and flexible. These systems allow vehicles to be charged by placing them on ground pads or even charging in different directions. This, in turn, helps the grid to be supplied with electricity and can help to cope with peak demand times, which in turn showcases the shift towards integrated and smart energy systems.

With the help of this advancement, charge control is becoming more adaptable and suitable for developing more intelligent and sustainable EV ecosystems using modern technologies. The technological advancement in the control and management of the charge field is one of the most promising applications of cloud-based technologies, which makes it possible to increase the scalability and capacity management of EV charging systems. These cloud platforms constitute the data collection and analysis done from the numerous charging stations in different places, which invariably leads to centralized control activities and an efficient allocation of energy.

These kinds of systems will be able to effectively react to any changes in the grid operation, EV demand, or energy tariff schedule dynamically, remaining as seamless as possible in users' eyes. In addition to that, the use of AI technology in the charge controllers can reduce the charge to a more advanced level. AI algorithms allow not only accuracy in the prediction of usage patterns that may help to schedule charging to minimize the costs of energy and maximize renewable resource usage but also the creation of a more efficient charging system in which the users have access to charge their EVs.

Chapter 3:
METHODOLOGY

3.1 Introduction:

This chapter goes into the methodology section, which provides details on the solar-powered EV charger development using the solar panel as the initial source and the AC grid as the backup source. The proposed design includes a buck-boost converter with SEPIC topology, an Arduino controller for battery control, and connections and integration practices with both solar panels and AC to power an appliance. The structured designs ensure the optimization of the charging process by using an efficient source control technique and implementing battery protection designs that aim for sustainability and reliability.

3.2 System Architecture:

A variety of key components constitute the EV charger based on solar power, including thin-film and crystalline silicon solar panels, a power conditioning unit, and a battery charger. Among these units, there are the SEPIC converter, power converter, Arduino controller, AC grid input, and solar arrays. In this section, we will introduce you to the system architecture and the component data flows, which show the way these components interact with each other.

A. AC Grid Rectification

In this configuration, the grid works as an alternating current source. This input voltage, which is alternating current, transforms directly into a DC voltage using a bridge rectifier. The grid consists of four diode arrays that are arranged in a bridge form, which leads to an AC signal changing into a DC signal with pulses. Next, as such, there comes a filter capacitor that regulates pulse width to provide smooth and steady DC output.

B. Solar Panel Source

In this configuration, the grid works as an alternating current source. This input voltage, which is alternating current, transforms directly into a DC voltage using a bridge rectifier. The grid consists of four diode arrays that are arranged in a bridge form, which leads to an AC signal changing into a DC signal with pulses. Next, as such, there comes a filter capacitor that regulates pulse width to provide smooth and steady DC output.

Apart from this, the sun's beam leads directly to the production of DC power, whereas the solar panels. Solar panel voltages and amperes depend on the temperature, of course, as well as on radiation levels. A lithium-ion battery, being the energy storage system, gets its charge through a solar panel.

Solar panels act as the main source to charge the EV's battery, and they ensure that car driving is more sustainable than others. This is how these panels converted the sunlight directly into electrical power and the SEPIC converter, which regulates the voltage for optimal charging of the battery. The system initially provides the home with solar energy, and only then does it solve the AC grid when the solar system cannot supply enough power.

C. Sepic Converter

With the help of the rectifier converter, the DC outputs of the solar panels and the supply go through a buck-boost converter. The main role of the SEPIC (Single-Ended Primary Inductor Converter) is to remedy the input voltage issues, either higher or lower than the battery's volatile range, for better charge of the Li-ion batteries.

D. Data Flow and Interaction

The data flow within the system is as follows:

i) The rectifier is a component that redirects the AC power input from the grid to

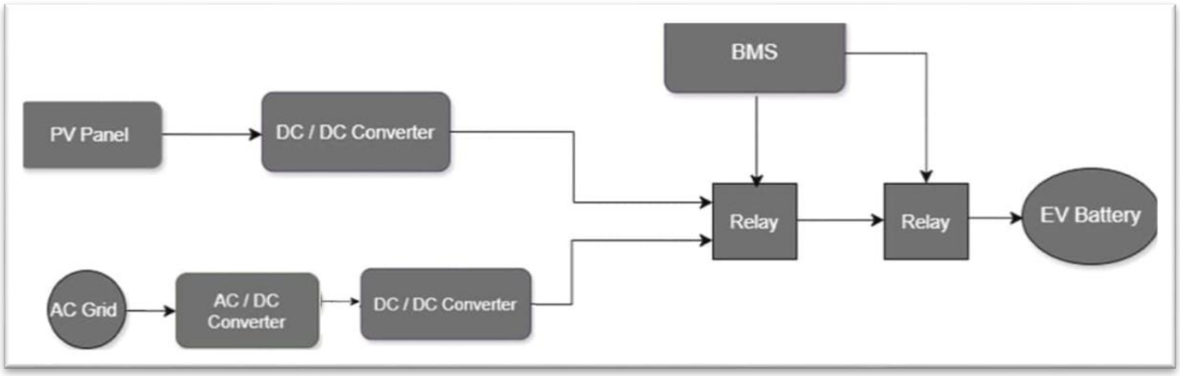
ii) It stores the solar power in the battery in variable direct current form.

iii) Arduino compares both sources, and if the precedence of one source over the other is established according to need, then Arduino will use that for charging the battery

iv) The SEPIC converter feeds on two DC inputs: one from the variable rectifier and the other from the photovoltaic panel.

v) The battery will be charged until the minimal value of the cut-off voltage is reached.

3.3 Block Diagram:



3.4 AC Grid Integration:

The latter showcases AC power from the grid being DC power into the battery, singled by lithium-ion. Here, exemplify, there may be a bridge rectifier circuit, which consists of four diodes that follow a formation called "the bridge," and the reason for the name is that. As the ripple DC waveform is created by magnetism, it helps to overcome the drawbacks of steady DC current delivery, in which there is no synchronization of the power circuit motion.

There is also a capacitor that will keep the DC output stable. It is very useful for filtering ripples, waves, and high-frequency currents. which results in the reduction of ripple voltages to a steady DC voltage and thus becomes a filter capacitor. The DC voltage given from the CRI should be regulated for proper matching to the needs of the charging process. The main parameters are the power reverse voltage max capacity of the diodes and the capacitance value that is being chosen considering the existing load volume in order to minimize the unstable voltages.

Nevertheless, the discussion aims to understand why the integration of a regulator is required and how it stabilizes the output voltages to within the limits that are recommended for charging the lithium-ion batteries. Furthermore, this chapter touches upon matters associated with the efficiency and methods of reducing heat dissipation and rectification that are generated by diodes. The results produced have effects on the system's performance.

The following factors are discussed in this section: First, conversion of AC power from grid into DC power that would charge up lithium-ion type batteries incorporated within them; next come those items about how we can get rid of or decrease ripples inside capacitors thus making their values stay below acceptable levels (which may later cause unwanted accidents); finally it explains more about regulating devices like Zener diode whose purpose usually depends upon maintaining steady-state conditions throughout operation times such as when using solar energy sources having variable powers due daylight intensity changes occurring frequently which alternately make panels generate higher altitudes at some periods than others resulting into outputs ranging between zero volts plus infinity ,then ends up comparing different ways used manage construction structures found among other components while trying achieve stable electrical connections.

3.5 Solar Panel Integration:

Solar panels with an inbuilt EV charge are the core component of power generation, as they endorse a direct transformation of sunlight into electrical energy to charge up the EV's lithium-ion battery during the day. These panels form the basis of the mindset that is inspired by environmental friendliness, using renewable energy to contribute towards a reduced environmental impact.

The solar panels are configured for the potential scenarios associated with fluctuating light conditions to ensure high performance. The SEPIC converter must be integrated. The SEPIC converter has changed the output voltage from the solar panels to the necessities of the battery charging. This setup provides the guarantee that the voltage supplied is always kept in the best possible range for a battery's performance, which ensures both safety and battery system longevity.

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The technical specifications of the solar panels include wattage, efficiency, and size, among many others, having to do with their role in delivering the energy required for the charging system.

Meanwhile, by positioning the panels in an optimal path of sunlight with trackers that will tilt the panels with respect to the angle of the sun during the whole day, we can ensure energy acquisition at its peak. The advantage is greatly in favor of dynamic positioning because the system is still productive with partial sunlight and ensures that the energy conversion is more efficient. Moreover, rugged industrial precautions are undertaken to secure the panels from various weather conditions, including rainfall, dust, and temperature fluctuations, which in turn eliminate panel degeneration. Such a comprehensive solar panel integration framework is the fundamental factor that demonstrates the charger's soundness regarding the efficiency of utilizing renewable energy sources for eco-friendly EV charging operations.

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Simultaneously, by ensuring the course of solar panels in the sunny direction by platforms with pivots and coils that recline the panels with respect to sun rays' degree during the latent day, this arrangement will provide energy at maximum effect. There is a clear benefit to DP, as the system is still functional in partial sunlight and transmits more energy by ensuring a high efficiency of the conversion process. In addition to that, calipers of industrial style are used to protect the panels from rainfall, dust, and temperature changes so that solar panels are not damaged. On this account, the integrated solar panels are solid evidence of the charger's soundness, which is rarely found in the EV charging businesses of the industry that utilizes renewable sources of energy to a greater extent.

3.6 Arduino Controller Design:

The Arduino controller is a key part of the DC power generation unit of the solar-powered EV charger. It makes the appropriate decision to determine the source of power to be used solar panels or an AC grid—before prioritizing the use of solar energy. It constantly enhances the performance of the battery by continually monitoring its state of charge and making a correct decision between the PV source and the grid in accordance with the availability and significance of the situation. The controller guarantees that at the maximum rate, a solar power plant is operational before being wired to the public grid to make energy efficiency and sustainability more reliable.

Another key function of an Arduino, namely battery management, is the second important point. It would make the established voltage limits stricter, charging would be stopped at the level of 14 volts to save the battery from overcharging, and charging would be resumed when the battery came back to the level of 12 volts to prevent deep discharge of the battery, prolonging the battery usage cycle. The present automated system is not only an ultimate answer to the questions of availability and maintenance of the charges in optimum conditions, but it is also a tangible contribution to the overall security and performance of the electric charging stations. With its complete control ability and monitoring mechanics, the Arduino controller helps to regulate and implement proper operation of the solar charge of an electric vehicle.

3.7 SEPIC Converter Design

This part details the design of a buck-boost converter, which is a crucial component in the solar powered EV charger. Buck boost converters will provide an output voltage that is different from the input voltage that either rectifiers or solar panels use during the battery charging process, regardless of the voltage level, whether it is higher or lower at the time of battery charging.

Design begins with figuring out the resistors, capacitors, diodes, and inductors. Resistors, capacitors, diodes, and inductors are at the early stages of this project. In a steady-state regime, a choke temporarily stores energy before passing it at a rated current condition to a part load. MOSFET acts as a switch in the control procedure. Diodes are unidirectional and flow current just in one direction; therefore, it is regulated by them. Also, capacitors that are connected simultaneously on the output line decrease output voltage ripple.

The main task of the Arduino microcontroller is to control the buck boost converter. It allows the duty cycle frequency of the MOSFET to be modified as per the input voltage and battery charging specs. Through the injection of the designed duty cycle, Arduino will make sure that the output voltage of the charger is stabilized properly, which eventually will provide the required steady charging current to the lithium-ion battery.

The way the Arduino control process is designed makes it possible to observe and control the input voltage and currents in real-time. The Arduino will manage the switch frequency as well as the switch duty cycle in a manner that will ensure that the output voltage is at the desired level. From an AC rectifier or solar panels, the matter is related to the fact that one needs a dynamic adjustment depending solely on the changes in input voltage.

This portion of the work includes modeling parts for buck and boost converter owners, determining component values, and making design recommendations for high efficiency and stability. Besides, the implementation portion contains detailed information on the installation of components into the circuit, soldering of the components, measurements of load conditions, and testing it in different conditions. Without a doubt, the buck-boost converter is relevant because it is the backbone of the whole EV charger that makes the lithium-ion battery charge more efficient and reliable.

Chapter 4:
IMPLEMENTATION

4.1 Introduction

Here is a description of the implementation process of our electric vehicle charging station, which has both grid and solar energy input facilities for efficient charging. The paragraph consists of the hardware implementation and software implementation, control feedback design for the SEPIC converter, and coding in the Arduino environment. Every segment there will elaborate in detail on the process as well as the numerous factors considered to bring the intended product from an idea to success.

4.2 Hardware Implementation

The hardware side involves the process of composition and integration of various parts to create a working charging infrastructure. The primary parts consist of a SEPIC, a bridge rectifier and filter, several relays, a TL494 PWM controller, and an Arduino microcontroller.

SEPIC Converter:

The SEPIC is selected because, despite the voltage variations that could take place in the solar panel, it is an excellent device for generating a stable output voltage. The SEPIC converter has an inductance L, a capacitor C, a diode at the controller, and a switch to regulate the input voltage. The original fluctuating input voltage of the solar panel is then fed to the SEPIC converter, which converts it into a stable 12 V output voltage needed for charging the battery.

The converter is designed in such a manner that the solar input is either more or less than the target output, but the designed output voltage stays constant. Supporting a reliable charging process is also crucial for the charging station's operation. The SEPIC is selected because, despite the voltage variations that could take place in the solar panel, it is an excellent device for generating a stable output voltage.

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Bridge Rectifier and Filter:

Inverters typically run on grid power of 110V AC or 220V (taken from a transformer). These lowering-level AC voltages are then converted to DC using a four-diode bridge rectifier, which is an arrangement in which two parallel halves are connected in reverse polarity. The diode rectifier converts the input AC pulses into leading DC that is passed through the filter, which then smooths it out. Usually, this filter is a capacitor that plays a role in cleaning a direct current so that a ripple is reduced, which leads to a smooth and steady 12V DC output. This avoids the mishap when the grid power is on charge, meaning it does not get mixed up with the charging system.

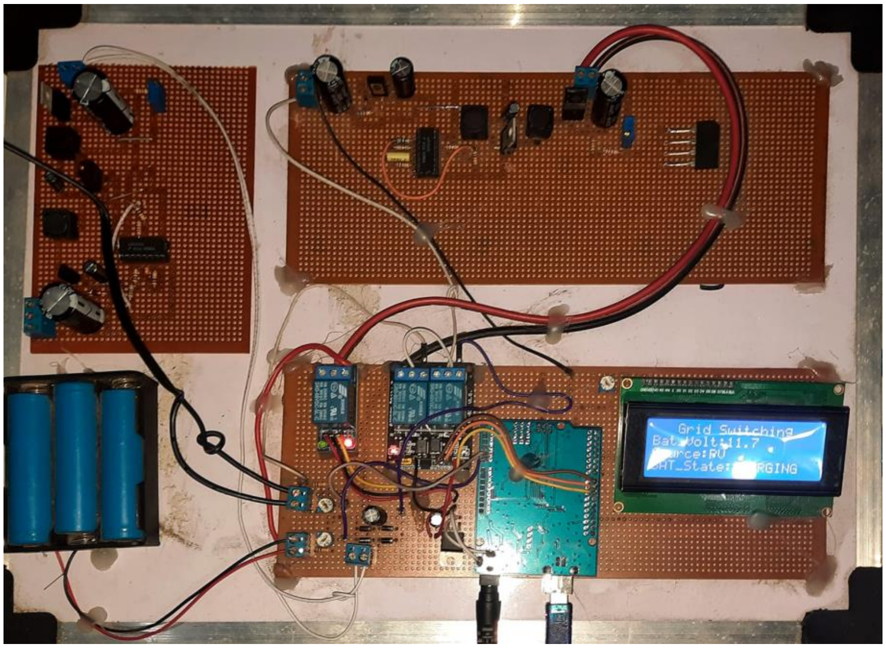
TL494 PWM Controller:

The TL494 PWM Player (PWM-C), which comes with the regulating of the SEPIC converter, belongs to the critical group of the components. It is a variable duty cycle and is used to control the switching transistor of the SEPIC converter, hence the purpose to change the output voltage. This superiority is provided through such characteristics as quiet time control, error amplification, and pulse width modulation making it perfect for this application.

The TL494 is connected to the output voltages of the SEPIC converter via a resistive divider circuit. A feedback signal compared with the reference voltage of TL494, an error signal employed in adjusting PWM signal duty cycle. Through the control of duty cycle, TL494 makes the output voltage 12V with the required mark, provided that the fluctuation in input voltage is occurring in the solar panels.

Arduino Microcontroller:

Arduino microcontrollers play a key role in the neuromechanical system [brain] of the device, which interprets inputs and sends them to the outputs to run the entire system. The binary input pin monitor battery voltage always and software tags for the power supply source choice and battery charging. Microcontroller exchanges data with voltage sensors, relays, etc., so that the system is guaranteed to be dependable through efficiency. Very precise details and diagrammatic representations are shown real in the schematic to highlight the hookups and interactions between the Arduino and the other stuff.



The TL494 pairs with the Arduino breathe more life into the microcontroller system that manages regulating the operation of the SEPIC converter. As illustrated in the Arduino, this device can change the value of VREF on the chip TL494 to adjust the output voltage according to specified needs.

The SEPIC converter has been designed to provide the best performance from the solar system, and the inclusion of the TL494 helps us in precisely controlling this charging station, enabling high voltage output with minimal input. The forthcoming part proves the software load, feedback mechanism and Arduino program that will be used to complete the system.

4.2 Software Implementation

This software implementation is achieved by programming the Arduino to conduct the specific work of the charging station that requires controlling several parameters. The structure of the Arduino program is designed to manage the source of power, check the voltages of the batteries, and control the relays.

Power Source Selection:

The chosen programming language is Arduino which has a choice to make solar power n after the priority. The code checks the amount of sunlight on a regular basis to ensure solar energy is abundant and it will meet the requirement. The Arduino only pulls in the relay to activate the charging system once the solar array has the solar resource and ability to do so. Under the condition of solar power inadequacy, the code finds its way through the grid power and based on it, the corresponding relay is activated. Consequently, this prioritization leads to the likelihood of renewables to be used whenever they are available, increasing the sustainability of the model.

Battery Charging Control:

The potential of a battery is checked by using an analog input pin which is connected to a voltage sensor in the case of the Arduino. Voltages are influenced by current in this sensor, which creates an instantaneous voltage reading. This instantaneous voltage reading is then used by the Arduino to decide the charging state. Voltage beyond 14V causes Arduino to shut down the charge relay that protects battery from being overcharged. This uncharged battery can get damaged owing to excessive charging. Moreover, the incorporation of charging relay makes sure that battery voltage is kept above the threshold of 10V to avoid deep discharge which can be equally detrimental to the battery. As soon as the battery voltage reaches 10V and 14V, the Arduino keeps the relay connected to avoid discharging which will let the battery charge. This regulator enables the battery to be kept at a safe and best operating interface.

Flowcharts and Logic Diagrams:

Making use of flowcharts and logic diagrams will help someone understand how the Arduino program implements the decision-making process. The diagrams depict the functioning of the microcontroller in accepting the data from the sensors, controlling the relays, and managing the charging process thus. They become aids for gaining such an insight into the operational procedure and cutting the bugs from the system by which they help to easily understand the whole flow.

4.4 Feedback Design for SEPIC

The feedback regulator of the SEPIC converter is overly critical. It performs its duty by keeping 12V outflow constant. The next part will introduce the use of reciprocal feedback network that controls this regulation.

Resistive Feedback Circuit:

According to the resistive divider network principle, the sense the output voltage of the SEPIC converter will provide such function. An example may be used to be this network: the resistors are connected in series across the output voltage. The internal control IC takes as input a part of the output voltage measured in the middle of the resistive divider. It then uses this feedback to change the analyzer. Using composition of both feedback voltages and reference voltages, the control IC dynamically modulates the duty cycle of the switch which usually exists inside the SEPIC converter, then the output voltage would reach the expected 12V.

Design Calculations:

In the construction of the feedback network, it is imperative to have correct choice of resistor values that entails making of detailed calculations. These values are decided considering the desired voltage output in addition to the reference voltage of the control IC. Calculations of such type ensure that the feedback signal closely mirrors the output voltage. Here, the article presents the use of the equations and the step-by-step calculations for choosing the rectifier values. These values will aid in creating the restitution and performance of the SEPIC converter.

4.5 Arduino Programming

The Arduino programming session comes in from the basic facts of logic and the functions that control the charging station to the deep end. This involves requirements for the system startup, main control of process, and control of the relay and voltage.

Setup Function:

The setup function just starts the hardware and software configuration of the Arduino which is the main part. This is done by properly setting the input (+ output pins), initializing serial communication for debugging, and configuring the relay right at the start. The setup function enables a forum in which all components are safely checked to guarantee that they are adequately configured and prepared for production without problems upon system startup.

Main Loop Function:

The most important function in the main loop is the computational core for processes that run endlessly. It manages the fundamental duties including the measure of the battery voltage, decision-making about power source choice, and the governing of the relays. The loop function ensures that the system is running indefinitely, and it is actively checking the battery voltage, running low signal, and constant source control, to keep the best charging conditions all the time.

Voltage Reading and Decision Making: Voltage Reading and Decision Making:

The manner of getting the density depends on ADC of Arduino and is used to measure the battery voltage correctly. The program with similar features as this one is based on these readings, analyzing the decision-making logic time to activate the relays. And if the battery voltage goes off the upper bound of 14V, the Arduino turns off the switching relay so that the battery cannot be supercharged. If the voltage drops beneath the 10V threshold then the relay is also deactivated as deep discharging having reduced service life is also avoided. If the voltage belongs to the proper continuum, the Arduino holds the connection to the source of charging and thus prevents inefficient and hazardous charging.

Chapter 5:
RESULTS

Introduction:

This chapter presents the results of the implementation of our EV charging station, which integrates grid and solar energy sources to ensure efficient charging. The performance of the SEPIC converter, Arduino-controlled input source choice, and Arduino-controlled battery charging are analyzed and discussed in detail.

5.1 Constant Output of Converter

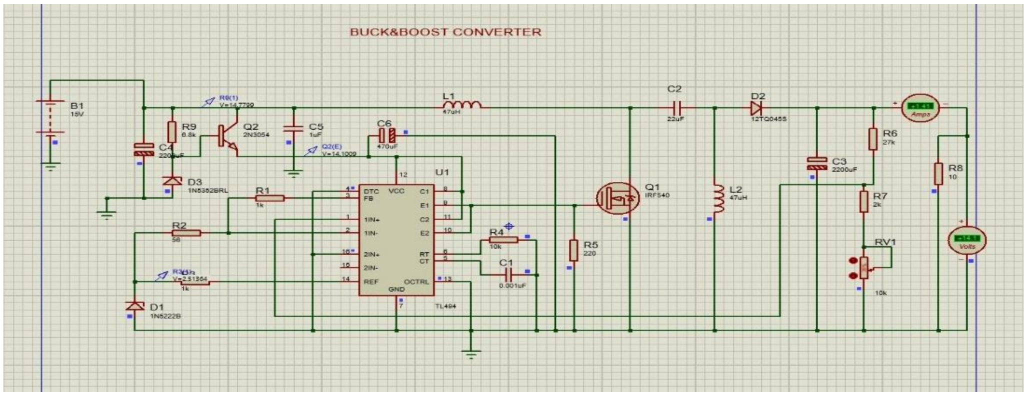
Among others, the primary purpose of using SEPIC converter to our project made is to deliver the constant 14V output even may the solar panels gives out the changing voltage. The significant role of the TL494 PWM controller is supporting the required level of stability.

Evaluate Setup:

For verifying the performance, the configuration of SEPIC converter was evaluated under several input voltages that represented different solar weather. Using a digital multimeter, the output voltage was measured with a scope ranging from 5V to 20V.

Results:

The SEPIC converter managed to hold the output voltage static at 14V, and this happens when the input voltage is highly fluctuating. With the TL494 PWM controller, the duty cycle was tweaked as required, to compensate for the input fluctuations, thereby producing a steady output.



Graphical Representation:

A graph drawing the above-mentioned relationship between input voltage and corresponding output voltages was plotted which showed the constant output voltage of around 14V as (Vout=14) V for all the input voltages (Vin). This shows that the power supply is steady, and the voltage output is clogged, which is important for battery charging.

Discussion:

Conclusively, the experiment findings prove the feasibility of the SEPIC converter and the stabilizing control action of the TL494 circuit. Now, it comes to battery stability which is exceptionally important for being-receiving the constant charging voltage, hence, battery performance is preserved.

5.2 Arduino Controlling Input Source:

The Arduino microcontroller regulates the house to use solar energy, primarily, and switches to grid power as a backup measure. This segment employs Arduino to count the best qualities of this source of selecting inputs.

Evaluate Setup:

The system was evaluated in many ways some of which the solar energy availability was simulated by manipulating the voltage input to SEPIC' inverter. Arduino made the decision to switch on and off between the solar and grid power and as such, the process was seen and recorded.

Results:

The Arduino, placing the penultimate focus on solar energy harnessing, has succeeded. The Arduino was engaged to activate the relay once there was adequate amount of solar power input and connected the SEPIC converter output to the charging system. Whenever solar energy was not enough or unobtainable, Arduino switched the relay that managed the incoming power line, which then became operational.

Event Log:

An event log was created where each record was exact moment when the power was changed. The log documented instantaneous breaking and easy rationality which was essential to avoid interruption of the battery charging process.

Discussion:

But when it comes to Arduino's better control over input source choices it becomes significant in enhancing the system's reliability and efficiency. By being the kind of system that chooses solar power first, it improves the use of renewable energy so that it depends on grid power a lot less and being sustainable is one of its goals.

5.3 A one Arduino-regulated process for battery charging:

The Arduino checks the charging procedure by reading the battery voltage to prevent overcharging. When the battery gets full, the charging relay is turned off and then on as needed. This part shall display the effects of this mechanism of application.

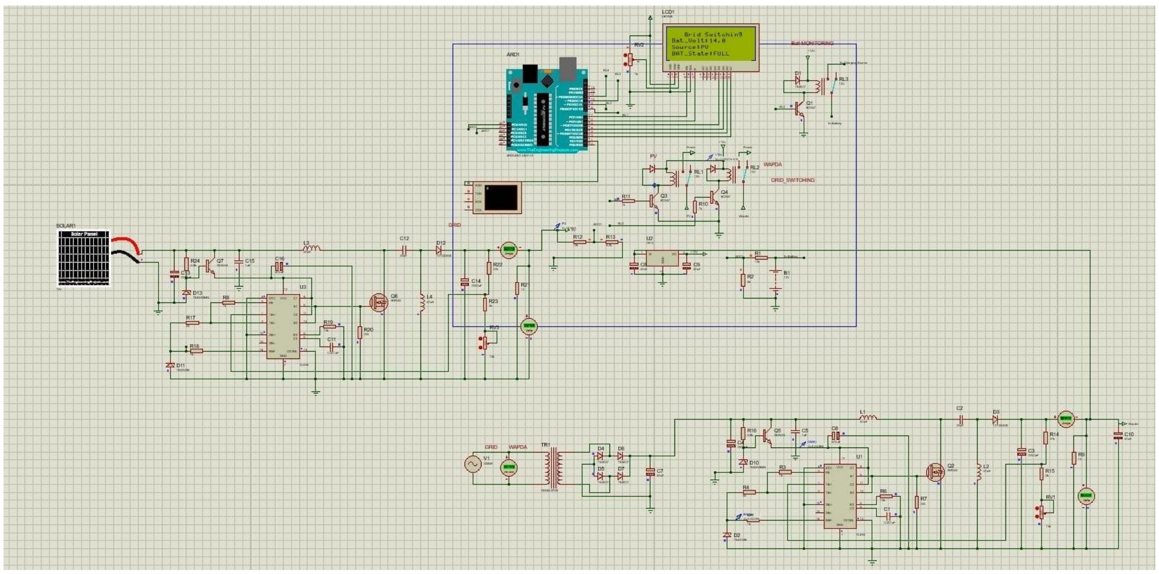
Evaluate Setup:

An Arduino was plugged in, and the battery was charged up and discharged but under controlled conditions to see what its response will be. Threshold values were set up, and Arduino was used to check the output of its activity.

Results:

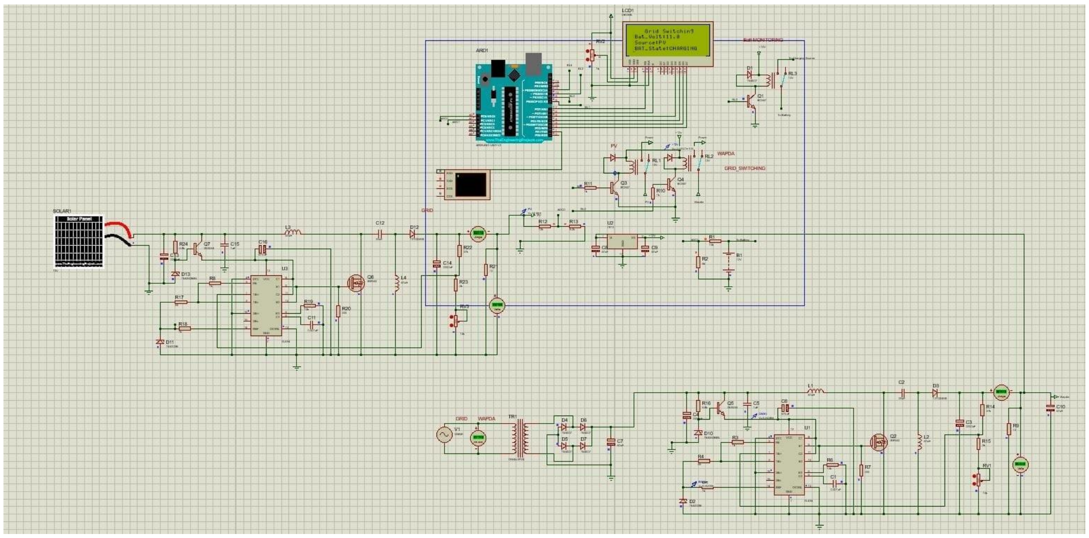
The Arduino accurately checked the battery voltage and controlled the charging relay based on the predefined thresholds: The Arduino accurately checked the battery voltage and controlled the charging relay based on the predefined thresholds:

- With the help of the Arduino, it was possible to turn off the charging relay when voltage passed 14V, in this way overcharging was prevented.



- However, around 10V, the voltage falls in the range, the Arduino automatically deactivated the charger relay to prevent the battery from discharging fully.

- From 10V to 14V, the battery switch relay will remain active during all voltages.



Graphical Representation:

A graph of the voltage-time was plotted showing the battery voltage ending up over time along with the markers depicting the relay input to function. The sensational graph depicts that Arduino efficiently collected and stabilized the input potential so that the output deviation was within the safe operating range.

Discussion:

Arduino control over the charging process guarantees the charging done safely and effectively by managing the entire process. Through the prevention of over-charge or a dying of deep discharge, the system can extend the battery life and keep its performance. This feature allows for the automation of the control unit, so the user is less likely to experience any issues with usability or reliability.

Summary of Results

The SEPIC converter during the study that employed the TL494 PWM controller, and Arduino base system for input source selection and charged battery, has been found to be successful. The data of the DC output voltage condition, which functioned as a constant output voltage, and how solar energy is prioritized when others fail, and making sure that the battery voltage stays within a safe level, were effectively captured. This outcome proves the credibility as well as the dependability of the EV charging station plan, emphasizing the station’s potential for being practical and practical.

Chapter 6:

Discussion and Future Enhancements

6.1 Introduction:

- Improved User Experience: It will enable remote management or scheduling as well as real-time monitoring of energy consumption via mobile apps and user-friendly interfaces as will simplify EV charging process also. All these activities aim at enhancing user experience while improving sustainable mobility options which will result in an increased uptake of EVs.
- Reliability assurance plus ruggedness feature designs: Consequently, even when there is severe weather or power interruptions this system remains strong.

6.2 Discussion of Findings:

The data shows that, with the launch of this initiative, environmentally friendly transport options tend to be more attractive to commuters. Similarly, charging stations from photovoltaic (PV) sources are another renewable energy option available to charge EVs, thereby minimizing the EV running cost against the grid electricity cost. Besides, the atmosphere is another persuasive argument since it is consistent with global efforts to mitigate climate change, indicating that mobility can be powered by energy that is free or renewable.

6.3 Challenges and Limitations:

On the other hand, infections and challenges reported on the back-end part had a solution. These notably involve questions with respect to the current EV charging infrastructure, the intermittent nature of solar panels (in comparison to hydropower, for instance, which can be much more stable), and the limited area at one's disposal. There is a possibility that legal or financial objections might disturb the general adoption. A heating system that caters to the challenges of modern life while improving efficiency and scalability will be the ideal one.

6.4 Recommendations for Improvement:

Following are some recommendations to improve the project: Following are some recommendations to improve the project:

- The correct alignment of a solar panel in both position and direction is measured to obtain the maximum capture of solar radiation.

- The integration of the energy storage system into the EV charging process ensures charging process stability and helps with EV storage intermittency.

- A legislative amendment streamlining the requirements for both parliamentarians and representatives of companies reflecting the infrastructure of renewable energy financing.

- Continuous research and development for the improvement of PV and EV technologies, which make up a significant portion of the earth's expenses.

6.5 Future Enhancements:

As noted, this is the case. Following these recommendations will help their multi-terminal EV charging station with PV support function very well. Thereby, this station will be more convenient, which will help it be accepted across the board the board and therefore have the highest impact on the green transport mode. The integrated EV charging station with PV support presented above may not be optimally maximized; the approach adopted in achieving this may be reviewed to enhance performance. Some of the potential areas for further study include some of the potential areas for further study include:

- Grid Integration and Smart Charging: Having smart grid integration skills is the ability to complete the power transition from only one-way to two-way power between the grid and EV charging stations. In addition, demand response mechanisms, coupled with vehicle-to-grid (V2G) technologies, play a vital role in stabilizing the grid, further maximizing utilization of electricity, and additionally providing owners of EVs with a new source of revenue.

- Technical advances in innovative smart control methods would be crucial for expanding power accumulation from PV. However, for instance, adaptive control methods that combine machine learning algorithms may improve the efficiency of energy harvesting in its ability to respond to changes in its environment by sense and automatically make modifications to the power output. Aside from these, these tests could eventually result in a major enhancement to the internal reliability and performance of the main photovoltaic system because of reviewing and continually adjusting relevant control strategies via the long-term study.

- Scalability and modular design: Along with the charging dock itself, consideration was also made for future expansion of this project. Therefore, there is a need to create a space for distinct EV model interfaces and communication protocol development so that charging infrastructure is compatible with different EV models.

- Improved User Experience: It will enable remote management or scheduling as well as real-time monitoring of energy consumption via mobile apps and user-friendly interfaces as will simplify EV charging process also. All these activities aim at enhancing user experience while improving sustainable mobility options which will result in an increased uptake of EVs.

- Reliability assurance plus ruggedness feature designs: Consequently, even when there is severe weather or power interruptions this system remains strong.

6.6 Social and Ethical Implications:

It is important to contemplate the social and ethical implications of spreading multiple EV charging points supported by PV. Here are some areas that need to be considered:

- Accessibility and Equity: Therefore, even in remote or deprived areas there should be all renewable power sources and every facility for EV charging. By doing this access bias can be fought against hence promoting both environment and social justice.
- Data privacy and security: This involves securing users’ privacy through encryption of specific customer data obtained by charging stations and monitoring devices. It is essential to comply with both data protection legislation and strong cybersecurity measures to maintain people’s confidence.
- Environmental Impact: Constant monitoring of life cycle emissions, depletion of resources, ecological footprints among others on PV installations and EV charging stations will help. Life cycle assessments should use sustainable methods as a means of reducing adverse environmental impacts.

- Technology Dependency: Thus, it becomes necessary to evaluate risks associated with an over-dependence on technological solutions like digital divide, cyberattacks, system breakdowns etc. Promoting technical knowledge and diversifying energy sources can enhance resilience towards these risks.

6.7 Conclusion:

Additionally, it is a demonstration project for using renewable energy (RE) to promote resilience and sustainability in addition to the EV charging infrastructure. Beyond problem solutions and future research, the initiative can better the transition to environmentally friendly and efficient mobility options through smart grid integration and enhanced user experience. However, all these must consider their social, ethical, and environmental impacts if fair sustainable growth is to be ensured.

Chapter 7:

Conclusion and Future Work

7.1 Summary of Findings:

The EV charging station, combined with the PV support, may act as a means of sustainable transport and regeneration. The project deals with the solar power to EV charging systems, which eventually result in fewer running costs, increased energy security, and resulting CO2 emissions.

7.2 Contributions of the Study:

We have a question: Will the addition of solar panels at charging stations for electric vehicles be part of the trend of making sustainable infrastructure in transport in this manner being promoted by the incoming knowledge? Although they convey this message effectively, these results should be used in transportation policies with climate change as a key issue.

7.3 Implications for Remote Healthcare:

The trials only revealed a few things that were not monitored. Indeed, it is committed to the transition to green infrastructure around the city, which will improve public transport. Such as, through PVs and EV charging stations, that fossil fuels turn out to be irrelevant in society, public health is and can be attained. Thus, letting infrastructure that supports clean energy run services can also bring to the more remote villages the ones that offer medical assistance and where the supply of energy is unstable or completely absent in those off-grid places. Therefore, by facilitating persons (or communities) belonging to the weaker sections to access health amenities operating on solar power.

7.4 Future Directions and Recommendations:

The recommended future directions that can be followed are:

- Collaborative Research: interdisciplinary investigations on joint resolutions to problems related to the energy, transport, and health sectors through the involvement of expert professionals.

- Pilot studies: demonstration of multi-terminal EV charging with PVs in different socio-economic and geographic areas, which serves the purpose of pollution reduction. This way, we diverge from the mainstream and borrow something fresh.

- Community Engagement: Promote engagement between stakeholders, including government agencies, utilities, businesses, and social organizations in the process—who are interested in sustainable transportation, clean energy, and community involvement during the process of project planning and execution.

- Long-Term Monitoring: This purpose was to have long-term monitoring stations to observe and assess multi-terminal PV-assisted EV charging station performance trends and to measure and evaluate their reliability and environmental impacts towards the technology improvement process.

These future project's alignments will be integrated by the working parties as a strategy to improve sustainable transport systems based on green power over a shorter timeline.

Relay switching code:

```
#include<LiquidCrystal.h>

LiquidCrystal lcd(7,6,5,4,3,2);

#define PV_sensor A0

#define bat_sens A1

int RL1=8;

int RL2=9;

int RL3=10;

int RL4=11;

float bat_volt=0.00;

float PV_volt;

float PV_value;

String d1 ="PV";

String d2 ="WAPDA";
```

```
String d3 ="CHARGING";
String d4 ="FULL";
String d5 ="DISCHARG";

void setup() {
  Serial.begin(9600);
  lcd.begin(20,4);
  pinMode(RL1,OUTPUT);
  pinMode(RL2,OUTPUT);
  pinMode(RL3,OUTPUT);
  pinMode(RL4,OUTPUT);
  lcd.setCursor(3,0);
  lcd.print("GRID_SWITCHING");
  delay(2000);
  lcd.clear();
  digitalWrite(RL1,HIGH);
  digitalWrite(RL2,LOW);
  digitalWrite(RL3,HIGH);
}

void loop() {

  PV_value=analogRead(PV_sensor);
  PV_volt=(PV_value*5.0)/1024*2.4;
  Serial.println(PV_volt);

  float value= analogRead(bat_sens);
  float volt=(value*5.0)/1024;
```

```
bat_volt=(volt*3.0);
delay(20);
Serial.println(bat_volt);

  lcd.setCursor(3,0);
  lcd.print("Grid Switching");
  lcd.setCursor(0,1);
  lcd.print("Bat_Volt:");
  lcd.print(bat_volt,1);




if (PV_volt<10)
{
  digitalWrite(RL1,LOW);
  digitalWrite(RL2,HIGH);
  lcd.setCursor(0,2);
  lcd.print("Source:");
  lcd.print(d2);
  lcd.print("     ");
}
else
{
  digitalWrite(RL1,HIGH);
  digitalWrite(RL2,LOW);
  lcd.setCursor(0,2);
  lcd.print("Source:");
  lcd.print(d1);
```

```
  lcd.print("     ");
 }


 if(bat_volt>14)
 {
  digitalWrite(RL3,LOW);
  lcd.setCursor(0,3);
  lcd.print("BAT_State:");
  lcd.print(d4);
  lcd.print("     ");
 }

else if(bat_volt<10.5)
 {
  digitalWrite(RL3,LOW);
  lcd.setCursor(0,3);
  lcd.print("BAT_State:");
  lcd.print(d5);
  lcd.print("     ");
 }
 else
 {
  digitalWrite(RL3,HIGH);
   lcd.setCursor(0,3);
  lcd.print("BAT_State:");
  lcd.print(d3);
  lcd.print("    ");
 delay(5);
 }

delay(250);}
```

Complex Engineering Problem: Integrating a Multi-Terminal EV Charging Station with Photovoltaic (PV) Systems

The design and deployment of an EV charging station with multiple terminals and a solar panel (PV) as a single system should include engineering nuances. The complexity brings with it the necessity to seamlessly integrate renewable energy sources with electric transportation infrastructure, of all things, ensuring efficiency, reliability, and scalability. Below is a detailed breakdown of the complex engineering problem: Below is a detailed breakdown of the complex engineering problem:

- **Collaboration and system integration:**
  - Challenge: This may be achieved by bundling together different subsystems, including PV arrays, EV chargers, ESS, and grid connections, thus forming a coherent and effective system.
  - Solution: Create ambitious algorithms for controlling and monitoring purposes as well as for communication between the modules in real-time in order to ensure smooth work for all elements.

- **Energy Management Operation:**
  - Challenge: Successfully balance solar energy's capacity variations and frequent changes in EV charging with uncertain demand.
  - Solution: Develop and EMS with predictive analytics and machine learning to preemptively create energy production and consumption patterns, as well as balance the power across the system with a scope to balance supply and demand dynamically.

- **Stability and reliability of power:**

- Challenge: The task is to maintain power quality and reliability with the integration of RESs with the grid and the charging infrastructure, for example, by ensuring nominal and controlling fluctuations in voltage, frequency stability, and other reliability issues.

- Solution: Utilize state-of-the-art power electronics equipment such as inverters and converters with an enhanced control regime to shape the position of voltage and frequency. Teach ESS to be used in the power backup service and to lower frequency fluctuations.

- **Scalability and flexibility to the existing infrastructure:**

  - Challenge: Incorporate the system features that enable scaling and flexibility should it be later that a substantial amount of EVs and renewables are overturned to the power grid.

  - Solution: Make use of modules to simplify the installation of PV systems, fast charging stations, and stationary storage units. Implement the scalable software technologies that will allow you to incorporate new technology and control the expanded data and control requirements.

- **Affordability and Cost -Effectiveness:**

  - Challenge: Juggle the initial investment costs against the long-term operational savings and economic benefits so that the compound prevails economically and a return on investment (ROI) is achieved.

  - Solution: Take a properly full techno-economic analysis that can locate cost-reducing opportunities, enhance the system's effectiveness, and explore the financial incentives and subsidies that are available for renewable energy projects.

- **Regulation and Compliance (R&C):**

  - Challenge: Find your way in the regulatory terrain and make sure to observe all applicable standards and stipulations that influence the way the city maintains sustainable energy resources and EV infrastructure.

- Solution: Participate in regulatory bodies to understand specifications and comply with the rules.

- **User experience and accessibility:**
    - Challenge: Set up a responsive and user-friendly interface to make it an EV driver's best friend; you have to ensure a system is available to all, including those who are visually impaired or have the difficulty hearing.
    - Solution: Launch mobile application and a user interface that provide one click checkouts, clear navigation, and real-time status details. Physical design of the charging station shall be properly extended with the intent to make it level with accessibility standards.

- **Environmental and social impact**
    - Challenge: Evaluate and evaluate the social and environmental impact the project can produce, including land use, the community's attitude, and long-term sustainability.
    - Solution: Go for Environmental Impact Assessments (EIA) and work with local communities to rectify concerns as well as provide support for sustainable development targets. Adopt sustainable methods of building and use to ensure minimal unwanted effects.

References:

[1] R. Garcia-Valle and J. A. Peças Lopes, *Electric Vehicle Integration into Modern Power Networks*, Springer, 2012.

[2] S. S. Refaat and H. M. Emara, *Smart Grid and Enabling Technologies*, CRC Press, 2020.

[3] R. A. Messenger and J. Ventre, *Photovoltaic Systems Engineering*, CRC Press, 2010.

[4] J. Ekanayake, K. Liyanage, J. Wu, A. Yokoyama, and N. Jenkins, *Smart Grid: Technology and Applications*, Wiley, 2012.

[5] L. E. Jones, *Renewable Energy Integration: Practical Management of Variability, Uncertainty, and Flexibility in Power Grids*, Academic Press, 2014.

[6] M. Rahmani-Andebili, *Planning and Operation of Electric Vehicles in Smart Grids*, Springer, 2021.

[7] Y. D. Wong, *Sustainable Transportation and Smart Logistics*, Springer, 2021.

[8] R. E. Brown, *Electric Vehicle Charging Infrastructure: Economic and Environmental Perspectives*, Elsevier, 2019.

[9] G. Boyle, *Renewable Energy: Power for a Sustainable Future*, Oxford University Press, 2012.

[10] B. K. Bose, *Power Electronics and Renewable Energy Systems: Proceedings of ICPERES 2014*, Springer, 2014.

[11] P. Siano and P. P. Mancarella, *Smart Grid Handbook*, Wiley, 2016.

[12] B. Kroposki, *Renewable Energy Integration: Challenges and Solutions*, Academic Press, 2017.

[13] A. Emadi, *Advanced Electric Drive Vehicles*, CRC Press, 2014.

[14] P. C. Jain, *Energy Storage for Smart Grids: Planning and Operation for Renewable and Variable Energy Resources (VERs)*, Elsevier, 2017.

[15] J. Dunlop, *Photovoltaic Systems Design and Installation Manual*, McGraw-Hill, 2010.

[16] I. L. Azevedo, *Grid Integration of Electric Vehicles in Open Electricity Markets*, Springer, 2015.

[17] G. N. Tiwari, *Renewable Energy Resources: Basic Principles and Applications*, Alpha Science International, 2005.

[18] S. A. Kalogirou, *Solar Energy Engineering: Processes and Systems*, Academic Press, 2013.

[19] J. D. Glover, M. S. Sarma, and T. Overbye, *Power System Analysis and Design*, Cengage Learning, 2016.

[20] W. Kempton and J. Tomic, *Vehicle-to-Grid Power Fundamentals: Calculating Capacity and Net Revenue*, Wiley, 2014.

[21] J. Twidell and T. Weir, *Renewable Energy Resources*, Routledge, 2015.

[22] N. Hatziargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 2014.

[23] T. Denton, *Electric and Hybrid Vehicles*, Routledge, 2020.

[24] D. Mukherjee and S. Chakrabarti, *Fundamentals of Renewable Energy Systems*, New Age International, 2005.

[25] C. C. Chan and K. T. Chau, *Modern Electric Vehicle Technology*, Oxford University Press, 2001.