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DESIGN AND IMPLEMENTATION OF SOLAR CHARGING STATION FOR ELECTRIC VEHICLES

Dr S. Thangalakshmi[1], Dr K. Sivasami [2]& Saad Khan[3]

Abstract

With the increasing demand for sustainable transportation solutions, electric vehicles (EVs) have gained significant popularity as an eco-friendly alternative to traditional internal combustion engine vehicles. However, the widespread adoption of EVs is still hindered by limited charging infrastructure and concerns about the environmental impact of electricity generation. This research project focuses on the development of a Solar Charging Station (SCS) tailored specifically for EVs. The primary objective is to design an efficient and environmentally sustainable charging system that utilizes solar energy as its primary power source. The SCS integrates state-of-the-art photovoltaic panels, energy storage systems, and advanced power management techniques to optimize energy capture, storage, and delivery to EVs. The primary objective of this research is to develop a solar charging station inside the IMU Chennai Campus for PHASE 2 of its EV project that maximizes energy utilization, minimizes grid dependency and ensures optimal charging performance for EVs.

Keywords: Solar charging station; electric vehicle; carbon footprint; solar panel & sustainability.

1. INTRODUCTION

The transition to electric vehicles (EVs) is a crucial step towards reducing greenhouse gas emissions and combating climate change. To support this transition and promote sustainable transportation, the development of efficient and environmentally friendly charging infrastructure is imperative. This paper introduces a novel concept of a Solar Charging Station (SCS) for the Electric Vehicle – Minsara Meen, developed by IMU Chennai Campus. This will include

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renewable energy sources with an effective charging technology to create a sustainable and convenient solution.

The SCS integrates photovoltaic (PV) solar panels, energy storage systems, and advanced charging equipment into a comprehensive infrastructure [Khan et al., 2018]. The PV panels harness solar energy during daylight hours, converting it into electricity and storing excess power for later use. This stored energy can then be used to charge EVs during the day or night, reducing the strain on the grid and ensuring uninterrupted charging services.

This paper presents the SCS as a viable and sustainable solution for the future of EV charging infrastructure. Its environmentally friendly approach, cost-effectiveness, and grid independence make it an attractive option for governments, businesses, and individuals looking to support clean transportation and reduce their carbon footprint. As the world continues to prioritize sustainable transportation, the SCS represents a step forward in aligning EV charging with renewable energy sources, ultimately contributing to a cleaner and more sustainable future for all.

2. ELECTRIC VEHICLE OF IMU CHENNAI CAMPUS

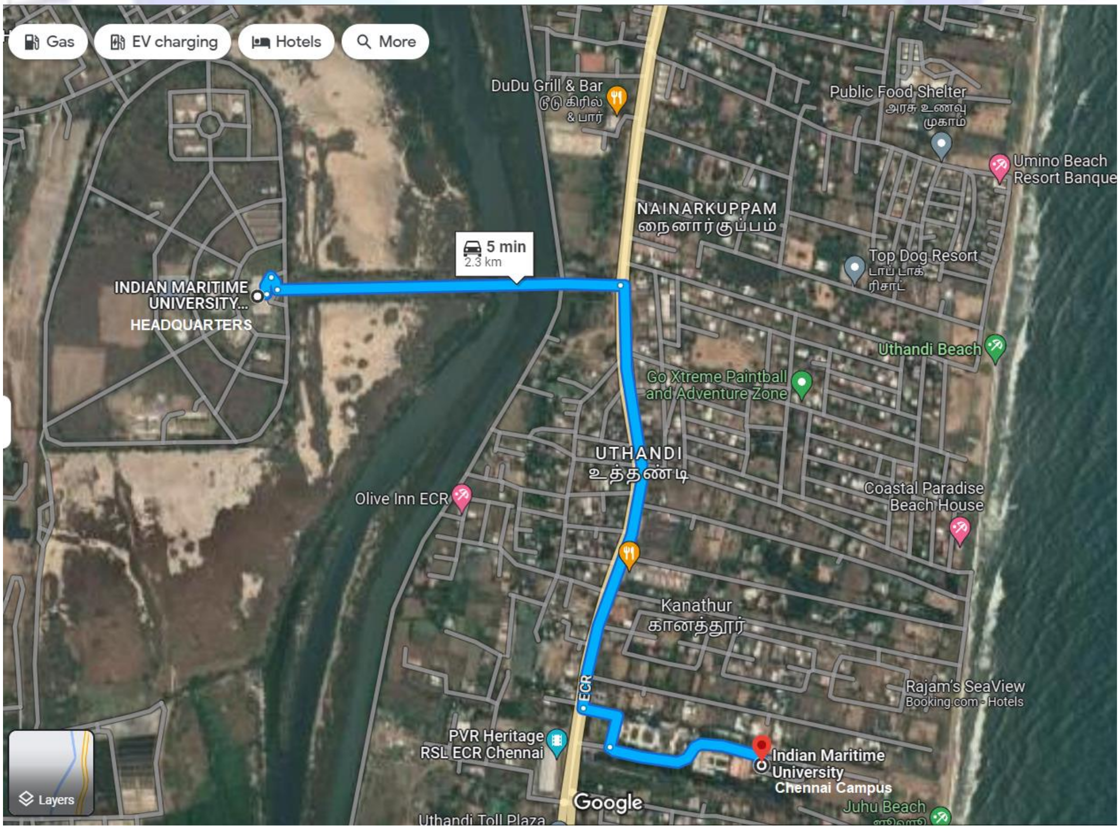
The distance between the Academic and Administrative Block from the Residential Block inside Semmencherry premises is around 1Km and the distance between the Semmencherry premise and the Uthandi premise is around 2.5Km. The EV was developed to reduce the dependence on fossil-fuel burning vehicles to commute and transport which will in turn reduce carbon emissions [Thangalakshmi et al., 2023].

Using an EV for commute will help both in the conservation of university resources and easy means of transport for faculty, staff and cadets.

As the development of the EV is completed, planning PHASE 2 which includes development of Solar charging stations at strategic locations in the campus is currently under works. This paper includes the plan of action, calculations, requirements and technical details for the same.

Figure 1 - The Electric Vehicle developed by IMU Chennai

Figure 2 - Map Showing Semmencherry and Uthandi Premises of IMU Chennai Campus

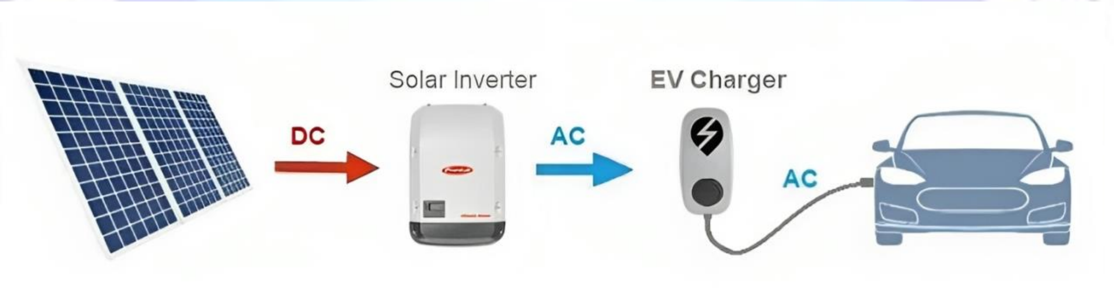


3. OBJECTIVES AND SCOPE

The main objective of the project is to design a solar hybrid charging station for our electric vehicle considering all parameters such as sunlight availability, charging area required for solar panel, battery and power calculation and considering every parameter about charging and equipment. The design should be such as to prevent local grid overload and guarantee a higher percentage of clean energy. A combined system of grid-connected PV modules and battery storage could support the charging station.

The demand for rooftop solar charging stations is expected to increase in the near future as the number of electric cars increases [Alkawsi, Gamal, et al., 2021]. Solar energy can serve as an alternative source of energy and be used to address excess electricity demand. India can use solar energy to generate electricity and store energy in batteries. It can also be used to charge electric cars. This will not only fill the energy generation deficit but will also contribute greatly to green energy generation that will help reduce climate change issues.

Figure 3 - A Simple Sketch of Solar Powered EV Charging Station



4. PROPOSAL AND ACTION PLAN

It is of great importance that the PHASE 2 of the project should be carried out station by station due to both the complexity and the cost required to erect a couple of charging stations across the two campuses of IMU Chennai.

4.1 Proposed Sites for Solar Charging Stations

In consideration of sustainable and convenient solutions for charging electric vehicles, two prime sites have been identified for the installation of solar charging stations:

4.1.1. Semmencherry Premises

The parking lot of IMU HQ is recommended for the erection of the 1st Solar Charging Station due to the following advantages:

- Solar Panels required can be directly installed on the top of the canopy which pre-exists currently on site.
- There is no need to construct anything for shade for the safety of the electric vehicle.
- If the SCS is set up on this site, HQ staff and Faculty Members can charge their own Hybrids or EVs conveniently.
- Only requirement will be to make arrangements for the storage of batteries.
- The site is practically situated at the center point of the premises and hence at an approachable distance from anywhere inside the premises.
- This site guarantees safety and is closest to the main gate situated on ECR road.

4.1.2. Uthandi Premises

The facade of IMU Chennai Campus Main Building is recommended for the erection of the 2nd Solar Charging Station due to the following advantages:

- Solar Panels required can be directly installed on the top of the terrace of Main Building without any extra effort and cost.
- If the SCS is set up on this site, Chennai Campus staff and Faculty Members can charge their own Hybrids or EVs conveniently.
- The site is practically situated at the entrance to the main building hence preventing the passengers to walk unnecessarily.
- This site guarantees safety and is closest to the premise’s main gate situated on ECR road.

Figure 4 - Map Showing the proposed site for SCS at Semmencherry Premises

Figure 5 - Map Showing the proposed site for SCS at UTHANDI Premises

5. COMPONENTS OF A SOLAR CHARGING STATION

In the construction of an efficient solar charging station, several key components play a vital role. These components ensure the optimal generation and management of clean energy for electric vehicles. Let's delve into each of these components to understand their significance in the system.

5.1 Solar Panels

The solar panel serves as a charging module for EVs using a renewable energy source, which is solar energy. We planned to install monocrystalline solar panels on top of our electric vehicle. Photovoltaic cells convert sunlight into electricity that can be used to charge an electric car. The same will be used in a solar charging station.

5.2 Charge Controller

A solar charge controller acts as a regulator for your solar battery, preventing it from overcharging and overheating. Batteries are rated for a specific voltage capacity and exceeding this voltage can lead to permanent battery damage and loss of functionality over time.

5.3 Solar Tracker

The use of Solar Tracker systems increases the amount of solar energy received by the solar collector and improves the energy output of the electricity produced. The solar tracker will increase the output of the solar panels by 20-30%, which increases the system economics of the solar panel project.

5.4 Battery

Batteries in photovoltaic systems are subject to frequent charging and discharging. Lithium-ion batteries with deep discharge technology are commonly used for automobiles and for photovoltaic applications.

5.5 Inverter

It is a combined solar inverter and EV charger that can be charged directly from rooftop solar panels. Integrating the charger with the solar inverter is a smart solution that eliminates the need for a separate EV charger as well as additional wiring and possible electrical upgrades.

5.6 DC Charger

The battery uses direct current for charging. A DC charger is an external module that converts AC mains power into DC power for charging an electric vehicle. It works in parallel with the solar panel when connected to the charging station and charges the battery.

Figure 6 - Recommended Solar Panel (330W 24V POLYCRYSTALLINE)

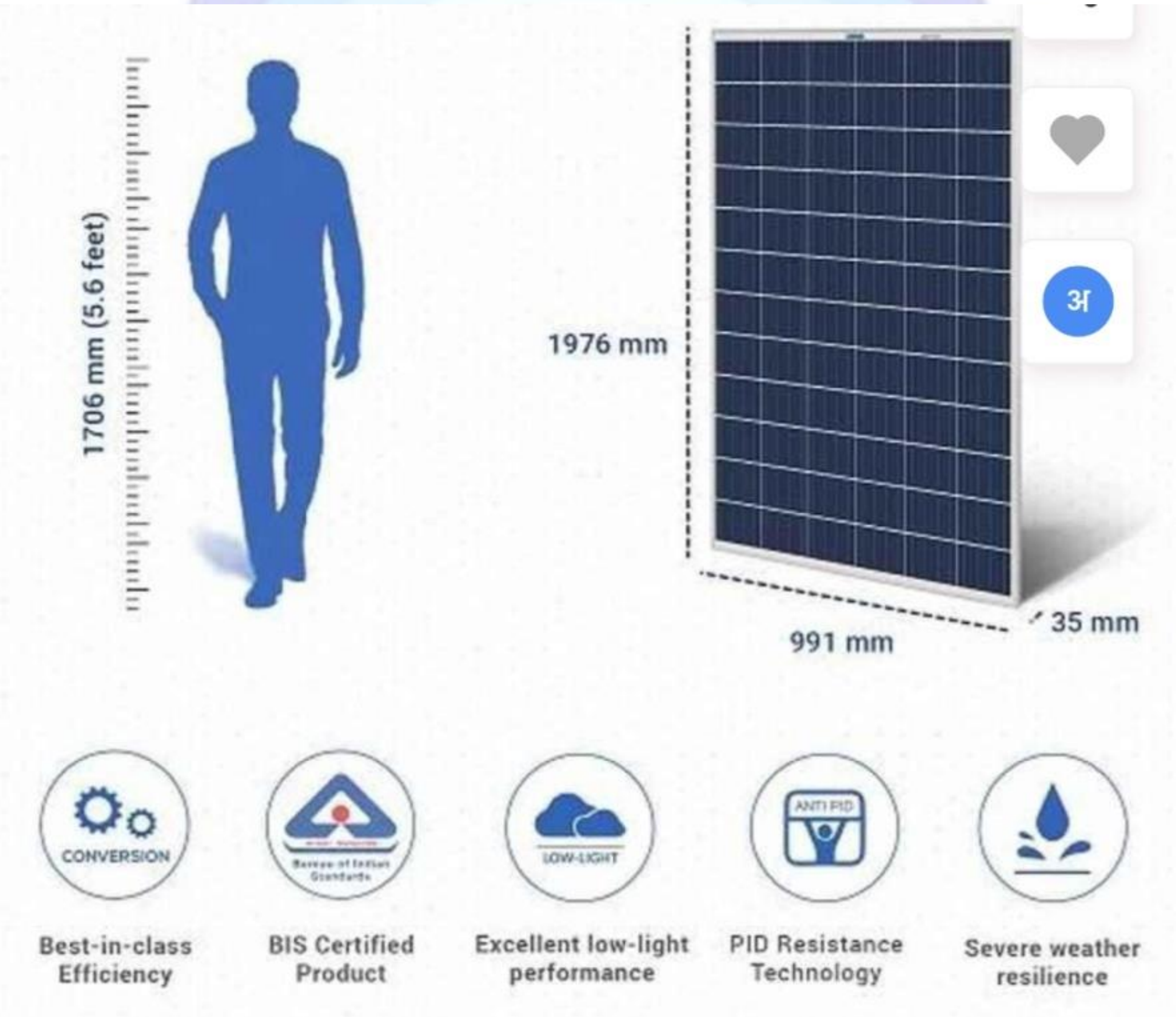


Figure 7 - Battery and Charger used in the EV

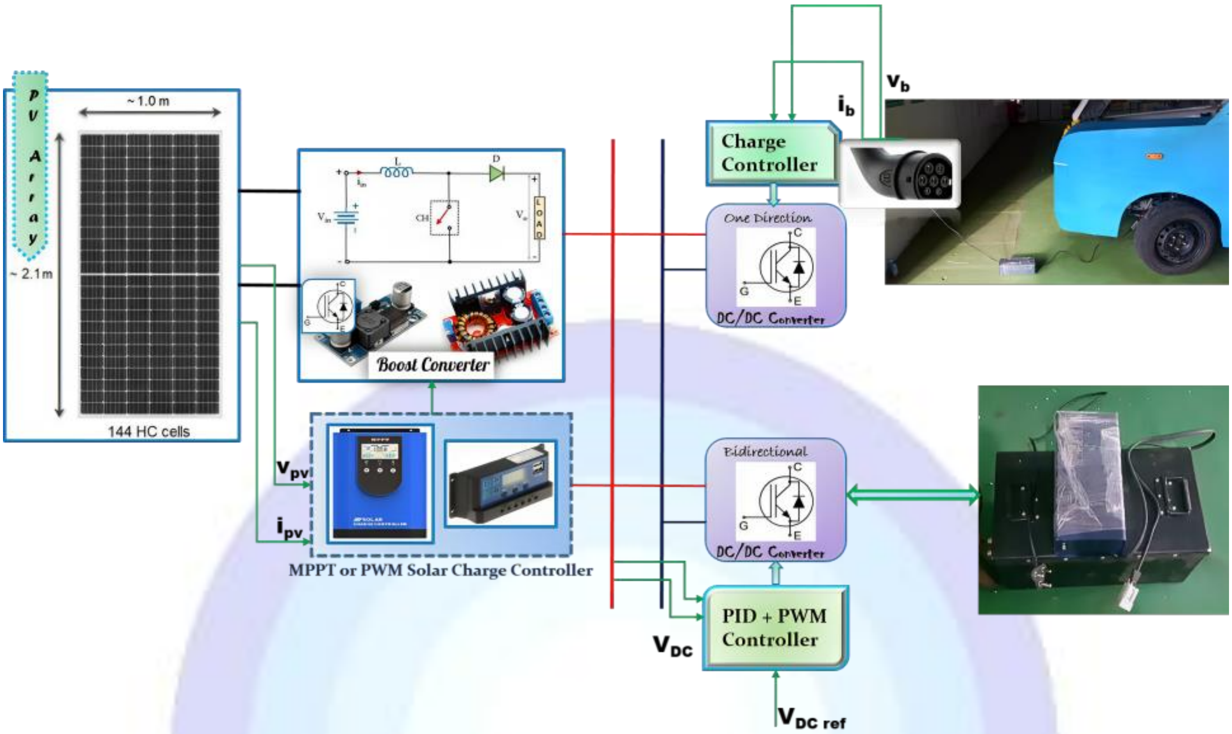
6. DIFFERENT SOLAR CHARGING SCHEME

In the realm of solar charging stations, different charging schemes and systems are employed to efficiently harness renewable energy for electric vehicles. These schemes encompass a variety of innovative approaches, each designed to cater to specific needs and environmental conditions. Let's explore the diverse solar charging schemes and their unique attributes in the following sections.

6.1 PV Grid Charging System

The photovoltaic grid charging system is an advanced future development [Al-Ezzi et Al., 2022]. The given architecture shows the photovoltaic charging system, which studied from different papers. Given architecture shows that there are two stages obtained from DC-to-DC converter and DC to AC converter [Ye et al., 2015]. The dc bus is more importance because it makes the interface the PV array, energy storage battery of electric vehicle including other dc power electronics. Furthermore, the dc bus has a high importance, because it is proposed to interface the PV array, the ESU and the EV battery pack including other dc powered electronics.

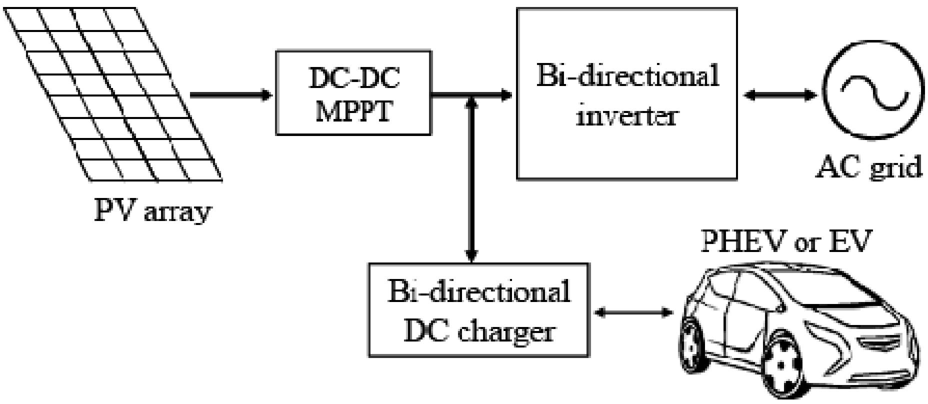
Figure 8 - Proposed Solar EV Charger



6.2 Standalone PV Charging System

Standalone PV charging system: In off grid station, energy is provided to EV's batteries without any connection of grid [Bagher et al., 2015]. The charging system is connected with an Energy Storage Device unit (ESD) for to deliver power continuously to the EV battery during night period [Chen et al., 2016].

Figure 9 - PV Charging System



7. CALCULATIONS

To comprehend the entire system, the following calculations are performed:

Solar system [at 1000W/m^2 of solar irradiance at 25^{0}C]:

Consider, 50 kW of solar system [i.e., daily output]; Average sunshine in India = 5 Hours.

kW = (50 kWhr)/5 hrs = 10 kW

10 kW system will be needed for obtaining 50 kW output per day.

We cannot harness the full power of the sun since its intensity changes throughout the day. Taking into account a solar panel with a peak output of 385 watts

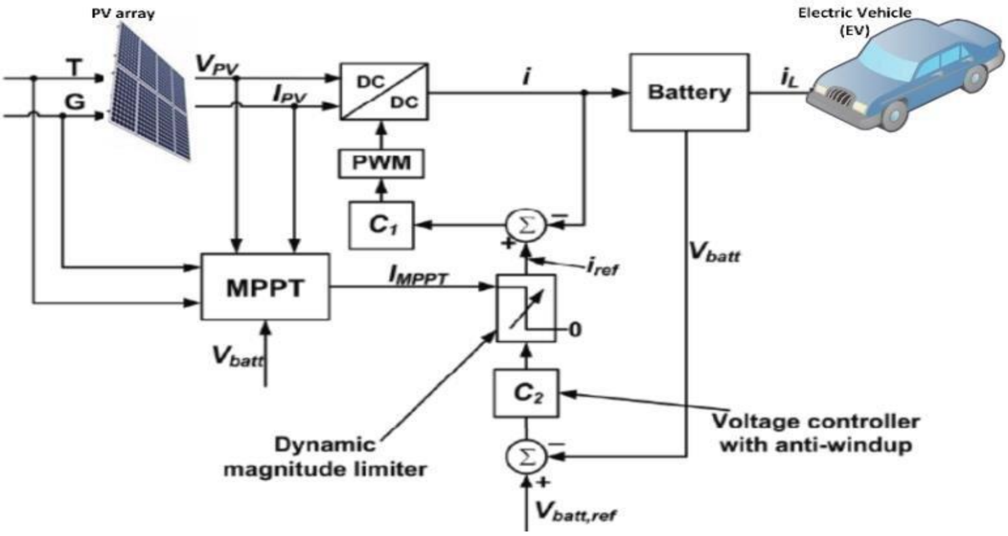
(with V_{peak} = 40.3 V & I_{peak} = 9.56 A; P = V_{peak} * I_{peak}),

∴ No. of panels required for 10 kW system will be:

(10 *10^3 Watts) / 385 Watts = 25.97, or almost 26 panels.

Panels are connected in series to boost voltage output and in parallel to boost current output. The current and voltage requirements determine the series parallel combinations or the arrangement of connecting the panels.

Figure 10 - PV Stand Alone Charging System



Solar panel dimensions are:

Length = 197.6 cm; Width = 99.1 cm; Thickness = 3.5 cm.

∴ Area of Solar Panel = Length * Width = 19582.16 cm^2 = 1.95 m^2.

∴ Total Area for 26 panels = 26 * 1.95 = 51 m^2.

Dimensions of the EV are:

Length = 4.95 m; Width = 1.69 m; ∴ Area of EV = Length * Width = 4.95 * 1.69 = 8.366 m^2.

∴ Minimum Area required for Solar Charging Station is 51m^2.

Calculation for battery to be used for solar electricity storage:

The nominal voltage of Lithium-ion battery is 3.60V/cell and current is 2600mah.

P = V * I = 3.60 * 2.6 = 9.36 Watt (For one cell)

We considered a Lithium polymer battery with following specifications:

Capacity: - 30.2 kWhr & 320 V Lithium polymer battery.

To get the number of cells in a battery pack:

Total output power = 30.2 kW

Output power of one cell = 9.36 Watts.

∴ No. of cells = (30.2 * 10^3 Watts)/9.36 Watts

= 3226.49 cells No. of cells ≈ 3227 cells.

Calculating ampere output of battery

P = V * I = (30.2 * 10^3) = 320 * I

∴ I = 94.375 A.

∴ To calculate no. of cells in series / parallel.

$(P_{Battery})/(P_{cell}) = (V_{Battery})/(V_{Cell}) * (I_{Battery})/(I_{Cell})$

= (320/3.6) * (94.375/2.6 3227)

= 88.88 * 36.29 3227

= 89 * 36

∴ 89 cells are connected in series & 36 cells are connected in parallel to meet the battery capacity.

Operating voltage for batteries:

∴ Lithium-ion will operate safely within the designed operating voltages.

Normal cell voltage = 3.6 V Typical end of discharge

= 2.8V – 3.0V Maximum Charge Voltage

= 4.2 V. As 89 cells are connected in series,

∴ (89 * 4.2 = 373.8 Volt) is the maximum charge voltage of a battery pack. Voltage should not exceed this value; it may lead to temperature rise & battery damage.

∴ (89 * 2.8 = 249.2 Volt) i.e., when voltage reaches 249.2 Volt hence, battery will be in discharged state.

8. MAJOR LOSSES IN SOLAR POWER GENERATION

Converting solar energy to electrical energy involves a number of procedures. Many losses occur during the conversion as a result of the complicated system [Mouli et al., 2016]. The solar energy collected by the PV panel is significantly greater than the electrical energy produced. Because of the numerous components in a PV system, the majority of the energy is wasted as conversion loss in the components or transmission loss in the cables [Steinschaden at al., 2020]. Because no system on the earth is completely efficient, it can only transform a portion of the energy we provide as input into useable energy, and the remainder is lost to the environment. The losses through various sections of solar power scheme are given below:

8.1 Solar panel:

A solar PV panel's primary function is to convert sunlight into direct current (DC) electrical energy. Not all of the sun's rays that strike the panels are turned into direct electrical energy; a portion of it is reflected back or dissipated as heat into the surroundings. A one square-meter solar panel (PV) held on the earth's surface collects roughly 1,000 watts of solar energy in the afternoon and under clear skies. It is used to convert a little fraction of a solar panel's efficiency, around 18%, into electrical energy. The remaining 82% of the energy is either reflected back or lost as heat into the environment. This is referred to as energy conversion loss. The solar charge controller protects the battery from overcharging.

8.2 Battery:

When the energy from the PV panels is not utilized to charge the car, it is stored in the solar batteries as chemical energy, which may subsequently be used to power the vehicle when there is insufficient sunshine or late at night. Solar cells' primary job is to convert chemical energy into direct current energy, and losses may occur during this electrical conversion. For example, if a battery is 80% efficient, it will transform 80% of the stored chemical energy into direct current electrical energy.

8.3 Inverter:

The solar panels convert the energy into DC electrical energy, which is then sent to the inverter. An inverter's primary job is to transform direct current electrical energy into alternating current electrical energy. An inverter, for instance, has a 95% efficiency, which means it can transform 95% of the input DC electrical energy into AC electrical energy while the rest is lost through gearbox losses [Yap et al., 2019].

8.4 Wires:

Lead wires, which are conductors, also cause some losses. The distance between the solar system's components should be kept within a particular range. As the distance grows, so will the size of the wire, resulting in more wasted energy. Therefore, a minimum or optimal distance should be maintained between the various components and the electrical load, and the appropriate size of conductors should be chosen.

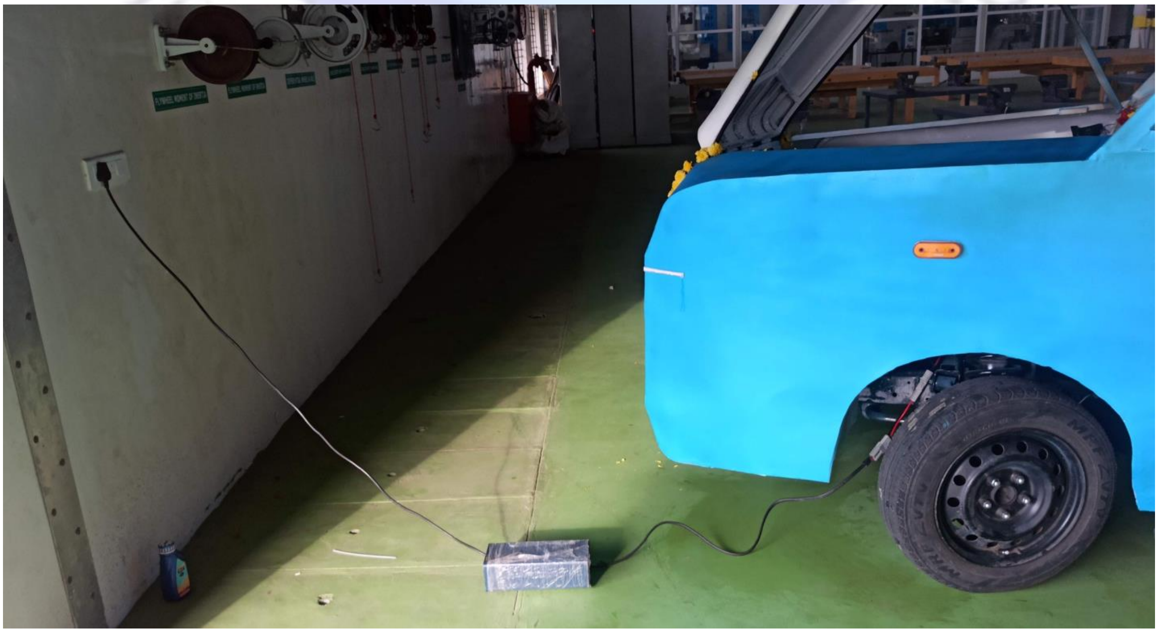
8.5 Loss of design:

When the angle of the sun's rays striking the surface of the solar panel is perpendicular, the panels perform optimally. However, due to the Sun's and Earth's relative motion, the sun's beams cannot always be perpendicular to the surface of the solar panel. Solar trackers assist panels in moving from east to west in line with the movement of the sun to capture the most sun rays, however because solar trackers are quite expensive, they cannot be used for tiny units [Tanveer et al., 2022]. Therefore, the best approach to save money and limit the usage of a solar tracker is to identify the ideal tilt and direction of the panels with regard to the sun's rays so that the panels receive the most sunlight during the day. The tilt and orientation are determined by the location of the panels.

8.6 Loss due to aging:

Solar PV panels frequently degrade with time, providing less direct current and becoming less efficient. Solar panels' output power will diminish to around 80% of their rated power in the 25th year.

Figure 11 - EV under charging through grid connection.



9. BENEFITS OF SOLAR CHARGING STATION

Sustainability: By utilizing solar power, the SCS significantly reduces carbon emissions associated with EV charging. It harnesses clean, renewable energy, thereby contributing to a greener transportation ecosystem.

Cost-Effective: Over time, the SCS offers cost savings compared to traditional charging stations, as it generates its own electricity and reduces reliance on grid power. Additionally, it benefits from government incentives and tax credits for renewable energy installations.

Grid Independence: The inclusion of energy storage systems allows the SCS to operate independently from the grid, providing reliable charging services even in remote locations or during power outages.

Scalability: The modular design of the SCS allows for easy scalability, enabling the addition of more PV panels and charging stations to meet growing demand.

Smart Management: The SCS incorporates advanced monitoring and management systems, allowing operators to optimize energy use, track station performance, and provide real-time data to users through smartphone apps or online platforms.

10. CONCLUSION

According to reports, India has 21 of the world's 30 most polluted cities, and the country is rated fifth on the list of most polluted countries. The electricity generating industry is now India's greatest carbon emitter. Furthermore, carbon particle emissions from the automobile industry are fast increasing as the number of gasoline-powered cars increases. The highest accomplishment of pollution control goals is related with effective pollution management from these two expanding industries. Thus, this paper attempts to build a model that combines solar charging stations for electric cars and the usage of EVs to reduce pollution from both the power generating and automotive sectors at the same time. The SCS for Electric Vehicles is a viable approach for improving EV charging infrastructure accessibility and sustainability. This technology, by using solar power, not only diminishes the environmental effect but also adds to the general expansion of electric mobility, encouraging a more sustainable and cleaner transportation for future automotive sectors.

To summarize, EV SCS are a sustainable and forward-thinking solution to the issues of modern transportation. They lower emissions, increase charging accessibility, improve energy efficiency, and give economic incentives, all of which contribute to a more ecologically benign and economically viable future for electric transportation. As technology progresses and solar energy becomes more widely available, these stations will play a critical role in hastening the transition to a cleaner, more sustainable transportation system.

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Cadet. Sadd Khan, Cadet of Batch-08 (2019-2023) of B. Tech Marine Engineering at Indian Maritime University, Chennai Campus has signed a contract with MSI and is serving as a Trainee Marine Engineer in oil tanker.

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