

Smart EV Charging Station Based on Renewable Energy Sources

Miss. Hembade Priyanka T., Miss. Mote Arya A., Mr. Bankar Yogesh M.,

Mr. Chaugule Ajay S., Prof. Priyanka Ujanikar

U.G. Students, Department of Electrical Engineering, Fabtech College of Engineering and Research, Sangola, Maharashtra,

ABSTRACT: A solar charging station converts solar energy into electricity and stores it in a battery bank to ensure that automobiles are fully charged while being environmentally friendly. And if the battery's capacity is exceeded, it will draw power from the grid. It is imperative to charge electric vehicles using sustainable sources of electricity, such as solar or wind energy, if they are to be genuinely indestructible. In this project, a charging station powered by a solar panel provides electricity to recharge the battery. Operating off-grid is possible because of the integrated battery storage in the charging station. Raspberry Pi is accustomed to managing charging. Electric vehicles are being developed in order to lessen the pollution caused by motor vehicles. The fuel for these electric vehicles is electricity, which can be stored by using solar energy. Smart charging stations for electric vehicles are a promising alternative and an environmentally sustainable response to the current energy crisis.

KEYWORDS: Controller, Solar panel, Grid power supply, Smart charging

I. INTRODUCTION

Solar energy conversion is a significant topic in renewable energy, converting solar radiation into thermal and electrical energy. Solar electricity has applications in various systems, including rural electricity, water pumping, and satellite communications. Large-scale grid systems and small remote photovoltaic plants are commonly used. The increasing human population and economic expansion have led to the development of new energy conversion and storage systems, reducing fossil fuels and increasing environmental concerns like greenhouse gas emissions. New technology is replacing manpower in projects, leading to increased energy consumption. Solar energy, obtained from the sun's radiation, is the primary renewable energy source and can be obtained through various methods like photovoltaic, solar thermal, artificial photosynthesis, solar heating, and solar architecture. Research shows that solar energy is nuclear energy, generated by fusion between hydrogen and helium atoms, resulting in 3.8×10^{26} joules of solar energy per second. This energy source is environmentally friendly and can be used to sustain humanity even after traditional energy sources are exhausted. Solar energy provides abundant and sustainable energy to Earth, making photovoltaic processes a viable solution for charging electric cars worldwide without environmental pollution. This simple and elegant method harnesses the sun's energy, bringing the world closer to a greener community. Sweden, with limited fossil fuel extraction and a rapidly growing population, is an example of a country that can harness solar energy to provide electricity for electric cars.

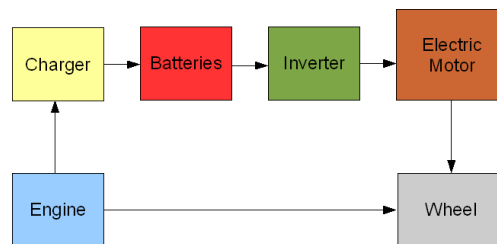


Figure 1: Basics of EV (Block Diagram)

Hybrid Renewable Energy

Today, EV battery packs are charged via park stations, roadside devices, and regular household outlets. The amount of time required by the EV's storage system to recharge the battery packs varies depending on their capacity. Chellaswamy et al. present a brand-new way of recharging EVs. Without the driver's involvement, the control system in this device charges the battery packs automatically. The results of the performance analysis are compared to those of other EVs. The adoption of plug-in EVs helps to lower greenhouse gas emissions. The traction battery packs are charged using a high-frequency ac-dc converter, which is coupled with a high-frequency transformer and an electromagnetic interference (EMI) filter to reduce EMI noise. The slip angle measurement of EV is estimated using a camera with a sensor and a high sampling rate. Yafei et al. used multi-rate Kalman filtering to examine how well this model-based estimator performed. Under European law, a hybrid EV's running costs, ideal scheduling, and CO2 emissions are calculated using linear programming. This process also regulates how much electricity EVs use. To maintain the state of charge (SOC) of all the NiMH battery packs found in EVs consistently, a control algorithm has been devised. Man et al. have researched the SOC fluctuation for various temperatures and the percentage of improvement. A clever algorithm has been designed to restrict the rate of charge and the cost, and Mosaddek et al. have investigated the performance of the method. The plug-in EVs are being powered by conventional parking garage outlets thanks to an experimental configuration. A comparison of SOC at various temperature conditions has been done. It is believed that the EV motor controller is a perfect controller with no power loss and no time latency. To fulfil the greater voltage requirements of the motor, the controller just raises the battery voltage. In order to satisfy the requirements of the motor, the dimensionless constant gain, or K ratio, of the input and output voltages is established. To modify the current such that the input and output power values are identical, the same K ratio is used.

High side voltage is equal to K times the low side voltage:

$$V_H = K \times V_L$$

Controller High Side Current: High side current is equal to 1/K times the low side voltage

$$I_H = \left(\frac{1}{K}\right) \times I_L$$

Models of batteries depict them as sources of electricity with internal resistance. The resistance of the battery is used by the model to account for internal power loss. The model doesn't include a time lag component. It is assumed that the battery's internal voltage, E_B , is constant. The internal voltage and the resistance voltage drop are added to obtain the battery terminal voltage, or V_B . The controller's low side voltage and current are equivalent to the battery's voltage and current.

$$V_B(\text{Volt}) = I_A(\text{Amp}) \times R_A(\text{Ohm}) + E_B(\text{Volt})$$

The battery model determines the necessary battery's internal voltage using the motor controller's current and voltage data.

EV Charging Station

Fast charging technology is essential for boosting the adoption of EVs since it eliminates a hurdle that has prevented many people from buying their first EVs. However, building rapid charging points has substantial negative effects on the grid and decreases the quality of its electricity. It also necessitates a parallel increase in the power supply from the utility companies. Customer preferences for EV charging infrastructure, including the effects of fast charging on the power grid. However, despite their thorough review, the authors were unable to reach any firm conclusions regarding a number of issues, including the cost of charging, where it happens, when it happens, and any effects these fast charges may have on electricity grids. This suggests that more research in the area is required. It is well known that when several EVs are being charged simultaneously, DC fast chargers have a very high power consumption and are significantly more expensive than other lower rate chargers, causing issues with the utility supply. Total harmonic distortion (THD), voltage, and frequency variations are examples of these effects. One viable strategy for reducing these effects is the usage of renewable energy sources.

II. LITERATURE SURVEY

Aanya Singh, Shubham Sanjay Shaha, Nikhil P G, Yendaluru Raja Sekhar, Shaik Saboor and Aritra Ghosh has studied in the article, "Design and Analysis of a Solar-Powered Electric Vehicle Charging Station for Indian Cities" that results from the design of a solar-powered EV charging station for an Indian context. PVsyst 7.2 software has been used for the system design. The analysis, based on the number of cars charged annually, the monthly variation in energy generation, the investment cost, and the decrease in carbon dioxide (CO2) emissions using different module technologies for six Indian cities, has been deliberated. The study presents a grid-connected solar-wind

hybrid system for a small shopping complex in India, incorporating a charging station for electric vehicles. The system is designed to meet electrical load requirements and EV charging demand, considering energy costs and minimizing power supply loss. The system's LCOE and LPSP are calculated at 0.038 \$/kWh and 0.19%, respectively, with a renewable component of 0.87. By effectively managing load needs and renewable power generation, a cost-effective and dependable system can be designed.

Abdullah Azhar Al-Obaidi's article presents a model for a fleet system's central controller that allows flexible use of EV batteries and distributed energy for simultaneous services to transportation and power grids. The model manages real-time ticket pricing, adaptive energy and reserve margin allocation, communication with grid operators, and achieving fleet target income. It incorporates slack factors and control parameters to give EV drivers flexibility in managing battery capacity based on availability and transportation service demand estimation. The EV fleet optimization challenge is solved by developing a dynamic pricing system that limits fare prices in a competitive market while calculating real-time fare rates. The model can manage multiple EVs for different services while improving fleet financial metrics.

The article "Smart Online Charging Algorithm for Electric Vehicles via Customised Actor-Critical Learning" by Yongsheng Cao and Mostafa M. Mahfouz explore the scheduling of EV charging under uncertain future information. They create an EV charging problem and research the problem online, utilizing actor-critic learning-based smart charging algorithms (SCA) to plan EV charging against uncertainties. The SCA develops an ideal EV charging strategy through continuous charging activities, lowering the state dimension and enhancing computational efficiency. Simulation findings show that CALC can reduce EVs' projected cost by 24.03%, 21.49%, and 13.80%, with a cost difference of 5.56%.

In "Autonomous Operation of the DC Fast-Charging Station," Mostafa M. Mahfouz designs, tests, and validates a supervisory controller (SC) for autonomous operation of a battery-enhanced DC fast charging station. The SC is designed using supervisory control theory (SCT) of discrete event systems and is non-blocking, minimally restrictive, modular, and scalable. The SC runs the station in grid-connected mode and enables a smooth transition between modes. The SC is built on an industrial programmable logic controller and the OPAL-RT testbed to verify its performance in real-time hardware-in-the-loop environments.

In this study, Cihat Keçeci examines the efficiency of electric vehicle (EV) charging coordination in the presence of cheating customers. The research examines the impact of incorrect information, such as parking length, on the charge coordination mechanism. The study employs a linear optimization problem to represent the charging coordination technique. The research reveals that the percentage of dishonest customers and the length of dishonest behavior relative to normal parking periods determine the effectiveness of the charge coordination mechanism. The study also highlights the growing effect of cheating behavior as more fast chargers are added to charging networks. This article evaluates the effectiveness of long-short-term memory networks (LSTMs) for predicting individual EV charging behavior on the next day. The study considers charging duration, time slots, and whether the following day will be a charging day. The evaluation uses changing training data lengths to account for increasing resolutions. Real-world EV charging data is used to validate the strategy's effectiveness. The best performance is achieved using data from the previous 8-10 months.

Although LSTMs' performance suffers when resolution is increased, charging time slot prediction suffers less than duration prediction. The article also suggests a novel method to enhance charging duration prediction performance. Zhonghao Zhao's paper discusses capacity planning for electric vehicles (EVs) by considering fuzzy quality of service and multiple charging options. The study provides an optimization model for charging station capacity planning, considering queuing behavior, blocking reliability, and battery technical specifications. Fuzzy numbers with triangle membership functions represent EV arrival and service time uncertainty, while a defuzzification method based on cuts is suggested. This approach leads to a more reliable strategy, allowing decision-makers and operators to offer a variety of charging alternatives and better serve consumers.

The transportation industry is transitioning away from petroleum-based cars due to the increasing number of electric vehicles (EVs). The rapid growth of EV charging stations (EVCS) is crucial for their deployment. However, the growing penetration of randomly dispersed rooftop PV systems makes it difficult to integrate EVCSs. A hybrid bacterial foraging optimization algorithm and particle swarm optimisation (BFOA-PSO) approach is suggested for the best placement of EVCSs in distribution networks. The multi-objective optimization problem aims to maximize voltage stability index while minimizing active and reactive power losses and average voltage deviation index.

Mohd Rizwan Khalid's comprehensive review on structural topologies, power levels, energy storage systems, and standards for electric vehicle charging stations and their impacts on the grid addresses barriers such as expensive EVs, range anxiety, lack of EV charging infrastructure, and grid pollution. The paper covers on-board and off-board chargers, low- and high-frequency transformers, charging power levels, and inductive power transfer (IPT)-

based EV chargers. The essay also discusses the drawbacks of EV charging and possible solutions, global standards, and upcoming advancements in EV technology.

III.METHODOLOGY

A. Types of EV Chargers Rapid DC:

Most common chargers in India. These chargers provide power at 50 kW (125A). Connectors typically charge an EV to 80% in 20 minutes to an hour, depending on battery capacity and starting state of charge.

Ultra-Rapid DC

Provide power at 100 kW or more. These are mostly either 100 kW, 150 kW, or 350 kW – though other maximum speeds between these figures are possible. According to Zap- Map, "These are the next-generation of rapid charge points, able to keep recharging times down despite battery capacities increasing in newer EVs."

Tesla Superchargers:

Tesla’s Supercharger network also provides rapid DC charging to drivers of its cars, but use either a Tesla Type 2 connector or a Tesla CCS connector – depending on model. These can charge at up to 150 kW. Tesla models are designed for Supercharger units, but many use adaptors for public rapid points. CCS and CHAdeMO adaptors are available, allowing drivers to access more UK rapid charging infrastructure.

Rapid AC chargers

Rapid AC chargers provide power at 43 kW (three-phase, 63A) and use the Type 2 charging standard. Rapid AC units are typically able to charge an EV to 80% in 20-40 minutes depending the model’s battery capacity and starting state of charge.



Figure 2: Rapid and Ultra Rapid DC Chargers

Fast Chargers

These are Type-2 AC Chargers. Fast chargers are rated at either 7 kW or 22 kW (single- or three- phase 32A). Charging times vary on unit speed and the vehicle, but a 7 kW charger will recharge a compatible EV with a 40 kWh battery in 4-6 hours and a 22 kW charger in 1-2 hours. Fast chargers tend to be found at locations such as car parks, shops, supermarkets, or leisure centres, where you are likely to be parked for an hour or more.

Unmetered units are more flexible and can be used by any EV with the correct cable. Charging rates depend on the car’s on-board charger, with some models only drawing the maximum power accepted. Most EVs and PHEVs can charge on Type 2 units, with the correct cable. Fast chargers typically provide AC charging, with some networks installing 25 kW DC chargers with CCS or CHAdeMO connectors.



Figure 3: Types of Fast Chargers

Slow chargers:

The most common chargers in the Indian market have a power output of 3 kW-6 kW and can charge a car for 8-12 hours. Slow charging devices are rated at up to 3 kW, with most ranging from 2.3 kW to 6 kW. Cars typically draw 2.3 kW (10A) on a three-pin plug, while lamp-post chargers are 5.5 kW due to existing infrastructure. Charging times vary

depending on the unit and EV being charged, but a full charge on a 3 kW unit takes 6-12 hours. Most chargers are untethered, requiring a cable to connect the EV to the charge point. Slow charging is a popular method for charging electric vehicles, often used at home overnight. It can also be found at workplaces and public points. Slow public charge points are less common due to longer charging times. To ensure regular charging, it is recommended to have a dedicated EV charging unit installed by an accredited installer due to higher current demands and longer charging times.



Figure 4: Types of Slow Chargers

B. Modes of Charging of EV Mode 1:

Mode 1 is a direct connection of electric vehicles to normal current sockets without special safety systems. It is prohibited in public areas in Italy, Switzerland, Denmark, Norway, France, Germany, the United States, Israel, and England. The rated values for current and voltage must not exceed 16 A and 250 V in single-phase and 16 A and 480 V in three-phase.

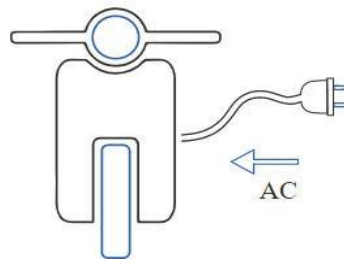


Figure 5: EV Charging Mode 1

Mode 2:

Mode 2 requires a safety system on the charging cable, called the Control box, to ensure safety between the electrical network and the car in charge. It is typically installed on portable electric vehicle chargers. Mode 2 is only allowed for private charging in Italy and subject to restrictions in the US, Canada, Switzerland, Denmark, France, and Norway. Current and voltage rated values must not exceed 32 A and 250 V in single-phase and 32 A and 480 V in three-phase.

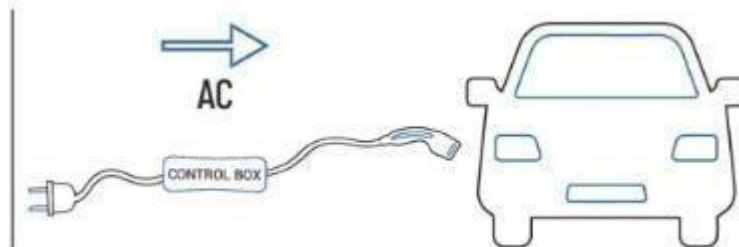


Figure 6: EV Charging Mode 2

Mode 3:

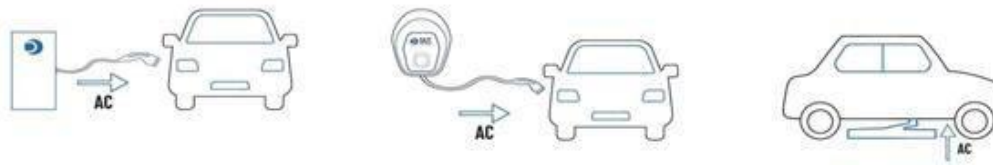


Figure 7: EV Charging Mode 3

Mode 3 requires a vehicle to be charged through a permanent power supply system connected to the electrical network. The Control Box is integrated into the dedicated charging point, and it is the only mode allowed in public spaces in Italy. Charging stations in mode 3 typically allow up to 32 A and 250 V in single-phase and 32 A and 480 V in three-phase, even without legislation setting limits. Examples of mode 3 charging systems include Daze Box and Daze Plug, both manual and automatic.

Mode 4:

The charging mode 4 provides direct current and requires an external current converter for charging cables. It is characterized by voluminous charging stations, with two standards: CHAdeMO and CCS Combo. Mode 4 charging stations can charge up to 200A and 400V, even without a maximum limit specified by legislation.

C. System Development Block Diagram of System:

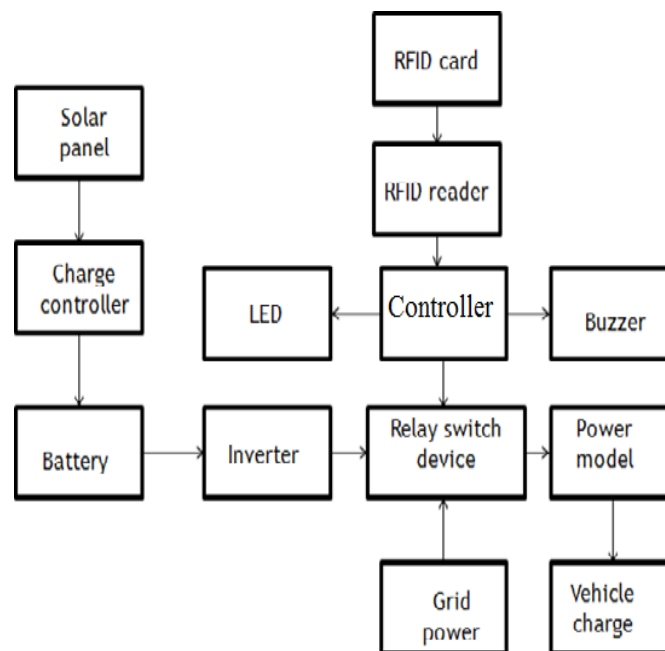


Figure 8: Block Diagram for Proposed System

Working Circuit

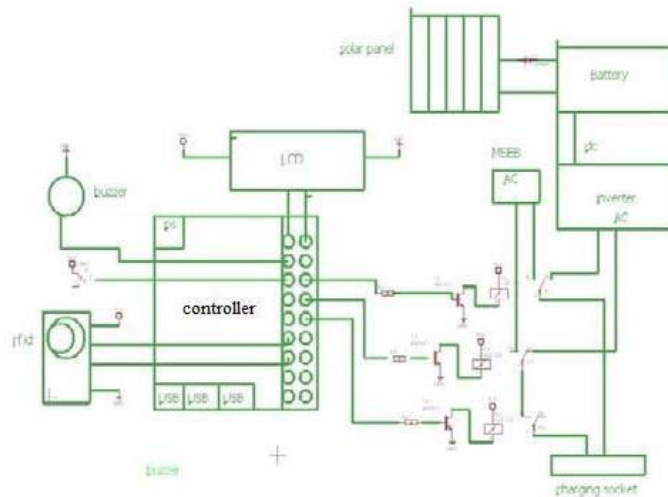


Figure 9: Circuit Diagram for Proposed System

IV. CONSTRUCTIONAL DETAILS

Components:

- Solar Panel:



Figure 10: Solar Panel

A solar cell panel, also known as a solar electric panel or photo-voltaic (PV) module, is an assembly of photo-voltaic cells mounted in a framework for installation. These panels use sunlight to generate direct current electricity, and are typically made of wafer-based crystalline silicon or thin-film cells. The structural load-carrying member of a module can be either the top or back layer. Cells must be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are also available. The power of a module is the mathematical product of the voltage and current. Manufacturing specifications are obtained under standard conditions, not the actual operating conditions the panels are exposed to on the installation site. A PV junction box is attached to the back of the panel, and external connections use MC4 connectors or USB power interfaces. Metal frames, including racking components, brackets, reflector shapes, and troughs, support the panel structure.

- Charge Controller



Figure 11: Charge controller

A Charge Controller is a switching device that disconnects the charge from a battery and controls its charging. It protects batteries from damage and regulates power flow from the solar panel to the batteries. A microcontroller in the circuit reads the battery level and cuts off the solar panel's source once it sees the battery is fully charged. This prevents overheating and damage to the internal components. Charge controllers are sold as separate devices, often in conjunction with solar or wind power generators, for use in RV, boat, and off-grid home battery storage systems. Some charge controllers have additional features, such as a low voltage disconnect (LVD), series charge controllers, shunt charge controllers, simple charge controllers, pulse-width modulation (PWM), and maximum power point tracker (MPPT) technologies. These technologies adjust charging rates based on the battery's level, allowing charging closer to its maximum capacity. Charge controllers with MPPT capability can save system designers from matching available PV voltage to battery voltage, resulting in efficiency gains. They can also monitor battery temperature to prevent overheating and display data, transmit data to remote displays, and log electric flow over time.

- Inverter:



Figure 12: Inverter

An inverter is a compact, rectangular electrical equipment that converts direct current (DC) to alternating current (AC) in common appliances. It is used in various small electrical equipment, such as solar power systems, power batteries, and fuel cells. Inverters convert DC power into AC, which can be supplied to homes and industries through public utilities or power grids. AC power can be used in batteries to store DC power, and household appliances and other electrical equipment can function based on AC power. Inverters are standalone devices for applications like solar power and are available in different types based on their switching waveform shape.

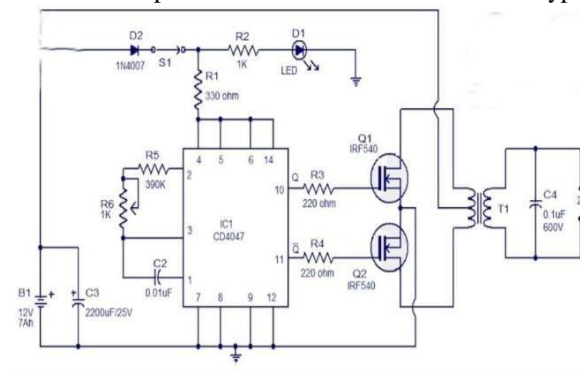


Figure 13: Inverter Circuit Diagram

- RFID Card



Figure 14: RFID Card

RFID cards provide drivers with a secure way to pay for charging sessions, linked to their driver account. Chargefox charge stations have RFID card readers that recognize valid cards and driver accounts, enabling drivers to manage charging sessions by touching the card.

V. WORKING AND PRINCIPLE OF OPERATION

Working Principle:

Source one is a solar panel which convert light energy into electrical energy. This converted energy is stored in the battery storage. To avoid reverse flow of power charge controller is connected between solar panel and battery. The power stored in the battery is in the form of DC, but we required power in the form of AC. Therefore inverter is connected to the battery to convert DC to AC.

RFID cars gives driver alternative way to pay for charging. When card is swipe it gets read by RFID reader raspberry pi gives signal to the buzzer and buzzer will be beep. Raspberry pi also gives signal to the relay switching device. Relay works as an open or close circuit. When single is given by raspberry pi relay switch is on and through power model electrical vehicle will gets charge. And also to provide continuous supply to the charging station grid contention is also provided.

- Overview of Components used in the System:

| COMPONENTS | SPECIFICATION | COST |
|------------------------|---------------|------|
| Solar Panel | 12V DC,10W | 900 |
| Battery | 12V DC, 8.6A | 1400 |
| Controller | - | 3200 |
| Inverter | 100W | 450 |
| Buzzer | 5V DC | 50 |
| RFID reader | 5V DC | 420 |
| RFID card | - | 100 |
| Relay switching device | 12V DC | 210 |
| Memory card | 32GB CLASS A | 700 |

| | | |
|-------------------|----------|---------------|
| LCD Display | - | 180 |
| Adaptor | 5V D, 2A | 140 |
| Charge Controller | 12 V | 550 |
| Total | | 11,300 |

- Battery Charging Calculations

1. Inverter : 100 W
2. Battery Specifications : Voltage – 12V
DC Current – 8.6 A Wattage = 12X8 = 96 W
3. Solar Panel : 12 V DC
Wattage – 10 W/Hr

Charging Time:

$$\text{Charging Time} = \frac{\text{Battery Capacity}}{\text{Solar Panel capacity}}$$

$$\text{Charging Time} = \frac{96}{10} = 9.6 \text{ Hr}$$

Therefore, time required for the charging of battery should be around 10 Hours.

VI.

RESULTS

Power Generation:

| Sr. No | Voltage(Dc) | Sun Intensity | Efficiency of Power Generation(Dc) |
|--------|-------------|---------------|------------------------------------|
| 1 | 0 | 0% | 0% |
| 2 | 1.5 | 10% | 10% |
| 3 | 2.4 | 14% | 16% |
| 4 | 3 | 20% | 23% |
| 5 | 4.5 | 24% | 28% |
| 6 | 6 | 32% | 37% |
| 7 | 6.7 | 39% | 45% |
| 8 | 8.5 | 45% | 55% |
| 9 | 9 | 70% | 75% |
| 10 | 12 | 90% | 100% |

Vehicle Charging Station Details

| Sr. No | Load | Voltage(ac) | Current(ac) | Power |
|--------|------|-------------|-------------|-------|
| 1 | 5W | 240 | 0.05 | 12 |
| 2 | 18W | 230 | 0.1 | 23 |
| 3 | 20W | 220 | 0.125 | 27.5 |
| 4 | 60W | 200 | 0.25 | 50 |

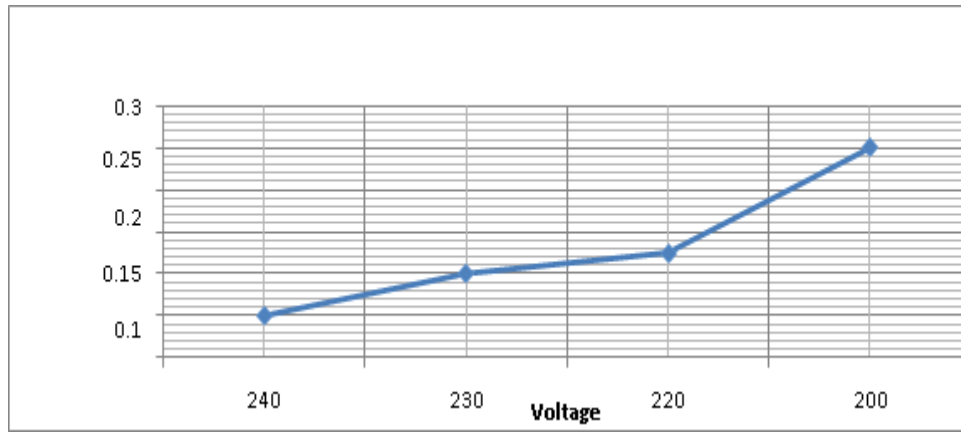


Figure 15: Current vs Voltage Characteristics

VII. CONCLUSION

This paper presenting PV-based model with grid supplied for charging Electric vehicle, which is generally used to reduce the use of non-renewable energy sources. This study develops a model that combines the solar power station and Electric vehicles to mostly reduce pollutants emission from the power generation and transportation sector in a suitable way.

The main function of the EV is to provide mobility services expected by its user. At higher penetration levels, uncontrolled EV charging can congest the power grid operation and smart charging stations can control the EV charging session by imposing the charging power rates, leading to an improvement of the power grid operations.

The most conventional charging scenario for charging EVs is the plug and charge. The charging process starts immediately when the user arrives at the charging station and plugs the EV to charge as a fixed load. However, the smart charging scheme is ideal for smart grid application.

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