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# Hybrid Energy-Based Battery Storage Swapping Station for Electrical Vehicles and Net Metering in Bangladesh

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**Abstract**— The majority of electricity used to charge electric vehicles (EVs) through conventional methods is sourced from fossil fuels, which can harm the environment and strain the electrical grid, thereby limiting access to charging. As the demand for EVs grows, there is an urgent need to develop a robust and reliable charging infrastructure to support widespread adoption. At the same time, local electricity grids are experiencing increased pressure, necessitating the integration of renewable and cost-effective energy sources like solar power. The purpose of this research is to pioneer sustainable energy infrastructure and EV battery swapping stations by utilizing novel methodologies. It proposes integrating photovoltaic (PV) panels, energy storage devices and enhanced net metering techniques to efficiently collect and preserve solar energy on-site. This stored energy can be used not only to charge EVs but also to support grid stability through net metering, thereby promoting a sustainable and resilient charging network.

**Keywords**— Electric Vehicles (EV), Net Metering, Charging swapping station.

## I. INTRODUCTION

The world is these days confronting a big obstacle of decreasing carbon emissions to mitigate the effects of climate change. Electric vehicles (EVs) may be powered by renewable energy sources such as solar and emit zero exhaust emissions, making them a viable alternative. Widespread EV adoption creates hurdles. EV owners are concerned about charging infrastructure, particularly in areas with few facilities. The current power grid infrastructure may not be capable of handling EV demand, resulting in reliability and stability issues. Solar-powered energy storage switching stations for electric vehicles, as well as net metering, could address these difficulties. The program will save time, reduce grid dependence, and reduce carbon footprint. The energy storage device would store additional solar energy and give backup power during grid breakdowns, providing EV owners with reliable and sustainable electricity [1].

The Dublin Institute of Technology (DIT) investigated on-campus photovoltaic charging stations (PV-CS) with lightweight electric vehicles (LEVs). To better understand campus PV-CS architecture, vehicle tracking, storage unit sizing, and LEV load use were all analyzed. The researchers utilized a GPS and an energy meter to examine the daily charging and load utilization patterns of LEVs. I also used conceptual calculations to examine five distinct design options. When comparing different setups, "Coupled PV-grid with storage" comes out on top. Storage battery size was determined by differences in average and peak demand. The key difficulties were battery density, weight, and efficiency, which necessitated further financial and scientific research [2].

Electric vehicle charging is a challenge of optimization with a receding horizon. The transformer and line capacities, phase imbalance, and network voltage stability make up the restrictions. In order to account for the dynamic nature of changing demand and vehicle arrival

and departure, the solution to the problem can be estimated periodically in near real-time using a linear approximation of voltage drop inside the network. It is shown that this linear approximation of the network constraints ensures that all of the constraints are met while being computationally efficient [3].

The operation of charging infrastructure may become more difficult as power networks incorporate electric vehicles (EVs). An aggregator may find it more difficult to optimize EV charging schedules in order to reduce costs. Despite earlier research assuming a constant maximum charging power, the maximum charging power can change based on the current state of charge (SOC). Both preemptive and non-preemptive pricing are permitted by this idea. The primary distinction is whether charging can be avoided. Outages can be decreased by developing the scheduling problem for electric vehicle charging for each scheme [4].

An Easy-Bike charging station that runs on solar electricity. Excess energy is returned to the grid via net metering (NEM). Use grid power to charge the vehicles instantaneously. Saves a significant amount of money by using fewer batteries. The system can function without funding in the absence of a battery storage system and upkeep. PV system generation was computed using PVsyst simulation. It has been determined how much a PV system with BESS costs compared to one with NEM. The suggested structure shows potential for cost and environmental effect savings based on the data [5].

Analyzing all these research works, developing a project which creates a solar-power energy storage switching station for electric vehicles and net metering is essential to a sustainable, low-carbon future. This project will contribute to a more resilient and decentralized energy system, promote the adoption of clean energy, reduce the carbon footprint as well and minimize the fuel and gas consumption of the transportation sector.

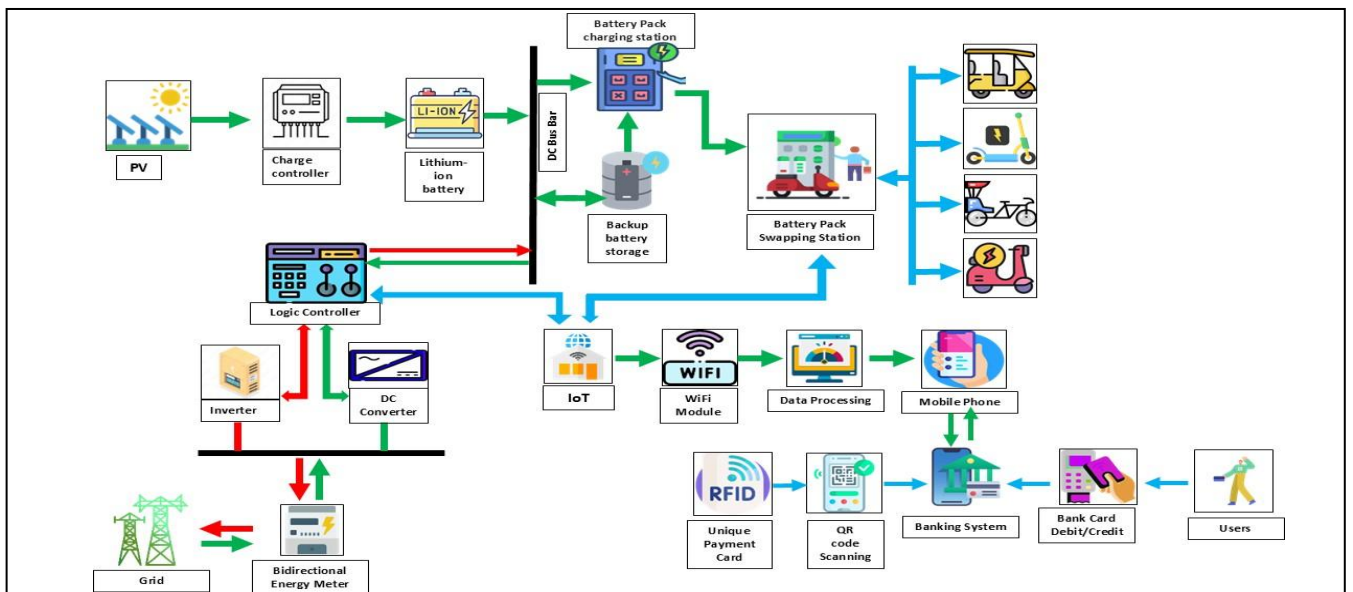


Figure 1: Block diagram of Battery Storage Swapping Station for Electrical Vehicles and Net Metering.

## II. METHODOLOGY

### A. System Structure

A bidirectional process is shown in this image. There are two sides: the net-metering side and the electric vehicle side. A thorough rundown of the project's essential components, such as the electric car, lithium-ion battery pack, and the environmentally friendly inclusion of a solar charge swapping station, is given in this figure 1 block diagram. Here, power is generated via solar technology. Solar panels absorb sunlight and convert it into electrical energy. The electrical energy is subsequently managed by a charge controller prior to being stored in a Li-ion battery. The energy is transformed into an EV-compatible form and used to charge each of the pack's individual battery cells. A fully charged battery pack powers the EV. The process by which sunlight produces electricity is ongoing. when every EV battery is completely charged. Net metering then makes use of additional power suppliers. The boost converter supplies a set DC voltage to the DC output voltage, while the solar panels receive a variable DC voltage. DC voltage is then converted to AC voltage using an inverter. However, the voltage is not pure AC. provides the passive filter with the pure AC voltage. Pure AC voltage appropriate for household usage is provided by the passive filter.

### B. Function of system components

PV arrays and DC/DC converters form the basis of a PV system. PV arrays, which are made up of PV cells linked in series and parallel, directly convert solar energy into electricity and are connected to the DC bus via DC/DC converters. The DC/DC converters are operating in maximum power point tracking (MPPT) mode. The actual output of a PV system is determined by both solar irradiation and ambient temperature in relation to its rated capacity [15].

The grid-connected system mainly comprises a transformer, bidirectional AC/DC inverter, bidirectional DC/DC converter, and storage batteries. Operating, the system has

three principal objectives: a) transferring energy between the power grid and BPCS (Battery Pack Charging Station) b) keeping voltage on a stationary DC bus constant and; c) selling back surplus solar energy to the grid with the help of inverters. Voltage transient may occur in the AC/DC inverter output power because of the variability of PV output power.

The EVB (Electric Vehicle Battery) system comprises the EV batteries and their relevant chargers. Rechargeable modules are available when the EV batteries run out. And such unnecessary batteries shall be recharged so that they will be available for some other electric vehicles. So, some of the batteries are situated in the EVs whereas some of them are still in the BSS. At first, the EV battery, more often than not will be charged using constant current. Electrically fueled vehicles (EVs) are often charged using the constant current mode for quite some time, until the state of charge (SOC) reaches a certain predefined level after which the constant voltage charging begins. The period taken for charging a low battery is not constant because it depends on the initial SOC of the battery in question and the SOC threshold at which the EVB will finish charging the battery.

The operation of components is monitored and controlled by EMS in the PV-based BPCS (Battery Pack Charging Station), including status information of battery swapping, EVB charging power, output of the photovoltaic system, online payment system, and grid-connected system power. Monitoring data provides the basis on which the EMS will determine how much charging power the EVB system needs and how much electricity should be supplied by the PV system or the distribution grid. The relevant components will implement control messages for the process of power distribution.

### C. Proposed Flowchart

A comprehensive methodology based on engineering principles support the design of a Photovoltaic (PV)-based

energy storage and swapping station for electric vehicles with net metering. The PV system uses photovoltaic cells to convert solar energy into electricity. Energy storage optimizes energy use and simplifies electric vehicle shifting using innovative battery technologies and control systems. Net metering allows surplus electricity to be fed back into the system. This thorough technique uses mathematical modeling, simulation, and rigorous testing to assure the energy station's dependability, viability, and sustainability, contributing to clean and renewable energy solutions for a better future.

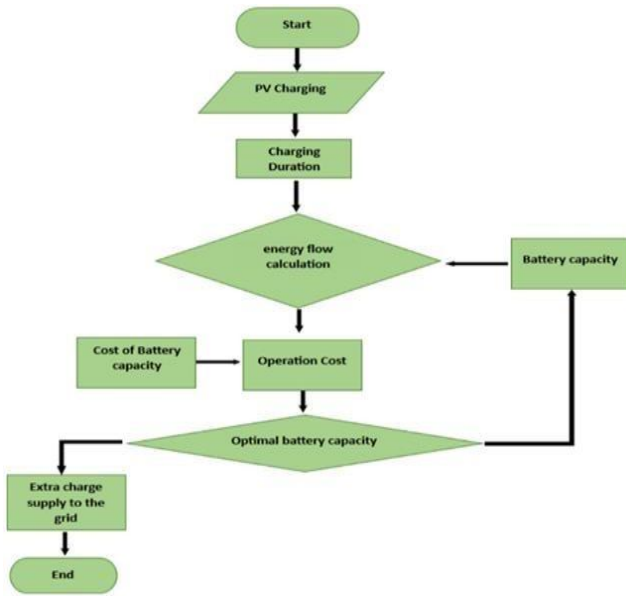


Figure 2: Proposed flow chart

This figure 2 displays the whole paper's workflow, including how to charge batteries, switch out batteries, and add more power to the grid.

### III. SIMULATION MODEL

An artificial solar power system with net metering and a battery backup appears in the picture. Solar panels, a backup battery, an Arduino microcontroller, an RFID system, net metering components, a display, and virtual terminals are all part of the system. The Arduino is in charge of all system operations, including RFID, net metering, and battery charging and discharging. It looks that the system is built for effective grid integration and energy management. An essential component of this arrangement is the Arduino, which enables real-time data monitoring and display.

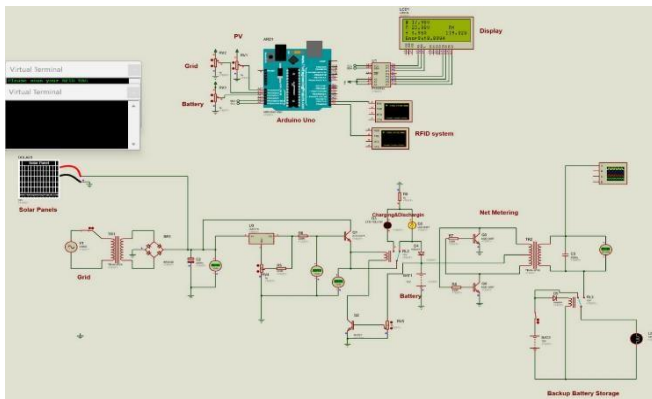


Figure 3: Simulation Schematic for proposed design

Thoroughly measuring the voltage produced by the solar panel is made possible by the voltage sensor. Here also showing

charging and discharging methods in particular part. How extra power supplies to net metering which also show in simulation. This simulation not only demonstrates the versatility of Arduino-based systems in data acquisition and display but also underscores the practicality of monitoring solar energy systems.

### RFID-based lock system

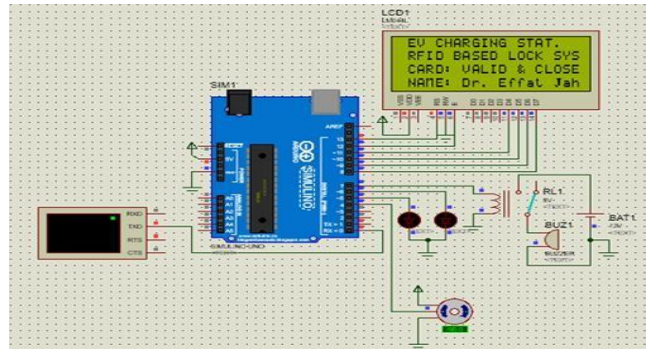


Figure 4: Simulation Schematic of RFID-based lock System

The intricate simulation relies on RFID authentication to control access. Figure 4, illustrates a proteus simulation of an RFID-based lock system with strong security and automation. The intricate simulation relies on RFID authentication to control access. When an RFID tag matches the system's database, a servo motor gracefully rotates to 90 degrees, opening the locked space. Also, the simulation provides security and functionality. A relay module opens an electronic lock or gate for authorized employees after RFID authentication. Simultaneously, a buzzer emits an audible signal, serving as both a confirmation of access and a security alert mechanism.

### IV. HARDWARE MODEL



Figure 5: Hardware model of the device.



The hardware model in Figure 5 includes the charge swapping station, RC car, and solar panels. The charge swapping station is essential for electric car charging and energy exchanging. A RC car shows the model's practicality and power exchange efficiency. Renewable solar energy powers the charge swapping station, and the solar panels emphasize sustainability. This hardware model integrates electric mobility, renewable energy, and energy efficiency, following green technology and sustainable transportation trends.

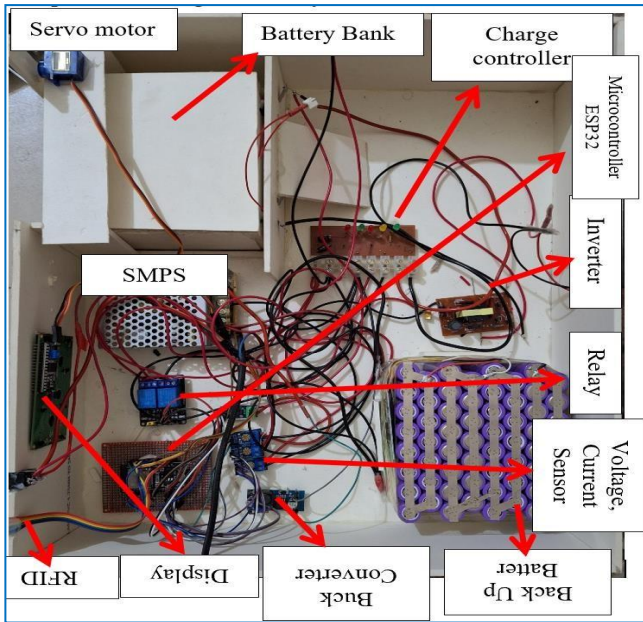


Figure 6: Proposed hardware design.

The research will involve monitoring battery charge percentage in a range that is achievable, using a 16X4 lcd display. In addition to that, the real voltage whenever charging is required is shown, together with the Charging Station Location and bidirectional meters costs. Each of these sensors collects information which it sends to an Arduino Uno board. The System Data from Arduino UNO is sent to ESP32 via we have developed Wi-Fi module. The Battery Status Energy Monitoring System (EMS) that will be used here is designed through ESP32 as well as Arduino IoT Cloud integration. As a result, through this project, the Internet of Things (IoT) can immediately inform interested parties. Lastly, this project will rely more on the Arduino Uno because it governs all their systems. These equipment and instruments depend mainly on hardware components to operate. These microcontrollers and sensors were tested by building a test board, mounting all sensors and modules based on the model shown in the simulation and operating the system as shown in Fig. 3 & 4. A hardware model for implementation in Electric Vehicles charging station is also shown in Fig. 5.

## V. RESULT ANALYSIS

Figure 7 shows the LCD display carefully set up to display vital information. A large display of the battery voltage and percentage of charge in the top row (0,0) shows real-time energy storage system data. The LCD display gives essential net metering statistics in the row below at (0,1). This comprises energy input units and their overall cost. This

makes energy use transparent. However, net metering output units and their total costs are shown at (0,2) in the same row. This well-organized information display helps users comprehend the system and track energy usage, expenses, and net metering activities, which aids energy management and financial accountability.



Figure 7: Hardware result of LCD Display



Figure 8: Car battery percentage & voltage on LCD Display

This figure 8 shows the RC car's display reveals both the battery's capacity and voltage.



Figure 9: QR code for online payment



Figure 10: Showing online Payment System User interface

Figure 9 and 10 shown the payment mechanism at this swap station. Battery payments could be made by scanning a barcode and RFID card.

### A. Calculation of Lithium-Ion Battery charging & discharging

Lithium-ion batteries are commonly utilized due to their high energy density and efficiency. Lithium-ion batteries supply power when other sources are unavailable, requiring frequent charging and discharging cycles in systems. The battery charging and recharging cycle affects all battery characteristics. To compute power, use the well-known equation shown below as in (16),

$$\text{Power (W)} = \text{Voltage (V)} \times \text{Current (A)} \quad (1)$$

This paper used three 3.7V, 6800mAh lithium-ion batteries installed in series to generate 12V and a 6.8Ah operational current for the system. 15% percent of the battery's Ah rating should be the charging current. So, 15% of 6Ah = 6 Ah x (15 ÷ 100) = 1.0 A is the battery for a 14.8V, 6.8Ah battery. Allowing for a charging loss of 0.12A.

$$\text{Battery Charging time (hour)} = \frac{\text{Battery Capacity}}{\text{Charging time}} \quad (2)$$

There are 0.12 or 20% losses when charging and draining the battery [16].

Because lithium-ion batteries are deep cycle, their Depth of Discharge (DoD), which measures the amount of energy utilized in relation to total capacity, is approximately 95%. Energy saving compared to energy spent during charging is measured by charging efficiency. When a battery is new, its DoD is 100%; but, as it matures, even when completely charged, it might not reach 100%.

### B. Net metering calculation

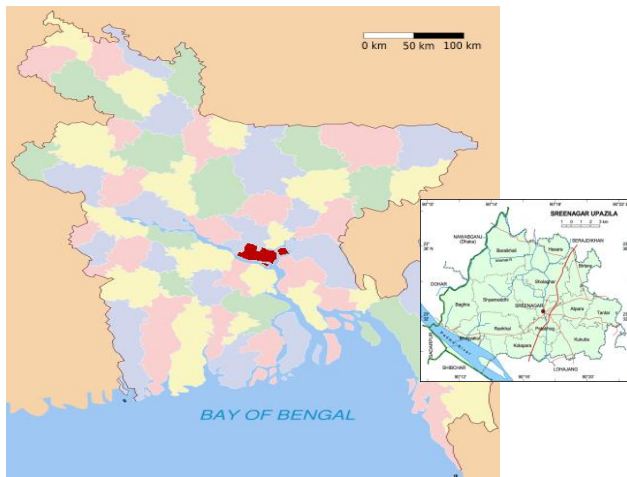
The system is made up mostly of solar photovoltaic (PV) modules or panels, which convert sunlight into direct current (DC) electricity. An inverter converts the DC source into alternating current (AC). AC power travels through a bidirectional meter to the grid, allowing electricity to be imported and exported as in (17),

$$\text{Net billing} = \{ \text{Energy consumed from utility (kWh)} \times \text{Gazetted tariff} \} - ( \text{Energy exported to utility} \times \text{Displace cost} ) \quad (3)$$

By deducting the value of the energy exported to the grid, which is determined by the displaced cost, from the energy used from the grid at the appropriate tariff, this equation calculates the net billing [17].

## VI. RESOURCES AND TECHNIQUES

The intended research was conducted in Bangladesh's Sreenagar, Munshigonj.



This origin's latitude and longitude are 23°32.7'N, 90°31.8'E. Figure 11 shows the research origin's geographic perspective. Sreenagar is a small union with 2,59,887 members, according to Wikipedia [18]. Since the majority of the population in this area is well-educated and employed, EVs and other cars are frequently used as modes of transportation to go to their destinations. In this area, there are about 300 electric vehicles (EVs), and they are stored and charged in 30 garages. From the viewpoint of the garage owner, the cost of charging EVs can be costly because they are powered by electricity from the grid. Thereby, this study proposes an autonomous system, such as Hybrid energy-based swapping station for EVs, to reduce the charging time and cost.

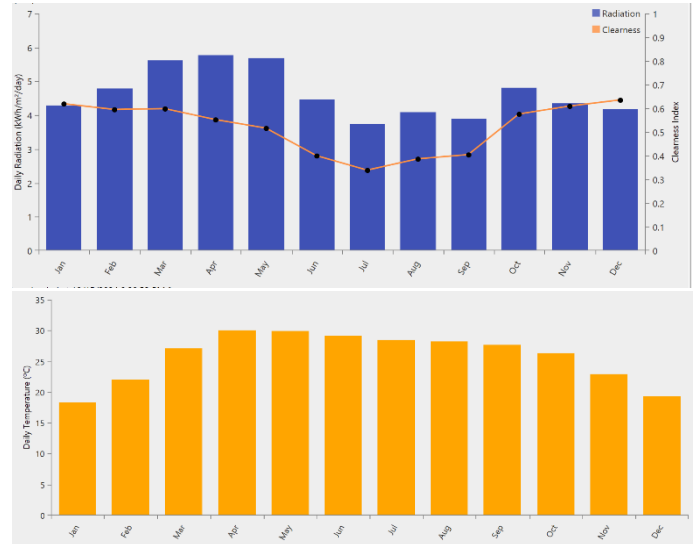


Figure 12 ,13: A graphical representation of the variation of solar irradiation and temperature throughout the whole year of the selected origin. Data from ref. [21].

March to September when Bangladesh gets the highest levels of sun radiation. Winter solar radiation exists as well, however it is not as powerful. As a result of its practical qualities, solar radiation is considered as a preferable source of power as grid. Figure 12 displays the chosen origin's annual variations in sun irradiance. Surface radiation divided by extraterrestrial radiation is another way to characterize it. Figure 13 shows the temperature of the atmosphere on a daily

## VII. MATHEMATICAL MODELLING

Figure 14 shows the system configuration, which includes a PV panel, grid, and a bidirectional converter with battery storage. The grid and bidirectional converter are connected to the AC bus.

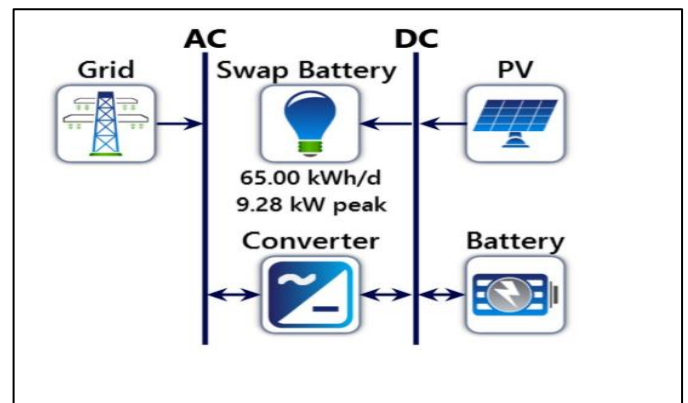


Figure 14: The proposed solar and grid-based hybrid swapping charging system.

Figure 11: The research's geographic origin (Sreenagar, Munshigonj.) modified and re-illustrated from [18, 19].

The PV module and UPS battery storage are connected to the DC bus. In addition, the converter is connected to both the DC and AC busses. The many technological, financial, and emission components used in the system.

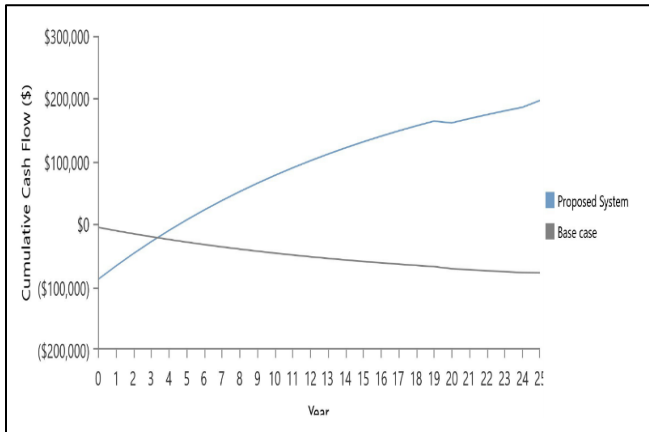


Figure15: This is system Annual Nominal Cash Flows.

This figure 15 is showing the financial performance of the Proposed System is noteworthy. Its Internal Rate of Return (IRR) of 33.6% surpasses that of the Base System, indicating a higher profitability. However, the Discounted Payback Period, which takes into account the time value of money, is 3.37 years for the project to recover its initial investment. The Simple Payback Period, which does not consider the time value of money, is shorter at 2.97 years. This indicates that it takes 2.97 years for the project to recover its initial investment without factoring in the impact of inflation and interest rates.

### VIII. ENERGY ANALYSIS

The solar PV system and the grid system are utilized to meet the EV load demand in the proposed work. The proposed method mainly focuses on the available sun irradiation on PV energy in the studied region. The figure16 displays changes in the proportion of renewable energy production over time, most likely as a result of changing demand and weather patterns. Greater dependence on renewable energy sources is indicated by higher percentages, while lower percentages point to the necessity of grid management techniques to balance supply and demand.

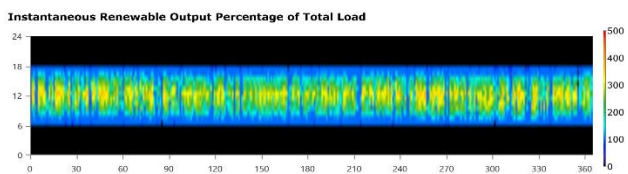


Figure 16: Renewable output percentage of the total load.

A sustainable, low-carbon future depends on the development of a project that develops a solar-power energy storage switching station for electric vehicles and net metering. This figure 17 will help to create a more decentralized and resilient.

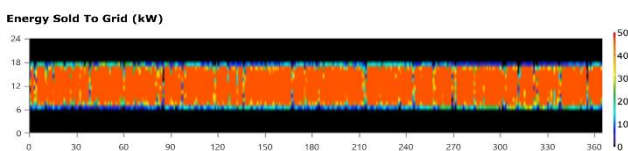


Figure 17: Energy Slod to the grid in (kW)

energy system, encourage the use of clean energy, lower the carbon footprint, and minimize the transportation sector's fuel and gas consumption.

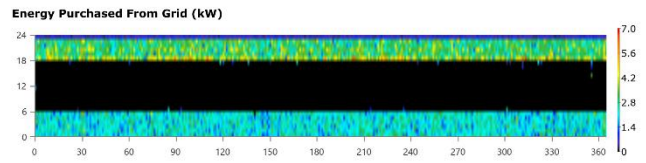


Figure 18: Grid-sourced energy cost.

The grid-purchased electrical power during a 365-day period is shown on the figure 18. With red indicating the biggest quantity and blue the lowest, the color scale shows how much energy was bought. With peaks and dips throughout the year, the graph illustrates how the amount of energy purchased varies over time has context menu.

### IX. FUTURE SCOPE

In the fields of net metering and electric vehicles, this project has cleared the path for effective and sustainable energy solutions. Even if the current deployment marks an important turning point, there are still chances and space for this cutting-edge system to be improved in the future. The situation might be improved by sophisticated energy management systems and artificial intelligence (AI). These technologies have the potential to increase power shifting and storage efficiency, estimate user demand, and improve energy distribution. Seek methods to expand these switching stations and add more in other parts of the nation to reduce carbon emissions and encourage the adoption of electric vehicles. Current research and development should also look at new battery chemistries and materials with high energy storage capacities. This could increase energy storage, speed up battery charging, and increase battery life.

### X. CONCLUSION

The project effectively achieved its goals by providing an innovative approach for sustainable energy management, electric vehicle infrastructure, and renewable energy integration. It was created to use excess energy through net metering and to meet the pressing need for environmentally friendly energy sources for electric vehicles. A complete energy exchange station was created, complete with a working prototype that captures solar energy, stores it effectively, and allows EV drivers to switch energy sources easily. This strategy not only lowers carbon emissions but also shows how renewable energy can be used in the transportation industry. It demonstrates how intelligent engineering can transform energy use and hasten the uptake of environmentally friendly technologies. An important step toward a more sustainable energy and electric vehicle charging future is represented by this research.

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