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INNOVATIVE HYBRID CHARGING STATION FOR EV VEHICLES USING SOLAR PV, BATTERY AND DIESEL GENERATOR

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Abstract
This study explores the design and implementation of an integrated electric vehicle (EV) charging station utilizing renewable sources, namely solar photovoltaic (PV) panels, batteries, and a diesel generator. The proposed charging station aims to address the growing demand for sustainable transportation solutions while ensuring reliability and efficient in charging operations. The integration of solar PV panels enables the utilization of clean energy to power the charging station during daylight hours, supplemented by energy storage in batteries to provide continuous charging capability in periods of low solar irradiance or at night. Additionally, the inclusion of a diesel generator serves as a backup power source to ensure uninterrupted charging services, particularly in remote or off-grid locations or during extended periods of inclement weather.
Keywords: EV Charging Stations, Solar PV energy, power generation, Diesel power unit, electric vehicle.

I. Introduction
The integration of solar photovoltaic (PV), battery storage, and diesel generator systems presents a promising solution for establishing sustainable electric vehicle (EV) charging stations. This innovative approach not only addresses the growing demand for clean transportation but also tackles the challenges of intermittency and grid reliability. By harnessing renewable energy sources and leveraging energy storage technologies, these charging station aims to reduce carbon emissions and promote energy independence. This research investigates the optimal sizing and configuration of the components, considering factors such as energy demand, charging patterns, geographical location, and cost-effectiveness. Through modelling and simulation analyses, the performance and viability of the proposed charging station design are evaluated in terms of energy efficiency, environmental impact, and economic feasibility. Solar panels convert sunlight into electricity. By installing solar PV panels at charging stations, you can harness clean and renewable energy to power EVs. Batteries play a vital role in storing additional solar energy generated during the day to use during periods of low sunlight or high demand. Diesel generator acts as a backup power source during extended periods of low solar irradiance or battery depletion. The findings of this study provide valuable insights for the deployment of resilient and sustainable EV charging infrastructure, contributing to the advancement of green transportation initiatives. overall, the implementation of a charging station using solar PV, batteries, and a diesel generator represents a sustainable approach to power electric vehicles.[1] [7] [8] [10].

II. Literature
The review explores the integration of battery storage, solar PV and DG for electric vehicle (EV) charging stations. It highlights the importance of renewable energy integration, battery technologies, and diesel backup for sustainability and reliability.
Topics covered include system integration, optimization, economic viability, environmental impact, case studies, regulatory considerations, and future trends. Overall, the review offers insights into the opportunities and challenges of implementing these hybrid charging stations to support EV adoption. [3] [1] [4]

III. Methodology

3.1 Site Selection Process of EV Charging Station

Implementing a Solar PV, Diesel Generator and Battery based charging station involves a systematic site selection process. This includes assessing demand, evaluating solar potential, considering grid connection feasibility, ensuring space availability, prioritizing accessibility, addressing environmental concerns, ensuring security and safety, conducting cost analysis, and planning for scalability. This approach ensures the successful deployment of sustainable and efficient charging infrastructure. [2]

3.2 Solar PV System

Solar panels, comprising photovoltaic cells, capture solar energy and transform it into electrical power. These cells are constructed from semiconductor materials, predominantly silicon, which absorb photons emitted by sunlight, thus initiating an electric current via the photovoltaic phenomenon. [8] [10]

3.3 Battery storehouse simulation

Batteries serve as the primary energy source for electric vehicles (EVs), with various technologies utilized over time. These include lead-acid, Ni-Cd, Ni-Zn, Ni-MH, Li-polymer, and Li-ion batteries. Lithium-ion batteries are commonly employed in portable electronics and EVs due to their high energy density, relatively low self-discharge rate, and absence of memory effect. They function by facilitating the movement of

3.4 Diesel Engine Simulation

Diesel engines are commonly employed as prime movers connected to self-excited induction generators (SEIGs) serving as backup power sources. The diesel engine functions as the primary source of mechanical power by combusting diesel fuel to generate rotational motion, which is then transmitted to the generator shaft. The SEIG, an asynchronous generator, converts the mechanical energy from the diesel engine into electrical energy. It comprises a stator and a squirrel-cage type rotor. The stator is linked to the grid or load. Once electricity generation begins, the voltage from the output terminals is looped back to the excitation winding through a rectifier and voltage regulator. This feedback loop maintains the generator's magnetization, allowing it to self-excite autonomously without external power sources. [1]

3.5 Single Phase Grid

A single-phase grid denotes an electrical power distribution system that transmits electricity using a single alternating current (AC) waveform. [5] [6] Managing power derived from a single-phase grid entails employing synchronizing switches arranged in an H-bridge configuration featuring Insulated Gate Bipolar Transistors (IGBTs).

This arrangement enables accurate regulation of electricity flow within the system. The synchronization of switches within the H-bridge configuration, facilitated by IGBTs, enables efficient control over the power flow in the single-phase grid. This precise control ensures optimal utilization of generated power and enhances the grid's stability and reliability. [3]

3.6 Synchronizing Switches

Synchronizing switches serve a crucial role beyond simple closure; they act as switches synchronizing two independently controlled wave sources. This synchronization ensures that their respective waveforms align precisely at the moment of closure, hence earning the name "synchronizing switch." [6] In MATLAB representations, synchronizing switches are symbolized using Insulated Gate Bipolar Transistors (IGBTs) equipped with internal body diodes. These IGBTs are arranged in an H-bridge diode configuration, enabling the establishment of a reverse current path when necessary. [7] [10]

3.7 Filtering Circuits

A filter functions as a circuit capable of allowing specific frequencies to pass through while suppressing others, enabling the extraction of important frequencies from signals containing undesirable or irrelevant frequencies. In our context, RLC filtering circuits are employed on the AC supply side of VSC (Voltage Source Converter), both at the beginning of the single-phase grid and after the point of common coupling.

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RLC filters are electronic circuits designed to selectively pass or reject certain frequencies from an input signal using resistors (R), inductors (L), and capacitors (C). These filters are utilized to enhance power quality by reducing switching harmonics, ripple content, and voltage fluctuations in electrical supply systems. [11]

3.8 DC-DC Boost Converter

It is a power converter that elevates (boosts) a DC voltage to a higher level. Its components usually include an input capacitor, a switch (typically a transistor), an inductor, a diode, and an output capacitor. The fundamental principle revolves around storing energy in the inductor while the switch is on, and subsequently releasing that energy to the output when the switch is off, thereby increasing the output voltage. This converter is integrated into the DC link through VSC, a storage battery, and a solar panel, forming a connection to the electric vehicle charging station (EV2).[3] [9]

IV. PRINCIPLE OF OPERATION

In Fig 1, The architecture of the integrated system comprises three primary components: solar PV arrays, battery storage systems, and a diesel generator. The solar PV system plays a crucial role in converting light energy into electrical energy through photovoltaic energy conversion. It consists of two inputs: Sun irradiance in W/m2, generated by a stair generator that produces a signal changing at specified times, and cell temperature maintained at a constant 35°C. The output is 72 volts and 11.5A. To maximize power extraction from solar panels, an MPPT controller is utilized, placed across the solar panel. The electricity generated is then used to charge EV2 via a Boost converter, adjusting the voltage based on EV2's demand, or stored in batteries for later use. These Lithium-ion batteries act as a buffer, ensuring continuous power supply even when sunlight is unavailable, such as during nighttime or cloudy days, due to their high energy density and longer lifespan. They are connected across the solar panel via bidirectional VSC, with a rated capacity of 14Ah and a rated voltage of 360V.

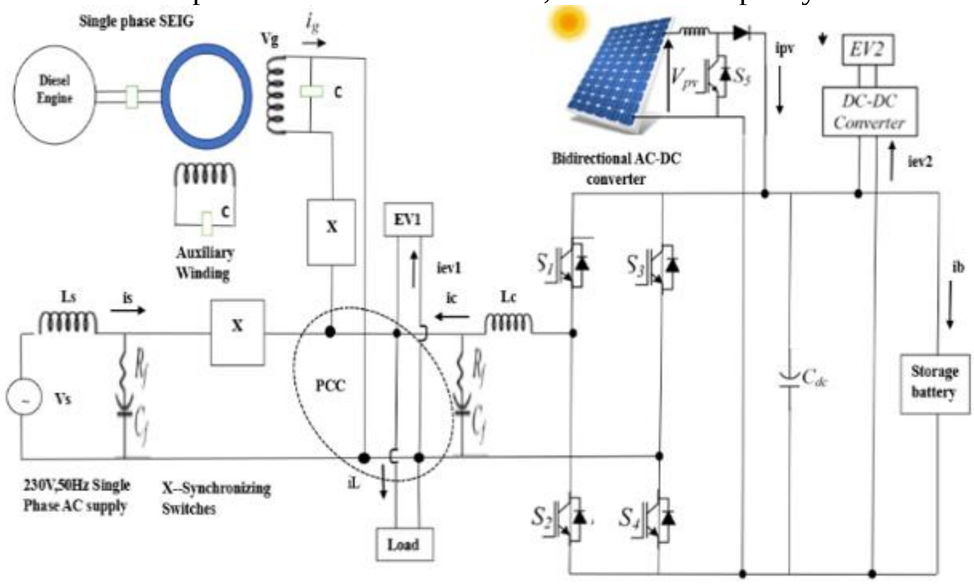

Fig 1. Architecture of EV Charging Station

From fig1, The charging station is integrated with local power grid to facilitate energy exchange. Here we assume single phase 230V, 50Hz ac supply as local grid, also the grid power can be used to supplement charging during peak demand or battery depletion through bidirectional VSC. And the grid power is used to charge EV2 when there is insufficient solar energy or battery depleted and also used to charge EV1 and supply the power to non-linear load that is connected in series to grid through universal bridge directly. In case of insufficient solar energy or battery depletion, a diesel generator is used in an electrical vehicle charging station which serves as a backup power source to ensure continuous charging capabilities, particularly in areas with unreliable grid power or during emergencies. Here, the diesel engine is used as a prime mover to provide mechanical energy to the

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self-excited induction generator (SEIG). The speed of the Diesel generator is regulated by changing the frequency and voltage of DG set instead of using mechanical relays.
The nominal power, voltage and frequency of diesel generator (SEIG) is 3.7e3VA, 230V, 50Hz. It can kick in order to provide additional/sufficient power to charge EV1 directly and EV2 through bidirectional converter which converters AC to DC when diagonally connected IGBT switches are triggered with gate pulses. This ensures uninterrupted charging service, especially during periods of high demand or unfavorable weather conditions. Synchronizing switches are connected in series with the local grid and diesel generator which operates only when the two different system waveforms come to closed command. Two RLC filters are used at the AC supply side of bidirectional VSC to improve power quality by reducing the switching harmonics and ripple content. The values of resistance, inductance and capacitance used in RLC filers is 5ohms, 10e3 and 10e-6F respectively. The dc link i.e. a capacitor placed across the bidirectional VSC for filtering the dc output voltage coming from the rectifier circuit. It reduces the ripple content in dc output to obtain the rectified output into pure dc signal. In above fig1, the circled region is the region of common coupling, it is the point where the generating facilities local electric power connects to the utility electric system.

Software specifications:

Operating System: Windows 11
RAM Used: 16GB
Software Used: MATLAB 2016a
Processor: 11th Gen Intel(R)Core-i5

Simply, this report discuss that the Solar PV arrays are strategically installed to capture solar energy, which is then converted into electrical power for charging EVs and replenishing the battery storage. The battery storage system serves as a crucial buffer, storing excess solar energy for use during periods of low solar irradiance and significant demand. Additionally, a diesel generator provides backup power to ensure uninterrupted charging operations during extended periods of adverse weather conditions or high demand.

V. CONTROL STRATEGIES

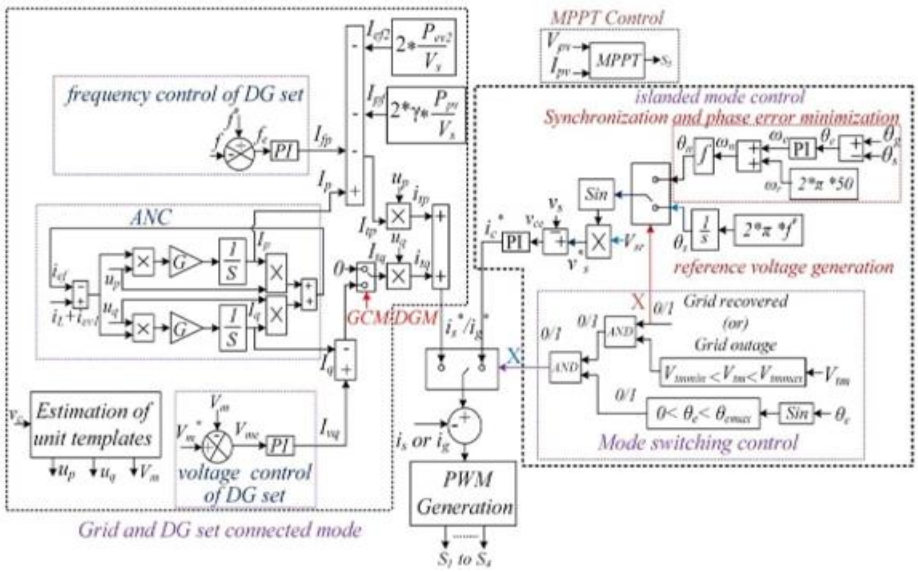

Fig 2. Control Strategies used in the charging station

5.1 VSC Control in single operation mode (only solar and battery)

The CS guarantees the steady functioning of the CS in the absence of the grid when operating in single operation mode without a grid or DG set. This means that both the AC and DC charging of the EV continue uninterrupted, as does the solar power generation. The storage battery can handle both DC charging and solar PV generating without requiring significant control revisions. Even yet, in order to generate the original voltage reference in the event of grid failure, the AC charging requires a separate regulator for the VSC. Therefore, in accordance with the sense shown in Fig. 2, which integrates the frequency and pass through, the islanded regulator generates the internal voltage reference of 230V and 50 Hz., as shown in Figure 2. This reference voltage is then compared with the motor's terminal voltage, ultimately providing the reference motor current after minimizing voltage errors using an integral (PI) regulator. [1] [2] [3] [5]

5.2 VSC Control in DG connected and Single-phase Grid Connected Modes

While in DG mode, the regulator runs in constant power mode for maximum energy efficiency, in grid-connected mode it decides how much strength to exchange with the grid. To extract the EVs fundamental frequency current and allow for independent control of the active and reactive currents, adaptive notch cancellation (ANC) is employed.

By sending extra power to the grid from shown in fig 2, a feed-forward term from the PV array controls battery charging. It adjusts according to the battery's state of charge (SOC) to avoid overcharging. Synchronising signals establish the reference current for the grid or distributed generation (DG), while a hysteresis regulator generates switching signals depending on the reference and real currents. [8] [9]

5.3 Control mechanism for voltage and frequency in DG connected mode

To regulate voltage and frequency in a DG set represented in fig2, a severed control of VSC is used, employing two PI regulators, to control frequency and voltage. The discrete expression of the frequency PI regulator includes (error in frequency) In grid-connected control, the outputs of these regulators are combined, but outputs will be zero while grid is connected. [2] [3] [5]

5.4 Control of EV2

The control of EV2 represented in fig2, involves charging it in constant current (CC) mode until the battery reaches near-full charge, then switching to constant voltage (CV) mode. This transition is managed by two PI controllers. The charging current is determined by the battery voltage error and controller gains. Additionally, for vehicle-to-grid power transfer, the battery discharges based on reference power, controlled by a separate pathway. [6] [7]

5.5 Coordination and transition management

The charging station needs a method to shift between various operating modes like islanded, grid-connected, and DG set-connected. It achieves this by synchronizing voltage phases using a PI regulator, which also fine-tunes voltage frequency during islanded operation. Specific parameters are used to minimize phase differences, and once synchronization is achieved, a signal enables mode transitions. [8]

VI. SIMULATION MODEL

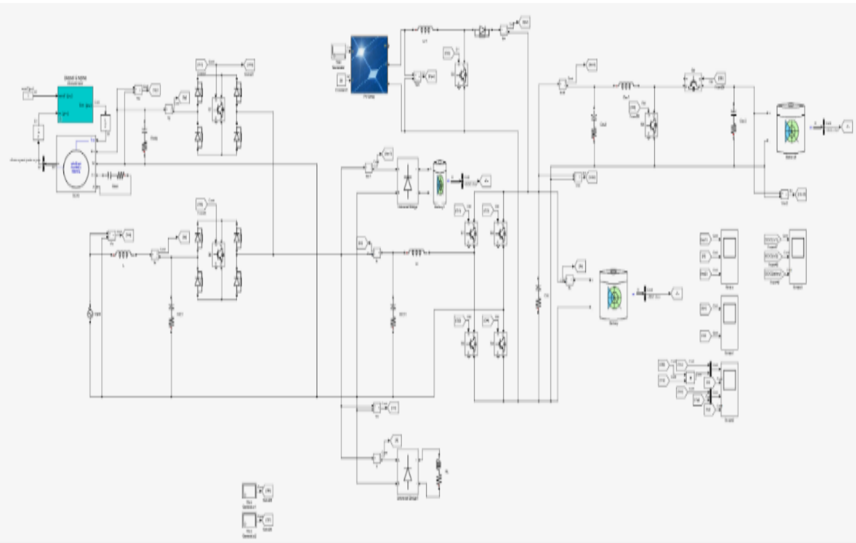

Fig. 3 Simulation Model for EV Charging Station

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A simulation model for a solar PV, battery and DG used EV station replicates its operation to predict performance and optimize resources. It includes components like solar panels, batteries, diesel generators, EV chargers, and control logic. The simulation model allows for testing of control algorithms and operational strategies in a risk-free environment before implementation in the real system. This iterative process of simulation, analysis, and optimization helps refine the charging station's design and operation, leading to more efficient and sustainable charging infrastructure for electric vehicles.

VII. RESULT

Below are the figures of result of simulation model of solar energy battery and diesel generator, load {EV1 current, EV2 current, load, Vc & Vs of grid, Vg &Vs of diesel generator} and simulation of output of grid connected mode and diesel generator connected mode.

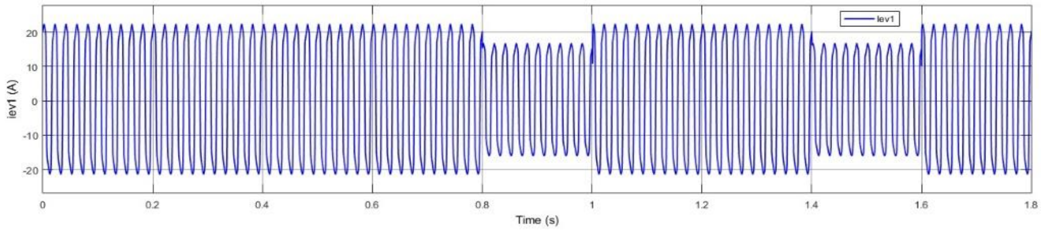

Fig. 4 Simulation result of EV1 Current

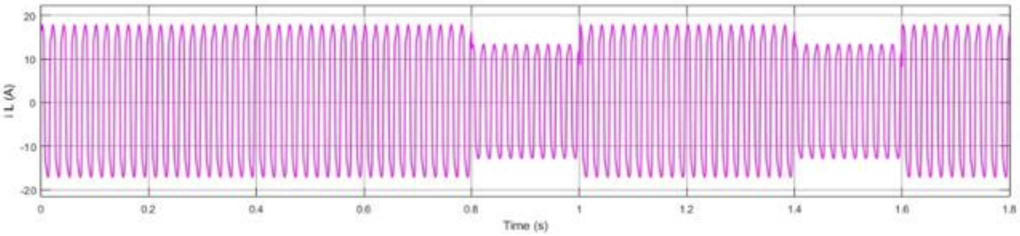

Fig. 5 Simulation result of Load

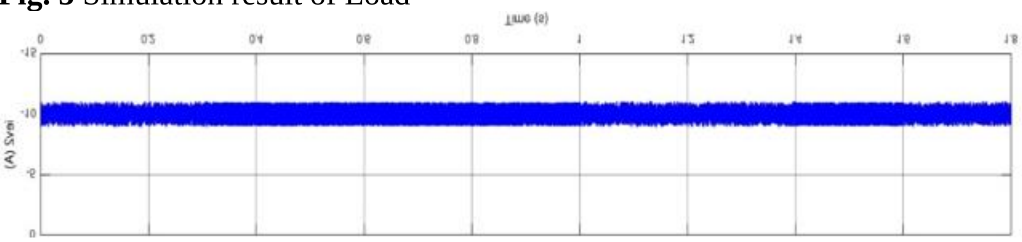

Fig. 6 Simulation result of EV2 current

Figures 4, 5, 6 shows the simulation result for current at electric vehicle charging station 1 and 2 and the load current at load current at load during all modes of operation: islanded mode, DG mode as well as grid connected. we are maintaining constant and uninterruptible power supply to EV1, 2 and load.

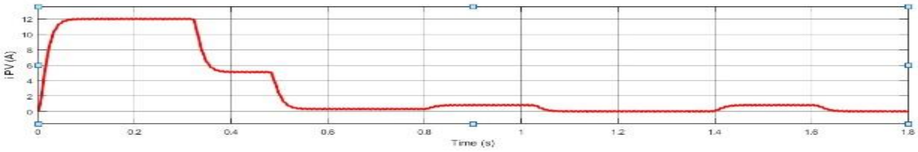

Fig. 7 Simulation result of Solar energy

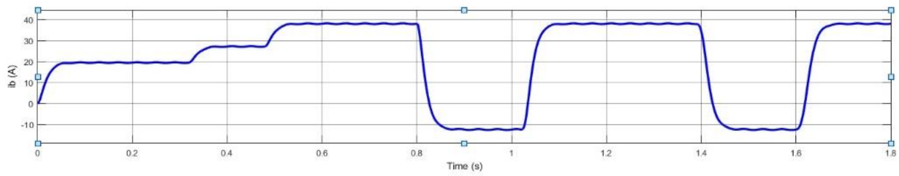

Fig. 8 Simulation result of Battery

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Figures 7, 8 During single operation, solar power charges EVs from 0.2 to 0.32 sec, with excess stored in batteries. Solar output decreases after 0.32 sec, leading to battery discharge. By 0.48 sec, solar power diminishes entirely, prompting battery discharge.

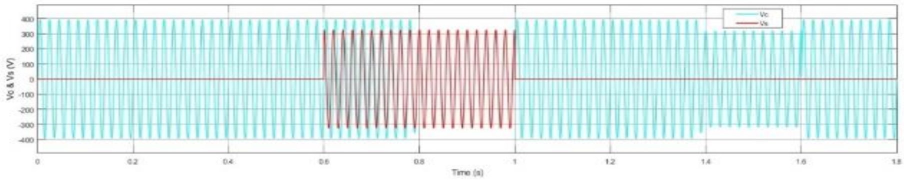

Fig. 9 Simulation result of Vc & Vs for Single-phase grid

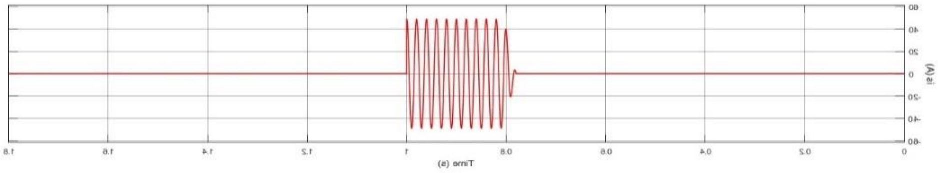

Fig. 10 Simulation output of Is for grid connected mode

The figures 9, 10 shows the voltage and current waveforms during grid connection at the charging station (CS). After the battery fully discharges, the CS connects to the grid between 0.8 and 1.0 sec. During this time, grid current flows through the circuit, charging the battery via bidirectional VSC with power from the local grid.

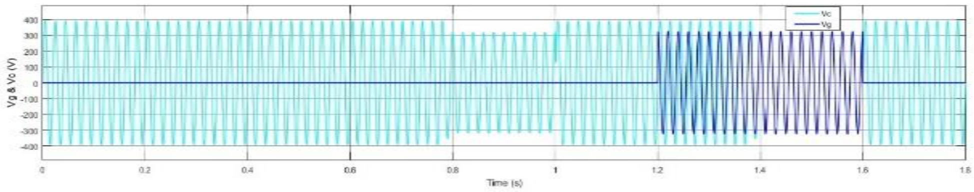

Fig. 11 Simulation output of Vg, Vc for Diesel Generator

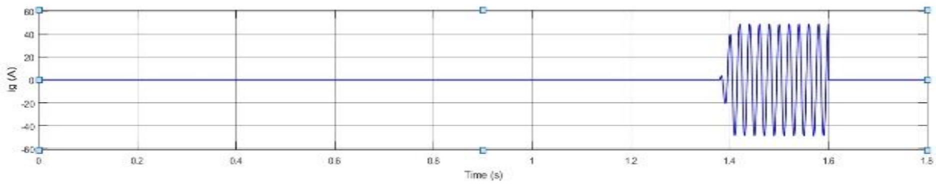

Fig. 12 Simulation output of Ig for DG connected mode

Figures 11,12. show the simulation result for the voltage waveforms across the Vg, Vc and the current waveform (ig) when DG is connected during the interval of 1.2 to 1.4sec.

VIII. COMPARISION WITH THE PRESENT SYSTEM

Aspect	Present System	Future System
Power Source	Either Grid or Solar	Solar PV, Battery, Diesel generator
Environmental Impact [Carbon Emissions]	Moderate [Dependent on grid source]	Reduced with Solar PV, Diesel [Used as Backup]
Energy Independence & Reliability	Dependent on Grid	Increased with Solar PV, Battery
System Resilience	Limited	Enhanced with Battery backup and Diesel generator.

Table 1. Comparison between present system and future system

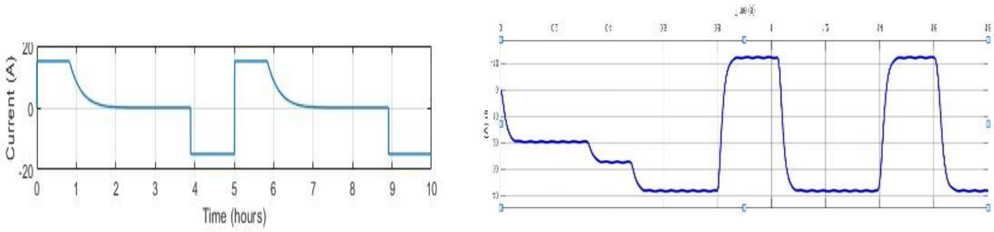

Fig. 13 Comparison graphs Existing System and proposed system graphs of battery

IX. CONCLUSION

In conclusion, Innovative hybrid vehicle charging station for EV vehicle using solar PV, battery and diesel generator represents forward-thinking solution that addresses the growing demand for sustainable transportation infrastructure. By harnessing renewable energy sources such as solar power and integrating energy storage capabilities, these charging stations offer numerous advantages, including reduced environmental impact, lower operating costs, grid independence, and enhanced resilience against power outages. Furthermore, the scalability and flexibility of this approach allow for customization to meet varying power demands and enable deployment in diverse locations, including remote or off-grid areas. Through community engagement and education, these charging stations also serve as catalysts for promoting renewable energy adoption and sustainable transportation practices. Overall, innovative hybrid vehicle charging station for EV vehicle using solar PV, battery and diesel generator not only facilitates the widespread adoption of electric vehicles. By embracing innovative technologies and sustainable practices, we can create a transportation infrastructure that is not only efficient and reliable but also environmentally friendly and resilient to future challenges.

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