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Analysis on Rapid Charging for Electrified Transportation Systems

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ABSTRACT- *Background:* To improve system resilience when charging electric vehicles, a new control mechanism for converters that convert voltage from sources in micro-grids is presented. *Methods:* This deals with an evolving continuous current and stable voltage charging method for electric automobiles (EVs) with the objectives of speedy charging, constant voltage stability, deviation from voltage reduction, and cost reduction. *Results:* The study uses spectrum evaluation and state of health evaluations to look at the effects of different voltage sag thresholds on the automotive charging parking's. *Conclusions:* In the end, the research offers a power management algorithm created for a green energy-based electric vehicle charging station that maximizes the use of sources of Clean Conventional Energy Systems (CCES) with best process while optimizing real-time charging prices.

Keywords: Constant Current, Constant Voltage, Fast Charging, Voltage Stability

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1. INTRODUCTION

System-forming resources (SFRs) and dynamic controls are being used in European projects to incorporate 100 percent of clean energy into the power system. This approach combines renewable energy technologies with power electronic converters, ensuring overall system security and stability. The implemented scheme includes a control and protection system that rapidly maintains power balance, controls voltage, and enhances transient stability, effectively demonstrating the GFRs' potential in establishing a secure and renewable electric power system [1].

In this study, an enhanced control method is presented for microgrid grid-connected voltage source converters, with an emphasis on enhancing system resilience. By combining current control and a logical switching table, the method improves both steady-state and dynamic performance, effectively addressing challenges such as power fluctuations and faults. Simulation and experimental results demonstrate its superior effectiveness and performance compared to other control methods [2].

The research investigates the coexistence and stability of paralleled PLL-synchronized CCES under severe grid voltage sags. To improve transient stability and voltage support, the paper proposes a current injection design method based on the analysis of current injection angles and magnitudes [3].

The ideal positioning and sizing of distributed generating units (DGs) powered by renewable energy sources, such as solar power (PV) and wind turbine (WT) systems, is another issue covered in this study. The study improves Renewable Energy based DG (REDG) planning while taking into account numerous objectives such power loss reduction, stability of voltage, voltage deviation minimization, and financial savings. It does this by introducing a unique technique using the Artificial Hummingbird Algorithm (AHA). Evaluations on IEEE 33-bus and 69-bus systems show that the proposed method surpasses other current meta heuristics (HHO-PSO and PPSOGSA) in terms of solution quality and techno-economic advantages [4].

One of the new stability issues caused by the rapid spread of inverter-based Renewable Generation (RG), for instance, is the capacity to shut down RGs based on predetermined operation conditions. This research offers a unique strategy for discovering the smallest relaxations of these limits that can increase voltage security without endangering system stability to solve this issue. A model for optimization must be created, key RGs must be determined, and a series of sensitivity-based tests must be run on proposed solutions [5].

Power systems with significant proportions of RESs confront particular difficulties such poor system inertia and vulnerability to oscillations. In order to overcome these problems, the research provides a unique strategy that combines Virtual Inertia Control (VIC) with load frequency control (LFC). Superconducting Magnetic Energy Storage (SMES) is used for VIC, and cooperative tilt-based controls and a hybrid Modified Particle Swarm Optimization with Genetic Algorithm (MPSOGA) are used. The optimization procedure takes into account the coordinated management of LFC and VIC in order to reduce the frequency nadir settling time during rapid fluctuations. The method outperforms conventional optimization strategies in handling oscillations in renewable generation and shifting loading circumstances, as shown by a case study of a two-area power system with different generating sources [6]. This study provides a droop-based decentralized control technique for Electric Vehicle (EV) charging. The main goal is to reduce excessive voltage increase and voltage imbalance in Low-Voltage (LV) distribution networks brought on by unbalanced loads and rooftop solar PV installations. The technique uses nodal voltages, voltage imbalance, and the State-of-Charge (SOC) to dynamically modify the charging rates for EVs. The suggested technique is shown to be successful in lowering voltage increase and voltage imbalance in the network using simulations on an IEEE 13 node test feeder [7]. This article explores a cost-effective solution for energy storage and grid services by utilizing electric vehicle (EV) parking lots. By treating the parking lot as a market aggregator, the approach accounts for uncertainties such as EV arrival/departure, battery state of charge, and EV owner participation. The article provides an illustrative example and outlines a roadmap for a comprehensive integration into power distribution networks, highlighting the potential benefits of this approach for enhancing grid services and optimizing energy storage [8].

In-depth analysis of EV charging technologies and their effects on power grid design, operation, stability, standards, and safety are provided in this article. It thoroughly examines the architecture of EV charging stations, power converter configurations, and international standards. Both onboard and off-board chargers are discussed, along with alternating current to direct current and direct current - direct current converter configurations, as well as alternating current and direct current -based charging station architectures. The review also delves into recent developments in charging systems integrated with renewable energy sources. Additionally, the article outlines future trends and challenges in EV charging and grid integration, providing valuable insights for researchers and practitioners [9].

Given the transportation sector's significant contribution to greenhouse gas emissions in Saudi Arabia, adopting electric vehicles (EVs) is seen as a global solution for de-carbonization. This article proposes utilizing off-grid EV charging stations powered by renewable energy resources. By doing so, the existing grid network can be relieved of pressure while meeting the growing demand for EV charging [10].

This work focuses on optimizing the energy management of multiple Micro Grids (MGs) within a Multi-Micro Grid (MMG) system, taking into account the uncertainties in Renewable Energy (RE) generation and loads. The paper introduces an adaptive energy scheduling algorithm that minimizes long-term operation costs while efficiently utilizing RE resources. Virtual queues and the Lyapunov framework are employed to handle unused RE, enhancing reliability, reducing power loss, and increasing RE penetration. Simulation results demonstrate the algorithm's effectiveness in coordinating multiple MGs within the MMG system, leading to significant cost reductions and improved RE resource utilization [11]. This study provides a hybrid solar and biogas-based Electric Vehicle Charging Station (EVCS) energy management algorithm. The program optimizes real-time charging prices and renewable energy use by taking into account techno-economic and environmental parameters and using a fuzzy inference system in MATLAB SIMULINK. Results show a huge 74.67% decrease in energy expenses as compared to current flat rate tariffs, reduced charging prices throughout the week and on the weekends, and a sizable drop in greenhouse gas emissions. The proposed project also offers a relatively short payback period, ensuring profitability for charging station owners [12]. This paper addresses the impact of plug-in electric vehicle (PEV) charging demand on distribution networks and proposes an optimal location and capacity determination for charging stations. We take into account the views of CS investors, PEV consumers, and distribution network operators. To reduce grid stress, it is advised that renewable energy sources (RESs) be incorporated at the charging station. Utilizing energy management techniques such as Vehicle-to-Grid (V2G) discharge and battery storage system (BSS) regulation can reduce peak power consumption and maximize the use of renewable energy sources. For handling uncertainty relating to PV power generation and PEV charging needs, the Monte Carlo Simulation (MCS) approach is utilized [13]. This study investigates how different voltage sag levels affect the batteries and EV charging system. The research introduces a DVR-FRTC system that successfully injects voltage during the sag period, maintaining the load voltage at a standard value, to improve load voltage quality. With this strategy, the EV charging system is guaranteed to operate in a steady mode for all voltage sag levels, enhancing system reliability and shielding EV batteries from voltage fluctuations [14].

This article introduces a smart charging technique for EV and distributed generation (DG) scheduling in a distribution system. The approach focuses on peak shaving, effectively reducing peak congestion and system power loss. Moreover, the optimal placement and size of DGs are determined to further reduce power loss and improve the voltage profile of the distribution system. This research suggests a new distributed real-time alternating direction method of multipliers (ADMM) technique for electric vehicles (EVs) and battery storage systems (BSSs) to control voltage while optimizing utility function. The technique conforms to power flow equations and optimizes a combined convex objective taking into consideration EV and BSS welfare and voltage management by exchanging information with nearby nodes over the communication network. In order to include rooftop photovoltaic (PV) systems with Electric Vehicle Charging Stations (EVCSs) into a distribution network, this study uses a hybrid BFOA-PSO optimization approach. A multi-objective function is created to optimize the voltage stability index while lowering the average voltage deviation index, active and reactive power losses, and other metrics. Random distribution of the PV systems mimics the consumer-based integration of PV systems in everyday life.

India's rapidly growing population and concerns about environmental degradation and fossil fuel depletion necessitate the creation of alternative transportation modes. As the market for electric vehicles (EVs) expands in India, it becomes vital to

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develop the necessary charging infrastructure for widespread EV adoption. This study addresses the challenge of planning the charging infrastructure for Guwahati, India, as it transforms into a smart city. The problem of charging station allocation is approached using a multi-objective framework that considers random road traffic, economic factors, and power grid features like voltage stability, dependability, and power loss. A hybrid approach based on Pareto dominance is used to solve the placement issue, integrating the chicken swarm optimization (CSO) and teaching learning-based optimization (TLBO) algorithms. Fuzzy decision-making is used to compare the resultant Pareto optimum possibilities, producing well-informed choices [18]. The development and adoption of electric vehicles (EVs) are largely influenced by their battery life. On a smart grid, a solution involving superconducting magnetic energy storage (SMES) is suggested to increase charge efficiency and extend battery life. To restore the load terminal voltage and improve transient stability in the event of a malfunction, the SMES unit reacts fast and modifies both active and reactive power. Additionally, it has been shown that the installation of a SMES unit stabilizes power distribution networks for EVs, improving their power quality and successfully minimizing transient voltage dips at the load terminal.

2. CHARGING METHODS

2.1 Some common charging methods:

2.1.1 Constant Current (CC) Charging

In this method, the battery is charged using a consistent and uninterrupted current until it reaches a predefined voltage level. At the beginning, when the battery voltage is low, a constant current is applied. As the charging proceeds, the battery voltage increases, resulting in a gradual decrease in the charging current. When the battery attains the desired voltage, the charging process may transition to constant voltage charging.

```
+-----------------------------------------------+
|             Renewable Energy Source           |
| (Solar Panels, Wind Turbines, etc.)           |
+---------------+------------------+------------+
                |                  |
                v                  v
+---------------+------------------+------------+
|         Energy Storage System                 |
|      (Batteries, Super Capacitors, etc.)      |
+-------------------+---------------------------+
                    |
                    v
+-------------------+---------------------------+
|              Fast Charging System             |
| (DC Fast Chargers, Power Electronics, etc.)   |
+-------------------+---------------------------+
                    |
                    v
+-------------------+---------------------------+
|             Electric Vehicle                |
| (Battery, Charging Port, and Vehicle System)  |
+-----------------------------------------------+
```

Figure 1: Power Flow

2.1.2 Constant Voltage (CV) Charging

In this approach, the voltage across the battery terminals is maintained at a constant level, ensuring that the charging current decreases gradually as the battery approaches its full charge capacity. This careful control of voltage prevents overcharging during the entire charging process.

2.1.3 Trickle Charging

Trickle charging is a slow and continuous charging method used to maintain fully charged batteries. A low and constant current is supplied to the battery, compensating for self-discharge and keeping the battery at its maximum capacity. This method is commonly used with lead-acid batteries in applications such as storing motorcycle or car batteries.

2.1.4 Pulse Charging

Pulse charging involves applying short pulses of high current to the battery, followed by rest periods. The goal is to enhance battery efficiency, reduce charging time, and prevent overheating. This method is utilized in certain fast charging technologies.

2.1.5 Fast Charging

Fast charging methods are designed to recharge batteries quickly, making them common in modern electronic devices and electric vehicles (EVs). These methods often combine constant current and constant voltage charging, considering battery chemistry, temperature, and state of charge to optimize the process and reduce charging time.

2.1.6 Solar Charging

Solar charging utilizes solar panels to convert sunlight into electrical energy, which is then used to charge batteries or energy storage systems. It is particularly useful in off-grid or remote areas where traditional power sources are limited.

2.1.7 Inductive Charging

Also known as wireless charging, inductive charging relies on electromagnetic fields to transfer energy between the charger and the device without requiring a physical connection. This method is popular in charging smartphones, electric toothbrushes, and other small electronic devices.

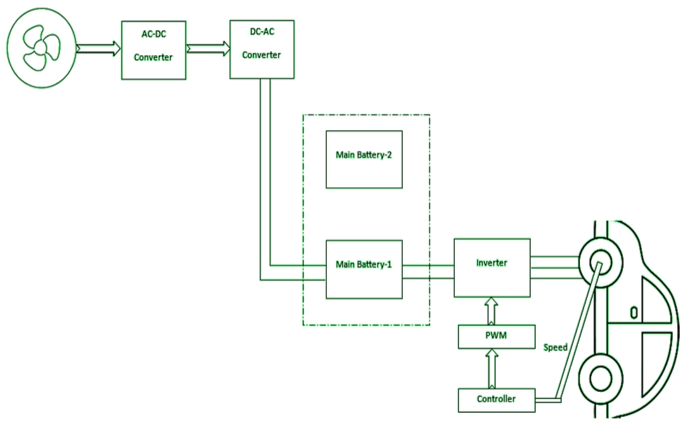

Figure 2: Block diagram on fast charging on EV

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The hybrid solar and biogas-based EV charging station energy management algorithm in steps,
Step 1: Define Objectives and Goals
Step 2: Data Collection and Monitoring
Step 3: Load and Energy Force Data Preprocessing
Step 4: Mathematical Optimization
Step 5: Load Balancing and Prioritization
Step 6: Demand Response Strategies
Step 7: Energy Storage Control
Step 8: Grid Interaction
Step 9: Fault Detection and Diagnostics
Step 10: User Interface and Control
Step 11: Integration with Renewable Energy
Step 12: Security and Reliability
Step 13: Reporting and Analytics
Step 14: Continuous Optimization and Learning
Step 15: Compliance and Regulations
Step 16: Testing and Validation
Step 17: Deployment and Integration
Step 18: Training and Maintenance
Step 19: Monitoring and Improvement

2.2 The Fast-Charging flow assists renewable energy for electric vehicles

2.2.1 Reducing Charging Time

Fast charging is a highly effective method that significantly decreases the time required to charge an electric vehicle. Traditional charging options, like Level 1 (110-120V) or Level 2 (220-240V) chargers, may take several hours to fully charge an EV. However, with fast chargers, commonly known as Level 3 DC fast chargers, an EV can reach 80% capacity in as little as 30 minutes or even less. This remarkable speed reduces range anxiety often linked to EVs and enhances their practicality for longer journeys.

2.2.2 Grid Management

Renewable energy sources, such as solar and wind, are subject to intermittency and rely on weather conditions. At times of peak production when renewable energy generation surpasses demand, the surplus energy can be directed into the electricity grid. Fast chargers can leverage these surplus renewable energy resources to expedite the charging of EVs. This approach is referred to as "smart charging" or "demand response," enabling the adjustment of EV charging rates to align with the availability of renewable energy. By intelligently synchronizing EV charging with renewable energy abundance, this process optimizes energy utilization and promotes sustainable practices.

2.2.3 Load Balancing

Fast charging infrastructure can help balance the load on the grid, especially when multiple EVs are charging simultaneously. By implementing smart charging solutions, fast chargers can distribute the demand for electricity more evenly throughout the day, reducing strain on the grid during peak periods.

2.2.4 Off-grid charging solutions

In some remote areas or places with limited access to the electricity grid, fast charging combined with renewable energy can offer off-grid charging solutions. Solar panels or wind turbines can be used to generate electricity, which is then directly utilized for fast charging EVs, promoting sustainable mobility in remote locations.

2.2.5 Storage Integration

Fast charging stations can be combined with energy storage systems such as batteries. This integration allows excess renewable energy to be stored when it's available and utilized for fast charging later when renewable generation may be lower or unavailable. Energy storage systems help to ensure a stable and reliable source of energy for EV charging.

2.2.6 Environmental benefits

Using fast charging with renewable energy helps reduce greenhouse gas emissions from the transportation sector. EVs charged with electricity from renewable sources have a significantly lower carbon footprint compared to internal combustion engine vehicles powered by fossil fuels.

3. REDUCING CHARGING TIME

By proper modeling of switching frequency, proportional constant, integral constant, inductance value of transformer, winding factor, the charging time is reduced as mentioned in *table 1*.

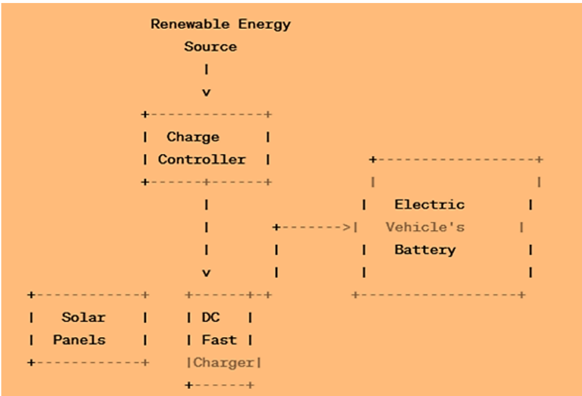

Figure 3: Block diagram on fast charging

Table 1: required parameters for reduction in charging time

S.No	Parameters	Specifications
1	Inverter. Switch Frequency	10 kHz
2	Inverter controller.kp	2%
3	Inverter controller.ki	1%
4	Inverter inductance	10 micro-Henry
5	Transformer magnetizing, L	1 H
6	Transformer winding Factor	0.50%
7	Chopper Voltage Sensor, G	1%
8	Chopper Voltage Sensor, T	1/(10*inverter Switch Frequency)
9	Chopper Current Sensor, G	1%
10	Chopper Current Sensor, T	1/(10*inverter Switch Frequency)

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4. ENERGY STORAGE SYSTEM

An overview of the theory and working principles of lead acid batteries, detailing their construction, charging and discharging mechanisms, and key factors influencing their performance.

i. *Lead Acid Battery Construction*: Lead acid batteries are typically designed with lead plates immersed in a sulfuric acid electrolyte. These batteries consist of positive (PbO2) and negative (Pb) lead plates, acting as electrodes. To prevent short circuits, these electrodes are separated by insulating separators. The electrodes are immersed in a dilute sulfuric acid solution, typically with a specific gravity around 1.28.

ii. *Charging Process*: During the charging process, an external electrical source is connected to the lead acid battery. When charging commences, electrical energy is applied to the battery, triggering a chemical reaction that converts lead sulfate (PbSO4) formed during discharge back into lead dioxide (PbO2) at the positive plate and lead (Pb) at the negative plate. This process is known as the reverse of discharge.

iii. *Discharging Process*: The lead acid battery's chemical energy is transformed back into electrical energy when a load is attached to it. Lead sulfate (PbSO4) is created during discharging when lead dioxide at the positive plate combines with sulfuric acid, and lead at the negative plate similarly does the same. Electrical energy that may be utilized to power various systems or devices is produced by these chemical processes.

iv. *Electrolyte Concentration and Specific Gravity*: The concentration of the sulfuric acid electrolyte and its specific gravity significantly impact the performance of lead acid batteries. Specific gravity is a measure of the electrolyte's density relative to water. Throughout the charging and discharging process, the specific gravity changes as the concentration of sulfuric acid alters due to chemical reactions.

4.1 Factors Influencing Battery Performance

Several factors influence the performance and lifespan of lead acid batteries, including:

a. *Temperature*: Extreme temperatures, both hot and cold, can impact battery performance and lead to reduced efficiency and capacity.
b. *Depth of Discharge (DOD)*: Deep discharges put more stress on the battery and may reduce its overall lifespan.
c. *Overcharging*: Overcharging can lead to the breakdown of electrolyte and loss of water, damaging the battery.
d. *Sulfation*: If a lead acid battery is left in a discharged state for extended periods, sulphate crystals may form on the plates, reducing battery efficiency.

4.2 Reactions at Electrodes and Mathematical Model of Lead-Acid Battery

Reaction at the negative electrode

Pb+SO42- ↔PbSO4+2e- (1)

Reaction at the positive electrode

PbO2+4H+ SO42- ↔ PbSO4+2H2O (2)

Overall Reaction

Pb+PbO2+2H2SO4↔2PbSO4+2H2O (3)

Mathematical Model of a Lead-Acid Battery

$$E=IR+V \text{ or } V=E-IR \quad (4)$$

E is open circuit voltage, *I* is the current flowing through the circuit, V is the voltage across the load.

R is the internal resistance of the battery. Internal Resistance of a Battery pack can be given as:

$$R=n.\frac{0.022}{C_{10}}\ \text{Ohm} \quad (5)$$

where *n* is the no. of cells, Capacity of a battery changes according to the rate of discharge.

$$Cp=ikT \quad (6)$$

The method to find the Peukaert coefficient is fairly easy and only requires battery capacity at two different discharge times.

The two different ratings give two different rated currents.

$$I_1=\frac{C_1}{T_1} \quad (7)$$

$$I_2=\frac{C_2}{T_2} \quad (8)$$

$$\left(\frac{I_1}{I_2}\right)^K=\left(\frac{T_2}{T_1}\right) \quad (9)$$

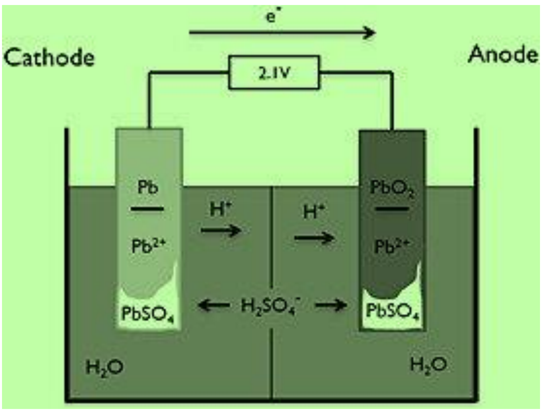

Figure 4: Lead acid battery

5. MODELLING

The MATLAB Simulink is utilized to model a fast-charging station by incorporating the components of frond end converter, DC-DC converter, EV battery bank and the controlling technique as phase lock loop, continuous current and continuous voltage technique are applied as shown in *figure 5*.

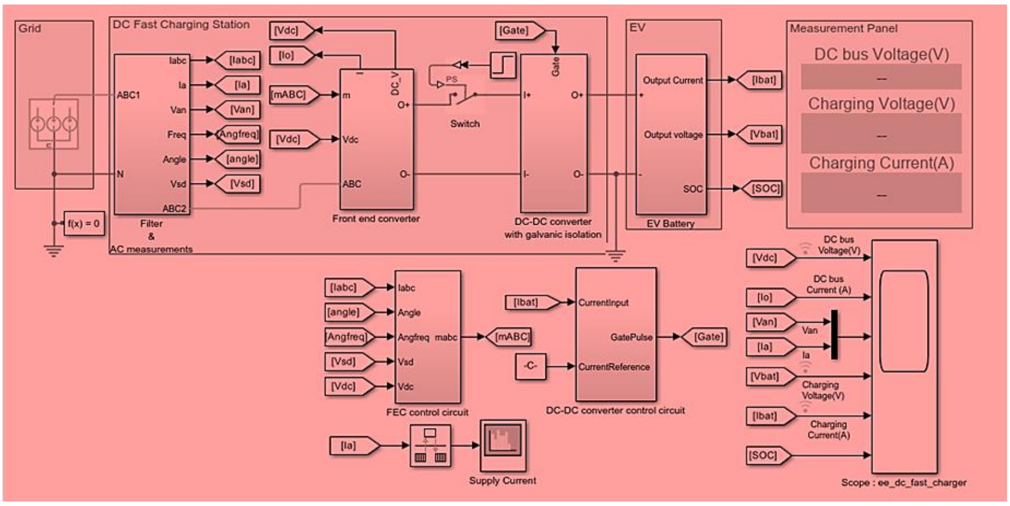

Figure 5: Modeling of fast EV charging station

5.1 Rectifier-Front-End Convertor Modelling

Table 2: Required parameters for Front-End Converter

S.No	Parameters	Specifications
1	Rectifier AC Voltage, PP	415 V
2	Rectifier AC Voltage, PN	Rectifier. AC Voltage, PP/sqrt(3);
3	Rectifier AC Voltage Peak	Rectifier AC Voltage, PN * sqrt(2)
4	Rectifier DC Current	700 A
5	Rectifier DC Voltage	800 V
6	Rectifier System Frequency	50 Hz
7	Rectifier Switch Frequency	10 kHz
8	Rectifier min Vdc Possible	Rectifier. AC Voltage, PP*sqrt(2/3)/0.5; % V
9	Rectifier. AC Current	sqrt(2)*rectifier.DCCurrent*rectifier.DCVoltage/(sqrt(3)*rectifier.ACVoltagePP);
10	Rectifier Max L	0.95*((rectifier.DCVoltage*0.5)-rectifier.ACVoltagePP*sqrt(2/3))/(2*pi*rectifier.SystemFrequency*rectifier.acCurrent)
11	Rectifier max AC current	100 A
12	Rectifier min AC current	-100 A
13	Rectifier max AC voltage	515 V
14	Rectifier min AC voltage	-515 V
15	Rectifier min DC voltage	0.5*rectifier DC Voltage
16	Rectifier line Inductance	0.1 m-H
17	Rectifier line Resistance	20 m-ohm
18	Rectifier line T	Rectifier line Inductance/rectifier line Resistance
19	Rectifier Output Capacitance	20 mF
20	Rectifier a	2%
21	Rectifier G	Rectifier DC Voltage/2;
22	Rectifier K	Rectifier AC Voltage Peak/(rectifier DC Voltage)
23	Rectifier Td	1/(2*rectifier Switch Frequency)
24	Rectifier T phi	Rectifier Td + rectifier Current Sensor T
25	Rectifier T del	(2*Rectifier Tph, i) + Rectifier .Voltage Sensor T
26	Rectifier controller Current G	Rectifier line Inductance/ (2*Rectifier G* Rectifier Current Sensor G* Rectifier Tph, i)
27	Rectifier controller Current T	Rectifier .line T = rectifier controller Voltage G
28	Rectifier controller Voltage T	4*Rectifier T del

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5.2 Two Level Inverter Fidelity

This inverter is responsible for converting the available DC or AC power source into the desired voltage and current levels required to charge the battery. Ensuring high fidelity in the inverter's output waveform is crucial for several reasons. Firstly, it promotes battery health and efficiency by delivering a smooth and controlled charging current, which minimizes heating and stress on the battery cells, leading to prolonged battery life and optimal performance. Additionally, a well-controlled and accurate waveform allows for optimized charging profiles, enhancing charging speed and efficiency. Safety is another vital aspect, as a high-fidelity waveform reduces the risk of overcharging or undercharging the battery, thereby avoiding potential safety hazards and preserving battery performance. Moreover, a clean and low-distortion waveform reduces electromagnetic interference (EMI) and ripple current, contributing to a stable and reliable charging process. Achieving high waveform fidelity involves employing advanced control algorithms, pulse-width modulation (PWM) techniques, and high-quality power semiconductor devices like IGBTs or SiC MOSFETs. Performance metrics such as Total Harmonic Distortion (THD) and Crest Factor (CF) are used to assess the waveform quality, with lower THD and CF values indicating a more sinusoidal and stable waveform. Overall, a two-level inverter with high fidelity is crucial in battery charging applications to ensure safe, efficient, and reliable charging while maximizing battery life and performance. Continued advancements in control and power electronic technologies contribute to further improving the fidelity of inverter output waveforms for diverse battery charging systems.

5.3 Front-End Converter Variants

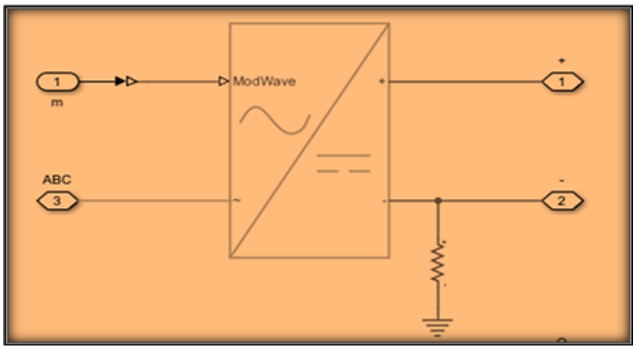

Figure 6: 2-level inverter

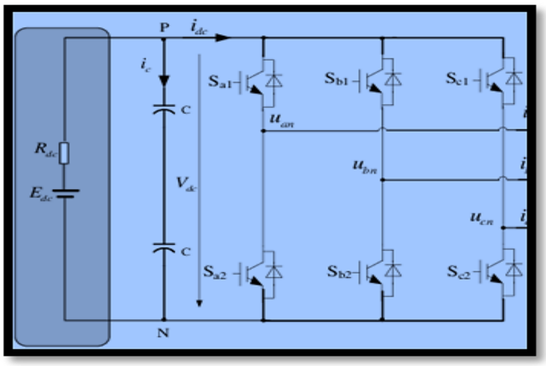

Figure 7: Simulink of 2-level inverter

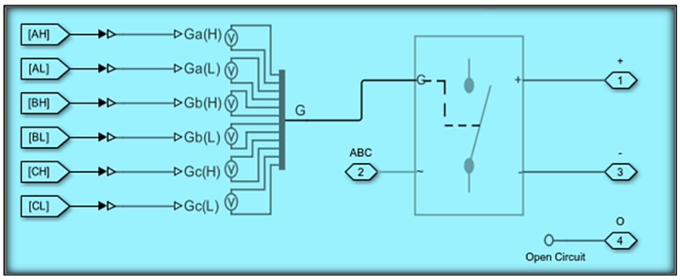

Figure 8: Typical MATLAB 2-level inverter

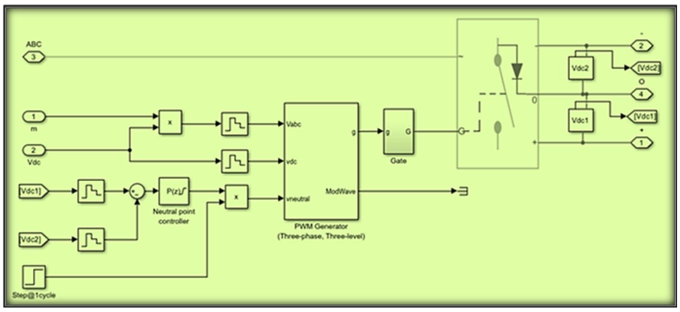

Figure 9: Pulse generation for 2-level inverter

5.4 Battery Pack Modelling

The following parameter are essential for battery pack arrangement as reference current, initial state of charge, ampere hour rating, number of cells in series and parallel.

Table 3: Required parameters for Battery pack modeling

S. No.	Parameters	Specifications
1	Current Reference	100 A
2	Initial SOC	0.2
3	AH Rating	50%
4	Inductance	5 mH
5	Cells-In-Series	100
6	Strings-In-Parallel	1

6. RESULTS

The *figure 10, figure 11, figure 12, figure 13, figure 14, figure 15* and *figure 16* shows the simulation results on charging current, spectrum, state of charge, front end converter DC output voltage, battery terminal voltage, battery charging current and front-end converter Dc output current respectively. *Figure 10* states the inference on DC bus voltage, charging voltage and current as 800 V, 918.63 V, 101.44 A respectively.

Figure 11 infers the maximum amount of harmonic content with 120 V with a frequency around 10^{-1} Hz. *Figure 12* demonstrates the required time as 0.08ms for steady state charging by implementing phase lock loop. *Figure 13* implies DC output voltage from front-end converter as 800 V at 0.015ms. *Figure 15* shows 918 V as battery terminal voltage by 0.02ms. *Figure 16* implies DC output current from front-end converter as 200 A at 0.02ms.

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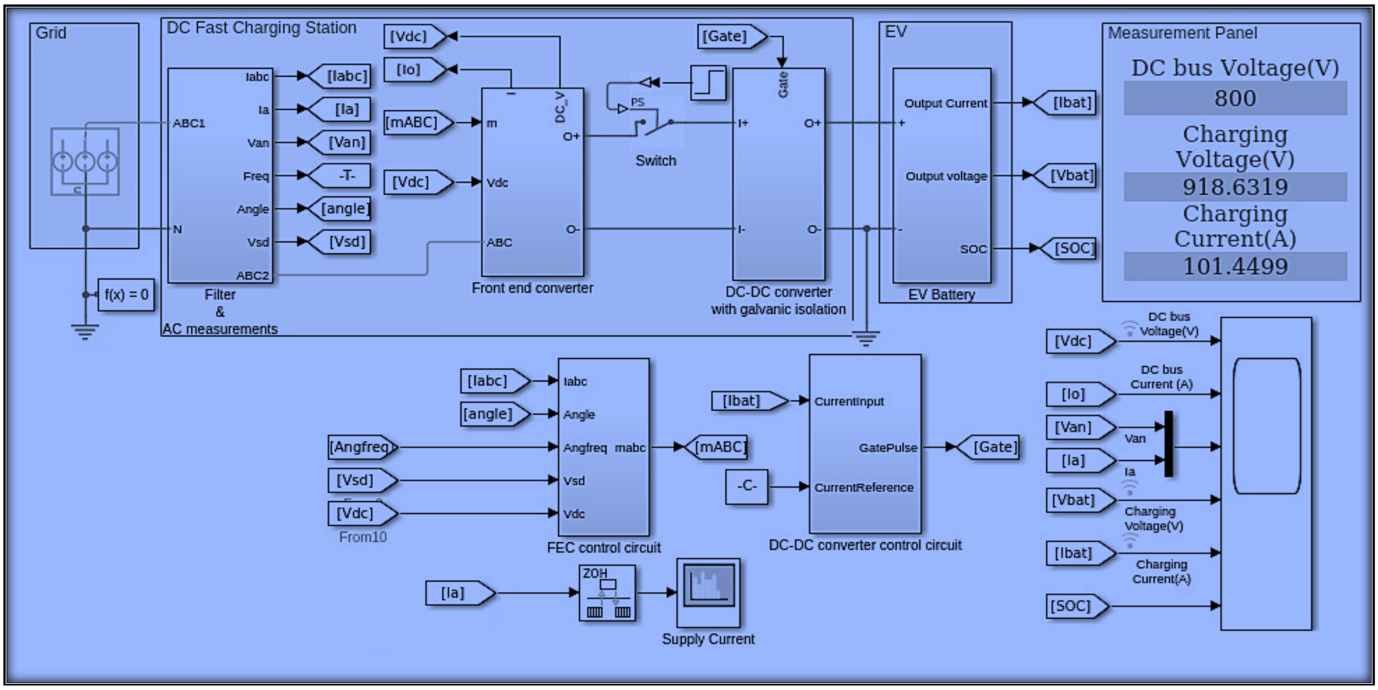

Figure 10: Modeling of fast EV charging station with results

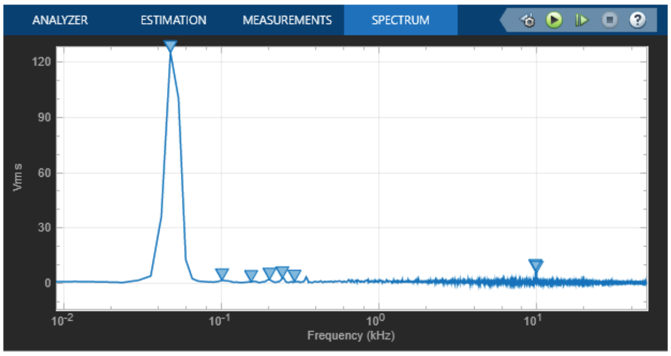

Figure 11: Spectrum analysis

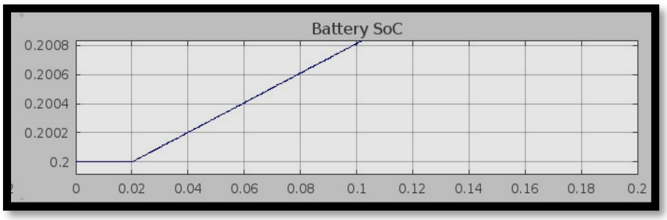

Figure 12: State of charge on Battery management system

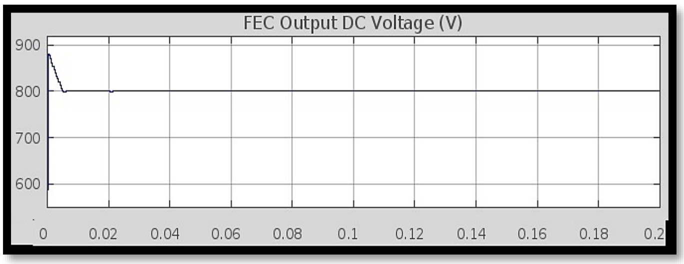

Figure 13: DC output voltage from front-end converter

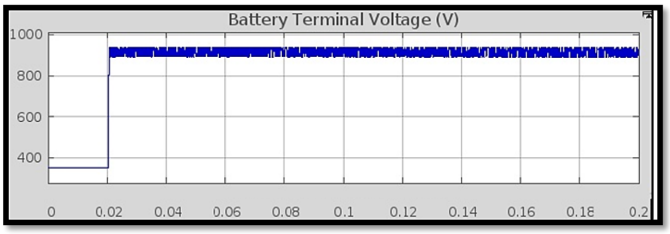

Figure 14: Battery terminal voltage

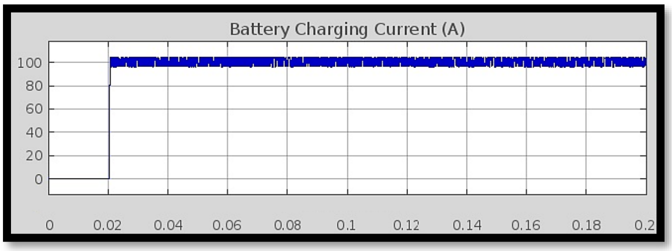

Figure 15: Battery charging current

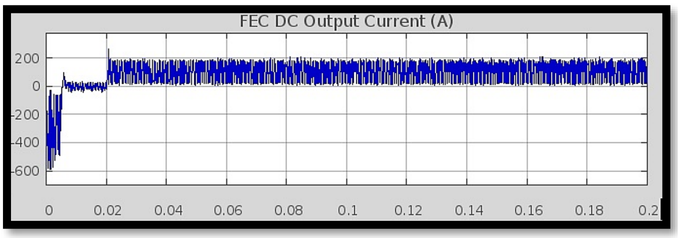

Figure 16: DC output current from front-end converter

7. CONCLUSION

The article explores how dynamic controls and grid-forming resources (GFRs) are being used in European efforts to incorporate 100% renewable energy sources into the power system. To achieve complete system security and stability, GFRs integrate power electronic converters with renewable energy technologies. The interaction and stability of paralleled PLL-synchronized RES systems under significant grid voltage sags are also investigated in the study. The report also discusses the difficulty of locating and scaling distributed generating units (RDGs) powered by renewable energy sources, such as photovoltaic (PV) and wind turbine (WT) systems. To minimize future operating expenses an adaptive energy scheduling technique is described that ensures the effective use of renewable energy (RE) resources. The research also presents a hybrid solar and biogas-based EV charging station energy management algorithm. This algorithm efficiently maximizes the use of renewable energy and real-time charging prices, resulting in lower energy expenditures, lower charging costs, and lower greenhouse gas emissions. The article's main points emphasize the need of cutting-edge control strategies and optimization approaches for successfully integrating renewable energy sources into the power grid and improving the efficiency of EV charging infrastructure. The potential advantages of such integration for a more sustainable and effective energy landscape are emphasized.

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