Efficient Fast Charging of Plug in Electric Vehicle Using Adaptive Slide Mode Controller

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Abstract: With technological improvement, the interest in electric vehicles (EVs) has regained in the 21st century, as well as the focus on renewable energy sources and a potential to reduce the negative impacts of transportation on environmental issues like the climate change. The fast charging stations are gaining popularity with electric cars as they can shorten the time, and help to reduce range anxiety. For effective alleviating grid stress and reduction of carbon emissions, it is essential to integrate solar systems with conventional direct current fast charging stations. However, challenges exist since GIC are underutilized and ESS are too expensive. To fully leverage the advantages of electric vehicle (EV) installations and their supporting charging infrastructure, these challenges must be effectively addressed. A proposed direct current (DC) fast-charging station architecture, designed to operate solely with photovoltaic (PV) systems and without incorporating energy storage systems (ESS), aims to minimize costs. In scenarios where an ESS is absent from the fast-charging setup, the suggested Smart Charging Algorithm (SCA) ensures optimal alignment between power sources and loads from both the grid and EVs. This optimization enhances power output from the PV system while maximizing the efficiency of grid-integrated chargers (GICs). The GICs function based on a grid-regulated algorithm (GRA), while EVs follow a self-regulated algorithm (SRA). As long as DC bus voltage fluctuations remain within an acceptable range, the SRA dynamically adjusts the charging power for each EV according to its state-of-charge (SOC) feedback, ensuring power balance within the fast-charging system (FCS). Both simulation and experimental results validate the effectiveness of the proposed SCA. Additionally, the GRA takes part in the regulation process when the DC bus voltage remains within the predefined excitation voltage range, ultimately reducing the overall charging time for EV batteries.

1 INTRODUCTION

Consequently, electric vehicles (EVs) and hybrid electric vehicles (HEVs) are widely advocated to reduce the reliance on fossil fuels and lower carbon emissions. Direct Current Fast Charging Systems (DC FCS) can enhance the charging speed and extend the driving range of EVs; however, they also increase stress on the utility grid and introduce new challenges. To mitigate grid stress and decrease carbon emissions, DC FCS integrated with photovoltaic systems is employed.

At the megawatt scale, photovoltaic technology proves to be both practical and cost-effective. Overall, hybrid power supply systems (HPSS) or DC FCS that utilize renewable energy sources help to eliminate dynamic power fluctuations.

Significant research results have been obtained about the optimization of the ESS cost, but the elimination of the ESS cost of FCS has not been explored. Clearly, the removal of the ESS will save a considerable amount of money for FCS. However, the previous ESS based energy management strategies for the HPSS are retained to highlight the important role of ESS in power flow balancing. However, without ESS power support, traditional energy management strategies become ineffective for the FCS. The DC FCS architecture based on ESS free is introduced and studied to address the large cost of ESS. At the same time, the smart charging algorithm (SCA) is proposed for the effective coordination of the grid and EVs' source or load properties to minimize power fluctuations of FCS in the absence of ESS.

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2 PROBLEM DEFINITION

In several nations, the technology of electric vehicles (EVs) has been advocated as the way to minimize local air pollution and increase transportation energy security. Electric vehicles are still very immature, with their cost still very high, especially for pure electric vehicles, and there is still not very suitable infrastructure. This paper covers some of the roadblocks and challenges that are likely to obstruct progress in this challenging area. The current problems can be divided into two groups Battery performance and prices, as well as battery manufacturing, including material supply concerns. The environmental benefits of electric vehicles are dependent on the energy sources used to generate electricity and their carbon intensity. The length of time it takes to charge an automobile is determined by the battery capacity and other factors.

3 LITERATURE SURVEY

This study (Akhtar Hussain et al., 2020) presents an optimized approach for determining the appropriate size of a battery energy storage system (BESS) in a fast-electric vehicle (EV) charging station that experiences power outages. The research focuses on minimizing energy storage system costs, enhancing EV resilience, and reducing peak power demand to establish the most effective BESS configuration. Additionally, it emphasizes the robustness of EV operations during power interruptions. In the initial phase, the stochastic demand of the fast-charging station (FCS) and the resilience of EV loads are analyzed using probability distribution models. To ensure EVs remain operational despite power losses, the energy levels in the storage system are maintained at a stable level. Based on this, the annualized cost rate of the BESS is determined, considering yearly interest rates and component lifetimes. The optimal BESS size is then derived by factoring in the annualized cost, penalties for peak-hour power purchases, and penalties for resilience violations. Furthermore, simulations and sensitivity analyses are conducted to assess the impact of various parameters, such as the number of EVs at the charging station, converter ratings, and uncertain factors like market price fluctuations, EV arrival times, and residual energy levels. Simulation results indicate that increasing costs during peak intervals effectively reduces overall FCS expenditures while managing peak capacity efficiently.

Primary and Secondary Control in Dc Microgrids a Review offered a Direct and indirect control in DC microgrids are discussedThe concept of microgrids is well-known in the field of electrical engineering due to the rapid advancement of power electronics technology. DC microgrids (MGs) are becoming increasingly common due to the advantages of DC power distribution networks, such as reduced losses and simplicity in connecting with energy storage resources. A DC microgrid with multiple sources is gaining importance as a research issue with the increasing acceptance of distributed generation. The challenge with a multi-source DC microgrid is to supply voltages that effectively facilitate power sharing. Given the significance of the control method in ensuring the power system reliability of the microgrid, an extensive analysis of current condition control techniques in DC microgrids is necessary to ensure their efficacy. This work covers both the direct and indirect control techniques used in hierarchical control.

Integrated Pv Charging of Ev Fleet Based on Energy Prices, V2g, An Offer of Reserves developed an integrated reserve offer, V2G, and energy price PV charging solution for EVs. There are several advantages to using office building photovoltaic (PV) panels to charge electric vehicles (EVs) while at work. This includes using PV energy that is generated locally, using it to charge electric vehicles, and establishing energy exchanges with the grid through the use of dynamic grid pricing.This study presents an original mixed-integer linear programming (MILP) formulation designed to tackle distribution network constraints, aiming at effective electricity management and grid overload prevention. Utilizing a receding-horizon methodology, the MILP model governs the charging of electric vehicle fleets through photovoltaic sources.

4 DESCRIPTION

In light of the rapidly increasing global demand for energy and the need to locate a substation of fossil fuel resources before their eventual long-term depletion, this recommended solution reduces the time required for charging an electric automobile as well as the energy storage system.

5 BLOCK DIAGRAMS

Solar panels capture sunlight, and a direct current (dc-dc) converter is employed to transfer this energy to the battery. The electric vehicle is charged using a dc/dc converter within a charging station. Additionally, the power grid serves as an alternative power source. Refer to Figure 1 for the block diagram of the suggested system.

Fast-charging stations (FCS) commonly utilize energy storage systems (ESS) to mitigate power fluctuations caused by the unpredictable and frequent charging demands of electric vehicles (EVs), as well as the variability of photovoltaic (PV) power generation. The primary goal of the scheduling coordination approach (SCA), which integrates the scheduling regulation approach (SRA) and global regulation approach (GRA), is to optimize the use of ESS within the FCS through coordinated management of EV charging and grid-interface converters (GICs). The power fluctuation range of the FCS is effectively represented by variations in DC bus voltage. Due to the frequent fluctuations in power, GICs may experience lower utilization rates, given that EVs exhibit distinct temporal and dynamic load characteristics.

Since EV charging durations typically fall within the hourly range, this study employs the SRA method to regulate EV charging power, thereby mitigating minor power fluctuations in the FCS. By implementing a modified droop charging strategy with state-of-charge (SOC) feedback, SRA enables proportional and dynamic power adjustments across EVs. However, while SRA effectively reduces fluctuations, it may either slow down EV charging or negatively impact battery lifespan—both of which are undesirable for users. To address this limitation, GRA is introduced to ensure that EVs receive adequate charging power for handling larger power fluctuations while simultaneously improving the utilization efficiency of GICs.

5.1 Solar Panel

The primary HPSS component in FCS is the PV system. A photovoltaic system with many parallel array sets is connected to the DC bus. In the planned FCS, PV systems will be given preference while charging EVs, which will ease the load on the electric grid, particularly during peak hours.

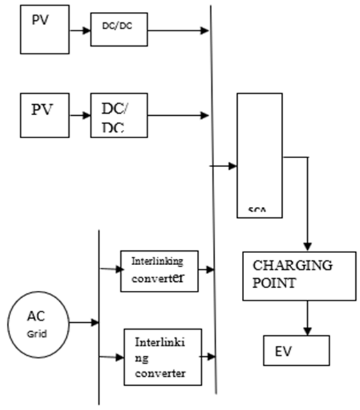

Figure 1: Proposed Block Diagram.

5.2 Converter

A converter is an electrical circuit that takes a direct current (DC) input and delivers a DC output at a different voltage level. This is typically achieved through high-frequency switching, along with the use of inductive and capacitive filtering components. Depending on its design, a converter can serve multiple functions while altering the input voltage. In the proposed system, a DC-DC converter is utilized, which integrates both boost and buck conversion capabilities to regulate the voltage as needed.

5.2.1 Boost Converter

This proposed system employs a dc-dc converter that combines the operations of a buck and a boost converter. Figure 2 depicts the boost converter used in the PV system to achieve maximum power point tracking (MPPT).

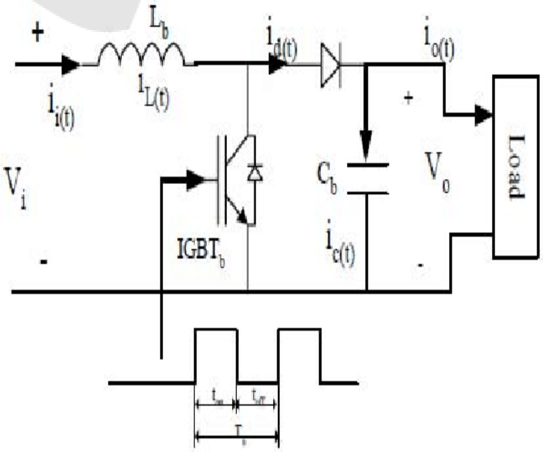

Figure 2: Boost Converter.

Each boost converter is assessed based on its capacity to operate efficiently, as well as its size and implementation cost. Traditional boost converters and interleaved boost converters are extensively used topologies in solar systems, although they have the disadvantage of varying efficiency levels depending on the weather.

5.2.2 Buck Converter

The charging station has the buck converter shown in Figure 3. The DC/DC stage is the second stage of power conversion in an EV charging station. It does this by changing the incoming DC link voltage to a lower DC voltage, which charges the battery of an electric car. The buck converter is a typical DC-DC converter that turns a high voltage to a low voltage.

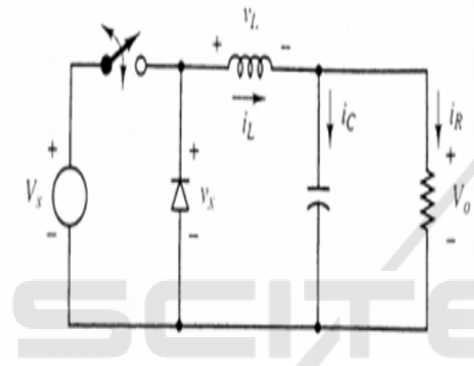

Figure 3: Buck Converter.

5.2.3 Interlinking Converter

By granting control over the exchanged active and reactive power, interlinking converters enable the direct management of power flow between grids. A key component of the stability of the entire hybrid microgrid is the interlinking power converter, which connects the AC and DC sub grids in Figure 4.

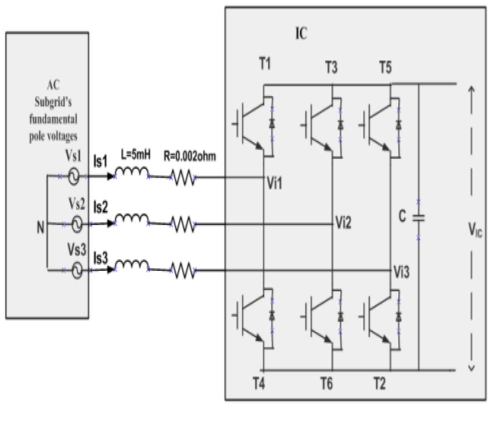

Figure 4: Interlinking Converter.

In grid-connected mode, the utility grid could assure power balance, and the converter could ensure DC bus voltage stability. In both micro grids, an interlinking converter is employed for power balance, transferring power from one micro grid to the other if one is overwhelmed.

5.3 Battery

In applications involving electric vehicles (EVs), lead-acid batteries make up 25–50% of the vehicle mass overall. At 30–50 Wh/kg, their specific energy is less than that of petroleum fuels, which is the standard for all batteries. Figure 5 shows an example of a lead-acid battery. Even the most sophisticated batteries, when used in cars with a conventional range, typically lead to larger masses; however, this difference is lessened because an EV's drivetrain is lighter.

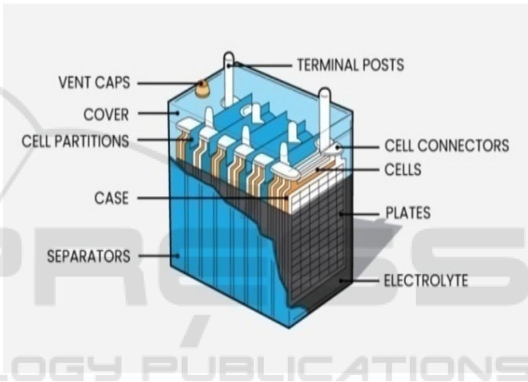

Figure 5: Lead Acid Battery.

Batteries release hydrogen, oxygen, and sulfur during charging and usage. These gases are naturally occurring and, when properly vented, are typically safe. Among the various types of batteries, lead-acid batteries are the most affordable. In situations where vehicle speed is not a concern, this type of battery is commonly used in professional settings.

6 SMART CHARGING ALGORITHM

Power fluctuations caused by the intermittent nature of the PV system and the irregular and frequent access of EVs are the most important reasons that the ESS needs to be used in order to eliminate this. In this work, the ASMC aims to cooperatively allocate the power distribution of EVs and GICs in order to replace the ESS in FCS. The SCA flow chart is as shown in Figure 6. The FCS power fluctuation range can be well indicated by the DC bus voltage. EVs have different temporal and dynamic load characteristics, therefore frequent power fluctuations will lead to a poorer usage of GICs.

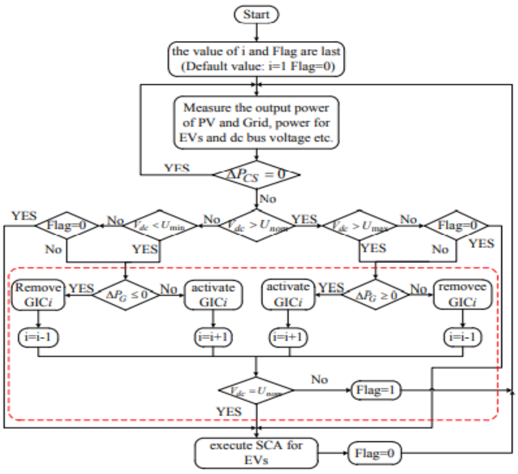

Figure 6: Flow Chart of ASMC.

Because EV charging time is measured in hours, this article employs the Self-Regulated Algorithm (SRA) to adjust EV power input in order to smooth out minor power variations in FCS. With SOC feedback, the ASMC for EVs can accomplish proportionate dynamic power control among EVs via modified droop charging.

1. Since FCS has large power fluctuations, GICs should be involved in the regulation of the charging power of EVs.

2. To maintain the stability of the High-Performance Storage System (HPSS), it is essential to adjust the droop coefficient based on the operational status of the Grid Interface Converter (GIC) and fluctuations in DC bus voltage. When the GIC is not operating at full capacity, it retains its initial droop coefficient, and the DC bus voltage remains proportional to the output power. However, once the GIC reaches its maximum power output and an additional GIC is activated, the droop coefficient adjusts in response to changes in DC bus voltage. By implementing a dynamic adaptive management approach, the output voltage of each GIC can be effectively synchronized with the DC bus voltage, ensuring optimal system performance.

6.1 AC Grid

Grids are typically consistently synchronous, indicating that all distribution areas operate on synchronized three-phase alternating current (AC) frequencies, allowing voltage fluctuations to happen nearly simultaneously. In FCS, the AC module is movable and is made up of many parallel GICs. The GICs will turn on when EVs are unable to manage power fluctuations to the point where the DC bus voltage rises over the predetermined threshold range. To guarantee that EVs are charging at the proper power, GICs are able to endure significant power fluctuations. To increase the converter's usage, use numerous GICs.

6.2 Charging Point

Every CP is connected to the common DC bus, which is managed and maintained by the FCS, and each CP has a buck converter installed independently. When an EV battery pack is being charged, the CP keeps track of its voltage, current, and state of charge (SOC) and relays this data to the control center. The enhanced CC&CV charging mode provided by the CP guarantees the efficiency of EV charging.

7 SIMULATION DIAGRAMS

By working together to coordinate the power distribution of EVs and GICs, the ASMC hopes to accomplish ESS replacement within FCS. In Figure 6, the ASMC flow chart is shown. The power fluctuation range of FCS is effectively represented by the DC bus voltage. Due to frequent power fluctuations, the unique temporal and dynamic load characteristics of EVs might lead to a decline in the usage of GICs. Figure 7 depicts the suggested system's simulation diagram.

The Smart Regulation Algorithm (SRA) for electric vehicles (EVs) relies on feedback mechanisms to ensure balanced and dynamic power distribution. However, continuously using Adaptive Sliding Mode Control (ASMC) to suppress power fluctuations can lead to undesirable effects—either slowing down charging due to reduced power levels or causing battery degradation from excessive charging power. To address these challenges, an optimized control approach is required.

To manage significant power variations, ASMC is employed to regulate charging power levels and improve the efficiency of grid-interface converters (GICs). During this process, there is a continuous exchange of power between the fast-charging station (FCS) and the utility grid. ASMC is activated only when voltage fluctuations caused by power variations remain within a defined range.This study presents an enhanced droop control strategy that integrates state-of-charge (SOC) data to achieve power balance in an

FCS handling multiple EVs. Additionally, it provides a comprehensive analysis of droop behavior in both constant current (CC) and constant voltage (CV) charging phases.

To maintain optimal charging power, GICs play a vital role in stabilizing power fluctuations within the FCS. Deploying multiple GICs significantly enhances system efficiency compared to using a single unit. To ensure the stability of the hybrid power supply system (HPSS), the droop coefficient must be dynamically adjusted based on the DC bus voltage and the operational state of the GICs. When a GIC is not fully utilized, the DC bus voltage remains proportional to output power, preserving the initial droop coefficient. However, when a GIC reaches its capacity limit, the next GIC is activated, which may lead to variations in the droop coefficient relative to the DC bus voltage. By implementing an adaptive droop coefficient management strategy, each GIC’s output voltage aligns with the DC bus voltage, ensuring optimal system performance.

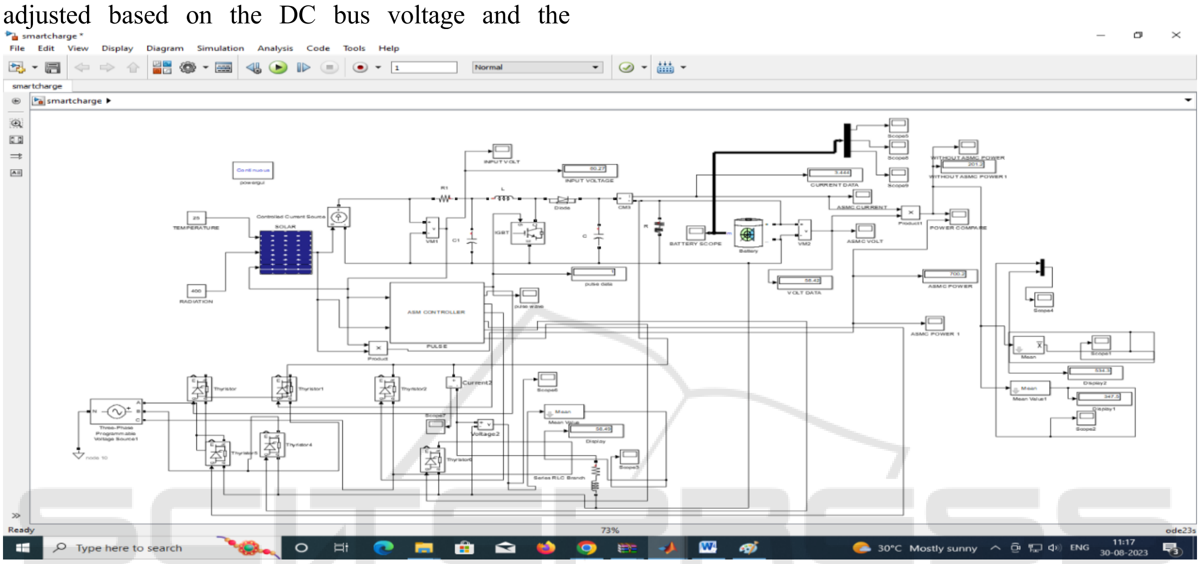

Figure 7: Simulation Diagram of Proposed System.

8 RESULTS AND SIMULATION

The simulation output and analysis of solar panel, converter, battery, inverter, grid and charging time with ASMC were shown in following figures. The output of solar panel after using dc-dc boost converter is shown in Figure 8.

The power taken from the grid to charge the battery of electric vehicle by using smart charging algorithm is shown in the Figure 9 The power is drawn from the grid only when there is high power fluctuation is observed.

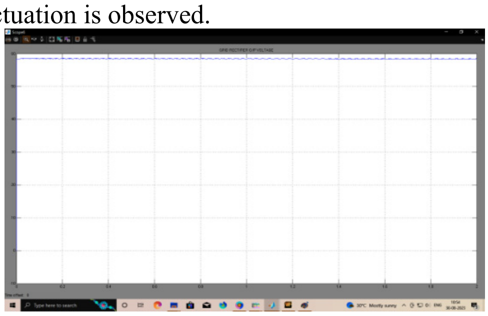

Figure 8: Solar Voltage.

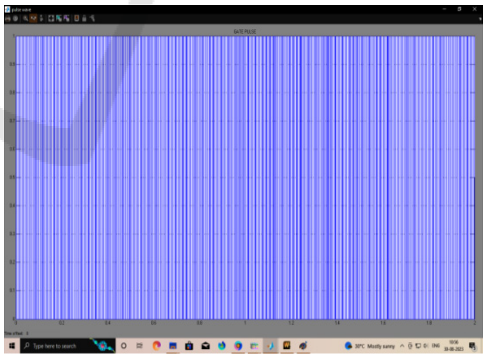

Figure 9: Grid Voltage.

The gate pulse shown in Figure 10 is given to the switch by using the smart charging algorithm. This gate pulse is used to trigger the gate of the switch to fasten the process of open and close of the switch. This process can speed the flow of charge through the circuit. So, that charging speed can be increased.

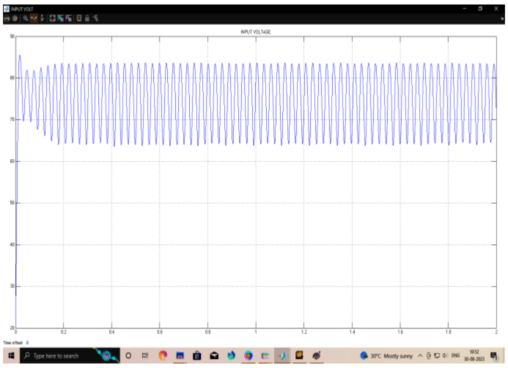

Figure 10: Gate Pulse.

The battery gets charged by using the source such as solar power and grid. The charging source of battery is decided by using the controller such as smart charging controller. The current, voltage and state of charge of a battery is shown in the Figure 11

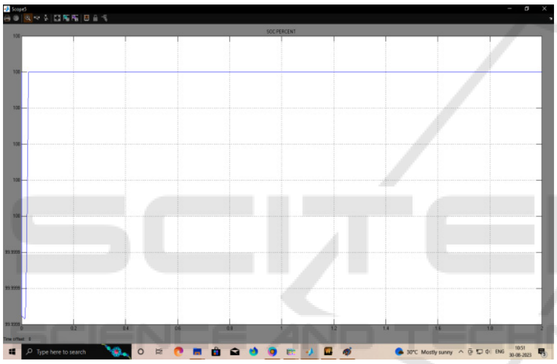

Figure 11: SOC of Battery.

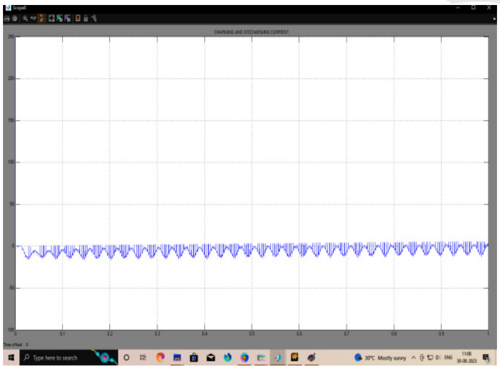

Figure 12: Battery Current.

The aim is to reduce the charging time of electric vehicle. This is obtained by using the newly proposed algorithm called smart charging algorithm. This algorithm is basically a switching technique which controls the switching operation of the system. The comparison of charging time of an electric vehicle with ASMC and without ASMC is shown in the figure 13. Figure 12 shows the Battery Current.

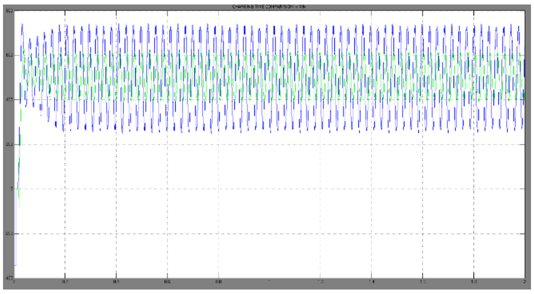

Figure 13: Time Comparison of Charging EV.

9 CONCLUSIONS

In a DC fast-charging station (FCS) that employs a hybrid power supply system (HPSS), it is crucial to lower the costs associated with energy storage systems (ESS) while enhancing the performance of grid-integrated chargers (GICs). The proposed DC FCS incorporates an Adaptive Sliding Mode Control (ASMC) strategy that functions independently of the ESS. Simulation outcomes demonstrate the algorithm's effectiveness in sustaining power stability. By removing the reliance on ESS, the ASMC optimizes power delivery from both GICs and electric vehicles (EVs) within the FCS. This approach mitigates power fluctuations resulting from the erratic arrival of EVs and the variable output of photovoltaic (PV) systems, thereby ensuring a stable power supply. The ASMC employs a dynamic droop control mechanism that modifies EV charging power based on state-of-charge (SOC) feedback, allowing it to effectively respond to the changing load characteristics of EVs and enhance power support within the FCS. Utilizing an adaptive droop control strategy, the ASMC improves the efficiency of multiple GICs in comparison to depending on a single unit. A significant benefit of this method is its capacity to decrease the number of battery charging cycles in EVs, which in turn promotes battery longevity and enhances overall system efficiency.

10 FUTURE SCOPE

In further research, the vehicle-to-grid mode (V2G) will be taken into consideration to enhance power support to the grid. The load (motor) will be charged using a battery that provides feedback to the ASM for the protection of battery life. This approach is suggested to keep the electrical grid's voltage stable.

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