REDUCTION OF CHARGING TIME OF PLUG-IN ELECTRIC VEHICLE USING SMART CHARGING ALGORITHM

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Abstract - *In order to improve the air quality and to reduce the usage of fuel, the preference for Electric Vehicle (EV) is increased. The Direct Current Fast Charging Station (DCFCS) with renewable energy source which has Energy Storage System (ESS) and converters will relieve the stress on grid and mitigate the emission of carbon. DCFCS placed on Photovoltaic system and without ESS method were proposed for the purpose of reducing the cost. To get high output power from PV and under usage of Grid Interlinked Converter (GIC) in non-ESS system is done by using Smart Charging Algorithm (SCA) which completely correlate the properties of source and load on the grid and electric vehicle. The SCA was processed by using two algorithms: self regulated algorithm (SRA) and grid regulated algorithm (GRA). SRA operation depends upon the load requirement (i.e., electric vehicle) and it triggers the switch when there is low power fluctuation. GRA triggers the switch to GIC when there is high power fluctuation. The charging time of electric vehicle is reduced by triggering the switching process quickly which is done by smart charging algorithm. The simulation result shows that this proposed system reduced the charging time of electric vehicle.*

Key Words: Electric vehicle, non-energy storage system, Grid interlinked converter, fast charging station, smart charging algorithm.

1. INTRODUCTION

Electric vehicles are being pushed around the world intending to mitigate the carbon emissions and utilization of fossil resources. The fast charging station (FCS) uses direct current (DC) to boost the charging rate and range of electric vehicles. As a result, the DC FCS based on a photovoltaic (PV) system is used to relieve grid stress while also lowering carbon emissions. [1-4].In general, the energy storage system (ESS), such as the battery, super capacitor, flywheel, and so on, is used in the hybrid power supply system (HPSS) or DC FCS based on renewable systems to remove dynamic power fluctuation.[5-7] To achieve multi-mode operation and consumption minimization for the HPSS, the literature [8] offered a power management technique based on adaptive droop control. The literature [9] looked at how to get the most out of ESS in DC FCS. DC FCS architecture and operation mode have also been extensively researched. Several DC FCS architectures were developed and explored in the literatures [12]-[13]. PV, grid, ESS, and EVs were proposed in the literatures [14]-[15]. However, the enormous cost of large-scale ESS use in FCS is mostly ignored in these research. The cost optimization of FCS was studied in the literatures [16]-[19]. In the literature [16], the appropriate size of the ESS for FCS is investigated in order to lower the cost of ESS. The ESS cost degradation model is used, as well as the levelized cost of a PV system [17]. Literature [18] proposed an ideal real-time coordinated charging and discharging technique for ESS in FCS to attain maximum economic benefits. A new energy management system for the optimum operation of power sources in FCS was reported in literature [19]. To decrease the high cost of ESS, the DC FCS architecture based on ESS-free is first used and researched in this study.

Meanwhile, in the absence of ESS, the smart charging algorithm (SCA) is proposed to fully coordinate the grid and EV source/load attributes, which can balance the power fluctuations of FCS. Constant current (CC) and constant voltage (CV) charging modes are extensively employed in battery [20]-[21] to ensure maximum charging efficiency. The literature [23] proposes comprehensive DC power balance control in conjunction with a high-power three-level DC-DC converter based on the fast charger, which may minimise fluctuating neutral-point currents and provide balanced operation for DC FCS. Literature [24] developed an integrated rapid-charging navigation method that considered both traffic information and grid status fully to address the impact of quick charging on power systems. Literature [25] provides an optimal charging rate control of EVs based on a multi-agent system framework to allocate the available charging power. The charging power of EVs is modified based on the DC bus voltage to ensure optimal DC FCS power management.

According to the preceding discussion, while removing the ESS can considerably reduce the cost of FCS, balancing the power fluctuation in FCS is difficult, and power management strategies have not been researched for this condition in prior literatures. Furthermore, maximizing the dynamic load characteristic of EVs has the added benefit of enhancing FCS power stability. Furthermore, the underutilization of GICs due to frequent power exchange is not well addressed. The following are the contributions of this study to solving these problems:

- The DC FCS based on PV system and ESS-free is developed and implemented first, which effectively reduces the ESS design and maintenance expenses as compared to standard FCS.

- When there isn't any of ESS assistance, the proposed SCA fully coordinates the grid and EV source/load properties to provide optimum PV power output, high GIC utilization rate, and optimal charging of all EVs in FCS.
- SRA redistributes the charging power of each EV to ensure grid and FCS power transfer is stable. The SRA with modified droop control for EVs can achieve proportionate charging power regulation among the EVs based on SOC feedback.
- GRA is proposed to prevent bigger power fluctuations based on DC-side adaptive droop control for GICs. When compared to a single GIC, employing numerous GICs can significantly improve converter utilization.

The following is a breakdown of the paper's structure. The structure of FCS is defined in part II, and the major components are examined. The SCA and control plan are the emphasis of Section III. In Sections IV and V, the proposed control technique is validated through a series of simulation and experimental result. Section VI concludes with a prediction and a conclusion.

2. OBJECTIVE

The main objective of this proposed system is to minimize the amount of time it takes to charge, to alleviate grid stress, to lower the price, to compensate for power fluctuations during EV rapid charging and to extend the battery's life span.

3. STRUCTURE OF FAST CHARGING STATION

3.1 Architecture of the proposed system

The solar energy is absorbed by the PV panel and then transmitted to the battery via a dc-dc converter. The charging station uses a dc/dc converter to charge the electric vehicle. The grid can also be used to provide power. In a typical FCS, ESS is employed to mitigate power fluctuations produced by EV access that is irregular and frequent, as well as the PV system's intermittency. In this study, the SCA, which is made up of SRA and GRA, tries to achieve ESS substitution in FCS by coordinating the power distribution of EVs and GICs. The DC bus voltage is a good representation of the FCS power fluctuation range. Due to the unique temporal and dynamic load characteristics of EVs, frequent power fluctuations will result in reduced GIC use. Because the charging period of EVs is at the hour level, this work uses SRA to control the charging power of EVs in order to prevent tiny power oscillations in FCS.

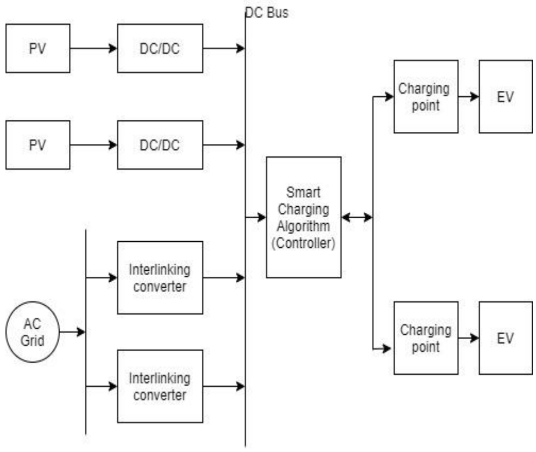

Fig -1: Block diagram of proposed system

The proportional dynamic power regulation among EVs can be achieved using the SRA for EVs based on modified droop charging with SOC feedback. If the power fluctuation is large, continuing to employ SRA to minimize the fluctuation will slow down EV charging or shorten battery life, both of which are unacceptable to users. GRA is used to ensure that EVs retain appropriate charging power and increase the utilization rate of GICs in the event of higher power fluctuations.

3.2 Solar panel

In FCS, the PV system is the most important part of the HPSS. The DC bus is connected to a PV system made up of numerous sets of parallel arrays. PV systems will be prioritized for charging EVs in the proposed FCS, decreasing utility grid stress, especially during peak hours. The boost converter is selected for usage in the PV system in order to achieve maximum power point tracking (MPPT). The PV system's intermittency, on the other hand, needs to be handled.

3.3 Grid

Grids are usually invariably synchronous, which means that all distribution zones use synchronized three-phase alternating current (AC) frequencies (so that voltage swings occur at almost the same time). In FCS, the AC module, which consists of a series of parallel GICs, is flexible. The GICs will be engaged if the EVs are unable to balance the power fluctuation to the point where the DC bus voltage exceeds the defined threshold range. GICs can absorb large power fluctuations, ensuring that EVs receive the proper charging power. Using numerous GICs can help you get the most out of your converter.

3.4 Converter

A converter is an electrical circuit that accepts a DC input and provides a DC output of a different voltage, which is commonly accomplished using high frequency switching and inductive and capacitive filter elements. A converter can perform one or more functions while producing an output that is different from the input. The dc-dc converter, which is both a boost converter and a buck converter, is used in this

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suggested system. The dc-dc converter, which is both a boost converter and a buck converter, is used in this suggested system. The boost converter is selected for usage in the PV system in order to achieve maximum power point tracking (MPPT). Each boost converter is assessed based on its capacity to operate efficiently, as well as its size and implementation cost.

4. SMART CHARGING ALGORITHM

The ESS is utilized to decrease power fluctuations produced by EV access that is irregular and frequent, as well as the PV system's intermittency. In this study, the SCA, which is made up of SRA and GRA, tries to achieve ESS substitution in FCS by coordinating the power distribution of EVs and GICs. The SCA flow chart is given in Fig. 2. The DC bus voltage is a good representation of the FCS power fluctuation range. Due to the unique temporal and dynamic load characteristics of EVs, frequent power fluctuations will result in reduced GIC use. Because EV charging times are measured in hours, this study uses a Self Regulated Algorithm to control EV charging power and prevent tiny power oscillations in the FCS. The flow chart of smart charging algorithm was referred in the literature [10].

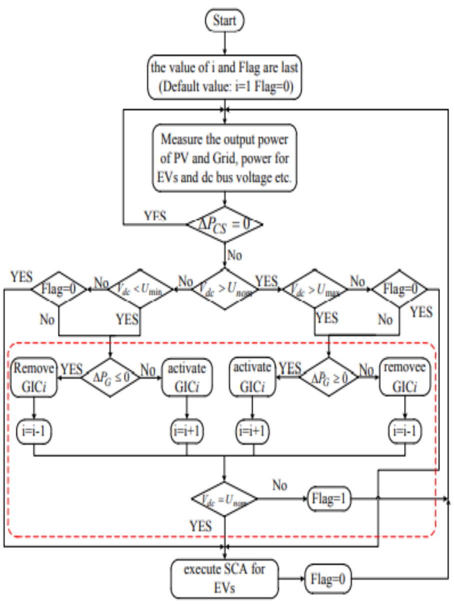

Fig -2: Flow chart of SCA

The power exchange between FCS and the electrical grid is constant during the SRA regulating process. SRA will begin power regulation among the EVs if the voltage shift induced by the power fluctuation is not greater than the voltage threshold range. A modified droop control based on the SOC value is presented to accomplish FCS power balancing via SRA of numerous EVs. Then, in the CC and CV stages, a full study of the droop features will be presented. GICs must be involved in moderating big power fluctuations in FCS to keep EVs at a proper charging power. GRA based on multiple GICs can effectively enhance the usage rate, given the poor utilization rate of single GICs.

The droop coefficient must be changed adaptively based on the working states of GICs and the DC bus voltage to ensure HPSS stability. GIC maintains the initial droop coefficient and the DC bus voltage is proportionate to output power even when it does not achieve its maximum output power. When the GIC achieves its maximum output capacity and the next GIC is engaged, the droop coefficient of the GIC varies with the DC bus voltage. The droop coefficient can be dynamically adjusted to ensure that the output voltage of each GIC matches the DC bus voltage.

5. EXPERIMENTAL RESULT

5.1 Simulation

The SCA, which is made up of SRA and GRA, intends to achieve ESS substitution in FCS by coordinating the power distribution of EVs and GICs. The DC bus voltage is a good representation of the FCS power fluctuation range. Due to the unique temporal and dynamic load characteristics of EVs, frequent power fluctuations will result in reduced GIC use. Because EV charging times are measured in hours, this study uses a Self Regulated Algorithm to control EV charging power and prevent tiny power oscillations in the FCS. The proportional dynamic power regulation among EVs can be achieved using the SRA for EVs based on modified droop charging with SOC feedback. If the power fluctuation is considerable, continuing to utilize SRA to minimize the fluctuation will slow down EV charging (low charging power) or shorten battery life (high charging power), both of which are unsatisfactory to users.

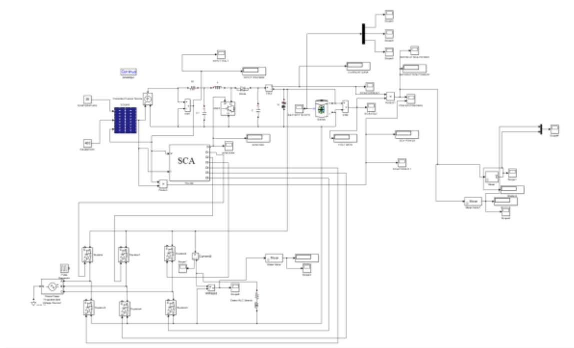

Fig -3: Simulation of the proposed system

GRA is used to ensure that EVs retain appropriate charging power and increase the utilization rate of GICs in the event of higher power fluctuations. The power exchange between FCS and the electrical grid is constant during the SRA regulating process. SRA will begin power regulation among the EVs if the voltage shift induced by the power fluctuation is not greater than the voltage threshold range. A modified droop control based on the SOC value is presented to accomplish FCS power balancing via SRA of numerous EVs. Then, in the CC and CV stages, a full study of the droop features will be presented. GICs must be involved in moderating big power fluctuations in FCS to keep EVs at a proper charging power.

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5.2 Result

The simulation output and analysis of solar panel, converter, battery, inverter, grid and charging time with SCA were shown in following figures. The output of solar panel after using dc-dc boost converter is shown in Fig. 4.

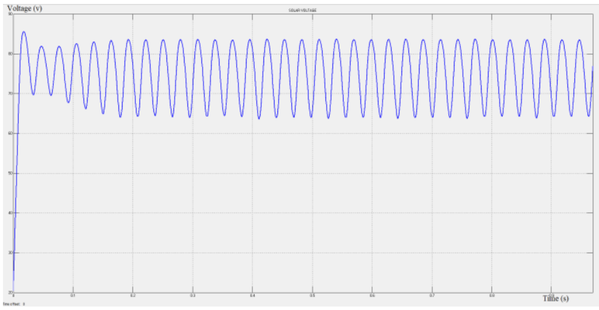

Fig -4: Solar Voltage

The power taken from the grid to charge the battery of electric vehicle by using smart charging algorithm is shown in the Fig. 5. The power is drawn from the grid only when there is high power fluctuation is observed.

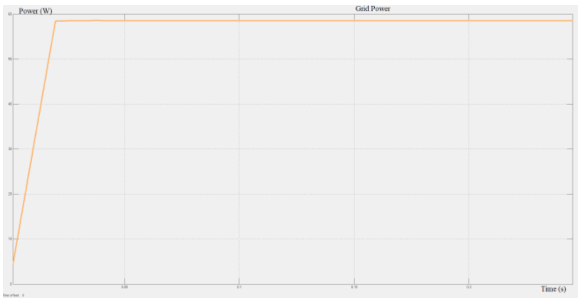

Fig -5: Grid Voltage

The gate pulse shown in the Fig 6 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.

Fig -6: 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 Fig. 7.

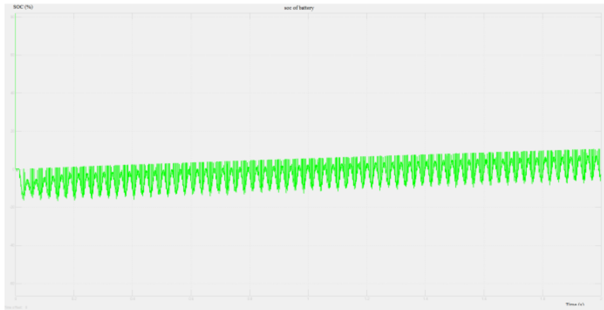

Fig -7: SoC of Battery

The main objective of using this method is 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 SCA and without SCA is shown in the Fig.7 proves that the charging time electric vehicle is reduced by 200sec while using SCA.

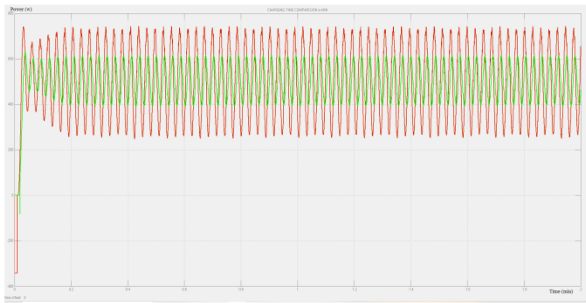

Fig -8: Time Comparison of Charging EV

6. CONCLUSION

Reduced ESS costs and improved GIC usage are critical in DC FCS based on HPSS. For DC FCS, a SCA based on ESS-free is proposed. Simulation is used to demonstrate the usefulness of the suggested approach. In the absence of ESS, SCA can fully deploy the power transfer of GICs and EVs in FCS to balance power fluctuations caused by EV irregular access and PV system intermittency, ensuring FCS power balance. The suggested SRA, which is a dynamic droop regulation of EV charging power based on SOC data, can effectively use the dynamic load characteristics of EVs and improve FCS power supply. GRA with the adaptive droop control approach can obtain a higher usage of several GICs than a single GIC. The efficiency of SCA is measured by the amount of time it takes to charge the battery of an electric vehicle.

7. FUTURE SCOPE

In a future study, the load (motor) will be charged by the battery, which will transmit feedback to the SCA for battery life protection, and the Vehicle to Grid mode (V2G) will be studied to improve grid power support. This strategy is proposed to keep the electrical grid's voltage stable.

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