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DC Fast Charging Station for Electric Vehicle

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ABSTRACT: The developments in the field of electric vehicles (EVs) has been propelled by the need for reduction of carbon emission due to their advantages over the vehicles with internal combustion engines.Typically, they must be recharged by connecting to the power grid at home or in public areas. Usually, the charging systems for electric vehicles consist of an AC-DC converter used to rectify the AC voltage to a DC voltage, followed by a DC-DC converter used to adapt the rectified voltage required by the battery and to control the batteries charging process. Additionally, the charging systems can communicate with the power grid using power line communication devices to adjust the charging based on power grid conditions. DC fast charging stations uses an external charger (off-board) to supply high voltage up to $500V_{DC}$ directly to the vehicles battery. It converts the mains voltage to a DC voltage enabling to deliver high current (up to 400A) and is capable to charge the electric vehicle in about 20 to 30 minutes, while a Level I or Level II chargers can charge the vehicle in 4 to 8 hours. The DC fast charging station greatly reduces the charging time and hence promoting EHVs as an efficient replacement for conventional IC engines.

KEYWORDS: Vienna Rectifier, Interleaved Buck Converter, Synchronous Switching.

I.INTRODUCTION

Electric vehicles are an essential strategy in the immediate term to reduce local emissions and help improve local air quality. Due to the increased outflow of greenhouse gases and the significant contribution of IC engines to it, the need for an alternative method to power a vehicle is requisite. The introduction of electric vehicles has helped to mitigate the negative impact on the environment due to the working of combustion engines. As the demand for EVs increases, fast charging the EV batteries gains more attention. A remedy for this major issue was to introduce a fast charger that can charge the Li-ion cell within a short period of time. The main challenge included was that the converters used for fast charging was bulky and could not be installed within the vehicle. Thus, a DC fast charging station was introduced which would convert the AC to DC, within the charging station and bypass the DC current directly into the battery, thus eliminating the converting process within the EV.

Types of chargers: Level I, Level II and Level III. The level I charger is used for small batteries which can be charged in about 8 to 10 hours depending on the energy capacity of the battery. The charger can be installed in homes with a supply of 230V. This station passes on the current onto the charger (on board charger) present inside the EV. The level II charging station uses a three-phase supply (240V or 480V) to charge the EV. The working of a level II charging station is same as that of level I charging station but takes less time to charge. The level III charging station (DC fast charging station) converts the three-phase supply into DC within the charging station and is fed directly into the EV, which is used directly to charge the Li-ion battery. The DC fast charging station converts the mains voltage to a boosted voltage of about 400V and can deliver a maximum current of 125A which charges the vehicle within 20-30 minutes.

II.DESIGN OF COMPONENTS

A charging system should be such that, it charges quickly, detect state of charge of the vehicle battery and moreover should be adaptable to various battery types and vehicle models to make the charging process more efficient. The level III chargers, also known as the DC fast chargers is the most recent available product in this field. These fast charging stations uses an external charger (off-board) to supply high voltage up to $500V_{DC}$ at up to 400A directly to the vehicle's battery. These DC fast charging stations differ from AC charging stations due to the existence of the power factor correction (PFC) circuit and DC-DC converter. A DC fast charging station has an integrated AC-DC power stage and DC-DC power stage. Each power stage comprises of power switches, gate drivers, current and voltage sensors and controllers.

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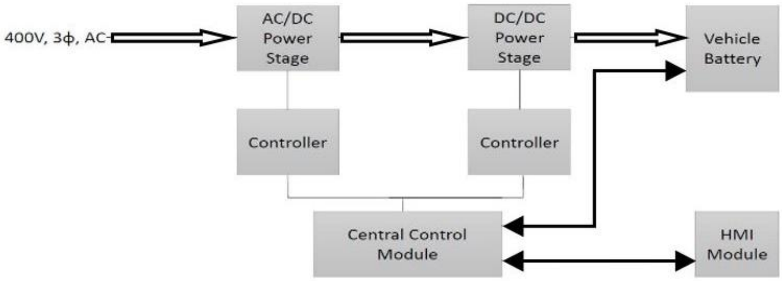

Fig.1. Block diagram of a DC fast charging station.

III.AC-DC POWER STAGE

The AC-DC power stage is realised by Vienna topology. The single phase Vienna rectifier accommodates one boost inductor, two fast rectifier diodes, and two bidirectional semiconductor switches with DC split capacitors at the output side. The DC split capacitors are used to reduce the voltage stress across the semiconductor switches. The power factor, total harmonic distortion, capacitor voltage, and output voltage are controlled by controlling the power semiconductor switches. The figure 3.3 shows the structure of the Vienna configuration. The switch diagram of the Vienna model consists of six fast rectifier diodes and one semiconductor switch has been explained in the below MATLAB simulation model.

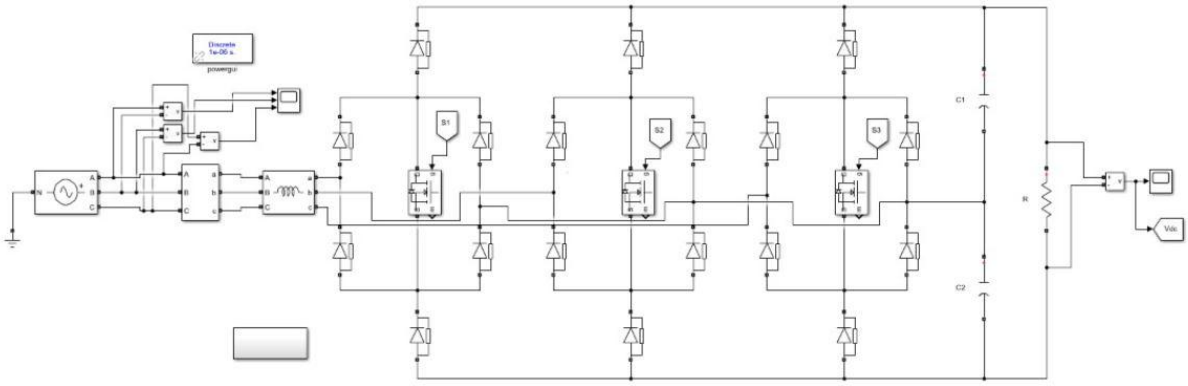

Fig.2. MATLAB simulation of Vienna rectifier.

The Vienna rectifier power topology is used in high-power, three-phase power factor correction applications. The Vienna rectifier is popular due to its operation in continuous conduction mode (CCM), inherent multilevel switching (three level), and reduced voltage stress on the power devices.The simulation results of a Vienna rectifier is given in the following figures.

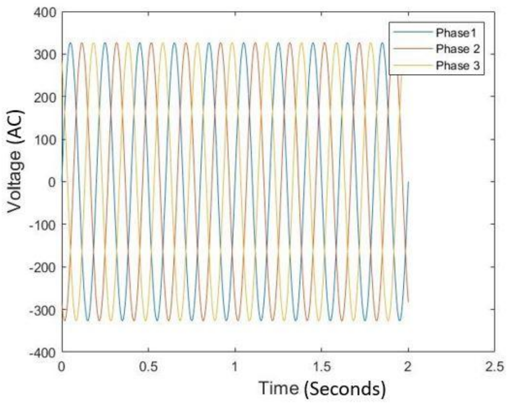

Fig.3. Input waveform

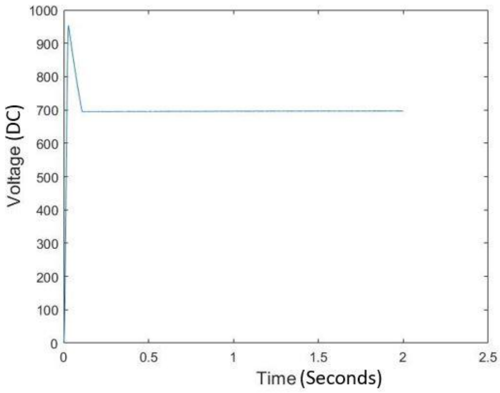

Fig.4. Output waveform

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IV.DC-DC POWER STAGE

There are different topologies for high-power DC-DC conversion in electric vehicles. It converts the incoming DC link voltage to a lower DC voltage to charge the battery of an electric vehicle. The second power stage for the DC fast charging station is based on the synchronous interleaved Buck topology.In the MATLAB simulation for the interleaved buck converter a programmable voltage source is given to provide a three phase supply of about 440V. It is then rectified using a universal bridge which leads to a DC bus with a series RC branch connected across the bus. Then again, a buck converter is present which steps down the DC supply to a lower level. In the buck topology instead of the diode a MOSFET is used to reduce the losses due to diode and hence reduces the power losses. Since a multiphase buck converter is used, these multiple drives drive FETs grouped into different phases, reducing the effective RDS (on). This also helps in spreading out of the heat among the MOSFETs. A logical operator is given for performing the switching operation.

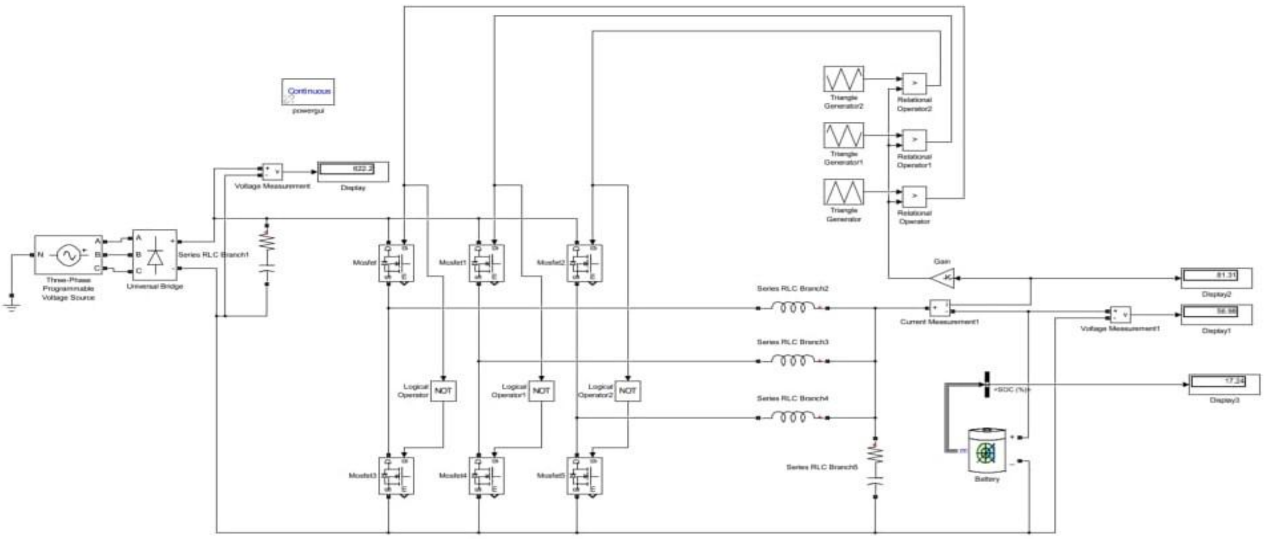

Fig.5. MATLAB Simulation of Interleaved buck converter.

The input given to the MOSFETs are square waves and is close looped by giving output current as a feedback through the gain block to the relational operator. Ultimately the batteries act as the sink and the output is then verified as in the below given results.

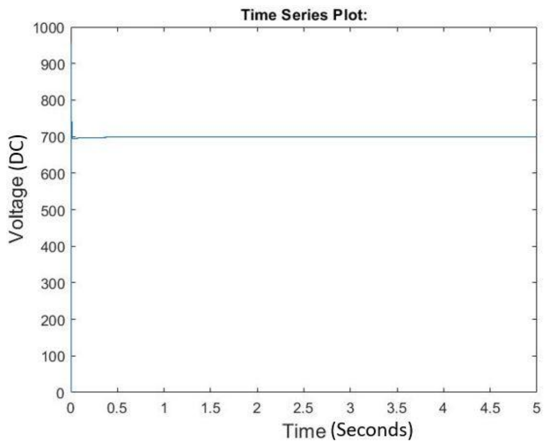

Fig.6. Input voltage waveform

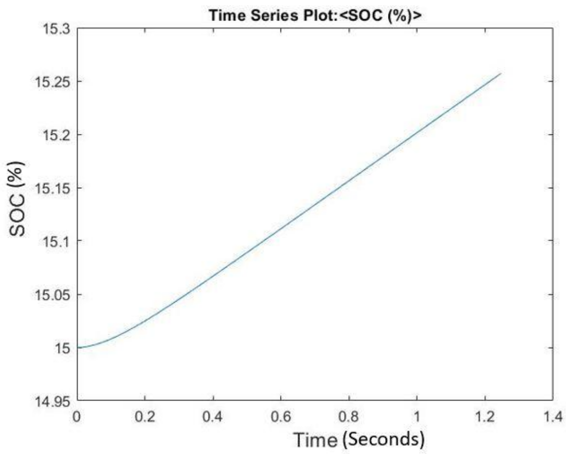

Fig.7. State of charge of battery

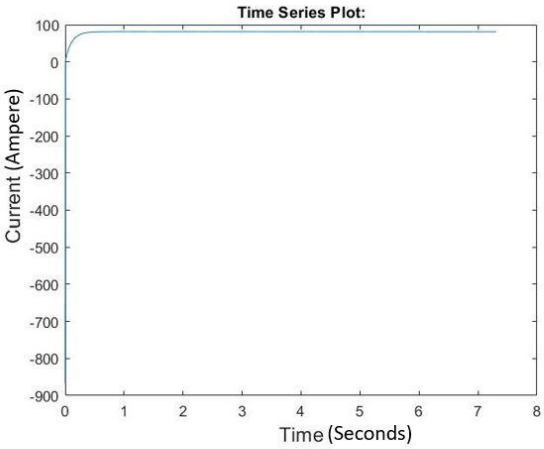

Fig.8. Output current waveform

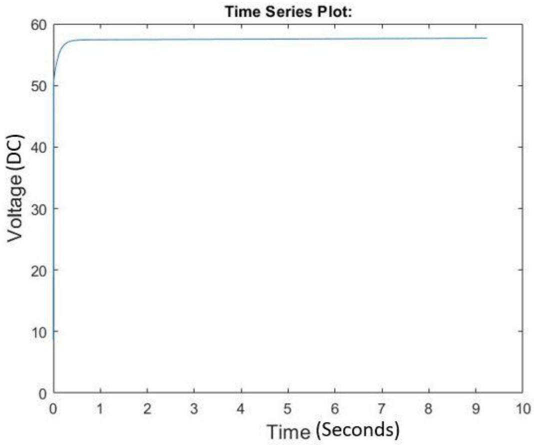

Fig.9. Output voltage waveform

V. CONCLUSION

As the number of electric vehicles (EVs) increase, there is a growing need to create more energy-efficient charging infrastructure systems around the world that can charge vehicles faster than ever before. This is where Level III chargers comes into picture, which typically charge batteries to 80 percentage State of Charge (SOC) in under 30 minutes. To achieve such high power levels, modular converters which can be stacked are used. The ultimate choice of a power topology boils down to the intended use-case of that specific EV Charger namely, the targeted power levels, efficiency and power density targets to name a few. The simplified design of a DC fast charging station is explained here by the means of MATLAB simulation model and their resulting graphs. This model can be used for further prototyping and validation by including more features into the proposed design.

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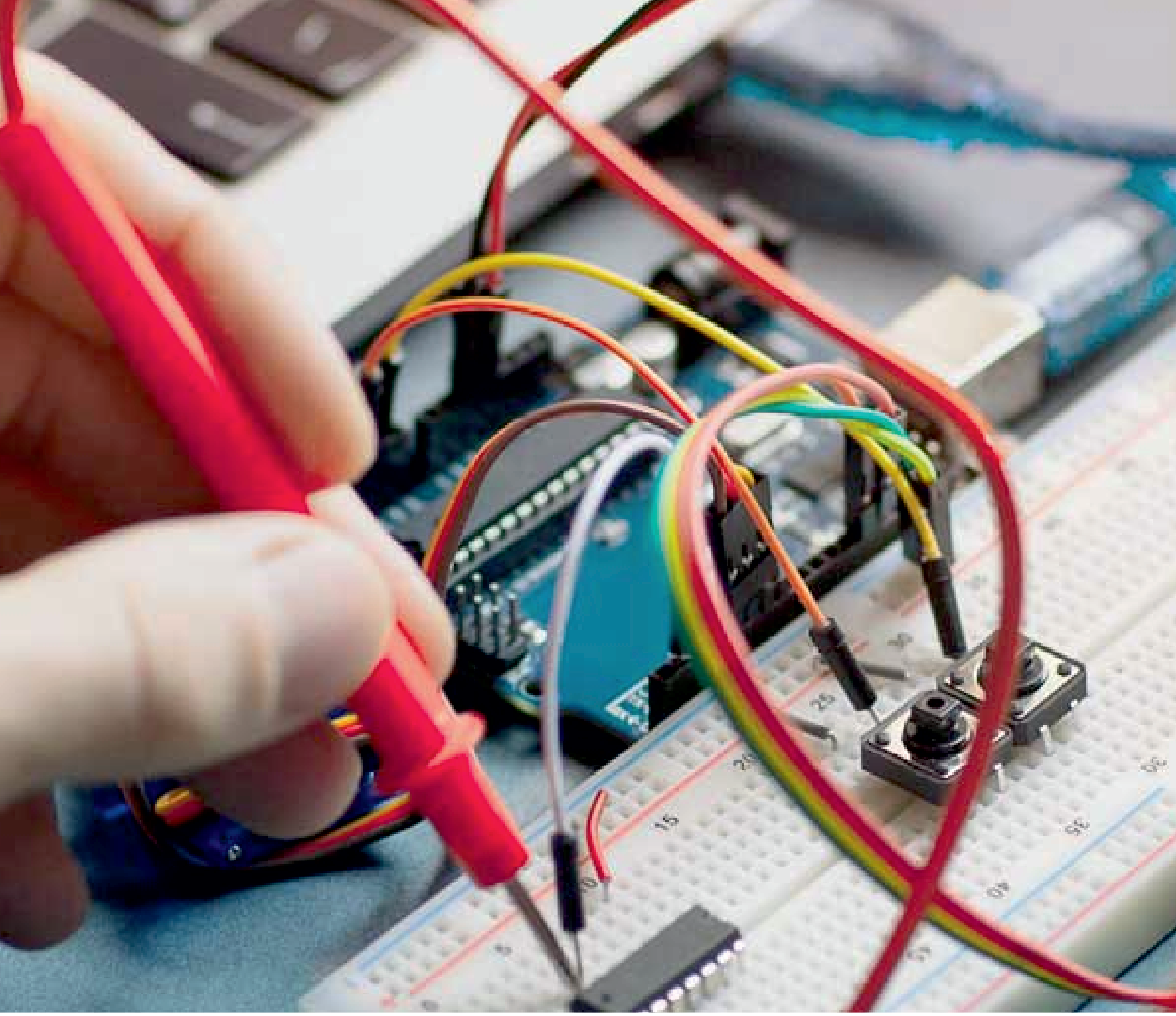

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