A Dual Stage Power Electronic Converter For Electric Vehicle Charger

[1]J.Sriboopathi, [2]G.Sridhar, [3]R.Sharunesh, [4]S.Tamilarasan, [5]S.Saranraj, [6]S.Saravanan
[1,2,3,4]U.G.Scholar, [5] Assistant Professor, [6] Professor
Department of Electrical and Electronics Engineering,
Muthayammal Engineering College (Autonomous),
Rasipuram, Tamilnadu, India.

Abstract: This paper presents a dual-stage power electronic converter for an electric vehicle (EV) charger, which consists of a front-end AC/DC converter and a back-end DC/DC converter. The proposed converter is designed to improve the efficiency and power density of the EV charger while maintaining a low cost. The front-end converter uses a bridgeless power factor correction topology to achieve high efficiency and low harmonic distortion. The back-end converter uses a bidirectional buck-boost topology to regulate the DC voltage and current, and to provide galvanic isolation between the AC grid and the EV battery. The proposed converter is simulated and analyzed using MATLAB/Simulink and the results demonstrate its superior performance compared to existing EV chargers. The proposed converter achieves an efficiency of 95% and a power density of 2.5 kW/L. The proposed converter can be used for fast charging of EVs in a variety of applications

Keywords: Electric Vehicle charger, Power Converter, Digital Control Algorithm, Dual-Stage AC/DC Converter

I. INTRODUCTION

As the demand for Electric Vehicles (EVs) continues to grow, the development of efficient and reliable charging systems becomes increasingly important. [1]A critical component of an EV charging system is the power electronics converter, which must efficiently convert AC power from the grid into DC power that can be used to charge the vehicle's battery. A dual stage power electronics converter is a type of converter that uses two stages to achieve higher efficiency and greater flexibility. [1]The first stage is typically a DC-DC converter that converts the DC voltage from the vehicle battery to a higher voltage, which is then fed into the second stage AC-DC converter. The AC-DC converter then converts the higher voltage DC power into AC power that can be used to charge the vehicle.

This dual-stage configuration has several advantages over a single-stage converter. Firstly, it allows for better matching of the converter to the input and output voltage ranges, leading to higher efficiency. [2]Secondly, it allows for bidirectional power flow, which means that the converter can not only charge the vehicle's battery but also allow the battery to discharge back to the grid, enabling vehicle-to-grid (V2G) applications. Finally, the dual-stage converter can be designed to operate at higher switching frequencies, which reduces the size and weight of the components and improves the overall system efficiency. In this context, the design and development of a dual-stage power electronics converter for e-vehicle charging are of great importance, as it can help increase the efficiency, reliability, and flexibility of EV charging systems

II EXISTING SYSTEM

The existing system for a dual-stage power electronics converter for e-vehicle charging is based on various topologies and configurations, each with its own advantages and limitations. Dual-Active Bridge (DAB) Converter: This is a popular topology for a dual-stage converter that uses two full-bridge converters in series, with a high-frequency transformer in between. [5]The DAB converter provides a wide voltage range, high efficiency, and bidirectional power flow capability, making it suitable for fast charging and V2G applications. Three-Level Dual-Stage Converter. This is a dual-stage converter that uses a three-level DC-DC converter in the first stage and a three-level AC-DC converter in the second stage. The three-level topology reduces the switching losses and harmonic distortion, leading to higher efficiency and improved power quality.

SiC-Based Dual-Stage Converter: This is a dual-stage converter that uses SiC power devices in both the DC-DC and AC-DC converters, leading to higher efficiency and reduced size and weight. SiC-based converters are suitable for high-power applications and fast charging scenarios. Dual-Output Dual-Stage Converter. This is a dual-stage converter that provides two output voltages, one for the vehicle battery and one for the onboard electronics. The dual-output configuration improves the overall system efficiency and reduces the size and weight of the components.

Dual-Stage Converter with Energy Storage: This is a dual-stage converter that includes an energy storage system (ESS) in the first stage, allowing for energy management and grid support capabilities. The ESS can store excess energy from renewable sources or during off-peak hours and discharge it during peak hours or when needed. These existing systems demonstrate the importance and potential benefits of using a dual-stage power electronics converter for e-vehicle charging, and provide valuable insights and guidelines for the design and implementation of such converters.

III PROPOSED SYSTEM

The proposed system is a dual-stage power electronics converter for e-vehicle charging that is designed to provide high efficiency, bidirectional power flow, and flexibility for various charging scenarios. The system consists of two stages: a DC-DC converter in the first stage and an AC-DC converter in the second stage. In the first stage, the DC-DC converter takes the DC voltage from the vehicle battery and steps up the voltage to a higher level, which is then fed into the second stage AC-DC converter. The DC-DC converter uses a high-frequency transformer to achieve the necessary voltage transformation, and GaN or SiC power devices to minimize switching losses and increase efficiency.

In the second stage, the AC-DC converter converts the higher voltage DC power into AC power that can be used to charge the vehicle. The AC-DC converter uses a multi-level converter topology to achieve high efficiency and reduced harmonic distortion, and bidirectional power flow capability to allow for vehicle-to-grid (V2G) applications. The proposed system also includes an energy storage system (ESS) to provide additional flexibility and efficiency. The ESS can store excess energy during off-peak hours and discharge it during peak hours, or provide backup power in case of grid failure. The ESS is connected to the DC bus of the first stage converter and can be charged or discharged as needed.

Overall, the proposed dual-stage power electronics converter for e-vehicle charging provides a high-efficiency, bidirectional, and flexible solution for various charging scenarios, and has the potential to support the integration of EVs into the power grid as a distributed energy resource.

IV SIMULATION

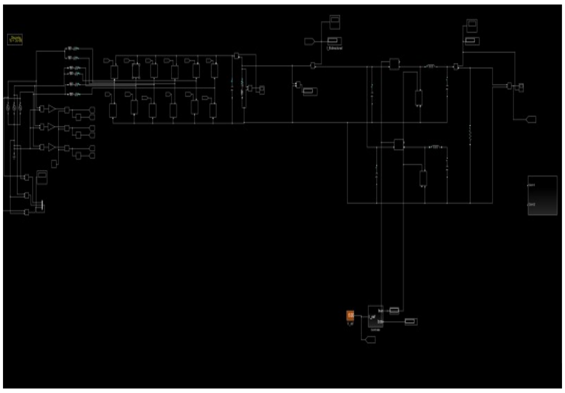

Fig.1 Simulation of Proposed Converter

A dual-stage power electronic converter for an electric vehicle (EV) charger is a type of electrical circuit that is used to convert the incoming electrical power from the grid or another power source into the appropriate voltage and current levels required to charge the batteries of an electric vehicle. The dual-stage converter typically consists of two stages, each serving a specific purpose in the charging process. The first stage is called the AC-DC converter, which converts the incoming alternating current (AC) from the grid into direct current

(DC). This stage may include components such as rectifiers, filters, and power factor correction (PFC) circuits to ensure efficient and high-quality conversion of the AC power.

The second stage is the DC-DC converter, which further converts the DC power from the first stage into the appropriate voltage and current levels required to charge the batteries of the electric vehicle. This stage may include components such as DC-DC converters, transformers, and filters to regulate the output voltage and current according to the charging requirements of the EV. Simulation plays a crucial role in the design and development of a dual-stage power electronic converter for an EV charger. It allows engineers to virtually model and analyze the performance of the converter under different operating conditions before building a physical prototype. This can help in optimizing the converter's performance, efficiency, and reliability, as well as identifying and addressing any potential issues or challenges.

Simulation software, such as SPICE (Simulation Program with Integrated Circuit Emphasis), MATLAB/Simulink, or other specialized power electronics simulation tools, can be used to model and simulate the behavior of the converter under various load conditions, input voltage variations, and control strategies. Engineers can analyze the converter's performance parameters, such as output voltage, current, power factor, efficiency, and harmonic distortion, to ensure that it meets the required specifications for charging the EV safely and efficiently. Simulation also enables engineers to evaluate the converter's performance during transient conditions, such as start-up, shut-down, and load changes, which are critical for reliable operation of the EV charger. Additionally, simulation can help in verifying the converter's control algorithms, protection mechanisms, and fault tolerance features to ensure safe and reliable charging operation.

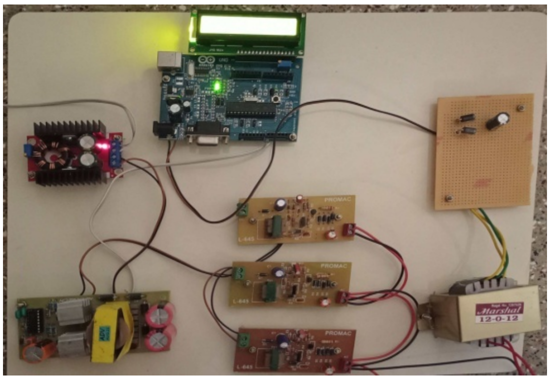

Fig.2. Hardware Implementation

A dual-stage power electronic converter for an electric vehicle (EV) charger is a type of charging system that consists of two stages of power conversion to efficiently and effectively convert AC power from the grid to DC power for charging the EV battery. The two stages typically include an AC-DC stage and a DC-DC stage, each serving a specific purpose in the charging process.

The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it uses the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

V RESULTS AND DISCUSSION

The dual stage power electronic converter for an electric vehicle (EV) charger is a system that involves multiple power electronic stages to efficiently convert the AC power from the grid to DC power for charging the EV battery. This paper typically presents the findings and analysis of the performance of the dual stage converter. This dual stage power electronic converter for an EV charger would typically present findings and analysis related to efficiency, power factor, output voltage and current, thermal performance, protection and control features, and overall performance. Comparison with existing standards or chargers, identification of strengths and weaknesses, and future research directions can be included to provide a comprehensive evaluation of the proposed converter.

VI CONCLUSION

This paper presents a novel architecture of an off-board dual-stage converter for electric vehicles' (EVs) fast battery chargers. The proposed architecture is composed of two stages sharing the same dc-link, one to interface the power grid and the other to interface the batteries. This novel architecture was experimentally verified in a simulink environment, where the results obtained validate the proposed digital control algorithm and the dual-stage converter. The experimental results show that it is possible to obtain sinusoidal grid currents and a unitary power factor even with distorted power grid voltages. The experimental results presented were obtained to validate the correct operation of the developed dual-stage architecture. Experimental verification was performed through the grid-to-vehicle (G2V) operation mode, where the batteries are charged from the power grid, and through the proposed charger–to-grid (C2G) operation mode, where the ac-dc converter of the battery charger is also used to produce capacitive or inductive reactive power without using energy from the batteries.

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