Charging Systems of Electric Vehicle: A Review

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Abstract:

The availability fossil fuel resources are very low, high demand for green transportation are gradually increasing, thus there is high demand for the use of Electric Vehicles in the world. Electric Vehicles are playing an important role in greenhouse emission. This paper focuses on different topologies for an Electric vehicle. The topologies and charging structure which comprises AC-DC converter, buck converter, and high frequency transformer are discussed. In addition, this paper summarizes charging systems of EV and comparison of charging levels for electric vehicle and trend for the future development of electric vehicles.

Keywords: Green transportation; Electric Vehicles; fast charging systems; AC-DC converter; DC-DC converter; charging structure

1. Introduction

In early years dc to dc converters are used to change one voltage level to another voltage level. Different types of DC-DC converters are available to step up or step down the voltage level. Basically buck, boost, buck-boost and cuk and full bridge converters are used to charge the batteries of electric vehicle **[1].** The converters are non-isolated and isolated type. Non-isolated DC-DC converters are simple in construction with no isolation between input and output. In isolated DC-DC converters isolation is provided by transformer. The buck converter is used to step down the voltage. Buck converter converts output voltage lower than the input voltage by using (SMPS) circuits. The input given to buck converter rectified to DC by rectifier **[2].** Electric vehicles have less fuel cost, better fuel economy as compared to conventional vehicles. Infrastructure with fast charging is necessary for public **[3].** In public area level 2 or 3 charger are installed in parking lots, shopping centers, hotels, restaurants, etc. Battery charger must be efficient and reliable with high power density, low cost and low volume. Its operation depends on components, control and switching strategies. Battery chargers plays important role in the performance of Electric vehicle **[4].** Charging time and battery life affects the characteristics of the battery charger. In public area level 2 or 3 charger are installed in parking lots, shopping centers, hotels, restaurants, etc.

Charging of electric vehicle can be done in off- board and on- board mode **[5]**.The on board chargers are mounted on the electric vehicle Fig.1 a and off-board chargers are outside the electric vehicle Fig.1 b. The power flow in this mode is unidirectional or bidirectional .In unidirectional mode power flows only in one direction in a circuit .in bidirectional mode power given to grid in feedback to the circuit.

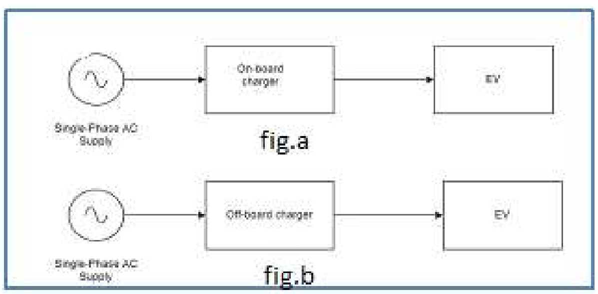

Fig. 1 a) On board charger b) Off-board charger

On board chargers, cost, volume and weight are high as they are mounted on the Electric vehicle **[6]**, **[7]**. The power flow in on-board charger is unidirectional power flow. They are usually used with level 1 and level 2 as off-board charger is outside the Electric vehicle. The power flow in off-board charger is unidirectional or bidirectional power flow **[8]**, **[9]**, and **[10].**

2 Literature Survey

There are different topologies are available for charging the electric vehicle. Few of them described below

2.1 Converter topologies

Nor Hanisah Baharudin et al. 2017 discussed the various topologies in solar PV applications **[11]**. The buck, boost and buck-boost converter integrated with solar PV systems. The MPPT algorithms were developed to obtain maximum output power from the PV arrays. They concluded the advantages and disadvantages of DC-DC converter in terms of cost, components , efficiency and limitations. Sajib Chakraborty et al. 2019 reported on Non-isolated and isolated converter. DC-DC converters are used as electronic device with high frequency switching frequency for charging the battery of electric vehicle. The design of such converters gives higher efficiencies **[12]**. Use of High frequency switching circuit increases cost of passive components.

Shafinaz A. Lopa et al. 2016 presents design of DC-DC converter. Here for the buck, boost and buck boost converter output voltage is varied by values of inductor, capacitor, switching frequency **[13]**. These systems gives study of new skills and increase the knowledge in circuit design. Hua Bai proposed plug-in hybrid Electric vehicle topologies **[14]**. Forward converter, fly back converter, half bridge and full bridge converter is studied. For high voltage applications full bridge converter is most suitable as compared to fly back and forward converter. Full bridge converter gives small current stress, least voltage stress and highest efficiency.

2.2 Existing Charging systems

Murat Yilmaz et.al 2012 search over the current status and implementation of battery, charging power levels and infrastructure for plug-in electric vehicles and hybrids **[15]**. Theyworked on Inductive and conductive charging. They recently uses integrated charger. They reported on board and Off Board charger. Nopparat Moungkhum et al. 2013 reported on pulse width modulation rectifier using mat lab/simulink. They present result of pwm AC-DC converter circuits to control output voltage **[16].** They convert input voltage from three phase AC system to stabilized DC output voltage. Yu Zhang et al.2017 presents electric vehicle fast charging stations in public area **[17].** In order to meet rapid charging during journey they establish fast charging stations. They reported about fast charging utilization at the service station. Del Puerto-Flores et.al.2011 introduced power based controller for full bridge converter **[18].**The beneficial of full bridge converter gives frame work for the average constant output voltage. Muhammad Aziz et al. 2016 have presented an alternating current-to-direct current inverter, a direct current to direct current voltage converter, a stationary battery, and an electric vehicle charger of possible resonance phenomenon in electrical networks which concentrated on DP inverters **[19].** For the home connection, there is difference in charging rates for different seasons. For different seasons charging rate determined initially to measure the effect of electric vehicle battery temperature. The developed system can improve the charging performance of electric vehicle chargers in terms of the charging rate, while maintaining the contracted power capacity.

Luis De Sousa et.al 2011 has explained the battery charger without additional power components. They combined rotor and stator of the electric drive **[20].** The traction system solution is presented, the feasibility of this combination topology is studied and the effect of the electrical machine's windings configuration is analyzed. Chang-Yeol Oh et.al 2013 developed non-isolated on board charger with minimum size and improved efficiency **[21]**.They overviewed conventional topologies for application to the OBC. Nonisolated cascade buck-boost converter has been selected for high- power density and high efficiency. The theoretical operation of the proposed OBC has been analyzed in detail. The proposed system was verified through experiment with the implemented hardware of 3.7 kW achieving 97.6% efficiency and PF of 0.99.

Morsy Nour et al. 2020 has presented review of potential negative impacts of EVs charging on electric power systems mainly due to uncontrolled charging result presented uncontrolled EVs charging such as peak demand, voltage deviation from the acceptable limits, phase unbalance due to the single-phase chargers, harmonics distortion, overloading of the power system equipment, and increase of power losses on the system **[22].** Also they reviewed positive impacts of controlled EVs charging and discharging. Ali T. Al-Awami et al. 2015 has proposed an adaptive voltage feedback controller for an onboard EV charger that does not require any real-time communication between the EV and the utility **[23]**.This controller compares the system voltage at the point of charging with a preset reference voltage therefore EV charging is reduced as the system voltage approaches this reference. The simulation results show system voltage violations with a good performance in the presence of other voltage control devices and distributed generation units.

3. Analysis and discussion

Charging of EV can be done in three levels such as level 1, level 2, and level 3 are used for charging of battery electric vehicle. For example Uwakwe C. Chukwu et al.2014 **[24]** proposed V2G parking lot system which supports PV systems and initially formulas were developed for battery efficiency. This paper describes the mathematical models for grid gain factor. They compared three levels of charging of batteries Level 1 required more time to charge the battery as compared to the level 2, level 3, respectively.

In this paper L. Tan, B. Wu et al.2016 implements **[25]** high power three level DC-DC converter useful as bipolar-dc-bus fed EV charging station infrastructure. The benefits of this level are voltage balance control, neutral-point-clamped. These low-frequency voltage fluctuations are removed from the charging stations. S. Rivera and B. Wu et al. 2022 **[26]** proposed Non-isolated three level bidirectional DC-DC converter .The proposed converter which supports closed control strategy. In this paper, converter shows superior performance, large conversion ratio.

The following **Table. 1** shows comparison between levels based on properties like charging voltage, charging rating, charging time. In the paper authors compare power levels and infra structure and [13] paper author developed fast charging level at service stations.

Authors and Years	Charger Type	Charging voltage	Charging Rating	Levels	Charging Time
Uwakwe C. Chukwu et.al.2014	On-board	120V	1.44-1.92 kW	Level 1	5.8 miles for each hour
L. Tan et.al.2016	On-board	240V	20 kW	Level 2	60 miles for eachhour
S. Rivera et.al.2022	Off-board	480V	100 kW	Level 3	300 miles for each hour

Table.1 Comparisons between charging levels

4. Conclusion:

The batteries of electric vehicles are charged using a DC-DC converter. Infrastructure and electricity levels affect current charging systems. On board charger depends on standard ratings and limited voltage range. Off board chargers could charge the batteries of electric vehicle with desired rating and power levels. This paper discussed different topologies and charging systems and compared three levels of charging the batteries for electric vehicle. Level 1 and 2 will be used for fast charging of the electric vehicle.

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