International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 198-203 www.ijaem.net ISSN: 2395-5252

Different Fast Charging Methods for Electric Vehicle

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Date of Submission: 15-07-2020 Date of Acceptance: 31-07-2020

ABSTARCT:A network of fast charging method is of great importance for widespread adoption of electric vehicles (EV). As with petrol stations, we expect that multiple chargers will be co-located to form charging stations. This layout allows for the fast-charging method to make use of a common rectifier stage and several dc/dc stages to charge multiple EVs. We proposed a novel dc side filter for the 12-pulse rectifier and investigated the power profile for a MWfast chargingstation. In order to charge themain battery bank for EV, the safety andcharging time must be contemplated. The battery charger also requires that it is a capable ofthe high power capacity. Therefore, three phaseAC-DC boost converter is suitable for thebattery charger for EV. The battery charging algorithm is required to reduce the charging timeand preservethe battery from overcharging. In this paper, Constant Current, Constant Voltagecharging method is adapted for safely chargingbattery. However, it takes a long time for fullycharging the battery, so improved CC-CV chargingmethod is presented. It helps reducing the total charging time. It is described by comparisonof conventional CC-CV method and verifiedthrough the experimentalresults.

KEYWORDS: Fast Charging, Electric Vehicle, Charging Methods.

I. INTRODUCTION

With the introduction of electric vehicles (EV)by majorcarmanufacturers,electricallypropelledcarsare becoming more variable.Therefore,the reisaneed to designfastchargersthatcanquicklyreplenishthecharg einanEVbattery.Fast charging stations will then be composed ofmultipleindividual fast chargers. SAEJ1772standarddefinesthreelevelsofchargingasa clevel1(upto 1.9 kW), ac level 2 (up to 19.2 kW), and dc charging (upto100kW). The competing CHAdeMOstandardallowsforchargingratesupto62.5 kW.Researchersat ABBenvision, ultra fast charging as aviable option withpowerlevelsintherangeof125–300kW. Acommonalitybetweenallproposedfast-chargingst and ardsisthatthe charger will be located off-board, and that they will interface directly with the vehicle battery.Withmultipledcfastchargersco-locatedtomimicthearchitecture of a petrol station, there is the possibilityofoptimizingthefast-chargingstationarchitecture.In,researchershave roposed fast-charging station architectures withacentralizedrectificationstageandmultipledc/dc stagesthatsupplypower directly to the battery. The resulting dcdistribution system has the benefit of eliminating multiple rectifierand inverterstagesprovidingasinglepointofcommoncoup lingtothegrid allowingeasyintegrationofdc sidestorageandrenewablesandsimplifyingstation-wideenergymanagement.Inwe showedthattheaveragepowerdemandofthefast chargingstationishighlydynamicwiththeaveragedem andbeingmuchlowerthanthepeak.Therefore,weprop osedtointegrateanenergystoragesystemonthedcbusto reducethedemand charges support the recharging stationinparticipatingindemandresponse andsmoothoutthepowerdrawfrom the grid. We showed that a system with1.1-MWgrid tieand20kWhdc-sideenergystorageunitcansupporttenultrafastchargers rated at 240 kW.We also proposed to use the 12-pulse rectifier as a simple and cost effective method to obtain the common dc bus for multiple fast chargers. In,weproposedanovelmethod toprofiletherectifieroutputcurrenttobetriangular,whichresults in low ac-side harmonics. The approach is based on inserting current sources on the dc side of the rectifier to shape the current directly into a triangularform.Inthispaper,weproposeanovelcontrol methodthat,instead of shaping the current of the 12-pulse rectifier into a triangular waveform, controls the dc side LC filter resonance and quality factor to closely approximate the triangular waveform, thus reducingtheac-sideharmonics.Weachievethisbyinjectingvirtualimp edanceintotheLCfiltertoshapetheacanddcvoltages and currents. This method is fundamentally different from thegoalis controltheharmoniccontentbyadjustingthe filterimpedanceratherthanbyshapingtherectifiercurrentinto a triangular waveform. We show that the new control approach yieldsbetterresultsthanthecontrollerin,measuredbylower total harmonic distortion (THD), lower filter VA ratings, lower dc-busripple,andbetterrobustnesstoLCfilterdetuning.In addition,wedemonstrateexperimentally,thattheinsertedcurrentsourcesarecapableofdeliveringandabsorbingpower,therefore effectively integrating energy storage on the dcbus.

II. CHARGING METHODS

Following are the commonly used charging methods

1. CONSANT VOLTAGE

In a constant voltage charge, the charging voltage is maintained at the maximum voltage that should be applied to a certain type of battery while the charging current slowly decreases as the full batterychargeisapproached.Thisisaneffectivemethodwhenusinglowervoltages,astemperature usually isn't an issue, but lengthy charge times are of concern.

2. CONSTANT CURRENT

As the name implies, this charging method applies a constant current as the battery voltage builds up to its full charge value. Even if the constant current applied is within the rated current, theconstantcurrenttothebatterycaneasilycauseoverheatinganddamage,compromisingthelifeof the battery.

3. CONSTANT CURRENT – CONSTANT VOLTAGE (CC-CV)

Originally referred to as simply "Voltage Controlled Charging" , constant current-constant voltage charging is a common approach to battery charging where the charger applies a constant currentuntilthebatteryreachesapredefinedvoltagepotential,atwhichpointvoltageisheldconstantandthecurrentcontinuestodecreaseuntilafullchargeisreached.Thisisillustratedinand is the traditional method for charging batteries, yet it is limited in fast-charging applications because battery polarization becomes an issue. As may be expected, the CC-CV method has been further modified to include multiple constant current steps, thereby further improving the rate of charging of the batteries.

4. PULSE CHARGING

Pulsechargingsendspulsesofcurrenttothebatteryinafashionthatoptimizesthechargingtime while considering polarization, battery heating, SoC, and variable battery impedance . The rest time of each pulse period allows the ions to diffuse through the electrode materials, increasing the efficiency of the charging process.

5. NEGATIVE PULSE CHARGING

Negative Pulse Charging methods, originally developed to enhance the efficiency of chargingconvertersforleadacidbatteriesbutnowextendedtolithiumionbatteries,imposessmalldischarges to the battery during the pulse charging rest period . The negative impulse decreases stresses in the cell and helps minimize temperature rise of the cell . Since the negative pulse pulls a small amount of energy from the battery, circuit configurations that recapture that energy have been devised.Byoccasionallydepolarizingthecell,highcurrentscancontinuallybepumpedintothebattery,enablingahigherchargerateandlowerchargetime.Thismethod helpsthechemicalreactions within the battery and can significantly improve the life of the battery.

III. CHARGING SYSTEM

The charging system needs to be compatible with the EV battery system and are classified as either a slow charger or a fast charger depending on the power it handles. The slow charger usually handles 3-4 kw of power and takes approximately 6-7 hours for full battery charging. For this reason the slow charger is utilized for charging using a household gird power during the night time. However the fast charger handles approximately 50kw power and quickly charges the EV (less than one hour). Most of the EV manufacturers in view of optimum battery size for a given range are going for the battery that can take high charge current and thus necessitate fast charging facility. The fast charger can installed in public places or at petrol pumps. The chargers essentially create power quality issues in view of non-linear devices in it and will be more prominent with the usage/popularity of EVs. The power quality issues arise in terms of voltage harmonics, Current harmonics, poor power factor quality including low power factor may arise. The power factors correction technology can be considered in order to resolve power factor problems.

IV. BLOCK DIAGRAM

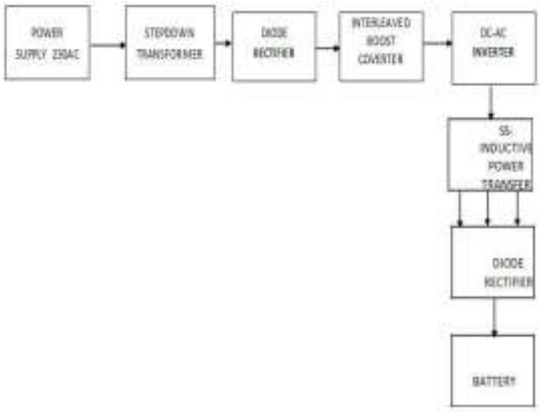

Fig.1. Block Diagram of Charger Circuit for EV

This paper involves the design and implementation of a contact less battery charger for electric vehicles, usingaseries-series(SS) inductive power transfer system. The contactless charging circuit is composed of ac-dc converter with an interleaved Power factor correction (PFC) converter, a series-series converter with an H-bridge and a secondary rectifier. The interleaved PFC converter reduces the Total harmonic distortion (THD) of the input current and controlling the primary side dc-link voltage. The H-bridge inverter is simulated with different modulation techniques and compared. The block diagram of proposed charger circuit for EV is shown in Fig.1

V. CIRCUIT DIAGRAM

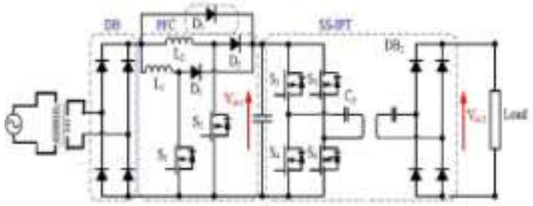

Fig.2. Circuit Diagram of Charger Circuit for EV

RECTIFIER AND INTERLEAVED BOOST CONVERTER

In general, all the AC/DC converters comprises of a transformer following the input filtering, and then passes to rectifier in order to produce rectified DC. The AC-DC converters use multi-stage conversion topologies [5]. Diode bridge rectifiers conduct current in only one direction and even silicon controlled rectifiers (SCR) and triode for alternating current (TRIAC) are also used as rectifiers. During positive half cycle of the input voltage, the upper end of the transformer secondary winding is positive with respect to the lower end. Thus during the first half cycle diodes D1 and D3 are forward biased and current flows through the load resistance. During this negative half of each input cycle, the diodes D2 and D4 are reverse biased and current is not allowed to flow as shown in Fig.3.During second half cycle of the input voltage, the lower end of the transformer secondary winding is positive with respect to the upper end. Thus diodes D2 and D4 become forward biased and current flows through arm CB, enters the load resistance.

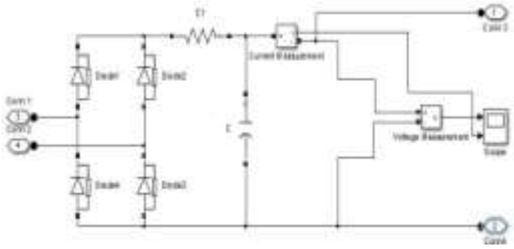

Fig.3. Rectifier at the primary side

Interleaving is to connect the N number of boost converters in parallel at same switching frequency but with 360/n phase shift. Interleaved boost converter has the benefits of low ripple content in input and output voltage, reduced peak current value and high ripple frequency [6]. This leads to high efficiency and high reliability. Since the proposed converter operates at high frequency, the size and losses of the magnetic components can be reduced. The two-phase interleaved boost converter is considered in this work where pulses to the MOSFET switches are displaced by 180 degrees. With this, the flow of current gets divided in two paths which leads to reduced conduction (I^2R) losses and increased overall efficiency compared to the conventional boost converter. The ripple frequency gets doubled because the two phases are combined at the output capacitor, which makes ripple voltage reduction much easier. Likewise, ripple requirements is reduced as the input capacitor are staggered. Thus the total harmonic distortion (THD) of the input current is reduced to meet the harmonic standards [7 &8]. The circuit diagram for interleaved boost converter is shown in Fig.4.

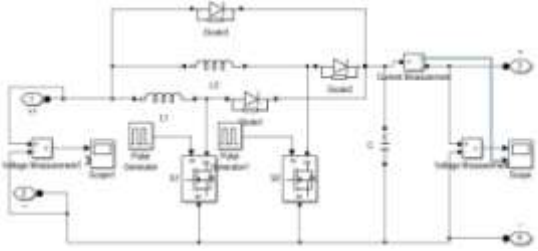

Fig.4.Simulink diagram of interleaved boost converter

PWM VOLTAGE SOURCE INVERTER AND COIL DSESIGN

Inverter plays a major role which does the conversion of fixed dc into variable ac [9]. Renewable energy sources can act as an input to the inverter or dc supply derived from an ac source can be used as input to the inverter. The single phase inverter has two arms with four semiconductor switches connected with anti parallel diode. During turn-off condition of the switches the reverse current flows through the anti parallel diode. The switches (are S_1, S_2, S_3 and S_4) are turned on alternatively so that no switch on the same leg can conduct which leads to 'shoot-through problem'. But at certain period of time called blanking time, both the switches turned off to avoid short circuiting [10]. The load is connected in between the two arms. The simulink diagram of proposed single-phase inverter is shown in Fig.5.In SS (series-series) compensation, the power transfer depends on the values of bus voltages, the operation frequency and the mutual inductance between the two inductive pads. To achieve minimum commutation losses, the frequency is maintained as constant and equal to resonant frequency. And for maximum bus voltage and maximum mutual inductance, the maximum power will be obtained [11]. The alignment of two inductive coils plays a major role. If two coils are close to each other, maximum coupling will be reached and if two coils are separated, the bus voltage will get reduced. Thus the alignment characteristic of inductive power transfer system is limited by single-phase inverter characteristics. To maintain the proper alignment of inductive coils, an iterative design process has to be framed.

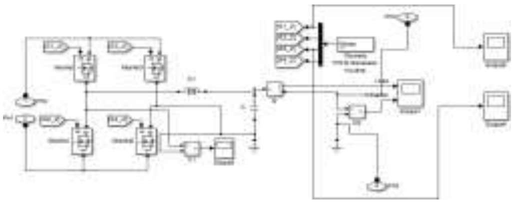

Fig.5. Single phase inverter

In the series-series compensation, the resonant frequency depends only on the self-inductance values of each inductive pad:

[illegible] $= \frac{1}{L_1 C_1} = \frac{1}{L_2 C_2}$ (1)

where L_1 and L_2 are the self-inductance values of the primary and secondary, respectively, and C_1 and C_2 are the required capacitance values for a specific resonant frequency.The main drawback of the SS compensation is the voltage gain varies with the load and the associated control difficulties. However, the transferred power depends directly on both bus voltages, as well as the mutual inductance of the coils and the angular frequency.

[illegible] $= \frac{8 V_{dc1} V_{dc2}}{\Pi^2 \omega M}$

(2)

where V_{dc1} and V_{dc2}, are the primary and secondary busvoltages respectively,is the angular frequency and M the mutual inductance between the inductivecoils.

VI. SIMULATION RESULT

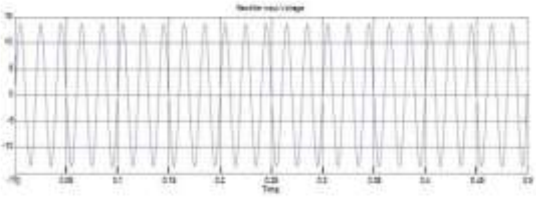

Fig.6.Input rectifier voltage

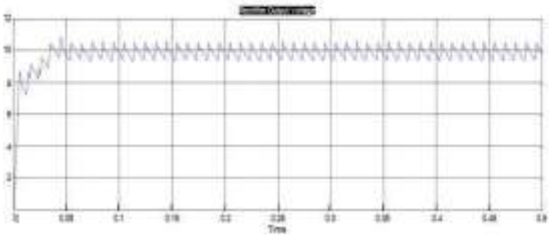

Fig.7. Rectifier output voltage

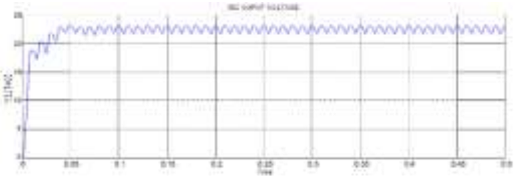

Fig.8. IBC output voltage

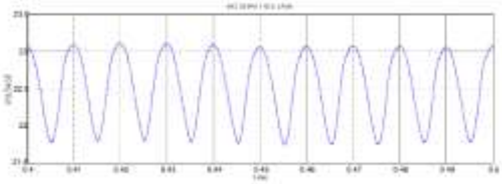

Fig.9. Output voltage ripple of IBC

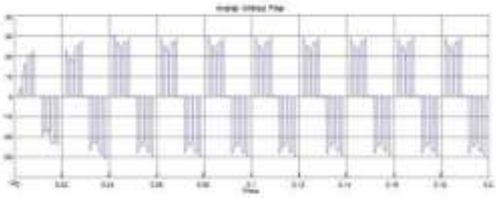

Fig.10. Single-phase inverter output without filter

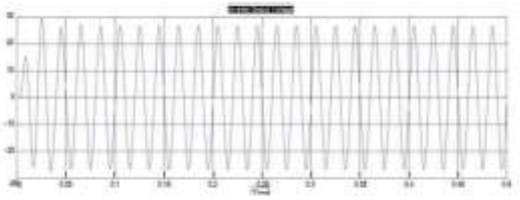

Fig.11.Single phase inverter output with filter

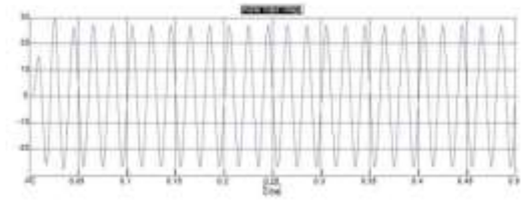

Fig.12.Inductive coil primary side voltage

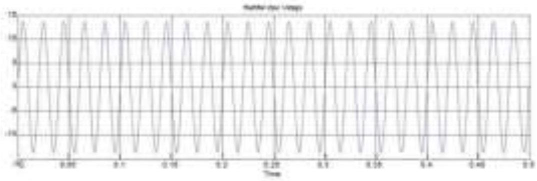

Fig.13.Inductive coil secondary side voltage

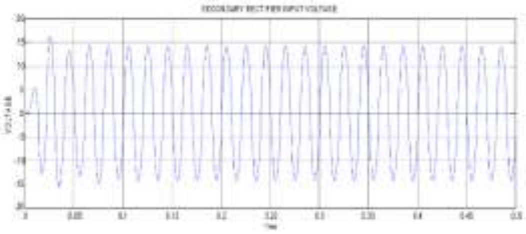

Fig.14. Input voltage of secondary sides rectifier

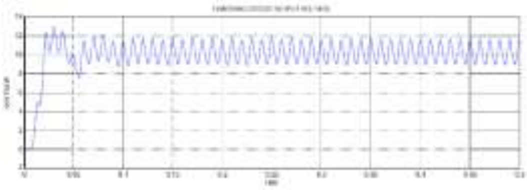

Fig.15.Output voltage of secondary side rectifier

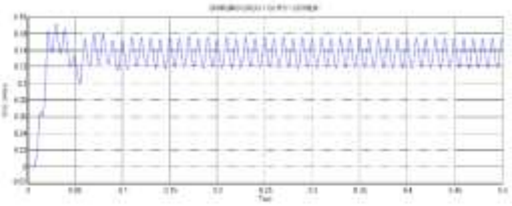

Fig.16.Output current of the charger circuit

VII. CONCLUSION

We make the case that the architecture based on the diode rectifier is a cost effective and robust approach to providing a common dc bus at 1-MW power rating. We note that the mainissuewithlow pulserectificationistheunacceptableharmonic content, and we propose a novel solution specific to the 12-pulse diode rectifier. We use virtual resistance injection to profile the rectifier output current, and thus indirectly reduce ac side harmonics. This concept is further extended to inject virtual reactance, such that the detuning of the LC filters can be compensated. Energy storage integration and dc side voltageripple compensation are additional benefits of theproposed method that have important implications for the fast charging station design.

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