Review of Different Methods and Topologies for Fast Charging of Electric Vehicles

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Abstract: **To encourage clean and green atmosphere and to decrease carbon emission, the Government of India aims for a country with 100 percent electric vehicle mobility by the year 2030. For a vast number of electric vehicles to be running on Indian roads, there is a need for fast charging stations and infrastructure. This paper presents different fast charging systems along with different power converter topologies for electric vehicles. To charge battery of electric vehicle, the safety and charging time of battery must be considered.lithium-ion battery in electric vehicles has advanced the need for new optimum charging methods to improve the speed and reliability of the charging process without weakening battery performance. Efforts have been employed to develop optimal charging strategies for commercial Li-ion batteries over the last decade. The active optimal charging strategies have great potential to meet the requirement.**

Keywords: **Fast charging, Electric vehicle, Charging methods, ZVS, DC-DC converter.**

I.INTRODUCTION

A Major concern has been generated by increasing carbon pollution in the atmosphere, leading to high emissions of CO2 from internal combustion engine vehicles (ICEVs). Because of their environmental benefits and growing oil prices, electric vehicles (EVs)[1] offer a huge potential to become desirable alternatives to ICEVs.In developing economies such as India, growth in quick charging infrastructure for electric vehicles[2] has therefore become a challenge. An operating system, a customer information system and a charging system make up the charging infrastructure. Among these, the most vital and necessary part of the charging infrastructure is the charging device. With the EV battery system, the charging system needs to be appropriate and is defined as a slow and fast charger depending on the power it handles. For full battery charging, the slow charger handles 3-4 KW of power and takes about 6-7 hours, so that the slow charger is used during the night to charge a household grid power. The fast charger, however, handles about 50 kW of power and charges the EV rapidly (less than an hour). In view of the optimum battery size for a given range, most EV manufacturers go for the battery that can take up high charge current and thus enforce fast charging facilities. In public places or at gas stations, a quick charger can be mounted. In view of the non-linear equipment in it, the chargers produce power quality problems[3] and will be more prominent with the use of EVs. In terms of voltage & current harmonics, power quality issues arise, poor power quality with a low power factor may arise. The correction of the power factor[4] can be considered to address the issue of the weak power factor. The key variables of the electric car are travelling longer distances and decreased refueling time. As a result of their higher energy capacity and longer lifetime relative to lead-acid and nickel-metal hydride batteries[6][7], lithium-ion batteries[5] have been advertised for plug-in hybrid and electric vehicles. Unlike the fuel-driven internal combustion engine, due to slow charging speed and uncertain impacts of charging strategies on battery efficiency, the battery charging mechanism is more complex[8][9]. Charging a lithium-ion battery becomes a bottleneck for the promotion of EVs[10][11].The charging speeds often trigger temperatures to rise and produce side reactions[12][13]. The trade-off between quick charging and battery health must be taken into account[14][15]. In the research field of EVs / PHEVs[16][17], the battery charging device has therefore attracted a great deal of interest. In order to improve charging performance, to maintain a safe operation of a lithium ion battery system, an effective charging control is required. In order to find out the most effective charging technique, several studies have been conducted. Depending on the internal mathematical models, the existing Li-ion battery charge can be split into three groups. The first category is a model-free approach that involves constant-current, constant voltage, constant current-constant voltage, multi-stage CCCV and pulse charging techniques[18][19][20]. These approaches can be taken into account by their predefined charging profiles with fixed current , voltage and power constraints, but ignoring battery dynamic responses. The consistent programmes are observed as heuristic, given the model-free methods. This includes the need for advanced charging methods to fulfil the criteria for quick charging and boost the impact on the state-of-health of the battery (SOH). Empirical models such as analogous circuits are used in the second type of charging strategies. Neural Network Models and Dependent Models[21]. Using past experimental data, these models forecast battery states and quantify electrical components. For the estimation of battery states, Kalman-type filters [22], recursive least squares [23], sliding mode observers [24] and moving horizon estimates [25] have been adopted using various circuit models. Frequency optimization[26], multi-objective optimization[27], fuzzy control[28], linear quadratic control[29] and predictive model control[30] have also been introduced. To enhance charging efficiency, were framed. The empirical models are fast and quick, but are incapable of representing parameters based on physics and battery ageing. Thus, after several cycles, an empirical model-oriented charging control protocol can fail to function correctly[31][32].

II. CHARGING METHODS

Commonly used charging methods for battery are

2.1.Constant Voltage

In this technique constant voltage is kept across the battery. And it draws higher current but Li-ion cells have 4.2+/-50mV as nominal set-point voltage and allowable charging current is 1C .This process of charging is chosen for Pb-acid batteries as each individual cell balance the charge between them .The lead acid cells used for cars and backup power systems. The disadvantage of this technique is battery does not charge fully and time required for charging is more than 2 hours[42]

2.2 Constant Current Charging Scheme

The battery is charged with uniformly constant current in this technique, and the voltage can be steadily built up. As the maximum charge [33] voltage is reached, the charger is turned off. This method of charging is not used if there are more cells in the battery, since certain cells are fully charged than others. This approach is not successful and contributes to the cells becoming over stressed. Higher charging current is important to add quick charging to Li-ion batteries using this process. But the movement rate of Li-ions exceeds the insertion rate of Li-ions into the graphite layer when the charging current is too high. This allows certain Li-ions to be deposited on the electrode layer instead of being inserted into the layers. This is called plating with lithium. To prevent lithium plating, ample settling time must be given for Li-ions to be inserted into vacant graphite electrode locations. Because of joule heating, higher charging currents reduce charging efficiency. This heating takes place via the internal resistance of the battery due to the flow of electric current. For these purposes, quick charging is not feasible.

2.3 Pulse charging

In this process, the charging current is applied to the battery in the form of pulses[34]. By changing the width of the pulses, the charging rate can be controlled. The pulses are followed by short rest periods during the charging phase that help the chemical actions in the battery to stabilize by equalizing the reaction through the majority of electrodes, enabling the chemical reaction to keep pace with the rate of input of electrical energy .This technique reduces undesirable chemical reactions, such as gas formation, crystal growth, at the electrode surface. A quick and efficient charging method for lithium-ion batteries is known as the pulse charge [35][36].

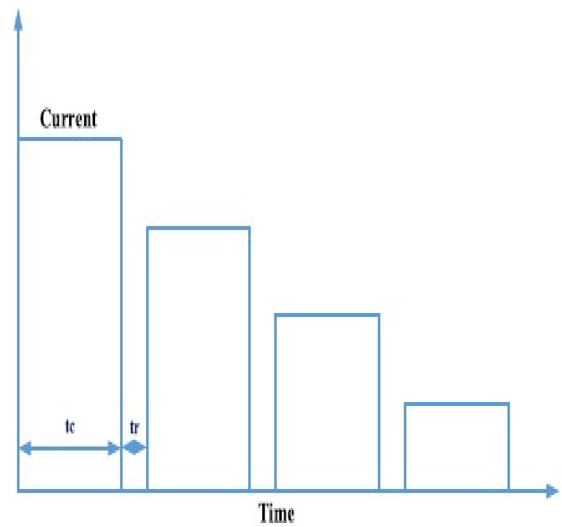

Fig 1.Nonlinearly decreasing pulse charge technique

2.4 Negative Pulse charging

For the pulse charging strategy[43], this method is used. Very short pulses of interval discharge are applied to depolarize the cell during the charging rest time. These discharge pulses eliminate gas bubbles produced during charging on the electrodes, which improves the whole process of charging. The gas bubbles' escape and diffusion is known as "burping."

2.5 Constant Current Constant Voltage charging

Constant current constant voltage charging is the method used for charging Li-ion batteries and is simple to implement, effective and has many benefits. In charging Li-ion batteries, the CC/CV charging method is used as it is simple and easy to implement[37][38]. The battery is charged with constant current in the CC / CV phase until the battery voltage reaches a pre-set maximum charging voltage, then the charging voltage is kept constant until the current is reduced to a preset minimum value [39]. The charging curve of the CC/CV is shown in Fig.2.

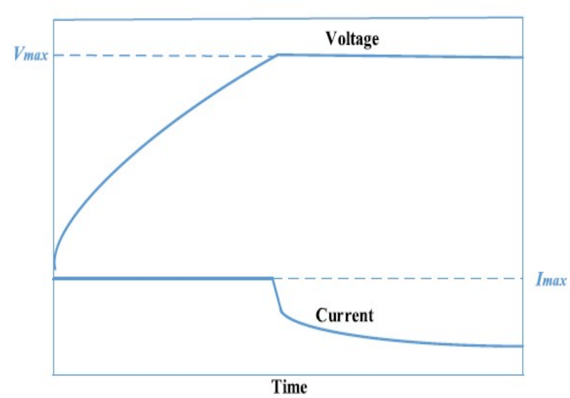

Fig 2.Constant current-Constant voltage curve.

There are four distinct periods in this CCCV process, as shown in Fig. 3

2.5.1. Pre-charge mode: In this, 10 percent of the complete charge current is charged to the deeply discharged cells (below 3V). This is significant to avoid cell overheating before the full charge current can be obtained.

2.5.2.Constant current mode: The battery is below 1 C rate in this charging mode before the battery reaches 4.2 V. If charging current rates are high, the cell voltage risesquickly and the constant current stage becomes shorter and there is no reduction in charging time.

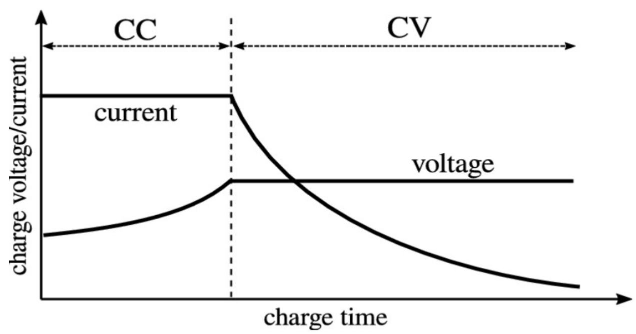

Fig 3. CCCV charging method

2.5.3. Constant voltage mode:The battery is charged at a constant voltage of 4.2V. To avoidoverheating, stress on the cells, the constant current mode is not continued until 100%SoC. It does not mean that the battery is fully charged if the battery exceeds 4.2 V, so it has to be charged more in the constant voltage mode. In this step, when charging is completed, the current drops to 0.1C.

2.5.4.Charge termination mode:Termination is carried out by the new minimum charge process. Charging current is continuously tested in the minimum current system when it reaches a value in the range of 0.02C-0.07C charging is stopped. This method of charging lithium ion batteries takes a long time, i.e. more than 2 hours to fully charge the battery.

2.6 Slow Charging

CC charging is a method that is used by adjusting the charging voltage to resist the flow of charging current to the battery. It will remaintill the voltage of battery moves to a pre-set value. A lower current level is injected to the discharge battery by this process. The CC charging method is best for nickel-metal hydrate batteries and nickel-cadmium batteries .Battery overcharging can also cause gassing and overheating problems. Due to constant over or under charging situations, significant damage to the battery pack occurs. Aappropriate control is thusessential for battery charging with regard to current and voltage profiles. In CC charging, the battery uses much higher power during the charging phase. If the higher power is not used properly, due to a higher rate of current injection under lower charging conditions, the life of the battery pack may be reduced. The constant charging voltage is applied by changing the charging current in the CV charging system. The process continues till the charging current of the battery falls to nearly zero. In the CV charging process, the problem of drawing unnecessary power can be avoided, and the possibility of overcharging the battery is avoided due to less current drawn in the charging state. To charge the battery at a constant level of power, the CP charging method is used. The taper charging method is carried out by using a constant unregulated voltage source, and the charging current decreases in an uncontrolled way due to high cell voltage due to higher charging rate. This causes considerable battery pack damage by overcharging. This method is enough for lead-acid batteries normally used for back-up conditions for backup power. The trickle current charging technique is used to charge the EV battery with a lower current value to counteract the discharge of the battery.

2.7 Fast Charging

We combine the constant current and voltage charging methods as in Figure 4(a) to deliver quick and stable charging of EV batteries. The charging profiles are divided into three main parts, followed by a pre-charging mode in the first section, CC charging mode in the second section and CV charging mode in the last section. In the pre-charge mode, the current is raised up in small stages to increase the battery voltage to a maximum. As in fig 4(a), the certain limit is denoted as a constant current threshold. This is done to confirm the injection of power into a managed manner during the initial time to avoid damage to the battery. By regulating the charger, the higher value of constant current is given above the threshold limit. To achieve 80% of its State of Charge, the battery charging phase is donequickly. At this point, the battery charger is moved to the CV charging mode to limit the level of current and protect the battery from damage due to overcharging.The battery charging phase is directed with a reduced current level in this mode, thus conserving the constant charging voltage. Small rest stages are involved in the process of reducing the battery temperature during quick charging. In contrast with the CC-CV, deterioration is reduced to appropriate degree. As a result , it increases battery life and efficiency. Charging is used in the Pulse Current (PC) to charge the EV batteries rapidly. By using the charge pulses in each second to flow the charging current into the battery, this method lets the EV battery charge. It is vital to monitor the pulses as the chemical action of the battery is soothed by inducing small rest gaps among charging pulses of about 20-30 milliseconds, as in Figure 4(b).The purpose of rest gaps is to balance the chemical reaction speed and the process of charging. Thus, the creation of gas at the electrode surface is reduced. As in Figure 4(b), negative pulse-charging uses a very small discharge pulse during this remaining pulse charging system gaps. The purpose of this is to depolarize the EV charging battery and to avoid gas bubbles that form during the pulse charging state on the electrode surface. This charging method is used to maximize the full charging phase and improve the life of the EV battery.

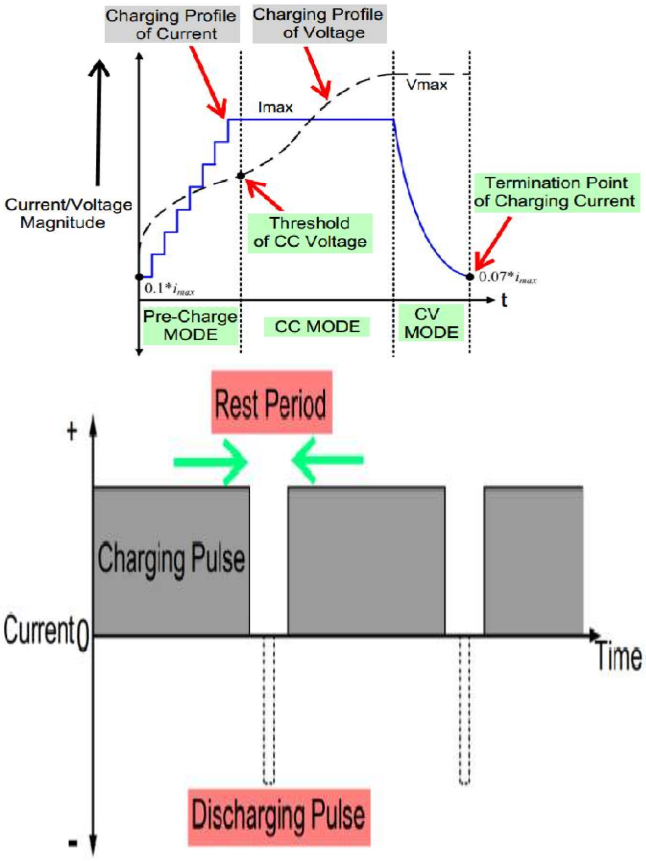

Fig4.(a) CC and CV Charging Profiles of a EV Battery Pack(b) Operation of Pulse-Charging method.

Table 1:Comparision of different charging methods.

Sl.no	Method	Typeof Charging
1	CC	Constant Current
2	CV	Constant Voltage
3	CC-CV	Constant current & constant voltage
4	PC(pulse charging)	Pulsed Current
5	NPC(Negative Pulse Charging)	Positive pulse, rest period, discharge pulse
6	FC(Float charge)	CV Charge

2.8 Smart Charging

A collection of charging parameters, such as output powers at various chargers, charging time patterns etc, are directly controlled by smart charging.With improved control flexibility, and smart charging, compared to uncontrolled charging, can support higher EV penetration. Smart charging systems are caused by framingcontrolled optimization issues, where the constraints can preserve the quality of power within Tolerable thresholds, to avoid destructive grid destabilization and to meet all demands for charging.

III. CHARGING TOPOLOGIES

In the growth of EVs, battery chargers play a critical part. The qualities of the battery charger are charging time and battery life. With high power density, low cost , and low volume and weight, a battery charger must be powerful and reliable. Its operation relies on modules, control and techniques for switching. Charger control algorithms are used, depending on the cost, controllers, digital signal processors and specific integrated circuits, based on theprice, and types of converters. In order to reduce the effect of power quality and at a high power factor, an EV charger must confirm that the utility current is drawn with low distortion to improve the actual power attainable from a utility outlet. EV battery chargers comprise a diode bridge boost converter for active power factor correction to rectify ac input voltage to dc, which is followed by the boost unit. Converting AC to DC converter stage and DC to DC converter stage.

3.1 Full Bridge SCR Controlled Rectifier

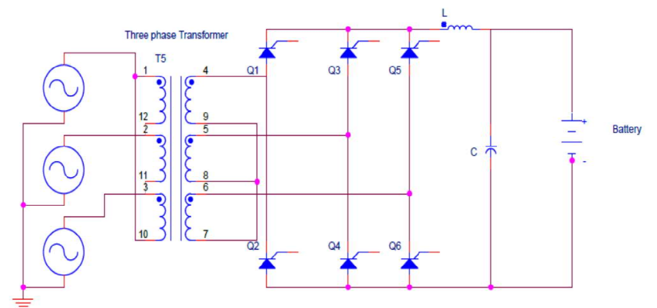

Fig5. Full Bridge SCR Controlled Rectifier

For charging the battery, a 3ph, 6 pulse SCR designed rectifier is used. To separate the 3ph source from the power converter, a 3ph transformer is used. A PID loop has been used to track the current in CC and voltage in CV profiles that affect the angle of firing the thyristor.The benefits of this topology are easy to use, dc-dc conversion is not essential, thyristors can handle large voltage and current and, reduced difficulty in firing thyristors.

3.2.Twelve pulse diode bridge rectifier with full bridge DC DC converter

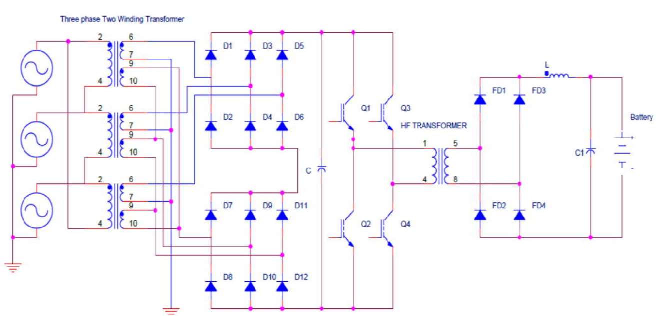

Fig 6. Twelve pulse diode bridge rectifier with full bridge DC-DC converter

A 12 pulse diode bridge rectifier, 3 phase ac is rectified. To produce twelve pulses, a three-phase isolation transformer is used with two secondary windings. To minimize the current, the two diode bridges are connected in sequence. Inverter bridge, high-frequency transformer, high-speed diode stack and filter are given the rectified DC voltage to achieve the charging voltage as required[40]. The IGBTs are diagonally swapped in pairs to Q1 and Q4 forming one pair and Q2 and Q3. A discrete PID loop that steadies the battery current and voltages, closed loop operation is completed. At its charging voltage and current, the service cycle needed for the IGBT will select the output voltage required to charge the battery. The current ripple is reduced, due to the insertion of the 12 pulse diode bridge rectifier; the input current harmonics are low. The design includes the process of high frequency transformers and diodes, and the presence of two transformers makes it more expensive.

3.3. Six pulse Thyristor bridge rectifier with by full bridge DC- DC converter

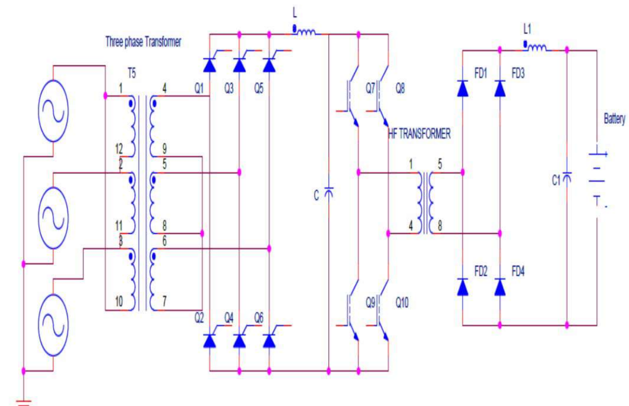

Fig7. Six pulse thyristor bridge rectifier with full bridge DC-DC converter.

For rectification, a six pulse SCR based rectifier is used. The bridge converter portion for DC to DC remains same. As per the need for battery voltage, the DC voltage can be changed by changing the SCR's firing angle, which gives a two-way control, but the input current has more harmonics and the input power factor is low, SCR bridge is used at the primary stage to control DC connection voltage, because of this low input power factor of 6 pulse thyristor bridge.

3.4. Twelve pulse diode bridge rectifier with midpoint clamped three level buck converters

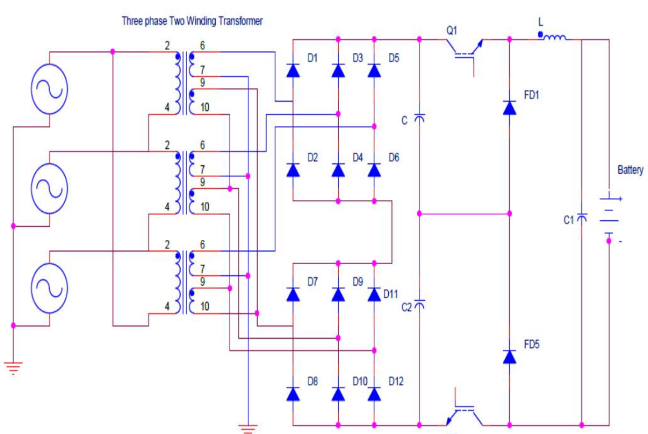

Fig 8. Twelve pulse diode bridge rectifier with midpoint clamped three level buck converter.

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To produce the rectified DC voltage, a 12 pulse diode bridge rectifier is used. The next stage contains a three-level buck converter, and this three-level buck converter[41] decreases the voltage stress on each switch by half with the help of two capacitors. This topology will work with all the switches on, only one switch on and both switches in off condition as well, A dual PID loop is added. The battery charging voltage is kept by the outer PID loop and the inner current loop holds the full current.The cycle for the two IGBTs is changed based on the current state. The advantage of this topology is that there are few switches, high input power factor due to 12 pulse rectifier, reduced current stress on rectifier diodes as two rectifier stages linked in sequence, reduced voltage stress on buck converter IGBTs as the voltage through them is halved by using midpoint clamped three level buck converter the current and voltage stress is reduced by half .

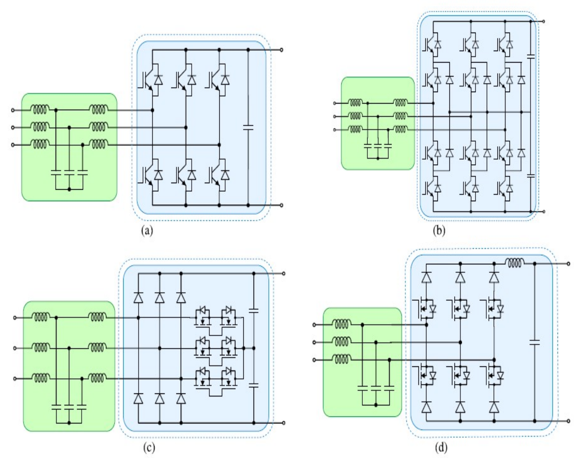

Fig 9. AC–DC front-end topologies for dc fast chargers (a) Three-phase PWM rectifier (b) NPC rectifier (c) Vienna rectifier (d) Buck-type rectifier.

3.5 Grid-Facing AC/DC Converters

An interface between the grid and a controlled dc bus is provided by grid-facing ac / dc converters. High power quality on the ac and dc sides, attained by input current and output-voltage control[44][45], is a necessity for these converters. In Fig9, the ac / dc converters are shown. Converters are further characterized as Bidirectional and unidirectional.

3.5.1 Bidirectional AC/DC Converters

The three-phase active pulse width-modulated converter with an LCL filter shown in Fig9(a) is the regularly used grid-facing ac / dc converter. The output voltageis higher than the input voltage for this boost-type converter. The six-switch PWM converter offers low-harmonic input currents, offers bidirectional power flow, and allows control of arbitrary power factor . This topology is used in dc fast chargers due to the simple structure, and control schemes, the availability of low-cost IGBT devices with suitable current and voltage ratings. The boost converter shown in Fig9(b) with the neutral point-clamped converter. This three-level converter lets lower voltage rating devices to be used that can have lower switching losses. The resulting three-level voltage waveform reduces the harmonics and dv / dt of input current. With the leakage inductance of the input transformer at the ac-side filter, an EV charger with an NPC front end attains a low total harmonic distortion (THD). The advantage of using an NPC converter as the front end of ac / dc is that a bipolar dc bus is created. This is used to introduce a bipolar dc bus EV charging station, allowing the dc / dc converters to link to half of the dc bus voltage.

3.5.2 Unidirectional AC/DC Converters

The buck-type converter can work at very high efficiency. The buck-type rectifier is modified to allow two input phases connecting to each phase leg. With two phase legs conducting the current, the device conduction loss is reduced keeping low THD of the input current ,addition of fourth diode bridge leg coupled to the midpoint of the diode bridge and the star-point of the input capacitors leads to reduced voltage stress on the switches . This allows the use of switches with lower voltage rating and better performance, achieving higher system efficiency.

3.6 Non- isolated DC/DC Converters

The use of NPC converter as the front end of ac / dc is that a bipolar dc bus is created. This is used to familiarize a bipolar dc bus EV charging station, allowing the dc / dc converters to link to half of the dc bus voltage. The range of the achievable reactive power is narrow due to the small modulation vector and depends on the output voltage. An EV charger uses a Vienna rectifier and two independent dc / dc converters with half of the dc bus voltage interfacing with each dc / dc converter. One step of the Vienna rectifier is PWM at a time, increasing the device efficiency by using the dc / dc converters to insert the sixth order harmonic into the dc bus voltage. If the output voltage is lower than the input line-to-line voltage, a buck-type unidirectional ac/dc converter shown in Fig 9(d). Fig. 10(b) shows an interleaved boost converter withthree phase legs. Due to its simple structure, good performance, and scalability to high power, this topology has beenwidely explored in literature for EV charging application [46][47].Over boost-type topologies, such as inherent short-circuit safety, inrush current control and lower output voltage, this converter has advantages, and the input current can be regulated in an open loop. if the output voltage is reversed the power flow can be reversed. Hence, with a set output-voltage polarity, the converter is unidirectional. Thepossible phase difference among the input voltage and the current depends on the output voltage needed. The converter is operated with a reduced output-voltage range to attain a greater phase difference. For the boost-type converter, the conduction losses are higher, and more devices are in series, the switching losses can be smaller. At high efficiency, the buck-type converter can operate. To allow two input stages connecting to each step leg, the buck-type rectifier is changed. The system conduction loss is minimized by two phase legs conducting the current, keeping the input current low THD, adding the fourth diode bridge leg connected to the midpoint of the diode bridge, and the star point of the input capacitors contributes to reduced voltage stress on the switches. This allows lower voltage and better performance switches to be used, attaining higher device efficiency.

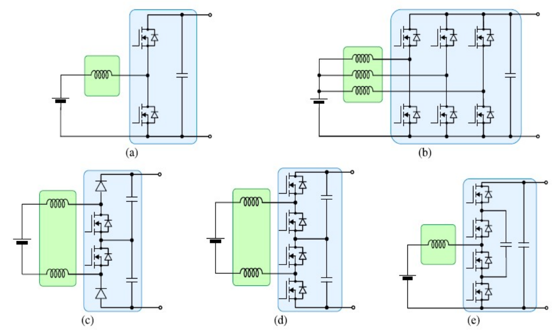

Fig10. Non isolated dc–dc converter topologies for dc fast chargers (a) Boost converter (b) Interleaved boost converter (c) Unidirectional three-level boost converter (d) Bidirectional three-level boost converter (e) Three-level flying capacitor converter.

It is possible to use a non-insulated dc / dc converter instead of an isolated one, but it provides the vehicle battery with a floating power supply. For these reasons, non-isolated dc / dc converters are used. Firstly, due to synchronous rectification, the performance of bidirectional converters is greater than unidirectional ones. Second, the bidirectional process of isolated dc / dc converters does not add more difficulty to the control of dc / dc converters that are not isolated. As the battery voltage is lower than front end of the ac / dc output voltage. The basic non-isolated topology with the battery and a boost converter is shown Fig10(a). This converter's power rating is reduced, because a single switch carries the current. If the current ripple is small, the inductor size is high. Two or more step legs may be interleaved to create a multi-pulse to increase the current carrying capacity and decrease the current ripple seen by the battery. An interleaved boost converter with 3 step legs is shown in Fig10(b). Because of its simple structure, good performance , and high power scalability, this topology has been used in EV charging application. By splitting the bus voltage into two components in order, the interleaved boost converter uses the partial power principle. Switches with lower voltage ratings can be used with the converter connecting to part of the bus voltage, likely reducing the losses. The downside of this method is that the three-level boost converter and its bidirectional shape, as shown in Fig 10(c) and (d), are the additional hardware and control effort to balance the two dc bus voltages, other topology that deliversimproved harmonic efficiency than the boost converter. The current ripple in the three-level boost converter is only one-fourth of that in the boost converter if the same inductor is used, which means a smaller inductor must be used to meet the current ripple. The three-level boost converter will boost the efficiency of the magnetic components and reduce their scale. But, in terms of common-mode noise, the three-level boost converter has heavy electromagnetic interference, which has a negative effect on the battery system. Also, it is not possible to parallel the three stage boost converters. If there is a phase change among parallel three-level boost phase legs, the interphase inductors are used among the phase legs, broad circulating currents will result. When multiple parallel phase legs are needed for high-power applications, circulating currents can be suppressed by synchronously switching the phase legs, avoiding the reduction of inductor size due to interleaving. The flying capacitor converter shown in Fig 10(e) is a three-level topology for fast chargers. This three-level topology enables the use of an inductor smaller than a boost converter. Also, by paralleling and interleaving several phase legs, the converter's power rating can be increased. But, because of the existence of the flying capacitor, the short-circuit safety design is exciting. In addition, the flying capacitor converter's switching commutation loop, including the upper and lower devices, is greater than that of the boost converter and the three-level boost converter, during switching, can cause undesired voltage overshoot.

3.6.1. Traditional Boost Converter

The DC-DC boost converter changes the lower input voltage to a high stage. As in Figure11, the topology contains a capacitor, an inductor and two switches with an antiparallel diode. The inductor on the input side of this converter holds the input current ripples at a minimum level and a capacitor works as the output voltage ripples are reduced by a filter. The benefits of Boost DC / DC converters are a lower components with a low EMI output voltage gain in the range of < 4 percent.For EV applications, the flexibility of circuit and the low cost make it a suitable alternate. The drawbacks of this converter are that it is impossible to attain high voltage gain over all weight by using large capacitor. The inductor in the boost converter, in the case of an electric vehicle, resists changes in current by creating and destroying a magnetic field. The operation of boost DC-DC converter can be as follows.

*(a) Switch closed:*The current flows via the inductor and inductor from input to output and begins to energize via magnetic field.

*(b) Switch open:*Due to high impedance, the polarity across the inductor will be reversed and the magnetic field formed through the inductor is lost to maintain current flow. As a result, at output, voltage addition occurs. This high voltage will charge the capacitor through Diode D.

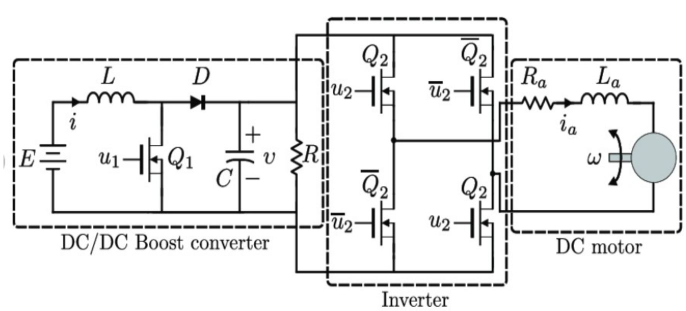

Fig11. DC-DC Boost Converter

The capacitor will send voltage and stored energy to load when the switch is closed, and the diode prevents the capacitor from discharging through the switch. To stop the capacitor from liberating energy, the switch must act quickly. By comparing the sensed DC capacitor link with the reference DC link voltage, DC capacitor connection error voltage signals are produced. For voltage sensing at the output of a positive converter, a voltage sensor is given. The regulated voltage signals should be compared with the carrier's signals after the PI controller. The produced PWM are given to switching device.

3.6.2 Boost Resonant DC-DC Converter

For the the traction motor, Boost DC / DC converters are used to raise the battery voltage. To decrease the size of inductive and capacitive components and improve device efficiency, high-power high frequency switching action is required. There are insufficient switching losses in a boost converter, the system output is affected, a regenerative-snubber circuit is given, At high switching frequency, this circuit is operated and the switching losses can be decreased. Thecircuit is simple in design and controlwhich results in high performance with a reduction in converter size. Switch turn-off loss is greater than turn-on loss in high-power IGBT-based boost dc / dc converters. By reducing the reverse-recovery of boost diode, the turn-on loss can be minimized, which can be attained by using silicon carbide diodes, as they show zero reverse-recovery. In this, a condenser-switched regenerative snubber concentrate can be carried out without attaining the thermal limits of the IGBT to reduce the losses during turn-off in boost converters and high frequency switching.

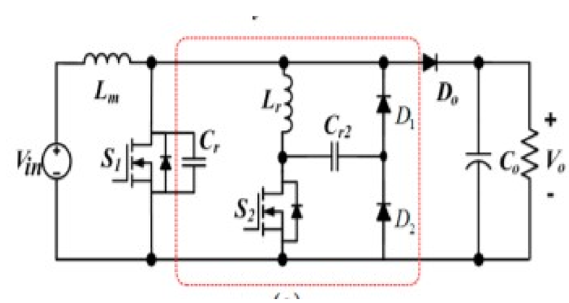

Fig12.Boost DC-DC converter with Resonant circuit

The regenerative snubber boost circuit is shown in Fig12, Cs snubber capacitor is charged, which occurs at one instance of turn-off and discharges in the next instance of turn-off,the voltage stress across the switch is minimized by this operation. The relation of the snubber capacitor to the main switch needs to be reversed at successive turn-offs to know this mechanism adjust the voltage across the snubber capacitor from zero voltage to Vout and during charging/discharging reverse flow occurs.

3.6.3 Interleaved 3-Phase Boost DC/DC Converter

To minimize input current and output voltage ripples, the Interleaved 3-Phase boost DC / DC converter is used, raising the voltage ratio by four times,this has a parallel combination of some converters with the same phase shift and frequency of switching given. The basic 3-phase interleaved boost converters shown in Figure 13. Here, the multiphase structure allows each boost to combine the output capacitor into one capacitor Co, which is an addedadvantage. The frequency multiplication of this converter allows the filtering of the output to be minimized. In addition, the input current is increased on the input side, and due to frequency multiplication, input filter requirements are minimized. There are fewer dv / dt and di / dt noises in this DC-DC converter. The process is initiated by switching on switches T1,T2,T3 and this process energizes the inductors.And after that, every switch is regulated by the switching time Ts/3.

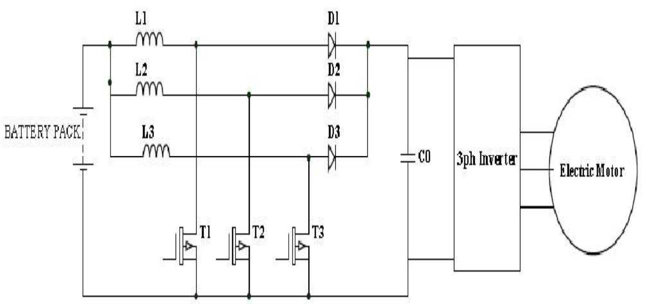

Fig13**.** Interleaved 3-Phase boost DC-DC converter.

3.6.4. Interleaved unidirectional charger topology

Interleaving, a unidirectional arrangementshown in Fig 14, has been proposed to decrease battery charging current ripple and inductor size. It needs two out-of-phase boost converters 180 times in parallel. The interleaved boost converter has the benefit of parallel semiconductors. It also lessens stress on output condensers with ripple reduction at the output. However, similar to boost, the heat management for the input bridge rectifier must be given by this topology.

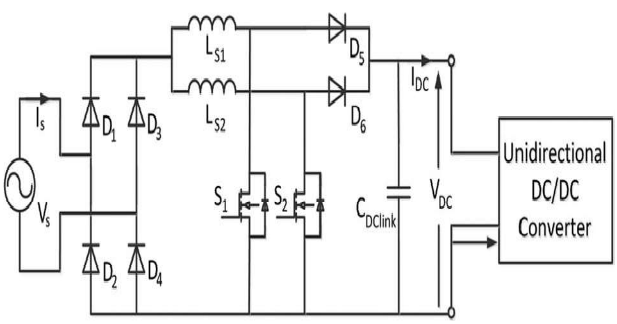

Fig 14. Interleaved unidirectional charger topology

3.6.5 Bidirectional LCL Resonant DC-DC Converter

This topology falls under the group of non-isolated bidirectional DC / DC converter for Battery vehicle interfacing. The converter has a two-parts front-end half-bridge boost converter and an LCL resonant circuit that assists in soft-switching. The gain is improved by a voltage doubler circuit at output and LCL resonant circuit. As with other topologies, this topology offers high benefit. Using high voltage condenser divider, half is split during buck action to get high voltage step down ratio. To avoid use of filters the circuit is run under high frequency, soft switching is attained without having extra circuitry. The converter feeding current on the left side offers a Vin/(1-D) gain for boost action, and the resonant circuit helps to increase the gain with doubling the output voltage. The capacitors split voltage boosted to half in buck action. For switches M1 and M2, the gate signals are opposite to each other by providing enough dead time for boost action and M3 and M4 are off-state during this process. with, additional gate signals with ample dead time for buck operation are supplied to M3 and M4.

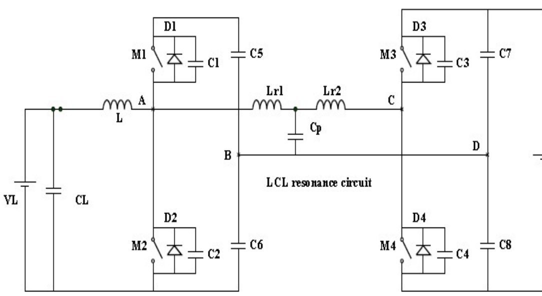

Fig15.Bidirectional LCL Resonant DC-DC Converter

3.6.6 .Three-level diode-clamped bidirectional charger circuit

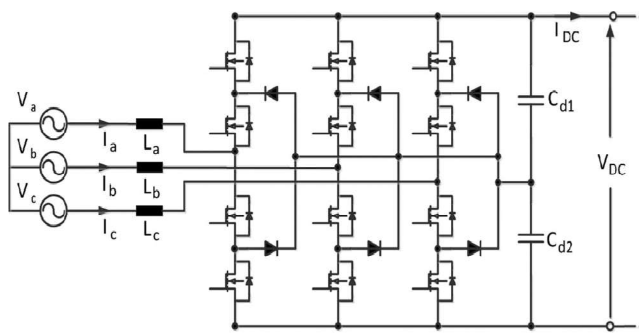

Fig 16.Three-level diode-clamped bidirectional charger circuit.

Fig16.Bidirectional charger circuit with three-level diode-clamped,multilevel converters are ideal for Level 3 EV chargers and can minimize scale, switching frequency, and stress on devices. They use a filter that is smaller and less costly. The added components increase the cost and the control circuitry required. Most EVs recharge their batteries using a single-phase on-board charger. The topology of a single-phase unidirectional multi-level charger is suitable in Fig16, and is a typical multilevel charger topology for low-power charging levels 1 and 2. For high power Level 3 charger systems, three-phase bidirectional multilevel converters are used. With reduced THD, high power factor and decreased EMI noise and boost, and ripple-free, controlled dc output voltage insensitive to load and supply disturbances, these converters offer a high level of power quality at input mains. These converters are categorized by low switch voltage stress and used in smaller energy-storage devices such as inductors and capacitors.

3.7 Isolated DC/DC Converters

3.7.1 Full Bridge DC-DC Converter

In Fig 17, this type of DC-DC converter comprises of three stages: an inverting stage, a portion of the high frequency transformer and a rectifying stage. Using the PWM method, the control signal for each switching action can be regulated to vary the output voltage, where the duty ratio for the effective action of semiconductor switches must be kept above 50 percent. The High Frequency Transformer used offers galvanic isolation between the input and load side,permitting excessive step-up voltage.

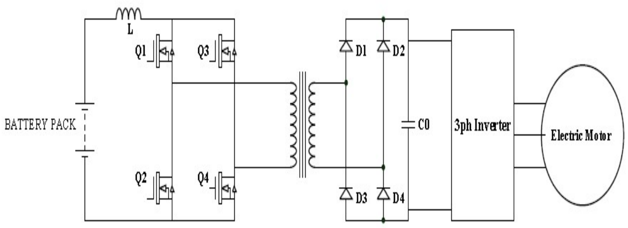

Fig 17.Full bridge DC/DC converter

Also, the switching losses of PWM converters are needed for additional snubbers and other means of protection, resulting in losses and lower efficiency. The converter used is a two-leg switch and neither switches in the same leg are not functioned in full bridge PWM DC-DC converter. When all four switches do not work, the freewheeling of the load current takes place through the diode rectifier. This causes voltage oscillations across switches, so to correct this effect, an additional snubber is required. If snubbers are not used, high-power rating devices must be used to minimize the parasitic ringing effect, the lower switches of the gate signals are equipped with a phase shift associated to those of upper switches so that either primary transformer is connected to the input, the leakage inductance energy is used to discharge MOSFET capacitances to achieve soft switching conditions for input. ofthe four switches, here the converter needs no added resonant components.

3.7.2 Soft-Switched Bidirectional Half-Bridge Dc–Dc Converter

It uses a DC-DC converter with bidirectional power flow and zero voltage switching. The use of this topology is that ZVS does not have any elements attached, which provides easy structure. These converters are mostly used in electric vehicles and power generation for medium and high-power applications, where high-power density, low cost, light weight and high reliability power converters are needed. Fig18 shows the bidirectional DC-DC converter for Electric Vehicle applications. The circuit contains an input inductor and two half-bridges on both sides of the transformer, with parallel capacitance between switches providing soft switching. The power flow for the boost mode is from left to right. The circuit runs in buck mode in the reverse flow direction of power and recharges the battery. The half bridge has two functions on the low voltage side serving as

1)step up boost converter2)An inverter producing the high frequency at the inductor and the half bridge at the low voltage side of AC helps to improve action. Here, the ZVS draws less current from the voltage source at load, despite maximum bridge configurations. This makes the topology more helpful than other topologies. Low current stress and transformer rating are the significance. The leakage inductance of the transformer is used to link and transfer energy between half-bridge inverters, low voltage side and high voltage side half-bridge inverters.

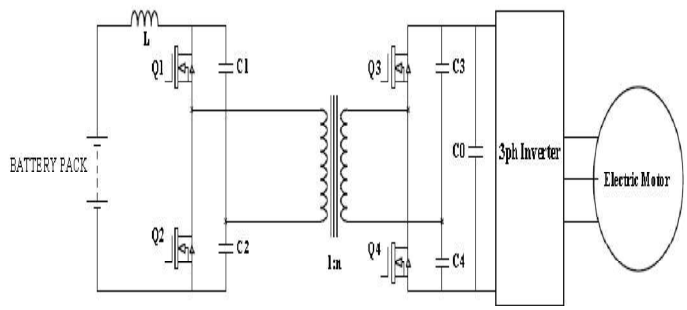

Fig18. Soft-switched bidirectional half-bridge DC-DC converter

3.7.3 Multiport isolated Bidirectional DC-DC Converter

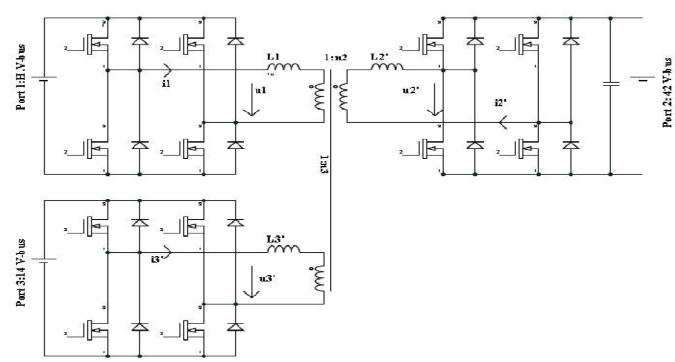

Fig 19. Multiport isolated DC-DC Converter

3.7.4 Multidevice DC-DC Bidirectional Converter with Inter leaved structure

A bidirectional DC-DC isolated three-port converter is shown. One is duty cycle control and the other is power management between ports. These controls boost system output by minimizing total errors,two controls are used here. The isolated bidirectional multi-port converter is shown in Fig19. Using an inverter, an electrical traction motor may be connected to a high voltage bus. The transformer provides electrical separation corresponding to various levels of voltage. The interleaving method used is the phase interleaving method, thus increasing the number of phases. Interleaving not only reduces the current of the input ripple, but also decreases the number of parallel devices per point. The design challenge for EV systems is that electronic power interfaces must have low volume, weight , high gain, high performance with minimal ripples and cost. The filter capacitors, high-power inductors and heat sinks are the components that will provide additional weight. These must be avoided to get a safe electric vehicle battery interface device by offering high frequency switching and interleaving methods.

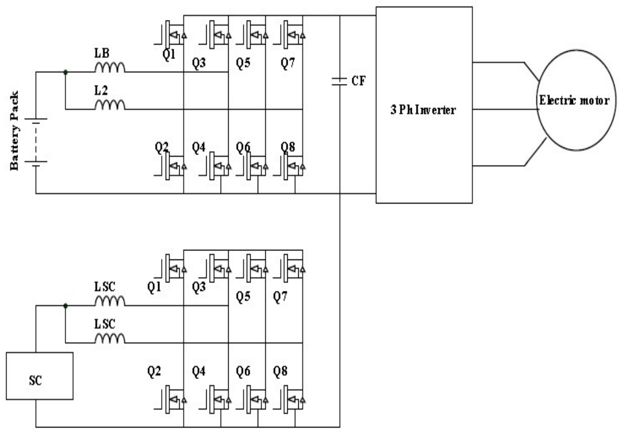

Fig 20. Multidevice DC-DC Interleaved Bidirectional Converter

3.8 Integrated Chargers

The integration of the charging mechanism into the electrical drive system has been projected to reduce weight, volume. The charging and traction are not simultaneous, the feature can be combined. For filter inductors or an independent transformer, motor windings are used in an integrated charger and the motor drive inverter acts as a bidirectional ac-dc converter. The advantage is with unity power factor; low-cost high-power (levels 2 and 3) bidirectional quick charge can be aided. In consumer products, control complexity and extra hardware are challenges to introduce.

3.8.1Classifications of Integrated Battery Chargers

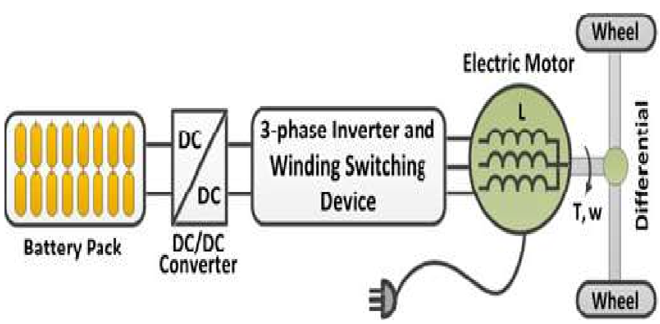

Fig21. Typical structure of integrated PEV charger.

Based on motor count and inverter count, integrated charger topologies can be considered. Two inverters are used here to drive the main and auxiliary motors and use them as an ac-dc converter for charging, while two three-phase motors with their neutral points connected to the grid are used as inductors for the converter. Each motor can be operated by its inverter Byadding the driving force as a traction motor, the first unit plays a part in supplying regenerative energy to the battery. The engine starts up or charges the battery on the second unit. Both motors and inverters act as an ac-dc boost converter in the charging mode. The large number of additional components and control complexity are the difficulties of this charger. The operating theory is the same as the configuration of two motors and two converters. Cost is saved and weight is less than in traditional chargers, but twelve power switches, three contactors and the special double winding machine are still needed in the arrangement.

3.8.2 One-Motor with One-Power Converter Topology

An integrated topology can be categorized by motor type with one motor and one power converter: induction, permanent magnet (PM) and switched-reluctance motor (SRM) with isolated or non-isolated circuitry.

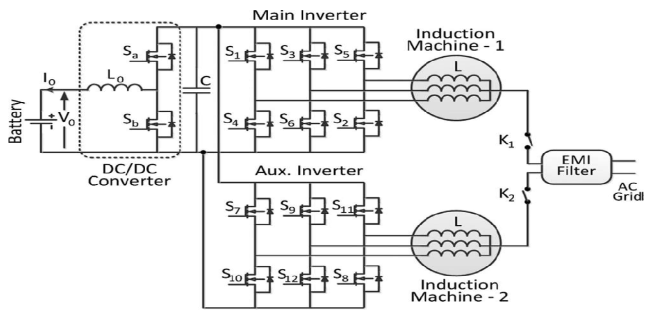

Fig 22. Integrated charger with two motors and two inverters

Table 2. Different converter Topologies used for fast charging of lithium-ion batteries

SLNO	Topology	No of semiconductor devices used
1	Full Bridge SCR Controlled Rectifer	Six SCR’s
2	Twelve pulse diode bridge rectifier with DC -DC Converter	Twelve SCR’s,4 IGBT’s,4 Diodes
3	Six pulse thyristor bridge Rectifer with full Bridge DC-DC Converter	Six SCR’s, 4 IGBT’s,4 Diodes
4	Twelve pulse diode bridge rectifier with midpoint clamped three level buck converter	Twlve SCR’s,2 IGBT’s, 2Diodes
5	Three-phase PWM rectifier	Six IGBT’s
6	NPC rectifier	Elecven IGBT’s,6 diodes
7	Vienna rectifier	6 diodes,6 MOSFETS
8	Buck-type rectifier.	6 diodes,6 MOSFETS
9	Boost converter	2 mosfets
10	Interleaved boost converter	6 mosfets
11	Unidirectional three-level boost converter	2 mosfets, 2 diodes
12	Bidirectional three-level boost converter	4 mosfets
13	Three-level flying capacitor converter	4 mosfets

IV. CONCLUSION

A large number of specifications need to be taken into account for a fast DC charger, such as high power, isolation, low current and voltage ripples etc. Different charging methods & topologies are discussed and compared in this paper. The simplest to implement and also the most stable topology is the Scr based full bridge operated rectifier, but the battery current ripple is greater and the power factor is also low. Better control is attained in Twelve pulse diode bridge rectifier followed by full bridge DC-DC converter, and the power factor is high, but due to the high power rating components such as high frequency transformers and diodes, it is more costly .In the six pulse SCR bridge, the twelve pulse diode bridge is replaced and the full bridge DC-DC converter remains the same. The input power factor is minimal and the cost consequences are the same as the rectifier for the Twelve pulse diode bridge. Due to reduced voltage and current tension, thermal stress, reduced complexity and above all better control over battery parameters, twelve pulse diode bridge rectifier followed by midpoint clamped three-level buck converter is the most suitable for EV charging application based on the comparison of all topologies. Also, the benefits and limitations of both methods to quick charging design have been addressed and the various DC-DC converters used in electric vehicles are presented. These converter designs are carried out to achieve high performance at low sizes and costs. This research explores the outline of converter topologies used primarily in interconnecting electric vehicles. Isolated and non-isolated are the primary DC-DC converter topologies. In electric vehicle interfacing, bidirectional non-isolated topologies are considered to be more suitable among these topologies due to the advantages of these topologies than other topologies. The existence of a transformer, as in the case of isolated topologies, makes system design and control complex and thus reduces overall system efficiency.

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