ELECTRIC VEHICLE SUPPLY EQUIPMENT

Asheesh Dhaneria, Hardik Khambhadiya

Electric vehicle supply equipment (EVSE) or charging station is a piece of equipment that supplies electrical power to an electric vehicle (EV) to recharge the vehicle's batteries. EVSE systems include the electrical conductors, related equipment, software, and communications protocols that deliver energy efficiently and safely to the vehicle. The charging stations are of two types: AC charging stations and DC fast chargers. In AC charging station, power is supplied to the onboard charger with and AC to DC converter (mounted on electric vehicle). The DC charging station may be of different levels. Level 1 chargers has power rating upto 15 kW with voltage levels greater than or equal to 48 V. Level 3 chargers have power rating upto 400 kW with voltage levels in the range of 200 to 1000 V. The DC charging station is directly interfaced with the battery of the vehicle bypassing the onboard charger. Figure 1 shows a typical block diagram of a DC charging station.

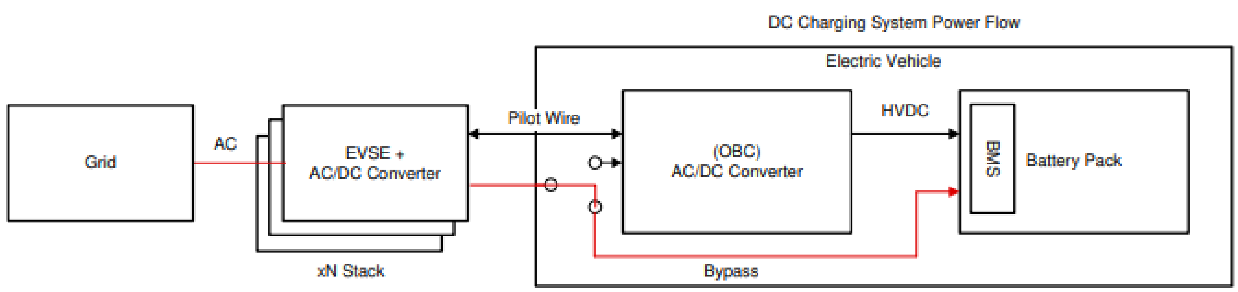

Figure 1: DC charging station

DC fast charger consist of two stages i.e. AC to DC converter stage (Rectifier) and DC to DC converter stage (Chopper). There are number of topologies and circuits to achieve the required AC to DC conversion. Below discussed are few topologies along with their merits and demerits based on the simulation results in Matlab Simulink and circuit.

A. Topology 1: SCR based full bridge controlled rectifier:

This topology consists of a three phase, 6 pulse SCR based rectifier. A three phase transformer is used to isolate the three phase source from the power converter. A PID loop can be used to strictly follow the current in CC and voltage in CV profiles which will directly affect the SCR firing angle. Benefits of this topology includes ease of implementation, no need of a DC-DC converter stage, robustness of the design, SCRs capability to handle large amounts of voltage and currents and reduced complexity in firing of SCRs.

Simulation results shows more than 3% ripple in battery current and low input power factor. Another demerit of this topology is that pulse charging scheme cannot be adopted as SCR remains conducting till zero crossing of the input ac signal.

B. Topology 2: Twelve pulse diode bridge rectifier followed by full bridge DC – DC converter:

In this topology, three phase AC is rectified by using a 12 pulse diode bridge rectifier. Three phase isolation transformer with two secondary windings (one in delta and other in star connection) is used to generate twelve pulse. The two diode bridges are connected in series in order to reduce the current stress. The rectified DC voltage is processed by the inverter bridge, high frequency transformer, high speed diode stack and filter to obtain the required charging voltage.

In this topology current ripple gets reduced to less than 0.5% as it has better control derived by high switching frequency of full bridge DC-DC converter. Input current harmonics are also low due to inclusion of 12 pulse diode bridge rectifier. But the design requires high frequency transformer and high frequency diodes to operate. Also there are two transformers which makes it costlier.

C. Topology 3: Six pulse Thyristor bridge rectifier followed by full bridge DC – DC converter:

In this power scheme instead of diode bridge which is uncontrolled rectifier, a six pulse SCR based controlled rectifier is used for the rectification stage. The DC to DC full bridge converter part remains same as above topology.

Here as per the battery voltage requirement, the DC voltage can be changed (which was fixed in the previous topology) by varying the firing angle of the SCR. Thus it gives a two way control. But the input current has more harmonics and input power factor is low compared to previous topology. In this topology in order to have control over DC link voltage, SCR bridge is used at the primary stage. input power factor is low due to 6 pulse thyristor bridge.

D. Topology 4: Twelve pulse diode bridge rectifier followed by midpoint clamped three level buck converter:

In this power scheme a 12 pulse diode bridge rectifier is utilized to generate the rectified DC voltage. The next stage here comprises of a three level buck converter. This three level buck converter with the help of two capacitors reduce the voltage stress on each switch by half. A dual PID loop is implemented in the simulation. The outer PID loop maintains the battery charging voltage and the inner current loop maintains maximum current. Depending on the current requirement the duty cycle of the two IGBT's are adjusted.

This topology has following advantages:

- Less number of switches
- Higher input power factor due to 12 pulse rectifier
- Reduced current stress on the rectifier diodes as two rectifiers stages are connected in series
- Reduced voltage stress on buck converter IGBTs as voltage across them is halved by the use of midpoint clamped capacitors
- Reduced inductor size
- Control part is simplified as only two IGBTs are to be controlled
- Economical design

In this topology due to the use of 12 pulse diode bridge rectifier input power factor is high. Also due to the use of midpoint clamped three level buck converter the current and voltage stress is reduced by half as each power switch is exposed to half the voltage which leads to more economical design.

Based on the comparison of all the topologies it can be concluded that topology 4 comprising of twelve pulse diode bridge rectifier followed by midpoint clamped three level buck converter is the most suited for EV charging application due to reduced voltage and current stress, thermal stress, reduced complexity and better control over battery parameters.