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Improvements of battery charging of an Electric vehicle using onboard and off board charging with controllers

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Abstract- **This paper explains Improvements of battery charging of an Electric vehicle using onboard and off board charging with controllers, Improvements in stability of an on-board charger in electric vehicle. On board and off board charging system use to charge the EV, on-board charger is the additional weight for the vehicle, but it is necessary to meet the charging requirement in certain condition, in case non availability of Off board charging. To use the system safe and efficient method, controller is required. Controller is pure electronics device.**

Keywords- On board charging, off board charging, Electric Vehicle, Opportunity charging

I. INTRODUCTION

Due to the lack of fossil fuels, environmental pollution, and the other reasons, the conventional internal combustion engine (ICE) powered vehicles faced with limitations. On the other hand, the electric vehicles (EVs), hybrid EVs (HEVs), have been growing steadily with the development of the vehicular battery over the last few years. Especially, HEVs can be a compromise of ICE powered vehicles and EVs[1].

The transportation sector takes part approximately 25% in GHG (green house gas) emission. These methods are using the on-board charger (OBC) to charge the battery-module by using the grid source, which is normally provided in household.

It is a very challenging to find the alternative of the fossil fuel use for transport. Many of the companies are putting efforts to make the efficient, convenient, economic and reliable alternative of the fossil fuel by providing EV.

A vehicle is got energies by an electric motor and draw power from electric source install inside the vehicle. By design it is more simple, economic, durable, and simple in mechanical design as compared to IC Engine vehicle. Here, we get more fuel efficiency because of we don't get any emission as IC engine vehicle. For the implementation of the alternate of the IC engine, EV we need an established and validated network of the charging system similarly as now a days we have for fossil fuel. [1]

To establish the charging network many private and government sectors are working. Here the main challenges are the grid capacity and transportation of the electricity. Here Renewable energy and efficient charging infrastructure implementation can provide us solution to meet the increased demand due to EV implementation.

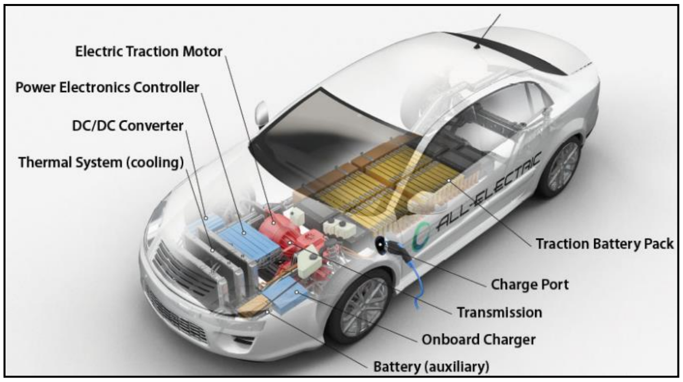

Figure 1- Basic Details of an EV

II. CHARGER

A charger refers a device that provide energy into the charge storage device (battery), by providing an electric current in controlled and safe manner.

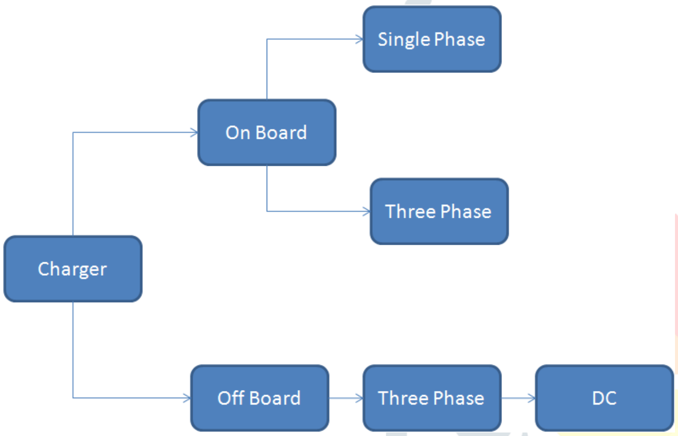

Figure2- Charger tree

A) ON BOARD CHARGING

At the heart of any electric (EV) or plug-in hybrid (HEV) vehicle lays the high-voltage (200 to 450 VDC) battery and its associated charging system. The on-board charger (OBC) mounted inside the vehicle and provides the means to recharge the battery with right voltage and current from the AC mains either at home or from outlets found in private or public charging stations. From a 3.6 kW single-phase to a 22 kW three-phase high-power converter, today's (OBCs) On-Board Chargers must have the highest possible efficiency and reliability to ensure rapid charging times as well as meet the limited space and weight requirements.[2]

An on-board charger, or OBC, serves one main purpose: to convert AC power from the grid to DC power stored in the high-voltage vehicle battery. This conversion is all happening inside the actual vehicle, or “on-board.” These OBC systems can vary in power level and charging speed (the higher the power delivered, the faster the battery charges).

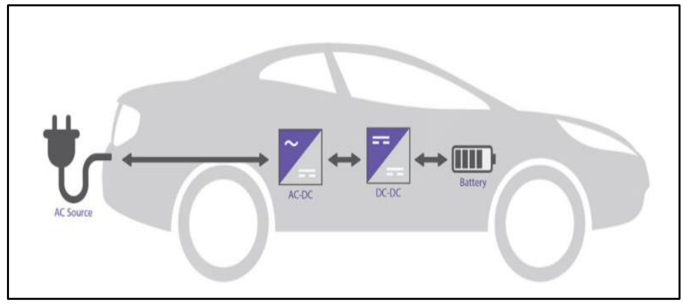

Figure3- On board charging

B) OFF BORD CHARGING

An off-board charging system is in big size and put outside of the vehicle, takes incoming AC power and converts it to the DC power needed to charge the battery system. The term “off-board” refers to charging systems not native to the vehicle itself (e.g., public vehicle charging station). One critical performance aspect of an off-board charger is its ability to quickly recharge the vehicle. For example, some modern fast chargers can recharge more than 250 kilometers of range in less than 30 minutes.[2]

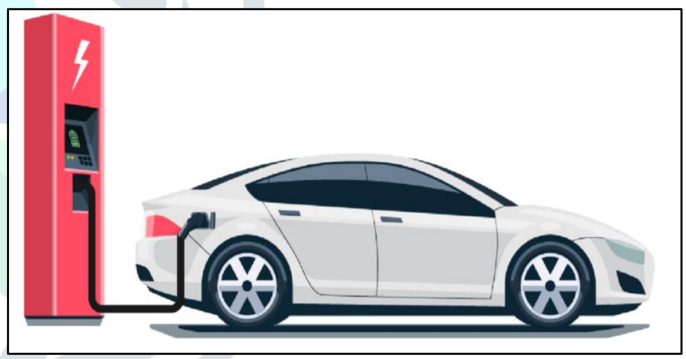

Figure4- On board charging

III. CONTROLLER

Controller has the primary task of controlling and monitoring the charging process of an electrical vehicle. Controllers for electric vehicles are safety devices with programmable components that protect the electrical distribution circuit also.

An electric vehicle consists of just two components, the motor that provides the power and the controller that controls the application of this power Controller has the primary task of controlling and monitoring the charging process of an electrical vehicle. Controllers for electric vehicles are safety devices with programmable components that protect the electrical distribution circuit also.

The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle‘s speed and acceleration much like a carburetor does in a gasoline-powered vehicle. The controller transforms the battery’s direct current into alternating current (for AC motors only) and regulates the energy flow from the battery. Unlike the carburetor, the controller will also reverse the motor rotation (so the vehicle can go in reverse), and convert the motor to a generator (so that the kinetic energy of motion can be used to recharge the battery when the brake is applied).[3]

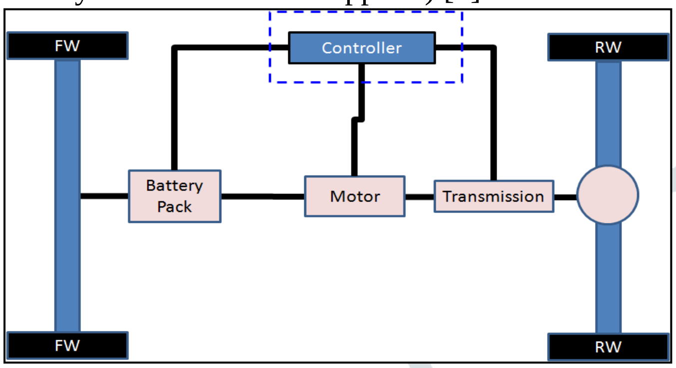

Figure5- Basic Block Diagram of EV

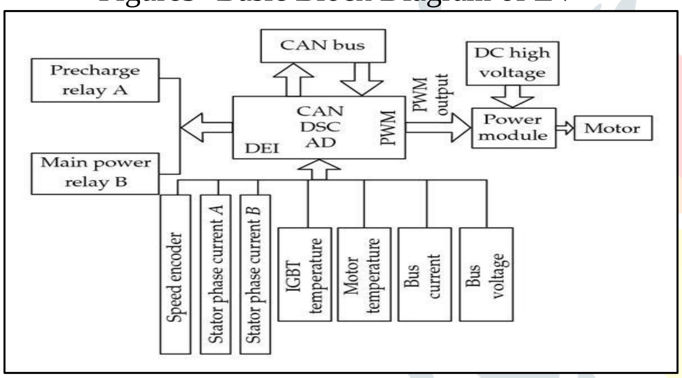

Figure6- Basic block diagram, Internal of a controller

IV. ROLE OF CONTROLLER IN BATTERY CHARGING

A battery charge controller (BCC) regulates the flow of electricity from the grid or renewable energy generator to the battery. Its function is to regulate the voltage and current from the grid or renewable energy generator array in order to prevent overcharging and also over discharging of the battery.

The intelligence of an AC charging station or an AC charging infrastructure is largely determined by the charge controller used. A smart charge controller has the primary task of controlling and monitoring the charging process of an electrical vehicle.[4]

The features that characterize a smart charge controller include communication with a backend system and the associated authorization of users, as well as the efficient distribution of load currents by means of dynamic load management to prevent an overload of the existing AC system.

The term Charge control is a technology that lets an electric utility control, in real time, the charging of a grid able (plug-in) vehicle, such as a plug-in hybrid (PHEV) or a battery electric vehicle (BEV). Through charge control, the utility is able to postpone charging of the vehicle during time of peak demand.

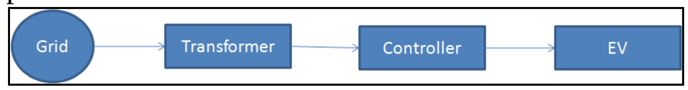

Figure7- Flow of Electricity in EV

V. TYPE OF CHARGE CONTROLLER

a. Series charge controller- A series switch is included between the charger and the battery. Depending on the state of charge of the battery, the controller's series switch opens to cut off the charging current from the PV array. The limitations of this series controller regarding the ability of the component to handle current during switching operation. [4]

b. Shunt charge controller- Shunt controller just work as an on - off switch. When battery voltage observed low (charging is required), switch will be operate and charge will flow from charger to battery. When battery voltage observed high (charged up to a certain level), switch become close and no charging will continue.

c. Combined series and shunt charge controller- It is combination of both Series charge controller and shunt charge controller.

d. Pulse width modulation- The PWM (pulse wave modulation) charging controller uses the charging current generated by the power supply directly. PWM has less-expensive charge controller topology

VI. DIFFERENCE BETWEEN ONBOARD AND OFF BOARD CHARGING

Sl. No	Onboard	Off board
1	Less energy (in kW) transfer	Higher energy (in kW) transfer
2	Battery heating, no concern	Need to take care of battery heating
3	Charger weight added to vehicle	No added weight, separate from vehicle [5]
4	Slow charging	Fast charging
5	Flexibility, Recharge	No Flexibility to

	at any place	recharge at various places [5]
6	Complex BMS Charging	Easy (Less complex) BMS Charging
7	Need domestic power level	Need higher power level

Table 1-Difference on board Off board charger

VII. COMPARISION BETWEEN ONBOARD BOARD VS OFF BOARD CHARGING

Batteries all have different capacities; because they require different charging currents and voltages, both EVSE and onboard chargers must support different charging levels, types and modes, which ultimately determine the battery charging time. [6]

There are mainly two types of charging systems, AC and DC charging systems. An AC charger powers the battery through the vehicle's onboard charger, while a DC charger directly charges the vehicle's battery.[6]

The power subsystem (module) of an onboard charger and an off-board charger are split based on the charging power levels. The power subsystem of an off-board (DC) charger is generally designed to transfer higher kilowatts of power and requires a more sophisticated BMS on the PHEV.

It removes significant weight off the PHEV, which can increase the vehicle's overall efficiency. On the other hand, an onboard charger is generally designed for lower kilowatts of power transfer and adds significant weight to a PHEV

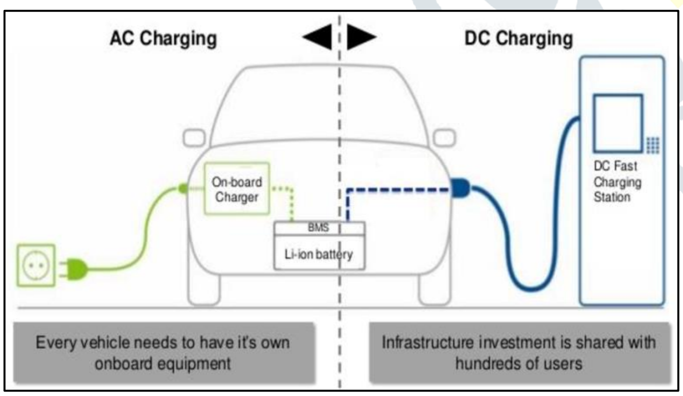

Figure8- Comparison of on board and off board charging

VIII. IMPROVEMENTS BY USE OF CONTROLLER FOR CHARGING

- Maximize charging efficiency- By maintaining the ideal charging condition charging efficiency can be maximize
- Minimize the power consumption for charging- Controller also works to use minimize the power consumption while charging.
- Maintain Ideal charging conditions- It keeps making the charging condition ideal, which is good for electrical system, charger and vehicle.
- Save the battery life- To save the battery life controller work is most important. Controller prevents a battery from excess charge or discharge.
- Improve the battery efficiency- Optimize use of the battery charge with the help of controller.
- Safe charging condition- Controller keeps the charging condition safe by preventing any overcharging.
- Performance of battery can be improve- As we know by controller we can keep the charging condition safe for battery, so anyway we can improve performance of the battery.
- Improve the discharge of battery- Now used battery have very low slow discharge rate of the battery, but due to the vehicle all time connected with battery and use the energy, example security system, GPS etc.
- Can use the electrical system for long time- To improve the fault detection strategy with the help of the controller we can improve the life of the electrical system.

IX. CONCLUSION

In this paper we are trying to explain, it is very basic requirement to make a safe and efficient charging station for EV. These should be user friendly because many of the charger will used directly by EV owner. With the help of controllers, we can make a charging system efficient, economic and safer.

We should be clear about the role of a controller in a charging system. For the function of a charger, it is responsible in a charging system to monitor the health of the entire charging mechanism.

We also make clear about the on board charging and off board charging system. As the charging phenomena, charging location, charging duration and level of electricity consumption are totally different, in on board and off board charging system.

A Case study about available standard and methods of charging -

Chargers, which supply a DC to the vehicle battery, must communicate with the vehicle in order to supply the battery with the correct voltage and current. This is particularly case with non-dedicated chargers as used in public charging stations, which should be able to supply vehicles with varying battery voltages and chemistries.

The communication protocol for this data link was intended to be the part 24 of IEC 61851. The document was never published by IEC however, and the European pre standard ENV 50275-2-4, which the IEC standard would supersede, was transferred in 2006 to Technical Specification 50457-2 [7].

The proposed protocol is largely based on the ISO road vehicle diagnostic standards as defined in ISO 14229 and ISO 14230. These concern requirements for diagnostic systems implemented on a serial data link layer, which allows a tester to control diagnostic functions in and on vehicle electronic control unit [7].

The protocols were specifically adapted for the selected application: after the initialization phase by the off-board charger, the vehicle's charge control unit controls the charging process of the off-board charger. Contrary to the standard communication according to ISO 14230 where the server and the client are fixed during all the session, their roles are definitively reversed after the initialization phase [7].

The AC conductive battery charger can be classified by the level of power they can provide to the battery pack. According to SAE EV AC charging power levels, the HV battery charger specifications can be summarized as-

Content	AC Level1	AC Level2	AC Level3
Power (kW)	1.08–1.44	3.3–6.6	≥ 14.4
AC input voltage (*Vac*)	230	440	230~440
Maximum output current (A)	12–16	16–32	≥ 80
Charger location	Single-phase	Single-phase	Three-phase

Table2- HV Battery Charger Specifications with Different Power Levels

The conductive charger for EVs has the advantages of maturity, simplicity and low cost because it simply makes use of plugs and sockets to conduct electrical energy via physical metallic contacts.[7]

According to the SAE J1772 standard, two AC levels (AC level 1 and 2) are defined while two DC levels (DC level 1 and 2) are proposed for EV conductive chargers. Currently, AC level 3 and DC level 3 are under active discussion. As listed in Table below, AC level 1 and 2 are designed for single-phase on-board chargers, whereas DC level 1 and 2 are dedicated for off-board chargers. These charging levels essentially satisfy all charging needs of various EVs [7].

AC level 1	**DC level 1**
Single-phase, 120 V, 16 A, 1.9 kW (max)	200–450 V, 80 A, 36 kW (max)
AC level 2	DC level 3
Single-phase, 240 V, 80 A, 19.2 kW (max)	200–450 V, 200 A, 90 kW (max)
AC level 3	DC level 3
Single-phase or 3-phase, > 20 kW	200–600 V, 400 A, 240 kW (max)

Table3- Standard power levels of conductive chargers

Safety is the key concern for conductive chargers. The SAE J1772 standard includes measures to avoid electrocution.

Charging Infrastructure Deployment-

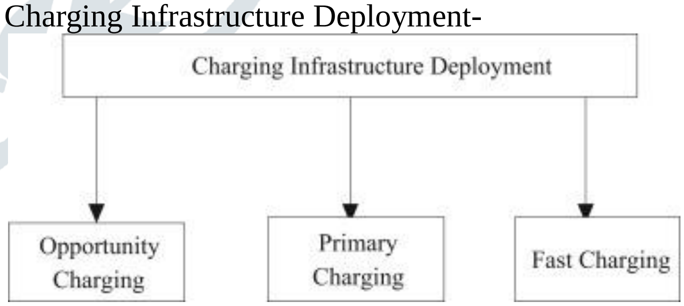

Figure9- Charging Infrastructure Deployment

On-board AC slow charging-

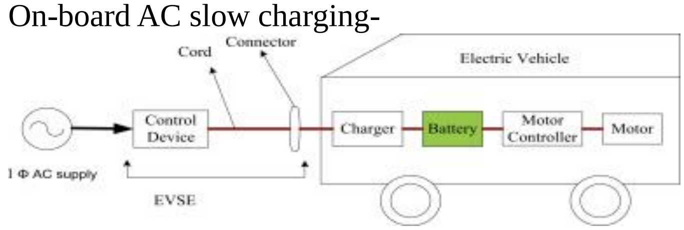

Figure10- Charging On-board AC slow charging

EVSE arrangement for on-board AC slow charging

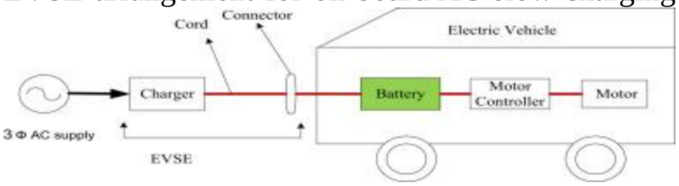

Figure11- EVSE arrangement for on-board AC slow charging

EC configuration for battery chargers plays a critical role in the sustainable development of BEVs/PHEVs. The challenge of transforming BEVs/PHEVs from concept to reality is to make it safe, convenient, and affordable for consumers to charge batteries [7]. In order to improve convenience and increase charging efficiency, a number of charging schemes have been proposed as house charging, solar charging station, park and charge (PAC), move and charge (MAC), and regenerative charging. A battery charger composed of several PECs should be reliable and efficient with high power delivery capacity at low cost and weight. Its operation depends on power electronics component, switching strategies, and control algorithms. A BEV/PHEV charger must ensure the operation at unity power factor or close to unity power factor to draw maximum amount of real power from utility grid with less distortion in current to minimize the power quality impact on grid. The battery charger should be designed according to IEEE-1547, SAE-J2894, and similar standards such that the amount of harmonic and dc current injected into the utility grid must be controlled within the preset limit.[7]

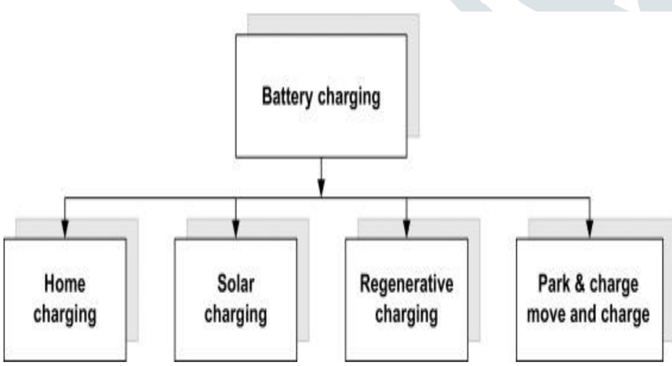

Figure12- Multiple options for charging of BEVs/PHEVs

A variety of PEC (Configure Enterprise Communicator) configurations and control methods have been developed as BEVs/PHEVs battery chargers, which includes single-stage and multistage power conversion.

Single-stage conversion (ac/dc) configuration suffers with large low-frequency ripple in the output current, and hence, its application is limited to lead-acid batteries only.

Multistage conversion configuration (ac-dc and dc-dc) inherently offers low-voltage ripple and relatively high-power rating and hence is suitably adopted for lithium-ion and Ni-MH batteries, which are being used in PHEVs

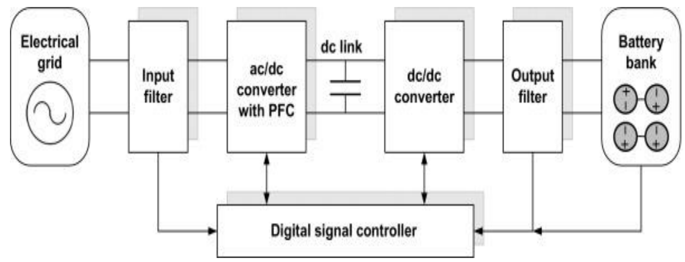

Figure13- Simplified diagram of universal battery charger.

Charging type	Charger location	Charger interface	Power rating (kW)	Charging time (h)	Vehicle technology
Type-I	Onboard 1-phase	Home outlet	1.4 (12 A) 1.9 (20 A)	4–11 11–36	BEV(5–15 kWh) PHEV (16–50 kWh)
Type-II	Onboard 1-phase	Dedicated public or private outlet	8 (32 A) 19.2 (80 A)	1–4 2–6	BEV(5–15 kWh) PHEV (16–30 kWh)
Type-III	Off-board 3-phase	Dedicated commercial outlet	50 100	0.4–1 0.2–0.5	BEV(20–50 kWh)

Table-4, Charging types and power level

Battery chargers for BEVs/PHEVs can be classified as follows:

I. On-board and off-board charger
II. Unidirectional and bidirectional charger
III. Integrated charger
IV. Inductive charger

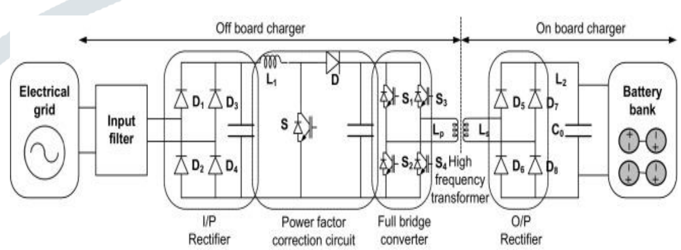

Figure14- Classification of conventional battery charger topology

At present, the onboard chargers face constraints on weight, volume cost, and space over specific power capacity of the battery. To overcome the abovementioned problems, charger configuration with integrated propulsion inverter-motor drive has been proposed [93,94]. The concept of integrated charger is feasible only if the vehicle is at rest. In an integrated charger, the propulsion inverter serves as a bidirectional ac/dc converter, and motor windings are used as filter inductors. Low cost, high-power-density bidirectional power flow, and fast charging with unity power factor are the advantages of the system. However, extra component requirement and control complexity are some of the challenges in its successful implementation. The schematic of a typical single-motor- and single-converter-based integrated charger system is shown in Fig.

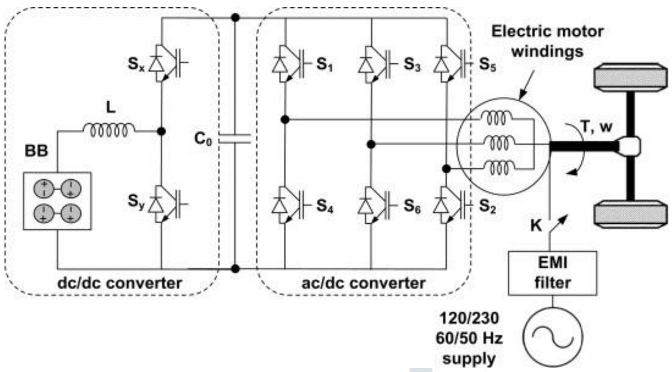

Figure 15- Typical structure of integrated BEV charge

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