E-Vehicle Charging Infrastructure Based on Inductive Wireless Power Transfer Scheme

Chetan Gadge
PG Student
Department of Electrical Engineering
Matoshri College of Engineering and Research Centre, Nashik

Dr. S. S. Khule
Associate Professor
Department of Electrical Engineering
Matoshri College of Engineering and Research Centre, Nashik

Abstract- With regards to the future transport arena, electric vehicles (EVs) are considered as the likely replacement of internal combustion engine driven vehicles, especially given the CO_2 reduction and alternative energy perspectives. It is extremely useful as a metropolitan mode of transportation.
For the success of E-vehicle, establishment of an easy and fast charging station is the ultimate requirement. Wireless power transfer technique adapted with resonant Inductive scheme provides an effective way of implementing the charging station. In this study, a conclusive study of Charging infrastructure is done with a major focus on the use of Inductive power transfer based wireless charging method.

Keyword – E-Vehicle, Charging Station, Wireless Charging, Inductive power transfer

I. INTRODUCTION

Electric cars have the potential to reduce carbon emissions, local air pollution and the reliance on imported oil. In Europe, the European commission aims to reduce road transport emissions by 70% by 2050 [1]. Taking into account the fact that road transport is expected to double by 2050, passenger cars need to reduce their emissions significantly. Advanced internal combustion engine (ICE) technologies are expected to enable emissions reduction, but are not expected to meet long term targets. Electric vehicles, especially plug-in ones (PEVS), [2] are penetrating the market and they are currently counted as zero emissions vehicles. Electric vehicles (EV) are evolving fast in current times, and there are numerous motives for the scenario. The most significant one is their exposure to reducing emissions of greenhouse gases (GHGs).[3] In 2009, 25 per cent of GHGs generated by energy-related sectors were exported by the transport sector [4]. An EV is smooth, pleasant to run, which does not have the cost of fuel associated with conventional automobiles.

The International Electro technical Commission's Technical Committee 69 (Electric Road Vehicles) indicates that cars using various combinations of power sources, battery devices or converters should be referred to as HEVs as long as at least one of them provides electricity. [5] For HEVs, such as ICE and battery, battery and flywheel, battery and resistor, battery and fuel cell, this concept makes several combos feasible. Such colloquial expressions have become widely understood and EVs can be categorized according to the same standard as shown in:

- Battery Electric Vehicle (BEV)
- Hybrid Electric Vehicle(HEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle (FCEV)

II. VEHICLE CHARGING INFRASTRUCTURE

For EVs to succeed, it is important to implement a charging infrastructure that responds to the needs of EV driver's and allow everyone the so essential mobility. The charging infrastructure can be seen as the energy and economic transaction needed to support the viability of EVs. The infrastructure can be divided into parking charge and ongoing charge. The focus of this study is mainly on fast charging station as a part of the ongoing charge process.

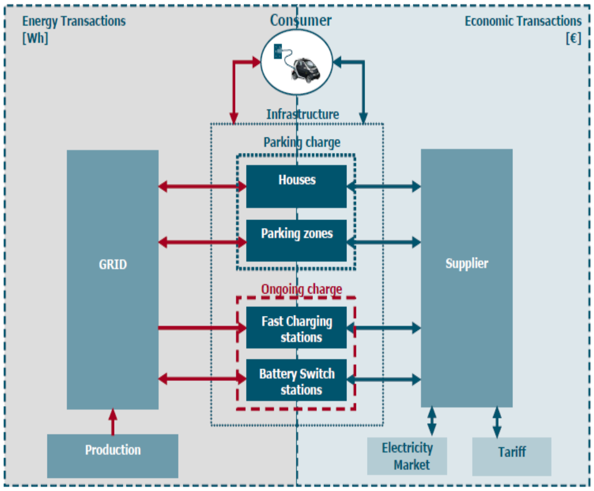

Fig 1 - Electric vehicle's infrastructure diagram

Fast charging points must offer charging power levels of up to 350 kW and guarantee the charging of vehicle batteries with differing battery voltages and capacities. Powerful multipoint charging stations for long-haul electric traffic with several charging points will require their own medium voltage connection. In contrast to AC charging stations, which are connected to the vehicle for many hours, DC charging stations do not need to provide regenerative feed-in capability out of the vehicle's battery into the energy network (V2G function). For a high degree of network friendliness, peak load management, and ride-through capability during brief power losses, these charging stations can optionally offer the integration of battery banks and solar power plants. If these also have to contribute to support of the supply network, the charging station must be equipped with a negative feed capable AFE (Active Front End) mains rectifier. From today's perspective, an increased charge current of 350A will be possible with future battery technology using liquid-cooled charge plugs. This means that an operating range of 400 km could be achieved with a charge voltage of 1000 V within about 11 minutes.

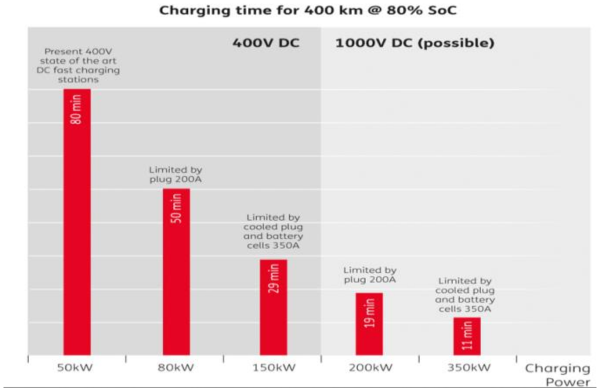

Fig 2 - Charge times for a travel distance of 400 km

There are two possible architectures suggested for the placement of vehicle charging scheme:

a) Parking charge

Parking charge can be defined as the charging process that happens when the EV is parked for some time, like at houses, offices, parking lots, shopping centers, etc. In these types of places, it is expected to be used a normal outlet. But not everybody has a garage or a dedicated place to charge an EV. This means probably that an infrastructure of outlets is also necessary along the curbs of cities and towns, parking lots, shopping centers, offices, etc, to give the possibility for everybody to charge their EV while parked.

b) Ongoing charge

An ongoing charge can be defined as the fast process to charge EVs that intend to support charging on long distances journeys and provides a similar function as the gas stations. There are, for now, two main possible infrastructures that can perform this objective: battery switch stations and fast charging stations.

III. SCHEMATIC OF FAST CHARGING STATIONS

Fast charging stations are one possible way to charge an EV in a fast process and when the driver is not at home and has not arrived to the destination. Fast charging is for commercial and public applications and is intended to perform similar to a commercial gasoline service station. It typically uses an off board charge system serviced by a 480-VAC, three-phase circuit.

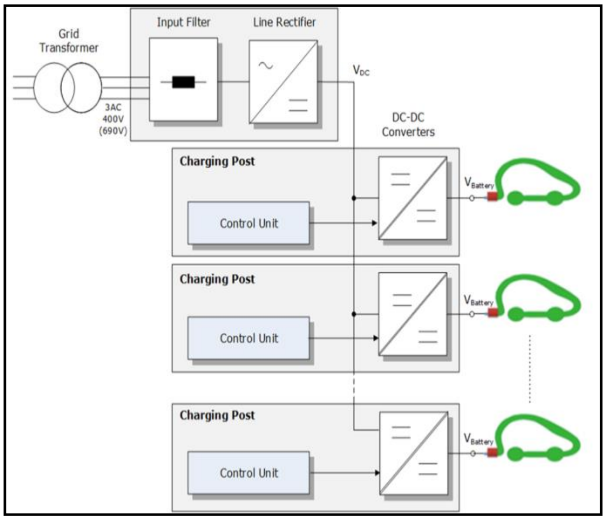

Fig 3 - Charging station configuration

In practice, equipment sizes can vary from 50 to 150 kW, and if battery EVs achieved a 50% charge in 10 to 15 minutes, this is considered to meet the intent of fast charging [3]. But still 15 minutes is a while to wait compared to filling up at a gas station in less than five. There are some ideas suggesting that companies like coffee shops or shopping centers should get into fast charging, creating charge stations in their parking lots so that people can charge up while using their services. So it appears that the opportunity exists for somebody to enter the fast-charging business, or partner with a fast-charging provider.

IV. METHODS FOR POWER HANDLING IN FAST CHARGING SETUPS

The various power transfer schematics that are idealized for a fast charging station include:

1. Use of Active front end mains rectifier for Power Transfer

To minimize phase effects on the system, the mains rectifier can also be configured as an IGBT-based AFE rectifier without energy recovery from optional energy storage units. As this functions as a step-up converter, only step-down converters are required in the charging points, even if high battery voltages have to be generated from low input voltages.

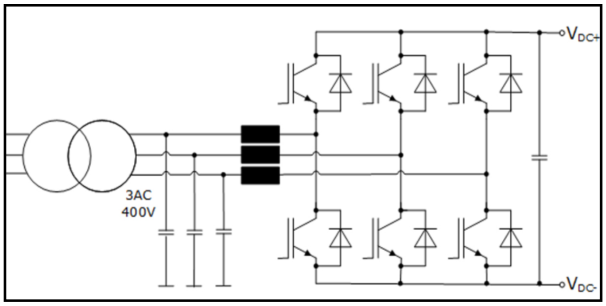

Fig 4- AFE mains rectifier

2. Use of DC-DC converter with galvanic isolation

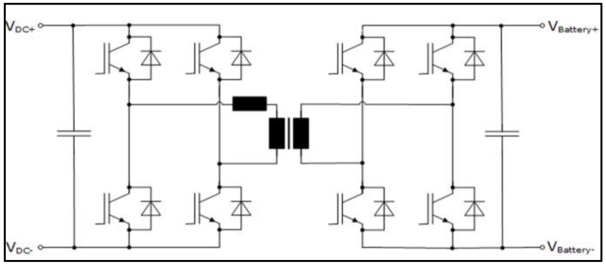

Fig 5 - DC-DC converter with galvanic isolation (Dual Active Bridge)

To minimize the isolation cost in the vehicles, the charging voltage must be galvanically isolated from the supply voltage. In charging points with their own mains connection, this can be done with the mains transformer as shown in Fig. 2. Alternatively, galvanic isolation inside the DC-DC converter provides the advantage that very small transformers can be used due to the high switching frequencies. This is essential in the case of charging points in a charging station with a central rectifier. Another advantage of a high switching frequency in the DC-DC converter is the decreased smoothing requirement for the battery-side output for an increasing switching frequency.

3. Wireless charging

The charging process can also be performed wirelessly by means of inductive power transmission using an air gap between two opposing resonant circuits in resonant mode. The primary winding is located in the floor panel and the secondary winding on the underside of the vehicle. As the air gap can be 150 mm or more, the power transmission takes place at frequencies of between 10 and over 100 kHz. A possible topology for power transmission is one high frequency H-bridge in the charging station and one in the vehicle. If the primary and secondary coils are close enough, the two H-bridges operate in resonant mode.

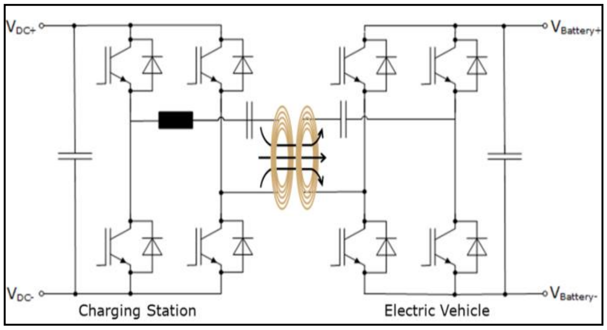

Fig 6 - Circuit diagram of power transmission with wireless charging

The transmittable power and efficiency are limited by the magneto-motive force of the winding and by the quality and coupling factor of the resonant circuits. As this is less than 20 kW with efficiency of about 80% in today's applications for passenger cars, the technical cost is significantly higher than for wired charging. These factors ensure that wireless charging is still a niche solution for now.

V. INDUCTIVE POWER TRANSFER FOR WIRELESS CHARGING SCHEME

Implemented through Inductive Power Transfer, the wireless charging for car drivers is convenient as far as safety and comfort are concerned: the user should not be worried about handling power cords, thus avoiding the electrocution risk, and could park the car in proper spaces, so that the charging operation can automatically start. The coils are generally placed in the following way: the one connected to the grid is placed on the ground and the other one, connected to the battery, is placed in the bottom of the vehicle chassis. The minimum power level for electric car charging is generally 3 kW. Different examples of commercial wireless charging stations for electric cars can be provided, since the EV companies are increasingly interested to this innovative charging technology.

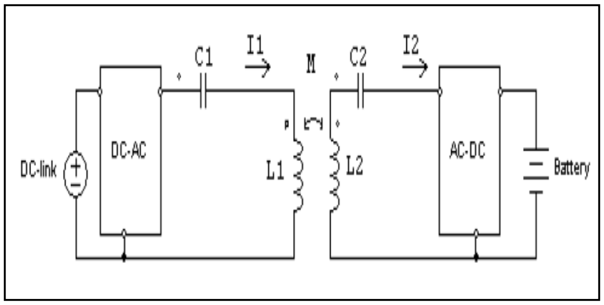

Fig 7- A typical schematic of an IPT system

For battery charging applications, the electrical power flows from the DC-link to the battery. The inductive power transfer occurs between two magnetically coupled coils. Their self-inductances are L1 and L2; the mutual inductance is M. L1 and L2 correspond respectively to the primary and the secondary coil. The primary-side DC voltage source is connected to the electrical grid; the secondary-side DC section is the load representing the battery to be charged. Since the power transfer between the coupled coils is in AC, two intermediate stages are needed: a DC-AC in the primary side and an AC-DC in the secondary side. Since the coils are loosely coupled, a reactive network is needed in order to maximize the power transfer efficiency and to optimize the power factor, if the system works at the resonance. This reactive network is named compensation circuit and includes two capacitors, one for each side. In the example of the figure, both the compensation capacitors C1 and C2 are connected in series with the primary and the secondary coils. The schematic is shown in figure 7.

VI. BENEFITS OF IPT BASED WIRELESS CHARGING

Based on studies and outcomes of many demo models conducted in many research areas, it can be concluded that use of IPT based wireless power transfer scheme for charging Electric vehicle can be advantageous with respect to the following:

- Full autonomy: The application of autonomous vehicles is yet to be fully realized because they are still being developed. However, if there is no need to stop in order to charge autonomous vehicles, they can move indefinitely – or at least until repairs are needed. This may increase the scope and efficiency with which they can be utilized
- Charging station not required: There is no need to insert a cable with wireless charging, which means it’s a more user-friendly approach. You can go about your day without even thinking about charging the car and it will automatically take care of itself
- Smaller battery units: The increase in charging points means the size of the battery pack can be reduced. This reduces the cost and weight of the vehicle

VII. CONCLUSIONS

Electric vehicle fleets require very different charging infrastructure from the existing infrastructure built for passenger cars. The rising population of electric vehicle demands newer ways of fast charging schemes, Different segment of vehicles (2W, 3W, PVs, CVs) may require a different type of charging standard With new battery technologies, like solid-state lithium-ion batteries, sodium-ion batteries and silicon-based batteries under development, charging ecosystem is expected to be disrupted. Inductive power transfer scheme for wireless power transfer provides a beneficial option for developing an easy and effective power transfer infrastructure for charging batteries.

VIII. REFERENCE

[1] Reddy KJ, Sudhakar N. “A new RBFN based MPPT controller for grid-connected PEMFC systemwith high step-up three-phase IBC”,. Int J Hydrogen Energy 2018;43(37):17835e48.

[2] Wang MH, Yau HT, Wang TY, “Extension sliding mode controller for maximum power point tracking of hydrogen fuel cells”, In: Abstract and applied analysis. vol. 2013; 2013

[3] Aouzellag H, Ghedamsi K, Aouzellag D, “Energy management and fault tolerant control strategies for fuel cell/ultracapacitor hybrid electric vehicles to enhance autonomy, efficiency and life time of the fuel cell system”, Int J Hydrogen Energy 2015;40(22):7204e13.

[4] Ahmadi S, Abdi S, Kakavand M, “Maximum power point tracking of a proton exchange membrane fuel cell system using PSO-PID controller”, Int J Hydrogen Energy 2017;42(32):20430e43.

[5] Kim J-S, Choe G-Y, Kang H-S, Lee B-K, “Robust low frequency current ripple elimination algorithm for grid-connected fuel cell systems with power balancing technique”, J Renew Energy 2011;36:1392e400.

[6] G.J. Offer, M. Contestabile, D.A. Howey, R. Clague, N.P. Brandon, 2011, Techno-economic and Nbehavioral analysis of battery electric, hydrogen fuel cell and hybrid vehicles in a future sustainable road transport system in the UK (Energy Policy, vol 39, issue 4) p. 1939

[7] A. Sakti, J.J. Michalek, 2015, A techno-economic analysis and optimization of Li-ion batteries for light-duty passenger vehicle electrification (Journal of Power Sources, vol 273) p. 966

[8] C. Alaoui, 2013, Solid-State Thermal Management for Lithium-Ion EV Batteries (IEEE Transactions on Vehicular Technology, Vol 62, issue 1) p. 98

[9] A, Lajunen, J. Suomela, 2012, Evaluation of Energy Storage System Requirements for Hybrid Mining Loaders (IEEE Transactions on Vehicular Technology vol 61, issue 8) p. 3387