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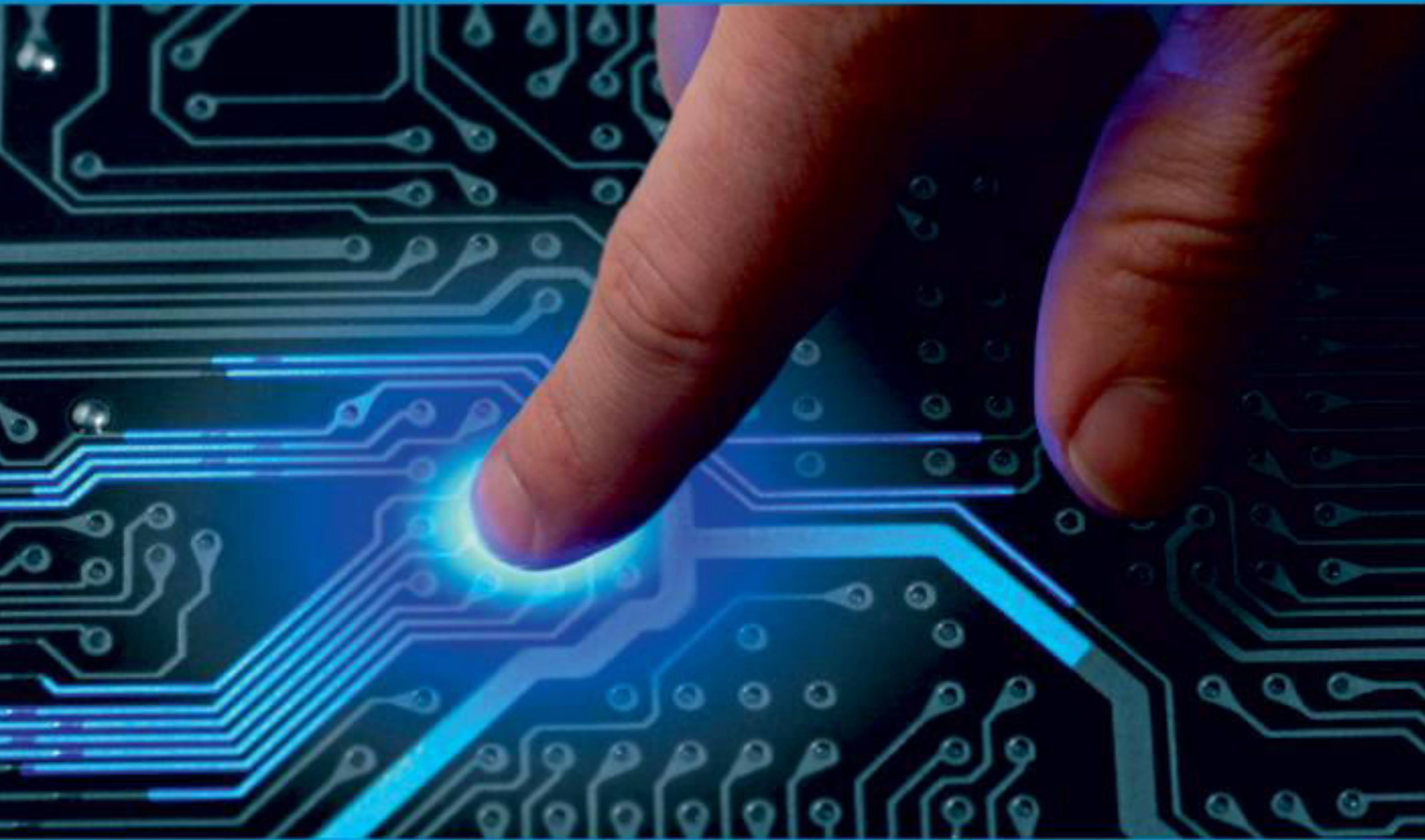

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Analysis of Fast Charging Methods of Battery

Mrs.Sonali Fapal, Prof.Gawade Shashank

MIT School of Engineering, MIT Art, Design & Technology University, Pune, India[1,2]

ABSTRACT: Recent transportation is operating on fossil fuel. Now there is a need to substitute fuel for conventional vehicles with electrical vehicles. There are so many reasons to adopt electric vehicles, like environmental benefits due to less pollution, making the country independent of foreign countries for its fuel needs, and to achieve the target of the EV30@30 goal. In the case of daily commutes by electric vehicle, level 1 and 2 chargers can charge vehicles, but for longer distances, the adoption of electric vehicles has a major worry regarding range anxiety. To overcome this, India needs to work on the various technologies to charge electric vehicles faster. Her reviewed various fast charging methods for electrical vehicles in the fast-charging. Fast charging advantages and disadvantages are also studied. Its impact on the power grid customized EV policies for India and their impact on Indian economic growth, empowerment, and employment.

KEYWORDS: Electric vehicle, fast charging method CC-CV, CP-CV, MCC-CV, Pulse Charging, Boost charging, VCP, Environment, policy.

I. INTRODUCTION

One of the big obstacles to electric vehicles (EVs) adoption is just range anxiety and charging vehicle every day for 7 to 8 daily. One more problem is that long range journey it's difficult to charge frequently and for longer duration. As the of EVs moving on the road increasing with time government also taking lots of initiatives to increase EVs on road, mostly because environment safety and energy preservation are chiefworries these days. Increasing e-mobility is asignificantpart on the road to avoid carbon dioxide pollution. Government rules to encourage the usage of EVs are a keyaspect in the increase of EV productions by various corporations. The automotive companies are growing fast with time and theirnumber of EV models offeredto customer is increased [1].A big alarm for the society Currently is global warming and its significances signify. In 2015, road transference showed the 18,8% total EU-28 greenhouse gas emissions in EU countries[2]. According to [3], Market has had an aggressive development in the last years for the electrical vehicles, and some European and US based car companies have promised to go all electric over the next four years. Still, there are some majorcommon barriers that must be overcome to get the expected BEV market acceptance, those are

- Charging time is approximately 8-10 hours
- They are costly
- Driving range is limited
- Lack of charging Infrastructure
- Difficulty in finding a mechanic.
- Limited vehicle choice

As electric charging grows to provide electric vehicle entree to a wide and dependable infrastructure, energy systems will need to be ready to source the extra power required. Current days EVs effortlessly top the 200-miles dent of range being provided by their battery making the "poor range" factor less of aobstacle as progresses are being made in the EV battery technology. With additional 350 new, feature packed EV models to debut the car marketplace by 2025. The factor of suitable and fast charging is gradually becoming the importance of consumers as well as the EV makers. As e-mobility continues to nurture charging solutions and packages have been launched by several energy suppliers[1].

The charging infrastructure is collected of an operating structure, customer data and identification system and charging system. Between these, the charging system is most crucial and integral element of the charging infrastructure. The charging system needs to be well-matched with the EV battery system. Battery charging can be classified as either a fast charger or slow charger that is depend on the power handling capacity. EV slow chargers' charges with power 1.3 to 4 KW power so it takes 7 to 9 hours to get complete battery charge. Because of this reason slow chargers are good for daily commute you can plug in vehicle to house hold grid during night time and charge.

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Longer journey more than 500KM distance or beyond range of one charge battery capacity. While have a break for lunch or dinner or any snacks break vehicle need to charge. This can be possible by fast charger; fast charges can charge though power range of 50KW to 100 KW.Every EV manufacturer in view of ideal battery size for a specified range.They design or select the battery that can take high charge current and charge vehicles fast that create necessity of fast charging infrastructure. The fast charger can be fitted in public places like highwayrestaurants, petrol pumps, mall, parks. The chargers fundamentally create power quality problems in view of non-linear devices in it and will be more projecting with the usage/acceptance of EVs. The power quality issues arise in terms of current harmonics ,voltage harmonics, power factor including low poor power quality may arise[7]. The concern of charging the electrical vehicle battery and is considered as one of the technological developments in EV domain.Conductive charging is currently used worldwide, again it is divided in to two AC and DC charging. While the inductive charging has happened, it has still not been standardized yet. On the other hand, battery swap technology is something which we hope to have in the future and currently used for 2-wheeler sector.Mr. Navpreet Hans & Mrs. Shikha Guptahave investigated Trends In Electric Vehicle (EV) Charging and Key Technology Developments which is review of EVs. As the Electric Vehicle (EV) sales are increasing day by day; a heavily electrified mobility is holding a promising future. With long-range Electric vehicles becoming a reality, the time consuming and inconvenient process to charge an EV is slowly becoming a major hurdle for consumers to accept the e-mobility revolution the auto industry is going through. This paper reviews the current state of the art technology used to charge an EV, the types of chargers being used in the different regional auto markets and the key future developments being made in the charging field to make the charging experience of an EV owner less time consuming and effective. Camilo Suarez & Wilmar Martinez investigated Fast and Ultra-Fast Charging for Battery Electric Vehicles – A Review. Intends to establish an overall up-to-date review on Fast Charging methods for Battery Electric Vehicles (BEV). This study starts from basic concepts involving single battery cell charging, current and future charging standards. Then, some popular power converter topologies employed for this application are introduced, and finally a summary of the industrial solutions available on the market are presented, as well as the ongoing projects related to the extreme fast charging (XFC) network expansion. Practical insights, considering the current BEV scenario, are employed to get a better understanding of this topic. Special attention is given to the modular design approach, analyzing its advantages and some of the factors that influence the number and size of modules that conform a fast charger solution. Mohan P. Thakre & Yogesh investigated Fast Charging Systems for the Rapid Growth of Advanced Electric Vehicles (EVs).The aim of project is give the exact view by check the Various sources of energy available to mankind.This study provided facts on rapid charging station infrastructure, why fast charging is good and its impact on distribution grid systems, customized India's EV policy, made them economically viable, and their impact on economic growth and employment, along with areas of improvement. In the decades ahead, oil-based transport will not sustain the world. Developed methods are emerging to start moving the global community to feasible electric transport. Here highlighted the development of fast charging stations and the government's interest in making EV accessible for use in every job. Innovations would be streamlined as well as standards will also be developed with ongoing charging research, that would encouraging creative adoption and Implementation of EVs , contributing to another more country 's development.Gautham Ram Chandra Mouli& Prasanth Venugopalinvestigated Future of Electric Vehicle Charging. Work focused on five technologies that will play a fundamental role in this regard: smart charging, vehicle-to-grid (V2G), charging of EVs from photovoltaic panels (PV), contactless charging and on-road charging of EVs. Smart charging of EVs is expected to enable larger penetration of EVs and renewable energy, lower the charging cost and offer better utilization of the grid infrastructure. Bidirectional EV chargers will pave the way for V2G technology where the EV can be used for energy arbitrage and demand-side management. Solar charging of EV will result in sustainable transportation and use of the EV battery as PV storage. Lt. Col Pankaj Kushwaha& Dr. Asha Gaikwad studied Review: Li-ion Batteries: Basics, Advancement, Challenges & Applications in Military. Study made on Li-ion battery technology has become very important in recent years as these batteries show great promise as power source. The power most of today's portable devices and seem to overcome the psychological barriers against the use of such high energy density devices on a larger scale. Lithium-ion batteries are being widely used in military applications for over a decade. These man portable applications include tactical radios, thermal imagers, ECM, ESM, and portable computing. In the next five years, due to the rapid inventions going on in li-ion batteries, the usage of lithium batteries will further expand to heavy-duty platforms, such as military vehicles, boats, shelter applications, aircraft and missiles. The aim of this paper is to review key aspects of Li-ion batteries, the basic science behind their operation, the most relevant components, anodes, cathodes, electrolyte solution as well as important future directions for R&D of advanced Li-ion batteries for demanding use in Indian Armed Forces which are deployed in very harsh conditions across the country.Anna Tomaszewska&Zhengyu Chu studied proposed study regarding fast charging impact on lithium-ion battery. In the recent years, lithium-ion batteries have become the battery technology of choice for portable devices, electric vehicles and grid storage. While increasing numbers of car manufacturers are introducing electrified models into their offering,

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range anxiety and the length of time required to recharge the batteries are still a common concern. The high currents needed to accelerate the charging process have been known to reduce energy efficiency and cause accelerated capacity and power fade. Fast charging is a multiscale problem, therefore insights from atomic to system level are required to understand and improve fast charging performance. The present paper reviews the literature on the physical phenomena that limit battery charging speeds, the degradation mechanisms that commonly result from charging at high currents, and the approaches that have been proposed to address these issues. Special attention is paid to low temperature charging. Alternative fast charging protocols are presented and critically assessed. Safety implications are explored, including the potential influence of fast charging on thermal runaway characteristics. Finally, knowledge gaps are identified and recommendations are made for the direction of future research. The need to develop reliable onboard methods to detect lithium plating and mechanical degradation is highlighted. Nitin Trivedi & Nikhil S studied different fast charging methods and topologies for EV charging. Compared four different topologies based on their MATLAB simulations.Topology 1 is the easiest in implementation and also the most robust topology but the battery current ripple is more and also the power factor is low. In topology 2, better control is achieved and the power factor is also high but it is costlier due to the high-power rating components like high frequency transformers and diodes. In topology 3, twelve pulse diode bridge is replaced by six pulse SCR bridge and full bridge DC-DC converter remains same. The input power factor is low and also the cost implication is same as topology 2. Based on the comparison of all the topologies, topology 4 comprising of twelve pulse diode bridge rectifiers 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 above all better control over battery parameters.ZhenGuo, Bor Yann Liawstudied optimal charging method for lithium-ion batteries using a universal voltage protocol accommodating aging. An effective optimum charging technique made for lithium ion batteries using a universal voltage protocol(UVP) that can accommodate cell aging is presented here. This charging method demands less learning tovarying state-of-health (SOH) conditions with potential to improve charging efficiency and cycle life. Thesimplicity of UVP makes the implementation easier than the conventional constant currenteconstantvoltage (CCCV)-based methods. Here, the mathematical formulation, optimization targets (e.g. minimaltime) and constraints (terminal voltages and other instrumental and cell electrochemistry-limited ones)are explained from the protocol design considerations. An equivalent circuit model was used and itsparameters derived from the analysis of test data, which could yield a nonlinear varying current profile(VCP) by simulation and a genetic algorithm-based optimization. Both UVP and VCP were used in thevalidation to illustrate better charging efficiency and capacity retention, which showed a much-improvedcycle life.

Combining an Electrothermal and Impedance AgingModel to Investigate Thermal Degradation Caused by Fast Charging:

Fast charging is an exciting topic in the field of electric and hybrid electric vehicles (EVs/HEVs). In order to achieve faster charging times, fast-charging applications involve high-current profiles which can lead to high cell temperature increase, and in some cases thermal runaways. There has been some research on the impact caused by fast-charging profiles. This research is mostly focused on the electrical, thermal and aging aspects of the cell individually, but these factors are never treated together. In this paper, the thermal progression of the lithium-ion battery under specific fast-charging profiles is investigated and modeled. The cell is a Lithium Nickel Manganese Cobalt Oxide/graphite-based cell (NMC) rated at 20 Ah, and thermal images during fast-charging have been taken at four degradation states: 100%, 90%, 85%, and 80% State-of-Health (SoH). A semi-empirical resistance aging model is developed using gathered data from extensive cycling and calendar aging tests, which is coupled to an electrothermal model. In this study presents Joris de Hoog & Joris Jaguemont et.al did a modeling methodology that is usable to predict the potential temperature distribution for lithium-ion batteries (LiBs) during fast-charging profiles at different aging states, which would be of benefit for Battery Management Systems (BMS) in future thermal strategies

Salman Habib & Muhammad Mansoor Khan studied a Comprehensive Study of Implemented International Standards, Technical Challenges:

Inspects the present status, latest deployment, and challenging issues in the implementation of Electric vehicles (EVs) infrastructural and charging systems in conjunction with several international standards and charging codes. It further analyzes EVs impacts and prospects in society. A complete assessment of charging systems for EVs with battery charging techniques is explained. Moreover, the beneficial and harmful impacts of EVs are categorized and thoroughly reviewed. Remedial measures for harmful impacts are presented and benefits obtained therefrom are highlighted. Bidirectional charging offers the fundamental feature of vehicle to grid technology. In this paper, the current challenging issues due to the massive deployment of EVs, and upcoming research trends are also presented.

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Smart Electric Vehicle Charging System: Proposed the design of a system to create and handle Electric Vehicles (EV) charging procedures, based on intelligent process. Due to the electrical power distribution network limitation and absence of smart meter devices, Electric Vehicles charging should be performed in a balanced way, taking into account past experience, weather information based on data mining, and simulation approaches. In order to allow information exchange and to help user mobility, it was also created a mobile application to assist the EV driver on these processes. This proposed Smart Electric Vehicle Charging System uses Vehicle-to-Grid (V2G) technology, in order to connect Electric Vehicles and also renewable energy sources to Smart Grids (SG). This system also explores the new paradigm of Electrical Markets (EM), with deregulation of electricity production and use, in order to obtain the best conditions for commercializing electrical energy.

Design considerations for fast AC battery chargers:

This paper writers ManueleBertoluzzo and Giuseppe Buja et.al considers the AC supply option and deals with the main issues that it poses like an onboard high-power battery charger and its impact on the grid. To face with these issues, a possible arrangement for the battery chargers consists in the integral use of the inverter bound to supply the traction motor and in the proper conditioning of the current absorbed from the grid. In the paper, design considerations for this arrangement are given and applied to the case study of a purely electric, mid-size car.

Writers MatjazKnez, & Gasper KozeljZevnik studied a review of available chargers for electric vehicles: United States of America, European Union, and Asia:

focused on the research of incompatibility of chargers for electric vehicles between different vehicle brands and types. The basics of electric vehicles and their charging are presented. A short overview of various countries' policies for these markets is included as regards promoting and favoring electric vehicles and standardizing the chargers. This study has revealed that the most common charger in the USA is J1772, in the European Union Mennekes and in China GB/ T. The number of J1772 and CHAdeMO chargers is decreasing rapidly, while Mennekes (which also has the highest share) and especially GB/T chargers are on the rise. China also made the most significant breakthrough in 2015 with GB/T as a leading charger type.

High Efficiency Electric Vehicle Fast Charging:

Electric vehicle fast charging station based on 3-level T-type topology offering much higher efficiency than other three-level inverter topologies. Using two voltage compensation algorithms simultaneously, the proposed charger keeps neutral point voltage constant and prevents grid current distortion during different DC loading scenarios. In addition to balancing the neutral point voltage by established modulation-based control methods, this research overcomes the conventional balancing method limitations by adding an auxiliary circuit to the T-type topology. This additional circuit which comes in the form of a new leg to the inverter and consists of nothing more than an inductor in comparison with the existing legs plays a significant role in DC-link voltage balancing functionality. Furthermore, a novel control method is proposed which manages the simultaneous application of the mentioned voltage balancing methods in an efficient and smart way.

Findings & Gap:

1. The idea of EVs is promising to address climate change by cutting down on carbon emission. EVs are being supported as the apparent substitute to fuel-powered cars; they are assured for a rapid growth phase with the blending outcome of longer range, lower battery cost and faster charging rate. However, the range and charging of EVs are still considerable concerns.

2. Fast charging for electric vehicles is a decisive green light to the prevailing acceptance of EVs. It could be a solution to consumers' range anxiety and the assurance of electric vehicles. The potential to recharge swiftly and efficiently is a critical demand for a storage battery. Likewise, a critical barrier to fast charging is temperature.

3. To be truly competitive with gasoline vehicles, EVs should enable a driver to recharge swiftly parallel to gasoline-fuelled vehicles. None of today's EVs, however, grant fast charging in low temperatures.

India needs good infrastructure to accommodate the following needs and fast charging can fill these needs.All the metro cities in India are polluted to reduce pollution and provide clean air.To make India independent from the gulf countries for fuel need.India has to achieve the goal of the EV30@30 campaign, which targets to have at least 30% EVs on the road by the year 2030.To keep fuel pricing under control.To reduce Range Anxiety of EV owners.Maximizing use of EVs on the road.Gaps and challenges in the adaption of fast charging.Higher losses in

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battery by the Fast charger and in battery (I2R).Only 70 to 80% battery can charge in fast charging. As C rate of charging is increases life of battery get decreases. Due to high ampere current requirement charger needs thicker and rigid cables are needed which are not good for handling due to less flexibility.The Standards of Fast Charging for Electric Vehicles. Battery Technology Gap & Lithium Plating. Thermal Management Systems. Economic and Infrastructure Issues. Convincing Utility Providers.Fast charging benefit to the electricity gridCharging stations requires electricity and this is managed by electricity grid. These grids play a valuable role in setting up the fast-charging stations. Most prospective charging terminals are connected to efficient medium-voltage distribution grids. It works to eliminate this same load from the susceptible lowvoltage grid.Large, fast charging stations to ten plus chargers have been capable of serving hundreds of cars each day, and yet necessitate only one grid connection. The above eases the cost of linking to grid firms significantly.

This same fast charging stations attached to a medium voltage grid are indeed very appropriate besides extra storage of batteries. On-site battery packs could even (a) increase the overall capacity of a station at peak periods (b) throughout aggregate, such batteries could even behave as just a large-scale adaptable asset for the grid operator.

Value of fast charging to renewable energy integration: Charging stations drags a ton of load on grid but that can be managed by adding renewable near to or with them. By connecting these extra sources for electricity generation and using them to charge them batteries helps to reduce the load from electricity grid. A stable and predictable load curve through the day tends to follow the requirement at fast charging stations.Fast charging mainly occurs during day, whenever the sun shines more and more and renewable energy has been generated. Fast charging could therefore immediately absorb an increasing supply of solar energy. Fast charging (which mostly happens naturally) does seem to be complementary to slow charging. Thereby, fast charging could really continue to enhance the total charging requirement over 24hrs. With even more self-driving EVs mostly on road in the coming years, a significance of embracing grid & renewable energy could be further increased. In order to optimize rapid charging for moments of high renewable output, completely autonomous EVs will react dynamically to price signals from fast charging stations.
India needs good infrastructure to accommodate the following needs and fast charging can fill these needs.

Conductive Fast Charging WorkingOn board Fast Charger (AC Fast Charger):

A typical electrical power train of an EV/PHEV that consists of a propulsion machine driver followed by a DC/DC converter, and an additional three phase on-board charger with input filters is illustrated in Fig. 2. Generally, a 6-switch topology is most likely to be chosen as motor inverter and a DC/DC two quadrant bidirectional converter is usually utilized to condition the power flow between battery and inverter. This DC/DC converter has capability of boosting battery voltage up to the operating limit range of the inverter in driving mode, and bucking the voltage across motor windings to an appropriate voltage level as to charge battery during regenerative braking. For charging battery with Level 3 charging rate, three phase active buck rectifier seems to be the most suitable AC/DC topology due to the fact that battery voltage is mostly chosen as not to exceed 480V. Therefore, there is no need to boost input voltage while charging battery. Taking advantage of these compatible voltages, charging power can be controlled by sensing battery voltage and charging current without need for a DC/DC converter, however, it is hard to regulate the power factor and the shape of the input current. Thus, an L-C input filter for each phase is strongly needed which adds up to the cost of the additional rectifier. These two addon components diminish the feasibility of possible use of a level 3 on-board charger. In other words, a cost-effective on-board charger configuration allowing a direct charge through three phase outlets is required to make fast charging more appealing and feasible.

Off-board charger(DC Charger)

EV charger transfers energy from the grid to the battery in a controlled way. This process of fast charging in controlled way can be in vehicle by using on-board charger, which is AC charging which is slow charging as compared to off-board charger. An off-board charging system takes incoming AC power and converts it to the DC power needed to charge the battery system.

The power of on-board chargers is restricted because of the space, cost, and mass limitations to some limited tens of kilowatts. This charging system lets the vehicle to be charged straight from conventional 1-phase or 3-phase AC systems, by using AC/DC converter controlling the DC output voltage and current. But the off-board chargers are not limited by space or mass, these chargers are placed outside the vehicles so higher power rating component can be used for converting ac to dc and rectified and required dc current and voltage provided by the demand. Fig. 1.2 shows a conventional fast charger topology arranged by an AC/DC converter, a DC/AC converter, a high frequency

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transformer and a rectifier. As showed, the output of the charger is coupled directly to EV on-board battery, providing a communication link between the charger and the BMS to control the safety procedures and charging process.

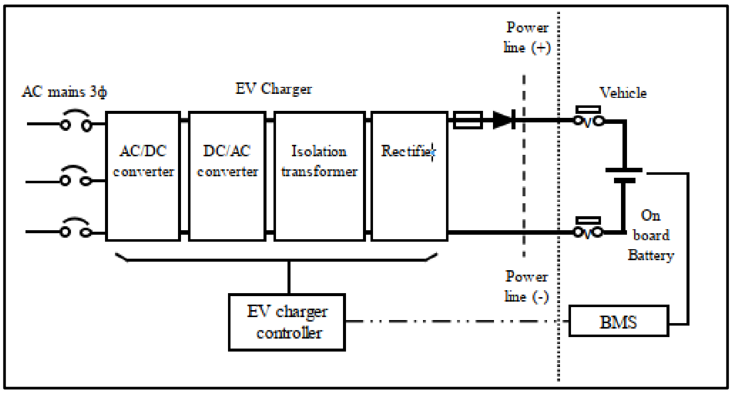

Fig 1. Battery cell model at charging process[2].

Different substantial parameters including impacts on the power grid, cost, equipment, location, total charging time, and the amount of power can be understood with the help of charging infrastructure and various charging power levels. There are many considerable issues that need to be discussed regarding deployment and development of charging infrastructure, and electric vehicle supply equipment (EVSE) such as:

1) Standardization of charging stations, 2) Time and Extent for charging, 3) Demand and Distribution policies, 4) Regulatory procedures. Cost and requirements for on-board energy storage systems can be reduced with the availability of charging infrastructure. The main components for EVSE are:Charging codes and Connectors for vehicle.Charge stands on public or residential locations.Various plugs required for attachment.Power outlets and protective equipment [9]

Two sets of configurations are mostly utilized to have all the above-mentioned equipment: a specific cord set, and a pedestal mounted box set. Basic configurations are changed from country to country and sometimes location may also affect the design based on various significant parameters to consider such as: connections of electrical grid, voltage, frequency and standards regarding transmission systems]. Generally, the expected charging time of EVs is an overnight duration at home by different EV owners as described by Electric Power Research Institute (EPRI)

Fast charging strategies are

1.Constant Voltage

In this method constant voltage is maintained across the battery. Initially it draws higher current but as the battery charges, the battery charging current tapers down. Such simple designs are often found in cheap car battery chargers. The lead-acid cells used for cars and backup power systems typically use constant voltage chargers.

2. Constant Current

In this method, constant current is maintained across the battery and the voltage is allowed to build up gradually. The charger is switched off as soon as the full charge [2] voltage is reached.

Pulse Charging:

In the charging mode the charging current in form of pulses [7] is applied to the battery. The charging rate (based on the average current) can be precisely controlled by varying the width of the pulses. During the charging process, the charging pulses are followed by short rest periods which allow the chemical actions in the battery to stabilize by equalizing the reaction throughout the bulk of the electrodes. This enables the chemical reaction to keep pace with the rate of inputting the electrical energy. This method can reduce unwanted chemical reactions at the electrode surface such as gas formation, crystal growth and passivation.

Negative Pulse Charging: This method is to be used along with the pulse charging method. During the charging rest period, very short duration discharge pulses (2 to 3 times of the charging current magnitude) are applied in order to depolarize the cell. These discharge pulses remove gas bubbles developed on the electrodes during the charging, which enhances the stabilization process and the whole charging process. The release and diffusion of the gas bubbles is known as "burping"[7].

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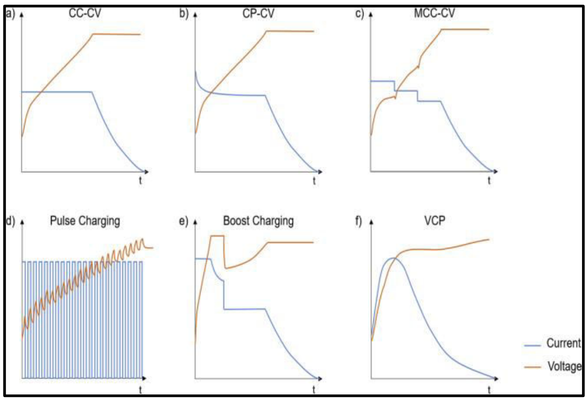

Fig.2Schematic representation of common types of charging protocols proposed for fast charging. a) Constant Current - Constant Voltage (CC-CV), b) Constant Power – Constant Voltage (CP-CV), c) Multistage Constant Current - Constant Voltage (MCC-CV), d) Pulse charging, e) Boostcharging with a CC-CV-CC-CV scheme, f) Variable Current Profile (VCP,based on Ref. [8]).

Boost Charging:

Boost-charging is characterised by high average current in the beginning of charge, followed by a CC-CV part with more moderate currents. The first, boost-charge stage could simply comprise a CC profile (making the protocol identical to MCC-CV), a CV profile where the cell is immediately brought to a set maximum voltage by means of high initial current (CV-CC-CV), or an entire CC-CV profile (CC-CV-CC-CV) The boost-charge stage should, in any case, allow higher currents or higher maximum voltage compared to the following CC-CV part in order to reduce the overall charging time [7] Interestingly, some of the boost-charging protocols seemed to achieve marginally better capacity utilisation at the beginning of life compared to the slower 1C CC-CV. It is, however, unclear whether this could be due to manufacturing differences as cell capacities were not measured by a standardised test at the beginning of life. Keil and Jossen [8] arrived at contradicting conclusions after experimentally comparing cycling data from three types of 18650 cells of different chemistries charged by CC-CV, boostcharging and pulse charging protocols. An increased rate of capacity fade was reported for boostcharging compared to CC-CV with a similar charging time, while no significant differences in capacity fade rates were observed for pulse charging. The authors concluded CC-CV was suitable for fast charging high power cells, however mentioning that MCC could be useful in conditions when lithium plating is likely to occur[6].

CC-CV:CC-CV method:a typical charging process of a single lithium battery cell is shown in Fig. 1.3a It consists of two stages. During the first one a constant current (CC stage) is applied to the cell, having as result a voltage increase from 3.0 V, associated with a depleted state, up to 4.2 V which corresponds to the nominal cell voltage. At this point the cell voltage is controlled to remain constant (CV stage) until the current reaches a value close to zero. The battery charging time can be reduced increasing the current employed during the CC stage. However, high currents can reduce the lifetime of the cell or cause permanent damage [15]. A simple analysis using a rough battery model, as the one presented in Fig. 1.2 a, shows that employing higher currents results in higher losses due to the internal cell resistance. These losses are basically expressed as a temperature rise in the cell, as described in [6]. Therefore, fast charging requires an adequate thermal management, maintaining the battery temperature within its safe operating area.

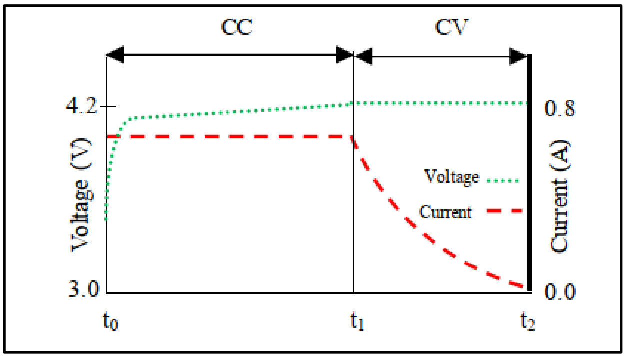

Fig 1.3 a Single lithium battery cell charging process, based on [2].

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CC = Constant Current, CV = Constant Voltage.

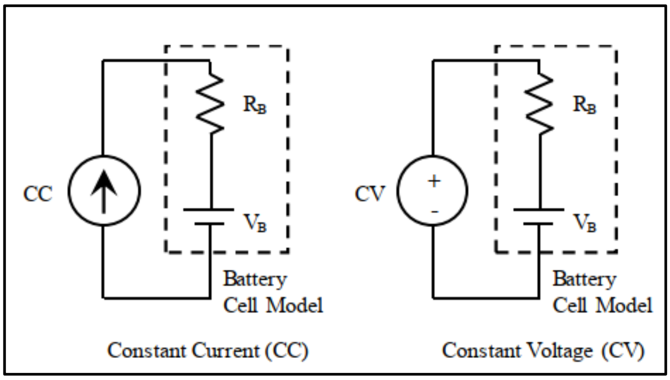

Fig 1.3 bBattery cell model at charging process[2].

Determining the right moment to end the CC stage of the charging process is another important aspect to be considered during fast charging. A high current implies a high voltage drop in the internal resistance of the battery, meaning that the actual cell voltage could be still far from its maximum. This could result in a premature start of the CV stage, increasing the overall charging time. On the other hand, extending the duration of the CC stage might lead to a cell overvoltage, which is also an undesired state. A lithium battery cell is a complex electrochemical system, and the estimation of its SoC can be done by measuring the cell voltage only under certain circumstances: no-load testing, and long rest periods. These conditions are not met during the charging process. However, an accurate estimation of SoC and other parameters like SoH are needed to determine the maximum charging current the battery can accept, as well as the end of the CC or CV charging stages. This task requires a dedicated independent system, often referred as the Battery Management System (BMS).

Nissan Leaf,As a case study, the Leaf electric car has been selected. Leaf, which is depicted in Fig. 3, is a 5-doors hatch back sedan manufactured by Nissan Company; it is propelled by a PM synchronous motor and mounts a Li-ion battery pack based on the NMC (Nickel, Manganese, Cobalt) chemistry.The characteristics of battery and motor found in data sheet are reported in italic type in Tab. 3, while the data in plain type are derived in next Subsection. The battery pack of Leaf is formed by 192 cells organized in 48 modules. The four cells of each module are placed in a 2-series x 2-parallel architecture so that the battery pack has a 96-series x 2-parallel structure. The cells have a nominal voltage of 3.7 V, a cut-off voltage of 3 V and can be charged up to 4.1 V without affecting their working life, the maximum value of the charging voltage being 4.2 V. Therefore, the battery voltage goes from a maximum value of 400 V to a minimum value of 250 V, with a nominal value of 345 V. Charging and discharging currents of a NMC-based lithium battery can reach 5 C in steady state and 30 C in pulse mode. Charging is accomplished via a port located at the front of the car. Completely replenishing the battery requires 4 hours via a 220 V socket-outlet with a 6.6 kW onboard charger (optional on the S,standard on the SV and SL trims) complying with Mode 2. An available quick charge port allows charging of the battery to 80% capacity in 30 minutes at public charging stations equipped with a DC Quick Charge (50 kW) complying with Mode 4.

AC battery charger & Charging process

In the framework of a project financed by the Italian Ministry for Industry, “Ricerca di Sistema”, which deals with electro mobility, an AC on-board battery charger arranged according to the scheme of Fig.1 and ruled to according Mode 3 has been studied for the Leaf, for comparative assessment with the standard Mode 4. Then, the maximum current that it can absorb from the AC charging station is 63 A. With an allowed excursion of the grid voltage from 360 to 440 V, the maximum power that the AC battery charger can draw varies from 39 kW to 48 kW, respectively.

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Battery pack	
Nominal voltage	*345 V*
Maximum voltage	*400 V*
Minimum voltage	*250 V*
Stored energy	*24 kW·h*
Maximum power	*90 kW*
Nominal current	69 A
Maximum current	360 A
Traction motor	
Peak power	*80 kW*
Peak torque	*280 N·m*

Table.1: Battery pack and motor characteristics.

From the data on the nominal voltage and the stored energy in Tab. 3, the nominal current of the battery results in about 69 A. When the maximum power is delivered at the minimum battery voltage, the current is 360 A, i.e. about 5 C that is just the upper limit of the NMC lithium chemistry. The same current value is expected for the maximum charging current.

Charging process : Normal charging of the lithium-ion batteryencompasses two zones, namely the constantcurrent zone (CC) zone, which can be travelled at the maximum allowable battery current, and the constant voltage zone (CV) zone, which is travelled at the maximum battery voltage. The two zones are sketched in Fig. 4, where VB is the battery voltage, VB,M is the maximum battery voltage, IB is the battery current, IB,M is the maximum allowable battery current and PB is battery power.

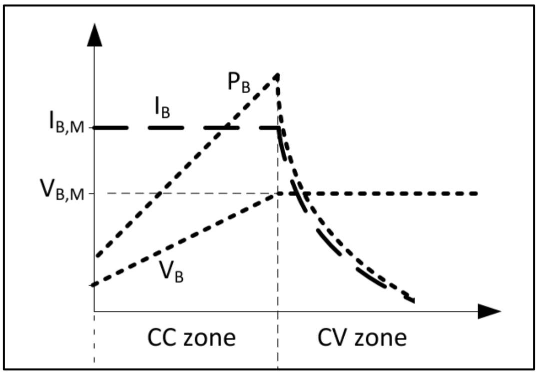

Fig 4. Battery voltage, current and power during the normal charging process[13]

In the case study, the battery cannot be charged at the maximum allowable battery current because this would require drawing a power greater than 43 kW from the AC charging station. Indeed, even by neglecting the losses in the AC battery charger and by drawing from the grid the maximum power of 48 kW, it comes out that the battery charging current ranges between 121 A and 168 A depending on the battery voltage. This means that the charging process is limited by the power of the AC charging station.

Profiles of the battery voltage, current and power during the charging process under power limitation are sketched in Fig. 5, where PAC is the AC charging station power. In the first zone, the charging process takes place at constant power, equal to the power of 43 kW, and this is obtained by decreasing the charging current as the battery voltage increases. As for the normal CC charging, the charging process in this zone ends when the battery reaches the maximum voltage. Travelling this zone takes a longer time than in the normal charging due to the lower charging current

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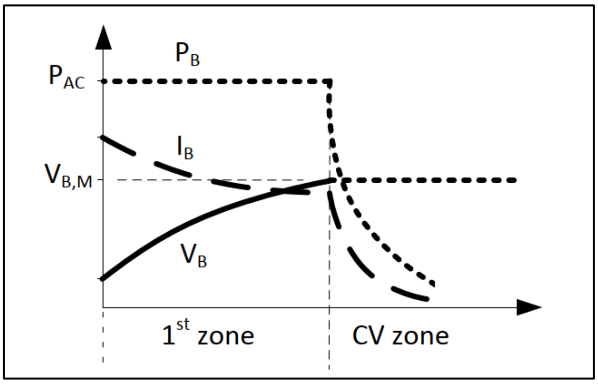

Fig 5. Battery voltage, current and power during the charging process with limited power[13].

Global EV DC Fast Charger Market ;The report study has analyzed the revenue impact of the COVID -19 pandemic on the sales revenue of market leaders, market followers, and market disrupters in the report, and the same is reflected in our analysis.

Market Dynamics : The exciting vehicles pollutes the environment due to carbon emission and the electric vehicles is promising to address climatechange lowering the carbon emission, is a factor which increase the demand of electric vehicles which directly increase the sales of EV DC fast charger market. In addition, the demand for rapid charging for long-distance journeys is also fueled the growth of the EV DC Fast charger during the forecast period. Furthermore, the initiative taken by the several nations for adoption of pollution free vehicles in order stop carbon emission are likely to initiative the installation of the more DC charging station. The adoption of electric vehicles across the global also helps to drive the EV DC fast charger market. These are the key factors which anticipated to propel the EV DC fast charger market during the forecast period. However, higher the installation cost of DC fast charging station hampers the market during the forecast period. The use of DC fast chargers requires electric infrastructure and these chargers are not cheap which is not possible for every nation which hamper the growth of the market. The DC fast charger requires additional insulation, which may add mass and volume to electrical components, connectors, and cables of the vehicle, increase overall cost of vehicle which restrain the growth of the EV DC fast charger market during the forecast years. As we move to renewable energy, the convenience provider change the business strategy are the major challenge of this market.

Market Segmentation: The Global EV DC Fast Charger Market can be segmented by Type, by Charging Power, by End-user, and by region. Based on Type, the Global EV DC Fast Charger Market is segmented intoCHAdeMO, SAE Combo Charging System (CCS), and Supercharger.CHAdeMO segment is subjected the highest CAGR during the forecast period as it offers quick and fast EV charging speed and above. Based on the charging power the EV DC Fast charger is segmented into Below 100 KW, 100-200 KW, and above 200KW. The 100-200KW segment leads the global EV DC fast charger market as likely to expand the growth rate due to rise in adoption of fast charging station. Based on End-user, the market is segmented into Home charging unit and Public charging station. The public charging station segment is expected to grow during forecast period as it is mostly found across the highways and expressways.

Regional Analysis:Geographically, the global EV DC Fast Charger market is classified into five major regions namely North America, Europe, Asia-Pacific, Latin America, and Middle East and Africa.Asia Pacific dominate theGlobal EV DC Fast Charger Market, followed by the Europe. High rate of adoption of electric vehicles in emerging countries like India, Japan, and China. The key player Tesla is enter India when the government is pushing the India automotive companies to expedite the EV manufacturing, so the demand of EV DC Fast charger is also increase in this region. The objective of the report is to present a comprehensive analysis of the Global EV DC Fast Charger Marketincluding all the stakeholders of the industry. The past and current status of the industry with forecasted market size and trends are presented in the report with the analysis of complicated data in simple language. The report covers all the aspects of the industry with a dedicated study of key players that includes market leaders, followers, and new entrants. PORTER, SVOR, PESTEL analysis with the potential impact of micro-economic factors of the market has been presented in the report. External as well as internal factors that are supposed to affect the business positively or negatively have been analyzed, which will give a clear futuristic view of the industry to the decision-makers. The report also helps in understanding the GlobalEV DC Fast Charger Marketdynamics, structure by analyzing the market segments and projects the GlobalEV DC Fast Charger Marketsize. Clear representation of competitive analysis of key players by

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Sales Channel, price, financial position, Product portfolio, growth strategies, and regional presence in the GlobalEV DC Fast Charger Market make the report investor's guide.

Challenges of Fast Charging For Electric Vehicles: Fast charging for electric vehicles is a decisive green light to the prevailing acceptance of EVs. It could be a solution to consumers' range anxiety and the assurance of electric vehicles. The potential to recharge swiftly and efficiently is a critical demand for a storage battery. Likewise, a critical barrier to fast charging is temperature.To be truly competitive with gasoline vehicles, EVs should enable a driver to recharge swiftly parallel to gasoline-fueled vehicles. None of today's EVs, however, grant fast charging in low temperatures. With this in mind, we are going to look at fast charging for electric vehicles and its complications, so let's get to it!

The Standards of Fast Charging for Electric Vehicles: Fast charging for electric vehicles is viewed as tricky and organized technology. The mainstream power level of fast-charging EVs prescribes six to eight hours to score utterly charged batteries. Fast charging reduces the charging period to around thirty minutes. This ridiculous achievement comes stocked with some rules; EVs desire a source of AC and DC power to pump up their batteries. This source of power is oft-times supplied from a power grid.

However, the use of DC fast chargers requires electrical infrastructure adopted for high power, and these chargers do not come cheap. The increased voltage will require additional insulation, which may add volume and mass to the electrical components, cables, and connectors of the vehicle.A higher battery voltage will also require a pack with more cells aligned in series. This will require more sensing and balancing circuits to monitor and balance the battery pack so as to meet the low resistance requirements for high-accuracy measurements.Charging takes planning, you have to know the specifics of the car you are driving and be aware of a charger's capability when you are in public.

Battery Technology Gap & Lithium Plating: Fast charging for electric vehicles is known to cause lithium plating which happens in cold temperatures when lithium deposits form around the anode of the battery during charging; it deteriorates battery life and safety. In practice, this offers the development of battery materials with no temperature restrictions. This could make fast charging truly weather-independent. But the team is not done yet. They are looking at what kind of materials they might need to fully charge an EV battery in just five minutes. The kind of charging speeds you wouldn't rather do anything else other than watch your EV top-up.

Thermal Management Systems: Temperature and humidity levels highly affect the performance, safety, and lifetime of battery cells, thus forging their dominance in a fundamentally provocative situation for battery integration into vehicles. We pointed out at the early stages of the article, the barrier between temperature and Fast charging for electric vehicles.As we now know lithium-ion batteries or rather, all batteries pivot on the electrochemical process whether charging or discharging and by some unspecified means, these chemical reactions hinge on temperature.

Economic and Infrastructure Issues: The key analysis for economic and infrastructure success for fast charging for electric vehicles includes grid stability and remittance of power, the design of fast charging stations and the design and use of electric vehicle service bits and pieces. The excellence of all these issues will positively impact the high power demand of fast charging for electric vehicles and the cost of operation of charging infrastructure and EVs.The starting price of EV is still much higher in comparison with conventional IEC vehicles due to higher costof EV batteries.Despite the remarkable advancements in battery technology, the current charging technologies are not fully developed. The limitations of the current Li-ion batteries are lower energy density and reduced life cycle. Maintenance is required after one to two years due to limited life cycle. Moreover, the weight and size of batteries are approximately one-third of the vehicle. The superior performance can be achieved from few battery technologies, but they are in an experimental stage and not fully matured.The development is needed for efficient battery management systems to achieve optimal performance of batteries. The designing procedures involved in sizing the battery subsystems need to be improved. High performance, maximum range and greater life cycle of batteries are achieved through appropriate choice of battery subsystem.The current charging technology of EVs has certain restrictions in relation to V2G technology. The battery chargers are not fully matured for V2G deployment in smart grid environment. In the present situation, unidirectional chargers are mostly adopted in the market. However, advance bidirectional chargers are needed for standardized V2G implementation. Therefore, additional focus is required for advance research techniques in planning and development of bidirectional chargers.The V2G technology is an alternative solution to cater many significant issues of a power network. It can accelerate the integration of RES. However, V2G concept requires the significant involvement of EV owners. At the same time, new management policies and some reward schemes should be introduced to motivate the EV owners to majorly participate in V2G implementation. Otherwise, implementation of

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V2G technology becomes difficult. As a result, comprehensive technical studies need to be implemented to realize the best possible solution which is based on energy management techniques and reward-based schemes.

Conclusion:

The most common topologies which are suitable candidates for each level of an EV charger have been presented. Level 1 and level 2 charger topologies are usually mounted inside the vehicle forming in this way the so-called onboard charger. On the other side level 3 chargers are installed off board the vehicles, in this way their collection leads to the creation of the so called FCSs which are promising candidates for future EV high penetration.This study also provided facts on rapid charging station infrastructure, why fast charging is good and its impact on distribution grid systems, developed methods are emerging to start moving the global community to feasible electric transport. This paper highlights the working of fast charging stations and standards of power level of chargers.Latest deployment andchallenging issues in the implementation of EVs infrastructural and charging systems , charging methods, grid integration, power quality issues, safety limitations, which are requiredfor large-scale deployment of EVs. Moreover, the beneficial and harmful impacts of EVs are categorized and thoroughly reviewed with remedial measures for harmful impacts and prolific benefits for beneficial impacts. A Nissan leaf vehicles fast charging process is studied. Global market of fast charging report study has analyzed the revenue impact of the COVID -19 pandemic on the sales revenue of market leaders, market followers, and market disrupters are also analyzed.

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