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Case Study on Infrastructure of EV Charging Station and Battery Technology

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ABSTRACT: Electric vehicles (EVs) are a relatively forth coming technology in the automobile and energy sectors, with several economic and environmental benefits. India's rapidly growing population, along with contemporary issues about fossil fuel depletion and pollution, has necessitated the development of alternative modes of transportation. Electric Vehicle (EV) market in India is increasing rapidly. Several models of electric cars were introduced in the 21st century, raising hopes that they might eventually replace conventional internal combustion engine cars; nevertheless, a number of obstacles have prevented their widespread popularity. Providing a higher proportion of charging stations and optimizing the architectural design of their infrastructure will assist in the resolving of some of the current issues. This paper discusses about the infrastructure of electrical vehicle charging station and Battery technology.

KEYWORDS: Electric vehicle, internal combustion engine, Battery technology, energy sector, charging station.

I. INTRODUCTION

Electric vehicles (EVs) have lately received a lot of attention because of rapid depletion of fossil fuels and enormous amounts of carbon emissions. No doubt they will frequently be utilized in the future [1]. An electric vehicle offers several key advantages, including reduced carbon emissions, no pollutant, and prevention of accidents, less service, and less expensive [1, 2]. An electric vehicle can be self-reliant using a battery, solar panels, or an electric generator to convert fuel to energy, or it can be powered by energy from off-vehicle sources using a collector system [3]. In compared to other Alternative Fuel Vehicles (AFVs), one of the advantages of electric vehicles is the ability to charge the vehicle while it is parked. Fast refueling stations are no longer required [4]. Due to technology advancements and a greater focus on renewable energy in the twenty-first century, EVs witnessed a rebirth. Many people believe the arrival of the Toyota Prius was the first significant event. The Prius was the first bulk hybrid electric vehicle when it was introduced in Japan in 1997. The Prius was introduced to the worldwide in 2000, and it quickly became a celebrity favourite, helping to enhance the car's popularity. Convenient and quick charging is gradually becoming a priority for both customers and automakers. Several energy providers have developed charging solutions and bundles as the need for mobility grows. The goal of this paper is to provide an outline of how electric vehicles are currently charged. The automobile sector is about to undergo a significant transformation. It isn't just about the items and technology; it's about how people utilize them and their whole ownership experience. To provide customers with a more favourable, well-planned, and time-saving charging experience than what is now available [5]. Charging stations should be placed in such a way that an electric vehicle's driving range may be extended to every part of the city by having the vehicle refilled at a charging station nearby [6]. An electric vehicle's battery is just that: a battery. A collection of interconnected individual battery cells in a series and/or parallel arrangement Existing Li-Ion batteries still have safety problems such as chemical exposure, thermal runaway, electric arcing, and fire initiation. Apart from the safety concerns, battery performance is also an issue. Due to the damage, it's also possible that it'll be significantly decreased. Component deterioration the restricted range of travel and another impediment to cost-effectiveness is the high starting cost. An electric vehicle's success or failure is determined on its battery performance. R&D groups, automobile corporations, and universities throughout the world have been working to create new solutions to address the limitations of present battery technology. In addition to the advancement of Li-Ion batteries, Lead acid battery, Nickel cadmium battery, and graphene battery are developed to assist EV and to obtain the desired performance characteristics [7].

II. BATTERY TECHNOLOGY

The EV batteries are refillable (secondary) lithium-ion batteries. These batteries are designed to have high ampere-hour potential. Electric vehicle batteries differ from starter, lights, and illuminated batteries in that the heavy batteries are designed to supply power over extended periods of time. Over the last six years, there have been significant advancements in battery technology. Battery cells nowadays have better energy densities and are significantly smaller [8].

DIFFERENT TYPES OF EV BATTERIES

1. **Lithium-ion batteries:** The majority of electric cars already employ lithium-ion batteries (LIB's), and it's expected that this trend will continue over the next decade. Several companies, especially Tesla and Nissan, have made significant investments in this technology. This technology was enlarged by John Goodenough, Stanley Whittingham, Rachid Yazami and Akira Yoshino during the 1970s–1980s, and then commercialized by a Sony and Asahi Kasei team led by Yoshio Nishi in 1991. LIB's have a high cyclic stability (the number of times the battery can be recharged without losing efficiency), but a low energy density. LIB's have a safety problem because they contain a flammable electrolyte that may cause explosions and flames if broken or wrongly charged [7].
2. **Lead Acid Battery:** Lead acid battery is the ancient technology. It has energy density of 30-50 Wh/kg and voltage per cell of 2 V, used to power internal combustion vehicle and backup power supplies. It has the lowest cost per cycle, around \$0.10, and a maximum discharge rate of 3 "C," where "C" rate is a current numerically equivalent to the Ah rating of the cell. Drawback of lead acid battery is slow charge and limited life [9].
3. **Nickel-Based Battery:** The nickel-metal hydride (NiMH) battery has always been the preferred option. In the 1990s for electric vehicles and hybrid electric vehicles (HEV) applications in the 2000s, due to its established safety and low cost. However the drawbacks of nickel based battery are high self-esteem, self-rate, voltage drop per cell (1.2V). Nickel Cadmium (NiCd) batteries are another form of nickel-based battery. Despite having a cheaper price per cycle (about 2.98 rupee) and an extended life cycle (about 2,000 cycles), NiCd batteries have been rapidly supplanted by NiMH and Li-ion batteries due to their drawbacks of requiring a sophisticated reuse and a larger memory impact [9].
4. **Graphene Battery:** Graphene has maximum mechanical properties (1060 GPA) and thermal stability for every product (3000Wm-1k-1). The graphene battery works by relying on a quick surface reaction to occur in both electrodes, resulting in a higher power density than a traditional lithium ion battery. The graphene batteries characteristics include highly permeable shape and high electrical conductivity. Because of their high energy density, graphene are a good contender among different high-performance energy-storage technologies such as lithium-ion batteries (LIB's), superconductors, and lithium-ion capacitors (LIC's). However, the present LIB's power density is insufficient for use on a wide basis, and price is prohibitively expensive [7].

MANUFACTURING PROCESS OF EV BATTERIES

The three major steps of the EV battery manufacturing process are: material production, cell manufacturing, and integration is shown in fig1. The active substance, conductivity additives, polymer binder, and solvent are combined initially in the materials production process. And then, they're coated on the current collectors for drying process. The electrode and the chemistry define the approaches for generating active compounds at this stage. Transition metal oxides, such as lithium nickel manganese cobalt oxides (Li-NMC), and lithium metal phosphates, such as lithium iron phosphates, are two of the most often utilized cathode chemistries (LFP). Graphite is now the most preferred anode chemical. However, a number of companies have lately begun to produce Si mixed anodes (Sila Nanotech, Prologium) and Li metal anodes (Cuberg, Solid Power). The manufactured electrode will be processed to the proper shape for packaging in a cylindrical, rectangular, or pouch format during the cell manufacturing stage. The fluids are filled as well as the batteries are sealed, the battery packs are gently operated to generate SEI, which secures the anode. Finally, those batteries are put together as modules and are ready to be installed in automobiles.

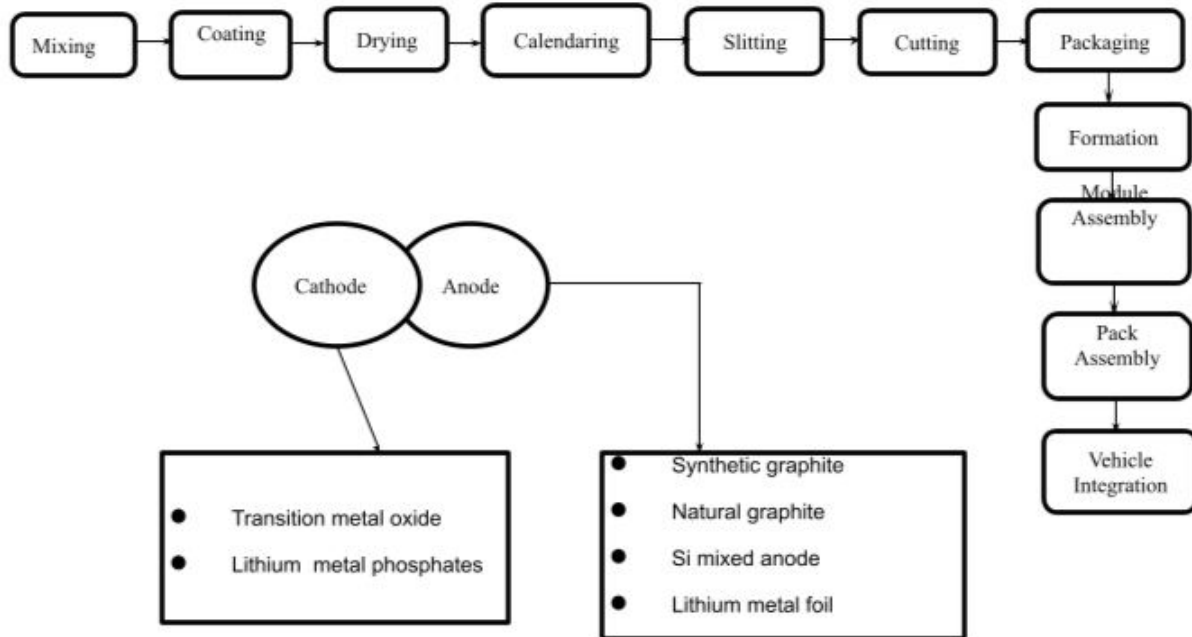


Fig 1: Manufacturing process of EV batteries.

EQUIVALENT CIRCUIT MODEL OF EV BATTERIES

The Battery modeling is classified into three main categories such as electromechanical model, mathematical model, and electrical model. The Electrochemical Model defines physical parameters of the battery pack, such as mass and energy, using partial differential equations. It is the most accurate of all the models, but solving it needs a complex calculation procedure. In mathematical model, empirical equations or stochastic techniques are used. It gives a less precise outcome and is only appropriate for certain applications. Electrical Model is more approachable and helpful for electrical engineers, and it strikes a balance between reliability and time for estimation. This paper discuss about the electrical circuit model of EV batteries [9].

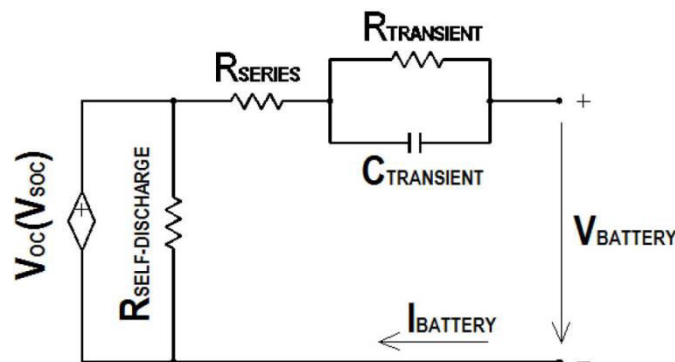


Fig 2.Thevenin battery model [9]

The open circuit voltage V_{oc} is determined by the state of charge SOC, and the voltage-current characteristic is represented by an R_{series} is a series resistance. The parallel RC circuit is a representation of the batteries transient reaction. It gives accurate current-voltage performance [10]. R_{series} , $R_{transient}$, and $C_{transient}$ are included in a Thevenin-based model that predicts cellular response for transient load at a SOC by assuming $V_{oc}(V_{soc})$ is stable, however It inhibits the model from accumulating time period and DC outputs. To collect battery DC output and time period information, add a resistor ($R_{self-discharge}$), a capacitor ($C_{capacity}$), and a current controlled current source ($I_{battery}$) to this model. The self-discharge is represented by $R_{self-discharge}$. Long-term power storage results in greater loss. The original



voltage across C_{capacity} (V_{soc}) can be adjusted to 1v or 0v to start the battery at 100 % SOC or 0 % SOC. I_{battery} is used to charge or discharge C_{capacity} . The reactive power is used for the measurements of DC pulse charging and discharging tests which is used to identify the battery model's characteristic parameters as shown in fig2 [9].

METHODS TO CHARGE EV BATTERIES

The battery pack inside an electric car is the most important component, and it must be charged on a regular basis. There are several ways to charge the EV batteries such as.

1. Conductive charge
 - a. AC
 - b. DC
2. Battery swap
3. Inductive charging

Inductive charging has been there for a while; it has yet to be standardized. In contrast, battery swapping technology is something we expect to see in the future [5].

1. Conductive Charging:

AC Charging: To charge the traction battery, an AC charger employs integrated chargers to convert AC power to DC power. A charging cable connects the automobile socket to the electric current charging station, and cars have a common vehicle inlet. The charging wire is sometimes properly attached to the charging station, much like a gasoline pump. For a safe and reliable charging procedure, there should be numerous vital components in this station.

Types of Ac charger: Because of the variation in AC voltage and frequency throughout the world, unfortunately, the EV industry has yet to agree on one. As a result, depending on the automobile, a separate AC connector is required. The connector's form, size, and pin layout varies depending on the manufacturer and country. An AC connection usually consists of two or more bigger connectors for power transmission and a few smaller connectors for communication. Four kinds of AC connectors exist as shown in fig 3 [5].

Type 1 connector

1. Used in USA and Japan.
2. There are two single-phase AC connectors, one protective earth pin, and two signal pins for communication.
3. The max voltage and the nominal current of this type are -Voltage 120V or 240V; Current up to 80A.

Type 2 connector

1. Used in Europe, including Tesla automobiles built in European specifications.
2. The top row contains two pins for communication, while the middle and bottom rows have five pins for AC power transmission (Three pins for three-phase AC and two pins for neutral and protective GND).
3. 1 phase 230V, up to 80A; 3 phases 400V, up to 63A are the maximum voltage and current ratings.

Type 3 connector

1. Used in Europe, however Type 2 connections are gradually displacing it.

Tesla US connector

1. They use own connector.
2. They use the Type 2 connector in Europe.
3. Tesla utilizes the same connector for AC and DC load.

Ratings for maximum voltage and current: Maximum when connected to a power source, the charging power is 17.2kW. A 240V AC outlet is required [5].



Fig 3.AC Charger types [5]

DC charging: DC chargers are used to quickly recharge EVs. They have a charging output of 50kW-350kW and operate at level 3 charging powers. DC chargers are implemented as off-board chargers rather than on-board chargers because high-power operation requires larger and more expensive AC/DC converters, DC/DC converters, and power management circuits, making it unfeasible to implement as an on-board charger. As a result, to save space in the car, they are set up as off-board chargers that may be used by several users'. There are four kinds of DC connectors exist as shown in fig 4 [5].

CCS-combo 1

1. Used in the USA.
2. The AC type 1 connector is the source of the connection.
3. Two DC pins have been added for rapid charging, although the fundamental architecture of the AC type 1 connector has not changed.
4. CCS chargers can produce up to 350 amps at 200 to 1000 volts, resulting in a maximum power output of 350 kW.

CCS-combo 2

1. Used in Europe.
2. Two DC pins have been added to the bottom of the connection for high-power DC charging, but the rest of the AC Type 2 connection connections have been retained.
3. CCS chargers have a maximum power output of 350 kW and can produce up to 350 amps at voltages ranging from 200 to 1000 volts.

Chademo connector

1. Used in Japan.
2. It is a type 4 EV connector.
3. Chademo's voltage, current, and power levels are 50-500V and up to 400A, with a peak output of 200kW.

DC Charger – China GB/T standard

1. China has developed its own DC connector.
2. It features four signal pins, 2 for the proximity driver and two for CAN communication. Maximum current 250A, Nominal Voltage 750V or 1000V.



Fig 4.Dc charger types [5]

2. **Battery swap:** This method works by exchanging a depleted battery with a fully charged one. It entails driving into a cell switching facility, where an electronic system will position the car and replace the current cell with a rechargeable one. The station then charges the exhausted batteries for eventual deployment. The upside of battery switch technology is that it terminates the range problem and makes it as simple as filling a tank [5].
3. **Inductive Charge:** Inductive charging is a wireless power transfer mechanism. A power-generating source system is located close to a power-storing or power-transfer system [5]. There are two types in inductive charge: Static charge and Dynamic charge.

SELECTION OF ADVANCED EV BATTERY

In this approach, the quality requirements of several battery technologies are chosen, analyzed, suitably balanced based on significance, and combined to provide a result that is then used to evaluate the battery technologies. For the selection of advanced EV batteries, the following design parameters have been discovered and taken into account:

1. **Cost effectiveness:** One of the greatest obstacles to widespread production of EVs is the high cost of batteries. As a result, the batteries price must be as cheap as feasible.
2. **Perform-ability:** The batteries ability to perform when the C-rate, E-rate, and other factors are combined. A C-rate is the rate of discharge expressed as a percentage of maximum capacity, whereas an E-rate is the discharge power. Increases in C- and E- rates decrease nominal capacity and energy. After a few thousand charging cycles, a standard battery's performance begins to deteriorate. The EV battery pack cannot keep up with the demands of powering the car. As a result, for electric cars, batteries with lower C and E rates are desirable.
3. **Safety:** Despite the fact that battery producers are working to resolve battery-related safety problems, malfunctions are certain to occur during use. For EV applications, battery technology should offer optimal safety.
4. **Life:** Batteries deteriorate with time, if they're not in use. Furthermore, breakdowns are accelerated by high temperatures and charging and discharging cycles. As a result, it's critical to think about the batteries' ageing characteristics before putting it in an electric vehicle.
5. **Weightlessness:** It is critical to employ low weight batteries in order to lower the EV's gross vehicle weight.
6. **Recyclability:** Environmental laws have compelled EV manufacturers to implement closed-loop battery recycling. Battery researchers and manufacturers must ensure that their products are completely recyclable. [7].

III.CHARGING STATION INFRASTRUCTURE

TYPES OF EV CHARGING STATION

1. Level 1: These chargers use alternating current at 110-120 Volts (V) 15Amps (A) (12A useable) or 20A (16A useable) branch circuit. These chargers can only deliver a tiny amount of power, therefore completely charging the car might take anywhere from 10 to 20 hours, depending on the battery capacity. These kinds of chargers are still fairly widespread in residential areas owing to the availability of 120V outlets and their relatively modest installation cost.

2. Level 2: These chargers employ a single-phase, 30-80A branch circuit with a voltage range of 240-280V alternating current. In 4 to 8 hours, EVs may be fully charged. These characteristics make chargers acceptable for both private and public use.

3. Level 3: Sometimes level 3 are also referred as DC fast charging. These Chargers are comparable to petrol stations and are used in public spaces. They employ a three-phase circuit with 480V alternating current. In less than 30 minutes, EVs may be charged to 80% capacity. It should also be mentioned that if they are used on a frequent basis, they may shorten the batteries lifespan [11].

DESIGN OF EV CHARGING STATION INSTALLATION

Depending on the design of the parking lot, the availability of electricity, and other site factors, there are a variety of feasible configurations and designs for EV charging station installations.

General EV charging station site plan considerations include:

- a. Power availability (240V for Level 2, 3 phases for DC fast charging).
- b. Accessibility for disabled users.
- c. Signs and pavement markings to designate sites and restrict their use as shown in fig 5 [3].

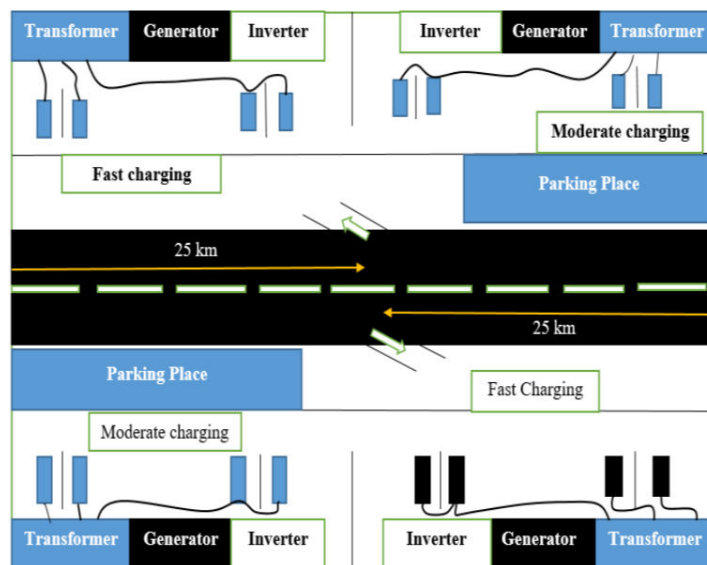


Fig5. Infrastructure of EV charging station [3]

SELECTING THE LOCATION OF EV CHARGING INFRASTRUCTURE

The availability of charging infrastructure has a significant impact on EV market adoption. As a result, concerned governments and electric car manufacturers consider the growth of infrastructure for EV charging as a top priority. This additional charging load must be absorbed by the current power system, which is an essential element to consider in this respect. The electrical system would gain from the availability of commercialized charging stations. When compared to the lower Level 1 and Level 2 charging modes, which take a long time, for fast charging whereas level 3 at public charging stations is definitely the better option for EV drivers. Selecting locations for charging stations that



meet the needs of both consumers and the power system would be a more realistic approach to planning. From that perspective, the ideal location is one that meets all of the criteria [12, 13].

The location should be convenient to those who use electric vehicles.

1. The site should be picked such that it contains productive EV locations such as commercial areas, office buildings, residential regions, and road networks.
2. The site must be located such that permissible limit voltage and line MVA flows aren't really exceeded, and the power system suffers the fewest losses.

Optimization approaches has genetic algorithms, simulated annealing, virtual ant algorithms, and particle swarm. Optimization is utilized in charge infrastructure planning [13, 14]. Particle swarm optimization is explained in paper [14].

COST ANALYSIS OF EV CHARGING INFRASTRUCTURE

The overall price of constructing an electric vehicle charging infrastructure includes the price of equipment, installation fees, and operation and maintenance costs. As the number of electric vehicles (EVs) on the road increases in the next years, likewise the EV chargers cost will be decreased. The cost of electric vehicle charging equipment varies significantly across manufacturers. Apart from the original equipment cost, installation costs for the charger and grid connectivity are necessary. The installation cost comprises civil works, transaction expenses connected to distribution system operator approval, and other associated costs, which vary based on factors such as whether a new grid connection is required or whether an existing connection has to be upgraded. If there is an existing connection, the cost of installation may be significantly reduced. Other factors which influence installation prices include the number of chargers installed at the same time, which can save money due to shared labor and grounding prices, mutual components, and so on. Apart from the equipment and installation charges, regular maintenance is required during the operating duration. Then there is a charge of operation and maintenance, which may be 10% of the overall installation cost [12].

BARRIERS AND SOLUTION OF EV CHARGING STATION

In order to increase EV penetration in the Indian automobile market, numerous obstacles and hurdles relating to infrastructure, market, technological limits, and policies should be resolved. Technical challenges include improving battery technology, lowering battery capacity, and providing enough speed experience for electric vehicles. A key restriction is the poor particular power density of Battery systems, such as lead-acid batteries. As a result, larger batteries are necessary to attain longer driving ranges, increasing the vehicle's overall weight. To solve this issue, battery manufacturers are attempting to build batteries with high particular power density. The scarcity of lithium-ion resources in India, which are required for large batteries, is a major source of worry. There is a shortage of charging infrastructure and business concepts to match the special demands of electric vehicles and lack of dedicated lanes are all market and infrastructure barriers. Setting up charge stations in parking garages and building basements might be one answer to the problem of charging infrastructure. Many countries, including China, have embraced this technique. There is also a need to develop business models that will allow consumers to pay less upfront and have more trust in electric automobiles [12].

IV.STANDARDS OF EV

There are numerous EV charging infrastructure standards in use across the world. SAE and IEEE are commonly utilized by manufacturers in the United States, whereas IEC is largely used in Europe. Chademo is a charging standard for electric vehicles developed in Japan. For AC and DC charging, China utilizes the Guobiao (GB/T) standard, where GB/T AC charging requirements are identical to IEC standards. The IEC and SAE are widely used in electrical vehicle [15].

1. IEC 61851-1: This standard defines 3 different types of wires as well as plugs for charging electric cars [16].

Case A: The point at which the electric vehicle is securely connected to the wire.

Case B: The point at which the cable is not firmly fixed in any place.

Case C: The point at which the wire is always linked to the charging station.

2. IEC 61851-23: The current protection, harmonics, testing platform, and transmission design requirements for DC

fast charging stations are all specified in this standard.

3. IEC62196: It specifies connectors, socket ports, car connections, and car inlets for conductive charging of electric vehicles (EVs).

SAEJ2293: It specifies the criteria for on-board and off-board charging devices. There are two portions of this standard. J2293-1 examines the energy requirements and system design for three different operating scenarios (conductive AC, conductive DC, and inductive charging). J2293-2, on the other hand, is concerned with the data transmission and network configuration for electric vehicle charging [15].

SAEJ1773: This standard lays forth the essential criteria for EVs using an inductively linked charging system [15].

V. FUTURE SCOPE OF EV

The current EV development trend may be boosted further with the use of energy internet technologies. Currently, the dynamic WPT system is at the development stage. Furthermore, bidirectional power flow for dynamic charging has yet to be created. Researchers must be more emphasized in order to create a bidirectional dynamic WPT system. The benefits of autonomous EVs can be fully used with the shared economy idea. A well-developed business model may benefit EV owners, users, and utility companies alike [14]. To meet the government's 2030 objectives, at least 3,500 GWh of batteries would be needed, with a total cost of \$300 billion (about Rs. 20 lakh crore). If Indian producers assemble packaging in the local market, they may grab 25 to 40% of the market's value. As a result, cell imports will be in the range of 12-15 lakh crores INR. Imports of gasoline and diesel should be decreased to 17 INR lakh crore, resulting in an 8 INR lakh crore savings. The country's geography and diversity will bring issues that will necessitate deliberate answers that are not yet apparent in the field [17].

VI. CONCLUSION

This paper reviewed the different types of batteries and manufacturing of Electrical vehicle batteries, equivalent circuit model, and different methods such as conductive, inductive, battery swap, Charging infrastructure, Design of charging infrastructure, Cost estimation, Barrier and solution, Standards of EV. Finally, Future opportunities in India were detailed.

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