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TOWARDS THE FUTURE OF ELECTRIC VEHICLE

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ABSTRACT:

Electrical vehicle is an optimistic technology that was introduced to achieve sustainability in transportation since internal combustion engine consumes non-renewable fuel and causes greenhouse effects so electric vehicles have become a crucial part of today's generation being one of the forerunners. Though electric vehicles are a cleaner solution with numerous advantages over internal combustion engine, it also has some disadvantages due to the lack of suitable infrastructure for EV charging, the thermal instability of lithium-ion batteries, and the power peaks caused by EV charging. In this paper, we have addressed a few emerging technologies in the EV sector like wireless charging which eliminates the usage of cables and takes EV battery charging infrastructure a step ahead, a fast charging EV battery-Solid state batteries that prevent the risk of explosion and vehicle to grid (V2G) technology which entails two-way communication and bidirectional flow of electricity from EV to the grid and back to EV during peak demand and other new developments which would overcome these disadvantages.

KEYWORDS:

WIRELESS CHARGING, SOLID-STATE BATTERIES, VEHICLE-TO-GRID TECHNOLOGY.

INTRODUCTION

EV plays a significant role in the transition towards a clean environment and also reduces the greenhouse effects as they cause only small pollution. The market for electric vehicles is increasing and it's necessary to make them user-friendly by making them more reliable, smarter, lower cost, and green. Reducing the duration of charging by using wireless charging, and replacement of lithium-ion batteries with solid-state batteries and V2G technology where EVs act as distributed resources where power can be sent back to the grid are a few emerging technologies in EVs.

In this paper, the concepts, working, and benefits of these technologies are discussed.

SOLID STATE BATTERIES:

Electrolyte batteries have been a recent trend in modern devices. They have many advantageous features because of their high-power density but it causes danger due to unexpected leakage, inefficient chemical stability, and it is highly inflammable. To overcome these drawbacks solid-state batteries are considered a safer alternative to these liquid electrolyte batteries.

Solid-state batteries consist of solid electrolytes instead of liquid electrolytes. It has higher energy capacity and quick charging capacity, a longer lifespan, and is obviously a safer option. This is mostly preferred due to its high energy density which has been its power for adopting to newer technologies. Ionic conductivity is directly proportional to the battery's power density.

A. Replacing lithium-ion batteries with solid-state batteries in EV

The electrolyte constitutes the major difference between solid-state and lithium-ion batteries. The electrolyte of lithium ions is in liquid form. In addition to this, multiple battery packs must be connected to experience high energy. Solid-state batteries use solid electrolyte which has a simpler manufacturing process. There is no need for multiple layers of batteries to be connected to achieve higher energy. The intermediate benefit of shifting to solid electrolyte is that the energy density may increase because it uses solid state separator which is as conductive as liquid, prevents dendrite formation and it is unreactive with lithium metal. Solid-state batteries deliver twice as much as power than lithium ion batteries. The thickness of liquid electrolyte batteries is 20-30 micron whereas solid state technology has a thickness of about 3-4 microns each, thus saving space .Solid electrolytes tend to be less reactive than liquid's or gel so they can be expected to last longer and these batteries won't catch fire or burst if they are damaged .Solid state batteries can be composed of a mixture of many chemical components whereas this is not possible in liquid electrolyte batteries. These make solid-state batteries better from lithium-ion batteries.

B. Future of Solid-State Batteries in EV

A recent study by transport & environment states that solid-state batteries can cut carbon emissions by up to 39% compared to existing lithium-ion batteries. While EVs are often thought to be a greener alternative they aren't actually eco-friendly. The problem lies with the manufacturing of lithium-ion batteries which emits greenhouse gases, in addition to this lithium and cobalt mining calls for damage to local ecosystems. Solid-state batteries are expected to lower carbon emissions by 24 % to 39%. Additionally, these batteries are expected to be cheaper because of a lower number of materials are used at its production. This technology indeed uses 35% more lithium but it cuts out graphite and cobalt to a larger extent. Mining and extraction take place in a sustainable way which lowers the threat of climatic changes. Top companies like Toyota, QuantumScape, and Chinese automakers BYD AND CATL are currently at the forefront of technology. Nissan now promises to have production of EVs with solid-state batteries by 2028. Several automotive manufacturers like BMW and Ford have invested in battery maker solid power which was established in 2011 and claims SSBs will be safer, offer higher energy and cost less than lithium-ion batteries. The future of EVs lies with solid-state batteries but there is a lot of development required to get rid of all the disadvantages of using solid-state batteries in EVs.

C. How Solid-State Batteries Are Made

The essential components include two electrodes i.e. anode and cathode, a solid electrolyte and a casing. Redox reactions are the main source of energy transfer, electrons are taken up in the anode by oxidation whereas in the cathode it is taken up by the reduction mechanism.

D. Choice of Material

Anode: It acts as a storage area for electrons after the battery is charged. Lithium metal is used as anode as it is promising in terms of low electrochemical potential, less density and very high specific capacity. This is not yet used commercially due to growth of lithium dendrites during charging and discharging process. Dendrite formation affects the battery's performance causing it to decay.

Anodic reactions are based on intercalation mechanism where lithium ions reside in the interstitial sites of host metal i.e. lithium. This is more advantageous because it avoids dendrite formation. Intercalation mechanism takes the help of layered structure of graphite to work efficiently. Lithium metal is able to withstand large number of charge and discharge cycles and has a good retention capacity over many cycles. Silicon, Tin, Germanium are also recommended to be used as an anode.

Cathode: The main function of the cathode is to supply necessary ions during the charging process to achieve thermal and chemical stability. Lithium metal oxides are used as cathodes these days and often lithium cobalt oxide is preferred due to the octahedral arrangement with lithium atom layers between oxygen and cobalt. This provides structural stability and rigidity. High production costs of this metal poses threat to its widespread usage. Lithium manganese oxide is another better option for cathode which has a spinel-based structure.

Electrolyte: An electrolyte must satisfy the following characteristics to work efficiently: high ionic conductivity, high electronic resistance, low internal resistance which is required to obstruct the electron movement through the electrolyte. The most widespread use of solid electrolytes is under development because of the low rate of performance and high risk of failure. The electrolytes can be sulfides, oxides or phosphates-based and crystalline structures.

WIRELESS CHARGING TECHNOLOGY:

Unlike vehicles with internal combustion engines, EVs are required to charge their batteries with electricity instead of using fuels such as petrol and diesel. With the prodigious invention of wireless charging, EVs are becoming highly efficient and user-friendly. Nikola Tesla invented wireless charging technology which is used to charge electric vehicles that has gained prominent momentum over the past decades. The intense urbanization as well as the escalation in the level of depletion of non-renewable resources has increased the demand for EVs in today's world. The wireless charging system being integrated into EVs enables the users to charge their EV without the usage of cable wires or leaving the vehicles. This emerging technology of wireless charging would be a game changer for the automotive industry and it would also increase the charging efficiency making it smoother and less time consuming. Today we can charge the vehicles at home, charging stations or at the owner's place but in future the technology will be upgraded with easy and quick wireless charging where we can charge our EVs anywhere at our working places, stores, streets etc. and this can attract a large number of new customers and employees. However, adopting this technology also has some real and perceived problems that need to be solved.

Wireless charging isn't new in today's world, we use it everywhere from mobile phones to wearable smart gadgets such as electric toothbrushes, laptops, household appliances, automobiles etc. Inductive charging method has been in use for a long period of time for charging which works under the principle of electromagnetic induction but in the case of electric vehicles, it is a completely different ball game as it requires a considerable amount of power. Lithium batteries require constant voltage or constant current therefore it requires a stable and load independent wireless power transfer system with a constant current and constant voltage as output. So, MIT proposed a Magnetic resonance method for wireless power transfer in EVs which mainly focuses on long transmission distance, improvement in the efficiency of transmission and ensuring the safety of the electromagnetic environment. This method has been from the history of the induction charging method but it shifts it in a radical new way. This technique is still inductive in which the alternating magnetic field generated by the primary coil induces a current in the secondary coil but it takes the advantage of strong coupling that occurs between the coils even when it is separated by many centimeters apart. The basic theme of wireless charging is similar to the transformer. This consists of two coils where one is the transmitter and the other is receiver. These two coils are made in resonance to enhance the transmission performance. Due to misalignment and parking deviation in EVs, LCL topology is considered as desired compensation topology in transmitter coil because it is independent to the change in impedance at suitable design. However, ensuring a constant current in the transmitter side alone is not enough to achieve a stable performance but the coupling coefficient between the transmitter and receiver coils play a major role in this design. Many studies were undertaken to emphasize the enhancement on coupling coefficient with 88% efficiency when the transmission power was 500 w at 15 cm distance which was based on mutual inductance coefficient optimization and avoidance of frequency splitting. Besides, many studies were also made to accomplish the requirement of constant current and constant voltage at its output under equivalent load variations of battery. And one of the primitive ways to get this output was to introduce a conversion circuit either on the primary or secondary side of the wireless charging system. The voltage and current on each component and level is studied using MATLAB under imperfect resonant conditions.

Zt= Up/Ip= (Lf^2) Rl/M^2

This equation shows that constant voltage can be achieved with LCL-s topology and the current in the transmitting coil is stable even with misalignment. For constant current LCL-LCL compensation topology is used.

Zt=Up/Ip= ωLf^2Lg^2/M^2RL

From the given equation for total input impedance, using LCL-LCL compensation topology we can achieve constant voltage output for batteries which have no imaginary parts. Designing and optimization of coupling structure is done followed by compensation topology which includes selection of coil structure. Coil structure designing is important as it can effectively improve the coupling between magnetic fields and increase the offset ability. In wireless power transfer methods, it is obvious for the coupling coefficient between transmitting and receiving coil to have some variations in the case of misalignment. During misalignment, an assurance of less affected coupling coefficient is one of the most important issues and this can be addressed through appropriate designing of coil structure. Generally, circular, square and rectangular coil structures are used in wireless charging systems. Square coil has a high coupling coefficient when it is laterally offset. To design an appropriate coil with higher coupling strength, simulation software such as Ansoft Maxwell and Simplorer circuit simulation tools are widely used to design, optimize and compare the structure of coils.

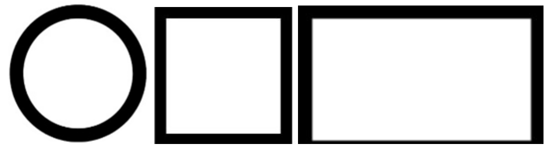

FIG1: STRUCTURE OF COIL

Now the electric current between two objects is transferred to induce an electromagnetic field with the help of these coils. The power is transferred from the transmitter coil to the receiver coil where it is used to charge the battery in an EV. The main voltage is converted into alternating current with high frequency and is sent to the transmitter coil via the transmitter circuit. This alternating current induces some amount of oscillating magnetic field in the transmitter coil which is extended to the receiver coil. This extended magnetic field along the receiver coil side generates the current within the receiver coil. Now, this current within the receiver coil is converted into direct current by the receiver circuit which is used to charge the battery of the electric vehicles. This process is called the magnetic resonance method.

A. Advantages of wireless EV charging

Wireless charging was introduced to eliminate the usage of heavy cables and is one of the convenient methods of charging. It is user-friendly and one can charge his/her electric vehicle whenever and wherever required. Wireless charging attracts many customers to buy and promote EVs. The entire process of EV charging is made simple where users can simply align the vehicle on the transmitter pad and the charging begins automatically. This method also preserves the lifespan of the battery when compared to the traditional charging with cables and moreover they are time-consuming. Since the magnetic resonance method is adopted in wireless power transfer, there is no need of different height, size or offset as long as it is operated in the same sort of frequency unlike the traditional method of inductive wireless charging where the alignment should be of perfect size, height and match with shorter distance of charging.

B. Requirements for wireless EV charging

Factories for wireless power transfer for EV batteries need to be installed and developed in the areas where EVs are highly in use. Wireless charging pads can be embedded in the grounds of public places such as workplaces, stores, and markets etc. where people can easily access them. Coils structure with an even higher coupling coefficient can be designed to increase the charging efficiency. Fast wireless charging can be introduced in order to attract customers.

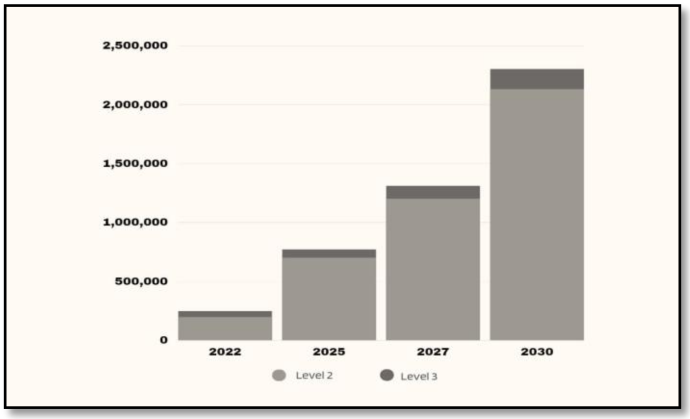

FIG 2: EV DEMANDS

C. challenges faced in implementation of wireless EV charging

This method for wireless charging works only within a certain amount of distance and in most cases the alignment of the transmitter and receiver should be the same. The other biggest challenge faced is safety and mass production such as electromagnetic interference, foreign metal objects, heat production etc. The coil is very unstable as it can change its characteristics due to various factors such as temperature deviation etc. It is of high cost and the customers will not be willing to spend such a huge amount of money for wireless.

VEHICLE-TO-GRID TECHNOLOGY:

Renewable energy is an inexhaustible energy that is clean and cheap yet even it has a few disadvantages as it is not continuous and it depends on the climate that is the sun and wind. When they don't meet the peak demands we use non-renewable energy. The amount of electricity used by us doesn't remain the same always. The peak of electricity is usually from 6 to 10 in both morning and evening. When the demand of electricity is high the grid needs to be in balance. This is where vehicle-to-grid (V2G) technology plays its role where the stored energy in EV battery is given back to the grid when demand is high and when the demand gets low, energy can be stored in the EV that avoids the wastage of power. This also stabilize the grid and prevents blackout. Vehicle-to-grid (V2G) technology has 3 major advantages:

1. It reduces the size of peak electricity
2. We can work towards a cleaner grid
3. We would able to save our money

Buying energy when the cost of electricity is low and selling it back to the grid when the cost of electricity is high saves a lot of money. The future of the power grid is going to be more renewable energy, up to 70% by 2050. In that case, smoothening of peaks are really important. If EVs can freely access to the grid it would affect the grid due to large charging demand if the grid is in peak load periods. Therefore, it is necessary to bring in V2G technology to coordinate the charging and discharging of EVs and the grid so that the grid doesn't get affected.

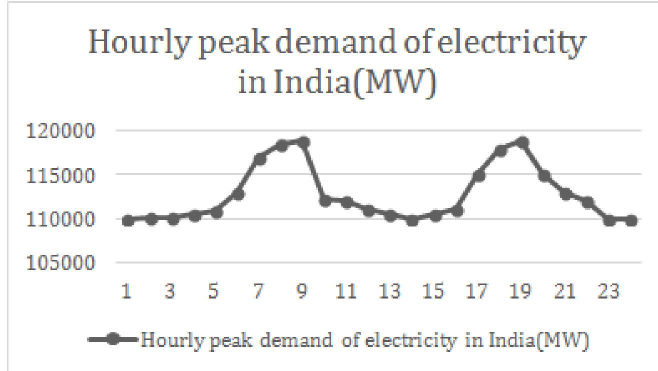

FIG3: HOURLY PEAK DEMAND OF ELECTRICITY IN INDIA.

A. Various other technologies in this category

V2L: Vehicle to Load- Alternating current taken from the car is used to power appliances or charge another EV

V2H: Vehicle to Home – Stored energy in EV is used to supply power to home or business

V2G: the Dutch city of Utrecht with the help of a company named we solar drive brought in 800 bidirectional chargers but many EV aren't having the V2G capability. Nissan electric van and Nissan Aria are the only full EV that are V2G capable. Even Hyundai modified their 25 ionic fives.

V2X: vehicle to anything- The stored energy in EV is used to power anything, it may be appliances, grid, EV etc.

B. Various types of EV and V2G

The current market has 3 types of EV: hybrid electric vehicles, battery electric vehicles and fuel-cell electric vehicles. All these vehicles can generate clean AC power from 10kW to 200kW. When connections are made in EV such that it allows electricity to flow from cars to power grid, we then call it as "vehicle to grid", or V2G technology.

1. Hybrid electric vehicles: They are usually powered by internal combustion engine (ICE). Hybrid electric vehicles doesn't have charger in them as the battery of a hybrid electric vehicle cannot be charged by just plugging it into a source. The battery is charged only through regenerative braking and by the internal combustion engine. In V2G technology hybrid EV can be used only to supply power to grid when required which makes it act as a backup source. Implementation of V2G might cost you quite high in a hybrid EV.

2. Plug-in hybrid vehicles: It gets only partially charged through regenerative braking as it has larger battery that requires large power. Hence it needs to be connected to an external power source to completely recharge its battery. On the other hand, Full hybrids can recharge their electric batteries just by regenerative braking. In V2G technology Plug-in hybrid vehicles can be charged from a grid and during peak demand it would be able to supply back to the grid and acts as storage as it has large batteries.

3. Battery electric vehicles: They store energy in batteries electrochemically. When these need to be charged they are plugged into the grid and it's unplugged to drive. Compared to all other types of EVs, the cost of adding V2G technology in battery electric vehicles is low. This acts as a storage for renewable energy and it can be utilized during peak demand.

4. Fuel-cell electric vehicles: Compressed hydrogen is used to power fuel-cell Electric vehicles. The compressed hydrogen feeds to the on-board fuel cell that transforms the chemical energy of the fuel into electrical energy. This electricity then powers electric motors in the EVs. The fuel cell is not a battery and does not store energy in it. Basic elements required for V2G technology:

1) Power connection is needed for electrical energy flow from vehicle to grid as it can act as a backup source.

2) To determine available capacity of the vehicle logic operations are necessary for the grid operator.

C. Functions provided by V2G:

1. Peak power: It is commonly generated by power plants which will provide electricity for a short period of time yet costs high. Electric vehicles can supply power to the grid in peak hours and can consume power during off-peak hours. This would reduce the difference between the maximum and minimum of the power load and this would save a lot of money.

2. Renewable energy storage and backup: The most significant role for V2G may be in emerging power markets that support renewable energy. The two largest renewable sources for the future that would be widely used are photovoltaic and wind turbines. As renewable energy is increasing lately, various other resources are necessary to match the fluctuating supply. This can be done either by backup or storage. "Backup" refers to the generators that provide power when the renewable source is insufficient. "Storage" refers to the absorption of excess power. By utilizing the V2G technology, fuel-cell electric vehicles and hybrid electric vehicles can provide backup, plug-in hybrid electric vehicles and battery electric vehicles can provide storage.

D. Benefits of V2G technology

When there is a local demand, stored energy in the battery can be used to serve a portion of the demand that reduces the peak load demand.

This reduces transmission congestion, line losses, and stressed operation of a power system. It mainly reduces the cost of electricity during peak periods.

The vehicle owners can store energy in EVs during the night-time when the price of electricity is low and can supply back to the grid during the peak time when the price is high, EVs here act like pumped-storage units. So, vehicle owners can gain revenue from the difference in prices.

CONCLUSION:

The market for electric vehicles will continuously be increasing in upcoming years. As the demand gets high the efficiency should also be higher to make it user-friendly. There are various emerging technologies in recent days to improve the standard of EVs. This paper reviews the basic concepts major 3 emerging technology.

Solid-state batteries which have higher energy and quick charging capacity is a good alternative to lithium-ion battery as it is thermally unstable but it requires a lot of research and innovation to get rid of all the disadvantages of using solid-state batteries in EVs.

Wireless charging eliminates the usage of heavy cables and preserves the lifespan of the battery yet there are a few drawbacks that it works only for short distances and the power transmitter and receiver should be in proper alignment. These are to be resolved to make it the future of charging EVs.

Vehicle-to-grid technology supports renewable energy and manages peak demand. When it is used for a long term it will also be advantageous for the environment. Though there are many problems that are to be resolved, V2G could be emerging into the future of power markets.

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