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Literature Review Of Electric Vehicle And Its Impact On The Distribution System

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***Abstract*—The purpose of this paper is to overview the research done on electric vehicles and their impact on the distribution system. It will be our effort to provide information on the various charging stations for electric vehicles, their impact on the distribution system, and how we can design our power systems accordingly. An insight is thrown on the various parameters used to know more about electric vehicle such as state of charging, battery capacity, battery efficiency, etc. Furthermore, it will describe the various methodologies utilized for charging electric vehicles, while also highlighting the ongoing trend of electric vehicles replacing fossil fuel vehicles in recent years. Additionally, it delves into the continuous advancements that contribute to the constant improvement of electric vehicles. Lastly, it discusses electric vehicles' future prospects. An individual can easily gain a thorough understanding of electric vehicles and the research that has been done on them after reading this review paper.**

***Index Terms*—Electric vehicle, charging station, battery capacity, battery efficiency.**

I. INTRODUCTION

In today's society the biggest concern raised is the exhaustion of fossil fuels, as fossil fuels constitute the backbone of the major day-to-day functions we carry in our everyday life, most importantly transport. In early days, transport did not hold the essential place in a man's life but now our life is completely dependent on it. As fossil fuels are depleting, it creates an urgency to find a suitable alternate for it, which is Electrical Vehicles (EV's). Electrical Vehicles can be defined as a vehicle that uses one or more electric motor for propulsion. It can be powered by a collector system, with electricity from extravehicular sources, or it can be powered autonomously by battery (sometimes charged by solar panels, or by converting fuel to electricity using fuel cells or a generator). EV's include, but are not limited to, road and railway vehicles, surface and underwater vessels, electric aircraft and electric spacecraft [1].

The different types of EV includes- battery electric vehicle, hybrid electric vehicle, plug-in hybrid vehicle. Based on the type of electric vehicles, the components present inside them varies. In battery electric vehicle there is a battery instead of a gasoline tank, and an electric motor instead of an internal combustion engine [2]. The hybrid car (also shortened to HEV for "Hybrid Electric Vehicle") is designed around a simple principle: a combustion engine (gasoline or diesel) and one or several electric motors working together. This leads to a reduction in fuel consumption and CO_2 emissions thanks to its ability to run in all-electric mode [3].Plug-in hybrid electric vehicles (PHEVs) are a combination of gasoline and electric vehicles, so they have a battery, an electric motor, a gasoline tank, and an internal combustion engine [4] The difference between a hybrid and plug-in hybrid is found, on the latter, in the presence of a charging socket and a higher-capacity battery, lending each type of vehicle to different uses [5]. In earlier eras fossil fuels were meeting the demand of transportation, as they were being used in all the types of vehicles. Now, with the new technology in trend the customers are changing their preferences and getting more inclined towards it. Electric vehicles comes with many advantages, but as the saying goes, every coin has two sides, the disadvantages of electric vehicles are no less, due to the same reason there are a lot of aspects which needs to be worked upon to make it the ideal customers vehicle and most preferred choice. Our review paper which conducted a thorough research about electric vehicles gives us a rough idea from the different literature's we have read about electric vehicles. Electric vehicles can definitely not run without charging. The charging of EV's can be done at various stations, but the charging of EV's at various stations can have an impact on the distribution system. The degree to which the distribution system gets affected depends largely on the type of station chosen to charge the EV. As the amount of energy required to charge the EV is massive, so it can impact the distribution system terribly, as the EV's are increasing in number day by day and the load demand on the distribution system of the already existing equipments all together affects it to a noticeable extent. The research also helped us examine the different methodologies designed by people to reduce this impact on the distribution system and developing a technology which can find an appropriate solution to the problems faced due to EV's and their substandard impact on distribution system. While reading of several papers, gaps were encountered in each paper which needs to be addressed and solved. The designers and planners of power system-which includes generation, transmission and distribution system, were not well aware of the problem which could come across in the near future, despite of re-structuring and re-planning of the power system the problem cannot be solved immediately, but with gradual advancements it can be eradicated in the coming years. Research has shed light on the varying load charging demands across different regions. The demand for load charging is expected to be highest in metropolitan cities, lower in urban areas, and least in rural areas.

After reading this overview the reader can easily grasp the concept of EV, types of EV, different types of charging station, the impact of charging on the distribution system, different models for reducing the impact on the distribution system and the advantages and disadvantages of EV's.

Fig 1. Types of Electric Vehicles

II. DIFFERENT CONCEPTS IN EV

A. Charging Station

A charging station, also known as a charge point or electric vehicle supply equipment (EVSE), is a piece of equipment that supplies electrical power for charging plug-in electric vehicles[6]. Charging stations are necessary as they help in charging the EV's and making them go-able. According to the U.S. Department of Energy, 80 percent of EV charging happens at home, so figuring out how all of these cars will affect their owners' electric bills — and the utility grids they're connected to — will become a far more pressing matter[7]. From the research of different literatures the data we have collected is that maximum number of EV's charge at home, as it allows the EV owner to cut some cost here, moreover if the EV owner has a solar panel installed at their place, the running cost of EV is null. The owners when come home after their daily routine plug in their vehicles to charging. Charging your vehicle at a public station can be extravagant. Sometimes when the owner is driving and runs out of charging in the middle it created the urgency to charge at a public station, else sometimes due to other cases, such as during a power outage. According to research EV's which charge art public stations are 20%. The advantage of public charging station over a home charging station is, that it gives a better mileage and it gives some additional hours for driving the car. The cost of charging, at both public and home station varies from country to country, the source of power and power supplier [8]. From our research, we now know how charging station also plays a crucial part in EV's efficiency and life. Other than destination, types of charging stations are also classified on another criterion, according to that criterion-the two types of charging stations are- AC charging station and DC charging station. Batteries can only be charged with direct current (DC) electric power, while most electricity is delivered from the power grid as alternating current (AC). For this reason, most electric vehicles have a built-in AC-to-DC converter, commonly known as the "onboard charger". At an AC charging station, AC power from the grid is supplied to this onboard charger, which produces DC power to charge the battery. DC chargers facilitate higher power charging (which requires much larger AC-to-DC converters) by building the converter into the charging station instead of the vehicle to avoid size and weight restrictions. The station then supplies DC power to the vehicle directly, bypassing the onboard converter. Most fully electric car models can accept both AC and DC power[9]. For home charging purposes mostly users use level 2 charging which is a 240-volt charger, which users install at their homes to charge the vehicle. It charges at the rate of 20-35 miles per hour.

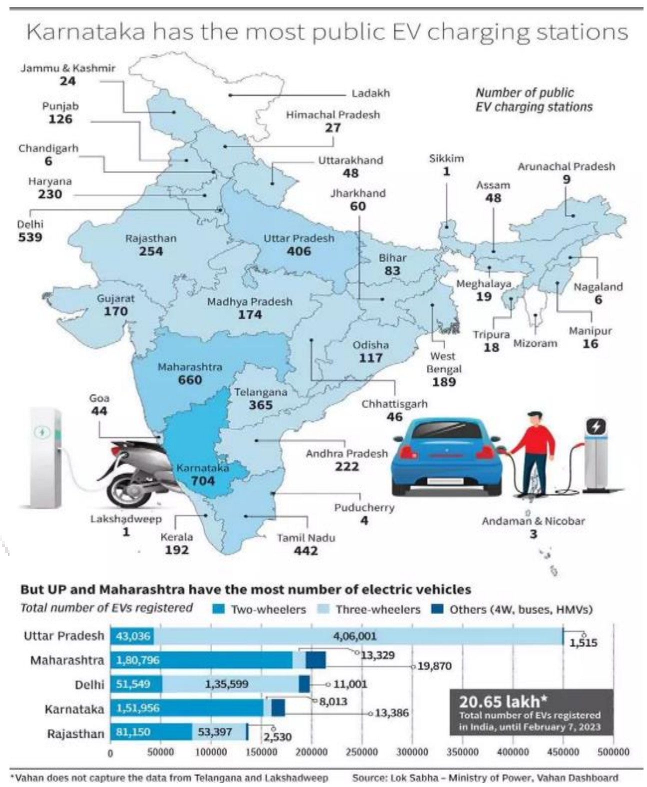

Fig 2. A Map Showing no. of Charging Stations in Different States of India

Fig 3. EV Charging at Home Station

Fig 4. EV Charging at Public Station

B. Distribution System

The distribution system is the part of an electric system after the transmission system that is dedicated to delivering electric energy to an end user[10]. EV charging station can affect various parameters of a distribution system, degradation of voltage profile, increase in peak load, harmonic distortions are some of the consequences of the uncoordinated charging of EV's [11]. In a research it was mentioned that "As electric vehicle demand increases so too does the corresponding load requirements for charging the vehicles. The expansion of power generation and transmission capacity is therefore a critical question to address whether the electricity grid can handle the increase in electricity load [12]." This issue has been examined in capacity investment models and for transmission systems. Generally, studies have indicated that the greater amount of load flexibility is taken advantage of, the lower the capacity requirements are for wholesale generation and transmission within the electricity system. However, in most examinations of future scenarios, the required capacity increases needed to meet EV charging loads are still relatively small[13]. When the load demand from different destinations such as residential, industrial and commercial falls on the distribution system, it adds up with the already existing load demand and becomes the reason why distribution system starts acting abnormally. The distribution system is designed in a way to bear a specific amount of load. When the load applied to it exceeds beyond a certain level, it leads to abnormal working of distribution system, this abnormality doesn't continues for a long time, after some time, the system fails and does not operate. When the load from residences is applied on the grid, the grid is simultaneously facing heavy load due to the heavy appliances installed at the homes. Much of the existing literature on electric vehicle charging employs modeling charging behavior based on large-scale travel diaries of internal combustion engine (ICE) gasoline vehicles. However, there are important distinctions between travel behavior between vehicle technologies (particularly for early adopters of EVs) as well as observed charging patterns compared to modeled patterns [14]. The technology which allows the bidirectional flow of energy between EV and grid is known as vehicle-to-grid (V2G). It is achieved by the integration of Information and Communication Technologies (ICT) with the EV charging system. The modelling research of EV interaction with the distribution network has transitioned from unidirectional mode in the initial stage to bidirectional mode in the current stage [15]. With the increasing level of EV penetration, the associated technical issues, e.g., system imbalance, decreased stability, and power quality, as well as increased system cost, are becoming more prominent, due to additional energy and power demand. The unidirectional approach, i.e., G2V mode, has been extensively studied in the literature in the form of topics like smart charging, safety, and control features. The focus of these studies is on minimizing the charging cost or minimizing the impact on the distribution system [16]. However, in the bidirectional mode, EV is not only the load for the grid, but also a distributed generation and storage. The initial idea was to use EV battery to store energy and send it back to the grid in peak period, known as peak load shaving [17]. Reference [25] presents a review of peak shaving strategies using demand-side management, energy storage systems, and electric vehicles. Table 1 illustrates the characteristically differences between the unidirectional and bidirectional modes. As an individual EV has a small battery capacity, a major challenge is the synchronization of a large number of EVs charging/discharging operation required for them to be an effective storage system. Also, the limited uptake of EV did not quite make this idea of using EV in the bidirectional mode mainstream. Research later indicated that the application of bidirectional V2G in the ancillary market: Spinning reserve and voltage control is much more important than peak load reduction. Spinning reserve is the extra generation that can be made readily available, and it is paid for the availability along with the time it is called for deployment (compared to peak load shaving), which makes deployment of EV in ancillary service provision very

Table 1. Modes of interaction between EV and grid [35]

Features	**Unidirectional**	**Bidirectional**
Power Flow	Grid-to-vehicle (G2V)	G2V & vehicle-to-grid
Infrastructure	Communication	Communication bidirectional charger
Cost	Low	High
Complexity	Low	High
Services	Loadprofile management, frequency regulation	Backup power support, frequency regulation, voltage regulation, active power support
Advantages	Overloading prevention, load levelling, profit maximization, emission minimization	Overloading prevention, profit maximization, emission minimization, renewable energy sources(RES)integration, voltage profile improvement, harmonic filtering
Disadvantages	Limited services	Battery degradation, high complexity and cost social barriers

economically favourable. Moreover, in terms of frequency of deployment, the voltage regulation is needed more than 300 times per day compared to the need for peak load shaving, which is only a few hundred hours per year [18].

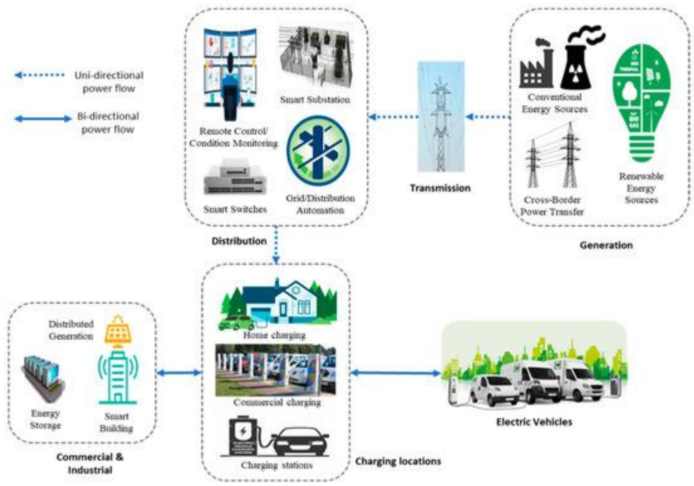

Fig 5. EV integration with the electrical grid

III. METHODOLOGIES

In accordance with the research conducted we perceive that different researchers owned different ways to reduce the burden on the distribution system that it experiences due to charging of EV's. The methodology proposed by different researchers had some parameters in common which needs to be first calculated or measured. The parameters found in common in all the researches were- SOC, arrival time, disconnected time, battery capacity, battery efficiency, charger capacity, time required to charge the EV's and energy required by EV. To calculate these parameters there are some equations which are generally used. Arrival time and disconnected time are the times at which EV arrives at home as the name itself explains and the disconnected time also called as departure time is the time at which EV gets charged fully and gets disconnected from the grid. Various researchers carried their research for different time slots. Some did it from 6 P.M.-11 P.M, some from 6 P.M.-12 P.M while others from 5 P.M-11 P.M. As the time slots in different literatures vary, the results vary accordingly. SOC is the abbreviation for state of charging, which can be defined as he level of charge of an electric battery relative to its capacity. SOC is usually expressed as percentage [19]. The time and energy required largely depends upon SOC, as when the vehicle arrives home and the percentage of charging present in it will decide the time and energy the vehicle will require. Some regulated the research taking in consideration the value of SOC from 0.2-0.9, others from 0.2-0.75 while rest others from 0.2-0.7 SOC has minimum and maximum values, i.e. the minimum percentage of charging present in EV and the maximum charging present in the EV. For the methodology SOC_min (minimum) and SOC_max has to be taken care of individually. All these parameters are normally distributed, as far as generation of the data is concerned, some literatures generated this data randomly, and some collected data whereas others took it further from some reference papers. SOC required is the charging required by the vehicle. It can be calculated as:

SOC_Required = SOC_Final-SOC_Initial

"Battery capacity" is a measure of the charge stored by the battery, and is determined by the mass of active material contained in the battery. The battery capacity represents the maximum amount of energy that can be extracted from the battery under certain specified conditions [20]. Battery capacity was observed to be a standard value in different literatures which was chosen according to the vehicle and the methodology proposed. Battery efficiency is a measure of energy loss in the entire discharge/recharge cycle. eg. for an 80% efficient battery, for every 100kWh put into the battery, only 80kWh can be taken out [21]. Its value was also standard in different literatures. Energy required is the energy required by the vehicle to run. It can be calculated as:

Energy Required = SOC_Required *Battery Capacity/Battery Efficiency

Time required is the time taken by the EV to charge to its maximum level. It can be calculated as:

Time Required = Energy Required/Charger Capacity

Shahab Bahrami and Vincent W.S. Wong in 'A Potential Game Framework for Charging PHEVs in Smart Grid' focused on proposing a frwamework that is based on potential games, a class of games where the players; best response strategies converge to a Nash equilibrium. The PHEVs are considered as players in the game, and the framework aims to achieve a Nash equilibrium where the charging cost is minimized and the grid stability is improved [21]. D.Q. Oliveira, A.C. Zambroni de Souza, L.F.N. Delboni in 'Optimal plug-in hybrid electric vehicles recharge in distribution power systems' proposes a recharging process with the help of Artificial Immune Systems, to Improve recharging of PHEV. The authors propose a two-stage optimization method that considers the EV users; charging preferences, the available grid capacity, and the distribution network constraints. The first stage optimizes the charging schedule form each EV, and the second stage optimizes the overall grid operation by coordinating the EV charging with the distribution network operation. To minimize greenhouse emission and decreasing oil dependence [22]. Shidong Liang, Bingqing Zhu, Jianjia He, Shengxue He, Minghui Ma in 'A pricing strategy for electric vehicle charging in residential areas considering the uncertainty of charging time and demand' proposes a two-part tariff pricing strategy for electric vehicle charging in residential areas that takes into account the uncertainty of charging time and demand. The authors also develop a mathematical model to optimize the pricing strategy [23]. Mohammad Sohrab Hasan Nizami, M. J. Hossain, and Khizir Mahmud in 'A Coordinated Electric Vehicle Management System for Grid-Support Services in Residential Networks' the proposed system uses a distributed algorithm to minimize the overall energy cost of the network while satisfying the charging requirements of the electric vehicles and meeting the demand of the residential load. The system considers various factors, such as electricity tariff rates, battery degradation, and the availability of renewable energy sources, to optimize the operation of electric vehicles in the residential network. The effectiveness of the proposed system is demonstrated through simulation studies [24]. Milad Soleimani , Mladen Kezunovic in 'Mitigating Transformer Loss of Life and Reducing the Hazard of Failure by the Smart EV Charging' proposes that the effectiveness of smart EV charging in mitigating transformer loss of life and reducing the hazard of failure. The methodology includes collecting data on electric vehicle power demand, transformer loading, and voltage levels, analyzing the data to identify correlations, developing simulation models, and discussing the findings in the context of the existing literature. The study will conclude with recommendations for power utilities, charging station operators, and policymakers to implement smart EV charging strategies to reduce the risk of transformer failure in the power distribution system [25]. Chuangxin Guo , Dongyu Liu, Wei Geng , Chengzhi Zhu, Xueping Wang, Xiu Cao in 'Modeling and Analysis of Electric Vehicle Charging Load in Residential Area' is to collect the data on electric vehicle charging patterns in a residential area by development of a mathematical model of the charging load. The model is used to simulate different charging scenarios and evaluate their impact on the power grid. It explores the impact of various charging management strategies, like time of use pricing and smart charging on the charging load and the power grid. This paper identifies potential solutions to mitigate the challenges associated with electric vehicle charging in residential areas [26]. Visvakumar Aravinthan, Ward Jewell in 'Controlled Electric Vehicle Charging for Mitigating Impacts on Distribution Assets' is based on collecting the data on EV adoption rates and grid characteristics, developing a distribution grid model, simulating the impact of uncontrolled EV charging, evaluating different controlled charging strategies, conducting an economic analysis, performing a techno-economic assessment, identifying regulatory and policy barriers, and applying the methodology to a case study.

It can be performed on two methods -:

1. First step, the number of vehicles to be charged during each hour is optimized based on day ahead requests for charging.

2. The second step determines the maximum number of vehicles

that can be charged based on operating conditions during the next hour to ensure distribution reliability requirements are met [27].

Lisa Calearo , Andreas Thingvad , Kenta Suzuki , and Mattia Marinelli in 'Grid Loading Due to EV Charging Profiles Based on Pseudo-Real Driving Pattern and User Behaviour' proposes to collect the data on real-world driving patterns and EV charging behaviour through surveys and other sources. Create a pseudo-realistic driving pattern model based on the collected data. Simulating the charging profiles of EV owners based on the driving pattern model and user behaviour data and analyze the impact of the simulated EV charging profiles on the electric grid, including peak demand and grid stability. Proposing strategies to mitigate the potential negative impact of EV charging on the electric grid, such as smart charging technologies and time-of-use [28]. Chin Ho Tie, Chin Kim Gan, Khairul Anwar Ibrahim in 'The Impact of Electric Vehicle Charging on a Residential Low Voltage Distribution Network in Malaysia' modeled a residential LV network in Selangor, Malaysia using Open DSS simulation tool, and considered the self-impedance and mutual-impedance of the cable in the LV network modeling. EV and charging profile modeling were done using the Nissan Leaf as a case study, with each EV load modeled at a constant power demand of 3.3 kW [29]. Lunci Hua, Jia Wang and Chi Zhou in 'Adaptive Electric Vehicle Charging Coordination on Distribution Network' proposes the following:

- DC Power Flow-Based Optimization
- Parallel AC Power Flow Verification
- Incremental Feasibility Improvement Procedure
- Experiments [30]

Maksym Oliinyk, Jaroslav Džmura, Daniel Pál in 'The Impact of Electric Vehicle Charging on the Distribution System' proposes the following:

1. Load flow analysis to simulate impact on voltage levels

2. Transformer overloading analysis to evaluate potential overloading

3. Proposed control strategies to manage impact

4. Case study in Slovak Republic to demonstrate application [31]

T. Simolin, A. Rautiainen, J. Koskela, P. Järventausta in 'Control of EV Charging and BESS to Reduce Peak Powers in Domestic Real Estate' proposes how to utilize real-time measurements and memorized peak power consumption to determine available power, control EV charging and BESS to flatten power demand curve, use renewable energy sources to maximize clean energy, conduct simulation studies to evaluate effectiveness, and analyze impact of EV penetration [32]. Kristien Clement-Nyns, Edwin Haesen in 'The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid' proposes to analyze the impact of PHEV charging, propose coordinated charging strategies, compute optimal charging profile of PHEVs using stochastic programming techniques, and analyze the effectiveness of proposed strategies [33].

Table 2. EV features under analysis [36]

EV Model	Battery Capacity (kWh)	Charging Power (kW)	Electrical Driving Efficiency (km/kWh)	EV number
Chevrolet Volt	16.00	3.50	3.75	01;06;11;21;26;31;36;41;46
Nissan Leaf	24.00	4.00	6.70	02;07;12;17;22;27;32;37;42;47
BMW i3	22.00	11.00	7.20	03;08;13;18;23;28;33;38;43;48
Tesla S	60.00	11.00	6.70	04;09;14;19;24;29;34;39;44;49
Renault Zoe	22.00	3.50	6.70	05;10;15;20;25;30;35;40;45

The various methodologies mentioned above taken from various literatures had some gaps. These gaps needs to be taken care of and worked in order to make these vehicles an ideal choice for the customers. EV is the present of the indispensable transportation of our lives, with some more advancement in it can be the best choice and future of the vehicles. It is a clean fuel, and does not have any detrimental environmental affects, it increases the efficiency of the vehicles and reduces the cost to a considerable extent. Recent venture of EV, an EV bus from Jaipur to Delhi costs a fare of Rs. 280 only and is a 2 hour journey, whereas in any other mode of transport i.e. bus, rail or car it takes in about 6 hours of time. So clearly EV's are contributing not just to save our money but also to save something which is very precious, time. We should adapt ourselves to changes, replacement of vehicles based on fossil fuels now needs to be replaced with electric vehicles. In a big boost to electric vehicles in Uttar Pradesh, chief minister Yogi Adityanath has said that all state government vehicles will be gradually replaced with EVs by 2030. To meet this target, departments have been told that purchase of EVs can be done without tendering, on the basis of nomination and that if required, more than the maximum limit set for purchase of EVs can also be spent [34].

IV. CONCLUSION

In conclusion, this review paper has extensively examined electric vehicles (EVs) and their various types. The discussion encompassed key concepts pertaining to EVs, including charging stations and the distribution system. Furthermore, the paper explored the impact of different types of load on the distribution system, as well as how charging EVs can affect it. The methodologies employed in different literature sources and the parameters utilized in these methodologies were also analyzed. The advantages of EVs were emphasized, underscoring their pivotal role in the future of transportation. Ultimately, this paper has provided readers with a comprehensive understanding of all the aforementioned concepts, equipping them with a profound familiarity with the pertinent research domains.

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