Note

Electric vehicles' charging demand on grid:
Requiring city distribution system to be strengthened

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Abstract

In view of climate change considerations, the Government of India is putting all efforts and asking the auto manufacturers to reduce the internal combustion engine driven vehicles and increase the electric vehicles on the Indian roads. The Government has announced that 30 per cent of all the vehicles must be electric by 2030 and has also made policies related to the charging infrastructures required. But there will be millions of e-buses, private e-cars and e-cabs, mostly concentrated in large/metro cities; and that would demand enormous power to be supplied to these cities. By computations of power demand in 2030 for e-buses, private e-cars, e-cabs, e-rickshaws and e-scooters, this paper proposes to highlight this aspect of power demands of electric vehicles on major cities, which has not been covered in any technical literature so far, especially for the Indian National Grid.

Keywords

charging load on Indian National Grid, electric four-wheelers, electric three-wheelers, e-scooters, fast and slow charging

1. Introduction

For climate change mitigation, all the governments in the world and also the Government of India (GoI) are actively pursuing the goal to reduce the consumption of fossil fuels in the two major sectors of high consumption. The first one is electric power generation, where the main approach by all the Governments has been not to have new coal-fired power plants and to have increased electric power generation by renewable energy sources (RES). Transportation is the second sector, where the use of fuels (giving tailpipe emission) is also causing the problem of pollution, affecting the health of people of all ages. For GoI, the reduction in consumption of petroleum products in transport sector is very important as it would reduce the import bill for the country because most of the petroleum products are imported due to very low indigenous production.

Therefore, in order to reduce the pollution in cities due to tailpipe emission from the internal combustion engine (ICE) operated vehicles, GoI has announced various measures, implementation dates and the other guidelines related to the increased use of "Pure Battery Electric Vehicles" (hereafter referred to in this paper as "EVs") in all the different types of transport segments. The paper does not propose to touch the hybrid electric vehicles.

In simple explanation, an EV consists of electric motor powered by a battery bank through a power electronic controller. In this paper, the discussions will be related only to lithium-ion batteries, as by 2030 all the EVs would certainly have only these. The battery bank capacity in kilowatt-hours (kWh) is an important design consideration for EVs; because the distance travelled by the EV with a fully charged battery increases with the increase in kWh of the battery bank. But as at present, the cost of lithium-ion battery bank is about 30 to 40 per cent of the cost of EV, the increased kWh of battery bank increases the initial cost of the EV. Therefore, the designer has to make a compromise between the EV cost and the distance range depending upon the type of EV.

With a given kWh of the battery bank, it has to be recharged after EV has covered the designed travel. The battery experts normally advice people to see that the battery bank does not get discharged below about 40 per cent; and then it must be recharged till the charge become more than 90 per cent [Battery University, 2018]. For lithium-ion battery, it is advisable not to go for full charging. Thus, recharging a battery bank normally involves top-up of charge from about 40 per cent to about 90 per cent; that is, the charging requires energy equal to about 50 per cent of the battery kWh. Another related factor is the charging duration. Lithium-ion battery can be charged for time duration ranging from one to three hours. These two considerations of charging energy required and charging duration help in designing the charging infrastructure for the EV.

The main policy by GoI on EVs sets a target of 30 per cent of all vehicles to be electric by 2030 [RMI-NITI, 2017]. For some categories of vehicles, GoI would like the per cent penetrations of EVs to be more and the target dates to be earlier; these are being finalized based on discussions with the manufacturers.

For having 30 per cent of all the vehicles to be EVs by 2030, the various vehicles to be considered for Indian roads are: buses (both with Government owned transport operators and with private owners), cars (both private and cabs), three-wheelers and two wheelers. With regard to the charging power demand, it becomes necessary to consider the situation for each category of vehicle separately. This is because, for each category of vehicle, the number of vehicles in India is different at present and the growth rate depends upon the consumers' demand. Therefore, the number of vehicles for each category by 2030 has to be computed separately. Further, the charging requirements for each category will be different, because that depends upon the battery bank kWh and the charging duration.

The present paper tries to analyze the effects of battery charging on city distribution system as per the situation in

2030. For this, as discussed above, power demand for each category of vehicle will be calculated separately considering number of vehicles as of now, growth rate for the next 11 years, per cent of vehicle fleet that would be electric by 2030 (for this, the paper proposes to consider that the per cent of the fleet that would be electric could also be lower so as to be realistic for some categories of EVs), and average kWh of battery bank in the EV fleet.

2. Electric buses

2.1 Status of buses in India

In India, transport services are under control of the State Governments. A few decades ago, the passenger road transport in every Indian State was managed only by the Public Sector Undertaking (PSU) under control of the State Government. This PSU was called as "State Road Transport Corporation" (SRTC). For example, the intra-city and inter-city bus services in the Indian State of Andhra Pradesh were being organized by "Andhra Pradesh State Road Transport Corporation" (APSRTC). But, gradually, because of the financial limitations of the State Governments and SRTCs, the private operators were allowed to enter in transportation of people, in both intra-city and inter-city services. Therefore, most of the addition of number of buses in Indian cities in the last two decades has been only by the private operators, with not much addition by the SRTCs (due to their weak financial conditions). As given in Table 1 based on the report by the Indian Government [OGD PMU, 2017], the total number of buses in India increased from 633,900 in 2001 to nearly three times to 1,907,500 in 2015.

Thus, with increase in the number of passengers travel, there was a requirement of increase in the number of buses; and this opportunity was grasped by the private operators. Due to the bad financial position of the SRTCs, there was only a marginal increase in their number of buses, resulting in continuous decrease in their per cent share of buses during that period from 18.14 to 7.13.

Another observation from Table 1 is that there was annual growth rate of about 11 to 12 per cent during 2001 to 2011, but it was only 4.3 per cent during 2011 to 2015. Assuming an optimistic value of linear growth of 10 per cent in number of buses, it can be said that, as on March 2019, the total number of buses in India could be about 2.793 million. Most of these buses (say, 94 – 96 per cent) would be with the private operators. Further, assuming a linear growth of 10 per cent per year for the next 11 years also, the total number of buses in India can be estimated to be about 8 million by 2030. With very small growth in buses with SRTCs, it can be taken that the number of buses with them would be about 200,000 (0.2 million) and the remaining 7.8 million buses will be with the private operators.

2.2 Requirement of e-buses by 2030

Although GoI has set a target of 30 per cent by 2030, it appears to be difficult because there are 7.8 million buses with private operators. As the e-buses are costlier as compared to the diesel or gas operated buses, the private operators would not be able to invest the required huge amount every year to procure the e-buses (even considering the incentives being offered by GoI). Therefore in this paper, it is assumed that GoI will be able to have 30 per cent of EVs (that is 0.06 million) in the fleet of SRTCs by 2030. But for the computation of EV charging load on Indian National Grid for the private bus operators, it is taken that the number of e-buses in the total fleet by 2030 could be: 10 per cent (0.78 million) for Case-1; 20 per cent (1.56 million) for Case-2; and 30 per cent (2.34 million) for Case-3. Combining these figures of private buses with those with SRTCs (0.06 million), the total number of buses to be charged becomes: 0.84 million for Case-1; 1.62 million for Case-2; and 2.40 million for Case-3.

2.3 Power demand for charging of e-buses

The computation of power demand of e-buses in 2030 for these three cases has been done in Appendix-A. When the buses are charged in one hour during day time, then for Case-1, Case-2 and Case-3, the charging of e-buses would put a power demand of 12.6 GW, 24.3 GW and 36 GW, respectively, on the National Grid. For the installed power capacity of 356 GW now and certainly of more than 700 – 800GW in 2030, this demand may not be of any concern. But, as most of these e-buses will be concentrated in 10 metro cities, each metro city has to provide for the additional EV charging power load of: about 1.3 GW for Case-1; about 2.4 GW for Case-2; and about 3.6 GW for Case-3. This power demand for metro cities is certainly quite substantial and requires proper planning by the city administrations along with the distribution companies (DISCOMs). Of course, as the number of e-buses in the different cities would not be the same, there would be variations in the power demands in the different metro cities from the GW values calculated.

Table 1: Growth in number of buses in India

	Total No. (× 1,000)	No. with SRTCs (× 1,000)		No with Private Operators (× 1,000)	
As on	Total No. of Buses	No. of Buses	% of Total	No. of Buses	% of Total
Mar-01	633.9	115.0	18.14	518.9	81.86
Mar-06	992.0	112.1	11.30	879.9	88.70
Mar-11	1604.4	130.6	8.14	1473.8	91.86
Mar-15	1907.5	140.5	7.13	1767.0	92.87

3. Private electric cars

3.1 Status of private cars in India

Although there is a double-digit growth of buses in India, the growth is not able to match the increased requirements of public transport in all the major cities. As per the news report, India needs 3,000,000 buses, but has only 300,000 (only 10 per cent of the requirement) [Dash, 2018]. In many major cities, the Governments have also introduced "Metro Train" services; but even then, those have not been sufficient to cater to the increasing needs of the working people and the students. Therefore, people have to use the other mode of transport. With a large number of cars from the reputed Indian and international players readily available in Indian market during the last 10-15 years and with easy availability of car loans from banks for the working group, people have gone to purchase cars if they could afford it. That has resulted in explosive growth in the number of private vehicles on the Indian roads, giving the problems of traffic congestion on roads (particularly during the peak periods of 0.8.30 to 10.30 hrs and 17.00 to 21.00 hrs) and air pollution due to the tail-pipe emission of gases from these petrol / diesel-driven cars, leading to several diseases in the people of all age groups.

Table 2 shows the number of cars [Maps of India, 2016] in 10 major cities of India in 2016. One striking observation is that the number of cars in Delhi is more than the total number of cars put together in the three major cities of Bengaluru, Chennai and Mumbai; clearly bringing out the reason for regular congestion on Delhi roads and also why Delhi has become one of the most polluted cities of the world. With about 6 million cars in 10 major cities, the total number of cars in India was about 10 million in 2016; and with linear growth rate of 10 per cent per year, the number of cars in March 2019 would be more than 13 million. Assuming linear growth rate of 10 per cent per year for the next 11 years also, it can be said that the number of cars on Indian roads would be more than 37 million by 2030.

3.2 Requirement of e-cars by 2030

In order to have more than 30 per cent e-cars on Indian roads by 2030, total number of e-cars is required to be more than 11 million. But, with high cost of electric cars in India compared to the mass-produced petrol / diesel-engine cars, the number of electric cars sold in India [Auto Car, 2019] has been just 1,200 in 2017-18 and 3,600 in 2018-19. In India, it is a typical "hen and egg" situation; there is low demand of EVs because the production is low and there are very few charging infrastructures; and the manufacturers are not coming forward because there is low demand.

With such low volume sales of electric cars, reaching a target of 11 million e-cars in the next 11 years looks really challenging for the Indian Government. Therefore, for computing the load demand of charging infrastructure for cars on National Grid in 2030, here also three cases are considered; Case-4 where e-cars could be 10 per cent = 3.7 million; Case-5 with e-cars of 20 per cent = 7.4 million; and Case-6 having 30 per cent of total cars = 11.1 million.

3.3 Power demand for charging of e-cars

The computation of power demand for charging of private e-cars on Indian National Grid for these 3 cases is given in Appendix-B. Thus, the power demand on the National Grid for these three Cases-4, 5 and 6 in 2030 would be about 23 GW, 46 GW and 69 GW, respectively. Assuming that these cars will be mostly concentrated in 10 metro cities, the day time power demand in each metro city for the charging of 25 per cent of e-cars will be about 2.3 GW for Case-4, 4.6 GW for Case-5 and about 6.9 GW for Case-6. These levels of power demands also require proper planning by the DISCOMs for the concerned cities. For the night time charging of e-cars at residences, the power demand in each metro city for the charging of 75 per cent of e-cars has been computed to be the same as given above (for the day time charging), which may not be significant at nights, when anyway the power demand of the other city load is very less.

As given in Table 2, the number of cars in the different cities is different. The number of cars in Delhi is about 6 to 10 times of those in Pune, Chandigarh, Ahmedabad, Jaipur and Kolkata;

Table 2: Number of cars in 10 major Indian cities

Rank	City	No. of Cars
1	Delhi	2,172,069
2	Bengaluru	800,866
3	Chennai	653,270
4	Mumbai	617,556
5	Hyderabad	558,081
6	Pune	332,293
7	Chandigarh	286,584
8	Ahmedabad	239,558
9	Jaipur	235,310
10	Kolkata	222,069

Source: As on March 16, 2016.

and about 2.5 to 4 times of those in Bengaluru, Chennai, Mumbai and Hyderabad. Therefore, the power demand in the different cities would also be different.

4. Commercial electric cars

4.1 Status of e-cabs in India

Table 3 gives the number of cabs in 13 major States of India [Statista, 2016]. (Note: The numbers have been taken from a graph and, therefore, rounded off for the sake of explanation.) With about 2 million cabs in 13 Indian States, the total number in 2016 in all the Indian States would be about 2.5 million. Assuming a linear growth rate of 10 per cent per year, the total number of cabs in March 2019 would be about 3.3 million (which happens to be about 25 per cent of the total cars) in India. Some of the reasons for this rapid growth of cabs in Indian cities during the past few years could be as given below.

A number of "App-based" cab operators are available in all major cities, each offering many discounts and schemes to compete with each other. Also, with a large number of cabs with each operator, a user can get the cab at the desired location in a few minutes. Therefore, most of the young people working in information technology (IT) or service industries with disposable income are using these cabs every day for point-to-point travels. With a competitive market, many times, the travel of 3-4 people using a cab costs nearly the same or marginally more (but with more comfort) than a three-wheeler auto-rickshaw. Therefore, many people are regularly using these cabs instead of the auto-rickshaws. Thus, it has become a chain reaction. As number of users is increasing, more cab operators are appearing in the market, resulting in decrease in fare and the availability in a short time, and so more people start travelling by cabs.

There are many contract services (being operated by "Travel Agents"), who are regularly providing vehicles to many public sector and private organizations. These vehicles are being used for bringing the senior people from their residences, dropping them back after office hours and for their travel required for meeting the clients or attending the meetings etc at the other locations.

4.2 Requirement of e-cabs by 2030

A report by Reuter has brought out the policy framed by the Central Government that all the cab operators must plan to go to electric vehicles in a gradual manner: 2.5 per cent by 2021; five per cent by 2022; ten per cent by 2023, before hiking it to forty per cent by April 2026 [Reuter, 2019b]. The Government also recommended that all new cars sold for commercial use should only be electric from April 2026. Thus, unlike personal cars, GoI has desired to have a large number of e-cabs even by 2026.

The number of commercial cars in 2019 is about 3.3 million. Assuming a linear growth of 10 per cent per year for the commercial cars, their number would be about 6.43 million by 2026. With 40 per cent of cabs becoming electric by 2026, the number of e-cabs would be = $0.4 \times 6.43 = 2.572$ million. Continuing the trend of 10 per cent linear growth, the number of e-cabs would be = 3,766,114 by 2030.

The Government of India has already planned [MOP, 2018] that in all the large cities "at least one charging station should be available in a grid of 3 km × 3 km". Therefore with easy availability of charging stations within every metro city, the drivers can have fast charging of e-cabs at one of these charging stations during day time. The cabs normally cover about 200 to 300 km per day and need 2 times fast top-up (each of about 30 minutes or 0.5 hour) during day time apart from slow charging at night (of about 3 hours) at their residences.

4.3 Power demand for charging of e-cabs

It is assumed that the average capacity of battery bank of each cab is 50 kWh and 50 per cent top-up at each time re-

Table 3: Number of cabs in Indian States

S No.	State	No. of Cabs
1	Tamil Nadu	370,000
2	Karnataka	250,000
3	Maharashtra	240,000
4	Rajasthan	130,000
5	West Bengal	130,000
6	Gujarat	120,000
7	Kerala	110,000
8	Uttar Pradesh	100,000
9	Odisa	100,000
10	Telangana	100,000
11	Bihar	90,000
12	Delhi	90,000
13	Andhra Pradesh	80,000

Source: As on March 2016.

quires = 0.5 × 50 kWh = 25 kWh. If this charging is done in 0.5 hour, then the power required = (25 kWh) ÷ (0.5 hour) = 50 kW. If the cab driver does 2 times top-up during day time, then it can be assumed that about 20 per cent of the e-cabs would come to the charging stations simultaneously.

Therefore, number of cabs to be charged simultaneously = 0.2 × (3,766,114) = 753,223; Charging power = (50 kW) × 753,223 = 37,661,140 kW = 37,661 MW = 37.7 GW.

As this power demand for cabs will be divided into 10 major cities, the power demand in each city during day time would be about 3.77 GW. This again requires proper planning by the DISCOMs in the respective cities. For e-cabs also, the number in the different cities would not be the same; and therefore, the computations of power demands for charging of e-cabs must be done correctly for each city, so that the city administration and DISCOM can have the distribution system of adequate capacity.

5. Electric rickshaws

5.1 Status of rickshaws in India

India is the largest manufacturer of all types of three-wheeler vehicles. The three-wheeler segment (mostly with ICE) has reported a robust 24 per cent growth in overall volume (sales) in 2018-2019, due to 49 per cent growth in exports. Total sales of three-wheelers during 2018-19 stood at 1.269 million units, against 1.017 million units in 2017-18 [Ravichandran, 2019]. The domestic sales during 2018-19 saw about 10 per cent growth to 701,011 units as compared to 635,698 units in 2017-18, mainly because of increase in demand of auto-rickshaws in cities necessitated by increase in population there. Exports supported the domestic sales heavily with about 49 per cent growth to 567,689 units in 2018-19, against 381,002 in the year-ago period; this could be possible primarily due to enormous demand for the low-cost Indian three-wheelers in Asian and African regions. A study in India [Majumdar and Jash, 2015] had shown that during the last decade there was a double-digit growth in use of auto-rickshaw by people.

5.2 Electric rickshaws in India

The e-rickshaws were introduced in Delhi during the "Commonwealth Games" in 2010. But, these have gained popularity in India since 2015. Almost 300,000 battery powered rickshaws have now replaced the cycle rickshaws in key markets of the North-East, Uttar Pradesh, West Bengal, Delhi and Bihar States of India [Philip, 2019]. These battery-powered three-wheeler vehicles have become one of the fastest growing segments in India, with a compounded growth rate of 20 per cent in the past four years. In the year 2014-15, e-rickshaw sales were 170,000 units. The e-rickshaw sales were 350,000 units in 2017-18; and in 2018-19, the sale of e-rickshaw was 630,000 units, which interestingly was 83 per cent of total EV sales in India [Wadhwa, 2019]. The figure is estimated to grow 25 per cent annually to e-rickshaw sale of one million units by 2024-25. Continuing the 25 per cent growth rate, the sales of e-rickshaws in 2030 would be about 3 million. There is no official data available regarding the total number of e-rickshaws on roads in 2019; this is due to the fact that the e-rickshaws are not registered in many Indian States. But, taking the above trend of growth, it can be estimated that the total number of e-rickshaws would be about 17 million units by 2030.

5.3 Power demand for charging of e-rickshaws

In this paper "Treo" e-rickshaw of "Mahindra & Mahindra" is taken as the specimen EV for computation of charging load. This EV has 3.69 kWh of lithium ion battery bank, required to be charged in 2 hours 30 minutes (2.5 hours) [M&M, 2019]. Again taking that top-up required would be 50 per cent of the battery capacity:

Charging energy = 0.5 × (3.69 kWh) = 1.845 kWh in 2.5 hours; Power demand of each e-rickshaw = (1,845 kWh) ÷ (2.5 hours) = 0.738 kW.

All the e-rickshaws would be put for charging as soon as the driver comes back to home or gives it back to the owner. For this computation, a factor of 30 per cent is assumed as there are many hours available for charging in the night.

Therefore, power demand on Indian grid = (0.738 kW) × (0.3 × 17,000,000) = 3,763,800 kW = 3,764 MW = 3.764 GW.

As this demand for e-rickshaws is distributed in a large number of cities, towns and even small places, this would not pose problem for the Indian National Grid or for cities and that too in the night time when the other loads are very small.

6. Electric scooters

6.1 Status of two-wheelers in India

In the calendar year 2016 [Bora, 2017], about 17.7 million two-wheeler vehicles were sold in India (mostly operated by ICE), with India becoming the number one country in the sale of two-wheelers, pushing China to the second place with sale of about 16.8 million two-wheeler vehicles. Scooter sales alone accounted for over 5 million of those figures in India, while commuter motorcycles of 100-110 cc had nearly 6.5 million unit sales. In 2017-18, the Indian auto makers cumulatively crossed for the first time the sales of 20 million units of two-wheeler vehicles.

6.2 Electric scooters in India

As reported by "The Hindu Business Line" based on report by Reuter, sales of e-scooters in 2017-18 was 54,800 which was double of the figure in 2016-17; and the sales are expected to cross 2 million in 2030 [Reuter, 2019a]. For the purpose of computation of charging load on National Grid, it is assumed that the total number of e-scooters in India in 2030 would be about 8 million. Also, it is taken that the average capacity of lithium-ion battery pack in each scooter would be about 3 kWh, which when fully charged is sufficient for the running of e-scooter for the full one day. Therefore, the employees in the government/public sector/private sector having facilities of charging (taken about 25 per cent of the total e-scooters) can do the charging in the office complex in 2 hours during day time; and the remaining 75 per cent e-scooters can charged in 2 hours during night time at their residences.

6.3 Charging demand of e-scooters

With 50 per cent top-up required during each charging:

The energy required will be = 0.5 × (3 kWh) = 1.5 kWh

When charged in 2 hours, the power demand of each e-scooter = (1.5 kWh) ÷ (2 hours) = 0.75 kW. For 25 per cent of the total e-scooters charged during day time:

Power demand = (0.75 kW) × 0.25 × (8,000,000) = 1,500,000 kW = 1,500 MW = 1.5 GW

For 75 per cent of the total e-scooters (8 million) charged during night time:

Power demand = (0.75 kW) × 0.75 × (8,000,000) = 4,500,000 kW = 4,500 MW = 4.5 GW

The above power demand would be distributed all over India (because scooters are being used even in small places apart from towns, cities and metros). Therefore, the power demand of this magnitude may not be of any problem in 2030 for the National Grid and also in parts of India both during day time and night hours.

7. Discussion

The computations have been done in this paper for the power demand of EVs on the Indian National Grid in 2030. The demands have been calculated separately for e-buses, private e-cars, e-cabs, e-rickshaws and e-scooters.

For buses, as there are about 7.8 million units with private operators, it appears difficult that those operators would be able to put so much investment in the next 11 years to get 30 per cent e-buses (that is, 2.34 million, taken as Case-3). Therefore, two more cases are considered assuming that only 10 per cent (taken as Case-1) and 20 per cent (taken as Case-2) of buses might be electric with the private operators. When the buses are charged in one hour during day time, then for Case-1, Case-2 and Case-3, the charging of e-buses would put a power demand of 12.6 GW, 24.3 GW and 36 GW, respectively, on the National Grid. For the installed power capacity of 356 GW now and certainly of more than 700-800 GW in 2030 during the day time and also during the night time, this demand may not be of any concern. But, as most of these buses will be concentrated in 10 metro cities, each metro city has to provide for the additional e-bus charging power of: about 1.3 GW for Case-1; about 2.4 GW for Case-2; and about 3.6 GW for Case-3 throughout the day. Although these power demands are average values for cities, the value for different cities would vary. But, these levels of additional power demand for charging of e-buses for most part of the day in all metro cities is certainly quite substantial and requires proper planning by the concerned city administrations along with DISCOMs.

Similarly, as there would be a large number of private cars (37 million) by 2030, getting 30 per cent e-cars (11.1 million) would also be difficult to be attained. Therefore, again taking 3 cases of 10 per cent e-cars (Case-4), 20 per cent of e-cars (Case-5) and 30 per cent of e-cars (Case-6), the power demand on the National Grid for these three Cases-4, 5 and 6 in 2030 would be about 23 GW, 46 GW and 69 GW, respectively. Assuming that these cars will be mostly concentrated in 10 metro cities, the day time power demand in each metro city for the charging of 25 per cent of e-cars will be about 2.3 GW for Case-4, 4.6GW for Case-5 and about 6.9 GW for Case-6. These levels of power demands also require proper planning by the DISCOMs for the concerned cities although the values would vary for different cities. For the night time charging of e-cars at residences, the power demand in each metro city for the charging of 75 per cent of e-cars has been computed to be the same as given above (for the day time charging), which may not be significant at nights, when anyway the power demand of the other city load is very less.

For cabs, the policy has been framed by GoI [Reuter, 2019b] asking all the cab operators to plan to go to electric vehicles in a gradual manner, attaining 40 per cent by April 2026. The Government also recommended that all new cars sold for commercial use should only be electric from April 2026. Assuming that this policy gets implemented, the total number of e-cabs would be 3.77 million by 2030, giving power demand of 37.7 GW during day time. As this power demand for cabs will be divided into 10 major cities, the power demand in each city during day time would be about 3.77 GW. This again requires proper planning by the concerned city administration along with DISCOM.

For e-rickshaws, the power demand computed came to 3.76 GW. As this demand for e-rickshaws would be distributed in a large number of cities, towns and even small places, this would not pose problem for the Indian National Grid or for cities and that too in the night time.

For e-scooters, the power demand was computed as 1.5 GW during the day time and 4.5 GW during the night time. The above power demand would be distributed all over India (because scooters are being used even in small places apart from towns, cities and metros). Therefore, the power demand of this magnitude also may not be of any problem in 2030 for the National Grid.

Thus, as discussed above, the charging of e-rickshaws and e-scooters (mostly during night time) does not appear to be of any concern for the power system in 2030. But the power demand on the National Grid would be quite substantial due to the charging of e-buses, private e-cars and e-cabs. For the worst case scenario of 30 per cent for each category of vehicles (e-buses, e-cars and e-cabs), the total power demand on each metro city for charging of these EVs would be = (3.6 + 6.9 + 3.8)

= 14.3 GW. With power demand of the order of 5 to 7 GW for most of the metro cities in 2019, which might become 10 to 14 GW (without EV charging load) in 2030, providing additional load of about 14.3 GW would really be unmanageable unless planned properly and in advance by the city administrations and DISCOMs.

8. Recommendations

GoI has desired to have 30 per cent (or more) of the total road vehicles to be electrified by 2030. But with a large number of vehicles (buses with private operators and private cars), having 30 per cent EVs would require enormous funds with bus operators and general public which could be difficult. For cabs, GoI has demanded 40 per cent of e-cabs by 2026; which also appears difficult. Therefore, GoI must have proper assessment of the ground situation after discussion with the stakeholders, so that some realistic target of EVs by 2030 could be decided.

For charging infrastructures also, GoI must have discussions with the cash-rich petroleum companies (Bharat Petroleum Corporation Ltd, Hindustan Petroleum Corporation Ltd, Indian Oil Corporation etc) and other public and private sector organizations to install EV charging stations within the cities and on the highways, so that the private e-cars or e-cabs could be charged when required.

As shown by the computations done in this paper regarding the power demands for the charging of EVs by 2030, the city administrations and DISCOMs must start planning for meeting the situation. Also, the load on the substations at bus depots, at charging stations on the city roads and in residential complexes could be quite significant when a large number of EVs come for charging at the same time; this would require strengthening of the corresponding distribution systems.

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Appendix A: Power demand for charging of e-buses in 2030

- Case-1, EVs = 0.84 million
- Case-2, EVs = 1.62 million
- Case-3, EVs = 2.40 million

Assuming that on an average the e-bus battery capacity is 300 kWh; and, as explained earlier, each bus charging of 50 per cent top-up would demand (300 kWh) x 0.5 = 150 kWh.

Charging of e-buses during day time

As the number of buses for most of the operators (including SRTCs) is small, each bus would require fast charging in one hour during day time, so that the bus can go again fast for the next trip. Thus, charging of each bus during day time demands a power of (150 kWh) ÷ (1 hr) = 150 kW.

Assuming that 10 per cent of the e-buses get charged simultaneously, the total charging load on National Grid would be as given below.

- Case-1:
  No of e-buses being charged simultaneously = 0.1 × (No of e-buses = 840,000) = 84,000
  Total load = 84,000 × (150 kW) = 12,600,000 kW = 12,600 MW = 12.6 GW
- Case-2:
  No of e-buses being charged simultaneously = 0.1 × (No of e-buses = 1,620,000) = 162,000
  Total load = 162,000 × (150 kW) = 24,300,000 kW = 24,300

MW = 24.3 GW

- Case-3:
  No of e-buses being charged simultaneously = 0.1 × (No of e-buses = 2,400,000) = 240,000
  Total load = 240,000 × (150 kW) = 36,000,000 kW = 36,000 MW = 36.0 GW

It may be pointed out that the power demand values have been calculated above assuming 10 per cent of the e-buses to be charged simultaneously. The power demand values would become 2 times if the number of buses being charged simultaneously becomes 20 per cent.

Charging of buses during night time or "battery swapping"

For bus operators, it is advisable to go for battery swapping during day time. For this, the electrical staff of the bus depot quickly removes the partially discharged battery bank from the bus as soon as a bus comes back to the depot after one trip and puts a fully charged battery bank in the bus. In this way, the bus can go back for the next trip in a short time. The partially discharged battery bank can be charged afterwards in 3 hours by the electrical staff. After completion of all the trips by the e-buses, the battery banks can also be charged in 3 hours during night hours.

Then the power requirement for each bus = (150 kWh) ÷ (3 hours) = 50 kW.

As the power demand for each bus in this situation has become one-third, the power demand on the National Grid will be the same as computed above (for charging during day time in one hour) even if 30 per cent of the buses or the partially discharged battery banks (removed from the buses during the day time) are charged simultaneously.

Appendix B: Power demand for charging of private e-cars in 2030

- Case-4 taking 10 per cent, the number of e-cars = 0.1 × 37 million = 3.7 million
- Case-5 taking 20 per cent, the number of e-cars = 0.2 × 37 million = 7.4 million
- Case-6 taking 30 per cent, the number of t e-cars = 0.3 × 37 million = 11.1 million

It is assumed that most of the cars would have lithium-ion battery bank with average capacity of 50 kWh. It is expected that by 2030, a good number of government/public-sector/private-sector organizations will be providing charging points in the office complexes to encourage the employees to purchase and come to offices by e-cars; and so it is taken that about 25 per cent of the total e-cars are charged in the offices with fast charging in one hour during day time. Fast charging is desirable, so that more number of employees can use the limited charging facilities. The remaining 75 per cent of the e-cars (belonging to the shopkeepers, or for the staff of offices not providing charging points) will be charged in the houses in 3 hours during night time.

With 50 per cent of top-up for the 50 kWh battery bank, the charging for each e-car will consume = 0.5 × (50 kWh) = 25 kWh.

For day time charging in offices in one hour for 25 per cent of e-cars, the power demand on the National Grid will be as given below. Power required = (25 kWh) ÷ (one hour) = 25 kW.

- Case-4:
  (25 kW) × (0.25 x 3,700,000) = 23,125,000 kW = 23,125 MW = 23.125 GW
- Case-5:
  (25 kW) × (0.25 × 7,400,000) = 46,250,000 kW = 46,250 MW = 46.250 GW
- Case-6:
  (25 kW) × (0.25 × 11,100,000) = 69,375,000 kW = 69,375 MW = 69.375 GW

For night time charging, the per cent of e-cars being charged simultaneously would be small as the car owners may get the charging done for 2 to 3 hours any time from 20.00 hrs to 06.00 hrs. Also with small distances travelled by the personnel cars, the battery bank of cars would not get discharged much and the cars can be charged even after one or two days. Further, the loads in cities during night time are small and additional loads of e-car charging would not be of much problem.

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