Augmentation of charging infrastructure for electric vehicles growth in India

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Abstract: India, one of the fastest growing economies, has been a front-runner in fulfilling its commitments towards a cleaner Earth. In this pursuit, it intends to adopt electric vehicles (EVs) to the tune of 30% by 2030. Central and state governments of India have launched several financial incentives to encourage adoption of EVs. While considering various adoption rates of EVs from 5% to 30%, the requirements of additional amounts of electricity and various types of charging stations to feed power to EVs are estimated. At 30% adoption rate, about 140 million EVs (include different categories of vehicles studied in this paper) may become the part of transportation system and correspondingly need about 24,600 MWh of electricity daily. In the high density areas of EVs, such as bus depots, residential complexes, malls etc., large power may be needed at a single point. Thus, it may require sufficient receiving substation capacity and an equivalent high-voltage distribution network.

Keywords: charging stations; distribution network; electric vehicles; EV adoption rates; energy.

Reference to this paper should be made as follows: Goswami, R. and Tripathi, G.C. (2020) ‘Augmentation of charging infrastructure for electric vehicles growth in India’, Int. J. Electric and Hybrid Vehicles, Vol. 12, No. 1, pp.44–58.

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1 Introduction

Road transport is one of the vital sectors in the sustained development of a nation and is also considered as a major contributor to greenhouse gases (GHG) emissions (IEA, 2018). The Organisation for Economic Cooperation and Development (OECD) has estimated the cost of air pollution effects on health of about $500 billion in India (OECD, 2014). Road transport in India carries about 60% and 80% of the freight and passenger loads, respectively (Ramachandra and Shwetmal, 2009). In India, with the growth of population and GDP, the number of registered motor vehicles has grown swiftly from 81 million in 2005 to 210 million (Guite, 2016) in 2015 (Figures 1 and 2), which eventually increased the consumption of fossil-fuel (CNG, LPG, diesel, gasoline). India’s crude oil production fulfils only about 17% (Abdi, 2018) of its demand and the rest has to be imported.

Figure 1  Population and vehicles growth in India (see online version for colours)

The ever-rising fossil fuel price, mounting GHG emissions and depleting natural resources have amplified the burden on society and environment. Therefore, it is important to substitute the internal combustion engine (ICE) vehicles with non-fossil-fuelled ones. Presently, battery electric vehicles (BEVs) are emerging as an optimistic eco-friendly modes of road transport. The ICE vehicles swapping with EVs may have various economic and environmental advantages. India has embarked on an ambitious plan of 30% electric vehicles (EVs) by 2030 (Shah, 2018). Presently, battery capacities and limited driving range of EVs could limit the adoption rate. However, different people or groups may have different need and the current EV technology may fulfil their travelling/driving need. With the present subsidies and policies, the demand for EVs may continue to grow upward and become accessible substitute of ICE vehicles. However, adequate charging infrastructure may facilitate EVs penetration to the Indian automobile market. Charging infrastructure, which include uninterrupted supply of quality electricity and charging stations (slow and fast chargers) to transfer power from grid to EV, will play an important role for EV adoption. Therefore, to increase the adoption rate of EVs,
Government of India (GoI) should aggressively build the prerequisite charging infrastructure of EVs. The growing number of EVs would increase the demand for an uninterrupted supply of electricity to feed the increased charging points. In order to achieve this target, development of requisite charging infrastructure and supply of electricity is a must.

Figure 2 GDP per capita and CO$_2$ emission in India (see online version for colours)

Rest of the paper is organised as follows. Section 2 depicts the background and perspective of this study. Section 3 described data and methodology. Section 4 contains significance of increased adoption rate of electric vehicles. Section 5 discusses the results obtained from the data analysis. Based on research outcomes, Section 6 presents policy implications, and finally, Section 7 concludes the research findings.

2 Literature review

Globally, there is an increasing consent to reduce carbon emissions from transport sector and to sustain this, considerable research on various aspects of electric mobility is required. Therefore, a balanced-mix of research & development (R&D), innovative EV policies, consumer behaviour, and prerequisite infrastructure development, is required to be studied. Environmental and economical benefits of EVs and governments’ policy recommendations for individual/s as well as for the society have been studied (Vidhi and Shrivastava, 2018). From the business and societal perspective, a study in Austria has found that employers’ financial incentives to their employees for purchase of EVs can play an important role in endorsing EVs in rural areas (Soder and Peer, 2018). Li et al. (2017) have studied the impacts of renewables and socio-economic factors on the demand of EVs (Li et al., 2017).

The impact of building new charging stations on peak load demand in the distribution network has been studied (Fan et al., 2013; Sehar et al., 2017). For stability, a static load model has been developed and authors have evaluated the impact of load of charging
stations on voltage stability (Dharmakeerthi et al., 2014). De Hoog et al. (2015) have studied the network constraints and voltage requirement at distribution level with individual charging loads in the network. The impact of harmonic distortion on the distribution sub-stations has been analysed and it has been found that due to direct connection of number of EVs to the grid and large charging load with high temperature may damage the distribution transformer (Gómez and Medhat, 2003). A multiphase model of the primary and secondary systems has been conducted and it has been found that plug-in hybrid EVs (PHEVs) have no major harmonic impact on power systems (Jiang et al., 2014). The effects of charging station loads on the power losses, economic losses of the distribution network, reliability indices, and voltage stability have been studied and authors have concluded that strong grid can take the large loads of EVs’ fast charging stations up to a certain level, however, installation of fast chargers at the weak grid may affect the efficiency of power system operations (Deb et al., 2018).

However, there is a dearth of literature on the effect of various adoption rates of EVs, on the electricity requirement and impact of charging stations loads on the Indian distribution network and requirement of developing distribution lines, distribution sub-stations and so on. In this paper, various adoption rates of EVs are appraised to explore additional electricity requirement and prerequisite charging infrastructure. Therefore, it is important to systematically analyse various categories of EVs (public and private transport), battery capacity, charging level, state of charge (SOC: percentage of power remained in the battery), average daily run, number of charging stations and amount of additional electricity needed for re-charging the battery.

3 Data and methodology

3.1 Study area

In 2016, population of India had increased to 1.3 billion and GDP to $ 1717 per capita and number of registered vehicles had also grown to 230 million as compared to 55 million vehicles during 2001 (OECD, 2018). More than 80% of the total numbers of vehicles are personalised ones; of these, about 74% are two-wheelers and 12% are cars. The steady increase in the personalised mode of transport has resulted in slow growth of public transport (buses), which corresponds to only 1% of the total market share. The light motor vehicles (LMV), which include three-wheelers, tractors, trailers, etc., have a share of about 2%. More dependency on personalised transport has resulted in increased consumption of fossil fuel, resulting in increased GHG emissions, which have made 14 cities of India are among the world’s most polluted (BBC, 2018).

3.2 Types of electric vehicles and battery capacities

An electric vehicle uses electric motor/s for propulsion and gets power from batteries. The EV batteries get charged during reduction of speed using regenerative braking system, especially in cars and buses. But, when the depth of battery discharge goes down below a certain level, the batteries are required to be re-charged.

EVs comprise two-wheelers, three-wheelers, cars, and buses. Additionally, electric vehicles also include PHEVs, which also have internal combustion engine and also use
electricity to charge the batteries. However, this paper considers only the following battery EVs types: two-wheelers, three-wheelers, cars, and buses.

The battery capacity is the main feature to determine the cost and operating range of EVs. EV battery capacity and type depends on the type of vehicle, weight and driving range. Generally, electric two-wheelers and three-wheelers have batteries of 2–10 kWh capacities and provide driving range from 50–120 km. Daily average distance run by a two-wheeler and three-wheeler is about 25 km and 100 km, respectively. The battery capacity of electric car can be in the range of 20–30 kWh depending upon its cost, weight, and driving range. The daily average distance travel is about 35 km for a private car and about 190 km for a commercial car. The battery power of electric bus (e-bus) depends on the cost, seating capacity, airconditioned/non-airconditioned and operating range. Average run per day for a bus is about 200 km. For the diverse categories of EVs, electrical energy consumption (mileage) km per kWh and daily power usage with battery capacity are described in Table 1.

### Table 1  Battery capacity and power consumption of various types of EVs

<table>
<thead>
<tr>
<th>Type of EV</th>
<th>Battery power (kWh)</th>
<th>Operation range (km)</th>
<th>Average Run (km/day)</th>
<th>Mileage (km/kWh)</th>
<th>Electricity needed/EV/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Wheeler</td>
<td>2–5</td>
<td>50–100</td>
<td>25</td>
<td>25–30</td>
<td>0.7–1 kWh</td>
</tr>
<tr>
<td>3-Wheeler</td>
<td>5–10</td>
<td>80–120</td>
<td>100</td>
<td>14–18</td>
<td>6–10 kWh</td>
</tr>
<tr>
<td>Car (domestic)</td>
<td>20–30</td>
<td>100–150</td>
<td>35</td>
<td>6–7</td>
<td>5–6 kWh</td>
</tr>
<tr>
<td>Car (commercial)</td>
<td>20–30</td>
<td>100–150</td>
<td>190</td>
<td>6–7</td>
<td>27–32 kWh</td>
</tr>
<tr>
<td>Buses</td>
<td>150–325</td>
<td>110–220</td>
<td>200</td>
<td>0.6–0.8</td>
<td>265–350 kWh</td>
</tr>
</tbody>
</table>

*a*Mileage depends on various factors such as vehicles type, load on vehicle, weather and road conditions, city or highways driving, uphill or plains, etc.

*b*Charger efficiency considered as 95%.

### 3.3 Level of charging of EV batteries

Like the fuel gauge in ICE vehicles, the state of charge (SOC) indicates the energy remaining in a battery, suggesting the requirement of recharging and preventing the battery from overcharging/discharging. Various models/algorithms have been studied to estimate SOC to derive drawbacks and benefits (Hannan et al., 2017). In this paper, it is considered that when EV battery depth of discharge reaches 20%, it will be recharged. Fast chargers will recharge the EV battery up to 80% and slow chargers will recharge up to 100% of its capacity.

**Assumptions of an EV charging:** Bus battery capacity is 250 kWh and after daily trips, bus comes for charging when its battery energy level is down to 20% (50 kWh). With the fast charger, bus is charged up to 80% (200 kWh). Thus, charging is required to feed 200 – 50 = 150 kWh.

For slow charging of 200 kWh (to charge 100%) in 8 h, power needed would be 25 kWh for 8 h because slow chargers are of good efficiency (99%). For fast charging of 150 kWh (can charge up to 80% of battery capacity) in 30 min (1/2 h), power needed would be 300 kWh for half an hour. Fast chargers are considered to be 90–95% efficient. Thus, power required = 300 kWh/charger efficiency (90 to 95%).
As per the type of EV and battery capacity, daily power requirement is described in Table 2.

### 3.4 Adoption rate of EVs

In 2016, India had about 23 million vehicles, which include 9% of transport (freight, commercial) and 91% of non-transport vehicles (public transport, which also includes commercial). Transport vehicles include about 25% trucks, 27% light motor vehicles goods (LMV), 8% buses, 12% taxis, and 28% LMV passengers. Non-transport vehicles comprise 81% two-wheelers, 13% cars, 4% tractors and 2% others. In metro cities, the ratio of number of cars to the total number of vehicles is more than the national average and that of two-wheelers is relatively less. For example, Delhi has lower number of two-wheelers (67%) and more of cars (30%) as compared to the non-metro and rural areas in India. NITI Aayog, a think tank of India, has aimed at achieving 30% of EVs by 2030. Therefore, different adoption rates of 5%, 10%, 20%, and 30% for each category of vehicles are considered to project the number of EVs on Indian roads by 2030.

### Table 2 Electricity requirement to power EVs’ batteries

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Battery remains charged (kWh)</th>
<th>Energy required to 80% charge (kWh)</th>
<th>Energy required (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>fast charger</td>
<td>slow charger</td>
</tr>
<tr>
<td>2-wheeler</td>
<td>0.4–1.0</td>
<td>1.2–3.0</td>
<td>2.4–6.3</td>
</tr>
<tr>
<td>3-wheeler</td>
<td>1.0–2.0</td>
<td>3.0–6.0</td>
<td>6.3–12.6</td>
</tr>
<tr>
<td>Car (domestic)</td>
<td>4.0–6.0</td>
<td>12.0–18.0</td>
<td>25.3–38</td>
</tr>
<tr>
<td>Car (commercial)</td>
<td>4.0–6.0</td>
<td>12.0–18.0</td>
<td>25.3–38</td>
</tr>
<tr>
<td>Bus</td>
<td>30.0–65.0</td>
<td>90.0–195.0</td>
<td>95–205</td>
</tr>
</tbody>
</table>

*Battery considered to remain charged up to 20%.

*With fast charging, battery will be charged up to 80% in 1/2 h.

*With slow charging, battery will be charged up to 100% in 8 h.

*Fast charging for buses considered to be in 1 h.

### 3.5 EVs charging infrastructure

The EVs available in the Indian market have been considered in order to evaluate the charging infrastructure requirement. For charging infrastructure, home charging may be the preferred option for domestic EV users due to the convenience and cost advantage (Schroeder and Traber, 2012; Madina et al., 2016). Hou et al. (2013) have studied that in cities, most of the people travel short distances and thus self-charging at home is sufficient to meet the daily travel demand. Therefore, public charging infrastructure may not have significant impact on the adoption of EVs for domestic users; but the adoption of EVs for commercial use is likely to be influenced by the commercial charging infrastructure.

Electric two-wheelers used for commercial purposes (e.g., city courier services, home delivery of food, and online commercial goods, etc) have higher daily run and would need fast chargers. But, the private two-wheelers can be charged with domestic slow chargers. Similarly, most of the private car owners would recharge their EVs at
homes. Electric three-wheelers and cars, being used for longer distances per day for commercial purposes, would mostly need fast charging. The charging mode and frequency (how many times a day) of buses would depend on the battery capacity and daily usage.

If there would be same electricity tariffs at home or at commercial charging points, then people would generally prefer fast charging options available at commercial stations. With the upcoming charging technologies, it is considered that fast chargers would be able to recharge the two-wheeler’s battery in 30 min and slow chargers (at home) in 4–8 h. Fast chargers would charge the electric three-wheelers and cars in 30 min and slow chargers in 8 h. Electric buses’ batteries depending on capacities would be recharged in 30–60 min with fast chargers (at terminals) and in 8 h with slow chargers at depot.

3.6 Charging stations
EVs are charged using alternating current (AC, level-1 and level-2: slow charging) or direct current (DC: fast charging) chargers (Shahan, 2015). Battery charging infrastructure may influence demand for the EVs in each category. GoI has proposed to set up charging stations at every 3 km in the cities with population of more than a million and every 50 km on highways (Business Today, 2018). Municipal authorities will facilitate land and also offer monetary incentives for setting up charging stations. In the next 5 years, it is projected to have 30,000 slow charging and 15,000 fast commercial charging stations in India (Singh, 2018). State owned energy sector utilities like NTPC, PGCL, IOCL, etc. have planned to build charging stations at several identified locations in the selected cities in India. Presently, more than 60,000 fuel stations are dispensing gasoline and diesel in India and these may also be the potential locations to be selected for installing EVs charging stations. The fast growing cab operators (Ola, Uber, etc) are also planning to introduce EVs and set up charging stations in various cities in India (Mukherjee and Gaur, 2018).

4 Significance of increased adoption rate of EVs
The effective policy environment would make EVs more attractive to customers (both individuals as well as fleet owners) and drive the EVs’ adoption. GoI has initiated (Faster Adoption and Manufacture of Hybrid and Electric Vehicles (FAME) India, which is a part of the National Electric Mobility Mission Plan (NEMMP, NMEM, 2018) and encourages EVs by giving financial subsidies in most electric vehicle segments: two-wheelers, three-wheelers, cars, and buses. State governments have also encouraged e-mobility by offering various financial incentives to reduce acquisition cost of EVs. Various incentive schemes of GoI and state governments would drive demand to meet India’s target of 30% EVs by 2030. Additionally, public procurement would encourage increasing the EVs production, which would facilitate reducing costs and increasing the setting up of the charging stations and stimulate the visibility of EVs in the society. Therefore, Energy Efficiency Services Limited (EESL, under the Ministry of Power, India) has planned to replace GoI vehicles (about 500,000 cars) with EVs (Das, 2017).

It is assumed that previous 10 years of compound annual growth rate (CAGR) would continue to the next 12 years as well and on that basis, total numbers of vehicles in each category are estimated (Table 3). Although, GoI has projected to achieve 30% adoption
Augmentation of charging infrastructure for electric vehicles

This paper considers different adoption rates of 5%, 10%, 20%, and 30% to estimate the number of EVs in different categories by 2030 and correspondingly, evaluates the additional electricity requirement to fuel these EVs.

Table 3: Number of EVs expected and additional power requirement by 2030 in India

<table>
<thead>
<tr>
<th>Vehicle category</th>
<th>Number of vehicles in thousand (Ratio)</th>
<th>Total vehicles by 2030 (thousand)</th>
<th>EV adoption rate</th>
<th>Expected EVs by 2030 (thousand)</th>
<th>Electricity requirement (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fast charging</td>
</tr>
<tr>
<td>2-Wheelers</td>
<td>154,000 (74%)</td>
<td>388,000</td>
<td>5%</td>
<td>19,400</td>
<td>681–1135</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>38,800</td>
<td>1361–2269</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>77,600</td>
<td>2723–4538</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30%</td>
<td>116,400</td>
<td>4084–6807</td>
</tr>
<tr>
<td>3-Wheelers</td>
<td>5028 (2%)</td>
<td>7169</td>
<td>5%</td>
<td>358</td>
<td>63–126</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>717</td>
<td>126–252</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>1434</td>
<td>252–503</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30%</td>
<td>2151</td>
<td>377–755</td>
</tr>
<tr>
<td>Cars (private)</td>
<td>26,000 (13%)</td>
<td>65,472</td>
<td>5%</td>
<td>3274</td>
<td>766–1149</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>6547</td>
<td>1532–2297</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>13,094</td>
<td>3063–4595</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30%</td>
<td>19,642</td>
<td>4595–6892</td>
</tr>
<tr>
<td>Cars (commercial)</td>
<td>2250 (2%)</td>
<td>5666</td>
<td>5%</td>
<td>283</td>
<td>398–447</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>567</td>
<td>795–895</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>1133</td>
<td>1590–1789</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30%</td>
<td>1700</td>
<td>2386–2684</td>
</tr>
<tr>
<td>Buses</td>
<td>1527 (1%)</td>
<td>4213</td>
<td>5%</td>
<td>109</td>
<td>1146–1241</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>218</td>
<td>2292–2483</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>435</td>
<td>4583–4965</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30%</td>
<td>653</td>
<td>6875–7448</td>
</tr>
</tbody>
</table>

*Number of ICE vehicles by 2016 (percent of vehicles of the total).

*Expected number of vehicles by 2030 with the CAGR of 8%, 3%, 8%, and 3% for 2-wheelers, 3-wheelers, cars (private and commercial), and buses, respectively.

*Different adoption rates for EVs are considered.

*Fast charging considered to be spread over 48 slots over 16 h and slow charging spread over 3 slots over 24 h in a day for 3-wheelers and cars (private and commercial); and 24 and 3 slots for fast and slow charging for buses spread over 24 h.

International Energy Agency (IEA) forecasts the growth of EVs to 125 million by 2030, globally (DiChristopher, 2018). There is a diverse set of growth rates for different categories of vehicles. On that basis, last 10 years of CAGR (compound annual growth rate) is being used to calculate the total number of vehicles in each category assuming that the ratio amongst vehicles category would remain the same (Table 3). Correspondingly, electricity requirements for recharging each category of EVs are also described in Table 3.
5 Discussion

This research is to appraise impact of various adoption rates of EVs on the additional demand for electricity and required charging infrastructure to fuel the EVs. Adoption rate of EVs is mostly dependent on availability of charging stations at easily accessible locations (within the city or on highways) and security of uninterrupted supply of electricity. Keeping the target of achieving 30% of adoption rate as the highest, various adoption rates of EVs from 5% to 30% have been evaluated. The numbers of EVs with different adoption rates (on a national scale) and resulting electricity requirements are given a base position to evaluate. Charging stations and EVs (personal use) ratio is expected to be 1 : 1, but in reality the number of EVs would be more. Therefore, the required number of charging stations is also considered.

5.1 Electric two- and three-wheelers

The adoption rate can differ for various types of EVs. For example, two- and three-wheeler EVs may have higher adoption rate than the electric cars and buses. India is the world’s largest market of two-wheelers and one of the largest markets for three-wheelers for personal and cargo transportation. With 8% of CAGR, it is expected to have 38.8 million two-wheelers and considering 5% to 30% adoption rate, the number of electric two-wheelers in India would be from 1.9 million to 11.6 million. Two-wheelers, except those employed for commercial purpose, may be charged easily at home with slow charging system. In such scenario, vehicle-to-charger (AC chargers) ratio may need to be 1 : 1. At the 5% of adoption rate, 647 to 1078 MWh of electricity per day may be required to power EVs with slow charging points. If EVs at 5% adoption rate are considered to be charged with fast charging points then 681 to 1135 MWh of electricity may be needed per day.

With EV adoption rates from 5% to 30%, electric three-wheelers on Indian roads may be from 0.36 to 2.1 million (Table 3). Three-wheelers may also be charged overnight (during non-peak hours) at slow charging stations. As compared to fast chargers (90%–95%) efficiency, slow chargers are 99% energy efficient and also charge the vehicles’ battery to its full capacity, and thus, are more cost-effective. To fuel 0.36 to 2.1 million electric three-wheelers, 126–755 MWh (with fast chargers) and 119–717 MWh (with slow chargers) of electricity may be required daily. Considering one fast charger powering up to 32 vehicles in a day, then by 2030, to cater 30% of EVs in three-wheelers category may need about 65,000 commercial fast charging stations. If, electric three-wheelers come with swappable batteries, then number of charging stations may be significantly reduced and may become convenient to EV owners to extend their trips, whenever needed and battery capacity may not be a challenge any more.

5.2 Electric cars

With the CAGR of 8%, total number of cars would become 65 million (private) and 5–6 million (commercial). Correspondingly, with the adoption rate from 5% to 30%, electric cars used for private and commercial purposes in India would become 3–20 million and 0.3–1.7 million respectively. Although, in the coming years, shared mobility would grow significantly and commercial cars would grow higher than the estimated but the overall number of cars may remain the same (Navy, 2018). Unless going for long drive, most
electric cars (personal use) would be charged at home. As per Ferris (2016), domestic charging will suffice for the daily travel needs of 90% of car owners and thus, only 10% privately owned cars may need commercial fast charging stations. However, cars used for commercial purposes, may need fast chargers. In a day, a fast charger can power about 32 cars. If each fast charger reduces the charging time and powers more cars, then the number of fast chargers needed would be less. With 30% of adoption rates of electric cars for commercial use, about 1.7 million cars may need fast charging. However, 30–40 percent of commercial cars are expected to be charged with slow chargers during non-peak hours. Therefore, at the adoption rate of 30%, 70% commercial and 10% personal electric cars (about 3.1 million) would require about 98,000 fast charging points. To fuel 3.1 million electric cars with fast chargers, 2130–2568 MWh of electricity may be required daily. At the adoption rate of 30%, 90% personal and 30% commercial electric cars (about 18 million) would require equal numbers of slow charging systems. Similarly, for electric cars, swappable batteries may help in reducing the number of commercial fast charging stations as well as reduce power consumption during battery charging because slow chargers have higher efficiency. This may further reduce the risk of short operation range of presently available EVs in India.

5.3 Electric buses

Unlike electric two/three-wheelers and cars, e-buses have different types of chargers: AC chargers (type-1 up to 7.4 kW and type-2 up to 43 kW)—slow chargers, CHAdeMO chargers (fast charge with AC and DC, up to 170 kW), and pantograph (super-fast chargers, up to 450 kW) DC chargers. Each bus needs 310–410 kWh power to complete its travel every day.

Numbers and types of chargers for e-buses depend on battery capacities and daily travel need and also on driving area (either on highway or within the city). With the CAGR of 3% and different adoption rates, the number of electric buses would be from 0.1 to 0.6 million and these EVs would be charged using both the charging systems (slow or fast), depending on the business hours. The following are the choices for the electric bus:

- The bus may be provided with a smaller battery capacity of 100–150 kWh. This will give a lower cost for the e-bus but will require frequent e-charging at intermediate bus stops using pantograph type chargers. The pantograph chargers can recharge the bus battery during the period of unboarding and boarding of passengers, which is sufficient for the bus to travel up to the next bus stop to be charged by another pantograph charger. Thus, the cost of buses will be lower, but the transport undertaking has to incur cost in providing pantograph chargers at a few locations along the bus routes.

- The bus may be provided with a battery of 250–300 kWh capacity, which is sufficient for a bus to travel from one bus depot to another or return to the initial bus depot. The battery can be charged by fast charger in 20–30 min, which is available for the bus to start its next trip. Many bus operators are also going for battery-swapping in few minutes at the bus depot, so that the bus can resume its journey early. While the bus gets a charged battery immediately, the discharged battery can be charged at the bus depot using a slow charger.
For the inter-city bus operators, the bus is required to be of a higher (250–300 kWh) capacity. At the intermediate stations, the bus would require recharging of its battery in 20–30 min by fast chargers.

5.4 Overall scenario for all EVs

Thus, for 30% adoption rate, the daily energy required would be about 6800 MWh for two-wheelers, 750 MWh for three-wheelers, 9600 MWh for private and commercial cars, and 7500 MWh for buses. The aggregate energy requirement comes to about 24,600 MWh per day, which can easily be met by all-India grid. However, the point to remember is that this requirement of energy for recharging EVs would be concentrated only in major cities having a large number of EVs, needing corresponding charging infrastructure. For example, a transport bus depot having a total of 500 buses and a fleet of 250 EVs would require energy of 350 kWh $\times$ 250 = 87,500 kWh per day. Even if the charging is spread over 16 h, the power demand comes to more than 5 MW, apart from the power required for the other purposes as at present. This large power would need sufficient receiving substation capacity and corresponding high voltage distribution network of Distribution Company (DISCOM) of that bus depot. Similar would be the power requirement at a large residential complex having simultaneous slow charging of electric cars, or at a large mall having simultaneous fast charging of a large number of electric two-wheelers and cars at their parking places.

Also for the charging stations on the highways, designed for simultaneous fast-charging of 10 buses and cars would require about 2000 kWh in $\frac{1}{2}$ h, demanding about 4 MW. Such a large power would demand a 33 kV sub-station at the charging station.

GoI has proposed to install two types of charging stations (CHAdeMO-DC: fast charging and Type-1 & Type-2 AC: slow charging), 40 chargers on each of the selected highways, which connect the following metro cities: Ahmedabad-Vadodara, Bengaluru-Chennai, Bengaluru-Mysore, Delhi-Agra, Delhi-Jaipur, Mumbai-Pune, and Surat-Mumbai. One high-power charging station at every 3–5 km distance in nine metro cities with the population of more than four million (Ahmedabad, Bengaluru, Chennai, Delhi, Greater Mumbai, Hyderabad, Kolkata, Pune, and Surat) are proposed. In this ratio, Delhi would need about 400 such chargers. Additionally, under FAME-II scheme, GoI has granted Rs. 10 billion to build 4230 charging stations in 53 cities, which has more than one million populations (Datta, 2018). These infrastructure development activities by GoI would not be sufficient to cater for even 1% adoption rate of EVs across the nation, and would thus only act as initiators. Therefore, aggressive installation of various charging stations by Public Sector Undertakings (PSUs) or private players is a must to cater for the increasing adoption of EVs. With adoption rate of 30%, many petroleum companies (already having a vast network of fuel pumps) would certainly see a commercial interest to install EV charging stations (Pathak, 2017).

The vast increase in the network of charging stations within the city and on highways would require the corresponding network of high voltage distribution system feeding the high voltage sub-stations at the charging stations.
6 Recommendations

The following are some recommendations to the requirement of uninterrupted power supply and number of charging stations to support EVs adoption:

- It would be challenging for government/s (central and states) to set up large numbers of charging stations across India. Therefore, entrepreneurship should be catalysed in this area by granting initial subsidies, exempting import duties on procuring related software and hardware, facilitating land acquisitions and providing easy loans.

- Encourage manufacturers of EV charging infrastructure to design charging points to be compatible with different types of EVs. For example, commercial charging stations must be designed such that they can provide fast charging to two-wheelers, three-wheelers and cars.

- EVs should come with easily swappable and changeable batteries so that EV owners can replace their batteries with fully charged ones in just a few minutes at the authorised ‘swap centres’ and continue the drive.

- Charging stations at different places, such as home, commercial centres, etc., may lead to different tariffs. Therefore, it is crucial for designing balancing tariff plan (during peak or off-peak hours) at different charging locations (domestic and commercial). With plans in a large number of cities in India for making smart grid, which would have smart meters even for domestic consumers, the making of a suitable tariff would not be a challenge (National Smart Grid Mission: Ministry of Power, Government of India).

- For domestic EV users (mostly two-wheelers and cars), distribution companies (DISCOM) should allow installing charging points at homes.

- DISCOM must encourage the EV owners to go for vehicle-to-grid (V2G) supply during the peak-hours, if the vehicles (cars or buses) are not in use. This will help the DISCOM and also reduce the energy bill of EV owners as they can charge batteries during off-peak hours.

- With increased adoption of EVs, monitoring and control of charging stations is required to lower the peak load of stressed power distribution network.

- DISCOM must also plan expansion of their high voltage networks within the city and also on highways to feed the large number of charging stations.

7 Conclusions

This study aims to appraise the impact of different adoption rates of EVs on the additional power and charging infrastructure requirement. By 2030, at 30% EV adoption would need additional demand of 24,600 MWh of electricity per day and subsequently number of charging infrastructure (slow or fast charging depending on vehicle type and its use). To fuel large numbers of EVs in major cities, energy requirement would be concentrated to specific areas, for example, large residential complexes, bus depots, malls, etc., needing corresponding receiving sub-stations and high voltage distribution
networks. Various actors of EV industry (manufacturers of EVs and charging systems, charging service providers, utility companies, regulators, DISCOM, funding agencies, etc.) should energetically collaborate to develop a sustainable ecosystem for building large numbers of charging stations.

Acknowledgements

We gratefully acknowledge NTPC School of Business to support this research. We are grateful to acknowledge Dr S.N. Saxena (NTPC School of Business, Noida) for his invaluable suggestions during this study.

References


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Website