

Evaluating Smart Charging of Electric Vehicles on Power Consumption

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ABSTRACT

The 21st century is grappling with numerous challenges, with sustainability being a central concern. While innovation has propelled humanity into the modern era, it has also contributed to environmental issues, particularly through the extensive use of fossil fuels. In India, a developing nation with limited power generation capacity, the rapid shift toward electric vehicles (EVs)—driven by rising fuel prices—could lead to a substantial increase in electricity consumption. This shift places a significant strain on the power grid, making it essential to understand the impact on power generation and distribution systems. The study compares traditional charging models with smart charging solutions, finding that while the current impact is relatively minor, smart charging is expected to become increasingly effective by 2034 and 2040, when EV adoption reaches critical thresholds. The smart charging model proves to be more efficient in managing power consumption and can help optimize the power distribution system, providing a viable solution for the anticipated surge in demand.

Keywords: Electric vehicles, Smart charging model and Sustainable development

1. INTRODUCTION

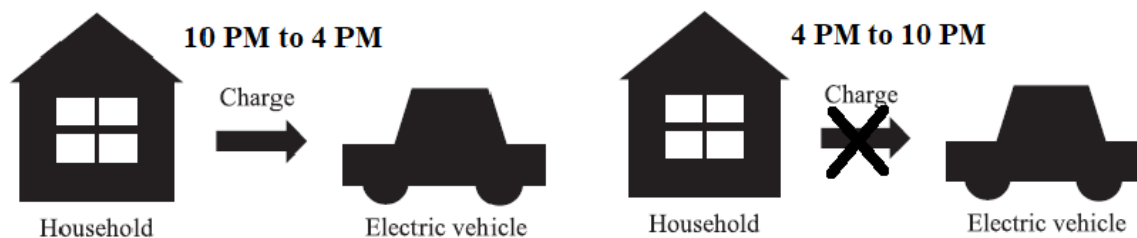
Electric vehicles (EVs) are being widely used in India in an effort to address air pollution and lessen reliance on oil. However, controlling the demand for electricity is made more difficult by the growing number of EVs connected to the national grid, especially during periods of high load. Between 6 and 9 p.m., when household and industrial power use is at its maximum, electricity consumption in India rises. The overall demand for power rises dramatically at this time, which could overload the grid if improperly managed.

Gaur et al. (2016) state that the increasing use of EVs during this peak demand period may increase the load on the electrical system. The risk of power shortages and system instability is increased when EVs are added to the grid during these peak hours, raising the overall demand for electricity. The energy supply may be negatively impacted by this increase in demand, particularly in areas where power shortages are already present.

A smart charging model for EVs is being offered as a solution to these problems. The concept can lessen the strain on the grid during peak hours by charging EVs between 1 and 5 AM, when demand is at its lowest. By assuring more effective grid management and stabilizing the electrical demand curve, this would lessen the need for expensive infrastructure upgrades.

2. SMART CHARGING

Adding a unique breaker to the car's charging circuit is how the smart charging concept operates. This breaker stops the car from charging between 4 and 10 p.m., when power usage is at its highest. The car will not be charged during this period, even if it is plugged into the charger. The breaker is switched off after 10 PM so that the car can charge regularly. Because of this, 90% of charging takes place between 10 PM and 6 AM, when there is less demand for electricity. To prevent overtaxing the grid, the remaining 10% of the charging is distributed evenly throughout the day, from 6 AM to 4 PM



To put it simply, the system makes sure that EVs are primarily charged during off-peak hours, which helps to balance the demand for electricity and lessens the strain on the power grid during peak hours.

3. DATA COLLECTION TOOLS

The secondary data used in this study came from a variety of sources, including government agencies such as the Ministry of Power, Ministry of Statistics, and Ministry of New and Renewable Energy, as well as studies on patterns of energy demand published by Gaur et al. (2016).

4. OBJECTIVE OF THE STUDY

- To find whether Smart charging model is efficient compare to Traditional charging model.
- To find whether the model improve the power distribution system
- To find out when it will be effective for impementation

5. ANALYSIS OF DATA

5.1. Power Consumption Estimation for EVs During Peak Hours

- Step 1: Charging Rates and Assumptions
 - EV Car Charging Rate: 6.5 kWh
 - EV Scooter Charging Rate: 1.1 kWh
 - Charging Efficiency Loss: 10%, leading to a 1.1x increase in power consumption.
- Step 2: Number of Vehicles Charging During Peak Hours
 - Out of 2 million EV car, we assume 30% are charging during peak hours (6 PM - 10 PM), which results in 600,000 car charging.
 - Out of 15.70 million EV scooters, we assume 40% are charging during peak hours, resulting in 6.28 million scooter charging.
- Step 3: Power Consumption During Peak Hours (4 Hours)
 - Power Consumption for EV Cars = $600,000 \times 6.5 = 3,900,000$ kWh
 - Power Consumption for EV scooters = $6,280,000 \times 1.1 = 6,908,000$ kWh
- Step 4: Total power consumption during peak hours
 - Power Consumption = power consumed by car + power consumed by scooter
 - $= 3,900,000 \text{ kWh} + 6,908,000 \text{ kWh} = 10.88 \text{ GWh}$
- Step 5: Total Power Consumption During Peak Hours after adjusting for Charging Efficiency
 - The total power consumption $= 10.88 \times 1.1 = 11.97 \approx 12 \text{ GWh}$

5.2. Effect on power consumption at peak hour Consumption in india

India's peak hour consumption rate is around 220 GWh

Impact precentage = $12 \div 220 \approx 2.7\%$

5.3. Approximate power consumption reach 10% Power of total Consumption Growth

To achieve a 10% impact, we need 22 GWh in 2025 and 35.43 GWh in 2030, considering a 5% annual growth in power consumption.

- Step 1: Number of EVs Required for 10% Impact

EV need if Consumption 22 GWh

For EV Cars $\rightarrow 22 \text{ GWh} = (22 \times .35 \times 10^6) \div (7.15) \approx 1,078,000$ cars connected

Giving us the total car number to be around **3.6 million** cars approximatly

For EV scooter $\rightarrow 22 \text{ GWh} = (22 \times .65 \times 10^6) \div (1.21) \approx 11,811,000$ scooter connected

Giving us the total car number to be around **29.5 million** scooters approximatly

For 10 GWh = $10 \div (7.15 \times 1000) = 1,398,000$ cars

For 12.74 GWh = $10 \div (7.15 \times 1000) = 1,780,000$ cars

EV need if Consumption 35.43 GWh

For EV Cars $\rightarrow 35.43 \text{ GWh} = (22 \times .35 \times 10^6) \div (7.15) \approx 1,740,000$ cars connected

Giving us the total car number to be around **5.8 million** cars approximatly

For EV scooter $\rightarrow 35.43 \text{ GWh} = (22 \times .65 \times 10^6) \div (1.21) \approx 19,100,000$ scooter connected

Giving us the total car number to be around **47.5 million** scooters approximatly

- Step 2: Year When EV Numbers Reach Required Levels

We have ued the formula Future EVs=Current EVs $\times$ (1+Growth Rate)^t

We found out that by 2034, scooters will reach their adoption threshold, and by 2040, cars will. Starting from 2025, this shift will likely have a significant impact on power consumption

6. ASSUMPTIONS

- a. To make a impact atleast 10% deference in power consumption should ne nedeed.
- b. India consumption power is increating on an avergea 5 %
- c. 30% of EV Cars Charging During Peak Hours:

India's EV car market is still growing, but studies show that car owners in urban areas, especially in metros like Delhi, Mumbai, tend to charge in the evening after returning from work. Based on data from US studies (e.g., U.S. Department of Energy), which found that around 30-40% of electric vehicle owners charge during evening peak hours, a 30% charging rate is reasonable for India.

- d. 40% of EV Scooters Charging During Peak Hours:

Electric scooters in India have much shorter daily ranges compared to cars, leading to more frequent charging. Research on Indian two-wheeler users (e.g., a study by NITI Aayog in 2022) shows that scooter owners are more likely to charge daily, especially in urban settings where scooters are used for daily short trips. A 40% charging rate during peak hours reflects this high frequency of use and the popularity of scooters as the main mode of transport in many Indian cities.

7. FINDINGS

The findings from the research are provided under the theme topics. Testing of the models in futuristic aspect:

I. Comparing the Smart Charging Model's Efficiency to the Conventional Charging Model

According to the study, power consumption is less significantly impacted by the Smart Charging approach in the current situation. However, the Smart Charging model is anticipated to become significantly more efficient by 2034 and particularly by 2040 as the use of electric vehicles increases. This might result in a 10% change in power consumption.

II. Effect on the System of Power Distribution

Electric car adoption is slower in the current market condition, the Smart Charging model initially has a negligible effect on the power distribution infrastructure. However, the model will have a greater positive impact by 2040 as a result of the widespread use of electric vehicles, enhancing grid stability, managing peak loads more skillfully, and optimizing power distribution

III. Timeline for Effective Implementation

The results show that although the Smart Charging model won't have a significant impact right away, it should start to work more efficiently by 2034 for scooters and 2040 for vehicles. These benchmarks indicate the turning points at which smart charging will have a significant influence on grid management and power consumption.

8. RECOMMENDATIONS

It is advised to expedite the construction of smart charging infrastructure and optimize grid management technologies in order to get ready for the future effect of electric cars (EVs). Governments should promote flexible energy pricing models and encourage the use of EVs through regulations and incentives. For implementation to be successful, cooperation between automakers, power companies, and tech firms will be essential.

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