# Prediction of load profile in the presence of electric vehicles for microgrid: A Review

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**Abstract:** This is right time to move towards pollution free traffic and penetration of electric vehicles are the key to maximising the benefits of low-carbon electricity and clean transportation. As the EV industry growth rate increasing in the coming future which in turn the requirement of charging stations to supply EVs. But uncontrolled charging may cause the grid to experience more peak load, needing distribution-level improvements. This paper proposes a conceptual framework to know the peak load of the system, energy requirement in a day, month & year for prediction of load profile to manage the electricity demand in the presence of EVs.

**Key Words:** EVs, load profile, micro-grid, load forecasting.

## 1. Introduction

EVs are considered to be a sustainable alternative to the internal combustion engine vehicles (ICEVs). Transportation sector account for approximately 28 % of the global greenhouse gas (GHG) emissions [1]. Since EVs having batteries with high energy storage capacity will require the increased electricity consumption. The EVs charging patterns will disrupt the load profile.  Due to issues such high initial costs, battery deterioration, a lack of adequate charging infrastructure, and range anxiety, the adoption of EVs is still slow [3]. Governments around the world implement a variety of policies and incentives to encourage the use of EVs and to overcome the barriers that prevent a complete transition to electrified transportation. According to the International Energy Agency's "Global EV Outlook 2021," the total number of EVs is expected to reach 145 million by 2030 [4].

In the global EV market India is a big market in comparison to other countries. Figure (1) shows the deployment of electric vehicles in various countries. At present **870141** EVs have been registered in India [5]. It is forecasted that India will be the fourth largest market for EVs by the year 2040 [6].

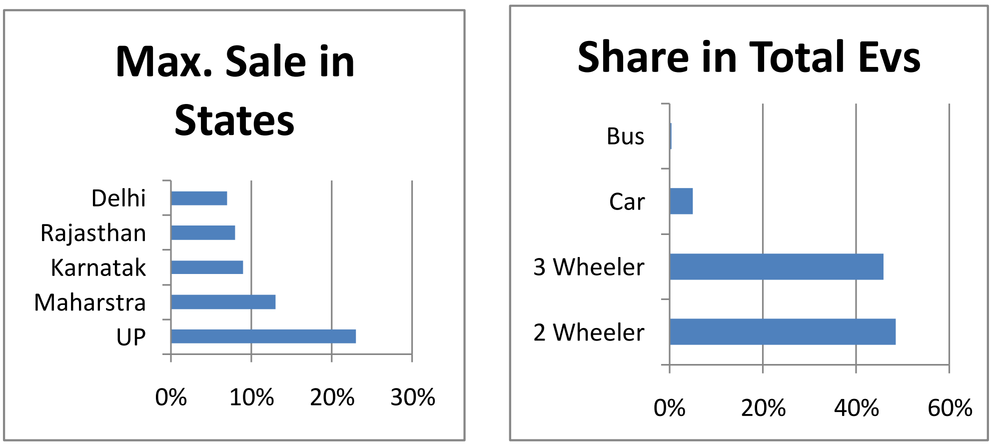



Fig. 1: Max. Sale & Share of EVs

According to JMK research and analytics report in December 2021 first time EVs sale crosses the figure of **50000** units (i.e. 50866). It was **42055** in November. Due to rise in price of petrol-diesel the sale of EVs increasing. It is expected that in 2022 the sale of EVs would be more than **10 Lac.** In the next 5 years total number of EVs would be expected more than 12 % in the country [7].

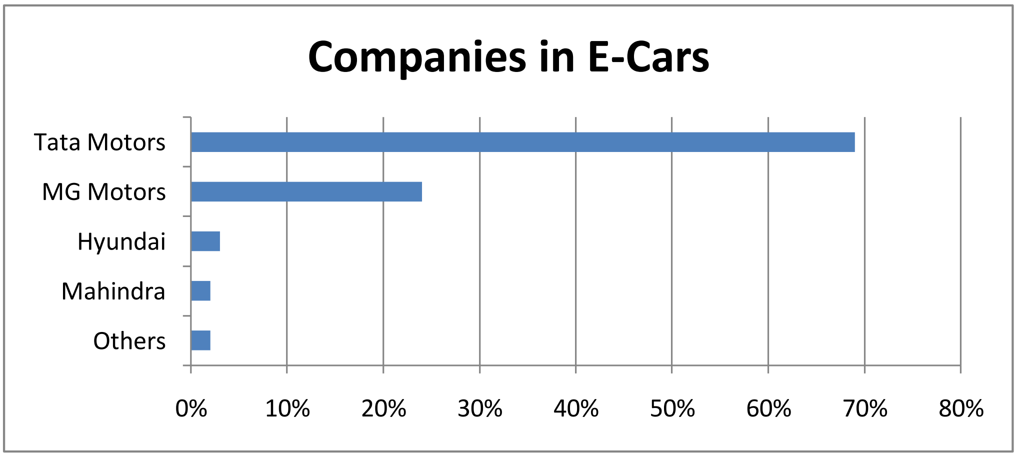



Fig. 2: Companies in E-Cars

From fig.1 & 2 it is obvious that maximum sale of EVs registered in Uttar Pradesh in India. Rajasthan is fourth largest state in sale of EVs. Almost 95% share in total EVs is of two and three-wheeler vehicles. In India for E-cars Tata Motors is leading company.

## 2. Modes of EV integration with the electrical grid

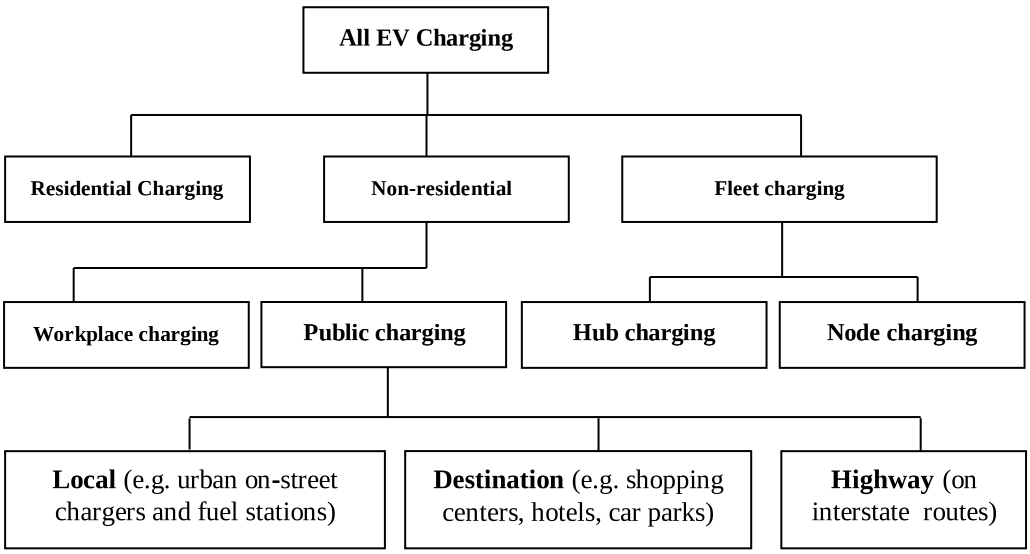
(1) Unidirectional mode (2) Bi-directional mode

Unidirectional mode is also known as G2V mode. Into this mode Electric power flows from grid to vehicle i.e. battery is charging. The goal of this mode is to reduce the impact on the distribution system or the cost of charging [8-10]. From generation to transmission & transmission to distribution, power flow is uni-directional [8]. Vehicle-to-grid technology allows for the bidirectional flow of energy between EVs and the grid (V2GInformation and communication technologies (ICT) are combined with the electric vehicle charging infrastructure to achieve this. In bidirectional mode, an EV is both a load and a distributed generation and storage system for the grid. When grid is in peak period, EV battery send the energy back in the grid, known as peak load shaving [11, 12]. A research letter claims that peak load reduction is not at all as essential as V2G mode in the auxiliary market: spinning reserve & voltage management. In contrast to peak load shaving, spinning reserve is the additional generation that may be created or made available, and it is compensated for both the availability and the time it is asked for deployment, making the deployment of EVs in the provision of ancillary services highly economically possible. Additionally, compared to peak load shaving, which only requires a few hundred hours per year [18], voltage regulation is necessary more than 300 times per year[19]. Only energy was transferred from EVs to the distribution system when V2G first started. However, two new energy transfer modalities have emerged as a result of scientific advances (V2H and V2V). According to Assad Mohammad in his study [3], the bidirectional energy transfer from EV is now classified as follows:

i) Energy transmission from an electric car to a distribution network is known as vehicle-to-grid (V2G).
ii) Energy transmission from an electric car to home or building is known as vehicle-to-home/building (V2H/V2B).
iii) Energy transmission from one electric vehicle to another electric vehicle is known as Vehicle-to-vehicle (V2V).

## 3. EV Charging and Control Methodologies

Appropriate charging infrastructure is a must for this paradigm shift to sustainable transportation, promoting EV use as a practical choice for short- and long-distance travel.



Based on the occupancy patterns and parking provisions in the various types of the buildings, charging infrastructure for EVs must be 20% of total parking capacity of the building [21]. The basic infrastructure of EV charging is shown as below [22]:
Charging infrastructure requirements for public charging station must include: connection and metering, charger types, additional charger, no. of charging points etc. Guidelines and standards for charging infrastructure are prescribed and notified by ministry of power [21]. At least one charging station must be available within the range of (3Km* 3Km) and battery swapping station may be added with charging station.

## 4. Key factors affecting load profile

As we know the nature of electrical load is resistive, inductive and capacitive. All natures of power system load can be broadly classified into domestic, commercial, industrial and agriculture load & how they affect the electricity market [24-26]. With electrical vehicles on microgrids load depends on the followings:

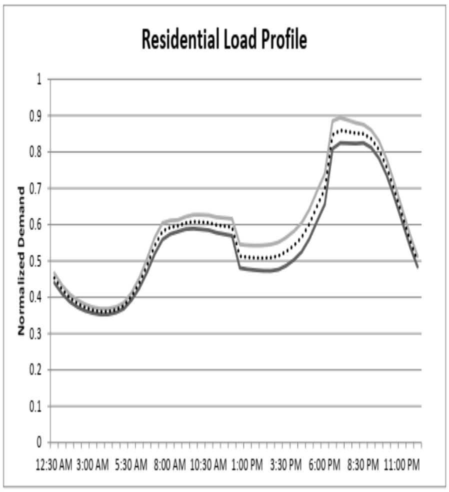
- Universities
- Shopping centers
- Airport parking
- Public car parks
- Workplace charging
- Apartment buildings
- Hotel parking
- Local parking
- Highway charging
- Dedicated fast charging stations
- Taxi fleets
- Bus fleets
- Clusters of local and destination chargers

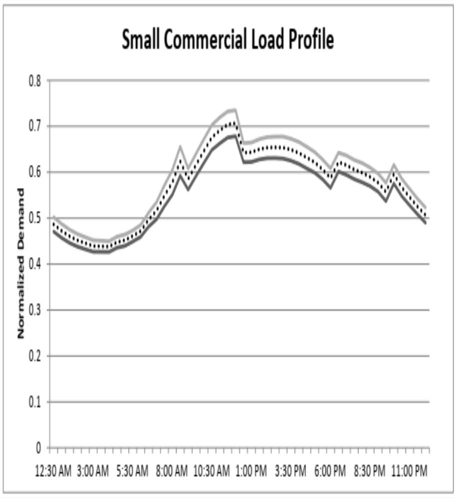
## 5. Estimating load profile & prediction of load

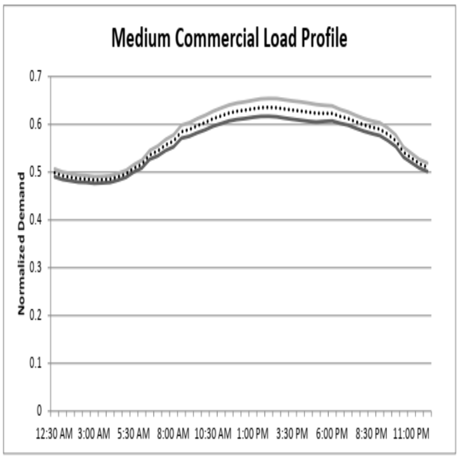
The calculation of load profiles consists of two major tasks:
(1) Selection of a portion of individual profiles, and (2) Expansion to the total population
This decision is made after calculating the individual charging profiles, which identify each individual's electricity usage and demand from the grid..

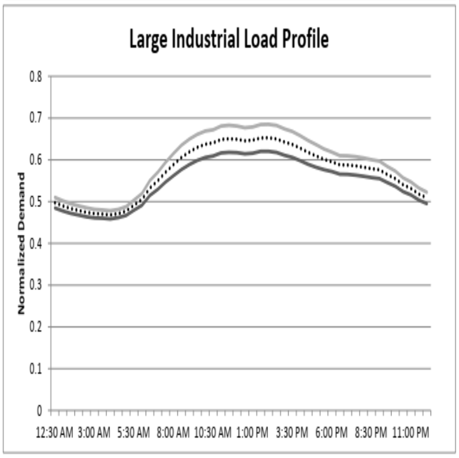
### 5.1 Prediction of load

Given the uncertainties surrounding vehicle adoption rates as well as the future growth of the transportation sector in terms of the mix of mobility types and infrastructure solutions for charging, predicting the load profile due to EVs on distribution networks is a challenging task. At the same time, the energy market is being disrupted by a shift toward renewable energy sources, both on a grid scale and through distributed generation.. Following graphs shows the individual load profiles [30-33]: (Residential; Small commercial; Medium commercial; & Large industrial load profile). From the observation of the graphs it can be concluded that (i) during evening hour residential load profile shows maximum demand & small commercial load profile indicates that load is maximum during noon hours, (ii) medium commercial & large industrial load profile indicates flat load demand from morning to evening hours.




## 5.2 Approaches

Distributors need to make sure the network has the capacity to accommodate the variety of charging infrastructure being built as the EV market matures. This will most likely be done through a variety of techniques, such as:

- Making use of "smart" EV charging
- Pricing cues to encourage charging outside of times of high demand
- Promoting the use of high-powered public chargers when network capacity is available
- Specific network improvements
- Identify possible network charging hotspots, or locations where heavy charging demand may be experienced (such as shopping malls, quick chargers, workplace chargers, etc.).

## 6. Proposed methodology & mathematical model

- **Renewable energy generation forecast**
- **Net load forecast**

Usually following three types of model can be used for renewable energy generation and net load forecast.

(1) The autoregressive model (AR) is a time-series regression model. The output of this model can be expressed as a linear combination of previous outputs/measured values.

(2) Exogenous input autoregressive model (ARX)

ARX model is an extension of the AR model that includes external inputs such as renewable energy generation forecast values.

(3) Regression with Support Vectors (SVR)

The supervised machine learning algorithm underpins the Support Vector Regression technique.

### 6.1 Methodology steps

Step 1: Electric Load forecasting

- Knowledge-Based Approaches
- Data-Based approaches
- Utilize abundantly available historical data available with utilities
- Persistence forecast model

Step 2: Load profile analysis

- Clustering to determine the Active and passive load

Step 3: Household load flexibility

- Disaggregated load profile
- Evaluate the flexibility of Energy consumption

Step 4: Prediction of household flexibility

- Prediction of disaggregated load profile

### 6.2 Mathematical model

Persistence forecast model

$$P(t+k/t) = \frac{1}{T}\sum_{i=0}^{n-1} P(t-i.\Delta t)$$

Where $P(t+k/t)$ is the forecast for time (t + k) calculated at instant t; T is the prediction interval length, and n is the number of historic measurements; $P(t-i.\Delta t)$ is the measured power for time t and the previous i time steps within T; and $\Delta t$ is the measured time series time step length. During the forecast algorithm implementation, data is available every minute for 24 hours.

## 7. Conclusion

The impact of EVs on the electricity sector is determined by the following factors:

- Market penetration
- Charging timing (peak/off-peak)
- Charging duration (slow/fast)
- Load and demand management
- Power sector structure
- Access to renewable energy sources

Future power systems must use the most flexible renewable energy sources possible, just as future transportation must become increasingly electrified. Smart charging reduces the load impact of electric vehicles while enabling increased solar and wind power usage.

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