International Journal of Electrical Electronics & Computer Science Engineering
Volume 5, Issue 1 (February, 2018) | E-ISSN : 2348-2273 | P-ISSN : 2454-1222
Available Online at www.ijeecse.com

Impact of EV Charging Units on the Power Grid

Jahnavi Chowdary[1], N. Ram Chander[2]
[1]UG Scholar, [2]Assistant Professor, Department of Electrical & Electronics Engineering
B V Raju Institute of Technology, Hyderabad, Telangana, India
[1]jahnavichowdary15@gmail.com, [2]ramchander.nirudi@bvrit.ac.in

***Abstract:** Electric vehicles are creating a boom over the automobile industry from past few years. Electric vehicles serve as an alternate to fuel powered vehicles and have several advantages over fuel powered vehicles. Till now automobile industry is one of the largest consumers of fossil fuels and also tops as one of the largest source of emission of green house gases. In order to make our future less dependent on fossil fuels, it is desirable to have battery powered vehicles. A lot of research and development is taking place in this field to improve the existing technology and develop efficient ones. This paper elucidates impacts of EV charging stations on the existing power grid.*

***Keywords:**Electric Drive Vehicles, Power Grid, EV Charging Units, Vehicle To Grid.*

I. INTRODUCTION

With rapidly evolving technology there is a need to adopt new pathways to provide clean and green, cost effective and efficient mobility services which are safe with less environmental damage and with reduction in dependence on oil imports. Electric drive vehicles are preferable due to low operating cost, low road emissions and are more energy efficient. This transformation of automobile industry affects technological, managerial, environmental and business models. Hybrid electric vehicles (HEV), plug in hybrid electric vehicles (PHEV) and battery powered electric vehicles (BEV) come under electric drive vehicles. An EV requires 20 kWh to fully recharge and the rate is 12 cents per kWh, that's $2.40 to fill up the vehicle i.e. it costs lesser than internal combustion engine vehicle (ICE). Usage of the electric vehicles instead of internal combustion engine (ICE) vehicles reduces the environmental pollution. However diffusion of these electric vehicles (EV) is still effected by some issues such as driving ranges, load capacity, more rechargeable time, high initial cost and integration of Electric vehicles with existing power grid.

The major effect of increasing number of plug in electric vehicles (PEV) on power grid is creation of significant domestic demand of electricity as the user of these vehicles will need charging units in the home and readily available in common public locations. The demand for electricity by electric drive vehicles cause many changes in power grid and also even challenge for better performance of the power system. There are only few plug-in electric vehicles on road today with a relatively low number of stations and a small number of participating vehicles. So the result would be negligible amount of impact on the power grid. But future will not be the same as of now; the number of plug-in vehicles will increase and utilities will face challenge in many aspects such as in determining when their customer purchase electric vehicles and also in determining when and where to satisfy the charging needs. Smart grid technologies such as advance metering infrastructure (AMI) can help the utilities to face these challenges. Advance metering infrastructure enables the utilities to analyse the charging units' behaviour.

II. GRID IMPACTS

The Electric vehicle (EV) charging units will definitely create a technical impact on the power grid and the utility should be aware of this for a better operation. In order to know about the technical impacts, Power quality (PQ) should be known first. Power quality is the measure of fitness of electric power from utility to the distribution system. The electric vehicle load is non-linear and cause harmonic distortion, DC offset, voltage deviations' and system imbalance in power distribution system. Power quality (PQ) encompasses some specific concepts such as harmonic distortion, DC offset, phase imbalance, and voltage deviations. Low power quality can cause variation and disturbances in voltage and current, issues with continuity of power supply from the utility to distribution system. EV charge controllers are non linear loads and it cause issues with power quality.

The concepts describing disturbances within electric power distribution systems are discussed below.

A. Harmonic Distortion:

In the case of EV charge controllers which are non linear loads, current distortion is very common due to the need for using power electronics switches. These distorted currents at the load side can cause distortion at the utility which can cause undesirable characteristics. The harmonic distortion introduced into the distribution system by these charge controllers can be measured in terms of Total Harmonic Distortion (THD). The Total Harmonic Distortion of charger changes as firing angles of the power electronics switches in response to various phases of charging cycle. So there are prescribed levels to maintain THD for good operation and less disturbances of the system [1].

- High harmonic content in the system may cause losses i.e. IR^2 losses.
- The IR^2 losses can create undesirable behaviours and also can damage the distribution assets such as transformers, power cables, relays, switch gear equipment, capacitors.

B. Over Loading:

Excessive demand on any particular circuit can cause the adverse impacts on the grid include overloading of the circuits. Charger demand capacity is independent from the size of the car battery pack because the grid-connected chargers are divided into three levels based on the American standards. DC fast chargers provide charging at usually 480 volts. Level 1 AC provides charging at 120 volts and Level 2 AC provides charging at 240 volts. With increased volumes of plug in electric vehicles, there is a cost and reliability impact if an excessive number of charging sessions occur during the peak hours of the day [2]

C. Load Imbalance:

EV charge controllers are non-linear loads. Non linear loads cause imbalance in the system and that imbalance in system can be termed as system imbalance. The system imbalance makes the current and voltage in one phase differs from that in another. This produces zero-sequence components which are troublesome and causes weird behaviours in the system i.e. cause of excessive current which results into conductor heating and deterioration of the conductor.

D. DC Offset:

DC offset is a mean amplitude displacement from zero. When a current change i.e. the current harmonics occurs in the primary ac system, one or more of the three-phase currents will have some dc offset. An item that should be noted about the harmonic spectrum is the peak at 0 Hz (i.e., DC). This denotes a DC offset in the AC power flow In general, there shouldn't b DC offsets in an AC power distribution/transmission system, as the systems aren't designed to handle them.

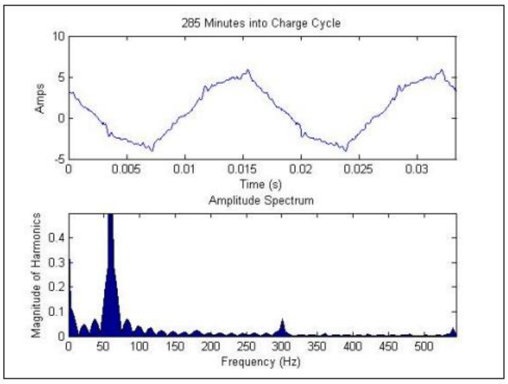

Fig. 1. DC Offset in a Single Phase Charger [1]

To allow local networks to estimate how many EVs can be safely connected to their network at any time, they need to have access to powerful software provided with appropriate sets of information like Demand side management system (DSM) and SCADA which is a system operating with coded signals over communication channels to provide control of remote equipment. Instead of totally depending on the power grid for vehicle charging, it is preferable to install renewable energy sources at the roof-top of the public charging stations.

III. CHARGING BEHAVIORS

Electric Vehicle can be charged at residential places or at the public charging stations. Participants generally prefer charging their vehicles over night at home. Time based rate encourages off peak charging. Commercial and public charging units are mostly used at the day time. Public charging stations are used mostly in emergency cases and also in case of vehicles with quicker charging time. The charging time varies from minimum of 2 hours or less to the maximum of 10 hours or more depending on whether it is faster charging or normal charging. Public charging stations are infrequently compared with residential units as of now. Public charging stations installations require high investment and require substantial coordination between host installers' equipment vendors, installers, safety.

Due to the dependence on the penetration level of EVs and the charging patterns, EV integration may increase load peaks and creates new quantities in load profiles. The charging patterns are stochastic as they are affected by the travel behavior of the vehicle user and the charging opportunities which imply that the EV integration also will have an effect on the load variations. There are three key factors are needed in order to be able to estimate EVC load profiles and EVC impact on the power system namely the charging location, the charging need and the charging moment. The charging location represents the site where the vehicle is connected for charging. The charging need reflects the approach to find the electricity that is used by the vehicle during driving. The charging moment represents when the vehicle battery is charged.

Public charging stations operate mostly on peak load and domestic charging is done at off peak load. However there might be cases where instead of waiting for the vehicle to charge, battery replacement can be done. Battery swapping can be done at Public charging stations. In that case there would be continuous charging of the batteries in the off-peak and on-peak load. Charging behaviours vary depending on whether the vehicle is plug in Hybrid Electric Vehicle or a pure plug in electric vehicle. Plug-in Hybrid vehicles with quickest charging station end usually in an impressive way. Either the users of pure plug-in electric vehicle or hybrid vehicle strongly prefer shorter charging sessions, but this requires higher-voltage charging stations.

IV. VEHICLE TO GRID

Vehicle-to-Grid Technology (V2G) serves as the potential future allowing plugged-in Electric vehicles (EVs) or Hybrid electric vehicles (HEVs) to feed electricity back into the grid by communicating with the

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power grid. Vehicle to Grid system acts as a reverse charging system. V2G is a version of battery to grid power applied to vehicles. The Demand Side Management (DSM) and Vehicle to Grid (V2G) will open an intellectual gate toward the higher efficiency of power system. The concept of Vehicle to Grid allows to provide power balance in the grid, which can be acheived by charging at night when demand is low and sending power back to the grid when demand is high. Adding to the valley filling and demand peaking there are new ways like providing regulation services (keeping voltage and frequency stable). This results in a better integration of renewable energy resources and more stability to the electricity grid.

Vehicle to grid (V2G) is classified into

1) Unidirectional Vehicle to Grid

2) Bidirectional Vehicle to Grid

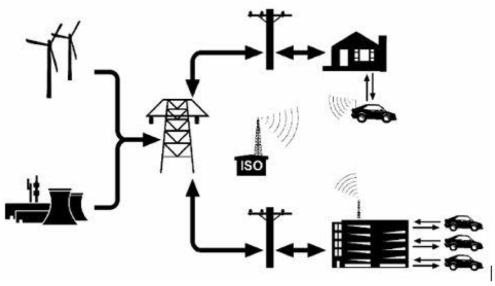

Fig. 2. Schematic Diagram for V2G [3]

The main benefits of V2G integration are:

- Using underutilized utility resources
- Financial and economic benefits
- Improving power stability in the grid.

V. ECONOMIC IMPACTS

Plug-in electric vehicle or hybrid electric vehicle users prefer shorter charging sessions but this requires high voltage charging stations which add up additional installation cost. And that incremental cost will have a longer payback. Reducing the installation cost is the top priority for the pubic charging stations and the electric vehicles. The charging time can be shortened by higher power charging units. As the EV users prefer fast charging at public charging stations, the cost of these fast charging units is also higher. Charging flexibility due to price sensitivity is defined as an individual charging strategy (ICS). Charging station technology is not yet mature and has some interoperability issues.

VI. INDIAN EV SENARIO

An electric and connected mobility system is the zenith goal of India. Additional xEV (i.e. PHEV, BEV) can play important roles in reducing congestion and pollution and strengthen India's economy. This strong starting point enables India to leapfrog towards ambitious goals of 6–7 million xEVs by 2020 with an investment of approx 3billion USD and 175 GW of renewable energy by 2022.

By pursuing electric mobility future India can save 64% of anticipated passenger road-based mobility-related energy demand and 37% of carbon emissions in 2030. This would result in a reduction of 156 Mtoe in diesel and petrol consumption for that year, this would imply a net savings of roughly 60 billion USD in 2030 [4].

In context of electricity act 2003 and it provisions –

- The provision of public EV charging service for user amounts to the distribution/supply of electricity
- Specific amendments to the act can be made, allowing EV charging business to resell the electricity without any license agreement [5].

VII. CONCLUSION

With advancement in technology, there are many challenges to be overcome simultaneously. Distribution and system operators may invest in new things to upgrade the efficiency and capacity of the grid. For uninterrupted performance of the power grid the operators must maintain frequent rapport with current technology, frequent monitoring, and analysis of the system should be made. To meet the market requirement, many factors should be noted and worked accordingly. Charging the EVs during off peak load is preferable for balancing the total power consumption across the load.

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