Analysis and Development of Plug-in Vehicle Charge Control in a Smart Grid

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Abstract - *In today's world the vehicle is essential for every human activities regarding transportation. The use of fossil fuel is more which deplete the availability of fuel, So Electrical vehicle is the best option. Electrical vehicle needs the battery for its operation and this battery is charged through electric grid supply. As it imparts the additional load on the grid, which may cause loss in synchronisms of power lines. So it is necessary to develop counter system for balancing the frequency variation. Depending on frequency response the electrical vehicle is charged which takes the account of peak load and off peak load condition. So that the performance of smart grid can be improved and transportation load of vehicle will be minimize to some extend. This paper introduces the strategies in charging structure for minimization of frequency imbalance to make the charging of vehicle at off peak hours and less stressed environment on the grid.*

Key Words: **EVs (Electrical Vehicles), PEVs (Plug-In Electrical Vehicles), Load Frequency Control, Power Grid, Smart Grid, Valley Filling Concept.**

1. INTRODUCTION

The charging strategies for electric vehicle has to be developing on a smart grid network this are not possible in normal grid. As smart grid smartens the electricity supply to the consumer, it manages the demand flow and continuity of operation of power depending upon certain typical condition. This paper inferred that the use of electricity network to increase the potential of light duty electric vehicle for miniscale transportation and commercial purposes, the role that smart grid technology can play in encouraging the take-off electrical vehicle and utilize the benefits of smart grid. It also calculates how these developments may affect the electricity utility business model and current status of research and development of smart grid technologies. A new technology on electrical energy storage system with storage capacity in MW scale is emerging to store off-peak period energy and supply to the grid on peak period appropriately to balance the load side management. At present technology are emerging fast and are complimentary to each other.

1.1 Necessity for Smartening the Electricity Grid

Electricity system faces the challenges containing ageing infrastructure, increased in growth of demand, the changes resulting from the increased use of electrical vehicle and variability of some sources of renewable based supply. So smart grid implementation offer a cost effective solution to fulfilling this challenges and contributing the establishments of energy system that is more reliable, more secure and sustainable. Accommodations of wind and solar as a generation technologies is a major driver for smart grid investment. The importance of such technologies in response to need to reduce the effects of greenhouse gas effects and reliance on imports of the fossil fuels. Smart grid develops the greater deployments of generation technologies with real time systems information that enables to manage the generation, load and power quality problems.

1.2 Smart-Grid Technology Management

A smart grid is an electricity network that incorporates a suite of information, communication and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids allow for better co-ordination of the needs and capabilities of all generators, grid operators, electricity market stakeholders in operating all parts of the system. Smart grid integrates modern advanced sensor technology, measurement technology, communication technology, information technology, computing technology, and control technology into it, where information and electricity flow bi-directionally and the smart grid can enable active participation by customers. India is the third largest country in the world in electrical transmission and distribution.

Therefore it needs a strong and efficient system for distribution, where the smart grid technology manages its distribution very efficiently and makes the continuity in the operations.

1.3 Architecture of Smart Grid Communication Network

One key characteristics of the Smart Grid is a completely two-way communication network between the energy suppliers and their customers. The smart grid has a communication network to communicate to various electrical devices in the power network through wired and wireless network.

The communication network comprises five levels via

a. Wide Area Network (WAN) to connect the substation and control center in distribution center.
b. Neighborhood Area Network (NAN) through wireless networks, power line communication network or Ethernet to connect smart meter and data collectors in distribution system.
c. Field Area Network (FAN) for monitoring and information exchanging between PEVs and control centers.
d. Home Area Network (HAN) to control and monitor PEVs.
e. Control Area Network (CAN) to connect charge controller and charging station.

Smart grid communication networks has a several advantages such as secure, bidirectional control and communication mechanism for accommodation PEVs is needed for reliable billing, demand response arrangement for V2G(Vehicle to Grid) integration, reliable, stable load balance and cyber security breaches to meet integrity and availability of PEVs integrated system in the communication networks.[1]

2. Impact of EVs on Grid System

As in normal scenario the load is distributed through residential, commercial, industrial and home based load. Due to penetration of EVs in the grid system imbalances the parameter of the power system. The most important is the frequency variation, as due to sudden increase the load of the EVs at particular time makes the abnormal changes in the system responsible for disturbing the continuity of supply. Due to use of renewables energies in the electricity grid the synchronisms get lost especially due to wind farm as wind is not constant throughout the year so it is necessary to develop counter mechanism to assist the changes in the system. The basic line diagram about penetration of EVs in the Grid is shown in fig: 1. assuming the penetration level of EVs, several cases are considered to predict the overall effect of EVs on the future power system. It is also important to properly set the battery size, efficiency, charging place, charging time, and charging method. g on model and use of vehicles. In order to make the reasonable scenario, vehicles are classified into four types depending on model and use of vehicles. By focusing on the impact of EV introduction on the load profile of the future power system in various scenarios, the estimation is carried out by allowing for considerations of actual charging characteristics of the EV batteries and the EV user charging behaviors.

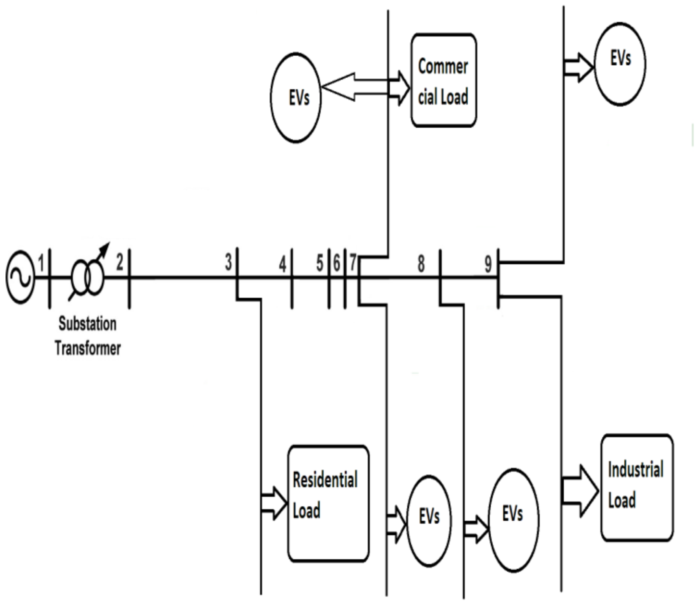

Fig -1: Penetration of EVs In a grid system.

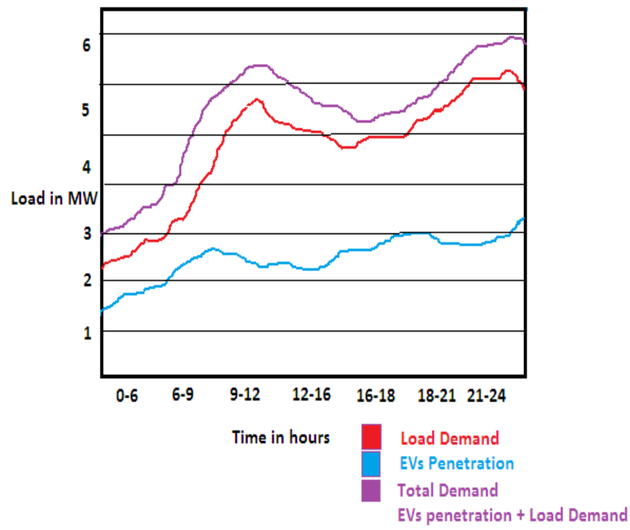

Chart-1: Load Variation during the EVs Penetration.

The above curve shown indicates the variation of load demands of power consumption due to entering EVs in formulation of power grid. The total demand on the system integrates, so it is necessary to limit the power consumption up to certain extend such that the EVs owners get the benefits of that by charging the vehicle at low peak hour's conditions. The idea behind this charging strategies can be developed with the help of frequency variation relation with exceed or reduction in the load demand.

3. Prediction and Demonstration Modeling

This model is designed to shows how the EVs are charged during the peak and off peak hours depending upon the frequencies inputs. Frequency falls when demand exceeds supply; conversely, frequency rises when supply exceeds demand. With the increasing usage of renewable technologies and electric vehicles (EVs), balancing supply and demand becomes a much more important issue. The penetration of EVs in the power grid, including grid configuration and load configuration is explained in fig: 1.

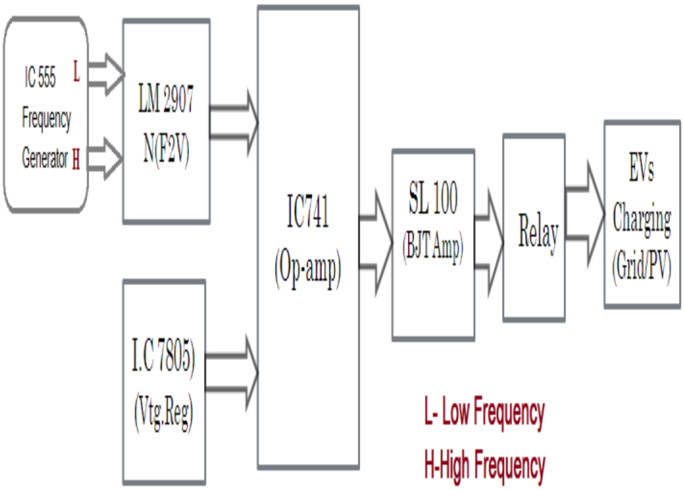

Fig.-2: Demonstration of Plug-in in an EVs during peak and off-peak hours.

It is unpredictable to shows the frequency variation in low rating grid such as 440V and 230V. The changes in frequency is observed in a large rated grid, So for formulation and analysis in frequency variation the high voltage is needed which will tend to extra expenditure on the project. So this paper introduced the basic ideas regarding how the vehicle is charged through the grid during the peak and off peak hour conditions.

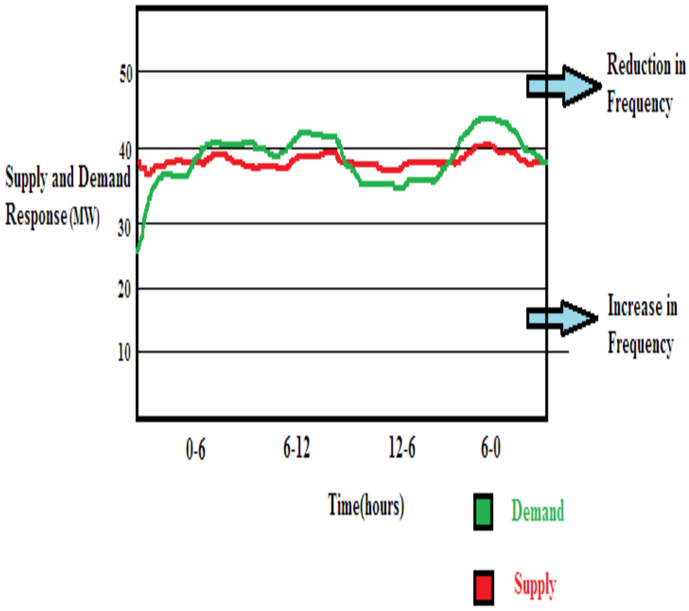

Chart-2: Graphical representation of variation in frequency.

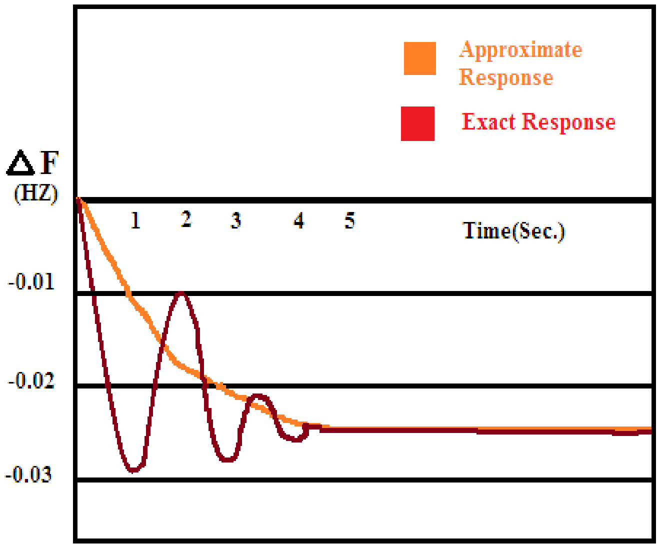

Chart-3: Basic Load frequency control logic analysis.

When there is a deviation between supply and demand which will responsible for fractional changes in frequency. The chart 2 explains the behavior of frequency for different timing slot. So changes in frequency taken into account and according to that the load will be triggered as set by priority and make the frequency constant. The controller which will take automatic action depending upon frequency selection is installed at Electrical vehicles charging station, so it will charged the vehicle at normal condition which will lower the cost for charging and synchronous the system stability. The load-frequency control strategies are available for synchronizing the frequency variation and maintain the constant supply and demand which will improve the system performance. The basic idea for load frequency control is shown in chart 3.

4. Methodology for EVs Charging Scheme

Different control methods are available to avoid load peaks due to charging PEVs and to make full use of their demand response potential for balancing the electricity system. The system is estimated in such a way that the charging of electric vehicle is done, when the charges per unit for the electricity are less in a smart grid. For that the time of use based tariff system in various countries when there is the condition of peak load charges per unit of electricity are high whereas during off load hours charges per unit of electricity are less should be take into account.

Now the question arises how to determine off load and peak load hours in a smart grid system? Answer to this question is the sensing of frequency. When the system frequency will be high that implies the grid load is lesser and when the system frequency is less means grid is on peak load. **(Chart 2)**

5. Working of Demonstration Model

When a frequency input to the frequency to voltage (F2V) converter LM 2907 N is 40 Hz (say) then a corresponding voltage of 4.80 V will be generated. Now , as we have a fixed reference input for the comparator IC 741 i.e. 5 V generated with the use of IC 7805 and is fed to the non inverting terminal of comparator (IC 741) and the inverting terminal of IC 741 is fed with the output of the frequency to voltage converter LM 2907 N (say 4.80) i.e. at the input frequency of 40 Hz such that the output of the comparator will be the positive biasing to it as the non inverting input of comparator is more than the inverting input . Now this + 12 v output will be amplified by the help of SL 100 i.e. BJT as amplifier and then is fed to relay input terminals such that with the +12 v relay will get activated and hence will disconnect the electric plug in vehicle from the charger unit and hence charging will be stopped when frequency is low (reference frequency 42 Hz) that implies load on the smart grid is larger i.e. the period of peak load

Now considering another case, when a frequency input to the frequency to voltage converter LM 2907 N is 45 Hz (say) then a corresponding voltage of 5.40 V will be generated. Now , as we have a fixed reference input for the comparator IC 741 i.e. 5 V generated with the use of IC 7805 and is fed to the non inverting terminal of comparator (IC 741) and the inverting terminal of IC 741 is fed with the output of the frequency to voltage converter LM 2907 N (say 5.40 V) i.e. at the input frequency of 45 Hz such that the output of the comparator will be the positive biasing to it as the inverting input of comparator is more than the non inverting input . now as Now this -12 v output will be amplified by the help of SL 100 i.e. BJT as amplifier and then is fed to relay input terminals such that relay will not get activated and hence will not trip the output such that the electric plug in vehicle will get charging from the charger unit and hence charging will be there when frequency is high (reference frequency 42 Hz) that implies load on the smart grid is smaller i.e. the period of off load. **(Refer fig. 2)**

6. Design Considerations:

To have the operation of this model at various reference frequencies on the basis of countries of operation of this charger control unit we can have different set values of reference voltage and correspondingly the values of R (resistance) and C (capacitance) involved in frequency to voltage converter LM 2907 N could be designed

Let's take the example of country INDIA where frequency of generation of electricity is 50 Hz so according to the mathematical expression for V out of frequency to voltage converter LM 2907 N is

$$V_{out} = F_{in} \times V_{cc} \times R \times C$$

$$= 50 \text{ X } 12 \text{ X } 10{,}000 \text{ X } 10^{-7}$$

$$= 6.00 \text{ V}$$

So, a 6 V reference would be required for the operation of the proposed circuit.

Similarly, for countries like Russia where frequency of generation of electricity is 60 Hz so according to the mathematical expression for V out of frequency to voltage converter LM 2907 N is

$$V_{out} = F_{in} \times V_{cc} \times R \times C$$

$$= 60 \text{ X } 12 \text{ X } 10{,}000 \text{ X } 10^{-7}$$

$$= 7.20 \text{ V}$$

So accordingly for operation of this charger control unit in various countries a design procedure as explained above can be followed considering values of R,C and F in to the frequency to voltage converter LM 2907 N .

7. Future Scope and Development

Such type of charge controller has a very bright future ahead. As due to increasing energy crisis in world an efficient use of energy is the demand of present, so in such a scenario this controller is of great importance. This controller can help us in following ways:

- Demand Response Improvement
- Valley filling concept
- Improving power profile

This controller could be designed with the help of microcontroller too. Also further the vehicle to grid and grid to vehicle concept could be added as a feature to this controller by the use of ac to dc converter and dc to ac converter.

8. CONCLUSIONS

The new technology of modernizing the grid is the smart grid that is emerging to integrate the power network with a smart digital technology of communication network. This paper exhibits new load distributing strategy for plug-in hybrid electric vehicle charging to reduce peak load, regarding the impacts of generation capacity and vehicles charging rates on the electricity price. A multi-objective scheduling method will be proposed based on the optimal charging of single-phase by developing the frequency based charge controller and charging would be done through required time slot that lowers the electricity price bill at minimum cost. The major part of the charging task by the proposed method is carried out at off-peak hours to achieve a cost-effective solution by keeping grid energy losses low at the same time. In addition the implementation of smart grid will greatly improve the integratability, compatibility and capability over the normal power grid.

REFERENCES

[1] Yu Cunjiang, Zhang Huaxun and Zhao Lei "Architecture Design For Smart Grid," China 2012 International Conference on Future Electrical Power and Energy Systems, Electronics and Information Engineering College , Changchun University, Changchun.

[2] A. Sheikhi , Sh. Bahrami, A.M. Ranjbar and H. Oraee "Strategic charging method for plugged in hybrid electric vehicles in smart grids; a game theoretic approach" Sharif University of Technology, Electrical Engineering Department, Tehran, Iran.

[3] Mart van der Kam and Wilfried van Sark "Smart charging of electric vehicles with photovoltaic power and vehicle-to-grid technology in a micro grid; a case study, "Utrecht University, Copernicus Institute of Sustainable Development, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands.

[4] Changhua Zhang, Qi Huang, Jiashen Tian, Lei Chen, Yongxing Cao and Ran Zhang "Smart Grid Facing the New Challenge: the Management of Electric Vehicle Charging Loads," ICSGCE 2011: 27–30 September 2011, Chengdu, China.

[5] Somayeh Hajforoosh, Mohammad A.S. Masoum and Syed M. Islam "Real-time charging coordination of plug-in electric vehicles based on hybrid fuzzy discrete particle swarm optimization," Department of Electrical and Computer Engineering, Curtin University of Technology, Perth, WA, Australia.

[6] R. Pillai and B. Bak-Jensen, "Integration of Vehicle-to-grid in the Western Danish Power System," IEEE Trans. Sustainable Energy, Vol. 2, No. 1, pp. 12-19, Jan. 2011.

[7] Z. Darabi and M. Ferdowsi, "Aggregated Impact of Plug-in Hybrid Electric Vehicles on Electricity Demand Profile," IEEE Trans. Sustainable Energy, Vol. 2, No. 4, pp.501-508, Oct. 2011.

[8] K. Clement-Nyns, E. Haesen, and J. Driesen, "The impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid," IEEE Trans. Power systems, Vol. 25, No. 1, pp. 371-380, Feb.2010.