International Journal of Applied Science and Mathematics
Volume 3, Issue 2, ISSN (Online): 2394-2894

Modelling and Analysing of The Impact of Charging Plug in Electrical Vehicles on Residential Distribution Grid

Dr. R. Muthu Kumar

Ms. Vimitha P

Abstract – **This paper deals with modelling and analysing of the impact of charging plug in electric vehicle on residential distribution grid in etap. Alternative vehicles, such as plug-in hybrid electric vehicles, are becoming more popular. The batteries of these plug-in hybrid electric vehicles are to be charged at home from a standard outlet or on a corporate car park. These extra electrical loads have an impact on the distribution grid which is analysed in terms of power losses and voltage deviations. Without coordination of the charging, the vehicles are charged instantaneously when they are plugged in or after a fixed start delay. This uncoordinated power consumption on a local scale can lead to grid problems. Therefore coordinated charging is proposed to minimize the power losses and to maximize the main grid load factor. The optimal charging profile of the plug-in hybrid electric vehicles is computed by minimizing the power losses. As the exact forecasting of household loads is not possible, stochastic programming is introduced. Two main techniques are analyzed: quadratic and dynamic programming.This article wants to emphasize the improvements in powerquality that are possible by using coordinated charging or smart metering. It also wants to indicate that uncoordinated charging of PHEVs decreases the efficiency of the distribution grid.**

Keywords – **PHEV, EMS, Etap-12.6, Power loss.**

I. Introduction

An **electric vehicle** (EV), also referred to as an **electric drive vehicle**, uses one or more electric motors for propulsion. An electric vehicle is powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery or generator to convert fuel to electricity. energy management strategy(EMS) for a dc distribution system in buildings is being proposed. The dc distribution system is considered as a prospective system according to the increase of dc loads and dc output type distribution energy resources (DERs) such as photovoltaic (PV) systems and fuel cells. Since the dc distribution system has many advantages such as feasible connection of DERs and electric vehicles (EVs), reduction of conversion losses between dc output sources and loads, no reactive power issues, it is very suitable for industrial and commercial buildings interfaced with DERs and EVs. The establishment of an appropriate EMS based on the economic point of view can reduce energy costs of buildings and provide benefits to participants in energy management. Applicable elements for the dc distribution system are identified and the real-time decision making-based algorithm for minimizing operating costs is proposed in this paper. The EV service model for the EMS to offer incentive to EV owners who participate in battery discharging is described. To verify the performances of the proposed algorithm, computer simulation and economic analysis are being performed where the results show that the proposed EMS reduces energy costs, motivates EV owners, and can be applied to the dc distribution buildings.

II. Modelling of EV

During the last few decades, environmental impact of the petroleum-based transportation infrastructure, along with the peak oil, has led to renewed interest in an electric transportation infrastructure. EVs differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, and wind power or any combination of those. The carbon footprint and other emissions of electric vehicles varies depending on the fuel and technology used for electricity generation. The electricity may then be stored on board the vehicle using a battery, flywheel, or super capacitors. Vehicles making use of engines working on the principle of combustion can usually only derive their energy from a single or a few sources, usually non-renewable fossil fuels. A key advantage of hybrid or plug-in electric vehicles is regenerative braking due to their capability to recover energy normally lost during braking as electricity is stored in the on-board battery.As of September 2014, more than 600,000 highway-capable plug-in electric passenger cars and light utility vehicles have been sold worldwide, consisting of more than 356,000 all-electric cars and utility vans, and about 248,000 plug-in hybrids. The United States is the market leader with about 260,000 units delivered since 2008.

A plug-in electric vehicle (PEV) is any motor vehicle that can be recharged from an external source of electricity, such as wall sockets, and the electricity stored in the rechargeable battery packs drives or contributes to drive the wheels. PEV is a superset of electric vehicles that includes all-electric or battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and electric vehicle conversions of hybrid electric vehicles and conventional internal combustion engine vehicles The most obvious advantage of electric car batteries is that they don't produce the pollution associated with internal combustion engines. However, they still have environmental costs. The electricity used to recharge EV batteries has to come from somewhere, and right now, most electricity is generated by burning fossil fuels. Of course, this produces pollution. But how does the pollution produced by burning fossil fuels to recharge electric car batteries compare to the pollution produced by internal

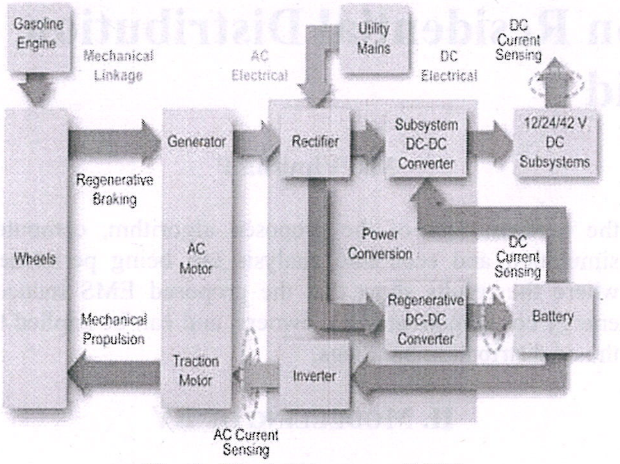

Fig. 1. Block Diagram of EV

The major disadvantage of battery-powered cars, is the time required to recharge the batteries. With lithium-ion battery technology, a fully charged EV can travel a distance comparable to an internal combustion engine vehicle with a full tank of gas, but it still needs to be placed on a recharger at the end of that time. At present, this means a drained EV will be out of service for several hours before it's fully recharged. Of course, this is a serious disadvantage. In the future, faster recharging technology may become available, but in the near term, electric cars won't be the vehicles of choice for long trips. Even so, most driving is done relatively close to home and for this reason, battery power will serve as well as gasoline power. A possible solution to the recharging situation may be battery-replacement stations, where instead of recharging your EV you can simply swap your drained battery for a fully charged one. This system would allow batteries to be recharged outside of vehicles and would greatly reduce the amount of time required to get an EV up and running again after its battery is fully discharged.Another disadvantage of electric car batteries is their weight. Because they need to do more than traditional car batteries, electric car batteries need to be linked together into arrays, or battery packs, to provide additional power. These collections of batteries are heavy. The lithium-ion battery pack in a Tesla Roadster weighs about 1,000 pounds (453.6 kg). That's a lot of weight to carry and it can greatly reduce the car's range. However, the designers of the Roadster have offset this battery weight with a light frame and body panels. The entire car only weighs 2,690 pounds (1220.2 kg) – not terribly heavy when you consider that more than a third of that weight is battery.

III. Modelling of Charging Station

An electric vehicle charging station, also called EV charging station, electric recharging point, charging point, charge point andEVSE (Electric Vehicle Supply Equipment), is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles, including all-electric cars,neighborhood electric vehicles and plug-in hybrids.As plug-in hybrid electric vehicles and battery electric vehicle ownership is expanding, there is a growing need for widely distributed publicly accessible charging stations, some of which support faster charging at higher voltages and currents than are available from domestic supplies. Many charging stations are on-street facilities provided by electric utility companies, mobile charging stations have been recently introduced. Some of these special charging stations provide one or a range of heavy duty or special connectors and/or charging without a physical connection using parking places equipped with inductive charging mats. A special form of a charging station is a battery swapping station in which the batteries are switched instead of charged.

Different Modes of Charging for an EV

Mode 1: Household Socket and Extension Cord

The vehicle is connected to the power grid through standard socket-outlets present in residences, which depending on the country are usually rated at around 10 A. To use mode 1, the electrical installation must comply with the safety regulations and must have an earthing system, a circuit breaker to protect against overload and an earth leakage protection. The sockets have blanking devices to prevent accidental contacts.

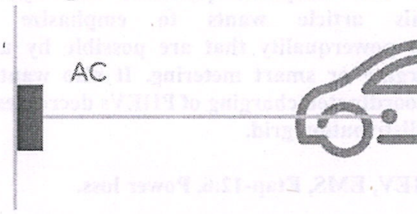

Fig. 2. Household Socket And Extension Cord

The first limitation is the available power, to avoid risks ofheating of the socket and cables following intensive use for several hours at or near the maximum power (which varies from 8 to 16 A depending on the country)fire or electric injury risks if the electrical installation is obsolete or if certain protective devices are absent.

The second limitation is related to the installation's power managementas the charging socket shares a feeder from the switchboard with other sockets (no dedicated circuit) if the sum of consumptions exceeds the protection limit, the circuit-breaker will trip, stopping the charging.All these factors impose a limit on the power in mode 1, for safety and service quality reasons. This limit is currently being defined, and the value of 10 A appears to be the best compromise.

Mode 2: Domestic Socket And Cable With Protection

The vehicle is connected to the main power grid via household socket-outlets. Charging is done via a single-phase or three-phase network and installation of an earthing cable. A protection device is built into the cable. This solution is more expensive than Mode 1 due to the specificity of the cable.

International Journal of Applied Science and Mathematics
Volume 3, Issue 2, ISSN (Online): 2394-2894

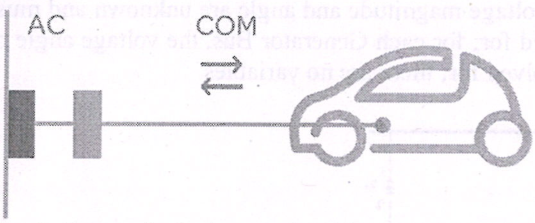

Fig. 3. Domestic Socket And Cable With Protection

Mode 3: Specific Socket on A Dedicated Circuit

The vehicle is connected directly to the electrical network via specific socket and plug and a dedicated circuit. A control and protection function is also installed permanently in the installation. This is the only charging mode that meets the applicable standards regulating electrical installations. It also allows loadshedding so that electrical household appliances can be operated during vehicle charging or on the contrary optimise the electric vehicle charging time.

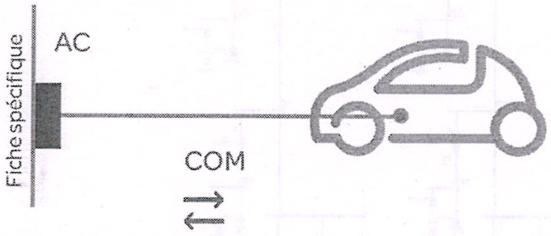

Fig. 4. Specific Socket On A Dedicated Circuit

Mode 4: DC Connection for Fast Charging

The electric vehicle is connected to the main power grid through an external charger. Control and protection functions and the vehicle charging cable are installed permanently in the installation.

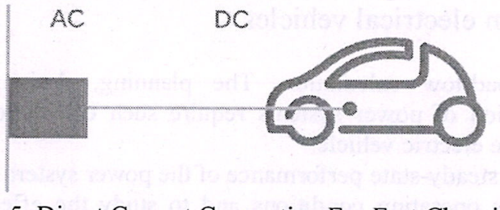

Fig. 5. Direct Current Connection For Fast Charging

IV. Load Flow Analysis

In power engineering, the power-flow study, or load-flow study, is a numerical analysis of the flow of electric power in an interconnected system. A power-flow study usually uses simplified notation such as a one-line diagram and per-unit system, and focuses on various aspects of AC power parameters, such as voltages, voltage angles, real power and reactive power. It analyzes the power systems in normal steady-state operation.Power-flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power-flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line.Commercial power systems are usually too complex to allow for hand solution of the power flow. Special purpose network analyzers were built between 1929 and the early 1960s to provide laboratory-scale physical models of power systems. Large-scale digital computers replaced the analog methods with numerical solutionsA load flow study is especially valuable for a system with multiple load centers, such as a refinery complex. The power flow study is an analysis of the system's capability to adequately supply the connected load. Transformer tap positions are selected to ensure the correct voltage at critical locations such as motor control centers. Performing a load flow study on an existing system provides insight and recommendations as to the system operation and optimization of control settings to obtain maximum capacity while minimizing the operating costs. The results of such an analysis are in terms of active power, reactive power, magnitude and phase angle.

An *AC power-flow model* is a model used in electrical engineering to analyze power grids. It provides a nonlinear system which describes the energy flow through each transmission line. The problem is non-linear because the power flow into load impedances is a function of the square of the applied voltages. Due to nonlinearity, in many cases the analysis of large network via AC power-flow model is not feasible, and a linear (but less accurate) DC power-flow model is used instead.Usually analysis of a three-phase system is simplified by assuming balanced loading of all three phases. Steady-state operation is assumed, with no transient changes in power flow or voltage due to load or generation changes. The system frequency is also assumed to be constant. A further simplification is to use the per-unit system to represent all voltages, power flows, and impedances, scaling the actual target system values to some convenient base. A system one-line diagram is the basis to build a mathematical model of the generators, loads, buses, and transmission lines of the system, and their electrical impedances and ratings.

4.1 Load Flow Problem for Formulation

The goal of a power-flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions. Once this information is known, real and reactive power flow on each branch as well as generator reactive power output can be analytically determined. Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance.The solution to the power-flow problem begins with identifying the known and unknown variables in the system. The known and unknown variables are dependent on the type of bus. A bus without any generators connected to it is called a Load Bus. With one exception, a bus with at least one generator connected to it is called a Generator Bus. The exception is one arbitrarily-selected bus that has a generator. This bus is referred to as the slack bus.In the power-flow problem, it is assumed that the real power P_D and reactive power Q_D at each Load Bus are known. For this reason, Load Buses are also known as PQ Buses. For Generator Buses, it is assumed that the real power generated P_G and

International Journal of Applied Science and Mathematics
Volume 3, Issue 2, ISSN (Online): 2394-2894

the voltage magnitude $|V|$ is known. For the Slack Bus, it is assumed that the voltage magnitude $|V|$ and voltage phase Θ are known. Therefore, for each Load Bus, both the voltage magnitude and angle are unknown and must be solved for; for each Generator Bus, the voltage angle must be solved for; there are no variables

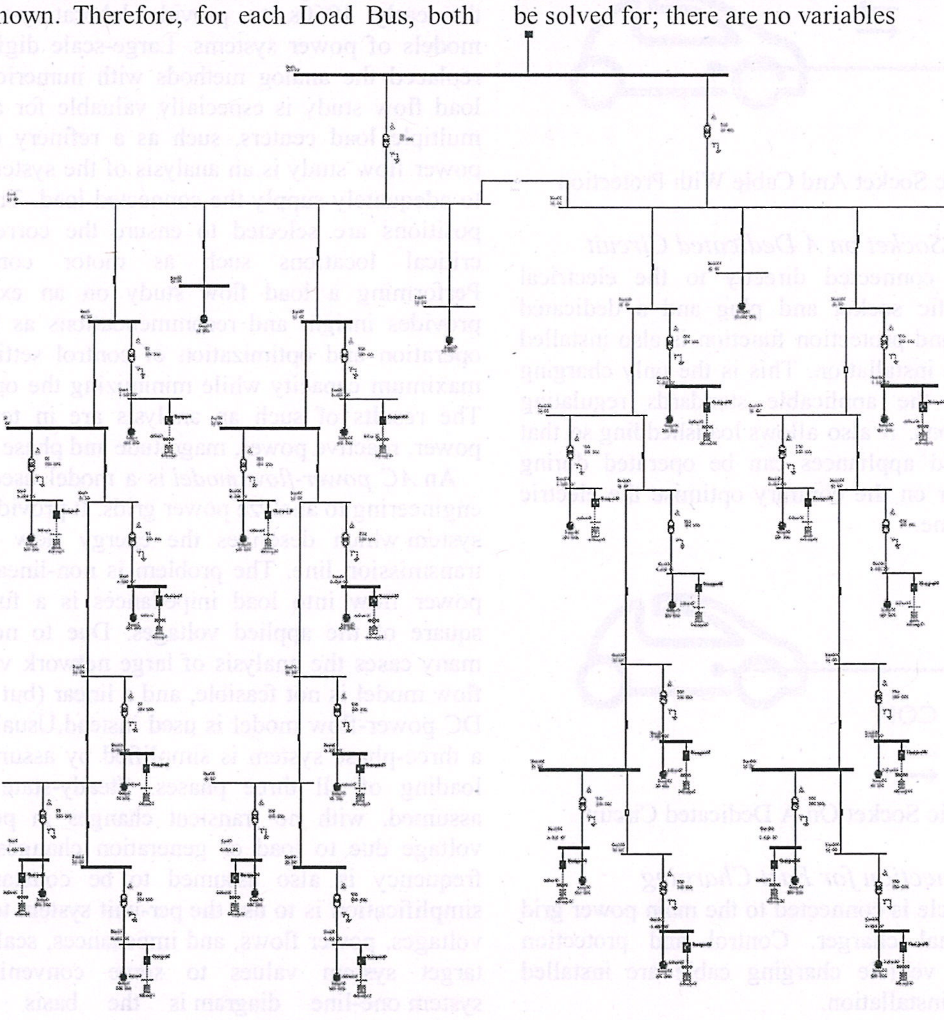

Fig 6. Load flow analysis of plugin electrical vehicles

that must be solved for the Slack Bus. Equations included are the real and reactive power balance equations for each Load Bus and the real power balance equation for each Generator Bus. Only the real power balance equation is written for a Generator Bus because the net reactive power injected is not assumed to be known and therefore including the reactive power balance equation would result in an additional unknown variable. For similar reasons, there are no equations written for the Slack Bus.In many transmission systems, the voltage angles θ_{ik} are usually relatively small.

There is thus a strong coupling between real power and voltage angle, and between reactive power and voltage magnitude, while the coupling between real power and voltage magnitude, as well as reactive power and voltage angle, is weak. As a result, real power is usually transmitted from the bus with higher voltage angle to the bus with lower voltage angle, and reactive power is usually transmitted from the bus with higher voltage magnitude to the bus with lower voltage magnitude.

However, this approximation does not hold when the voltage angle is very large. One of the most common computational procedures used in power system analysis is the loadflow calculation. The planning, design, and operation of power systems require such calculations to analyze electric vehicle.

The steady-state performance of the power system under various operating conditions and to study the effects of changes in equipment configuration. These load flow solutions are performed using computer programs designed specifically for this purpose. The basic load flow question is this load power consumption at all buses of a known electric power system configuration and the power production at each generator, find the power flow in each line and transformer of the interconnecting network the voltage magnitude and phase angle at each bus.

V. Simulation Results

The Harmonic analysis are done because of the utilization of power electronics devices like charger in the EV which produce the harmonics are analysed in this section. In these area other than fundamental component frequency can be found with distorted voltage and current waveform. These components are the integer multipliers of the fundamental frequency called harmonics.

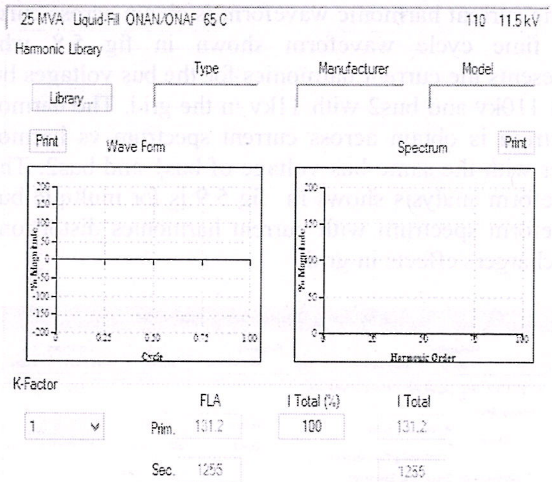

Fig. 7. Harmonics in grid

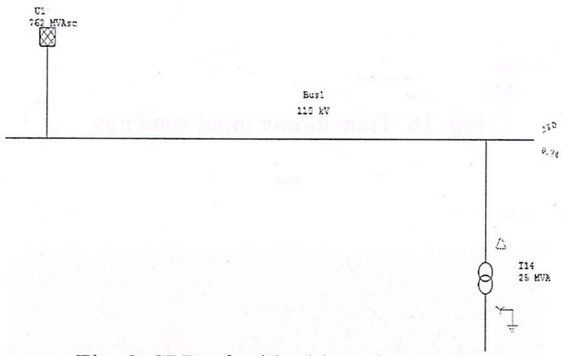

Fig. 8. SLD of grid with no harmonics

The above diagram shows no harmonics in the grid with the absence of power electronic EV charger hence the total harmonic distortion value of each bus zero and pure sine waveform obtained.

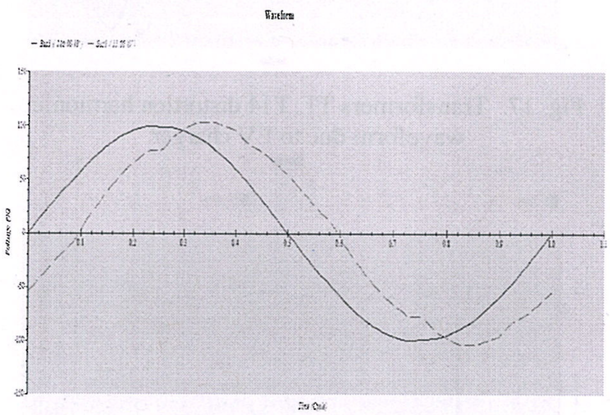

Fig. 9. No Harmonics waveform in bus 1 & bus 2

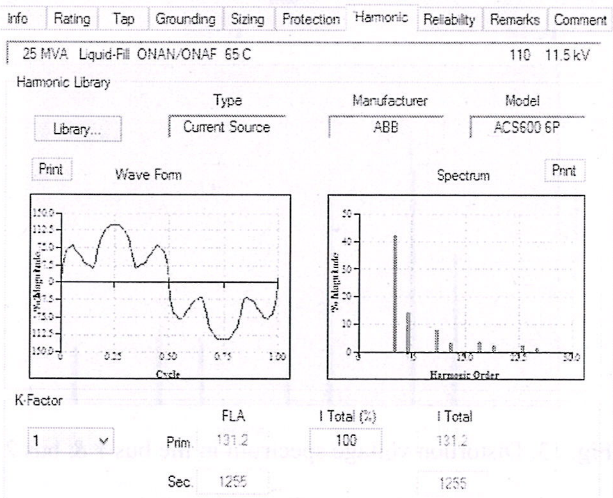

Fig. 10. Harmonics in the grid

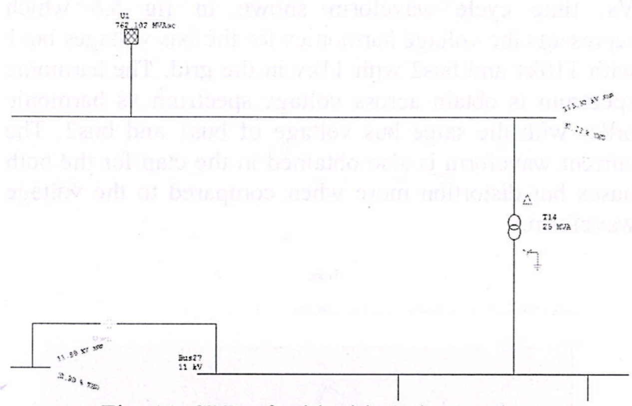

Fig. 11. SLD of grid with 6P harmonics

With THD of 33% exceeds above nominal 6% THD causes distortion sine waveform

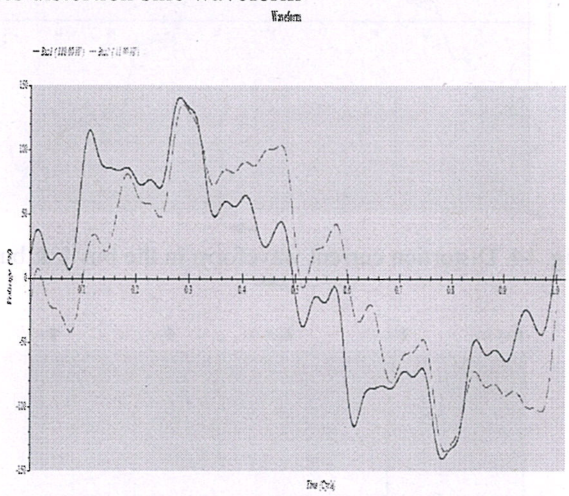

Fig. 12. Distortion voltage waveform in the bus 1 & bus 2

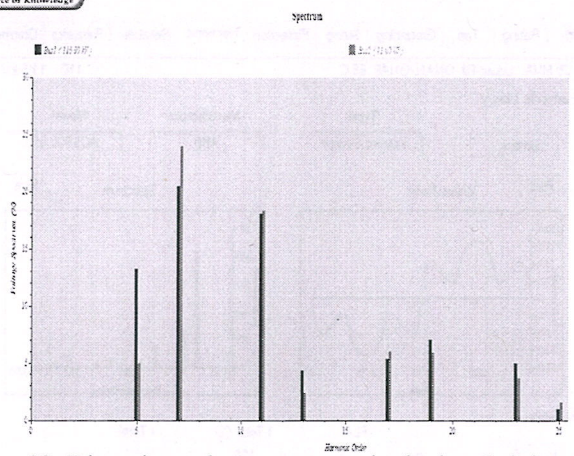

Fig. 13. Distortion voltage spectrum in the bus 1 & bus 2

The voltage harmonic waveform is obtain across voltage Vs. time cycle waveform shown in fig 5.6 which represents the voltage harmonics for the bus voltages bus1 with 110kv and bus2 with 11kv in the grid. The harmonic spectrum is obtain across voltage spectrum vs harmonic order with the same bus voltage of bus1 and bus2. The current waveform is also obtained in the etap for the both buses but distortion more when compared to the voltage waveform.

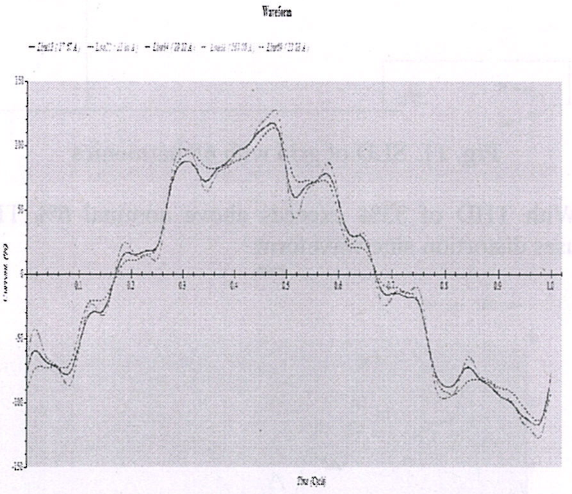

Fig. 14. Distortion current waveform in the bus 1 & bus 2

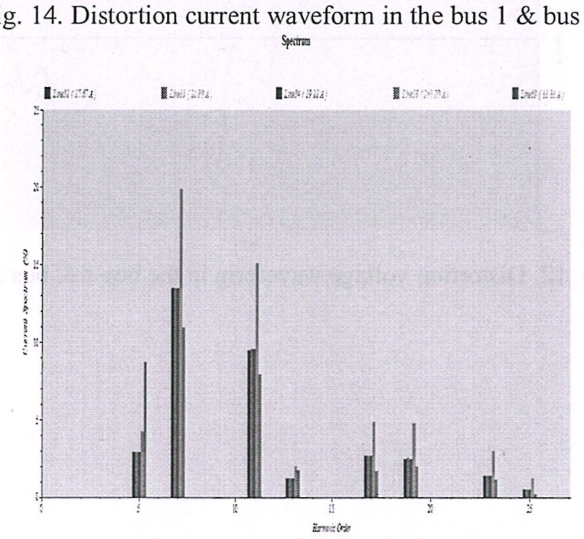

Fig. 15. Distortion current spectrum in the bus 1 & bus 2

The current harmonic waveform is obtain across current Vs. time cycle waveform shown in fig 5.8 which represents the current harmonics for the bus voltages bus1 with 110kv and bus2 with 11kv in the grid. The harmonic spectrum is obtain across current spectrum vs harmonic order with the same bus voltage of bus1 and bus2. These waveform analysis shows in fig 5.9 is for multiple buses waveform spectrum with current harmonics distortion of EV chargers effects in grid.

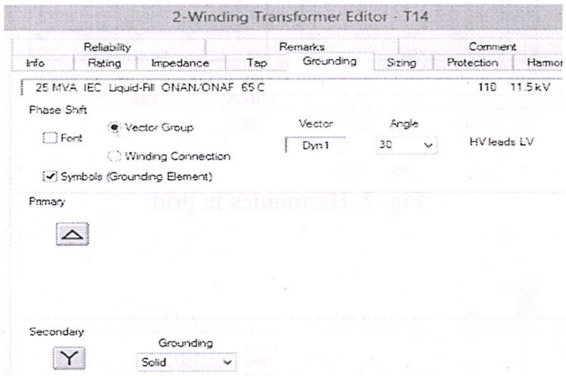

Fig. 16. Transformer input windings

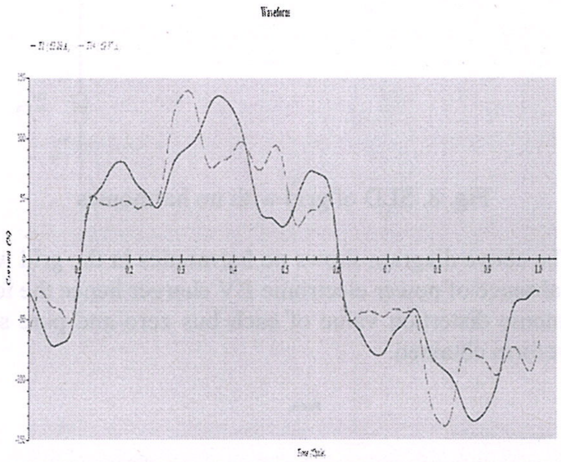

Fig. 17. Transformers T1, T14 distortion harmonic waveform due to EV charger

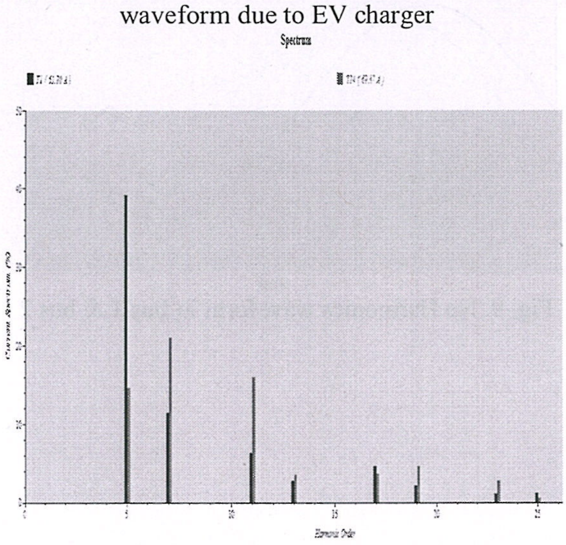

Fig. 18. Transformers T1, T14 distortion harmonic spectrum due to EV charger

The above three figure shows the transformer connections interchanged also produce harmonics in the grid, fig 5.11 shows the harmonic distortion in the main grid with comparison of T1 with 62 A and T2 with 69 A. Fig 5.12 shows the harmonic spectrum for the T1 and T14.

Table 1. Harmonic analysis of the system with transformer windings

SOURCE	THD BUS1	THD BUS2
NO EV	0%	0%
6 PULSE	8%	8%
Y-Y	7.93%	7.33%
Δ-Y	0.73%	3.90%
12 PULSE	1%	1%
Y-Y	1.83%	1.52%
Δ-Y	0.15%	1.52%

Table 2. Harmonic analysis of the system with source impedance of grid

SOURCE IMPEDANCE	THD BUS1	THD BUS2
40KA	0.75%	15.15%
30KA	1.01%	15.93%
10KA	2.92%	17.64%
5KA	5.58%	20.05%
1KA	20.73%	33.01%
0.5KA	28.6%	40.22%

Table 3. Harmonic analysis of the system with 6P,12P & 18P

HARMONICS	THD BUS1	THD BUS2
6 PULSE	32.22%	31.9%
12 PULSE	42.88%	49.09%
18 PULSE	41.09%	47.87%

Tabulation results with above nominal 6% THD shown in red colour. It clearly indicates as the source impedance of the grid level deceases then THD level is increased. Δ-Y connection of transformer winding is more efficient and less harmonic compared to Y-Y connection.

VI. Conclusion

This work emphasizing the three things the impact of various charger configuration studied on power quality, the impact of Source impedance and its impact on harmonic is studied and the Impact of Transformer winding configuration and its impact of power quality is studied. Suitable transformer winding configuration recommended.

References

[1] A. Raskin and S. Shah, *The Emerge of Hybrid Electric Vehicles*. New York: Alliance Bernstein, 2006. [Online]. Available: http://www.calcars.org/alliance-bernstein-hybrids-june06.pdf.

[2] Anderman, "The challenge to fulfil electrical power requirements of advanced vehicles," *J. Power Sources*, vol. 127, no. 1–2, pp. 2–7, Mar.2004.

[3] K. Clement, K. Van Reusel, and J. Driesen, "The consumption of electrical energy of plug-in hybrid electric vehicles in Belgium," in *Proc. 2nd Eur. Ele-Drive Transportation Conf.*, Brussels, Belgium, May 2007.

[4] M. Duvall and E. Knipping, Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: National Wide Greenhouse Gas Emissions, EPRI, 2007, Tech. Rep.

[5] P. Denholm and W. Short, An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles, Oct. 2006, Tech. Rep.

[6] W. H. Kersting, "Radial distribution test feeders," in *Proc. IEEE PowerEng. Soc. Winter Meeting*, Jan. 28–Feb. 1, 2001http://ewh.ieee.org/soc/pes/dsacom/.

[7] W. Kersting, *Distribution System Modeling and Analysis*. BocaRaton, FL: CRC, 2002.

[8] En 50160, Voltage Characteristics of Electricity Supplied by Public Distribution Systems, 1999.

[9] E. Haesen, J. Driesen, and R. Belmans, "Robust planning methodology for integration of stochastic generators in distribution grids," *IET J.Renew. Power Gen.*, vol. 1, no. 1, pp. 25–32, Mar. 2007.

[10] J. Linderoth, A. Shapiro, and S. Wright, "The empirical behavior of sampling methods for stochastic programming," *Ann. Oper. Res.*, vol.142, no. 1, pp. 215–241, Feb. 2006.

[11] J. Labadie, "Optimal operation of multireservoir systems: State-of-the art review," *J. Water Resource Plan. Manage.-ASCE*, vol. 130, no. 2, pp. 93–111, Mar.–Apr. 2004.

[12] R. Bellman, *Adaptive Control Processes: A Guided Tour*. Princeton, NJ: Princeton Univ. Press, 1962.

[13] J. Yi, J. Labadie, and S. Stitt, "Dynamic optimal unit commitment and loading in hydropower systems," *J. Water Resource Plan. Manage.-ASCE*, vol. 129, no. 5, pp. 388–398, Sep.–Oct. 2003.

[14] S. S. J. P. Green and G. Strbac, "Evaluation of electricity distribution system design strategies," *Proc. Inst. Elect. Eng., Gen., Trans., Disturb.*, vol. 146, no. 1, pp. 53–60, Jan. 1999.

[15] H. L. Willis, *Power Distribution Planning Reference Book*. New York: Marcel Dekker, 1997.

Author's Profile

Dr. R. Muthukumar, completed B.E in Electrical and Electronics Engineering in the year 2002, and completed M.E. Power Systems Engineering in Government College of Technology, Coimbatore. He Received PhD from Anna University, Chennai in the year 2014, Tamilnadu He is having 12 Years of Teaching Experience. He has published 4 Papers in National Conferences and twelve papers in International journals. He is Currently working as a Associate Professor in Shree Venkateshwara Hi-tech Engineering College, Gobi. He is a Life member of the Indian Society for Technical Education (ISTE). His research interest includes power system planning, voltage stability and application of evolutionary algorithms.

Ms. Vimitha. P, completed her B-Tech in Electrical and Electronics Engineering from university of Calicut in the year 2012 and pursuing her M.E in Power System Engineering at Shree Venkateshwara Hi-Tech Engineering College. She worked as a lecturer in Electrical and Electronics Engineering at Malabar polytechnic campus, Cherpullassery, Kerala.