International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-7, Issue-6, March 2019

An Extensive Power Balance Management of Hybrid Electrical Vehicles Fast Charging Stations Architecture using NPC Converter

M Sankaraiah, K Krishna Sai, B Loveswara Rao

Abstract*: *As there is a high growth in number of hybrid vehicles day by day there is more need to decrease the time to charge, so that there is a need of development of high power charging stations with quick charging is needed so that we can reduce the excitement of drivers. The charging stations based on neutral point converter(NPC) have many advantages but it has an unbalanced problem in the bipolar dc bus. To solve this unbalanced problem in the dc bus An extensive power balance management system with the help of space vector modulation technique is proposed in this paper. This power balance management(PBM) is proposed to support the central neutral point clamped converter(NPC) in balancing the power and to maintain the fluctuating neutral point current zero and to make sure the balanced operation of fast chargers so that the dc bus is maintained constant and balanced. The overall architecture and the effective integration of solar, wind and fast charger connected to NPC converter is proposed. Simulation results are presented and results are verified in the paper.

Index Terms*: *Dc power balance management, electrical vehicles, fast charger, Svpwm technique.

I. INTRODUCTION

There is a much more growth in the conventional internal combustion engine vehicles (ICEVs),the electrical vehicles (EVs) and the plug in hybrid vehicles (PHEVs) are increasing day by day in the present scenario due to decrease in the fossil fuels consumption and decreased green house emissions[1]. The main things that survey shows is that the vehicle journey(span) per charge ,time to charge the battery ,the accessible charging facilities are the important consideration of end users, which are also the main important factors guiding the customers to purchase the EVs .In order to use EVs for further there is an urgent need for developing an fast charging architecture to decrease the charging time to reduce range excitement of users .If fast chargers reduces the EV to recharging duriation within sustainable levels comparable to the normal refuelling of ICESs, and the high power charging stations spread all over the cities and highways like usual petrol bunks do.

The high power charging station architectures includes two different groups one is normal ac bus and another is normal dc bus but later it is used to be preferred one as the less conservation stage is needed for that higher system efficiency is needed, but it is easy to integrate storage systems like batteries, ultra capacitors etc and the integration of renewable energy sources like photovoltaic and wind system.

The normal dc bus architecture can be realised as two types, one is only uni polar dc bus using two level voltage source converters and the other one as bipolar dc bus this one use as bidirectional flow by using the three level neutral point clamped converter(NPC). As the power rating is increasing to decrease the current rating of the converter for that we are going to use high voltage switching devices. compared to the normal switches high voltage switching devices are similarly more costlier and also cannot be switched at high power switching frequency. To overcome this problems many new converter topologies have been used in the high voltage application. The circuit topologies of the converter can be classified into 3 types

- Neutral point clamped (NPC) converter
- cascade H bridge converter
- Flying capacitor clamped converter

cascade H-bridge converter Neutral point clamped converter(NPC) and are mostly used for the more power converter applications.

The number of levels in the converter bridge states the number of voltage steps that are required by the converter bridge in order to attain a certain voltage levels as its output. since power semi conductor switches have limited voltage handling capability, the total voltage of the converter bridge split into a number of voltage steps, so each voltage step can be handled by individual power switch .Depending on converter voltage level converters are classified into two types:

- Two level converters
- Multilevel converters.

multilevel converters are receiving enhanced attention recently, because of its capability of medium voltage and high power applications.

Revised Manuscript Received on 30 March 2019.
* Correspondence Author
M Sankaraiah*, B.Tech, Department of EEE, Koneru Lakshmauah Education Foundation, Vaddeswaram, AP, India.
K Krishna Sai, B.Tech, Department of EEE, Koneru Lakshmauah Education Foundation, Vaddeswaram, AP, India
Dr. B Loveswara Rao, Professor Department of EEE, Koneru Lakshmauah Education Foundation, Vaddeswaram, AP, India.

The benefits of the multilevel converters square measures low voltage rating of power semiconductors, low voltage harmonics and fewer magnetic attraction interference. The central NPC converter stage plays a important role in the charging architecture[2]and it is capable to provides many features such as low distortion operation, fully adjustable power factor, high power capability, and to decrease the size of the input filters, while promote a reduced quantity in the both passive and active components. Among the different alternatives, conventional two level voltage source converter might arise; however it is used for the limited capacity to fulfill the power ratings, efficiency requirements due to semiconductors voltage/currents limits, and power quality and its unidirectional power flow capability reduces the possible potential of the charging station.

This paper work proposes the central neutral point clamped (NPC) converter as the rectifier stage, as it shows the several different advantages: higher grid power quality(five levels),lower switching frequency ,medium voltage(MV) ,high power, less transformer ratio, bidirectional converter i.e., grid to vehicle and vehicle to grid flow of power takes place in the NPC converter although this has many advantages .In this we are going to integrate the loads and sources they are wind, solar, fast charging ports however this design suffers a unbalanced power between the positive and negative bus because indivisual bus is independent and the loads connected to the dc bus changes most of the time. The imbalanced problem leads to the bad grid side currents and made this bus unbalanced. In order to solve this unbalance problem in the dc bus we are going with the space vector modulation technique in order to give the appropriate switching pulses to the central neutral point converter(NPC) in order to operate this loads efficiently and to balance the dc bus which is tied to the central NPC converter. SVPWM have a lot of advantages those are low output voltage distortion, less switching, conduction losses, fast dynamic response, smaller total switching numbers of power switches etc.,

II. NPC CONVERTER

The NPC converter is also called diode clamped converter. It is used in three level converter.NPC converter of three legs each legs contains four power switches and two clamping diodes those clamping diodes clamp this switching voltage to half the level of total dc bus voltages. It has eight switch NPC converter [3]and 12 switch NPC converter. These NPC converter consist of 3 terminals positive negative and zero. Although this has many advantages but it has some unbalance problem in the dc bus because the connected dc bus loads differs most of the time and it causes the worst grid side current. so we have to balance the capacitor voltages these capacitors are connected to the positive and zero and negative to zero as shown in fig 1 so due to change in the capacitor voltages the total dc bus is getting unbalance. In order to eliminate this unbalance in the dc bus we are implementing a SVPWM technique[4] to give the appropriate switching signals to the NPC converter whenever the power on the +(positive)dc bus is lesser than the -(negative) dc side it is need to make the dwell time for that switch and vice versa for that we are giving the switching pulse to the appropriate connected switches to balance the power so that the rapid chargers draw more quantity of power from that bus to help the charging station to balance the power.

fig2.1 shows a topology of neutral clamped converter(diode clamped) three level converter. The circuit employs 12 power switching devices (s_{11} - s_{34}) .

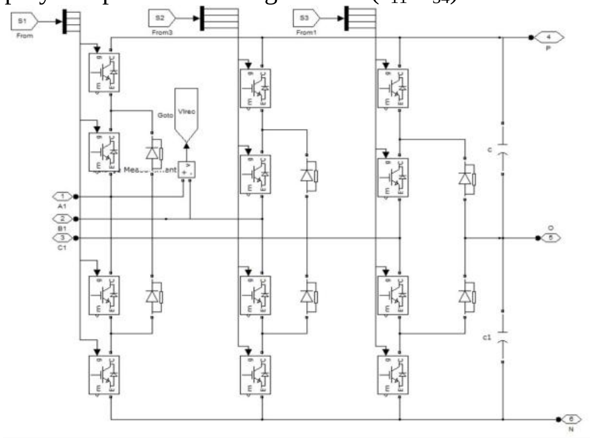

Fig 2.1.proposed three level NPC converter

Total all the power switches are assumed as ideal power semiconductor switches in the converter but where as in practical condition IGBTs can be used as the switching devices to operate the central grid side npc converter. The dc bus voltage is divided into two different series connected capacitors c1and c2 these two are connected to the midpoint can be defined as neutral point 'o'. simultaneously As there is a diode clamped as the switch voltage can be restricted to half the level voltage of the dc bus voltage Vd/2.so that the voltage stress of switching devices is decreased. when these switches are make it turned on ,the converter input terminal A1 is attached to the neutral point of NPC converter through one the clamping diodes. The voltage Vao has 3 stages positive zero and negative $+V_{dc}/2$,0 and $-V_{dc}/2$ similarly for other two legs. Here take one leg A as example ,For the voltage level $+V_{dc}/2$, s_{11} and s_{12} switches be on; and for the $-V_{dc}/2$, s13 and s14 will be turned on. We can describe these states as +1, 0, -1 accordingly. The switching stages of each individual bridge leg of three phase,five level converter[4]is described by the switching variables F_{a}, F_{b}, F_{c}. In different level converter each bridge leg has different switching stages if it is three level each bridge has three different stages.

Three voltage levels are generated on the grid side that is on the ac terminal voltages V_{ac} and v_{bc}. different voltage levels are generated on the voltage v_{ab} based on the proper actual operation of the (neutral point clamped) NPC legs. The space vector modulation is to choose to take up to get the time span on the selected voltage vectors. The time intervals of power switches coincide with the particular selected voltage vectors are calculated to handle the circuit. The control goal of the neutral point clamped(NPC) converter is to get constant balanced dc link voltage even though the connected loads are changed those are wind, solar, charging ports, balanced three phase three line ac source is used in the new proposed system. The total addition of sum of the immediate three phase voltages and currents is zero.

$$x_{s1} + x_{s2} + x_{s3} = 0 \qquad (2.1)$$

where in above equation (2.1)x is the phase voltages (or) line currents .

The three phase voltages and the currents in the normal state can be demonstrated as

$$\begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} = \begin{bmatrix} v_{sm}\cos(wt) \\ v_{sm}\cos\left(wt - \frac{2\pi}{3}\right) \\ v_{sm}\cos\left(wt + \frac{2\pi}{3}\right) \end{bmatrix} \quad (2.2)$$

$$\begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} = \begin{bmatrix} I_{sm}\cos(wt - \emptyset) \\ I_{sm}\cos\left(wt - \emptyset - \frac{2\pi}{3}\right) \\ I_{sm}\cos\left(wt - \emptyset + \frac{2\pi}{3}\right) \end{bmatrix} \quad (2.3)$$

Where I_{sm} and V_{sm} are the peak current and peak voltage of three-phase ac source accordingly, where ϕ is the phase angle between the source voltages and the line currents. For a unity power issue action, the phase angle ϕbetween the load currents and part voltage is zero. Fig 2.2 shows the phasor diagram of the device for unity power issue operation. For the rectification action, the line current is in phase with the phase voltages. There is a some part lag between the supply voltage Vs and reference management voltage V.

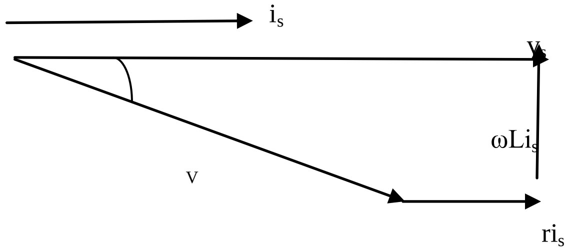

Fig 2.2.Phasor Diagram of the NPC Converter for the Unity Power Factor action.

From the voltage equations on the ac terminal side of the NPC converter as shown in Fig 2.1, we have

$$L\left(\frac{d}{dt}\right)\begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} = \begin{bmatrix} v_{sa} - ri_{sa} - v_{aN} \\ v_{sb} - ri_{sb} - v_{bN} \\ v_{sc} - ri_{sc} - v_{cN} \end{bmatrix} \quad (2.4)$$

The differential Eqn. (2.4) can be rewrite according to orthogonal and expressed as

$L\,(dI_s/dt) = V_s - rI_s - V$ (2.5)

$V = V_s - rI_s - L(dI_s/dt)$ (2.6)

Where in the above equation(2.5) and(2.6) V is the reference control Voltage.

Vs is source voltage and

Is is the source current

If the voltage drop on the resistor r can be eliminated and then the reference control voltage on the ac terminal in the synchronous preferance frame can be showed as

$V_d = V_{sd} - L(di_{sd}/dt) + \omega i_{s,q}$ (2.7)

$V_q = V_{sq} - L(di_{sq}/dt) + \omega i_{s,d}$ (2.8)

Where,

$$\begin{bmatrix} v_{sd} \\ v_{sq} \end{bmatrix} = T\begin{bmatrix} v_{s\alpha} \\ v_{s\beta} \end{bmatrix},\ \begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} = T\begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} \quad (2.9)$$

$$\begin{bmatrix} v_{s\alpha} \\ v_{s\beta} \end{bmatrix} = C\begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix},\ \begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} = C\begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} \quad (2.10)$$

$$C = \sqrt{2/3}\begin{bmatrix} 1 & -\frac{1}{2} & -1/2 \\ 0 & \frac{\sqrt{3}}{2} & -\sqrt{3}/2 \end{bmatrix} \quad (2.11)$$

By Using these co relate transformation from the above synchronous preferance frame into the stationary preferance frame, the voltage commands V_α and V_β are attained.

Vα and Vβ are the projections of reference control voltages in normal stationary reference frame. Vα and Vβ can be showed as

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = T^{-1}\begin{bmatrix} v_d \\ v_q \end{bmatrix}, \text{where } T = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \quad (2.12)$$

The magnitude and phase angle of the reference control voltage V can be calculated and expressed as below 2.13

$$|v| = \sqrt{v_\alpha^2 + v_\beta^2},\ \theta = \tan^{-1}\frac{v_\beta}{v_\alpha} \quad (2.13)$$

III. SVPWM Technique for NPC Converter

whenever the power on the positive bus is lesser than the negative dc bus there is a need to make the dwell time for that state switch and vice versa for that we are giving the switching pulse to the appropriate connected switches to balance the power so that the fast chargers and other dc bus connected loads draw more power from that bus to aid the charging station to balance power. In order to give the appropriate pulses to the neutral point clamped NPC converter the svpwm technique is used. There are three different workable switching states are there in each converter leg in order to achieve three different voltage levels they are $+v_{dc}/2, 0, -v_{dc}/2$ on the ac terminal side. For an example NPC converter each leg, the top two switches s_{11} and s_{12} are closed in order to achieve the voltage $v_{a0} = v_{ac} = v_{dc}/2$,in this operating point, line current i_{sa} is reduced because $v_{sac} = v_{sa} - v_{sc} > v_{dc}/2$. In order to want to get a zero voltage level on the v_{ac} then mid two switches s_{12} and s_{13} are shut down, for that operating condition the phase current i_{sa} is increasing if the line voltage is V_{sac} is positive or decreasing if the line voltage V_{sac} is negative .The three operation states in each converter leg have several workable switching options in the converter in order to manage the neutral point line currents. The voltage on the ac terminals depends on the states of switches can be demonstrated as

$v_{aN} = v_{a0} + v_{0N} = f_a\frac{v_{dc}}{2} + v_{0N}$ (3.1)

$v_{bN} = v_{b0} + v_{0N} = f_b\frac{v_{dc}}{2} + v_{0N}$ (3.2)

$v_{cN} = v_{c0} + v_{0N} = f_c\frac{v_{dc}}{2} + v_{0N}$ (3.3)

Where v_{0N} in the above equation is the voltage potential between the point Neutral point on the ac source and the dc bus midpoint 0 voltage

$$f_a = \begin{Bmatrix} 1 \text{ if } s11 \text{ and } s12 \text{ are closed} \\ 0 \text{ if } s13 \text{ and } s12 \text{ are closed} \\ -1 \text{ if } s13 \text{ and } s14 \text{ are closed} \end{Bmatrix}$$

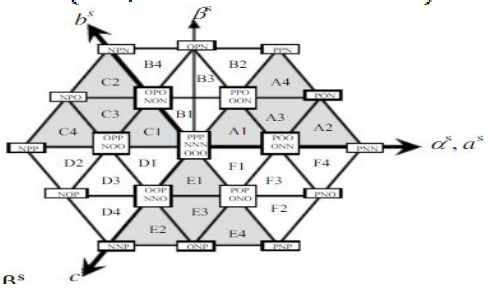

Fig 3.1 switching states and vectors for svpwm

$$f_b = \begin{cases} 1 \;\; if\; s21\; and\; s22\; are\; closed \\ 0\; if\;\; s23\; and\; s22\; are\; closed \\ -1\; if\; s23\; and\; s24\; are\; closed \end{cases} \qquad (3.4)$$

$$f_c = \begin{cases} 1 \;\; if\; s31\; and\; s32\; are\; closed \\ 0\; if\;\; s33\; and\; s32\; are\; closed \\ -1\; if\; s33\; and\; s34\; are\; closed \end{cases} \qquad (3.5)$$

Based on the different combination of the switching positions of the each switch there are different voltage vectors are generated. where s11=0 denotes the switch is closed and s11=1 denotes the switch is open and the same sign is applied for the different switches present in the NPC converter. In order to control the dc bus voltage to operate the svpwm we are taking the reference control voltages v_α and v_β in the abc coordinate system by using eq (3.6) & (3.7)

$v_\alpha = \frac{1}{\sqrt{6}}\left(f_a - \frac{f_b}{2}\right)v_{dc},$ ----------(3.6)

$v\beta = \frac{1}{2\sqrt{2}} f_b v_{dc}$ -------(3.7)

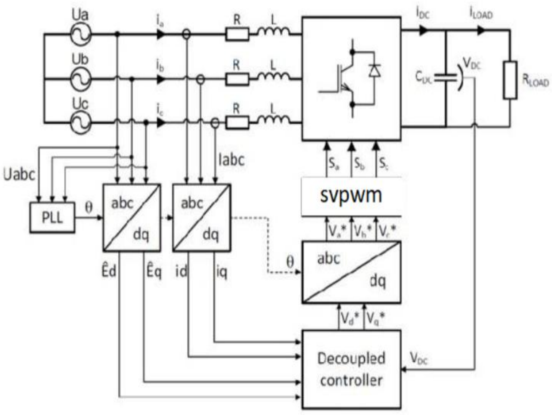

Fig 3.2. Block diagram for adopted control algorithm

In the above figure 3.2 we are taking the grid voltages and the grid side currents those are converted from normal form to dq conversion form those are given to the decoupler .And same as the Dc output capacitor voltages are given to the same decoupler controller in the decoupler the difference between them is funtioned and when ever there is a variation from normal values then it is converted to the dq to the normal abc form and the change in values are observed and given to the svpwm (space vector pulse width modulation) in this we already created a logic from fig for different changes in the dc bus then the appropriate pulses are given to the NPC converter to balance the dc capacitor voltages[5] and there fore the dc bus maintained constant.

IV. OVERALL PROPOSED ARCHITECTURE

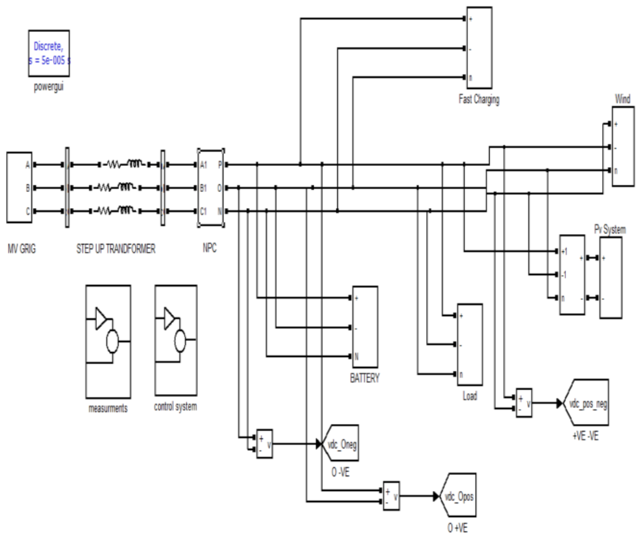

fig.4.1.proposed charging architecture using NPC converter

In the above fig 4.1 architecture[7] there are different sources and the loads are connected to the NPC converter DC bus.In the above architecture there are 3 points coming out from the NPC converter $+v_{dc}$,0,$-v_{dc}$ so that we can connect different number of loads this is the main advantage but it suffers with unbalancing of the Dc bus so we have connected loads and sources to the all the points i.e., positive negative and neutral but in [6] there is a additional balancing circuit to balance the dc bus. Because one case is all the loads and the sources those are wind, solar, charging ports all are connected to the neutral point so that it get neutral current fluctuations so that the loads will not operate properly and leads to unbalance of Dc bus .Second case is NPC converter in built consist of capacitor connected parallel to the two dc buses so that it may get charge and discharge due to operation of loads unevenly so that the capacitor are connected parallel to dc bus it may get unbalance due to charging and discharging of capacitors. In order to maintain the dc bus constant we are going to give appropriate switching pulses to the NPC converter by using the SVPWM technique [9-11].

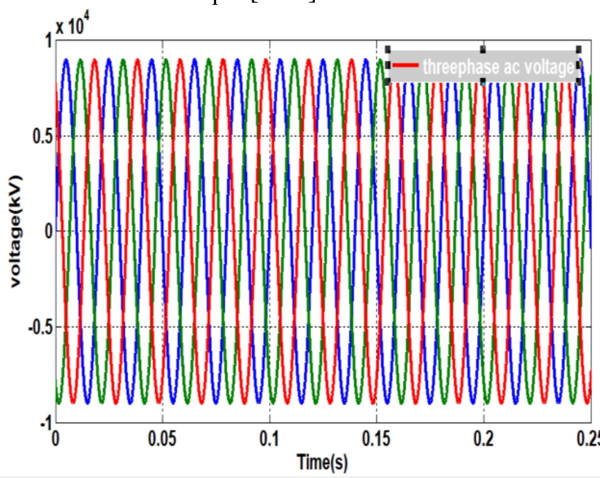

Fig 4.2.three phase grid voltage

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

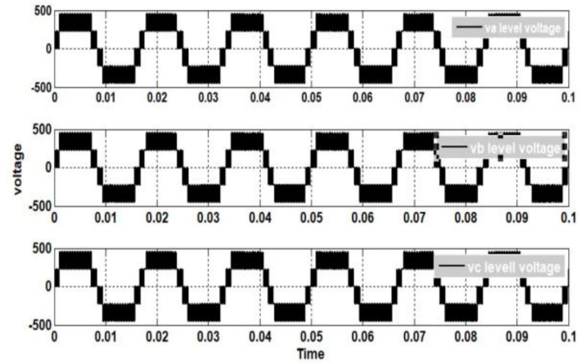

Fig 4.3.five level voltage

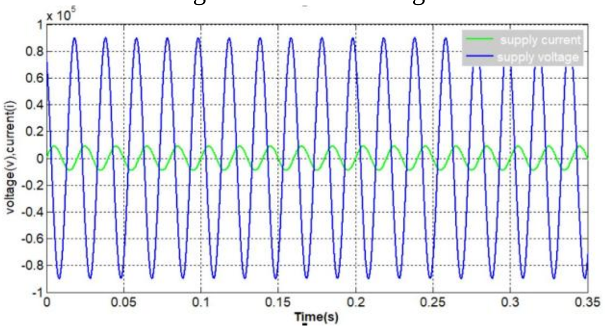

Fig 4.4.phase A supply voltage and supply current

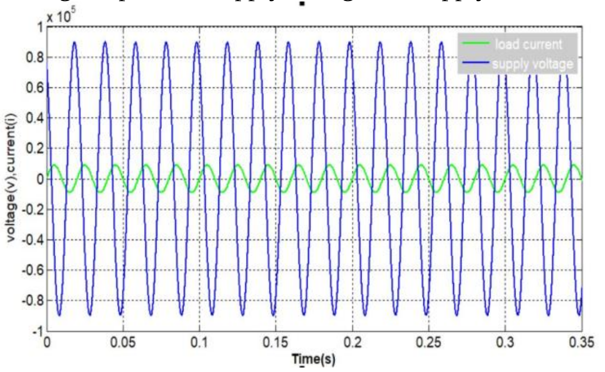

Fig 4.5. phase A supply voltage and load current

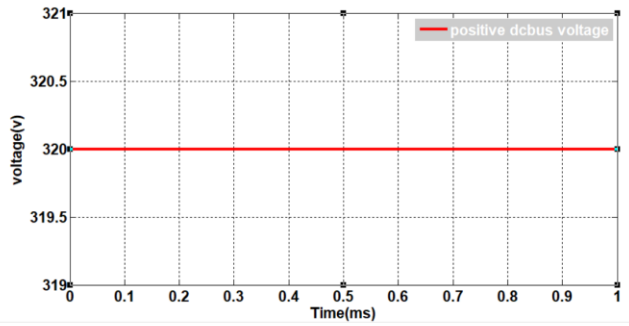

Fig 4.4.positive dc bus voltage

The above fig 4.4 shows the positive dc bus voltage that is the voltage between the positive bus and the neutral point it is showing the 320 volts dc .

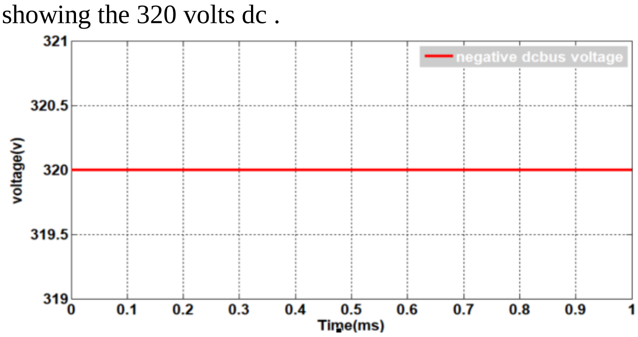

Fig 4.5.Negative dc bus voltage

The above fig 4.4 shows negative dc bus voltage that is the voltage between the negative bus and the neutral point it is showing 320 volts dc

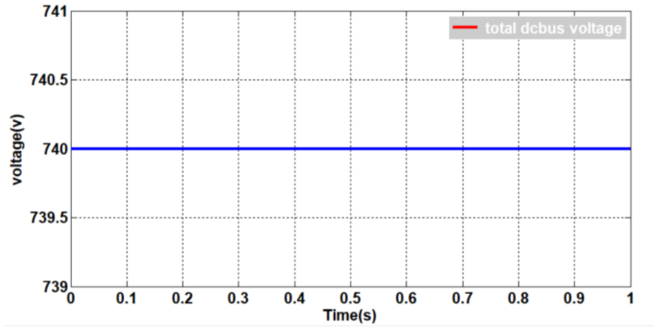

Fig4.6 total dc bus voltage

The above fig 4.6 shows the total dc bus voltage that is the voltage between the positive and the negative dc bus voltage that is showing the 740 volts dc even though there is a change in loads that which are connected to the dc bus we are maintaining the dc bus constant.

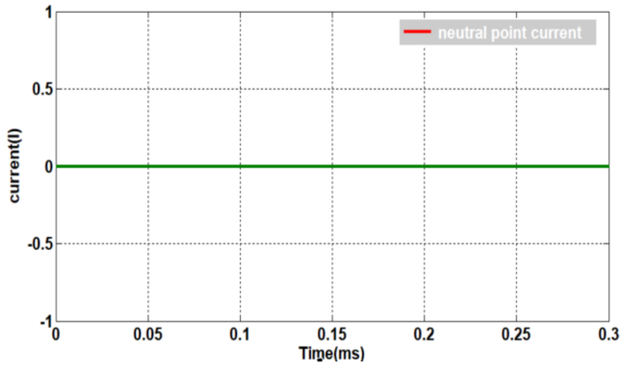

Fig 4.7 neutral point current

The above fig 4.6 shows the neutral point current maintaining zero amps.In the above proposed fig 4.1 architecture every load and the sources are connected to the neutral point so we may observe the neutral point current fluctuation because every loads will vary time to time that leads to the system unbalance .In order to eliminate unbalance we are maintaining neutral point current to zero.

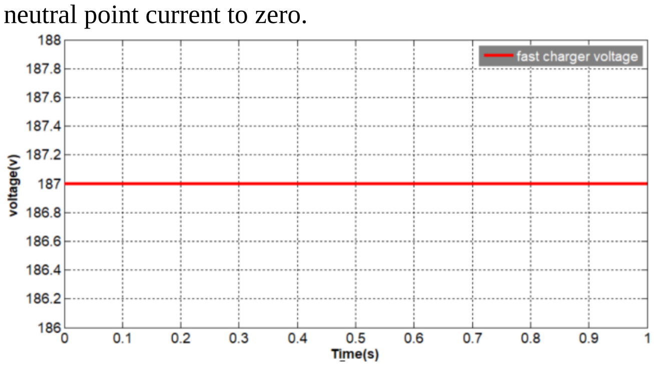

Fig4.8 fast charging port voltage

V. CONCLUSION

In this paper an architecture for the fast charging stations for electrical vehicles and the integration of wind solar to the NPC converter is proposed and evaluated.

The use of this NPC converter enables the different applications in mv improved power quality and the total harmonic distortion.The unbalancing of the neutral point clamped(NPC)onverter is eliminated by using the SVPWM technique we have balanced the dc bus voltage constant in any any load operating conditions. The adjusting idea permits to decrease the dc free flowing in the balancing technique, to just a small amount of the requested current, permitting to decrease the weight on the switches, the span of the inductor and furthermore utilize atmost higher switching frequencies. This is conceivable in light of the fact that the plan misuses the balancing capacities of the injection and just helps the adjusting circuit as a tribute.The dc bus structure allows to decrease the power steps in the system improving the over all efficiency decreasing the cost.In added to this it facilitates the integration of solar wind and battery(energy storage system) this allows the reduce in power demand of chargers and provide support to the grid

REFERENCES

1. M. Hajian, H. Zareipour, and W. D. Rosehart, 'Environmental benefits of plug-in hybrid electric vehicles: The case of Alberta,' in Proc. IEEE Power & Energy Society General Meeting, pp. 1–6, 2009.
2. Donald Karner ,J. F. Kevin Morrow, Plug-in Hybrid Electric Vehicle Charging Infrastructure ,' Fin, p. 40, 2008.
3. Ta-Chag-Wei and Bor-Ren Lin,'Space Vector Modulation Strategy for Eight-Switch Three-Phase NPC Converter'*IEEE Transactions on Aero-space and Electronic Systems Vol.40, No.2, 2004, pp.553-566.*
4. A Novel Concept of Nine Level Active Neutral Point Converter" R. Hari Nandeeswara Rao* and K. Narasimha Raju Department of EEE, KL University, Vaddeswaram, Guntur - 522502, Andhra Pradesh, India. Indian Journal of Science and Technology, Vol 8(31), DOI 10.17485/ijst/2015/v8i31/70388, November 2015.
5. DC capacitor voltage stabilization for five-level NPC inverter based STATCOM under DC offset in load" S. Ravi Teja1*, Md. Enamullah2 1Assiatant Professor, Dept. of EEE, Kl university Guntur, AP, India
6. Venu Gopala Rao Mannam," analysis of discrete & space vector pwm controlled hybrid active filters for power quality enhancement" Jarupula Somlal1 , International Journal of Advances in Engineering & Technology, Jan 2012.
7. Yaramasu,S. Kouro, , J. Wang, andS. Rivera, 'Electric Vehicle Charging Station employesa NPC Converter with Bipolar DC Bus,' *IEEE Trans. Ind. Electron., vol. PP, no. 99, pp. 1–1, 2014.*
8. N. Celanovic and D. Boro-yevich, "A comprehensive pbm of neutral-point voltage-balancing solution in three-level neutral-point-clamped voltage supply PWM inverters," *IEEE Trans. Power Electron., vol. 15, no. 2, pp. 242–249, 2000.*
9. VM Jyothi, TV Muni, SVNL Lalitha, "An optimal energy management system for pv/battery standalone system*," International journal of Electrical and Computer Engineering*, 2016.
10. T. Vijay Muni, D. Priyanka, S V N L Lalitha, "Fast Acting MPPT Algorithm for Soft Switching Interleaved Boost Converter for Solar Photovoltaic System", Journal of Advanced Research in Dynamical & Control Systems, Vol. 10, 09-Special Issue, 2018
11. T Vijay Muni, SVNL Lalitha, B Krishna Suma, B Venkateswaramma, "A new approach to achieve a fast acting MPPT technique for solar photovoltaic system under fast varying solar radiation", International Journal of Engineering & Technology, Volume7, Issue 2.20, pp-131-135.