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A NOVEL 48 PULSE THYRISTOR RECTIFER TOPOLOGY FOR FAST CHARGING STATIONS OF EV's

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ABSTRACT

In this paper the understanding of the harmonic analysis of a transformer- rectifier combination which makes it robust and high controllable rectifier for the electrical vehicle charging station. The main focus of the paper model and simulate the non-identical rectification replicas including with harmonic analysis with Total Harmonic Distortion (THD) along with the power factor. The non-isolated multi-pulse converter which is required for the high power rating applications for major applications. The converter configuration includes single phase bridge, 6-pulse, 12-pulse, 24-pulse, 48-pulse rectifier circuit. The single phase is used for charging low level power applications. With three phase converters are implemented for high level power appliances i.e cars, electrical buses, Hybrid vehicles heavy duty vehicles. The circuit has been modulated and simulated using Matlab to achieve the objective. The output reveals the thyristor levels with pulses increases the harmonics are totally decrease which improves the quality of power factor.

Keywords-Power quality, harmonics, total harmonic distortion,Harmonic analysis, AC to DC converters, Electric vehicles.

1. INTRODUCTION

Electric vehicles have become some portion of our lives altering the vehicle part. They are ecological well-disposed as they are not controlled by non-renewable energy source. The fundamental pack in an electric vehicle is a battery which is a DC power supply. Along these lines, to give maintainability and long life to the battery, stations are expected to charge the battery. The main standard pack source accessible framework which gives AC, which implies the AC will be changed over to DC by utilizing a charger. It is essentially a rectification which converts AC to DC. The issue is when rectifiers are viewed as atrendingin the market. Along these lines, the main issue shows up the moderation to the grid [1].Most of the impacts of Total Harmonic Distortion are brought about by the idea of nonlinear sinusoidal signal which are associated with in the framework. The Total Harmonic Distortion (THD) represents the distortion and guideline are needed for the purpose of association with in the sequence [2].Diode rectifiers are ordinarily used for the power transformation, connected setup is one of them and it creates high resistance and THD. The 6-pulse is generally utilized on the grounds that it is modest and has the least complex structure. A 12-pulse rectifier comprises of two arrangements of 6-pulse rectifier and it is ordinarily utilized for high levelapplications [3].A MPTR framework basically is involved two attractively coupled electrical systems, as appeared in Fig1, driven by a high- exchanging power supply. In increasingly complex systems with numerousindividual systems whichcan rely on single distribution system [4]. Every charger made out of three stage thyristor based rectifier as they are generally utilized in before charging station because of the high usage and alongside the benefits of cost and innovation, while [5]diodes used in rectifiers are mainly used in charging station for the cost effective way while the harmonic distortion is effecting tremendously [6]. To reduce the constraintsinside the circuit sequence during the recharging time, many schemas have been tested but for the problem is with the Harmonic Distortion which effects the performance of charging. The development and designis presented in a large proportion of the accessible vehicle charging stations, where the normal transport or the basic dc-transport is received inside the topology. In any case, power unevenness for the positive and negative transportation. An ultra-capacitor-based pack is required with both dc drives to upgrade the balance [9]. Nearly, dc transport liberates for power and displays the adaptability of utilizing single direction or multi direction dc converter. The examination in [10] proposed with single direction has proposed a single direction dc by a 12-pulse diode-based rectifier in a utilization of 24.7KW charging station for EVs. The 12-pulse diode-based rectifier works as the correcting unit and in this manner as follows DC-DC converter assumes responsibility for controlling the final voltage.Different station works have displayed the comparative designs while with various dc converter stages [11]–[13]. Notwithstanding the advantages of direct structure and cost-viability of the diode-based rectifier, it is a troublesome issue to analyse the sequence which will infuse into the sequence side when it works. To unwind this, dynamic techniques are introduced. The conventional diode-based rectifier in addition to help Power Factor Compensation (PFC) stage might be a normally utilized setup to reduce the malicious injections [14]. In any case, its drawbacks of high current wave the capacitor value has been increased to its highs to withstand the noise generating it relevant for much influence application. For diminishing the wave, a 12-pulse diode-based rectification is maintained [15], and a totally special technique intending to bring down the injection. It is accomplished by changing the current of the rectifier into a required shape with the guidance of two extra current sources associating with the dc supply. A substitution control approach is proposed to a proportional 12-pulse diode-based rectifier for diminishing losses, from the similar of infusing virtual resistor to the dc-side channel [10]. As opposed to forming the final current into the three sidedwaveform, as proposed in [15], it accomplishes lower and higher current wave by managing the channel impedance. Other than the previously mentioned dynamic wave-forming strategies, inactive wave procedure create multi-pulses or multi-stage dc converter additionally catches numerous conditions. It's viewed as a single and efficient approach to improve the power quality [16], [17].

2.Schemas & Prototype

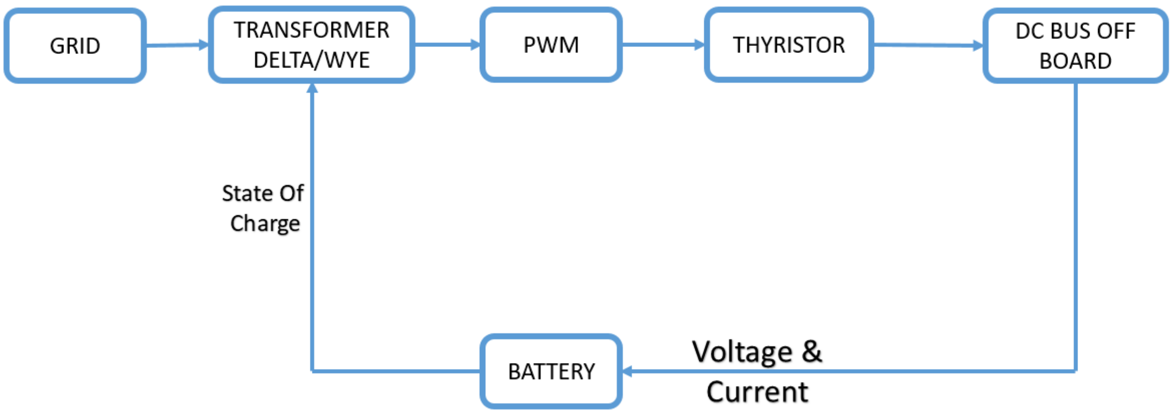

Fig1:Block Diagram of 48PTR

The diagram for the EV battery charger dependent on the 48PTR is appeared in Fig1.DC-DC converter typically utilized in regular battery charger to alter the final voltage is dropped right now, to decreasing the transformation arranges and improving the engineering. The charging station requires various schemas for charging different EVs. On this regards we have developed the multi pulse charging system where the system consists of eleven switches with adaptable sequence i.e. (PM48P, SM48P, HM48P, PM24P, SM24P and HMI48P) are picked up by modifying and consolidating the conditions of the twelve switches. The various blends of the switches states create distinctive working modes, which are recorded in Table1. Here the digit 1 means that the switch is turned on while digit 0 is turned off. It is significant that the HM48P is efficient but with come constraints 48-pulse rectifiers that just have arrangement and equal modes. This mode is developed when the 48PTR changes from SM48P to PM48Pon the other side. Along these lines, the final voltage right now between that of SM48P and PM48P.The another variety of HM48P is obviously utilized is proposed right now HMI48P where it the intermixing of the both HM48P and SM48P for picking the consistent voltage and current stream with expanding the measure of exchanging and changing the exchanging succession. It creates more measure of current and voltage w.r.t to HM48P however keeps up them until the battery is completely energized. It very well may be obviously seen increase of progress in SOC. At the point when 48PTR works in SM24P and PM24P, the four 12-pulse rectifier is associated in arrangement only an out of a regular 24 pulse circuit as observed in Fig. 3(a) and (b). Right now proportion of voltages of contribution to final voltage is decreased as two circuits are associated, the four 6-pulse rectifiers are isolated into two gatherings in which mode1 and mode2, mode3 mode4 and mode5 are associated in equal separately in then in arrangement and as appeared in Fig 4 right now proportion with each number of increase in pulse creates a decrease in total harmonic distortion.

Table.1 Sequence of operation of different modes

Modes	S12 – S9	S8 – S3	S2 – S0
PM 48P	0000	111111	000
SM 48P	0001	000000	111
HM 48P	1110	000000	101
SM 24P	1001 01	000000 000000	101 101
PM 24P	0000 00	100101 111001	000 000
48PI HM	0011	111111	010

A DC-DC rectifier normally used for battery charger tochange the final output voltage at the present time, to decreasing changes and improving the designing. Because of charging station application, the DC-DC converter is required to differentiate voltages for various loads, for instance, assuming EVs. The architecture of the proposed MPTR is presented in Fig2. It contains four 6-pulse thyristor rectification to manage the charging current from the rectifiers are interconnected to low load like charging bike or cycle. As can be found in the figure.2 eleven switches are related with the rectifiers, planning to execute the variable topology switching. Six working modes (PM48P, SM48P, HM48P, PM24P, SM24P and HMI48P) are changing and merging the states of the eleven switches. The various mixing of the switches states makes working modes more efficient, which are recorded in Tab I.It is noteworthy that the novel HMI48P is differentiating from standard 48-pulse rectifiers that simply have strategic plan and equivalent modes. This mode will create when the 48PTR changes from SM48P to PM48P, or a different way. Thus the final voltage is between that of SM24P and PM24P.The another assigned voltage of HM48P is clearly used is proposed right now HMI48P where it the intermixing of the both HM24P and SM24P for picking the steady voltage and current stream with extending the proportion of voltage and current with increasing progression. It makes more proportion of current and voltage w.r.t to HM24P anyway keeps up them until the battery is totally charged. It might be clearly seen with pace of improvement in SOC with been increasing for two groupings. When 24PTR works in SM24P and PM24P, the 24-pulse rectifier is related in plan just an out of a standard 48 pulse circuit as saw in Fig. 3(a) and(b). At the present time extensions of voltages of circuit to conclude voltage is decreased as two circuits are related, the 24-pulse rectifiers are scheduled into some occasions in which mode1, mode2,mode3,mode4 and mode5 are related in equivalent independently in then in course of action and as showed up in Fig4 is represented as extension to voltage is increased with the aim of elimination of the THD in the current. With the mode of SM48P the voltage is increased and highest voltage is calculated and in the PM48P the highest current is calculated. The circuit topologies are determined with the inter mixing of both topologies for the formation of new interphase.

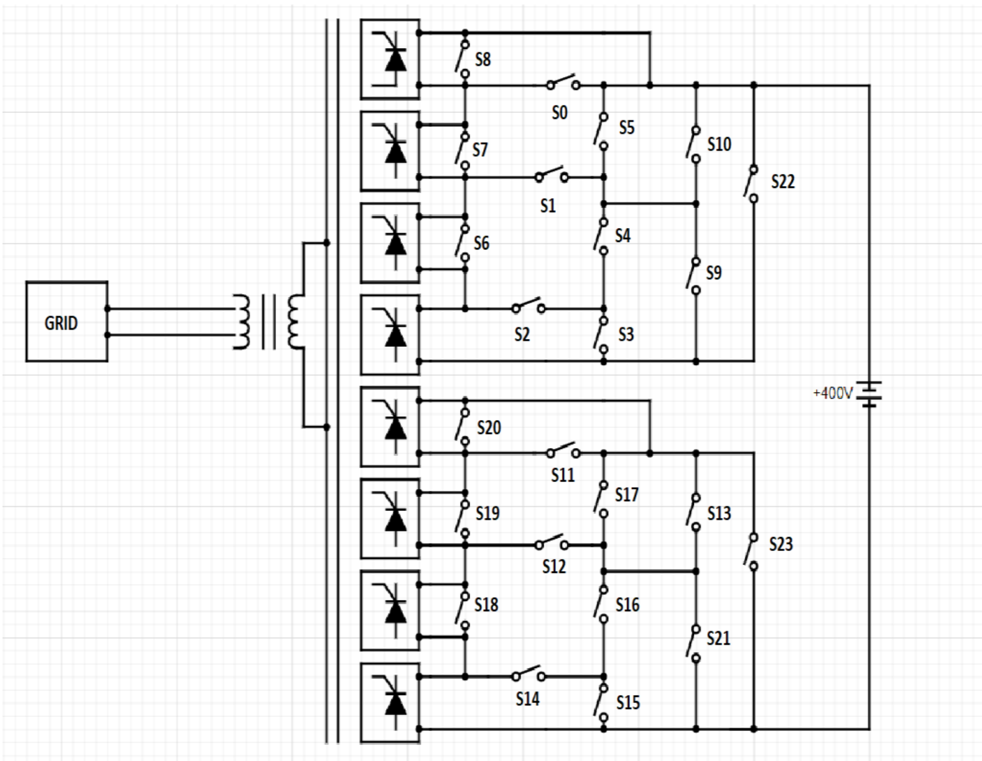

Fig2: Proposed 48PTR

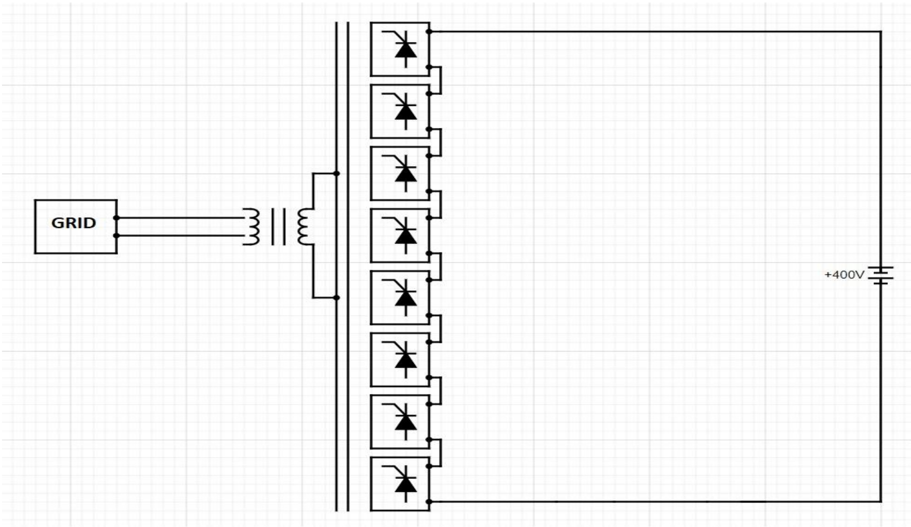

Fig 3a: Topology of 48PTR working in SM48P

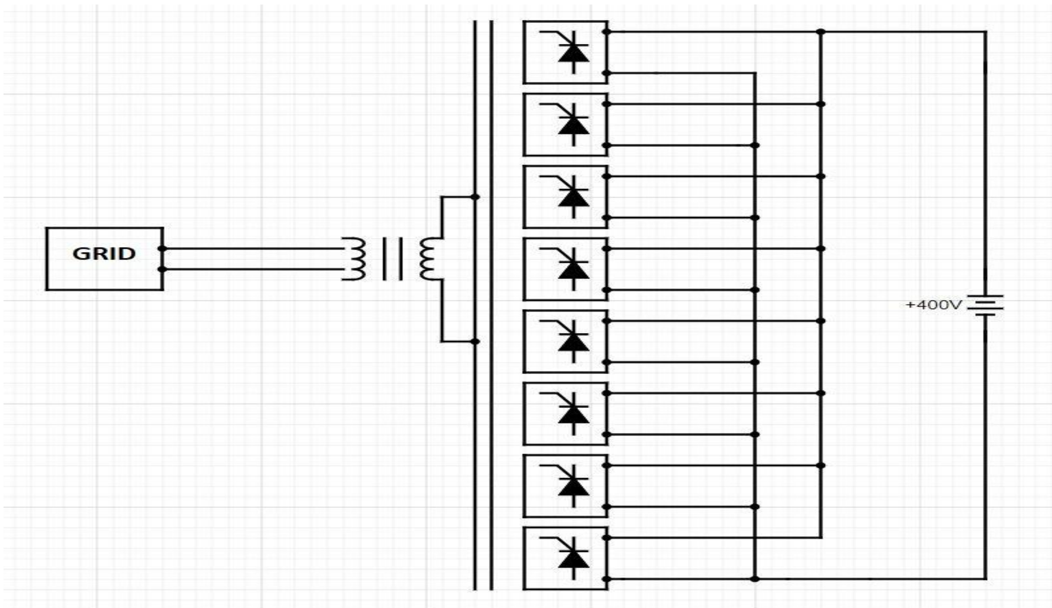

Fig 3b:Topology of 48PTR working in PM48P.

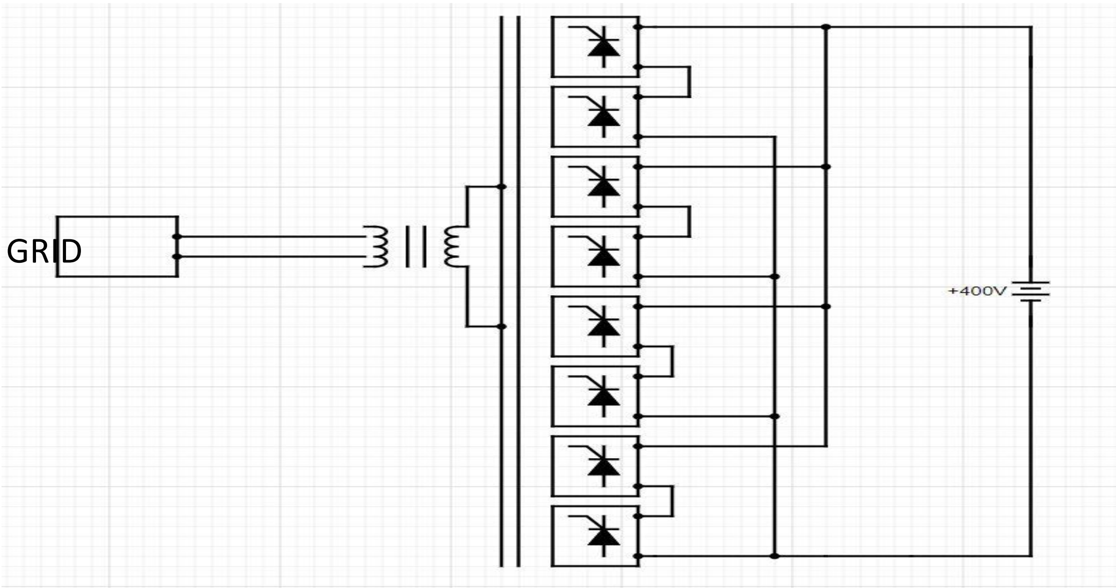

Fig 4a: Topology of48PTR working in HM48P

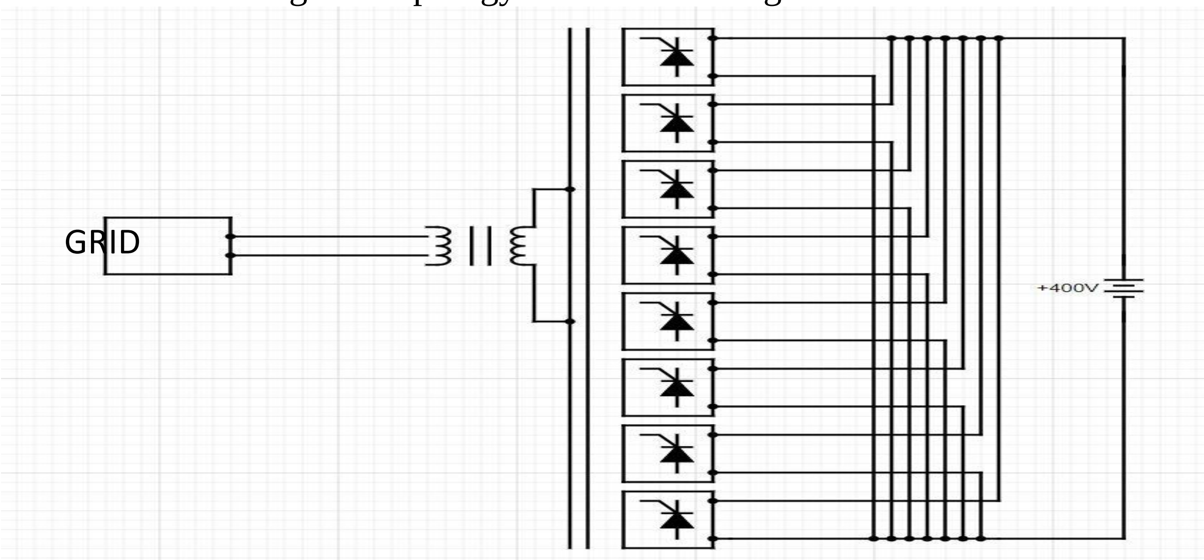

Fig 4b: Topology of48PTR working in HMI48P

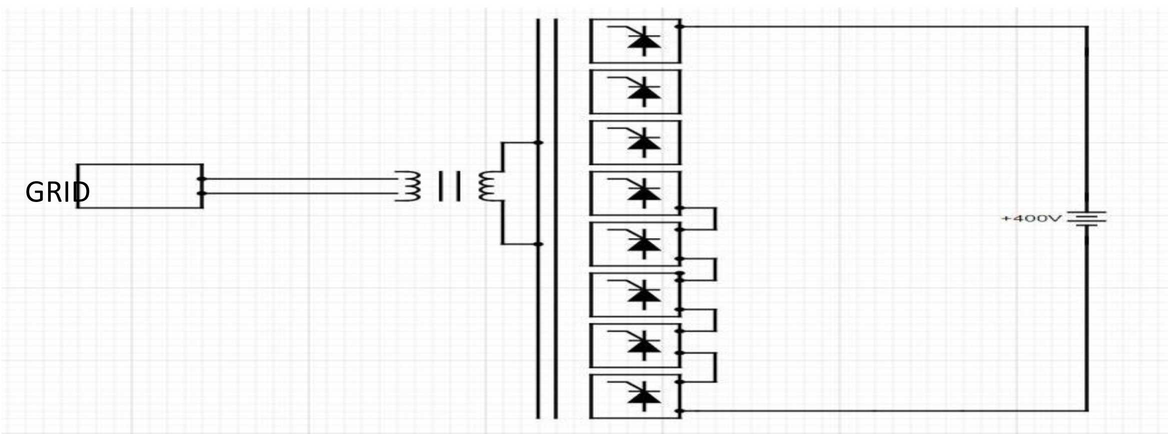

Fig 5a: Topology of48PTR working in SM24P

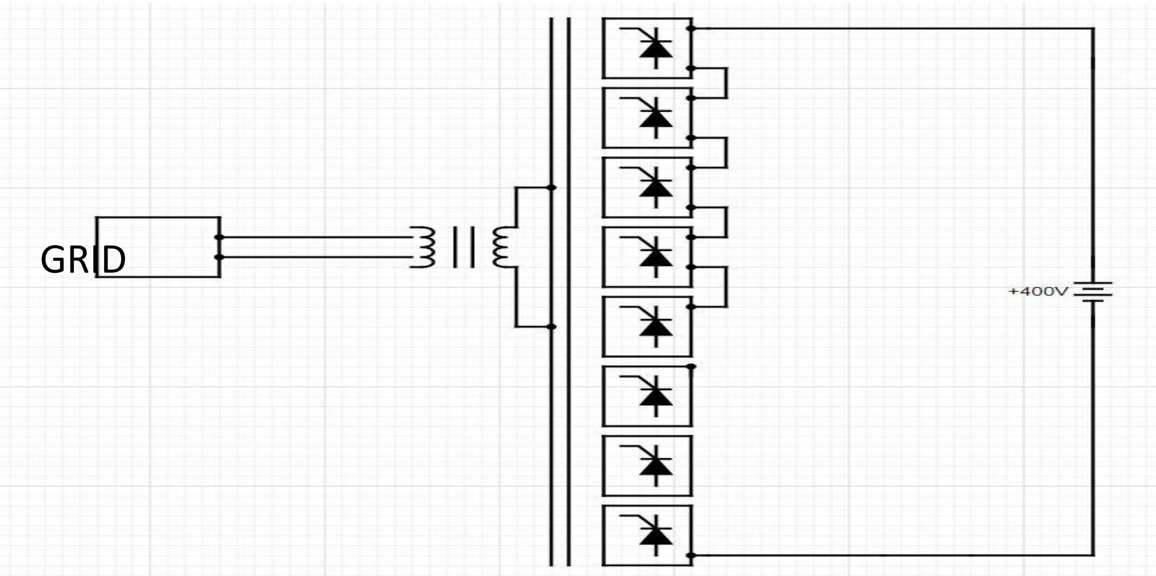

Fig 5b:Topology of48PTR working in SM24P

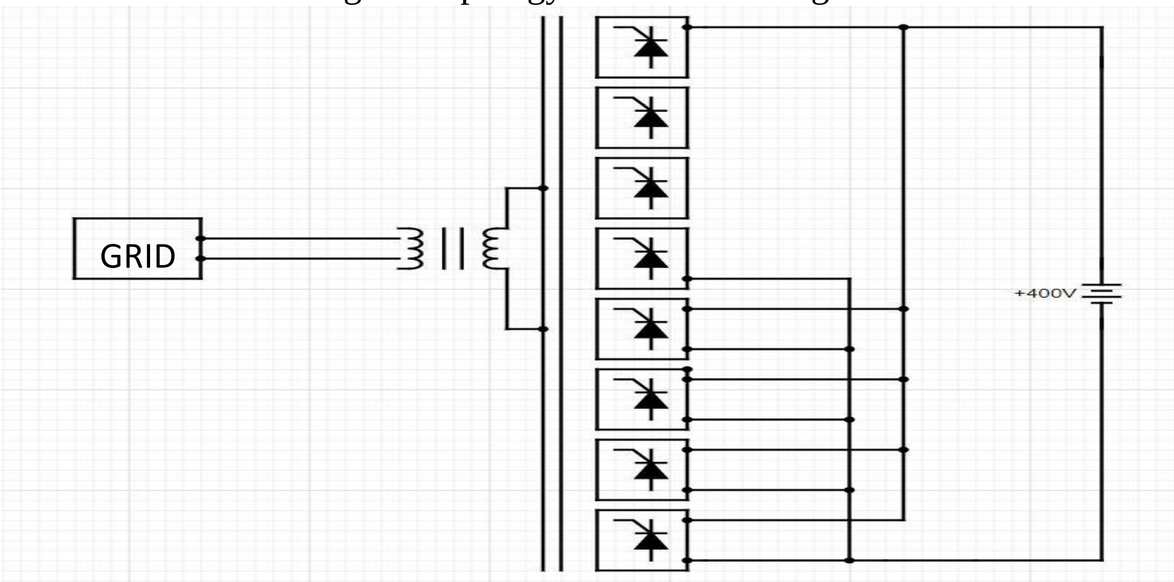

Fig 6a:PM24P

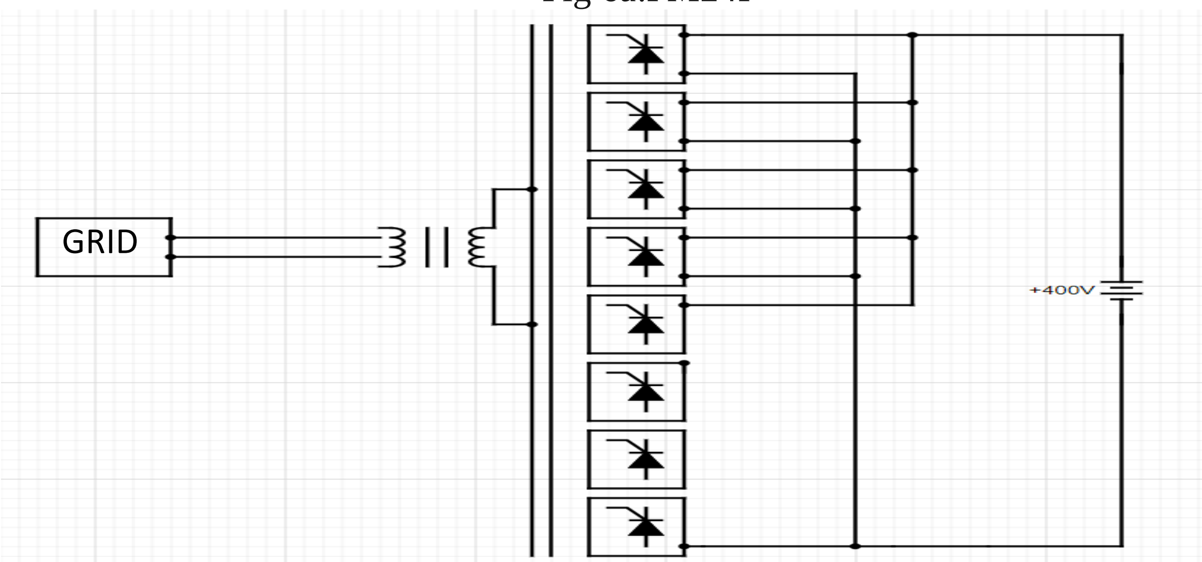

Fig. 6b PM24Pb

Fig.2 represents the complete layout design of the 48 pulse thyristor with the connection of VSC which are distributed into four pairs which are operated with various phase displacement angles are represented as (–11.25°, 161.25°), (3.75°, 176.25°), (18.75°, 191.25°), and (33.75°, 206.25°).The delay angle is maintained as 7.5° with PWM.Out of the four transformer units (Delta mode1,2,3,4), the first (Delta mode1), third (Delta mode3), and fourth (Delta mode4) units are Phase Shift Transformers(PST)providing phase shift of -15°, +15°, and +30°, respectively. The -15° and +15° PSTs are designed with open-wye primary and zig-zag connected open-wye secondary connections whereas the +30° PST is configured with zigzag/inter-connected star as primary and open-wye as secondary. The transformer unit (Delta mode2) is a normal 3-phase 2-winding step-up transformer having open-wye secondary and open-wye primary terminals. The phase-displaced output from each pole of the first VSC pair (–11.25°, 161.25°) is fed into the opposite ends of open-wye secondary's of the Delta mode1, the output from the second VSC pair (3.75°, 176.25°) fed into the opposite ends of openwye secondary's of the Delta mode2, the output from the third VSC pair (18.75°, 191.25°) fed into the opposite ends of open wye secondary's of the Delta mode3, and the output from the fourth VSC pair (33.75°, 206.25°) fed into the opposite ends of open-wye secondary's of the Delta mode4. The transformers' primaries at Power Control Centre (PCC).The AC multi-stepped output voltage waveform across the terminals (open) of the proposed 48-pulse Thyristormodel as obtained from the MATLAB simulation results is shown in Fig. 5.

The concept of this system is to reduce the harmonics where we could able to achieve the pure DC for charging batteries at any given time and also best utilize of the system while controlling the pulses with the state of charge.

The circuit consisting of the supply from distribution station to the transformer and then supplied AC and is converted to DC with thyristor by pulse widthmodulation technique. In this charging system the complete charged battery is controlled by SOC from the battery.

The supply of 400KV AC is fed from the distribution station is then its converted by the transformer using Delta/Star transformer which converts the AC to pulsated AC which further converts it into the DC in later stages .This conversion is used pulse width modulation as the pulses as the pulses can be varied from six pulses to 48 pulses with the variable inductor and variable capacitor in parallel to the battery for reducing the leakage current from the battery. From the battery SOC is measured which acts as the feedback for the controller and the pulses are reduced until the battery is completely charged. The charging system is capable of charging the many different schemas like level-1, level-2 and level -3.

The controller connected after the battery for ideal switching and the switching is done using controlled pulses with balancing of the temperature and also reducing the total harmonic destruction with multi-level current control.

The EV battery needs to be protected from the sudden changes of current and voltages which affects the battery performance. To avoid such scenarios the battery is connected with the thyristor which acts as the current control with the circuit current flow and creates the secondary connection breaker to the battery. This state of protection needed to keep the battery intact and maintain its performance with the variation of currents.

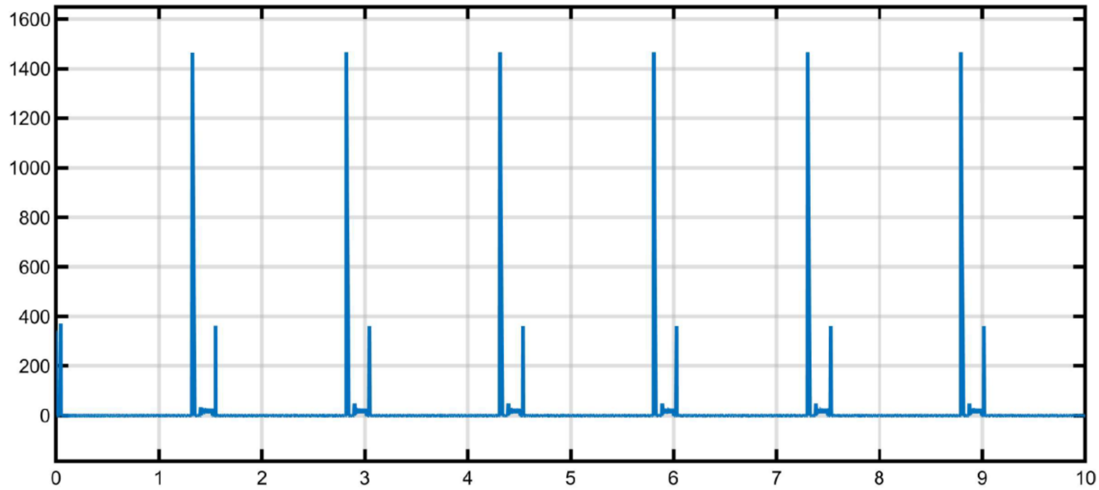

Fig7:Voltage of HMI 48 P

Here the voltage remains constant but reaches peaks when the current is dropped as per the Constant Current schema but to maintain constant power the voltage is tremendously increases and results in peaks.

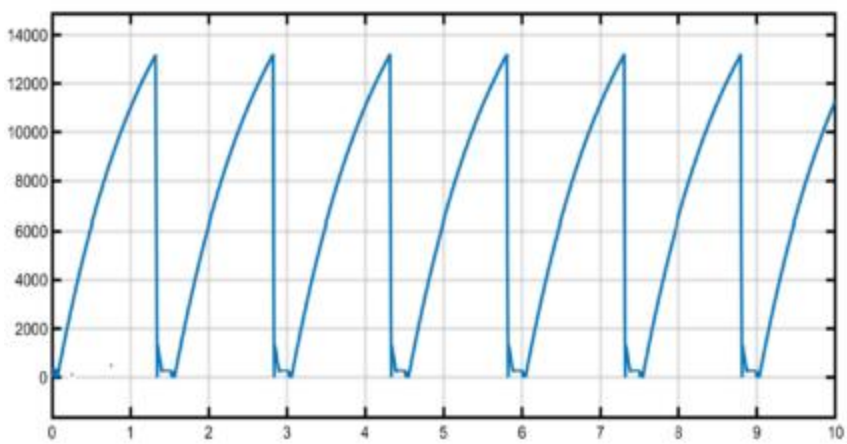

Fig8: Current of HMI 48P

It's the terminal current when the switching mode on to HMI48P where the terminal current initially low and then increased and then decreased to maintain the internal temperature of the battery as per the Constant Current schema.

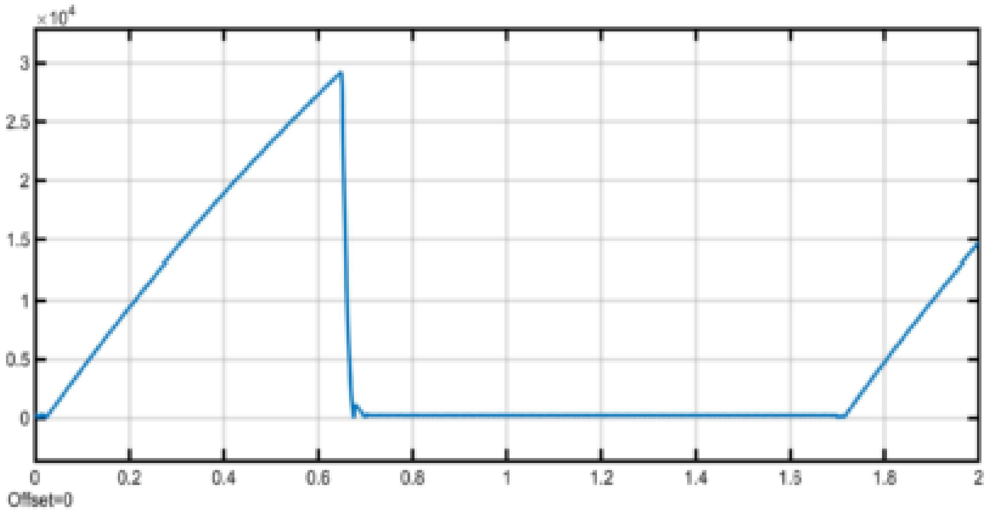

Fig9: Current of HM 48P

It's the terminal current when the switching mode on to HM48P where the terminal current initially low and then increased and then decreased to maintain the internal temperature here with the Hybrid switching sequence the peaks are common but less when compared with HMI48P switching schema.

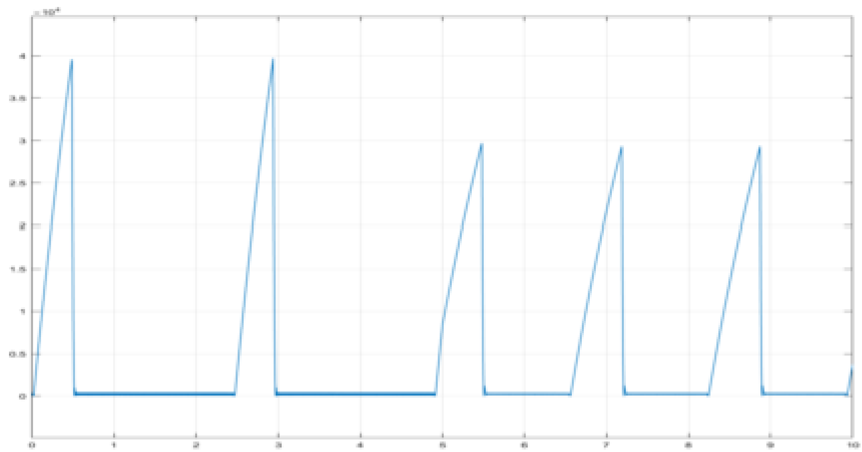

Fig10: Current 24 PM24 – PM48P

Here the amount of current decrease as the switching sequence is changed from PM24P to PM48P as the in parallel sequence the amount of current increase but the total power delivered is less. With increase of the pulses the current decreases but the peaks increase which impacts the rapid battery charging.

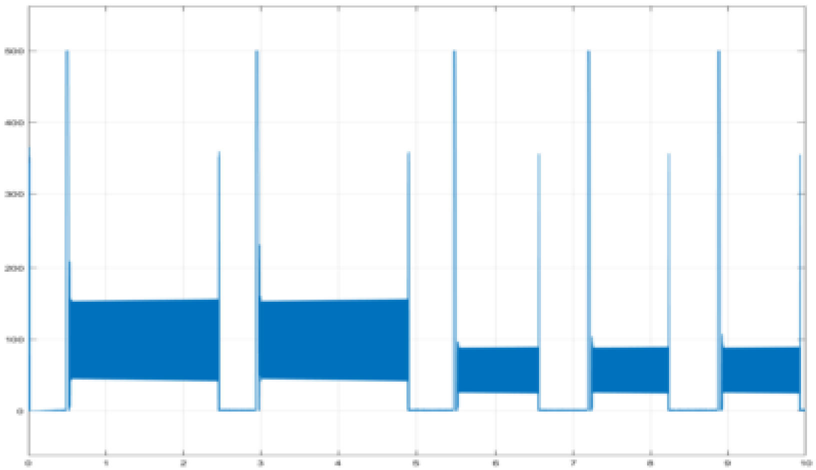

Fig11: Voltage PM24P - PM48P

As mentioned above the voltage graph represents the same but here the total amount of voltage increase with increase in pulse and leads to less total harmonic distortion.

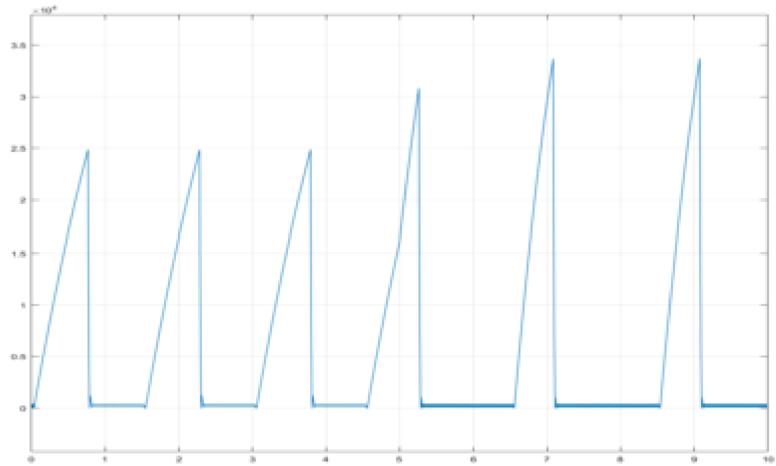

Fig12: PM24P – HMI24P Current

The schematic current control methodology joined with MSCCC technique is executed to accomplish quick current charge, which is appeared in Fig9 where the 48PTR works in HMI48P. Right now, limit voltage for solid charging is available as 326.6 V. The charging current, constrained by the Schema, change in current from the HMI48P to HM48P is (300 A) to 250 A, and afterward to 220 A, with 30 A with a reduction. The real charging current finds its reference current with no higher voltage when the reference decreases down, as can be seen from Fig9 where the detail perspective on the charging current is shown Fig7. The comparative study of voltage and current inclination of the 48PTR can be picked up when it works in SM48P or PM48P. In any case, the THD (Total Harmonic Reduction) estimations of the information of current will be a constraint in the three modes. The constant charging current is fed to the various charging mechanism flows are estimated and thought about among the three modes (PM48P, HM48P and SM48P), and the outcomes are depicted in Fig10. As can be seen, the THD got from the HM48P is between those from the SM48P and from the PM48P, which demonstrates that the presentation of HM48P will represents the purpose with parameters influencing the charging methodology with current with regular 48-pulse rectifiers in arrangement. At the point when the charging current arrives at its obsolete worth (100 A), it is seen that the THD esteems in the PM48P, HM48P and SM48P are 1.52%, 3.644%, 2.45% , 1.07%, 3.4% and 3.62% individually. They will be additionally diminished as the charging current keeps on expanding. The plots of current and voltage are shown in Fig17 which represents the information of current is near sinusoidal waveform, aside from a particular point, Fig12 determine the dynamic changes of the 48PFTTR when it changes from the PM24P to the PM48P, the HM48P to SM24P separately. No overshoot happens when the 48PTR changes from one working mode to the next.

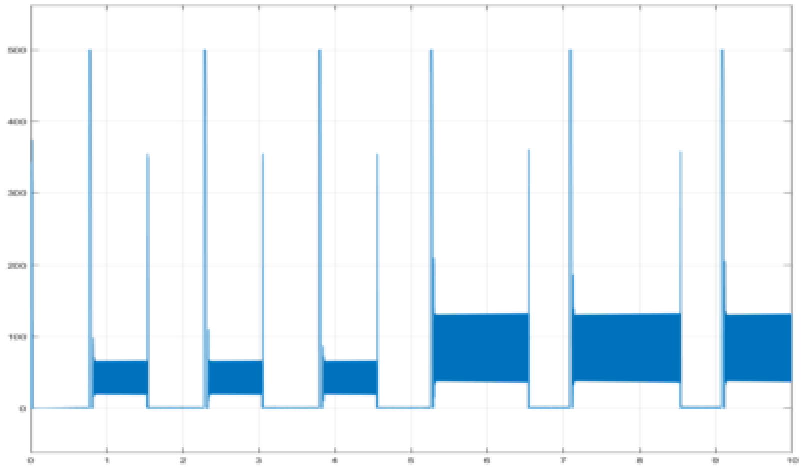

Fig13:PM24P – HMI24P Voltage

Here in the parallel sequence is changed to Hybrid sequence switching which tends to increase in the overall output power delivered within the circuit

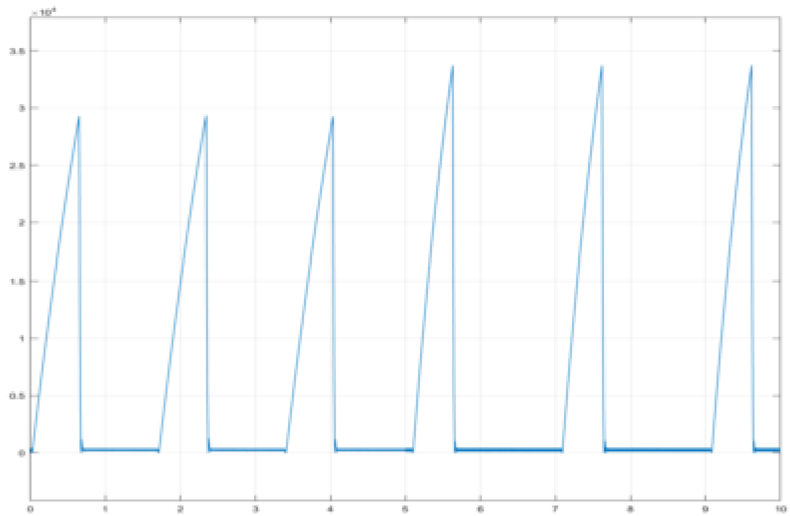

Fig14:HM48P-HM48P2 Current

Here the switching takes place between HM48P to HM48P2 where the increase in peak voltage and current and overall amount of total power delivered is represented. This is clearly represented in the State of charge in fig. 16.

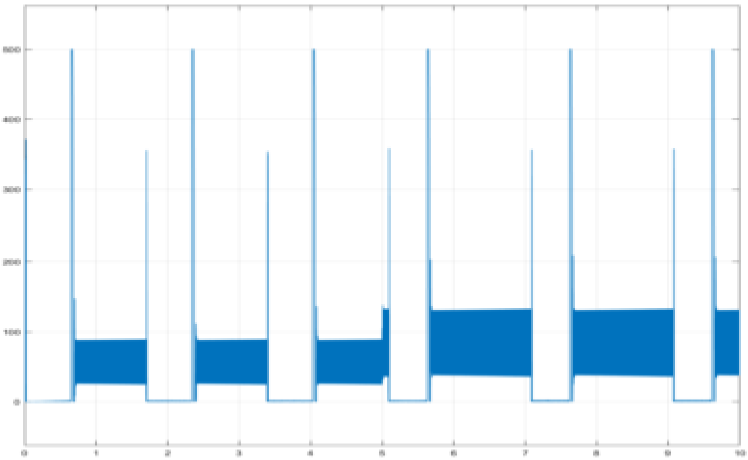

Fig15:HM48P-HM48P2 Voltage

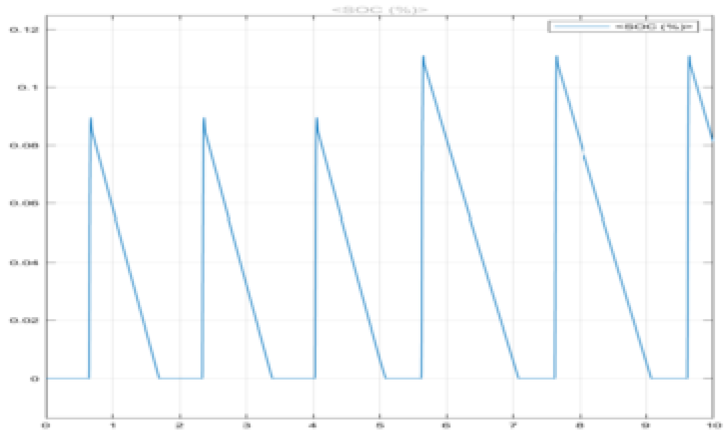

Fig16:SOC OF HM48P – HM48P2

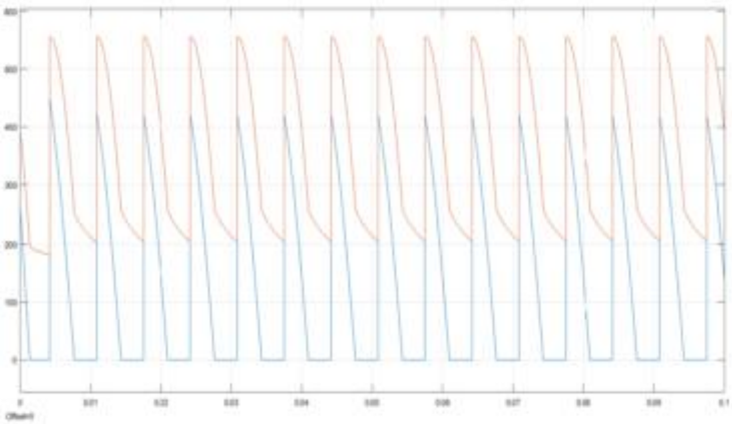

Fig17. Voltage and Current

Here the source voltage and current are represented and it maintains the same throughout the circuit. The operation of thyristor is controlled by the pulse assigned to them and creates a large variation from 6 pulse to 48 pulse circuit with in the same circuit.

3. Simulation Characteristics & implementation requirements

Here the constant current schema is implemented with the implementation on Li-ion battery which is commonly used in the common electrical vehicles. The parameters of the electrical vehicles are 400V/160Ah. The results are represented in the below with 48IPHM.

Table 2: Simulation specifications

SLNO	ITEMS	DESCRIPTION
1	Line-line voltage of grid side	400V(RMS)
2	Four-output Phase-Shift transformer	Δ/WYE
3	Shift angle	15
5	Capacities of Li-ion Battery Pack	400V/160Ah
6	Inductance	25.9mH
7	capacitance	600µF/700V

4. Effect of Pulse in Harmonics

The effect of the Harmonics can be reduced by basic reduction technique is the application of filters in the circuit which is series and parallel combination of the capacitors and inductors with multi bridge rectifier with six SCR's 450V. The output voltage is equalling as given below.

$$V_{dc} = nV_{dci}$$

Here the value n is represented as the number of bridges which are connected in series (in this case, n_{max} =6) Vdci the output dc voltage is given by

$$V_{dc} = 2.7V_{LLi}cos\alpha$$

Where α is represented as the delay angle and V_{LLi} is represented as the voltage between line to line of the rectifier bridge. The output voltage can be varied between in two variations with controlling with delay angle (α) in steps

Table3.Harnomic removal factor

No of Pulses	controlled THD	Uncontrolled THD
6- pulse (2-level)	0.371796	0.456738
12-pulse (2-level)	0.142863	0.277389
24-pulse (3-level)	0.019593	0.083163
48-pulse (4-level)	0.012729	0.030384
5-pulse (4-level)	0.006729	0.023352
7- pulse (4-level)	0.002340	0.015819
9- pulse (4-level)	0.001851	0.009987
11- pulse (4-level)	0.001476	0.003558

13- pulse (4-level)	0.000884	0.002928
15- pulse (4-level)	0.001077	0.002184
17- pulse (4-level)	0.022812	0.057545
19- pulse (4-level)	0.021732	0.043721
21- pulse (4-level)	0.0201	0.031441
23- pulse (4-level)	0.0115	0.024821

Table.3 shows the voltage and current of THD examination of different converter levels and pulses. The THD level will continue to decrease as the quality of the pulse are expanding in the rectification. The voltage and current has been with decrease of the THD with 2-level,3-levek with are 0.0110% and 0.0052% individually, contrasted with 0.22% and 0.12% of the five-level converter. It tends to be reasoned that by expanding the quantity of pulse/levels, offers noteworthy preferred position as far as force quality

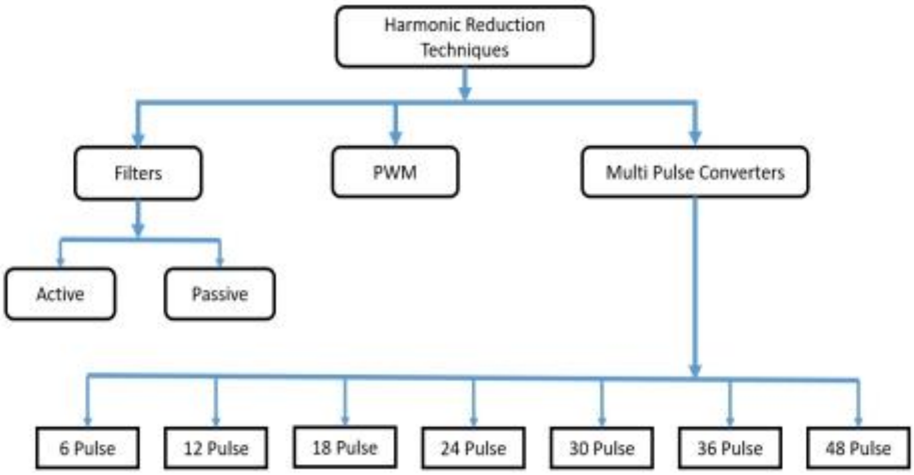

Fig18: Harmonic reduction techniques.

4.1 Six pulses

The six pulse converter rectifier as the basic rectification unit, the power transferred from the ZIG/ZAG transformer to the rectifier and then converted to DC by dividing it into six pulses. The thyristor gets the fired on receiving the small pulse. The characteristic AC harmonics are generated and these harmonics are in the order of 6n±1 and are represented below.

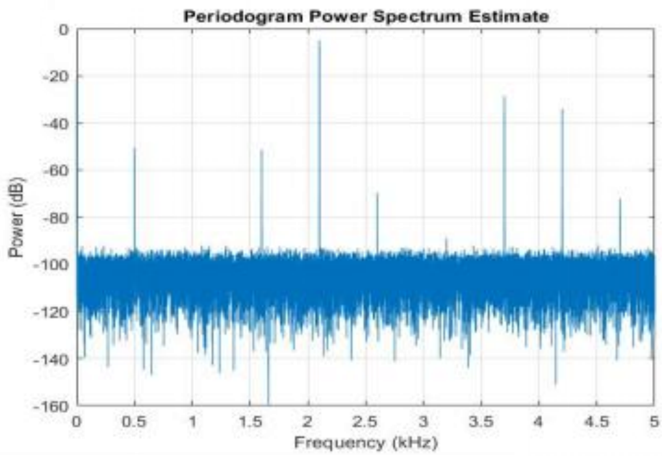

Fig 19: THD for six pulse converter

4.2: Twelve Pulses

The 12-pulse converter rectification as the basic unit, the power transferred from the ZIG/ZAG transformer to the rectifier and then converted to DC by dividing it into 12 pulses. The thyristor gets the fired on receiving the small pulse. The characteristic AC harmonics are generated and these harmonics are in the order of 12n±1 and are represented below.

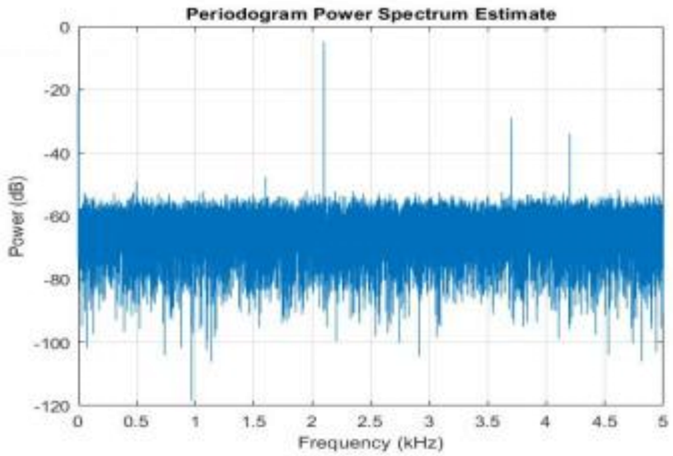

Fig 20: THD for twelve pulse converter

4.3: Twenty four Pulses

The 24-pulse converter rectifier as the basic rectification unit, the power transferred from the ZIG/ZAG transformer to the rectifier and then converted to DC by dividing it into 24 pulses. The thyristor gets the fired on receiving the small pulse. The characteristic AC harmonics are generated and these harmonics are in the order of 24n±1 and are represented below.

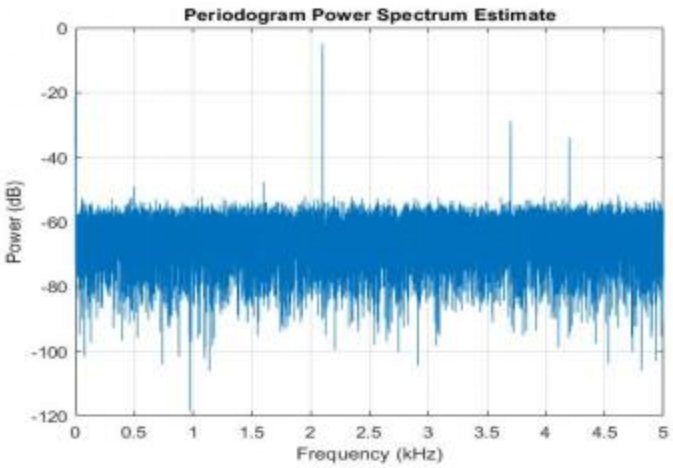

Fig 21: THD for twenty four pulse converter

4.4: Fourth Eight Pulses

The 48 pulse converter rectifier as the basic rectification unit, the power transferred from the ZIG/ZAG transformer to the rectifier and then converted to DC by dividing it into 48 pulses. The thyristor gets the fired on receiving the small pulse. The characteristic AC harmonics are generated and these harmonics are in the order of 48n±1 and are represented below.

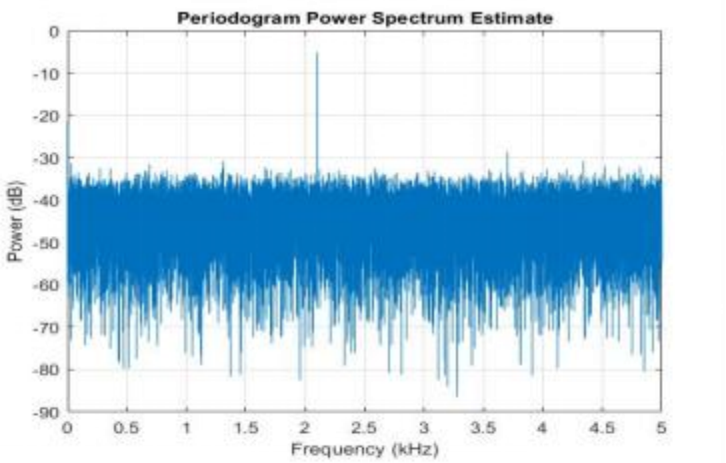

Fig 22: THD for fourthy eight pulse converter

5. Conclusion

A 48-pulse two-level thyristor-VSC based ± 100MVAR, 50Hz, 132kV Thyristor has been modelled in MATLAB environment by using 8x6-pulse VSCs operated using phase angle control algorithm employing PWM controllers. With the implementation of the six pulse thyristor along with interacting magnetics with the design on implementation of the multi stage compensation circuit with two stage implementation with 48- pulse thyristor. The circuit configuration for voltage regulation for the system of 132KV system. For this single stage configuration for the overall capacity requirement of 24.7(KVA).the commercially available compensates the transformer with PWM modulation technique. The increase of pulses had an impact of the harmonics with multi pulse thyristor for the PWM modulation with internal current control for smooth control of load in the system with various operating conditions with and THD levels are well within the IEEE Std. 519-1992 operating limits. The impact of zero sequence harmonics has been neutralized by adopting the zig-zag configuration of the 30° Phase Shifting Transformer in the magnetic circuit.

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