

# A New Method of Five Level Single-Stage Power Factor Correction of AC–DC Converter for Industry Applications

M Rama Prasad Reddy, Karanam Deepak, Y Hazarathaiiah

**Abstract:** In this article proposed a simulation of three-phase PFC AC-DC single stage 5 level converters uses capacitors in series. In the proposed 5 level converters utilize a flying capacitor arrangement through a normal phase shift Pulse Width Modulation toward develop efficiency, principally on light load circumstances. The implementation of the new method of three phase conventional method three level and proposed five level of the integrated AC – DC converter. The main advantages of the proposed rectifier are compared to conventional converter, with high input power factor and also it reduces harmonics of the input current. The possibility of the new 5 level converters is established with recreation results obtain from a proposed system converter. The proposed 5 level converter integrate the function of the improve PFC along with the five-level converter. During the proposed rectifier can be operated with low voltage stress along with control and the dc bus capacitors while it is five level converters is used in proposed converters. So the proposed method is more capable because of using very less diodes in the dc busses. The turn on losses is very less in proposed system. So in this paper proposed those 3 levels is implemented to five levels AC-DC converter for PFC correction.

**Keywords:** PFC (Power Factor Correction), 5 level converters, AC-DC converter for PFC correction, PWM Pulse Width Modulation, phase shift Pulse Width Modulation.

## I. INTRODUCTION

In the Three phase converters like ac-dc contain be urbanized toward a developed level through the power quality improvement within provisions of power- factor correction (PFC), its reduces the THD (total Harmonic distortions) at the input side of the ac mains, and the output voltage is synchronized in dc output. By using buck converter, buck-boost converter, boost converter, multilevel converter and multi pulse modes of converter with operated in both unidirectional and bidirectional directions power flow. And

In the three phase converters of ac-dc renovation of electrical power is commonly used in ASDs [1], UPS AND high voltage direct current transmission, with the renewable applications like solar system, battery storage systems, in development knowledge such as electroplating system, welding unit systems, and battery charging of the EHV (Electric Vehicles) and also implemented in telecommunication systems [2][3]. In conventional method the ac-dc converters are recognized like rectifiers. These rectifiers are urbanized by via the diodes and also using semi conductor devices like thyristors to offer the both controlled and uncontrolled dc power. And these converters having main problem is power quality issues nothing but a voltage distortion problems, harmonic distortion problem, and poor power factor problems, complex size of using filters of both ac and dc filters [3][4]. so due this drawbacks in the present rectifiers are developed with new power electronic devices like IGBT'S, MOSFETS, and also used GTO'S. So in proposed technique we can develop the rectifier circuit by using the above power electronic devices. And the converters are classified as 1) Multi level converters 2) multi pulse converters 3) power factor type of converters 4) switched converters. Etc. So for the reason that of the firm condition of PQ is needed on the system effort side of ac mains, a number of principles contain the urbanized as well as compulsory happening the customers. Since the strictness of the power quality troubles a few additional options like passive filters of the system, and Active power Filters, as well as also used cross filters all along through the previous rectifiers have been widely urbanized, mainly for the large voltage rating and previously accessible installations[5][6]. But, the cost of the filters is high, complex in size and has sensible losses, which decrease the on the whole effectiveness of the entire scheme. During a few cases the converter evaluation of APF's is approximately secure toward the evaluation of the output ratings. Due to those conditions, it is consider the improved alternative to utilize such converters as a natural component of the proposed structure of the AC-DC conversion, and the features of the proposed converter is size is reduced, efficiency is high and also controlled the generated DC to supply contented and flexible type of procedure of the system. It is consider appropriate challenge toward there a extensive point of view happening the position of proposed ac-dc converters equipment in favor of the engineers by means of them as well as commerce through PQ problems. The present manuscript is proposed that a new five level single stage five level Ac-dc PFC converter.

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\* Correspondence Author (s)

**Dr M Rama Prasad Reddy\***, Professor and Head of the Department Department of Electrical & Electronics Engineering, G. Pullaiah College of Engineering and Technology, Near Venkayapalle, Pasupula Village, Nandikotkur Rd, Kurnool, Andhra Pradesh, India

**Karanam Deepak**, Assistant Professor Department of Electrical & Electronics Engineering, G. Pullaiah College of Engineering and Technology, Near Venkayapalle, Pasupula Village, Nandikotkur Rd, Kurnool, Andhra Pradesh, India

**Y Hazarathaiiah**, Assistant Professor Department of Electrical & Electronics Engineering, G. Pullaiah College of Engineering and Technology, Near Venkayapalle, Pasupula Village, Nandikotkur Rd, Kurnool, Andhra Pradesh, India

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That circuit is designed with the current power semiconductor components; this interleaved structure is more trendy structure [7]. And the proposed converter also having a few of the drawbacks, In the proposed design using midpoint tap transformer is extremely expensive headed for build, which outcomes similar voltage lie happening the each partially of the inferior side windings. In addition to the final load output becomes the partially of the inferior side of the voltage, and each one diode employ the individual partially of the supply voltage of the secondary side of the transformer. And the final production voltage of the transformer in inferior side is the times of the magnetizing voltage i.e.; 2.

**II. CONVENTIONAL METHOD**

The existing converter is as shown in the Figure. 1. In a existing converter employ a secondary windings with the purpose of in use as of the converter transformer toward operate while the switch is “magnetic switches” toward terminate the voltage of dc bus capacitor voltage consequently with the purpose of the electrical energy so as to appear transversely the diode connection amount produced is equal to 0. suppose in the transformer primary winding is positive then the auxiliary transformer winding cancel away the total voltage of the dc bus thus the final production voltage of the diode based bridge rectifier is (DB1) is equal to the 0 value as well as the key input currents of the inductors are La1, Lb1, and Lc1 increase. And the main transformer principal side voltage is negative polarity, And the auxiliary side of winding 2 can be cancel the voltage of dc bus therefore the main total productivity voltage of the diode bridge rectifier is (DB2) be equal to 0 value as well as the key input currents of the inductors are La1, Lb1, as well as Lc1 increase. If the no voltage transversely then the main principal part winding of the transformer, then the total dc capacitors bus voltage across the closing productivity of the bridges DB1 and DB2 and the primary side of the total input state currents reduce the voltage is better than the primary side of the key voltage. but the participation currents are irregular, then the covering of the total input stage current determination be in sine form as well as also during stage through the contribution stage voltages.

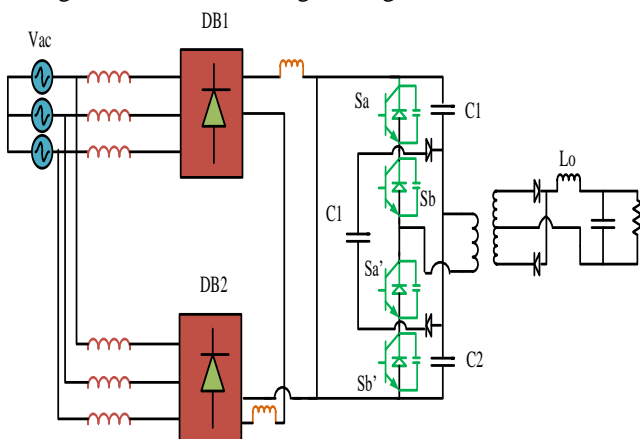


Figure.1. Conventional method of three level converter.

**III. PROPOSED SYSTEM**

The essential figure of projected five level converters is as revealed in the figure2. The necessary diagram is connected toward so as to of proposed five levels AC-DC converter

while obtainable during the previous article [21]. At this point Vabc is the 3-φ ac provide voltage. The three effort inductors Labc1 is united near apiece further toward a DB1 and the further three effort inductors Labc2 be related toward every further toward a DB2. In a conventional method using only three level converters but in the proposed method we are using five level converters for accurate ac supply and also reduce the harmonic distortions. The 5 level converters use the capacitors during sequence toward separate voltage of the dc bus keen on a place the voltage planes. In the direction of fabricate m no of levels of the voltage, then in a n level multi level converter needs the n-1 dc busses capacitors are used. So the proposed 5 Level implementation of the converters as shown in figure 2. In the proposed converters there are (n-1=5-1=4) total four capacitors are used they are C1, C2, C3, and C4. and also each capacitor of dc voltage is nothing but a Vdc/4 And the limitation of the each capacitor dc bus voltage is Vdc/4 throughout the clamp diodes. And the diode clamped multi level inverter output dc bus voltage is Vdc/4.

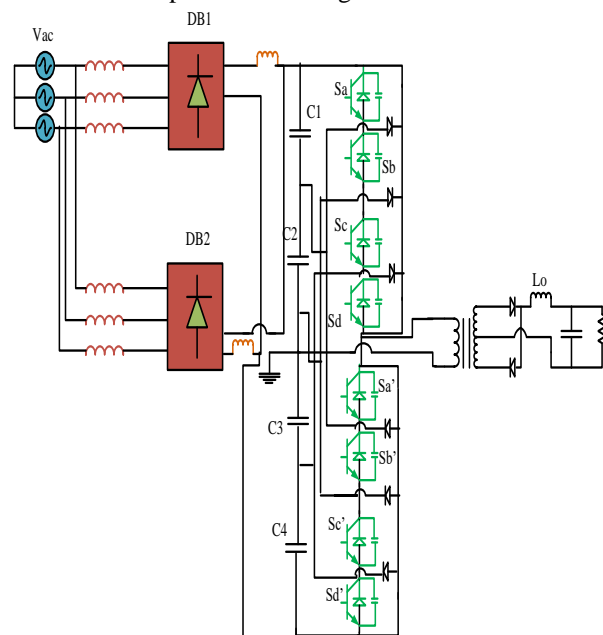


Figure 2. A New Three-phase five level AC-DC converter.

**(IV) Five level converter Operation**

**Mode 1 (t0 ≤ t ≤ t1):** At the first mode of operation of first four switches are in turn ON state. For the duration of this period the flying capacitor of the first four switches capacitors cf as well as mutually the output dc bus capacitors c1, c2, c3 and c4 are charged to the output load bus dc voltage, as well as followed by the dc capacitor c1 surge toward the load amount produced. since the reason of the attractive pairing method, and the voltage can be appear as of the extra windings be equivalent toward the bus dc voltage as well as after that the voltage completely cancel the bus dc side voltage next to the capacitor; And the production side of the diode connection category voltage be fasten awake, therefore the total inductor currents (ila1, ilb1, ilc1) will be amplify. In addition to then the derived elevation of the transformer of the diodes d1 along with d2 start conduct by the side of the similar instance to the flow of the energy stored into the load.



And the output dc voltage of the secondary side equal to  $V_{dc}$ .  
**Mode 2**( $t_1 \leq t \leq t_2$ ): At the mode-2 of operation the  $S_1, S_2', S_3', S_4'$  switches are in turn off position and remaining switches are  $s_2, S_3, S_4, S_1'$  will remains ON State Position. During the previous mode-1 of the operation and total power store in the input extra inductor start creature the transfer into the output of the dc bus capacitors after that this energy can be transfer into the capacitor  $cs_1, c'_{s2}, c'_{s3}, c'_{s4}$  accusation as well as capacitor  $cs_4'$  expulsion during the cf (flying capacitor) awaiting the voltage transversely  $cs_4'$ , the capacitance production of  $cs_4'$  is hold tightly toward nil. And the output dc voltage of the secondary side equal to  $3V_{dc}/4$ .

**Mode 3**( $t_2 \leq t \leq t_3$ ): At the mode-3 of operation the  $S_1, S_2, S_{a3}, S_{a4}$  switches are in turn off position and remaining switches are  $S_{a3}, S_{a4}, S_{a1}', S_{a2}'$  will remains ON State Position. In the previous mode-2 of function of the energy stock up control during the extra inductor contribution L1 transfer towards the output bus dc capacitors. During in supplementary windy L1 and the voltages with the purpose of preserve be show in fasten format. And the most important transformer of the main side of the current will be passes during the diode of d1 along with switches of the circuit is  $S_{a3}, S_{a4}, S_{a1}', S_{a2}'$ . So this mode of operation is help to the converters output side division, and also the output current passes through the inductor free wheels through the main transformer secondary side, can be passed through the diode d1 and switches of  $S_{a3}, S_{a4}, S_{a1}', S_{a2}'$ . Through the assist of converters cargo elevation division, the production inductor current free of charge controls the key transformers inferior elevation, So the dc production side of the secondary side is equal to  $-V_{dc}/2$ .

**Mode 4**( $t_3 \leq t \leq t_4$ ): during the method of procedure together the switches  $s_1, s_2, s_3, S_{a4}'$  be twisted OFF Position. The power accumulates during the other inductor input L1 is unmoving relocate towards the bus dc capacitors. The key transformers main current preserve survive expulsion during the remainder diodes of the switches  $s_4, S_{a1}', S_{a2}', S_{a3}'$  appropriate toward the sufficient power during the steady flow inductance. through deference toward the capacitor c2 this main current determination be charge during the body diodes of switch  $s_4, S_{a1}', S_{a2}', S_{a3}'$ . Whenever the switch  $s_3$  and  $s_4$  resolve survive switch ON afterward this method trimmings. Along with the diodes d3 d4 be conduct by the side of the similar point in occasion during the inferior elevation of the transformer toward stream the power to consignment. Through the assist of converters consignment elevation segment, the production inductor current free of charge swing the major transformers secondary side, after that the production inductor voltage is equivalent toward  $V_{dc}/4$ .

**Mode 5**( $t_4 \leq t \leq t_5$ ): During this method of procedure together the switches  $t_3$  as well as  $t_4$  be curved ON as well as the power flow beginning capacitor c2 toward the consignment and the voltage consequences beginning spot toward turn supplementary winding is equivalent toward so as bus dc voltage though through resources of overturn split that preserve invalidate the voltage of the voltage dc bus. The voltages next to improve inductors 2 happen to simply the correct bring voltage of each time as well as the current curving during the every inductor amplify. The liveliness stock up during the inductor L1 is entirely discharge addicted to the capacitor of the dc link subsequently this method determination be finished. Among the facilitate of the converters weight elevation sector, the production inductor

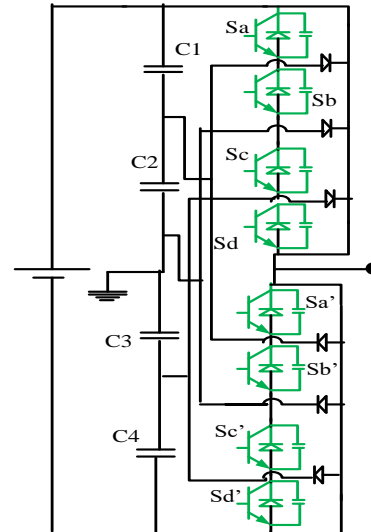
present without charge wheels the key transformers inferior elevation, afterward the production inductor voltage be equivalent near zero.

**Table 1 Switching Operation Of Five-Level Converter**

Load output voltage $V_0$	Switch state							
	$S_{a1}$	$S_{a2}$	$S_{a3}$	$S_{a4}$	$S_{a1}'$	$S_{a2}'$	$S_{a3}'$	$S_{a4}'$
$V_5 = V_{dc}$	1	1	1	1	0	0	0	0
$V_4 = 3V_{dc}/4$	0	1	1	1	1	0	0	0
$V_3 = V_{dc}/2$	0	0	1	1	1	1	0	0
$V_2 = V_{dc}/4$	0	0	0	1	1	1	1	0
$V_1 = 0$	0	0	0	0	1	1	1	1

**IV. FIVE LEVEL CONVERTER STRUCTURE**

In the 5 level converter used for harmonic reduction. When in the conventional method conventional converter inside the middle voltage point is described while the impartial summit. But in proposed converters using capacitor be connected in sequence is toward be dividing to the voltage dc side is enthusiastic to the situate the number of levels. Suppose we create the n stages of point voltages and the capacitors used as n-1. If n=5 the no of phase voltages is equal to 5 and the capacitors is equal to 5-1=4. Then the capacitors is used as C1, C2, C3, and C4.



**Figure 3: Basic architecture of 5 level converters**

To clarify the voltage is staircase produce, at a position O be measured while the production phase voltage position at a spot. By via main method of the proposed converter revealed in the Fig. 3, in present be total switches arrangement toward make the 5 level output voltages diagonally. In the above Table 1 shows output phase voltage level as well as the equivalent switch position are explained in table.



Since in a Table 1, switch on state represent to facilitate the switch state is 1, and switch off state represent to facilitate the switch state is 0. But in the each one stage leg, is a position of four adjoining switches is lying taking place at a few specified instance. At present four gracious switch couple during every one of the phase, i.e., Sa1-Sa1', Sa2-Sa2', Sa3-Sa3' and Sa4-Sa4'.

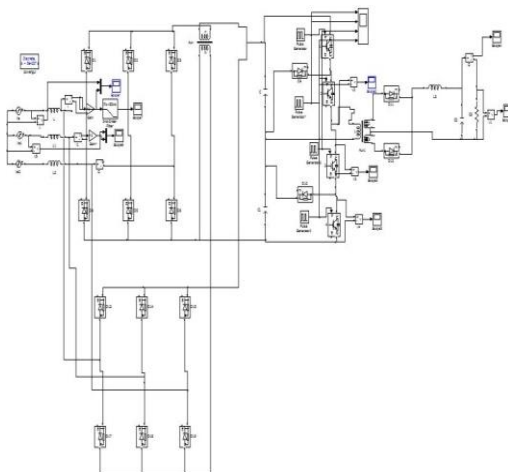
**Main Features of 5 level converter**

- If voltage rating is to be rise so essential for Blocking Diodes. while every active state of the switching tool is simply necessary towards the obstruct a output voltage stages of  $V_{dc}/(n - 1)$ , for the total compress diodes
- Advantages of the proposed five level converters:**
- The entire of the phases divide up a general type of system dc voltage bus, As a minimize the total capacitance necessities of the proposed Method. Designed for the cause, a new end-to-end method is't simply probable excluding the realistic used for uses such as a increasing the level to the elevated voltage end-to-end interlink otherwise a variable speed constrain is used.
- The no. of capacitors are pre-charged as a grouping.
- And having the high Efficiency at essential switching frequency.

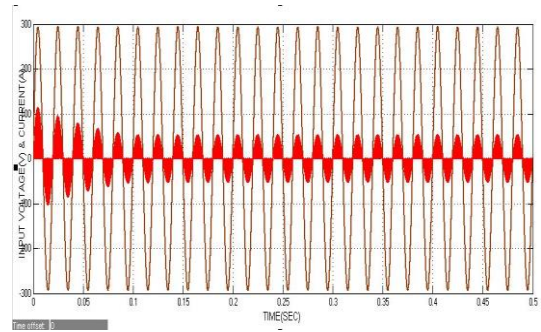
**Disadvantages of the proposed five level converter:**

- Real power flow is complex for the single stage converter since the midway type of the input dc levels will have a tendency to the charge too much or expulsion lacking the exact supervises as well as system power.
- And the total number No. of compress diodes necessary be quadratic ally connected toward the total No of stages, so these are used for elevated the total number of certain levels.

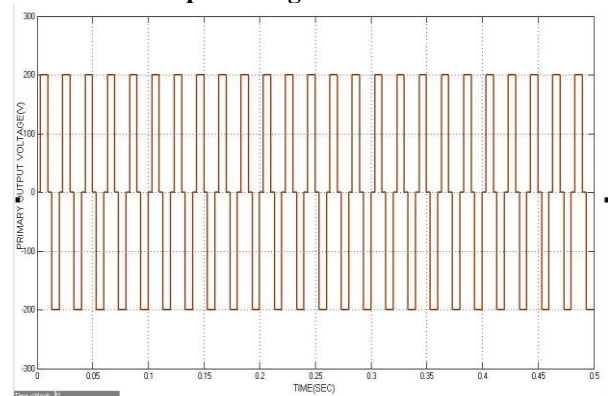
**V. SIMULATION RESULTS**



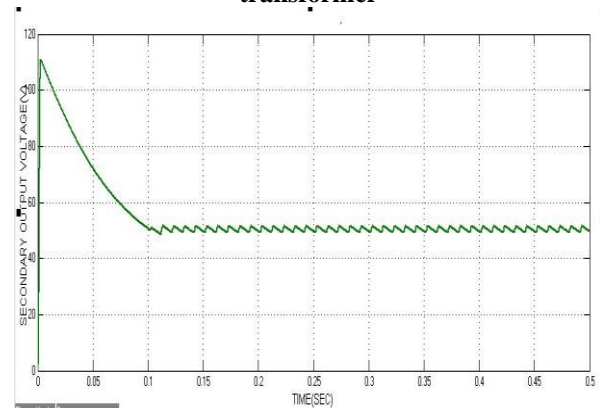
**Fig.4 Mat Lab simulink Block diagram of the conventional Three Level converter**



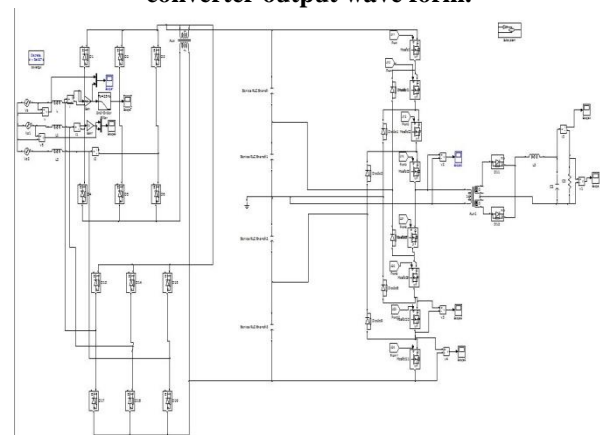
**Fig.5 simulation wave form of the conventional Three converter input voltage and current waveform**



**Fig.6. simulation wave form of the conventional Three converter input voltage at primary winding of the transformer**



**Fig.7 simulation wave form of the conventional Three converter output wave form.**



**Fig.8 Mat Lab simulink Block diagram of the Proposed Five Level converter.**

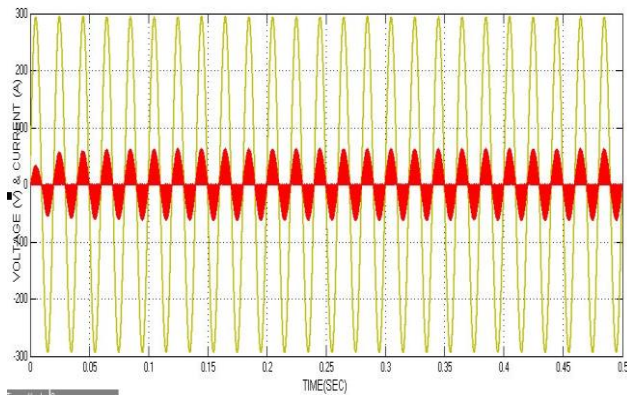


Fig.9 simulation wave form of the Proposed Five Level converter input voltage and current waveform

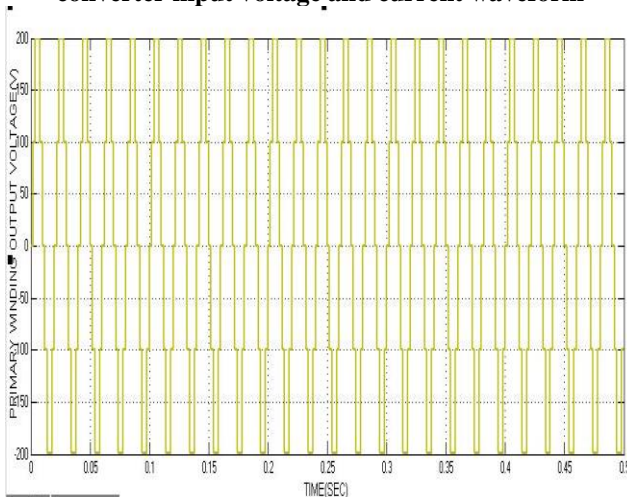


Fig.10. simulation wave form of the Proposed Five Level converter input voltage at primary winding of the transformer.

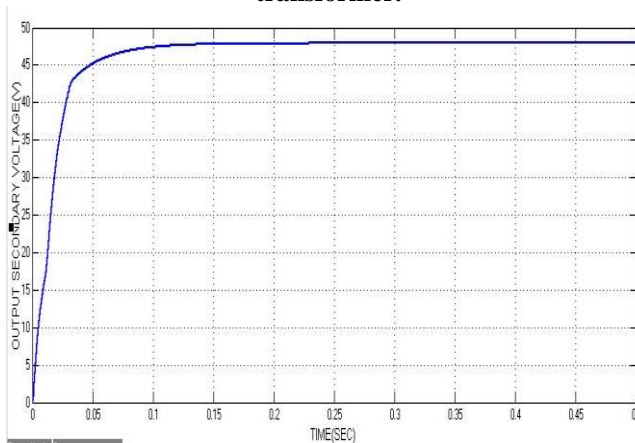


Fig.11 simulation wave form of the Proposed Five Level converter output wave form.

### I. CONCLUSION

A novel multilevel single – stage AC – DC converter so as to perform contribution power factor correction as well as output voltage parameter is projected in the manuscript. The exceptional characteristic of the Five Level converter is with the purpose of it merge the presentation of dynamic increase preregulator and five level multi – level DC – DC converter. Several industrialized appliance contain begin toward need advanced power equipment during present days. The Power electronics drives are appropriate fashionable in favor of a range of industrialized appliance. During this theory a new

five and three stages of AC toward DC converter in favor modernize the presentation of the PE drives with a five-level single-stage PFC based ac–dc converter during the input have be projected during this manuscript. The 5 level converters operate through a particular regulator toward control the production voltage as well as use secondary windings in use since its influence transformer while magnetic switches toward stop the voltage of dc bus therefore the contribution segment operate similar to a increase in a proposed converter. The proposed five level converters preserve work through inferior hit the highest point voltage strain crosswise the switch as well as the capacitors of dc bus while it is a five level proposed converter. This proposed five level converter offer changeable production voltage through enhanced PFC. The each and every one simulation results be established in the course of Matlab software.

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### AUTHORS PROFILE



**Dr M Rama Prasad Reddy**, Received the Ph.D degree in Electrical and Electronics Engineering from JNTU Hyderabad ,A.P, India. He has completed M.Tech in High Voltage Engineering from JNTU Kakinada, A.P, India. Currently working as a head of the department & Professor in G. Pullaiah College of Engineering and Technology since last three years. And his areas of interest are Power Systems, Power electronics and drives, Electrical Circuits. He has 19 years of teaching experience.



**Karanam Deepak**, Received the B.Tech degree in Electrical and Electronics Engineering from Prakasam Engineering College, Kandukur, Prakasam (DT),A.P,India,in 2013.He has completed M.Tech in Power Electronics and Drives from VNR Engineering College,Ponnuru,Guntur (DT),A.P, India . Currently working as a Assistant Professor in G. Pullaiah College of Engineering and Technology since last one year. And his areas of interest are Power Systems, Electrical machines, Electrical Circuits and VLSI design.



**Y Hazarathiah**, was graduated in Electrical & Electronics Engineering from G. Pulla Reddy Engineering College, Kurnool in the year 2007. he received her M.Tech in Electrical Power Systems from Sri Kottam Tulasi Reddy Memorial College of Engineering , Mahaboob Nagar, in the year 2013. Presently he is working as Assistant Professor in Department of Electrical and Electronics Engineering at G. Pullaiah College of Engineering & Technology, Kurnool. he has 11 years of teaching experience. Her area of interest is Power Systems.