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Simulation Of 28 Pulse Ac-Dc Converter Using Matlab/Simulink

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Abstract

This paper presents a 28-pulse ac-dc converter for enhancing the power quality at the point of common coupling. The elimination of harmonics in the input supply current results in low THD. The design and analysis of the proposed ac-dc converter is carried-out in detail.

Keywords: *28-pulse ac-dc converter, phase-shift transformer, multiphase, THD.*

1. INTRODUCTION

Modern ac–dc converters used in power supply are expected to draw sinusoidal input ac current. In these three phase ac–dc converters, the ac supply voltage is rectified by a multipulse diode bridge rectifier with output filters. A high frequency dc–dc converter yielding regulated output dc voltage is then connected between the rectifier and the load. Higher pulse number-based ac–dc converters have been reported and these are simple to implement. These converters are found to be simple, rugged and reliable. When a multipulse converter is fed by an autoconnected transformer, it results in reduction in the harmonics, as each portion of this autoconnected transformer carries only a small portion of the total kVA of the output load. With this in view, a 28-pulse AC–DC converter is designed using asymmetric polygon arrangement.

Power supplies used in telecommunication applications should have stiffly regulated output voltages and galvanic isolation. Many researchers have worked on providing a simple utility interface to these power supplies circuits and yet meeting voltage regulation requirements successfully. In fact, multipulse converters have been used as an improved power quality utility interface in a variety of applications such as telecommunication power supplies, electric aircraft applications and variable frequency induction motor drives [1].

The proposed 28-pulse rectifier is fed from delta/polygon transformer[2]. As the power to the load is transferred at low-voltage levels, the use of parallel bridge configuration is justified. The input transformer secondary is asymmetric polygon extending two sets of seven phases for the two diode bridge converters. The design is based on the fact that for a rectifier having prime number of input phases (excluding 3) will have rectified output waveform that repeats itself only after one complete cycle of transformation. This is different from the conventional rectifiers where the cyclical repetition in the rectifier output can occur within one cycle of transformation.

The proposed transformer is capable of feeding two diode bridges (each having seven legs) that is connected in parallel. This parallel connection produces 28-pulse configuration for AC–DC conversion.

2. Proposed 28-pulse AC–DC conversion

Fig 1 shows a delta/polygon configuration of 28 pulse. In this proposed configuration, a single polygon secondary is used which generates two sets of seven-phase supply for each bridge.

2.1 Design of 28-pulse AC–DC converter:

Fig. 2 shows the schematic of the proposed delta/ polygon transformer arrangement and its graphical representation depicting angular position of various phasors. It is based on hybrid of multiphase and phase– staggering techniques for AC–DC conversion.

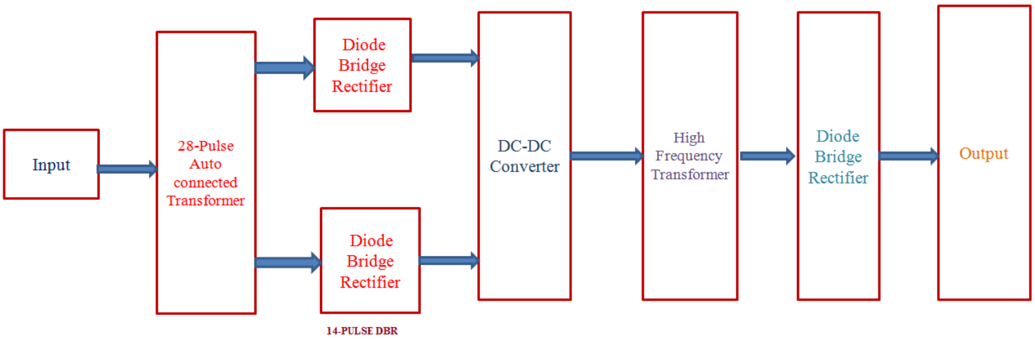

Fig 1: Delta/polygon transformer configuration for 28-pulse AC–DC conversion

A multiphase 14-pulse rectification by seven-leg diode bridge rectifier requires seven-phase supply, where the displacement between the phase angles selected is 360°/7 = 51.43^0

In phase-staggering AC–DC converter technique, the phase displacement between the AC supplies connected to bridges is given by 60°/(no.of six-pulse bridges employed). This means for 12-pulse AC–DC converter of 30° and for 18-pulse AC–DC converter 20° is the phase displacement between the bridges. Similarly, if two seven-leg bridges are employed the phase-staggering angle selected is ((360°/14)/2) =12.86º.

The two seven-leg diode bridge converters 1 and 2 are connected to two sets of seven-phase secondary winding output terminals of the autoconnected transformer

The converters 1 and 2 have each seven sets of voltage as a', b', c', d', e', f', g' and a", b", c", d", e", f", g" respectively. These two sets of converters are displaced by 12.86° from each other at -6.43º and +6.43° respectively from the input supply voltage of phase 'a'.

3-phase voltages are considered as follows:

$V_a = V \angle 0^0$; $V_b = V \angle 120^0$;$V_c = V \angle -120^0$ **……….. (1)**

Voltage equations are considered:

$V_a' = V \angle +6.43^0$; $V_b' = V \angle -45^0$; $V_c' = V \angle -96.43^0$; $V_d' = V \angle -147.86^0$; $V_e' = V \angle -199.28^0$; $V_f' = V \angle -250.71^0$;$V_g' = V \angle +302.14^0$ **……….. (2)**

$V_a'' = V \angle -6.43^0$; $V_b'' = V \angle -57.86^0$;$V_c'' = V \angle -109.28^0$; $V_d'' = V \angle +160.71^0$; $V_e'' = V \angle +212.14^0$; $V_f'' = V \angle -263.57^0$ $V_g'' = V \angle -315^0$ **……….. (3)**

$V_{ab} = \sqrt{3}\ V_a \angle 30^0$;$V_{bc} = \sqrt{3}\ V_b \angle 30^0$; $V_{ca} = \sqrt{3}\ V_c \angle 30^0$ **……….. (4)**

From the phasor diagram of autoconnected transformer for 28-pulse ac-dc converter as shown in Fig 2 the voltage equations for the converter 1 are as follows

$V_a' = = V_a - K1\ V_{ca}$ **……….. (5)**

$V_b' = V_a - (K1 + K2)\ V_{ab} + K3\ V_{bc}$ **……….. (6)**

$V_c' = V_b' - K4V_{ab} + K5V_{bc} + K6V_{ca} - K7V_{ab}$ **……….. (7)**

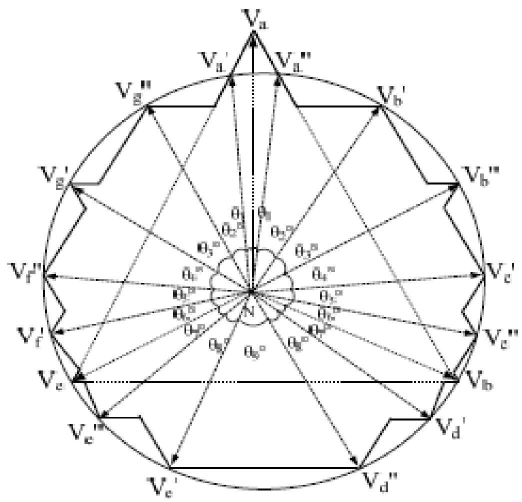

Fig 2: Schematic of the proposed delta/ polygon transformer arrangement

$V_d' = V_b - K_{12}V_{bc} + K_{13}V_{ca}$ ……….. **(8)**

$V_e' = V_c + (K_{12} + K_{14})\,V_{bc} - (K_{13} + K_{15})\,V_{ab}$ ……….. **(9)**

$V_f' = V_c - K_{11}V_{ca} + K_{10}V_{ab}$ ……….. **(10)**

$V_g' = V_a' + (K_2 + K_4)\,V_{ca} - (K_3 + K_5)\,V_{bc}$ ……….. **(11)**

In the same way the voltage equations for converter2 are

$V_a'' = V_a - K_1V_{ab}$ ……….. **(12)**

$V_b'' = V_a'' - K_4V_{ab} + K_5V_{bc}$ ……….. **(13)**

$V_c'' = V_b + K_{11}V_{ab} - K_{10}V_{ca}$ ………..**(14)**

$V_d'' = V_d'' - K14\,V_{bc} + K15\,V_{ca}$ ……….. **(15)**

$V_e'' = V_c + K12V_{bc} - K13V_{ab}$ ……….. **(16)**

$V_f'' = V_a'' - K9V_{ca} + K13V_{ab}$ ……….. **(17)**

$V_g'' = V_a' + K2V_{ca} - K3V_{bc}$ ……… **(18)**

By substituting equations (1)-(4) in equations (5) to (18) the values of constants K1 to K16 are obtained as follows:

K1 = 0.2239, K2 = 0.3309, K3 = 0.4297, K4 =0.202, K5 = 0.0386, K6 = 0.2248, K7 = 0.5188, K8 = 0.1759, K9 = 0.0762, K10 =0.0672, K11 =0.2369, K12 = 0.3505, K13= 0.2921, K14 = 0.1458, K15 = 0.1122,K16= 0.6606.

The values of these constants determine the number of winding turns. These values are used for the simulation.

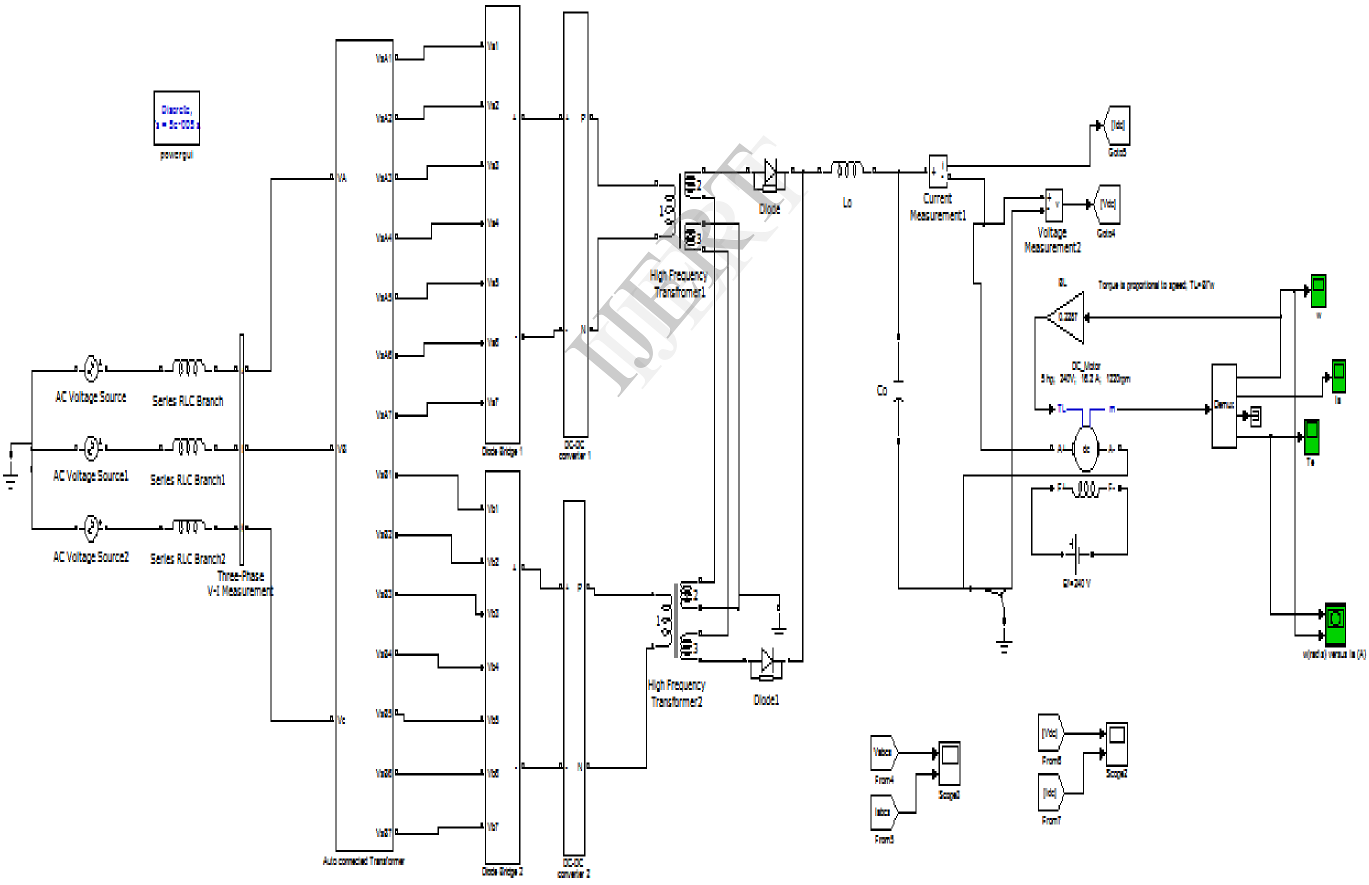

Fig 3 MATLAB model of the proposed transformer for 28-pulse AC–DC converter system

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3. Results and Discussion

The proposed 28-pulse AC–DC converter is simulated in MATLAB environment along with SIMULINK and power system block set toolboxes. The 28-pulse AC– DC converter system is fed from 380 V, 50 Hz AC supply and 12 kW. The value of source impedance considered is 3%. The MATLAB model of this 28-pulse AC–DC converter is shown in Fig. 3. Table 1 shows the comparison of THD ac mains for different loads at output. The simulation parameters needed for Simulink/PowerSystem modelling are given in Appendix.

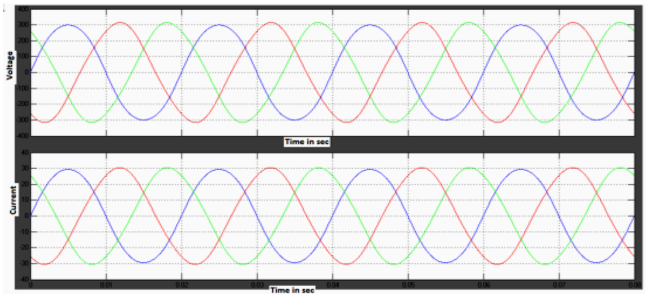

Fig 4 Input Voltage and Current waveform of 28 pulse ac-dc converter

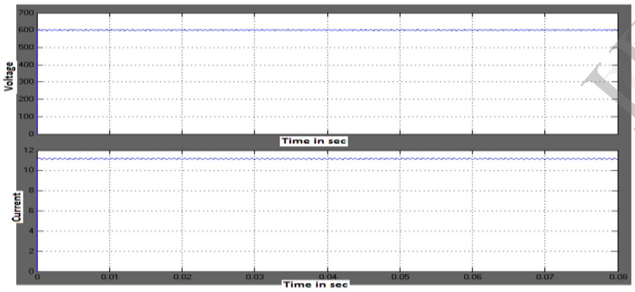

Fig 5 DC Link Voltage and Current of 28 pulse ac-dc converter

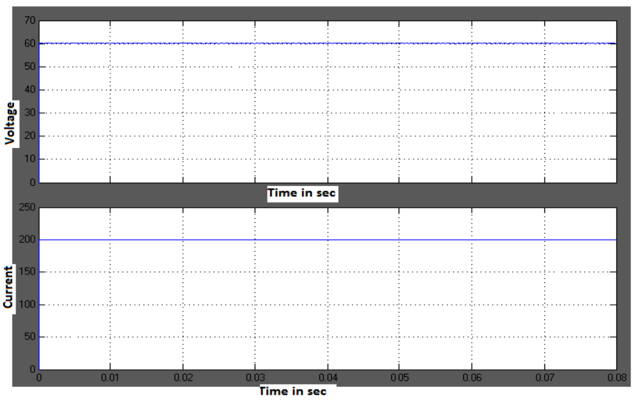

Fig 6 Output Voltage and Current waveform of 28 pulse ac-dc converter

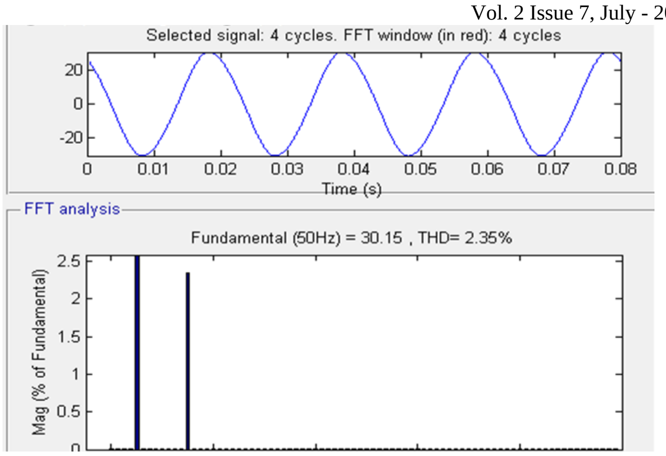

Fig 7 THD Spectrum of 28 pulse ac-dc converter

Tropology	THD of input ac main		
	R	RL	DC MOTOR
6-pulse	25.89%	26.48%	21.46%
12-pulse	17.66%	18.22%	18.36%
18-pulse	9.27%	9.37%	9.46%
28-pulse	2.35%	2.31%	3.16%

Table 1 Comparison of THD

With load as DC motor the THD spectrum of 6 pulse and 28 pulse is shown in below figures.

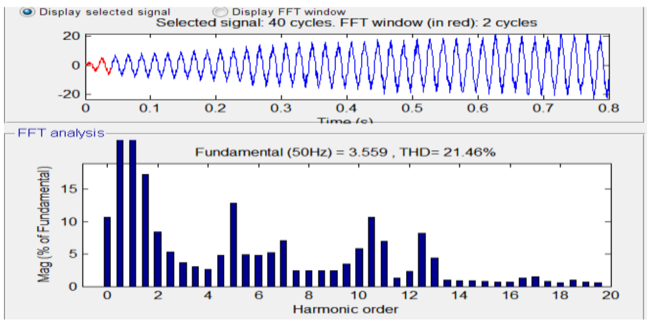

Fig 8 THD Spectrum of 6 pulse ac-dc converter with DC motor

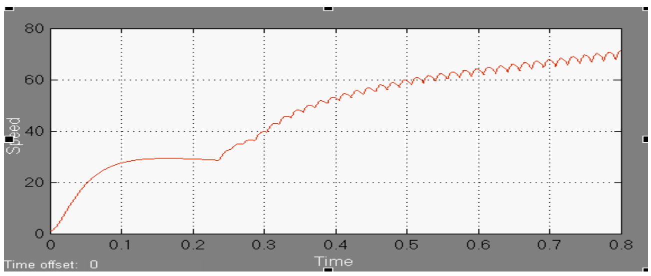

Fig 9 Speed Vs Time Characteristics of 6 pulse ac-dc converter with DC motor

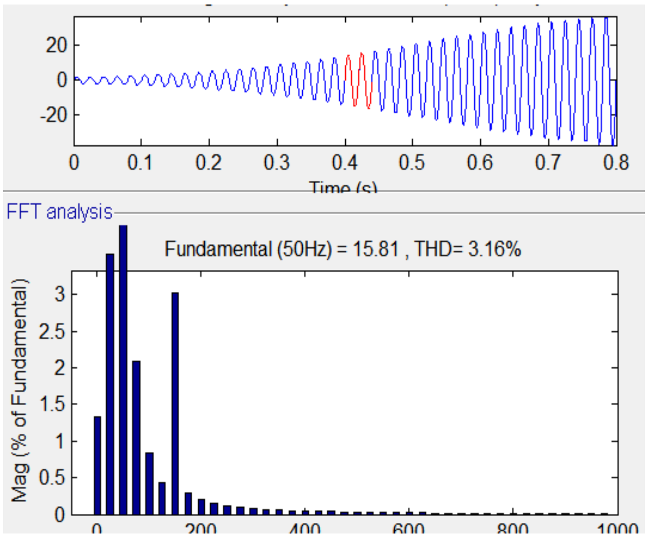

Fig 10 THD Spectrum of 28 pulse ac-dc converter with DC motor.

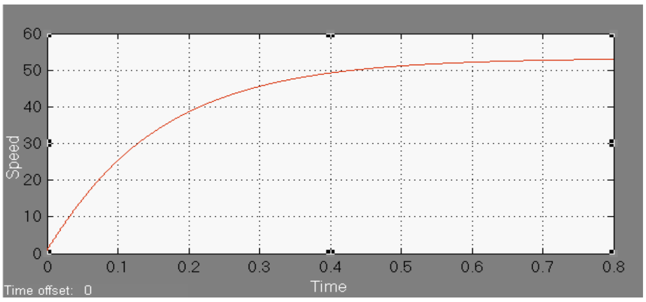

Fig 11 Speed Vs Time Characteristics of 28 pulse ac-dc converter with DC motor

Comparing to 6 pulse, the speed of motor in 28 pulse ac-dc can controlled within short period. Fig 9 and Fig 11 shows the speed vs time characteristics of 6 pulse and 28 pulse ac-dc converter respectively.

4. Conclusion

A new auto connected transformer based 28-pulse ac-dc converter has been presented for a 12kW supply. A complete analysis and design methodology of the proposed ac-dc converter is also presented. The behavior of the converter is studied in MATLAB based simulation and the % input ac mains current THD has been found less than 5%. The delta/polygon transformers used for a 28-pulse AC–DC conversion system have single secondary and it has provided balanced output voltages. The total number of diodes used is 28 only which is less than that of 30- and 36-pulse converters. The resulting AC–DC converter system has exhibited a high–level performance with clean power characteristics to be used in the uncontrolled front-end rectifiers. The THD of input current is observed to be less than 5%. The performance of 28 pulse is observed with load as DC motor.

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6 Appendix

Simulation model parameters of the Transformer:

These parameters employed for MATLAB modeling in Simulink/SimPowerSystems for 380 V, 12 kW load for three phases are as follows.
Frequency of supply is 50 Hz.
Power rating for each phase is 7800 VA.
Primary winding (delta-connected)
Phase A: winding no. 12: 380 V.
Phase B: winding no. 10: 380 V.
Phase C: winding no. 12: 380 V.

Secondary winding (polygon-connected)
Phase A: winding nos. 1–11: k_1, k_2, k_4, k_7, k_9, k_{11}, k_{15}, k_{13}, k_{10}, k_8, k_6.
Phase B: winding nos. 1–9: k_{12}, k_{14}, k_{16}, k_{14}, k_{12},

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k_5, k_3, k_5.
Phase C: winding nos. 1–11: k_{11}, k_9, k_7, k_4, k_2, k_1, k_6, k_8, k_{10}, k_{13}, k_{15}.
Leakage inductance for each phase winding is 0.02 p.u.
Resistance for each phase of winding is 0.005 p.u.
Magnetising reactance L_m and magnetisation resistance R_m is 500 p.u. each.

Velupucherla Obul Reddy received his M.Tech in Power Electronics from the JNTUH, India in 2011 and a B.Tech in Electrical and Electronics Engineering from JNTUH, India, in 2009. He is presently working as a Asst. Professor in Aurora's Engineering College, AP, India. His main research areas are Switched Mode Power Converters, Renewable Energy Sources, Electrical Drives.

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