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A 24-Pulse AC-DC Converter for Vector Controlled Induction Motor Drives by using Pulse Doubling Technique

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Abstract:

This paper deals with various multipulse AC-DC converters for improving the power quality in vector-controlled induction motor drives (VCIMD) at the point of common coupling (PCC). These multi-pulse AC-DC converters are realized using a various transformers. Moreover, DC ripple reinjection is used to double the rectification pulses resulting in an effective harmonic mitigation. The proposed AC-DC converter is able to eliminate up to 21st harmonics in the supply current. The effect of load variation on VCIMD is also studied to demonstrate the effectiveness of the proposed AC-DC converter. A set of power quality indices on input AC mains and on the DC bus for a VCIMD fed from different AC-DC converters is also given to compare their performance.

Keywords:

Transformers, Multi-pulse AC-DC converters, Inter-Phase Transformer, Vector control, Point of common coupling (PCC), THD, power quality.

1.INTRODUCTION:

The advances in power semiconductor devices have led to the increased use of solid-state converters in various applications such as air conditioning, refrigeration, pumps, and etc. Employing variable frequency induction motor drives. These variable frequency drives generally use the three phase squirrel cage induction motor as the prime mover due to its advantages like rugged, reliable, maintenance free, etc. these induction motor drives are mostly operated in a vector control mode due to its capability of giving performance similar to that of a DC motor. These drives are fed by a six pulse diode bridge rectifier, which results in injection of harmonics in the supply current, thus deteriorating the power quality at the point of common coupling (PCC), there by affecting the nearby consumers. This paper presents a various transformer based 24-pulse AC-DC converter. A pulse multiplication technique is used to have harmonic free system. The scheme needs two diodes along with a suitably tapped interphase reactor [IPT] for increasing the number of pulses. This arrangement results in elimination up to the 21st harmonic in the input line current [3].Moreover, the effect of load variation on the vector controlled induction motor drive (VCIMD) is also studied. The proposed AC-DC converter is able to achieve near unity PF in a wide range operating range of the drive [5]. A set of tabulated results giving the comparison of total harmonic distortions(THD) of AC main current and THD of supply voltage is presented for VCIMD fed from an existing six pulse AC-DC converter referred to as topology ‘A’, 12-pulse converter, topology ‘B’and proposed 24-pulse AC-DC converter, Topology ‘C’[5-7].

1.Six-Pulse Diode Bridge Rectifier fed VCIMD Block Diagram

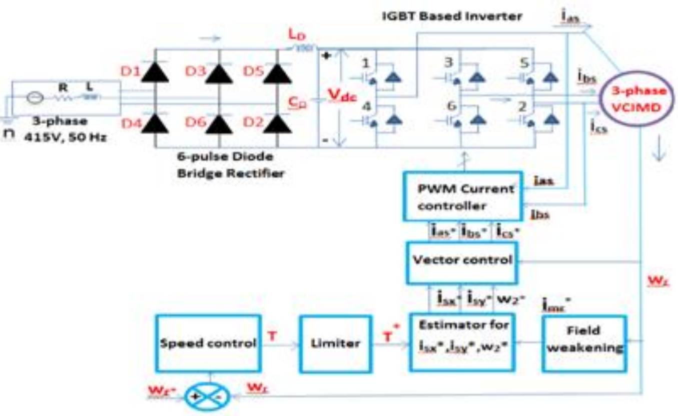

Fig.1: Six-pulse diode bridge rectifier fed induction motor block diagram.

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2.Twelve-Pulse Diode Bridge Rectifier fed VCIMD

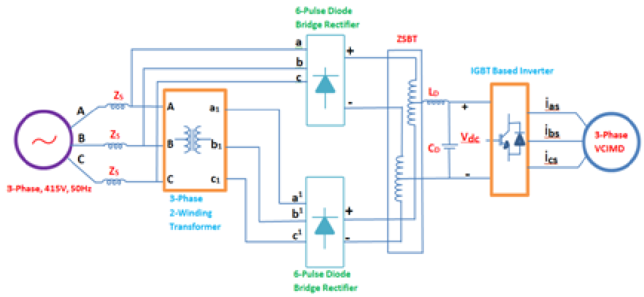

Fig.2: Twelve-pulse diode bridge rectifier fed induction motor block diagram.

The conventional 12-pulse AC/DC converters are [1-3] shown in Fig. 2. The power factor and harmonic components of the utility input line current can be improved by shifting the input voltages 30^0 in the Delta-Star connected AC/DC converter as well as in the 3-phase 2-winding transformer phase-shifted AC/DC converter. But the output voltages of these AC/DC converters are not controllable. The output voltage of the 12-pulse AC/DC converter can be controlled by using the IGBT. The 12-pulse phase control AC/DC converters with Delta-Star isolated transformer. In this configuration we are using two diode bridge rectifier, each bridge consist of 6-diodes,which are parallelly connected for high voltage, more current for our requirement.

The zero-sequence transformer shall meet the following basic requirements:

1 Neutral current carrying capacity shall be three times the phase conductor capacity.

2. The transformer shall be suitable for loads having a K-factor of up to 20.

3 The impedance to zero sequence currents shall be less than (1%) one percent.

4 Fundamental frequency impedance shall be less than 0.5%.

Twenty Four-Pulse Diode Bridge Rectifier fed VCIMD Load using Multi- winding Transformer Block Diagram

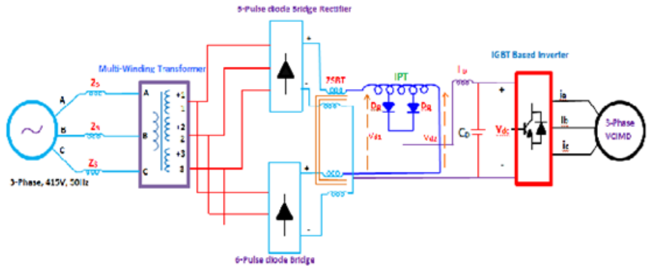

Fig.3: Twenty four-pulse diode bridge rectifier fed induction motor block diagram.

This technique is used for increasing the number of pulses resulting in harmonic reduction on both the AC as well as the DC side. Fig. 3 shows the proposed Multi-winding transformer based 24-pulse AC-DC converter fed VCIMD [7]. It inherently exhibits high impedance to zero sequence currents, resulting in 120° conduction for each diode of the bridges and also results in equal current sharing in the output. An inter-phase reactor tapped (IPT) suitably to achieve pulse doubling has been connected (Fig. 3) at the output of the ZSBT [8].

Design of the Inter-phase Transformer (IPT) for Pulse Doubling

A required condition to achieve the pulse doubling is to ensure that the instantaneous output voltages of the two converters, D_P and D_Q, are the same and displaced by an angle of 30°. It is already known that an IPT or inter-phase reactor (IPR) with suitable diode[8] taps can effectively double the pulses in 12-pulse converters where the two converters are fed from 30° phase–shifted voltages.

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IPT Circuit Diagram

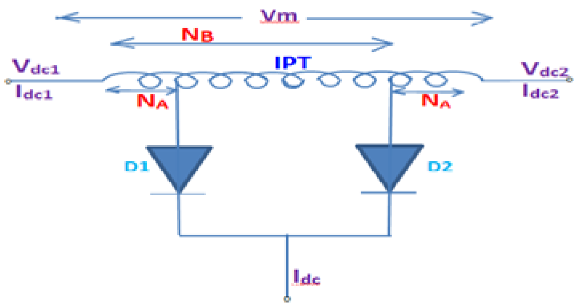

Fig.4: Inter-phased tapped Reactor block diagram.

B. OPERATION OF THE IPT:

Whenever the voltage V across the IPT goes positive (V_m>0) , Diode D1 is forward biased and is turned ON. D_q is reversed biased and is turned OFF (P- mode), therefore diode D1 carries Load current Idc.

$idc1.N_A = idc2.\ N_B$ (7)

Where N_A and N_B are the number of turns as shown for the IPT

Moreover,

$idc1+idc2 = idc$ (8)

From eqn. (7) and eqn. (8), output currents of the two diode converters I and II are given as:

$idc1 = (0.5-K_T)\ idc$ (9)

$idc2 = (0.5+K_T)\ idc$ (10)

Where $\mathbf{K_T = (N_B/\ N_{0)}}$ **and** N_0 is the total no. of turns $\mathbf{N_0 = N_A + N_B}$.

Similarly, for D2 conduction when voltage across the IPT Vm is negative, Diode D2 is forward biased and is turned ON and D1 is reversed biased and is OFF. Therefore, diode Dq carries Load current Idc (Q-mode).

Similarly, the MMF relationships can be written for the Case when diode D2 is conducting

$idc1 = (0.5 + K_T)\ idc$ (11)

$idc2 = (0.5 - K_T)\ idc$ (12)

Therefore, depending on the polarity of voltage Vm, the magnitudes of the rectifier output currents are modulated and this changes the shape of the rectifier input currents and, thereby, doubles the pulses [9].

The turn ratio of the interphase transformer for suppressing the 19th and 21st harmonics is given as: K_T = 0.2457.

- ❖ Using 6-Pulse Diode Rectifiers
- ❖ Using 12-Pulse or 24-Pulse Diode Rectifiers
- ❖ Using Phase Controlled Thyristor Rectifier
- ❖ Using IGBT Bridge
- ❖ Using larger DC or AC Inductor

II. SIMULATION, ANALYIS AND RESULTS:

Six-Pulse Converter Fed Vector Control Induction Motor Drive:

A three phase source is fed to the diode rectifier which converts the three phase AC supply into a fixed amount of DC supply. Here L-C is used to smoothen the waveform of output voltage and current waveform. This output is fed to the inverter and the inverter output is fed to the induction motor which is a vector control drive

Six-Pulse Converter Simulink Block Diagram

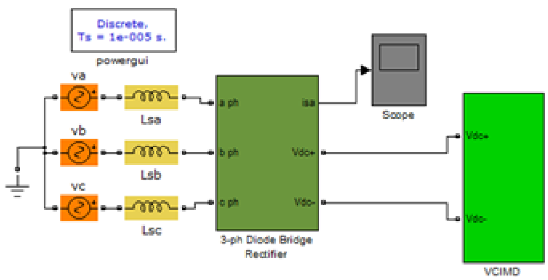

Fig 5: Six-Pulse Converter Simulink Block.

Twelve-Pulse Converter Simulink Block fed 3-phase 2-winding T/F

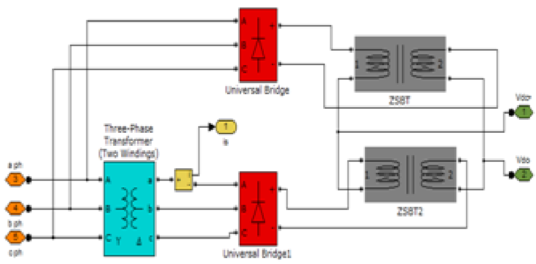

Figure 6: SIMULINK Block of 3-Phase 2-Winding T/F (Topology B)

Twelve-Pulse Converter fed VCIMD output Waveforms:

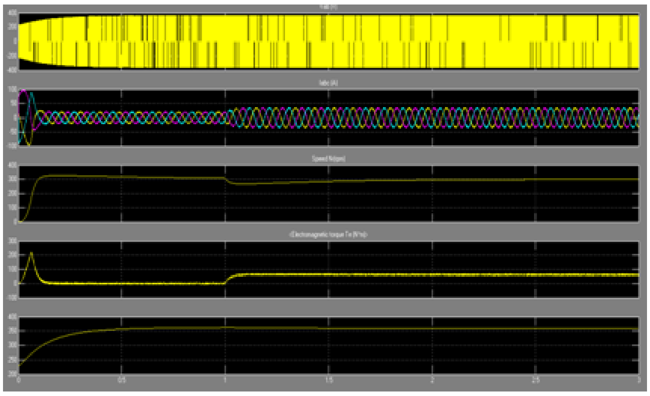

Figure 7: Simulink Waveform of (Topology B) V_s, N_s, I_{abc} T_e and V_{dc}

Twelve Pulse Converter Main Current Waveform

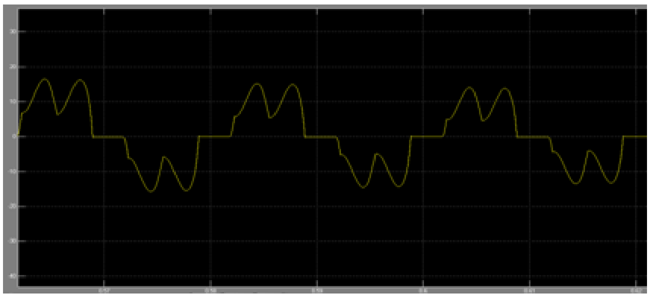

Fig 8: MATLAB/SIMULINK 12-pulse Supply Current Waveform

Twenty-Four Pulse Converter Multi-winding Transformer Simulink Block Diagram internal block

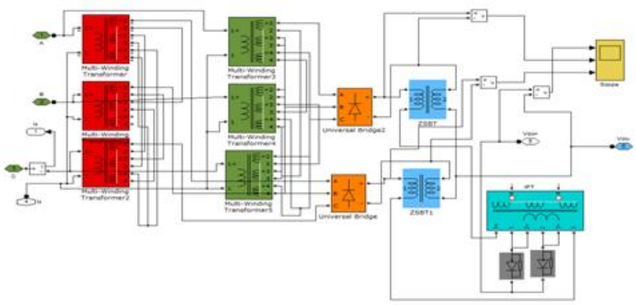

Figure 9: MATLAB/SIMULINK Block of Multi-Winding Transformer fed ZSBT and IPT

Twenty-Four Pulse Converters fed VCIMD Output Waveforms

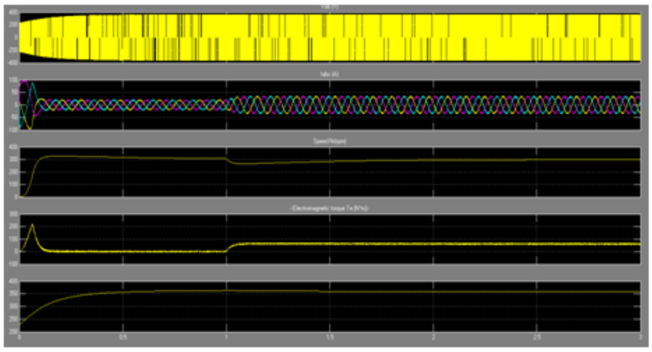

Figure 10: Simulink Waveform of (Topology C) V_s, N_s, I_{abc} T_e and $V_{dc.}$

Twenty- four Pulse Supply Current Waveform

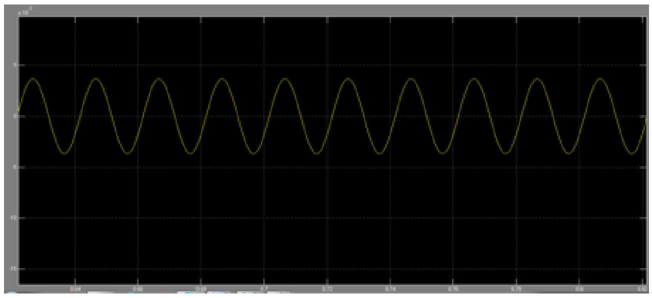

Figure 11: MATLAB/SIMULNK Supply Current Waveform

Table 1: THD values of input voltage and current at different Loads:

s.no	Topology	THD Vs (%)	Is		THD Is (%)		Vdc	
			FL	LL	FL	LL	FL	LL
1	A	6.94	42.6	10.22	31.1	68.7	550	582
2	B	4.04	32.66	8.54	11.82	15.66	566	598
3	C	3.37	3.166	4.5	4.64	8.6	562	577

III. CONCLUSION:

Based on the proposed design, simulation, and test results, it has been observed that power quality has been improved significantly by employing the proposed various transformers based 24-pulse AC-DC converter. The resulting 24-pulse converter has exhibited a high level of performance with clean power characteristics required for diode based front end rectifiers.

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Simulation and test results have shown that the total harmonic distortion of the input current remains below 8% while power factor remains above 0.99 at varying loads and meets the requirements of IEEE-519 Standards for power quality. The improvement in power quality indices has been observed to be significant in the 24-pulse AC-DC converter.

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