International Conference on Systems, Science, Control, Communication, Engineering and Technology 2016 [ICSSCCET 2016]

ISBN	978-81-929866-6-1		**VOL**	02
Website	icssccet.org		**eMail**	icssccet@asdf.res.in
Received	25 – February – 2016		**Accepted**	10 - March – 2016
Article ID	ICSSCCET042		**eAID**	ICSSCCET.2016.042

Direct Torque Control Based Induction Motor Drives with Improved Power Quality Converter

S Maheswari[1], M Logeswari[2], A Nandini[3], T Balasudha[4]
[1,2,3,4] Assistant Professor, Karpagam Institute of Technology

Abstract: *This paper proposes the performance of a Direct Torque Control (DTC)-based Induction Motor Drive (IMD) with improved power quality converter. An improved power quality converter known as Vienna rectifier is used in the system to mitigate the power quality problems. The Vienna rectifier is a three switch converter to improve the power quality in terms of reduced total harmonic distortion of ac mains current adjustable speed drives. The switches in the rectifier is less, switching losses are reduced and hence it is more efficient than the PWM rectifier and also it reduces the blocking voltage stress across the semiconductor to reduce the conduction losses and give low total harmonics distortion less than 50%. It is designed, modeled, simulated in MATLAB/SIMULINK platform.*

I. INTRODUCTION

In general, the three-phase induction motor is also known as an asynchronous motor. It is the most commonly used type of motor in industrial applications. There are two types of Induction motor, Squirrel cage Induction motor and Wound rotor Induction motor. Mechanical energy is more than often required at variable speeds, where the speed control system is not a trivial matter [1].

A. Direct Torque Control (DTC)

Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. It has the main features like it can control the flux and torque directly and control the stator currents and voltages indirectly. It can give approximately sinusoidal stator fluxes and stator currents and it can perform even at standstill conditions. The main advantages of DTC are absence of co-ordinate transforms absence of voltage modulator block, as well as other controllers such as Proportional Integrative

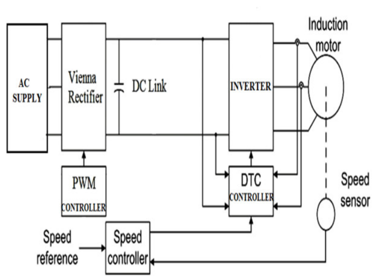

Figure. 1 Direct Torque Control

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B. Pulse Width Modulation (PWM)

The capability of forming sinusoidal currents is provided by the technique called Pulse-Width Modulation (PWM).This technique provides the series of width-modulated pulses to control power switches. Inverters employing PWM principle are called PWM inverters. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is modulated to obtain inverter output voltage control and to reduce its harmonic content. The advantages of PWM technique are the output voltage control can be obtained without any additional components, lower order harmonics can be eliminated or minimized along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimized. Many PWM techniques have been developed according to special requirements. Generally pulse-width modulation techniques may be classified as follows: Carrier-Based Sinusoidal PWM, Hysteresis-Band PWM, Space Vector PWM, Selected Harmonic Elimination PWM, Minimum Current Ripple PWM, Sinusoidal PWM with Instantaneous Current Control and Random PWM.

C. Vienna Rectifier

Vienna Rectifier is a Carrier-Based Sinusoidal PWM, where it is a three phase, three levels, three switch rectifiers and it is a unidirectional converter. The applications of Vienna Rectifier are Telecommunication power supplies, UPS, input stages of AC drive converter systems.

In this paper, a DTC based IMD is combined with Vienna rectifier to reduce the Total Harmonic Distortion.

II. System Description

D. DTC Controller

The way to impose the required stator flux is by means of choosing the most suitable Voltage Source Inverter state. If the Ohmic drops are neglected for simplicity, then the stator voltage impresses directly the stator flux in accordance with the following equations,

$$\frac{d\psi_s}{dt} = V_s \tag{1}$$

Decoupled control of the stator flux modulus and torque is achieved by acting on the radial and tangential components respectively of the stator flux-linkage space vector in its locus. Figure 4 shows a six step voltage source inverter. The inductor L is inserted to limit shot through fault current. A large electrolytic capacitor C is inserted to stiffen the DC link voltage.

E. Modules of Vienna Rectifier

The air cooled Vienna Rectifier is shown in Fig 5.Vienna Rectifier power modules are available in DCB (Direct Copper Bonding) ceramic base plate. Their uses are:

1. These modules have isolation voltage of 3600 Volts AC, ensuring personal and equipment safety and are U/L recognized. There is no need for external isolation.
2. Kelvin source for reliable driver connections for the MOSFET.

III. Vienna Rectifier for DTC Based IM Drive

An improved power quality converter namely Vienna rectifier is used for eliminating ac mains current harmonics at the front end of the DTC-based three-phase IMD. Each leg of the Vienna rectifier consists of a bi-directional switch which is realized by connecting an MOSFET (metal–oxide–semi-conductor field-effect transistor) across the dc terminals of a DBR and two free-wheeling diodes. It provides sinusoidal input currents and controlled dc-voltage if appropriately controlled. The energy cannot be fed back to the ac mains by using this converter. So, where the drive applications do not require regeneration, Vienna rectifier seems to be a suitable solution for improving the power quality with Total Harmonic Distortion (THD) operation at the ac mains.

IV. Simulation and Results of Vienna Rectifier with DTC Drive

F. Existing System

In this system, the uncontrolled bridge rectifier is connected to ac main to convert AC to DC. While converting AC to DC there occurs non-sinusoidal current and injection of harmonic currrents takes place in the system. Hence the THD value is increased and power quality problem occurs.

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The disadvantages of Existing system are,

- Equipment overheating because of harmonics current absorption.
- Interference in telephone and communication lines and decreased rectifier efficiency.

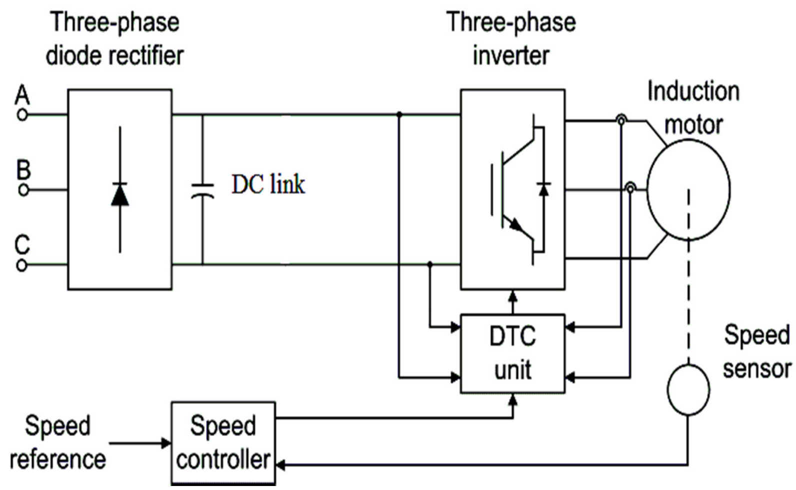

Figure2. Block Diagram of Existing System.

G. Proposed System

In this system, the Vienna rectifier is connected instead of uncontrolled bridge rectifier to ac main to convert AC to DC. While converting AC to DC there occurs sinusoidal current and injection of harmonic currrentsis less in the system. Hence the THD value is decreased and power quality problem is minimised.

The advantages of proposed system are,

- Improved power Quality.
- Switches in Vienna rectifier is less, switching losses are reduced and hence it is more efficient than the PWM rectifier and the size of the heat sink reduces.

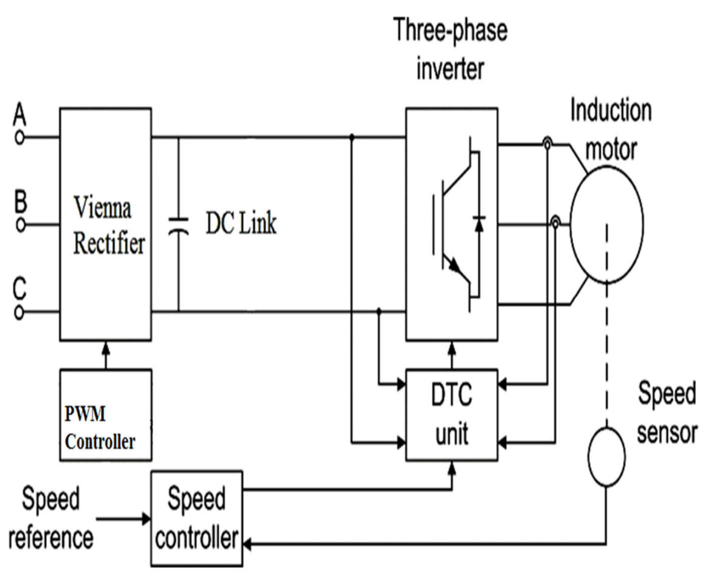

Figure.3 Block Diagram of Proposed System.

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V. Comparison with Existing System

Table III Performance evaluation

Type	Source Side THD Analysis		Load Side THD Analysis
	Voltage	Current	Induction Motor Current
Induction Motor	216.71%	45.42%	45.42%
Vienna rectifier fed Induction Motor	66.82%	29.54%	45.42%

From the performance evaluation table the Vienna rectifier fed induction motor drive gives the minimum THD value compared to the existing system in the source side.

VI. Conclusions

The power quality problems in a conventional un-controlled six-pulse DBR-fed DTC-based IMD have been mitigated using a three-phase Vienna rectifier in this paper. Thus completed the design of DTC based IMD with the power quality converter and reduced THD value which is compared with source and load side.It has been shown that by employing an improved power quality converter known as Vienna rectifier, sinusoidal input currents have been achieved with THD. This improved power quality converter has used only three active switches for a DTC-based IMD for improving the power quality at the utility interface. The performance of the proposed system has been analyzed for distorted ac mains voltages, load torque and speed. The proposed system, i.e. Vienna rectifier-fed DTC-based IMD has been validated by implementing a MATLAB simulation

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