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A review & analysis of harmonics in Variable Frequency Drives (VFDs)

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Abstract: In this manuscript, the author has tried to analyze a study of Variable Frequency Drives. Variable frequency drives are energy saving drives. But they generate harmonics generates. Harmonics introduced by any means affect the performance parameters of any system The presence of harmonics is the system for a long duration & that, too, of higher order affect the various parameters in a Power distribution system. Harmonics change the shapes of current & voltage waveform there by affecting the overall power quality. In this work, it is concluded that Variable Frequency Drives introduce harmonics that affect the current signal waveform and increase Total Harmonics Distortion (THD). The results showed that by placing a three phase harmonic filter in the circuit where VFD is used for speed control of motor the THD is reduced considerably. This method of eliminating harmonics is a very cost effective and robust. It is also applicable in industries where VFDs are used for motor speed control especially higher rating motors.

Keywords: energy, frequency, drives, harmonics, motors.

Introduction

For any country, high energy consumption is one of the major inputs for its economic development. In the case of developing countries, energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them. A technological solution to improve energy efficiency not only decreases the burden on environment but also resulting cost savings. In recent years, Power demand in India has grown by approximately 9% per year. To achieve energy savings new energy efficient equipment need to be developed, but there also lays a great potential to accomplish energy savings in older existing processes. Use of Variable Frequency Drives (VFDs) is the one of best energy saving measures while controlling speed of motor. It reduces thermal and mechanical stresses on motors. AC induction motors combined with pulse width modulated (PWM) VFDs are just beginning to realize their potential.

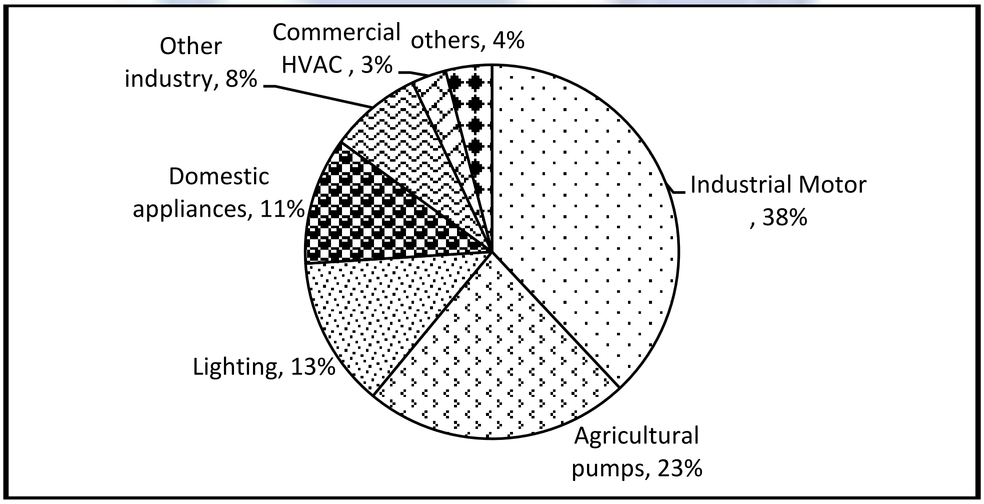

Figure: 1: Distributionof Electricity End Use –All Sectors

Related Work

Steaven L. Mecker examined the effect of VFDs on the Induction Motor and recommends suitable approaches to ensure reliable system designs. Discuss the Speed-Torque-Current characteristic of motor using VFDs and also its operational features of using Pulse width modulation (PWM). The author stresses before applying PWM technology its effect on motor's insulation and cooling system must be considered. The paper furthers explain current and voltage waveform of VFDs.

Bimal K. Bose gave a brief review of variable frequency drives technology and some drive applications. In the VFD, the static as well as dynamic performances are important, because the machine is usually placed within a feedback loop. One problem in VFD is that the machine's electrical and mechanical parameters vary with operating conditions. As a result the high performance control systems and the controller parameters require tuning with the machine parameter. VFDsare widely used in transportation, residential, commercial, industrial and military environments. Some more applicationsmentioned in the papers are pump and fan drives,electrical vehicle drive, wind energy system, position servo drive and rolling mill drive.

B. Jayant Baliga provided an overview of semiconductor devices for Variable Frequency Drive applications. The development of power semiconductor devices with the MOS-gate structures has enabled the control of large amount of energy with very little input power. Now a day the power semiconductor chips are made from silicon. The devices fabricated from silicon carbide have the potential for completely displacing silicon devices. IGBT are widely used for the motor control application. Before IGBT the speed control drives used wereThyristor.

Peter W. Hammond, In this paper, medium Voltage Variable Frequency drives (VVFDs) introduced a new approach to enhance Power Quality. From this new approachpower quality improves up to 94%at full load and is above 90% at 10% load. Motor voltage and current waveforms are improved & torque pulsations are reduced. Peak voltage stress on motor insulation does not exceed peak input line voltage, and no zero sequence voltage is imposed. Drive efficiency exceeds 96%. There are some drawbacksto these current-source drives. These drives provide harmonic currents into the supply line and operate at a reducedpower factor at lower speeds. Low-order harmonics atthe drive output may excite torsional resonances.

Swamy et al. In this paper, a new topology to soft charge the dc bus capacitor is proposed also other techniques that have been evaluated are introduced. Experimental tests, soft-charge circuit configuration with Magnetic Contactor (MC),thyristor, and thyristor based rectifier showed the feasibility of the proposed idea is provided.

Dr. Hanna and Mr. Randall, The paper shows that recent advancements in the VFD technology and flux vector control have made it practical technically and economically to replace ECC with more efficient and reliable medium voltage VFD for extruder application.

Irvine and Gibson, Author explained the proper selection guidelines of VFDs for use with the centrifugal pump, to provide pressure, temperature and flow control. In this paper application examples of VFDs used as the final control element in both the upstream and downstream sectors of the petroleum industry. The use of Variable Frequency Drives (or Adjustable Frequency Drives) on electric motors driving centrifugal pumps can offer many advantages over using control valves when you need to control the fluid flow. Some of the advantages include energy savings, efficiency, power factor, installation, specification, ability to control, maintenance, fugitive emissions, reduced wear on the bearings and seals of the pumps. One of the main incentives for using variable speed drives is the energy saving one get from their implementation. This is due to the pump affinity laws that govern a centrifugal pump (or fan) operation. These laws can be summarized as follows:

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \quad \text{..... (1)}$$

$$\frac{H_1}{H_2} = \frac{(N_1)^2}{(N_2)^2} \quad \text{..... (2)}$$

$$\frac{P_1}{P_2} = \frac{(N_1)^3}{(N_2)^3} \quad \text{..... (3)}$$

Where:

Q: Pump discharge flow-rate (m^3/s)

H: Pump discharge head (m or ft)

P: Pump shaft input power (kW)

N: Rotational speed of the pump (RPM)

Experimental Work

The analysis is carried out on a 3-phase squirrel cage induction motor. The specifications of the machine are given Table 3.1. The simulation work is done using space vector PWM in Simulink tool box within MATLAB -10.

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The experimental work is divided into five main parts

(i) Drive run without Variable frequency controller

(ii) Drive run with Variable Frequency Controller (VFD)

(iii) Design of harmonics filter in Simulink

(iv) Drive run using VF Controller and with filter

(v) Effects on current harmonics (I_{THD})

VFD schematic diagram shown below is built from six main blocks. The induction motor, the three phase inverter and the three-phase diode rectifier models. In this work the space vector PWM Induction motor drive used is as shown in fig. 2.

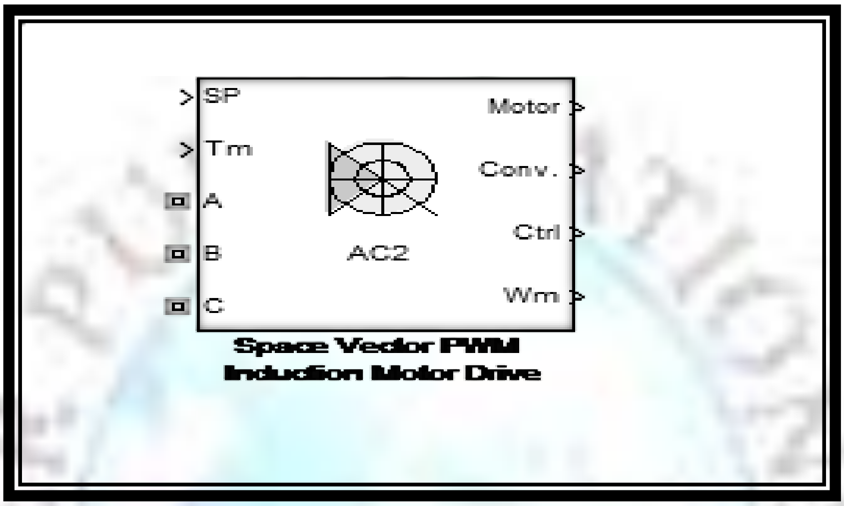

Figure: 2 AC Motor Drive

Where:

SP: Speed and torque Set Point
T_m: Mechanical input - load Torque
A,B,C: 3- phase terminal of the motor drive
Motor: Motor measurement output
Conv.: 3-phase converters measurement vector.
Ctrl: control measurement vector
W_m: mechanical output - motor speed

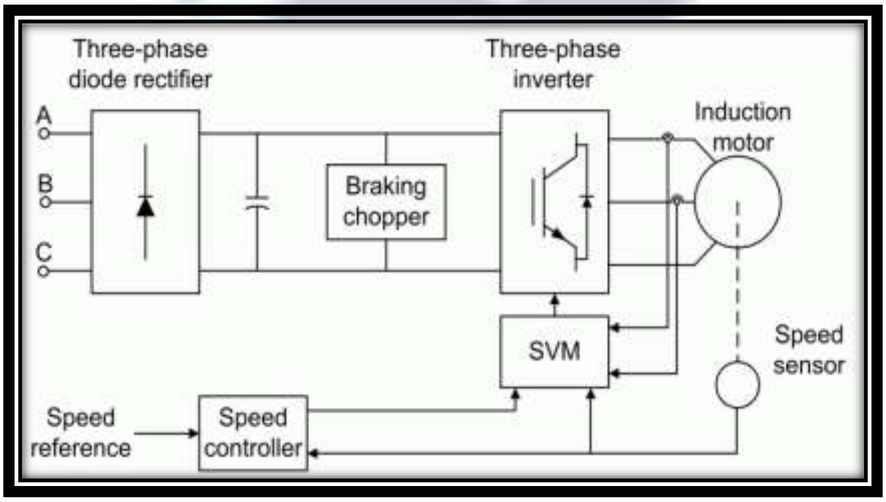

Figure: 3 Schematic diagram of Variable Frequency Drive

The computer simulation employed in thisstudy is MATLAB/Simulink tool box.

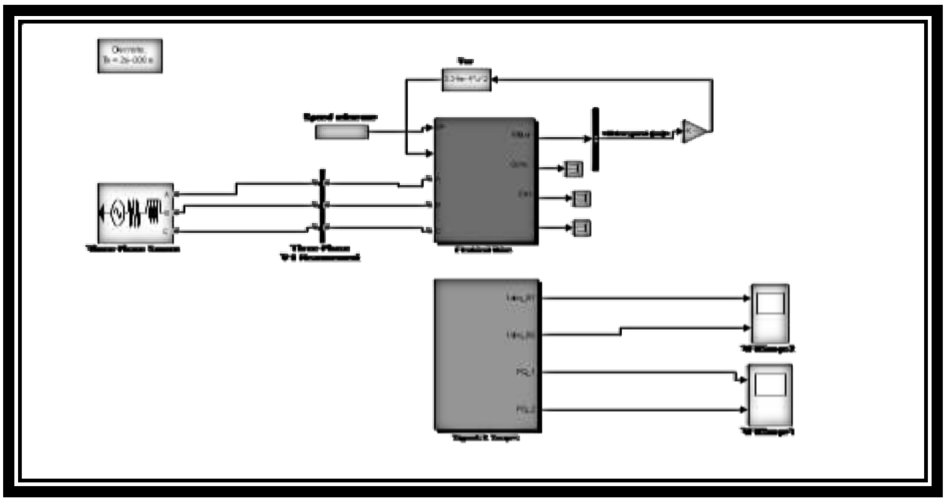

Figure: 4 Drive run with Variable Frequency Controller

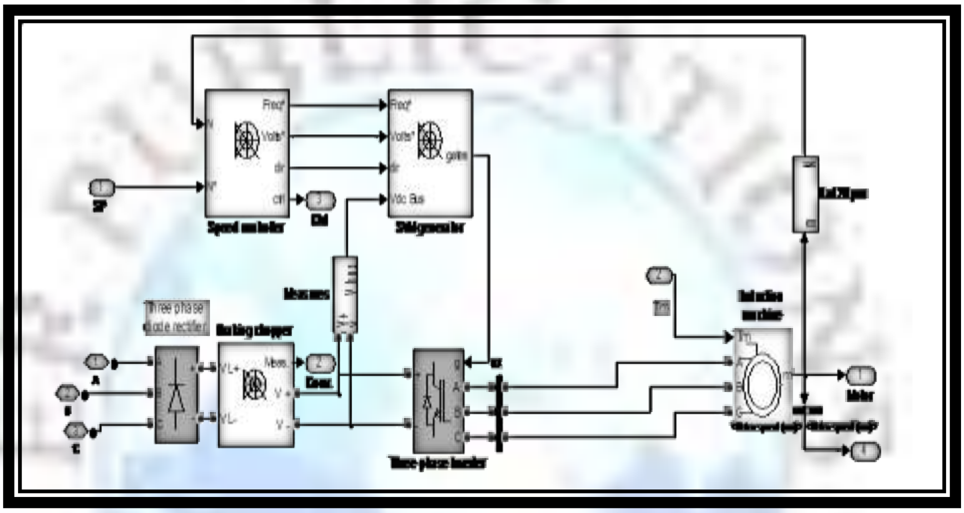

Figure: 5 Circuit of VF Controller

Conclusion

The analysis of harmonics and the comparison of result in the simulation work concluded that mere presence of higher frequencies is the cause of higher current THD (ITHD).Total harmonics distortion (THD) present in the VFD in this simulation work is 29.83%. It can be reduced to 27.81% with the use of harmonic filter circuit. AC lines and DC links though may improve the performance of drives by reducing input harmonics and partially improve the power factor, but the objective can be achieved by identifying and distinguishing the order of the harmonics present in the Power system. This data can then be used for the design of harmonic filter for each harmonic order that contributes a major part in the sample. This thesis work describes the methodology to simulate induction motor (squirrel cage) using the Simulink tool box with in MATLAB. The results of the simulation work for a given set of induction motor parameter are presented that gives very cost effective robust filter design applicable to the frequency control drives. The work is also helpful to check the injection of harmonics back into the system, that deteriorates the quality of power. This work also concluded that the line losses which are the function of active power, reactive power and power factor supplying such loads can also be reduced in the similar proportion. The overall burden on the substation can thus be reduced up to 6.5%.

Future Scope

This work can be further extended by incorporating other filter design parameters and transient analysis of harmonic filter to determine proper rating of filter components. It is suggested that improvement in the results can be achieved by increasing the sampling rate of the harmonics sample. The analysis can be used as the driving force for the enhancement of the performance of the VFDs that will be enable to save sufficient energy and it will lead to the creation of smart energy saver, that could be commercially viable. The present work may also be applied to other types of motors and control drives. The work can be extended to check and resolve the problem of detuning of filters from device to device.

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