International Journal of Scientific and Technical Advancements
ISSN: 2454-1532

Effect of Harmonics on Performance Characteristics of Three Phase Induction Motor

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***Abstract*—**Harmonic Distortion in power system increasing everyday due to increase in the use of nonlinear loads such as wave rectifiers and other solid state controlled devices. Some of the sources of harmonic currents in household appliances include the electronic components we use like computers, printers, telecom equipment, micro ovens, UPS systems and other electronic loads will increase the flow of harmonic currents. In industries use of variable frequency drives and other power electronic equipment's such as rectifiers, inverters enhance the flow of harmonic current. This paper present modeling and simulation of effect of harmonic on three phase induction motor. Since induction motors are the main operating electrical machine in our industrial system. The effect of harmonic are studied on parameters like rotor speed, electromagnetic torque, rotor current and stator torque. The results are compared with the system having less or zero harmonics. The whole system is employed by using MATLAB/SIMULINK software.

***Keywords*—** Induction motor, Harmonic distortion, Variable frequency drives.

I. Introduction

The subject of power quality has been given increased attention over the past decade. Broadly de-fined, power quality refers to the degree to which volt-ages and currents in a system represent sinusoidal waveforms. Harmonics have become a serious concern for electrical engineers following the wide use of electronic appliances. The quality of electrical power in commercial and industrial installation is undeniably decreasing [1], [7]. In addition to external disturbances, such as outages, sags and spikes due to switching and atmospheric phenomena, there are inherent internal causes specific to system that result from the combined use of linear and non-linear loads. Solid examples of degradation are:

- Untimely tripping of protection devices
- Harmonic overloads
- Voltage and current distortion
- Temperature rise in conductors and generators
- Reliability of low-voltage AC systems

With the increasing use of solid-state circuit equipment, harmonic distortion in supply systems becomes more frequent and severe due to non-linear characteristics of such circuits. Well known non-linear devices include converters, inverters, electronic-ballast, and lifts and especially computer equipment. These volt-age or current distortions may cause unsafe and unreliable electrical power supplies, malfunction of equipment, overheating of conductors and can reduce the efficiency, and life of most connected loads. Therefore, harmonic distortion is an undesirable effect for electrical systems

Nowadays non-linear and fluctuating loads, such as a diode/thyristor rectifiers, semi converters, arc furnaces, adjustable-speed drives, ac voltage regulators, etc., are widely used in industrial and commercial applications. These non-linear loads create harmonic and distortion current in electrical networks and have dis-advantages such as: reducing electric power quality, increasing the losses of the distribution system and changing in power quality [3]. On the other hand this electric power delivered under conditions of unbalanced and non-sinusoidal source voltage system

II. Technical View of Harmonics

Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency. If the fundamental power frequency is 50 Hz, then the 2nd harmonic is 100 Hz, the 3rd is 150 Hz, etc. [2].When harmonic frequencies are prevalent, electrical power panels and transformers become mechanically resonant to the magnetic fields generated by higher frequency harmonics. When this happens, the power panel or transformer vibrates and emits a buzzing sound for the different harmonic frequencies. Harmonic frequencies from the 3rd to the 25th are the most common range of frequencies measured in electrical distribution systems.

All periodic waves can be generated with sine waves of various frequencies. The Fourier theorem breaks down a periodic wave into its component frequencies.

The total harmonic distortion (THD) of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental [5]. It provides an indication of the degree to which a voltage or current signal is distorted as in figure:

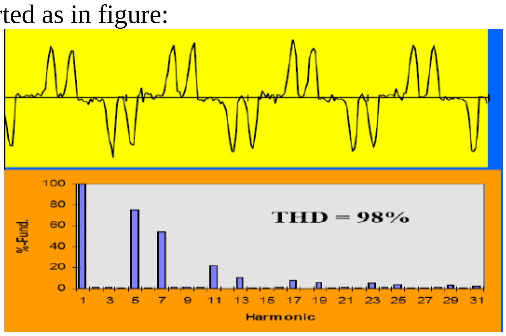


Fig: Total harmonic distortion.

Ankush Raina and Anshu Khosla, "Effect of harmonics on performance characteristics of three phase induction motor," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 4, pp. 221-226, 2016.

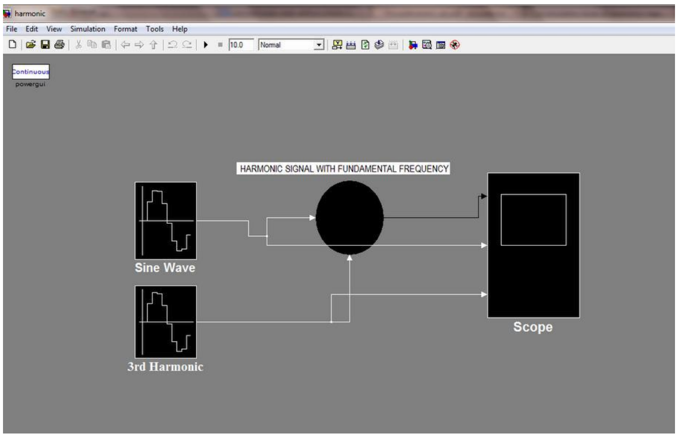
THD vs. TDD
THD (I) = Total Harmonic Current Distortion
Measured distortion on actual instantaneous current flowing–“Sine wave Quality Factor”
• Lower the % THD, the closer the current waveform is to a true sine wave
TDD (I) = Total Current Demand Distortion
Calculated harmonic current distortion against the full load (demand) level of the electrical system. The greater the amount of Linear load, the less of an issue the current distortion becomes

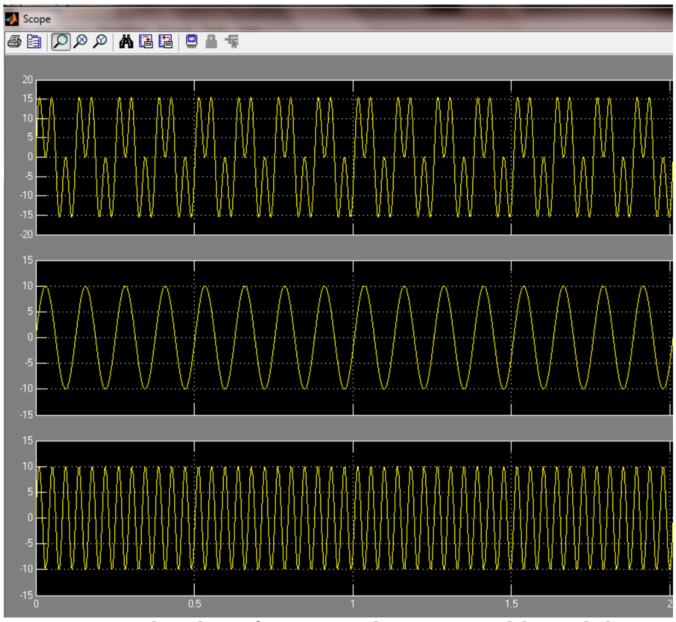
$$TDD = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_L} \times 100\%$$

If non-linear loads are a small % of the full system current demand, the TDD is less [1].

SIMULINK is a simulation program used to virtually observe a circuit under working conditions. Power System Toolbox is a collection of tools related to power systems used to generate different kinds of power circuits for simulating in SIMULINK. There are a number of toolboxes available for different applications in MATLAB.

For example there are two block sources, one is sine wave with fundamental frequency and other is 3rd harmonics which are introduce in pure sine wave and their result is shown in oscilloscope.
a) The top wave shows the output wave form which is the sum of both fundamental and harmonic wave forms.
b) The middle wave form shows the input pure sine fundamental frequency 50 Hz.
c) The bottom wave form shows the input 3rd harmonic signal.





Design and Analysis of Harmonic Filters using Mat lab Simulink

III. Proposed System And Simulation Results

MATLAB is the solution for all these problems. It has a high level language compiler very close to natural writing techniques. It has a vast collection of well designed functions and tools to aid in all kinds of applications. It supports Object Oriented Programming (OOP) thus same functions can be used again and again. It has support for drawing all kinds of 2-dimentional and 3- dimensional graphs as well as charts and function mapping techniques [4]. It has a Graphical User Interface Development Environment (GUIDE) which can be used to make input of data and output of results easier to understand and comprehend for a novice user.

MATLAB application software is developed by MathWorks Inc. It rightfully claims to be the ‘Language of Technical Computing. It can be used for extensive graphical and technical facilities and functions available for all kinds of computation and calculations involving simple everyday procedures to complex higher order mathematical applications.

Powergui
The Powergui block allows you to choose one of the following methods to solve your circuit:

- Continuous, which uses a variable step solver from Simulink
- Ideal Switching continuous
- Discretization of the electrical system for a solution at fixed time steps
- Phasor solution.

The Powergui block is necessary for simulation of any Simulink model containing Sim Power Systems blocks. It is used to store the equivalent Simulink cir-cuit that represents the state-space equations of the model.
When using this block in a model, you must follow these rules:

International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

- Place the Powergui block at the top level of di-agram for optimal performance. You can place it anywhere inside subsystems for your con-venience; its functionality will not be affected.
- You can have a maximum of one Powergui block per model.
- You must name the block Powergui.

Three-Phase Programmable Voltage Source

Use this block to generate a three-phase sinusoidal voltage with time-varying parameters. You can pro-gram the time variation for the amplitude, phase, or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal. This block implements a three-phase zero-impedance voltage source. The common node (neutral) of the three sources is accessible via input 1 (N) of the block. Time variation for the amplitude, phase and frequency of the fundamental can be pre-programmed. In addition, two harmonics can be super-imposed on the fundamental.

Three-phase asynchronous machine

Implements a three-phase asynchronous machine (wound rotor, squirrel cage or double squirrel cage) modeled in a selectable dq reference frame (rotor, stator, or synchronous). Stator and rotor windings are connected in wye to an internal neutral point.

The Asynchronous Machine block implements a three-phase asynchronous machine (wound rotor, single squirrel-cage, or double squirrel-cage). It operates in either generator or motor mode. The mode of operation is dictated by the sign of the mechanical torque:

- If Tm is positive, the machine acts as a motor.
- If Tm is negative, the machine acts as a generator.

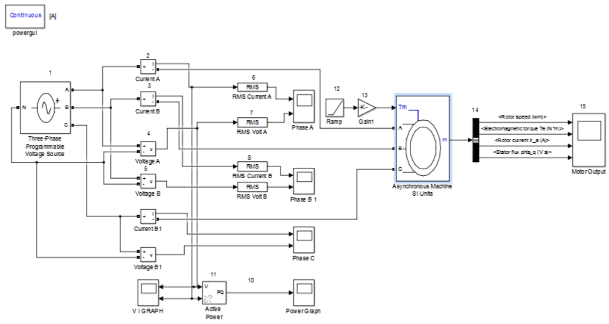
The electrical part of the machine is represented by a fourth-order (or sixth-order for the double squirrel-cage machine) state-space model, and the mechanical part by a second-order system. All electrical variables and parameters are referred to the stator, indicated by the prime signs in the following machine equations. All stator and rotor quantities are in the arbitrary two-axis reference frame (dq frame).

IV. Simulation Results

To study the effect of harmonic as it not only distort the sine wave shape but it also result in the decrease in the efficiency of the machines or electrical appliances. The harmonic result in the insulation damage by heat-ing and voltage stresses. So make a different models which help us in the study the effect of harmonic separately system with given parameters has selected.

System parameters

Induction motor	5.4 Hp, 400V, 50Hz,1430 rpm
Rotor type	Squirrel cage
Stator Resistance	1.395 Ω
Stator Inductance	0.005839 H
Supply Voltage	400V (Vrms ph-ph),50 Hz
Mutual Inductance	0.1722H



Block 1 is the Three-Phase Programmable Voltage Source.

The main function of this block is to provide three phase input to the Asynchronous motor in our circuit. The main advantage is that it can be programmed ac-cording to our requirements of the order, amplitude, and frequency for fundamental input supply and same for the harmonics.

Block 2, 3, 4 and 5 are Current meter and Voltmeter Blocks.

There are used to measure the line current and the line voltage in the circuit coming from Block 1 as the input to three phase synchronous motor.

Block 6, 7, 8 and 9 are RMS Blocks.

Its main function to track the RMS value in a sequence of inputs over a period of time. The Running RMS parameter selects between basic operation and running operation. The value of this block is fed to their respective phase scope so that we can study the variation in the waveform of different phase currents and volt-ages.

Block 10 and 11 are RMS power and Active power Block

It has almost similar operation as above with the difference that here RMS power is shown in waveform with the help of scope as it is measured by active power block.

Block 12 and 13 are Ramp Block and Gain Block.

The Ramp block generates a signal that starts at a specified time and value and changes by a specified rate. Here it is used to provide the ramp signal as starting torque to the three phase induction motor with the Gain block multiplies the input by a constant value (gain) to increase the torque signal.

The three phase input supply phase A, phase B and phase C are fed to their respective input terminal of the three phase asynchronous motor. And with the help of ramp signal the motor start working.

Block 14 is the Bus Selector.

The Bus Selector block outputs a specified subset of the elements of the bus at its input. The block can out-put the specified elements as separate signals or as a new bus. From the various parameter we separate four main parameters to analyze further.

Block 15 is the Motor output Block.

The four parameter we analyze is fed from block 14 to this block to get the various wave shapes so that various variation in motor characteristics are studied, analyzed so that a conclusion is made from various graphs.

The various performance characteristics of the three phase synchronous motor is shown.

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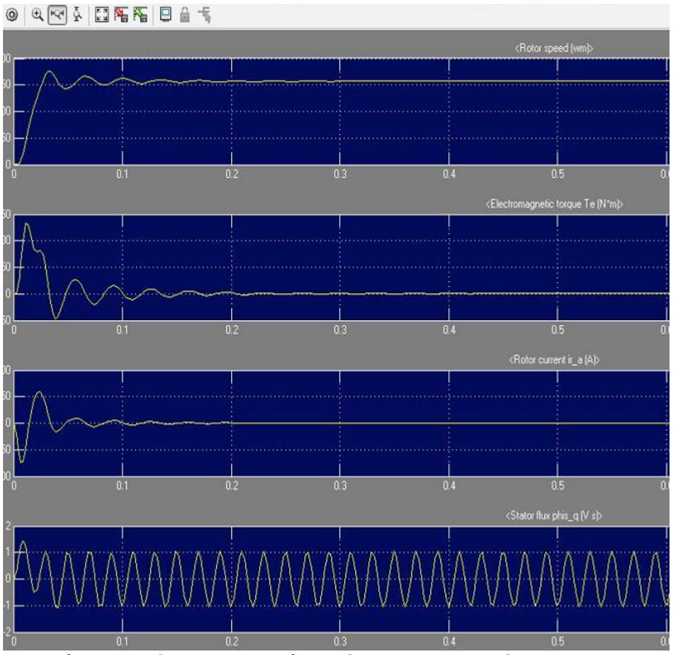
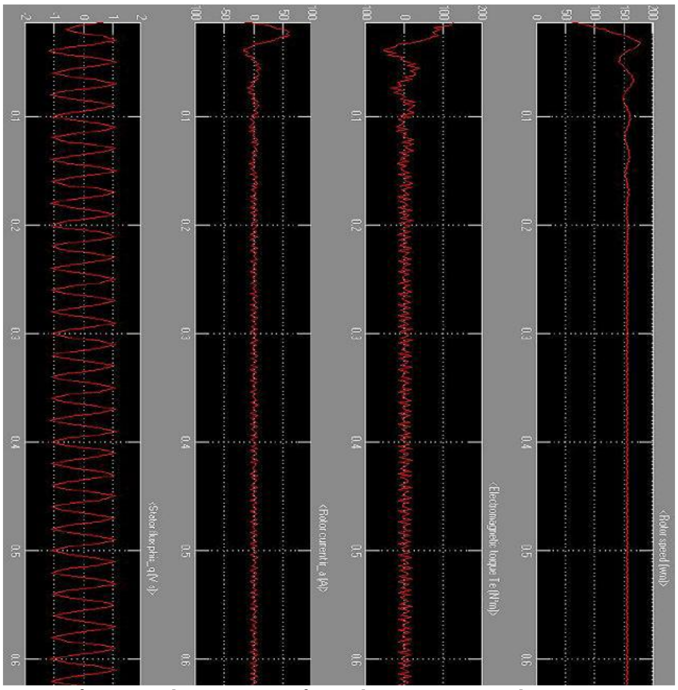
Fig 1. Shows the characteristics of the motor without introduction of the harmonics. i.e these are the characteristics on the bases of pure sine wave input.

Fig 2.Shows the characteristics of the motor with introduction of the harmonics. i.e. these are the characteristics on the bases of pure sine wave along with harmonics added in it. So these characteristics are due to distorted signal input.



Performance characteristics of asynchronous motor without Harmonics



Performance characteristics of asynchronous motor with Harmonics

V. Comparison of the Various Performance Curves of Three Phase Asynchronous Motor

Curve 1 is rotor speed.

Curve 1 show that, the motor speed start increasing from zero to its maximum value and that slowly gets almost constant taking load setting constant.

As by comparing both the curves we conclude that with the introduction of the harmonic results in de-creases of motor speed along with vibration. However fig 1 shows that the rotor speed increases and that get constant in very smooth constant periodic formation however fig 2. Shows a lot of vibration in the rotor speed which result in heating effect and the mechanical parts like bearing are much effected and thus effect the performance of the motor.

Curve 2 is Electromagnetic torque.

Electromagnetic torque shows a different pattern when comparing feeding the three-phase induction motor through a sinusoidal source and through a distorted source. Fundamental frequency of the induction motor produces forward operating torque. However it is ob-served that harmonics frequency will generate torque in both forward and in reverse direction. For example 5th 7th and 11th harmonics produce torques in reverse direction and on the other hand 7th, 13th and 19th har-monics components produces torque in forward direc-tion.5th harmonic components will have higher magni-tude compared to 7th harmonics as we are using it in this project. Hence harmonics torque will reduce the operating torque of the machine.

Curve 3 is rotor current.

It is also an important factor to decide the performance of the motor. Since due to the harmonic the rotor speed come under a lot if vibration. Thus there is a lot of variation in the current of the rotor. Since change in the speed in the rotor results in the variation in the load and thus with its variation slip of the motor changes and thus changes in the rotor current. In other words the rotor current wave shape is smooth in fig 1. Shows smooth operation of motor and wave shape of fig 2. Shows a lot of variation which results that large number of core losses. Core loss in any machine constitutes both hysteresis loss and eddy current loss. Hysteresis loss of the induction machine is proportional to the applied frequency and eddy current loss is proportional to the frequency squared. Frequency of the harmonics will be in the order of the multiples of the fundamental frequency. Therefore core loss is ma-jor concern at higher frequencies due to harmonics. Also harmonic currents and voltages reduce the over-all efficiency of the machine.

Curve 4 is stator flux.

This performance curve shows almost similar wave shapes with very little variation. This is mainly due to the fact that the load is in direct contact with the rotor. So rotor is mainly effected with load required torque, speed and vibration in load. However stator flux is as much important as rotor flux but since it has to pro-vide a field according to number poles which are fixed already without any relation with variation of load. Thus these are almost same wave curves.

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VI. CONCLUSION

In this paper effect of harmonics on performance charcteristics of induction motor is analyzed. It has been seen that the purposed system is suited for under-standing the effect of harmonic on the major load of our power system. It also helps to understand the need of development in new technologies keeping the power quality of the system at higher priority as any type of distortion results in losses in our system and in overall system these small losses when combined result in dip in power system efficiency.

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