5th International Conference on Control Engineering&Information Technology (CEIT-2017)
Proceeding of Engineering and Technology –PET
Vol.33 pp.58-60
5th International Conference on Control Engineering & Information Technology (CEIT2017) , 17-19 December,2017, Sousse , Tunisia

Effects of Harmonics on Motors in Electrical Networks

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***Abstract* – The main function of an electrical motor is to produce a sinusoidal voltage and current waveforms that have stable amplitude and frequency. Practically this is very hard to attain and over all parts of the electrical network, because these motors generate unclean voltage and current waveforms due to the rotating nature of these motors as well as the non linearity of loads within electrical power system, especially industrial systems, which distorts the shape of the voltage and current waveforms.**

In this paper a simulation is done on such motor using Matlab Simulink in order to study and analyze the generated harmonics so to calculate the total harmonic distortion (THD). The obtained results show that generated harmonics has an effect on the produced voltage and current waveforms and the amount of THD could reach as high as 47% which reduces the motor efficiency by 10%.

***Keywords*—motor, harmonic, THD, voltage, current, waveform, loads.**

I. Introduction

In the past it was normal to use electrical supplies to drive asynchronous motors for industry, lighting, heating and other similar applications that draws sinusoidal current and does not affect the shape of the voltage waveform and this is known as linear loads. Also electrical supplies are used to feed non linear loads that affects the shape of the voltage waveform since it draws non sinusoidal current from the network and hence it causes distortion to the voltage waveform.

Lately nearly all load are non linear and hence distortion became a serious problem especially to the sensitive equipment that depends in their operations on electrical current as well as causing equipment overheating. This distortion is in the form of sinusoidal wave forms which imposed on the fundamental wave form and these waveforms are a multiple of the fundamental which are known as harmonics [1].

According to the Fourier theorem, any periodic function with period T generally continuous and limited may be represented by a series of infinite sinusoidal terms with a frequency equal to integer multiples of the frequency of the original function.

The harmonic with the frequency corresponding to the period of the original waveform is called fundamental harmonic and the harmonic with frequency equal to "n" times the fundamental one is called *harmonic of order "n"*.

Based on the Fourier theorem, a perfectly sinusoidal waveform does not present harmonics of different order from the fundamental one. Therefore the presence of harmonics in an electrical system is an indicator of the distortion of the voltage or current waveform and this implies such a distribution of the electric power that malfunctioning of the equipment may be caused.

The presence of harmonics in the electrical network may be the cause of malfunctioning of the equipment, such as in the case of overloading of the neutral conductor, of increase of losses in the transformers, of disturbances in the torque of motors, etc. In particular, harmonics are the phenomenon which most heavily affect power factor correction capacitors.[2] .

Many research in the literature concerning the effect of harmonics on different type of electrical motors. In [3] the authors studied the effect of harmonics on the performance of three phase induction motor and found out that the speed decreases when harmonics are introduced, the motor torque is also affected by harmonics, since these harmonics generate in forward and reverse directions and the rotor current get distorted by harmonics due to variation in speed.

The advantage of replacing the induction motors (IM) by permanent magnet synchronous motors (PM) was studied in [4], where the author found that the PM has a better efficiency because of its lower stator resistance and because of rotor high resistance and low skin effect the harmonics losses were minimized.

In this paper, the effect of harmonics on the performance of the asynchronous motors is analyzed by the means of simulation using Matlab Simulink, where the THD was estimated.

II. Harmonics

Harmonics in electrical power systems are sine waves imposed on top of the fundamental voltage or current wave and its frequency is a multiple of the fundamental frequency and causes distortion to either voltage or current waves or both. These distorted waves can be analyzed by Fourier series to the sum of an infint number

ISSN 2356-5608

of sine waves that have the multiple of the fundamental frequency of 50/60 Hz. Fig (1) shows the fundamental waveform and the third, fifth and seventh harmonics, where it can be noted that the harmonics amplitude is a lot less than the fundamentals.

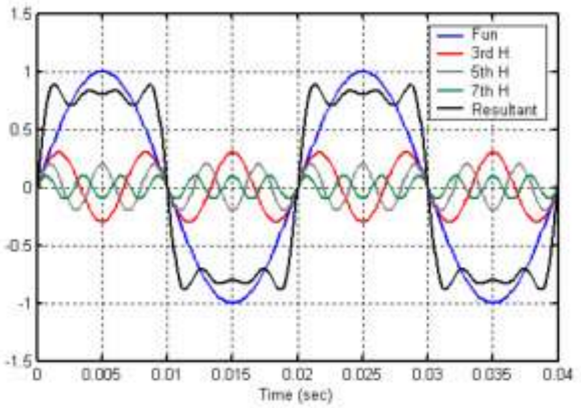

Fig (1) the Fundamental waveform and harmonics

Harmonics are divided according to their frequency to three types: even harmonics, where their frequency is an even multiple of the fundamental, odd harmonics, where their frequency is an odd multiple of the fundamental and inter harmonic, where their frequency is a fractional number of the fundamental. the odd harmonics have the greater effect.

The reasons behind the existence of harmonics in electrical power systems is the non linear loads, where the relationship between the voltage and current is non linear. There are many sources of harmonics such as electrical converters, electromagnetic machines and fluorescent lamps [1,5].

III. MOTORS

Electric motors are powered by variable frequency drives (VFDs) . The voltages and currents delivered by a VFD that go to a motor are rich in harmonic frequency components. Magnetic fields are setup in the core by the voltage supplied to a motor , which create iron losses in the magnetic frame of the motor. Iron losses are normally consist of hysteresis and eddy current losses that are part of that are produced in the core due to the alternating magnetic field. Hysteresis losses are proportional to frequency, and eddy current losses vary as the square of the frequency. Therefore, additional losses in the core of AC motor are produced by higher frequency voltage components, which in turn, increase the operating temperature of the core and the windings surrounding in the core. Application of non-sinusoidal voltages to motors results in harmonic current circulation in the windings of motors.

The losses in the motor windings vary as the square of the rms current. Actual losses would be slightly higher than calculated values due to skin effect,. Stray motor losses, which include winding eddy current losses, high frequency rotor and stator surface losses, and tooth pulsation losses, also increase due to harmonic voltages and currents.

The phenomenon of the motor shaft torsional oscillation due to harmonics is not clearly understood, and this condition is often disregarded by plant personnel. Torque in AC motors is produced by the interaction between the air gap magnetic field and the rotor-induced currents. When a motor is supplied non-sinusoidal voltages and currents, the air gap magnetic fields and the rotor currents contain harmonic frequency components[1,5] .

IV. SIMULATION MODEL

In order to simulate the effect of harmonics on the motor under test a model was setup consisting of a 400V voltage source, a Thyristor circuit to generate harmonics ,20HP electrical motor that has an output power of 15kw, 1600 rpm rotation speed and 50Hz mains frequency and voltage, current and speed measuring gadgets. This model is connected to the network as shown in fig (2).

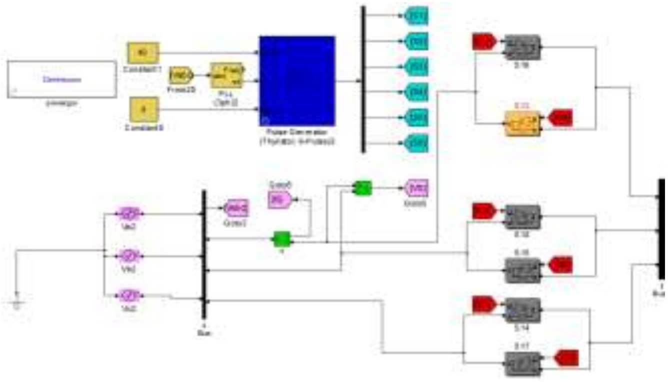

Fig (2) Voltage supply part of the simulation model

Fig (3) shows the other part of the simulation model that contains the motor under test.

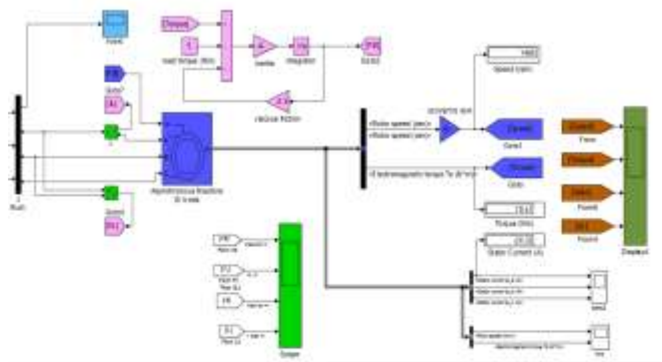

Fig (3) Simulation circuit showing motor and measuring tools

V. RESULTS AND DISCUSSION

Fig (4) shows the input signal to the motor, which is the output of the Thyristor circuit . The signal is distorted due to the injected pulses by the Thyristor. From the figure it can be clearly noted that voltage is high at the

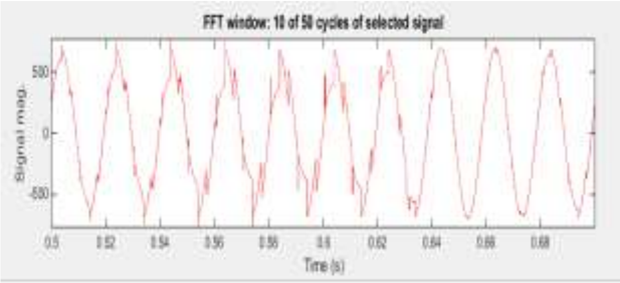

Fig (4) Distorted voltage input signal to the motor

fifth harmonic and it is less at the seventh and third harmonics respectively. Percentage of distortion due to fifth harmonic was 7.27% , 3.12% due to seventh harmonic and only 0.07% due to third harmonic. The THD was 19.42% during the time period 0.566s to 0.605s as can be seen in fig (5).

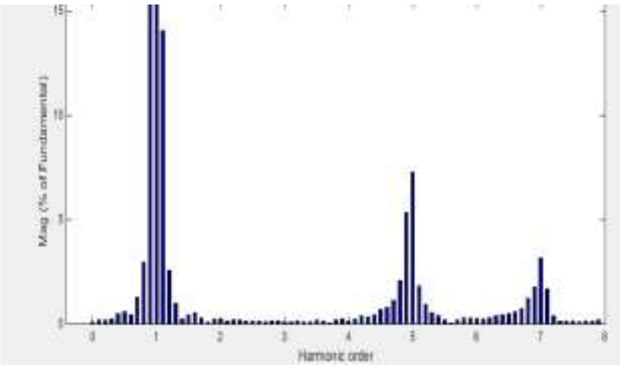

Fig (5) Distortion percentage due to harmonics in voltage signal

Fig (6) shows the input current signal to the motor, which is very evident that there are many harmonics of which the third, fifth and seventh that clearly indicates the amount of distortion is higher than the input voltage signal.

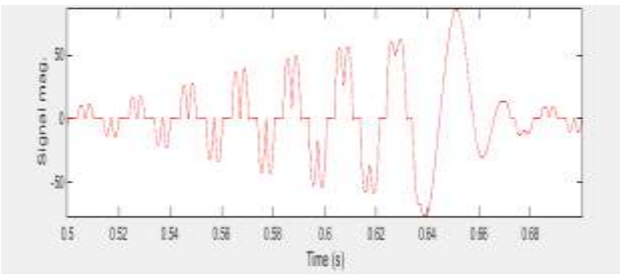

Fig (6) Distorted input current signal to the motor

From fig (6), it can be clearly seen that distortion due to fifth is higher than that due to seventh and third harmonics. The distortion due to fifth harmonic was 28.05% and due to the seventh harmonic was 8.85% and lastly due to the third harmonic was 0.15%, where the THD in this case was 46.89% as can be clearly seen in fig (7)

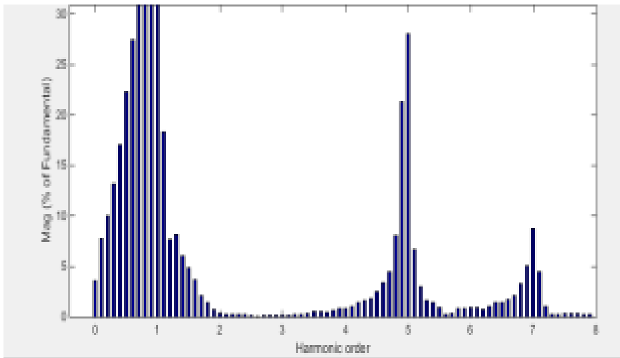

Fig (7) Distortion percentage due to harmonics in current signal

Harmonic have a serious effect on motor's efficiency since it reduces the efficiency by about 10%, and causes overheating and affects the torque as well as mechanical vibration and load noises.

The measured speed by simulation was 1519 rpm i.e. harmonics caused a reduction of the motor speed by about 5%, and the measured toque was 122.5 Nm

VI. CONCLUSION

The main cause of harmonics in networks is non linear loads, which has many forms and causes many different types of harmonics. Harmonics can have many destructive effects on electrical motor such as overheating, reduction of efficiency and this in turn will shorten the useful life span of these motors. These effects were very clear from the obtained simulation results, where the voltage and current signals were severely distorted by harmonics. The THD for the voltage signal was 19.42% and for the current signal 46.89 % and these effects caused a reduction in the motor speed by 5%

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