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A Review on Impact of Harmonics on Induction Motor Efficiency

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Abstract — In this paper, the output voltage harmonics of three-phase induction motor is reviewed. Several main factors which influence harmonics elimination also are discussed. Today, numerous industries use induction motors with variable frequency drives. These VFDs produce various harmonics, which heat up the motor, introduce EMI, and cause measuring equipment to malfunction. The mechanical force that results from these fault circumstances is strongly influenced by the motor's rate of rotation. Low motor speed causes the mechanical issue to exert less effort, which reduces frequency harmonics in the stator current. The stator current spectrum exhibits fault signals, however, even when the drive input frequency is very low, according to the data. Additionally, because the frequency components of interest are substantially lower than the drive frequencies, the harmonics of the drive frequency have little impact on defect identification. The majority of harmonic distortion occurs when loads draw non-sinusoidal current from the system. It predominates in areas where AC is converted to DC.

Keywords: Induction Motor; Power Quality Index; Motor Losses; Motor Efficiency; Energy Audit

I. INTRODUCTION

Industrial and home appliances have grown significantly in recent years. Appliance malfunction, motor insulation failure due to overheating, and a decrease in the effectiveness of circuit breakers can all be results of power system misbehavior in an electrical system. The most typical power system issues include voltage spikes, transients, and sags. The amount of harmonic distortion that a nonlinear load can produce is the departure from a pure sinusoidal waveform [17].

Key components of a sustainable future include the development of energy efficiency activities, laws, and incentives to encourage greater environmental and energy economies. With over 300 million installed motors accounting for more than 50% of worldwide electricity usage, industry is one of the areas with the most prospects for energy efficiency [22].

Low motor speed causes the mechanical issue to exert less effort, which reduces frequency harmonics in the stator current. The stator current spectrum exhibits fault signals, however, even when the drive input frequency is very low, according to the data [11].

Power quality (PQ) is a significant driving force behind the industry's expansion and development. As a result of the many PQ problems, low quality of power is perceived. Sag, interruption, swell, harmonics, etc. are some of these problems. Modern power systems are intricate networks where extensive power transmission and distribution networks connect thousands of load centers and hundreds of producing stations.

Consumers' principal worries revolve on the caliber and dependability of the power supply at the various load centers where they are situated. Even while the majority of highly industrialized nations have pretty consistent electricity generation, the supply's quality is less so. In a perfect world, power distribution systems would supply their consumers with a steady stream of energy at a smooth sinusoidal voltage at the agreed-upon magnitude level and frequency.

II. OVERVIEW

In adjustable drives systems with an induction motor a harmonic regime is manifested, whose knowledge and analysis is always necessary [3]. The largest single electrical end-use, which consumes more than twice as much energy as lighting, is electric motors and the systems they power. Electric motor-driven systems (EMDS) are thought to be responsible for between 43% and 46% of all the power consumed worldwide, resulting in roughly 6040 Mt of CO2 emissions. Without extensive and efficient energy-efficiency policy measures, it is anticipated that by 2030, annual CO2 emissions will reach 8570 Mt and energy consumption from electric motors will reach 13,360 TWh. Electricity used in EDMS is currently costing end-users USD 565 billion annually; by 2030, that figure may reach over USD 900 billion [3]. Almost 60% of the electricity used by drive systems is consumed by motors in the IE_0 and IE_1 classes (non-regulated and standard efficiency, respectively). Around 30 million new electric motors are supplied each year. By offering incentives, governments can encourage the replacement of outdated, inefficient motors with newer, more environmentally friendly ones [22].

Low motor speed causes the mechanical issue to exert less effort, which reduces frequency harmonics in the stator current. The stator current spectrum exhibits fault signals, however, even when the drive input frequency is very low, according to the data. They result in a decrease in power factor and the presence of harmonics. These harmonics are caused by non-linear equipment used in industries, such as power electronic converters, which are induced into the system during the switching process. In addition, they are produced by changes in loads and unusual conditions that occur in a power system. Several techniques have been used to lessen the effects of these industrial loads on power quality. The primary sources of energy inefficiencies in industries are the power factor and its impact on reducing energy usage. The power factor correction measures how effectively the factory uses electricity (PFC). The advanced electronic components used in textile automation machinery increase the system's complexity and susceptibility to nonlinearities, which causes harmonic pollution. The optimal size, soft beginning, and star-delta transition are employed to achieve maximum efficiency with good power quality

A. Effect of Harmonic on Rotating Electric Machines

Direct algebraic analysis enables the determination of machine current, voltage, and torque waveforms when harmonic effects are significant extraordinarily high effectiveness. Unfortunately, due to the massive amount of work required to derive the initial algebraic equations, this efficiency, which allows for significant computing time reductions over alternative methods, has only been used in simple scenarios [19].

Rotating machines are regarded as harmonic sources because the windings are encased in slots that can never have a precise sinusoidal distribution, distorting the mmf. Coil spanning is employed in three-phase machines to lessen fifth and seventh harmonics, as will be seen later. Furthermore, big generators are typically connected to power grids via delta-connected transformers, which prevents third harmonic currents from flowing. In comparison to harmonics produced by other sources, those produced by rotating machines are typically regarded as inconsequential [9].

The induction motors are widely utilized in industrial, commercial, and residential systems due to a number of technological and economic advantages. Induction motors will suffer severe consequences once the voltage is out of equilibrium [20].

B. Motor Losses

These references have led to the discovery that induction motors experience the following losses. Intrinsic losses that can only be decreased by modifying the motor's design are what define a motor's efficiency [5]. Fixed losses and variable losses are the two categories of intrinsic losses.

1) Fixed losses
2) Variable losses
3) Core Losses
4) Winding and Friction Losses
5) Stator Losses
6) Rotor Losses
7) Stray Load Losses

1) Fixed Losses:

Magnetic core losses, friction and winding losses are examples of fixed losses that are independent of motor load. Eddy current losses and hysteresis losses in the stator make up magnetic core losses, which are also referred to as iron losses.

2) Variable Losses:

Resistance losses in the stator and rotor as well as other stray losses are examples of variable losses that vary on load. Heat is produced by obstructions to current flow in the stator and rotor in a proportionate relationship between the material's resistance and the square of the current (I^2R).

3) Core Losses:

Core loss includes losses resulting from the generation of eddy currents that flow inside the core and is defined as the energy necessary to magnetize the core material (hysteresis). The stator-rotor magnetic steel experiences core losses, which are brought on by the hysteresis and eddy current effects that occur when the core material is magnetized. These losses, which make up 20–25% of overall losses, are irrespective of load.

4) Winding and Friction Losses:

Due to bearing friction and air resistance, winding and friction losses happen. Motor load has no bearing on core losses, winding losses, or friction losses. Friction and winding losses, which make up 8–12% of overall losses, are brought on by bearing friction, winding, and airflow through the motor. The use of a smaller fan is enabled by the reduction in heat produced by stator and rotor losses.

5) Stator Losses:

Stator losses appear as heating due to current flow (I) through the resistance (R) of the stator winding. This is commonly referred to as an I^2R loss. These losses are major losses and typically account for 55–60% of the total losses. I2R losses are heating losses resulting from current passing through stator and rotor conductors. I^2R losses are the function of a conductor resistance, the square of current.

6) Rotor Losses:

I^2R heating in the rotor winding is a symptom of rotor losses. Rotor losses, another type of power loss, are also known as slip losses since they are mostly but not entirely reliant on the amount of slip the motor exhibits. Rotor losses can be decreased by enlarging the conductive bars and end rings.

7) Stray load losses:

Stray load losses only occur when the motor is working under load and are caused by leakage fluxes (I) via the resistance (R) of the stator winding. These losses, which make up 4-5% of all losses, vary according to the square of the load current, are brought about by leakage flux brought about by load currents in the laminations.

C. Motor efficiency

A single equivalent circuit is suggested in place of the method of superposition of the equivalent circuits corresponding to each harmonic level while analyzing motor efficiency in the presence of voltage harmonics in. It is inappropriate to take into account a single parameter value when there are harmonics present, as is the case with stator reactance, magnetizing branch reactance, rotor reactance, and rotor resistance. These factors change significantly with frequency, necessitating their analysis for each harmonic circuit [3].

Positive and negative sequences can be created by breaking down unbalanced harmonics. In contrast to balanced harmonics, the consequences on the spinning field of the electric machine are different [7].

Due to the growing use of various types of static converters and receivers provided by electronic power equipment, the harmonics repercussions are highly current. Because to the increased iron and copper losses at the harmonic frequencies, operating motors on a polluted harmonic system reduces machine efficiency and service life. Harmonics in voltage and current can also have an impact on the torque created. Moreover, harmonics in rotating machinery can produce noises and vibrations. The global motor efficiency decreases as a result of the negative torque produced by negative sequence harmonics, which opposes the fundamental motor torque [3] [15].

An investigation of the electrical, vibration, and torque consequences of supply harmonic effects on the operation of an IM is provided by the authors in [15]. In paper [9], it is investigated how the degree of current distortion affects the noise and vibration levels of machines.

The consequences of the voltage waveform distortion on the IM, both electrically and mechanically, are systematically examined in this work. To do this, the supply voltages are distorted, overlapping on a single harmonic's fundamental.

Positive-sequence harmonics k€{7,13,19} and negative sequence harmonics k€{5,11,17} are the harmonics that are added to the supply voltage one at a time, respectively, and each has percentage level ΥV_k\{2 of 5%, 10%, 15%, 20%, 25%,}and 30% of the fundamental [9].

D. *Energy Audit*

Energy audit is a methodical process used to track industrial energy use and identify sources of waste. An energy audit study assists a company in better understanding and analyzing its energy use, pinpointing areas where energy use can be cut, choosing how to budget energy use, planning and putting into practice workable energy conservation measures that will increase their energy efficiency, reduce energy waste, and significantly lower energy costs. Any manufacturing process must have energy input, which frequently accounts for a sizable portion of the plant's expenses.

Types of Energy audit:-

1) Preliminary audit
2) Single audit
3) Comprehensive

1) Preliminary audit:

An expedited preliminary audit process is used. The primary energy sources and needs of the sector are the focus. This audit's objective is to highlight energy expenses and pinpoint instances of important equipment processes that waste energy. It also establishes goals for reducing energy usage. This style of energy audit examines factory energy use and management.

2) Single audit:

This kind of audit offers a thorough study of one or more project categories. The projects under analysis can be the outcome of a preliminary audit, a vendor selection, or a facility staff decision to repair or upgrade the project. Examples include those that are solely concerned with energy management systems for electric motors.

3) Comprehensive:

The goal of a detailed energy audit is to generate suggestions by quantitatively evaluating the level of rational energy consumption, taking instrumented measurements, and testing the main energy-consuming sub-systems that are sensitive to the energy cost of the product.

III. CONCLUSION

It has been determined from the review that an energy audit is a useful approach for gathering the information required to estimate motor energy use. Finding the sources of energy waste enables the implementation of the appropriate solutions. In this paper impact of harmonics on motor has been discussed. This paper introduces about energy audit, motor efficiency. Various motor losses have been reviewed in this paper. It has been clear that due to the growing use of various types of static converters and receivers provided by electronic power equipment, the harmonics repercussions are highly current.

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