A Review on Different Types of Faults in Induction Motor and Methods to Control Speed of Induction Motors

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Abstract: It is crucial from a practical standpoint to address the issue of speed control for electrical motors in general and induction motors in particular. Many industries have very strict requirements for speed characteristics, including range, smoothness of control, and cost-effectiveness. Motors must meet these requirements. Induction motors are inferior to dc motors in terms of speed control features. A dc shunt motor's speed can be varied over a wide range while maintaining good efficiency and speed regulation, but an induction motor's speed cannot be changed without compromising both of those factors. This article discusses the various induction motor fault types. In this paper, various researchers' methods for regulating the speed of induction motors are also discussed.

Keywords: *Induction motors, faults, VFD,*

I. Introduction

A typical AC electric motor is an induction motor, also referred to as an asynchronous motor. In an induction motor, as depicted in Figure 1, the rotating magnetic field of the stator winding is used to electromagnetically induce the electric current required to produce torque in the rotor. An induction motor's rotor can be either a wound type rotor or a squirrel cage rotor. Because they run at a speed lower than their synchronous speed, induction motors are known as "asynchronous motors." Synchronous speed is the rate of rotation of a rotary machine's magnetic field, and it is dependent on the machine's frequency and number of poles. Always operating at a speed lower than its synchronous speed.The rotor will rotate because of the flux produced in the stator by the rotating magnetic field in the stator. The rotor will never reach its rotating magnetic field speed because of the delay between the flux current in the rotor and the flux current in the stator (i.e. the synchronous speed). Induction motors can be broadly divided into two categories. The input supply determines which induction motor types are used. Induction motors come in single-phase and three-phase varieties. Although three phase induction motors are self-starting, single phase induction motors are not.

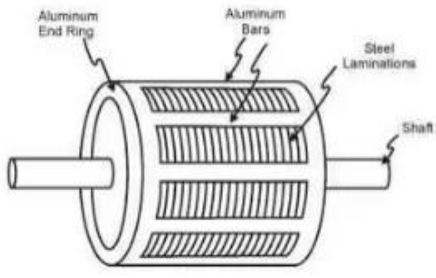

Figure 1 Induction Motor

In our environment, a variety of motor types are used for general purposes in everything from household appliances to industrial machine systems. In many industries today, the electric motor is a necessary and indispensable source of energy. These motors must perform and function within an excessively broad range. An AC induction motor runs at a certain speed when a voltage is applied. A 3-phase motor and an inverter or VFD are typically used to meet the variable speed requirements for AC induction motors. The inverter, also known as a variable frequency drive, is the most popular speed control technique for AC induction motors (VFD).
It is crucial from a practical standpoint to address the issue of speed control for electrical motors in general and induction motors in particular. Many industries have very strict requirements for speed characteristics, including range, smoothness of control, and cost-effectiveness. Motors must meet these requirements. Induction motors are inferior to dc motors in terms of speed control features. A dc shunt motor's speed can be varied over a wide range while maintaining good efficiency and speed regulation, but an induction motor's speed can never be changed without compromising both of those things.

The majority of single-phase induction motors are unidirectional, or one-direction rotating devices. The direction of rotation can be altered by adding additional windings, external relays and switches, or gear mechanisms. One can modify the system's speed using microcontroller-based control systems. Depending on the motor control algorithms being used, it may also be possible to change the rotation's direction in addition to speed. The most common kind of single-phase induction motors are those that use permanent split capacitors (PSCs).

II. FAULTS IN INDUCTION MOTORS

Due to the development of vector control based converters, induction machines can be controlled similarly to or even better than DC machines. Due to their reliability, affordability, and efficiency in terms of power consumption, induction motors (IM) are currently the main component in almost all industrial systems. Typically, squirrel-cage IMs, which use about 85% of the power in industrial plants, are the most widely used IMs. Even though IMs are durable and dependable, harsh environments can still cause faults. According to Figure 2, there are two main types of IM faults: mechanical and electrical faults.Electrical faults in the stator account for 30 to 40% of all faults, while rotor faults account for 5 to 10%. Mechanical flaws, such as eccentricity and bearing flaws, account for 40 to 50 percent of all defects. Several failure detection surveys provided these fault percentages. Other external faults may develop as a result of unbalanced utility supplies or incorrect stator winding connections. The rotor is subjected to a variety of stresses from electromagnetic, thermal, dynamic, environmental, and mechanical sources, which together lead to rotor failures. The list below includes various induction motor fault types:

- Electrical Faults
- Mechanical Faults
- Environmental Faults

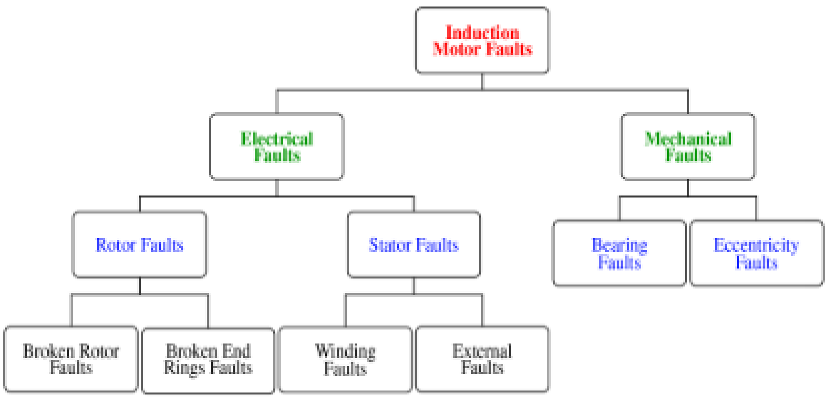

Figure 2 Classification of Induction Motor Faults

A. Electrical Faults - These faults are further sub dived into seven types such as,

- Single phasing faults occur when one phase of the supply voltage is lost, as three phases of voltage are necessary for a three phase induction motor to function normally. This flaw has the potential to burn or overheat the motor.
- Reverse Phase Sequencing Fault: This fault occurs when any one phase of a three-phase voltage supply is reversed, which means the supply voltages are switched in phase order. This flaw has changed the motor's rotational direction.
- Under or Over Supply Voltages Fault: This fault happens when supply voltages fall below or exceed a certain threshold. When three phase ac supply voltages exceed their 380 to 440 volt limit, the motor risk being burned or catching fire.
- Overload Fault: This fault occurs when a motor is overloaded, which means a higher load is connected to the motor's output side. As a result of this load, the motor may overheat or vibrate excessively.

- Earth Fault: When any one supply voltage phase is connected to the motor housing, there is an earth fault and the motor is completely shorted. Anyone who touches the motor in this situation will receive a strong shock, and the motor will also draw more current than it should, which could be hazardous for an induction motor.

- Inter Turn Short Circuit Fault: This type of fault occurs when two turns, either of the same phase or of different phases, are short circuited. The motor may sustain complete damage during this fault, or the coils of that particular phase may sustain damage.

- Crawling Fault: In a three-phase induction motor, crawling fault essentially refers to an electromechanical fault. When a motor is fully loaded and receiving full supply voltages, this fault occurs. Although the motor accelerates, it only runs at about one-seventh of its synchronous speed. Crawling is the name given to this particular induction motor phenomenon.

B. Mechanical Faults

- Mechanical faults are the kind of faults that typically affect the three phase induction motor's internal housing. These flaws are further divided into three categories, including

- The squirrel cage induction motor's rotor bars and shorted end ring make up the broken rotor bar fault. The term "rotor broken bar fault" refers to a fault where one or more of these bars is broken or partially cracked. Although there are many potential causes for this fault, it has primarily been found that a manufacturing defect is to blame. Because rotor bars may experience non-uniform metallurgical stress during the brazing process, which could cause the rotor bars to fail during rotation. In figure 3, a broken rotor bar fault is depicted.

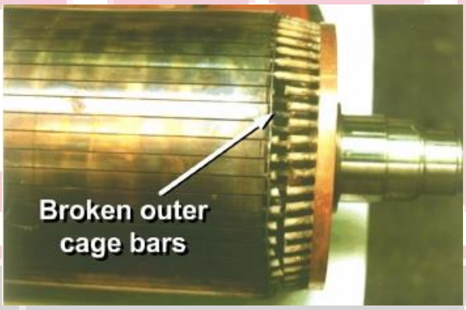

Figure 3 Broken Rotor Bar Fault

- Rotor Mass Unbalance Fault: If we focus on the design of an induction motor, we can quickly understand that the rotor is positioned inside the stator bore and rotates coaxially with the stator. It is symmetrically aligned with the stator in heavy motors, and its rotational axis coincides with the stator's geometric axis. Thus, there is no difference in the air gap between the stator's inner and outer halves. Similar to the previous example, eccentricity would occur if the air gap was not the same. The rotor fault, also known as the rotor unbalanced fault, would manifest itself in this eccentricity situation. Figure 3 depicts this rotor mass unbalance fault.

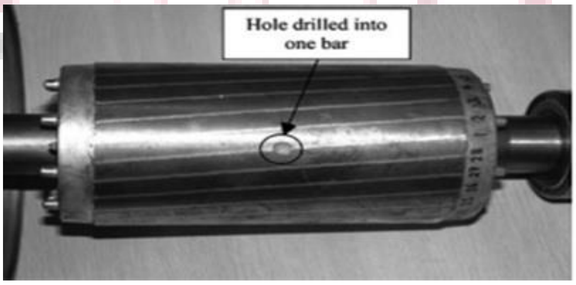

Figure 4 Rotor Mass Unbalance Fault

- Two sets of bearings are installed inside the motor housing of three-phase induction motors to support the motor shaft. These bearings' primary functions are to allow the motor shaft to freely rotate and to minimize fiction. They are made up of rolling elements known as balls and an outer and inner ring known as races. The balls, which are fixed to the inner and outer sides of the ring and lessen shaft fiction, The lubrication of these balls might further lessen the fiction.When a bearing's balls, outer ring, or inner ring are damaged because of a physical issue, a fault will sometimes result. The motor completely jammed or struck as a result of this fault, which is known as a bearing fault. In figure 5, a motor bearing issue is depicted.

Figure 5 The Motor Bearing Fault

C. Environmental Fault: Multiple faults can occur simultaneously in a three-phase induction motor, and environmental fault is a significant factor in these faults. Environment factors that affect induction motor performance include ambient temperature, humidity, and others. These elements lower the induction motor's performance. In addition, the performance of an induction motor can be affected by vibration, which can be caused by a variety of factors, including improper installation. Therefore, this consideration should be made when installing a three-phase induction system.

III. Literature review

(Mamdouh et al., 2018)provides a critical assessment of the effectiveness of recently proposed methods for choosing the weighting factors for PTC with a finite control set. The methods are divided into offline and online methods based on how the weighting factor is calculated. Since online methods can update the weighting factor automatically if the operating point changes, they will receive more attention in this study. In this study, four recently created methods as well as the traditional method are taken into consideration. The judging criteria for this comparison are flux ripple, torque ripple, current total harmonic distortion, and average switching frequency.The effectiveness of each method is evaluated using simulations at various operating points, and the characteristics of each method are contrasted using the performance indices suggested. Each method's advantages and disadvantages are highlighted. As a result, the appropriate method can be found based on various application requirements.

(Singh et al., 2018)represents the Mat-lab / Simulink modeling parameters for the Permanent Magnet Brushless DC (PMBLDC) motor drive. Permanent Magnet Brushless DC (PMBLDC) motor drive modeling is useful for a variety of phenomena, including aerospace modeling and more. The modeling of the PMBLDC motor drive is carried out in this paper using a number of different components, including current, speed controllers, and sensors, which are installed to sense the various factors, including speed, current, and the output from the inverter. The main goal of developing such a drive is to impart specific knowledge regarding the design of a motor drive using Mat-lab and Simulink and how it benefits numerous applications, including electric traction, the automotive industry, and more.

(MacIejewski et al., 2020)Due to their low cost and long lifespan, which are among their most appealing qualities, induction motors are the primary components for converting electrical energy into mechanics for the productive sector. Additionally, the need to cut maintenance costs and implement predictive techniques to reduce disruptions caused by unforeseen production line disconnections becomes crucial and a major impetus for the creation of systems that can detect faults. In order to reach the state-of-the-art and the technique of the theme of monitoring faults in induction motors, this paper employs a systematic search to identify papers and other scientific and technological papers.Due to the identification of the main techniques employed for this purpose, it is now possible to suggest new directions for investigation into the topic of locating and diagnosing induction motor faults.

(Hassan et al., 2018)The most widely used motor in energy conversion and commercial drive systems is the induction motor. This popularity is a result of its dependability, affordability, and simplicity of upkeep. The induction motor experiences faults as a result of electrical, mechanical, thermal, magnetic, and environmental stresses while it is operating. The creation of trustworthy, effective induction motor fault diagnosis techniques is one of the difficult subjects for many researchers. Due to its sudden severe damages, the broken rotor bar fault is one of the critical faults that requires early detection. This study's goal is to present an analysis of current broken rotor bar fault detection methods with new classifications based on fault signatures.For the detection process, various monitoring circumstances and signal processing methods are taken into consideration. Each fault signature includes a thorough reference list and is categorized according to the following criteria: loading level, number of broken bars, validation, and signal processing.

(Tian et al., 2018)The field of mechanical health monitoring and fault diagnosis has entered the big data era with the traction motor industry's rapid development. A common technique known as motor current signature analysis finds the line current's precise harmonic signals. The various induction motor faults, including rotor, stator, bearing, vibration, and air gap eccentricity, as well as their various diagnosis methods, are also explored. In fact, artificial intelligence has made significant advancements in the area of fault detection itself. It is undeniably clear that this topic has a broad scope. Recognizing the need for further study, this review paper provides an overview of the various traction induction fault types and their diagnostics approaches.

(S. Kumar et al., 2019)discusses the induction motor's condition monitoring aspects, its current status with potential mitigation measures, and upcoming maintenance difficulties. The majority of motors used in domestic and industrial settings are induction motors. These motors are subject to various failures and faults related to eccentricity, stator, bearing, insulation, and bearing. In fact, unless proper introspection is achieved, these flaws may ultimately increase the likelihood of failures. Early detection is essential to reducing failure time and operating costs, necessitating a condition-based approach as opposed to scheduled maintenance. Condition monitoring is a top contender for diagnosing issues with machinery failure and unreliability.In this context, a thorough analysis of the literature is reported with a focus on various approaches to such objective.

(Liang et al., 2020)The reliable operation of crucial industrial processes depends on the condition monitoring and fault diagnosis of induction motors. The fundamental principles and actual physical functioning of the machine can be greatly understood using the finite element method (FEM). This article conducts a review of the literature on FEM-based techniques for diagnosing induction motor faults. Three streams are used to group the state-of-the-art methods reported in the literature: First, a fault diagnosis method based on FEM, then a method based on FEM and signal processing, and finally a method based on FEM, machine learning, and other cutting-edge methods. The benefits of fault diagnosis methods using the FEM are shown, and it is suggested that future research go in this direction.

(Zaihidee et al., 2019)As highly efficient motors, permanent magnet synchronous motors (PMSMs) are gradually replacing induction motors in a variety of industries. PMSM systems have high-order complex dynamics and time-varying parameters. They are nonlinear systems. Researchers look into how PMSMs are currently implementing sliding mode control speed control. In order to increase the robustness of the controller and/or lessen SMC chattering, our goal is to highlight various sliding surface and composite controller designs with SMC implementation. The development of SMC enhancement using fractional order sliding surface design is supported by simulation results. The noteworthy characteristics and drawbacks of earlier works are enumerated. Ideas for potential new works are also discussed, focusing on the research's current gaps.

(Xu et al., 2020)The use of sensorless AC motor drives has grown in recent years in everything from commercial applications to home electronics. The benefits of sensorless motor drives include lower costs, higher reliability, simpler hardware, better noise immunity, and reduced maintenance needs. More sophisticated sensorless control strategies are required as a result of the advancement of contemporary industrial automation to meet application needs. Inverter nonlinearities and motor parameter variation have a significant impact on the stability of the control system for sensorless motor drives operating at low and zero speeds. High observer bandwidth is necessary in the high-speed region, meanwhile. This article provides an overview of recent developments in sensorless AC motor drives.This paper also presents the sensorless control approaches we studied for real-world industrial and domestic applications. This paper presents advanced sensorless induction motor (IM) and permanent magnet synchronous motor (PMSM) drives.

(R. H. Kumar et al., 2018)Since the development of direct torque control (DTC) for alternating current (AC) motor drives in the later 1980s, it has undergone numerous improvements to the control strategy. This study offers a thorough analysis of recent developments in DTC for induction motors (IM) over the previous ten years. The key findings and algorithms of the adopted switching table, constant switching frequency operation, intelligent control, sensorless control, and predictive control strategies are extensively discussed.

(Korzonek et al., 2019)Induction machines have recently become very popular in variable-speed drives due to their robust design, relatively low manufacturing costs (brushless), lack of maintenance requirements, and well-developed control techniques. The information on the rotor speed, which can be determined using various speed sensors, is necessary for high-precision control and efficiency optimization. All sensors need a place to mount and a way to connect to the system's wiring, which adds to the costs and decreases the dependability of the system. All well-known sensorless techniques are briefly discussed in this article, but the Model Reference Adaptive System (MRAS)-based solutions are the main topic of interest. In this article, all MRAS-type speed estimators that are known from the literature's mathematical models and schemes are compiled.The Lyapunov theory-based speed adaptation mechanism, stability issues near zero speed and in the regenerating operation mode, and the sensitivity of MRAS estimators to induction machine parameter changes are all considered in the comparative analysis of these speed estimators.

(Alwadie, 2018)The workhorse of the industry and a key component in energy conversion are induction motors. Electricity would be saved significantly if the outdated non-adjustable speed drives were replaced with the more recent variable frequency drives. The performance and efficiency of variable frequency drives can be improved with a suitable control strategy. This paper makes an effort to present a thorough analysis of different induction motor control schemes and offers suggestions for further investigation. A thorough investigation of sensor-based and sensor-less control schemes has been conducted. Different types of optimization techniques have been proposed to get around the shortcomings of control techniques, and the operation, benefits, and limitations of the various control schemes are highlighted.

(Hannan et al., 2018)presents a critical analysis of the various switching methods, voltage space vector switching patterns, and switching times to address current issues and improve TIM performance. The paper also discusses various scalar control and vector control intelligent controller techniques. As a result, a thorough analysis of artificial intelligence controllers such as artificial neural networks, adaptive neural fuzzy inference systems, and fuzzy logic control is provided, along with an explanation of their structure, algorithm, and mathematical model.In addition, the different TIM drive controller integrated circuits are examined along with advantages and disadvantages, present problems and challenges, and recommendations are made at the end. Hopefully, all the noteworthy findings from this review will spur increased work on creating sophisticated switching methods and controllers for induction motor drives in the future.

(Chougala et al., 2020)Modern machinery must perform efficiently, especially in the industrial sector. To efficiently drive the motor, variable speed drives are employed. Variable speed drive control strategy is crucial to this. Therefore, it should be carefully chosen based on the application. Encoders are typically used to control motors, but in more recent times, estimation techniques have taken their place due to a few drawbacks. Additionally, there are both online and offline estimation methods. Online parameter estimation techniques are used for accurate estimation, but they are somewhat complex. This process of the motor is also known as self-commissioning. This paper compares two methods for self-commissioning induction motors from two different manufacturers.Both the Rockwell voltage current lag angle method and the Danfoss frequency injection method are employed. In this paper, a review of both of these techniques is provided.

(Sharma et al., 2017)Different issues with over-voltage, over-current, over-current, over-temperature, over-speed, in-rush current, and vibration monitoring that an induction motor (IM) encounters during operation are covered in this review paper. Programmable logic controllers are used for fault detection and to safeguard an induction motor against these potential issues (PLC). While there are a number of devices that can be used to protect an induction motor, including contactors, timers, voltage and current relays, as well as variable frequency drives (VFDs), the best, most reliable method is a programmable logic controller (PLC), as it has no mechanical parts.

(Gangsar & Tiwari, 2020)Modern industries are required to use induction motors (IMs) continuously and without interruption. The paper begins by reviewing the traditional time and spectrum signal analyses of the two most useful types of signals, namely the vibration and the current, for various IM faults. Using the signals measured from various faulty IMs from a laboratory setup, the vibration and the current signal analyses (time and spectral) are carried out. After that, the benefits and challenges of using these traditional methods are discussed. The following section of this paper summarizes and presents the research and development that has been done so far in the area of signal-based automation of condition monitoring methodologies for the identification and diagnosis of various electrical and mechanical faults in IMs.Artificial intelligence (AI) techniques are now used to diagnose IM and other machine faults. The developments in AI-based fault diagnosis, along with the widely used methods, are reviewed in detail.

(Alsofyani & Idris, 2013)Variable frequency drives (VFDs) can offer dependable dynamic systems and significant energy and induction motor cost savings (IMs). For critical applications like electric vehicles, high performance machine tools, fans, compressors, etc., sensorless controlled IM drives have advantages in terms of efficiency enhancement and energy savings. Due to their lower price and higher reliability, IM drives without speed sensors or optical encoders mounted at the motor shaft are appealing. When a mechanical speed sensor is removed, the stator voltages and currents measured at the IM terminals are used to estimate the rotor speed.The sensorless methods used with IM drives in this paper are highlighted for their long-term dependability and energy efficiency. In order to provide a physical foundation for the sensorless schemes used, a brief summary of the IM mathematical model is provided.

(Böcker & Mathapati, 2007)The induction motor is renowned for being the industrial workhorse. Induction motor drives with variable speeds have been developed for more than 40 years. The years-long, intensive research and development that went into creating today's sophisticated industrial drives. The historical and contemporary developments and significant turning points in the control of induction motors are highlighted in this paper, followed by a discussion of how research findings were transformed into current industrial standards, and finally a summary of the current trends in both research and industry.

(Journal, n.d.)discuss using a variable frequency drive to control the speed of an induction motor (VFD). An electronic device called a variable frequency drive (VFD) is used to control an AC motor's variable speed operation by switching the utility power source to a variable frequency. An induction motor's load is not constant. Depending on the required load, it may vary. As a result, speed must adjust in accordance with the load's increase or decrease. Motor torque decreases along with supply voltage drops. The relationship between supply frequency and motor speed is direct. Therefore, supply voltage and frequency must vary appropriately in order to maintain speed. Variable Frequency Drive can be characterized in various ways (VFD).This essay aims to give readers a fundamental understanding of terms related to variable frequency drives (VFDs) and how they work..

IV. CONCLUSION

Due to various factors like cost, cabling, robustness, and construction limitations, speed and position sensors are undesirable. For speed sensorless induction motor control, numerous different strategies have been put forth. The majority of electrical machines used in domestic and industrial processes are induction machines. Induction motors make up about 85% of the motors used in industrial appliances. Its main benefits include low cost, toughness, robustness in structure, low maintenance requirements, ease of availability, and ability to function in harsh working environments. The various faults that can occur with induction motors are discussed in this paper. In this paper, various researchers' methods for regulating the speed of induction motors are also discussed.

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