A Ph.D SYNOPSIS

in the area of

Electrical Machines

on the topic

Health Monitoring System for Three Phase Induction Motor using Soft Computing Techniques

Submitted by

Md. Sharif Iqbal

Department of Electrical Engineering
Faculty of Engineering
Dayalbagh Educational Institute
Dayalbagh, Agra.
July. 2013

A Ph.D SYNOPSIS

In the area of

Electrical Machines

on the topic

Health Monitoring System for Three Phase Induction Motor using Soft Computing Techniques

Submitted by

Md. Sharif Iqbal

Under the Supervision of

Prof. D. K. Chaturvedi

Supervisor

Prof. V. P. Pyara
Head, Dept. of Electrical Engineering
&
Dean, Faculty of Engineering

Dayalbagh Educational Institute

Dayalbagh, Agra.

July 2013

INDEX

Content **Page No.**

1. Introduction

An induction motor is a singly excited machine. The power is supplied to the stator winding only. The voltage (and current) is induced in the rotor of this machine and that's why this machine is named as induction motor. The rotor is not connected to any external supply. Induction motor works on alternating current (AC) supplied directly to the stator winding and by induction or transformer action to the rotor winding. In fact an induction motor can be considered as a sort of rotating transformer, in which stationary winding on stator is connected to the AC source, while the other winding is mounted on a rotor receives its power by transformer action while it rotates. Motor of this type are designed to operate either on single phase or on three phase AC supply and accordingly called single phase induction motor and three phase induction motor [HUS 04, BIM 11].

For domestic applications single phase induction motors are used, where as for industrial purpose three phase induction motors are preferred. In industries almost 95% of the motors are three phase induction motors due to certain advantages over other types of motors such as [AND 99, COL 05, ADE 06, COL 07, XIA 10]:

1. Three phase induction motors are very simple, compact and extremely rugged in construction.
2. Absence of brushes reduces frictional losses and reasonable good power factor makes it very efficient machine.
3. Three phase induction motors are most reliable and low cost motors.
4. Induction motors don't require any extra motor at the time of starting, as required in case of plain synchronous motor.
5. Induction motors have almost no maintenance cost.

In spite of these advantages these motors are also suffer from the following drawbacks:

1. These motors run at low power factor at light load conditions and hence the efficiency is also low at this load.
2. The starting torque of these motors is also less compared to d.c. shunt motor.

3. These motors run at almost constant speed, hence the speed control cannot be possible without sacrificing the efficiency.

2. Constructional Details

There are two types of Induction motor based on the construction of the rotor.

1. Squirrel cage type Induction motor or Cage rotor type Induction motor.
2. Slip ring Induction motor or Wound rotor type Induction motor

The main parts of the induction motors are (i) Frame (ii) stator (iii) rotor.

(i) Frame: Depending upon the application to which they are used for, the various types of frames are used. The main function of the frame is to support the bearing and to protect the other machine parts such as coil ends and the core. Generally in the small induction motors frames are made up of cast iron to reduce its cost. The different types of the frames normally used are (a) Open type (b) Totally enclosed type (c) Drip proof types (d) Enclosed, self ventilating (cooing type) (e) Enclosed, separately ventilated type (f) totally enclosed fan cooled type (g) Splash proof type. In case of large induction motors the frames are made up of laminated sheets to reduce losses.

(ii) Stator: It is the stationary part of the motor. It is like hollow cylinder which is made up of slotted laminations of sheet steel punching as shown in fig.1. The lamination thickness is normally between 0.1 to 0.3 mm. The laminations are insulated by coating of an insulating varnish or an oxide coating. Thicker laminations can be used for the small motors as loss is not important and cost is important for a small motor. Ventilating ducts are used of an interval of 5 to 7 cm along the length of the core. The windings are insulated from the core and the three phase windings are placed in slotted stator core. When three phase supply is given to the stator winding, one rotating magnetic field is produced. The stator is having definite number of poles. The speed of the rotating magnetic field is called synchronous speed, denoted by N_s. Now N_s is inversely proportional to the pole.

$$N_s = \frac{120f}{P}$$ Where P=Number of stator pole and f =supply frequency in Hz.

The conductor may be either round conductor or rectangular bar type depending upon the rating of the motor. Stator conductors are fixed in position with the help of fiber wedge as shown in Fig.1

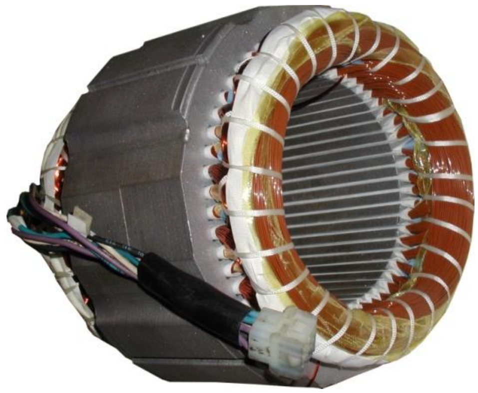

Fig.1: The Stator of an Induction motor

(iii) Rotor: The rotating parts of the motor is called rotor. There are two types of rotors, and the motor is classified according to the construction of the rotor, into two types as (a) Squirrel cage motor and (b) Slip ring motor.

(a) Squirrel cage rotor or Cage rotor: It consist of a cylindrical laminated core with slots nearly parallel to the shaft axis, or slightly skewed. Each slot contains an uninsulated bar conductor made up of either aluminum or copper. At each end of the rotor, the rotor bar conductors are short circuited by heavy end rings of the same material as shown in Fig.2. This type of the frame was commonly once used for keeping squirrels, hence it's name. In industrial application about 90% of the induction motors are the cage type motor. The rotor bars are slightly skewed due to the following advantages [VIC 10]:

1. More uniform torque and less noise and
2. To reduce the magnetic locking tendency of the rotor.

Fig.2: Squirrel Cage rotor of an Induction motor

(b) Wound rotor or slip ring rotor: Slip ring rotor is also called as wound rotor. The rotor consists of three phase double layer distributed windings whose one end of each winding is short circuited permanantly with an end ring forming a star connection. The other end is connected to the slip rings as shown in Fig. 3. Insulated slip rings are placed on the shaft, this construction helps in adding external resistance to the rotor circuit. The winding of the rotor is similar to the stator winding and is placed in the slots of the rotor. The purpose of the slip ring and brushes is to provide a means for connecting external resistors in the rotor circuit. The external variable resistance serve two purposes [MOG 99]:

(i) To increase the starting torque and decrease the starting current.

(ii) To control the speed of the motor.

Fig.3: Construction of Slip ring rotor

3. Working Principle

When three phase supply is given to the stator winding, the rotating magmetic field of constant magnitude and of synchronous speed is produced. When this rotating field is cut by the stationary rotor conductor, according to the Faraday's law of electromagnetic induction, an emf is induced in the rotor conductors. Since all the rotor conductors together form a closed circuit the induced emf in the rotor conductor sets up rotot current. Thus, being in the magnetic field produced by the stator windings, each current carrying conductors of the rotor experiences a mechanical force which ultimately results into rotating of the rotor. But the rotor speed always will be slightly less than the synchronous speed (N_s). The difference of the rotor speed to the synchronous speed is called slip, indicared by s and always calculated in percentage [GOM 02, BAY 07].

$$\% \text{ Slip (s)}=\frac{(Ns-N)}{Ns} \text{ x}100$$

Induction motors are universally used in different types of industries. This type of motor are robust in construction used not only for general purposes, but also in hazardous locations and severe envionrment. It is generally applied for pumps, conveyors, machine tools, centrifugal machine, press elevators and packing equipment. It is also applied for hazardous location like petrochemical and natural gas plants, while severe enviornment applications for induction motors include grain elevator. shredders, and equipment for coal plants. Moreover induction motors are highly reliable, require less maintenance and relatively highly efficient. Wide range of induction motor starting from watts to mega watts, satisfies the production needs of most industrial processes. A motor failure that is not identified in the initial stage may become catastrophic and the induction motor may suffer severe damages.Thus undetected motor fault may cascade into motor failure, which inturn may cause production shutdown. Such shutdown are costly in terms of lost production time, maintenance costs and obviously wasted raw material. To reduce these losses, it’s necessery to identify the fault at very earlier stage and prevent the motor from the large fault and failure [KPH 92, ADE 06, SUD 07].

4.Common Faults in Induction Motor

4.1 Introduction

Although Induction motors are highly reliable industrial drive, these motors are often exposed to hostile environments during operation which leads to early deterioration leading to the motor failure [LUK 98, CHI 99a]. Faults and failures of induction machines can lead to excessive downtimes and generate large losses in terms of maintenance and lost revenues. Even small fault can causes increased losses such as reducing efficiency and increasing temperature, which will reduce insulation lifetime, and increasing vibration, in turn may reduce bearing life time [SCH 71, ROL 78, MAI 92, THO 99, CRA 11]. All they are due to the operating environment condition and machine internal factors. The different type faults which are commonly occurred in the induction motor are shown in Fig. 4. The proper study and knowledge of motor faults are very essential, then only we can go for the condition monitoring of motor and proper diagnosis of the problem which prevent the expensive maintenance cost. A statistical study in 1985 was conducted by Electric power research institute provides (EPRI) and found as bearing faults (41%), stator faults (37%), rotor faults (10%) and others (12%). According to IEEE standard 493-1997, the most common faults and their statistical occurrence are tabulated in Table -1. This IEEE statistics about induction motor faults are almost matched with EPRI data [ADE O6, AKA 12, PEZ 12].

Table – 1 Statistics of Induction motors faults and Failures [AKA 12]

	IEEE-IAS (%) Electrical Safety Workshop	**IEEE-IAS (%) Electrical Safety Workshop**	**EPRI (%) Electric Power Research Institute**
Number of faulty motor	380	304	1052
Bearing-related	44	50	41
Winding-related	26	25	36
Rotor-related	8	9	9
Other	22	26	14

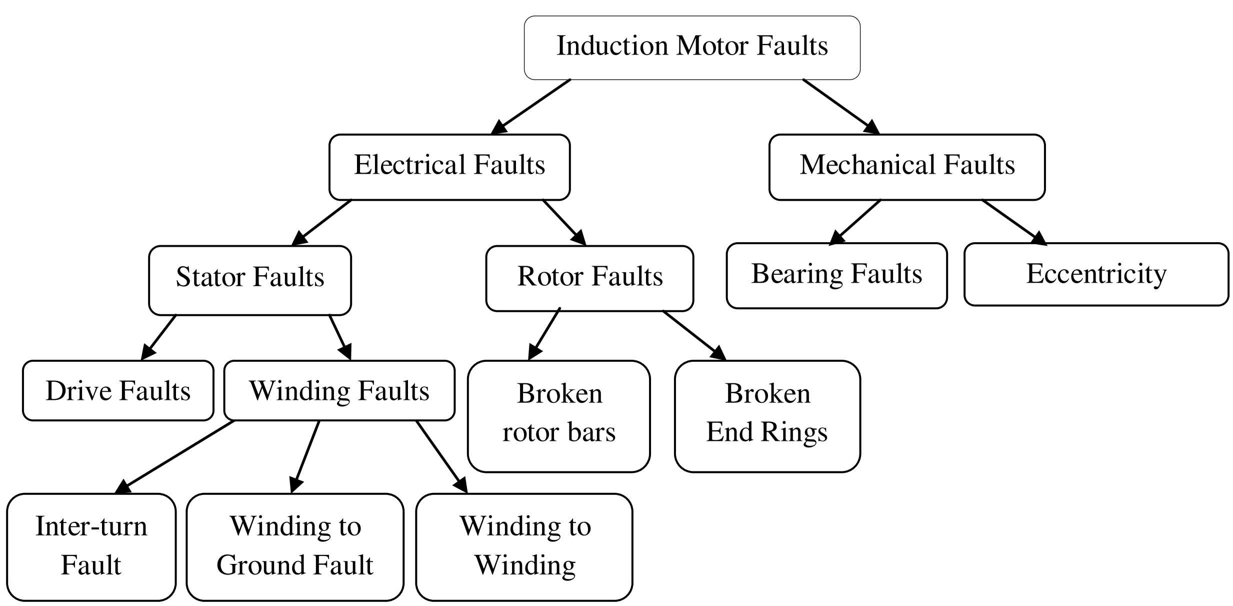

Fig.4: Types of faults in Induction Motor

4.2 Winding Faults

According to published surveys, Induction motor short turn (stator winding) failure is in the range of 30-40% of the total failure [DAS 08]. Moreover it is generally believed that a large portion of the stator winding related failures are initiated by insulation failures in several turns of the stator coil within one phase[EMA 03,CEL 04,GOL 04, CHA 08]. This type of the fault is known as 'stator inter turn fault'. Inter-turn short circuits in stator windings constitute a category of faults that is most common in induction motors. Typically, short circuits in stator windings occur between turns of one phase, or between turns of two phases, or between turns of all phases. Moreover, short circuits between winding conductors and the stator core also occur known as winding to ground fault [WIL 85, GRI 86, MCC 93, RAN 95, PAN 00, ROD 08, GNA 08].

There may be different types of short turn faults and at different combinations as mentioned below [PEN 94, KLI 96, SID 05, JAN 07, JAN 09]:

1. Burning of the winding insulation and consequent complete winding short circuits of all phase windings which are usually caused by motor overloads and blocked rotor, as well as stator energized by sub-rated voltage and over rated voltage power supplies. This type of fault can be caused by frequent starts and rotation reversals [VIC 11a].
2. Inter-turn short circuits between turns of the same phase, winding short circuits, short circuits between winding and stator core, short circuits on the connections, and short circuits between phases, are usually caused by stator voltage transients and abrasion [SCH 56, MIR 06].
3. Complete short circuits of one or more phases can occur because of phase loss, which is caused by an open fuse, contactor or breaker failure, connection failure, or power supply failure [LUK 98].
4. Inter-turn short circuits are also due to voltage transients that can be caused by the successive reflection resulting from cable connection between motors and ac drives. Such ac drives produce extra voltage stress on the stator windings due to the inherent pulse width modulation of the voltage applied to the stator windings. Again, long cable connections between a motor and an ac drive can induce motor over voltages. This effect is caused by successive reflections of transient voltage [THO 84].
5. Short circuits in one phase are usually due to an unbalanced stator voltage, an unbalanced voltage is caused by an unbalanced load in the power line, bad connection of the motor

terminals, or bad connections in the power circuit. Moreover, an unbalanced voltage means that at least one of the three stator voltages is under or over the value of the other phase voltages [AKP 96, DEV 98, HOD 02, JAN 09, SAR 12].

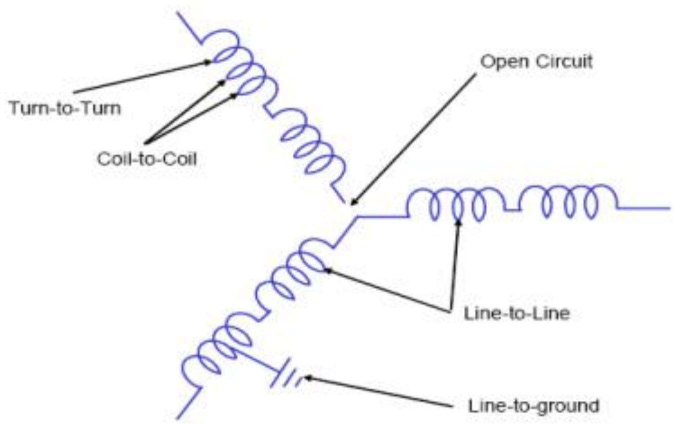

Fig.5: Different types of short turn faults

4.3 Rotor Fault

Squirrel cage of an induction motor consists of rotor bars and end rings. Usually lower rating machines are manufactured by die casting techniques where as high ratings machines are manufactured with copper rotor bar. Broken Rotor Bar/End-ring failures of medium size Motors Rotor cage fault (broken rotor bar/end-ring) accounts for approximately 5-10% of all induction motor failures [SMI 75, SHU 78, PAT 86, TES 01, MAR 06, FAI 06, FAI 10]. For any medium size motors, the rotor cage fault is even more common than that of small motors, due to the extensive thermal stresses on the rotor. There may be different reasons for the rotor faults as below [STA 10, MEH 11, KRE 12, DAS 13, YON 13]:

1. During the starting of machine, a rotor bar may be unable to move longitudinally in the slot it occupies, when thermal stresses are imposed upon it.

2. Heavy end ring can produce a large centrifugal force, which can cause dangerous stresses on the bar [MIR 05].

3. During the brazing process in manufacture, non uniform metallurgical stresses may be built in to cage assembly and these can also lead to failure during operation.

There may be two types of breakage in the cage as shortly described below [BRE 94, PIR 09, ARA 10, MEH 11, PEZ 12]:

(a) *Breakage of skewed bars:* The rotor bars can be partially or completely cracked during the operation of SCIM, due to stresses and/or improper rotor geometry design. The bar breakage is the major fault in the rotor of SCIM. Once a bar breaks, the condition of the neighboring bars also deteriorates progressively due to the increased stresses. To prevent such a cumulative destructive process, the problem should be detected early, that is, when the bars are beginning to crack [KLI 88, HAJ 01, HUA 06, KUR 10, DRO 12, KEC 13].

(b) *Breakage of end-rings:* The conductive rotor bars are short-circuited on the both sides by end-rings. Defective casting in the case of die-cast aluminum rotors, and/or poor end-ring joints in the case of fabricated rotor cages during manufacturing are the source of the end-ring faults. Once the initial defect occurs, localized overheating may develop in the cage. Therefore, propagation of the fault is continued by multiple start-ups as well as load fluctuations, which produce high centrifugal forces. Accordingly, the broken end-ring faults are extremely severe and cause drastic increase in the speed and current fluctuation.

Early detection of a broken rotor bar minimizes motor damage and reduces repair costs. In some cases, the broken bar condition starts with a fracture at the junction between the rotor bar and the end ring as a result of thermal and mechanical stresses. These stresses are more significant when starting motors with high-inertia loads. The bending of a fractured bar due to changes in temperature causes the bar to break. When one bar breaks, the adjacent bars carry currents greater than their design values, causing more damage if the broken bar condition is not promptly detected. Inter bar currents that appear because of the broken bar affect the evolution of the fault in the rotor, causing damage in the laminations of the rotor core [TRZ 00, DAS 08, KIA 09, SOU 09, FIR 12,].

4.4 Load Fault

In some particular application such as aircrafts, the reliability of gears and load faults may be critical in safeguarding human lives. Due to that the detection of load faults (especially related to gear) has been an important factor of research. Motors are often coupled to mechanical loads and gears. Several faults are also can occur in mechanical arrangement. Examples of such faults are coupling misalignments and faulty gear systems that couple a load to the motor [SCH 71, BRI 82, BAI 88, FAI 07, MIT 10, FAI 10].

Induction motor has broad application in a variety of industrial control and electric drive system. In the use of on-site motors for various reasons, often lead the overload failure occurred. Motor overload will tends to the motor overheated, cause the motor burning, and make significant damage to the national economy. Normally one over load protection technology is used to prevent this [ELS 89, BON 98, DEV 99, TOU 01, RAN 11, VIC 11, VIC 11a]. Because of the motor itself has certain overload capacity and motor overload protection doesn't have precise mathematical model. The motor overload protection has been the academic and engineering research hot spot. Winding overheated or the insulating ability reduced is the result of overload fault. But the winding over-hot is the effect when the current flowing through the winding is too large. Therefore, at present the main motor overload protections means other way current detection and temperature detection. A motor can run over-loaded for a short time, provided its temperature limit is not reached. Direct monitoring of the temperature of the motor can provide thermal protection, but it also has its own inherent drawback [REG 78, CUM 85, PAO 89, SCH 94, GOU 10].

4.5 Air gap eccentricity

Air gap eccentricity is a common rotor fault of induction motor. Air gap eccentricity is the situation when the air gap between the stator and rotor is unequal. Severe air gap eccentricity may lead to unbalanced magnetic pull and eventually result in the rotor to stator friction which make the machine vibrating and produced noise. This can be responsible for the damage of the stator and rotor core. There are three types of air gap eccentricity (i) Static eccentricity (ii) Dynamic eccentricity and (iii) Mixed eccentricity [THO 84, THO 99a, ZHE 04, FAI 06, NAN 11].

In static eccentricity, the rotor rotates around its natural axis which is inclined compare to the stator one. Static eccentricity is a steady pull in one direction which create unbalanced magnetic pull (UMP). UMP caused by static eccentricity may lead to bend rotor shaft, bearing failures, dynamic eccentricity and eventually stator to rotor rub, causing a major breakdown of the motor. It is difficult to detect this fault unless special equipment is used. Intrinsic static eccentricity even exists for newly manufactured motors [BEN 99, PIN 09].

In dynamic axial eccentricity, the rotor natural axis inclined compare to its rotational axis, which is superimposed to the stator axis. Dynamic eccentricity produces an unbalanced magnetic pull that rotates at the rotational speed of the motor and acts directly on the rotor. This makes the unbalanced natural pull in a dynamic eccentricity easier to detect by vibration or current monitoring[HSU 92, THO 99a, NAN O5].

The combination of static and dynamic eccentricity is called mixed eccentricity.

In fact, static and dynamic eccentricities tend to coexist. Exact centric condition hardly exists in machine. Therefore, an inherent grade of eccentricity is implied for any real machine.

4.6 Bearing Fault

Over the past several decades, rolling-element (ball and roller) bearings have been utilized in many electric machines while sleeve (fluid-film) bearings are installed in only the large industrial machines. In the case of induction motors, rolling-element bearings are overwhelmingly used to provide rotor support[FIN 95].The rolling-element bearing in an induction motor is one of the most critical components because bearing related failures have been accounted for 41% of all failures. Moreover, bearing fault in an induction motor may be responsible later for winding failure. Hence, incipient detection of bearing fault is crucial for prevention of drive failures [THO 97, THO 99, KON 11, TRA 08,TRA 09].

Bearing fault can be classified as: (i) single- point-defects and (ii) generalized roughness. Single-point-defects are visible defects that appear on the raceways, rolling elements or cage. Examples of this type of fault include spilling, brinelling, and electrical pitting. A single-point-defect typically produces characteristic fault frequencies in the machine vibration. It is certainly possible for a defected bearing to posses many single-point-defects. The other group of bearing faults, generalized roughness, refers to an unhealthy bearing with no visible defects. This failure mode does produce the predictable fault frequencies that a single-point-defect produces;

nevertheless, it typically alters the machine's current and/or vibration. Examples of this type failure include deformation of the rolling elements, deformation or warping of the raceways, or excessive heating caused by contamination of the lubricant. Natural bearing faults can be due for example to corrosion, contamination, ineffective lubrication or electric arcing induced by the use of PWM voltage source. Then, artificially damaged bearings are made to be realistic regarding to such critical faults [SCH 95, THO 98, TRA 08a, SEN 10, SAA 11, MCE 11, JAE 12].

.

5. Condition Monitoring Technique for Induction Motor

5.1 Introduction

Condition monitoring can be explained as the continuous evaluation of the health of the plant and instrument throughout its working duration. It is important to detect faults while they are developing which is called incipient failure detection. Incipient failure detection can provide safe operating environment. In many applications, these motors are operated under environmental stresses, such as high ambient temperature, high moisture, etc, which could lead to motor malfunction. Malfunction of these motors leads to not only high repair expense, but also extraordinary financial loss due to unexpected downtime. Therefore, reliable monitoring and protection for MV motors is of great value to avoid catastrophic unscheduled downtime [FAR 08, PIN 09, PIN 11, IND XX].By using the condition monitoring we can give the warning, well in advance to correct the situation and avoid shutdown. This can result in minimum downtime and optimum maintenance schedule. Condition monitoring and fault diagnostic technique can help the operator to be ready with the spare parts before occurring the shutdown situation and hence reduce outgoing time [LUK 98, HUN 11]. There may be different types of condition monitoring technique as discussed below:

5.2 Monitoring Techniques

5.2.1 Thermal Monitoring

Thermal monitoring of induction motor can be performed either by measuring the local or bulk temperatures of the motor or by parameter estimation. A stator winding faults produce huge heat and the amount of heat indicate the severity of the fault until it reaches at a dangerous level [HEI 58, SMI 75, DEC 95, ALB 02, MAX 04, PIN 08, PIN 09].

Stator thermal overload has drawn a lot of attention in the past several decades, as it is one of the root causes for the stator insulation failure. Different types of relays have been developed to provide thermal protection and overload protection for induction motors. Embedded thermal sensors are broadly used for MV large motors, to monitor the temperature of the stator winding to avoid thermal overload [POT 33, SAN 02, BAY 08, LEB 08a]. However, the thermal sensors are highly undesirable in some applications. Thermal protection for the rotors of these motors are necessary for reducing bearing and rotor cage failures. Therefore, the development of sensorless thermal protection methods for both the stator and the rotor of MV motors are highly desirable [EID 70, BOO 74, SID 05, FAR 07, PIN 09].Therefore some researchers have developed the thermal model of the induction motor [HUR 96, BEG 99, GNA 08, YID 08].

Generally thermal model of induction motor are classified in two categories as discussed below: [VEN 05, YID 09]

1. Finite element analysis based model
2. Lumped parameter thermal models

Based on the thermal models, both finite element analysis methods and lumped parameter analysis methods have been developed by researchers. Finite element analysis methods are not appropriate for online temperature estimation as they are computationally intensive. Lumped parameter analysis methods divide the motor into several homogenous components and use lumped thermal resistors and capacitors to model the heat transfer. By using general electric circuit analysis methods, the temperature of each component can easily be solved [GRI 86, FIL 94, DIS 98, WHA 08, BUL 11].

Thermal model-based approaches calculate the motor losses and apply thermal models to estimate the motor temperature. The first-order, the second-order and higher-order models have been proposed by the researchers [YID 08, YID 09, HUN 12].

(a) *First-order Thermal Models:* In many relays, the first order thermal models are utilized for thermal protection. These models can consider only the stator winding temperature and are generally too conservative, thereby tripping off the motor before the maximum temperature is reached.

(b) *Second-order Thermal Models*: These models are proposed for modeling the stator and the rotor temperature separately with better accuracy. The losses and the thermal capacitance are divided into the stator part and the rotor part [YID 08].

(C) *Higher-order Thermal Models*: For the better predictions of the thermal behaviors, several higher-order models are proposed in the literature [YID 08]. In this category stator end windings, stator core, end cap air, rotor winding and rotor iron are modeled separately. The thermal resistances and capacitances are calculated from the off line experiments or the motor dimensions [YID 08].

5.2.2 Vibration Monitoring

Each electrical machine has its own vibration signature and analysis of vibration can be used to monitor the condition of motor performance. Vibration of the machine has certain relation with its noise. Even small amplitude of vibration can produce a huge noise for the machine. Noise and vibration in the electric machines are caused by the forces which are magnetic, mechanical and aerodynamic origin. The vital reason of vibration in the electrical machine is radial force due to air gap field [THO 84, THO 99a, HAN 12, THO 05].

Practical condition monitoring techniques for three-phase induction motors are generally performed by some combination of mechanical and electrical monitoring. In the mechanical monitoring, vibration based condition monitoring has attracted the attention of many researchers working in the area of induction machines and has gained industrial acceptance, as vibration analysis techniques are more effective in assessing a machine's health [HUA 07].

Vibration monitoring is the most reliable method of assessing the overall health of a rotor system. Newly made electrical machines also generate some level of vibration. Vibration monitoring is based on vibration transducers, virtual measuring accelerometers of piezo-resistive types with linear frequency spectrum, normally placed on the bearings for detecting mechanical faults. However, by placing probes on the stator as well, it is also possible to detect, stator winding or rotor faults, an uneven air gap, unbalances in the driven load and asymmetrical power supply. This is based on the fact that vibration spectrum will change if there is any change in the normal flux distribution in the motor. This is very effectiveness method for analyzing the mechanical faults [SID 05, THO 05, MAR 05, MCE 11]. Vibration signals can be analyzed in either time domain or frequency domain. Frequency domain analysis can provide more detailed information concerning the status of the machine [THO 97, HAN 05]. The difficulty in electrical fault detection is the problem of sorting through the enormous frequencies present in vibration spectra to extract useful information associated with the electrical faults. To overcome this problem, researchers generate characteristic frequencies as model of motors to detect the faults.

However, in this method a thorough understanding of the motor, like knowledge on the frequency response functions are required, which makes it less attractive in practical applications.[HAN 12] Vibration spectra also can provide little diagnostic information about the health of motors. Thus, these old existing methods using vibration signals are not very effective, or accurate for electrical fault detection of induction machine. The modern researchers have developed artificial neural network (ANN) modeling in vibration spectra to analyze the motor fault in a better way. The ANN can represent any nonlinear model without knowledge of its actual structure and can give result in a shout time during the recall phase [HUA 07].

5.2.3 Torque Monitoring

All type of motor faults produces the side bands at special frequencies in the air gap torque. Presently the commercially available methods for detecting rotor bar defects of induction motors are based on various identifications of side bands of a line current. This study suggests a new method for detecting not only the rotor defects but also the stator shorted coils. Air-gap torque is the torque produced by the flux linkages and the currents of a rotating machine [ANA 82, THO 97, THO 99a, LAS 00, THO 02, KAR 08]. Air-gap torque can be measured while the motor is running. No down time is required for its measurement. This can be financially attractive to many industries, where an unscheduled down time of a motor posts a heavy loss in the operation of a production system. Because the rotor, shaft and mechanical load of a rotating machine constitute a specific spring system that has its own natural frequencies, the attenuations of the torque components of the air-gap torque transmitted through the spring system are different for different harmonic orders of torque components. From the input terminals, the instantaneous power includes the charging and discharging of the energy in the windings. That's why the instantaneous power cannot represent the instantaneous torque. Generally speaking, the waveform of the air-gap torque curve is different from that of the torque measured from the shaft [ELK 92, HSU 92, HSU 95, WEN 99, KOA 00, HAJ 02, SID 05, BAS 08, JAE 12, DAS 13].

5.2.4 Noise Monitoring

Noise monitoring can be done by measuring and analyzing the acoustic noise spectrum from the induction machines. Acoustic noise from air gap eccentricity is helpful to detect the faults of the induction motor. However this method is not very much useful in large industry because of the noisy atmosphere will disturb the original sound produced by the machine. As a result it's very difficult to get accurate reading [SID 05, NAN 05]. In paper [ELL 71] the researchers are described the method to calculate the air gap eccentricity by using noise signature. They have conducted the test in an anechoic chamber and verified that the slot harmonics in the anechoic noise spectra from a small power induction motor were functions of static eccentricity.

5.2.5 Electrical Monitoring

There are different types of electrical monitoring described by the researchers such as Current Park's vector[ONE 06,SAH 13], Zero sequence and negative sequence current monitoring, and current signature analysis [THO 00,ELH 00,BEL 01] etc. In all these methods stator current is used to detect various kinds of induction motor faults. In most of the cases generally stator current is monitored to protect the motor form the destructive over current and ground current. Therefore, current monitoring is a sensor less detection can be implemented for different type of motor protection without any extra hardware. This current monitoring is more effective, more efficient and moreover it is highly sensitive as compared to other monitoring methods. Therefore, this electrical monitoring is more preferable for the modern researchers [CRU 99, ZOM 00, HAB 02, RAM 04, PIR 09].

5.2.5.1 Current Signature Analysis

Large machine are often equipped with mechanical sensors, primarily vibration sensors based on proximity probes. But they are very delicate and expensive. Moreover, in many situations, vibration monitoring methods are utilized to detect the presence of incipient failure. However, it has been suggested that stator current monitoring can provide the same indications without requiring access to the motor. Therefore, the researchers are concentrated their research on the so-called motor current signature analysis. This technique utilizes results of spectral analysis of the stator current (precisely, the supply current) of an induction motor to spot an existing or incipient failure of the motor or the drive system. Spectral analysis of the stator current allows to obtain a characteristic spectral signature which can be easily distinguished from abnormal operating condition and then identified as a potential failure mode. Some of the faults can be analyzed by the above methods are broken bars in the rotor cage, rotor eccentricity, worn or damaged bearings, shaft speed oscillation, and electrical-based faults (unbalanced voltage and single-phasing effects). Experimental investigations, for high-resolution analysis, have been carried out only for electrical-based faults detection and localization [WAL 92, BEN 99, THO 00, HAB 02, TRA 08, DRO 12, MED 13].

The combination of current signature analysis to detect rotor related problems and partial discharge monitoring to assess the health of high voltage stator windings can therefore provide a very powerful monitoring strategy for induction motor drives [SWE 10].

In the papers [RAN 95, SCH 95, BEN 99, ELH 00, BEL 01] an intended overview is given on the induction motors signature analysis as a medium for fault detection. In [RAM 04] described the design and application of an on-line diagnostic system for squirrel cage induction motors based on inductive acquisition and sideband analysis of phase current. Frequency and time domain phase current study allows sideband analysis and its correlation to motor diagnosis. Faults included are broken bar and eccentric gap to evaluate current phase modification according to faults severity. In [CHA 93,HAB 02] a complete summary of techniques for monitoring and protecting each major component of a low voltage, line connected induction motor is given.

5.2.5.2 Current Park's Vector

Another important electrical monitoring technique is Current Park's vector technique. The basic concept of Current Park's vector technique is the connection to stator windings of a three phase induction motor generally does not use a neutral [HAR 88, ZHE 04]. The stator current has no zero sequence component for star connected induction motor. Current park's vector is the two dimensional representation of three phase current. This current park's vector is regarded as the description of motor condition. Under ideal condition balanced three phase currents lead to a park's vector that is a circular pattern centered at the origin of coordinates. Therefore the motor condition can be monitored and presence of the fault can be detected by monitoring the deviation of Current Park's vector [ONE 06, ABI 13, SAH 13].

In [NEJ 99, NEJ 00] various applications of artificial neural networks (ANNs) presented in the literature prove that such technique is well suited to cope with online fault diagnosis in induction motors. The proposed methodology is based on the so-called Park's vector approach. In fact, stator current Park's vector patterns are first trained, using artificial neural network's (ANN), and then used to discern between "healthy" and "faulty" induction motors. The obtained results provide a satisfactory level of accuracy, indicating a promising industrial application of the hybrid Park's vector-neural networks approach. In the paper [CAR 97, CAR 99, CAR99a] the subject of on-line detection and location of inter-turn short circuits in the stator windings of three-phase induction motors is discussed, and a noninvasive approach, based on the computer-aided monitoring of the stator current Park's vector, is introduced. The researchers are also shown the experimental results, obtained by using a special fault producing test rig and hence effectiveness of the proposed technique is proved. In [CRU 99, MIR 04] on-line detection of rotor cage faults in three-phase induction motors is discussed, and a noninvasive approach, based on computer-aided monitoring of the stator current Park's vector, is introduced. Both simulation and laboratory test results are shown to prove the effectiveness of the proposed technique, for detecting broken rotor bars or end-rings in operating three-phase induction machines.

6. Diagnostic Techniques for Induction Motor Faults

6.1 Model based techniques

Model based diagnosis defines an asymmetrical induction motor whose model is used to predict failure fault signatures. The difference between measured and simulated signatures is used as a fault detector [HUR 96, VEN 05, PED 07, ADH 09]. In the paper [ZHI 05,BAG 07] a low order differential model is proposed and through which mathematical analysis is introduced for induction machine for faulty stator. An adaptive Kalman filter is proposed for recursively estimating the states and parameters of continuous-time model with discrete measurements for fault detection ends [OHY 06]. Typical motor faults as inter-turn short circuit and increased winding resistance are taken into account. In the paper [WAL 92,YON 13] authors propose a new frequency analysis of stator current to estimate fault-sensitive frequencies and their amplitudes for broken rotor bars (BRBs). The proposed method employs a frequency estimator, an amplitude estimator, and a fault decision module. Feng Lu, Hai-Lian Du [FEN 04] explained rotor fault detection system based on multi-sensor data fusion estimation of induction motor model, which makes use of strong tracking ability to the abrupt state [ROG 95, SHE 04]. Due to the soft computing era there is a trend to make the mathematical modeling of the machine and through the parameter estimation technique the different faults are diagnosed. This parameter estimation is a novel technique which helps us not only to diagnose the fault, but also provides accurate and fast detection [KEY 95,FAI 95, SHA 97, XIA 03, ALJ 03, TAN 05, GHO 09, WIE 10]. Model based technique has been implemented in two ways (a) parameter/state estimation method and (b) residual generation method [ZOC 85, SHA 99,LEB 08, BOG 11a, MON 13, CON 13, YON 13].

6.2 Signal Processing Techniques

Signal based diagnosis relies on advances in digital technology. It looks for known fault signatures in quantities sampled from the actual machine [KAI 09]. The signatures are then monitored by suitable signal processors. Signal processing can be used to enhance signal to noise ratio (SNR) and to normalize data in order to isolate the fault from other phenomena and decrease sensitivity to operating conditions. Data based diagnosis does not require any knowledge of machine parameters and model. It relies only on signal processing and on clustering techniques. Signal processing techniques can be further divided into different subclasses. The subclasses are shown here and discussed individually [BEN 99, DRI 02, ROD 08a, SEU 11, KUM 11, ELH 12, KEC 13]

(i)Spectrum through Frequency Domain Method

(a) Fast Fourier Transform (FFT)

(ii) Spectrum Through Time Frequency Domain method

(a) Short Time Fourier Transform (STFT)

(b) Gabor Transform (GT)

(c) Winger-Ville Distribution (WVD)

(iii) Wavelet Transform

6.2.1 Fast Fourier Transform (FFT)

Although Discrete Fourier Transform (DFT) is the most straight mathematical procedure for determining frequency content of a time domain sequence, but it is terribly inefficient. As the number of points in the DFT is creased to hundreds or thousands, the amount of necessary number crunching becomes excessively large. Hence, modified algorithm is proposed and it is known as the Fast Fourier Transform (FFT) [VEN 01, LIU 10, BOQ 13]. A lot of intensive research has been done on the motor current signature analysis. This technique utilizes the results of spectral analysis of the stator current. Reliable interpretation of the spectra is difficult, since distortions of the current waveform caused by the abnormalities in the drive system are usually minute [BOQ 12]. Benbouzid M. E. H. [BEN 99a] used the frequency signature of asymmetrical motor faults are well identified using the fast Fourier transform (FFT), leading to a better interpretation of the motor current spectra. It is shown that the motor current signature FFT-based analysis is still reliable tool for induction motor asymmetrical faults detection. In the paper [BEL 08] statistical time-domain techniques are used to track grid frequency and machine slip. Here either a lower computational cost or a higher accuracy than traditional discrete Fourier transform techniques can be obtained. Then, the knowledge of both grid frequency and machine slip is used to tune the parameters of the zoom fast Fourier transform algorithm that either increases the frequency resolution and/or reducing the computational cost. The proposed technique is validated for rotor faults. Traditional analysis methods, based on the fast Fourier transform (FFT), have some limitations, such as diagnosis under low load conditions, due to the spectral leakage effect, or the need of using long time samples for achieving sufficient resolution in the frequency domain. [BEN 99a].

6.2.3 Short Time Fourier Transform (STFT)

In the paper [ARA 07], an experimental study for detecting of rotor faults in three-phase squirrel cage induction motors has been done by short time Fourier transform (STFT). The frequency spectrum of motor line current is exploited for the detection. By obtaining a number of frequency spectrums from a current data with STFT and averaging these spectrums, faults are diagnosed instead of fast Fourier Transform frequently applied at the detection of broken rotor faults in the literature.

6.2.4 Gabor Transform (GT)

Gabor transform (GT) is a liner time-frequency analysis method that computes a liner time frequency representation of time domain signal. Gabor spectrogram has the better time frequency resolution than that of STFT spectrogram method. Gabor spectrogram can be used for fault diagnosis of induction motor. Time-frequency analysis of the transient current in induction motors (IMs) is the basis of the transient motor current signature analysis diagnosis method. IM faults can be accurately identified by detecting the characteristic pattern that each type of fault produces in the time-frequency plane during a speed transient. A fine tuning of their parameters is needed in order to obtain a high-resolution image of the fault in the time-frequency domain, and they also require a much higher processing effort than traditional diagnosis techniques. The new method proposed in the paper [RIE 12] addresses both problems using the Gabor analysis of the current via the chirp z-transform, which can be easily adapted to generate high-resolution time-frequency stamps of different types of faults. Here, it is used to diagnose broken bars and mixed eccentricity faults of an IM using the current during a startup transient.

6.2.5 Winger-Ville Distribution (WVD)

Refaat etal. [REF 13] developed a novel, non-intrusive approach for fault-detection and diagnosis scheme of bearing faults for three-phase induction motor using stator current signals with particular interest in identifying the outer-race defect at an early stage. The empirical mode decomposition (EMD) technique is proposed for analysis of non-stationary stator current signals. The stator current signal is decomposed in intrinsic mode function (IMF) using empirical mode decomposition. The extracted IMFs apply on the Wigner-Ville Distribution (WVD) to have the contour pattern of WVD. Then, artificial neural network is used for pattern recognition that can effectively detect outer-race defects of bearing. The experimental results show that stator current-based monitoring with WVD based on EMD yields a high degree of accuracy in fault detection and diagnosis of outer-race defects at different load conditions [WEI 06, NIN 11].

6.3 Soft computing Techniques

Soft Computing Techniques (Artificial Neural Networks, Fuzzy Logic Models, Adaptive Neuro Fuzzy inference system) have been recognized as attractive alternatives to the standard, well established "hard computing" paradigms. Traditional hard computing methods are often too cumbersome for diagnosing the different faults in induction motor. They always require a precisely stated analytical model and often a lot of computational time. Soft computing techniques, which emphasize gains in understanding system behavior in exchange for unnecessary precision, have proved to be important practical tools for detecting and diagnosing the faults in induction motor [MOY 91, GOO 95, CHI 99, TIE 02, SID 03, JAN 04, KIL 07, YUL 09, MAH 10, BOG 11]. Different types of **soft computing** methods found in the literature are discussed below.

6.3.1 Artificial Neural Network Technique

A neural network can substitute in a more effective way the faulted machine models used to formalize the knowledge base of the diagnostic system with suitably chosen inputs and outputs [TAL 00, SID 04, MOO 12a]. Training the neural network by data achieved through experimental tests on healthy machines and through simulation in case of faulted machines, the diagnostic system can discern between "healthy" and "faulty" machines. This procedure substitutes the statement of a trigger threshold, needed in the diagnostic procedure based on the machine models. Many research papers [MOY 91, FIL 93, RAJ 99, TSO 99, KOL 00, KOL 07 UDD 07, OZG 10, ARA 10,GAN 12, MOO 12, MOO 12a, BOU 13] presented in the past for monitoring and fault identification of a three-phase induction motor using artificial neural networks (ANNs). Three-phase currents and voltages from the induction motor are used in the proposed approach. A feed forward multi-layered neural network structure is used. The network is trained using the back propagation algorithm. The trained network is tested with simulated fault current and voltage data. In the papers [RON 02, CRI 04, HUA 07, BAL 08, RAM 10, GHE 11 , NUS 11, , DEV 11] a protection scheme based on Wavelet Multi Resolution Analysis and Artificial Neural Networks are proposed which detects and classifies various faults like Single phasing, Under voltage, Unbalanced supply, Stator Turn fault, Stator Line to Ground fault, Stator Line to Line fault, Broken bars and Locked rotor of a three-phase induction motor.

6.3.2 Fuzzy Inference system

Fuzzy logic is a type of mathematics and programming that helps the making a model by using learning and experience for representation of vague concepts in mathematical expressions. Therefore, fuzzy systems are very useful in situations involving highly complex systems whose behaviors are not well understood and in situations where an approximate, but fast, solution is warranted. Fuzzy systems are robust because the system has been designed to control within some frame of uncertain conditions**.** In many papers**,** fuzzy logic-based induction motor protection systems was developed [LAS 00, BEN 01, ZID 03**,** TAN 05, UDD 07, UYA 13]. The motor condition is described using linguistic variables. Fuzzy subsets and the corresponding membership functions describe stator current amplitudes. A knowledge base comprising rule and data base is built to support the fuzzy inference. The induction motor condition is diagnosed using a compositional rule of fuzzy inference. In fact, fuzzy logic is reminiscent of human thinking processes and natural language enabling decisions to be made based on vague information. In the paper [AKA 12] presents the implementation of broken rotor bar fault detection in an inverter-fed induction motor using motor current signal analysis (MCSA) and prognosis with fuzzy logic. In the paper [LAS 00a**,** ROD 08] describes the application of fuzzy logic based artificial intelligence procedures to the development of a novel method for the condition monitoring and fault diagnosis of induction motors. The finite element method (FEM) is utilized to generate virtual data that support the construction of the membership functions and give the possibility to online test the proposed system. The layout has been implemented in MATLAB/SIMULINK [MAM 04, ROD 08a]; with both data from a FEM motor simulation program and real measurements. The proposed method is simple and has the ability to work with variable speed drives [VAR 99, CHE 01].

6.3.3 Adaptive Neuro Fuzzy Inference System (ANFIS)

ANFIS uses fuzzy Sugeno model as fuzzy inference system incorporated with ANNs training. It maps inputs through input membership function, rules, normalization and output membership function to output membership functions. Jang and Sun introduced the adaptive neuro-fuzzy inference system (ANFIS) in 1995. This system is called as hybrid system because it uses two different training rules to reduce the error. For ANFIS system, it uses a gradient descent algorithm training paradigm and a least square algorithm to tune the parameter of the membership function [UDD 07, MAH 10]. Fuzzy logic systems lack ability of self learning and fuzzy membership functions and fuzzy rules cannot be guaranteed to be optimal. Fusion of neural network and fuzzy logic like Adaptive network based fuzzy inference system and fuzzy adaptive learning control/decision network partly overcome the problem with reducing convergence time. Genetic Algorithm can also be used to optimize the parameter and structure of neural network and fuzzy logic systems. In the paper [GOO 95] an overview of complete current based noninvasive monitoring and protecting techniques for stator rotor, bearing and thermal overload related failure is presented. In the paper [JAN 04, TAN 05] investigates the fault diagnosis for open-switch Damages in a voltage fed PWM motor drive system. Researchers proposed a robust diagnosis method based on the Neuro-Fuzzy algorithm. For this, the Clustering Adaptive Neuro Fuzzy Inference System(C-ANFIS) has been adopted to recognize the various and vague fault patterns [UDD 07].

6.4 Wavelet Transform Analysis

The wavelet transform method can nicely be utilized for online fault detection. This method has good sensitivity and short detection time. In this method the entire signal can be reconstructed from the sets of local signals by varying scale and amplitude, but constant shape. [SAR 08, GAE 11]. In the paper [SZA 05] motor current signature analysis (MCSA) is used an often cited. In this method it uses the results of spectral analysis of the stator currents. Generally the FFT (Fast Fourier transform) is used to obtain the power density vs. frequency plots to be analyzed. Here the use of a novel versatile tool of harmonic analysis, of the wavelet transform is utilized [MAM 04, KIA 09, HEW 12]. The proposed wavelet based detection method shows a good sensitivity and reliability. In order to overcome the problems of the FFT based technique, the Short Time Fourier Transform (STFT) Method was proposed. The STFT method also suffered from the drawback that it shows the constant window for all the frequencies. Therefore, it shows poor frequency resolution. In order to overcome all the problems stated so far, the most recent powerful mathematical tool i.e. Wavelet Transform (WT) has been used in the rotor broken bar fault detection purpose at all loading conditions. Ibrahim etal. [IBR 13] presented an effective method to detect broken rotor bars fault in the induction motors[ASK 10, MOI 12]. This method is based on the analysis of the q-component of the stator current and discrete wavelet transform (DWT). Using the dynamic model of the squirrel-cage induction motor taking account the broken rotor bars. The RMS values of the discrete wavelet transform coefficients are fed to the artificial neural network (ANN) to identify the machine state. In the papers [DAS 10, HEW 12] have proposed a simulation model with the help of experimental result and presents a fault detection techniques using direct wavelet transform (DWT). In [ERE 04] the stator current is analyzed via wavelet packet decomposition to detect bearing defects [KON 11, SAR 12].

7. Proposed Work

With the recent developments in the electrical machines and modern computing techniques changed the health monitoring of induction motor. Any unprecedented failure of induction motor component may cause a huge financial loss to the utilities. Therefore, every component of the induction motor needs to be continuously monitored. There are many methods for health monitoring of induction motor discussed in the past.

Evolution of soft computing techniques has encouraged the researchers to develop efficient algorithms and tools for health monitoring of induction motor. The basic outline of the proposed work is as follows:

- To develop an efficient integrated soft computing tool.
- Health monitoring of induction motor using soft computing tool developed above.
- To validate the results obtained by soft computing techniques by its hardware implementation and lab experimentation.
- Evaluation of the effectiveness of developed techniques for health monitoring of induction motor at different operating conditions.

The Various steps of the proposed work are given in Fig. 6

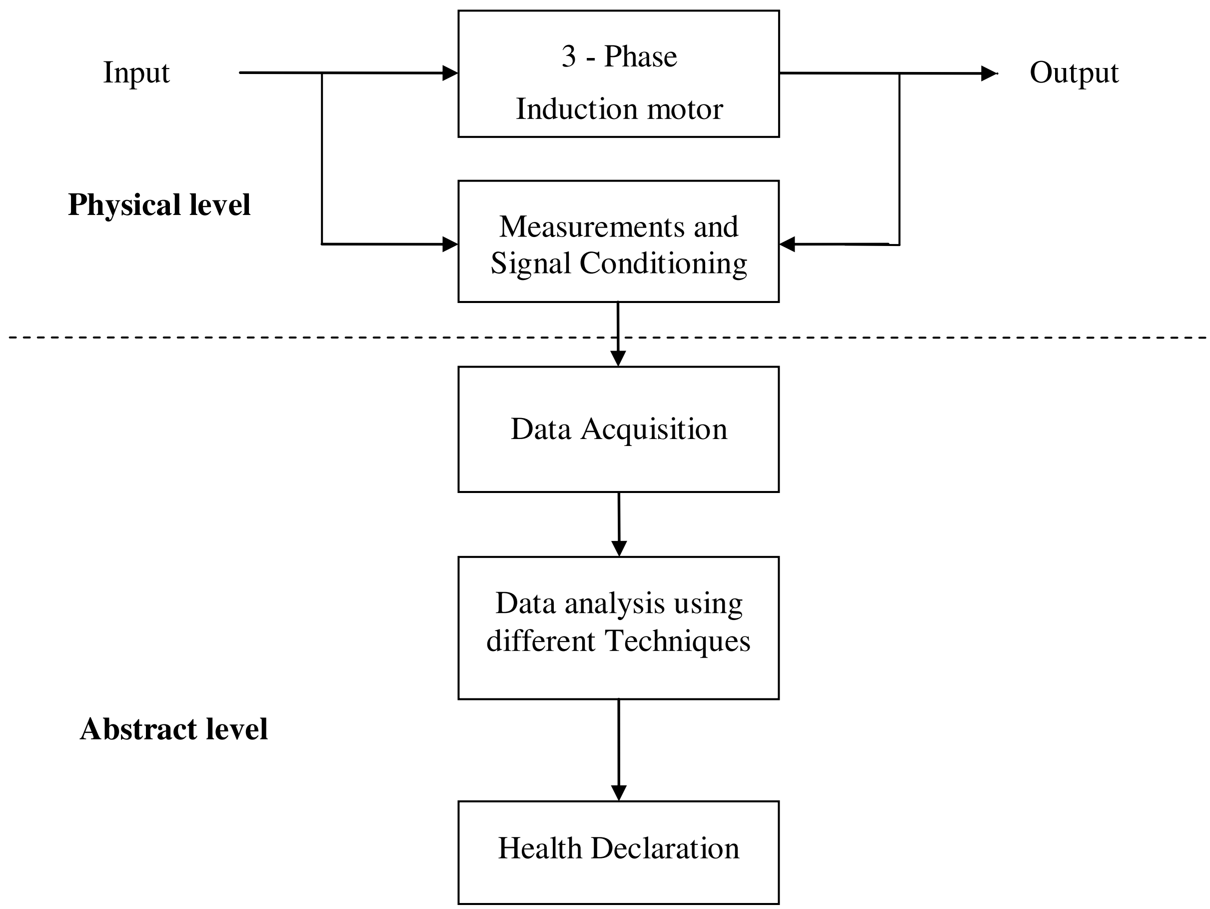

Fig.6: Flow chart of proposed method for health monitoring system for Three Phase Induction Motor

8. References

[ABI 13] Abitha M. W., Rajini V., (Feb 2013), "Park's vector approach for online fault diagnosis of induction motor", *Information Communication and Embedded Systems (ICICES), IEEE International Conference, pp. 1123 – 1129.*

[ADE 06] Aderiano M., Da Silva B. S., (May 2006), "Induction motor fault diagnostic and monitoring methods", *Milwaukee, Wisconsin, pp. 1 – 159.*

[ADH 09] Adhikari S., Fangxing Li, Huijuan Li, Yan Xu, Kueck J. D., Rizy D. T., (June-July 2009), "Preventing delayed voltage recovery with voltage-regulating distributed energy resources", *PowerTech, IEEE Bucharest, pp. 1 – 6.*

[AKA 12] Akar Mehmet, Ankaya Ilyas C., (2012), "Broken rotor bar fault detection in inverter-fed squirrel cage induction motors using stator current analysis and fuzzy logic", *Turk J Elec Eng & Comp Sci, Vol. 20, No. Sup. 1, pp. 1077 – 1089.*

[AKP 96] Akpinar K., Pillay P., Richards G. G., (Feb 1996), "Induction motor drive behavior during unbalanced faults", *Electric Power Systems Research, Volume 36, Issue 2, Pages 131 – 138.*

[ALB 02] Albers T., Bonnett A. H., (Nov-Dec 2002), "Motor temperature considerations for pulp and paper mill applications", Industry Applications, *IEEE Transactions on (Volume 38, Issue 6)., pp. 1701 – 1713.*

[ALJ 03] Al-Jufout Saleh A., (Nov 2003), "Modeling of the cage induction motor for symmetrical and asymmetrical modes of operation", *Computers & Electrical Engineering, Volume 29, Issue 8, November 2003, Pages 851 – 860.*

[ANA 82] Anazawa Y., Kaga A., Akagami H., Watabe S., Makino M., (Nov 1982), "Prevention of harmonic torques in squirrel cage induction motors by means of soft ferrite magnetic wedges", *Magnetics, 1982 IEEE Transactions on (Volume 18, Issue 6)., pp. 1550 – 1552.*

[AND 99] Anderson P., (1999), "Motor Protection", *Book Title: Power System Protection, Publisher: Wiley-IEEE Press., Edition:1., pp. 751 – 803.*

[ARA 07] Arabaci H., Bilgin O., (June 2007) "The Detection of Rotor Faults By Using Short Time ourier Transform", *Signal Processing and Communications Applications, SIU 2007. IEEE 15th, pp.1 – 4.*

[ARA 10] Arabacı Hayri, Bilgin Osman., (July 2010). "Automatic detection and classification of rotor cage faults in squirrel cage induction motor", *Neural Computing and Applications, Volume 19, Issue 5, pp. 713 – 723.*

[ASK 10] Askari M.R., Kazemi M.,(Aug-Sept 2010), "Using Wavelet theory for detection of broken bars in squirrel cage induction motors", *Universities Power Engineering Conference (UPEC), 45th International., pp. 1 – 6.*

[BAG 07] Bagheri F.,Khaloozaded H., Abbaszadeh K., (June 2007), "Stator fault detection in induction machines by parameter estimation, using adaptive kalman filter", *Control & Automation, IEEE MED '07. Mediterranean Conference, pp.1 – 6.*

[BAI 88] Bailey J.D., (Sept-Oct 1988) , “Factors influencing the protection of small-to-medium size induction generators”, *Industry Applications, IEEE Transactions on (Volume 24 , Issue 5)., pp. 955 – 964.*

[BAL 08] Ballal Makarand S., Suryawanshi Hiralal M., Mishra Mahesh K., (April 2008), “Detection of Incipient Faults in Induction Motors using FIS, ANN and ANFIS Techniques”, *Journal of Power Electronics, Vol. 8, No. 2, pp. 181-191.*

[BAS 08] Bastiaensen C., Deprez W., Symens W., Driesen J., (Dec 2008), “Parameter Sensitivity and Measurement Uncertainty Propagation in Torque-Estimation Algorithms for Induction Machines”, *Instrumentation and Measurement, IEEE Transactions on (Volume 57, Issue 12)., pp. 2727 – 2732.*

[BAY 07] Bayindir Ramazan, Sefa Ibrahim., (March 2007), “Novel approach based on microcontroller to online protection of induction motors”, *Energy Conversion and Management, Volume 48, Issue 3, Pages 850–856.*

[BAY 08] Bayindir R., Sefa I., Colak I. , Bektas A., (Sept 2008), “Fault Detection and Protection of Induction Motors Using Sensors”, *Energy Conversion, IEEE Transactions on (Volume:23 , Issue: 3)., pp. 734 – 741.*

[BEG 99] Beguenane R., Benbouzid M. E. H., (Sept 1999), “Induction motors thermal monitoring by means of rotor resistance identification”, *Energy Conversion, IEEE Transactions on (Volume 14 , Issue 3)., pp. 566 – 570.*

[BEL 01] Bellini A., Filippetti F., Franceschini G., Tassoni C., Kliman G. B., (Sept-Oct 2001), “Quantitative evaluation of induction motor broken bars by means of electrical signature analysis”, *Industry Applications, IEEE Transactions on (Volume 37 , Issue 5)., pp. 1248 – 1255.*

[BEL 08] Bellini A, Yazidi A., Filippetti F., Rossi C., Capolino G. A., (Dec 2008), “High Frequency Resolution Techniques for Rotor Fault Detection of Induction Machines”, *Industrial Electronics, IEEE Transactions on (Volume 55 , Issue 12)., pp. 4200 – 4209.*

[BEN 99] Benbouzid M. E. H., Vieira M., Theys C., (Jan 1999), “Induction motors' faults detection and localization using stator current advanced signal processing techniques“, *Power Electronics, IEEE Transactions on (Volume 14, Issue 1)., pp. 14 – 22.*

[BEN 99a] Benbouzid M. E. H., Nejjari H., Beguenane R., Vieira M., (Jun 1999), “Induction motor asymmetrical faults detection using advanced signal processing techniques” *Energy Conversion, IEEE Transactions on (Volume 14, Issue 2)., pp. 147 – 152.*

[BEN 01] Benbouzid M. E. H., Nejjari H., (Jun 2001), “A simple fuzzy logic approach for induction motors stator condition monitoring”, *Electric Machines and Drives Conference, IEMDC. IEEE International., pp. 634 – 639.*

[BIM 11] Bimbhra P. S. (2011), “*Electrical Machinery*”, Khanna Publication, New Delhi.

[BOG 11] Boglietti A., Cavagnino A., Lazzari M., (Sept 2011), “Computational Algorithms for Induction-Motor Equivalent Circuit Parameter Determination—Part I: Resistances and Leakage Reactances”, *Industrial Electronics, IEEE Transactions on (Volume 58, Issue 9)., pp. 3723 – 3733.*

[BOG 11a] Boglietti A., Cavagnino A., Lazzari M., (Sept 2011), “Computational Algorithms for Induction Motor Equivalent Circuit Parameter Determination—Part II: Skin Effect and Magnetizing Characteristics”, *Industrial Electronics, IEEE Transactions on (Volume 58, Issue 9)., pp. 3734 – 3740.*

[BON 98] Bonnett A. H., (June 1998), “Cause, analysis and prevention of motor shaft failures”, *Pulp and Paper Industry Technical Conference, Conference Record of 1998 Annual., pp. 166 – 180.*

[BOO 74] Boothman D. R., Elgar, Everett C., Rehder R. H., Wooddall R. J., (Sept 1974), “Thermal Tracking-A Rational Approach to Motor Protection”, *Power Apparatus and Systems, IEEE Transactions on (Volume PAS-93, Issue 5)., pp. 1335 – 1344.*

[BOQ 12] Boqiang Xu, Liling Sun, Lie Xu, Guoyi Xu., (Sept 2012), “An ESPRIT-SAA-Based Detection Method for Broken Rotor Bar Fault in Induction Motors”, *Energy Conversion, IEEE Transactions on (Volume 27, Issue 3)., pp. 654 – 660.*

[BOQ 13] Boqiang Xu, Liling Sun, Lie Xu, Guoyi Xu, (March 2013), “Improvement of the Hilbert Method via ESPRIT for Detecting Rotor Fault in Induction Motors at Low Slip”, *Energy Conversion, IEEE Transactions on (Volume 28, Issue 1)., pp. 225 – 233.*

[BOU 13] Boukra T., Lebaroud A., Clerc G., (Sept 2013), “Statistical and Neural-Network Approaches for the Classification of Induction Machine Faults Using the Ambiguity Plane Representation”, *Industrial Electronics, IEEE Transactions on (Volume 60, Issue 9)., pp. 4034 – 4042.*

[BRE 94] Bredthauer Jurgen, Struck N., (sep 1994), “Starting of large medium voltage motors design, protection and safety aspects”, *Petroleum and Chemical Industry Conference, Record of Conference Papers., IEEE Incorporated Industry Applications Society 41st Annual., pp. 141 – 151.*

[BRI 82] Brighton Robert J., Ranade Prashant N., (Nov 1982), “Why Overload Relays Do NOT Always Protect Motors”, *Industry Applications, IEEE Transactions on (Volume IA-18, Issue 6)., pp. 691 – 697.*

[BUL 11] Bulychev A. V., Erokhin E. Yu., (2011), Pozdeev N. D., and Filichev O. A., “Thermal model of induction motor for relay protection*”, ISSN 1068_3712, Russian Electrical Engineering, Vol. 82, No. 3, pp. 144–148. © Allerton Press, Inc., 2011.*

[CAR 97] Cardoso A. J. M., Cruz S. M. A., Fonseca D. S. B., (May 1997), “Inter-turn stator winding fault diagnosis in three-phase induction motors, by Park's Vector approach”, *Electric Machines and Drives Conference Record, IEEE International, pp. MB1/5.1 – MB1/5.3.*

[CAR 99] Cardoso A. J. M., Cruz S. M. A., Fonseca D. S. ., (Sept 1999), “Inter-turn stator winding fault diagnosis in three-phase induction motors, by Park's vector approach”, *Energy Conversion, IEEE Transactions on (Volume 14, Issue 3)., pp. 595 – 598.*

[CAR 99a] Cardoso A. J. M., Cruz S. M. A., Carvalho, J. F. S. , Saraiva E. S., (Oct 1999), “Rotor cage fault diagnosis in three-phase induction motors, by Park's vector approach”, *Industry Applications Conference, Thirtieth IAS Annual Meeting, IAS '95., Conference Record of the IEEE (Volume 1)., pp. 642 - 646.*

[CEL 04] Cele L. Z. , Chol A. M. , Chidzonga R. ., (Sept 2004), “Problems on high failure incidence of induction motors and protection”, *AFRICON, IEEE. 7th AFRICON Conference in Africa (Volume 2)., pp. 1143 – 1147.*

[CHA 93] Chattopadhyay S., Key Thomas S., (May 1993), “Predicting behavior of induction motors during electrical service faults and momentary voltage interruptions”, *Industrial and Commercial Power Systems Technical Conference, IEEE Conference Record, Papers Presented at the 1993 Annual Meeting., pp. 78 – 84.*

[CHA 08] Chafai Mahfoud, Refoufi Larbi, Bentarzi Hamid., (April 2008), “Reliability Assessment and Improvement of Large Power Induction Motor Winding Insulation Protection System Using Predictive Analysis”, *Wseas Transactions On Circuits and Systems, Issue 4, Volume 7, pp. 84 – 95.*

[CHE 01] Chen Li'an, Zhang Peiming., (2001), “Simulation of motor faults and protections based on MATLAB”, *Electrical Machines and Systems, ICEMS Proceedings of the Fifth International Conference on (Volume:1)., pp. 452 - 455.*

[CHI 99] Chich-Yi Huang, Tien-Chi Chen, Ching-Lien Huang, (Oct 1999), “Robust control of induction motor with a neural-network load torque estimator and a neural-network identification”, *Industrial Electronics, IEEE Transactions on (Volume 46, Issue 5)., pp. 990 – 998.*

[CHI 99a] Ching-Yin Lee., (June 1999), “Effects of unbalanced voltage on the operation performance of a three-phase induction motor”, *Energy Conversion, IEEE Transactions on (Volume 14, Issue 2)., pp. 202 – 208.*

[COL 05] Colak I., Celik H., Sefa I., Demirbas S., (Oct 2005), “On line protection systems for induction motors”, *Energy Conversion and Management, Volume 46, Issue 17, pp. 2773–2786.*

[COL 07] Colak I., Bayindir R., Bektas A., Sefa I., Bal G., (April 2007), “Protection of Induction Motor Using PLC”, *Power Engineering, Energy and Electrical Drives, IEEE, POWERENG 2007. International Conference., pp. 96 – 99.*

[CON 13] Concari C., Franceschini G., Tassoni C., Toscani A., (Sept 2013), “Validation of a Faulted Rotor Induction Machine Model With an Insightful Geometrical Interpretation of Physical Quantities”, *Industrial Electronics, IEEE Transactions on (Volume60, Issue 9)., pp. 4074 – 4083.*

[CRA 11] Craig K., Sinclair A., (April 2011), “Motor protection retrofit: A business case”, *Protective Relay Engineers, IEEE 64th Annual Conference., Protective Relay Engineers, 2011 64th Annual Conference., pp. 222 – 229.*

[CRI 04] Cristaldi L., Lazzaroni M., Monti A., Ponci F., Zocchi F. E., (May 2004), “A genetic algorithm for fault identification in electrical drives: a comparison with neuro-fuzzy computation”, *Instrumentation and Measurement Technology Conference, IMTC 04. Proceedings of the 21st 2004 IEEE (Volume 2)., pp. 1454 - 1459 Vol.2.*

[CRU 99] Cruz S. M. A., Cardoso A. J. M., (1999), “Rotor cage fault diagnosis in three-phase induction motors by the total instantaneous power spectral analysis”, *Industry Applications Conference, Thirty-Fourth IAS Annual Meeting. Conference Record of the 1999 IEEE (Volume 3)., pp. 1929 - 1934.*

[CUM 85] Cummings Paul B., Dunki-Jacobs John R., Kerr Robert H., (May 1985), "Protection of Induction Motors Against Unbalanced Voltage Operation", *Industry Applications, IEEE Transactions on (Volume IA-21, Issue 3)., pp. 778 – 792.*

[DAS 08] Da Silva A. M., Povinelli R. J., Demerdash N. A. O., (March 2008), "Induction Machine Broken Bar and Stator Short-Circuit Fault Diagnostics Based on Three-Phase Stator Current Envelopes", *Industrial Electronics, IEEE Transactions on (Volume 55, Issue 3)., pp. 1310 – 1318.*

[DAS 10] Dash R. N., Subudhi B., Das S., (2010), "Induction motor stator inter-turn fault detection using wavelet transform technique", *Industrial and Information Systems (ICIIS), IEEE International Conference, pp. 436 – 441.*

[DAS 13] Da Silva A., Demerdash N., Povinelli R., (Jan 2013), "Rotor Bar Fault Monitoring Method Based on Analysis of Air-gap Torques of Induction Motors", *Industrial Informatics, IEEE Transactions on (Volume PP, Issue 99)., pp.1 – 10.*

[DEC 95] De Castro J. E., Beck R. T., Cai C., Yu L., (Sept-Oct1995), "Stall protection of large induction motors", *Industry Applications, IEEE Transactions on (Volume 31, Issue 5)., pp. 1159 – 1166.*

[DEV 98] De Vault B., Heckenkamp D., King T., (June 1998), "Selection of short-circuit protection and control for Design E motors", *Pulp and Paper Industry Technical Conference, IEEE, Conference Record of 1998 Annual., pp. 220 – 232.*

[DEV 99] De Vault B. , Heckenkamp D., King T., (May-June 1999), "Selection of short-circuit protection and control for Design E motors", *Industry Applications Magazine, IEEE (Volume 5, Issue 3).*

[DEV 11] Devi N. R., Rao P. V. R., Gafoor S. A., (Dec 2011), "Wavelet — ANN based fault diagnosis in three phase induction motor", *India Conference (INDICON), 2011 Annual IEEE., pp. 1 – 8.*

[DIS 98] Dister C. J., Schiferl R., (Oct 1998), "Using temperature, voltage, and/or speed measurements to improve trending of induction motor RMS currents in process control and diagnostics", *Industry Applications Conference, Thirty-Third IAS Annual Meeting. The 1998 IEEE (Volume 1)., pp. 312 – 318.*

[DRI 02] Drif M., Benouzza N., Kraloua B., Bendiabdellah A., Dente J. A., (June 2002) "Squirrel cage rotor faults detection in induction motor utilizing stator power spectrum approach", *Power Electronics, Machines and Drives, IEE. International Conference on (Conf. Publ. No. 487)., pp. 133 – 138.*

[DRO 12] Drobnic Klemen, Nemec Mitja, Fiser Rastko, Ambrozic Vanja, (Aug 2012), "Simplified detection of broken rotor bars in induction motors controlled in field reference frame", *Control Engineering Practice, Volume 20, Issue 8, Pages 761–769.*

[EID 70] Eidson Leslie U., Regotti Alfred A., (May 1970), "Relaying Requirements for Pipe-Line Pump Motors", *Industry and General Applications, IEEE Transactions on (Volume IGA-6, Issue 3)., pp. 272 – 277.*

[ELH 00] El Hachemi Benbouzid M., (Oct 2000), "A review of induction motors signature analysis as a medium for faults detection", *Industrial Electronics, IEEE Transactions on (Volume 47, Issue 5)., pp. 984 – 993.*

[ELH 12] El-Halim Ahmed. F. Abd, Abdulla Mohamed. M., El-Arabawy Ibrahim.F., (Oct 2012), "Practical methodology of control and protection of field oriented induction machine using digital signal processing”, *Computer Theory and Applications (ICCTA), IEEE 22nd International Conference., pp. 122 – 126.*

[ELK 92] Elkasabgy N. M., Eastham Anthony R., Dawson Graham E., (Jan-Feb 1992), “Detection of broken bars in the cage rotor on an induction machine”, *Industry Applications, IEEE Transactions on (Volume 28 , Issue 1)., pp. 165 – 171.*

[ELL 71] Ellison A. J. Yang S. J., (Jan 1971), “Effects of rotor eccentricity on acoustic noise from induction machines”, *Electrical Engineers, IEE Proceedings of the Institution of (Volume 118, Issue 1)., pp. 174 – 184.*

[ELS 89] El-Sadek M. Z., Abdelbarr F. N., (Sept 1989), “Effects of induction motor load in provoking transient voltage instabilities in power systems”, *Electric Power Systems Research, Volume 17, Issue 2, Pages 119 – 127.*

[EMA 03] Emara H. M., Ammar M. E., Bahgat A., Dorrah H. T., (June 2003) “Stator fault estimation in induction motors using particle swarm optimization”, *Electric Machines and Drives Conference, IEEE. IEMDC'03. IEEE International (Volume:3)., pp. 1469 - 1475.*

[ERE 04] Eren, L., Devaney, M. J., (April 2004), “Bearing damage detection via wavelet packet decomposition of the stator current”, *Instrumentation and Measurement, IEEE Transactions on (Volume 53, Issue 2)., pp. 431 – 436.*

[FAI 95] Faiz Jawad , Sharifian M. B. B., (Set 1995), “Optimum design of a three phase squirrel-cage induction motor based on efficiency maximization”, *Computers & Electrical Engineering, Volume 21, Issue 5, September 1995, Pages 367 – 373.*

[FAI 06] Faiz J., Ebrahimi B. M., (2006), “Mixed fault diagnosis in three-phase squirrel-cage induction motor using analysis of air-gap magnetic field”, *Progress In Electro Magnetics Research, PIER 64, pp. 239 – 255.*

[FAI 07] Faiz J., Lotfi-fard S., Shahri S. H., (July 2007), “Prony-Based Optimal Bayes Fault Classification of Overcurrent Protection”, *Power Delivery, IEEE Transactions on (Volume 22, Issue 3)., pp. 1326 – 1334.*

[FAI 10] Faiz Jawad, Ebrahimi Bashir Mahdi, Toliyat H. A., Abu-Elhaija W. S., (July 2010), “Mixed-fault diagnosis in induction motors considering varying load and broken bars location”, *Energy Conversion and Management, Volume 51, Issue 7, Pages 1432 –1441.*

[FAR 07] Farahani H. F., Hafezi H. R., Habibinia D., Jalilian A. R., Shoulaei A., (Sept 2007), “Investigation of unbalance supplying voltage on the thermal behavior of Squirrel Cage Induction motor using monitoring system”, *Universities Power Engineering Conference, UPEC 2007. 42nd International., pp. 210 – 216.*

[FEN 04] Feng Lu, Hai-Lian Du, Zhe-Jun Diao, Xi-Yuan Ju, (Aug 2004), “Rotor fault diagnosis based on fusion estimation of multi-circuit model of induction motor” *Machine Learning and Cybernetics, Proceedings of 2004 International Conference, pp.2157 - 2161 vol.4.*

[FIL 93] Filippetti F., Franceschini G., Tassoni C., (Oct 1993), “Neural networks aided on-line diagnostics of induction motor rotor faults”, *Industry Applications Society Annual Meeting, Conference Record of the 1993 IEEE., pp. 316 - 323 vol.1.*

[FIL 94] Filho E. R., Riehl R. R., Avolio E., (May 1994), “Automatic three-phase squirrel-cage induction motor test assembly for motor thermal behaviour studies”, *Industrial Electronics, Symposium Proceedings, ISIE '94., 1994 IEEE International Symposium., pp. 204 – 209.*

[FIN 95] Finley W. R., Burke R. R., (June1995), “Installation of motors for trouble free operation”, *Pulp and Paper Industry Technical Conference, IEEE., Conference Record of 1995 Annual., pp. 153 – 164.*

[FIR 12] Fireteanu V., Taras P., (Feb 2012), “Diagnosis of induction motor rotor faults based on finite element evaluation of voltage harmonics of coil sensors”, *Sensors Applications Symposium (SAS), IEEE., pp. 1 – 5.*

[GAE 11] Gaeid K. S., Hew Wooi Ping, Masood M. K., Saghafinia A., (Dec 2011), “Induction motor fault tolerant control with wavelet indicator”, *Transportation, Mechanical, and Electrical Engineering (TMEE), IEEE International Conference., pp. 949 – 953.*

[GAN 12] G. Anand, (2012), “Application of Artificial Neural Networks in Electrical Machines: An Overview”, *World Academy of Science, Engineering and Technology 66 2012, pp. 409-410.*

[GHE 11] Ghate V. N., Dudul S. V., (May 2011), “Cascade Neural-Network-Based Fault Classifier for Three-Phase Induction Motor”, *Industrial Electronics, IEEE Transactions on (Volume:58, Issue: 5)., pp. 1555 – 1563.*

[GHO 09] Ghoggal A., Zouzou S.E., Razik H., Sahraoui M., Khezzar A., (May 2009), “An improved model of induction motors for diagnosis purposes – Slot skewing effect and air–gap eccentricity faults”, *Energy Conversion and Management, Volume 50, Issue 5, Pages 1336–1347.*

[GNA 08] Gnacinski P., (April 2008), “Prediction of windings temperature rise in induction motors supplied with distorted voltage”, *Energy Conversion and Management, Volume 49, Issue 4, Pages 707 – 717.*

[GOL 04] Golovanov N., Lazaroiu G. C., Leva S., Zaninelli D., (Sept 2004), “Induction motor supply voltage variations for distribution system faults”, *Harmonics and Quality of Power, IEEE 11th International Conference., pp. 272 – 278.*

[GOM 02] Gomez J. C., Morcos M. M., Reineri C. A., Campetelli G. N., (Aprl 2002), “Behavior of induction motor due to voltage sags and short interruptions”, *Power Delivery, IEEE Transactions on (Volume 17, Issue 2)., pp. 434 – 440.*

[GOO 95] Goode P. V., Mo-Yuen Chow., (April 1995), “Using a neural/fuzzy system to extract heuristic knowledge of incipient faults in induction motors: Part II-Application”, *Industrial Electronics, 1995 IEEE Transactions on (Volume 42, Issue 2)., pp. 139 – 146.*

[GOU 10] Guo Qiyi, Huang Shize, Guo Yuping, Hu Jingtai., (Nov 2010), “Research and Realization of Motor Overload Protection Algorithm”, *E-Product E-Service and E-Entertainment (ICEEE), IEEE International Conference., pp. 1 – 5.*

[GRI 86] Griffith J. W., Mc Coy R. M., Sharma D. K., (Sept 1986), “Induction Motor Squirrel Cage Rotor Winding Thermal Analysis”, *Energy Conversion, IEEE Transactions on (Volume EC-1, Issue 3)., pp. 22 – 25.*

[HAB 02] Habetler T. G., Harley, R. G., Tallam R. M., Sang-Bin Lee, Obaid R., Stack J., (Oct 2002), “Complete current-based induction motor condition monitoring: stator, rotor, bearings, and load”, *Power Electronics Congress, Technical Proceedings. CIEP 2002. VIII IEEE International., pp. 3 – 8.*

[HAJ 01] Haji M., Toliyat H. A., (Dec 2001), “Pattern recognition-a technique for induction machines rotor broken bar detection”, *Energy Conversion, IEEE Transactions on (Volume 16, Issue 4)., pp. 312 – 317.*

[HAJ 02] Haji M., Ahmed S., Toliyat H. A., (2002), “Induction machines performance evaluator 'torque speed estimation and rotor fault diagnostic'”, *Applied Power Electronics Conference and Exposition, APEC 2002. Seventeenth Annual 2002 IEEE (Volume:2)., pp. 764 - 769.*

[HAN 05] Hanna R. A., Hiscock W., Kinowski P., (sept 2005), “Failure analysis of three slow speed induction motors for reciprocating load application”, *Petroleum and Chemical Industry Conference, IEEE. Industry Applications Society 52nd Annua., pp. 239 – 245.*

[HAN 12] Hanna R., Schmitt D. W., (July-Aug 2012), “Failure Analysis of Induction Motors: Magnetic Wedges in Compression Stations”, *Industry Applications Magazine, IEEE (Volume 18, Issue 4)., pp. 40 – 46.*

[HAR 88] Harley R. G., Makram E. B., Duran E. G., (Jun 1988), “The effects of unbalanced networks and unbalanced faults on induction motor transient stability”, *Energy Conversion, IEEE Transactions on (Volume 3, Issue 2)., pp. 398 – 403.*

[HEI 58] Heidbreder J. F., (April 1958), “Induction Motor Temperature Characteristics”, *Power apparatus and systems, part iii. transactions of the American Institute of Electrical Engineers (Volume 77, Issue 3)., pp. 800 – 804.*

[HEW 12] Hew Wooi Ping, Gaeid K. S., (Oct 2012), “Detection of induction motor faults using direct wavelet transform technique”, *Electrical Machines and Systems (ICEMS), IEEE 15th International Conference, pp. 1 – 5.*

[HOD 02] Hodowanec M. M., Finley W. R., Kreitzer S. W., (2002), “Motor field protection and recommended settings and monitoring”, *Petroleum and Chemical Industry Conference, IEEE. Industry Applications Society 49th Annual., pp. 271 – 284.*

[HSU 92] Hsu J. S., Woodson H., Weldon W. F., (March 1992), “Possible errors in measurement of air-gap torque pulsations of induction motors”, *Energy Conversion, IEEE Transactions on (Volume 7, Issue 1)., pp. 202 – 208.*

[HSU 95] Hsu J. S., (Sept-Oct 1995), “Monitoring of defects in induction motors through air-gap torque observation”, *Industry Applications, IEEE Transactions on (Volume 31, Issue 5)., pp. 1016 – 1021.*

[HUA 06] Huang Jin, Niu Faliang, Yang Jiaqiang., (2006), “Induction motor rotor fault diagnosis method based on double *PQ* transformation”, *Translated from* Proceedings of the Chinese Society for Electrical Engineering, *26(13).*

[HUA 07] Hua Su, Wang Xi, Kil To Chong., (Nov 2007), “Vibration Signal Analysis for Electrical Fault Detection of Induction Machine Using Neural Networks”, *Information Technology Convergence, IEEE. ISITC 2007. International Symposium., pp. 188 – 192.*

[HUN 11] Hunt R., Luna R., Patel S., (May 2011), "Protection of remotely located motors", *Industrial and Commercial Power Systems Technical Conference (I&CPS), IEEE., pp. 1 – 9.*

[HUN 12] Hunt R., Luna R., Patel S., (Nov-Dec 2012), "Protecting Remotely Located Motors: Application Issues and Solutions to the Technical Challenges", *Industry Applications Magazine, IEEE (Volume 18, Issue: 6)., pp. 37 – 49.*

[HUR 96] Hurst K. D., Habetler T. G., (jun 1996), "A self-tuning thermal protection scheme for induction machines", *Power Electronics Specialists Conference, PESC '96 Record., 27th Annual IEEE (Volume 2)., pp. 1535 - 1541.*

[HUS 04] Husain Ashfaq,(2004), "*Electric Machines*", Dhanpat Rai and Co. (Pvt.) Ltd., Delhi.

[IBR 13] Ibrahim M. M, Nekad H. J, (May 2013), " Broken Bar Fault Detection Based on the Discrete Wavelet Transform and Artificial Neural Network", *Asian Transactions on Engineering (ATE ISSN: 2221-4267) Volume 03, Issue 02, pp. 1 – 6.*

[IND XX] ----------------- "Diagnostic Maintenance and Monitoring of Machines", Indian Institute of Technology, Roorkee., Chapter –11,Case Studies., pp. 1-44.

[JAE 12] Jaehoon Kim, Inseok Yang, Donggil Kim, Hamadache M., Dongik Lee., (Oct 2012), "Bearing fault effect on induction motor stator current modeling based on torque variations", *Control, Automation and Systems (ICCAS), 2012 12th International Conference., pp. 814 – 818.*

[JAN 04] Jang-Hwan Park, Dong-Hwa Kim, Sung-Suk Kim, Dae-Jong Lee, Myung-Geun Chun., (June 2004), "C-ANFIS based fault diagnosis for voltage-fed PWM motor drive systems", *Fuzzy Information, Processing NAFIPS '04. 2004 IEEE Annual Meeting of the (Volume 1)., pp. 379 - 383.*

[JAN 07] Jangho Yun, Kwanghwan Lee, Kwang-Woon Lee, Sang Bin Lee, Ji-Yoon Yoo., (Sept 2007), "Detection and Classification of Stator Turn Faults and High Resistance Electrical Connections for Induction Machines", *Industry Applications Conference, 42nd IAS Annual Meeting. Conference Record of the 2007 IEEE., pp. 1923 – 1931.*

[JAN 09] Jangho Yun, Kwanghwan Lee, Kwang-Woon Lee, Sang Bin Lee, Ji-Yoon Yoo., (March-April 2009), "Detection and Classification of Stator Turn Faults and High-Resistance Electrical Connections for Induction Machines", *Industry Applications, IEEE Transactions on (Volume 45, Issue 2)., pp. 666 – 675.*

[KAR 08] Karugaba S., Ge Wang, Ojo O., Omoigui M., (Sept 2008), "Dynamic and steady-state operation of a five phase induction machine with an open stator phase", *Power Symposium, IEEE. NAPS '08. 40th North American., pp. 1 – 8.*

[KEC 13] Kechida Ridha, Menacer Arezki, Talhaoui Hicham., (June 2013), "Approach Signal for Rotor Fault Detection in Induction Motors", *Journal of Failure Analysis and Prevention, Volume 13, Issue 3, pp. 346 – 352.*

[KEY 95] Key Thomas S., (Jan-Feb 1995), "Predicting behavior of induction motors during service faults and interruptions", *Industry Applications Magazine, IEEE (Volume 1, Issue 1)., pp. 6 – 11.*

[KIA 09] Kia S. H., Henao H., Capolino G. A., (July-Aug 2009), "Diagnosis of Broken-Bar Fault in Induction Machines Using Discrete Wavelet Transform Without Slip Estimation", *Industry Applications, IEEE Transactions on (Volume 45, Issue 4).,*

[KIL 07] Kilic E., Ozgonenel O., Ozdemir Ali Ekber., (May 2007), "Fault Identification in Induction Motors with RBF Neural Network Based on Dynamical PCA", *Electric Machines & Drives Conference, IEMDC '07. IEEE International (Volume:1)., pp. 830 – 835.*

[KLI 88] Kliman G. B., Koegl R. A., Stein J., Endicott R. D., Madden M. W., (Dec 1988), "Noninvasive detection of broken rotor bars in operating induction motors", *Energy Conversion, IEEE Transactions on (Volume 3, Issue 4)., pp. 873 – 879.*

[KLI 96] Kliman G. B., Premerlani W. J., Koegl R. A., Hoeweler D., (Oct 1996), "A new approach to on-line turn fault detection in AC motors", *Industry Applications Conference, Thirty-First IAS Annual Meeting, IAS '96., Conference Record of the 1996 IEEE (Volume:1)., pp. 687 – 693.*

[KOA 00] Koang-Kyun La, Myoung-Ho Shin, Dong-seok Hyun., (Oct 2000), "Direct Torque Control of induction motor with reduction of torque ripple", *Industrial Electronics Society, IECON 2000. 26th Annual Conference of the 2000 IEEE (Volume:2)., pp. 1087 – 1092.*

[KOL 00] Kolla Sri, Varatharasa Logan., (Sept 2000), "Identifying three-phase induction motor faults using arti®cial neural networks", *ISA Transactions, Volume 39, Issue 4, Pages 433–439.*

[KOL 07] Kolla Sri R., Altman Shawn D., (April 2007), "Artificial neural network based fault identification scheme implementation for a three-phase induction motor", *ISA Transactions, Volume 46, Issue 2, Pages 261 – 266.*

[KON 11] Konar P., Chattopadhyay P., (Sept 2011), "Bearing fault detection of induction motor using wavelet and Support Vector Machines (SVMs)", *Applied Soft Computing, Volume 11, Issue 6, Pages 4203 – 4211.*

[KPH 92] Kohler, J. L., Sottile J., Trutt F. C., (Sept-Oct 1992), "Alternatives for assessing the electrical integrity of induction motors", *Industry Applications, IEEE Transactions on (Volume 28, Issue 5)., pp. 1109 – 1117.*

[KRE 12] Kreischer C., Golebiowski L., (Oct 2012), "Detection of broken bars and rings in induction machines", *Electrical and Power Engineering (EPE), IEEE International Conference and Exposition., pp. 355 – 359.*

[KUM 11] Kumar R. S., Kumar S. S., Saravanakumar R., Selvakumar A.I., Reddy K., Varghese J.M., (July 2011), "Condition Monitoring of DSP Based Online Induction Motor External Fault Detection Using TMS320LF2407 DSP", *Process Automation, Control and Computing (PACC), IEEE International., pp. 1 – 5.*

[KUR 10] Kurek Jaroslaw, Osowski Stanislaw., (June 2010), "Support vector machine for fault diagnosis of the broken rotor bars of squirrel-cage induction motor", *Neural Computing and Applications, Volume 19, Issue 4, pp 557 – 564.*

[LAS 00] Lascu C. Boldea I., Blaabjerg F., (Jan-Feb 2000), "A modified direct torque control for induction motor sensorless drive", *Industry Applications, IEEE Transactions on (Volume 36, Issue 1)., pp. 122 – 130.*

[LAS 00a] Lasurt I., Stronach A. F., Penman J., (Jul 2000), "A fuzzy logic approach to the interpretation of higher order spectra applied to fault diagnosis in electrical machines", *Fuzzy Information Processing Society, IEEE. NAFIPS. 19th International Conference of the North American. pp. 158 – 162.*

[LEB 08] Lebenhaft E., Zeller M., (June 2008), "Estimating key parameters for protection of undocumented ac motors", *Pulp and Paper Industry Technical Conference, IEEE. PPIC 2008. Conference Record of 2008 54th Annual, pp. 1 – 7.*

[LEB 08a] Lebenhaft E., Zeller M., (Sept 2008), "Thermal protection of undocumented ac motors", *Petroleum and Chemical Industry Technical Conference, PCIC 2008. 55th 2008 IEEE., pp. 1 – 7.*

[LIU 10] Liu Yukun, Guo Liwei, Wang Qixiang, An Guoqing, Guo Ming, Lian Hao, (Nov 2010), "Application to induction motor faults diagnosis of the amplitude recovery method combined with FFT", *Mechanical Systems and Signal Processing, Volume 24, Issue 8, Pages 2961–2971.*

[LUK 98] Lukitsch W. J., (May 1998), "Selecting motor protection for plant and process optimization", *Textile, Fiber and Film Industry Technical Conference, IEEE Annual., pp. 9/1 - 9/6.*

[MAH 10] Mahamad A. K,. Hiyama T., (June 2010), "Fault classification performance of induction motor bearing using AI methods", *Industrial Electronics and Applications (ICIEA), The 5th IEEE Conference., pp. 56 – 61.*

[MAI 92] Maier R., (March-April 1992), "Protection of squirrel-cage induction motor utilizing instantaneous power and phase information", *Industry Applications, IEEE Transactions on (Volume 28, Issue 2)., pp. 376 – 380.*

[MAM 04] Mamat-Ibrahimm M. R., Tamjis M. R., Lachman T., (Nov 2004), "Condition monitoring algorithm for induction motor drive", *TENCON 2004. IEEE Region 10 Conference (Volume D)., pp. 9 - 12.*

[MAR 05] Maruthi G. S, Panduranga Vittal K., (Nov 2005), "Electrical Fault Detection in Three Phase Squirrel Cage Induction Motor by Vibration Analysis using MEMS Accelerometer" *Power Electronics and Drives Systems, IEEE. PEDS 2005. International Conference on (Volume 2)., pp. 838 – 843.*

[MAR 06] Martins Cunha C. C., Filho B. J. C., (Oct 2006), "Detection of Rotor Faults in Squirrel-Cage Induction Motors using Adjustable Speed Drives", *Industry Applications Conference, 41st IAS Annual Meeting. Conference Record of the 2006 IEEE (Volume:5)., pp. 2354 – 2359.*

[MAX 04] Maximini M., Koglin H. J., (March 2004), "Determination of the absolute rotor temperature of squirrel cage induction machines using measurable variables", *Energy Conversion, IEEE Transactions on (Volume 19, Issue 1)., pp. 34 – 39.*

[MCC 93] Mc Culloch M. D., Landy C. F., (Sept 1993), "Evaluation of the short circuit current in induction motors with deep bars", *Electrical Machines and Drives, IEEE. Sixth International Conference on (Conf. Publ. No. 376)., pp. 15 – 19.*

[MCE 11] McElveen R., Hillhouse J., Miller K., (Sept 2011), "Electric motor storage: Protecting your investment", *Petroleum and Chemical Industry Conference (PCIC), Record of Conference Papers Industry Applications Society 58th Annual 2011 IEEE., pp. 1 – 7.*

[MED 13] Medoued A., Lebaroud A., Sayad D., (Jan 2013), "Application of Hilbert transform to fault detection in electric machines", *Advances in Difference Equations, 2013:2.*

[MEH 11] Mehrjou Mohammad Rezazadeh, Mariun Norman N., Marhaban Mohammad Hamiruce, Misron Norhisam, (Nov 2011), "Rotor fault condition monitoring techniques for squirrel-cage induction machine—A review", *Mechanical Systems and Signal Processing, Volume 25, Issue 8, Pages 2827–2848.*

[MIR 04] Mirafzal B., Demerdash N. A. O., (March-April 2004), "Induction machine broken-bar fault diagnosis using the rotor magnetic field space-vector orientation", *Industry Applications, IEEE Transactions on (Volume 40, Issue 2)., pp. 534 – 542.*

[MIR 05] Mirafzal B., Demerdash N. A. O., (May-June 2005), "Effects of load magnitude on diagnosing broken bar faults in induction motors using the pendulous oscillation of the rotor magnetic field orientation", *Industry Applications, IEEE Transactions on (Volume 41 , Issue 3)., pp. 771 – 783.*

[MIR 06] Mirafzal B., Demerdash N. A. O., (March-April 2006), "On innovative methods of induction motor interturn and broken-bar fault diagnostics", *Industry Applications, IEEE Transactions on (Volume 42, Issue 2)., pp. 405 – 414.*

[MIT 10] Mittra D. K., Chatterjee T. K., Shikhar S., Kanodia, P., Uddin Nur., (March-April 2010), "A new approach for overload cum short circuit protection of three phase induction motors using axial leakage flux", *Developments in Power System Protection (DPSP). Managing the Change, 10th IET International Conference., pp. 1– 4.*

[MOG 99] Magnuson H. A., Cassidy D. J., (June 1999), "A case study of wound rotor induction motor protection", *Pulp and Paper, IEEE. Industry Technical Conference Record of 1999 Annual, pp. 233 – 237.*

[MOI 12] Moin Siddiqui K., Giri V. K., (March 2012), "Broken rotor bar fault detection in induction motors using Wavelet Transform", *Computing, Electronics and Electrical Technologies (ICCEET), IEEE International conference, pp. 1 – 6.*

[MON 13] Monjo L., Córcoles F., Pedra J., (March 2013), "Saturation Effects on Torque- and Current–Slip Curves of Squirrel-Cage Induction Motors", *Energy Conversion, IEEE Transactions on (Volume 28 , Issue 1)., pp. 243 – 254.*

[MOO 12] Moosavi S. S., Djerdir A., Ait-Amirat Y., Khaburi D.A., (June 2012), "Fault detection in 3-phase Traction Motor using Artificial Neural Networks", *Transportation Electrification Conference and Expo (ITEC), IEEE., pp. 1 – 6.*

[MOO 12a] Moosavi S. S., Djerdir A., Ait-Amirat Y., Kkuburi D. A., (Sept 2012), "Artificial neural networks based fault detection in 3-Phase PMSM traction motor", *Electrical Machines (ICEM), IEEE XXth International Conference., pp. 1579 – 1585.*

[MOY 91] Mo-Yuen Chow, Yee S. O., (Sept 1991), "Methodology for on-line incipient fault detection in single-phase squirrel-cage induction motors using artificial neural networks", *Energy Conversion, IEEE Transactions on (Volume 6, Issue 3)., pp. 536 – 545.*

[NAN 05] Nandi S., Toliyat H. A., Xiaodong Li., (Dec 2005), "Condition monitoring and fault diagnosis of electrical motors-a review", *Energy Conversion, IEEE Transactions on (Volume 20, Issue 4)., pp. 719 – 729.*

[NAN 11] Nandi S., Ilamparithi T. C., Sang Bin Lee, Doosoo Hyun., (May 2011), “Detection of Eccentricity Faults in Induction Machines Based on Nameplate Parameters”, *Industrial Electronics, IEEE Transactions on (Volume 58, Issue 5), pp. 1673 – 1683.*

[NEJ 99] Nejjari H., Benbouzid M. E. H., (May 1999), “Monitoring and diagnosis of induction motors electrical faults using a current Park's vector pattern learning approach”, *Electric Machines and Drives, IEEE International Conference IEMD '99, pp. 275 – 277.*

[NEJ 00] Nejjari H., Benbouzid M. E. H., (May-June 2000), “Monitoring and diagnosis of induction motors electrical faults using a current Park's vector pattern learning approach”, *Industry Applications, IEEE Transactions on (Volume 36, Issue 3), pp. 730 – 735.*

[NIN 11] Ning Ma, Jianxin Wang, (Jan 2011), “An Adaptive Method of Parameters Selection for SPWVD”, *Measuring Technology and Mechatronics Automation (ICMTMA), Third International Conference, pp. 363 – 366.*

[NUS 11] Nussbaumer P., Stojicic G., Wolbank T. M., (May 2011), “Exploiting switching transients for broken rotor bar detection in inverter-fed induction machines at all operating conditions”, *Electric Machines & Drives Conference (IEMDC), IEEE International., pp. 418 – 423.*

[OHY 06] Ohyama K., Asher G. M., Sumner M., (Feb 2006), “Comparative analysis of experimental performance and stability of sensorless induction motor drives”, *Industrial Electronics, IEEE Transactions on (Volume 53, Issue 1)., pp. 178 – 186.*

[ONE 06] Önel Izzet Y., Dalci K Burak Senol İbrahim., (2006), “Detection of bearing defects in three-phase induction motors using Park’s transform and radial basis function neural networks”, *Sadhana, Volume 31, Issue 3, pp. 235 – 244.*

[OZG 10] Ozgonenel O., Yalcin T., (March-April 2010), “Principal component analysis (PCA) based neural network for motor protection”, *Developments in Power System Protection (DPSP). Managing the Change, 10th IET International Conference., pp. 1 – 5.*

[PAN 00] Pankratov V., Nos O., Zima Y., (June-July 2000), “Stator current limitation in a high-performance induction motor drive”, *Science and Technology, IEEE. KORUS 2000. Proceedings. The 4th Korea-Russia International Symposium on (Volume 2)., pp. 261 – 264.*

[PAO 89] Paoletti G. J., Rose A., (May-June 1989), “Improving existing motor protection for medium voltage motors”, *Industry Applications, IEEE Transactions on (Volume 25, Issue 3)., pp. 456 – 464.*

[PAT 86] Patyk D. Sc. A., (1986), “Application of forward/backward components to the analysis of failure states of the squirrel-cage motor”, *Archiv für Elektrotechnik, Volume 69, Issue 6, pp. 439 – 443.*

[PED 07] Pedra Joaquín, Sainz Luis, Córcoles Felipe, (Oct 2007), “Effects of symmetrical voltage sags on squirrel-cage induction motors”, *Electric Power Systems Research, Volume 77, Issue 12, Pages 1672–1680.*

[PEN 94] Penman J., Sedding H. G., Lloyd B. A., Fink W. T., (Dec 1994), “Detection and location of interturn short circuits in the stator windings of operating motors”, *Energy Conversion, IEEE Transactions on (Volume 9, Issue 4)., pp. 652 – 658.*

[PEZ 12] Pezzani C, Donolo P., Bossio G., Donolo M., Guzman A., Zocholl S. E., (May 2012), "Detecting broken rotor bars with zero-setting protection", *Industrial & Commercial Power Systems Technical Conference (I&CPS), IEEE/IAS 48th., pp. 1 – 12.*

[PIN 08] Pinjia Zhang, Bin Lu, Habetler T. G., (April 2008) , "Practical implementation of a remote and sensorless stator resistance-based thermal protection method", *Condition Monitoring and Diagnosis, CMD 2008. International Conference., pp. 159 – 162.*

[PIN 09] Pinjia Zhang, Yi Du, Habetler T. G., (Sept 2009), Bin Lu., "A survey of condition monitoring and protection methods for medium voltage induction motors", *Energy Conversion Congress and Exposition, ECCE 2009. IEEE, pp. 3165 – 3174.*

[PIN 11] Pineda-Sanchez M., Puche-Panadero R., Riera-Guasp M., Sapena-Bano A., Roger-Folch J., Perez-Cruz J., (Aug-Sept 2011), "Motor condition monitoring of induction motor with programmable logic controller and industrial network", *Power Electronics and Applications (EPE), Proceedings of the 2011-14th European Conference., pp. 1 – 10.*

[PIR 09] Pires Dulce F., Pires V. Fernao, Martins J. F., Pires A. J., (April 2009), "Rotor cage fault diagnosis in three-phase induction motors based on a current and virtual flux approach", *Energy Conversion and Management, Volume 50, Issue 4, Pages 1026–1032.*

[POT 33] Potter C. P., (May 1933), "Protection of polyphase motors", *Electrical Engineering (Volume 52, Issue 5)., pp. 327 – 331.*

[RAJ 99] Rajeswaran N., Madhu T., Kalavathi M. Surya., (June 2012), "Fault diagnosis and testing of induction machine using Back Propagation Neural Network", *Power Modulator and High Voltage Conference (IPMHVC), IEEE International., pp. 492 – 495.*

[RAN 95] Rankin, D. R., (April 1995), "The industrial application of phase current analysis to detect rotor winding faults in squirrel cage induction motors", *Power Engineering Journal (Volume 9, Issue 2)., pp. 77 – 84.*

[RAN 11] Ransom D. L., Hamilton R., (April 2011), "Extending motor life with updated thermal model overload protection", *Protective Relay Engineers, IEEE 64th Annual Conference., pp. 230 – 238.*

[RAM 04] Ramirez-Cruz J. M., Garcia-Colon V. R., Carvajal-Martinez F. A., Angeles M. H., (July 2004), "Induction motors broken bar and eccentric gap on-line detection using motor signature current analysis under laboratory and field conditions", *Power Engineering, LESCOPE-04, IEEE Large Engineering systems Conference., pp. 65 – 69.*

[RAM 10] Rama Devi N, Gafoor S. A., Rao P. V. R., (June 2010), "Wavelet ANN based stator internal faults protection scheme for 3-phase induction motor", *Industrial Electronics and Applications (ICIEA), The 5th IEEE Conference, pp. 1457 – 1461.*

[REF 13] Refaat S. S., Abu-Rub H., Saad M. S., Aboul-Zahab E. M., Iqbal A., (Feb 2013), "ANN-based for detection, diagnosis the bearing fault for three phase induction motors using current signal", *Industrial Technology (ICIT), IEEE International Conference on, pp.253 – 258.*

[REG 78] Regotti Alfred A., Valentine Raymond D., (Jan 1978), "Grounding and Relaying for Pipeline Pump Motor Protection", *Industry Applications, IEEE Transactions on (Volume IA-14, Issue 1)., pp. 27 – 32.*

[RIE 12] Riera-Guasp M., Pineda-Sanchez M., Perez-Cruz J., Puche-Panadero R., Roger-Folch J., Antonino-Daviu J. A., (June 2012), "Diagnosis of Induction Motor Faults via Gabor Analysis of the Current in Transient Regime" *Instrumentation and Measurement, IEEE Transactions on (Volume 61, Issue 6), pp. 1583 – 1596.*

[ROD 08] Rodríguez Pedro Vicente Jover , Arkkio Antero., (March 2008), "Detection of stator winding fault in induction motor using fuzzy logic", *Applied Soft Computing, Volume 8, Issue 2, Pages 1112–1120.*

[ROD 08a] Rodrıguez Pedro Vicente Jover, Negrea Marian, Arkkio Antero., (July 2008), "A simplified scheme for induction motor condition monitoring", *Mechanical Systems and Signal Processing*, *Volume 22, Issue 5, Pages 1216–1236.*

[ROG 95] Rogers G. J., Beaulieu R. E., Hajagos L. M., (Aug 1995), "Performance of station service induction motors following full load rejection of a nuclear generating unit", *Power Systems, IEEE Transactions on (Volume 10, Issue 3)., pp. 1314 – 1320.*

[ROL 78] Rolls T. B., (Aug 1978), "Protection of induction motors", *Electric Power Applications, IEE Journal on (Volume 1, Issue 3), August 1978., pp. 72 – 76.*

[RON 02] Rong-Jong Wai., (Dec 2002), "Development of new training algorithms for neuro-wavelet systems on the robust control of induction servo motor drive", *Industrial Electronics, IEEE Transactions on (Volume 49, Issue 6)., pp. 1323 – 1341.*

[SAA 11] Saadaoui W., Jelassi K., (May 2011), "Induction motor bearing damage detection using stator current analysis", *Power Engineering, Energy and Electrical Drives (POWERENG), IEEE International Conference., pp. 1 – 6.*

[SAH 13] Sahraoui Mohamed, Ghoggal Adel, Guedidi Salim, Zouzou Salah Eddine., (June 2013), "Detection of inter-turn short-circuit in induction motors using Park–Hilbert method", *International Journal of System Assurance Engineering and Management, Springer-Verlag.*

[SAN 02] Sang-Bin Lee, Habetler T. G., Harley R. G., Gritter D. J., (March 2002), "An evaluation of model-based stator resistance estimation for induction motor stator winding temperature monitoring", *Energy Conversion, IEEE Transactions on (Volume 17, Issue 1)., pp. 7 – 15.*

[SAR 08] Sarlak M., Shahrtash S.M., "High impedance fault detection in distribution networks using support vector machines based on wavelet transform", Electric Power Conference, 2008. EPEC 2008. IEEE Canada.,pp. 1 – 6.

[SAR 12] Sarkar S., Das S., Purkait P., Chakravorti S., (Dec 2012), "Application of wavelet transform to discriminate induction motor stator winding short circuit faults from incipient insulation failures", *Power and Energy in NERIST (ICPEN), IEEE 1st International Conference., pp. 1 – 6.*

[SCH 56] Schmidt R.A.,(Jan 1956), "Calculation of Fault Currents for Internal Faults in A-C Motors", Power apparatus and systems, part iii. Transactions of the American institute of electrical engineers (Volume:75 , Issue: 3)., pp. 818-824.

[SCH 71] Schatz Marc W., (March 1971), "Overload Protection of Motors---Four Common Questions", *Industry and General Applications, IEEE Transactions on (Volume IGA-7, Issue 2)., pp. 196 – 207.*

[SCH 94] Schweitzer E. O. III, Zocholl S. E., (May 1994), "Aspects of overcurrent protection for feeders and motors", *Industrial and Commercial Power Systems Technical Conference, Conference Record, Papers Presented at the 1994 Annual Meeting, IEEE., pp. 245 – 251.*

[SCH 95] Schoen R. R., Habetler T. G., Kamran F., Bartfield R. G., (Nov-Dec 1995), "Motor bearing damage detection using stator current monitoring", *Industry Applications, IEEE Transactions on (Volume 31, Issue 6)., pp. 1274 – 1279.*

[SEN 10] Sentyurikhin N. I., Charakhchyan A. V., (Jan 2010), "Failures, monitoring, and diagnostics of parameters of super-high-power induction motors", *Russian Electrical Engineering, Volume 81, Issue 1, pp 45-48.*

[SEU 11] Seungdeog Choi, Akin B., Rahimian M. M., Toliyat H. A., (March 2011), "Implementation of a Fault-Diagnosis Algorithm for Induction Machines Based on Advanced Digital-Signal-Processing Techniques", *Industrial Electronics, IEEE Transactions on (Volume 58, Issue 3)., pp. 937 – 948.*

[SHA 97] Shaffer J. W., (May 1997), "Air conditioner response to transmission faults", *Power Systems, IEEE Transactions on (Volume 12, Issue 2)., pp. 614 – 621.*

[SHA 99] Shaw S. R., Leeb S. B., (Feb 1999), "Identification of induction motor parameters from transient stator current measurements", *Industrial Electronics, IEEE Transactions on (Volume 46, Issue 1)., pp. 139 – 149.*

[SHE 04] Sheng-Yen Huang, Yaw-Juen Wang., (Nov 2004), "Analysis of a three-phase induction motor under voltage unbalance using the circle diagram method", *Power System Technology, IEEE. PowerCon 2004. 2004 International Conference on (Volume 1)., pp. 165 – 170.*

[SHU 78] Shulman J. M., Elmore W. A., Bailey K. D., (Sept 1978), "Motor Starting Protection by Impedance Sensing", *Power Apparatus and Systems, IEEE Transactions on (Volume PAS-97, Issue 5)., pp. 1689 – 1695.*

[SID 03] Siddique A., Yadava G. S., Singh B., (Aug 2003), "Applications of artificial intelligence techniques for induction machine stator fault diagnostics: review", *Diagnostics for Electric Machines, Power Electronics and Drives, SDEMPED 2003. 4th IEEE International Symposium., pp. 29 – 34.*

[SID 04] Siddique A., Yadava G. S., Singh B., (Sept 2004), "Identification of three phase induction motor incipient faults using neural network", *Electrical Insulation, Conference Record of the 2004 IEEE International Symposium., pp. 30 – 33.*

[SID 05] Siddique A., Yadava G. S., Singh B., (March 2005), "A review of stator fault monitoring techniques of induction motors", *Energy Conversion, IEEE Transactions on (Volume:20, Issue 1)., pp. 106 – 114.*

[SMI 75] Smith F. D., Hanson K. L., (July 1975), "Rotor Protection of Large Motors by Use of Direct Temperature Monitoring", *Industry Applications, IEEE Transactions on (Volume IA-11, Issue 4)., pp. 340 – 343.*

[SOU 09] Soufi Y., Bahi T., Harkat M., Merabet H., (Nov 2009), "Detection of broken bars in squirrel cage induction motor", *Design and Test Workshop (IDT), IEEE 4th International., pp. 1 – 5.*

[STA 10] Stankovic Dragan, Zhiying Zhang, Voloh I., Vico J., Tivari A., Banergee A., Uppuluri S., Swigost Daniel., (March-April 2010), "Enhanced algorithm for motor rotor broken bar detection", *Protective Relay Engineers, IEEE 63rd Annual Conference., pp. 1 – 13.*

[SUD 07] Sudha M., Anbalagan P., (Nov 2007), "A Novel Protecting Method for Induction Motor Against Faults Due to Voltage Unbalance and Single Phasing", *Industrial Electronics Society, IECON 2007. 33rd Annual Conference of the IEEE., pp. 1144 – 1148.*

[SWE 10] Swędrowski Leon, (2010), "Current measurements and analysis for induction motor diagnostics", *Metrol. Meas. Syst., Vol. XVII, No. 1, pp. 87 – 94.*

[SZA 05] Szabó L., Dobai J. B., Biró K. Á., (2005), "Discrete Wavelet Transform Based Rotor Faults Detection Method for Induction Machines", *Intelligent systems at the service of mankind, vol.2., (eds:Elmenreich, W., Mmachado J. T., Redus I. J.,), Ubooks, Augsburg(Germany), pp. 63-74.*

[TAL 00] Tallam R. M., Habetler T. G., Harley R. G., Gritter D. J., Burton B. H., (Oct 2000), "Neural network based on-line stator winding turn fault detection for induction motors", *Industry Applications Conference, Conference Record of the 2000 IEEE (Volume 1)., pp. 375 - 380.*

[TAN 05] Tan W. W., Hong Huo., (Oct 2005), "A generic neurofuzzy model-based approach for detecting faults in induction motors", *Industrial Electronics, IEEE Transactions on (Volume 52, Issue 5)., pp. 1420 – 1427.*

[TES 01] Teske N., Asher G. M., Sumner M., Bradley K. J., (Nov-Dec 2001), "Encoderless position estimation for symmetric cage induction machines under loaded conditions", *Industry Applications, IEEE Transactions on (Volume 37, Issue 6)., pp. 1793 – 1800.*

[THO 84] Thomson W. T, Leonard R. A, Milne A. J, Penman J., (1984), " Failure identification of offshore induction motor systems using on-condition monitoring", *Reliability Engineering, Volume 9, Issue 1, Pages 49–64.*

[THO 97] Thorsen O. V., Dalva M., (Sept 1997), "Condition monitoring methods, failure identification and analysis for high voltage motors in petrochemical industry", *Electrical Machines and Drives, IEE Eighth International Conference on (Conf. Publ. No. 444)., pp.109 – 113.*

[THO 98] Thorsen O. V., Dalva M., (Oct 1998), "Failure identification and analysis for high voltage induction motors in petrochemical industry", *Industry Applications Conference, Thirty-Third IAS Annual Meeting. The 1998 IEEE (Volume 1)., pp. 291 - 298.*

[THO 99] Thorsen O. V., Dalva M., (Jul-Aug 1999), "Failure identification and analysis for high-voltage induction motors in the petrochemical industry", *Industry Applications, IEEE Transactions on (Volume 35, Issue 4)., pp. 810 – 818.*

[THO 99a] Thomson W. T., Rankin D., Dorrell D. G., (Dec 1999), "On-line current monitoring to diagnose airgap eccentricity in large three-phase induction motors-industrial case histories verify the predictions", *Energy Conversion, IEEE Transactions on (Volume 14, Issue 4)., pp. 1372 – 1378.*

[THO 00] Thomson W. T., Fenger M., (June 2000), "Industrial application of current signature analysis to diagnose faults in 3-phase squirrel cage induction motors", *Pulp and Paper Industry Technical Conference, IEEE. Conference Record of 2000 Annual., pp. 205 – 211.*

[THO 02] Thomas V. V., Vasudevan K., Kumar V.J., (Jun 2002), “Implementation of online air-gap torque monitor for detection of squirrel cage rotor faults using TMS320C31”, *Power Electronics, Machines and Drives, IEE, International Conference on (Conf. Publ. No. 487)., pp. 128 – 132.*

[THO 05] Thorsen O. V., Dalva M., (Oct-Sept 2005), “A survey of faults on induction motors in offshore oil industry, petrochemical industry, gas terminals, and oil refineries”, *Industry Applications, IEEE Transactions on (Volume 31, Issue 5)., pp. 1186 – 1196.*

[TIE 02] Tien-Chi Chen, Tsong-Terng Sheu, (Jun 2002), “Model reference neural network controller for induction motor speed control”, *Energy Conversion, IEEE Transactions on (Volume 17, Issue 2)., pp. 157 – 163.*

[TOU 01] Tourn D. H., Gomez J. C., (Ocr 2001), “Effect of system recovery on the induction motor protection using HBC fuses, following a short-circuit fault”, *Industry Applications Conference, Thirty-Sixth IAS Annual Meeting, Conference Record of the 2001 IEEE (Volume 3)., pp. 1838 – 1841.*

[TRA 08] Trajin B., Regnier J., Faucher J., (Jun-July 2008), “Indicator for bearing fault detection in asynchronous motors using stator current spectral analysis”, *Industrial Electronics, ISIE 2008, IEEE International Symposium., pp. 570 – 575.*

[TRA 08a] Trajin B., Regnier J., Faucher J., (Nov 2008), “Detection of bearing faults in asynchronous motors using Luenberger speed observer”, *Industrial Electronics, IECON 2008, 34th Annual Conference of 2008 IEEE., pp. 3073 – 3078.*

[TRA 09] Trajin B., Regnier J., Faucher J., (Nov 2009), “Comparison Between Stator Current and Estimated Mechanical Speed for the Detection of Bearing Wear in Asynchronous Drives”, *Industrial Electronics, IEEE Transactions on (Volume 56, Issue 11)., pp. 4700 – 4709.*

[TRZ 00] Trzynadlowski A. M., Ritchie E., (Oct 2000), “Comparative investigation of diagnostic media for induction motors: a case of rotor cage faults”, *Industrial Electronics, IEEE Transactions on (Volume 47, Issue 5)., pp. 1092 – 1099.*

[TSO 99] Tsong-Terng Sheu, Tien-Chi Chen., (Dec 1999), “Self-tuning control of induction motor drive using neural network identifier”, *Energy Conversion, IEEE Transactions on (Volume 14, Issue 4)., pp. 881 – 886.*

[UDD 07] Uddin M. N., Hao Wen., (July-Aug 2007), “Development of a Self-Tuned Neuro-Fuzzy Controller for Induction Motor Drives”, *Industry Applications, IEEE Transactions on (Volume 43, Issue 4)., pp. 1108 – 1116.*

[UYA 13] Uyar Okan, Çunkaş Mehmet., (July 2013), “Fuzzy logic-based induction motor protection system”, *Neural Computing and Applications, Volume 23, Issue 1, pp. 31 – 40.*

[VAR 99] Varatharasa L., Kolla S., (Oct 1999), “Simulation of three-phase induction motor performance during faults”, *Electrical Insulation Conference and Electrical Manufacturing & amp, Coil Winding Conference, Proceedings., pp. 595 – 598.*

[VEN 01] Vendrusculo E. A., Pomilio J. A., (March 2001), “Avoiding over-voltages in long distance driving of induction motors”, *Applied Power Electronics Conference and Exposition, APEC 2001. Sixteenth Annual 2001 IEEE (Volume:1)., pp. 622 – 627.*

[VEN 05] Venkataraman B., Godsey B., Premerlani W., Shulman E., Thaku M., Midence R., (April 2005), "Fundamentals of a motor thermal model and its applications in motor protection", *Protective Relay Engineers, IEEE 58th Annual Conference., pp. 127 – 144.*

[VIC 10] Vico J., Voloh I., Stankovic Dragan, Zhiying Zhang., (May 2010), "Enhanced algorithm for motor rotor broken bar detection", *Industrial and Commercial Power Systems Technical Conference (I&CPS), IEEE., pp. 1 – 8.*

[VIC 11] Vico J., Allcock D., Wester C., Ostojic P., Patel S., (May 2011), "Protection and control of low voltage motors used in industrial applications", *Industrial and Commercial Power Systems Technical Conference (I&CPS), IEEE., pp. 1 – 8.*

[VIC 11a] Vico J., Hunt R., (Nov-Dec 2011) "Principles in Motor Protection", *Industry Applications Magazine, IEEE (Volume 17, Issue 6)., pp. 52 – 61.*

[WAL 92] Walker J. D., Williamson S., (Oct 1992), "Temperature rise in induction motors under stall conditions", *Thermal Aspects of Machines, IEE Colloquium., pp. 7/1 – 7/4.*

[WEI 06] Weidong Li, Chris K. Mechefske, (Feb 2006), "Detection of Induction Motor Faults: A Comparison of Stator Current, Vibration and Acoustic Methods", *Journal of Vibration and Control, vol. 12 no. 2, pp. 165 – 188.*

[WEN 99] Wen-Jieh Wang, Jenn-Yih Chen., (Sept 1999), "A new sliding mode position controller with adaptive load torque estimator for an induction motor", *Energy Conversion, IEEE Transactions on (Volume 14, Issue 3)., pp. 413 – 418.*

[WHA 08] Whatley P., Lanier M., Underwood L., Zocholl S., (April 2008), "Enhanced Motor Protection With the Slip-Dependent Thermal Model: A Case Study", *Protective Relay Engineers, IEEE 61st Annual Conference., pp. 204 – 214.*

[WIE 10] Wieczorek M., Rosolowski E., (Sept 2010), "Modelling of induction motor for simulation of internal faults", *Modern Electric Power Systems (MEPS), Proceedings of the International Symposium., pp. 1 – 6.*

[WIL 85] Williamson S., Mirzoian K., (July 1985), "Analysis of Cage Induction Motors with Stator Winding Faults", *Power Engineering Review, IEEE (Volume PER-5, Issue 7)., pp. 50 – 51.*

[XIA 03] Xianrong Chang, Cocquempot V., Christophe C., (June 2003), "A model of asynchronous machines for stator fault detection and isolation", *Industrial Electronics, IEEE Transactions on (Volume 50, Issue 3)., pp. 578 – 584.*

[XIA 10] Xiang Qi., (May 2010), "Practical Circuit Design to Protect Motor's Phase Failure Operation", *Power Electronics and Design (APED), IEEE Asia-Pacific Conference., pp. 104 – 107.*

[YID 08] Yi Du, Habetler T. G., Harley R. G., (April 2008), "Methods for thermal protection of medium voltage induction motors — A review", *Condition Monitoring and Diagnosis, IEEE, CMD, International Conference, pp. 229 – 233.*

[YID 09] Yi Du, Pinjia Zhang, Zhi Gao, Habetler T. G., (May 2009), "Assessment of available methods for estimating rotor temperatures of induction motor", *Electric Machines and Drives Conference, IEMDC '09, IEEE International., pp. 1340 – 1345.*

[YON 13] Yong-Hwa Kim, Young-Woo Youn, Don-Ha Hwang, Jong-Ho Sun, Dong-Sik Kang., (Sept 2013), "High-Resolution Parameter Estimation Method to Identify Broken Rotor Bar Faults in Induction Motors", *Industrial Electronics, IEEE Transactions on (Volume:60 , Issue: 9)., pp. 4103 – 4117.*

[YUL 09] Yuling Tian., (July 2009), "On Diagnosis Prototype System for Motor Faults Based on Immune Model", *Business Intelligence and Financial Engineering, IEEE, BIFE '09. International Conference., pp. 126 – 129.*

[ZHE 04] Zhenxing Liu, Xianggen Yin, Zhe Zhang, Deshu Chen, Wei Chen., (Sept 2004), "Online rotor mixed fault diagnosis way based on spectrum analysis of instantaneous power in squirrel cage induction motors", *Energy Conversion, IEEE Transactions on (Volume 19 , Issue 3)., pp. 485 – 490.*

[ZHI 05] Zhi Gao, Habetler T. G., Harley R. G., (May 2005), "A robust rotor temperature estimator for induction machines in the face of changing cooling conditions and unbalanced supply", *Electric Machines and Drives, IEEE International Conference., pp. 591 – 596.*

[ZID 03] Zidani F., Benbouzid M. E. H., Diallo D., Nait-Said M.S., (Dec 2003), "Induction motor stator faults diagnosis by a current Concordia pattern-based fuzzy decision system", *Energy Conversion, IEEE Transactions on (Volume 18 , Issue 4)., pp. 469 – 475.*

[ZOC 85] Zocholl Stanley E., Schweitzer E. O., Aliaga-Zegarra Antenor, (Feb 1985), " PER High Interest Paper Thermal Protection of Induction Motors Enhanced by Interactive Electrical and Thermal Models", *Power Engineering Review, IEEE (Volume PER-5, Issue 2)., Transactions on (Volume PAS-103 , Issue 7)., pp. 17 – 24.*

[ZOM 00] Zamora J. L., Garcia-Cerrada A., (May-June 2000), "Online estimation of the stator parameters in an induction motor using only voltage and current measurements", *Industry Applications, IEEE Transactions on (Volume 36, Issue 3)., pp. 805 – 816.*