

Remote Surveillance Device in Monitoring Diagnosis of Induction Motor

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Abstract: The present contribution presents a review of the researches on the fault diagnosis and fault tolerant control of induction motors for the last six years as well as the classification of the faults which is another interested topics of this research finally the drawback of the method used in the fault diagnosis of the induction motor. The emphasis is on highlighting agrees, disagrees and tradeoffs in the reviewed topics. Sorting and classification is another goal. More attention is paid for theresearches done in the last six years and a brief description is presented for each issue. Extensive number of papers is reviewed and appointed in the present preview, to provide quantitative description

Key words: Fault diagnosis % Fault tolerant control % Induction motor % Review % Methods of fault diagnosis % Software

INTRODUCTION

Rotating electrical machines plays important role in many fields especially in the industrial processesbecause their rigid, rugged,low price, reliable relative simplicity and easy to maintenance which we can represents it as a core of these fields especially the induction motor which takes a great deal of attention for the above performance but, the companies still faces many critical situations results in losses in revenue, also the operators under continuous pressure so that the techniques of the fault diagnosis are very urgent aspects before the catastrophic results in the equipments.The faults of the induction motors Fig. 1 can be divided into two main parts electrical faults and mechanical fault as interpreted in the Fig.2 The fault diagnosis may be classified into two main parts: (cause-effect and effect cause) the main methods used in the fault diagnosis field are:

- C ANN artificial neural network better among many types of fault diagnosis for stable, speed, parallel processing but of some of its architecture cant apply for dynamic processing and need a lot of data compared with to finite element method, the solution time for calculating machine circuit parameters using neural network model has been dramatically reduced, while sufficient accuracy has been maintained., as opposed to the conventional

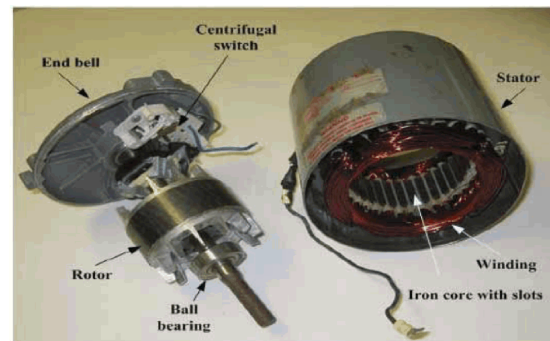


Fig. 1: Induction Motor components

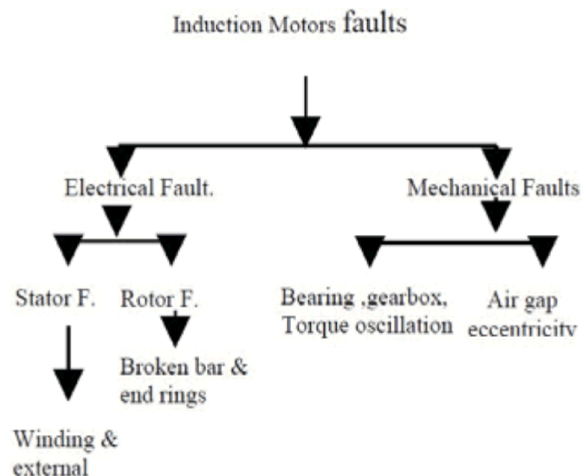


Fig. 2: Faults in the induction motors

techniques (expensive equipment, or accurate mathematical models required) Fuzzy and neural network not need it but just the data.

- C FFT the Fourier transforms is a representation of an image as a sum of complex exponentials of varying magnitudes, frequencies and phases. The Fourier transform plays a critical role in a broad range of image processing applications, including enhancement, analysis, restoration and compression.
- C FEM the benefits of this method include increased accuracy, enhanced design and better insight into critical design parameters, but all FE models are just that "models" they are mathematical "Idealizations" of continuous systems. Therefore, all results from any FEA code are not "closed formed solutions". The results are numerical approximations. Good approximations but approximations.
- C TSCFE-SS (time step coupled finite element-state space) Compute in sampled data form the time domain wave forms and profiles of the input phase and line currents,voltages.power, torques.

Many researches classifies the fault diagnosis according to the Model-based fault diagnosis methods and physical based model fault diagnosis but the model based take advantage of mathematical models of the Diagnosed plant. Different faults often require different mechanisms for their detection. A model based method using time-series prediction for fault detection and identification in induction motors is less common. Most methods use fault diagnosis based on data directly through some means of limit checking or classification and not through application of models of the motor itself. Some papers advocate physical model-based systems. These models have the advantage of containing meaningful physical variables, but what the models gain in physical relevance they often lose inaccuracy. For example when feeding a physical-based model with converter fed voltages the results are inaccurate. For purposes of fault diagnosis from the stator current the simple physical-based models do not give enough accuracy when applied to rotor and stator faults. This problem is also noted in research literature. Empirical coefficients are used for phenomena that cannot be accurately modeled, so that proper results are achieved for motors of standard design. Problems arise when motors are studied that are of new design, that are in transient states or are fed by non sinusoidal voltages. A reason for why a physical-based model cannot model the motor adequately is that it cannot properly take into

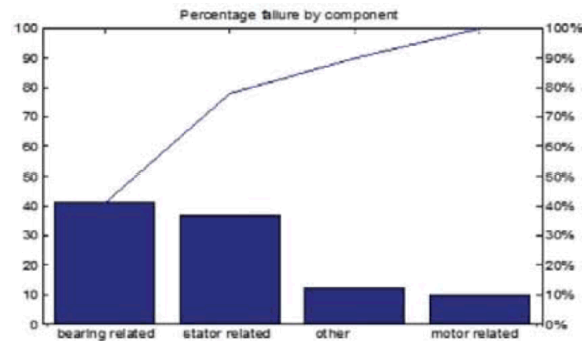


Fig. 3: Percentage failures by components

account all the mechanical, structural and operational details, which differ from motor to motor. As physical model based systems have their limitations, in this review we will classifies the faults of induction motor into the following, some faults implicitly included in some kinds of the faults such as the external faults of the induction motor, unbalance voltages, vibrations take place in the induction motors, one or more phase unbalanced, torque oscillation or any kind of the faults. For a methods such as ACSA, park's vector, motor parameter estimation,harmonic analysis of speed fluctuations and freq analysis of instantaneous power have some drawbacks such as (its need many sensors these should have high precision,its need knowledge about the internal structures). Negative sequence may fail under extremely low level of fault particularly when the supply voltage unbalance The main faults of the induction motor are depicted as in Fig. 2.

According to the above fault the percentage of each fault are as in Fig. 3

Signal Processing Techniques:

Air Gap Eccentricity: A mechanical fault that happened due many reasons such as machine manufacturing, assembly, unbalance load, bent shaft and bearing wear.

The static air gap eccentricity

$$f \text{ sece} > \left[KQ_r \frac{1.S}{p} \geq n \right].f$$

K=1, 2, 3...

n=1, 3, 5, order of stator time harmonics present in the power supply feeding the motor

The dynamic air gap eccentricity

$$f_{dfce} > \left| \left(KQ_r, nd \right) \frac{1.s}{p} \geq n \right| . f |$$

$K=1, 2, 3... ddn = \text{dynamic eccentric order } (n=1, 2, 3,...,n)$
same as above

The mixed air gap eccentricity

$$f_{micc} > f \left[1 \geq k \left(\frac{1.s}{p} \right) \right]$$

Gear Box and Bearing Faults: The mechanical frequency needed to investigate the mechanical fault such as gear box

$$f_{mixce} > |f + mfr, m|$$

f is the rotational frequency of the mechanical coupling equipment.

The damage in the outer bearing race

$$f_0 > \left(\frac{N}{2} \right) f \left[1 - \frac{BD}{PD} \cos(b) \right]$$

The damage in the inner bearing race

$$f_i > \left(\frac{N}{2} \right) f \left[1 - \frac{BD}{PD} \cos(b) \right]$$

The damage on the ball

$$f_b > \left(\frac{BD}{PD} \right) f \left\{ 1 - \left[\frac{BD}{PD} \cos(b) \right] 2 \right\}$$

N = Number of bearing balls

BD = Ball diameter

PD = Ball pitch diameter

\hat{a} = Contact angle of the ball with the races

However, these characteristic race frequencies can be approximated for most bearings with between six and twelve balls, Izzet Y O Nel *et al.* (2006) used the RBF neural network to detect the bearing of outer race defect of ball faults through MCSA techniques. A.R. Mohanty *et al.* (2006) states that for a three shafts and their corresponding gear mesh frequencies (GMFs) the gear

box faults can be detected by demodulation of the motor current waveform. Makarand S. Ballal, *et al* (2007) presents the facilities of ANFIS approach in the detection of inter-turn insulation of main winding and bearing wear of a single phase I.M Jafar Zarei *et al* (2006) studied the park's vector for monitoring I.M bearing faults by noticing the thickness of Lissajou's curve A.R. Mohanty *et al* (2006) deal with multistage gearbox of induction motors using tacho generator and dc generator to generate ripple voltage also use MFT. D.M. Yang (2007) detected the bearing fault in the intelligent diagnosis techniques uses wave transform and SVD techniques Wei Zhou (2007) presents new method to detect incipient faults based current techniques according to noise cancellation Martin Blodt (2006) presents one of the stator current monitoring to detect the rolling element bearing faults. Izzet Yilmaz *et al.* (2008), for 0.75 kw found the diagnosis capabilities of the park transform better than Concordia in the bearing fault diagnosis Baburaj Karanayil (2007) Present a neural net. To detect on line stator and rotor resistance in the sensor less motor. Wang Xu (2007) used B-spline membership of neural fuzzy to detect on line stator fault. Wang Xu (2007) proposed a technique to detect a fault in the stator winding using two DRNN to estimate the severity of the fault. Yushaizad Yusof (2003) introduce simple open loop inverter (PWM-VSI) fed induction motor to detect to estimate stator flux at zero voltage and low frequency by NN. Gamal Mahmoud (2007) investigates the connection path of uncontrolled rectifier of a variable v/f induction motor drive. Martin Blodt *et al* (2004) present the using of spectrum analysis to detect the damage bearing fault in I.M.

Abnormal Connection of Stator Winding: Gamal Mahmoud *et al* (2007) as a series of many paper deal this time with fault detection in the inverters Bilal Akin *et al* (2008) investigate the faults of low order PWM harmonic contribution to detect the faults of the inverter fed induction motor the faults of induction machine using the spectral density using the wavelet techniques are investigated in Bilal Youssef *et al* (2007) present the capabilities of the signature graphical tool to detect the faults in I.M. Mrs. M. Suidha' *et al* (2007) use the novel protection method to detect the unbalance voltage and single phasing faults J. F. Martins (2007) use the vector Eigen values to detect the faults of the closed loop induction motor Hongzhong Ma *et al* (2007) investigate the vibration faults in the winding based EMAM S.P.

Muley *et al* (2008) use the voltage/frequency control of induction motor to predict the fault inverter Tito G. Amaral *et al* (2007) presents a statistic moment based method for the detection and diagnosis of I.M stator fault R.N. Andriamalala *et al* (2006) presents a model of dual stator winding induction machine in case of stator and rotor faults for diagnosis purpose, Claudio Bonivento *et al* (2004) presents diagnosis of induction motors for implicit faults.

Shorted Rotor Field Winding: Daniel F. Leite *et al* (2007) present according to model based detect the alternators & I.M faults in real time, H. Razik *et al* (2007) used PDA in the monitoring and diagnosis. C. Concari, G *et al* (2007) study the torque and current peculiarities Bin Lu *et al* (2008) investigate the rotor fault diagnosis using wave let spectral analysis Ji-Hoon Choi (2006) present in his thesis the one of the modeling techniques based on the model of the induction motor and the pumps Aderiano M. da Silva (2006) in his thesis investigate many faults in the induction motor as well as the monitoring of the machine. Boqiang Xu *et al* (2006) presents a research on the rotor and stator double faults squirrel cage in the induction motor Peter Bikfalvi *et al* (2006) presents the methods and technologies of the rotor fault diagnosis Claudio Bruzzese *et al* (2006) presents the new faults indicators in the rotor for squirrel cage induction motor, S.M.A. Cruz *et al* (2006) presents a diagnosis of rotor faults in closed loop induction drive, Luis A. Pereira *et al*. (2006) applies the Welch, Burg and MUSIC methods to detects the faults on the rotor Lane Maria Rabelo *et al* (2006) presents the using of slide mode bserver in rotor fault diagnosis S.M.A. Cruz *et al* (2007) presents the faults indicators of the rotor in FOC Drives Carla C *et al*. (2006) presents detection of rotor faults in squirrel-cage induction motors using Adjustable Speed Drives Zhenxing Liu (2007) presents the PQ transformation technique in the rotor fault diagnosis Ferdinanda Ponci *et al* (2007) presents the some early detection approach for fault diagnosis Bin Lu *et al* (2008) presents the wavelet of One-Cycle Average Power in the rotor fault diagnosis F. Babaa *et al* (2007) presents in the part I- analytical investigation on the effect of the the negative sequence on stator fault, Mogens Blankes *et al* (2006) presents diagnosis and fault tolerant control and many examples in this book.

Artificial Intelligence Techniques: Compose of many types of methods deals with the fault diagnosis of induction motors such as neural networks Fig. 4 fuzzy logic, or the combination of both, genetic algorithm, even

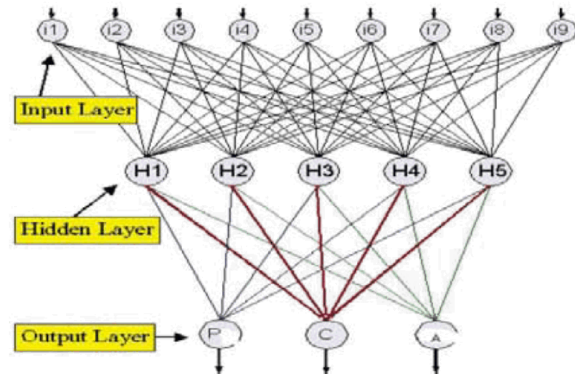


Fig. 4: Neural Network

Techniques	Required measurement	Application	Advantages	Drawbacks
Motor Current Signature Analysis (MCSA)	One stator current	1. Rotor broken bar 2. Stator winding turn fault 3. Air gap eccentricity	1. Low cost 2. Non invasive	1. Frequencies vary from motor to other 2. Liked to some states
Complex Park Vector (CPV)	Two stator currents	1. Rotor broken bar 2. Stator winding turn fault 3. Air gap eccentricity	1. Non invasive 2. Simple	Mismatches faults
Axial Flow (AF)	Axial flux	1. Rotor broken bar 2. Stator winding turn fault 3. Air gap eccentricity	1. Low cost	Non invasive
Torque Harmonics Analysis (THA)	Two stator currents and voltages	1. Rotor broken bar 2. Stator winding turn fault 3. Mechanical faults in load	1. Mechanical fault detection 2. Non invasive	Not effective in short cut faults
Impedances of Inverse Sequence (IIS)	Two stator currents and voltages	Stator winding turn fault	1. Incipient faults detection 2. Non invasive	Required great measurement precision
Artificial Neural Network (ANN)	Two stator currents and voltages	Stator winding turn fault	1. Incipient faults detection 2. Non invasive 3. Easy to adapt to each motor	1. Required training period 2. Not effective in the motors changes states

Fig. 5:

expert network can be included with introduce many facilities with respect to the signal processing techniques but its need a large amount of data about the motors which some times difficult to get it. M.J. Fuente (2004) present the hybrid model to detect some internal and imbalance faults. In Ramon A. Felix (2003) the controller is derived using neural network and slide model in the induction motor Carsten Skovmose (2006) propose the use of ARR technique to detect centrifugal pump Hainan Wang (2006). Deal with sensor faults of induction motor. Abdul Kadir (2006) [1] implements analogue device and dual core SP to detect the faults in the inverter. Ihan Aydin detect the faults. J. Cusi deal the detection of broken bar and air gap eccentricity through MCSA. Jee-Hoon Jung (2006) with high advance on line monitoring detect faults in the induction motor using MCSA H. Nakamura *et al*. (2006) use new diagnosis based on Markov's which is used in recognition of speech to detect the faults. Marving (2006) use the bon graph modeling to detect the fault. Toshiji Kato (2007) use the Kohen's SOM to detect the three phase inverter faults. E. evi, R *et al* (2007) give a good review for the multiphase of induction motor. Raj M. Bharadwaj *et al* (2004) deal with signals filter in the inverter fed induction motor using neural without

any sensor Sitao Wu *et al* (2004) use the self organize with radial bias function as a new techniques to detect the faults, M.A.S.K.Khan *et al.* (2007) present new approach in fault diagnosis of induction motor using wave let using real time implementation of Wavelet Packet Transform-Based diagnosis Toshiji Kato *et al* present the self organize method to detect the faults in the apparatus and induction machines. L.Cristaldi (2007) used soft computing techniques for fault diagnosis of uncertainty propagation J.A.Cortajarena (2007) presents indirect vector controlled induction motor using hybrid classical controller and fuzzy controller, O. Elmaguiri (2007) present new approach for fault diagnosis using back stepping digital techniques for induction motor, Eltabach *et al.* (2007) presents new procedure using non invasive Beirut diagnosis for the induction motor drives, Cusido *et al* present the wavelet convolution to detect on line system fault L. Cristaldi *et al* (2007) based on soft computing investigate the propagation uncertainty in fault diagnosis, JordiCusido (2008) presents.

Software Used with Fault Diagnosis: The main software programs that can be used with fault diagnosis techniques either with classical methods or the artificial methods to give high facilitate. here we manifests the most important among them: Matlab program, Tiberius program, Ansys program, Lab view program, Knoware program, ABAQUS program, SAMCEF program; OOFELIE program Calculi X program, OOFEM program, ALGOR program; Sundance program, JMAG; program; PERMAS program, STRANDS7 program, PAM program, solid work program, Neural net. Program, Jaffa neural program, Free Master program, Maxwell pc program, Motor monitor program, Neuro solution program, DLI watchman program COSMOS WORK, program, Maple Si program, Fault tolerant software, Sim20 software, pscad software, Free Master, etc [2-9]. here are much more deals with the modeling and simulation of the induction machines but those according to author's knowledge. These programs not applicable for all methods, for example the Tiberius program can be used with neural network and the ANSYS for the finite element method, electromagnetic field and so on.

Fault Tolerant Control: Many efforts in the control community have been recently devoted to study "Fault-tolerant" control (FTC) systems, namely: Ron J Patton *et al* (1997) present a fault -tolerant control systems,give in this paper good details for the types of fault tolerant control, its areas,architecture, control

systems able to detect incipient faults in sensors and/or actuators on the one hand and on the other, to promptly adapt the control law in such a way as to preserve pre-specified performances in terms of quality of the production, safety, etc..The fault tolerant control consists of two steps: fault diagnosis and re-design controller Currently, FTC in most real industrial systems are realized by hardware redundancy. For example, the majority-voting scheme is used with redundant sensors to cope with sensor faults. However, due to two main limitations of the hardware redundancy, high cost and taking more space, solutions using analytical redundancy have been investigated over the last two decades. There are generally two different approaches using analytical redundancy: (1) passive approaches and (2) active approaches. Recently, an elegant design method of passive approach was proposed, in which the linear matrix inequality method was used to synthesis the reliable controller. The disadvantages of passive approach are the method is based on an accurate linear state space model and therefore is not capable of controlling a non-linear process for which an accurate analytical model is usually unavailable. In addition, because the passive approaches consider fault tolerance in only the stage of controller design and without taking adaptation when faults occur, the amplitude of the faults that can be tolerable is usually

small and cannot meet the requirements in practice. There are many method deals with active fault tolerant control (adaptive control) such as linearization feedback, linear quadrature method, Pseudo inverse method, Eigen structure assignment method, neural network, control law rescheduling, model predictive control MPC, HY, norm optimization, 4 parameter controller, The main disadvantage of their designs is that they consider large fault effects which do not challenge the robustness problem! A consideration of smaller or incipient (hard to detect) faults would have given a more realistic and challenging robustness problem to solve, etc. the remote diagnosis is another type used with fault tolerant control.

CONCLUSION

Applying induction motor systems in critical path applications such as automotive systems and industrial applications requires design for fault tolerance as well as performance; the successful detection of induction faults depends on the selection of appropriate methods used. This review for more interest research for last six years in the fault diagnosis and some of FTC included the general

layout of the faults happen, methods to detects these faults and the agrees and disagrees of the most popular techniques deals with the fault diagnosis and fault tolerant control, There are a number of results related to using FDI to mechanical systems and control surfaces of an induction motors, while techniques for on-line identification of fault models with time-varying nonlinearities and robust FDI using closed loop models are still of research interest. Rapid detection and isolation of faults is necessary to minimize the undesirable effects of detection and reconfiguration delays finally the software programs, which acts as a tool to satisfy the above solving strategies. The author would like to thanks ThanisSribovornmongkol at same time apologize to those whose papers are not included.

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