Diagnosis and Fault Tolerant Control of the Induction Motors Techniques a Review

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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 the researches 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 for each agree or disagree

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 processes because 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:

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

2. 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.

3. 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.

4. 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.

5. MCSA this method take a great deal of attention because their easiness to use as well as it is not require to access to the induction motor parameters used signal spectral to find the faults according to the position of sidebands frequency harmonics and many another parameters effect the faults can be diagnostic but
there are drawbacks of this method, the amplitude of the current components depends on the loads connected to the motor thus the variation of system load make this method not applicable in all operation condition also when is that frequency s similar to those used for rotor bar can be generated by other causes such as low frequency oscillation.

6. Wavelet: it’s a signal analysis techniques to any kind of signal such as human speech, engine vibrations, medical images, financial data and many other types of signal but the draw back its difficult to be applied if the startup very faster and need minimums inertia factor. There more methods as in table 1

7. Complex Park Vector (CPV): the well-known Park transformation allows showing the variables of a three-phase machine through a system of two quadrature (ld & Iq) shafts, they are a measuring and diagnostic tool in electric three-phase systems. The properties of this method as in table 1

$$\begin{align*}
I_x &= \frac{2}{3}I_d - \frac{1}{6}I_a - \frac{1}{6}I_c \\
I_q &= \frac{1}{2}I_d - \frac{1}{2}I_a
\end{align*}$$

Where $i_d$, $i_a$, $I_c$ are the currents of the phases A, B, and C of the stator.

8. Axial Flow (AF): An axial-flow induction motor having an alternating magnetic field and associated harmonics, comprising a stator having a winding arranged in a slot and a rotatable supported laminated rotor spaced from the stator by an air gap, the rotor including relative to the stator a remotely positioned magnetically conductive layer and a more closely positioned electrically conductive layer, further more as in table 1.

9. Impedances of Inverse Sequence (IIS) as can be shown in table 1.

Many researches classify 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 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 classify 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.

II. Signal Processing Techniques:
2.1. 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

$$\omega_{\text{st}} > \left[ K \Omega_r \frac{1}{p} \geq n \right] f \quad (3)$$

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

$$\omega_{\text{dyn}} > \left[ (K \Omega_r, nd) \frac{1}{p} \geq n \right] f \quad (4)$$

K=1, 2, 3...

n_d = dynamic eccentric order (n_d =1, 2, 3,) same as above

The mixed air gap eccentricity

$$\omega_{\text{mix}} > f \left[ 1 \geq K \frac{1}{p} \right] \quad (5)$$

Several contributions deal with these faults. Xiaodong Li et al, (2007) shows that the air gap eccentricity can be detected by analyze the inclined static eccentricity of the I.M. Xianghui Huang et al, (2007) proposed that according to axial non uniform air gap due to off line monitoring of the variations of the surge waveform at the different rotor position the eccentricity can be detected. M. Sulowics et al, (2007) presents a paper for detect the faults of eccentricity using ANFIS (adaptive network based fuzzy inference system) techniques. F. Pedrayes et al(2007) designed a model of the I.M using a mesh of magnetically coupled reluctances. This model allows the dynamic simulation of the main induction motor variables to detect faults with high efficacy. M. hamed Drif (2008) presents a new strategy based on the signature analysis of the complex apparent-power for detecting the occurrence of air gap eccentricity in operating three-phase I.M. Jawad Faiz et al (2008) studied mixed (static and dynamic) eccentricity at the starting period using TSFE, the input of FE calculations was the applied voltage. Jason Grieger et al (2007) investigates static eccentricity severity by the features investigated of RSH and RSH side bands of both the line currents and vibration. Jason Grieger et al (2006) submit the evidence theory to find the motor static eccentricity using the BPA for each sensor by noticing the magnitudes features. Thomas M. Wolbank et al (2007) make a review for the best methods to deal with air gap eccentricity like the digital camera or laser sensors to detects the faults. M’hamed Drif et al, (2008) also investigate the squirrel cage induction motor eccentricity mixed faults through the Instantaneous Power Factor Signature Analysis. John F. Bangura et al (2003) develops a new technique to detect main faults in the induction motors through TSCFE–SS method which can generate large no. of healthy and faulty IMASD simulations with TSDM techniques, Xianghui Huang et al. (2007) in this paper deals with drive of induction motor as closed loop to detect the rotor eccentricity related harmonics in the stator voltage and current space vectors simultaneously using neural networks. Hamed Drif et al (2006) present new approach to detect air gap eccentricity using instantaneous power signature analysis Guillermo Bossio et al (2006) states that when the pre established pulse sequence applied by the inverter to the I.M the air gap eccentricity effect on the zero sequence voltage can be detected and the diagnostics results was quite visible. Martin Blodt et al (2008) presents a distinguishing load torque oscillations and eccentricity faults in I M using stator current, A Nikranjbar et al (2009) presents model-based mixed-eccentricity fault detection and diagnosis for induction motors.

2.2 Gear Box and Bearing Faults:
The mechanical frequency needed to investigate the mechanical fault such as gear box
\[ f_{mfr} \geq \left| f \pm mfr, m \right| \]  

(6)

\( f_{mfr} \) is the rotational frequency of the mechanical coupling equipment. The damage in the outer bearing race

\[ f_o \geq \left( \frac{N}{2} \right) f \left[ 1 - \frac{BD}{PD} \cos(\beta) \right] \]  

(7)

The damage in the inner bearing race

\[ f_i \geq \left( \frac{N}{2} \right) f \left[ 1 - \frac{BD}{PD} \cos(\beta) \right] \]  

(8)

The damage on the ball

\[ f_b \geq \left( \frac{BD}{PD} \right) f \left[ 1 - \left[ \frac{BD}{PD} \cos(\beta) \right]^2 \right] \]  

(9)

\( N = \) number of bearing balls  
\( BD = \) ball diameter  
\( PD = \) ball pitch diameter  
\( \beta = \) 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.

**2.3 Stator Faults Resulting of Opening or Shorting the Stator Coil or Phase Winding:**

\[ f_n > f \left[ n \left( \frac{1 - s}{p} \right) \pm k \right] \]  

(10)

\( n = 1, 2, 3... \)  
\( k = 1, 3, 5... \)


2.4 Abnormal Connection of Stator Winding:

2.5 Shorted Rotor Field Winding:

2.6 Broken Rotor Bar and Crack End Ring:
The rotor broken bar frequency in asymmetry condition:

\[ f_{\text{break}} > \left( \frac{k}{p} \right) (1 - \varepsilon) \pm \varepsilon f, \quad \frac{k}{p} = 1, 5, 11, 13, \]  

(11)

2.7 Shaft Bent:
M.Mohamdi et al (2006) presents for 1.5 kw an induction motor, shaft misalignment, damage bearing tests in José M. Machorro et al. (2009) different kinds of faults such as transverse cracks, imbalance, misalignment, bent shafts, and combinations thereof are considered. Off-line and on-line experimental tests are carried out, Yanli Lin et al. (2009) presents flexural vibrations of a rotor system with transverse or slant crack are analyzed under torsion excitation, The numerical and experimental investigations demonstrate these features can be used to distinguish between the transverse crack and the slant crack on the shaft of a rotor system.

III. 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 expert network can be included witch introduce many faci lities with respect to the signal processing techniques but its need a large networks Fig. 4 fuzzy logic, or the combination of both, genetic algorithm, even expert network can be

useful to distinguish between the transverse crack and the slant crack on the shaft of a rotor system.

IV. 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, CalculiX 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 Sim program, Fault tolerant software, Sim20 software, pscad software, Free Master, etc.
Table 1: Summary of Some of Fault Diagnosis Method Properties [164]

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Required measurement</th>
<th>Application</th>
<th>Advantages</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Current Signature</td>
<td>One stator current</td>
<td>1. Rotor broken bar</td>
<td>1. Low cost</td>
<td>1. Frequencies vary from motor to another</td>
</tr>
<tr>
<td>Motor Current Signature</td>
<td></td>
<td>2. Stator winding turn fault</td>
<td>2. Non invasive</td>
<td>2. Liked to some states</td>
</tr>
<tr>
<td>Motor Current Signature</td>
<td></td>
<td>3. Air gap eccentricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Park Vector</td>
<td>Two stator currents</td>
<td>1. Rotor broken bar</td>
<td>1. Non invasive</td>
<td>Mismatch faults</td>
</tr>
<tr>
<td>Complex Park Vector</td>
<td></td>
<td>2. Stator winding turn fault</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Park Vector</td>
<td></td>
<td>3. Air gap eccentricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Axial Flow (AF)</td>
<td>Axial flux</td>
<td>1. Rotor broken bar</td>
<td>1. Low cost</td>
<td>Non invasive</td>
</tr>
<tr>
<td>Torque Harmonics Analysis</td>
<td>Two stator currents and voltages</td>
<td>2. Stator winding turn fault</td>
<td>2. Simple</td>
<td></td>
</tr>
<tr>
<td>Impedance of Inverse Sequence (IIS)</td>
<td>Two stator currents and voltages</td>
<td>3. Mechanical faults in bad</td>
<td>Non invasive</td>
<td>Not effective in short etc. faults</td>
</tr>
<tr>
<td>Artificial Neural Network</td>
<td>Two stator currents and voltages</td>
<td>Stator winding turn fault</td>
<td>1. Incipient faults detection</td>
<td>Required great measurement precision</td>
</tr>
<tr>
<td>Natural ANN</td>
<td></td>
<td></td>
<td>2. Non invasive</td>
<td></td>
</tr>
<tr>
<td>Natural ANN</td>
<td></td>
<td></td>
<td>3. Easy to adapt to each motor</td>
<td></td>
</tr>
</tbody>
</table>

There 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.

V. 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.

Off board component has (nearly) unlimited computing power but has to cope with limited and possibly biased measurement data, on board component has to work with restricted computing power and memory size which limits the algorithm complexity of the task to be performed. Xiaodong Zhang in his Ph.D thesis present a novel isolation scheme with its robustness and sensitivity properties using adaptive thresholds in the residue evaluation stage in three tank system, a rigid link robotic manipulator and the Van der Pol oscillator system [141], Haider A.F. Mohamed et al. proposes a fault tolerant control design that consists of two parts: a nominal
The nominal controller can have any given structure that satisfies the performance specification. The detection element will operate in parallel with the system until a fault is detected. Fault tolerant operations of soft starters and adjustable-speed drives (ASDs) when experiencing power switch open-circuit or short-circuit faults are presented in, Jean-Etienne Dongmo et al. (2007) presents describe a method for designing switching controls and analyzing achievable performance for motor drives, a collection of results towards a unified framework for fault tolerant control in distributed control systems are given in, Amr Saleh et al. (2007) presents a fault tolerant strategy for the problem of loss of one phase in a field oriented controlled three phase induction motor. The proposed solution, rather than previously suggested solutions, is a control strategy in the single phase mode of operation of the induction motor, same above authors describes a novel strategy for restarting the three phase induction motor in a voltage fed field oriented drive operating in the single phase mode after the loss of one of the inverter phases. Sejir Khojet El Khil et al. (2006) presents an original strategy of fault tolerant operating in case of doubly fed induction machine (DFIM), C.B. Jacobina et al. (2004) investigates the voltage and current control of a five-phase induction motor drive under fault conditions, A.M.S. Mendes et al. (2003) exploits the advantages and the inconveniences of using remedial operating strategies under different control techniques, such as the field oriented control and the direct torque control. Global results are presented concerning the analysis of some key parameters like efficiency, motor line currents harmonic distortion, among others. H. Nademi et al. (2008) considers the problem of designing a fault tolerant system for IPMS motor drive subject to current sensor fault. To achieve this goal, two control strategies are considered. The first is based on field oriented control and a developed adaptive back stepping observer which simultaneously are used in the case of fault-free. The second approach proposed is concerned with fault tolerant strategy based on observer for faulty conditions. Halim Alwi et al. (2008) propose an on-line sliding mode control allocation scheme for fault tolerant control. The effectiveness level of the actuators is used by the control allocation scheme to redistribute the control signals to the remaining actuators when a fault or failure occurs, Anjali P. Deshpande et al. (2008) presents a novel intelligent nonlinear state estimation strategy is proposed, which keeps diagnosing the root causes of the plant model mismatch by isolating the subset of active faults (abrupt changes in parameters/disturbances, biases in sensors/actuators, actuator/sensor failures) and auto-corrects the model online so as to accommodate the isolated faults/failures[153] Matthew O.T. Cole considers a control system design for a rotor–magnetic bearing system that integrates a number of fault-tolerant control methods Wai et al. (2003) presents a plug-in robust compensator for speed and position control enhancement of an indirect-field-oriented-control induction machine drive is developed, S.N. Vukosavic et al. (2005) A vector control algorithm, based on indirect rotor flux orientation, is at first briefly described. Special attention is paid next to the current control issue, from the point of view of the minimum number of current controllers for six phase induction motor. The IFOC can transform the induction motor from nonlinear into linear system but with many assumption its well known the output response is sensitive to the plant parameters variations such as the rotor resistance. Youmin Zhang et al. presents a bibliographical review on reconfigurable (active) fault-tolerant control systems (FTCS) is presented. The existing approaches to fault detection and diagnosis (FDD) and fault-tolerant control (FTC) in a general framework of active fault-tolerant control systems (AFTCS) are considered and classified according to different criteria such as design methodologies and applications. As in Fig.5 Hui-Wei Liu et al. presents adaptive fault tolerant control (FTC) of nonlinearly parameterized systems with uncontrollable linearization. The progress was made due to the development of a novel feedback design technique called adding a power integrator, which was motivated by homogeneous feedback stabilization and proposed initially in (Q. Zhao et al.98) for global stabilization of nonlinear systems with uncontrollable linearization., A. Fekih et al. (2009) presents new strategy for the fault tolerant control for aircraft systems, Romero et al. (2009) proposes the uses of multisensor switching control strategy for fault tolerant direct torque and flux control of the induction motor, S.K Ghoshal et al. (2009) presents analytical redundancy relation (ARR) based approach for fault detection and isolation (FDI) with application to hydraulic and a thermo fluid process using Bond graph to modeling FDI. Stoyan Kanev (2004) introduce in his Ph.d thesis the main methods in the fault tolerant control, typically, an active FTCS consists of three parts: a reconfigurable controller, an FDD scheme, and a control law reconfiguration mechanism as shown in Fig.6.

The key issues of the fault tolerant control are how to design:

1. A robust reconfigurable controller,
2. An FDD scheme with high sensitivity to faults and robustness to model uncertainties and external disturbances,(include residual generation and residual evaluation, threshold determination) ,and
3. A reconfiguration mechanism which can organize the reconfigured controller in such a way that the pre fault system performance can be recovered to the maximum extent as shown in Fig.7.
Fig. 5: Active fault tolerant control methods

Fig. 6: Main component of fault tolerant control
According to the depth of the information used of the physical process, the approaches to the problem of failure detection and isolation fall into two major groups:

- Methods that do not make use of the mathematical model of plant dynamics, or, model-free FDI;
- Methods that do make use of the quantitative plant model, or, model-based FDI.

More than 13 papers published in the Journal of Control Science and Engineering about the fault tolerant control and fault diagnosis

The existing FDI approaches can be generally classified into two categories: (1) model-based and (2) data-based (model-free) schemes; these two schemes can further be classified as quantitative and qualitative approaches as shown in Fig.7

**VI. 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 motor 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 Thanis Sribovornmongkol at same time apologize to those whose papers are not included.
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