A Review on Motor Monitoring using Wireless Sensor System

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Abstract- Fault detection and isolation are important to improve the safety and reliability of practical control systems. Induction motor especially three phase induction motor plays vital role in the industry due to their advantages over other electrical motors. Therefore, there is a strong demand for their reliable and safe operation. If any fault and failures occur in the motor it can lead to excessive downtimes and generate great losses in terms of revenue and maintenance. Therefore, an early fault detection is needed for the protection of the motor. In the current scenario, the health monitoring of the induction motor are increasing due to its potential to reduce operating costs, enhance the reliability of operation and improve service to the customers. The health monitoring of induction motor is an emerging technology for online detection of incipient faults. The on-line health monitoring involves taking measurements on a machine while it is in operating conditions in order to detect faults with the aim of reducing both unexpected failure and maintenance costs. In the present paper, a comprehensive survey of induction machine faults, diagnostic methods and future aspects in the health monitoring of induction motor has been discussed.

Keywords- Fault detection, Wireless sensor system, Motor arrays, Induction motors

Literature Survey-

Bilal Youssef et al. (2007) presented a recently developed graphical signatures generation tool is used for system faults detection of induction motors (IM). The underlying diagnosis problem corresponds to variations affecting four of system's parameters, namely, the resistances and inductances for both stator and rotor. It is shown that this diagnosis method enables early detection of all considered faults using one graphical signature generated from the measurements of the stator current. The proposed detection procedure can be easily applied in a real time diagnosis context.

Bilal Akin et al. (2010) presented that reference frame theory approach can successfully be applied to real-time fault diagnosis of electric machinery systems as a powerful toolbox to find the magnitude and phase quantities of fault signatures with good precision as well. The basic idea is to convert the associated fault signature to a dc quantity, followed by the computation of the signal's average in the fault reference frame to filter out the rest of the signal harmonics, i.e., its ac components. As a natural consequence of this, neither a notch filter nor a low-pass filter is required to eliminate fundamental component or noise content. Since the incipient fault mechanisms have been studied for a long time, the motor fault signature frequencies and fault models are very well-known. Therefore, ignoring all other components, the proposed method focuses only on certain fault signatures in the current spectrum depending on the examined motor fault. Broken rotor bar and eccentricity faults are experimentally tested online using a TMS320F2812 digital signal processor (DSP) to prove the effectiveness of the proposed method. In this application, only the readily available drive hardware is used without employing additional components such as analog filters, signal conditioning board, external sensors, etc. As the motor drive processing unit, the DSP is utilized both for motor control and fault detection purposes, providing instantaneous fault information. The proposed algorithm processes the measured data in real time to avoid buffering and large-size memory needed in order to enhance the practicability of this method. Due to the short-time convergence capability of the algorithm, the fault status is updated in each second. The immunity of the algorithm against non-ideal cases such as measurement offset errors and phase unbalance is theoretically and experimentally verified. Being a model-independent fault analyzer, this method can be applied to all multiphase and single-phase motors.

Sunisa Sornmuang and Jittiwut Suwatthikul (2011) presented that condition maintenance has attracted more attention and interest due to its advantages over the conventional breakdown-based or time-based maintenance. CBM of electrical machines such as motors is based on using data obtained by real-time condition monitoring, and fault detection and diagnosis to recommend an optimized maintenance. This paper presents an application of an Artificial neural network for detecting a very small fault in a bearing shield of an induction motor. The experimental results show that the incipient fault can be efficiently detected. An alarm may be activated so that corrective actions are promptly taken before the detected fault manifests itself to be further serious failures. The paper has presented an application of artificial neural networks to bearing fault detection. A feed forward network was implemented to detect a very small fault in a bearing shield. The network was trained with real vibration data collected from a test bench. The results show that the incipient fault can be efficiently detected by the implemented network. Future work will focus on multiple faults and testing robustness of the system.

Sunisa Sornmuang and Jittiwut Suwatthikul (2011) presented Condition-based maintenance (CBM) has attracted more attention and interest due to its advantages over the conventional breakdown-based or time-based maintenance. CBM of electrical machines such as motors is based on using data obtained by real-time condition monitoring, and fault detection and diagnosis to recommend an optimized maintenance. This paper presents an application of an Arti a very small fault in a bearing shield of an induction motor. The experimental results show that the incipient fault can be efficiently detected. An alarm may be activated so that corrective actions are promptly taken before the detected fault manifests itself to be further serious failures. The paper has presented an application of arti fault detection. A feed forward network was implemented to detect a very small fault in a bearing shield. The network was trained with real vibration data collected from a test bench. The results show that the incipient fault can be efficiently detected by the implemented network. Future work will focus on multiple faults and testing robustness of the system.

Adouni Amel et al. (2012) presented a fault detection and isolation (FDI) of a DC motor described by linear dynamic models. Dynamic space parity approach is used to detect sensor and actuator faults. This approach is based on obtaining an input–output description of a given system and transforming it into the parity equations. Therefore, the theoretical symptoms matrix is established. The later is compared to an experimental one to isolate the faults. The validity and usefulness of the fault detection and isolation algorithms are thoroughly verified with experiments on 1kw DC motor using a dSpace system with DS1104 controller board based on digital signal processor (DSP) TMS320F240. An approach based on dynamic space parity for fault detection and isolation is discussed in this paper. The validity of the fault detection algorithms is verified with experiments on 1kw DC motor using a dSpace system with DS1104 controller based on DSP TMS 320F240.From these tests, it is shown that the used algorithms have successfully detected. All high performances of the used method depend on the performance of the used model. This work has successfully detected the different type of fault but it need to continue in order to isolate them for that reason we suggest to ameliorate it as a result to identify the element affected by fault to improve the performances of the used algorithms, a robust model is to be used. This will be the subject of author's future work.

Shubhasish Sarkar et al. (2013) described that induction motor plays a key role in ensuring functional execution and smooth progression of modern industries. But due to several harsh operational environments, different types of faults, in the form of stator winding fault, rotor fault etc. develop in the motor. If these faults, which are mostly minor in nature initially, don't get detected in earlier stages then they may inflict major damage in the motor and consequently may disrupt the plant's production capacity. So far, several studies primarily focusing on signature, model and expert system based techniques have been performed for conditioning monitoring of induction motors. Among all these techniques MCSA (Motor Current Signature Analysis) technique has been identified to be the most effective tool for diagnosis of induction motor faults. Most of the traditional condition and monitoring methods, using MCSA, that have been used till date are offline. Such offline analysis leads to delayed fault detection, resulting in plant production being eventually hampered, thus indirectly increasing the production cost. That is why, modern day industries demand online fault diagnosis methods which would analyze faults in real time and prevent any unforeseen production mishaps. FPGA or DSP where the signal is processed in hardware unit can be used for online analysis. This paper deals with 3-phase induction motor stator current acquisition using LABVIEW, FPGA embedded with NI cRIO-9075 real time controller and NI-9227 analog current input module looking towards online fault diagnosis.

Roy McCann et al. (2013) developed a new feedback control method for fault detection and real-time compensation of unbalanced three-phase motor drive systems. This method is based om an extension time-domain symmetrical component theory where B new transformation is used to express the sequence components in state-space form. Unlike previous analysis techniques, this method models the dynamics of positive and negative sequence components for systems with arbitrary resistance, inductance, and capacitance in a systematic manner. Dynamic models derived using the DISC transformation are well suited for real-time compensation and fault detection in three-phase motor drives. This paper develops the theory of the DISC trans- formation and gives an application to the optimal compensation of permanent magnet synchronous motor drive with a resistance imbalance. Experimental measurements from a laboratory inverter are provided to confirm the theoretical development.

Jorge O. Estima et al. (2013) presented three-phase inverters are currently utilized in an enormous variety of industrial applications, including variable speed ac drives. However, due to their complexity and exposure to several stresses, they are prone to suffer critical failures. Accordingly, this paper presents a novel diagnostic algorithm that allows the real-time detection and localization of multiple power switch open-circuit faults in inverter-fed ac motor drives. The proposed method is quite simple and just requires the measured motor phase currents and their corresponding reference signals, already available from the main control system, therefore avoiding the use of additional sensors and hardware. Several experimental results using a vector-controlled permanent-magnet synchronous motor drive are presented, showing the diagnostic algorithm effectiveness, its relatively fast detection time, and its robustness against false alarms.

Ben Hamed Mouna et al. (2014) presented fault detection and isolation of a DC motor is discussed. Dynamic space parity approach is used to detect faults. Based on structural residual method, the theoretical symptoms matrix is established. The later is compared to an experimental one to isolate the faults. The validity and usefulness of the fault detection and isolation algorithms are thoroughly verified with experiments on 1kw DC motor using Space system with DS1104 controller board based on digital signal processor (DSP) TMS320F240. An approach based on dynamic space parity for fault detection and isolation is presented in this paper. The validity of the fault detection and isolation algorithms are verified with experiments on 1kw DC motor using a dSpace system with DS1104 controller based on DSP TMS 320F240. From these tests, it is shown that the used algorithms have successfully detected and isolated actuator and sensor faults. All high performances of the used method depend on the performance of the used model. Generally, this model is established using mathematical equations and some hypotheses leading to modeling errors when these hypotheses aren't satisfactory. To improve the performances of the used algorithms, a robust model is to be used. This will be the subject of author's future work.

Mr. C. Ramachandran et al. (2014) presented the synergies between wireless sensor networks (WSNs) and nonintrusive electrical-signal based motor signature analysis and proposes a scheme of applying WSNs in online and remote energy monitoring and fault diagnostics for industrial motor systems. The main scope is to provide a system overview where the nonintrusive nature of the electrical signal-based motor signature analysis enables its applications in WSN architecture. Special considerations in designing nonintrusive motor energy monitoring and fault diagnostic methods in such systems are discussed. This paper also provides detailed analyses to address the real-world challenges in designing and deploying WSNs in practice, including wireless-link-quality dynamics, noise and interference, and environmental impact on communication range and reliability.

Ilhan Aydin et al. (2016**)** proposed that induction motors are the most utilized motor types of industrial applications. They are robust and have a simple structure. However, they can be exposed to some faults because of hostile environments. Many methods have been proposed for detection of faults at line-feed induction motors. However, fault diagnosis methods for inverter-fed induction motors are quite limited. In this study, a new fault detection method is proposed to detect stator related faults for inverter-fed induction motors. The proposed method takes three-phase current signals and applies the park's vector transform. The principal component analysis is applied to two park's vector components. The features obtained by applying principal component analysis are given to fuzzy logic and the severity of stator related-fault is determined. The proposed algorithm is implemented on a

STM32F746 microprocessor and good results have been obtained.

Turker Ince et al. (2016) presented early detection of the motor faults is essential and Artificial Neural Networks (ANNs) are widely used for this purpose. The typical systems usually encapsulate two distinct blocks: feature extraction and classification. Such fixed and hand-crafted features may be a sub-optimal choice and require a significant computational cost that will prevent their usage for realtime applications. In this paper, we propose a fast and accurate motor condition monitoring and early fault detection system using 1D Convolutional Neural Networks (CNNs) that has an inherent adaptive design to fuse the feature extraction and classification phases of the motor fault detection into a single learning body. The proposed approach is directly applicable to the raw data (signal) and thus eliminates the need for a separate feature extraction algorithm resulting in more efficient systems in terms of both speed and hardware. Experimental results obtained using real motor data demonstrate the effectiveness of the proposed method for real-time motor condition monitoring

Fernando Alvarez-Gonzalez et al. (2016) proposed hardware-in-the-loop (HIL) testing methods can facilitate the development of control strategies in a safe and inexpensive environment particularly when extreme operating conditions such as faults are considered. HIL methods rely on accurate real-time emulation of the equipment under investigation. However, no validated tools for real-time emulation of electrical drives under fault conditions are available. This paper describes the implementation of a high-fidelity real-time emulator of a Permanent Magnet Synchronous Motor (PMSM) drive in a platform suitable for HIL tests. The emulator is capable of representing the drive operation under both healthy conditions and during inter-turn stator winding faults. Nonlinearities due to saturation, higher order harmonics, slotting effects, etc. are accounted for using four dimensional look-up tables obtained by finite element analysis (FEA). The proposed model is computationally efficient and capable of running in real time in a FPGA platform and is validated against simulations and experimental results in a wide range of operating conditions. Potential applications of the proposed emulation environment to the development of drive control, fault detection and diagnostic algorithms are proposed.

Lei Zhang and Pang Li (2017) proposed a fault tolerant position estimation for Switched Reluctance Motor (SRM) is proposed in the paper based on relationship between inductance and rotor position. First, the particular position signal is obtained by comparing the real-time flux linkage with the particular position flux linkage, the position is estimated by the particular position signal. Second, the delay method is used based on inter-phase independence under the phase fault, the fault phase position is estimated by the normal phase the particular position signal. Finally, the experimental have been implemented in a 12/8 structure SRM prototype. The results show that the proposed methods are verified the correctness and feasibility.

Sourov Roy et al. (2017) presented a healthy PV array has a specific impedance between node pairs, and any ground fault changes the impedance values. Reflectometry is a well-known technique in electromagnetics, and it could be exploited to detect fault and aging related impedance variations in a PV system. A fault detection algorithm using the spread spectrum time domain reflectometry (SSTDR) method has been introduced in this paper. SSTDR has been successfully used for detecting and locating aircraft wiring faults. However, the wide variation in impedance throughout the entire PV system, which is caused by the use of different materials and interconnections makes PV fault detection more challenging while using reflectometry. Unlike other conventional ground fault detection techniques specifically developed for PV arrays, SSTDR does not depend on fault-current magnitudes. Therefore, SSTDR can be used even in the absence of the solar irradiation, which makes it a very powerful fault detection tool. The proposed PV ground fault detection technique has been tested in a real-world PV system, and it can confidently detect PV ground faults for different configurations of PV arrays (single and double strings) and fault resistances (0.5, 5, and 10 Ω). Moreover, it has been experimentally verified that our proposed algorithm works at low irradiance and can detect specific ground faults that may remain undetected using conventional ground fault detection and interrupter (GFDI) fuses.

Jonathan Medina-García et al. (2017) presented a wireless fault detection system for industrial motors that combines vibration, motor current and temperature analysis, thus improving the detection of mechanical faults. The design alsoconsiders the time of detection and further possible actions, which arealso important for the early detection of possible malfunctions, and thus for avoiding irreversible damage to the motor. The remote motor condition monitoring is implemented through a wireless sensor network (WSN) based on the IEEE 802.15.4 standard. The deployed network uses the beacon-enabled mode to synchronize several sensor nodes with the coordinator node, and the guaranteed time slot mechanism provides data monitoring with a predetermined latency. A graphic user interface offers remote access to motor conditions and real-time monitoring of several parameters. The developed wireless sensor node exhibits very low power consumption since it has been optimized both in terms of hardware and software. The result is a low cost, highly reliable and compact design, achieving a high degree of autonomy of more than two years with just one 3.3 V/2600 mAh battery. Laboratory and field tests confirm the feasibility of the wireless system.

Juan Aponte-Luis et al. (2018) presented the design of a wireless sensor network particularly designed for remote monitoring and control of industrial parameters. The article describes the network components, protocol and sensor deployment, aimed to accomplish industrial constraint and to assure reliability and low power consumption. A particular case of study is presented. The system consists of a base station, gas sensing nodes, a tree-based routing scheme for the wireless sensor nodes and a real-time monitoring application that operates from a remote computer and a mobile phone. The system assures that the industrial safety quality and the measurement and monitoring system achieves an efficient industrial monitoring operations. The robustness of the developed system and the security in the communications have been guaranteed both in hardware and software level. The system is flexible and can be adapted to different environments. The testing of the system confirms the feasibility of the proposed implementation and validates the functional requirements of the developed devices, the networking solution and the power consumption management.

Thimmapuram Swati et al. (2019) proposed today's word is internet world, Internet of Things (IoT) is expanding at rapid rate increasing technology. A network of connected computers hidden in every corner of our life monitoring and controlling things with minimal IOT supports to connect hard ware devices to the internet to process the data for monitoring and security. This system uses ESP32 and sensors helps to monitor the different parameters like temperature, humidity, smoke etc. are accessed and monitored from remote area by cloud computing the data using Blink and automatically controls the motor or system operation by computer or smartphone. This system is very useful for small scale industry for to achieve maximum throughput and to avoid from accidents by SMS alerts and email, it is a simple, smart monitoring and security system and also tells the importance of IoT in industrial applications. Proposed method very well suitable for small scale industries monitoring and controlling.

Dionisis Kandris et al. (2020) proposed Wireless Sensor Networks are considered to be among the most rapidly evolving technological domains thanks to the numerous benefits that their usage provides. As a result, from their first appearance until the present day, Wireless Sensor Networks have had a continuously growing range of applications. The purpose of this article is to provide an up-to-date presentation of both traditional and most recent applications of Wireless Sensor Networks and hopefully not only enable the comprehension of this scientific area but also facilitate the perception of novel applications. In order to achieve this goal, the main categories of applications of Wireless Sensor Networks are identified, and characteristic examples of them are studied. Their particular characteristics are explained, while their pros and cons ared enoted. Next, a discussion on certain considerations that are related with each one of these specific categories takes place. Finally, concluding remarks are drawn.

Mohammed Sulaiman BenSaleh et al. (2020) proposed wireless sensor networks (WSNs) have grown considerably in recent years and have a significant potential in different applications including health, environment, and military. Despite their powerful capabilities, the successful development of WSN is still a challenging task. In current real-world WSN deployments, several programming approaches have been proposed, which focus on low-level system issues. In order to simplify the design of the WSN and abstract from technical low-level details, high-level approaches have been recognized and several solutions have been proposed. In particular, the model-driven engineering (MDE) approach is becoming a promising solution. In this paper, we present a survey of existing programming methodologies and model-based approaches for the development of sensor networks. We recall and classify existing related WSN development approaches. The main objective of our research is to investigate the feasibility and the application of high-level-based approaches to ease WSN design. We concentrate on a set of criteria to highlight the shortcomings of the relevant approaches. Finally, we present our future directions to cope with the limits of existing solutions.

Conclusion:

The advantages of WSNs over traditional sensing have made them a promising platform for remote monitoring systems. The motor energy efficiency and health conditions are estimated using only motor terminal electrical data through WSNs in an online, remote, and nonintrusive manner. The feasibility of the proposed scheme has been demonstrated through a series of laboratory experiments and field tests. This paper has also addressed the challenges when applying the proposed WSN scheme in industrial environments, including wireless-link quality dynamics, noise and interference, and environmental impact on communication range and reliability. In summary, the following key contributions have

- An online and remote energy monitoring and fault diagnostic system in a WSN scheme has been proposed, and its feasibility has been demonstrated. The nonintrusive nature of the proposed scheme is well aligned with the current trend of electrical-signal-based motor fault diagnostics, such as the motor current/power signature analysis (MCSA/MPSA).
- The spatiotemporal impacts of industrial environments on the proposed WSN scheme have been experimentally investigated. The empirical measurements have demonstrated that the average LQI values provided by WSN radio components are closely correlated with PRR and can be used as a reliable metric for wireless-link-quality assessment during the deployment of the proposed WSN scheme.

References

1) A. Bellini, F. Filippetti, G. Franceschini, C. Tassoni, and G. B. Kliman, "Quantitative evaluation of induction motor broken bars by means of electrical signature analysis," in IEEE Transactions on Industry Applications, vol. 37, no. 5, pp. 1248-1255, Sep/Oct 2001.
2) Adouni Amel, Ben Hamed Mouna, Sbita Lassaâd, "Application of Parity Space Approach in Fault Detection of DC Motors" , 2012 First International Conferrence on Renewable Energies and Vehicular Technology.
3) B. Lu, T. G. Habetler, and R. G. Harley, "A survey of efficiency-estimation methods of in-service induction motors," IEEE Trans. Ind. Appl., vol. 42, no. 4, pp. 924–933, Jul./Aug. 2006.
4) B. Lu and S. Sharma, "A literature review of IGBT fault diagnostic and protection methods for power inverters," in Conf. Rec. IEEE IAS Annual. Meeting, Oct. 2008, pp. 1–8.
5) B. Lu, T. G. Habetler, and R. G. Harley, "A nonintrusive and in-service motor efficiency estimation method using air- gap torque with considerations of condition monitoring," IEEE Trans. Ind. Appl., vol. 44, no. 6, pp. 1666–1674, Nov./Dec. 2008.
6) Dionisis Kandris, Christos Nakas, Dimitrios Vomvas and Grigorios Koulouras, "Applications of Wireless Sensor Networks: An Up-to-Date Survey", Applied System Innovations 2020, 3, 14.
7) G. Zhou, T. He, J. Stankovic, and T. Abdelzaher, "RID: Radio interference detection in wireless sensor networks," in Proc. IEEE-INFOCOM, Mar. 2005, vol. 2, pp. 891–901.
8) Ben Hamed Mouna, Beni Hamed Salah and Sbita Lassaad, "Direct current motor real time application of sensor and actuator faults detection and isolation based on structural residual space parity approach", 978-1-4799-7300-2/14, 2014 IEEE.
9) Bilal Akin, Member, IEEE, Seungdeog Choi, Student Member, IEEE, Umut Orguner, Member, IEEE, and Hamid A. Toliyat, Fellow, IEEE, "A Simple Real-Time Fault Signature Monitoring Tool for Motor-Drive-Embedded Fault Diagnosis Systems", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 58, NO. 5, MAY2011.
10) Bilal YOUSSEF, "On Line Pararnetric Faults Detection in Induction Motors Based on Graphical Signature Tool", The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON) Nov. 5-8, 2007, Taipei, Taiwan.
11) C. Rodriguez-Donate, R. J. Romero-Troncoso, A. Garcia-Perez, and D. A. Razo-Montes, "FPGA based

embedded system for Induction motor failure monitoring at the start-up transient vibrations with wavelets," in Proc. IEEE International Conference on Industrial Embedded Systems, pp. 208-214, 2008.

12) E. Cabal-Yepez, R. A. Osornio-Rios, R.J. Romero-Troncoso, J. R. RazoHernandez, and R. Lopez-Garcia, "FPGA-based Online Induction Motor Multiple-fault Detection with Fused FFT and Wavelet Analysis," in Proc. IEEE International Conference on Reconfigurable Computing and FPGAs, pp. 101-106, 2009.
13) Fernando Alvarez-Gonzalez, Sunisa Sornmuang and Jittiwut Suwatthikul, "Detection of a motor bearing shield fault using neural networks", SICE Annual Conference 2016 September 13-18, 2011, Waseda University, Tokyo, Japan.
14) IEEE Standard Test Procedure for Polyphase Induction Motors and Generators, IEEE Std. 112-1996, Sep. 1996.
15) Ilhan Aydin ,Shubhasish Sarkar, Pranab Kumar Hembram, Prithwiraj Purkait and Santanu Das, "Acquisition and Pre-processing of Three Phase Induction Motor Stator Current Signal for Fault Diagnosis using FPGA, NI Compact-RIO Real Time Controller", 2016 IEEE Uttar Pradesh Section International Conference on Electrical, Computer and Electronics Engineering (UPCON) Indian Institute of Technology (Banaras Hindu University) Varanasi, India, Dec 9-11, 2016.
16) I. Aydin, M. Karakose, and E. Akin, "Fuzzy System Based Fault Detection Method Using ZCT Signals: An FPGA Approach", in Proc. IEEE International Conference of Acemp-Electromotion, Istanbul – Turkey, 2011, pp. 298-303.
17) Jonathan Medina-García, Trinidad Sánchez-Rodríguez, Juan Antonio Gómez Galán 1, Aránzazu Delgado, Fernando Gómez-Bravo 1 and Raúl Jiménez , "A Wireless Sensor System for Real-Time Monitoring and Fault Detection of Motor Arrays", Sensors 2017, 17, 469.
18) Jose de Jesus Rangel-Magdaleno, Rene de Jesus Romero-Troncoso, Roque Alfredo Osornio-Rios, Eduardo Cabal-Yepez, and Luis Miguel Contreras-Medina, "Novel Methodology for Online Half-Broken-Bar Detection on Induction Motors", IEEE Trans. On Instrumentation and Measurement, vol. 58, no. 5, May 2009.
19) Jorge O. Estima Ben Hamed Mouna, Beni Hamed Salah and Sbita Lassaad, "Direct current motor real time application of sensor and actuator faults detection and isolation based on structural residual space parity approach", 978-1-4799-7300-2/14, 2014 IEEE.
20) Lei Zhang and Pang Li "Real-Time Identification of Distributed Bearing Faults in Induction Motor", 0-7803-9772-X/06,2017 IEEE.
21) M. E. H. Benbouzid, "A review of induction motors signature analysis as a medium for faults detection," IEEE Trans. Ind. Electron., vol. 47, no. 5, pp. 984–993, Oct. 2000.
22) M. E. H. Benbouzid, M. Vieira, and C. Theys, "Induction motors' faults detection and localization using stator current advanced signal processing techniques," in IEEE Transactions on Power Electronics, vol. 14, no. 1, pp. 14-22, Jan 1999.
23) M. Blodt, M. Chabert, J. Regnier, and J. Faucher, "Mechanical load fault detection in induction motors by stator current time-frequency analysis," IEEE Transaction on Industry Applications, vol. 42, no. 6, pp. 14541463, Nov./Dec. 2006.
24) Mohammed Sulaiman BenSaleh, Raoudha Saida, Yessine Hadj Kacem and Mohamed Abid, "Wireless Sensor Network Design Methodologies: A Survey", Hindawi Journal of Sensors Volume 2020, Article ID 9592836.
25) N. Arthur and J. Penman, "Induction machine condition monitoring with higher order spectra," in IEEE Transactions on Industrial Electronics, vol. 47, no. 5, pp. 1031-1041, Oct 2000.
26) Odavic, Milijana, M. Summer, P. Wheeler, and J. Li, "Real-time fault diagnostics for a permanenet magnet synchronous motor drive for aerospace applications," 2010 IEEE Energy Conversion Congress and Exposition, 2010.
27) R. N. Bell, D. W. McWilliams, P. O'Donnell, C. Singh, and S. J. Wells, "Report of large motor reliability survey of industrial and commercial installations—Part I," IEEE Trans. Ind. Appl., vol. IA-21, no. 4, pp. 853– 864, Jul./Aug. 1985.
28) R. N. Bell, C. R. Heising, P. O'Donnell, C. Singh, and S..J. Wells, "Report of large motor reliability survey of industrial and commercial installations—Part II,"

IEEE Trans. Ind. Appl., vol. IA-21, no. 4, pp. 865– 872, Jul./Aug. 1985.

29) R. J. Romero-Troncoso, R. Saucedo-Gallaga, E. Cabal-Yepez, A. Garcia-Perez, R. A. Osornio-Rios, R. Alvarez-Salas, H. MirandaVidales, and N. Huber, "FPGA-Based Online Detection of Multiple Combined Faults in Induction Motors through Information Entropy and Fuzzy Interference", IEEE Transactions on Industrial Electronics, 2011.
30) Rajesh Patel, S P Gupta, and Vinod Kumar, "Real-Time Identification of Distributed Bearing Faults in Induction Motor", 0-7803-9772-X/06,2006 IEEE
31) Roy McCann, "Detection and Optimal Compensation of Unbal- anced AC Motor Drives Using DISC Analysis", SDEMPED 2003 -Symposium on Diagnostics far Electric Machi, Power Electronics and hives Atlanta, CA, USA 24-26 Augun 2003.
32) S. Sarkar, S. Das, and P. Purkait, "Wavelet and SFAM based classifiaction of induction motor stator winding short circuit faults and incipient insulation failures," 2013 IEEE 1st International Conference on Condition Assessment Techniques in Electrical Systems (CATCON), 2013.
33) Shahin Hedayati Kia, Humberto Henao,Senior Member IEEE, Gérard-André Capolino, Fellow IEEE, "A Real-Time Platform Dedicated to On-Line Gear Tooth Surface Damage Fault Detection in Induction Machines", 978-1-4799-4389- 0/14/$31.00 ©2014 IEEE.
34) Shubhasish Sarkar, Pranab Kumar Hembram, Prithwiraj Purkait and Santanu Das, "Acquisition and Pre-processing of Three Phase Induction Motor Stator Current Signal for Fault Diagnosis using FPGA, NI Compact RIO Real Time Controller", 2016 IEEE Uttar Pradesh Section International Conference on Electrical, Computer and Electronics Engineering (UPCON) Indian Institute of Technology (Banaras Hindu University) Varanasi, India, Dec 9-11, 2016.
35) Sourov Roy and Jittiwut Suwatthikul, "Detection of a motor bearing shield fault using neural networks" SICE Annual Conference 2017 September, Waseda University, Tokyo, Japan.
36) Sunisa Sornmuang and Jittiwut Suwatthikul, "Detection of a motor bearing shield fault using neural networks" SICE Annual Conference 2011 September 13-18, 2011, Waseda University, Tokyo, Japan.
37) Thimmapuram Swati, K. Raghavendra Rao, "Industrial Process Monitoring System Using Esp32", International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-7, Issue-6S4, April 2019.
38) Turker Ince, Adouni Amel, Ben Hamed Mouna, Sbita Lassaâd, "Application of Parity Space Approach in Fault Detection of DC Motors" , 2016 First International Conferrence on Renewable Energies and Vehicular Technology.