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PREDICTIVE MAINTENANCE OF INDUCTION MOTOR USING SUPPORT VECTOR MACHINE

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Abstract – *Induction motors are a critical component of many industrial processes and an integral part of daily life. It makes approximately 70% of the driven electrical loads. There is always a need to repair diagnose and predict the failures associated with machine. This project looks into the possibility of utilizing machine learning to predict the faults associated with induction motor using NI LabVIEW software. Proper maintenance techniques should be done in order to ensure continuity of operation to avoid shutdown, costly machinery repair, health problems and safety problems. In the model proposed here current data is used for detection of faults. A single phasing fault is given for testing. The process of fault diagnosis consists of data acquisition done by NI c-RIO, feature extraction done by statistical methods and fault diagnosis by SVM. Finally a monitoring system is proposed that can detect whether a machine is faulty or not and predict the chance for a fault.*

Key Words: **Predictive maintenance, Induction Motors, NI LabVIEW Software, Support Vector Machine, Feature Extraction, Feature Manipulation, Fault Diagnosis**

1. INTRODUCTION

The main aim of this project is to build a maintenance system for induction motors using predictive maintenance technique which could be used for industrial purposes. Predictive maintenance refers to intelligent monitoring of equipment to avoid future failures. While early detection and diagnosis of process faults while induction motors is still operating helps in reducing maintenance cost, shutdown and production stoppage. The major processes involved in this are current data acquisition from induction motor, feature extraction, feature manipulation and fault diagnosis.

Induction motors can be defined as machines that transform electrical energy into mechanical energy. Due to its high efficiency, low maintenance requirements, simplicity makes it one of the most useful inventions. They are reliable in operations but are subject to different types of undesirable faults. There is a need to detect it and solve it as early as possible in order to avoid catastrophes. The most susceptible parts for fault in the induction motor are bearing, stator winding, rotor bar and shaft.

Data can be acquired reliably and non-intrusively where a non-invasive technique called MCSA is used here. It is a powerful tool for detecting faults from the current variation and the data is processed to be used in studying the machine condition. All the signal processing, fault diagnosis is performed by LabVIEW software.

Instruments used for current data acquisition are cRIO and AC drive. c-RIO is the data acquisition device which collects information to PC. Both normal data and faulty current data of motor are taken. Fault is generated by disconnecting one of the phases of motor and this fault is called single phasing fault. AC drives are used for speed regulation.

Features are extracted by statistical techniques. Statistical features like mean, variance, kurtosis, skewness etc are found. Feature manipulation is done to eliminate features that do not contribute to the accuracy of the classifier. Predictive maintenance based on the analysis of statistical features using artificial intelligence is implemented here. AI has the advantages of simple configuration, easy to develop, quick detection and excellent handling of nonlinearity.

SVM (Support Vector Machine) is used here for fault diagnosis which has the capability to classify faults with 95% accuracy. The main advantages of this developed system will be minimizing downtime, reduced price and raw material consumption, increased availability or useful life of the machines, minimize unnecessary maintenance actions, risk of health & safety & environment incidents are reduced.

2. LITERATURE REVIEW

Considerable work on predictive maintenance was done in recent years. The recent techniques for predictive maintenance include signal processing and machine learning. H.M Hashemian [1] describes about condition-based maintenance techniques for industrial equipment and processes are described along with examples of their use and discussion of their benefits.

This research proposes [3] the conceptual aspects of the induction motor, and the measurement treatment, analysis of signals for techniques based on artificial intelligence. The research also includes fault types and their classification according to engine, software and hardware parts used and modern approaches or maintenance strategies. Dubravko and Miljkovic [4] describes about MCSA and its fundamentals, fault detection techniques and current signatures of various faults.

Thesis [6] gives a non-invasive, on-line method for detection of mechanical and stator winding faults in 3-phase induction motors from observation of motor line current supply input. Book [8] covers a comprehension of the principles involved in LabVIEW programming. Kareem A Noor et.al [12], proposes electrical method for online monitoring of IM by elimination of any other sensors implemented using MCSA in LabVIEW.

Ruiming Fang and Hongzhong Ma [13] propose a fault diagnosis system using SVM based classification techniques for induction machines rotor fault diagnosis. Shu-Ying Li and Lei Xue [14], describes about an induction motors early fault diagnosis method based on MCSA and multi-fault SVM classifier that achieved good performance of classification under nonlinear, high dimension and small sample set. In the tutorial [16], gives a brief introduction to SVM and data from various sources that gives a wide range of information about SVM classifier. D. Matic and F.Kulic [17] describes a method for broken bar detection based on MCSA of one phase of induction motor current.

Bouchemha Amel et.al [19] proposes a method to detect and localize the broken bar faults by using MCSA data with multi-class SVM. Keisuke Asano et.al [21] describes a method for fault diagnosis of bearings done by SVM algorithm by feeding features extracted into it which was extracted using FFT. Thesis [24] focuses on reviewing and evaluating several selected classification algorithms for machinery fault diagnosis modeling. Muhammad Achirul Nanda [30], it gives a method to detect termites non-destructively by acoustic signal extraction using Kernel functions in the SVM.

3. METHODOLOGY

3.1 Predictive Maintenance

This is also known as online monitoring or condition-based maintenance or risk-based maintenance. It is referred as intelligent monitoring of equipment to avoid future failures. Determines both what needs to be maintained and when it needs to be done. Preferred maintenance in 89% cases and in some industries maintenance now is the second highest or even the highest element of operating cost. It should be done not only when the equipment is old but throughout the life of equipment to identify the onset of degradation and failure of equipment.

3.2 Induction Motors

An induction machine is defines as an asynchronous machine which become an industry workhorse and play a pivotal role in industry for conversion of electrical energy to mechanical energy. Degradation of induction motors mainly includes wear, slackness, leakage, dust, dirt, corrosion, deformation, and adherence of raw materials, surface damage, cracking, overheating, vibration and other deformalities. Failures due to this degradation include broken rotor bars, air-gap eccentricity, bearing damage, rotor winding failure, stator winding failure, vibration of machine, foundation defect, unbalanced supply voltage/current, single phasing, under/over voltage of current, earth fault, overload, inter-turn short, circuit fault and crawling.

Table-1: Induction motor ratings

Number of phases	3
Voltage	415 ±10% V
Frequency	50 Hz
Current	7.5 A
Speed	1420 rpm
Power	3.7 KW

3.3 Data Acquisition

Data acquisition is defined as the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. MCSA is a condition monitoring technique used to diagnose problems in any dynamic energized system by monitoring the stator current (more precisely the supply current).

CompactRIO provides high performance processing capabilities like sensor-specific conditioned I/O, and a closely integrated software tool chain that makes them ideal for monitoring and control applications, which is optimized for programming with LabVIEW. An AC drive is a device that is used to control the speed of an electric motor and to enhance process control. Power Flex 40 AC drive is used for our purpose, providing end users with performance-enhancing motor control. Data is acquired by using NI c-RIO using LabVIEW software.

Table-2: NI cRIO-9068 specifications

Voltage input range	9V to 30 V
Maximum power input	25 W
Maximum power consumption	25 W
FPGA type	Xilinx Zynq 7020
Non-volatile memory	1 GB
DRAM	512 MB
Network interface	10/100/1000 Ethernet
Compatibility	IEEE 802.3
Communication rates	10 Mbps, 100 Mbps, 1000 Mbps auto negotiated
RS-232 Serial Ports: Maximum baud rate	230,400 bps

3.4 Feature extraction

Feature extraction means finding a good data representation and it can be defined as finding the most relevant data that indicates the presence of motor fault. It is domain specific and signal specific. It is necessary in machine fault diagnosis and obtains as many possible features because more features give more reliable information. In machine learning, feature extraction starts from an initial set of measured data and builds derived value features intended to be informative and non-redundant.

3.5 Feature Manipulation

Feature manipulation means eliminating features that do not contribute to the accuracy of the classifier or have negligible effect on the SVM success classifying rate. In this process the number of selected features is decreasing to a value that even acceptable to accomplish proper further diagnosis. Removing the irrelevant features is one of the most accepted methods in the field. A feature is treated as good or relevant when its discriminating ability is high among the classes.

3.6 Fault Diagnosis

Attributing features extracted preferably to a certain fault and then deciding severity of it is called fault diagnosis. In some situations, the diagnostic engine is fairly simple, but for efficient online CM, more advanced techniques are exploited. Fault detection is an absolute must for any practical system.

SVM are a set of related supervised learning methods used for classification and regression that belong to a family of generalized linear classifiers. It uses machine learning theory to maximize predictive accuracy while automatically avoiding over fit to the data. It is one of the diagnosing tools which determine the recognition results by categories.

One class SVM is an unsupervised learning algorithm that learns a decision function for uniqueness detection classifying new data as similar or different to the training set. A classification task usually involves training and testing data which consists of some data occurrence.

3.7 NI LabVIEW Software

LabVIEW is a system design platform and development environment based on the concept of data flow programming which creates programs with graphics. All the signal processing, fault diagnosis is performed by LabVIEW software. Using LabVIEW, we can build test and measurement, data acquisitions, instrument control, data logging, measurement analysis and report generation applications.

4. PROCEDURE

Pump which is part of a process automation training plant (pilot plant) is monitored for faults. First step is data acquisition, in which cRIO is used for data acquisition. cRIO is connected to AC drive and further it is connected to motor. cRIO send a sinusoidal reference signal for speed regulation to AC drive. In return line current is send back to cRIO which can be acquired by Ethernet cable to PC using LabVIEW. This is repeated for both normal and faulty conditions of motor. Fault is induced by disconnecting one of the phases of induction motor.

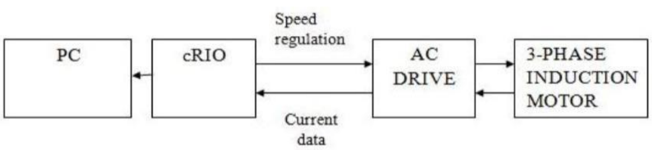

Fig-1: Block Diagram of Data Acquisition

Data collection from cRIO and the next steps feature extraction; feature manipulation and fault diagnosis are done in PC with LabVIEW software. Current data is stored in excel sheet. In feature extraction, statistical features such as mean, RMS, kurtosis, median and skewness is found. The values are stored together as an excel sheet for further processing. Data is divided into two set, test data and training data which is utilized for training and deployment. Feature manipulation is done after that which requires no extra program but giving a condition in data deployment program.

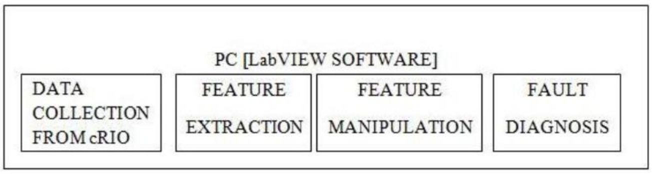

Fig -2: Steps performed using LabVIEW

Fault diagnosis is performed using SVM classifier. SVM is trained with features of normal data of motor. A model is saved after training. This model is further used for classification deployment program. Saved model is tested with trained data and we will receive a graph of predicted result as output. After fault diagnosis, proper maintenance action is planned.

5. RESULTS

Test data consists of both faulty and normal data. It is divided into two classes:

Table- 3: Two classes of data

Class 0	Normal data
Class 1	Faulty data

Table-4: Hyperparameters used in experiment

SVM type	NU_SVC
Kernel Type	Linear
Degree	3
nu	0.25
gamma	0.5
Coef0	0

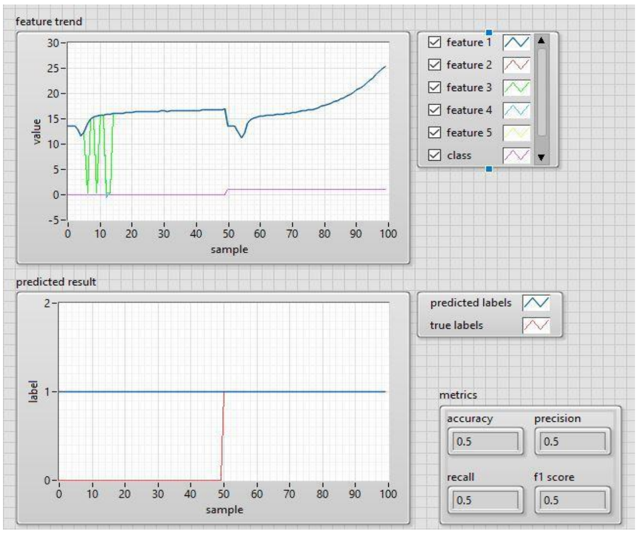

Chart- 1: Feature trend and predicted result graphs of classification using SVM

The final predicted result graph shows that the motor is faulty. The fault we given is disconnection of one of the phases of fault. It is detected using this classification. In addition to that in course of working, some wear and tear may occur in motors. Proper maintenance activities should be done at intervals in order to avoid sudden shutdown. Single phasing fault condition requires that the motor should be provided with protection that will disconnect it from the system before the motor is permanently damaged.

To troubleshoot and again run the motor, stop the motor immediately and switch to the standby motor. Check the parameters of the motor as stated in the data sheet. Do proper visual inspections of the motor winding. Once the problem is located and rectified, box up the motor. Before connecting the motor to the load, switch on the controls for the motor and test run for all the important parameters.

6. CONCLUSION

In this project, support vector machine (SVM) is utilized to predict the faults associated with induction motor using LabVIEW software. The proposed system used c-RIO to acquire current data from 3-phase induction motor. Both healthy and faulty data are taken. Fault is created by disconnecting one of the phases of 3-phase induction motor. It uses statistical features to extract the features from the current signal. Then the motor input current features are used for SVM training and testing. After detection of faults maintenance action is planned as further step.

Fault detection using the stator phase current signature is the simplest and cheapest technique. SVM could be successfully applied in predictive maintenance because it provides high accuracy classification. Choosing the right features also increases the classification accuracy Feature extraction using statistical methods makes the process easy. Timely detection of incipient faults is of great importance this can be easily applied in industries. Industries should deploy predictive and online strategies to avoid sudden failures and other catastrophes. Using LabVIEW for predictive maintenance makes the process easy and less time consuming.

Future scope includes:

- Use other feature extraction techniques like Wavelet transform, FFT, Park Vector approach etc.
- Use other fault diagnosis techniques like artificial neural networks, PCA, logical regression, fuzzy logic etc.
- Detecting multiple types of faults concurrently
- Implement more faults that are challenging like broken bar faults, eccentricity, bearing faults etc.
- Acquire other parameters like vibration, torque, speed, temperature to compare with current signature results.

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