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Analysing And Monitoring Faults Of Electric Motor By Current Signature Analysis

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ABSTRACT*-Motor electrical current signature analysis (MCSA) is detecting an electrical signal containing current parts that are immediate side-effect of special pivoting flux segments. Peculiarities in operation of the engine modify harmonic content of motor supply current. Enlistments engine drives are the most generally utilized electrical drive framework and regularly devour 40 to 50 percent of an industrialized country's aggregate producing limit. Electric engines have applications in the field of transportation, assembling, mining, and petrochemical and in practically every different fields managing electrical power. Along these lines, condition checking and fault diagnosis become necessary to monitor the health of the machine. The present paper talks about the basics of Motor Current Signature Analysis and blame recognition of the electric engine utilizing MCSA.*

Keywords: Electric motor; MCSA; Signature Analysis; FFT; Fault Detection

I. INTRODUCTION

Electric engines are predominantly utilized as a part of modern drives as they are tough, solid and temperate. Engine Current Signature Analysis (MCSA) is a condition checking method which finds and analyze issues in acceptance engines. MCSA is a technique from more extensive field of Electrical Signature Analysis (ESA), valuable for breaking down not just electrical acceptance motors, but generators, control transformers and additionally other electric hardware. Most well known strategies of mark investigation are: Voltage Signature Analysis (VSA), Current Signature Analysis (CSA), Instantaneous Power Signature Analysis (IPSA) and Extended Park's Vector Approach (EPVA) additionally incorporates Motor Circuit Analysis, including examination of resistance, impedance, inductance, phase angle, current/frequency response and insulation to ground faults [2].Basic uses of electric engine are found in all enterprises and incorporate all engine horsepower. For typical low to medium horsepower electric motors many of the commercial products to monitor electric motors are not cost effective. Advances in sensors, models and calculations are the important advances for compelling beginning disappointment identification. With the end goal of disappointment checking, an assortment of sensors could be utilized to gather estimations from an electric engine. These sensors can gauge stator voltages and streams, case vibrations, inward and outer temperature air-hole, yield torque, outside attractive flux densities, rotor position and speed and so forth [2].

A. Background

Electric motor particularly three stage acceptance engine assumes imperative part in the business because of their points of interest over other electrical engines. Thusly, there is a solid interest for their dependable and safe operation. On the off chance that any blame and disappointments happen in the engine it can prompt over the top downtimes and create extraordinary misfortunes regarding income and upkeep. In this way, an early blame recognition is required for the security of the engine. In the present situation, the wellbeing observing of the enlistment engine are expanding because of its capability to decrease working costs, upgrade the unwavering quality of operation and enhance administration to the clients. The wellbeing checking of electric motor is a developing innovation for online discovery of beginning deficiencies. The on-line wellbeing observing includes taking estimations on a machine while it is in working conditions to recognize deficiencies

with the point of decreasing both unforeseen disappointment and support costs. In the present paper, a thorough review of acceptance machine shortcomings, analytic techniques and future viewpoints in the wellbeing observing of enlistment engine has been examined.

B. Motivation

In the present paper, a comprehensive review of electric motor faults and their recognition systems have been done. The exact wellbeing checking method of the acceptance engine can enhance the dependability and diminish the support costs. It has been seen from earlier year's examination papers that the blame conclusion in the enlistment engine is as yet a testing errand for analysts and academicians. Numerous scientists found that the stator current is much appropriate flag for the blame finding reason. It has been seen from the different research papers that the lion's share of work was situated towards consistent speed electric motor. There are different strategies which are utilized to analyze deficiencies for the steady speed acceptance engine like fuzzy logic, neural networks and genetic algorithm etc. By the creation of a few advanced flag handling procedures, it will be less demanding to analyze shortcomings of the variable acceptance machines moreover. A considerable measure of work must be done for variable speed acceptance engine. In this way, for little appraising enlistment engine flaws has been dissected however for the huge rating engines that the blame conclusion and examination will be testing assignment. From the thorough overview, it has been discovered that the Fast Fourier Transform (FFT) strategy utilized for consistent state examination and the Wavelet Transform (WT) utilized for transient investigation with Digital Signal Processing (DSP) techniques gives extraordinary outcomes.Yet, it has been discovered that the FFT strategy is not ready to diagnose fault in the no-load conditions unlike WT. These strategies are called Motor Current Signature Analysis (MCSA) techniques with engine current. In this way, it has been watched that the MCSA strategy can be utilized as a part of the blame analysis of acceptance machine in the transient conditions with wavelet change. Yet, with the wavelet change just some constrained work has been done. It has been watched that the wavelet change analyze many blames effectively in the transient conditions. Yet, for inverter encouraged acceptance machines some basic level work has been finished by the scientists.Presently, it will be interesting to see, in the future whether the wavelet transform tool will be able to diagnose faults for the inverter fed machines also or not. In this manner, the time-recurrence transient blame recognition ability of this wavelet change device with enhanced determination could be the critical instrument for the early blame identification reason in the inverter encouraged machines as well. Actually, in the enterprises inverter sustained machines are utilized inspite of clamor. Consequently, now specialists should confront the difficulties to analyze acceptance engine blames in these conditions moreover.

II. LITERATURE SURVEY

A. Mechanical Faults

The mechanical faults occurrence priority is highest in the electric motor. The mechanical faults are classified as bearing fault, eccentricity fault and load fault respectively.

1) Bearing Faults

This fault contains over 40 % of all electric machine failures. The greater part of electrical machines utilize ball or moving component orientation and these are a standout amongst the most widely recognized reasons for disappointment. These bearing comprise of an inward and external ring with an arrangement of balls or moving components set in raceways pivoting inside these rings. Since, the moving components of a moving component bearing ride on races. The extensive race that goes into a drag is called external race, and the little race that the pole rides is called internal race. Faults in the inner raceway, external raceway or moving components will deliver one of a kind recurrence parts in the deliberate machine vibration and other sensor

signals. These heading deficiency frequencies are elements of the bearing geometry and the running pace. Bearing shortcomings can likewise cause rotor unconventionality [7,8].

A continuous stress on the bearing outcomes into the weariness failures. These disappointments are at inward or external races of the direction. This sort of disappointments brings about harsh running of heading which brings about perceptible vibrations and expanded commotion levels, tainting, erosion, uncalled for grease, disgraceful establishment and brinelling are the outer components which are likewise in charge of the bearing flaw. Presently when the flux aggravation like rotor erraticisms happens, it brings about lopsided shaft voltages and streams which are likewise the explanation behind bearing disappointments [6].

2) Eccentricity Faults

Air gap eccentricity is common rotor fault of electric machines. Unequal air gap that exist between stator and rotor is known as machine eccentricity. The eccentricity fault delivers the issues of vibrations and clamor. On account of solid machine, the rotor is focus lined up with the stator bore, and the rotor's focal point of pivot is the same as geometric focal point of the stator bore. At the point when the rotor is not focus adjusted, the lopsided outspread strengths (unequal attractive force) can make a stator rotor rub, thusly, harm the stator and rotor.

The eccentricity is divided into three parts:

(i) Static eccentricity

(ii) Dynamic eccentricity.

(iii) Mixed eccentricity

In the case of static eccentricity the position of the minimal radial air gap length is fixed in space. Wrong situating of the stator or rotor center at the dispatching stage comes about into static eccentricity.

In the case of dynamic eccentricity, the centre of the rotor is not at the centre of the rotation and the position of minimum air gap rotates with the rotor. The misalignment caused because of the few factors, for example, bowed rotor shaft, bearing wear or misalignment and so forth. An air crevice whimsy is passable upto 10%. A characteristic level of static eccentricity exists even in recently made machines because of assembling and get together techniques.

All things considered, the static and dynamic whimsies tend to exist together. Perfect driven conditions can never be accepted. Subsequently, an inborn review of unusualness is suggested for any genuine machine. The joined static and dynamic flightiness is called blended eccentricity.

3) Load Faults

It is likewise a one kind of mechanical fault. In a few applications, for example, flying machines, the dependability of apparatuses might be basic in shielding human lives. Consequently, the recognition of load flaws (particularly identified with gears) has been an imperative research range in mechanical designing for quite a while. Engines are regularly coupled to mechanical loads and riggings. A few flaws can happen in this mechanical game plan. Cases of such blames are coupling misalignments and flawed apparatus frameworks that couple a heap to the engine.

B. Electrical Faults

The electrical faults are classified as stator and rotor faults. The stator faults and rotor faults mainly occur in the windings.

1) Stator Faults

Under 40 % of all announced electric machine failures fall into this class. These issues happen for the most part due to between turn winding deficiencies caused by protection breakdown. They are for the most part known as stage to-ground or stage to-stage faults. The stator twisting comprises of loops of protected copper wire put in the stator spaces. Stator winding flaws are regularly caused by protection disappointment between

two nearby turns in a coil. This is known as a swing to-turn fault or shorted turn. The resultant induced currents produce extra heating and cause an imbalance in the magnetic field in the machine. If undetected, the local heating will cause further damage to the stator insulation until catastrophic failure occurs. The unbalanced magnetic field can also result in excessive vibration that can cause premature bearing failures [15-34].

2) Rotor Faults

Rotor faults occur about almost 10% of total electric motor faults. These faults are caused by rotor winding. The rotor faults are predominantly broken rotor bars in light of throbbing burden and direct on-line beginning. It comes about into vacillation of speed, torque throb, vibration, overheating, arcing in the rotor and harmed rotor covers.

Enclosure rotors are ordered in two sections: cast and created. Cast rotors were just utilized as a part of little machines. In any case, now days because of improvement of throwing innovation, it can be utilized for the rotors of machines in the scope of 3000kW. While manufactured rotors are by and large utilized as a part of uncommon application machines.

The reason for rotor bar and end ring breakages are as following.

(i) Thermal stresses
(ii) Magnetic Stresses
(iii) Residual stresses
(iv) Dynamic stresses
(v) Environmental stresses
(vi) Mechanical stresses

Due to the above reasons, rotor bar may be damaged and simultaneously rotor unbalance situation may occur.

II. PROPOSED MECHANISM

A. Block Diagram of Proposed Scheme

The proposed framework appeared in figure 1 consists of microcontroller alongside different peripherals. We utilized microcontroller Arduino Uno as appeared in figure 2. Different peripherals incorporate electric AC-DC engine, flag molding circuit, current transformer, a serial correspondence circuit, USB to serial converter, PC and power supply. We are utilizing electric engine with 3Kg-cm torque. Two deficiencies are checked first is broken rotor shaft and other is the vibration of engine. For broken rotor identification, we quantified the current. The current of the engine is observed through the present transformer. The current ought to adequately screen to accomplish enhanced condition checking and security framework for electric motor.

A Signal conditioning circuit is utilized to quantify current at microcontroller end. Signal conditioning is measured through inner ADC of the microcontroller. The present information as computerized Signal is transmitted to PC end through serial correspondence circuit and USB to serial converter. At the PC end, current information is prepared through different squares. FFT is performed on the information. Likewise, sound waveforms are put away in the database.

Likewise, second fault, the vibration of the motor is measured using vibration sensor ADXL335. The output of this sensor is analog. ADC needed to acquire the digital signal of the vibration sensor. Similar to a 1st fault, the signal of vibration sensor is also sent to MATLAB and is processed. FFT of the signals is calculated and compared with the previously stored healthy waveform.

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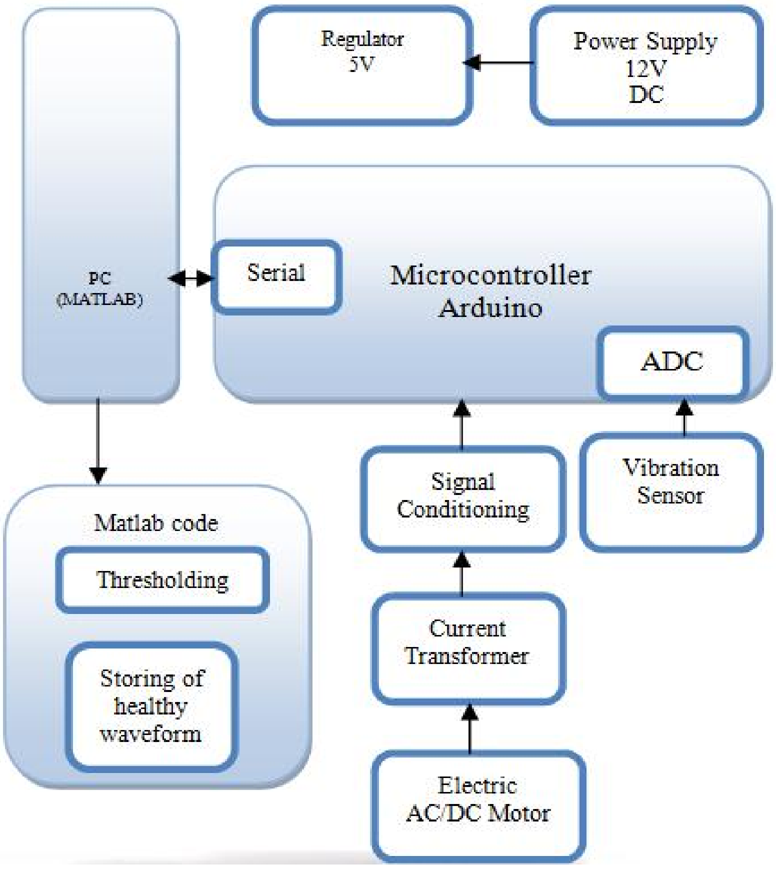

Figure 1. Block diagram of proposed electric motor fault detection system

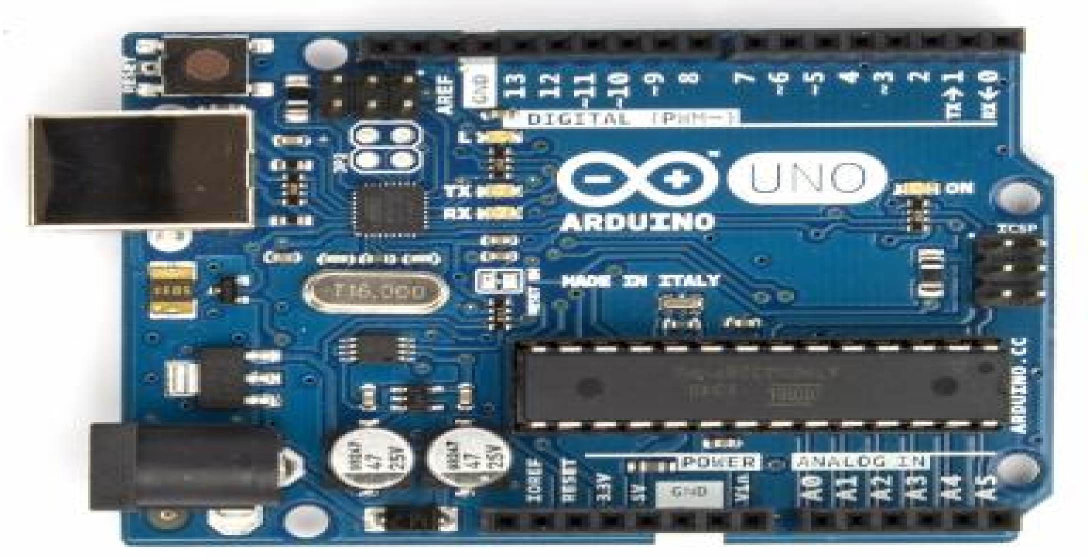

Figure 2. Arduino Uno Board

III. FAULT DETECTION AND ANALYSIS

A. Fast Fourier Transform

Motor current readings are recorded in the time domain. After that signal conditioning is performed and also signal is converted from analog-to-digital. For spectrum analysis of the motor current, spectral analysis techniques are used [4]. If signal is represented by x(t) as N discrete samples it can be expressed as a sum of N sinusoidal components of frequencies ωi, and phase shifts θi, as described in (1) and (2):

$$x(t) = A_0 + \sum_{i=1}^{N} A_i \sin(\omega_i t + \theta_i) \quad \text{……….(1)}$$

$$\omega_i = \frac{2\pi f_s i}{N} \qquad i=1, \ldots, N \quad \text{………………(2)}$$

Where ωi, is circular frequency and fs signal sampling rate. Same signal can be expressed using sine and a cosine term is given in (3):

$$x(t) = A_0 + \sum_{i=1}^{N} \left(a_i \cos(\omega t) + b_i \sin(\omega t)\right) \quad \text{…….(3)}$$

Values of coefficients can be determined by Discrete Fourier Transform, (4), (5), (6):

$$a_{i_i} = \frac{2}{N} \sum_{i=1}^{i=N} x(t) \cos(\omega_i t) \quad \text{……………………….(4)}$$

$$b_{i_i} = \frac{2}{N} \sum_{i=1}^{i=N} x(t) \sin(\omega_i t) \quad \text{…………..………….(5)}$$

$$A_i = \sqrt{a_i^2 + b_i^2} \quad \text{………………………………(6)}$$

Where,

a_i is cosine term,

b_i is sine term,

A_i amplitude for frequency component i.

For analyzing signals in the frequency domain, most common technique used is Fast Fourier Transform (FFT). It is a computational efficient version of Discrete Fourier Transform algorithm which reduces the necessary number of computations (from $O(N^2)$ to $O(N\log N)$). After applying FFT to stator supply current, amplitudes of frequency components are normalized by the value of the amplitude of first harmonic. The normalization of frequency components reduces influences of motor's load conditions.

B. Motor Current Signature Analysis technique

The motor current signature is recorded in a time domain format. The current is represented in a graphical format with the amplitude shown on the "Y" axis and the time on the "X" axis. It brings about a run of the mill current sine wave appeared in Figure 3. Keeping in mind the end goal to break down the information, a

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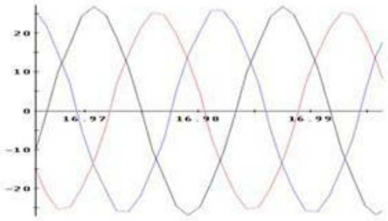
Fast Fourier Transform (FFT) is performed. A case of a FFT range is appeared in Figure 4. FFT range is an awesome hotspot for recognizable proof of rotor bar issues in engines.



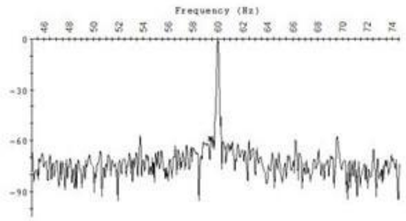


Figure 3. Current Time Domain Format **Figure 4.**Current Frequency Domain Format

C. Vibration Problem Detection and Analysis

To measure frequencies we utilize an accelerometer. The accelerometer measures the speeding up that it being is subjected to the model utilized as a part of the proposed framework is mounted on a breakout board from Spark Fun and utilize the ADXL335 3-pivot accelerometer from Analog Devices. It quantifies ±3 g in three orthogonal tomahawks marked the X, Y and Z bearing. It can read frequencies in the scope of 0.5 Hz to 1600 Hz for the X and Y axis while the Z axis has a scope of 0.5 Hz to 550 Hz.

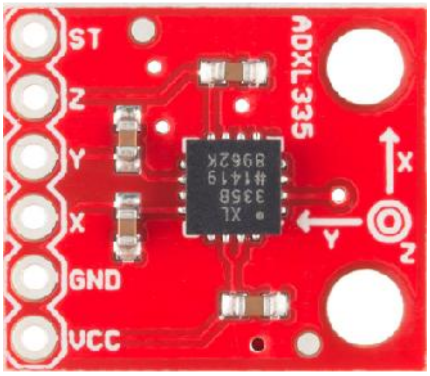


Figure 5. The accelerometer breakout board with the ADXL335

SparkFun model comes mounted with 0.1 μF capacitors that acts as a low-pass filter and limits the lower band-width of each axis to 50Hz.

Figure 6. Images of Healthy Rotor & Damaged Rotor bars

Figure 6. Demonstrates the photos of solid and harmed rotor bars. These sound rotor bars demonstrates that the state of electric engine is great and its working effectively. Harmed rotor bars debase the execution of

engine as the measure of current it was conveying already has changed. Such change in current going through engine is broke down by its present range in MATLAB.

IV. SIMULATION RESULTS

A. Output of opamp as level shifter on DSO:

The AC sine wave of current signal is shifted by some voltage as shown in fig. 7 so that the analog readings of current can be read by Arduino Uno for further computations.

Figure 7. Level Shifted Output of Op-amp on DSO

The blue color sine wave indicates the output of current transformer on DSO. Whereas the yellow color is the shifted output of op-amp obtained at the output of LM358 which is an level shifting IC.

B. Fault Detection of Broken Rotor:

Figure 8 shows the comparision between FFT's of current waveforms. Amplitude of FFT of the signal is plotted against frequency of signal.

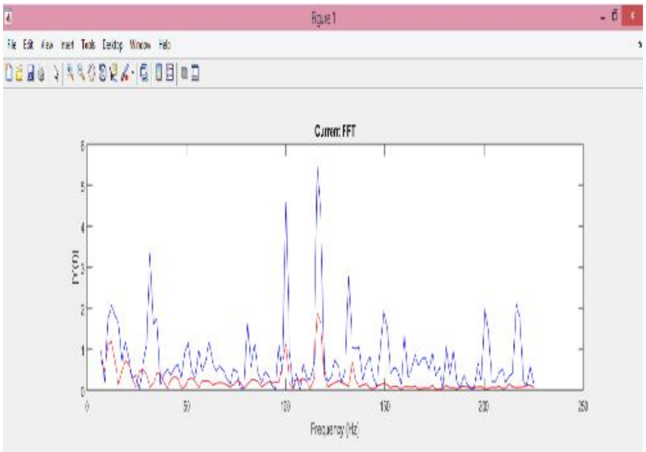


Figure 8. Comparision between FFT of healthy rotor current waveform and FFT of the broken rotor bar's current waveform

Serial data received by MATLAB is analysed and current spectrum is plotted to find out the faults in the electric motor. Blue color spectrum waveform indicates the FFT of healthy motor whereas red color spectrum waveform indicates the FFT of unhealthy motor.

C. Fault Detection of Vibration of motor

Figure 9 shows the difference in vibration spectrums due to the fault induced in motor.

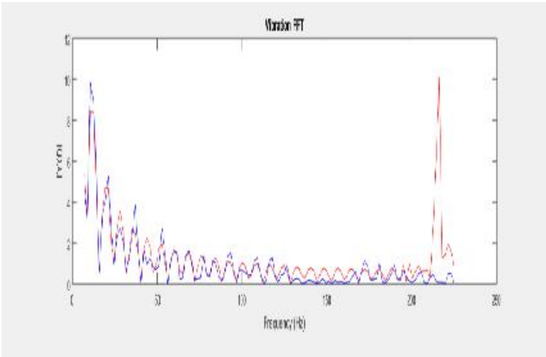


Figure 9. Comparision of vibration FFT spectrums

These spectrums are plotted against amplitude verses frequency of signal. Vibration is one of the fault used to monitor the health of the electric motor.

V. CONCLUSION

This paper talks about the basics of Motor Current Signature Analysis method which can be utilized for the fault detection and condition observing of electric engine. Two sorts of flaws are identified and checked. Blame investigation is finished by performing FFT of the info motion by utilizing MATLAB. Disappointments of electric engines cause generation downtime and may generate vast misfortunes as far as support and lost income. Auspicious identification of incipient engine shortcomings is thus of incredible significance. Contingent upon the framework accessible for information gathering and assessment, this system can be genuinely utilized as a part of conjunction with different advancements like engine circuit investigation, keeping in mind the end goal to examine an entire engine circuit

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