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On-Line Detection of Rotor Broken Bars of Three Phase Induction Motor by Digital Signal Processing Method

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***Abstract*—The paper discusses development and practical implementation of a novel recent advanced digital signal processing technique (DSPT) based system for the on-line real time condition monitoring and performance determination on rotor broken bar of three phase induction motor. The electrical signals are on-line acquired and digital processed to obtain the condition monitoring of machine status. This paper presents a reliable advance and most accurate rotor fault condition monitoring system using an ordinary hardware and LABVIEW software. The National Instruments DAQ used have 32 AI (16-bit, 2 Ms/s). This paper presents the system and results to monitor rotor winding faults using motor current signature analysis. The three phase current and voltage signals are acquired in healthy and faulty rotor conditions at load conditions. A number of tests carried out on small-size 415 V, 2.1 A, 1.00 HP, three phase induction motor highlight the excellent promptness in detecting faults, and very good diagnostic performance.**

***Index Terms*— Rotor broken bars Condition monitoring, Diagnosis, Parameter determination, Digital signal processing, Motor current signature analysis.**

I. INTRODUCTION

Three phase induction motor plays an important role in industry. As it is simple in construction, robust, cheap, minimum maintenance costs so it is economical for the industry. While operating induction motor various stresses like thermal stress, mechanical stress, electrical stress etc are produced which are acting on the parts of the motor so it may fail. There are various on-line and off-line methods to detect the faults occur in three phase induction motor. In off-line method, the motor is switched off from the supply and in on-line method the fault is detected when the motor is operating. In off-line method there is a huge revenue loss and time consuming so the researchers are attracted to on-line condition monitoring and faults diagnosis. The induction motor transforms electrical energy to mechanical energy at high efficiency between 85%-97 %. There is no electrical connection between stator and rotor very small maintenance costs. As per IEEE literature review the various faults occur in the motor is as, Bearing faults 42%, Stator faults 28 %, Rotor

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faults 8 % and other faults 22 %. The stator winding faults is one of the major faults in the motor so it essential to diagnose the stator winding faults. The stator winding faults are due to failure of insulation. The various stator winding faults are as under:

1. Short circuit between turns of same phase, called turn-to-turn fault,
2. Short circuit between two coils of same phase, called coil to coil fault,
3. Short circuit between turns of two phases, called phase to phase fault,
4. Short circuit between turns of all three phases,
5. Short circuit between winding conductors and the stator core, called coil to ground fault, and
6. Open-circuit fault when winding gets break

Causes and effects of stator winding faults

1. **Electrical Stresses:** The electrical stresses are due to the supply voltage transient. The voltage transient in the supply systems may be due to different faults, like line-to-line fault, line-to-ground fault, three-phase fault, lightning, circuit breakers On/Off and VFDs. electrical stress reduces life of stator winding.
2. **Mechanical Stresses:** It is due to the movement of stator coil and rotor striking the stator. The mechanical force acting on the coil so the coil movement occurs may cause damage to the copper conductor insulation. Rotor may strike the stator due to misalignment between stator and rotor or shaft deflection or bearing failure. The high mechanical vibration may disconnect the stator winding producing the open-circuit fault
3. **Thermal Stresses:** It is due to thermal overloading of the machine. Thermal stress due to over current, higher ambient temperature, obstructed ventilation, and unbalanced supply voltage, etc.
4. **Environmental Stresses:** these stresses may arise if the motor operates in environment with too hot, too cold or too humid. The presence of foreign material can contaminate insulation of stator winding and also may reduce the rate of heat dissipation from the motor resulting reduction in insulation life. Air flow should be sufficient and temperature rise should not increase.[3]

A. Broken Rotor Bar Fault:

Squirrel cage rotor winding is in the form of aluminium or copper bars which are short circuits at both the ends by the end rings of same material. The bars are thicker in size, the rotor bar current enters in the end rings so end rings are bigger in size than the rotor bars.

B. Causes of Broken Rotor Bar Fault:

There are many reasons for which rotor faults may occur in an induction motor. The main causes of rotor broken bar of an induction motor are as below:

• manufacturing defects, rotor asymmetry may occur during manufacturing process.

• thermal stresses, in rotor bars and end ring the heavy current is flowing which produce thermal stress which can damage the rotor bar and if one rotor bar damage the other rotor bars may damage.

• Mechanical stress, heavy rotor current produces more mechanical stress on rotor which can damage the rotor bars

• Frequent starts of the motor at rated voltage, the frequent start of the motor overheat the rotor which can damage the rotor bars.

• Due to fatigue of metal of the rotor bar. [2], [3].

The broken bar fault produces a series of sideband frequencies in the stator current signature given by

$$fbrb = f(1 \pm 2ks)$$

where f = supply frequency, Hz

s = slip, p.u. and

k = integer, 1, 2, 3,…..

The lower side band frequency at f (1–2s) is the strongest which will cause ripples in torque, and speed at a frequency of 2sf and this in turn will induce an upper side band frequency at f (1 + 2s) and this effect will continue to create the series of sideband frequency as per above equation. The magnitude of the lower sideband frequency is used as an indicator of rotor broken bar fault [4].

C. Experimental Set-up

The experimental set up is shown in fig. below. 3- phase Current & voltages are sensed by current & voltage sensors. The signals from CT's & VT's are given to NI-DAQ for processing. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display, and connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution. Data acquisition (DAQ) is the process of measuring an electrical quantities voltages, and currents. DAQ is interfaced with computer to obtain the signal in digital form.

The experimental set up consists of Hioki Japan make clamp- on sensors, VT's, Power Quality analyzer, DAQ, and motor

1. Current Transformer: ratio 120/0.2 A, 600V, 50Hz, burden 2.5VA, class 0.5 Gilbert & Maxwell make
2. Voltage transformer specifications: Ratio: 415/5 V, Burden: 0.5 VA, Class: 1.0/0.5, 1-Phase, 50 Hz. Gilbert & Maxwell make.
3. Power quality Analyzer: PW3198 Hioki Japan make
4. DAQ: 32 AI (16-bit, 2 Ms/s)
5. The motor nameplate specifications Volts: 415, HP/kW: 1/0.75, Hz: 50, Amp: 2.1, Pole: 4, Class of insulation: B, Duty: S1, Connection: Star, Frame: 80, Make: Link Servo-Systems Pvt. Ltd.

The highly sensitive three CT's and VT's are used to monitor the current input and supply voltage respectively.

3 Ph. 415 V, 50 Hz Supply

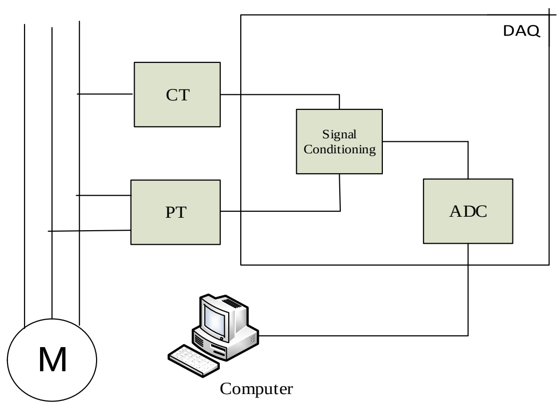

Figure 1 Block diagram of experimental setup

D. Experimental Results

Results on no-load condition on healthy motor

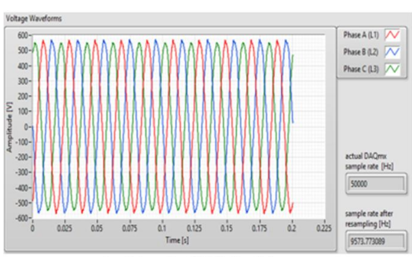

Figure 3 phase voltage (Volt) Vs. Time (Sec)

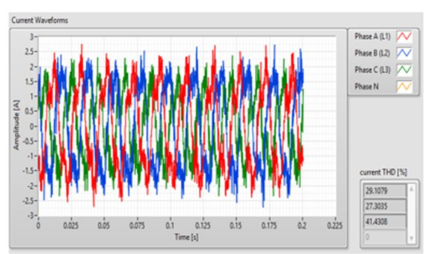

Figure 4 Phase current (Amp.) Vs. Time(Sec)

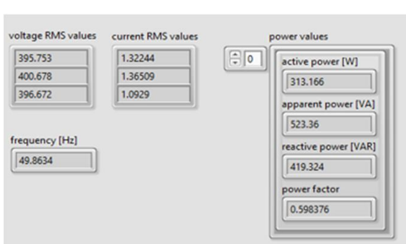

Figure 5 Results

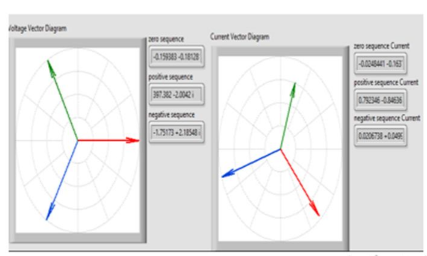

Figure 6 voltage and current phasors

Results on rotor one bar broken at full- load condition:

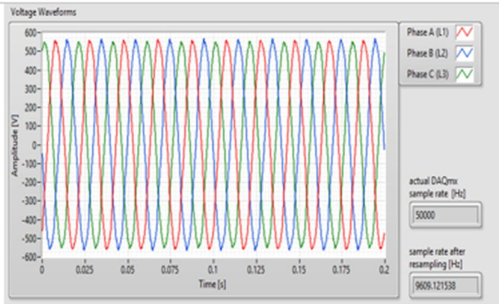

Figure 7 phase voltage (Volt) Vs. Time (Sec)

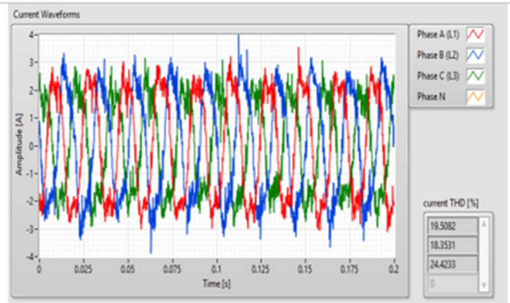

Figure 8 Phase current (Amp) Vs. Time (Sec)

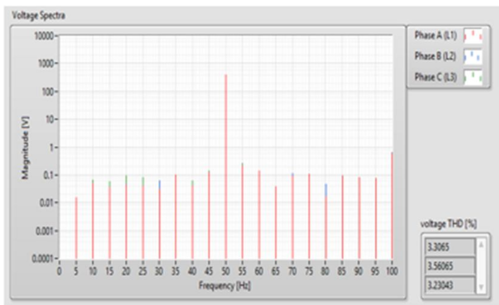

Figure 9 voltage side band frequency

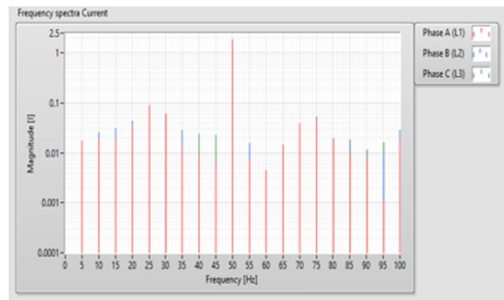

Figure 10 current side band frequency

Figure 11 Results

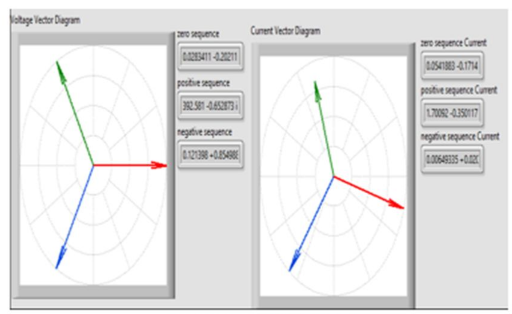

Figure 12 voltage and current phasors

II. Conclusion

The sideband frequency reflected in stator current due to, broken rotor bar, depend on speed. At no load condition, the speed is 1498 rpm measured by digital tachometer. So, slip is very close to zero. Therefore, no sideband frequency is observed in stator current at no load condition. As load increases, the speed decreases and slip increases. So, sideband frequency is observed in stator currents of all the 3 phases as shown in results.

Researchers have used various methods to detect the rotor broken bars. Among all these methods it is found that digital signal processing technique (DSPT) is more accurate for fault diagnosis and on-line condition monitoring.

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