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Speed Detection for Induction Motors Using Motor Current Signature Analysis

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Abstract

Single phase Induction machines have wide application in both industries and home appliances; hence the machine monitoring plays an important role for industries as well as domestic appliances for precise control. Electrical machine being the most sensitive part, various techniques are used to control the speed such as DTC (Direct Torque Control), Vector Control, Closed Loop Feedback Control etc. But these techniques have certain disadvantages like low resolution and reduced accuracy. Measuring the speed of an induction motor is possible by Tachometer. But in places where the motors are fixed at a remote place or inaccessible locations, tachometers cannot be used. In such conditions speed sensors are to be used which needs additional gadgets. In order to measure the speed of motors located in remote places the motor current is sensed using current sensor and the current signature is analyzed using software program. This Motor Current Signature Analysis (MCSA) method of speed sensing gives an accurate value of the speed of the motor. In this project, the current of a single phase induction motor is sensed and analyzed. The actual speed of a machine can be determined at the motor control center, remote from the machine. This may be subsequently used for speed control or protection.

Keywords *:* MCSA; Induction motor; Speed

1. Introduction

The condition monitoring of the electrical machines can significantly reduce the costs of maintenance by allowing the early detection of faults, which could be expensive to repair. Induction motors play an important role in the safe and efficient operation of industrial plants. Special attention is given to non-invasive methods which are capable to detect fault using major data without disassembling the machine. The operators of induction motor drives are under continual pressure to reduce maintenance costs and prevent unscheduled downtimes that result in lost production and financial income.

Motor Current Signature Analysis is an electric machinery monitoring technology. It provides a highly sensitive, selective, and cost-effective. It has been used as a test method to improve motor bearing wear assessment for inaccessible motors during plant operation. MCSA can be implemented using time domain or frequency domain analyses. Speed fluctuations monitoring can detect defects by measuring fluctuations in the rotational period of the motor. This method is particularly useful for the detection of rotor faults, vibrations, air-gap eccentricities, rotor asymmetries, damaged bearings, etc. MCSA instrument must be able to cope with induction motor drives in power stations, Petrochemical refineries, offshore oil and gas production platforms, mining industry, paper mills and car industry. Speed detection and diagnosis schemes are intended to provide advanced warnings of incipient faults, so that corrective action can be taken without detrimental interruption to processes.

2. MCSA Strategy

The fundamental principle of MCSA is based on the recognition that a conventional electric motor powering a machine also acts as an efficient and permanently connected transducer. Detecting small time dependent motor load variations generated within the mechanical system and converting them into electric current signals that flow along the cable supplying power to the motor. To obtain rotor speed, frequency domain analysis is chosen.

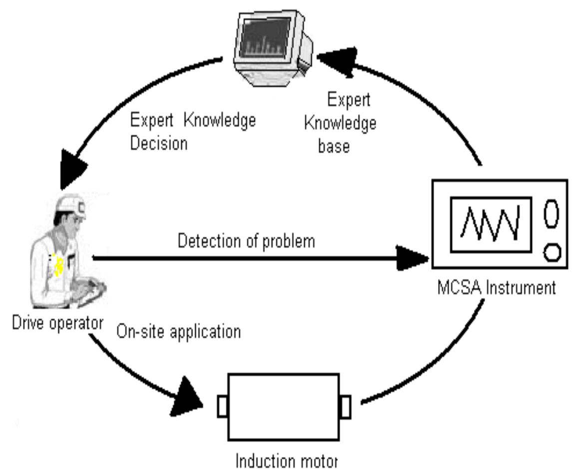

Fig 1: MCSA Strategy

Motor current signals can be obtained from the outputs of current transducers which are placed nonintrusively on one of the power leads. The resulting raw current signals are acquired by computers after they go through conditioning circuits and data interfaces. The signals are processed by Visual Basic in the computer after acquisition.

3. Fault Detection

A three-phase symmetrical stator winding fed from a symmetrical supply will produce a resultant forward rotating magnetic field at synchronous speed, and, if exact symmetry exists, there will be no resultant backward rotating field. Any asymmetry of the supply or stator winding impedances will cause a resultant backward rotating field from the stator winding. Now the same rotating magnetic field fundamentals to be applied to the rotor winding, the first difference compared to the stator winding is that the frequency of the induced voltage and current in the rotor winding is at slip frequency and not at the supply frequency.

The rotor currents in a cage winding produce an effective three phase magnetic field, which has the same number of poles as the stator field but it is rotating at slip frequency (f_2) with respect to the rotating rotor. When the cage winding is symmetrical, there is only a forward rotating field at slip frequency with respect to the rotor. If rotor asymmetry occurs, then there will be a resultant backward rotating field at slip frequency with respect to the forward rotating rotor. The result of this is that, with respect to the stationary stator winding, this backward rotating field at slip frequency with respect to the rotor induces a voltage and current in the stator winding at

$$\mathbf{f_{sb} = f_1 (1-2s)\ Hz} \qquad \mathbf{(1)}$$

This is referred to as a twice slip frequency sideband due to broken rotor bars.

4. Idealised Current Spectrum

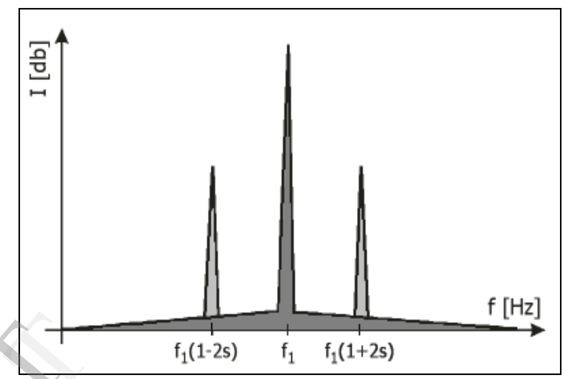

Fig 2: Idealized Current Spectrum

In the three-phase induction motor under perfectly balanced conditions (healthy motor) only a forward rotating magnetic field is produced, which rotates at synchronous speed,

$$n_1 = f_1\, p,$$

The rotor of the induction motor always rotates at a speed (n) less than the synchronous speed. The slip, s = ($n_1 - n$) n_1, is the measure of the slipping back of the rotor regarding to the rotating field.

The frequency of the rotor currents is called the slip frequency and is given by:

$$f_2 = n_2\, p = s\, n_1\, p \qquad (2)$$

$$n + n_2 = n + n_1 - n = n_1 \qquad (3)$$

With respect to a stationary observer on the fixed stator winding, then the speed of the rotating magnetic field from the rotor equals the speed of the stator rotating magnetic field, namely, the synchronous speed. Both mentioned fields are locked together to give a steady torque production by the induction motor.

The backward rotating magnetic field speed produced by the rotor due to broken bars and with respect to the rotor is:

$$n_b = n - n_2 = n_1(1 - s) - sn_1 = n_1 - 2sn_1 = n_1(1 - 2s) \quad (4)$$

The stationary stator winding now sees a rotating field at:

$$n_b = n_1(1 - 2s) \quad (5)$$

or expressed in terms of frequency:

$$f_b = f_1(1 - 2s) \quad (6)$$

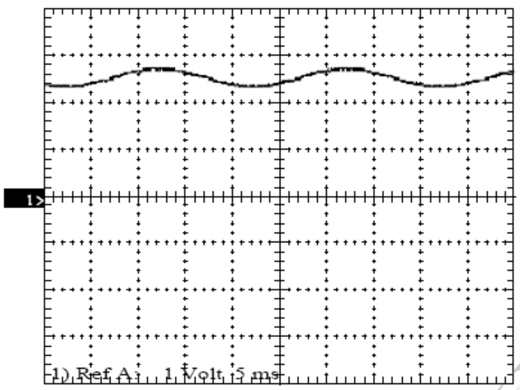

Fig 3: Output From Current Transducer

This means that a rotating magnetic field at that frequency cuts the stator windings and induces a current at that frequency (f_b). This in fact means that f_b is a twice slip frequency component spaced $2sf_1$ down from f_1. Thus speed and torque oscillations occur at $2s\, f_1$, and this induces an upper sideband at $2s\, f_1$ above f_1 .

$$f_b = (1 \pm 2s)f_1 \quad (7)$$

While the lower sideband is specifically due to broken bar, the upper sideband is due to consequent speed oscillation. In fact, several papers show that broken bars actually give rise to a sequence of such sidebands given by;

$$f_b = (1 \pm 2ks)f_1,\ k = 1, 2,3 \quad (8)$$

Therefore the appearance in the harmonic spectrum of the sidebands frequencies given by above two equations clearly indicates a rotor fault of the induction machine.

5. Conclusion

Thus the speed of an induction motor used in electrical drives of an industry is accurately measured using its current signature analysis method. Since the motors are located in remote/inaccessible areas, conventional method of speed measurement is not possible and also if speed sensors are used it involves additional gadgets. Hence just by measuring the current intake of the induction motor, its speed is sensed using this project motor current signature analysis, thus providing to be an effective method of speed sensing. The avoidance of catastrophic failures can be achieved via MCSA and other major benefits include the prevention of lost downtime, avoidance of a major motor repair or replacement costs.

VI. REFERENCES

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