CHAPTER VIII

CONCLUSION

8.1 Conclusions

The instrumentation for the Motor Current Signature Analysis was developed for online condition Monitoring of HT and LT motors ranging in various capacities. With this instrumentation, the laboratory and field trials were carried out to validate the algorithm and the system.

The following conclusions were derived.

1. It can be concluded that Online monitoring and diagnostic using Motor current signature analysis can be effectively applied for early detection of

- broken rotor bars,
- air gap eccentricity ,
- bearing degradation and
- Stator windings faults.
- Misalignment

2. Broken Rotor Bars

It is shown that presence of rotor faults such as bar failure, end ring failure or joint failure between bar and ring can be detected by current monitoring. The presence of side band LSB1 gives the indication of rotor faults. The magnitude of side band gives the amount of failure in the rotor. The increase in core losses and the load current also gives the indication of some problem with the rotor. With each failure in bar the efficiency and speed of the motor also decreases. It can be concluded that the online current monitoring can pin point the problem with the rotor faults. The increase in core losses and load current, subsequent decrease in efficiency and speed with each bar failure can also be used to detect the rotor faults.

The magnitude of the line frequency sidebands due to asymmetries may be comparable to or larger than those due to a broken bar in the same motor. However the magnitudes of the asymmetry components decay much more rapidly, in the higher harmonics, than those for a broken bar

The stator current is affected by load torque oscillations in a way similar to that explained above. In the sinusoidal steady state, it is clear that load torque oscillations produce an oscillation in the developed torque T. Therefore, since the mechanical system is assumed linear, the torque developed by an induction motor contains all the frequency components of the load torque. The magnitude of the developed torque harmonics is primarily dependent on the system inertia.

The impact of the load on a fault detection scheme is also dependent on the mechanical system inertia. In many cases, the load oscillation is heavily damped in the developed torque due to high inertia. In many cases, the load oscillation is heavily damped in the developed torque due to high inertia. In this situation, adequate detection can be accomplished by monitoring fault frequencies at sufficiently high harmonics.

3. Bearing Degradation

From the experimental results, it has been shown that there is feasibility of detecting the bearing faults using a spectrum of single phase of stator current of an induction motor. Since rolling element bearings support the rotor, bearing defect also produces variations in the air gap of the machine. These variations generate the noticeable effect in the current spectrum. The predictability of the air gap frequencies has been extended to include faults in rolling element bearings.

The magnitude of these faults frequencies being relatively small when compared to the rest of current spectrum, but they fall at locations that are different from supply harmonics and slot harmonics of the machine. With good spectral resolution, this discrimination makes the fault harmonics sufficiently distinct for use as effective detection of rolling element bearing damage.

The fault frequencies depend upon the construction and dimension of the bearings installed. Hence it requires the knowledge of the bearing dimension and construction.

A single point defect will cause certain characteristic fault frequencies to appear in machine vibration; therefore there is one characteristic fault frequency associated with each of the four parts of the bearings. However generalized faults produces unpredictable (often broadband) changes in the machine vibration and hence stator current. Hence they can be detected only if the data is trended over a period of time

4. Eccentricity Faults

The combination of interpreting the current spectra in two distinctly different frequency bands to identify components which are a function of static and dynamic eccentricity has proved to be reliable method for detecting the existence of abnormal levels of air gap eccentricity particularly in large induction motors.

The two distinct frequency bands are; one in the region of $f1 \pm fr$ and another in the region of rotor slot harmonics.

The frequency components in the current spectrum given by equation $f1 \pm fr$ are not only due to dynamic eccentricity but are function of both static and dynamic eccentricity. While the frequency components in the range of rotor slot harmonics can be identified the dynamic or static eccentricity.

The harmonics as described by rotor slot harmonics are not present in the machine for all combinations of p and R. In General, PSH components is only present when at R is given by

$R = 2p[3(m \pm q) \pm r]$, $m \pm q = 01,2,3......$ $r = 0$ or 1.

Static eccentricity components is only present when at R is given by

$R = 2p[3(m \pm q) \pm r] \pm 1$, $m \pm q = 01,2,3......$ $r = 0$ or

5. Stator Winding Faults

From the experimental results, it is verified that the presence of stator inter turn fault changes the current spectrum particularly some of the slot harmonics. The monitoring of variations in the slot harmonics in the current spectrum can detect the stator inter turn fault. Magnitude of some of the components may increase and some of components may reduce. Hence the trending of data is required.

However based on the experimental results only certain current components are selected from the classical theory to ensure the reliable diagnosis of shorted turn. Mainly components corresponding to k=1, n=3 and k=1, n=5 are good indicators of shorted turns in low voltage motors 2pole and 4 pole.

6. Hardware

Hardware is selected such that the simultaneous sampling of all 3 voltages and 3 current is possible. The sensors are non invasive so that online recording of the voltages and current is possible.

The sampling frequency and data length are adjustable so that required frequency resolution of 0.01 Hz is achieved, which enables to distinguish the different frequency components easily.

The all hardware is interfaced to the portable computer for control, which enables to record the sampled data into the hard disk for analysis.

7. Software

The software developed is in Excel platform so that it is user friendly. It consists of seven modules

1. Power Quality
2. Motor Loading
3. Rotor bars
4. Eccentricity
5. Misalignment
6. Stator Degradation
7. Bearings

The captured data is also used to give the information about the power quality of voltage and current drawn.

The captured data is also used to estimate the speed of the machine using the sensor less speed estimating technique. This also enables to estimate the efficiency of the motors online.

The different modules gives the information about the health of motors in respect the particular fault and the signature of the particular fault.

8. Laboratory and Field Trials

The laboratory experimentation was carried out. The different faults were simulated in the laboratory. The instrumentation along with the software was able to detect all above faults when simulated in the laboratory. The instrumentation was also subjected to field trials at different units. The instrument was able to perform satisfactorily under different operating condition in the different units. It successfully detected the misalignment which seems to be major problem in Indian conditions. This instrument also detected the torque pulsation observed in various applications of motors through VFD in bearing manufacturing plants. Hence giving indication that it can effectively differentiate the operating conditions and possible fault. This instrument has also detected the rotor fault in one of the motors of thermal power plant, showing the capability of instrument to detect effectively the faults at site.

SCOPE FOR FURTHER WORK

Further research should include extensive experimental testing to detect the core damage, loose wedges, Foundation looseness etc. The motor current is modulated by any form of vibration, which causes pulses in the torque and results in harmonics. Hence current spectrum analysis can also be used to detect problems in the driven loads such as Fan blade damage, Belt looseness, Gear tooth damage, Load bearing problems. This is highly versatile technology for condition monitoring and fault analysis of motors. In general the focus has been on the sensing and analysis of signals to diagnose only the problem or fault.

The identification of the fundamental cause of the problem has not featured in the monitoring strategy. In the future signals should also be analyzed that would provide knowledge on the possible causes of the problem that has been diagnosed. The concept of diagnostics systems that include problem and cause detection is the way forward.

This leads on to the prediction of remaining lifetime after a problem has been identified. The fundamental cause of the problem has to be determined at the same time as the diagnosis of the inception of the problem has been identified for there to be any chance of predicting the remaining life of the machine. The main challenge in the future is to create intelligent diagnostic systems that include "Fault diagnosis, Cause diagnosis, and Prognosis of Remaining Lifetime.