Vibration Monitoring for Electrical Equipment Faults Detection Using Fast Fourier Transform

MARIANA IORGULESCU, ROBERT BELOIU, DUMITRU CAZACU
Electric Engineering Department
University of Pitesti
ROMANIA
iorgulescumariana@mail.com, robertbeloiu@yahoo.com, cazacu_dumitru@yahoo.com

Abstract: - This paper describes vibration diagnosis based on electric faults. These faults could appear in electrical equipment in general, but this paper focuses on the case of transformer, induction and dc motor. In order to do the diagnosis there are analysed vibration signals from the piezoelectric accelerometer. This accelerometer is installed on the frame of the equipment. The signals acquired are applied the Fast Fourier Transform. The level of the fault frequencies in the vibration spectrum is higher than the level of other frequencies.

Key-Words: - transformer fault diagnosis, dc motor, induction motor, Fast Fourier Transform

1 Introduction

In the recent years and in the context of competitiveness there is an increasing demand for modern industry systems to become safer and more reliable. Process failure can potentially result not only on the loss of productivity but also on the loss of equipments and human lives. For these reasons, there is a growing need to develop a procedure for fault detection and diagnosis in order to increase reliability. An early detection and diagnosis can help to avoid system breakdown and material damage.

Many investigations have been done to develop fault diagnosis methods. In some of these approaches fast Fourier Transform are used to examine the presence of faults in the process and give a fault classification signal to determine whether or not the process is faulty. [1]

In the present paper, our propose is to find a solution to this problem. The results of diagnosis obtained on a transformer, a dc and induction motor are presented.

2 Electrical Equipment Faults

2.1 Transformer faults

The following transformer faults: short-circuit, overloading, oil leakage and insulation failure. In generally the protection equipment that is used for detection of all the faults mentioned above is an integrated safety detector. This device contains four switches: a pressure switch, which trips the transformer operation in case of a strong short-circuit; a thermostat switch which alarms when oil temperature exceeds a predetermined temperature level; another thermostat switch that stops the transformer operation when oil temperature reaches the trip level and an alarm switch that operates when oil is reduced to a specified level. The last switch also detects an insulation failure, as the generated bubbles reduce the oil level. The activation of the above switches notifies the personnel, and makes it capable of understanding the general type of the problem. The possible initial warnings are:

- alarm of the thermostat switch (thermostat switch cannot trip without earlier alarm),
- trip of the pressure switch, and
- alarm of the oil level detector.

In case of thermostat switch alarm, it can be a change to trip when the maintenance staff arrives to the transformer, depending on problem’s seriousness and the time required arriving in transformer’s area [2].

When the alarm or trip thermostat switch is activated, there is an overloading problem in the transformer.

In this paper we will diagnose an electric transformer by monitoring its’ vibrations.

2.2 DC motor faults

In the functioning of d.c. machines could intervene faults both when starting to function or after a long period of time of functioning.
The faults could be electric or mechanic.
Electric nature faults are:

- sparks at the collector,
- overheating,
- abnormal starting,
- abnormal speed,
- low possibilities of increasing the load of the motor.

The collector sparks are very frequent. They appear because of overloading, wrong position for brushes or wrong connection of commutation poles.
The overheating of the electric motors is due to over-voltage or a wrong succession of the poles. In some situations, the over-heating could be accompanied by collector sparks or a higher than nominal speed, or even not starting the motor. By using a temperature transducer it can be measured the temperature of the machine.
The abnormal starting could appear even if no load is present, it could be discontinue and could be accompanied by the automation tripping of the starting automata.
The abnormal speed appears after the machine started correctly. This defect could occur because of misplacement of the poles on the collector, they could be outside of neutral area. On the other side the speed could oscillate because the brushes are behind the neutral axis. The speed is usually measured by a speedometer.
Mechanical defects are: bearing support heating and machine vibrations.
The machine vibrations are measured by piezoelectric accelerometer. [3]

2.3 Induction motor faults

The major faults of electrical induction machines can broadly be classified as the following:
· Stator faults resulting in the opening or shorting of one or more of a stator phase windings,
· Abnormal connection of the stator windings,
· Broken rotor bar or cracked rotor end rings.
· Static and/or dynamic air-gap irregularities,
· Bent shaft (akin to dynamic eccentricity) which can result in a rub between the rotor and stator, causing serious damage to stator core and windings.

- Bearing wear and failure. As a result of bearing wear, air gap eccentricity can increase**,** and this can generate serious stator core damage and even destroy the winding of the stator**;**
- High mechanical unbalance in the rotor increases centrifugal forces on the rotor;
- Looseness or decreased stiffness in the bearing pedestals can increase the forces on the rotor;

Critical speed shaft resonance increases forces and vibration on the rotor core.

3.Vibration electrical equipment diagnosis

Vibration control and vibration diagnostics are different practical problems. In vibration diagnostics, the oscillation force that is applied to the defective zone defines the fault and the force is linearly related with the oscillation acceleration. For diagnostics, often both the vibration-acceleration and the vibration-velocity are measured in restricted low frequency ranges.
Most vibration measurements usually use sensors of vibration-acceleration that work based on the piezoelectric effect. For this type of sensors the output electric charge is proportional to the force applied to the sensor.
The vibration signal is converted in electric signals. It is necessary to analyse this signal without loosing the diagnostic information. There are very strict requirements for the analysing instruments. The operations that the vibration analyzing instruments must perform are the following:

- Measurement of overall vibration level in a standard frequency range and using the units required by these standards.
- Spectral analysis of the vibration, by using FFT.

Analysis of the oscillation power of separate vibration components extracted preliminary from the vibration signal. The analysis of the spectrum of random high frequency vibration signal is usually used.[4]

3.1 The vibration signature of dc motor and transformer

The transformer tested in this paper, has the following parameters:

- Primary voltage 220V,
- Secondary voltage 25 V
- rated power 2000 VA.

The dc motor tested in this paper, has the following parameters:

- rated voltage 150V,
- rated power 0.4kW,
- rated current 1.1A,
- speed 1000rpm.

Harmonic spectra are generated from collected data by the accelerometer using FFT.

The Fourier fast transform (FFT) is a mathematical operation that is used to extract from a time-domain signal the frequency domain signal representation.

The harmonic spectrum from fig.1,2,3,4 are generated from data obtained by the piezoelectric accelerometer. The electrical equipment frame has mounted a piezoelectric accelerometer. This way vibration signals transmitted to the analyser are very relevant.

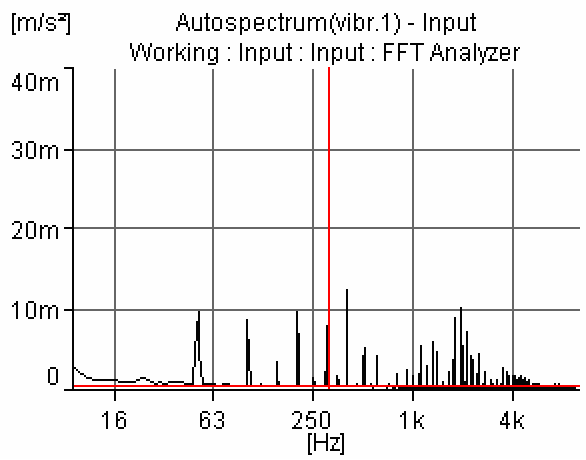

Fig1. Harmonic vibration spectra for transformer without faults

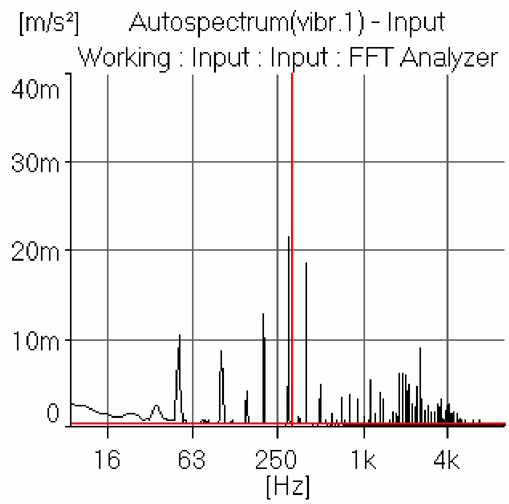

Fig. 2 Harmonic vibration spectra for transformer with short-circuit between windings

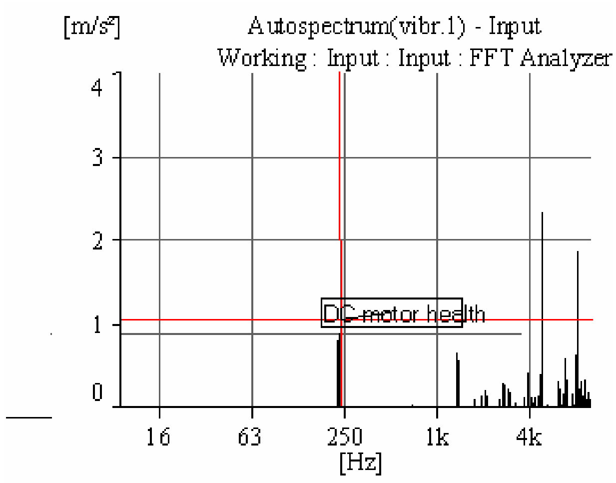

Fig 3. Harmonic vibration spectra for dc motor without fault

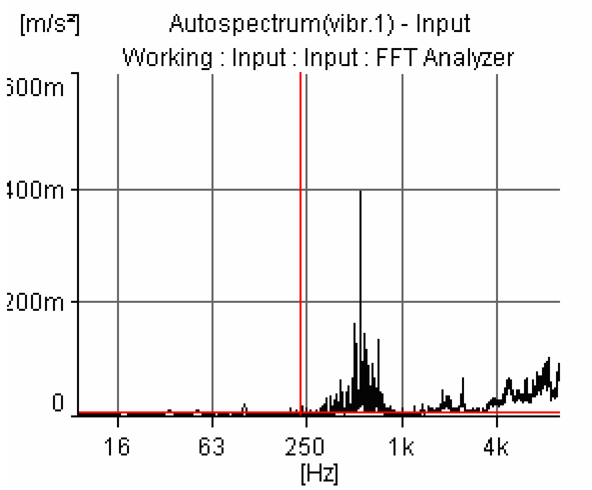

Fig 4. Harmonic vibration spectra for dc motor with short-circuit in the collector

. It is very important to analysed vibrations amplitude because difference greater than 10% will be an indication of bearings problems.

The important frequency for transformer is f = 250Hz. The vibration amplitude for this frequency is important and the amplitudes for other frequencies are small.

In dc motor case the analysed frequencies are f_1 = 750 Hz and also the bad 1000-5000 Hz

3.2 The vibration signature of induction motor

The induction motor tested in this paper is an 0.75kW induction motor.

The induction motor is equipped with 6202 ball bearing type having the number of balls N=8.

The amplitudes of the harmonic components for the induction motor being tested have been calculated according to equations (1.1,1.2, 1.3, 1.4, 1.5). Harmonic spectra are generated from collected data by the accelerometer using FFT.

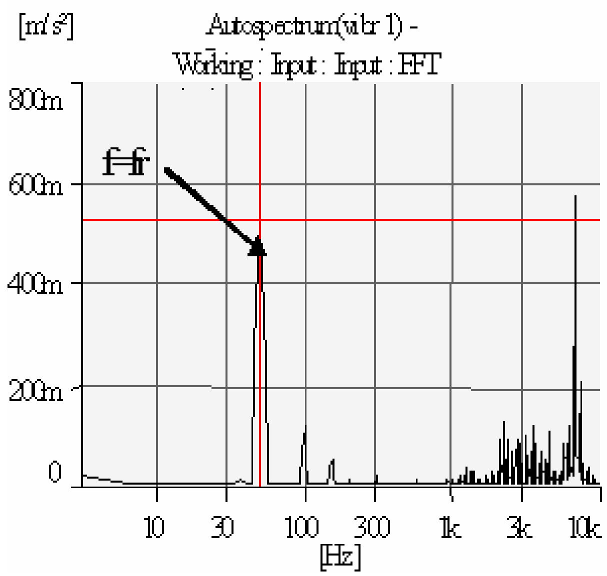

Figure 5 Harmonic vibration spectra for induction motor with “good” bearing

The harmonic spectrum from fig.5 is generated from data obtained by the piezoelectric accelerometer. The electrical machine frame has mounted a piezoelectric accelerometer. This way vibration signals transmitted to the analyzer are very relevant. The rotational frequency is $f = f_r = 50$Hz. The vibration amplitude for this frequency is important and the amplitudes for other frequencies are small. The analyzed frequencies are f_1=100 Hz, f_2=152Hz and also the bad 200-1000 Hz.

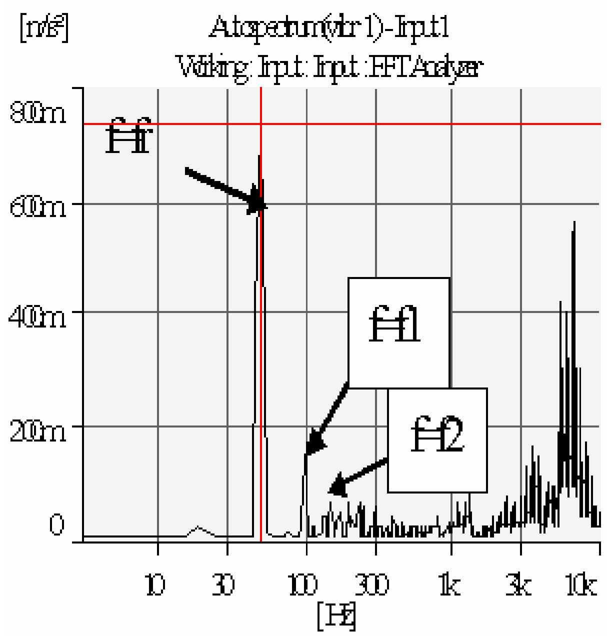

Figure 6 Harmonic vibration spectrum for induction motor with “bad” bearing

The vibration amplitude for the analyzed frequencies, f1, f2 and sideband 150-300Hz, for the induction motor with defective bearing (described in fig.6) is bigger than for the same motor without bearing fault.

It is very important to analyzed vibrations amplitude because difference greater than 10% will be an indication of bearings problems.

Table 1

		f1[Hz] 100	f2[Hz] 152	Average (150-300)Hz
“good” bearing	Vibration amplitude [mm/s2]	0.12	0.042	0.052
“bad” bearing	Vibration amplitude [mm/s2]	0.17	0.054	0.068

In table 1 we make this analysis, and observe an increasing of the vibration amplitude and of the noise in the defective bearing.

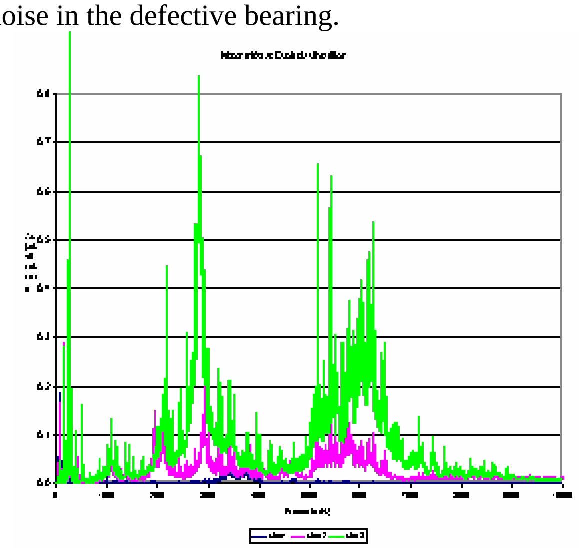

Figure 7 Comparation between harmonic vibration spectrums for healthy and bad bearing

In fig.7 we make this analysis, and observe an increase of the vibration amplitudes in the fault bearing.

4 Conclusion

The technique of evaluating the electrical equipment condition by performing a FFT of the dc motor vibration, induction motor vibration and transformer vibration has been verified by the experimental results [5,6]. In this case electric motor vibration motorizing is very useful to detect short-circuit between in the collector of dc motor, or bearing fault and short-circuit between windings of transformer. So, the plant maintenance can easily and successfully detect mechanical and electrical fault that lead to unexpected downtime.

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