Analysis and diagnosis of the different defects of asynchronous machines by vibration analysis

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***Abstract*— The electric machines and particularly the asynchronous machines act an important role nowadays in all industrial applications. To assure the availability and the safety of working of these is a fundamental job. It is therefore necessary to develop the systems permitting to supervise and to diagnose the state of health of these devices. This article has for object to determine the different anomalies that can harm the good working of an electric motor.**

Keywords-asynchronous machines; vibration analysis; Conditional Maintenance; spectral analysis; envelope analysis.

I. INTRODUCTION

Although the asynchronous machine is reputed robust, it presents sometimes different types off defects. These defects are declared in the different parts off the machine starting with the connection off the stator phases and ending with the mechanical coupling off the rotor to the load. These failures can be predicted or untimely, mechanical, electrical or magnetic, and their reasons are varied. A statistical study done on[1] on the asynchronous machines to squirrel cage, exploited in the domain off the petrochemical industry, reveals that some failures are more frequent than others as exposed by diagram in (Figure1) presenting the percentage off defects susceptible to affect these high power machines.

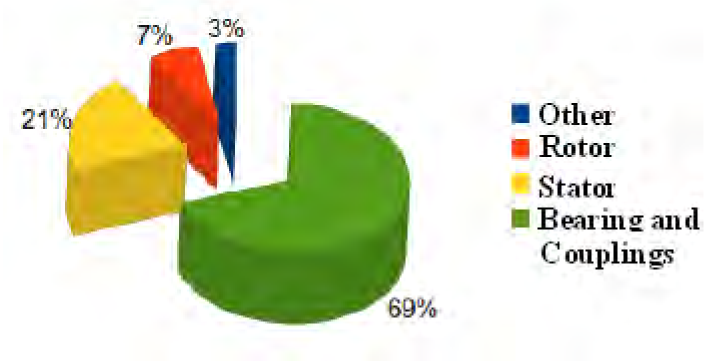


Figure 1: Percentage of defects

This distribution shows that the defects in high power machines comes mainly from bearings and statorique wiring, this is due by important mechanical strain in the case of these machines.

II. DEFECTS OF THE ELECTRIC MOTORS

A. Mechanical failures

More than 50% of asynchronous motors defects are mechanical defects. These defects can be bearing defects, or eccentricity defects.

1) Bearings defects

The main reason of the machines defects concerns the ball-bearings defects [2] which have many reasons such as the contaminated lubricant, an excessive load or electric reasons as traffic leakage currents led by the undulator [3]. The bearing defects entail of manner general several mechanical effects in the machines as an increase of the resonant level and the apparition of the vibrations.

2) Eccentricity defects

The consequences of the mechanical defects generally appear to the level of the air gap: by static eccentricity defects, dynamic [4] or mixed:

- The static eccentricity defects is generally due to a misalignment of the rotation axis of the rotor, the most common cause is the centring defect of the flange.

- The defect of dynamic eccentricity is usually caused by a deformation of the cylinder rotor, stator cylinder deformation or deterioration of ball bearings.

- The mixed eccentricity, the most common, is the combination of a static eccentricity and a dynamic eccentricity.

B. Electric failures

The electric failures, at the stator level or the rotor level, can take several shapes and several reasons. For example: the unbalance of the feeding tensions of the machine or the frequent starting which provoke an excessive overheating of the stator wiring eventually leading to local destruction of the insulation. In the same way, the electrodynamics efforts that the conduct phases undergo result of mechanical vibrations having the effect of damaging the insulator.

On the electric voltage fronts of tension generate the static converters accentuate the phenomenon and reduce, therefore, the life span of the insulator of the conducts. As for the environmental origins, we can mention the humidity, the corrosive or abrasive products. . .

1) At stator level

The stator defects occur in the form of a short circuit interspires, short circuit between two phases or of a short circuit between a phase and the carcass [5].

It is schematized by the straightforward connection between two points of the wiring.

The short circuit between spires of the same phase can appear either to the level of the heads of spools or in the slots, witch reduce the number of efficient spires of the coil.

A short circuit between phases would provoke a clean stop of the machine. However, a short circuit between a phase and the neuter (via the carcass) or between spires of a same phase doesn't have an effect as radical.

It drives to an unbalance of phases, what has a direct repercussion on the couple. This type of defect disrupts the orders developed on the basis of the Park model as appreciably (hypothesis of a model balances).

2) At the rotor level

A wired rotor can be affected by the same defects as the stator. For a rotor with cage the defects amount to the rupture of bar or the rupture of short circuit rings.

These bars ruptures or portions of ring can be due, for example, to a mechanical overcharge (frequent starting. . .), to an excessive local overheating or to a manufacture defect (bubbles of air or bad welding) [6] [7]. This defect makes appear oscillations on the currents and the especially obvious electromagnetic couple than the inertia is very high (constant speed). When the draw inertia is weaker, some oscillations appear on the mechanical speed and on the amplitude of the statorique currents.

The break ring portion it's a defect witch appear as frequently as the break of the bars. In fact, the breaks are either due to cast bubbles or to the differential dilations between the bars and the rings, especially since the rings portions of short circuit rings carry higher currents than those of rotor bars. Of this fact, a bad dimensionality of the rings, a deterioration of the working conditions or an overcharge of couple and therefore some currents can entail their break.

A defect rupture bar doesn't induce a stop of the machine, because the current that crossed the broken bars is distributed on the adjacent bars. These bars are overloaded then, witch can drive to their rupture, and so forth until the rupture of a number sufficiently important of bar to provoke the switch off of the machine.

Face to the multitude of the foreseeable defects and the consequences of their apparitions, the techniques of surveillance imposed themselves quickly by the users of the electric machines. They also begin to interest the inventors.

III. METHOD OF DETECTION OF THE SHORTCOMINGS OF THE ELECTRIC MOTORS

A. *Global analysis*

This type of measure is easy to use and it's efficient for the detection of the defect level. The generally used value is the vibratory amplitude that permits to situate the defect in relation to a level of alert but doesn't inform on the origin of the problem.

Therefore the global analysis consists in measuring the value efficient of the vibratory signal and to compare it at thresholds defined by norms (standards) that depend on the power of the machine and the industrial sector.

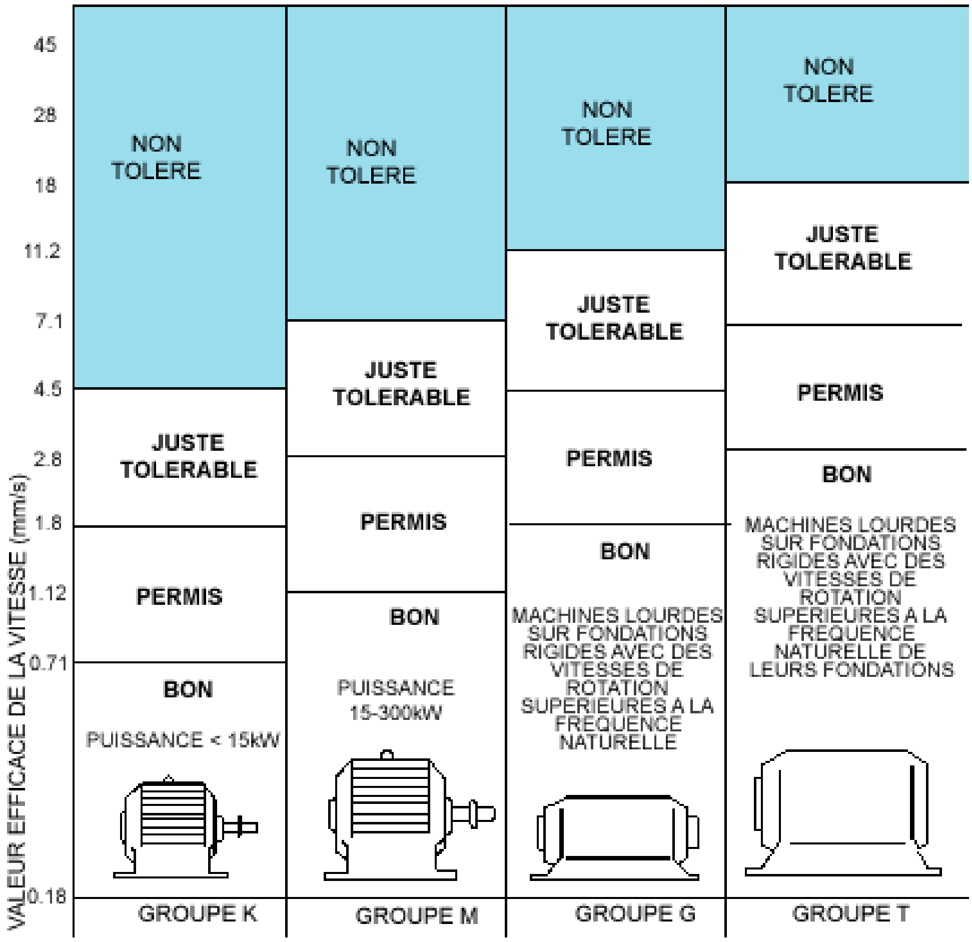


Figure 2 : determination of thresholds [8]

B. *The Spectral analysis* [9]

The temporal signals are often uncertain and therefore difficult signals to analyze; on the other hand, their spectra are very simple and easy to exploit.

This type of measure permits to distribute the vibratory energy according to the frequency and to give different amplitudes for different frequencies.

We will notice that a type of defect always occurs to a particular frequency. Thus, according to the amplitude at a certain frequency, we will be able to determine of where comes the defect. The spectral measure is used therefore to diagnose the origin of electrical and the unbalance defects.

C. Envelope Analysis

The envelope detection or (amplitude demodulation) [10]. Its principle consists in filtering pass-band of temporal signal, and then performs the Fourier transform of the signal obtained envelope. The method thus allows overcoming the low frequency interference signals issued by other defects of the machine (unbalance, misalignment, etc...), and to keep only the signals emitted by the defects of the bearings (high frequency). It's better than spectral analysis for the detection of bearing defects [11].

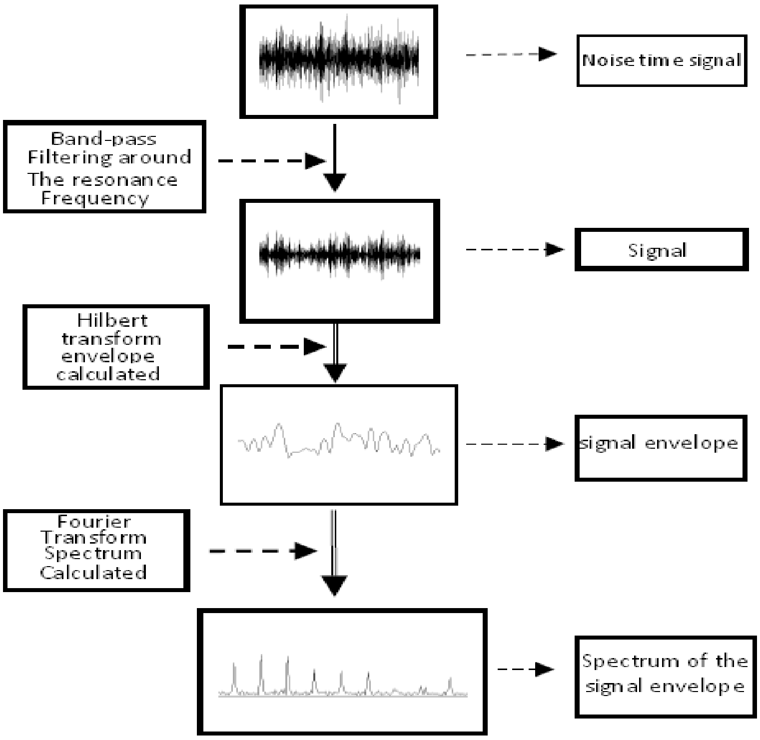


Figure 3: Principle of the envelope analysis [12]

1) characteristic frequencies

Defecting bearings generate equal vibrations frequencies to the speeds of rotation of each piece of the bearing. They correspond notably to the rotation of the balls, the rollers or the cage and to the passage of the balls on the rings. For every type of bearing and according to their production sizes we can consider the characteristic frequencies, see formulas below [13].

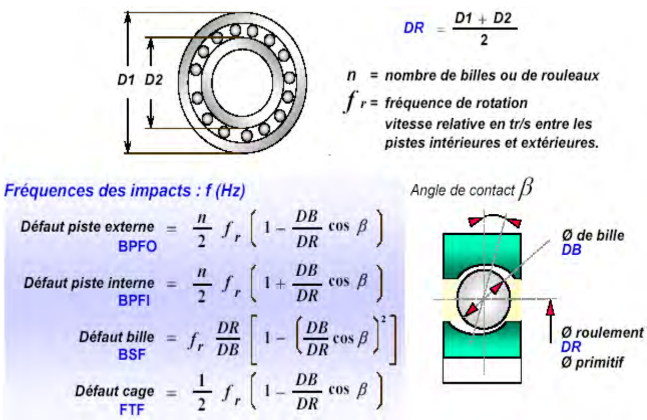


Figure 4. Frequency characteristics of the defects of elements of a bearing

IV. . EXPERIMENTATIONS TO THE LABORATORY

To make a study of a various defects that we can have on a bearing (defect of cage, ball, and interior track or outside track) we conducted a test bed in our laboratory (Figure 5) that facilitates us:

- The positioning of the sensors.
- Succession vibratory measurement.
- The change of the bearings.

The bench is constituted of:

- Single phase electric motor 0, 35 KW; 2800 RPM.
-Rigid deep ball bearing 6005-2Z.
- Elastic coupling.

Figure5. Picture of the test bench realized

A. Preparation of bearings for experimentation

We created three different defects (external ring defect, internal ring defect, defect of cage on the three bearings 6005-2Z (Figure6a, Figure6b, and Figure6c).

Figure 6.a

Figure 6.b

Figure 6.c

Figure 6.a: Bearing with defect on the cage**.**
Figure 6.b: Bearing with defect on the internal ring**.**
Figure 6.c: Bearing with defect on the external ring**.**

B. Vibrations measurements of bearings.

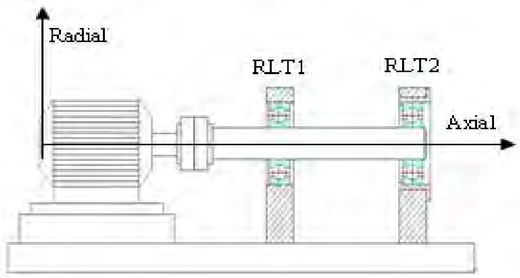
Using a vibration analyzer, we conduct a comparative study of detection by spectral analysis and analysis envelope on three bearings 6005-2Z (bearing with defect on the inert ring the second with defect on the external ring and the third with a defect on cage) and we observed spectra for each test.

The reading measurements where a radial measures and the changed bearing is the RLT2 bearing.

External track defect BPFO = 194 Hz.

Internal track defect BPFI = 274 Hz.

Cage defect of FTF = 20 Hz



Figur7. Layout of the test bench realized

1) The envelope analysis

a) Bearing breast

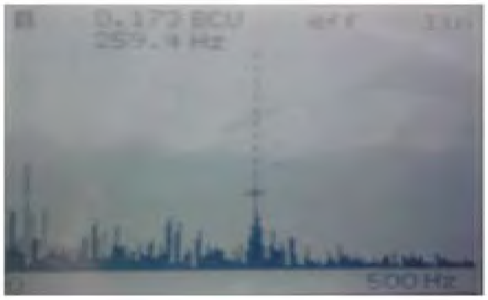


Figure 8. Envelope spectre of the Bearing breast

b) Bearing with default on the cage (figure 6.a)

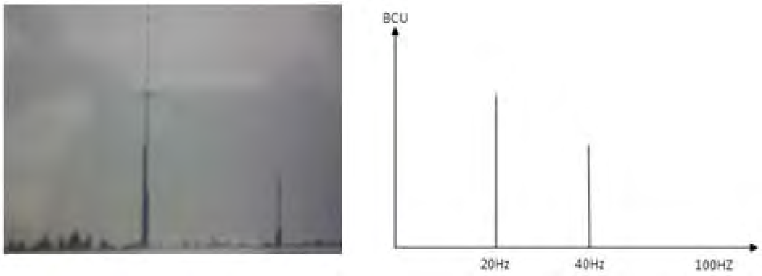


Figure 9. Envelope spectre of the bearing with defect on the cage

c) Bearing with default on the internal ring (figure 6.b)

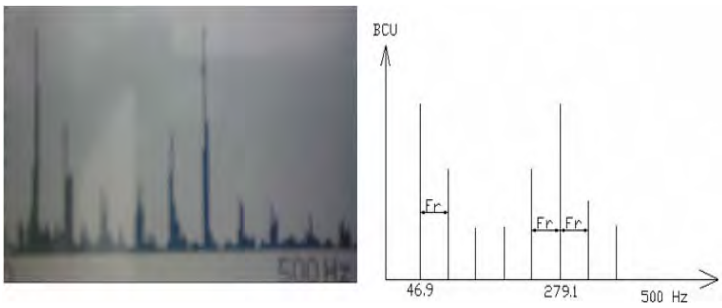


Figure 10. Envelope spectre of the bearing with defect on the internal ring

d) Bearing with default on the external ring (figure 6.c)

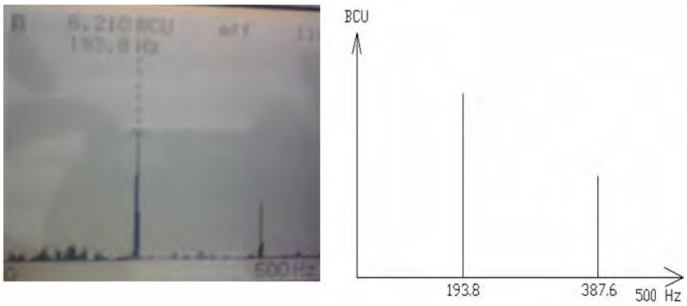


Figure 11. Envelope spectre of the bearing with defect on the external ring

Remark:

- For the good bearing, there is appearance of some peaks in frequencies that are not significant (18,8Hz; 259,4Hz…) with very weak amplitudes.
- For the bearing with a cage defect, there is appearance of the frequency of the cage defect 20 Hz and his multiple 40 Hz.
- For the bearing with defect on the internal ring, there is appearance of the peak of the rotation frequency (46,9 Hz), the frequency peak of the internal ring defect 279,1 Hz and harmonies surrounded the peak of the internal ring defect spaced of the rotation frequency.
- For the bearing with the external ring defect, there is appearance of the frequency of the external ring defect 193, 8 Hz and his multiple 387,6 Hz.

C. Unbalance defect (or Eccentricity defect)

We added a screw and nut on a disk mounted on the rotation axis of the motor witch rotates at 2850 rpm (47,5Hz) , to create an unbalance defect on the last (Figure12).

Figure 12.picture of the motor with Unbalance fault

To detect the unbalance fault we used the spectral analysis, because it's the best method for detecting this type of defect.

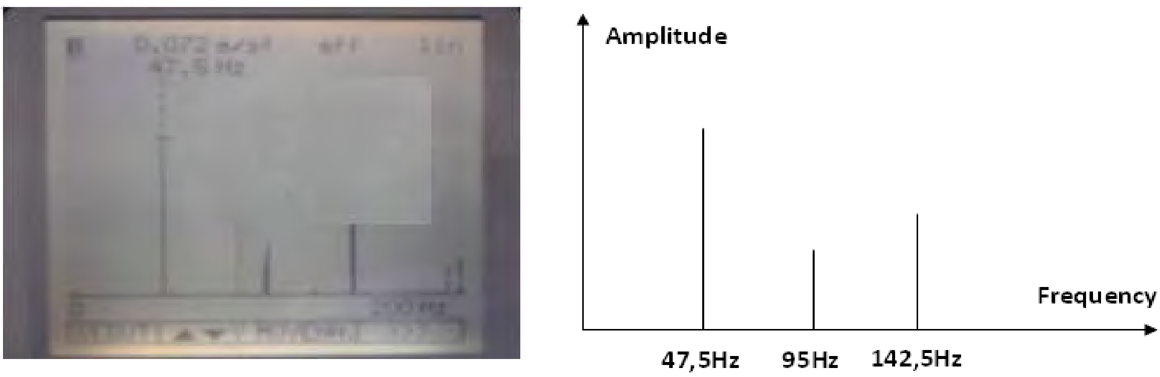


Figure 13.Spectre for the Unbalance fault

Remark:

-For the Unbalance fault there is appearance of the peak of the rotation frequency 47,5Hz and his multiples.

D. Electric defect

Because of the difficulty of creating defects rotor and stator of an electric motor, we bought two motors the first contains a defect on the stator (Figue14) and the second contains a defect on the rotor (Figue16). The rotation frequency of these motors is 3000rpm (50Hz).

1) *Stator Defect*

Figure 14.picture of the motor with a stator defect

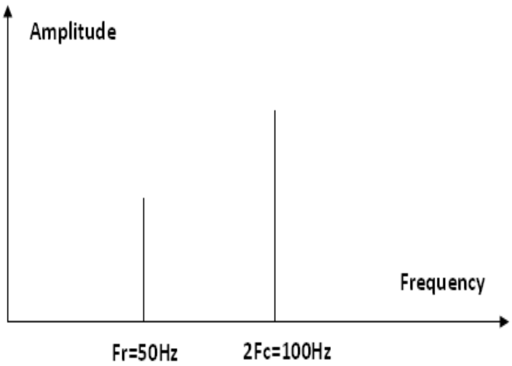


Figure 15.spectre of the motor with a stator defect

2) *Rotor defect*

Figure 16.picture of the motor with a rotor defect

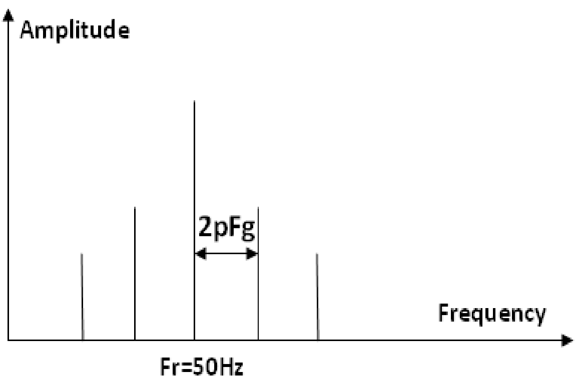


Figure 17.spectre of the motor with a rotor defect

p = poles motor number.
Fc = feeding current frequency.
Fg = slipping frequency.
Fr = Rotation frequency.

V. STUDY OF AN INDUSTRIAL CASE:

In this part we applied the two methods, the spectral analysis and the envelop detection, on a big DC motor coupled to a gearbox. The gearbox drives two rollers of rod mill stand. The characteristics of each element of the system are indicated in table 1.

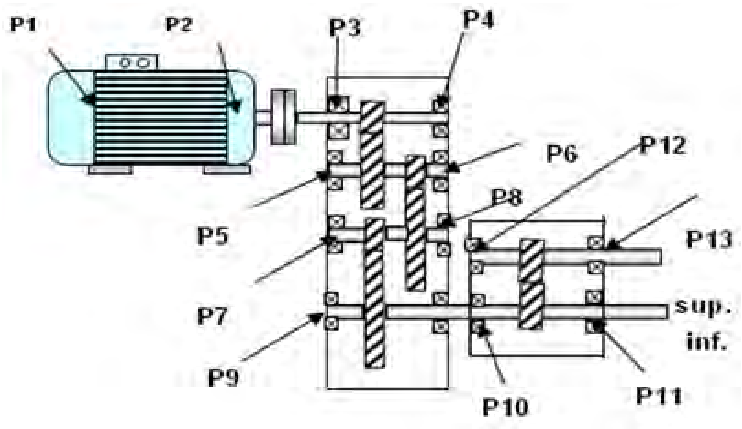


Figure 18. Diagram of the controlled industrial system

TABLE 1. Cracteristics and speeds of the controlled system elements.

NOM	
CAGE DEGROSS.N°1	
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NOTES TECHNIQUES	
POINTS	TYPE RLTS
MOT. HCO	6328 M
MOT. HCA	COOPER
RD.P1, P2	23222W33
RD.P3, P4	22328W33
RD.P5, P6	24148W33
TRAIN 1	z: 22 ; z: 143
TRAIN 2	z: 20 ; z: 94
TRAIN 3	z: 21 ; z: 74
TRAIN 4	z : 31
TRAIN 4 (inf.)	23064 ; 24056
TRAIN 4 (sup)	23048 ; 24056
Vitesse tr/mn	558

F1	9,30	P1-P2-P3 et P4
FE1	204,60	Train 1
F2	1,43	P5 et P6
FE2	28,62	Train 2
F3	0,30	P7et P8
FE3	6,39	Train 3
F4	0,09	P9-P10-P11-P12 et P13
FE4	2,68	Train 4

A. Spectral analysis at point (P1) of the motor

We do a spectral analysis, for detecting the electrical and the unbalance defects.

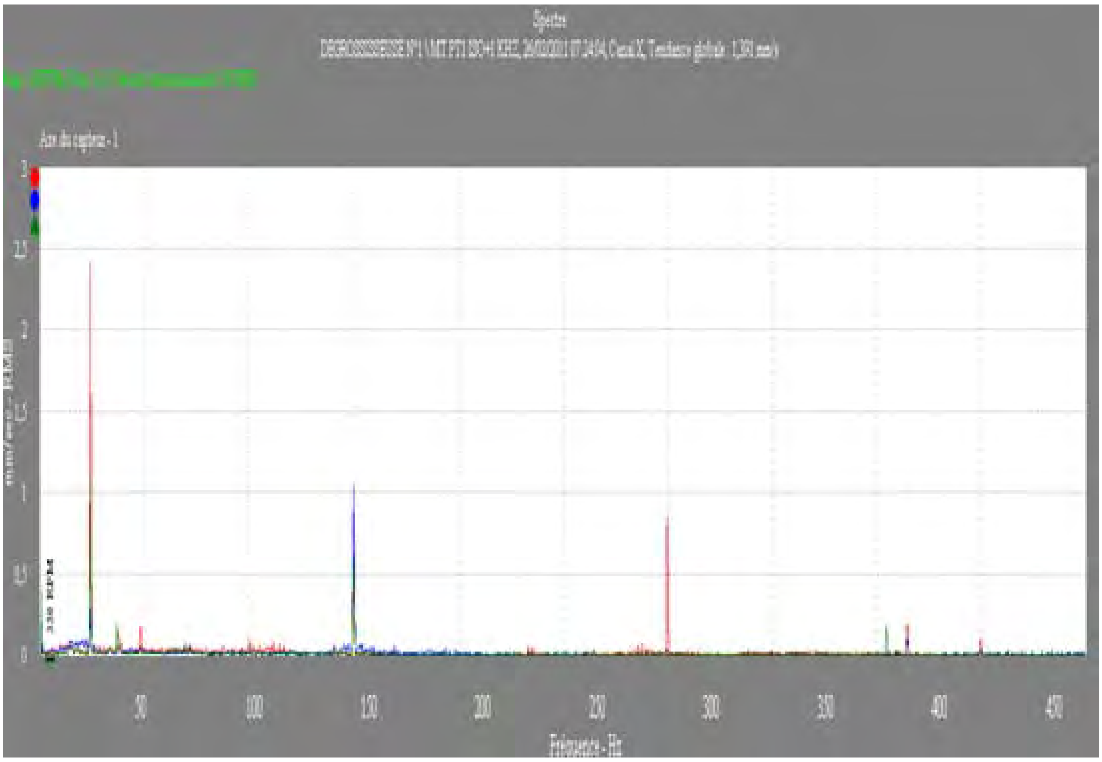

Figure 19. Spectre at point (P1) of the motor

B.   Envelope alaysis at point (P1) of the motor

We execute an envelope analysis at point (P1) of the motor, for detecting a bearing defect.

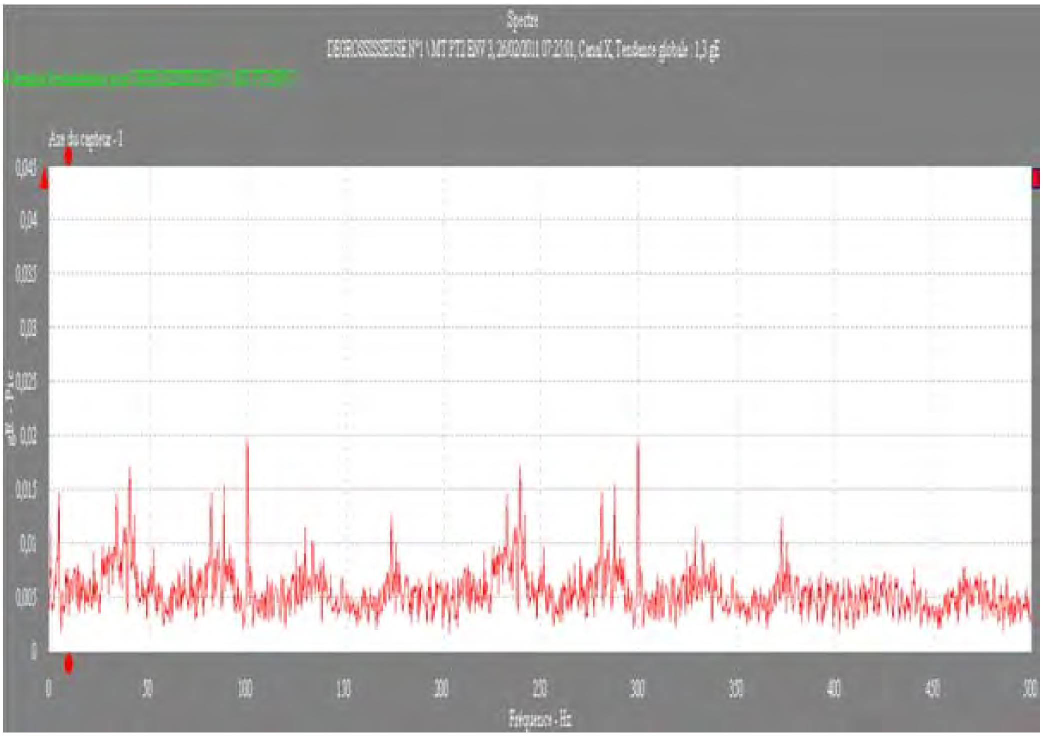

Figure 20. Envelope spectre at point (P1) of the motor

C.   Envelope analysis at point (P2) of the motor

We execute an envelope analysis at point (P2) of the motor, for detecting a bearing defect.

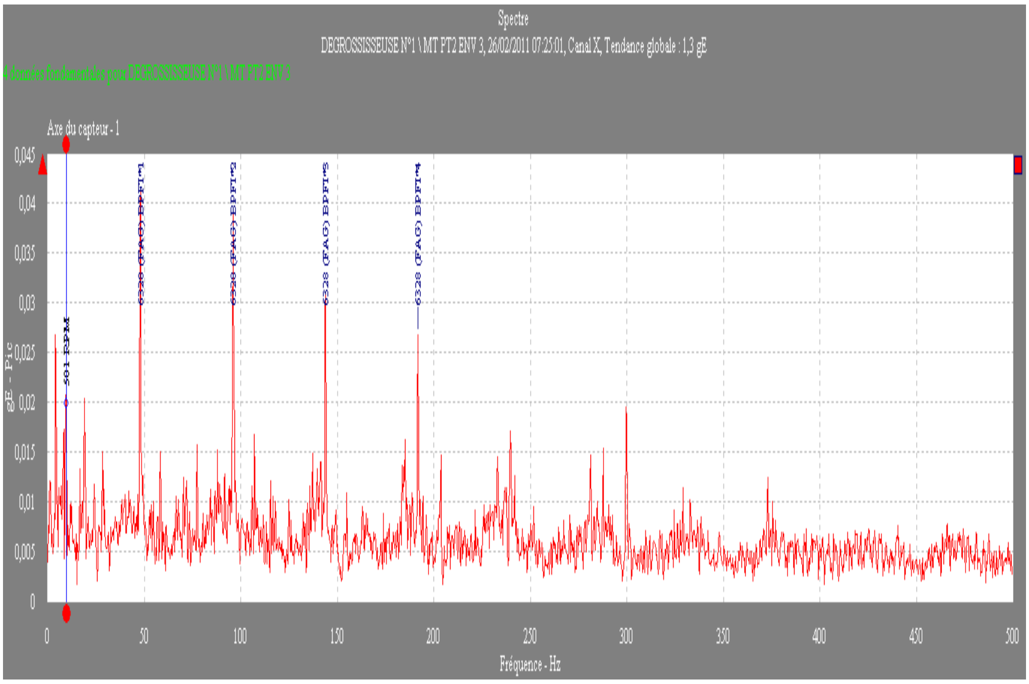

Figure 21. Envelope spectre at point (P2) of the motor

Remark:

- In the spectral analysis (figure 19), there is appearance of some peaks in frequencies that are not significant.
- In the envelope analysis at point (P1) of the motor (figure 20), there is appearance of some peaks with very weak amplitudes.
- In the envelope analysis at point (P1) of the motor (figure 21), there is appearance of the peak of the rotation frequency (9,3 Hz), the frequency peak of the internal ring defect (48 Hz) and his multiples, with a weak amplitudes.

VI. CONCLUSION

According to the tests conducted we concluded that:

- Bearings are the most requested items in the electrical motors.
- Envelope analysis is the best method for the detection of bearing defects.
- Spectral analysis allows us to detect the electrical and the unbalance defects.
- Despite the small failures, the bearing should not be changed if not exceeds the threshold defined by the standard (figure21).
- When there is unbalance defect, there is appearance of the peak of the rotation frequency (Fr) and his multiples (figure13).
- When there is a defect on the stator, there is appearance of the peak of the rotation frequency (Fr) and peak twice of the feeding current frequency (2Fc) (figure15).
- When there is a defect on the rotor, there is appearance of the peak of the rotation frequency (Fr) surrounded with a big lateral bands spaced to 2pFg (Figure17).
- When we have rotating shaft installation:
  - When there is a defect on the internal ring, there is appearance of the peak frequency of these defects and a big number of lateral bands, because are submitted to modulation of the shaft rotation speed (Figure10).
  - When there is a defect on the external ring or in the cage of bearing, there is appearance of the peak frequency of these defects and his multiples (figure9 and 11).

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