International Journal of Emerging Trends & Technology in Computer Science (IJETTCS)
Web Site: www.ijettcs.org Email: editor@ijettcs.org
Volume 6, Issue 6, November- December 2017 ISSN 2278-6856

Diagnostic Of A Thermal Power Plant Turbo-Alternator Group

Redouan Zarrouk[1], Hassan El Maati[2], Mostafa El Amrani[3] and Hortensia Santillan-Ortiz [4]

[1, 3] Laboratory of Electronic and Systems, Faculty of Sciences Oujda, Oujda, Morocco

[2]Department Mathematic and Mechanic, National School of Applied Sciences, Oujda, Morocco

[4]Department in Technological University of Mexico. Ecatepec, Estado de Mexico, Mexico

Abstract

In thermal power plants, Turbo-Alternator Groups (TAG) are classified as vital machinery, whose unavailability leads immediately to a waste of electricity production. They can also be a fault isolation that may result in grave accidents threatening directly the safe operation of the machine as well as the personnel safety. The inspection service is the most efficient solution to decrease the probability of such an accident; particularly the vibratory monitoring which can detect mechanical and electrical defects at a precautionary age. In this article, we present various vibration analysis techniques that we have applied to the TAG of the thermal central plant, in order to perform an effective diagnosis.

Keywords: Control and vibratory diagnostic of TAG frequency analysis, phase analysis, envelope analysis.

1. INTRODUCTION

To cop the growing consumption of electricity, it is necessary to ensure its production in an efficient and continuous way. In order to achieve this objective, the strategic installations of the production units, in particular, the turbo-generating units and the feed pump which constitute the main installations of the thermal power stations must be reliable and in a good working order.

The maintenance of these strategic installations aims to achieve two essential objectives: The first one is refers to safety, ensuring the safe operation of the machines and the safety of people. The second one is mainly related to ensuring the economic nature limiting the availability.

Should be note that the shut down of electricity production means a short fall of about $ 66,000 per day in our power station [1, 2]. Among the various conditions monitoring techniques, vibration control is the best for rotating machines [3, 4, 5, 6, 7, 8, 9]. Not only does it inform about the optimum mechanical operation, but it can also detect defective mechanical part and often the type of defect.

In fact, the vibratory signals generated by these machines could be contain valuable information about the optimum mechanical operation. The treatment of these signals can then lead to an accurate diagnosis.

Several analytical techniques depend directly on the type of signal processing used. These treatments are often complementary and necessary for a good diagnosis. We applied three types of analysis to our TAG in order to optimize their controls, namely spectral analysis, phase analysis and envelope analysis.

2. DESCRIPTION AND KINEMATICS OF THE TURBO-ALTERNATOR GROUP

The group studied turbo-alternator is composed of (Figures 1 and 2):

- A pump AZ 12.39.6T type, include three stages, it is a pump centrifugal high pressure oil, horizontal and multicellular, operating at a speed of 3000 rpm which correspond essentially to the rotation frequency of 50 Hz. The extreme stages each contains 7 blades, either a frequency of blading Fa1 = 350 Hz; whereas the central stage contain 8 blades, is a blading frequency Fa2 =400 Hz. The pump is connected to a transmission gear with 2 wheels of 13 teeth each. The meshing frequency Feng is so 650 Hz.
- A rigid cardan that connects the gear to the turbine shaft.
- A condensing steam turbine type k-50-90-4, with rated power 55 MW, speed rotation of 50Hz and flow rate 211 tons of vapors per hour. It is a single-cylinder machine with an adjustment stage and 22 pressure stages. The first 19 discs of the rotor are forged together with the shaft and the last three are locked. Each stage contains 75 blades which results a blade frequency FaT = 3750Hz.
- A mating semi-flexible which links up the rotor of the turbine with the alternator.
- An alternator of type TB Φ 55-2T, nominal potency 55 MW and speed of rotation 50Hz. It is constituted by a stator of 72 notches and a rotor of 32 notches. The frequency of notch is then Fea = 1600Hz.
- A mating rigid, consisting of trays with gear. It connects the alternator to the exciter.
- An exciter of type Low voltage 450-3000 T, potency with long length 470 KW, potency with short-term 1380 KW and speed of rotation 50Hz. It's constituted by a stator of 72 notches and a rotor of 32 notches. The frequency of notch is Fee = 1600Hz.

Figure 1 Picture of the turbo-alternator group

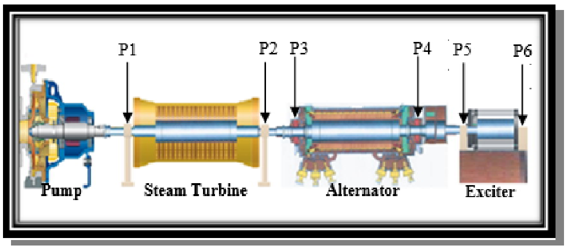

Figure 2 Synoptic schema of the turbo- alternator group

3. Vibratory Control of the Turbo-Generator Group

For control and vibratory diagnosis of the GTA, three different techniques were used: spectral analysis, phase analysis and envelope analysis.

The principle of spectral analysis is to measure the vibratory signal in the frequency band [0-Fmax], with a number NL of points. Knowing each failure, a specific spectral signature [10], the peaks of position of the measured spectrum determines the type of fault. The value of Fmax is chosen to contain the spectral signatures of the different defects by the side of the measuring point, whereas NL is chosen to acquire a sufficient spectral resolution to separate the present different peaks in the spectrum. This analysis can detect most of the rotating machinery-related defects. However, some defects such as unbalance and the fixing have the same spectral signature (peaks to the rotation frequency and its harmonics), in order to remove this indeterminacy, phase analysis is used, which consists in taking two orthogonal and simultaneous radial measurements and then measure the phase shift at the frequency of rotation of these two measurements. If the phase shift is close to 90 °, it is an unbalance; otherwise, it is a defect of fixing.

As for the envelope analysis, it is a complementary diagnostic to spectral analysis technique, which highlights the defects that lead to an amplitude modulation such as certain defects of the gear, some faults of bearing and certain defects of the electric motors [11, 12, 13, 14].

the principle of the envelope analysis consists in performing an amplitude demodulation around the carrier fp [15, 16]. in the case of gears, fp means meshing frequency [11, 12], in the case of electric motors, it denotes the frequency of notches and in the case of bearings, fp is The center frequency of a resonance situated at high frequencies.more precisely, we start by filtering the signal measured around the frequency fp, and then the analytic signal z(t) relative to the filtered signal x(t) is calculated by (1) :

$$z(t) = x(t) + x(t) * \left(-\frac{j}{\pi t} \right) \qquad (1)$$

By definition, $x(t) * \frac{1}{\pi t}$ is the Hilbert transform (TH) of the signal x(t). Z(t) can be expressed in the equation (2) :

$$z(t) = x(t) - jTH\{x(t)\} \qquad (2)$$

The envelope e(t) of the signal x(t) is defined by the module of the analytic signal, either:

$$e(t) = |z(t)| = \sqrt{x^2(t) + TH^2\{x(t)\}} \qquad (3)$$

The position of the peaks contained in the spectrum E (F) relating to the envelope e(t), reveals the type of defect that created this modulation.

We have applied these techniques to the signals measured in six different points of the turbo-generator group: P1, P2, P3, P4, P5 and P6 of figure 2.

The acquisition of the signals made by the Vibxpert system while viewing and processing of signals were provided by the V_System software [17]. On all these points, we measured spectra in the axial, radial horizontal direction and radial vertical direction in the frequency band [0-6.4KHz] with a number of lines NL=3200 to control on a same spectrum the defects which occur at low frequencies and those occurring in medium frequencies. We have also taken a phase measurement at these points in order to classify some defects.

With regard to the envelope analysis, we performed an envelope detection:

- At the point P1, around the meshing frequency Feng = 650Hz for the control of the gear;
- In points P3 and P4, around the frequency 1600Hz for control the alternator;
- In points P5 and P6, around the frequency 1600Hz for control the exciter;

4. Results And Discussions

We made 32 measurements; we present only the most significant results. At point P1, the spectrum measured in the axial direction and zoomed in the frequency band [0-1KHz] is shown in Figure 3. We notice that there is a stingray at the frequency of meshing Feng=650Hz surrounded by lateral bands spaced out 50Hz. The spectrum of the envelope measured around 650Hz (Figure 4) shows clearly the existence of a stingray at 50 Hz and its harmonics, which confirms the amplitude modulation. Therefore, a meshing fault leads to an amplitude modulation such as a broken or cracked tooth, a shaft deformation or a parallelism of wheels.

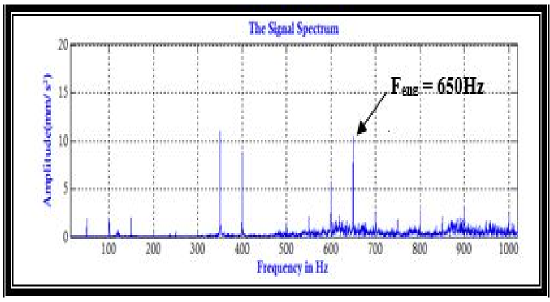

Figure 3 Measured spectrum, at point P1,in the axial direction

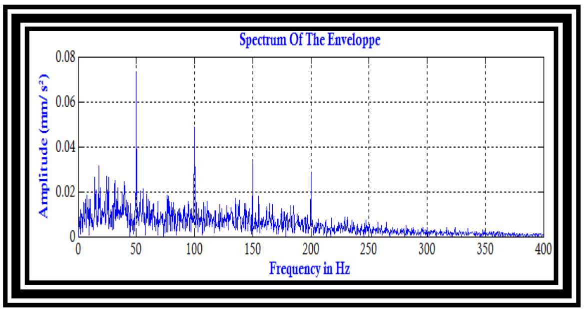

Figure 4 The measured envelope spectrum around the frequency of meshing Feng=650 Hz

At point P2, the spectrum measured in the vertical radial direction and zoomed in the frequency band [0-1KHz] is shown in Figure 5. A predominant stingray is observed at 100 Hz, twice the frequency of rotation of the shaft, which could be a parallel misalignment to the level of the turbine-generator coupling. To validate this hypothesis, we performed a phase analysis.The phase shift measured between two measures on each shaft end is close to 0 °, which confirms the presence of the misalignment.

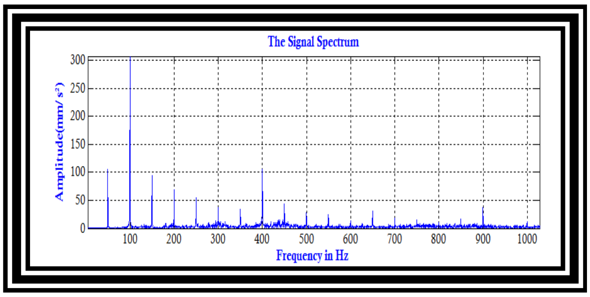

Figure 5 Measured spectrum, at point P2, in vertical radial direction

At the point P3, the spectrum measured in the vertical radial direction and zoomed in the frequency band [0-2KHz] is shown in Figure.6. It is noted that there is a preponderant line at 100 Hz that is to say twice the frequency of rotation. This line indicates the presence of a parallel misalignment, which is observed at point P2. The spectrum also contains multiple harmonics of the frequency of rotation, which indicates that there is a fixing defect. At medium frequencies, there is a peak at the frequency of notches of the alternator Fea =1600Hz, surrounded by lateral bands spaced 100Hz apart. Since these bands do not have the same amplitude, the alternator therefore contains a stator defect [10].

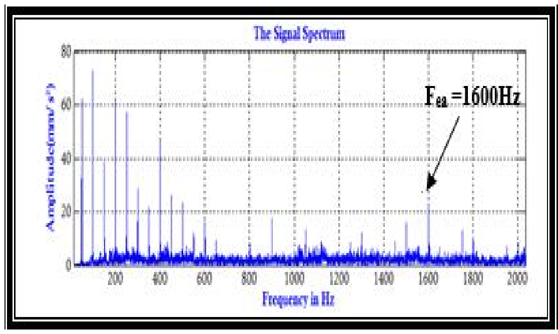

Figure 6 Measured spectrum, at point P3, in the vertical radial direction

At the same point P3, the spectrum measured in the vertical radial direction and zoomed in the frequency band [3-4 KHz] is shown in Figure.7. This spectrum contains a line at the blade frequency of the turbine FaT = 3750Hz surrounded by of the lateral bands spaced at 50 Hz, which is the signature of a defect of centering of the rotor from the volute or a play in the keying of the turbine [18, 19, 20,9].

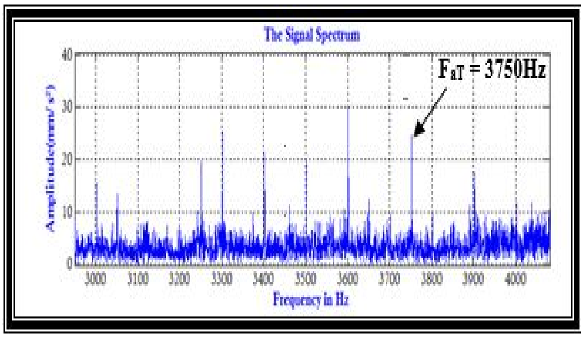

Figure 7 Measured spectrum, at point P3, in the vertical radial direction

At point P5, the spectrum measured in the vertical radial direction is shown in Figure 8. The 50Hz, 100Hz, 150Hz and 200Hz lines have a large amplitude; among the probable defects, one finds the unbalance, the fixation and the electrical excitation. In order to remove this indecision, we performed a phase analysis, which showed that the phase shift at the frequency of rotation is 90 °, which proves the existence of an imbalance.
However, the axial measurement at this same point reveals the existence of these four peaks, so we have, in addition to the unbalance, an electrical excitation because the defect of unbalance is not appear in axial. The exciter, therefore, presents an imbalance and an electrical excitation.

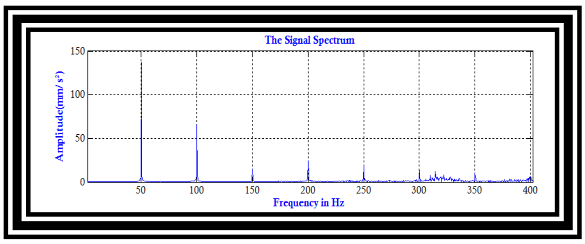

Figure 8 Measured spectrum, at point P5,

in the vertical radial direction

5. CONCLUSION

The Turbo-Generator Group constitute the strategic element for thermal power stations. Unavailability results in a total shutdown of energy production. Although TGA failures are rare, they can cause serious incidents, known as major accidents, even to the destruction of these machines or the emission of projectiles by the rotors. The implementation of conditional maintenance is necessary. Several techniques are used in the plant: vibration analysis, infrared thermography, non-destructive controls, etc.

Although these are complementary techniques, vibration analysis is the best technique for the control and diagnosis of rotating machines.
The application of spectral analysis, phase analysis and envelope analysis revealed the existence:

- A meshing fault;
- A misalignment at the coupling which connects the turbine to the alternator;
- A wrong centering of the rotor of the turbine;
- An alternator fixing fault;
- Of a stator fault of the alternator;
- An unbalanced as well as an electrical excitation at the exciter.

References

[1] H. Elmaati, A. Benbouaza, B. Elkihel, and F. Delaunois, “Development of a Vibration Monitoring System for Optimization of the Electrical Energy Production,” International Journal of Emerging Technology and Advanced Engineering, vol. 3, Issue 6, June 2013.

[2] H. Elmaati, A. Benbouaza, B. Elkihel, and F. Delaunois, “Implementation of a vibration monitoring system of a steam turbine for optimization of the maintenance,” International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), vol. 3, Issue 6, June 2013.

[3] Dr.N. Kuppuswamy, “Vibration and Cavitation Prediction and Control of Turbine Alternator in Hydro Electric Power Plants”, Australian Journal of Basic and Applied Sciences, 7(8): 19-28, 2013.

[4] P. Kumar, Y. Basavaraj, C. Nandeesh, “Vibration Based Condition Monitoring for Generator”, International Journal of Research in Engineering & Technology, Vol. 4, Issue 6, Jun 2016, 1-8.

[5] M. K. Chittora, “Condition Monitoring of Turbogenerator by Vibration Monitoring Technique”, Iosr Journal of Engineering (Iosrjen) E-Issn: 2250-3021, P-Issn: 2278-8719 Vol. 3, Issue 1(Jan. 2013), ||V1|| Pp 33-37.

[6] G. S. Babu, Dr. V. Chittaranjan Das, “Condition Monitoring and Vibration Analysis of Boiler Feed Pump”, International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013.

[7] W. Shuting, X. Zhaofeng, L. Yonggang, H. Zili, L. Heming, “Analysis of generator vibration characteristic on rotor windding inter-turn short circuit fault electrical machines and systems”, IEEE (2003) 882–885.

[8] S. Pejovic, Q.F. Zhang, B. Karney, A. Gajic, “Analysis of pump-turbine ‘S’ Instability and revers water hammer incidents in hydro power systems, ”
in: 4th International Meeting on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems, 2011, pp. 1–16.

[9] F. Pedro, G. Marquez, A.M. Tobias, J.M.P. Perez, M. Papaelias, “Condition Monitoring of wind turbines: techniques and methods”, Renewable Energy, Elsevier 46(2012) 169-178.

[10] A. Boulenger, P. Christian, monitoring of machines by vibration analysis, Paris, Dunod, 2009, ISBN 978-2-10-054190-4.

[11] S.S. Ajanalkar, Prof. Shrigandhi G. D, "Review on Fault Identification and Diagnosis of Gear Pair by Experimental Vibration Analysis", Journal of Emerging Technologies and Innovative Research (JETIR), Volume 2, Issue 5, May 2015.

[12] G. Diwakar, Dr. M R S Satyanarayana, P. Ravi Kumar, " Detection of Gear Fault using vibration analysis», International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, J Issue 9, September 2012.

[13] P. GRANJON, "contribution has the active compensation of vibration on the electrical machines". Doctoral thesis, Institut National Polytechnique of Grenoble, 19' December 2000.

[14] M. Sahraoui, A. Ghoggal, S. Zouzou, M. Benbouzid, "Dynamic eccentricity in squirrel cage induction motor - Simulation and analytical study of its spectral signature on stator currents ", ELSEVIER Simulation Modelling Practice and Theory, vol. 16, p. 1503- 1513, 2008.

[15] M. Feldman, "Hilbert transform in vibration analysis", Mechanical Systems and Signals Processing, 25(3):735–802, Avril 2011. ISSN 08883270.

[16] A. Medoued, A. Lebaroud and D. Sayad, "Application of Hilbert transform to fault detection in electric machines", a Springer Open Journal ,7 January 2013.

[17] R. Zarrouk, Mr. El Amrani, B. El Kihel, ‘’ V_System : Système d'Acquisition, d’Analyse et de Traitement de Signaux Vibratoires “, Conférence internationale, "Les matériaux innovants & leurs applications", Oujda, Maroc, 2016.

[18] J. Latcovich, T. Astrom, P. Frankhuizen, S. Fukushima, H. Hamberg, S. Keller, ‘’Maintenance and Overhaul of steam Turbines’’, International Association of Engineering Insurers 38th Annual Conference – Moscow 2005.

[19] A. Salem Abdulwahed, Ahmed Abu-Siada, Syed Islam, " Condition Monitoring Techniques of The Wind Turbines Gearbox And Rotor”, International

Journal Of Electrical Energy, Vol. 2, No. 1, March 2014.

[20] M. Entezami, S. Hillmansen, P. Weston, M.P. Papaelias, "Fault detection and diagnosis within a wind turbine mechanical braking system using condition monitoring", Renewable Energy, Elsevier 47 (2012) 175–182.

AUTHORS

Redouan ZARROUK PhD student research in industrial engineering on the theme maintenance the complex Installations industrials by vibration analysis. He is presently pursuing his PhD program in Laboratory of Electronic and Systems, Faculty of Sciences University Mohammed I, Oujda, Morocco, on the theme ‘’ Development of a system acquisition, analysis and processing of vibratory signals dedicated to the controls of rotating machines’’.

Mostafa EL AMRANI professor of Higher Education University Mohammed I, Oujda, Morocco. PhD of University Jussieu Paris 7 France in Non Destructive Testing. He was an engineer of maintenance in CEA Saclay France.

Hassane ELMAATI received his engineer degree in Materials engineering in 1997 at the National School of Mineral Industry (ENIM), Rabat, Morocco. Since 1998 until today, He is an engineer of maintenance in a thermal power plant in Morocco. Chief of technical division. He was pursuing his PhD program in industrial Engineering Department, National School of Applied Sciences University Mohammed I, Oujda, Morocco, on the theme “Optimization of the production by an intelligent maintenance”.

Hortensia Santillan Ortiz professor of Science, Department in Technological University of Mexico, Ecatepec, Estado de México.