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Analysis of 3-Phase Induction Motor at Chiller Room FKAAB Building Using Motor Current Signature Analysis and Vibration-Monitoring

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Abstract: Both synchronous and induction motors have been used in chiller systems. The chiller system which consists of pumps, compressor and fans is driven by AC motors. Induction motors are commonly applied in modern chiller systems, however synchronous reluctance motor (SynRM) is a relatively recent high-efficiency motor technology, according to Felipe Oliveira and Abhisek Ukil in their research paper Comparative Performance Analysis of Induction and Synchronous Reluctance Motors in Chiller Systems for Energy Efficient Buildings. In this context, early detection of fault is necessary and very important to reduce maintenance costs. The main objective of this project is to monitor the condition of the three-phase induction motor by using different techniques. The sub-objectives are to measure line current of low voltage motors at chiller room building, to measure vibration signal of low voltage motors at chiller room building and to analyse motor current signature and vibration frequency spectrum of low voltage motors. The induction motors for the chiller system have been analysed based on the motor current signature analysis (MCSA) and vibration analysis. There are 2 motors in total which are a motor for condenser water pump 1 and a motor for chilled water pump 1. The results indicate that the 2 motors have broken rotor fault by using MCSA technique. For the vibration analysis technique, there are various faults that can be assumed. For example, angular misalignment, bent shaft, mechanical looseness, cavitation, turbulence and electrical problem. The findings and recommendations of this study are obtaining the induction motor's handbook or datasheets can help in the detection of many other faults of the motor. This project was performed only on three induction motors for the chiller system located at the FKAAB building. Therefore, performing the same measurement for another chiller system in UTHM main campus would be interesting.

Keywords: Three-Phase Induction Motor, MCSA, Vibration Analysis

1. Introduction

In recent years, both synchronous and induction motors have been used in chiller systems. Chiller system which is consists of pumps, compressor and fans are driven by AC motors. Induction motors

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are commonly applied in modern chiller systems, however synchronous reluctance motor (SynRM) is a relatively recent high-efficiency motor technology, according to Felipe Oliveira and Abhisek Ukil in their research paper Comparative Performance Analysis of Induction and Synchronous Reluctance Motors in Chiller Systems for Energy Efficient Buildings [1]. It is being considered for use in HVAC and chiller applications.

Despite the significance of electric motors, condition monitoring should be carried out to confirm the motor’s condition. Condition monitoring is one method for preventing catastrophic failure of a machine, including an induction motor. This monitoring technique will use several sensors to evaluate the machine's state regularly, such as a vibration sensor, a current sensor, and others. Further analysis will be performed to analyse the data acquired from the sensors.

Motor current signature analysis (MCSA) and vibration analysis will be used to further analyse the data from the sensors using signal-based fault detection techniques. In the fault detection approach, signal processing techniques are often used to examine and compare the magnitude of the fault frequency components, where the magnitude tends to increase as the severity of the fault increases. Furthermore, signal processing is important because it may increase the signal-to-noise ratio and normalise data to distinguish additional defects caused by other sources.

1.1 Problem statement

Despite induction motors is high reliability, operating conditions can expose them to a variety of faults. The faults may be caused by components that face some damage such as rotors or shafts unbalanced, bearing failures, shaft misalignment, shaft bending, gear wear, mechanical looseness, and so on. These faults may cause a machine to shut down, resulting in a loss of industrial production. In this context, early detection of fault is necessary and very important to reduce maintenance costs as induction motors play an important role in the industry.

To prevent these faults, many techniques have been developed for early condition monitoring. Some of the methods are being studied the most among the various methods because of their good fault diagnosis performance for a wide range of machines [2]. Vibration signal analysis [3] and motor current-signature analysis (MCSA) [4] are among the popular methods to analyse the condition of rotating machines.

Both of the methods are signal-based methods that are mostly focused on frequency domain data. Aside from that, these processes use signal processing techniques that are not computationally expensive and have a basic implementation. As a result, fault detection using signal processing techniques is effective for condition monitoring.

1.2 Objective

The main objective of this project is to monitor the condition of the three-phase induction motor by using different techniques. Thus, the sub-objectives are to measure the line current of low voltage motors at the chiller room building. Next, to measure the vibration signal of low voltage motors at the chiller room building. After that, to analyse motor current signature and vibration frequency spectrum of low voltage motors.

2. Materials and Methods

Permission from the 'Pejabat Pembangunan dan Penyenggaraan' is necessary to measure the chiller system at the FKAAB building on the UTHM main campus. Furthermore, the measuring procedure in the chiller room will be attended by the office's in-charge representative. Personnel involved in the measuring procedure must follow safety instructions such as wearing suitable clothes and a safety helmet. Due to the high noise level in the chiller room, it is suggested that you use earplugs.

2.1 Materials

The equipment that are used in this project are as follow:

- Keysight oscilloscope
- TA018 current clamp meter
- Vibration analyser (accelerometer and 01 dB Movipack datalogger)
- Universal Serial Bus (USB)
- Socket extension

2.2 Methods

Project block diagram consists of three important steps as visualizes in Figure 1. Initial step was the measuring process. The current sensor must be clamped to the cable in the panel board. Measurement range was adjusted accordingly to the phase current of the motor. The accelerometer with temporary installed magnet was attached to the 3 directions of each end of the motor. The measured signal then will be process using the data acquisition process occur in the 01 dB Movipack for vibration signal and Keysight Oscilloscope for the current signal. FFT mode is selected to acquire frequency domain spectrum for current and vibration.

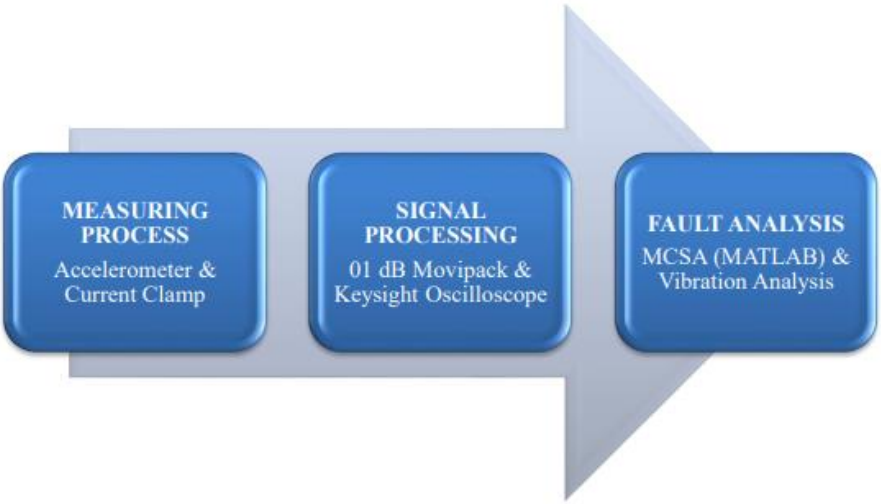

Figure 1: Project block diagram

The desired data is transferred to the PC to be diagnosed by MCSA and vibration analysis. The raw data collected from the oscilloscope will be in excel file stored in USB. These files then will be the input data for further MCSA analysis using MATLAB software. The data from 01 dB Movipack will be transferred to PC by using cable R232 cable and will be display by the Vib-Graph software. The vibration data will be compare and the spectrum analysis will be carried out manually by detecting the indicator frequencies specified for each types of fault through simple calculation.

3. Results and Discussion

The induction motors for the chiller system have been analysed based on the motor current signature analysis (MCSA) and vibration analysis. There are 2 motors in total which are motor for condenser water pump 1 and motor for chilled water pump 1.

3.1 Condenser Water Pump 1

3.1.1 Motor current signature analysis (MCSA)

The broken rotor bar sidebands pair (dotted lines) with lower sideband frequency and upper sideband frequency of 49 Hz and 51 Hz respectively as shown in Figure 2 and 3. The stator winding fault sidebands pair (solid lines) also presented in the range with the value of lower and upper sideband, 25 Hz and 75 Hz respectively. There was high magnitude happened at the broken rotor bar sideband frequencies.

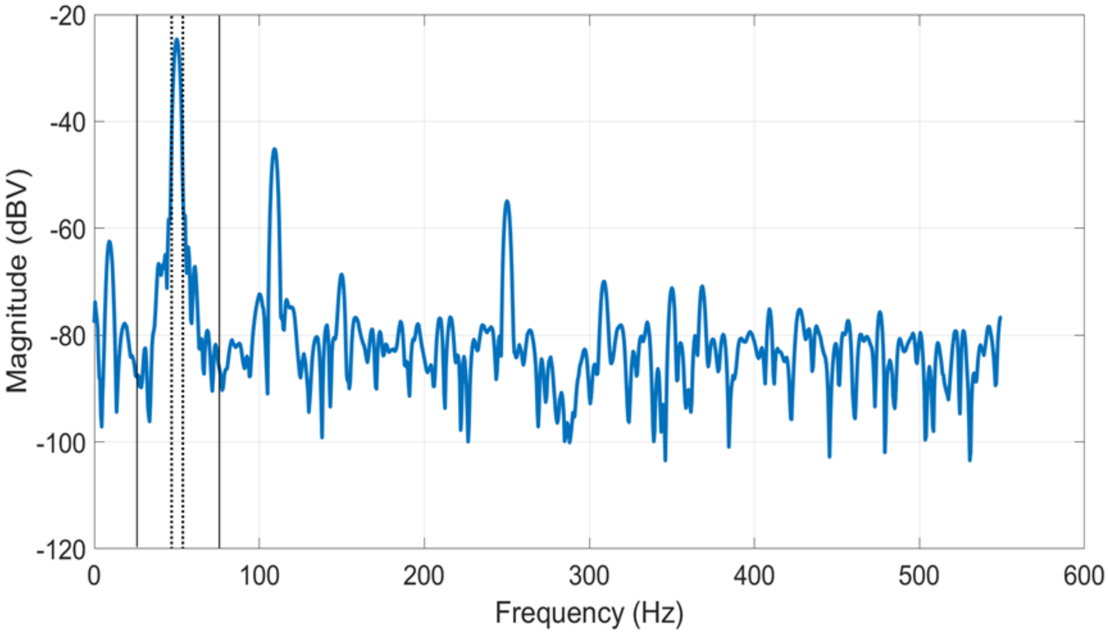

Figure 2: Phase current spectrum in frequency domain for condenser water pump 1

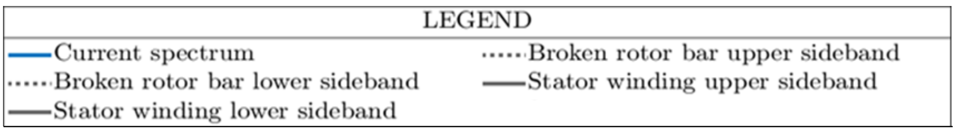

Figure 3: Legend of the detected sidebands for condenser water pump 1

3.1.2 Vibration analysis

Table 1 shows the motor's status based on the Vibration Severity as defined by ISO10816. This motor has a power of 45kW and a horsepower of 60. According to ISO10816, this motor is classified as Class II, with a power range of 15kW to 75 kW. Since these motor results also fell into unsatisfactory and unacceptable conditions, as shown Table 1, further analysis on the vibration spectrum also was done.

Table 1: Results of motor condition for condenser water pump 1 with power of 45kW and horsepower of 60

End type	Direction	Velocity, mm/s	Condition(Class II)
Motor non-drive end	Vertical	16	Unacceptable
	Horizontal	5.34	Unsatisfactory
	Axial	5.47	Unsatisfactory
Motor drive end	Vertical	18.7	Unacceptable
	Horizontal	8.24	Unsatisfactory
	Axial	22.0	Unacceptable

Table 2 shows the summary on the motor condition for condenser water pump 1.

Table 2: Summary on the motor condition for condenser water pump 1 with power of 45kW and horsepower of 60

Analysis	Types of possible faults
MCSA	Broken rotor bar
Vibration Analysis	Motor non drive end: • Mass unbalance • Structural looseness • Misalignment • Turbulence • Cavitation Motor drive end: • Bent shaft • Angular misalignment • Mass unbalance

3.2 Chilled Water Pump 1

3.2.1 Motor current signature analysis (MCSA)

This motor is suspected to experience both broken rotor bar 49 Hz and 51 Hz for lower and upper sideband respectively (dotted line) as shown in Figure 4 and 5. The stator winding fault with 0.5 Hz and 99.5 Hz for lower and upper sideband respectively has no high magnitude that can be seen (solid line). Therefore, this motor does not occur stator winding fault.

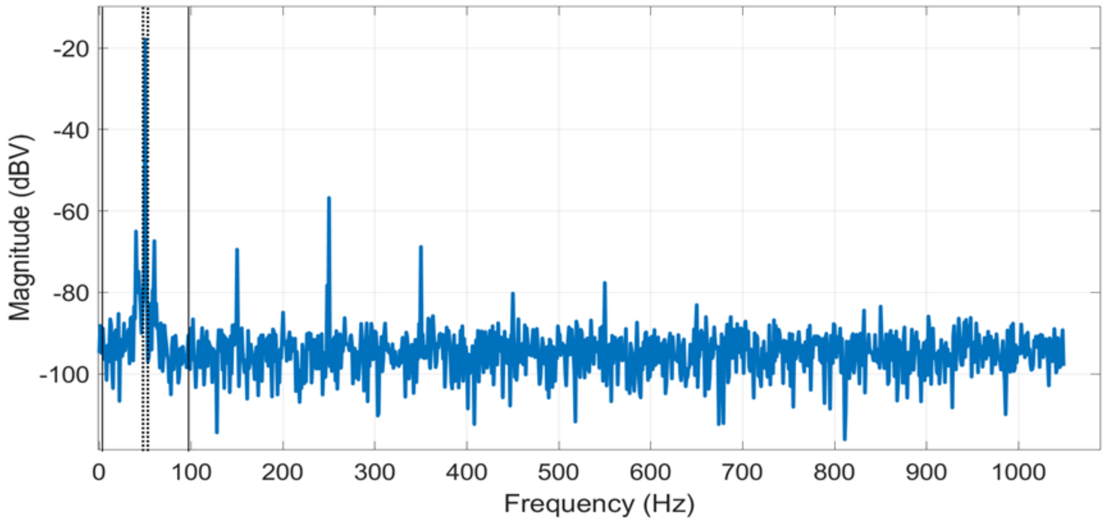

Figure 4: Phase current spectrum in frequency domain for chilled water pump 1

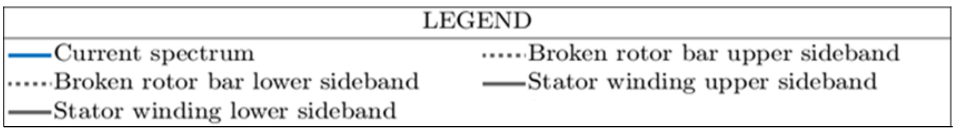

Figure 5: Legend of the detected sidebands for chilled water pump 1

3.2.2 Vibration analysis

Table 3 and 4 show the motor's condition based on the Vibration Severity as specified by ISO10816. This motor has a horsepower rating of 120 and a power rating of 90 kW. Since these motor results also fell into unsatisfactory and unacceptable conditions, as shown above, further analysis on the vibration spectrum also was done.

Table 3: Results of motor condition for chilled water pump 1 a horsepower rating of 120 and a power rating of 90 kW

End type	Direction	Velocity, mm/s	Condition(Class II)
Motor non-drive end	Vertical	9.64	Unsatisfactory
	Horizontal	4.58	Unsatisfactory
	Axial	26.6	Unacceptable
Motor drive end	Vertical	14.4	Unacceptable
	Horizontal	6.38	Unsatisfactory
	Axial	12.7	Unacceptable

Table 4: Summary on the motor condition for chilled water pump 1 a horsepower rating of 120 and a power rating of 90 kW

Analysis	Types of possible faults
MCSA	Broken rotor bar
Vibration Analysis	Motor non drive end: • Angular misalignment • Bent shaft • Mechanical looseness • Cavitation • Turbulence • Unbalance • Electrical problem Motor drive end: • Bent shaft • Angular misalignment • Mass unbalance

4. Conclusion

According to the findings of this project, MCSA and vibration analysis provide a wide range of detection of faults that rotating machines may encounter. Both motors for the condenser water pump 1 and the chilled water pump 1 were tested using both techniques, and the results indicated that both motors could experience the stated faults. The phase current waveforms of these motors were distorted. These could suggest that the motors are experiencing unwanted faults, which could be caused by harmonics of the motors' non-linear loads. The peak of vibrations of the tested motors was clearly shown by MCSA and vibration analysis using the frequency domain spectrum. Thus, based on the measurement data that already described, the probable faults that occurred can be assumed.

Acknowledgement

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References

[1] F. Oliveira and A. Ukil, "Comparative Performance Analysis of Induction and Synchronous Reluctance Motors in Chiller Systems for Energy Efficient Buildings," IEEE Trans. Ind. Informatics, vol. 15, no. 8, pp. 4384–4393, 2019, doi: 10.1109/tii.2018.2890270.

[2] V. Naik et al., "Routine Test of Three Phase Induction Motor," pp. 1745–1751, 2017.

[3] T. Mushiri and C. Mbohwa, "Vibration based condition Monitoring of rotating machinery using fuzzy logic," Lect. Notes Eng. Comput. Sci., vol. 2226, pp. 1018–1022, 2016.

[4] W. T. Thomson and R. J. Gilmore, "964Ffb69B942Ed4Efdd2674F2E332D79a77D," no. 1987, 2001