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Development of Graphical User Interface for Analysing Induction Motor Current Frequency Spectrum

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Abstract: In this paper, the development of a graphical user interface (GUI) for analysing the induction motor current frequency spectrum by applying the motor current signature analysis (MCSA) method is presented. Conventionally, analysing the current signature can be time-consuming and reduce the efficiency of the analysis work. Due to that, a GUI is developed to allow the engineer to conduct the analysis efficiently whereby many motors can be monitored. The faults that are analysed are broken rotor bars, stator winding faults, static eccentricity, and dynamic eccentricity. The software used to develop the GUI is the MATLAB App Designer, which allows the user to design the layout and specify the programming according to the desired outcome. To verify the GUI workability, the analysis is carried out by using the conventional method whereby the current measurements provided are analysed in MATLAB. Then, the same data is analysed in the GUI developed. The analysis from both MATLAB and GUI was developed to show that there is an occurrence of at least one type of fault in the motors analysed. It shows that the developed graphical user interface works successfully as the results obtained are the same as the results obtained from the conventional method which is from MATLAB. The motor for chilled and condensed water pump 1 experienced a broken rotor bar whereas the motor for chilled and condensed water pump 2 experienced a stator winding fault. This process can be improved by further investigating the motor condition by conducting a physical inspection of the motor that has been suspected to be faulty based on the results.

Keywords: MCSA, GUI, Induction Motor

1. Introduction

Induction motor is widely used in the industry. Therefore, it is considered a crucial component for electric utilities and process industries [1]-[2]. It is an undeniable fact that motors consume about half of the electrical energy produced worldwide. The failure of the motor may lead to interruption at the industry plant along with the costs to be borne. Motor failure can be categorised into electrical faults

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and mechanical faults. The electrical faults can be associated with stators such as voltage imbalance, phase drop, and inter-turn short circuit, etc. The mechanical faults are damaged bearings, broken rotor bars, and eccentricity faults, etc [1][3]. Motor condition deteriorates over time. Fault detection at an early stage is important to avoid high maintenance and repair costs, and the time consumed for the repairing process. There are various ways of condition monitoring available which include vibration monitoring techniques, acoustic monitoring, infrared thermography monitoring, oil analysis, and motor current signature analysis (MCSA) [4][5].

The MCSA is the most preferred technique used to analyse the occurrence of a fault in the motor as it is an effective, feasible, and reliable method. To diagnose the fault, a Fast Fourier Transform of the signal is involved to determine the motor frequency component [2]-[4]. Based on the current signature obtained, the current frequency will appear distorted due to the unavoidable slot harmonics which originated from the source itself. Apart from slot harmonics, if there is any fault in the motor, the frequency amplitude will eventually rise with specific harmonics that differ from other harmonics that take place in the other parts of the motor [1][2].

Based on the past project done, carrying out the MCSA technique, is quite a time-consuming to be done manually [6]. Therefore, the development of a graphical user interface (GUI) for this project will shorten the time for fault analysis and allow to analyse of as many motors as possible within the same period of time compared to the conventional way of applying the MCSA technique. The range of frequency to be observed is 0 Hz to 100 Hz for low frequency and 1000 Hz to 1300 Hz for high frequency.

2. Methods

The GUI is developed via App Designer available in MATLAB version 2021a. App Designer has the ‘drag and drop’ feature to lay out the design of desired GUI which is integrated with an editor to quickly program its behaviour. App Designer does not require a professional software developer although it allows users to create a professional app. The development of the GUI can be simplified as in Figure 1.

Figure 1: Block diagram of GUI developing process

The process will be initiated by opening the App Designer available in MATLAB itself. Then, the layout of the GUI is designed in the design view tab by clicking and dropping the components needed for the desired GUI. After that, insert the coding in the code view editor tab to specify the task of each component which includes a file button, motor specifications, run and clear button to display the sidebands and their value, and range of frequency with its show button. After that, run the GUI developed. If there is any error, troubleshooting is needed to remove it. If the app is functioning smoothly, save the app.

3. Results and Discussion

This section consists of the results of the developed GUI and analysis of the current spectrum obtained from the condensed water pump 1, chilled water pump 1, condensed water pump 2, and chilled water pump 2. The workability of the GUI is presented as well.

3.1 Developed GUI

Figure 2 shows the layout of the developed GUI. The layout of the GUI can be customized by using the available tools and settings. The type of file that can be read by this GUI is an xlsx file only. Users can start by opening the current measurement file, and then fill in the motor specifications. To analyse the current and obtain the sideband frequency, click the 'RUN' button. The spectrum will be presented, and the value of the sidebands' frequency are shown respectively. To clear the input and output data, click the 'Clear All' button. The interface can be maximized according to the user's screen size. The spectrum can be zoomed in and zoomed out to analyse it further.

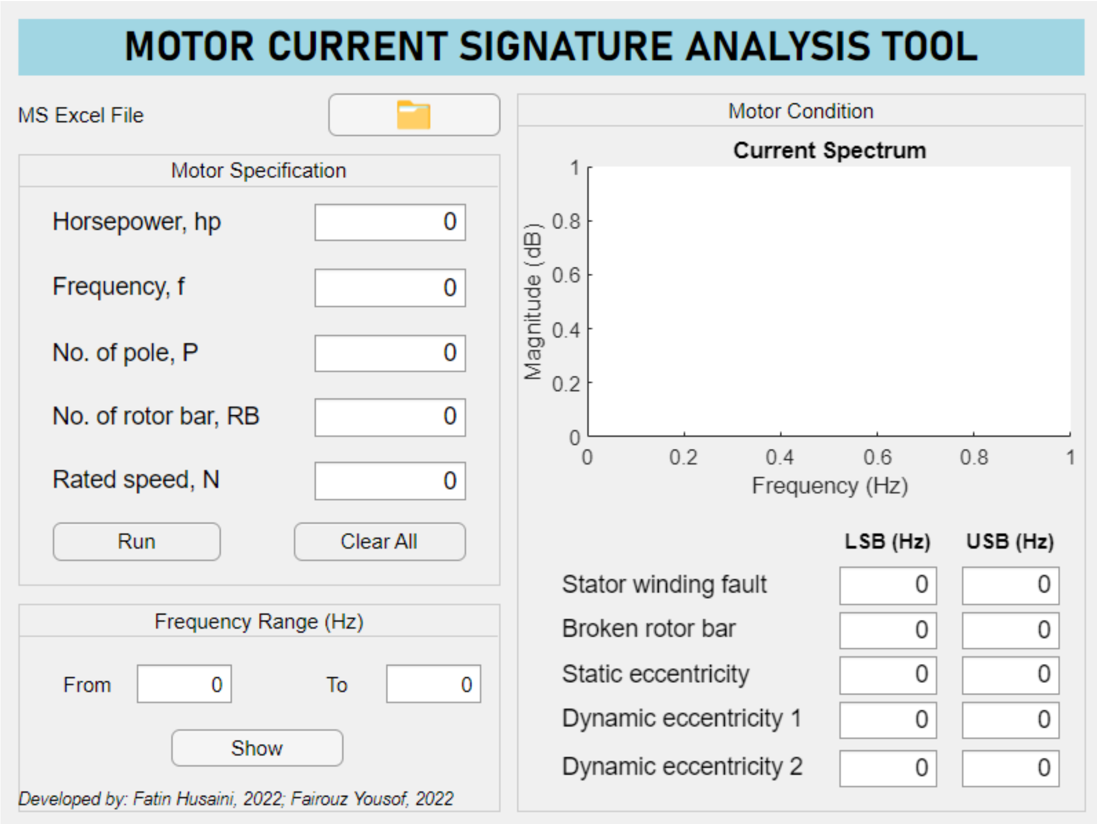


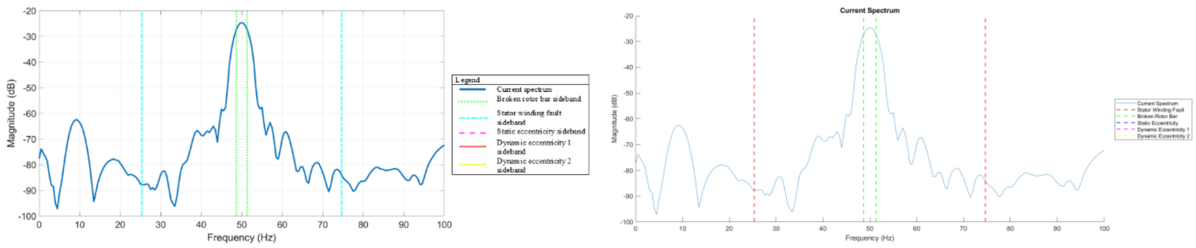
Figure 2: Layout of the developed GUI

3.2 Results of MCSA

The results of MCSA are obtained from condensed water pump 1 motor, chilled water pump 1 motor, condensed water pump 2, and chilled water pump 2. The current spectra are analysed and discussed.

The following Figure 3 shows the low-frequency current spectrum for condensed water pump 1. The legend to indicate the sideband frequencies concerning the observed faults is included in this figure.

As shown in Figure 3 (a), it can be observed that the motor experiences a broken rotor bar as there is a peak at both sidebands. As observed from the stator winding fault of the lower sideband, 25.33 Hz and upper sideband, 74.67 Hz, there is no significant rise in the magnitude which indicates that the motor is free from stator winding fault. The data for high frequency is unavailable. As shown in Figure 3 (b), observing from the broken rotor bar sidebands, the motor experience a broken rotor bar. There is no peak at other sidebands. It can be concluded that the fault analysis by using the graphical user interface developed is accurate.

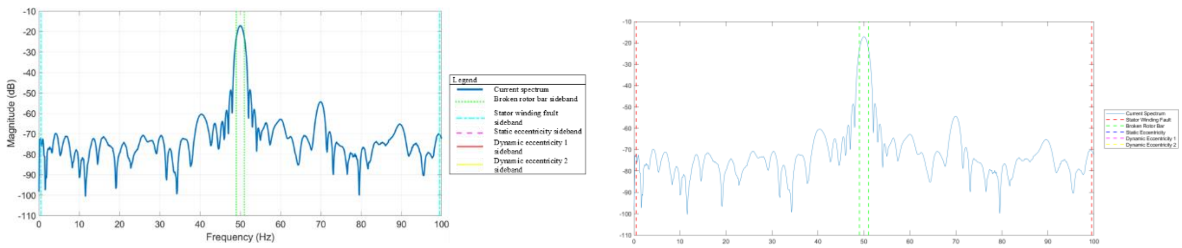


(a) **(b)**

Figure 3: (a) Low-frequency current spectrum in the frequency domain for condensed water pump 1 motor from a manual calculation using MATLAB, (b) Frequency spectrum for condensed water pump 1 from GUI

3.2.2 Motor for chilled water pump 1

As shown in Figure 4 (a), the current spectrum range is up to 100 Hz. It can be observed that the motor experience a broken rotor bar as there is a peak at both sidebands. As observed from the stator winding fault lower sideband, 0.5 Hz and upper sideband, 99.5 Hz, there is no significant rise in the magnitude which indicates that the motor is free from stator winding fault. The data for high frequency is unavailable. As shown in Figure 4 (b), observing from the broken rotor bar sidebands, the motor experience as a broken rotor bar. There is no peak at other sidebands. It can be concluded that the fault analysis by using the graphical user interface developed is accurate.

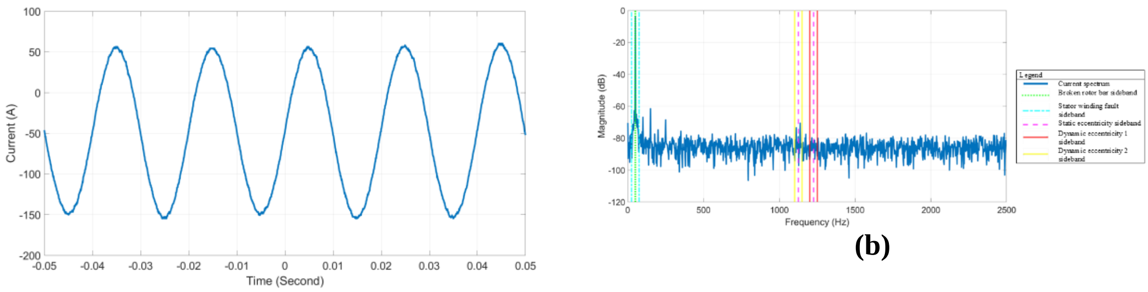


(a) **(b)**

Figure 4: (a) Low-frequency current spectrum in the frequency domain for chilled water pump 1 motor from a manual calculation using MATLAB, (b) Frequency spectrum for chilled water pump 1 from GUI

3.2.3 Motor for condensed water pump 2

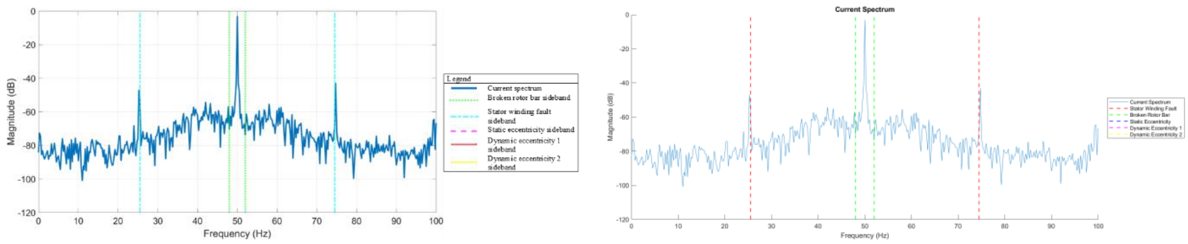
Following figures, Figure 5 (a) is the phase current waveform and Figure 5 (b) is the high-frequency current spectrum for condensed water pump 2. Figure 6 (a) and (b) present the current spectrum of low (0 Hz to 100 Hz) frequency from MATLAB and GUI. As shown in Figure 6 (a), the frequency spectrum is up to 100 Hz. It can be observed that the motor does not experience a broken rotor bar as there is no peak at both sidebands. As observed from the stator winding fault of the lower sideband, 25.5 Hz and upper sideband, 74.5 Hz, there is a significant rise presented at both sidebands. It can be concluded that there is a stator winding fault occurring in the motor. Figure 6 (b) depicts the frequency spectrum of low frequency from GUI. As observed, it can be concluded that the motor does not experience a broken rotor bar but experience a stator winding fault.



(b)

(a)

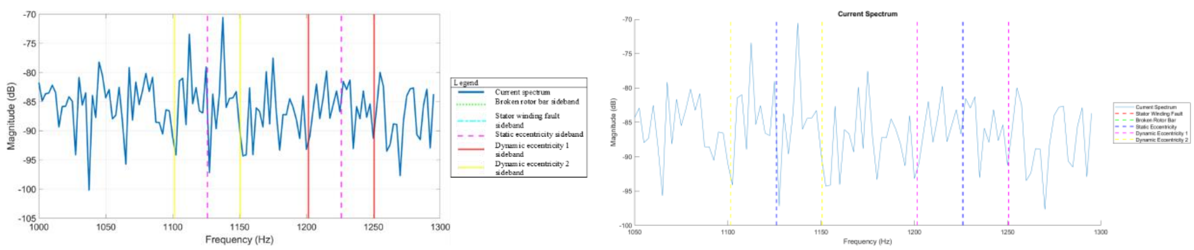
Figure 5: (a) Phase current waveform for condensed water pump 2, (b) High-frequency spectrum for condensed water pump motor 2 from a manual calculation using MATLAB



(a) (b)

Figure 6: (a) Frequency spectrum range 0 Hz to 100 Hz, (b) Frequency spectrum of low frequency for condensed water pump 2 from GUI

Figure 7 (a) and (b) present the current spectrum of high frequency (1000 Hz to 1300 Hz). As shown in Figure 7 (a), observing from the frequency spectrum obtained from MATLAB, there is no significant rise in sideband pairs of static eccentricity, at 1126 Hz, and 1226 Hz. Static eccentricity is absent in the motor. Observing both dynamic eccentricity sidebands' pairs, there is no significant rise in both sidebands pair of dynamic eccentricity. It can be concluded that the motor does not experience dynamic eccentricity. Figure 7 (b) depicts the frequency spectrum of high frequency from GUI. As observed, the motor is free from both static and dynamic eccentricity. It can be justified that the results obtained in GUI developed are the same as the results obtained from MATLAB.



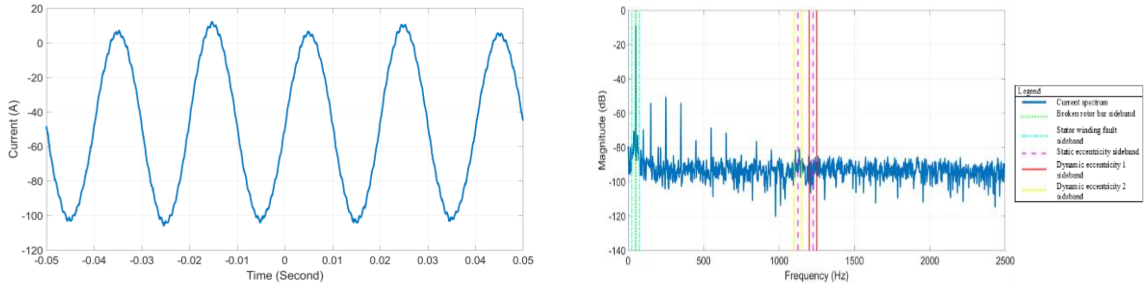
(a) (b)

Figure 7: (a) Frequency spectrum range 1000 Hz to 1300 Hz, (b) Frequency spectrum of high frequency for condensed water pump 2 from GUI

3.2.4 Motor for chilled water pump 2

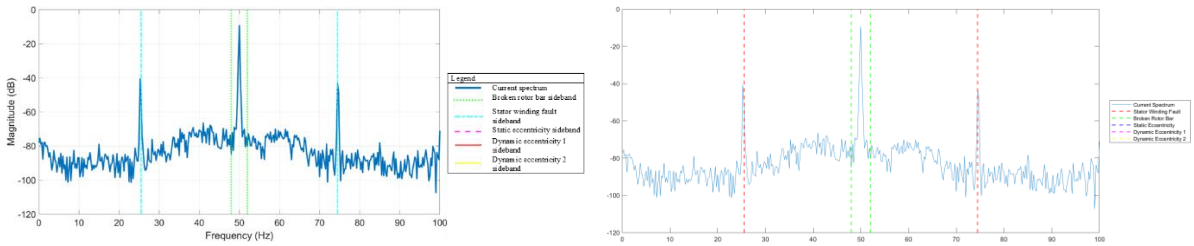
Based on Figure 8 (a), the current waveform measurement is taken from red phase shows slight distorted sine wave obtained from the oscilloscope. The magnitude of the phase current is approximately 15 A. Figure 8 (b)**.** depicts the overall current spectrum of the motor with its sidebands. The spectrum obtained is then observed through a smaller frequency range.

As shown in Figure 9 (a), it can be concluded that the motor does not experience a broken rotor bar as there is no peak at both sidebands. As observed from the stator winding fault of the lower sideband, 25.5 Hz and upper sideband, 74.5 Hz, there is a significant rise presented at both sidebands. It can be concluded that there is a stator winding fault occurring in the motor. Figure 9 (b) depicts the frequency spectrum of low frequency from GUI. As observed, it can be concluded that the motor does not experience a broken rotor bar but experience a stator winding fault.



(a) **(b)**

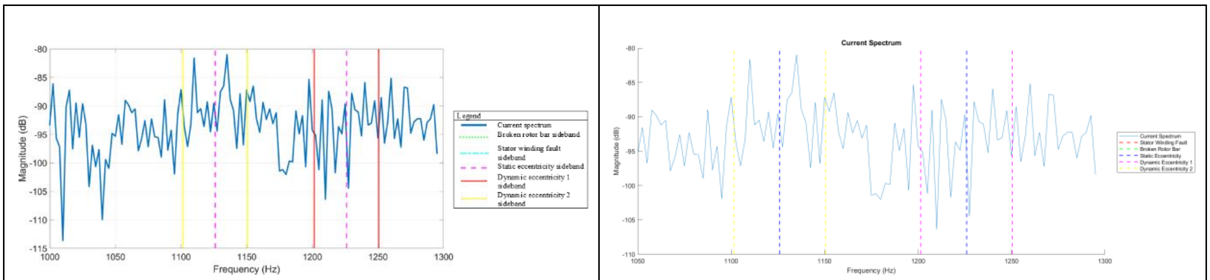
Figure 8: (a) Phase current waveform for chilled water pump motor 2, (b) High-frequency spectrum for chilled water pump motor 2



(a) **(b)**

Figure 9: (a) Frequency spectrum range 0 Hz to 100 Hz from MATLAB, (b) Frequency spectrum of low frequency for chilled water pump 2 from GUI

As shown in Figure 10 (a), the frequency spectrum is between 1000 Hz and 1300 Hz. It can be observed that there is no significant rise in sideband pairs of static eccentricity, at 1126 Hz, and 1226 Hz. Static eccentricity is absent in the motor. Observing both dynamic eccentricity sidebands' pairs, there is no significant rise in both sidebands pair of dynamic eccentricity. It can be concluded that the motor does not experience dynamic eccentricity. Figure 10 (b) depicts the current spectrum of high frequency from GUI. As observed, the motor is free from both static and dynamic eccentricity. It can be justified that the results obtained in GUI developed are the same as the results obtained from MATLAB.



(a) **(b)**

Figure 10: (a) Frequency spectrum range 1000 Hz to 1300 Hz from MATLAB, (b) Frequency spectrum of high frequency for chilled water pump 2 from GUI

To summarize, the comparison between the motors observed are presented in Table 1. Motor for condensed and chilled water pump 1 experienced broken rotor bar. Motor for condensed and chilled water pump 2 experienced stator winding fault.

Table 1: Comparison of fault detected between MATLAB and GUI.

Motor	Result	
	MATLAB	GUI
Condensed water pump 1	Broken rotor bar	Broken rotor bar
Chilled water pump 1	Broken rotor bar	Broken rotor bar
Condensed water pump 2	Stator winding fault	Stator winding fault
Chilled water pump 2	Stator winding fault	Stator winding fault

4. Conclusion

To conclude, the GUI has been developed successfully. Based on the analysis, the GUI developed is able to show the same result as obtained from MATLAB. The current spectrums presented for both MATLAB and GUI show a similar peak in magnitude on the same sidebands with respect to the motors monitored. A further investigation by physical inspection on the motor condition which has been suspected to be faulty based on the MCSA result can be carried out in the future.

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