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A Virtual Platform for Signal Processing Analysis Dedicated to the Monitoring and Diagnosis of Electrical Machines

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***Abstract*— This paper is about developing a virtual instrument platform for the diagnosis of Electrical Machines (EMs). Actually, signal-based diagnosis techniques are the preferred option for monitoring the health state of the EMs. The developed platform is dedicated to several time or frequency domain analysis derived from the instantaneous variable values of the machine, namely currents, torque, and speed. More specifically, the proposed platform allows the use of signal processing techniques, leading to the extraction of fault signatures, mainly represented by specific fault harmonics. The performance of the developed platform was tested by an associated 7.5kW three-phase PMSM controlled with a conventional Field Oriented Control (FOC) scheme implemented in Matlab Simulink™.**

***Keywords*— Diagnosis, Electrical Machines, FFT, Human Machine Interface, LabVIEW, Monitoring, Signal Processing,**

I. INTRODUCTION

It is a matter of fact that new communication technologies are becoming necessary for several emerging industrial fields, leading to new terminologies namely Smart Cities (SCs), Internet of Things (IoT), or big data analysis. Specifically, Electrical Machines (EMs) are widely used for domestic and industry applications. Effectively, monitoring and diagnosis of EMs have been of big interest for the last decade, with a special interest on signal-based techniques [1].

Electrical machines data analysis for fault signature investigations has been the aim of large number of contributions. More specifically, spectral signature analysis dedicated to mechanical fault detection, such as bearing or gear faults, static/and or dynamic eccentricities, mechanical unbalances, or rotor broken bars faults are exhaustively investigated in [1]-[7].

Electrical faults such as stator winding asymmetries, shorted turns, turn to turns, high resistance connections, magnet defect were the subject of another wide range of investigations [8]-[12].

Monitoring EMs can be a distance or local operation. It can be a subject for a Supervisory Control, and Data Acquisition (SCADA), which can be of interest for on-line, or off-line such as expert system. More specifically, Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is actually highly recommended for Human Machine Interface (HMI), SCADA [13]-[14], monitoring interface [15]-[22], acquisition interface [23]-[24]. In [25], a model of healthy and faulty induction motor is introduced.

Monitoring EMs, based on data analysis in time, or frequency domains via a LabVIEW interface is the subject of this paper. The presented results are a part of a project dedicated to the development of a multiprocessing signal data analysis, for fault detection at incipient stage in EMs. The paper is organized as follow: Section II presents the problem statement, the problem analysis is detailed in Section III. Section IV is devoted to some demonstrative tests. And finally, Section V ends the paper with some concluding remarks.

II. PROBLEM STATEMENT

In this section, the main functional and graphic requirements, are described in a non-exhaustive way.

A. Functional Requirement

A detailed list of featured requirements is illustrated in Fig.1. It is shown that a user can select a signal to be loaded, then processing functions are proposed. Once the technique is selected, it enables the detection of the machine operating condition using inputs as stator currents, shaft speed and torque as well as displaying signals in the required domain. The results can be exported as a picture or a file format.

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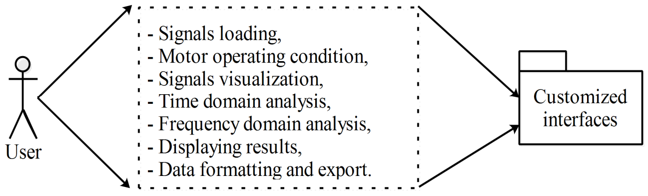

Fig. 1 User specification schema

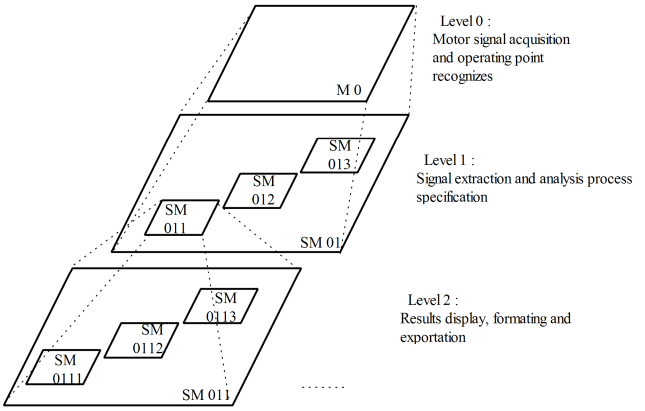

Fig. 2 Navigation specification schema

B. *Graphic recommendation*

The navigation and the interactivity between the menus are depicted in Fig. 2 User will have a main menu which gives him a multiple choice to transfer the data to other interfaces. The second level allows the user to enter the signal for being treated, and for being analysed, to choose an operating point, or to process the data already available. In the third level, the analysis domain should be selected, in which the signal will be displayed, and/or exported with a selected formatting.

III. Proposed Approach

The monitoring philosophy lead to define the design concept in the following subsection.

A. *Algorithm description*

Fig. 3 illustrates the home menu algorithm. It contains two tests. The first one is looking for the user interactivity to choose a process to be done. It allows to run and show the loading interface, where the condition point will be verified. It also show one of the processing interfaces relative to the second test result and only if signals are already loaded, otherwise it exists. The second test is executed when processing option is chosen. It allows user to specify the signal to be processed then the main program to activate the corresponding processing interface.

B. *State machine diagram*

Fig. 4 illustrates the different behavior transition scenario. First state is an initial main menu, where the processing feature is disabled. Two transitions are permitted, to move to motor specifications and loading menu or to exit.

After loading signal state, the principal main menu is shown with all features. Three transitions can be done from this main menu, to reload another signal so back to the loading state, or to exit or to move to signal processing state. In that state, two transitions are allowed, returning to main menu or moving to data export submenu. In the end, this submenu can only return back to the previous state.

IV. Case Study

To demonstrate the platform functionality, an example is treated in this section. A stored data base of a numerical simulation of a 7.5kW three phase Permanent Magnet Synchronous Motor (PMSM) controlled with a conventional Field Oriented Control (FOC) scheme (Fig. 5) are used as inputs for a healthy and faulty motor condition.
Fig. 6 represent the main menu with unhidden processing elements. It contain a short description, three buttons, which allow user to select a process to execute, two drop down menu which allow user to specific the desired signal input to be processed and the required analysis.

In the following demonstration, only the current will be used for processing and for different case of motor condition and analysis domain.

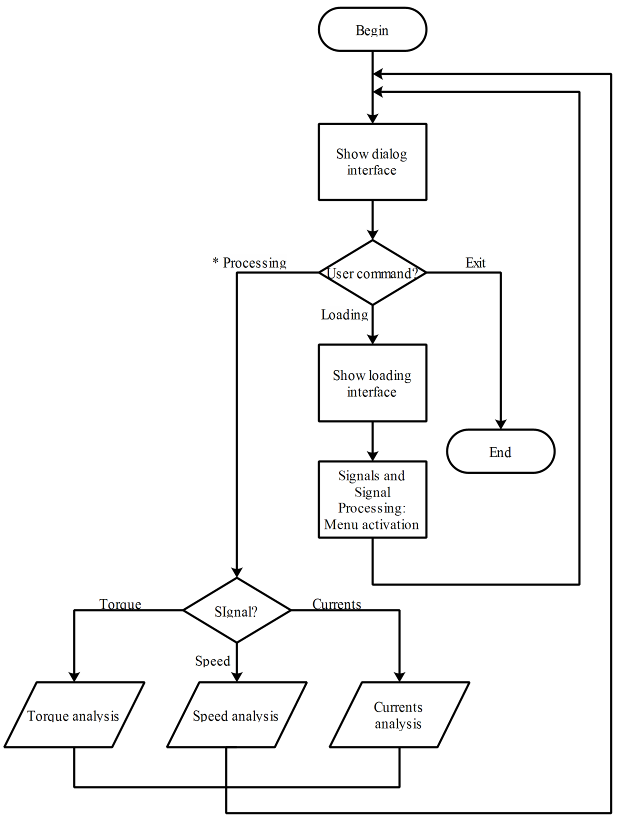

Fig. 3 The proposed main algorithm

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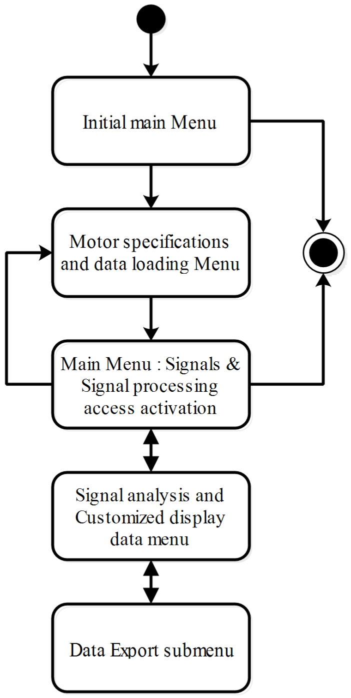

Fig. 4 State machine diagram

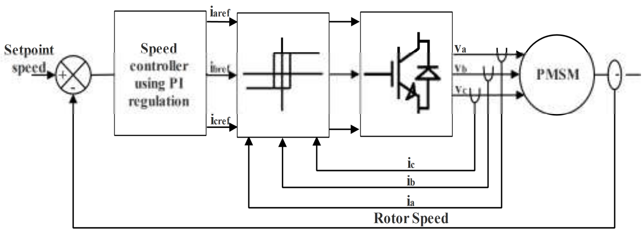

Fig. 5 The PMSM system control used for data generation.

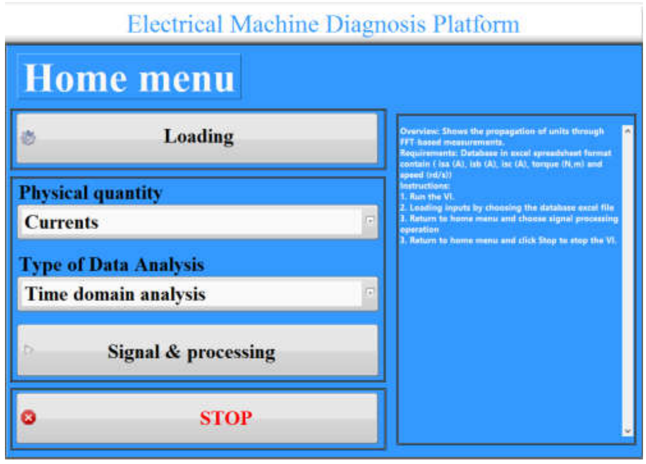

Fig. 6 A snapshot of the platform main menu

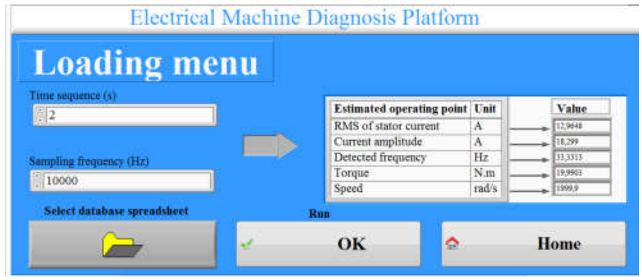

Fig. 7 A snapshot of the signal uploading and operation point detection.

Fig. 7 show the loading menu where user select the data base source, specify the duration and the sampling frequency then use a run button to upload and display the motor operating point specifications. A home button is available to return to the main menu. The execution show that the stator current is equal to 13 A, the supply frequency is 33.33 Hz, the torque is 20 N.m and the speed is 200 rad/s. Fig. 8 to Fig. 10 and respectively Fig. 11 to Fig. 13 are three different analysis interfaces. Fig. 8 and Fig. 11 show the time domain interface. Fig. 9 and Fig. 12 contain the frequency domain interface and Fig. 10 and Fig. 13 show both graphs for one input. It is all equipped by cursors to let user find a coordinate for a selected point or use time index to find its value and two export options to save graph as JPEG image or to Excel file.

A. *Healthy case*

Fig. 8 to Fig. 10 show a displaying result for a healthy state motor data. Fig. 8 depicted the three phase current in time domain. Fig. 9 and Fig. 10 show phase A current in frequency and time domains respectively. The spectral analysis show only the supply frequency component.

B. *Faulty case*

For the same purpose, Fig. 11 to Fig. 13 show a displaying result for a faulty state motor data.

Fig. 11 depicts the three phase current in time domain.

Fig. 12 and Fig. 13 show phase A current in frequency domain and time and frequency domains respectively.

The spectral analysis show the supply frequency component and other new components at frequencies $\pm$ (1 + 2k)f) $_{k=0,1,2,....}$ (f denotes the power grid frequency) which corresponds to a stator fault signature [9]. A button is available in spectral analysis interface to find the three first maximums values harmonics coordinates.

V. Conclusions

In this paper, a Human Machine Interface is presented and tested in section IV based on signal processing and analysis as an universal solution for ac electrical machines monitoring and fault recognition. The platform uses as input the measured data of stator current, torque and speed and displays them in time and frequency domains according to the user's request.

The platform can be extended in many version, as a monitoring didactic tool, an online expert consulting tool or to be integrated in a SCADA interface.

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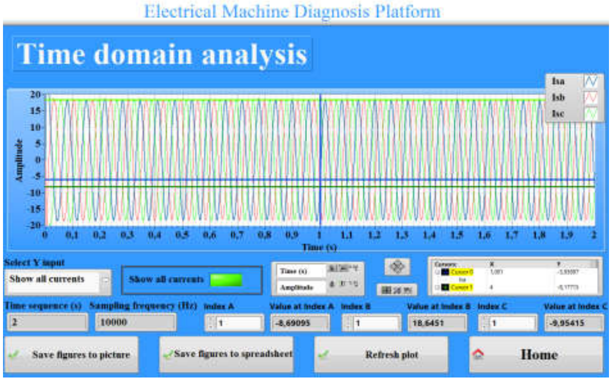

Fig. 8 A snapshot of the time domain analysis under healthy case.

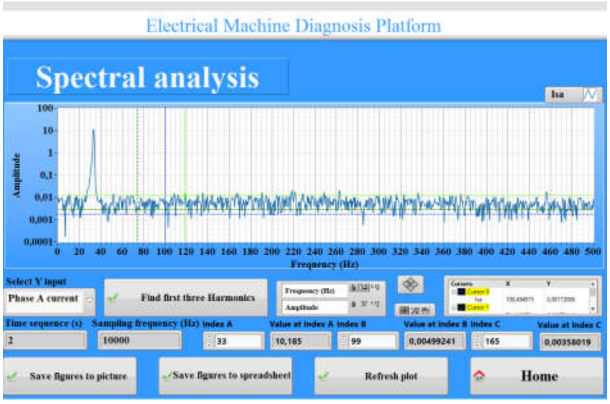

Fig. 9 A snapshot of the frequency domain analysis under healthy case.

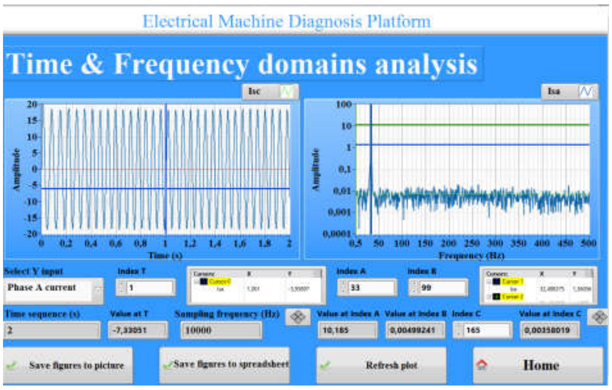

Fig. 10 A snapshot of time and frequency domains analysis under healthy operating conditions.

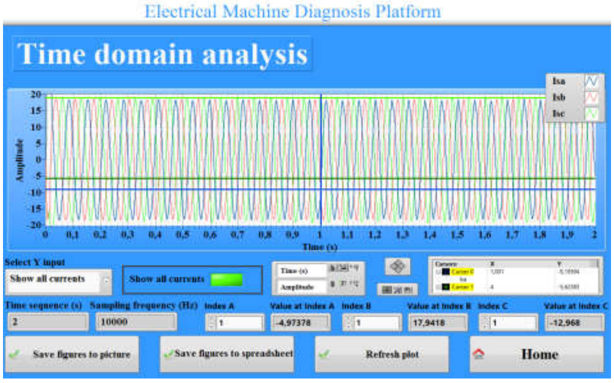

Fig. 11 A snapshot of the time domain analysis under faulty case.

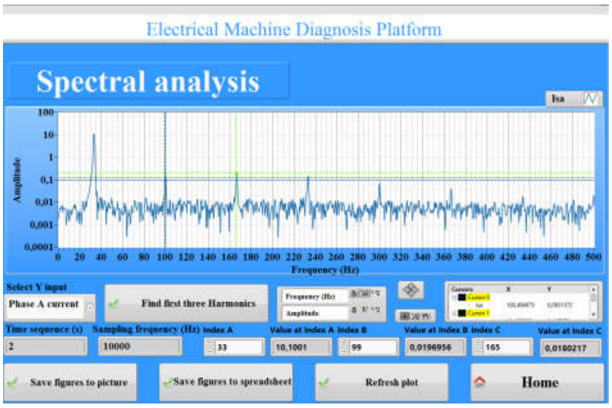

Fig. 12 A snapshot of the frequency domain analysis under faulty case.

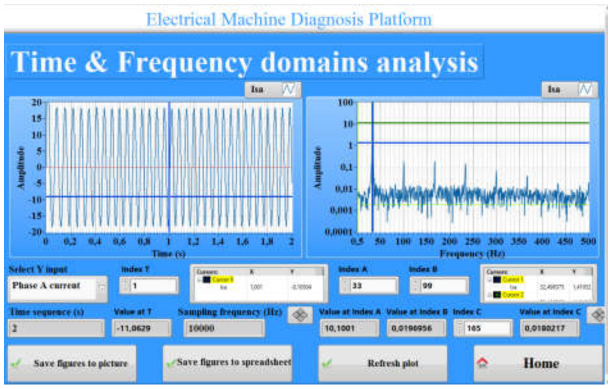

Fig. 13 A snapshot of time and frequency domains analysis under faulty operating conditions.

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