

DIAGNOSTIC SYSTEM FOR ASYNCHRONOUS MOTORS AND SYNCHRONOUS GENERATORS OPERATING IN AUTONOMOUS MODE DEVELOPED THROUGH THE USE OF DAQ DEVICES AND LABVIEW PROGRAMMING ENVIRONMENT

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Abstract. The paper explores the possibilities for the use of DAQ devices in developing specialised diagnostic systems for monitoring and diagnostics of electrical equipment with asynchronous electric drives and autonomous synchronous generators. The primary focus is on the construction of a system responsive to different complementary diagnostic methods, such as the spectral current-voltage analysis, Park's method, instantaneous power theories, etc. Such a system might be applied locally (discretely) and/or conjointly in a centralized equipment monitoring system with the use of the LabView platform.

Keywords: Diagnosis of Generators, Diagnosis of Motors, MSCA, MVSA, GSCA, GVSA

1 Introduction

Applied effectively in practice are various diagnostic systems and techniques for asynchronous motor (AM) and synchronous generator (SG) condition monitoring based on the analysis of electrical signals. In general, these techniques rely on the analysis of the signals measured directly or through relevant conversion. The subsequent AM condition assessment can be performed following the analysis of the measured electrical quantities. The inconsistencies (changes) uncovered during the analysis as regards the current, voltage and power, might be attributed either to some faults occurring in the AM or affected by the equipment being driven. The analysis of electrical quantities therefore would be also equally applicable in assessing the condition of the plant as a whole.

2 Measuring system

Brought forward in the paper is a special diagnostic system created on the basis of multifunctional DAQ devices and an exclusive author-designed LabView-based software application. The system, developed for the purposes of the present study, is constructed on a 16-channel DAQ device of National Instruments: cDAQ-9174 with modules NI 9242, NI9227 and NI9215 for sample rate of 250 kS/s. The block diagram of the DAQ device is shown in Figure 1. The data itself is collected, processed, analyzed and systematized through the use of the graphical LabView platform taking advantage of its distinctive capabilities for visualization and quick configuration of virtual instruments. Displayed in Figure 2 is the complete setup of the applied monitoring system comprising: conversion modules, a system for data collection, processing and analysis. The necessary virtual instruments (VI) are created by means of the graphical programming language allowing for accurate measurements of the instantaneous and rms values of the current and voltage. Provision is taken in the different sub-modules for a real-time calculation and visualization of: the power factor, the active and reactive power, Clarke's and Park's transformations, voltage and current spectra calculated via the fast (discrete) Fourier transforms FFT (DFT). The system helps analyze the relationship between the electrical energy quality indicators and the equipment condition.

The virtual instrument not only allows for an assessment of the condition and the parameters of the surveyed object through various methods of data analysis but also permits further expansion. The ideology behind the graphical display system is to offer an environment conducive to programming different instruments that are fully functional on different devices without requiring the user to install the appropriate software as detailed in the corresponding license agreement. Designing such VIs provides plenty of opportunities for their practical applications.

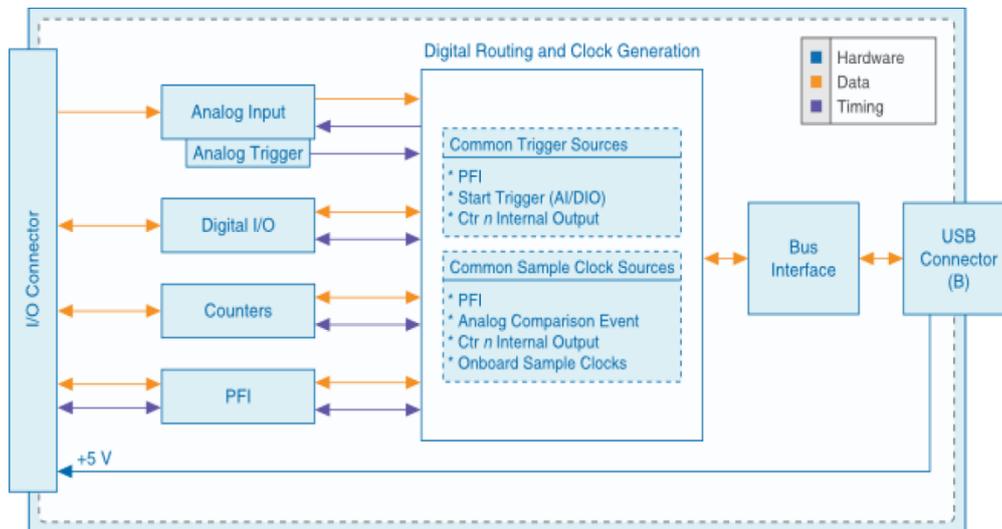


Fig. 1. National instruments - DAQ 6210 block diagram

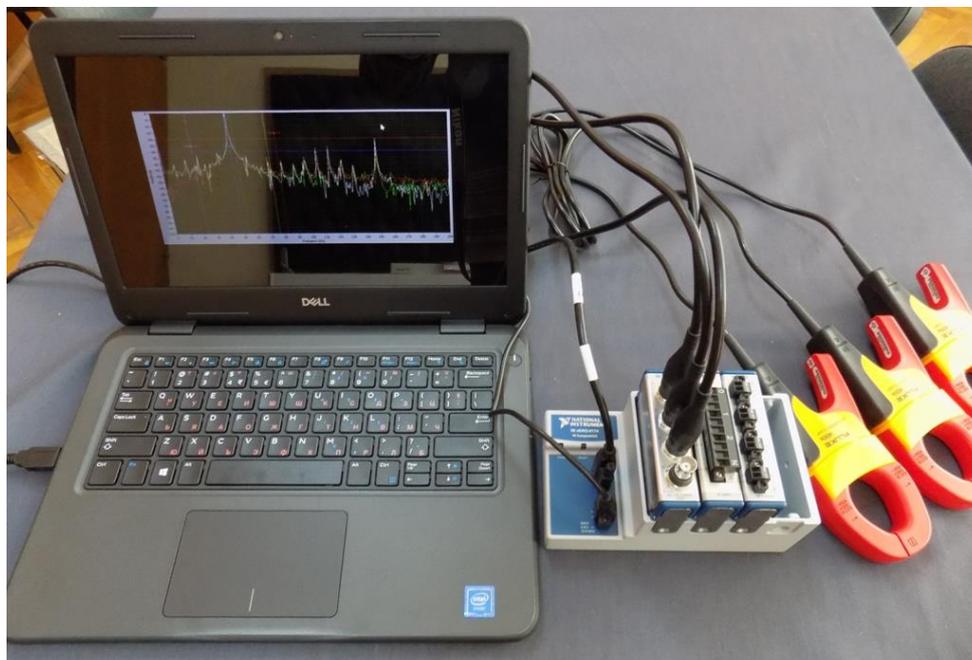


Fig. 2. General setup of the measurement and data processing system

3. Virtual Instrument Basic Blocks

- Calculation of the harmonic composition and graphical vector visualization of Park's transformation according to 1 and 2.

$$i_D = \sqrt{\frac{2}{3}} i_A - \frac{1}{\sqrt{6}} i_B - \frac{1}{\sqrt{6}} i_C \quad (1)$$

$$i_Q = \frac{1}{\sqrt{2}} i_B - \frac{1}{\sqrt{2}} i_C \quad (2)$$

The vector representation of the symmetrical current of a motor in good working condition is a circle whose center is at the base of the coordinate axes. In abnormal situations, the surveyed models are likely to deviate from their optimal performance relative to the failure. Park's vector method is considered appropriate to detect numerous malfunctions that might occur in three-phase asynchronous motors.

- Clarke's Transformation

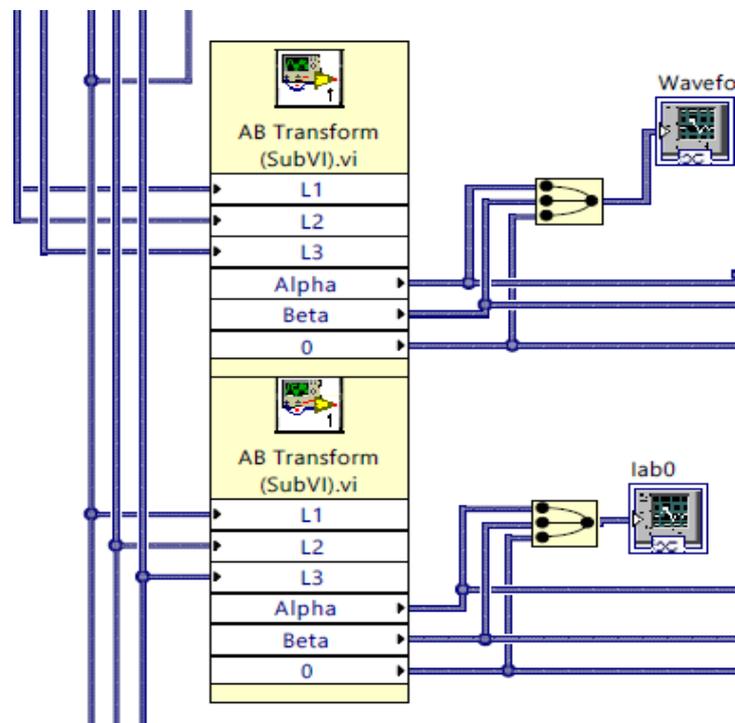


Fig. 3. Clarke's transformation

- Calculation submodule in line with the p-q theory

Transformation from a stationary system coordinates of a-b-c to a system of α - β -0 coordinates. It corresponds to Clarke's transformation, wherein the α - β coordinates are orthogonal relative to each other, and the coordinate 0 corresponds to the components of the zero sequence. The zero sequence components are different from those obtained by the method of symmetrical components (Fortescue's transformation) by means of a $\sqrt{3}$ factor.

The voltages and currents represented in α - β -0 coordinate system are determined through the following expressions:

$$\begin{bmatrix} u_0 \\ u_\alpha \\ u_\beta \end{bmatrix} = T \cdot \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = T \cdot \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{4}$$

$$T = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \tag{5}$$

The power components are calculated from the voltage and current values in α - β -0 coordinates, with each component being separated into its constant and alternating values.

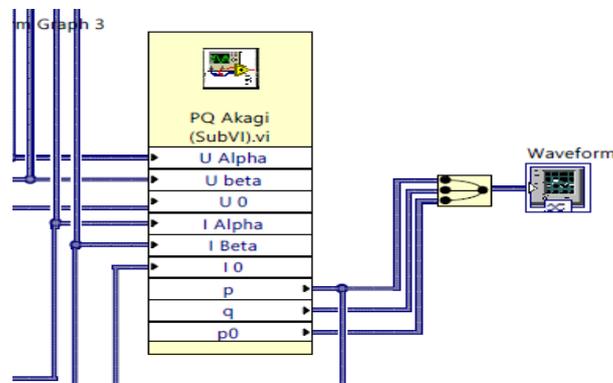


Fig. 4. Akagi's subsystem

- Spectral current-voltage analyzers

MCSA (motor current signature analysis) and MVSA (motor voltage signature analysis) methods are used as a means to detect AM malfunctions at an early stage and, thus, help prevent severe equipment failure, while regular preventive maintenance ensures prolonged and reliable operation of the equipment (Benbouzid 2000, Saad et al., 2018; Thomson 2001, 2003, 2017; ISO 20958-2013). Adopting such a diagnostic technique is useful in detecting the most common asynchronous motor malfunctions such as winding failure, eccentricity, bearing damage, imbalance, stator-winding damage, as well as potential faults in the driven mechanism. To ensure the reliability and validity of the obtained results, testing should normally be performed when AM load is 70%. Besides, through GCSA (generator current signature analysis) and GVSA (generator voltage signature analysis) a variety of faults can be additionally detected in synchronous generators (SG) operating in island mode (Salomon 2019, Nadarajan 2015, Fayazi 2015, Cruz 2001). The modules this particular function can be implemented are outlined in Fig.5. More specifically, the types of faults that are likely to be identified and subsequently analyzed are:

- Rotor winding inter-turn short-circuit fault of a synchronous generator– Such a fault leads to: increased rotor current, higher winding temperature, voltage harmonics, excessive vibration and possible occurrence and development of mechanical damage.
- Stator winding inter-turn short-circuit – as being characterized by the following features: appearance of pulsating current and reversed direction of the rotating fields.
- Mechanical failures of the rotor, referring to: shaft misalignment, mechanical imbalances, static and dynamic air gap eccentricity. These faults result in: increased vibrations, bearing wear and in the least favourable case rotor-to-stator friction/rubbing.

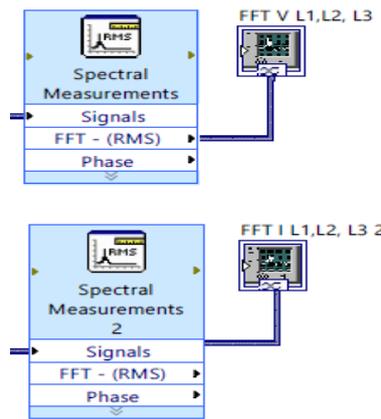


Fig. 5. Spectral current-voltage analysis

Depicted in Fig. 6 and 7 is a block diagram and one of the number of screens displaying the measurement and calculation visualization of the accomplished VI.

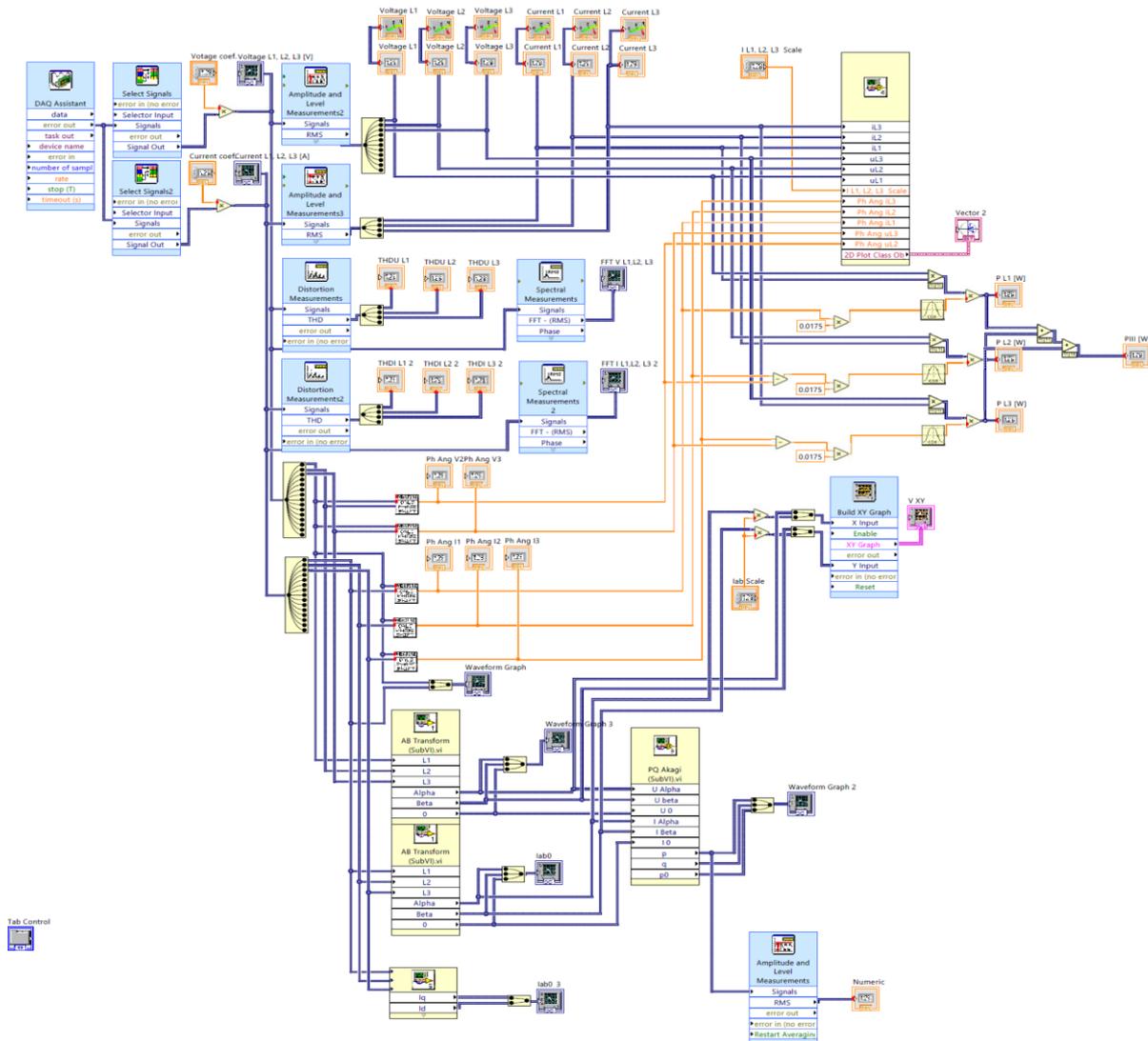


Fig. 6. Block diagram of the virtual instrument diagnostic process

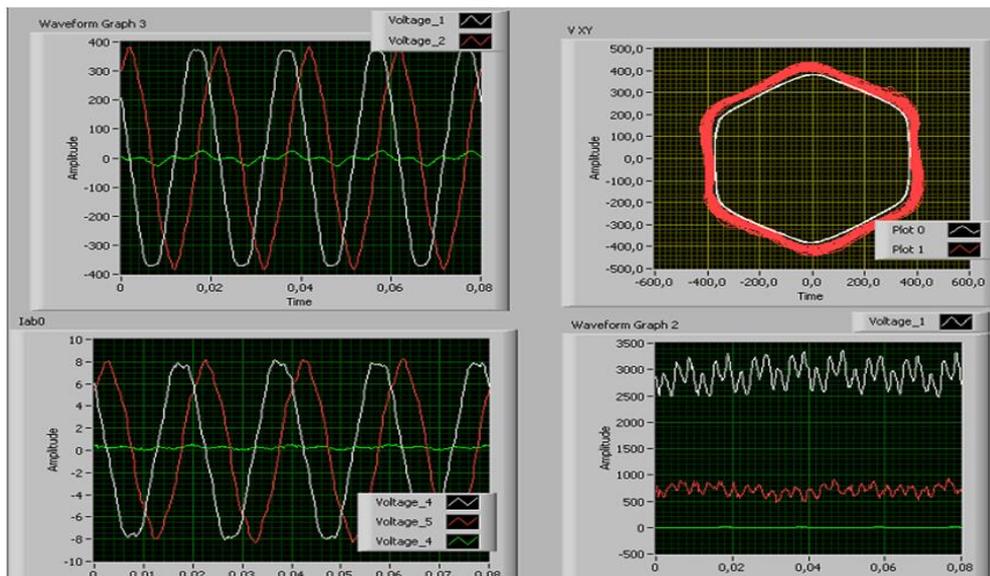


Fig. 7. Visualization of Clark's transformation

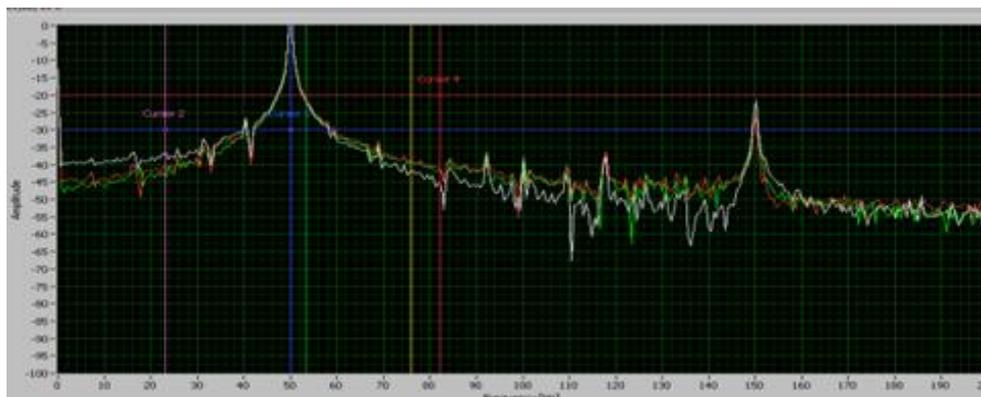


Fig. 8. Idling with no tensioning mechanism

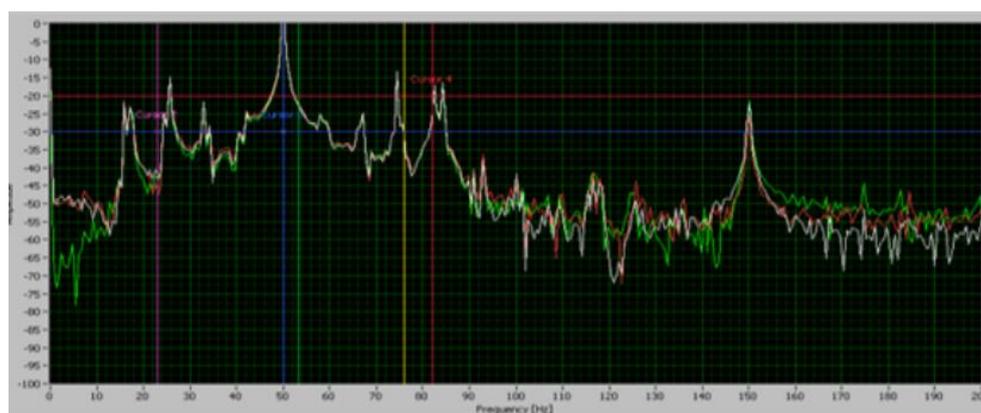


Fig. 9. Idling with no tensioning mechanism

Visualized in Fig. 8 and 9 are the obtained stator current spectra of asynchronous electric drive of the conveyor belt and a nominal power of $P_n=2,2$ [kW]; nominal voltage $U_n=400$ [V]; number of poles = $2p$. The research study is performed in idle mode with a selected nominal and minimum belt tension (loose belt). Clearly, this widely distributed fault can be easily identified by determining the characteristic frequency signals, especially effective when diagnosing industrial air conditioning units and other equipment with no access to the electric drive.

4 Discussion

A further development of the projected diagnostic system might include a wavelet analysis, as well as neural network algorithms. The variety of the methods adopted in the research offers ample opportunities for establishing greater reliability and validity of the obtained diagnostic data.

5 Conclusions

The virtual instrument hereto discussed based on a DAQ device provides an easy detection of particular faults and failures in AM and autonomous SG, and their manifestation in the current and voltage spectra. Its proper application in remote, hard-to-reach and hard-to-serve areas will contribute significantly to a more efficient maintenance and diagnostics.

Modern diesel generators are increasingly supplied with brushless excitation systems, which is, undoubtedly, to their advantage. Yet, one of the few drawbacks of such a block diagram is the absence of easy access to the points that facilitate the accomplishment of a more thorough generator diagnostics. GCSA and GVSA usage can further assist and enhance the diagnostic examination of synchronous generators operating in “island mode”.

The present paper introduces the authors’ substantial contribution to the technical solution for the design and implementation of a diagnostic system developed through the use of DAQ devices and LabView programming environment, which, from a practical point of view, proves to be workable with a wide range of application possibilities and a likely expansion of the range of the theoretical methods applied.

Acknowledgments

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