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Application of mobile devices with the Android system for the induction motors faults diagnosis

Abstract. *The article presents a prototype of a remotely controlled measurement system for the diagnostics of induction motors, which uses any mobile device with the Android system, and diagnostic software installed on it as its hardware component (e.g. a mobile phone or a tablet). In the measurement component of the system there are two current clamps measuring motor current in two phases and a microprocessor logger which sends measurement samples to the mobile device by radio waves using the Bluetooth technology.*

Streszczenie. *W artykule przedstawiono prototyp zdalnego systemu pomiarowego do diagnostyki silników indukcyjnych, który w części sprzętowej wykorzystuje dowolne urządzenie przenośne z systemem Android (np. telefon komórkowy, czy tablet) z zainstalowanym oprogramowaniem diagnostycznym. Część pomiarową systemu stanowią dwie przystawki cęgowe mierzące prąd silnika w dwóch fazach oraz mikroprocesorowy rejestrator, który przesyła próbki pomiarowe do urządzenia przenośnego drogą radiową, wykorzystując technologię Bluetooth. (**Zastosowanie urządzeń przenośnych z systemem Android w diagnostyce silników indukcyjnych**)*

Keywords: induction motor, diagnostics, frequency analysis of stator current, Android system.
Słowa kluczowe: silnik indukcyjny, diagnostyka, analiza częstotliwościowa prądu, system Android.

Introduction

In the last decade we were able to observe the rapid development of technology related to manufacturing and availability of the PDA type handheld devices (Personal Digital Assistant). Especially the mobile telephony market evolved in the direction of the propagation of the so called smartphones, i.e. mobile devices joining the function of a phone and a personal computer. Taking into account the hardware component, the devices are highly-efficient computers with a lot of peripheral systems extending their abilities, enriching them with additional multimedia and communication functions. The software component of such devices is usually a “light” operating systems dedicated for mobile devices, the most popular ones recently are: iOS, Windows Mobile (Windows Phone) and Android. The open structure of these systems creates practically unlimited opportunities to create one’s own software, and thanks to this the devices may be used in many technical fields different form the ones they were initially meant for. A very good example are all kinds of remote control systems, data acquisition systems, measurement systems or monitoring and diagnostics systems for electric drives.

Various types of measurement equipment are used for the ongoing monitoring of basic physical control signals to assess the technical condition of motors during their operation. Unfortunately diagnostic equipment, consisting of appropriate sensors and a specialist computer for measurement signals analysis, is very expensive this its practical use is limited to big machines. On the other hand low-power engines are the largest group of machines whose role in technological processes is very important. This is why inexpensive equipment solutions which will allow to implement the issues of operation diagnostics also in low-power drives are still sought after [1].

The article presents the possibility to apply inexpensive, generally available mobile devices with the Android system in measurement and diagnostic systems for induction motors, it will allow to assess their technical condition on the basis of phase current signals analysis.

Diagnostics of induction motors on the basis of the stator current frequency analysis

In phase current signals of induction motors there are various diagnostic characteristics resulting from electric and magnetic asymmetry of stator circuit and a rotor. These characteristics are visible in the phase current spectrum and in the spectrum of the current spatial vector in the form of spectral components characteristic for particular types of faults. That is why the stator current frequency analysis is frequently used as a simple and non-invasive diagnostic method in the detection of stator and rotor faults as well as other irregularities in induction motor drives [2].

In the case of the faults of squirrel-cage bars in the phase current spectrum there are components described by the following dependencies [3]:

(1) $$f_{sk1,2} = (1 \pm 2ks) f_s$$

where: f_s – supply voltage frequency, s – motor slip, k=1, 2, 3, ...

After transformation these components also appear in the spectrum of the current spatial vector module in the form of lines with frequency f_{Pk} [4]:

(2) $$f_{Pk} = 2ksf_s$$

In the case of feeding voltage asymmetry, in the spectrum of the spatial vector module component f_A appears with frequency:

(3) $$f_A = 2 f_s$$

The appearance of this component may also prove that there is asymmetry in stator winding caused by e.g. short circuit of a few turns of winding. In the case of the wrong coupling between a motor and a machine, when an engine axle does not coincide with a machine axle, in the spectrum of the spatial vector module of stator current there are components with frequency f_{mk}:

(4) $$f_{mk} = f_s - f_s\left[1 - k\left(\frac{1-s}{p}\right)\right]$$

Figure 1 presents a sample spectrum of the spatial vector module of stator current for a motor with a rotor fault, when four squirrel-cage bars are broken. The characteristic spectral components related to the faulty rotor (f_{P1}, f_{P2}), asymmetry of feeding voltage (f_A) and non-axial coupling between a motor and a machine (f_{m1}–f_{m4}) are marked on the graph. The amplitudes of these components depend on the degree of irregularities and faults in the tested motor. It should be mentioned, however, that these components may appear in the spectrum of a brand new motor as a result of its imperfect construction due to magnetic and electric asymmetry [5].

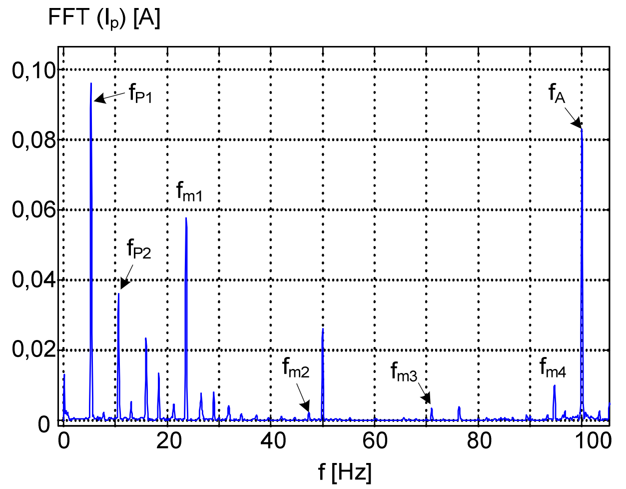

Fig.1. Spectrum of the spatial vector module of stator current for a motor with a rotor fault

The construction of the remotely controlled diagnostic system

A remotely controlled diagnostic system for an induction motor is made of composed of hardware – measurement system, and diagnostic software which is used for the analysis of the collected data. The measurement system records measurement signals of motor phase currents of a two-phase motor, next sends them by radio waves using Bluetooth® standard, to a mobile device. It can be any mobile phone or a tablet with the Android system, version 2.1 at least. Control-diagnostic software must be installed on the mobile device as it will be able to receive the records measurements samples and conduct the diagnostic analysis of these signals to detect the characteristics coinciding with particular motor faults. Figure 2 presents the block diagram of the measurement system.

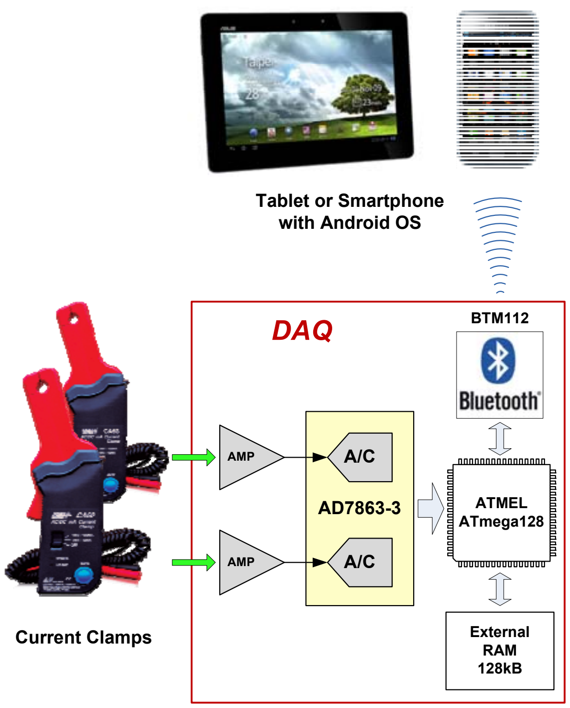

Fig.2. Block diagram of the measurement system

The task of current sensors in the system is performed by inexpensive current clamps, CA60 type, which allow to measure motor phase currents without switching off the supply system. These transducers have two measuring ranges (15A and 60A), which makes it possible to use them in the diagnostics of the majority of low- and medium-power machines.

The measurement signals of phase currents are later amplified and fed to an A/D converter input. In the prototype solution a four-channel AD7863 type ADC was used, it has 14-bit resolution with maximum sampling frequency in the range of 175kHz.

The main control element of the measurement system is a popular 8-bit microcontroller, ATmega128 type – Atmel AVR®, which manages the operation of ADC and records the measured signal samples in external RAM (size 128kB). The microcontroller is also responsible for data exchange with the mobile device, it is conducted by a Bluetooth communication module, BTM112 type made by Rayson Technology (Fig. 3). The module is also used for two-way radio communication using the Bluetooth® standard, where data exchange with the microcontroller is conducted by a standard serial interface.

Fig.3. Bluetooth communication module, BTM112 type

The prototype version of the remotely controlled measurement system for the diagnostics of induction motors has already been made and its photo is presented in figure 4. The measurement system has a compact form and uses its own power supply in the form of a lithium polymer battery. This eliminates the necessity to have access to an external source of supply and ensures long time of continuous work (over 12 hours). The measurement system is very easy to operate and it involves only switching on the recorder and current clamps as well as selecting measurement ranges. Controlling the measurement system and setting recording parameters take place in the MONITOR application which is installed on the mobile device.

Fig.4. Prototype of the remotely controlled diagnostic system

The software of the remotely controlled diagnostic system

The remotely controlled diagnostic system software (MONITOR) is dedicated for mobile devices with the Android system, mainly for modern mobile phones. To ensure service ergonomics, it is recommended to use devices with at least 4-inch display and minimum 800x480 pixels high resolution. The software is written in Java language using Eclipse Integrated Development Environment, with Android SDK tool. There are two functional components: a control module and a measurement data analyzer.

The main function of the control module is remote communication with the measurement system and parameterization as well as the control of measurement data acquisition process. The user may set sampling frequency in the range of 1–50kHz and select data buffer size for each channel in the range of 512–32768 samples. After the recording of measurement samples is finished, the data buffer is automatically sent to the mobile device over radio, using the Bluetooth standard. The received data may be recorded on an internal flash memory card which makes it easier to manage them later. The saved records have the form of (*.mat) files which are compatible with the data format accepted by MATLAB software. Thanks to this it is possible to export the saved data to a desktop computer for further analysis.

Figure 5a shows the main program window, the level from it which it is possible to select the main functions of the diagnostic system while figure 5b shows the recording parameters selection screen.

a) b)

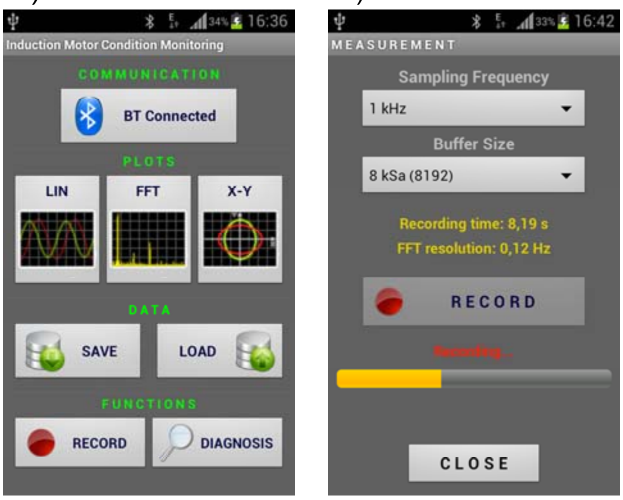

Fig.5. Sample diagnostic software screenshots: a) – the main program window, b) –"Measurement" window

The measurement data analyzer processes the recorded measurement data and performs a number of transformations and numerical calculations, such as: determination of the spatial vector module of stator current, calculation of RMS values, overlapping functions of time windows, frequency analysis (FFT), extracting selected spectral components from the spectrum. The results of these transformations are presented in a text and graphic form, in the form of plots which can be enlarged, rotated or scaled in any way using the touch screen of the mobile device with a multi-touch function. The graphic form of any screen can be saved, which results in generating a *.jpg image file. Figure 6 presents sample screens with recorded current waveforms in a time series form and in the form of the hodograph of a spatial vector on an orthogonal components plane i_α-i_β. Figure 7 presents sample screenshots of the MONITOR software operating in the FFT analyzer mode.

a) b)

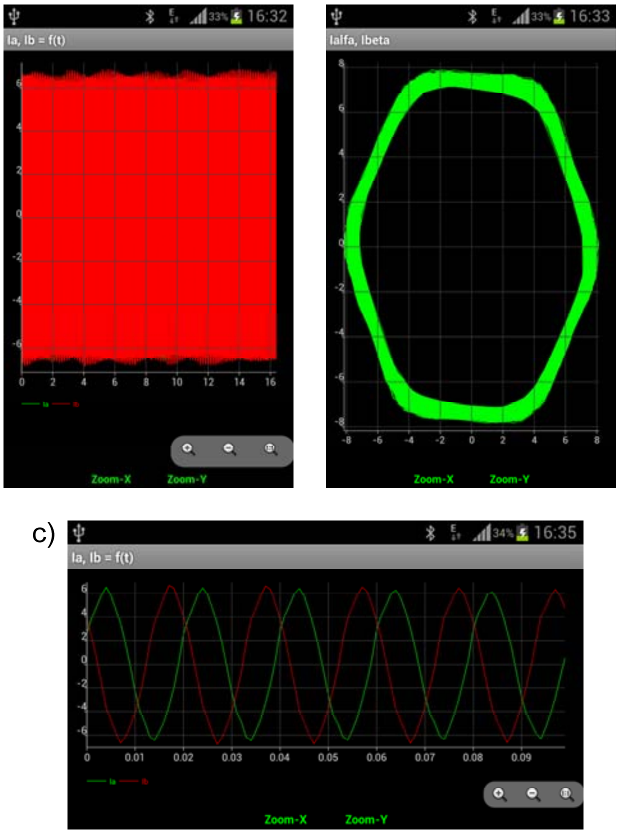

Fig.6. Sample screenshots of the MONITOR software: a) – recorded stator current plot, b) – hodograph of the spatial vector of current, c) – enlarged plots of current i_a and i_b, horizontal view.

a) b)

Fig.7. The MONITOR software operating in the FFT analyzer mode: a) – FFT settings window, b) – sample stator current spectrum.

The diagnostic software has the function of the automatic extraction of characteristic spectral components from a phase current spectrum and the spectrum of a stator current spatial vector module. The determination algorithm for these components is presented in a simplified form in figure 8. The components of the spatial vector (i_α, i_β) are calculated on the basis of the recorded signals of phase currents, the module of this vector ($|i_P|$) is determined on the same basis. Next the spectra of phase currents signals (i_a) and the spatial vector module (i_P) are calculated using fast Fourier transform algorithms. The following stage is the determination of the fundamental frequency (f_s) and calculating the motor slip (s). On the basis of comparisons (1–4) the frequencies of characteristic spectral components related to selected engine faults are determined. Knowing the position of these components in spectra, it is possible to read their amplitudes and next see them on the mobile device display. On the basis of the presented results, the user can recognize the type of fault in a given engine and roughly assess its size. However, the proper assessment of the technical condition of a drive system, is possible only with basic expert knowledge resulting mainly from experience. This is why the presented diagnostic software is still in the development phase. Currently research work is conducted to develop an effective algorithm for the automatic assessment of the technical condition of an engine. On the basis of the conducted research, it can be assumed that the application of artificial neural networks as fault detectors and classifiers will allow to automate the diagnostic process and will ensure the effective diagnostics of various machines in a wide power range [6].

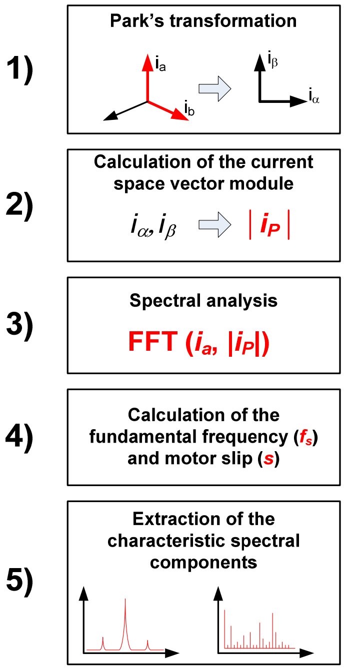

Fig.8. Simplified extraction algorithm of spectral characteristic components related to selected motor faults

Summary

The remotely controlled diagnostic system for induction motors, which is presented in this article, is a practical, mobile measurement set making it possible to determine the technical condition of induction motors on the basis of the measurements of stator current signals in two phases. The application of external current clamps for current measurements makes this measurement system universal and allows to use it in the diagnostics of various engines in a wide power range. The key system element is the control and diagnostic software, installed on a mobile device, which allows for remote communication with the measurement system by radio waves, using the Bluetooth standard, and the analysis of the collected data to detect various engine faults. For the purpose of determining the technical condition of the tested motor, it is possible to use the method of frequency analysis of phase currents and the stator current spatial vector module.

Undoubtedly an advantage of the presented diagnostic system is its low manufacturing cost which results mainly from simple hardware solutions combined with efficient diagnostic software. Any commonly used mobile device with the Android system, e.g. a mobile phone or a tablet, can be used as a diagnostic analyzer. Such a solution allows to reduce the total cost of the system eliminating the necessity to construct a specialist computer equipped with a graphic user interface. The prototype of the presented measurement and diagnostic system has been already made. Currently it is being tested and the diagnostic software is continuously developed and improved. In the future it is planned to add the function of automatic fault detection of a stator, a rotor and bearings of the tested engine.

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