A Web-Based Remote Laboratory for Monitoring and Diagnosis of AC Electrical Machines

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***Abstract*—This paper deals with the development of a virtual platform for a Web-based remote application dedicated to condition monitoring and fault detection for ac electrical machines. The platform is based on several tools developed by using the LabVIEW software. Various techniques of condition monitoring and diagnosis of electrical and mechanical faults in ac electrical machines have been integrated such as the broken rotor bar, winding short circuit, bearing damage, or static/dynamic eccentricities. The main features are related to a user-friendly interface, a low-maintenance source code, and a standardized database for ac electrical machine diagnosis. The platform architecture, as well as three different test-rig configurations, has been described. The complete system can be controlled in both local and remote modes by using a simple Internet connection. Some remote experiences have been carried out between the University of Picardie "Jules Verne," Amiens, France, and the University of Bologna, Bologna, Italy, to verify the effectiveness of the proposed system. The direct applications of this original package are based on diagnosis techniques applied to ac electrical machine faults. Some examples of rotor broken bar detection using classical techniques have been presented to show the effectiveness of the proposed platform. Further information will soon be available on the Open European Laboratory on Electrical Machines Web site: www.oelem.org.**

***Index Terms*—AC electrical machines, data acquisition (DAQ), data processing, data sockets, diagnostics techniques, digital signal processing, fault detection, induction machine, remote application, Web-based laboratory.**

I. Introduction

THE concept of a Web-based laboratory is not new since it has been introduced in the early 1980s. However, the fast progress of Internet-based networking technologies during the last ten years did allow the development of distance remote applications with significant and secure data flow rate. Since the research in all engineering areas should combine both theory and practice, the principle of the Web-based laboratory is very useful to provide researchers and engineers with the Internet access to various expensive but up-to-date setups located in different laboratories. In this way, the Department of Electronics Technology of the University of Vigo, Vigo, Spain, has developed a remote application for monitoring a number of distance sensors [1]. Researchers could have access to data coming from sensors using virtual instruments (VIs) developed within a LabVIEW environment. In the same way, the Department of Computer Science and Engineering of the Jaume I University, Castellón de la Plana, Spain, has developed an Internet-based remote laboratory which allowed controlling two robots [2]. In fact, the challenge of this work was to demonstrate that remote programming associated to an advanced multimedia user interface for control purposes was suitable, flexible, and profitable for the design of a virtual laboratory. In [3], the authors developed a distance laboratory for power electronic experiments based on systems which can be driven remotely using Internet and World Wide Web (WWW) services. In [4], advanced software for a remote platform dedicated to power electronics courses has been described. This system has been based on a tool that is able to build a wide range of circuit topologies with their own control techniques by enabling users to gain better usage of power converters through practical remote experiments. This platform consists of a reconfigurable power electronic setup, a Web-based distance laboratory, and a user-interactive remote platform. In the same way, the development and the implementation of a virtual engineering laboratory which uses WWW for real-time interactive control of a starter/alternator have been described [5]. Indeed, by using a standard Web browser, the developed virtual laboratory allows a hybrid electric vehicle starter/alternator to be remotely and interactively operated in real time by researchers from across a country. Other interesting contributions on Web-based remote laboratories have been recently published [6]–[9].

In this paper, a complete virtual and interactive software for a Web-based remote laboratory dedicated to condition monitoring and diagnosis of ac electrical machines is presented. It is the first initiative in the field of electrical machines, and it has been dedicated to develop a common platform for condition monitoring and fault detection research areas. Indeed, since diagnostics techniques for three-phase induction machines have been developed and improved during the last 20 years [10]–[13], during the Symposium on Diagnostics for Electrical Machines, Power Electronics and Drives held in Gijon, Spain, in 1999, it has been decided to create a laboratory without "walls" inside the European Union and to dedicate it to ac electrical machine diagnostics. The main goal has been based on data exchange between setups that are available within 12 countries and almost 50 research laboratories. This virtual laboratory has

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been called Open European Laboratory on Electrical Machines (OELEM) [14]. In order to reach the objective, it has been decided by the University of Bologna in Bologna, Italy, and the University of Picardie "Jules Verne" in Amiens, France, to jointly develop a general-purpose software called OELEM-Link for Web-based remote laboratory applications [15]. The data acquisition (DAQ) software LabVIEW was chosen to develop OELEM-Link because it is one of the standards in the DAQ field. The first objective has integrated all diagnostics techniques developed in the different laboratories [16]–[21] and tested them on different electrical machines by using a simple Internet access [22]. The development and the different tests have required two years of intensive work. Some 420 virtual and subvirtual instruments have been developed in order to integrate all the general functions of OELEM-Link into a virtual space allowing users to work in a simple and interactive environment by using remote experiments on different setups.

This work is different from those presented in [10]–[13] where the main objectives are to perform the online electrical machine diagnostics without any remote access. Indeed, the online diagnostics require experimenting directly in the laboratory where the setups are available with the user presence. On the contrary, the proposed platform allows different measurements by using a simple Internet connection on any setup that is available in any laboratory from the OELEM network. Therefore, the user presence that is close to the setup is not necessary since different tests can be remotely controlled. Of course, researchers needing data without having any setup in their laboratory because of economical problems could take the advantage of any particular setup in a different laboratory by using the OELEM-Link package.

After this introduction, the second section describes the software structure and the main features such as DAQ, database, and signal processing methods related to ac electrical machine area. Then, different techniques already developed by the authors have been described. Moreover, the description of the rotor fault diagnosis for three-phase induction machines has been provided. The same section presents the remote monitoring structure, including the description of different setups used in the experiments. In the third section, some experimental results related to a case study for efficient detection of induction machine rotor broken bars have been presented.

II. Platform Principle

A. Software

The proposed software has been designed under a LabVIEW environment which gives the possibility to remotely control setups by using an Internet access. It also performs control and exchange of data files for ac electrical machine condition monitoring and diagnostics. The software has been built around several interactive windows and graphic interfaces (Fig. 1) showing guidelines to make easy the environment handling. It provides error messages in the case of problems with everything being written in English as a first step. It is a flexible structure that is able to integrate any other function or set of functions. The goal was to design a user-friendly program that is able to unify research capabilities on ac electrical machines and to make them available on common databases for networked research units. For this reason, the architecture of OELEM-Link has been developed by using the characteristics of the LabVIEW software which is a graphical program environment considered as a standard in the DAQ field. However, the proposed program is very different from other software-based solutions. Other systems have used text-based languages to create lines of code, while LabVIEW has been based on a graphical programming language. Therefore, the complete program can be visualized by sets of block diagrams. The package has extensive libraries of functions which facilitate the programming task. The main features used in the proposed program are based on DAQ, data analysis, data presentation, and data storage. Moreover, a LabVIEW program is called a VI because its behavior is almost similar to a real instrument connected to any experimental setup. The interactive user interface of a VI is called the front panel because it looks like a real physical instrument. Owing to this last characteristic, it has been possible to develop user-friendly and interactive interfaces within any VI. Each VI corresponds with one of the main functions of the OELEM-Link software. Thus, OELEM-Link has used a pyramidal architecture (Fig. 2) which allows browsing easily all VIs and consequently all corresponding interfaces.

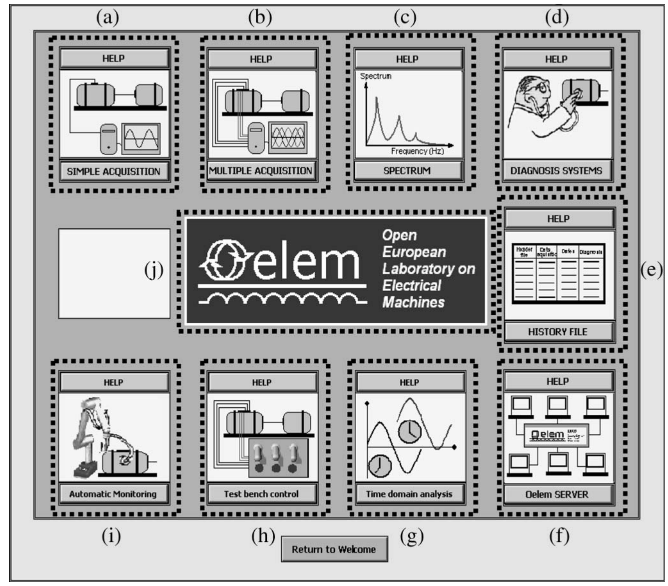


Fig. 1. OELEM-Link front panel: (a) Simple acquisition, (b) multiple acquisition, (c) spectrum computation, (d) diagnostics techniques, (e) database, (f) OELEM server, (g) time-domain analysis, (h) local setup control, and (i) automatic monitoring.

B. Hardware

The OELEM-Link software exchanges the data flow with the setup by using the DAQ board connected via an extension bus, a Universal Serial Bus port, or a wireless connection to the personal computer (PC). The analog inputs of the DAQ board are used to collect information coming from sensors implemented around the setup under test. Moreover, the digital outputs are used to control the power interface which is developed around

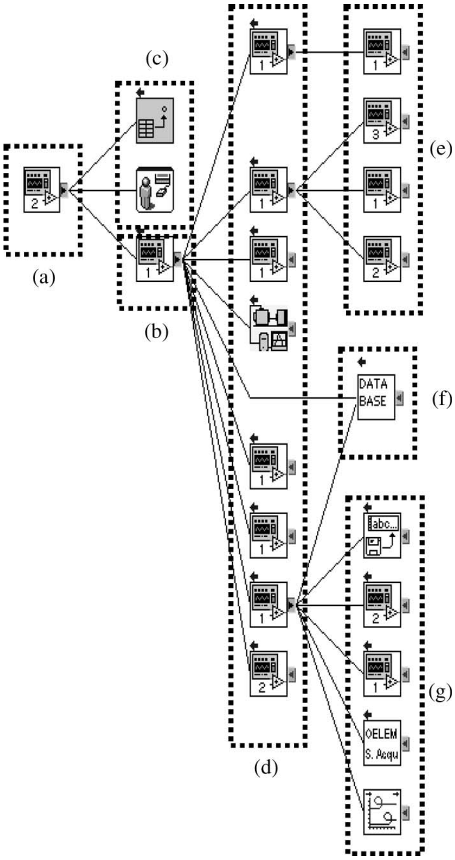


Fig. 2. OELEM-Link architecture: (a) Main program, (b) front panel program, (c) remote control and license program, (d) programs of functions described in Fig. 1, (e) subfunction programs, (f) database program, and (g) data storage and analysis programs.

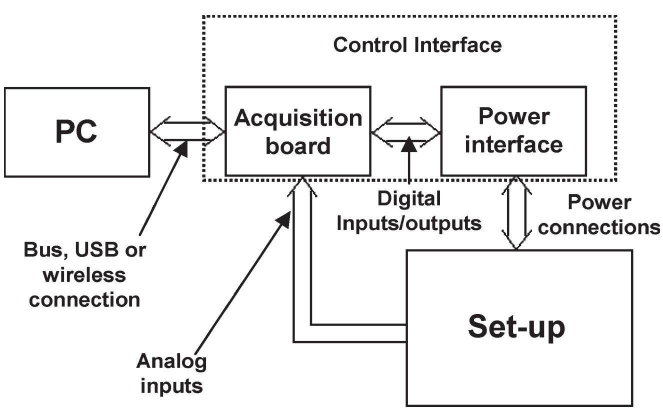


Fig. 3. Block scheme for the hardware configuration.

switchgears for the setup control such as the start-up period (ON/OFF), the load torque control, or the webcam orientation. Of course, the power interface is necessary to link the DAQ board to the setup (Fig. 3).

C. Remote Control

One of the main reasons for the development of this Web-based application is the extensive use in universities to share costly equipment between researchers. Since traditional experiments in laboratories can suffer from low usage, modern Web-based remote laboratories can remove the need to have a dedicated person to operate it. It can drastically reduce the cost by sharing the setups, and it can also be available for experiments 24 h a day during all the year. For these reasons, it has been decided to develop the OELEM-Link software with the aim to integrate a Web-based application called OELEM-Link server in order to use all features such as the DAQ, the database, and diagnostics techniques in remote mode. The OELEM-Link server has been developed under LabVIEW using the Internet toolkit. It is a mixture of different basic functions of communication technology such as the Transmission Control Protocol (TCP)/IP and the File Transfer Protocol (FTP). The following two main applications have been developed to ensure any setup control:

1) remote DAQ;
2) file exchanges.

Moreover, different laboratory setups in one site can be used by any member of the OELEM network with a secure access. Therefore, a remote laboratory can be defined as a computer-controlled site which can be accessed externally via a communication network. This remote laboratory allows researchers to experiment on setups and to test different methods for ac electrical machine condition monitoring and fault detection.

The setups are connected to DAQ boards and control computers through standard interfaces (DAQ devices, general-purpose interface bus, and serial bus) and with the host computer connected to the Internet [23]–[26]. The client can be any computer connected to the Internet but having access to the OELEM-Link with a software license. Once connected, the client has access to the same user interfaces as the local host as well as similar program capabilities. The only limitation is the data transfer rate which used to be slower in remote mode than for the local host. However, this limitation is not a strong drawback since the collected data file can be processed offline.

The OELEM-Link software uses the FTP to transfer files between OELEM-Link servers. This protocol represents a significant part of the traffic observed on the communication network. It is an optimal protocol for the exchange of these files between users. As any protocol of exchange, it consists of a server and a client. The server stands for a given port TCP, and it is in a waiting mode until clients are connected. In this way, data can be exchanged between the server and the different clients.

III. Web-Based Laboratory: A Case Study

A. Setup Configurations

In the University of Picardie "Jules Verne," three specific experimental setups have been adapted to the OELEM-Link software to be controlled by means of a simple Internet connection (Fig. 4) [27]–[29].

Any remote access application requires the installation of the OELEM-Link software setup with a user name and a password. An installation compact disk with licenses for different laboratories requesting the software has been developed. Further information will soon be available on the OELEM Web site: http://www.oelem.org.

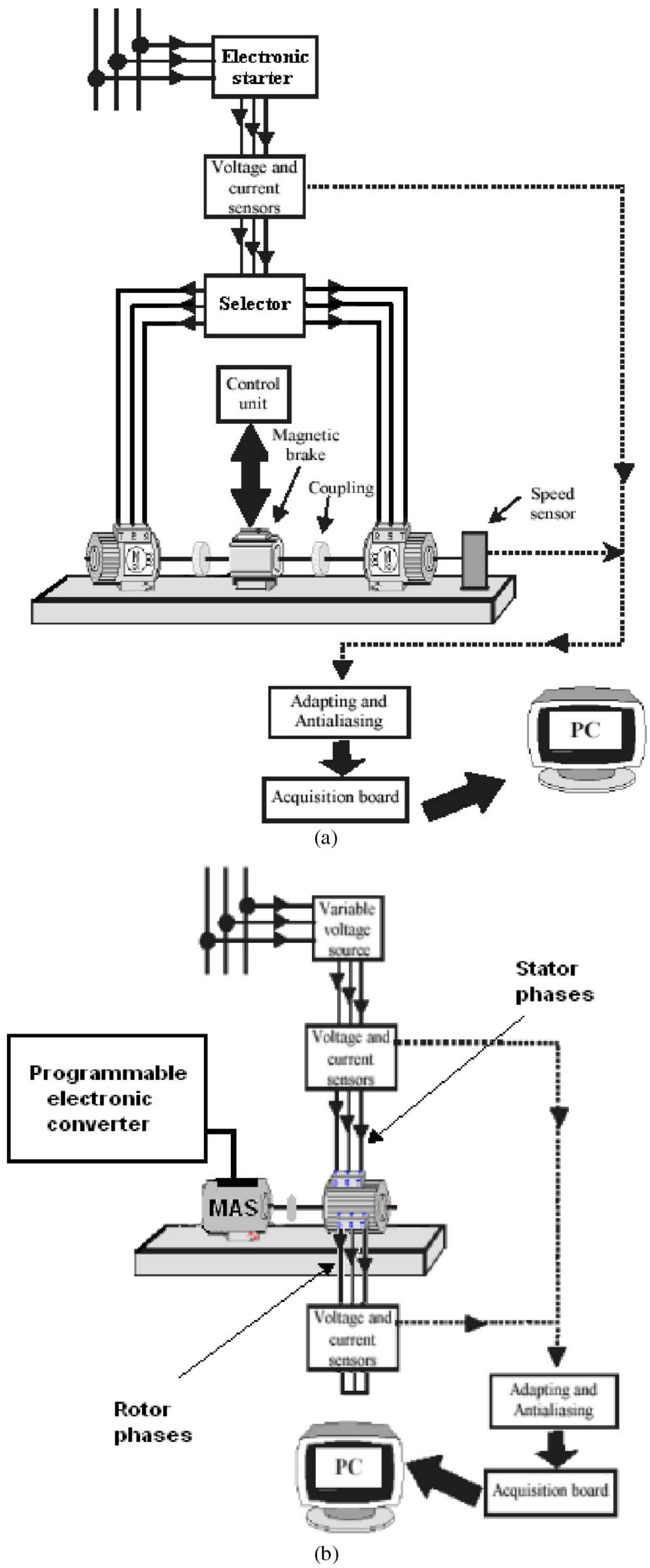


Fig. 4. Example of setup configuration schemes: (a) 18.5- and 1.2/1.8-kW units and (b) 5.5-kW unit.

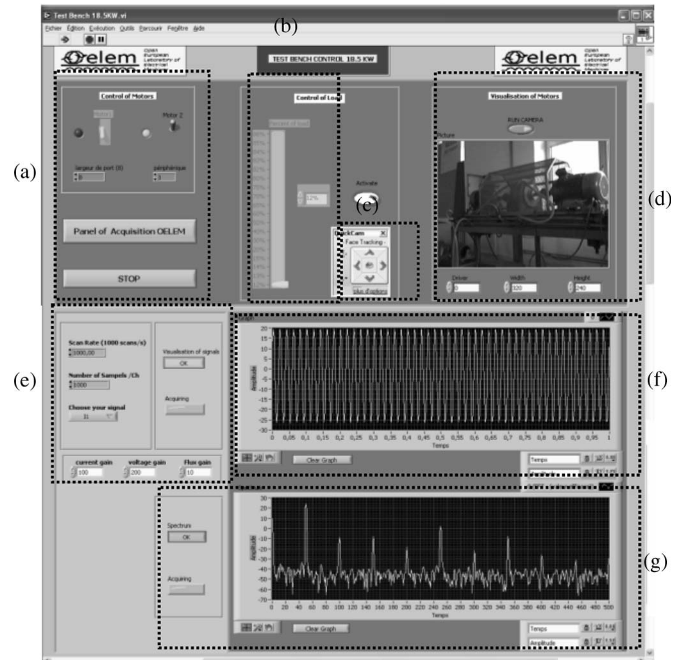


Fig. 5. 18.5-kW setup control panel: (a) Start-up period (ON/OFF), (b) load torque control, (c) webcam orientation control, (d) webcam screen, (e) acquisition parameters, (f) acquisition graph, and (g) acquisition spectrum.

The software allows each user the following:

1) access to all publications of different laboratories being members of the OELEM network;
2) access to built-in techniques for condition monitoring and fault detection in ac electrical machines;
3) possibility to save or load data files;
4) access to the OELEM database which contains all the history of acquisitions as well as all characteristics of ac electrical machines used in any laboratory member of the OELEM network;
5) exchange of data files via the OELEM server;
6) generation of data files coming from all available setups;
7) distance control of setups (ON/OFF for ac machines, load torque control, webcam orientation, selection of desired sensors, and more);
8) distance DAQ using specified parameters;
9) exchange of data files between databases using the FTP;
10) remote test of existing diagnostics techniques;
11) remote test of any new user-based diagnostics techniques.

The first two setups are built with three voltage sensors and three current sensors with galvanic insulation which are used to monitor the induction machine operation. A magnetic brake, which can be tuned by means of a programmable control unit, has been used to simulate the shaft load. Two 1.2-kW/1.8-kW 50-Hz 220-V/380-V six-/four-pole squirrel-cage three-phase induction machines are used for the first setup, and two three-phase squirrel-cage induction machines of 18.5 kW, 50 Hz, and 380 V/660 V are used for the second setup (Fig. 5). These two setups have been designed to show the effect of rotor broken bar on induction machine performances. In setup #1, the first induction machine is healthy, and it is used to define the reference spectrum. The second induction machine presents an incipient rotor bar fault. In setup #2, the first machine is healthy, and the second presents three consecutive broken rotor bars.

Setup #3 is based on a wound-rotor three-phase induction machine with four pole pairs and rated at 5.5 kW. This induction machine is driven by an electrical drive with a 7.5-kW three-phase squirrel-cage induction machine and a voltage static inverter rated at 11 kW for the emulation of the wind turbine system (Fig. 4). For the three setups, the induction machine voltages and currents are measured by means of sensors connected to machine terminals. These signals are used as inputs to the signal conditioning and the DAQ boards integrated into a PC. The current probes are built with Rogowski coils with a typical frequency bandwidth of 50 kHz. The voltage sensors are special transformers and differential probes with a frequency bandwidth of 20 kHz. The leakage flux sensor is built around an air coil with several hundreds of turns measuring a voltage that is proportional to the flux derivative with a frequency bandwidth of 50 kHz.

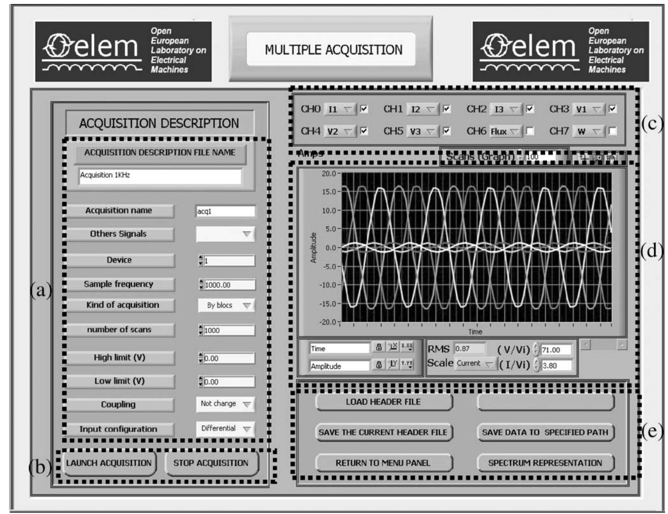


Fig. 6. Multiple-acquisition panel: (a) Acquisition parameters, (b) start and stop acquisition, (c) signal selection, (d) graph and scale for acquisition signals, and (e) control menu.

B. Web-Based Remote Laboratory Usage

Let us take the example of the University of Picardie "Jules Verne" remote laboratory, and let us try to make distance experiments to test the broken rotor bar fault detection technique. The first step is to connect to the distance OELEM-Link server via the IP address or the URL name of the University of Picardie "Jules Verne" Web-based laboratory. Once connected, the client will access to the same welcome panel as the local host. Then, by giving the user name and the password, the remote control can be authorized, and the client can choose the setup which is of interest to be controlled via a specific panel [23], [24]. The following step is to control the setup itself via a specific panel. Fig. 5 shows an example of the control panel for setup #2. It can be observed that the panel shows several modules allowing the adjustment of different parameters such as the start-up period, the stator current limitation, and the load torque control. On the other hand, the system is equipped with a module of remote visualization using a simple webcam. Then, the client will be able to visualize the setup to ensure a good remote operation and to stop the grid connection in the case of security problems. The next step is to perform the distance DAQ itself. For the proposed example, three stator currents, three stator voltages, and the leakage flux will be measured. It is very important to notice that the DAQ is the basic function of the proposed software since monitoring and fault detection are both based on data collected around the setup of interest. Some more parameters are needed to perform the DAQ such as the following: the sampling frequency, the number of samples, the used device address, the number of signals, and the type of signals (Fig. 6). In the proposed example, an acquisition related to the induction machine stator currents, voltages, and leakage flux with a sampling frequency Fs of 10 kHz and a number of samples N of 100 000 is presented. Under these conditions, the frequency resolution Δf is 0.1 Hz

$$\Delta f = \frac{Fs}{N}. \tag{1}$$

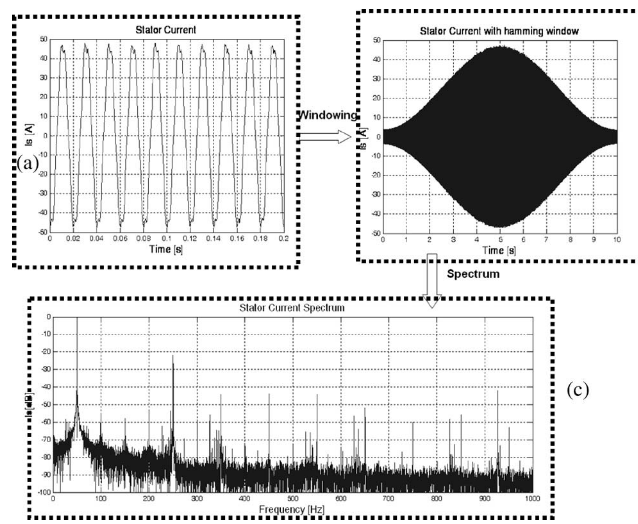


Fig. 7. Acquisition and spectrum of a stator current: (a) Zoom of the stator current in steady state, (b) stator current with a Hanning window, and (c) spectrum of the stator current in the frequency bandwidth 0–1000 Hz.

Then, the following step is the spectral analysis of all the signals. The aim of this function is to know the signal characteristics from a frequency detection point of view. In steady state, it is the most interesting function for both condition monitoring and fault detection purposes since it has been used during the last 20 years. The spectral analysis is extracting the energy spectrum from a signal to detect any signature specific to a normal usage or to know about electrical and/or mechanical faults. This function uses the classical signal processing technique related with digital data which is the computation of the spectrum by the fast Fourier transform (FFT) associated to a window function (Fig. 7).

The software proposes a specific graphical interface (Fig. 8) to make easy the signal spectral analysis. In addition, the OELEM-Link software proposes several advanced methods for digital signal processing even if not all of them have been investigated for condition monitoring and fault detection in the

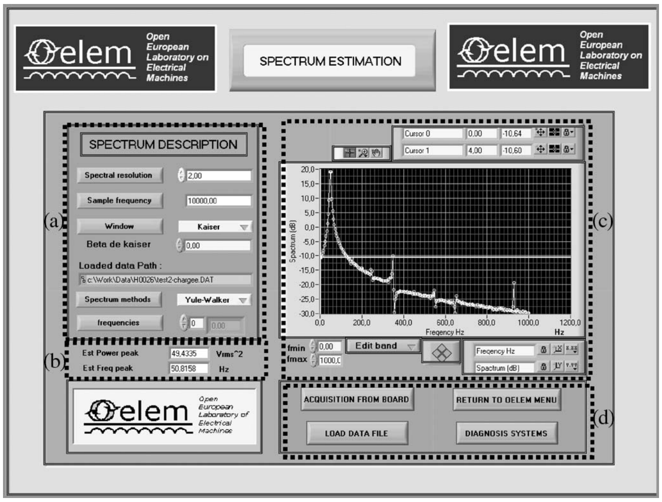


Fig. 8. Spectrum analysis panel: (a) Spectrum parameters, (b) frequency and magnitude of the fundamental, (c) graph and scale of the estimated spectrum, and (d) control menu.

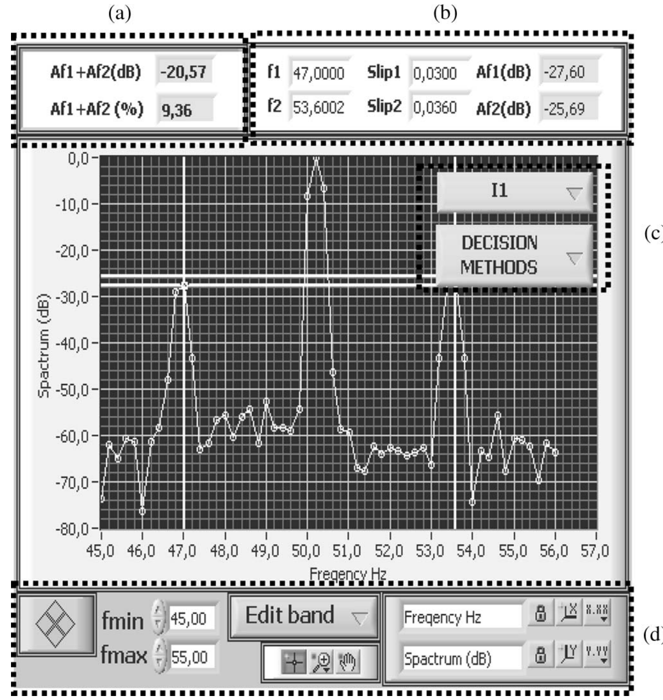


Fig. 9. Diagnosis session panel with decision method menu: (a) Index of broken bar faults, (b) frequencies and magnitudes of sideband harmonics and slip estimation, (c) choice of the signal and the diagnosis technique, and (d) scales and parameters of the graph.

field of ac electrical machines. Parametric and nonparametric methods for the estimation and the evaluation of the power spectrum are the classical options. Then, the Prony method, the MUltiple SIgnal Classification (MUSIC) algorithm, the periodogram computation, and the zoom-FFT (ZFFT) algorithm [13] have been implemented in the system as in most of advanced signal processing toolboxes. One of the most important methods used by the OELEM-Link software for the fault detection in ac electrical machines is the ZFFT. It is important to mention that the collected data could be saved in the database or they can be used immediately to perform the broken rotor bar fault detection techniques. The database makes the management, the filling, and the division of all files via a graphical interface. Its aim is of primary importance, owing to the fact that it makes possible any user to reach and load all available data in an easy, clear, and interactive way.

In the remote mode, users can test one of the classical techniques for detecting the broken rotor bar fault. Indeed, by choosing the selected diagnostics technique, the data collected in the last section are automatically loaded, and the diagnosis process can be performed. Two kinds of rotor faults can be tested in the University of Picardie “Jules Verne” Web-based laboratory: three broken rotor bars and an incipient broken rotor bar. In the following section, the two faults will be investigated.

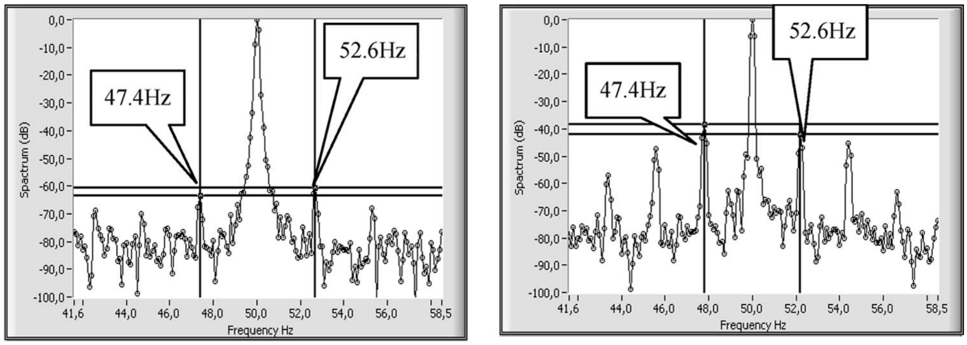
C. Distance Detection of the Three-Broken-Rotor-Bar Fault

The procedure used to diagnose the number of broken bars has been reviewed in [15] and [18], and it is a classical method for this kind of fault. References are made to three-phase induction machines supplied by a constant-frequency voltage source (i.e., the power grid) in steady-state condition considering the rotor speed ripple. This allows considering the so-called sideband frequencies $(1 \pm 2s)f_{\text{supply}}$ with s as the actual slip of the machine and f_{supply} as the grid frequency. These two frequencies are introduced by the rotor asymmetry in order to state the correlation between their magnitudes and the fault severity.

Fig. 9 shows the spectrum of one of the stator currents for a three-phase induction machine with three broken rotor bars. Any user can observe that the two sideband frequencies located at 47 and 53 Hz with relative magnitudes of -27.6 and -25.7 dB are well highlighted, as well as the grid frequency set at the reference 0 dB. These magnitudes correspond with the broken rotor bar situation. The panel contains the instruments to determine all the frequencies and their respective magnitudes used for the diagnosis session.

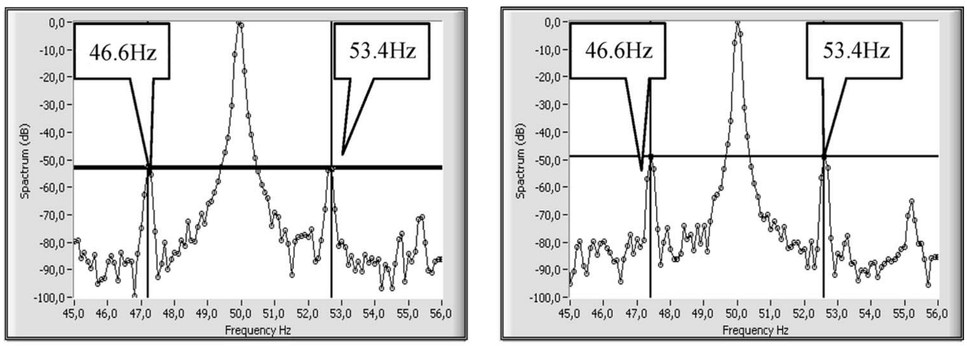
Then, the fault signatures may be evaluated manually or automatically by using the cursors in the data display block. The panel also shows the magnitudes of the sideband frequencies f_1 and f_2. The sum of the two magnitudes is expressed in per unit and in decibels to be used for the decision process.

After a first qualitative diagnosis by visual inspection, different decision methods can be selected. The most simple is based on a threshold determined by storing several sessions on the induction machine under test without any fault. All the data for which the sum of the magnitudes of the sideband frequencies f_1 and f_2 is lower than the threshold will be interpreted like data coming from a machine without fault. In this case, the panel informs the user about the diagnosis result. On the contrary, all the cases for which the indicator is higher than the threshold are considered as coming from an induction machine with rotor broken bars. This method gives a binary logic answer. To evaluate the fault severity by knowing the number of broken bars, it is necessary to use more complex methods such as simplified model-based approaches or artificial intelligence techniques. The simplified approach is well known, and many experiments have been performed to test its accuracy. This is the reason why it was implemented into the OELEM-Link software.



(a) (b)

Fig. 10. Spectrum of the leakage flux derivative (band 40–60 Hz) at rated load ($s = 0.026$) for an induction machine of 18.5 kW. (a) Healthy. (b) Faulty.



(a) (b)

Fig. 11. Spectrum of the leakage flux derivative (band 40–60 Hz) at rated load ($s = 0.034$) for an induction machine of 1.8 kW (four poles). (a) Healthy. (b) Faulty.

The same technique can be remotely applied by using the signal of the leakage flux. It is an efficient alternative to diagnose the three-phase induction machine rotor or stator faults. Instead of using the common techniques of current signature analysis in which the signals are based on stator currents, users can only take the leakage flux with just one single remote sensor. This technique is fully noninvasive because the flux sensor does not require any connection with the electrical machine under test. It allows the detection of the same faults that can be detected by using the current signature analysis. Certainly, the current signature analysis techniques are reliable for the detection of faults in any three-phase induction machine through their signatures over the stator current. However, sensing currents on an already installed electrical machine may be problematic and even not possible because new equipment has to be introduced in the electrical circuit. Sensing the flux could avoid system changes because the flux sensor can be installed outside the body of the machine, and it gives almost the same information as the current sensor. Thus, the final aim is to transfer a part of the current signature analysis knowledge to techniques that deal with the flux signature analysis. By remotely analyzing the leakage flux spectrum for this type of fault, the most sensitive frequency components correspond with the sideband frequencies around the fundamental frequency as it is the case with the stator current. In this case, the frequency components are located at 47.4 and 52.6 Hz with a magnitude of −62 dB for the healthy case, and they reach the level of −39 dB for the faulty case (Fig. 10). Then, the fault sensitivity of these frequency components is around 23 dB.

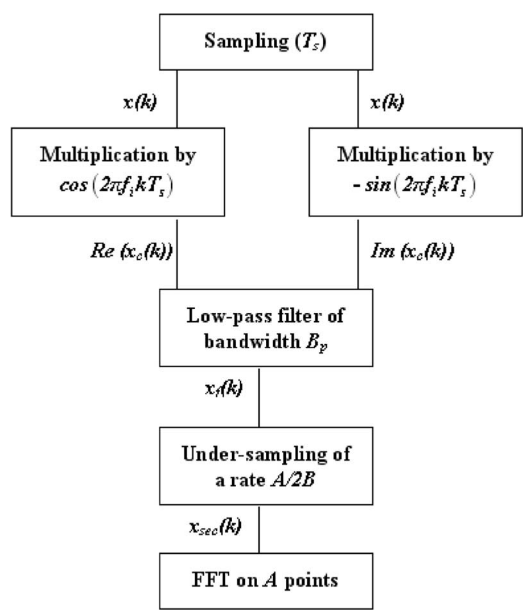
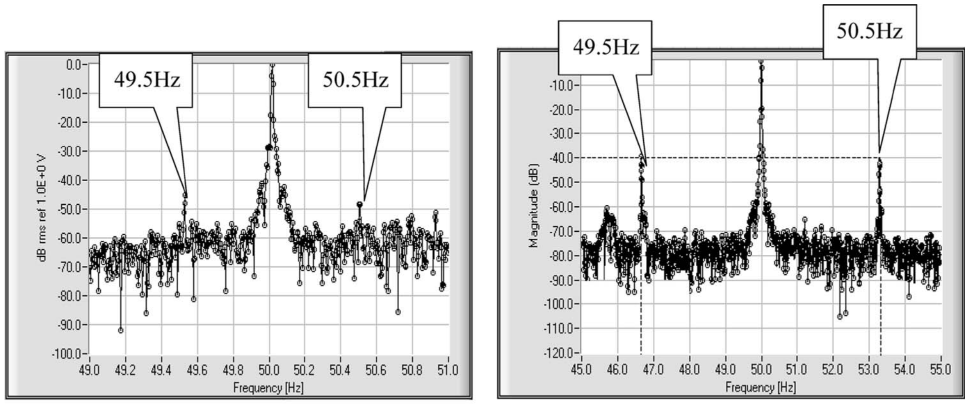


Fig. 12. ZFFT flowchart.

D. Distance Detection of an Incipient Rotor Bar Fault

In this case, users can analyze the effect of an incipient rotor bar fault (half-broken rotor bar) for the 1.2-kW/1.8-kW induction machine operating at 1450 r/min (1.8 kW, $s = 0.034$) by using the distance panel presented (Fig. 10). One more time, the user can observe that the most sensitive frequency components are the sideband frequencies around the fundamental frequency.



(a) (b)

Fig. 13. Leakage flux spectrum using the ZFFT for the healthy machine at no load ($s = 0.005$). (a) Healthy. (b) Faulty.

These frequencies are located at 46.6 and 53.4 Hz, and the fault sensitivity is 6 dB (Fig. 11).

In the case of small rotor slip values, the sideband frequencies cannot be detected by using the traditional FFT with the same number of samples which has been set to 100 000. In the case of the 1.8-kW induction machine presenting an incipient rotor fault and operating at no load, which is the worst case for the rotor fault diagnosis, users have the possibility to remotely test one of the complex methods of OELEM-Link which is the ZFFT. It is a very useful technique for zooming in a narrow frequency bandwidth before any spectral analysis. The frequency resolution of the FFT is only determined by the time interval between samples regardless of the sampling rate. At a high sampling frequency, a large number of samples have to be taken to span a large DAQ time and to achieve a given resolution. Therefore, for a high frequency resolution with a high sampling rate, where a narrow frequency bandwidth is of interest, the FFT size is inconveniently large and wasteful. Therefore, the ZFFT uses a reduction of the sampling rate to make a limited number of samples in order to increase the frequency resolution obtained from the traditional FFT. The technique is closely related to multirate filtering [13]. A narrow span centered on any frequency f_c allows a zoom around it in order to improve the frequency resolution. The frequency translation of the input signal sequence can be obtained by using a digital complex mixer. This element consists of two multipliers that give the product of the input sequence, which is a time complex unit vector with frequency f_i being the lower frequency of the frequency bandwidth of interest. From the point of view of the signal sequence spectrum, this means that, below the frequency f_i, the upper frequencies will remain positive and the lower ones become negative.

If A is the number of samples for the signal $x(k)$ and B is the number of samples in the desired frequency bandwidth, this allows sampling the signal every $A/2B$ points, and the spectral analysis is undersampled, giving the new signal. Therefore, the zoom factor C can be defined as (Fig. 12)

$$C = \frac{A}{2B}. \tag{2}$$

The users can apply the ZFFT in order to detect the sideband frequencies and to perform the fault detection. By using the diagnostics panel in remote mode, users can observe the leakage flux spectra (Fig. 13) for the induction machine operating with the slip value of 0.005 (no load) in the healthy mode and with the incipient rotor fault. Each spectrum can be obtained by using the ZFFT with the Hanning window in the frequency bandwidth 49–51 Hz where the sideband frequencies are located for this slip value and with a frequency resolution of 0.01 Hz. The sideband frequencies are at 49.5 and 50.5 Hz with the relative magnitude of -45 dB for the healthy machine and -40 dB for the faulty machine, corresponding to a sensitivity of 5 dB (Fig. 13).

To obtain the same frequency resolution with the conventional FFT for the same sampling frequency (10 kHz), it is necessary to use 1 Msamples.

IV. Conclusion

The development of the OELEM-Link software has been dedicated to the virtual platform structure fully dedicated to the remote condition monitoring and fault detection for ac electrical machines. The real contribution of this work has been the development of the platform itself by including different diagnosis techniques already developed by the authors. This development has required around two years of intensive work including tests with different laboratories to be finalized. It is important to mention that the included diagnostics techniques have not been applied online or in real time since the DAQ needs several seconds to be performed and transferred from the OELEM-Link server to the client. Of course, the platform has been developed in a research laboratory, but it could be used for education as well at its early stage. It gives the possibility to any researcher in any place to test new diagnostics techniques by using the Web-based laboratory. In this way, both comparison and objective evaluation on standard setups are recognized as a very efficient method. The remote access to sophisticated equipment is also very helpful for any research team working in the field of ac electrical machine condition monitoring and fault detection for which on-site availability could be an issue.

Since the field of diagnostics techniques for ac electrical machines is still open to research and development even within the OELEM network, it is possible to integrate very easily new computation and decision techniques without having to change all the software. An important point is that the OELEM database for ac electrical machine condition monitoring and fault detection will improve the knowledge for a large scientific community by exchanging results and experiences. It will open a very efficient way of collaboration between researchers without any border since it is based on remote experiments. The three setups already connected to the OELEM server have been operated successfully for several months with a minimal number of problems. Based on this experience, other remote experiments are under development by improving the OELEM-Link software with additive functions and interactive panels.

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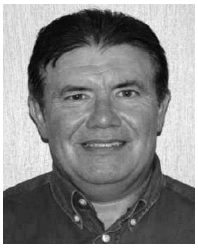

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