Teleoperation of an experimental platform of electrical machines through the Internet

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Abstract

Although access to remote equipment through the Internet is becoming an actively investigated topic, most current implementation are dedicated to specific application environments, for example, remote laboratory. A Remote laboratory offers a cost-effective and flexible means for students to shared access to physical experiments. This paper presents the implementation of a experimental platform of induction motor though the Internet account the following important features: Easy implementation based in Software, webCam for images and video capture, online Help based on IP telephony, computes to distribute the task. The developed scheme is versatile and robust, allowing the different control and observer actions remotely through the Internet.

1. Introduction

The remote access to complex (and possibly expensive) laboratory equipment and the possibility of remotely driving experiments and measurements represent appealing issues of great interest and relevance for research, educational, and industrial purposes. The range potentially involved is very large, including among others, applications in all fields of engineering [3],[17],[6].

The equipment and accessories used for electrical machines research and education are usually expensive, then they difficult the implementation and the learning of new strategies. Then, the possibility of using systems of this type for remote education become accessible to students that do not possess such laboratory equipment [16].

It is well-known that several experimental platforms are distributed in different laboratories in the word, and all of them are on-line accessible via Internet due to its versatility, since provides the user with a series of services, allowing the transmission of information in a simply way, besides being available to many people, having an interface with many multimedia resources, with easy manipulation. Currently, remote experimentation is used as an excellent alternative to offer access to equipment of high cost to teste and validate control strategies. Then, to solve the problem to test control algorithms on real-time we apply the advantages of the computer network, computer communication and teleoperation to develop new tools and given the possibility of using these equipment for research and remote education of the control theory.

Several remote laboratories offers to students an alternative to remote experimentation in: robotic [7], digital circuit [4], power electronic [13], etc. In electrical engineering some works related with electrical circuit is given [5] nevertheless exist few work related with remote experimentation of electrical machine, for example, induction motor.

On the other hand, Telecontrol platform offers an alternative to use remote laboratories, although for a long time, this technology was accessible for select persons due to the high cost of the equipment. Now, Internet technology offers the possibility to access to students and scientists of institutions that do not have such equipments. Although it is possible to use hardware or software elements to implement teleoperation platform, the software is most used because many of them are freeware and offer excellent alternatives of remote implementation.

Taking into account the above considerations, a structure of a teleoperation system for electrical machines based on freeware software and the Internet is given in this paper. More precisely, we present a telecontrol platform through the Internet for remote experimentation of electrical machines. This platform is composed of a induction motor

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connected by means of a DSpace interface in a computer, using a freeware software for the remote operation. Several computers distribute the task and giving greatest security and avoid to be used without permission. This structure uses a graphic user interface in order to introduce the commands and tuning the controllers. WebCam for image/video capture.

The remainder of this paper is organized as follows: In section 2, we introduce some important concepts with respect to telecontrol and teleoperation. Section 3 presents the available technologies in software, which are used in this paper for the teleoperation of an induction motor. Section 4 presents the teleoperation platform proposed and in section 5, we introduce the equipment used for implementing the control algorithms. In section 6, we show the advantage of using the Internet for controlling, from the Nuevo Leon University, Mexico; an induction motor located in IRCCyN laboratories from Nantes, France. Finally, some conclusions are given.

2. Some Concepts

Now, we introduce the concepts of telecontrol and teleoperation, which will be used in the sequel.

Teleoperation is defined as the continuous, remote and direct operation of a remote machine (see figure 1). With the introduction of teleoperation technology , it was possible the development of interfaces capable of providing a satisfactory interaction between man and machine. Nevertheless,the main aim of telecontrol is to extend the distance between controller and the plant. The distance has been increased with the development of the Internet (see figure 2).There exist a large number of schemes to describe teleoperation. This classification is based on the degree of automation of the system.

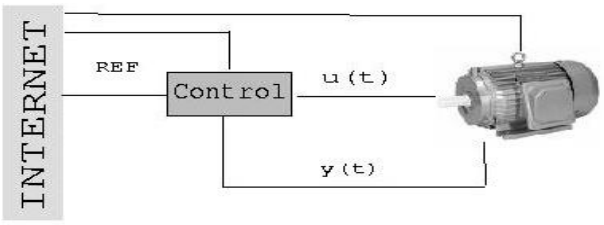

Figure 1. Teleoperation of machine schema

In the teleoperation systems via Internet the effects of the time delay and uncertainly property don't exist, because the controller and the plant are in the same layer, as shown in Figure 1.

Figure 2 shows a telecontrol system through the Internet, in which the two channels of communications are required, i.e. forward path (Ch1) and feedback path (Ch2). The problem in the telecontrol system is the network time delay in the forward and feedback paths. This delay must be less than sampling period, (see [12] - [8]). Network time delay and its uncertain property exists in the process of data-gram transfer in the Internet, which can affect the stability of telecontrol systems.

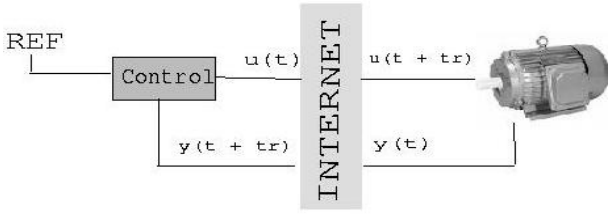

Figure 2. Telecontrol of machine schema

3 Available software technologies

The use of software as a technological way of remote communication, presents some considerable advantages with respect to the hardware, some of them are:

- A damage in the hardware represents a maintenance and cost, nevertheless a damage in the software practically is solved with the reinstalling of the program.
- Many programs used like communication resource are freeware.
- Since the use of the computer in the platform is necessary, therefore the use of the software also.
- With software it is possible to share many resources using a computer, for example: WebCams, VNC services, serial ports (RS232).
- The HTML Pages of the device servers are unalterable and simple, With software is possible to develop pleasant and interactive HTML Pages.

Several solutions have been implemented for the teleoperation of remote laboratories and equipment through the Internet. The proposed software structure is developed in order to facilitate the communication between the machine, interface, network and man. Three strategies based on software were used:

3.1. UltraVNC

VNC (Virtual Network Computer) is a graphical desktop sharing system which uses the RFB protocol to remotely

control another computer. It transmits the keyboard and mouse events from one computer to another, relaying the graphical screen updates back in the other direction, over a network. VNC is a platform-independent.

UltraVNC [11] is a freeware software that essentially ”converts” the computer into whichever computer you are connecting to. For those of you familiar with Windows Remote Desktop, UltraVNC does the same work, but allows you to connect to Unix or Linux machines. UltraVNC supports a number of advanced features making it unique among the various clients or users of VNC.

3.2. LogmeIN

LogmeIN offers a freeware VNC service, is similarly to UltraVNC, but LogmeIN offers the services in an external server (DSS), this server shares the resources between both computers, so that the concepts server/client appears on both sides.

Another difference between UltraVNC and LogmeIN is that UltraVNC needs the authorization or permission of the network administrator, and some times these are restricted or closed. LogmeIN does not require these permissions because this server works through 80 port, and usually they are ”always” opened.

3.3. Development tools

Development tools offer an excellent alternative to design software called ”Just on time”, so that it is possible to implement platforms as much for teleoperation as telecontrol. For example, in [2] presents a telecontrol platform of the same authors in telerobotic through the Internet using a development tool called Visual Basic 6.0. This platform uses the remote communication based on *winsock technologies*, which uses the TCP/IP, UDP protocol in order to send information by the network. Figure 3 shows a screenshot of the teleoperation module.

4 Teleoperation platform proposed

Because the remote experimentation of electrical machines is proposed, teleoperation platform schema and VNC software can offer an excellent solution by the reasons mentioned before.

Figure 4 shows the main elements of the teleoperation platform, where the three computers are in the server layer.

Computer A: Help on-line module. Allowing the communication established between client/server. The software used for this propose are:

- Messenger: Textual communication and the webCam (Videoconference)

Figure 3. Telerobotic module, development tools application

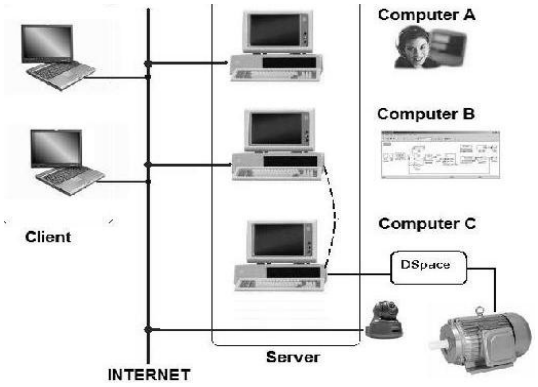

Figure 4. Teleoperation platform proposed

- Skype: Oral communication (IP Telephony).

Computer B: Software control module. Allowing the sharing of resources of the computers desktop, the main objective is to share the control software and to include the next software:

- Matlab Simulink. Software used in control and power systems.
- ControlDesk. Graphical tool to control in real-time the electrical machine.
- UltraVNC Server. VNC software
- LogmeIN. DSS software

Computer C: Machine Interface module. This computer has an interface with the data acquisition board (DAQ). This computer does not share any resources in the web, it only is shares information with the Computer B using the remote control by the software ControlDesk.

5 Experiment equipment proposed

Several laboratories of induction motors exist. In [15] introductory laboratory experiments are present to demonstrate how the experimental hardware can be integrated in induction machine for instructional laboratory. In [1] an easy procedure for cage construction of induction motors used for experimental work is given, using a three/phase wound-rotor induction machine that has been converters in a squirrel-cage machine with current measure capability on two bars.

Experiment equipment proposed can be see in the figure 5, the output parameters of the induction motor are: stator current, torque and the speed, the input parameters are: stator current and torque.

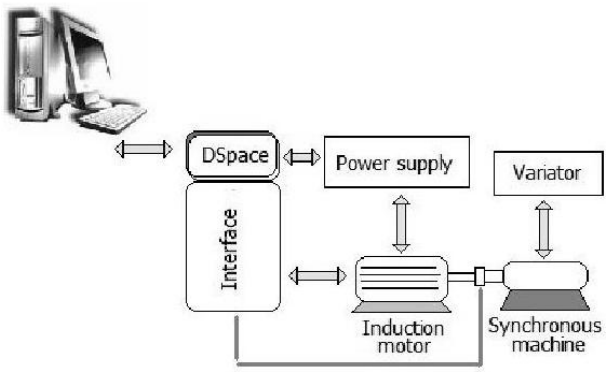

Figure 5. Equipment proposed schema

5.1. Data acquisition board (DAQ)

The DAQ allows the interchange of information between the plant's device and the computer. There are different models and characteristics of the DAQ. If a DAQ of general purpose is used, then it is important to consider some properties: a) the number of input and outputs, b) if it has analogical and/or digital signs, c) the sampling velocity, d) the software arranged for the communication with the PC.

There exists DAQ for a specific use. They are connected directly to the electromechanical device, since it is contains the necessary elements such that they don't depend on other converters. Usually, they have a manufacturer's software to use the computer as a way of communication with itself. The platform proposed uses the DSpace board DS1103 (see [9]).

5.2. DAQ Communication software

This element allows the read and interchange of information between the PC and the DAQ, which has to be considered in the selection of the DAQ. Most of these programs can realize actions of control. Some of them have graphics interfaces and of virtual instrumentation that allow the user to interact with the board in a more agreeable, friendly, easy and comprehensible form.

An important point that is necessary to consider is if the software has development tools in some language of programming and or it has the resources that allow access to dynamic libraries (DLL's) of other programs. This platform uses the ControlDesk software [9].

Figure 6 show an experimental equipment picture used to control of an induction motor using the proposed structure, which is located in IRCCyN, Nantes, France.

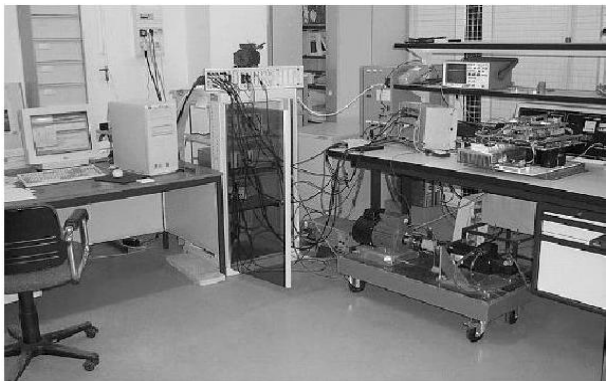

Figure 6. Experiment equipment proposed

5.3. Control software

It is important to have an application that allows the implementation of algorithms of experimentation. Simulink/Matlab offers an excellent way as software of control since it has libraries to communicate with other applications. Due to this requirements, the software selected for the communication with the DAQ interact preferably with Matlab, otherwise it will be necessary to adapt it with other must computational software . This platform is developed using Matlab/Simulink software, because several control algorithms can be easily implemented, download, modified on-line, and an important library of functions which the user can be used to design its programmed and execute them remotely.

5.4. Access remote software

One excellent option for remote access is to use some of the free programs distribute on the Internet. For example, UltraVNC is freeware and it is possible to obtain it on an official site [11], as a server customer and as a client customer. On the other hand, using the free services of the LogmeIN [14] to establish the connection through the Internet and the machine or interfaces.

6 Experimentation set-up

The methodology described in section 4 is applied to provide remote access to the set-up of electrical motor located in IRCCyN. The main components of the set-up are: an induction motor connected to a synchronous motor, inverters, a real-time controller board DSpace DS1103 and interfaces to connect all these elements. For the control of the plan (Induction Motor, inverters, load motor), the applied software are MATLAB/Simulink and ControlDesk.

The detailed structure of this remote control is shown in Figure 6. For this teleoperation, the proposed structure requires three computers and accessories in order to execute a desired control task. Each computer execute the following tasks

- **Computer A** is used for establishing the communication between clients, located in France and in Mexico via IP telephony and/or chat.
- **Computer B** is used to provide a remote communication, using the Ultra VNC server, **Computer C** is isolate and protect from intruders. On the other hand, **Computer B** sends and receives information from **Computer C**. By using the Ultra VNC service, the client controls **Computer B**, and thanks to the remote control mode of ControlDesk, the client can control **Computer C**, and hence the plant (the induction motor).
- **Computer C** transmitted to the DSpace card that communicates the desired actions to the induction motor. The resulting information is sent to **Computer B** in order to be transferred to **Computer A** under secure conditions.

For security reasons, an operator is required on site, in order to apply the inverters voltage and supervise the operation, as starting/stopping the machine.
To illustrate the user interface, the experimental results are shown in Figure 6. Figure 7 shows the screenshot and figure 8 an access sample.

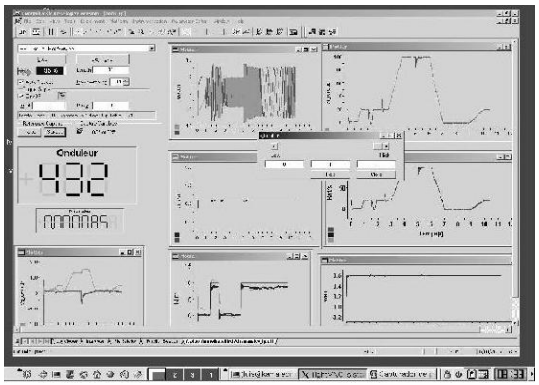

Figure 7. Remote controlDesk using UltraVNC

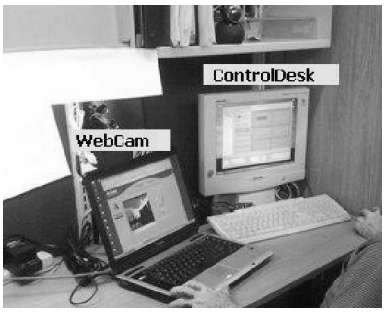

Figure 8. Remote access sample

7 Conclusions

In this paper, we have presented a platform for teleoperation allowing remote experimentation of electrical machines. This platform have been implemented and tested on an induction motor located in France which has been teleoperated from Mexico for developing new control strategies. The main characteristics of this platform are:

- Teleoperation through the Internet technologies.
- Using freeware software to remote operation.
- Using a security scheme and distributed task based on three computers.

The access to laboratories for remote experimentation is now a possible and thanks to the services provided by the Internet. Now, it is possible to have access to an experimental platform in order to make experiments and/or to validate results.

8 Acknowledge

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