

## DEVELOPMENT OF A DISTANT AC MOTOR LABORATORY

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**Abstract:** A remote induction motor bench into an industrial environment is presented in this paper. It lets a powerful way of studying new identification, control or predictive maintenance algorithms independently the place where the methods are implemented. The World-Wide-Web (WWW), as the fastest growing Internet service, is seen as an effective tool for this propose. In effect, the Web is a distributed multimedia environment, which potentially can provide this service. This paper describes the hardware and software constructs, which facilitate the experiment remotely and efficiently. *Copyright © 2002 IFAC*

**Keywords:** AC motors, fault diagnosis, remote education, World Wide Web.

### 1. INTRODUCTION

AC motors are used widely in industrial processes, and in many cases their work is critical for the right operation of the plants. This, and the improvement of the power electronics that have allowed a better control of the AC motors has made that the AC motors be used widely in the industry, replacing DC motors with a cheaper maintenance cost. This and the previous experience of the authors in the field of diagnosis of AC motors are the reasons why an AC motor bench has been chosen to implement a remote system.

The work reported in this paper is mainly concerned with the set up of a systematic control experiment on an AC motor bench which can provide real data from the motors for the different experimental conditions that the user could specify.

Distant education and remote experimental systems, with the tremendous potential in term of time and space flexibility, has much to offer to the experimental research. This is particularly true for the engineering profession where rapid advancement in technology and innovation need more efficient and flexible means of accumulating latest know-how and updated information (K.K.Tan,1997).

The WWW provides Internet users with a uniform and convenient means of accessing the wide variety of resources (pictures, text, data, video...). Popular software interfaces, such us Internet Explorer (IE) and Netscape, facilitate navigation and use of the WWW (Ertugrul,1997).

The system that has been developed may satisfy two objectives: the first is to provide an educational AC motor bench to the users in order to study and

understand the different ways of identification, control and fault diagnosis methods that are used nowadays (Patton, 1999). The second of them consists of offering to the users a remote motor bench (medium power) in an industrial environment that let them to obtain the different motor signals necessary to develop their works. Remote data stored in a file provide users enough information to make for example a motor identification. Also it's possible to study different control algorithms for the AC motors and obtain faulty data from the motor selecting the kind of fault that we want to study from a preselected list of faults.

## 2. HARDWARE AND SOFTWARE

The hardware necessary and used in the development of the distant laboratory at the serves's end, consists of a RTI real time control and acquisition card installed onto a Pentium II 450 MHz personal computer.

The acquisition card supplies 16 analog input channels (16bits), 4 analog inputs channels (12 bits), 8 analog output channels (14 bits). Besides there is a slave DSP that supplies 16 analog input channels (10 bits) and 18 digital TTL lines.

This hardware is programmed via Simulink using the standard simulink blocks and a special toolbox named RTI which includes special simulink blocks to manage input-output channels, generate PWM, manage encoders...

It is also possible to include special blocks programmed in C code to create more complex systems that are not possible to obtain with the standard blocks.

It's also included a graphical tool that let us to design a graphical interface for the different utilities that are provided.

The motor bench is composed by two AC motors of 5.5 Kw placed one in front of the other with a elastic coupling as it can be seen in the figure 1.

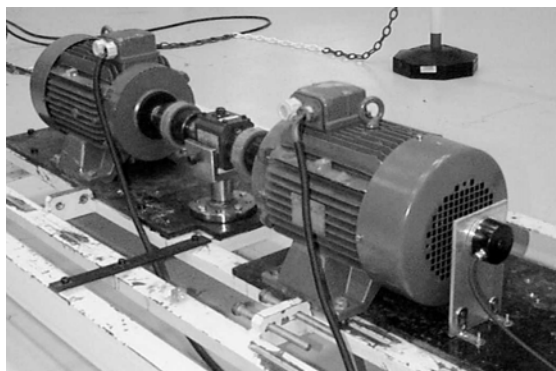


Fig. 1: Motor bench

First of motors is controlled by an educational inverter SEMIKRON that lets the user to develop the control law at each moment, selecting the thyristors shoots sequence. The second of the motors acts as the load. A commercial ABB inverter controls this motor. The load torque can be selected in the control panel of the inverter adding it a chopper card and a group of resistor that act as a lossor of the absorbed energy of the load motor that is working in the fourth quadrant (positive speed and negative torque).

The group of signals that can be obtained from the motor are supply voltages (inverter outputs), stator currents, rotor speed and load torque. These signals are obtained using the different sensors installed in the bench.

The complete scheme of the system can be seen in the figure 2.

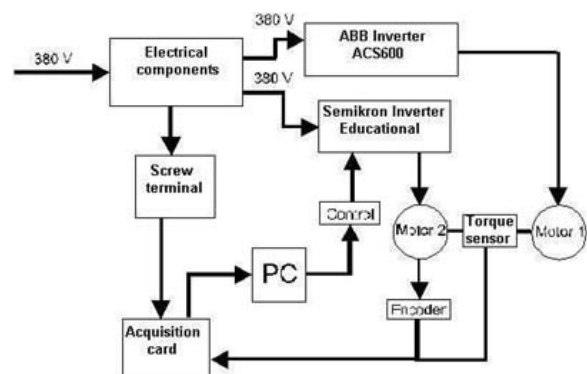


Fig. 2: Scheme of physical system

## 3. REMOTE ACCESS ARQUITECTURE

The global application has an open-oriented client/server architecture based on TCP/IP protocol. A briefly description of the modules is next.

### 3.1. Main module. The Local Server.

The primary application resides on the PC where the control is. Several control Matlab routines communicates with the Local Server through DDE protocol, given the system all the remote functionality required to run the experiments. The Server, written in LabVIEW 6i, runs independently as an executable program in parallel with Matlab.

In order to avoid communication task overheads and isolate the Control PC from the multiple possible clients, the Server only communicates with a unique Local net Client which centralizes all petitions. This means the Local Server only respond to this unique client which is responsible of managing all clients petitions. This provide a coherent and unique method to access the experiments.

Local Server accept the Local net Client petitions and translate it to Matlab functions which operates directly with the RT control board. Manage communication with the Local net client, send and store data.

### 3.2 Local net client/server.

As only through the Local net client the motor bench can be accessed, an intermediate local net server is required. This module act as a bridge between the Control PC and all the clients, supporting all the overhead tasks of data interchange, user recognition, client queue managing, etc... between main server and clients.

Multiple clients can simultaneously require data to the server, which will manage them as they reach it. Only through this server the experiments are accessible.

### 3.3 Clients.

Multiple clients has been developed allowing the system to be accessed from many platforms and sites. On-line motor bench experiments are accessible from the local net through LabVIEW and Java clients, internet access is done through a Java Server running on CARTIF's web server [www.cartif.es](http://www.cartif.es). The Java Serves act as Server to the internet client and also as a client to require data to the local net server. A Java applet running on the remote web browser acts as client to remote access to the experiments.

The web server also act as wap server, and all data – except graphic data- is available from mobile phones with wap protocol. The remote access architecture can be seen in the figure 3.

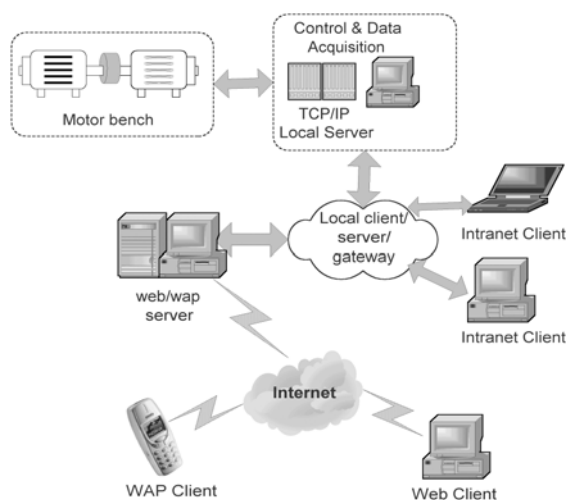


Fig. 3: Client-Server architecture scheme

## 4. APPLICATION DESCRIPTION

For accessing the on-line system it is necessary first to download a client. This is a Labview program that must be installed in the local computer and is used as user interface. The connection is transparent to the user that accesses to the system as if it were local.

The client will present the user a high variety of options to study the system and make experiments. These experiments will allow studying different ways of control, try different identification techniques or implement new diagnostic methods for the motors.

There are two types of connection for the clients: supervisor and experiment. In the supervisor mode the client can only read values from the system but in experiment mode all the parameters and references can be modified. Only one client can be connected in experiment mode, but multiple users can connect in supervisor mode at the same time.

In both type of connection the client presents the supervisory screen with the main parameters of the system and the real time values of the variables. In case of connecting in experiment mode several options are available: choose a new control, change references, simulate faults and make an experiment (figure 4).

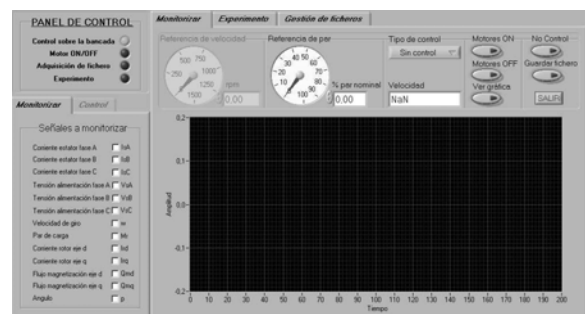


Fig. 4: Client control panel

The first parameter the user can choose is the control mode of the motor. The possibilities are no control, V/f control, vectorial control and direct torque control.

When the no control option is selected it is possible to vary the voltage and frequency of the voltage source that feed the motor in the 'Control' tab window (left of figure 4).

In case the selected option is any of the controls, the parameters to modify are the constants of the PIDs and the reference speed that is always the controlled variable. In both cases the load torque is the other reference that user can change to evaluate how the controls work in different working points.

The vectorial control has been implemented as a Pulse Width Modulation Voltage Source Inverter

(PWM VSI) using a rotor flux oriented reference frame (Vas, 1998) (figure 5). The user can modify two control loops: speed and magnetizing flux. In the first case both reference and PID can be modified as in most of commercial inverters. It is not so usual the possibility of change the flux loop PID parameters. This makes easier the understanding of the vectorial control and the influence of the flux in the control.

The Direct Torque Control is implemented monitoring source currents and voltages, so no model of the motor is needed but the stator resistor value (Vas, 1998) (figure 6). As in the vectorial control speed PID constants are accessible to the user.

This experiments can be made on line and the results are shown in real time to the user, so the differences sometimes will be not appreciated, specially the time response. That is why the application offers the possibility of designing experiments and save data for a further analysis.

When an experiment is designed the user can select the variables to acquire (current, voltage, torque, references...), the sampling frequency and the time of experiment. The type of control and its parameters can be selected as it was explained before, and the user defines the input variables with a signal designer that allows constructing the desired input signals. The options for these are constant values, ramps and pulse train that can be combined in consecutive intervals to generate complex signals (figure 7). The application checks in automatic mode if the request is physically possible.

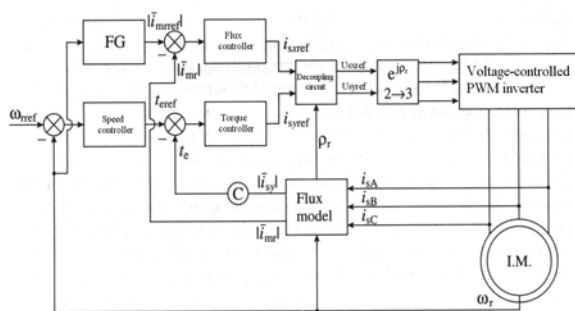


Fig. 5: Vectorial control scheme

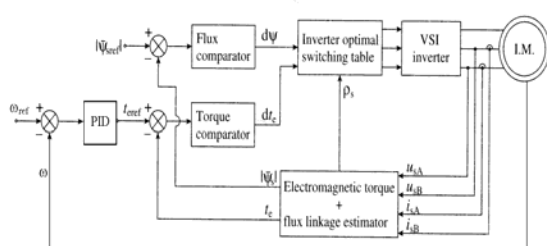


Fig. 6: Direct Torque Control scheme

The possibility of varying the inputs allows not only a detailed study of each of the control types but the design of identification experiments to study different identification techniques off line with the acquired data (Ljung, 1999). This acquired data is stored in Matlab format, and must be downloaded via ftp because in long time experiments the files are too large to be sent during the experimentation.

The application can be used in the field of the fault diagnosis selecting different faults to be simulated in the system. This can be made on line or off line via data acquisition. In the second case when the experiment is being designed the user besides the input signals can decide the faults to simulate, the time when they occur and if they are abrupt or evolutive (Gertler, 1998).

In the application is programmed a fault diagnosis system based in parity equations and neural network, but the experiments could be executed with another diagnosis system implemented like a Matlab S-function in C code. (Aranz et al., 2000; Pacheco et al., 2001).

A WAP client has been implemented with limited options focused in the supervision of the system and the start and stop of the motor bench.

## 5. CONCLUSIONS

Distant education is evolving to play a more significant role since its inception in the last century. It has been driven by the need of life-long learning, especially for engineering professionals. In research and industry, remote access also represents an opportunity for the scientists and engineers who wish to share unique and expensive equipment.

It has been obtained an educational remote system that allows users to obtain data from a squirrel cage AC motor. Users can also design their own experiments like identification, control or fault diagnosis methods.

Numero	Tipo	Duración (s)	Parámetros
1	Constante	1	Valor = 1400
2	Constante	0.5	Valor = 1400
3	Rampa	1	Pendiente = -100

Numero	Tipo	Tiempo inicio (s)	Error (%)
1	Sensor Corriente Fase S	1	100

Fig. 7: Experiment configuration screen

This motor bench is in C.A.R.T.I.F. that it's a Technological Centre placed in Valladolid (Spain). Remote access can be made from CARTIF web site.

This application is a good example about communication technologies with remote access via WAP and web.

#### ACKNOWLEDGEMENTS

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