Wireless Control for an Induction Motor

Benmabrouk. Zaineb, Ben Hamed. Mouna, Lassaad. Sbita

Abstract—This paper discusses the development of wireless structure control of an induction motor scalar drives. This was realised up on the wireless WiFi networks. This strategy of control is ensured by the use of Wireless ad hoc networks and a virtual network interface based on VNC which is used to make possible to take the remote control of a PC connected on a wireless Ethernet network. Verification of the proposed strategy of control is provided by experimental realistic tests on scalar controlled induction motor drives. The experimental results of the implementations with their analysis are detailed.

Keywords—Digital drives, Induction motor, Remote control, Virtual Network Computing VNC, Wireless Local Area Network WiFi.

I. INTRODUCTION

USING wireless technologies in industrial and factory automation is very attractive for many reasons.
The wireless way of communicating makes plant setup and modification easier, cheaper, and more flexible. It provides a natural approach towards communication with mobile equipment where wires are in constant danger of breaking. It enables new applications where wireless transmission is the only option, e.g., measurements and control of rotating or highly mobile devices, and provides a novel approach to existing applications, e.g., localization and tracking of goods. Furthermore, tasks like machine diagnosis and maintenance can be greatly simplified by equipping the maintenance personnel with wireless terminals.

In many factory and automation applications, the communication needs are traditionally served by wired technologies. These communication systems have been specifically designed to meet the stringent real-time and reliability requirements found in many industrial applications. Of course, wireless technologies should ideally provide the same type and quality of services to industrial users as the traditional, wired technologies do [10]. However, wireless technologies differ in a number of ways from wired ones. These differences present significant challenges for the design of network architectures, protocols, and tools for industrial and automation applications [1]–[2]–[3].

This paper describes our experiences combining wireless technologies the IEEE 802.11 family of standards and virtual network interface based on VNC (Virtual Network Computing), in order to achieve real-time control over an induction motor using a wireless data network ad-hoc. Wireless Control of an Induction Motor can be applied to carry out control and monitoring in different environments, such as dangerous environments.

II. COMPARISON OF WIRELESS SYSTEMS

At first, we examined three different systems. All three systems have been designed for use in different scenarios, thus offering various advantages and disadvantages over one another depending on their use. The 802.11 systems are suitable for transmitting large amounts of data. IEEE 802.15.4 is suitable when communication is infrequent, small packet sizes are used, and power consumption is an issue. Bluetooth fills the gap between these two by being able to transmit at medium data rates with a lower power consumption than IEEE 802.11[4] (see also Table I).

TABLE I
COMPARISON OF BLUETOOTH, IEEE 802.15.4 AND IEEE 802.11 TECHNOLOGIES

Protocols	Zigbee	Bluetooth	WiFi
IEEE	802.15.4	802.15.1	802.11a/b/g
Power consumption	very low	low	medium
Number of nodes	65 000+	7	32
Throughput max	250 Kb/s	1 Mb/s	11-54 Mb/s
Range	100m	10m	300m

Today, an IEEE 802.11 device is installed in many personal computers. It is very popular, known, available and easy to deploy. It is designed to provide users with high data rates (tens of Mbit/s) over ranges of tens to hundreds of meters. Bluetooth and IEEE 802.15.4 are designed to provide user with data rates in the order of hundreds of Kbit/s to a few Mbit/s and have ranges on the order of a few meters. To develop control of wireless Networked systems using personal computers, 802.11 wireless networks is most effective for this application.

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802.11 wireless networks operate in one of two modes: ad hoc or infrastructure. The IEEE standard defines the ad hoc mode as independent basic service set (IBSS) and the infrastructure mode as basic service set (BSS). In the remainder of this section, we explain the differences between the two modes and how they operate. In ad hoc mode, each client communicates with the other clients within the network.

Ad hoc mode is designed so that only clients within transmission range of each other (within the same cell) can communicate. If a client in an ad hoc network wishes to communicate outside of the cell, a member of the cell must operate as a gateway and perform routing.

In infrastructure mode, each client sends all of its communication to a central station or access point (AP). The access point acts as an Ethernet bridge and forwards the communications onto the appropriate network: either wired or wireless [5].

III. VNC VIRTUAL NETWORK COMPUTING

VNC (an abbreviation for Virtual Network Computing) is a great client/server software package allowing remote network access to graphical desktops. With VNC, you can access your machine from everywhere provided that your machine is connected to the Internet and you can see the desktop of a remote machine and control it with your local mouse and keyboard, just like you would do it sitting in the front of that computer. VNC is remote control software which allows you to view and fully interact with one computer desktop (the "VNC server") using a simple program (the "VNC viewer") on another computer desktop anywhere on the Internet. There has been much work on improving the performance and utility of VNC [6]–[7].

A very common business application of VNC is in remote system administration, where it is used to allow administrators to take control of employee machines to diagnose and fix problems, or to access and administer server machines without making a trip to the console [7]. VNC is in widespread active use by many millions throughout industry [8]–[9], academia and privately. VNC is widely used in educational contexts, for example to allow a distributed group of students simultaneously to view a computer screen being manipulated by an instructor, or to allow the instructor to take control of the students' computers to provide assistance.

There are several versions to choose from; including a free version and some substantially enhanced commercial versions.

Fig. 1 Networks with Virtual Network Computing

IV. DESIGN OF WIRELESS NETWORK WIFI FOR THE CONTROL OF AN INDUCTION MOTOR

A. Software architecture

Selected software architecture makes it possible to propose the interest of remote control for the user. The software tools used can be classified in two categories:
- Network software which makes it possible to the user to supervise and to manage the access to the distant process.
- Software dedicated to control.

1) The network software: The network software has a quite particular role. The VNC, which is free with the remote loading and makes it possible to take the remote control of a PC connected on a wireless Ethernet network and Internet. The control is carried out via IP address of the machine to direct.

For the installation, it is necessary to install VNC server on the station which we wish to take control (PC related to the process) and it is enough to carry out VNC Viewer on any PC with address IP and the password of connection of the station server.

The computer "viewer" is the computer which will view and to take the hand on the host computer server. The computer "server" is that which will be seen by the "viewer".

2) The software of control: The software of control is of two types:
- The software of control necessary to each operator in order to validate work in simulation and to prepare experimental work.
- The software of control necessary to operation real time of the process to be controlled.

This software rests on the core of Matlab calculation developed and distributed by the company Math Works.
The Simulink tool is used to conceive and simulate continuous or discrete systems.

On the level of the station server associated the process, two limp with tools associated with Matlab are necessary:
- Real Time Workshop which converts a Simulink model, codes C-ANSI of them.

-Real-Time Windows Target which carries out in real time of the Simulink models by managing input-outputs.

The software of control is installed in the station sever associated with the induction motor scalar control strategy illustrated in figure 2. The station server is used in order to manage the entries and the exits of the process to be controlled. The charts of acquisitions give access the entries and analogical exits of the system in a way to order it digitally.
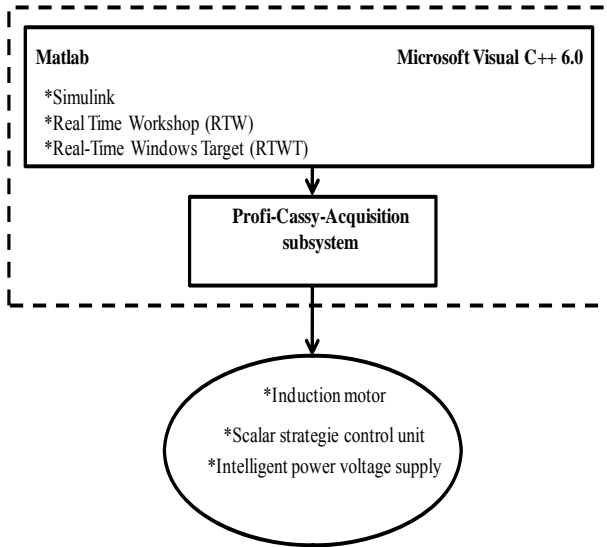
Fig. 2 The control device of an induction motor

B. The control of the induction motor

This paper is about the development of remote structure control of an induction motor using the wireless Network. The structure presents a client/server architecture aimed to ease communication between control station and server station connected to the process. The strategy to assume the control of the induction motor is the scalar control using the PI controllers. The block diagram of the control design is shown in Figure 3.
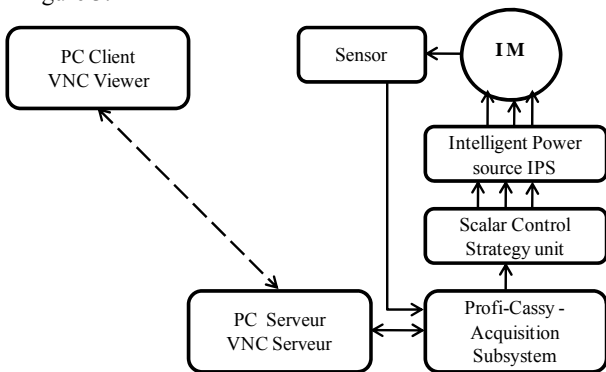
Fig. 3 Block diagram of the control design

Scalar control induction motor

Scalar control strategy is designed based on the steady state operation. Based on the mathematical equations governing electrical dynamic of an induction motor in a synchronous rotating frame in the steady state [11]-[12], we obtain:

$$v_{ds} = r_s i_{ds} - \omega_s \Phi_{qs} \tag{1}$$

$$v_{qs} = r_s i_{qs} - \omega_s \Phi_{ds} \tag{2}$$

$$v_{dr} = r_r i_{dr} - (\omega_s - \omega)\Phi_{qr} \tag{3}$$

$$v_{qr} = r_r i_{qr} + (\omega_s - \omega)\Phi_{dr} \tag{4}$$

The d and q axis can be referred in a space vector if they are respectively placed at real and imaginary axis. Hence,

$$v_s = v_{ds} + jv_{qs} \tag{5}$$

$$i_s = i_{ds} + ji_{qs} \tag{6}$$

$$i_r = i_{dr} + ji_{qr} \tag{7}$$

$$\Phi_s = \Phi_{ds} + j\Phi_{qs} \tag{8}$$

$$\Phi_r = \Phi_{dr} + j\Phi_{qr} \tag{9}$$

Employing (1) and (2) in (5) yields:

$$v_s = r_s i_s + j\omega_s \Phi_s \tag{10}$$

Similarly, the rotor voltage is defined as:

$$v_r = r_r i_r + j\omega_r \Phi_r \tag{11}$$

The stator and rotor flux are:

$$\Phi_{ds} = L_s i_{ds} + Mi_{dr} \tag{12}$$

$$\Phi_{qs} = L_s i_{qs} + Mi_{qr} \tag{13}$$

$$\Phi_{dr} = L_r i_{dr} + Mi_{ds} \tag{14}$$

$$\Phi_{qr} = L_r i_{qr} + Mi_{qs} \tag{15}$$

Based on the equation system and equations (5)-(8), the stator and rotor flux in vector space are defined by:

$$\Phi_s = L_s i_s + Mi_r \tag{16}$$

$$\Phi_r = L_r i_r + Mi_s \tag{17}$$

By replacing the flux with their expressions, (10) and (11) become:

$$v_s = r_s i_s + j\omega_s \left[L_s i_s + Mi_r \right] \tag{18}$$

$$0 = r_r i_r + j\omega_r \left[L_r i_r + Mi_s \right] \tag{19}$$

In what follows, we use the well known equivalent single phase model transformed to the stator where we consider the magnetic leakages are totalized and grouped in the rotor and designed by $N_e \omega_s$ [12]. Figure 4 shows this model.
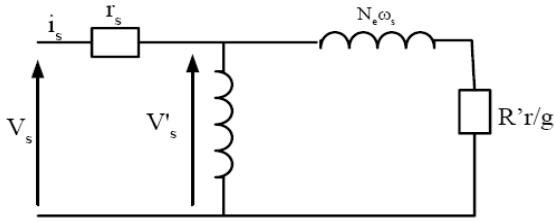
Fig. 4 Block diagram of the equivalent monophase of the induction motor model

Where $R_r^{'}$ and N_e represent respectively the rotor resistance and total leakage inductance located in the rotor.

The evolution of the stator synchronous field round the rotor produces an electromagnetic power which will be transmitted to the rotor at synchronous speed. The electromagnetic power is defined as:

$$P_{em} = T_{em}\Omega_s = 3\frac{R_r^{'}}{g}\frac{V_s^2}{(\frac{R_r^{'}}{g})^2+(N_e\omega_s)^2} \qquad (20)$$

By assumption, we neglect the stator resistance and we obtain:

$$T_{em} = 6\pi\Phi_s^2\frac{\frac{R_r^{'}}{f_r}}{(\frac{R_r^{'}}{f_r})^2+(N_e2\pi)^2} \qquad (21)$$

where f_r is the slip frequency.

The scalar induction motor model is represented by a first order system [12]-[13]. For the control of this system model, a PI controllers is used. By fixing the desired closed loop dynamic, we find the appropriate parameters of the PI controllers.

The scalar induction motor model is:

$$G_m(s) = \frac{k}{1+\tau s} \qquad (22)$$

Where k= 0.3478 and τ= 0.5184.
τ is the time constant and k is the static gain of the system.
The desired closed loop dynamic is:

$$F(s) = \frac{1}{1+0.259s} \qquad (23)$$

The PI controllers:

$$C(s) = \frac{F(s)}{G_m(s)(1-(F(s)))} \qquad (24)$$

$$C(s) = k_p + \frac{1}{\tau_i s} \qquad (25)$$

Where k_p= 5.720 and τ_i= 0.0899.

C. Experimental results

After the synthesis and the validation of the control law carried out in simulation using Simulink diagram and the validation of the control in experimentation, we carry out the scalar control of the induction motor based on a PI all using the wireless network WiFi. The experimental setup is shown in figure 5. It consists of appropriate hardware and its software implemented through a processor based digital controller.

The first stage consists to connect the station server with the Profi-cassy-Acquisition subsystem.
The second stage is the application of the remote control of the post office model by the starting of VNC Viewer in the second post office customer.

Induction motor drives are unsured in reversal speeds. The speed of the rotor follows the target; as shown in fig 6. If we move away from the station server by a well determined distance or there are obstacles for example wall then the motor remains moving in a desired drive.
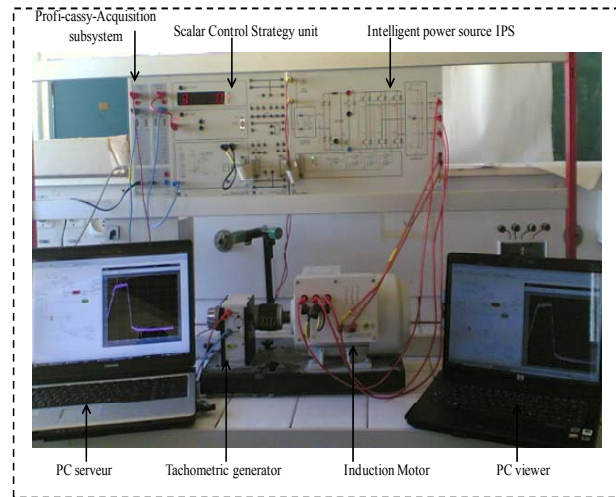

Fig. 5 A photo of the experimental set up

The reversal speed response of the induction motor is shown in figure 6. The speed tracks precisely the reference values of speed targets. The speed error which is obtained as the difference between the desired input signal and the actual system output that tends towards zero. The figure 7 shows the control signal.
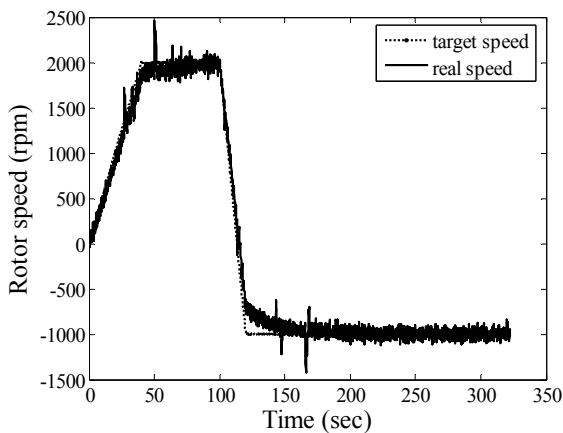
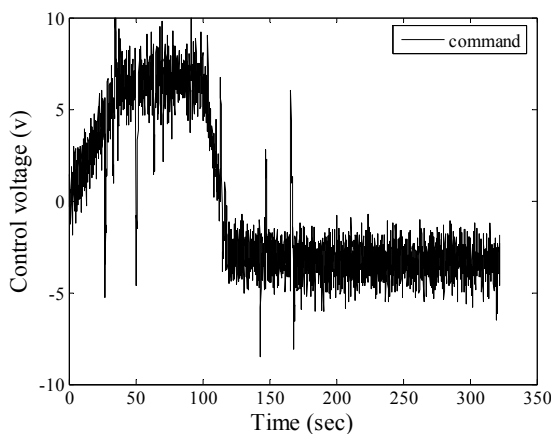Fig. 6 Evolution of the target and real speeds at reversal speed operation

Fig. 7 Evolution of the control voltage at reversal speed operation

V. CONCLUSION

In this paper, we studied the various types of the networks in order to choose the most adequate protocol for the application of a remote control of an induction motor drives. We presented the operating mode of network WiFi as well as the technical solution to carry out the wireless control of an induction motor. In this research, the focus is on the portability, reliability, flexibility and robustness while using wireless connectivity in the control of induction motor but the wireless network has disadvantages for example the delay and the losses of the data. In this context, it is necessary to develop control and diagnosis of wireless networked control systems. This will be the subject of further studies.

APPENDIX

Induction motor parameters:

Power	P_{rat}=1 Kw
Nominal voltage	U_{rat}=220/380 V
Frequency	f_{rat}=50 Hz
Stator resistance	R_s=2.3 Ω
Rotor resistance	R_r=1.5 Ω
Stator induction	L_s=261 mH
Rotor induction	L_r=261 mH
Number of pair pole	n_p=2
Inertia moment	J=0.0076 Kgm^2
Friction factor	f=0.0007 N.m.s/rad

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