Design and Implementation of Real Time Monitoring and Control System for Distributed Robotic Systems Supported with IOS/Android Application

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Abstract: In this study, a real time monitoring and control of the working parameters of distributed robotic systems used in manufacturing processes is presented. Additionally, a fault diagnosis and protection system is developed in the control and monitoring system to prevent possible errors during the working process. Unlike the conventional monitoring and control systems, Android/IOS based smart phones and tablets are used besides SCADA and the process is supported by cameras. 3 different robotic systems are used in the study and electrical, electronic and mechanical prototypes are designed for each of them. Thus, a complete robotic system being able to perform real time monitoring and control for industrial manufacturing processes that is supported by smart phone applications and fault diagnosis and protection system is developed successfully.

Keywords: distributed robotic systems; monitoring and control; PLC; robot arm

1 INTRODUCTION

The industrial manufacturing can be described as a process consisting of several procedures. Those procedures are monitored and controlled with various techniques. The real time monitoring and control of those procedures which work as distributed systems is an important fact. Technological developments provide the opportunity for real time monitoring and control of industrial manufacturing processes [1, 2]. One of the important parts of manufacturing processes is robotic systems which are developed with the combination of mechanical and electrical systems. Robotic systems consist of various mechanical designs. Using electrical motors is the common feature for any robotic system. Advanced motor control systems are generally based on motor drivers so that the motors are controlled by changing the driver parameters. An efficient manufacturing process is possible with the monitoring and control of the driver parameters which also provides the opportunity to predict any possible error during the operation.

The need to reduce the human factor during manufacturing processes brings the requirement for remote monitoring and control systems [1]. Various techniques are applied for monitoring and control of robotic systems [3-8]. The main purpose of those techniques is to obtain fast, reliable and efficient manufacturing processes. For this reason, conventional monitoring and control techniques are substituted by modern and smart systems [9, 10]. There are several studies in the literature that investigate modern monitoring and control systems [11-15]. Those studies generally focus on the monitoring and control of a single system. However, a manufacturing process of a product consists of many procedures. For this reason, monitoring and control of all the procedures at the same time is an important fact for the process to be completed successfully.

The robotic systems are widely used especially for the distributed work spaces in ceramic manufacturing factories. There are different types of motors such as step motors, servo motors and asynchronous motors that are used in robotic systems. There ought to be a real time monitoring and control system for those motors. That is important for the efficiency of the manufacturing process.

The aim of this study is to develop real time monitoring and control of robotic systems used in manufacturing processes. The developed system can perform monitoring and control for a distributed robotic system at the same time. The studies regarding this issue only focus on the design of the monitoring system. Those systems are generally performed by monitoring the parameters in CPU or using camera systems. In such systems, there is no possibility to intervene in the system in the situation of fault detection. This study includes both manual and automatic fault detection and protection system besides the monitoring of the whole system. Another important part of the study is the use of IOS/Android application to monitor and control the process.

This study consists of three main parts. First part focuses on the hardware configurations regarding the robotic systems, second part contains the developed software and in the third part, IOS/Android applications are presented.

2 SYSTEM ARCHITECTURE
2.1 Development of Axis Control

In a typical servo system, drivers take the inputs (velocity, position, direction etc.) to control the motors. Inputs are obtained from the controllers. According to the working situation, there are various feedback signals for the controllers to process and generate the necessary signals [16, 17]. This procedure needs to be done in a very short time. For this reason, the speed of the communication between the controllers, drivers and user interface systems is an important fact.

In this study, SCADA and Smart Phone are used for the user control while PLC (Programmable Logic Controller) is used as the controller. To increase the speed of the communication between PLC and SCADA, an open domain web named Device-Net is used. Besides its fast communication speed at short distances, Device-Net protocol is preferred also for its low cost of maintenance

because of the less amount of cable usage. Additionally, it is suitable with many devices that are used in industrial applications. The functional diagram of the axis monitoring and control system is presented in Fig. 1.
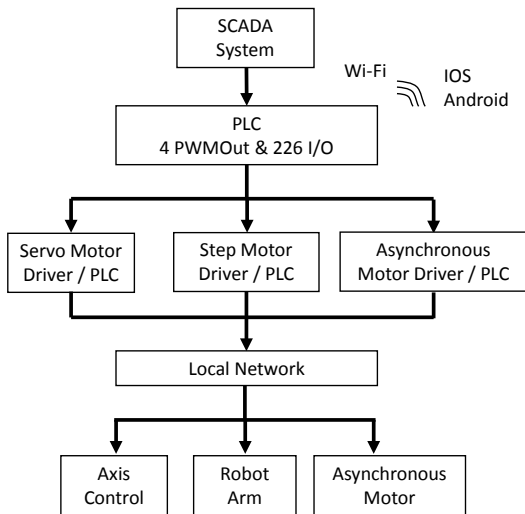

Figure 1 Functional diagram of monitoring and control

In this study, an Omron CX-Programmer is used for the programming of the Omron CJ2M-CPU31 PLC that consists of 16 digital input and 32 digital output. That PLC gathers the data from the SCADA through Device-Net protocol and sends the proper signal to the data bus to activate the axis control accordingly. Lastly, the signal is transmitted to the servo drivers (Omron R88D-KT04H) and servomotors (Omron K40030H). The data acquisition is provided by a USB port connection. The servomotor control process can be seen in Fig. 2.
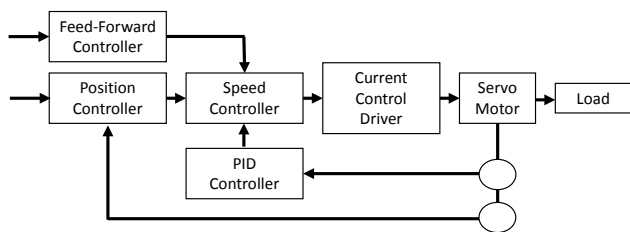

Figure 2 Servomotor control block diagram

Figure 3 Robot arm prototype

2.2 Robot Arm Design and Control Unit
2.2.1 Robot Arm Design

A six degrees of freedom robot arm is designed and built as a prototype. The joints are connected to each other by using a belt-wheel system. There are reduction gears at the joints that have high couples. The sketching of the parts is done via AutoCad. Fig. 3 shows the prototype of the robot arm.

2.2.2 Robot Arm Control Unit

In recent years, traditional systems have been substituted by servo motors and step motors due to their programmability and sensitivity [18]. For small systems that do not require high torques and speeds, step motors are preferred for their easy controllability and low cost. The method is the same as the one shown in Fig. 1.

The control system consists of three main components such as (i) PLC (the same model that is used in axial control), (ii) step motor and driver circuit and (iii) SCADA and smart phone software.

PLC is a control system that has input and output units and user interface that provide remote controlling of industrial automation systems [16, 19-25].

2.3 Asynchronous Motor

Alternating current asynchronous motors are multi variable, strong couple, nonlinear and time varying systems [26]. Therefore, asynchronous motors are the most common motor types used in industrial applications [27]. In this study, a PLC, a 3 phase asynchronous motor and a frequency converter are used. Fig. 4 shows the block diagram of the system.
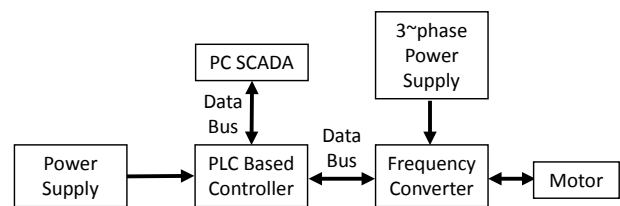

Figure 4 Block diagram of the asynchronous motor control system

The same PLC from the robot arm control system is used. The specifications of the PLC can be found in the previous section.

The 3 phase asynchronous motor has a star connection, 3.6 A of rated current, 380 V of input voltage and 3000 rpm rotation capacity.

The frequency converter type is A4022EE from speed controller series of Omron 3G3RX. It has a frequency range of 0-400 Hz.

3 SOFTWARE METHODOLOGY FOR MONITORING, CONTROL AND PROTECTION

In this section, the software units and flow diagrams used in the development of computer interface for the control, monitoring and protection with the data acquisition between the hardware system components are described. Several facts such as fast and reliable data transfer, ability to present data as graphs and flexible memory and monitoring are taken into account for the selection of software units. The flow diagram for monitoring, control and protection system is presented in Fig. 5. As seen in the figure, the optimum parameters are compared with the system parameters to obtain an automatic protection system.
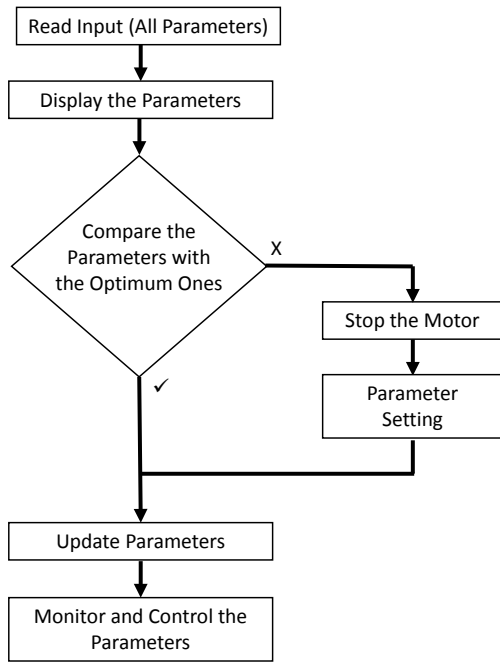
Figure 5 Protection, control and monitoring algorithm

3.1 PLC Software

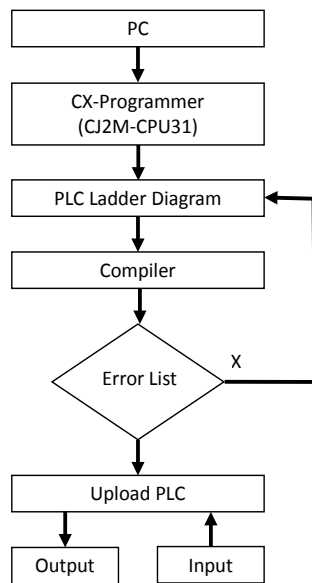The PLC model used in the system is controlled with CX-Programmer. Fig. 6 shows the software algorithm.

Figure 6 Block diagram of the PLC software algorithm

According to Fig. 6, the ladder diagram which is developed via CX-Programmer is loaded to the disc during the PLC programming. The loaded program is compiled later. If there is an error in the program code during the operation, a file named "ERR" is generated. Otherwise, the program code is uploaded to the PLC via USB port.

There are three different algorithms developed inside the PLC. The I/O systems that are digitally programmed inside the PLC activate the desired algorithm according to the independent working requirement. Thus, the units can operate independently.

3.2 SCADA Software

SCADA (Supervisory Control and Data Acquisition) is a data acquisition and observation system [28]. Omron CX-Supervisor is used to develop the SCADA software. 3 different interface screens are constituted based on the prototype model. Monitoring, control and protection fields are integrated to the interface screen through the SCADA software. Fig. 7 shows the block diagram of the developed SCADA software.
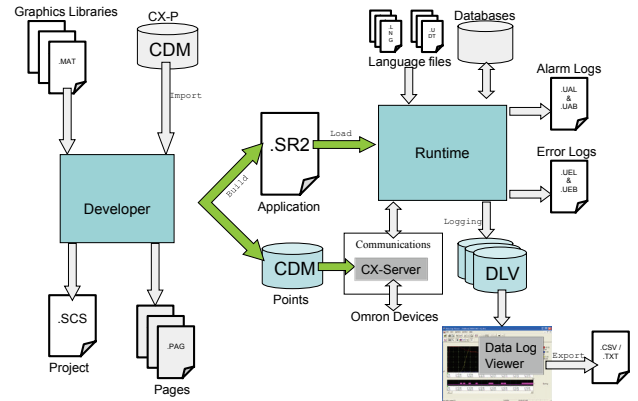

Figure 7 Block diagram representing the SCADA software

3.3 Smart Phone Software

The monitoring and control screen is designed via the software program called EasyBuilder-Pro. The screen and the PLC models are chosen prior to starting the design. The communication with PLCs is obtained with Ethernet connection.

The monitoring and control of the screen is uploaded to a server device named CMT-SVR which is connected to an access point for a wireless communication. Thus, this screen is available to reach for an IOS/Android device (smart phone or a tablet) having the application named CMT-Viewer. The control and monitoring of whole system can be obtained by just using that application.

4 APPLICATIONS

In this section, the software examples developed for smart phone applications via CX-Supervisor are presented.

4.1 SCADA Applications

The parameters that are received previously and transmitted to the addresses as categories can be monitored and controlled with SCADA screen as seen in Fig. 8. The user can perform an operation to parameters that belong to a selected category while also being able to control all the categories at the same time.

Fig. 8 represents the SCADA application software for monitoring, control and protection of the parameters that belong to 3 phase asynchronous motor. The same system is developed for the other prototypes, which is shown in Fig. 9 and Fig. 10 for axial control and robot arm respectively. The main purpose is to allow user to monitor the situation for any desired process in real time.

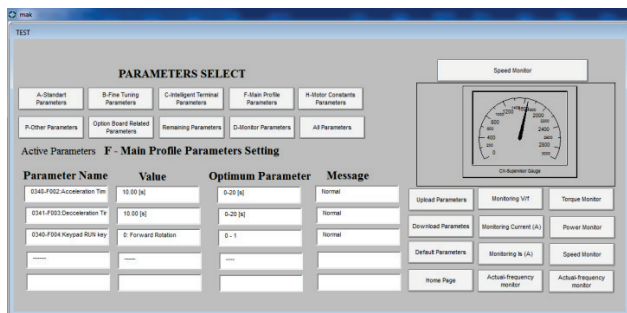Moreover, the user is also authorized to change any parameter at will.

Figure 8 Parameter selection and monitoring screen

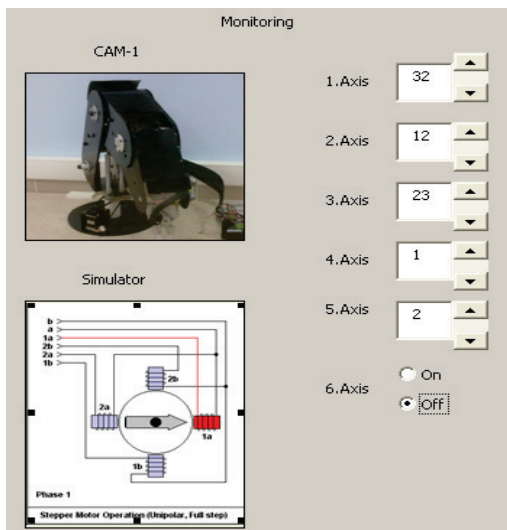**Figure 9** The position control for the axis

Figure 10 Monitoring and control screen for robot arm

4.2 IOS/Android Applications

Firstly, the software program called CMT-Viewer is downloaded from the application stores of IOS/Android systems. CMT-Viewer screen is presented in Fig. 11. There are six server devices used in this study.

The settings of each device seen in Fig. 11 ought to be organized to set the addresses of the channels of Ethernet 1 and 2. The IP address of the CMT-SVR, which is the server device, is set to 192.168.0.100 while address of Ethernet 2, which allows the communication with PLC, ought to be set carefully. The PLC IP address used in this

study is 192.168.250.1. Therefore, the IP address of Ethernet 2 is set as a static IP having the number of 192.168.250.32. Thus, the communication between CMT-SVR and PLC is obtained. If there is a mistake during the settings of those IP addresses, screen will display a communication error message.
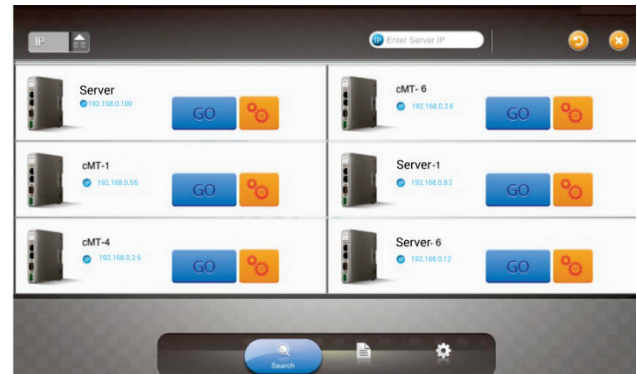

Figure 11 IOS/Android access screen

Once the required address settings are complete, server devices can be reached by clicking the "GO" button as seen in Fig. 11.

After the loading process, the monitoring screens for the axis control system, robot arm and asynchronous motor prototypes are shown in Fig. 12, Fig. 13 and Fig. 14 respectively. Besides the monitoring of the parameters, the user can also control and set new parameter values in real time via those screens.
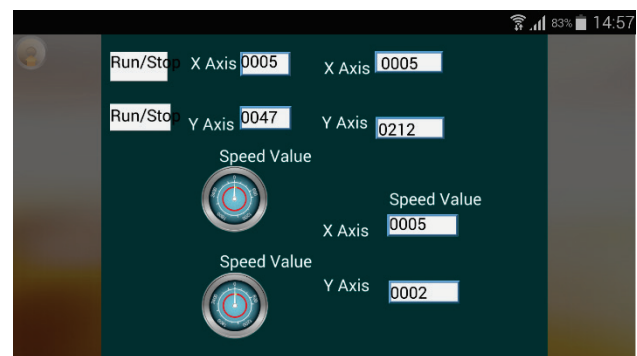

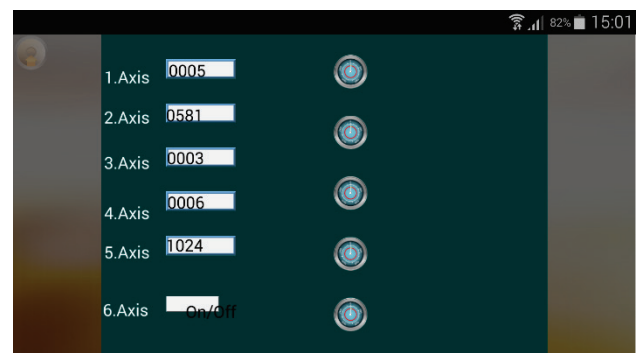**Figure 12** IOS/Android screen for axis control system

Figure 13 IOS/Android screen for robot arm control system

The system displays an error message if there is a connection problem or during a program modification. Fig. 15 shows an example of the error message.

The general view of the prototypes constituting the asynchronous motor control system is presented in Fig. 16.
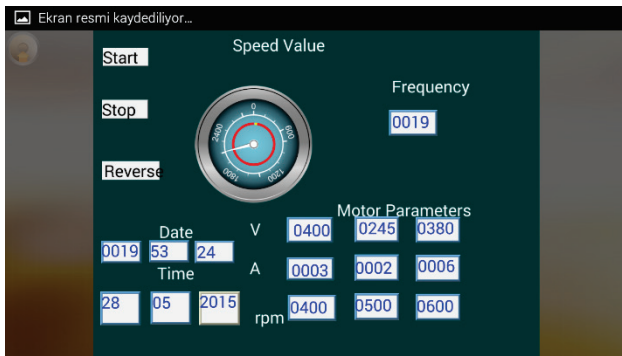
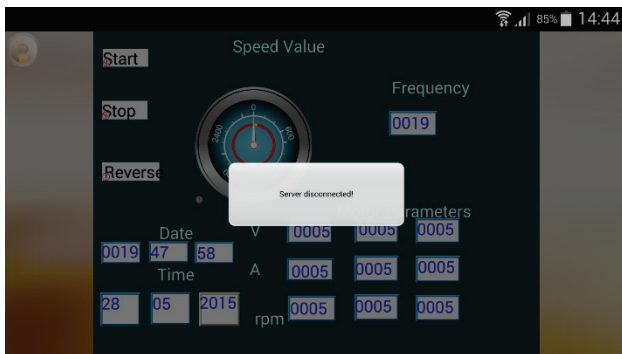**Figure 14** IOS/Android screen for asynchronous motor control system

Figure 15 Example of an error message

Figure 16 General view of the asynchronous motor control system

5 CONCLUSION

In this study, a web based monitoring, control and protection of the driver parameters of distributed robotic systems used in industrial manufacturing processes is developed successfully. The developed application is also important for the fault detection and protection for such systems. In a typical robotic system, possible errors are related to electrical motors. Therefore, it is important to observe and analyse all the processes. The SCADA software developed in this study presents a solution for the issue. A successful system is established for the real time monitoring, control and protection of all the processes. Additionally, the system is supported with IOS/Android based smart phones and tablets which are one of the important features of technology. Therefore, this study eliminates the requirement for user to spend time around CPU and brings mobility to the process.

The developed system can either be used for education purposes or experimental studies in institutions.

The necessary arrangements and modifications to the software can provide monitoring and control of any system at desired specifications.

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