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RESEARCH ARTICLE

SYNCHRONOUS REAL TIME CONTROL OF DISTRIBUTED SERVO DRIVE SYSTEMS BY WAY OF DEVICE NET NETWORK

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ABSTRACT

In this study, simultaneous and real-time control of distributed servo drive systems is provided. Behaviors of each drivers was investigated under various loads and without a load in the study. In the implementation phase, PLC is used as a controller and SCADA is used for monitoring and controlling. Device-Net, an industrial communication protocol, is used between PLC and SCADA. Beside the property of SCADA and servo drive systems working in a coordinated manner, both local and central control is provided. Optimum P (proportional gain), I (Integral gain) and D (differential gain) of AC servomotors which are used for position and speed control were obtained by the automatic tuning feature. By entering the obtained values into PID function located in PLC, minimum exceeding, maximum elevation, minimum settling time for simultaneous location and speed control for ac servomotors were provided to be obtained.

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INTRODUCTION

Continuous monitoring and control of motor and motor drivers used in predetermined processes at manufacturing phase have become the need. In addition, simultaneous and real-time control of more than one motor through the network has gained importance. Since servomotors have fairly low rotor inertia and a structure with the ability to produce high torque, they are widely used in the industrial applications (Khongkoom *et al*., 2000). Servomotors provide the opportunity to produce higher torque at low speeds via a gear box mounted to the shaft (Özkan *et al*., 1999). Servomotors are used in position control because of their properties of high power, high torque and fast feedback. Since servomotors are used in applications where precision work is required in the in industry, they are required to respond quickly to on-off processes and to maintain stable operating condition under sudden load changes. Even if modelling in some systems is done correctly, usage of the obtained model in controller design may cause complex problems and significantly high cost. Therefore, some control algorithms may not be implemented into not well-defined, time varying and complex systems (Akar, 2005). In addition, controlling new devices emerged with the developing technology and data transmission in the industrial applications have become more complex (Irmak *et al*., 2011). Communicating the protocols used in the controls performed through the network with many drivers is important. Device Net is an open network which can connect various control devices such as PLCs, computers, sensors and actuators. Since Device Net network requires less cabling, it reduces cabling and maintenance costs.

At the same time, it offers a convenient structure for the products produced by different manufacturers. Therefore, there are many devices compatible with Device Net. Furthermore, the most economical system can be set up with Device Net (Omron, 2008). Automation systems used in the manufacture processes should be cheap, effective and applicable. PLC is a good alternative for automation systems. PLCs include arithmetic and special mathematical operation commands as well as logical operations. For this reason, more complex operations can be performed with PLCs (Yilmaz, 2010).

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Table. 1. Technical specifications of omron servo drive

Servo Drive			
Drive Type			R88D- KT04H
Output Current (rms)			2,6 A
Input Power Values	Main Circuit	Power Supply Capacity	0,9KVA
		Power Supply Voltage	Mono phase 200- 240 VAC (170- 264 V), 50/60 Hz
		Nominal Current	4.1/2.4 A *1
	Control Circuit	Power Supply Voltage	Mono phase 200 - 240VAC (170 - 264V), 50/60Hz
Power			400W

Table 2. Technical specifications of omron servo motor

Servomotor		
Model		K40030H
Nominal Power		400W
Nominal Torque		1,3 Nm
Nominal Speed		3000 r/min
Maximum Rotation Speed		6000 r/min
Maximum Torque		3,8 Nm
Nominal Current		2,4 A(rms)
Maximum Current		10,2 (0-p)
Rotor Indictment	No Brake	0.26×10^{-4} kgm^2
	W/Brake	0.28×10^{-4} kgm^2
Mechanical time constant	No Brake	0.43 ms
	W/Brake	0.46 ms
Electrical Time Constant		3.4 ms

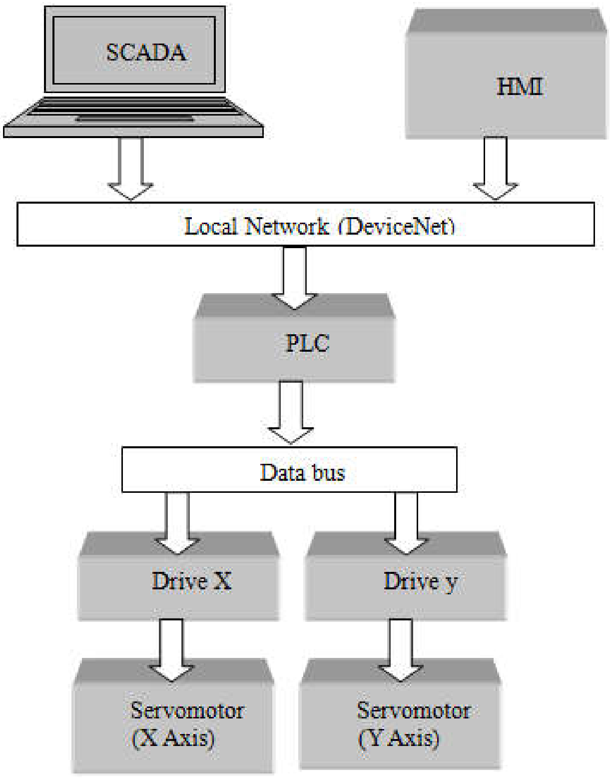

Fig. 1. Schematic layout of servo drives setup

Designed system

Schematic layout of the system architecture used is shown in Figure-1. While the developed system architecture has a flexible structure, a structure in which different drivers can be installed if required was developed. Omron brand operator panel was used and the training was provided. The developed training sets has PLC-based and HMI control, the flow diagram of the training sets is given in Figure 1.

The system consists of two AC servo motor and two AC servo drives driving them. Each drive can be controlled simultaneously through SCADA. While motion control system is controlled via SCADA, by providing the control with HMI also, two-way control mechanism was formed. Device Net network established between SCADA and PLC offers two-way and simultaneous control. SCADA is an important communication method used in industrial network systems (Irmak *et al*., 2011). The network structure of this study, DeviceNet was used. Device-Net, one of the protocols used in industrial automation networks and data transmission technologies have good performance on issues like remote control, data transmission speed, real-time transmission and system stability. Technical specifications of servomotors and drives used in this study are given in Table 1 and 2, respectively.

Hardware Description

Servomotor control systems take the signals (direction of rotation, speed and location) needed for the control from microprocessor, microcontroller or computer. Feedback of the signals applied to the motor is taken from the sensors, encoder or feedback potentiometer and transferred to the drive circuit. These obtained signals are entered to the drive circuit as real-time information. By making calculations of those signals, the drive produces signals required for driving process (Tamaki *et al*., 1986). In servomotor control, speed and position information from motor shaft can be obtained via tachometer, encoder or potentiometer (Khongkoom *et al*., 2000; Işik *et al*., 2004; Khoei, and Hadidi, 1996). Setting of the voltage applied to the motor is usually made by semiconductor, as switching element, semiconductor elements such as MOSFET, IGBT and GTO are used (Khoei, and Hadidi, 1996). Nowadays, in general, a structure where changing of working time of DC choppers is done by setting pulse width with a PWM (Pulse Width Modulation) is used as actuator in motor controls (Akar, 2005). Position control is generally done by microprocessors, microcontrollers or computers.

Servomotor Control

Servomotors with a connected encoder are connected to an AC servo drive which can control in high frequencies and can give PWM output. General operation condition belonging to servomotor control is shown in Figure 2.

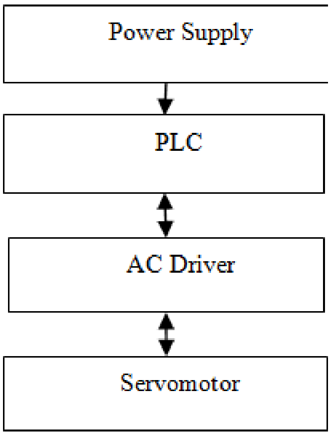

Fig. 2. Servomotor Operation Diagram

Block diagram of Servomotor control is given in Figure 3. When AC servo motor operates under a load, according to speed-torque characteristics (Venkateswaran, 2008) given in Figure 4, torque decreases with the increase of speed. High torque in high speed is required for servomotors to provide sudden acceleration. As it can be seen from Figure 4, torque increases with the increase of control voltage (e) (Nagoor Kani, 1999).

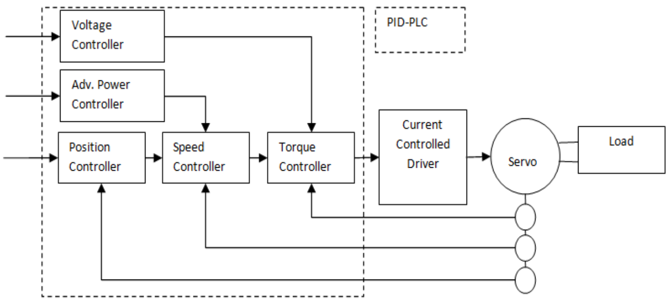

Fig. 3. Block Diagram used for Servomotor Control

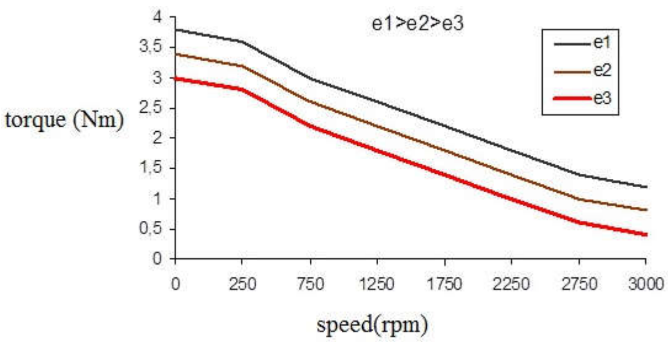

Fig. 4. Torque-speed characteristics of servomotor

RESULTS AND DISCUSSION

While separate location values can be entered for every AC servomotors used in simultaneous and real-time control application, different position values can be entered. For example, servos were asked to go 6^0 from SCADA system and HMI control panel, step response depending on PID control parameters formed in PLC was presented in Figure 5.

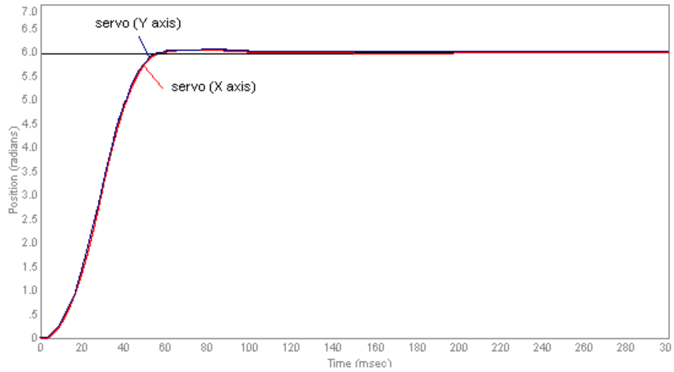

Fig. 5. Position control step responses for servomotors

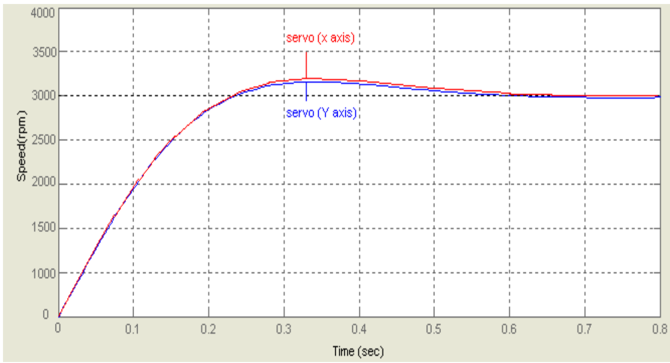

Fig. 6. Speed variation of servomotors in 3000 rpm and under no-load case

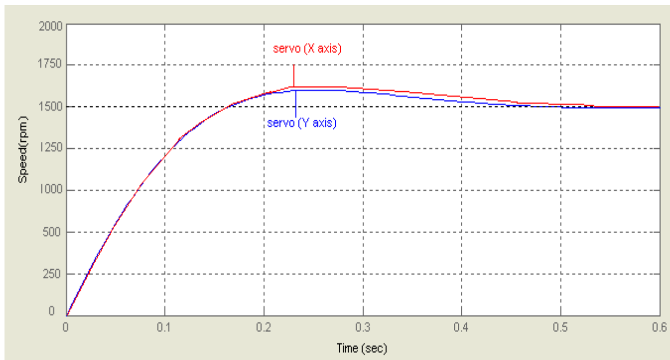

Fig. 7. Speed variation of servomotors in 1500 rpm and under no-load case

While rising time for x-axis in position control is 22 ms, this values is 24 ms for y-axis. While settling time is 102 ms for x-axis, this value is 103 ms for y-axis. From these values, it is seen that step responses of servo drives used have similar rising and settling time as well as they provide a simultaneous control. In addition, real-time and control strategy of drives used in motion control system depended operation characteristics were observed without load and with 25% load.

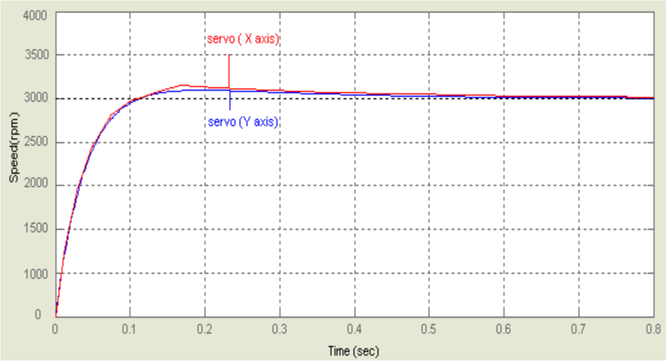

Fig. 8. Speed variation of servomotors with 3000 rpm and 25% load

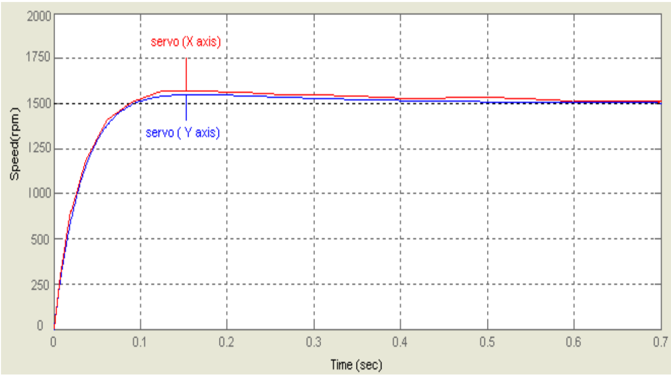

Fig. 9. Speed variation of servomotors with 1500 rpm and 25% load

No-load behaviors of AC servomotors were firstly examined. Dynamic behaviors of servomotors under 3000 rpm reference speed and under no-load are given in Figure 6. For x-axis servomotor, 3000 rpm considered as the reference value was reached in 0.512 s, the rise time is measured as 0.168s. For x-axis servomotor, 3000 rpm considered as the reference value was reached in 0.508 s, the rise time is measured as 0.165s. In the same way, dynamic behaviors of X and Y axis servomotors under no-load situation are given in Figure 7. X-axis servomotors reached to the specified reference speed at 0.412 s, the rise time was measured as 0.120 s. Y-axis servomotors reached to the specified reference speed at 0.410 s, rise time was measured as 0.118 s. Thus, servomotors moving in two axes reach to the reference speeds in similar times. These values show that two drives are controlled in simultaneous and real-time. It is also concluded that time response of servomotors at low speeds is faster. In order to examine the behaviors of servomotor under the load, a load is put after the dynamic behaviors of servomotors under unloaded cases. Dynamic behaviors of servomotors under 3000 rpm reference speed and under 25% loads are given in Figure 8. For X-axis servomotor, 3000 rpm considered as the reference value under 25% load was reached in 0.372 s, the rise time is measured as 0.0695 s. For Y-axis servomotor, 3000 rpm considered as the reference value under 25% load was reached in 0.368 s, the rise time is measured as 0.0695 s. Similarly, dynamic behaviors of X and Y axis servomotors in 1500 rpm under 25% load is given Figure 9. X-axis servomotors reached to the specified reference speed at 0.327 s, the rise time was measured as 0.0577 s. Y-axis servomotors reached to the specified reference speed at 0.325 s, the rise time was measured as 0.0577 s. Reaching to the reference speed in similar times for servomotors moving in two axis under load shows that simultaneous and real-time control is provided even under load. In addition, obtained values show that time response of servomotors under load and low speed conditions is faster.

Conclusion

Real-time SCADA system was used for operation, performance and control of AC servomotors used in the two-axis distributed drive systems. Performances of distributed servo drive systems under a load and no-load cases were analyzed. Both drives used are adapted to SCADA system and controlled with PLC. Real-time operation performances of drives used with various speeds and loads were investigated in detail. With this study, obtained graphs show that simultaneous control for distributed servo drive systems is provided. SCADA system and developed Device Net network structure were shown to work compatibly with PLC.

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