

Implementation Of Distributed Control System In Process Control Management Using MATLAB

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Abstract: In recent years, process automation has being used in various industrial plants. Especially, Distributed Control System (DCS) is more popular than any other control systems in the modern industrial processes. DCS is a computer control, a software application and also designed to work on the computer for the process by providing with all the devices. The advantages of the system are reducing process time, reducing labor costs, controlling, and monitoring real time condition. This research aims to develop the “Real Time Graphical User Interface Monitoring and Network System” for Industrial Automation. The current research project is based on the construction of DCS based bottle filling process system. The Industrial Local Area Network (LAN) is built between the server for the operator and the clients for the two robots control and only one CNC milling machine. In this research, the simulation of the overall process is conducted in real-time condition by using MATLAB software.

Keywords: Distributed Control System, Process Control Management, MATLAB, SIMULINK, Bottle Filling System.

INTRODUCTION

A DCS is a system of controllers linked by a data network, as a single system. Functionality, physical location, or both separate these controllers. The DCS is used in complex process applications where large amounts of I/O and data are required, such as chemical plants or oil refineries. They are well suited to batch processes and have an ability to handle complex interlocks and timing between operations. DCS are multitasking systems able to handle large common databases. A DCS allows for various control loops, using graphical representation of function blocks, and is easier to program than ladder logic-based PLCs. Scan rates can be more predictable than the PLCs. PLCs have scan rates dependent on the amount of I/O [2]. A DCS has safety features, redundancy, and even diagnostics built into its control philosophy to be more robust with less down time [1]. This project includes a computer connecting the devices setting in distributed manufacturing plant. It uses parallel port pins assigning input and output pins of the computer. The system block diagram of distributed control system based manufacturing process is shown in Figure 1.

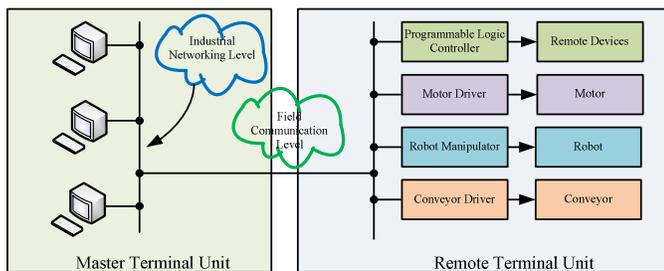


Fig.1. Block Diagram of DCS Based Manufacturing System

DESCRIPTION OF THE DCS ELEMENTS

The DCS system consists of one or more of the following elements.

- **Local Control Unit (LCU).** This is denoted as local computer in Figure. This unit can handle 8 to 16 individual PID loops, with 16 to 32 analog input lines, 8 to 16 analog output signals and some a limited number of digital inputs and outputs.
- **Data Acquisition Unit.** This unit may contain 2 to 16 times as many analog input/output channels as the LCU. Digital (discrete) and analog I/O can be handled. Typically, no control functions are available.
- **Batch Sequencing Unit.** Typically, this unit contains a number of external events, timing counters, arbitrary function generators, and internal logic.
- **Local Display.** This device usually provides analog display stations, analog trend recorder, and sometime video display for readout.
- **Bulk Memory Unit.** This unit is used to store and recall process data. Usually mass storage disks or magnetic tape are used.
- **General Purpose Computer.** This unit is programmed by a customer or third party to perform sophisticated functions such as optimization, advance control, expert system, etc.
- **Central Operator Display.** This unit typically will contain one or more consoles for operator communication with the system, and multiple video color graphics display units.

- **Data Highway.** A serial digital data transmission link connecting all other components in the system may consist of coaxial cable. Most commercial DCS allow for redundant data highway to reduce the risk of data loss.
- **Local area Network (LAN).** Many manufacturers supply a port device to allow connection to remote devices through a standard local area network.

DISTRIBUTED CONTROL NETWORKS FOR BOTTLE FILLING PROCESS

At first, the bottle is transferred to the machine through conveyor continuously. The bottle is transferred through air conveyor, then to Rinser. The bottles arrived to the rinser, the machine start to rinse through the bottle nip clamping and turning over 180 degree. The bottle turns over to origin after rinsing. Then the machine starts to fill the water into the bottles. And then start to cap onto the bottle mouth using filling valves assemblies respectively. So capping is performing. The bottle is transferred to the conveyor belt after capping. The machine will start to the next working procedure after the bottle is transferred to the conveyor belt. Filling valves assemblies use counter pressure filling system. It is designed for automatic and continuous operation. It can cope with various types of bottles simply with changing the filler bowl height and filling valves assemblies.

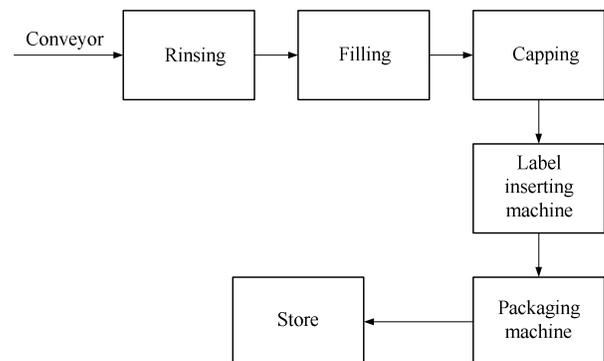


Fig.2. Block Diagram of Filling Process for Purified Water

IMPLEMENTATION

A. SIMULINK Model for PLC Remote Device

There are two main functional blocksets for PLC. They are PID controller for stability analysis and the PLC remote device. The rate limits is for applying the response limitation for PLC plant after controlled with PID. The saturation blockset is for supporting the rate limits input to control the process. The PID controller is for process control stability determination. The PLC is the main controller of the bottle filling process and there are three stage control scan. They are input scan, program scan, and the output scan. Before the program scan, the input commands are analyzed by using the situation of process. Therefore the time span of program scan is longer than other two scans such as input and output scan. But the debugging state of the PLC remote device button to control the process of bottle filling system has been reached and the simulation result for PLC remote device was evaluated by using MATLAB SIMULINK model.

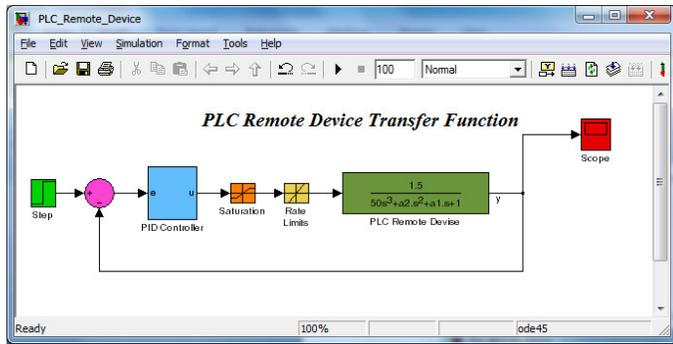


Fig.3. Screenshot Results for SIMULINK Model of PLC Remote Device

B. SIMULINK Model of Hydraulic Motor

In this SIMULINK model, there are two main portions for hydraulic motor system. They are valve and hydraulic motor portions. The rate limit for that model is to response limitation purpose and the gain 10 is for large response displayed on the scope according to the unit step response for hydraulic motor system. The feedback gain 0.002 is used to limit the feedback signal from the hydraulic motor response to compare with the unit step input for hydraulic motor system.

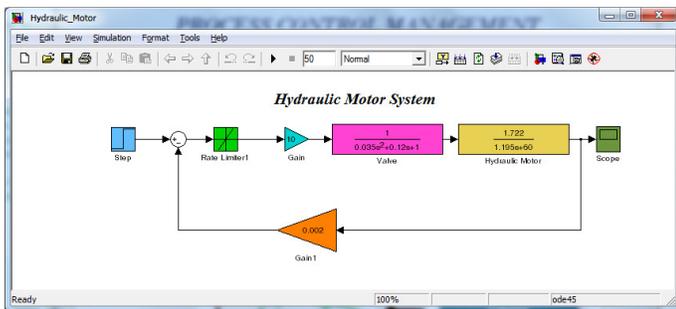


Fig.4. Screenshot Result for Hydraulic Motor

C. SIMULINK Model for Conveyor System

The main part of the conveyor system is the DC servo motor control system. Therefore the stability analysis on the DC servo motor is supported to design consideration of conveyor system. The controller for DC servo motor is the PID controller and it is very efficient controller design for high torque motor control system. According to the gain value for motor, the feedback gain was selected to optimize the performance of the motor control system.

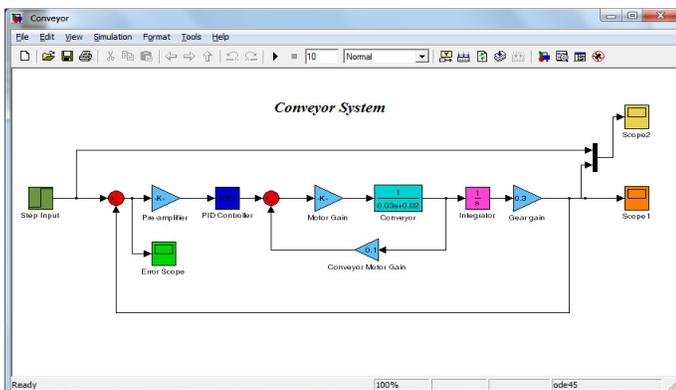


Fig.5. Screenshot Result for Conveyor System

The stable response for DC servo motor could be evaluated by using integrator after conveyor transfer function. The conveyor motor gain can be chosen based on the forwards gain for DC servo motor system.

D. SIMULINK Model for Bottle Filling Robot System

The purpose of bottle filling robot system is to carry the rank of bottle from bin to conveyor and from conveyor to bin respectively. The mathematical model for bottle filling robot system is discussed in previous section. There are two main transfer functions to control the bottle filling robot system. They are robot plant and controller stages. The robot plant could be represented by the rotational dynamic of the mechanical arm and the controller is stands for compensation of the robot plant for bottle filling robot system. The disturbance effect has to be considered to evaluate the performance of the bottle filling robot system. The gain value 20 is for simulation results displayed on the scope. The unit step input is very efficient to analyze the dynamic stable of the bottle filling robot system. Figure 6 shows the SIMULINK model for bottle filling robot system.

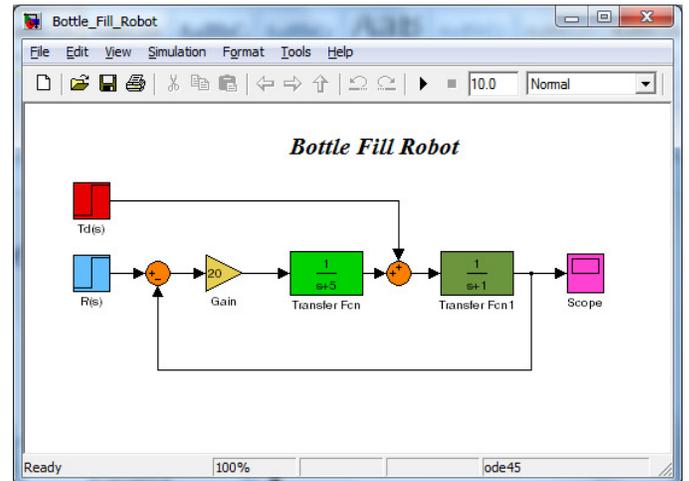


Fig.6. Screenshot Results for Bottle Filling Robot System

SIMULATION RESULTS

Based on the implementation of mathematical models of RTUs from bottle filling process, the main GUI window for DCS system is developed by using MATLAB. There are four main RTUs for remote units. They are conveyor control system for direction of bottle flow line, the filling system robotic control system, the hydraulic motor control system and the programmable logic controller for control process. The mathematical models and transfer function analysis on the process control management were developed. In Fig.7, the overall button represents the actual filling process operating condition. This button can be pressed to display the overall process control in main GUI window for information. This information supports the application of DCS based filling system process control.



Fig.7. Main GUI Window for Bottle Filling Process Control Management

E. Simulation Result of Process Control Management Using MATLAB

The main GUI window consists of the OPEN and EXIT button to control the filling system process control. The OPEN button covers the actual distributed remote devices for process managements.

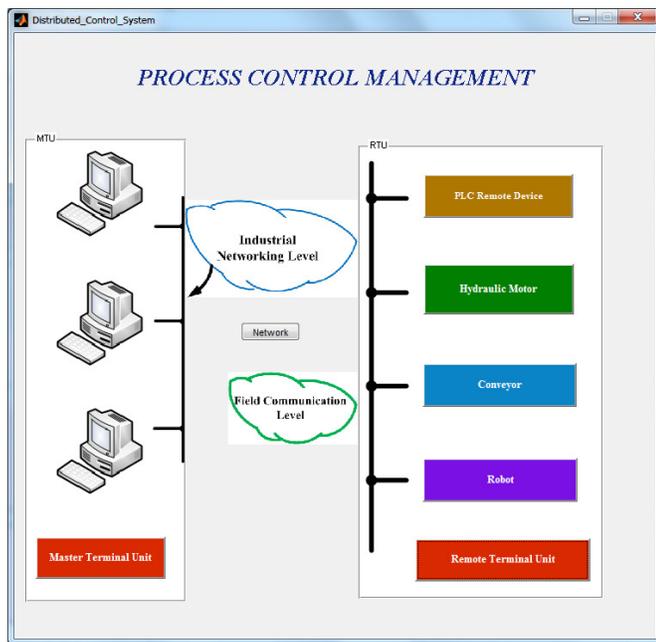


Fig.8. Screenshot Result for Overall Simulation Condition

After activating the Distributed_Control_System button under OPEN, the process control management window is displayed and the screenshot result for overall simulation condition is illustrated in Fig.8. In this Figure, there are three main portions which are separated by three push buttons. The master terminal unit (MTU), network and remote terminal unit buttons are to control the process stage of bottle filling system. If the master terminal unit button is pressed, the virtual images of

three computers which are connected via industrial Ethernet are displayed in the region of MTU from MATLAB GUI. The network button is for activating with the industrial Ethernet for DCS system. The remote terminal unit is for field level communication and RTUs activation system. There are four main RTUs devices for process control management of bottle filling system. They are PLC remote device, the Hydraulic motor, the conveyor, and the bottle filling robotic system. The dynamic stability response for PLC remote device is illustrated in Fig.9. According to this simulation result, the response curve approaches to one for unit step level after 100millisecond. This duration of process time is very accurate for PLC control process for bottle filling system.

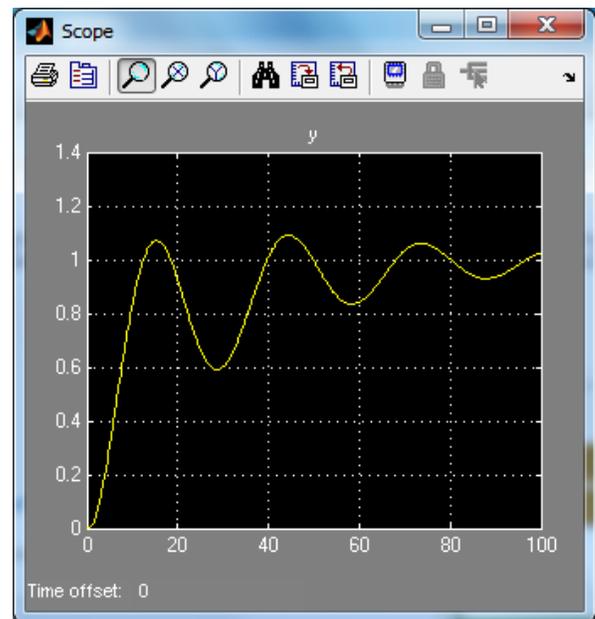


Fig.9. Step Response for PLC Remote Device

The scope result for hydraulic motor portion is shown in Fig.4. In this response, the dynamic stable for hydraulic motor is started from 4 milliseconds to the duration of operating condition. The peak value of the unit step response for hydraulic motor function is approximately 0.32 and it is very convenient to express the acceptable limit for transfer function of hydraulic motor. The step response for conveyor system is displayed on Figure 5.8. The unit step signal is very appropriate signal for analyzing the performance evaluation of conveyor system. Based on the step response for conveyor system output stage, the dynamic stable time for conveyor system is approximately 7 milliseconds after evaluating the transfer function of conveyor control system which based on DC servo motor. Figure 5.9 shows the comparison response for input and output stage of the conveyor control system. It is clearly stated that the performance of the DC servo control is met with the actual control system.

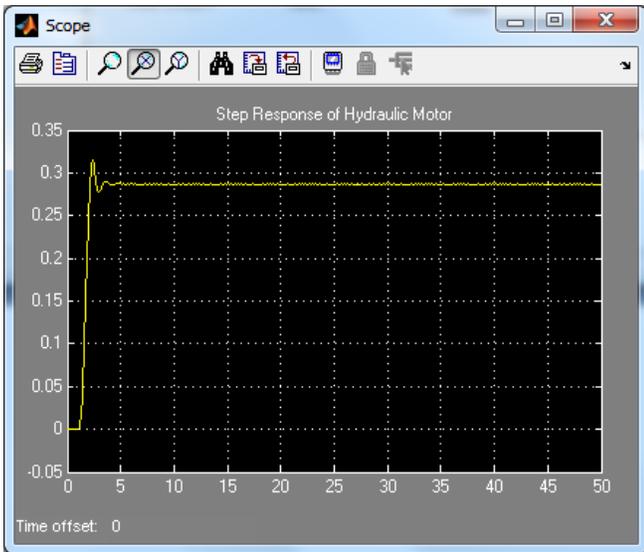


Fig.10. Step Response for Hydraulic Motor System

The error response for conveyor control system is illustrated in figure 5.10. The maximum overshoot under 7 milliseconds is not affected on the motor performance. Therefore the system is stable at dynamic stage with operating condition.

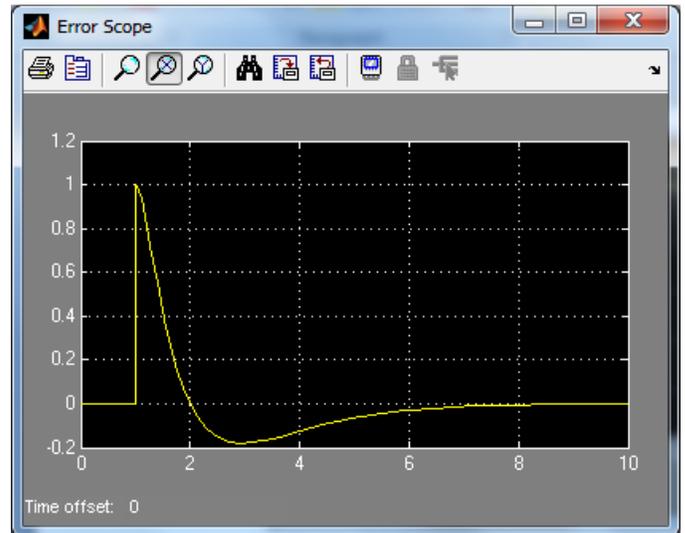


Fig.13. Error Response for Conveyor System



Fig.11. Step Response for Conveyor System Output Stage

Fig.14 mentions the step response for bottle filling robot system. This response says the dynamic stable at 3 milliseconds and the percent overshoot of this response is very less to accept the dynamic stable condition.

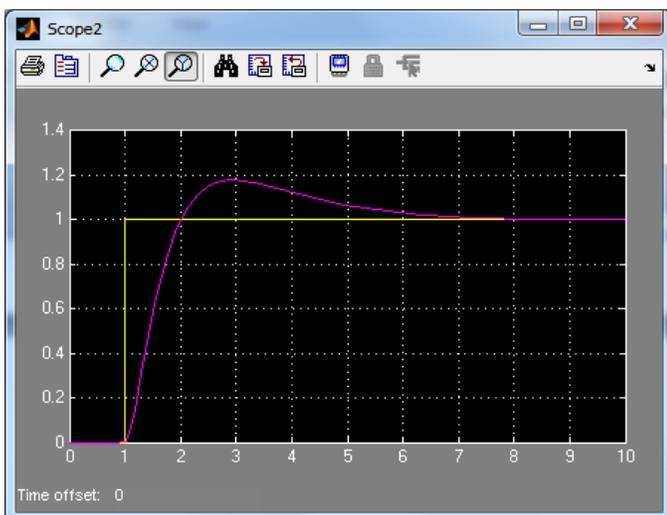


Fig.12. Comparison Response for Conveyor System Input and Output Stage

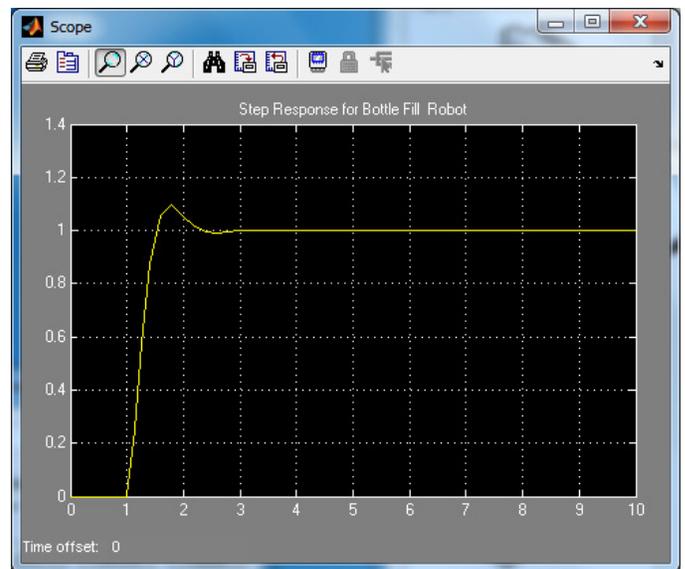


Fig.14. Step Response for Bottle Filling Robot System

CONCLUSION

This industrial process is quite complex to be controlled because of several aspects, both physical and technological. This research is implementation of distribution control system for process control management for bottle filling system. The main purpose of this research is to develop the controlling devices from anywhere by monitoring the whole system. This monitoring system can access with other process. In this

research, a low cost data acquisition, processing and monitoring system based DCS system has successfully developed. In this thesis motors, sensors and other devices are used and applied to with the help of MATLAB software. It is very low cost for applications and has shown that computers and automated control can be used as a tool to increase product quality and production flexibility. In this research, design and implementation of DCS based bottle filling system process that used MATLAB software. In this project, the conveyor one is moving to send the bottle to the desire location firstly. After arriving the object at the place where already assigned, the robot gripper pick up that bottle to send to filling system process. Thereafter, robot gripper will wait at somewhere to pick up the new bottle. Finishing the filling process via filling machine, the product is taken by the robot gripper to move to packing station. To reach the packing station, robot gripper has to draw the finished object to the next conveyor.

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