PLC – HMI and Ethernet based Monitoring and Control of MIMO System in a Petrochemical Industry

A. Selwin Mich Priyadharson¹*, S. Vinson Joshua¹ and C. Thilip Kumar²

¹ECE Department, Vel Tech University, Avadi, Chennai - 600 062, Tamil Nadu, India; selwin_priyadharson@yahoo.co.in, vinson.joshua@gmail.com
²EEE Department, Vel Tech University, Avadi, Chennai - 600 062, Tamil Nadu, India; thilipvedi@gmail.com

Abstract

A novel design and development of PLC - HMI and Ethernet based system is used to monitor and control various process variables such as temperature, pressure, level and flow as MIMO (Multiple Input Multiple Output) system in a petro-chemical industry. The project consists of two modules, one is monitoring of these parameters and the other is controlling of those parameters. In this design by using B&R (Bernecker and Rainer) - HMI (Human Machine Interface), the monitoring of the process is done and controlling is performed by PLC (Programmable Logic Controller). In this work in order to transfer the data from plant to the central control room in a single Ethernet cable is used rather than using enormous number of cables so as to reduce the time due to transportation lag and thereby to improve the efficiency. A prototype model is developed, executed and finally validated from the data accumulated from a Petrochemical Industry. From the results it is highlighted that while using PLC - HMI and Ethernet cable, the variables performed output without transportation lag of 15 seconds which will improve the overall plant efficiency, safety and performs online monitoring and control.

Keywords: Ethernet, MIMO System, Monitoring and Control, Petro Chemical Industry, PLC – HMI

1. Introduction

Multivariable or Multi-Input Multi-Output (MIMO) systems are repeatedly encountered in the chemical and process industries. In many refineries and petro chemical industries, the mode of operation is aged. The refineries and petro plants are using an old system for the monitoring and controlling of the different parameters and devices run over there. Parameters like temperature, pressure, level and flow are monitored and controlled in an old technique. Not only monitoring but controlling of the parameters is also very important mainly for the safety purpose in order to avoid accident and to improve efficiency. It can prevent the leakage, breakage and destruction of any device running in the plant. In the existing system controlling is done with a higher risk. Long cables are used for the transfer of data from plant to the central control room. The sensors used for monitoring are kept in risky area and the controlling section set up is in a safe area to avoid destruction of the controlling part. A safe distance of 1Km to 5Km is maintained between the monitoring and controlling section. For every single parameter, single cable is used which makes the transferring section clumsy. Large number of cables is used for transferring the data, which makes the mode to be more complicated. Again due to this long cable, sometime there is a chance of loss in the required data which is transferred to the control section. Moreover there is lack in the required accuracy and delay in time which

*Author for correspondence
will lead to poor efficiency and thereby economically not advantageous.

Alamelumangai explained that all chemical processes in process industries usually have two or more controlled outputs requiring two or more manipulated variables generally called Multi Input Multi Output (MIMO) process. They made an attempt to review the practical difficulty in applying control strategies for a multivariable process. Kanagasabai et al. designed the controller for three tank multi loop system using coefficient Diagram method. Ezzeldin Hamed et al. demonstrated a real-time distributed MIMO system, DMIMO. DMIMO synchronizes transmissions from 4 distributed MIMO transmitters in time, frequency and phase and performs distributed multi-user beam forming to independent clients.

Hichem Salhi et al. presented a constrained multi-variable model predictive control for discrete nonlinear systems based on Divided Difference Filters (DDFs) which are derive free state estimators. Kosonen et al. forms a method, Ethernet-supported packet-based communication medium over the motor power cable. Lee et al. designed 16 channel 12-bit Ethernet-based flash ADC (EFADC-16) unit operates at 250 MHz/ channel utilizing a gigabit Ethernet interface to parse time-stamped event signals in flash Analog to Digital (ADC) based read out system to be used for a Positron Emission Tomography (PET) system. Wenchao Meng et al. investigated adaptive neural control for a class of unknown Multiple Input Multiple Output nonlinear systems with time-varying asymmetric output constraints. Baruah et al. demonstrated the microcontroller based temperature monitoring and control. Selwin et al. demonstrated and explained the PLC - HMI based Monitoring and Control of process variables in pumped storage power plant. Ya-hui Wang et al. proposed a time delay identification method for linear MIMO system.

In order to improve the performance in terms of speed and efficiency, PLC-HMI and Ethernet based Monitoring and Control of MIMO system is proposed in a petrochemical Industry. The present paper is ordered as follows: Section 2 describes the proposed monitoring and control system. Section 3 demonstrates the prototype model. Section 4 illuminates experimental set up. Section 5 deals with the results and analysis. Section 5 & 6 deals with the conclusion and references respectively.

2. Proposed Monitoring and Control System

The proposed PLC-HMI and Ethernet based MIMO monitoring and control system is very much essential in industries to monitor as well as to control various parameters. This system is of two segments one is monitoring the parameters, that will be done online by HMI and another is controlling the parameters, which will be performed by PLC. The plant consists of various sensors/transmitters for measuring and displays the variables in the HMI. HMI is used to monitor online and if required it is possible to change the given inputs in the HMI depending on the necessity of the load demand. Signal from plant is taken to the central control room by using Ethernet cable. Thereby the data are transmitted from field to control room by an Ethernet cable instead of multiple cables. The received signal is given to the controller, PLC. From PLC control signals are taken from central control room to the plant.

3. Prototype Model

As shown in Figure 1, Prototype model, water is pumped from the reservoir to the tank through the inlet valve. In the tank temperature is maintained by using heater and the level is measured by using level float switch. The outflow from the tank is taken through outlet valve to drain. The inflow and outflow is controlled by inlet and outlet valves (solenoid valves) respectively. The temperature is controlled by the current flow entering into the heater. By
controlling the flow, level also set into control depending on the load demand.

**Temperature** - RTD (Resistance Temperature Detector) is used to sense the temperature of the fluid in tank as the range (-270°C to 670°C).

**Level** - Float switch is used to monitor the level of the fluid in tank as well as in reservoir to prevent the heater from unnecessary damage.

**Flow** - Flow transmitter is used to monitor the flow of the fluid.

**PLC** - PLC is utilized in this project to perform the necessary sequential control action. PLC will get various inputs and depending upon their condition, turning on/off of the outputs is performed. Based on the program in ladder diagram, the desired results for the various process variables are obtained.

Figure 2. B&R X20 standard CPU.

Figure 2 represents the PLC system which consists of Input/Output modules, power supply, CPU, memory and programming devices. A power supply integrated in the CPU with I/O supply terminals provides power for the backplane, I/O sensors and actuators, eliminating the need for additional system components.

In B&R - PLC, RS232, Ethernet, Flash memory card and USB are standard equipment. Ethernet is utilized in this work. In addition, CPU has a POWERLINK connection for real-time communication.

The optimally scaled X20 system CPU line used in this work is shown in Figure 3 and Figure 4. And it will satisfy a wide range of requirements with the highest performance. It will master cycle times of 100 µs. The PLC-HMI hardware set up is shown in Figure 5.

Figure 3. B&R PLC-X 20 standard CPU.

Figure 4. B&R X20 standard CPU module.

Figure 5. PLC – HMI hardware set up.
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4. PLC Programming

PLC records all the input data into its memory. Then it executes the program using the inputs. Finally it updates the status of the outputs by giving control signal to the final control element.

4.1 PLC-Program

The PLC Program in ladder diagram is shown in Figures 7 & 8

![Figure 6. Flow chart – PLC Programming](Image)

![Figure 7. PLC ladder diagram.](Image)

![Figure 8. PLC ladder diagram.](Image)

5. Experimental Set Up

![Figure 9. Experimental set up.](Image)

6. Results and Analysis

6.1 PLC-HMI Display Output

![Figure 10. PLC – HMI display.](Image)

Figure 10 represents the PLC-HMI display where the temperature is indicated in display and other three is indicated in lamp as per their function. By getting this online process in HMI display the Monitoring and control of the parameters is made user-friendly. Based on the load demand in the petrochemical industry and output of that particular parameters, Inputs can be varied and controlling of the plant is done through online.

Figures 11, 12 & 13 represents the graphical representation of level, temperature and flow with and without Transportation lag. While using Ethernet cable, Transportation lag is reduced and also the performance is better than the ordinary line. Ethernet cable reduces the time delay of about 15 seconds and so the settling time has been reduced which will augment the efficiency of the plant.
Flow ($l_p$)

![Flow Graph](image)

**Figure 13.** Flow with and without transportation lag.

8. References

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