Implementation of PLC-based Ratio Control System for Stirred Tank Reactor

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Abstract— Nowadays, the utilization of PLC is broadly known and used in this computerized world. PLC's application is clearly connected to the mechanical part. Ordinarily, the PLC's that have been utilized at the modern field is for the most important part to control a mechanical movement both of the machine or substantial machine so as to make a proficient creation and accurate signal processing. In this task we proposed to build up an experimental set-up of PLC based blending and control of Stirred Tank Reactor (STR). The PLC is associated with the level sensor and submersible motors is control dependent on the level in the tank reactor. This model likewise has the stirrer control unit which continuously stirrers the reactor and blends the reactants. The PLC utilized is Allen Bradley MicroLogix1400 and the software used is RsLogix500. In this way the level in the STR is continually observed and conveyed to a steady dimension as required for the operation. Automation is extremely versatile, making it an ideal aid to daily operations. As such, there are several areas where it can make an immediate and lasting difference for oil and gas companies.

Keywords— PLC, Stirred Tank Reactor (STR), Ratio Control.

I. Introduction

Programmable Logic Controllers (PLCs) are the solid control system that continuously monitors the status of devices connected to the inputs. PLC is a controller with functions to perform timing, counting, arithmetic manipulations, control logic, and sequencing. The chemical process is a process that leads to the production of finite quantities of material by subjecting quantities of input raw materials to an ordered set of processing activities over a finite period of time using one or more piece of equipment. It is also execution of a series of programs without manual intervention (non-interactive) [10]. Strictly speaking a process is considered to be a batch process consists of a sequence of one or more steps that must be performed in a defined order. The series of steps in a batch process is often called by the oxymoronic term batch job. All the desired parameters are predefined in the Programming which is also known as job control language. In [1], the authors developed the mixing and control of continuous stirred tank reactor using solenoid valve and level sensors [1]. The stirrer control unit which continuously stirrers the reactor and mixes the reactants in a CSTR in which they used solenoid valve in which leakage of chemical takes place so we are pumps so that the required amount of chemical is pump into tanks. In [2] authors have designed and developed the liquid filling and mixing process to provide an accurate volume of liquid in the bottle by saving operational time. PLC based batch process and automatic bottle filling. Based on earlier work we tried to achieve four objectives as

1. To design an appropriate model for automatic mixing.
2. To design a program using PLC for automatic mixing.
3. To interface the PLC module with the inputs and outputs component.
4. To design a prototype system for automatic mixing.

The rest of the paper is organized as follows. The hardware component description to implement the project is explained in Section II. The software description to implement the project is presented in Section III. Project description and results are presented in Section IV and paper is concluded in Section V.

II. Hardware Component Description

Automation of the chemical process requires a system that has the ability to deal with changing and uncertain environments. By usage of level sensor it allows only definite amount of liquid to be stirred and it maintains the level. It controls the level in both the sub-tanks and take the required amount of liquid from each subtank and it will send the liquid from both process sub-tanks to the main process tank [2]. In the main process tank when definite amount of liquid is present it starts to stirrer in main tank. It stirs for a time when we both liquids gets mixed well and give the required amount of chemical.

By the use of level switches in place of level transmitter it does not give the exact amount of liquid to be sent to main tank [3]. The level switches are placed in a position in sub-tanks and there are calibrated in the tank and they are placed at definite positions in the subtank. In this project it consists of three containers. For example, the first container contains the red coloured water and the coloured water is filled into the first sub-tank with the help of submersible pump [4]. Similarly, the second tank consists of yellow-colored water and it is also filled with help of submersible pump. Our final aim of the project is to get orange-colored liquid. Now in Allen Bradley Micrologix500 [9] first RS Classic is selected and we have communication in classic when we click on communication we get a downward toolbar in that we have to select configure drivers and we have to allow communication to happen between PLC and PC. When there is no communication between PLC and PC the process evaluated in known as simulation. So to get the results on the real-time application we use communicate drivers we either use communication source as Ethernet cable or else RS-232 communication. We create a ladder logic diagram for the project. The main aim of our project is to control the ratio which is done with scale with parameters. In this we can calibrate the process main tank and the scale with parameter consists of a raw value from 0 to 32767 which provide the minimum and maximum input. The minimum and maximum output are calculated from 0 to 100%, we can control both the process subtanks with the level sensor placed in main process tank. So a for definite amount of set value corresponding amount of liquids is drawn from first subtank and similarly from second subtank. The above step is known as 'level measuring' of liquid. Now the main tank consists of initiating stir motor and submersible pump. When both liquids fall into main process tank it starts stirring for a preset time. This process is known as 'mixing'. When the required chemical is obtained then it is sent to the drain storage. From drain it can be used for filling of bottles or cans or other processes can be connected to extending our main system. Thus, in a nutshell, there are three process tanks, first process tank contains chemical-1,second process tank chemical-2, and the middle main is process tank for mixing using the stirrer. The major components utilized in the project are

A. Programmable Logic Controller (PLC)
B. DC Power Supply 12V and 24V
C. Process Tanks and Sub-tanks
D. Submersible Pumps
E. Analog Level Sensor
F. Motor for Stir operation

A. PLC

The Allen-Bradley® MicroLogix™1400 [7] from the Rockwell Automation complements the existing MicroLogix family of small programmable logic controllers. MicroLogix1400 combine the features your requirments from the MicroLogix1400, such as EtherNet/IP, online editing, and a built-in LCD, plus provides you with the enhanced features, such as higher I/O count, faster High-Speed Counter/PTO, and the enhanced network capabilities. module [6]. It has the advantage of the built-in LCD with backlighting to set the Ethernet network configuration, display floating point values on a user-configurable display, display OEM logos at startup and read or write any binary, integer and long file elements in the table. Three embedded communication ports provide you with excellent communications capabilities. MicroLogix1400 offers an isolated RS232C/ RS485 combination port; a non-isolated RS232C port; and an RJ-45 port for 10/100 Mbps EtherNet/IP peer-to-peer messaging, DNP3 over IP and Modbus TCP/IP protocol. The PLC module is shown in Figure 1.

Figure 1. MicroLogix™1400 [7]

B. Process Tank

The tank shown in Figure 2 is a Process tank which is totally transparent and made of Acrylic [3]. The height is 60 mm, base is 30 mm, and the volume is 12 liters.

Figure 2. Process Tank [7]

The tank shown in Figure 3 is a process subtank. In order to carry out the process we need two tanks so that two different liquids can be filled in the tanks.

Figure 3. Process Subtank

C. Relay Module

When we need 12V DC for our outputs or 230V AC or some other rated voltage, it is slightly not possible as the PLC's output is 24 volts. When we need 12V DC for our outputs or 230V AC or some other rated voltage, it is slightly not possible as the PLC's output is 24 volts which is a standard one or sometimes 4 to 20mA by which we cannot trigger our output directly so to overcome this a relay module is employed between the PLC and the outputs. In Figure 4 we can see the layout of the OMRON relay module which has 8 channels. The output of the PLC is connected to the input of the relay module and from the output of the module every output component devices is given its respective rated voltage.

Figure 4. OMRON Relay Module [8]

D. *Submersible Pump*

In either centrifugal or positive displacement of pumps, the materials used in the soaked portions of the pumps are critical to their safe use. Whatever materials that are used for these wet parts, they should not infect the fluids being pumped nor should the fluids being pumped degrade the materials used in the pump. For the record, stainless steel will eventually rust in salt water and should be avoided when possible, titanium is OK but expensive and brittle. Most wetted parts of the pumps we use are plastic or other non-metallic materials, such as ceramics, that are safe for saltwater. The submersible pump used in our project is shown in Figure 5.

Figure 5. Submersible Pump

E. *DC Motor for Stir*

A DC motor is any of a class of turning electrical machines that changes over direct flow electrical vitality into mechanical vitality. The most well-known sorts depend on the powers created by attractive fields. The operating voltage is 12V, frequency 20-30Hz, and Speed is 500rpm. The DC motor used in our project is shown in Figure 6.

Figure 6. DC Motor

F. *Level Sensor*

A Level transmitter is simply an instrument that provides a continuous level measurement. Level transmitters can be used to determine different to a level switch which only alarms when the level of the material (liquid or bulk-solid) reaches a predetermined level. The supply voltage range is 10-24V DC and outputs current is 4-20mA. The level sensor used in our project is shown in Figure 7.

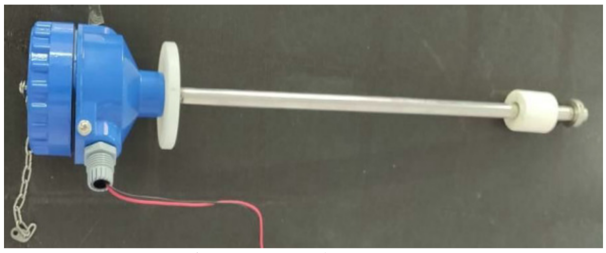

Figure 7. Level Sensor [9]

III. SOFTWARE DESCRIPTION

A. *PLC Software RsLogix500*

The programming language allows the user to communicate with programmable controller (PC) via a programming device to the PC manufactures use several different programming languages but they all convey to the system, by means of instruction a basic control plan [11]. The PLC software used in our project is Allen Bradley's RsLogix500. A view of the RsLogix500 software is shown in Figure 8 where MicroLogix1400 series B PLC is configured using Ethernet connection with applying the IP address of PLC as 192.168.0.1.

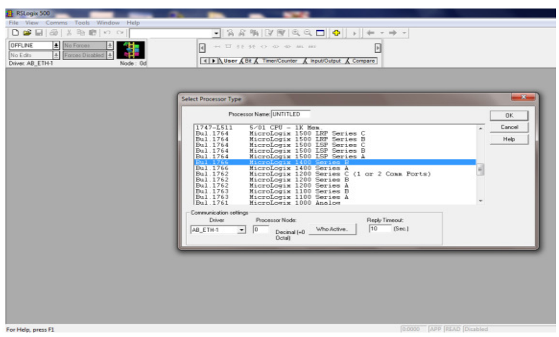

Figure 8. RsLogix500 Software [10]

The main ladder logic we used in our project is scale with parameter, as we need to continuously monitor the level in the tank using the level sensor [5]. The SCP (Scale with parameter) instruction to produce a scaled output it can be level or temperature value that has a linear relationship between the input and scaled values. The ladder logic for this block is shown in Figure 9. This instruction supports integer and floating-point value which is represented by N7:0. The Input Minimum, Input Maximum, Scaled Minimum, and Scaled Maximum are used to determine the slope and offset values. The input value can go outside of the specified input limits and no order is required. The input value can be a work address or an address of floating-point data elements as input minimum should be 0 (zero) as address is I:1.0.

The details for each of the parameter is described as follows.

- Input Minimum and Input Maximum values determine the range of data that appears in the Input Value parameter. The value can be a word address, an integer constant, floating-point data element or a floating-point constant the input maximum should be raw value as 32767.
- Scaled Minimum and Scaled Maximum values determine the range of data that appears in the Scaled Output parameter. The value can be a word address, an integer constant, floating-point data element, or a floating-point constant the scale minimum and scale maximum should set according to level which we needed.
- Scaled Output value can be a work address or an address of floating-point data elements the output should be in integer as N7:0 Where N7 stands for integer value.

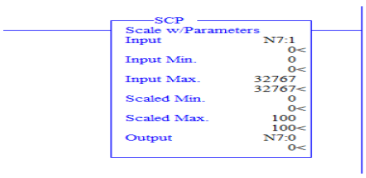

Figure 9. Scale with Parameter

IV. EXPERIMENTAL SETUP

The experimental setup of the entire project is shown in Figure 10. This set shows that chemical is fill in two sub tanks and pump into process tanks and level transmitter detect the level and mixing is start and then drain. The wiring connection of the Project is shown in Figure 11. Following table describes the input and output detail.

Table 1. Input and output Details

Inputs	Outputs
Start	P1-Pump1
Stop	P2-Pump2
Level Sensor	P3-Pump3
	M-Mixer

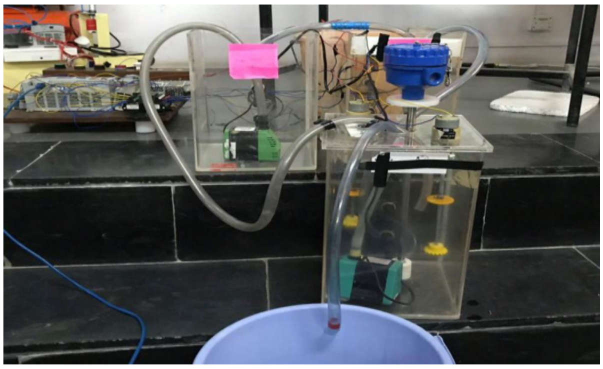

Figure 10. Experimental Setup of the Process

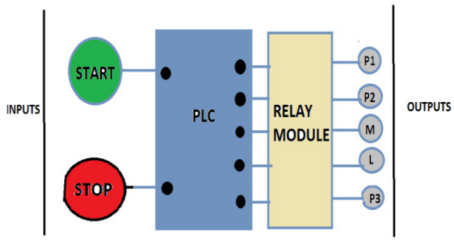

Figure 11. Wiring of components with PLC kit

The software logic shown in Figure 12 describes that pump 1 is ON up to level of 20% and pump 2 is ON up to level of 10% that means that tank 3 will fill the chemical up to 30%.

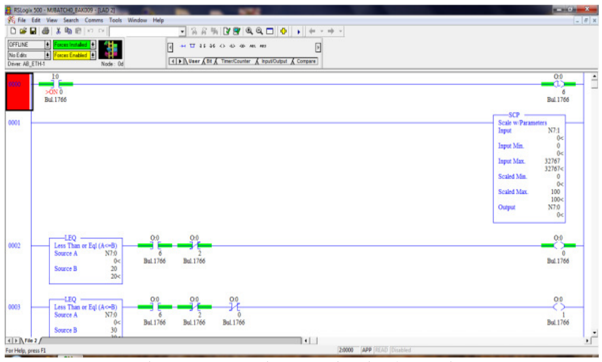

Figure 12. Logic to Maintain the Ratio

A logic shown in Figure 13 mixing is performed after the two pumps are OFF and then drain into the main process tank.

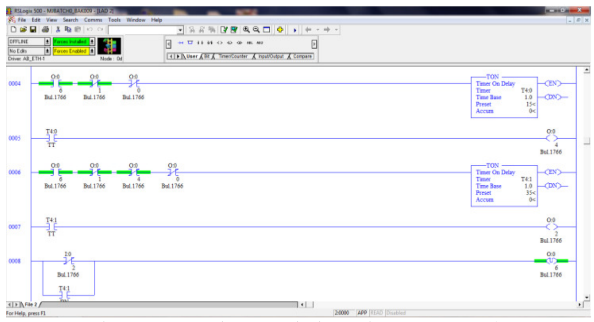

Figure 13. Logic to Drain in Main Process Tank

V. CONCLUSION

The system has provided to work effectively avoiding unnecessary spill or wastage of liquids. The system also provides high accuracy and precision in proportion in filling and mixing. Although the proposed system illustrates the mixing process of two liquids, any number of liquids may be mixed in varying proportions. It is true that the use of plc is a costly affair particularly for small industries but it offers many advantages that overcome its cost. Thus we intend to provide an experimental set-up for PLC and SCADA based mixing and control of stirrer tank. This setup aims at developing a low cost-effective automated system which may provide effective monitoring of the process. We can view, generate, report plots, alarm reporting as configured on the SCADA directly on the workstation or any other PC connected in the same network.

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