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Development of PLC Based Process Loop Control for Bottle Washer Machine

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Abstract

In this paper we are presenting a process loop that can be used in bottle washer machine. It is a holistic approach. Because wherever a control of liquid is required, it can be used. It can be used in chemical and oil industries also. Water is used for washing purpose in bottle washer machine. Total three parameters are controlled 1.level, 2.flow and 3.pressure etc. There is a very strong interaction in between these parameters. Pressure and flow are required to control for better washing. The aim is to maintain above listed variable by using Programmable Logic Controller (PLC). It increases efficiency and response time both. By modifying hardware this loop can use for bottle filler also. For that a valve is required at output side. Almost industry requirement is an output with safety. So, safety aspects are also considered in it. Different sensors and valves are used with PLC. They are controlled by a program. According to the program PLC generates different signals and valve is controlled. This way pressure, level and flow can control. As an extra feature a Human Machine Interface (HMI) is also connected. So, that user can change the set values directly.

Keywords: Process Loop, Pressure Control, Bottle Washer, Flow Control, Level Control, Loop Safety, Bottle Filler

1. Introduction

The process loop is used extremely in process industry like oil, gas, chemical, beverage etc. It maintains parameters of gas or liquid as per necessities. Process control technology is the tool that enables manufacturers to

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1. Introduction

The process loop is used extremely in process industry like oil, gas, chemical, beverage etc. It maintains parameters of gas or liquid as per necessities. Process control technology is the tool that enables manufacturers to
keep their operations running within specified limits and to set more precise limits to maximize profitability, ensure quality and safety.

We have designed a control loop that can be used in bottle washer machine. The system is designed for bottle washer machine. The output of bottle washer is around 30,000 to 170,000 bph (bottles per hour). To maintain a control of water, temperature and chemical composition is very important in this machine. Among them water control is very essential. Because machine uses thousands of litres water per day. With proper control we can save it. If these parameters imbalance, it will direct affect to product cost. So, parameters control is very essential in water cycle for this machine. There is a requirement of a flow with certain pressure. Otherwise it may damage water jets. Process loop fulfilled these requirements. Now in a modern era it is not efficient to use manual control techniques. It has a very low efficiency and accuracy. The old controlling device consumes more power,[6] For that a Programmable Logic Controller (PLC) can use. It is more efficient and makes a system automated.[7] The PLC is S7-300 with HMI (Human Machine Interface) of Siemens Corporation. It has advantage of the SCADA software, such as be rich in setting projects, convenient operation, friendly interface, be good at communication to PLC, energy saving and reduce the investment in manpower. Small changes in a process can have a large impact on the end result. So, controlled device should be very accurate.

2. Constitution of a Process Loop

The water flow is from tank-A to tank-B through pipe. In between it passes by some valves, sensor and pump. Tank-A is just a storage tank. So, we have given only On-Off type control to it. While in tank-B we have to implement a multivariable control for level, flow and pressure. Pump speed can change using electric drive.

![Flow Diagram of a Process Loop](image1)

When tank-A is full, LS-1(Level switch) gives a high signal. At this time a command will generate to turn off valve-1. As the level decrease from maximum, valve-1 will turn on again. Water will flows to tank-B. Flow will decrease as level increases in tank-B. To control the flow we have to close DRD valve at some limits. It is a flow control valve. Flow control can use for bottle filler machine. As DRD valve closes, pressure will generates inside the pipe because still pump runs on a same speed. So, we have to reduce a pump speed also. Whenever DRD valve closes, frequency will change from electric drive. It will control the pump. In any case pressure and flow exceed limit, pump speed will decrease. Level sensor continuous senses level of tank-B. All controls are generated by PLC.

![Hardware Setup](image2)

Safety aspects should also consider in designing. It prevents damage to the hardware.
1. An extra provision to stop the flow if DRD valve get failed. It will also useful when we want instant stop. Because DRD valve takes some time.
2. Care for liquid pressure inside the pipe.
3. If pump will run while tank-A is empty then a dry run may occurs and pump may get damaged.
3. Flowchart of a System

The water flow is from tank-A to tank-B through pipe. In between it passes by some valves, sensor and pump. Tank-A is just a storage tank. So, it has given only On-Off type control. While in tank-B we have to implement a multivariable control for level, flow and pressure. Pump speed can change by using electric drive.

![Flowchart of a System](image)

Here, PLC is used at place of control logic. It generates control signal according to the output of pressure sensor and level sensor. The control values are defined in below table.

<table>
<thead>
<tr>
<th>Tank-B water Level (%)</th>
<th>Motor speed (Hz)</th>
<th>DRD valve Open (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 to 10</td>
<td>42</td>
<td>90</td>
</tr>
<tr>
<td>10 to 35</td>
<td>37</td>
<td>60</td>
</tr>
<tr>
<td>36 to 75</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>75 to 95</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>&gt;95</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

In any case output flow should not exceed 5 m³/hr. If it crosses this value, pressure inside pipe will increase. So there is a chance to break the pipe. It can be defined by Hazan-Wilian equation.

\[
Q = (3.763 \times 10^{-6}) \times C \times D^{2.63} \times \left(\frac{\Delta P}{L}\right)^{0.54}
\]  

(1)

Where,

- \( Q \) = Flow in m³/hr
- \( C \) = Co efficient of material = 100 (cast iron pipe)
- \( D \) = Diameter of pipe (35 mm)
\[ \Delta P = \text{Differential pressure (5 bar)}; \ L = \text{length of pipe (4 m)} \]

From calculation we can get final flow \( Q = 5 \, \text{m}^3/\text{hr} \) and it can be seen from equation (1) that flow is direct proportional to differential pressure.

It is a multivariable process because at a time more variables are controlled. In industrial process most of complex systems can be found as a multivariable. This multivariable system can have such a complex interaction pattern that the adjustment of a single set point causes a profound influence on many other control loops in the process. PLC (Programmable Logic Control) can be a best option for it. It provides a control to valve/actuator as per programming [1].

4. Siemens S7-300

With the rapid changes in industrial automation and information technologies in current decades, the control of all equipments has been performed through the use of industrial computers.[4] Most applications use PLCs to connect with computers for monitoring and controlling loads. Total 256 inputs and outputs can connect with it. An extra CPU can also connect in series to increase range. The response time is 0.000075 ms. S7-300 is an average CPU in cost and provides better performance compare to others. The software called ‘Simatic Manager’ is used to write a program for PLC. Different languages are available to write the program.[8]

![Fig. 4 Inputs and Outputs of PLC](image)

In the process loop PLC has many inputs and outputs as shown in figure. Here, a motor is used for pumping purpose. Its rotation is controlled by Drive via PLC. DRD valve takes control action by combining all inputs. Though the calculation is done by the PLC, control action is done by DRD only. For the better control we can use P/PI/PID control in it. The function block fb-41 is provided for this purpose in PLC. It is a complex control but it gives desired efficiency and accuracy [9].

5. PI Control

The term PI means Proportional and Integral. The lack of derivative action may make the system steady in case of noisy data. This is because derivative action is more sensitive to higher-frequency terms in the inputs.[9]
**PI equation**

\[
CO = CObias + Kc \cdot e(t) + \frac{Kc}{Ti} \int e(t) dt
\]

Where,
- \( CO \) = controller output signal (the wire out);
- \( CObias \) = controller bias or null value;
- \( e(t) \) = current controller error;
- \( SP \) = set point;
- \( PV \) = measured process variable (the wire in);
- \( Kc \) = controller gain;
- \( Ti \) = reset time

**PI algorithm** works as per error signal. Level, pressure, Flow values are entered as measured variables. PI control adjusts the system pressure and flow according to the level change in tank-B. [13] Speed of pump will control via analog interface of PLC. We have used Variable Frequency Drive (VFD) to change frequency. PLC continuous monitors the storage tank and according to that it gives control signal to valves and save the motor from dry run.

6. **Human Machine Interface (HMI)**

Human machine interface is the part of the machine that handles the Human-machine interaction. In complex systems, the HMI is typically computerized. The software named ‘WinCC Flexible’ is used for programming. Output addresses of PLC have to be tagged in it.

![Configured parameters on HMI](image)

6. **Technical Configuration**

<table>
<thead>
<tr>
<th>Table 2. Components Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
</tr>
<tr>
<td>PLC</td>
</tr>
<tr>
<td>Level Sensor</td>
</tr>
<tr>
<td>Level Switch</td>
</tr>
<tr>
<td>Drive</td>
</tr>
<tr>
<td>Flow Control valve</td>
</tr>
<tr>
<td>Pump</td>
</tr>
<tr>
<td>Flowmeter</td>
</tr>
<tr>
<td>Pressure Sensor</td>
</tr>
</tbody>
</table>
8. Programming Example

In this section a program is included for level and pressure control. It gives idea about various controls for valves and pump speed. Simulation images are also included.[3]

Water level and pressure control with PLC using FBD (Functional Block Diagram) language

Pins used in PLC are described below.
PIW128 = Level Sensor, PIW132 = Pressure Sensor, PQW128 = Centrifugal PUMP

Fig. 7 (a) As start switch pressed monitor bit will set, (b) Butterfly valve-1 will on if water level below maximum in tank-A, (c) Butterfly valve-1 will off at maximum level of tank-A, (d) When minimum level detects in tank-A, pump will off (0 rpm) and valve-2, 3 become close, (e) Valve-2, 3 will remain open till level in tank-B reach at particular limit, (f) With the reference of fig. 4.e logic, pump will start and speeds will 23000 rpm. Pump condition can be recognized from bit M100.0. It will show whether pump is on or off, (g) If pressure goes beyond certain limit, pump speed will decrease at 20,000 rpm. So, pressure will decrease automatically
9. Simulation Windows

In Siemens S7-300, there is a provision for viewing parameters. Hardware connection is compulsory for that. They provide all data in ‘Variable Table.’ The pins used in PLC have to be specified in the table and it will give the status of that pin in Boolean/decimal/hexadecimal.

Here, 3 tables are shown in figures. The on/off control and data change can be seen in it.

Fig.8 (a) It shows that water in tank-A is at maximum level. So, butterfly valve-1 becomes off and at the same time valve-2, 3 sets in on position, (b) Level in tank-B is increasing, (c) Stop switch pushes down to all devices shut.

10. Conclusion

The aim of this project is to implement a process loop with an efficient control. Now days, industry requirement is an optimize output with accuracy. Required output in bottle washer machine is generally 30,000 to 170,000 BPH (Bottles Per Hour) in beverage industry. With these high numbers, to maintain accuracy becomes more complex. The use of conventional control in this case becomes quite undesirable here. So, PLC is the best solution for better output. To work with Siemens s7-300 gives much advantage like high response time, user friendly software (different programming languages) and provision for HMI etc. We have attached the HMI also. When there is a need to change in logic, HMI makes work very easy. Logic can be changed without using Simatic Manager. Safety also plays a major roll. Without safety there is a chance of damage device in various conditions. So, by taking care of all these aspects an efficient process loop can be developed.

References

[9] Yan Li, Chonghe Tang, Keping Liu, PID parameter self-setting method base on S7-1200 PLC
[10] Programmable Controllers Theory and Implementation, by Luis A. Bryan, Eric A. Bryan
[12] Lessons In Industrial Instrumentation, by Tony R. Kuphaldt