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AUTOMATION IN FERMENTATION PROCESS USING PLC-SCADA

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Abstract*—Fermentation is a metabolic process that converts sugar to acids, gases and/or alcohol. It occurs in yeast and bacteria, but also in oxygen-starved muscle cells, as in the case of lactic acid fermentation. Fermentation is also used more broadly to refer to the bulk growth of microorganisms on a growth medium The project titled "Automation in Fermentation Process" deals with controlling & monitoring major loops encountered in the Industrial Fermentation Process. Fermentation is a key process in Pharmaceutical Industries, Food & Beverage Industries etc. This project presents a scheme for controlling the major loops in fermentation process. Controlling and automation of the Fermenter is done using Ladder logic developed in Programmable Logic Controller. The project consists of four major loops encountered in the fermentation process. The following loops are involved: Introduction of media in the fermentation, sterilization of the media, pressure control in the fermenter, harvest and drain. PLC is used for maximum automation of the process. The PLC is programmed in Ladder logic. SCADA software is used to give a virtual display of the proposed system. The end system is a fully automated fermentation system for industrial application.

I. INTRODUCTION

Industrial Fermentation is the intentional use of fermentation by micro-organisms such as bacteria's & fungi to make product useful to humans. Fermentation is a process of conversion of sugar or glucose into acids (lactic acid) or acetates. This is usually done by introduction of various microorganisms, bacteria, yeast etc. Into the process the bacteria which are introduced in the process secrete enzymes which result in the fermentation process. The bacteria take some time to adapt to the medium in which they are introduced. This period is known as lag phase. After lag phase, there is rise in the growth rate of bacteria. This growth is observed to be exponential in nature.
After a certain level of growth is achieved, there is a decrease in the growth rate. This is due to the lack of nutrients required by the bacteria for the fermentation process thus, a steady state is achieved after a fall in the growth rate.

Hence the fermentation process is complete. Fermented products have applications food as well as in general industries.

II. LITERATURE SURVEY

Fermentation is required in pharmaceutical Industry, chemical industry, food industry etc. The sterilization of fermenter tank is usually done manually. Manual work and errors would be reduced if such a process is automated. Traditionally the heating cooling of the tank required for sterilization was supervised by humans on the actual site. Is required in pharmaceutical industry, chemical industry, food industry etc. Collection of the Harvest as well as the drain required human intervention. In the proposed system, all the above parameters monitored as well as controlled using PLC. SCADA is used for visual representation of the ongoing process.

III. HARDWARE

A. P & ID

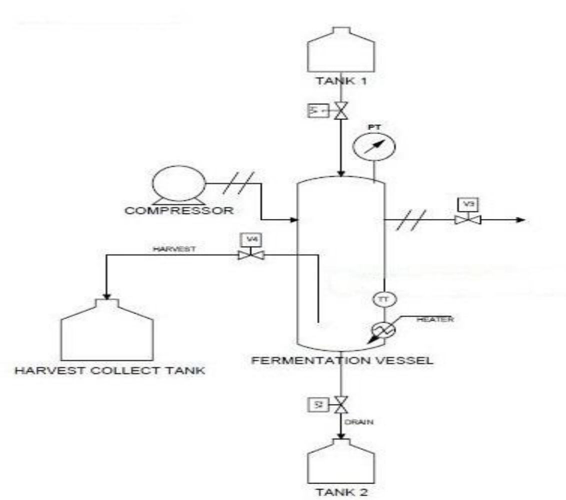

Fig. 1: Piping & Instrumentation Diagram of the Proposed System

B. Construction

It consists of a Fermentation Vessel, Input reservoir tank, drain collection tank & Harvest collection tank, which are interconnected through various pipe fittings & control valves. A heater is placed at the bottom end of the fermentation vessel along with a Temperature Transmitter. A Pressure Transmitter is placed at the top end of the vessel along with a Pressure Gauge. All the process control components are interfaced to PLC through proper wiring, for automatic controlling & monitoring. The main Fermentation vessel is made up of Stainless- steel material, which is best suited for the process as it does not react with the media i.e. the fluid to be fermented. Stainless-steel is chosen such that it can withstand the pressure developed inside the vessel during the process, by oxygen pump. The flow of fluid entering and leaving the fermentation vessel during the fermentation process is controlled through the solenoid valves. The size of the solenoid valves chosen is 0.25 inch. Also, the pipe material used for the fluid flow is PVC type and the size is chosen to be of 0.5inch.The valves & pipes being different in size, are connected through the brass connecters.

C. Working

On starting the automation process, liquid to be fermented present in the input reservoir tank enters the fermentation vessel through solenoid valve V1 which is controlled through the timer program developed in the ladder logic of PLC programming. The second step in the process after introduction of the liquid in the vessel is that, the temperature of the liquid is raised to the set point temperature in order to carry the sterilization of the liquid to be fermented. Sterilization ensures that all the unwanted organisms are made inactive. This is done by the temperature loop installed into the vessel which consists of a Heater (HT), a Temperature Transmitter (TT) etc. Once the media is sterilized, it is dosed with the organisms which actually ferment the media.

After the heater is switched off by contactor and the media is dosed, this liquid is filled with a pressurized oxygen maintained at pre-calculated Set point in order to carry out the fermentation effectively. Oxygen is essential for the growth of the bacteria and hence, for the fermentation also. This is done by controlling the input air coming from the compressor attached in the upper left side of the vessel through the control valve V2. A Pressure Transmitter (PT) installed on the upper end of the vessel helps in monitoring & controlling the pressure to be maintained inside the vessel, through pressure control loop. A pressure gauge is attached on the upper side of the vessel, for indication of the inside pressure.

Further, a constant pressure is maintained inside the vessel for a prescribed time interval which is required for fermentation after which the control valve V3 is opened, which allows the fermented liquid to pass to the harvest tank through the dip tube inserted inside the tank for the collection of the end product. The fermented liquid is actually forced through the dip tube by the pressure developed by the oxygen pump. Also, the pressure of the pump forces the drain out of the tank. Solenoid valve V4 is used for the collection of the drain in the drain tank situated at the bottom, below the fermentation vessel. The opening and closing of all the solenid valves is con- trolled through a PLC.

D. Flow Chart

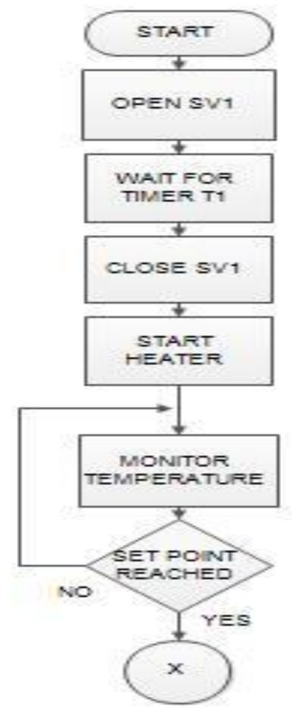

Fig. 2: Chart: 1

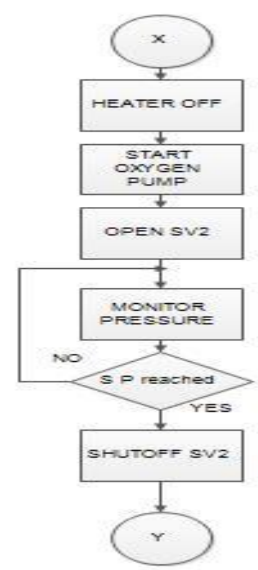

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Fig. 3: Chart: 2

Fig. 4: Chart: 3

E. Design Calculations

1) Tank calculations:
Radius of the Fermentation vessel(r) = 0.17m
Height of the Fermentation vessel(h) = 0.41m
$V = \pi \times r2 \times h$
V = 38 L
Volume to be Fermented = 15 L
So, head of liquid in vessel (h_1) = 0.16 m

2) Sterilization Calculations:
$Q = m \times C_p \times \delta t$
where, Q = heat required(kJ),
m = Mass of water = 15 kg
δt = differential temperature
C_p = 4.19K/J Hence, Q = 2514 Kj
Heater rating(Q_W) = 2 kW
So, Time required for sterilization(t) = 2514 s = 20 mins

3) Flowrate Calculations:
$m \times g \times h = 0.5 \times m \times v^2$
$v = (2 \times g \times h)^{0.5}$
where, h = 0.25m
$g = 9.8\ m/s^2$
v = 2.21m/s
Now, Cross sectional area of pipe(A) $= \pi \times r^2$
r = 0.003 m
So, $A = 28.26 \times 10^{-6}\ m^2$

Flowrate of liquid from tank1 (F) = v × A F = 225 lph

IV. SOFTWARE

A. ALLEN BRADLEY PLC

Programmable Logic Controller or PLC is an intelligent system of modules, which was introduced in the control and instrumentation industry for replacing relay based logic. Over a period of time, better I/O handling capabilities and more programming elements have been added along with improvement in communication. Basics of a PLC function are continual scanning of a program. The scanning process involves three basic steps.

Step 1: Testing input status
First the PLC checks each of its input with intention to see which one has status on or off. In other words it checks whether a switch or a sensor etc., is activated or not. The information that the processor thus obtains through this step is stored in memory in order to be used in the following steps.

Step 2: Programming execution
Here a PLC executes a program instruction by instruction based on the program and based on the status of the input has obtained in the preceding step, and appropriate action is taken. The action might be activation of certain outputs and the results can be put off and stored in memory to be retrieved later in the following steps.

Step 3: Checking and Correction of output status
Finally, a PLC checks up output signals and adjust it has needed. Changes are performed based on the input status that had been read during the first step and based on the result of the program execution in step two ? Following execution of step three PLC returns a beginning of the cycle and continually repeats these steps. Scanning time = Time for performing step 1+ Time for performing step 2+ Time for performing step 3.

B. Input-Output Configuration for PLC

1) Input Configuration
- Start, Stop and Emergency stop
- Temperature transmitter (Analog signal 4 - 20 mA)
- Pressure transmitter (Analog signal 4 - 20 mA)

2) Output Configuration
- Solenoid valves (4 digital outputs)
- Heater (contactor switching)

3) Total 2 Analog Inputs and 5 Digital Outputs are required for the given system

C. SCADA

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. It is used to monitor and control plant or equipment. The control may be automatic or initiated by operator commands. The data acquisition is accomplished first by the RTUs scanning the field inputs connected to the RTU. This is usually at a fast rate. The central host will scan the PTUs, the data is processed to detect alarm conditions, and if an alarm is present, it will be displayed on special alarm lists. Its function is to control process equipment at the remote site, acquire data from the equipment, and transfer the data back to the central SCADA system.

Proficy software enables you to configure a system environment that provides: Supervisory control, batch processing, data acquisition, continuous control, and statistical process control for industrial applications.

D. Interfacing

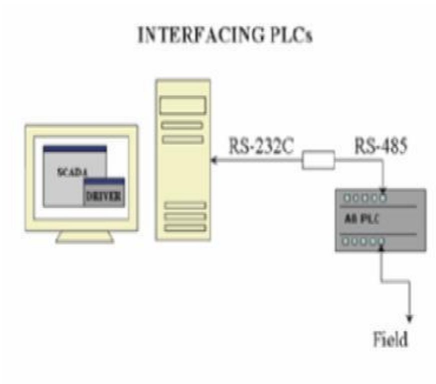

Fig. 5: Interfacing Diagram PLC

V. RESULT ANALYSIS

Automatic execution & control of fermenter is carried out successfully. The various loops involved give us the desired results. With the use of PLC-SCADA, the system is working satisfactory.

VI. CONCLUSION

For Fermentation process based on programmable logic controller has got faster execution time and is more efficient in working along with safety measures to give the desired results and ease in operation. Due to relay contactor logic, more hardware is required as well as wiring is more complex which has now been overcome by present PLC machine. The present system is superior in both performance and is more flexible in operation. Moreover the running time has got shortened. Thus desired requirement of industry has been fulfilled by this automation.

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