A Review on Design of Bottling Plant and its Automation

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***Abstract* - As per today's scenario of frequent improvement in technology in bottling industry, interdisciplinary principles of machine design and its automation are taken into account in order to improve efficiency and productivity which is necessary for competence. Machine design and automation is a comprehensive technology that studies design, operation control and production process of all kinds of industrial machinery equipment and mechanical-electrical products. One can easily handle the various parameters of the system when all the variables required to complete the task can be adjusted at will to vary them according to the need. Automation makes the whole process more user friendly. This paper gives a review on design of automated bottling system and teaches us the prerequisites to acquire this system.**

Keywords- PLC- Programable Logic Control, EFEU- Efficient Energy Use, SMPS- Switch Mode Power Supply, Fcr – Critical Load, Hydro-charger

I. Introduction

Machine design and its automation is an extensive technology that features the design and operation control of all kinds of industrial machinery equipment and mechatronic product. Machine design and automation takes machine design and manufacturing as the basis, the interdisciplinary subject integrating computer science, information technology, automatic control technology. And main task is using advanced design manufacturing technology theory and method, to solve the complicated technical problems in the field of modern engineering, in order to realize the intelligent product design and manufacturing. These have a wide range and should be used while developing, selecting and controlling machine design. It has broad applications from filling small containers to lifting heavy objects.

EFEU's (Efficient Energy Use) research (It is a closed cooperation between universities and equipment manufacturers to enhance fluid handling systems) focuses on improving fluid handling systems with help of advanced controlling methods and also enhancing next generation equipment such as pumps, power packs and hydro charger. Bottling systems account for the considerable part of industrial electricity consumption in electric motors. A systems-level or interdisciplinary principle approach is used for individual component efficiency.

The purpose of this review is to introduce the flexibility of fluid handling systems and automation. Traditionally it has been difficult to use automation in small batch production with high variation in volumes and high mix of products. However, this is changing as there exist new types of flexible automation techniques. The purpose of this paper is to review the requirements of enterprises to use automation in various production batches.

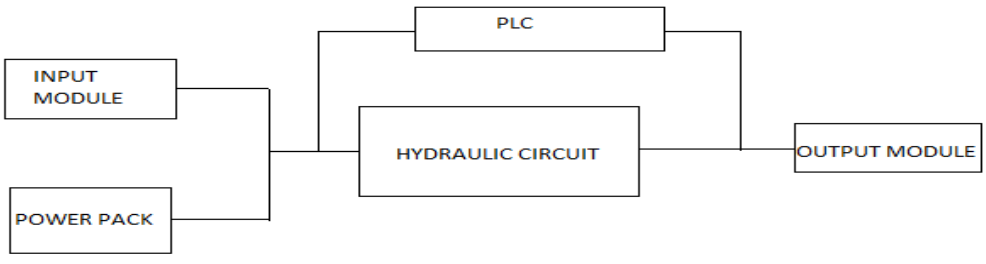

Fig1. Block diagram of Fluid handling system

II. Hydraulic Circuit Design

The basis for all hydraulic systems is expressed by Pascal's law which states that the pressure exerted anywhere upon an enclosed liquid is transmitted undiminished, in all directions, to the interior of the container.

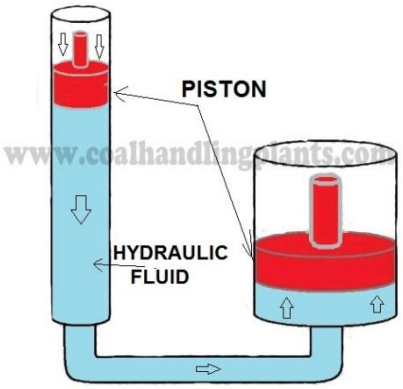

Fig2. Basic hydraulic system

In a basic hydraulic circuit, the force exerted by a cylinder is dependent upon the cylinder bore size and the pump pressure. The simplest hydraulic circuit consists of a reservoir, pump, relief valve, directional control valve, single acting cylinder, connectors and lines. This system is used where the cylinder piston is returned by mechanical force. With the control valve in neutral, pump flow passes through the valve and back to the reservoir. With the valve shifted, oil is directed to the piston side of the cylinder, causing the piston to move, extending the rod. If the valve is returned to neutral, the oil is trapped in the cylinder, holding it in a fixed position, while pump flow is returned to the reservoir. Shifting the valve in the opposite direction permits the oil to pass through the valve back to the reservoir. The relief valve limits the system pressure to a pre-set amount. Relief valves are commonly incorporated into the directional control valve.

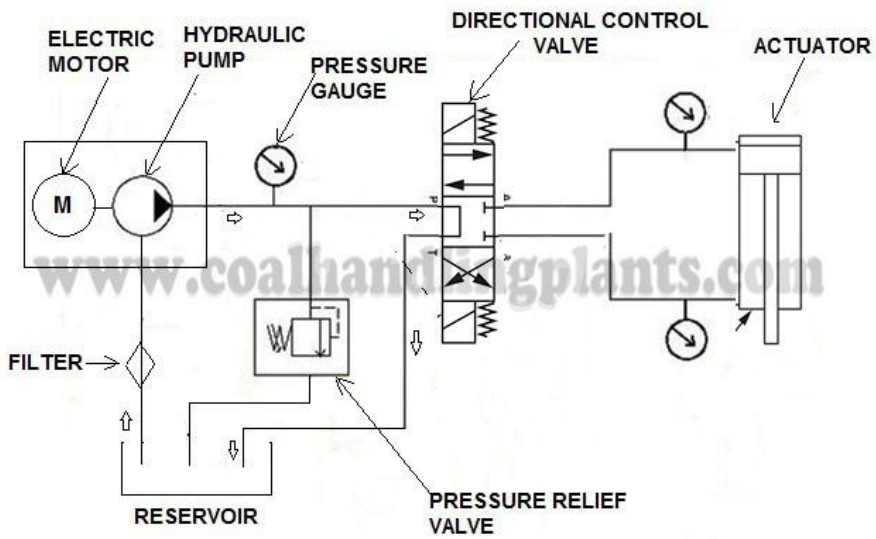

Fig3 Introduction to Hydraulic Circuit

A hydraulic system using a double acting cylinder can exert force in both directions. With the control valve, neutral flow is returned to the reservoir. When shifted in one direction, oil is directed to the piston side of the cylinder, causing the cylinder to extend. Oil from the rod side passes through the valve back to the reservoir. If the valve is shifted to neutral, oil in the cylinder is trapped, holding it in a fixed position. When the valve is shifted in the opposite position, oil is directed to the rod side of the

cylinder, causing the cylinder to retract. Oil from the piston side passes through the valve back to the reservoir. Cylinder extend force is the result of the pressure (psi) times the piston area (minus any force resulting from the pressure acting against the rod side of the piston). Retract force is a result of the pressure (psi) times the area difference between the rod and the piston (minus any force resulting from pressure acting against the piston side of the cylinder).

Consider a simple hydraulic circuit for PLC operated bottling plant.

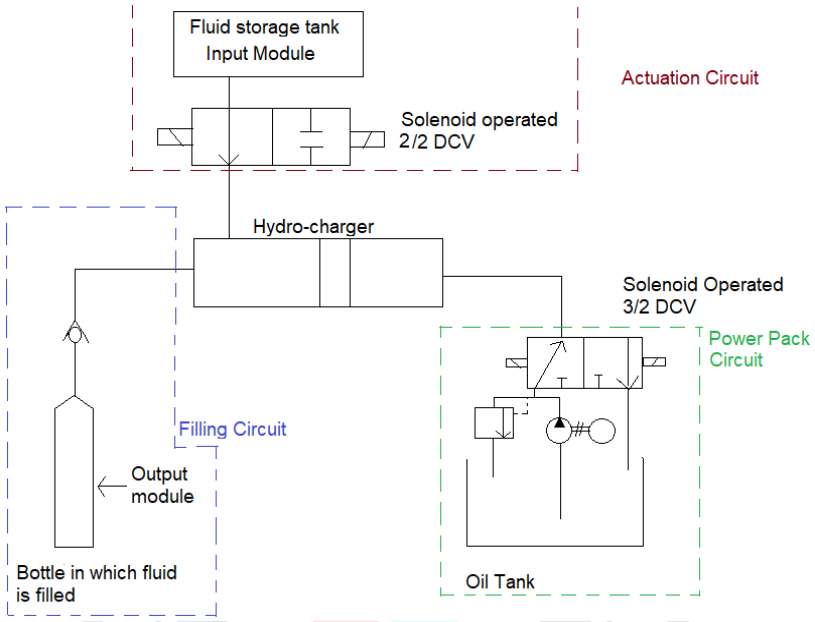

Fig.4 Hydraulic Circuit for bottling plant

The hydraulic circuit for fluid filling/ bottling plant can be divided into four parts: -

A. Power pack Circuit
B. Actuation Circuit
C. Filling Circuit
D. Hydro-Charger

A) Power pack Circuit- The power pack circuit comprises of oil tank, electric motor, coupling, pump and pressure relief valve. The oil tank is designed considering the space constraints and the volume of oil should suffice the amount of pressure required in the hydro-charger. A coupling is connected to electric motor on one side and to the pump on the other. The pressure relief valve is connected to the pump which is placed on the tank. The use of pressure relief valve is to release excess pressure when the pump exceeds certain pressure limit. The DCV used in powerpack system is operated by PLC.

B) Hydraulic Actuation Circuit: Actuation circuits consists of direction control valves, check valves, pressure relief valves and flow control valves which are driven by low grade and easily available fluids. A direction control valve serves the requirement of fluid flow into different path from one or more sources. A flow control valve is used to control the flow of fluid. A pressure relief valve is a type of safety valve used to control or limit the pressure in the system; pressure might otherwise build up and create a process upset or equipment failure. Check valve is a valve that normally allows fluid to flow through it in only one direction. Since the fluid which drives this circuit is not necessarily be taken under consideration in design aspect.

C) Filling System: The filling circuit comprises of various components like DCVs, FCVs, check valves which ensures the filling of liquid in bottle/output module in which the fluid is to be filled. Various valve can be used to vary logics so that various parameters of liquid flow can be manipulated accordingly. These valves are usually spring return, solenoid or pilot operated.

D) Hydro-Charger: Hydro Charger is a piston-cylinder arrangement used to pressurise and push the fluid to be filled in required container. It is available in various types, such as single acting cylinder and double acting cylinder. The hydro-charger used is a reciprocating / positive displacement type of hydro-charger. The flow in positive displacement hydro-charger is unidirectional which gives maximum pressure at its output whilst in hydro-dynamic cylinder, the discharge is variable and the pressure is constant but, the flow is bi-directional if the delivery outlet is closed. Following are the formulas and illustration of design of a hydro charger used in a circuit.

We know that Euler's critical load

Fcr = $(\pi^2 E I)/ L^2$ *[E=Young's Modulus*

I = $(\pi d\text{^}4)/64$ *I = Moment of inertia of rod*

D = 2.5d (Empirical) *d = Piston rod diameter*

Di = D+5 (Empirical) *D = Piston diameter*

Di = Internal diameter of cylinder]

For thin cylinder

$\sigma_t = \frac{Pi\ Di}{2t}$ *t = Thickness of cylinder*

Pi = Internal Pressure

σ_ ( )=Tensile stress

For thick cylinder *. . . (Clavation's equation)*

$t = \frac{Di}{2}\left[\frac{\sqrt{(\ \sigma_t + (1-2\mu)Pi)}}{\sqrt{(\ \sigma_t - (1+\mu)Pi)}} - 1\right]$ *μ = Poisson's Ratio*

Illustration 1. Consider a system having stroke length L=250 mm of the cylinder. Design a hydro charger for an output pressure of 200MPa. Piston rod diameter is 21mm. (Consider the cylinder to be thin)

Calculating diameter of piston rod using buckling equation-

Table 1. Given data

Maximum Pressure (P)	200 MPa
Stroke Length (L)	250 mm
Young's Modulus (E)	205 GPa

Fcr = $(\pi^2 E I)/ L^2$ = 309.04 N *E=Young's Modulus*

I = $(\pi$ d^4)/64 = $(\pi$ (21) ^4)/64 = 9546.56 mm^4 *I = Moment of inertia of rod*

D = 2.5d …(Empirical) *d = Piston rod diameter*

= 52.5mm ~58mm *D = Piston diameter*

Di = D+5 …(Empirical) *Di = Internal diameter of cylinder*

= 57.5mm ~63mm (Catalogue standard selection)

For thin cylinder

$\sigma_t = \frac{Pi\ Di}{2t}$ *t = Thickness of cylinder*

t = 3.07mm is required thickness.

Table 2. List of Manufacturers of Hydro-charger[10]

Sr no	Manufacturers	Images
1.	Bosch Rexroth	
2.	Kawasaki	
3.	Daikin	
4.	Eaton Corporation	

III. Automation:

Current scenario of a product-based industry is that all of them are focusing on high speed and quality of production. And, also, all of them are introducing the concept of automation. Automation is the technology of making any process less reliable on human interaction. Automation of a system can be done by adding various control systems which will manipulate the system parameters according to the need. These systems can be operated for range of machines like Hydraulic press, Fluid handling system to a thermostat controlling boiler temperature.

Automation can be achieved by various by various mediums. Two of them are given below-

A. Programmable logic control (PLC)
B. Microcontroller

A) Programmable Logic Control: It is a logic-based control system that gives the commands to the system programed by the manufacturer. This system is easy to program and is more reliable than any other mode. They are available at a meagre rate and can easily be reprogramed. A ladder diagram is formed to fix the logic for PLCs'.

Fig.5 PLC Controller [7]

B) Microcontroller: A microcontroller is also a control system used in various process to handle the various input parameters of an automatic machine. It consists of programing of higher-level programming languages such as "C" and assembly. For this the program is written in an IED software. This system is way more expensive than the other one and also needs more knowledge of high-level programming languages. This is the reason it is not used in many projects.

Fig.6 Microcontroller [8]

IV. Automation in Fluid Handling Systems

A fluid handling system as stated in earlier sections is the combination of hydraulic and pneumatic components to move different fluids with controlled parameters. These systems are being automated due to their need of accuracy in results and processing speed. These systems are used in chemical, pharmaceutical and various industries to fill the required fluids in specific quantities and at various physical conditions etc. To achieve these precise results, automation has been introduced in the industries. A common interface for automation in this field is the PLCs. A basic diagram shown below depicts how it is integrated in the system.

A) PLC in Fluid Handling Systems: A PLC is used to govern the various processes being performed in the circuit**.** A ladder diagram is fed to the system according to the need of the system. A ladder diagram is a graphical representation of the programmed logic which is fed. It has components like Normally ON/OFF switches, timers, coils, etc. which feeds information to the outputs namely motors, solenoids and instructs these elements to activate/deactivate. A typical ladder diagram for running a motor is shown below.

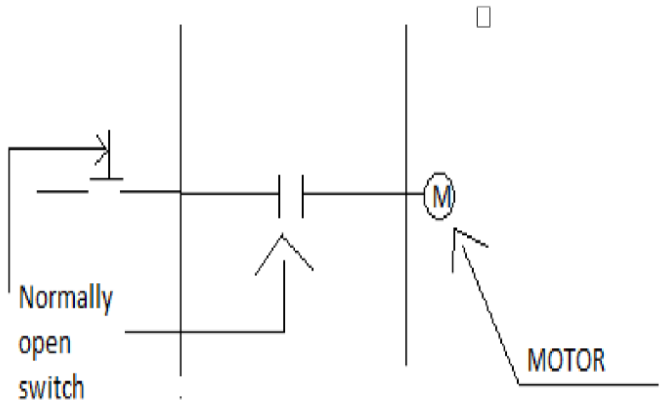

Fig. 7 Ladder Diagram for motor

Table.3. List of Manufacturers of PLCs [5]

Sr No.	Manufacturer
1.	Siemens
2.	ABB
3.	Schneider (Modicon)
4.	Rockwell (Allen-Bradley)
5.	Mitsubishi
6.	GE-Fanuc
7.	Omron

B) PLC PANEL: The PLC used in any system is accompanied by a set of devices which are used to connect input and output terminals such that all the requirements, like energy rating and fluctuation in inputs are taken care of. A current of very high voltage or an uneven power source can result in malfunction of the system. These types of breakdown could hit the production line with major loses. So, to avoid these problems, one has to understand few aspects of physical circuitry of the PLC panel.

A few basic components of this panel are stated below:

1. Input/output ports
2. SMPS (Switch Mode Power Supply).
3. Line Filter
4. PLC
5. Transformer

The SMPS is a device used to step down the current voltage from input source to the device rating and the line filter is used to nullify the effects of fluctuation of current from the source. A PLC is the device where the logic will be filled using various software and transformer is usually used to provide the neutral line to the system. These are some of the pre-requisites of the PLC panel.

C. Understanding The ladder logic: A ladder logic can be easily understood by any common person with basic engineering knowledge. It's this property that makes the system more favorable to everyone. Consider a hydraulic system as shown below.

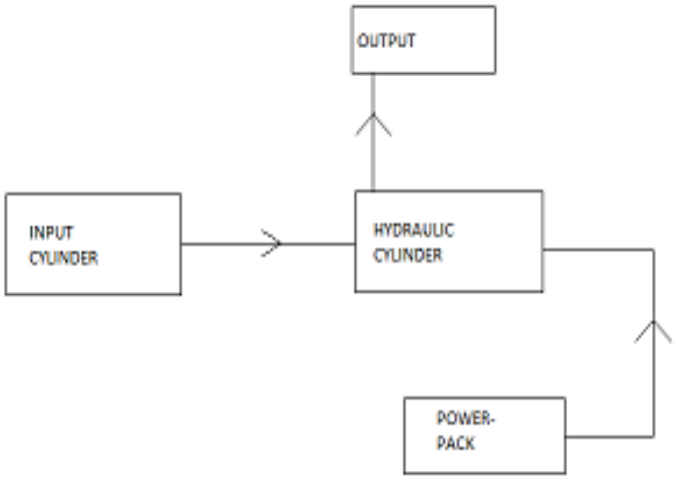

Fig.8 Block diagram of hydraulic circuit

Now the usual working sequence of this circuit will be:

1. The liquid enters the cylinder from pressurized container
2. After the cycle period, the PLC will stop the liquid inlet and start the motor to pump the hydraulic oil inside the cylinder
3. Once the cycle time of motor is completed the motor stops and the liquid is filled in the container
4. The cycle continues till the whole target is achieved

A ladder diagram is shown below for the particular operation stated as above.

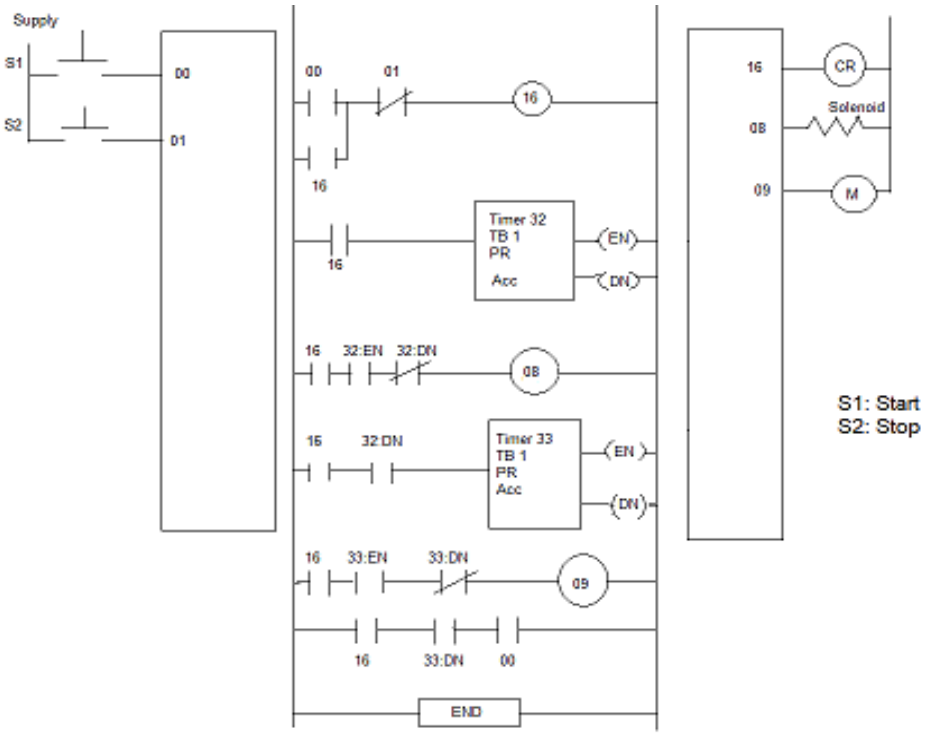

Fig.9 Ladder Diagram

V. CONCLUSION

The review gives us a brief idea of various design aspects of a bottling system. The study taught us about Hydraulic Circuit Design and its components. This study also helped us about the design of one of the major component that is the hydro-charger .It is an important knowledge to know how to design and select the size of various components of a hydraulic system or it may result in oversizing of the whole system which is a major factor for loss. Automation of this system have turned them into more precise and productive investments. Use of this automated Fluid Handling System have increased and are being used in most of industries as Special Purpose Machine for various purpose. We conclude from the review that the hydraulic and pneumatic system have got safer, compact and more approachable than earlier. The design and manufacturing of this system have been easier than they were earlier.

Acknowledgement

This review is supported by ICIIIST foundation. We thank our colleagues from Shree Systems Pvt. Ltd. who provided an insight and expertise that greatly assisted the review though, they may not agree with all the interpretations and conclusion of the review. We also thank our colleagues from Smt. Kashibai Navale College of Engineering, Pune for their valuable guidance. We also offer sincere gratitude for the support from friends and family.

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