Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

Design, Control and Automation of Well Head Control Panel

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***Abstract*-Crude oil is a naturally occurring, unrefined petroleum product which composed of hydrocarbon deposits. It can be refined to produce various types of products such as gasoline, diesel and various forms of petrochemicals. Crude oil is recovered mostly through drilling. A well head is a component which provides an interfacing platform between the drilling and production equipment .The underground crude oil of heavy pressure can be drilled and converted into controlled pressure using the well head and further control and automation can be done by a Well head control panel consists of PLC and SCADA system.**

Index terms- Christmas tree, Well head control panel

I. INTRODUCTION

A well head is also called as Christmas tree which contains an assembly of several spools, fittings and valves and it got its name because of the crude resembles to a decorated tree. A Christmas tree mainly equipped with four or five different types of hydraulic valves. Sequential opening and closing of these valves are done by well head control panel (WHCP). The valves are,

- SCSSV(surface controlled subsea safety valves or Down Hole valve)
- SSV(surface safety valves) which consist of the following valves.
  - Master valves(MV)
  - Wing valves (WV)

Lower most master valve will be manually operated, and the upper master valve is normally hydraulically actuated. The right most wing valve is called flow wing valve. Since it is in the flow path of hydrocarbons which are taken to production facilities it is also called production wing valve. The left hand wing valve is the kill wing valve which is used for the injection of fluids like corrosion inhibitors etc.

Hydraulic tree valves require active hydraulic pressure to stay open.Fig.1 shows the Christmas tree.
Usually WHCP is placed about 100 meters away from the well head and the Hydraulic or pneumatic output from the panel is connected to well head through properly sized tubes. Types of wellhead control panels:

- Pneumatic/hydraulic WHCP
- Electro/hydraulic WHCP
- Modular multi well WHCP
- PLC based electro-hydraulic WHCP
- Solar power WHCP.

Here in this paper PLC based electro hydraulic well head system is designed to meet functional safety, complete integrity high degree of reliability, availability etc.it combines PID control, high level logic sequence function, shut down functions, online fault monitoring, Diagnostic, Alarm& SCADA/RTU functions. When compared to other types, it has best possible system Architecture, programming and application software and IEC safety standards certified hardware and software configurations. HMI touch screen display will provide a user friendly environment by showing data/graphics, recorded history etc. This project aims to design, control and automation of an electro hydraulic well head control panel by sizing the components such as pumps, tank, tube and accumulator according to the customer need.

The paper is constructed as follows: section II describes the PLC based electro hydraulic WHCP. Section III is devoted to sizing of the components accomplished in the system. Design and implementation is explained in section IV and section V is the control and automation of the WHCP with PLC system. The paper ends up with the conclusion and future scope of section VI.

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Fig.1. Christmas tree

II. PLC BASED ELECTRO HYADRAULIC WHCP

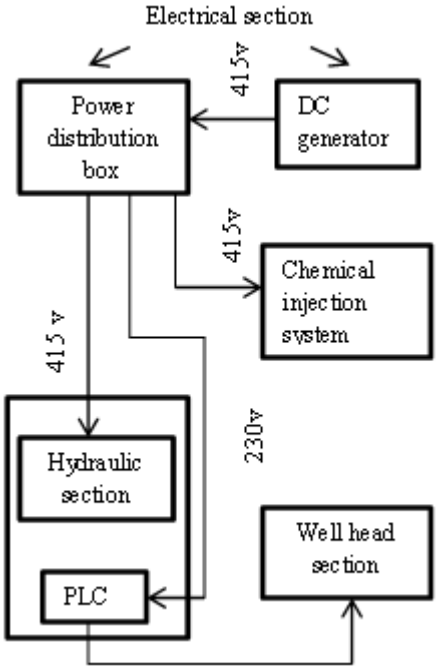

Fig.2:Block diagram of Well head control panel

i. Electrical sections

This section supply the necessary electric power to generate the hydraulic power for the functioning of the entire system.

ii. Hydraulic power unit

The section includes the hydraulic power generation needed to operate the valves of the WH for flowing the crude out. The following components take part of the same.

- Hydraulic reservoir

Provide sufficient quantity of oil to operate a wellhead. It is generally an atmospheric tank with flame arrester venting. Based on the parameters and safety measures the size varies.

- Hydraulic Pump
  It can be electrically driven and followed by non-returning valve, to drive the flow to a single direction.
- Filtration system
  To clean up the oil from the reservoir.
- Accumulator
  To ensure the hydraulic demand from the valves achievable, and to lead the pump supply quickly
- Pressure and level gauges, transmitters, and switches are provided to facilitate local monitoring and control.
- Pressure regulators
  To supply the regulated steady pressure to the each hydraulic loop.
- Pressure relief valves
  To ensure the safety from over pressure.

Fig.3. Well head control panel

iii. Well control section

This is the brain of the system and design of this section depends on the operating parameters and all control signals for the operation of the actuators.

iv. Chemical injection system (CI)

To inject corrosion inhibitors, production team will decide which chemical is to be used. Reciprocating pumps are tuned as required by the process and fills the tank. Fig.2. shows the block diagram of the WHCP. Fig.3. indicates the Well head control panel.

III. SIZING OF THE COMPONENTS

To obtain the controlled and sequential operation of well head proper sizing of the components are required. Sizing of accumulator, pump, tube and tank should be done. A user friendly platform in excel VBA allows the user to specify their requirements as input data.

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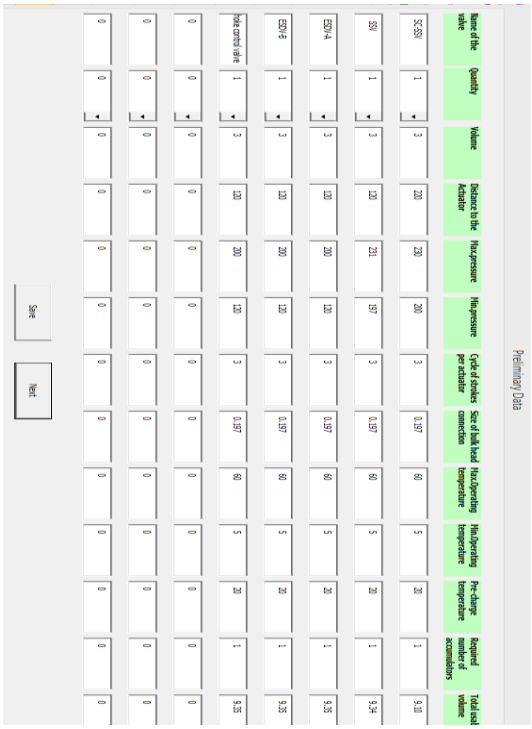

Fig.4. VBA user form for input parameters

According to the input parameters the system automatically calculate the correct sizing of the components needed. Thus reduces the manual calculation time, efforts and minimizes the error. The calculated values get saved and updated in the spreadsheet each and every time when the software is used. Screenshot of the application's initial page, is as shown in the Figure.4.Input parameters sample, containing 4 valves, taken to meet one customer requirement is included in Table1.

Table1. Input parameters

Name of the valve	ScSSV	SSV	Wing valve	Choke valve
Quantity	1	1	1	1
Volume	200 ml	3 lit	3 lit	3 lit
Max. pressure	230 bar	231bar	200 bar	200 bar
Min. pressure	200 bar	197bar	120 bar	120 bar
Max. temperature	60	60	60	60
Min. temperature	5	5	5	5
Number of accumulators	1	1	1	1
Cycles per stroke of accumulator	3	3	3	3
Size of bulk head connection	0.245 inch	0.245 inch	0.245 inch	0.245 inch
Pre-charge temperature	20	20	20	20
Total usable oil volume	9.34 lit	9.12 lit	9.35 lit	9.35 lit

IV. DESIGN

Based on the input parameters and sizing of the components the well head is designed. The complete design of the well head is shown in the Fig.5.The oil filled in the reservoir at atmospheric pressure. Pump is developing the pressure of 3000psi (as required by customer according to their valve data. This hydraulic pressure developed operates the valves of the well head sequentially in a controlled manner. 2 cylindrical reciprocating pumps when energized electrically, will pump the oil from the tank And generate the pressure. Only one pump will work at a time and the other is standby. Non returning valves are included in the line to prevent the oil flow back to the reservoir, and helps in the repairing of the pump when needed. Filters will filter out the oil. Accumulator is filled with N2 gas at 90% of the minimum operating pressure of the pump. When the oil enters the accumulator it will compress the N2 and occupies a particular volume within it. At each stroke this hydraulic pressure is released for the valve operation. Based on the number of strokes and requirements, the accumulator sizing can be varied. Pressure gauge, and level gauge monitors the pressure and level of the oil. Pressure and level switches are used here for safety purpose, by monitoring the violation of pressure and level from the required value and give a feedback signal to the PLC. Pressure relief valve Protects the loop from over pressure. A manually operated hand pump is included in the line which is standby.ie; when the electrical pump is not working properly, the entire system functioning can be continued by this hand pump. This concludes the hydraulic power unit. For each valve, the pressure required to operate the valve actuator is different. And ScSSV needs high pressure when compared to the others. Before shutting of the ScSSV, all other valves should be closed. ScSSV is closed only during fire conditions. So in each line pressure regulators to regulate the downstream pressure is connected.

Name of the component	Specification
Motor driven hydraulic Pump	3I/min, 3000psi
Accumulator	10lit/345 bar 100ml/345 bar 4lit/345 bar
Hydraulic pressure regulator	Inlet/Outlet 10000/500psi Inlet/Outlet 10000/500psi
Solenoid valve	¼" FNPT 300psi
Manual reset relay	¼" FNPT 220psi
Interface valve	¼" FNPT 10000psi
Discharge filter	6 micron
Pressure gauge	0-300psi, 0-5000psi, 0-10000psi
Pressure transmitter	0-5000psi
Pressure switch	60-600bar, 1.2-12bar
Level gauge	1000mm
Push button	2way/2position,1/4"FNPT 210 3way/2position,1/4"FNPT 320
Hand pump	700bar
Ball valve	1/4"FNPT,2 way,10000psi 1/4"FNPT,3 way,10000psi

Table.2. Component specifications

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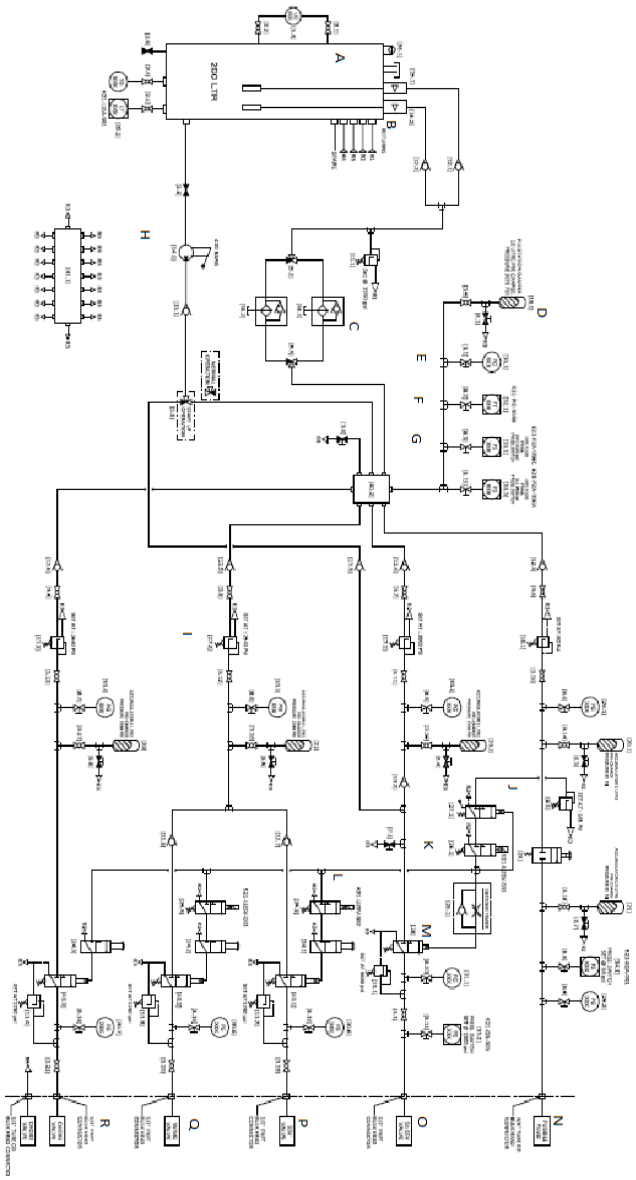

Fig.5 Electro hydraulic Well head control section

A- RESERVOIR
B- HYDRAULIC PUMP
C- FILTER
D- ACCUMULATOR
E- PRESSURE GUAGE
F- PRESSURE TRANSMITTER
G- PRESSURE SWITCH
H- HAND PUMP
I- PRESSURE REGULATOR
J- MANUAL RESET RELAY
K- SOLENOID VALVE
L- PUSH BUTTON
M- INTERFACE VALVE
N- FUSIBLE PLUG
O- SCSSV
P- SSV
Q- WING VALVE
R- CHOKE VALVE

Separate accumulators are included in each line to minimizes the cost and high pressure requirement to operate them, instead of a single accumulator. A manually reset relay followed by a solenoid valve controls the pressure at each line. The complete line will get pressure if and only if the manual reset relay is kept open and the solenoid valve receives the signal from the PLC. Interface valves at each line act as an interfacing platform between Pilot control pressure and valve actuator supply pressure. In the case of fire emergency, to stop the supply at each line, the main solenoid valve will be deactivated by the PLC which in turn closes the main manual reset relay and cuts the pressure supply of all lines. Thus the pressure get vent off back to the reservoir. Operators also can manually close the Manual reset relay in case of emergency. Each line also contain a manual push button followed by the solenoid valve for the same purpose for individual line control. More than one emergency stations are placed in nearby locations for the case of any emergency. Operation of emergency button will cause the emergency shutdown of the entire system. Fusible plugs near to the well will melt at predetermined temperature in the case of any fire. Flow line pilots in the oil flow line will give a feedback signal to shut down the system, if any violation of the flow line pressure occurs from the set value.

V. CONTROL AND AUTOMATION USING PLC

The Rockwell automation based system consists of ControlLogix controller (1756-L71). The system chassis are designed for horizontal-only, back-panel mounting. Place any module into any slot. The backplane provides a high-speed communication path between modules and distributes power to each of the modules within the chassis. Each chassis consists of the following components. The cause and effect flow chart of the program is as shown in Fig.7

a) ControlLogix Controller (1756-L61)

Allen-Bradley Logix platforms provide a single integrated-control architecture for discrete, drives, motion, process, and safety control. The Logix platforms provide a common control engine, programming software environment, and communication support across multiple hardware platforms. All Logix controllers operate with a multitasking, multiprocessing operating system and support the same set of instructions in multiple programming languages. One RSLogix 5000 programming-software package programs all Logix controllers. And, as part of the Integrated Architecture, all Logix controllers offer the benefits of the Common Industrial Protocol (CIP) to communicate via Ethernet/IP, Control Net, and Device net networks.

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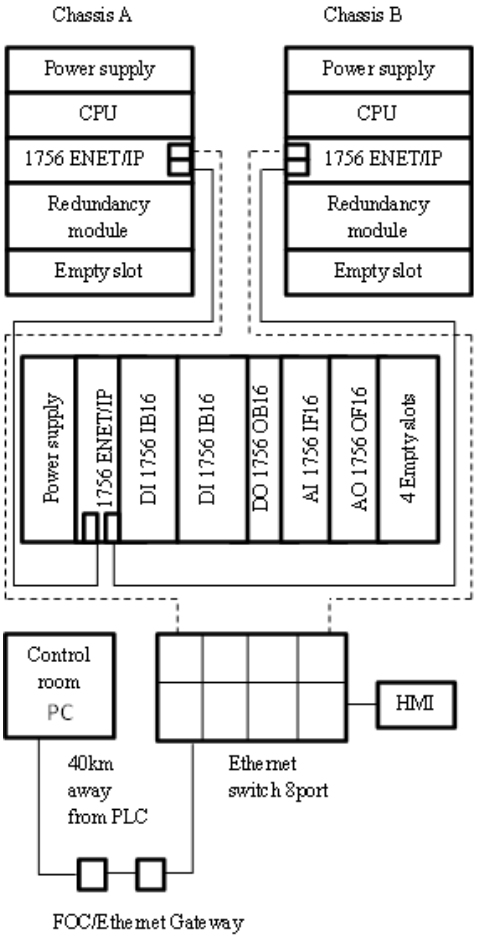

Fig.6. PLC based Automation system architecture

b) ControlLogix Redundancy Module (1756-RM)

Two 1756-RM ControlLogix redundancy modules working together supervise the operating states and state transitions, which establish the basic framework for redundancy operations. The redundancy pairs provide a bridge between chassis pairs that allow other modules to exchange control data and to synchronize their operations. The 1756-RM2 module helps to commission the redundant system in a plug-and-play manner without any programming.

c) ControlLogix Power Supply (1756-PB75)

ControlLogix power supplies are used with the 1756 chassis to provide 24V DC power directly to the chassis backplane. Provides all of the regulated voltages necessary for any ControlLogix module to operate in the chassis. Provides limited hold-up time for fluctuations in incoming line power. Signals modules in chassis of imminent voltage failure for orderly system shutdown.

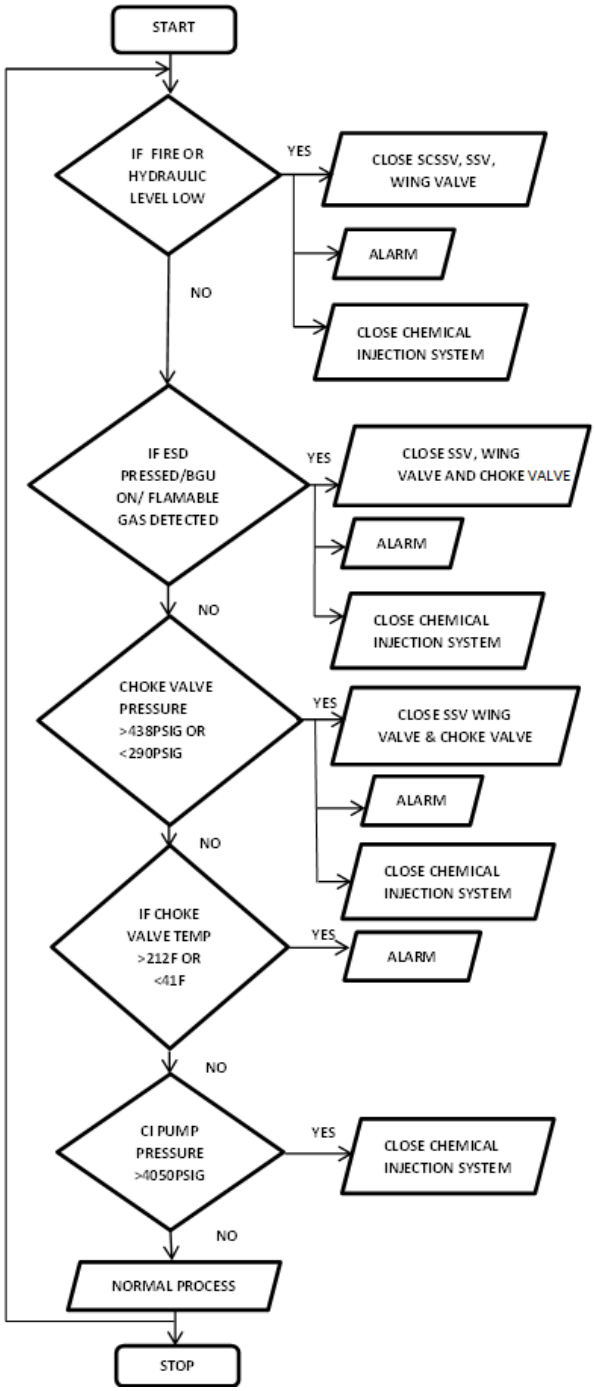

Fig.7.Cause and effect flow chart of the program

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d) ControlLogix Hi Capacity ENET/IP (1756-EN2TR)

The Rockwell Automation Control Logix 1756-EN2xx High Capacity Ethernet/IP Bridge Modules are the ideal solution for Ethernet/IP communication in demanding applications. The modules supports all the functionality of the 1756-EN2T (bridging, messaging, real-time control of I/O, and peer-to-peer interlocking over Ethernet/IP) with two times the capacity. They are equipped with a USB port which allows easy access for configuration of the module as well as access to other parts of the control system. Thumbwheel switches located on top of the module enable users to quickly set up an IP address to minimize configuration time. Like the 1756-EN2T, when used in conjunction with other Control Logix bridge modules in a gateway system, they can route messages between Ethernet/IP and other NetLinx networks without the intervention of a Control Logix controller. Along with these components, Control Logix 16 Point Digital Input (1756-IB16D), Control Logix 16 Point Digital Output (1756-OB16D), Control Logix 16 Point Analog Input (1756-IF16) are also used for the communication purpose.

Soft wares used for programming

- Ladder(RSLogix 5000,paid s/w)
- HMI(FTView studio Machine edition)
- RsLinx classic (internal communication for I/O level)
- RsLinx enterprise (server for Ladder and HMI)
- Excel VBA for component sizing

VI. CONCLUSION AND FUTURE SCOPE

The parameter sizing software developed can be used as a tool for the new projects where the client specifications can be used as the inputs. This will fetch the component sizes& dimensions to be considered. Further, PLC based solution for WHCP automation can be extended to new jobs and the programs are editable / modifiable for future changes in scope.

VII. REFFERENCE

[1] www.orbitalgrp.com
[2] Orbital project documents
[3] http://www.excel easy.com/vba/userform.html
[4] Automatic Control of Unstable Gas Lifted WellsBård Jansen, ABB Industri AS; Morten Dalsmo, ABB Corporate Research; Lars Nøkleberg, SPE, ABB Corporate Research
[5] Design of smart well head controllers for optimal fluid injection policy and producibility in petroleum reservoirs: A Neuro-Geometric Approch, Masoud Nikravesh, Lawrence Berkeley National university of california