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Enhancement of Instrumentation Safety System for Upstream Oil & Gas Sector

Mr. Mitesh Patel*
M.Tech, Instrumentation,
Dharmsinh Desai University, Nadiad
Mitesh_53@hotmail.com

Dr. Vipul Shah
Professor, Instrumentation
Dharmsinh Desai University, Nadiad
vashahin2010@gmail.com

Mr. Bhagatsinh Dodia
Executive Manager, CSD
Yokogawa India, Ltd
bhagatsinh.dodia@in.yokogawa.com

Abstract: This is paper discusses the implement of the close loop control PID block in Safety Instrumented System. PID Block can be implemented by user-defined block. Once the user defined block is created it can be used like normal function blocks like AND, OR, NOT. Here the block is created in Yokogawa safety systems Prosafe-RS. Normally the close loop control block is not used in the safety system so it can be used in non-safety function close loop. The PID blocked is designed by the structured text and the function block diagram language is used.

Keywords: SIS, PID, DCS, SCS.

I. INTRODUCTION

The onshore Mangala field of Cairn India Ltd is one of the largest onshore oil fields in India located at the Barmer, Rajasthan. The Mangala field has 150 wells artificial lift method Electric Submersible Pump (ESP) and Jet pump mechanisms are used for oil recovery. Almost 86% of well is Jet pump & 14 % of well ESP mechanism artificial lift method. [6]Mangala Field contains the 18 no's of Well pads as in fig.2.

Mangala oil field has Yokogawa control system network. All Wellpad has locally Installed SIS (Safety Instrumented System) and RTU (Remote Terminal Unit) all are communicating with the Fibre Communications Network to the CCR (Central Control Room). Yokogawa SIS has the Vnet/IP Communication Protocol. RTU has Ethernet Communication Protocol.

The Operator Interface is the Yokogawa DCS Centum VP Software. SIS and DCS are on same Vnet/IP Protocol so both is integrated directly. While the RTU Data integrated by OPC Server called SIOS (System Integration OPC Station).

All 15 Wellpads RTU Data are communicating by SIOS. So it is not reliable that the SIOS Server communication Fails, all Wellpads data & Alarms are not monitored the Power Fluid Closed loop is also not monitored & control. All Wellpads may shut down by the SIS. This cause the large Production Loss. Close Loop Control I required for the control the power fluid flow, which is currently controlled by the RTU.

Normally the Close loop Control Algorithm (PID) is not available in safety instrumented system. Closed loop Control Algorithm is to be implemented in SIS. So, the power fluid flow can be directly controlled by the SIS.

II. SAFETY INSTRUMENTED SYSTEM

A system designed to respond to plant conditions which may be hazardous by generating correct outputs to mitigate the hazardous consequences or to prevent the hazard. Consists of a separate and independent combination of sensors, logic solvers, and final elements. [1]

In the oil and gas industry, it is used to detect the onset of hazardous events and to mitigate their consequences to humans, material assets, and the environment. [5] A SIS is installed to detect and respond to the onset of hazardous events by the use of electrical, electronic, or programmable electronic (E/E/PE) technology. Emergency shutdown (ESD), Fire and gas detection (F&G), Process shutdown (PSD) and High integrity pressure protection system (HIPPS) are some of the SISs that have a crucial role in maintaining the overall safety in the oil and gas industry. [2]

Here the Input elements are the Pressure, Temperature Level transmitters or gas, flame detectors, Logic solver read process parameters from sensors and take pre-programmed actions (send a command to the final element) to prevent or mitigate process hazards. Final elements are the safety valves, deluge valves, electric fans and other final control elements systems. [6][7]

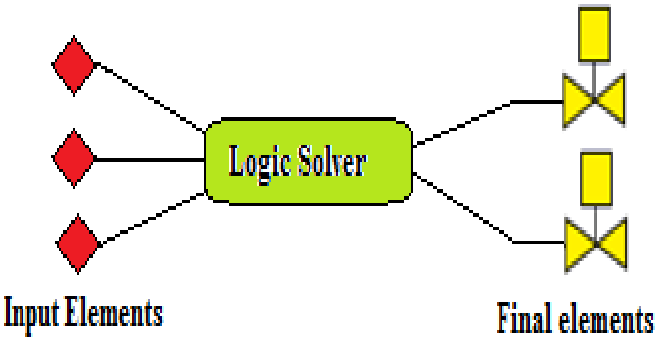

Figure 1: Simplified Example of SIS

The IEC 61508 and IEC 61511standards distinguish between four discrete safety integrity levels, which are used as a measure of reliability for SIFs. SIL 4 has the highest level of safety integrity, while SIL 1 has the lowest. [3][4] The higher the SIL value, the higher is the associated level of safety and the lower is the probability of a failure. This basically means that a high SIL value gives a lower tolerance of dangerous failures.

III. PID ALGORITHM

PV Proportional and Derivative Type PID Control Algorithm (I-PD)

The basic type PID control algorithm performs proportional, integral and derivative Control Action following the changes in the set point value.

This algorithm ensures stable control characteristics even when the set point value changes abruptly when the SV is set via numerical value entry. At the same time, the algorithm ensures proper control in response to the characteristic changes occurring in controlled processes, load variations, and disturbances by performing proportional, derivative and integral Control Action accordingly.

The computational expression of the PV proportional and derivative type PID control algorithm (I-PD):

$$\Delta MV_n = K_p \cdot K_s \left\{ \Delta PV_n + \frac{\Delta T}{TI} E_n + \frac{TD}{\Delta T} \Delta(\Delta PV_n) \right\}$$

ΔPV_n : Process variable change $\Delta PV_n = PV_n - PV_{n-1}$

$$E_n = PV_n - SV_n$$

$$K_p = \frac{100}{PB}$$

$$K_s = \frac{MSH - MSL}{SH - SL}$$

K_p: Proportional Gain
K_s: Scale Conversion Coefficient
MSH: MV Scale High Limit
MSL: MV Scale Low Limit
PB: Proportional Band (%)
PV_n: Process Variable
SH: PV Scale High Limit
SL: PV Scale Low Limit
SV_n: Setpoint Value
TI: Integral Time
TD: Derivative Time
$\triangle E_n$: Change in deviation $\triangle E_n = E_{n+}\ E_{n-1}$
$\triangle T$: Control Period

The dynamic ranges of PVn, SVn, SH, SL, MSH and MSL are fixed at 0 – 100 % in the PID FB. SV and PV are required to be normalized from engineering unit values to 0-100% values prior to inputting to this FB.

IV. PID IMPLEMENTATION ON SAFETY SYSTEM

PID implemented on Yokogawa Safety System Prosafe-RS Software. For Indication (PID faceplate and Graphics) the Yokogawa DCS Centum VP is used. Here the I-PD type PID Control Logic is developed by the Structured Text (ST) and Function Block Diagram (FBD). The PID Block is used as user defined block after the block is created it can be used as normal in-build blocks. Normally the Basic Process control system is different with the Safety System. Some application like Oil well are remotely location the safety function is not so complicated safety system can be integrated with the BPCS (Basic Process Control System). The benefit is to both system can be work with the same communication protocols, which is more reliable and easy to monitor.

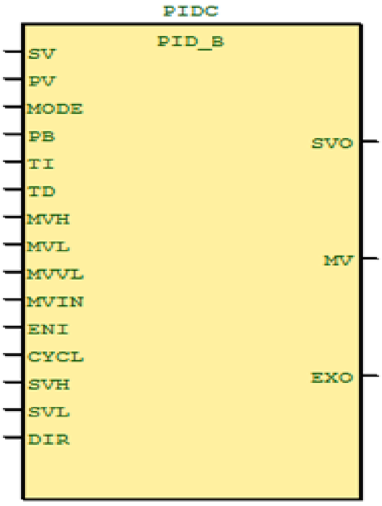

Figure 2: PID Function Block

V. INSTRUMENTATION MANGALA WELLPADS

(1)MP06TI1010 is Well head Temperature Transmitter for monitoring Purpose & Temperature is maintain By Electrical Heat-Tracing on Pipe line.

(2)MP06PI1010 & MP06PI1011 is Pressure Transmitter for Delta P Measurement, There should be some Pressure Difference before & after the chock valve (MP06HY1010) in order to maintain the difference from the Common Header

(3) MP06HY1010 Chock Valve is used to maintain the Pressure Difference. Pressure Difference Need to maintain to prevent the Reverse flow.

(4) MP06PI1013 Pressure Transmitter is used to measure Annulus-B pressure, it indicates the Gas leak from the well.

(5) MP06PI1012 Pressure Transmitter is used to measure Annulus-A pressure (Power Fluid Line)

(6) MP06FIC1010 is close Loop controller, controls the Power fluid flow to control the production fluid (Crude oil).

(7) All XSV101X are safety valves, used to shut down the well to Prevent Hazards.

(8) MP06PSIT1011 is safety transmitter will shut down all XSV on its trip HIGH & LOW-Pressure set points.

(9) H2S scavenger & Demulsifies is the Chemical Injection Lines to Prevent the Corrosions & Limits the H2S Producing.

(10) MP06AT1010 & 1011 are Gas the Detectors, if gas is detected then it will shut down the well. (Close all XSVs).\

The FIC1010 is implemented on SIS PID Controller. Previously controlled by RTU.

The Block diagram of System fig. 4 The Green Line is Vnet/IP Redundant Yokogawa Communication Protocol.

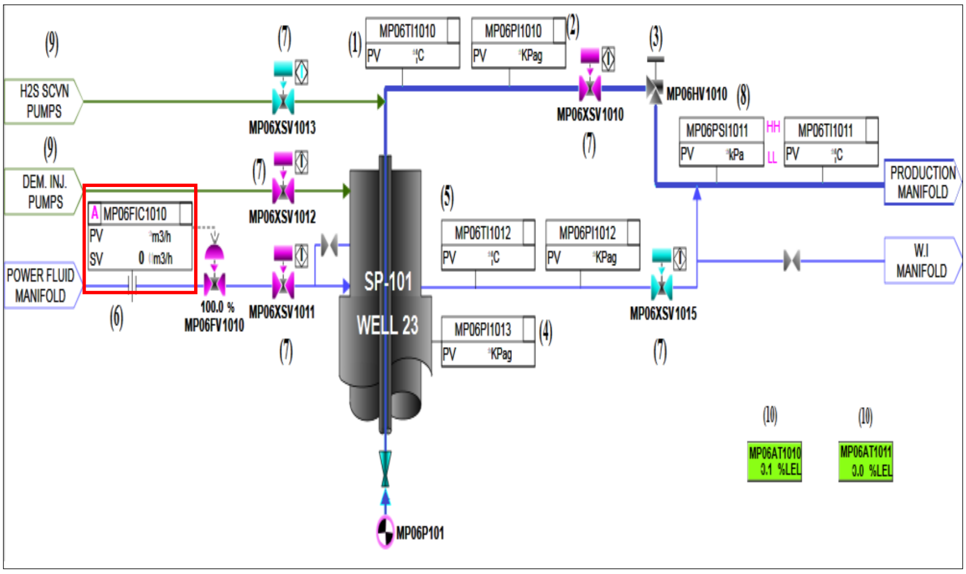

Figure 3: Mangala Wells Schematic

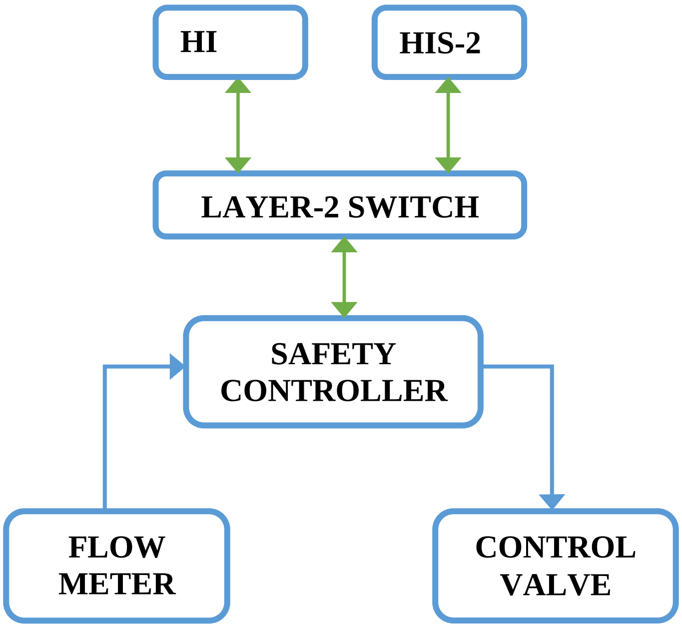

Figure 4: Block Diagram of the System

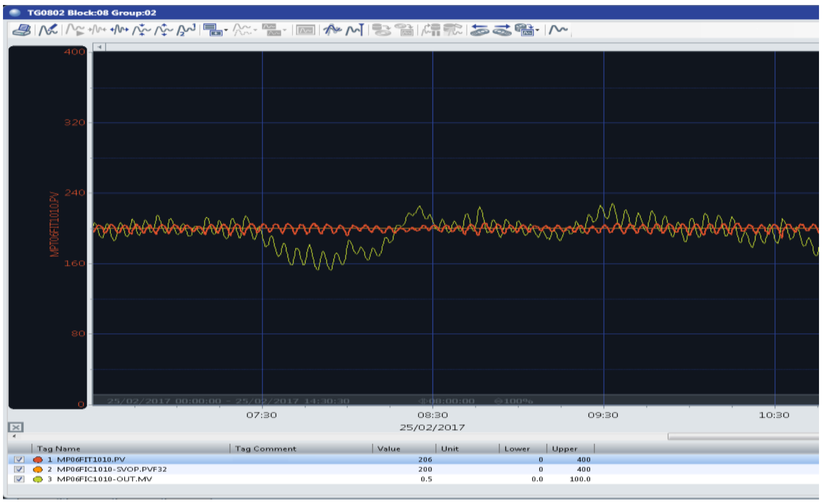

Figure 5: PID Controller Response

RESULTS

The PID Controller Response is as in fig 5. The Yellow line is Manipulated Variable, Orange line is Process Variable and Red Line is Set Variable.

After Power Fluid Close loop Control was implemented it becomes more reliable because all data is directly communicated via same Protocol. Safety System is SIL-3 Level

So Probability of failure in demand is 10-3 to 10-4. [13]

CONCLUSIONS

Implementation of Power Fluid flow control in Safety System increases the reliability and availability of the Control loop because of the Monitoring & Controlling Part is on Same Communication Protocols. Implementation of PID Control Block in Safety System can be used in other (non-safety function) close loop control.

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