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RESEARCH ARTICLE

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Design of DCS/ESD System for Oil Refinery Plant

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ABSTRACT
A distributed control system (DCS) is a modern control platform for automated control and operation of a plant or industrial process whereas when control system is in out of control, then emergency shutdown system (ESD) takes the action and shutdowns the whole Plant. The objective is to design DCS/ESD system for controlling and monitoring an oil refinery plant. It is a powerful tool for any large commercial plant which is specially designed with diagnostic capabilities and redundancy to improve performance and reliability. Controllers are connected to field devices and operating PC's (operating and engineering station) for data monitoring, data logging, alarming and controlling purpose through high speed communication networks. Profibus, Modbus, HART, foundation fieldbus and Vnet/Ip are the various communication protocols used.

Keywords: Distributed Control System, Emergency Shutdown System, Process, Analog signal, Digital signal, Factory Acceptance Test (FAT).

I. INTRODUCTION

Generally an automatic control system performs two actions: transmission of signals back and forth and decision making. To implement these actions in reality, it requires a set of hardware and instrumentation. A distributed control system (DCS) is an emerging control platform for controlling and operating a plant or process .A DCS combines the following into a single automated system: human machine interface (HMI), logic solvers, historian, common database, alarm management, and a common engineering suite. It is a powerful tool for any large commercial plant which is specially designed with diagnostic capabilities and redundancy to improve performance and reliability.

Distributed Control System is used to control complex and distributed applications in industrial processes in which controllers are distributed throughout the plant. Controllers are connected to field devices and operating PC's (operating and engineering station) for data monitoring, data logging, alarming and controlling purpose through high speed communication networks. Field devices can be pressure transmitter, temperature transmitter, sensors etc. which measures real world parameters like pressure, temperature and these devices are smart instruments which are capable of establishing communication with controllers.

The various communication protocols used are: Profibus, Modbus, HART, foundation fieldbus and Vnet/Ip. Two or more communication protocols can be used in between field devices and distributed controllers.

II. METHODOLOGY

There are thousands of field instruments installed in a process plant. It is practically difficult to lay straight individual cables from each field instrument to control room for displaying the process variables on the workstation. So, to avoid this problem field devices are wired and terminated in a junction box using field cables. Suppose, in a process plant there are 150 numbers of junction boxes and therefore 150 numbers of main cables are laid to control room. Practically it is impossible to direct these wires to IO cards and can be solved by using marshalling cabinet where main cables terminate. From marshalling cabinet, signal goes into system cabinet via prefab cable. System Cabinet consist of Power supply module, CPU, analog cards, digital cards, communication cards. Here 4-20 mA signal is converted into corresponding digital signal and the controller processes the data according to the logic created thereby display the measured process variables on the work station with the help of Ethernet communication link.

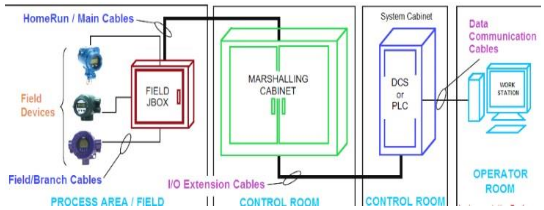

Fig 1. Process Overview

A, Hardware Design

1. Type of Signals: *Analog Input*: A controller can accept 4-20mA in case of an analog signal. From the field instruments signal passes through junction box and then barrier which is placed inside an analog marshalling cabinet. Barrier is used to protect controller from high currents. Signal then enters into board and finally to IO cards placed in system cabinet.

Analog Output: In case of analog output, the signal flows from controller to field instruments i.e. the way in which signal flow direction is reversed.

Digital Input: Here, signals can be either 0 or 1. Signals that come from the field is connected to barrier, board and finally to the IO cards. In the case of digital signals, two types of wiring are possible: dry contact or potential free and wet contact.

For dry contact no voltage is applied externally whereas in wet contact voltage is applied from either of the ends.

Digital Output: Signal passes from controller to field instruments. Output signal from controller enters into board, barriers which then finally controls the field instruments.

2. System Configuration: System Configuration shows how the control systems, communication protocols and network accessories are interconnected. The DCS architecture comprises Human Interface Station [HIS] for Operator interface and Field Control Station [FCS] for control and monitoring the process. The HIS and FCS are interconnected by redundant Vnet/IP control Bus. In addition, Vnet/IP interconnects HIS for file transfer functions and downloading engineering database and graphics from Engineering Stations.

The system configuration of this project includes mainly two sections : main control room and training (LPG control room) .In main control room, high level of system security is enabled and here we can change logics and perform modifications. Whole controlling takes place in main control room whereas monitoring can be done in training room .Also, DCS and PLC engineering are placed here. DON PC is documentation node and it is place whereas complete information of all system of all system resides. AIMS PC is alarm management system and it accumulates all alarms in field. PLC SOE station shows sequence of events and it records all abnormalities related to PLC. Two servers are there and are protected by firewall. Training (LPG control room) is used for daily usage and here core values cannot be changed.

GPS is provided to synchronize all PC. Redundant buses (bus 1 and bus 2) are connected to Ethernet switch. So, by changing any core values in main control room can be visible in all PC's. The connection Transmission Period is 100 msec. This correspondence is repetitive and called as Vnet/IP Bus1 and Vnet/IP Bus 2.

The communication between each unit and its remote location is carried out by FO cables. Fiber optic cables transmit large amounts of data at very high speeds. The fiber optic converter is used as an RS-485 point-to-point or point-to-multipoint connection for transmitting and converting full/half-duplex signals and their equivalents within a fiber optics environment. This kind of transmission offers the benefits of wide bandwidth, immunity to EMI/RFI interference, and secured data transmission.

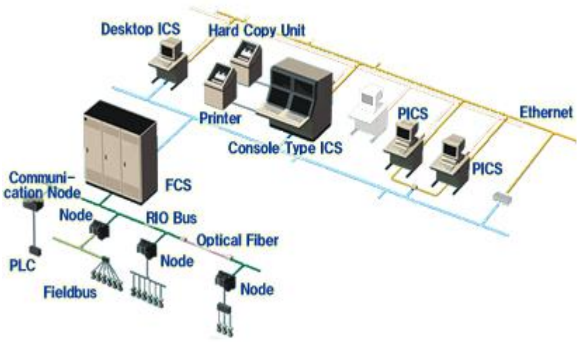

Fig.2 DCS Architecture

3. IO Modules: IO modules used for DCS: AAI141, AAI543 IO modules used for ESD: SAI143, SDV144, SDV541 ALR121 is the Modbus serial communication module.

4. System Cabinet: System Cabinet consists of two power supply units, redundant CPU's and IO cards. Maximum of five IO can be connected in one section (front /rear). One of the processor cards, one will be active and the other will be stand by card. The duplexed cards can switch from active to standby card without any interruption to control.

Field Control Station is the DCS Controller. It performs continuous control, sequence control and batch control functions. The DCS consists of Field Control Station and Node Interface Units with I/O modules

Duplex CPU modules are used for this project; it consists of redundant CPU Modules with 72 hrs battery backup, redundant V-net/IP bus, redundant ESB bus, redundant power supply units, and redundant ESB bus interface modules. Dual redundant FCS has two processor cards, which can be replaced online. Each processor card has two CPUs. Every CPU performs the same calculations and results are analyzed after every computation.

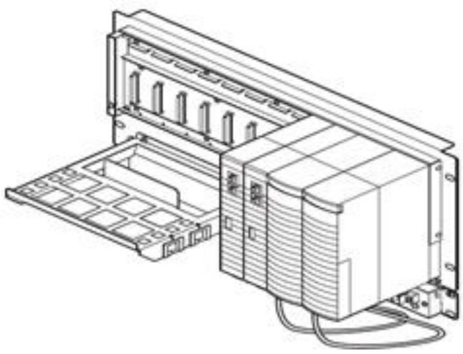

Fig.3 Field Control Station (FCS)

5. Marshalling Cabinet: Marshalling cabinet placed between field instruments and system panel. The word 'Marshalling' means grouping of all I/O's i.e. grouping of all I/O's like AI, AO, DI,DO and pulse I/O are done here. From Marshalling cabinet the signals are sent to controller which is placed in system cabinet via a prefab cable

Terminal boards are used to connect field signals to the I/O Modules. Individual signal cables run from terminal blocks to terminal boards. Then a single prefab cable (or System cable) will run up to the I/O modules.

6. Power Consumption and Heat dissipation : Power can be input power and output power. No losses are there when input power equals to output power and if is not equal some losses like copper loss, iron loss are present. UPS (Uninterrupted Power Supply) is used in case of power failure and it is used as backup power. For large scale applications, nickel cadmium batteries are used. Power consumption and heat dissipation are correlated. If some components in a circuit are consuming more power which results less power consumption for some other components. As a result, more heat will get dissipated. The power consumed by each components per cabinet are calculated, so that ratings of UPS can be decided. Similarly heat dissipation are also calculated and based on this number of fans in each cabinet are finalized.

B. Software design

1. *Open Loop :* The functional blocks for an open loop are: PIO Block and PVI Block

PIO (Process Input/Output) Block: It connects the process I/O signal to the function block

PVI (Process Variable Indicator) Block: It displays an input signal from the I/O modules as process variable (PV) and hence it can output PV from the OUT terminal.

Fig.4 Open Loop

2. *Close Loop*: In case of closed loop, the reading from the transmitter is taken for control action and

it is done via PID block. The transmitter converts process input into a 4-20mA current signal and is set as Process Variable to the controller. Similarly, set variable is also set to the controller. The main aim of the controller is to make the difference between the process variable and set variable as zero. For this, the controller checks the deviation continuously and generates manipulated variable (MV) which is also in terms of 4-2mA current signal

Fig.5 Close Loop

3. *Cascade Loop:* Cascade Control has multiple loop structures, where output of the outer loop controller is the set point of a controller in the inner loop. In this, the whole process is divided into two parts and consist of two controllers but only one is manipulated.

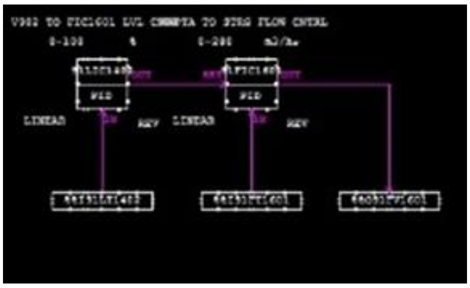

Fig.6 Cascade Loop

4. *Split Loop:* Here, control action is splitted. Output of one controller is split and sent to two or more control valves. In split range applications, the controller adjusts the opening of the valves when its output is in the range of 0% to 50% and the other valve when its output is in the range 50% to 100%.

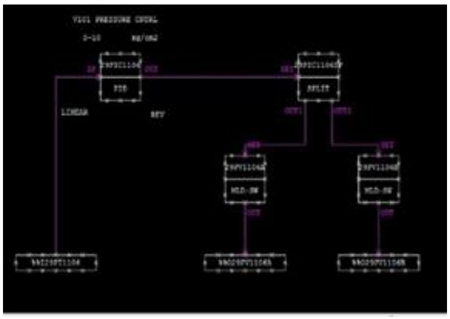

Fig.7 Split Loop

V – RESULTS AND DISCUSSION

The FAT is performed to ensure that the system is properly configured, assembled and functional in accordance with the intended design as specified in the approved documents. The objective of FAT is to demonstrate to customer that the system hardware and software is built in accordance to requirements as specified in the approved documents.

The aim of the Factory Acceptance Test is to verify the conformance of the system against the approved specifications and FAT procedure before delivery to site. It is conducted to test and verify the main items listed below:

- System Hardware
- Software
- Operator Station Application Software
- Control Station Application Software
- Network
- Cabinets
- Operator Consoles

For analog input signals, 4-20mA is injected over the marshalling cabinet with the help of calibrator and corresponding readings on the faceplate are noted for 0%, 25%, 50%, 75% and 100% whereas for analog outputs, values are forced on the faceplate and the current is measured using calibrator. In case of digital input signals, the marshalling terminals are shorted and corresponding changes are observed on faceplate and for digital output, tags are forced from the faceplate and the voltage /continuity across the marshalling cabinet is checked by using a multimeter.

VI - CONCLUSION

DCS (Distributed control system) controls and monitors the entire Oil Refinery Plant and here the control action is distributed. Redundancy is the main feature which means if one controller fails, then the other one continues to operate. ESD (Emergency Shutdown System) operates only when the control action is out of control and it shuts down the entire process. FGS operates after the failure. Mainly three sections are there: ATF, NFU and KRU. Signals from field enters into corresponding boards and from there to IO cards via prefab cable thereby process the data according to the logics created. The purpose of barriers is for protection against sudden surge and these are placed in marshalling cabinet. Here, both UPS and non UPS are used. In case of power failure UPS can support as backup power whereas non UPS is employed for powering lights and fans which are incorporated inside cabinets for cooling purpose. IO cards are arranged according to front loading and all the loops are checked during FAT.

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