AUTOMATION AND SUPPLY OF DISTRIBUTED CONTROL SYSTEMS FOR CRUDE OIL FIELD INDUSTRIES

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Abstract - *Establishment of an automation system for large-scale industries is certainly a tedious task to accomplish. But as the field of control and automation has improved tremendously, now more advanced and improved communication protocols are being used, new technology is being implemented, flexibility of an automation system has increased, it has become reliable, effective and accurate results are being obtained. Automation system, now a days is used in almost all industrial sectors. Implementing an automation system benefits the proper functioning of the crude oil field. This automation system comprises of DCS (Distributed Control system). The primary aim of this is to maintain the desired temperature and pressure while extracting the crude oil from the deep excavated wellpads by hydraulic fracture simulation in the industry, which has been carried out in stages in order to increase the total hydrocarbon development of the oil hill reservoirs. The system is designed in such a way that the redundancy principle id maintained in order to reduce the risk of the data loss. The designing processes of the DCSs are done based on the end-users specification and requirement. The software being used here for the design of DCS Field Control Station (FCS) is CENTUM VP.*

Key Words*: *CENTUMVP, DCS, FCS, CPU, Hydraulic Fracture Simulation, Process Automation

1. INTRODUCTION

The risk is the frequency of occurrence of problems which causes harm and also the grimness of that harm, gaining freedom from the risk is called as safety. Oil industries intend to increase the rate of crude oil production in the most economical way. From the past few decades, oil industries have risen enormously with respect to size and complexity. At the same time, by considering the factors like economy, safety etc., there is a need for more sophisticated and vast featured control and automation system. On a shorter note, as the business cycles has lessen; the numbers of customers have increased, distinctive clients require diverse data. With an enormous development of communication and problem-solving technologies, the automation system has significantly increased both internally and externally. Centralized monitoring system for the field instruments is necessary for a reliable and efficient performance of the industry. It also benefits the operator personnel to perform the control action remotely, providing a graphical display of the instruments that is being monitored, multiple process site environments, wide area communication, closed loop control performed by sub-systems and relatively high content sequential control. The FCS gets input from various kind of field instruments like flow meters, pressure, temperature and fault indicator, gauges, I/P converters, pressure, level and temperature transmitter, turbidity and conductivity analyzer, sand detector, opening and closing of control valve which comes under analog signal whereas ON-OFF valve limit switch, solenoid valve, etc. comes under digital signals. Altogether they make the system more reliable, flexible and accurate and also reduce total manpower. Initially the performance of the field was monitored manually. The problems that arise due to monitoring of the functions of all the field instruments manually are, requirement of more man power for continuous observation, more chances of error. Also, there are chances of missing an alarm while keeping track of the instrument activities which may result in disasters. To avoid such a scenario, the industry must be automated for its better performance and improved accuracy.

2. PROBLEM STATEMENT

The field of process automation has advanced in the several industries; however few industries have not penetrated deep into the adaption of the new technologies for maintenance of industrial control and safety. The maintenance of the desired low/high pressure or temperature for the hydraulic fracking or to just maintain the desired operating pressure or temperature throughout the process however, traditional pressure gauge or temperature meter is used to take the reading as few plants or refineries assume that traditional methods provides the accurate and précised values, but this method may create the hassles by paving the way towards the dangerous life hazards and the loss of productive time. The purpose of DCS is to enable the control patrol to control the hardware equipment at the plant site from the designated place called control room and to monitor the behavior of the process variable with respect to time during the process.

3. OBJECTIVE

Process automation requires a high level of redundancy in order to maintain the required factors for the smooth functioning of the plant operations. The plant architecture is been interfaced along with the DCS with the help of transmitters for the simulation of the hydraulic fracture of the hydrocarbon basin. The standard analog signal range will vary from 4-20mA, these signal transmissions are used to replace the foundation field bus, a bidirectional digital communication protocol for field transmission of data initiation. The test signals sent through the calibrator for the analog signals and digital bits using the P & ID control logics. Thus varying the signals from the signal face plate which are called on the HMI, reads the input in the form of P & ID control function blocks for controlling the process plant with the desired operating range.

4. SYSTEM DESIGN

The basic goal of system design phase is to produce the design of the process plant its requirements specifications, which describes the complete external behavior of the system. The emphasis in the system design is on identifying what is needed from the system and how the system will achieve its goal. The overall designing process flowchart of this system is shown below in the fig. 4.1

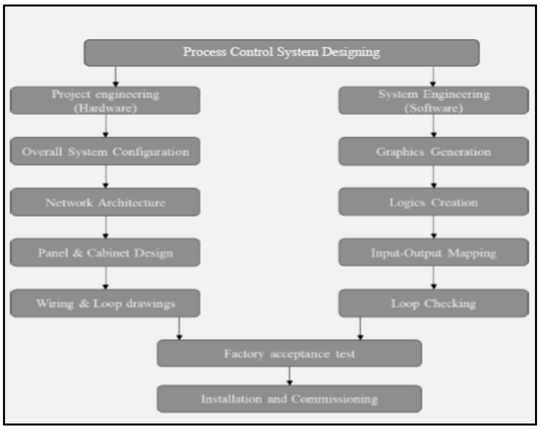

Fig.4.1: Flowchart of system design process

4.1. Distributed Control Systems

Distributed Control System or DCS is designed for a process plant with the distribution of autonomous controllers throughout the system. In a DCS, the independent distributed controllers in the system are under the supervision of a central supervisory control resulting in making this technique more reliable, cutting down the installation costs significantly by localizing the plants control functions but at the same time enabling remote supervisory control of the entire process cycle. DCS systems are used exclusively on high valued and critical area process plants where safety and security are of utmost importance. The superior reliability and safety features of the DCS system makes it ideal for implementation in large scale continuous processing plants. The control of field instruments by a DCS can be shown in the fig. 4.2, the following block diagram

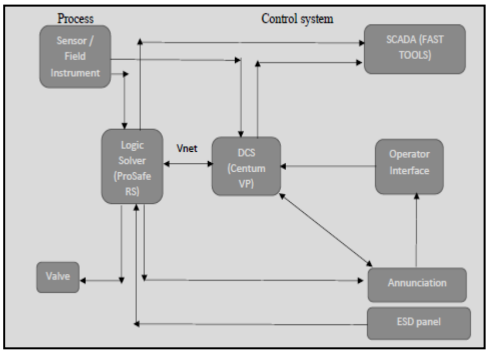

Fig.4.2: Block diagram of controlling of field instruments

For large industrial process, materialistic DCS network is shown below in the fig.4.3, in which various parts of the field/site and several parts of the DCS network elements are interfaced together via the field bus [1]. Field bus are also called as the data highway; the backbone for the DCS system which provides the information to the multiple displays on the various operator control stations sends new data and retrieve past data from the archival memory, and acts as a data link between the central control computer and the other parts of the system network.

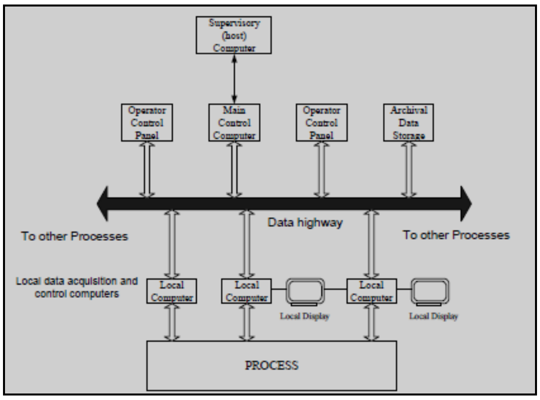

Fig.4.3: The DCS network elements [1]

4.1.1. Design Criteria of DCS

To provide the control actions, hardware designing is equally important. Establishing communication is one such primary task. To accomplish this, the System/cabinets are designed considering the End-user requirements.

Factors considered while designing the cabinets are:

1. Dimension of the cabinets must be properly decided such that all the hardware fit into it perfectly
2. The cabinets are provided with fan and filters. Fans help in lessening the temperature at the interior of the cabinet. There are 2 fans, namely, suction fans and exhaust fans. Suction fans suck out the heat from the

inside and sends outside while the exhaust fan brings cool air from outside. Filters are used to remove the noise

3. Wire/ Cable Sizes: Wire sizes depend on the rating of current and typical loops in line with the End-user requirements. The thickness/size of the cables depends on the rating of the current. There are different types of cables such as grounding cable, interconnection cable and inter-panel cables (Analog, Digital signal cables)

4. Requirement of number of relays, barriers, Terminal Blocks, Terminal Boards, depends upon the number of I/Os specified by the end-user.

5. MCBs, requirement depends on the rating of the current flow within the cabinet.

5. Duct Sizes are estimated based upon number of the cable wires connected in the cabinet.

7. Fuses ratings required are given by the End-user specifications.

The fig. 4.4 below shows the typical configuration of the system of DCS

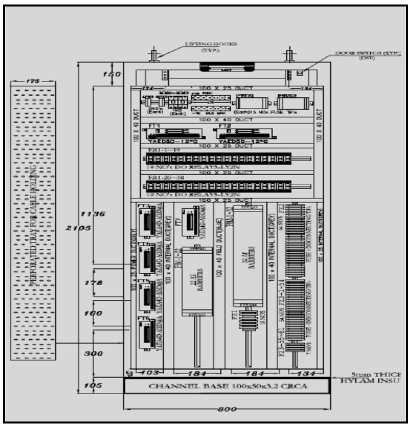

Fig.4.4: Typical configuration of DCS cabinet

4.1.2. DCS System Hardware

There are few important hardware equipment which are used in the designing of the DCS and they are as follows:

1. **Cables**: CAT series, RJ series connectors, prefabricated cables, and Power cables are those which are used for establishing communication between the components as per requirements. The fig.4.5 below shows the sample view of the cables connectivity

Fig.4.5:Node Unit of the controller with Pre-Fab cables connected.

2. **Network Accessories**: LAN and Ethernet Switches of 16 ports, 24 ports and 48 ports are used for interconnection between the components. WAN routers, GPS, which helps in time synchronization and Media converters, are also used for establishing the network. Fig.1.6 shows the interconnection of the LAN and Ethernet switches

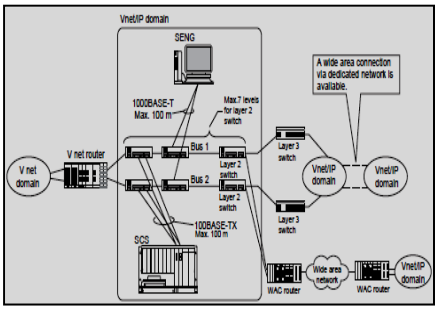

Fig.4.6: Interconnection of network accessories [2]

3. **Earthing:** It is a process of creating an alternative path for the flow of fault/excessive currents safely into the ground in the presence of minimal resistance or impedance. The DCS uses three ways of grounding schemes while designing the DCS such as System Earth is where the control systems are earthed in order to avoid leaking/fault current while tripping the fuse, Shield Earth, is where the Analog equipment is earthed to avoid the power surges and finally Panel Earth is used to avoid the overall power system, electrical equipment and personnel from the electric shock. The fig 4.7 below shows the sample of the grounding scheme of the DCS hardware system

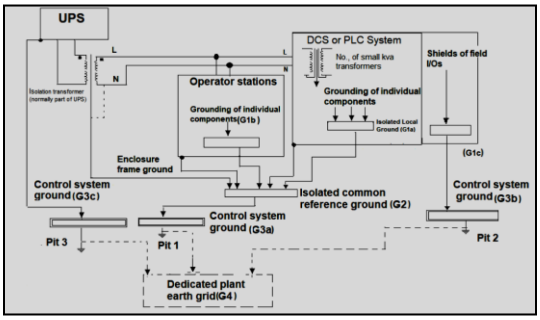

Fig.4.7: Pictorial representation of the grounding scheme (Earthing)

4. **Power Distribution:** Power distributions are of two types UPS and Non-UPS supplies. UPS power distributions are used as the standby generators between the two utility feeds, especially where power breaks are undesirable. Non-UPS supplies are used for the components which doesn't require critical load of power, like Fan Failure Detection Alarm, Receptacle Box, Power Sockets, and Alarm Terminal Blocks. The fig 4.8 (a) & (b) shows the

typical of the panel wiring considered in the DCS hardware.

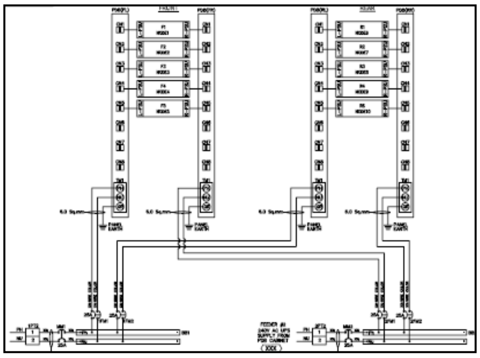

Fig.4.8 (a): Typical of Non-UPS Power supply

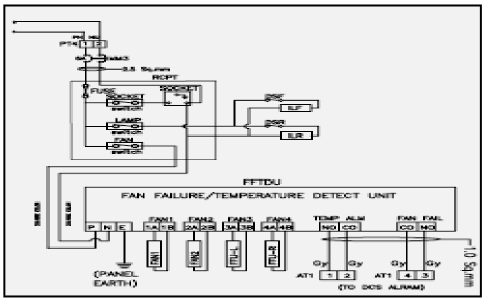

Fig.4.8 (b): Typical of UPS power supply

5. SYSTEM IMPLEMENTATION AND METHODOLOGY

The system implementation briefs out how the system components are brought together to achieve the final result. Hence the hardware module is first built and the functional logic blocks with the P & ID is been designed and dumped into the HIS. Initially the DCS is built and tested whether it can control, monitor accepts the incoming signals from the field and provides the signals to the HIS. The functional logics which are loaded into the HMI are programmed using CENTUM VP for the creation of the overall field view in a graphics style. The system implementation of DCS system is categorized into two parts and they are as follows:

- Project Design Engineering
- System Design Engineering

The fig.5.1 below shows the block diagram of the process flow of the system implementation

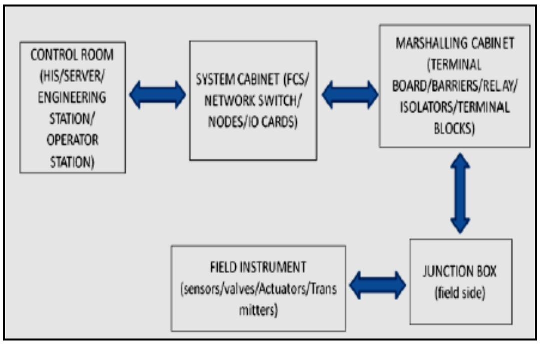

Fig.5.1: Block diagram of process flow of the system implementation

5.1. Project Design Engineering

To implement the designed DCS based on the requirements this phase is the core base of the implementation. The process automation of a crude oil plant/field and their operations are explained in the below subsections:

5.1.1. Power Consumption and Heat dissipation details

The components are wisely divided between both the feeders such as 230V AC and 110VAC which convert the incoming power to 24V DC, and ensured that the total power consumption of all the components connected to a feeder doesn't cross the rating of that feeder. Once, it is ensured that the power consumption of all the feeders is within the feeder rating, based on the feeder the power consumption helps in sizing of the feeders. The Heat dissipation is calculated as it's a measure of energy lost due to other forces. The current flow of each component and cabinet is calculated using the formulae;

For 230V AC Supply
$I=P/(V^*\phi)$
Where ϕ represents the power factor

For 24V DC Supply
$I=P/V$

5.1.2. System Configuration

The system configuration is a schematic representation of the process control station, in which the operator station, engineering work station and the control station are interconnected to each other through a TCP/IP link layer called the data link layer as all the system is been controlled by the network switch which produces the data to each and every work station, process control station and the logic controllers. The fig.5.2 below shows the system architecture of the interconnected station.

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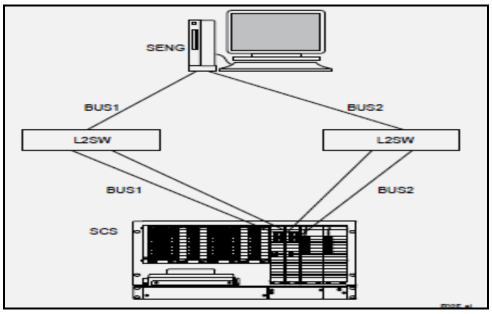

Fig.5.2: System Configuration

5.1.3. Control Room Layout

The control room layout provides the overall system design which has to be optimized. This layout gives the information of the estimated space available for the cabinets, consoles. This provides information about size, numbers and dedicated positions of the designed cabinets/consoles which can be accommodated in the control room. The fig.5.3 shows the schematic design of the control room

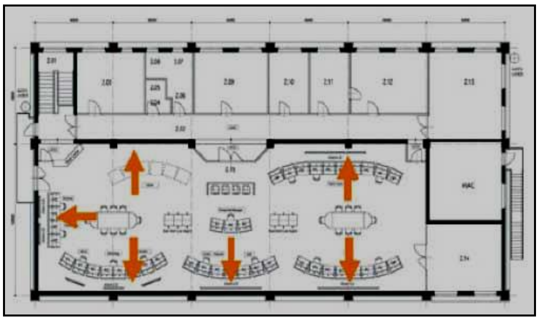

Fig.5.3: Sample schematic design of the control room layout

5.1.4. Front loading and Nest Loading

The DCS or any other DCS consists of a minimum of one FCS and a HMI. In FCS there are different nodes which consist of different cards to which the inputs are connected and the outputs are taken out after processing. The selection of cards and the number of cards depends on various and different parameters or based on the end user requirements. The selection of these cards and loading them in each node taken into account of all parameters is called as Front Loading. The arrangement of I/O cards based on the type of signals is known as Nest Loading. The fig.5.4 (a) & (b) below illustrates the sample pictorial representation of front loading and nest loading.

Station No:	FCS0551	Node_Model_No:	AFV30D-S41251	Node No.:	1	F1	Pre-fab Cable.:	KS1
IO_Module Model:	AAI143-H53/K4A00	Terminal Board:	YAEA4D	Slot No.:	1		Board_Location:	FT1

DCSTag	IO_Type	Range	JB_Number	JB_Term	Channel	Barrier_details	Relay_details	MR_Cabinet	Elco_Term	MR_Term
AWP01-TIT-2100	AI_FLD	0 - 125	AWP01-JB-PCS-A-0203	3	FCS0551N01S1			AWP03-PCS-MPA-001	1A	RZ5-3
				4					1B	RZ5-4
	2 WIRE	°C		#Error	Ch:1	-0			1	
AWP01-TIT-2119	AI_FLD	0 - 125	AWP01-JB-PCS-A-0203	7	FCS0551N01S1			AWP03-PCS-MPA-001	2A	RZ5-7
				8					2B	RZ5-8
	2 WIRE	°C		#Error	Ch:2	-0			2	
AWP01-PT-4011	AI_FLD	0 - 700	AWP01-JB-PCS-A-0203	9	FCS0551N01S1			AWP03-PCS-MPA-001	3A	RZ5-9
				10					3B	RZ5-10
	2 WIRE	Kpag		#Error	Ch:3	-0			3	
AWP01-XS-2110P	AI_FLD	- - -	AWP01-JB-PCS-A-0204	9	FCS0551N01S1			AWP03-PCS-MPA-001	4A	RZ6-9
				10					4B	RZ6-10
	2 WIRE	-		#Error	Ch:4	-0			4	
AWP01-XS-2120P	AI_FLD	- - -	AWP01-JB-PCS-A-0204	11	FCS0551N01S1			AWP03-PCS-MPA-001	5A	RZ6-11
				12					5B	RZ6-12
	2 WIRE	-		#Error	Ch:5	-0			5	
AWP01-PT-2112	AI_FLD	0 - 800	AWP01-JB-PCS-A-0202	1	FCS0551N01S1			AWP03-PCS-MPA-001	6A	RZ4-1
				2					6B	RZ4-2
	2 WIRE	Kpag		#Error	Ch:6	-0			6	
AWP01-PT-2113	AI_FLD	0 - 800	AWP01-JB-PCS-A-0202	3	FCS0551N01S1			AWP03-PCS-MPA-001	7A	RZ4-3
				4					7B	RZ4-4
	2 WIRE	Kpag		#Error	Ch:7	-0			7	
AWP01-FIT-2110	AI_FLD	0 - 25	AWP01-JB-PCS-A-0202	5	FCS0551N01S1			AWP03-PCS-MPA-001	8A	RZ4-5
				6					8B	RZ4-6
	2 WIRE	Kpa		[illegible]	Ch:8	-0			[illegible]	

Fig.5.4 (a): Front loading of DCS

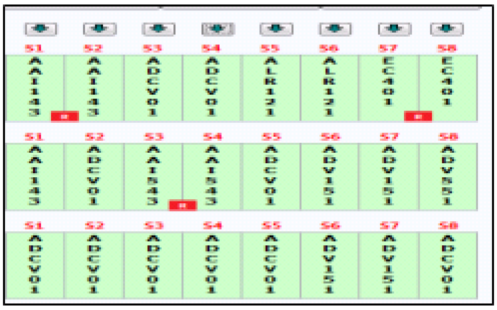

Fig.5.4 (b): Nest loading report

5.2. System Design Engineering

System Engineering starts with a specification prior to the system installation, which includes a various variety of tasks as designing, system generation, testing and addition & changing of functions and designing of the P &ID function blocks which is used to display the signal/graphics on the screen of HMI

5.2.1. DCS Engineering Station

This station, manages both engineering and maintenance of the CENTUM VP. The DCS engineering station consists an automation design suite/organizer, controller manager and several optional operating functions. The fig.5.5 below shows the DCS engineering station configuration.

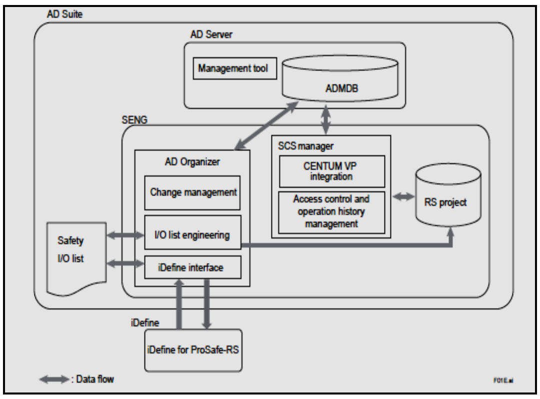

Fig.5.5: DCS engineering station configuration [2]

5.2.2. CENTUM VP

An integrated production control system which monitors and controls the various plant sites such as oil/gas refineries, upstream etc. The engineering of the control station is performed from the DCS engineering station and engineering of the field controller and the HMI is done from the engineering operator station of the CENTUM VP. The fig.5.6 below shows the CENTUM VP integration system.

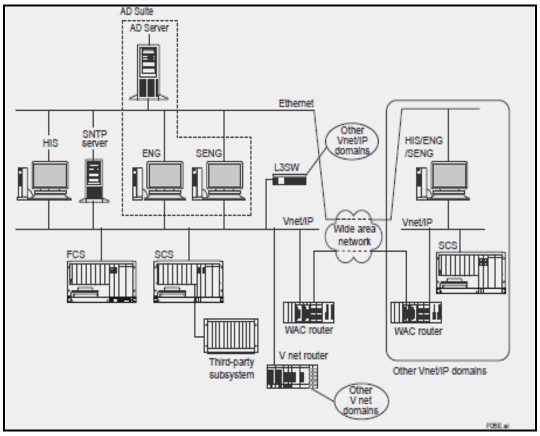

Fig.5.6: Example of CENTUM VP integration system [2]

5.2.3. Vnet/IP (Control Network)

An Ethernet-based and dual redundant control network which provides real-time communication with high reliability used normally for transmitting control data. The fig.5.7 below illustrates the example of the Vnet/IP network configuration

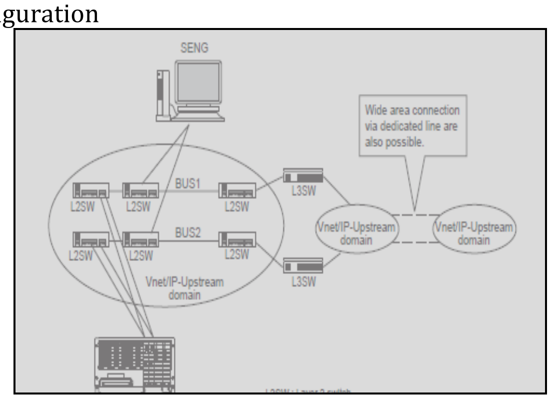

Fig.5.7: Vnet/IP network Configuration [2]

5.2.4. Function Block

The software of the DCS used here is CENTUM VP, the software program is in the form of predefined function blocks which are interconnected according to the control logic scheme to create the appropriate logic structure.

5.2.5. Data face plate block

A data faceplate block is a function block that maps data of controllers and the global variables. This faceplate block maps data of controllers to data item Process Variable (PV). The data can be monitored by accessing data item PV in data faceplate block from the HMI.

5.3. Methodology

The main motto of the designed system is to monitor and control the desired pressure and temperature continuously. If there occurs any variation in the pressure and temperature during the hydraulic fracking simulation of the hydrocarbon basin while extracting the crude oil from the deep wellpads, the signals from the field will get interfaced at the DCS which in-turn will send to the filed controller through the Ethernet cables which is connected from the terminal boards to the controller where in the typical range of analog signal that a controller can accept is 4-20mA, The signals can also be in the form of 1 or 0. However, when the field equipment like gas detectors, pressure transmitters etc, give the current output not in the range of 4-20mA. This recommends for the need for an intrinsic safety as the signals will be immediately sent to the HIS which is loaded with the functional logical blocks of the P & ID graphics leads to an extensive way for the indication of the exact spot at the field site and gives and alarm as their needs an action to be taken care by the control room panel personnel. The fig.5.8 below shows the block diagram of the signal flow of the input and output loops.

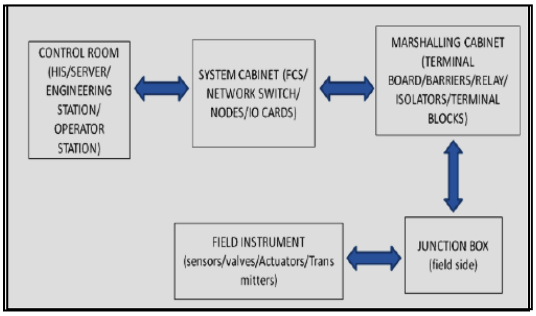

Fig.5.8: Signal Flow block diagram of input and output loops (vice versa)

6. Experimental Results

Once the programming is completed and communication between the cabinets and the controller has been set up, it is necessary to know if the logic set behind the program is giving out the output as desired. To ensure this, few tests are carried out.

6.1. Factory Acceptance Test (FAT)

The FAT is conducted at the supplier's site where the end user inspects, witness and validate the working of the system before the system gets dispatched to the plant site. During the FAT process complete system checks, complete hardware checks are carried out. Due to the absence of the field instruments to which the system will be connected at plant site, calibration devices are used to replicate the signals from/to the field instruments. The basic idea is that all analog signals are 4-20 mA and all digital signals are 0 or 1. This 4-20 mA signal is sourced from the calibration kit for testing purposes. The checks that are done during FAT are-

- Physical inspection of all components and cabinets
- Power supply connection and distribution checks are carried out before turning on the system
- System checks are carried out to check redundancy of power supply and network communication
- Hardware checks are carried out in the form of Loop checking, to check if the physical connections and wiring of the system is done correctly and also to check if proper addressing has been given to the field instruments at the software side
- Software checks are carried out by running the DCS system in Test Function mode
- Heat-soak testing is done to check if the system can perform well at different temperature levels

6.1.1. System Redundancy Checks

Most of the DCS are designed with redundant elements. Redundant engineering increases the system's reliability by utilizing backup processor/components in case of primary processor failure.
The redundancy test is carried out for the following components:

- Central Processing Unit (CPU)
- Power Supply Unit (PSU)
- Vnet/ IP
- Input-Output module
- Extending Serial Bus (ESB)

The Fig.6.1 below shows the sample screenshot of CPU redundancy check.

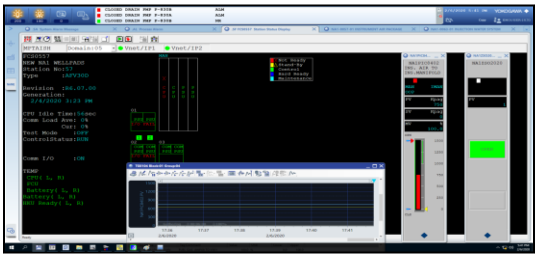

Fig.6.1: Sample screenshot of CPU redundancy check

6.1.2. System Configuration check

The various systems and the components of the project are connected as per the system configuration. The purpose of this test is to verify that all the systems are connected in line with the overall system configuration. This test is necessary to ensure that-

- All the controllers are connected as per the configuration
- All the HMI stations are connected as per the configuration
- All the network components are connected as per the configuration
- All the printers are connected as per the configuration
- The network connectivity between various systems is in order

7. CONCLUSION

Creating an automated refinery is easy but looking at the safety and the remote controlling and monitoring of the overall refinery/plant in order to reduce the hazardous life risks caused to the working personnel is the most tedious task. Hence, few MAC after a several surveys they introduced a way for the automation to supply a control and safety system which is integrated into a single system to online monitor and control the overall plant/refineries. This design aims at the automation and supply of DCS for crude oil field industries in order to maintain the desired temperature and pressure during the development of the hydrocarbon basin of the oil hill reservoirs by hydraulic fracture simulation process. To design a DCS we came cross the system design, its implementation and finally the working of the control system. These signals are sent across the FCS from the field-site/ Junction box station/transmitters/valves and then those signals are indicated on the HMI with the help of the P & ID control functional blocks interfaced via VNET/IP communication protocol throughout the system architecture. The one of the major concept is to find out the desired outcome is at FAT and also to attain the redundancy of the components used in the field controller.

8. REFRENCES

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