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RESEARCH ARTICLE

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DESIGN OF RTU, SCADA, AND TELECOM SYSTEM FOR A CRUDE OIL PIPELINE

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ABSTRACT

The act of monitoring and regulating control of a large pipeline system is a complex task to accomplish. The pipeline system mentioned henceforth pertains to the transport of crude oil across a vast geographical area. With improved technology in the field of control and automation, there are now solutions that allow us to execute such projects efficiently. Integrated systems involving Remote Terminal Units (RTU), Programmable Logic Controllers (PLC) and Supervisory Control And Data Acquisition (SCADA) System work in synergy to make this possible. The entire pipeline is continually monitored at different control/ pumping stations. The RTU hardware used here is STARDOM, the PLC hardware used is PROSAFE-RS and, the program is written in the language Functional Block Diagram (FBD) with FAST/Tools as the overall SCADA backbone.

Keywords: RTU, SCADA, Telecom System.

I. INTRODUCTION

There is a need for an efficient, quick, reliable and an effective control system in industrial sectors. Oil and Gas is one such sector where control and automation is highly required. The crude oil transmission pipeline has many intermediate stations for control and monitoring purposes. Amongst them, there are two main control stations, one is the SCADA Master Control Station (SMCS) and the other is the Emergency Control Station (ECS). The entire pipeline is also monitored at other intermediate pumping stations, refinery terminals, and repeater stations.

Monitoring of the pipeline system happens efficiently when the process variables like, Pressure, Temperature, Flow, Level etc., are periodically measured from the instruments connected to the system. The signals that come from measuring instruments will be both analog and digital. The analog instruments used here are pressure transmitter, level transmitter, temperature transmitter, differential pressure transmitter, and gas detectors. Instruments which give digital signals are Motor Operated Valve, Push Button, Fan Failure Alarm etc. The output of the controller can be in the form of both analog and digital. Analog outputs include, flow control valve, pressure control valve. Digital outputs are Beacon Signals, Hooter Signals etc

The entire pipeline has 34 intermediate stations which are distributed as 11 Pumping Stations, 16 Repeater Stations, 4 Refinery Terminals, and 3 Remote Work Stations. Each Station has a STARDOM RTU controller to regulate the flow of the crude oil in the pipeline. Totally, 37 RTUs are used for the controlling of the entire pipeline. It operates at a voltage rating of 24V DC. Each rack has 12 slots. Slots will be filled by the modules like, Power Supply, CPUs, I/O modules, Communication Ports. All the modules are redundant. In case of abnormal condition such as, power failure, Overheating, power surges, the redundant module takes the control within a fraction of second. The controller accepts the analog signals in the range 4 to 20mA.

II. SCADA ARCHITECTURE

The FAST/TOOLS SCADA system provides integrated centralized control and monitoring of pipeline. To see the control action provided by the RTUs on the pipeline graphically, the RTUs must interact with the SCADA software. The software used here is FAST/TOOLS version 10.02. The interconnection between the systems and their accessories is known as system configuration. The SCADA System at SMCS and ECS are the real time computing environment each consisting of two servers distributed over a dual redundant Local Area Network. Both the servers will be configured in dual hot standby mode of each other. These SCADA Servers consist of the entire real time database including historic database, archived database and alarm management summary of the entire pipeline. These databases will be synchronized between all the SCADA servers through dual LAN and WAN. Apart from SCADA server there are APPS, OPC, History and Web server. APPS Server is used to determine if there is any leakage in the pipeline. It uses the software Leakage Detection Software (LDS). It considers the factors like, Pressure, Temperature, level etc., and models the flow of the liquid in the pipeline for a set of intervals. If the modeled flow rate of the crude in the pipeline is less than the usual value, then a leakage in the pipeline is predicted. If a third party system needs to be connected to our software, then it uses OPC server (OLES for Process Control), as its gateway. This is mainly used in the process control industries. HISTORY SERVERS, store the history of the control actions given to the pipeline. WEB SERVERS let the user to know the status of the pipeline through internet.

The servers might fail due to the reasons like, power failure, failure of both the LAN, termination of SCADA software, hardware issues etc. A 100 Mbps redundant Ethernet LAN is provided for SCADA servers over SDH system. Optical Fibre Cable (OFC) is laid by the side of the pipeline. Technically, OFC has a data transferring speed much higher than the Ethernet cables since the former can transfer the data to a very large distance. If the OFC link fails, then the pumping stations communicate through a 6 Mbps Leased Line, whereas, the SMCS and ECS stations communicate through a 4 Mbps Leased Line.

The controllers at other pumping stations keep synchronizing the data with SCADA SERVER through dnp3 protocol, whereas the PLCs communicate through Vnet IP protocol. There are around 1500 conventional I/Os.

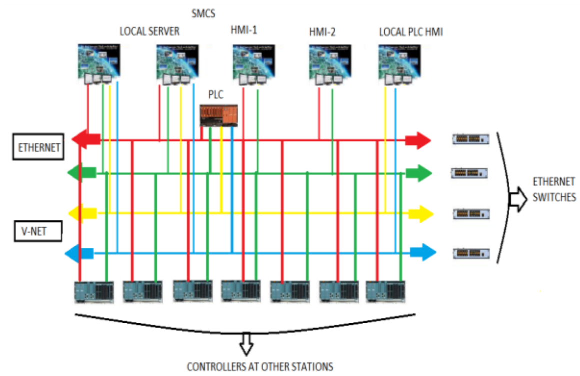

Figure 1: Interconnection of Servers and Controllers through Ethernet and V-NET IP

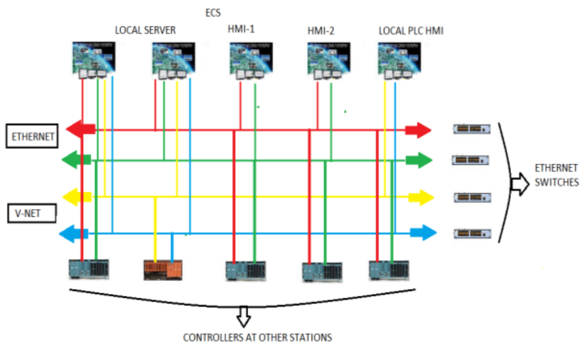

Figure 2: Interconnection of Servers and controllers through Ethernet and V-NET at ECS

III. INTERNAL ARRANGEMENT OF CABINETS

All the inputs from the field come to the cabinets/panels that will be located in the control room. These cabinets have all the equipments that help in establishing the communication between hardware and software. There are various types of cabinets used. They are System Panels, which accommodate the controller and its accessories. Marshalling Panels, this consists of relays, Terminal Blocks, Barriers, and Terminal Boards. The Signal from the field gets connected to the Terminal Blocks located here. Server Panels, have the servers being rack mounted inside them. PDB Panels, distribute the power to all the other panels located in the control room.

Each Panel has its own power consumption and heat dissipation factor. By calculating that, current rating of the MCBs of the panels could be decided.

Challenges faced while designing a panel are,

1. Size of the panels must be carefully decided.
2. Position of the fans that need to be placed in the panel door. There are two types of fans, namely, exhaust fans and suction fans.
3. Wire/ Cable Sizes: There are three different wires, Analog, Digital, and Grounding Cables. The thickness of which depends on the current passing through it.
4. Calculate the number of relays, barriers, Terminal Blocks, Terminal Boards, MCBs, and the Bus Bars that are required in a panel accurately.
5. Duct Sizes need to be decided based on the number of wires that could be accommodated inside it.
6. Size and type of the Terminal Blocks should be properly chosen

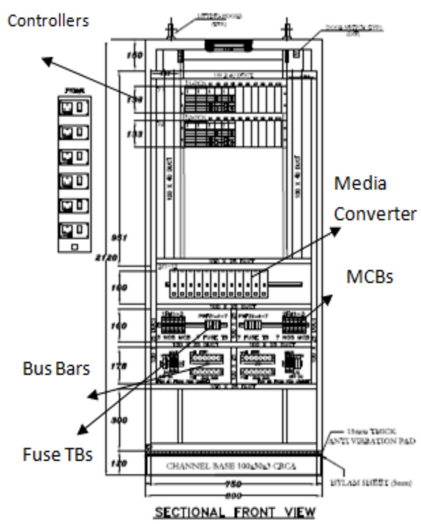

Figure 3: Front View of the Cabinet

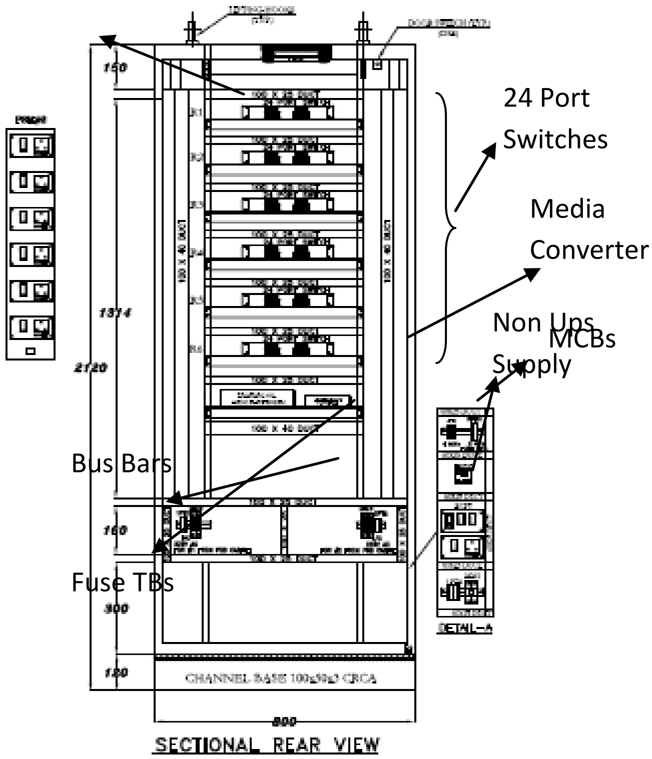

Figure 4: Rear View of the Cabinet

IV. POWER SUPPLY REDUNDANCY

To have the control action continuous, all controllers, servers, LANs, WANs, power supplies have to be redundant. In order to make the hardware components work continuously, the power being supplied to them must be uninterrupted. The power supply redundancy is the most important task to accomplish. There are two power supply units i.e., -48V DC and 230V AC Non UPS being used. The -48v DC source is converted to 24V DC by using a dual redundant power supply. It also has an inbuilt diode for reverse voltage protection. While the 230V AC supply is converted to 24V DC by a dual redundant power supply and a separate diode module is used for reverse current protection. One of them will be considered to be as a primary source and the other to be considered as a backup source. The primary source will be set at higher potential and will be in load sharing feature, whereas the secondary will be at a lower potential. Because of the above configuration, 100% load will be drawn from the source which is at the higher potential. In case the primary fails, then the load will be automatically shifted to the backup source.

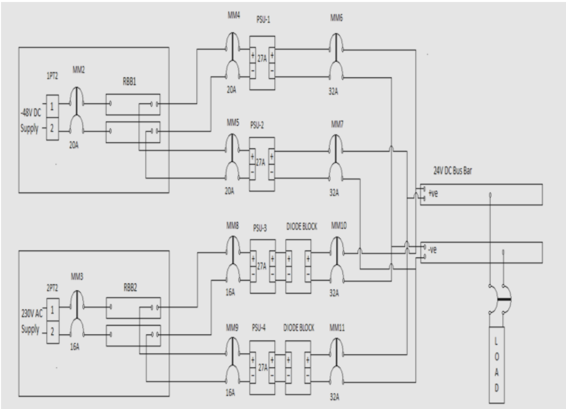

Figure 5: Power Consumption Redundancy Scheme

Once the panels are ready and the communication between STARDOM RTU and FAST/TOOLS is established, RTU starts controlling the pipeline based on the inputs obtained from the instruments that are connected to the pipeline and gives the control action accordingly.

V. PROCESS OF CRUDE TRANSMISSION

In olden days crude used to be transported through ships, tankers but now it's being transported majorly through pipelines. To monitor the pipeline's stable condition the process variables need to be monitored periodically using the measuring devices such as pressure transmitter, temperature transmitter, differential pressure transmitter, flow transmitters, level transmitters. Apart from these measuring devices, there are also other equipments like pumps, electric heaters, Motor Operated Valve (MOV), Flow Controlled Valve (FCV), and Pressure Controlled Valve (PCV).

The pumps and MOVs used here are actuated and tripped on certain specific conditions. The crude that passes through the pipeline will be pumped at intermediate points. The tripping of these pumps happen based on the 2 out of 3voting logic on pressure alarms.

The process variables first arrive at the Junction Boxes, Telemetry Interfacing Cabinets, Marshalling Cabinets, then finally the system cabinets, where our controllers are located. Junction boxes will help in troubleshooting the errors, if any, during the operation of the system.

Arranging the components and establishing the interconnection between them is one half of the project. The other half focuses on automating the control activities associated with the pipeline, such as, opening or closing a valve, power on the heater, sound an alarm during emergency conditions, power on the pump. There are programs written in the language Functional Block Diagram with logic behind it. The interlocks provide instruction on action to be taken on actuation of any equipment. So such interlocks majorly contribute towards automation of pipeline.

Apart from the above mentioned interlocks, all other DI, AI, AO and DO equipments are individually considered while programming.

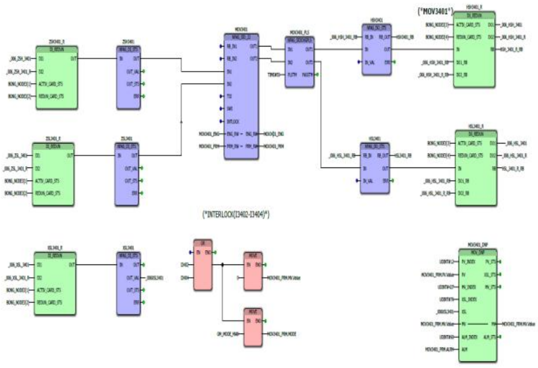

Figure 6: Logical program written in the language Functional Block Diagram for a MOV

VI. SOFTWARE DETAILS

To automate the process, a logical program in the language functional block diagram is written for both RTU and PLC. Following are the software tools used.

1. FAST/TOOLS Version 10.02: Helps the operator to monitor the pipeline in a graphical manner. Graphics for SCADA is developed in this software. It is a user friendly tool and could be interfaced with both RTU, and PLC. Generating alarms, trends based on both historical and current events, and generating reports are few among its vast features.
2. Logic Designer: The program with a logic written to the Stardom RTU is through this software. It allows the programmer to write

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the logic in multiple languages such as FBD, Ladder Logic Diagram (LLD), and STL and so on.

VII. TESTS CARRIED OUT

Factory Acceptance Test: This contains both hardware and software checks such as General Arrangement and Internal Arrangement check, I/O module redundancy check, system configuration check, wiring checks, Loop Check. Loop Check ensures if the loop formed between the physical elements is complete or not.

VIII. RESULTS

A project is successful only when the results obtained are satisfactory. The hardware and software developed have cleared all the tests and are functioning as desired. All MOVs pumps and heaters can now be controlled through SCADA. Cause and Effect matrices are developed to monitor the tripping action. System diagnostics give the status of the I/O modules, Power supply and CPU. Now the crude oil pipeline can be supervised, controlled and monitored by a SCADA system.

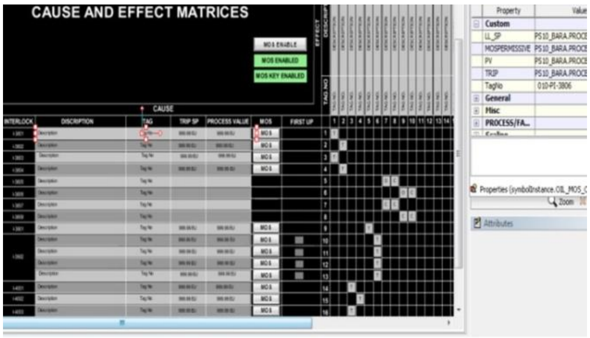

Figure 7: Graphic display of cause and effects matrices

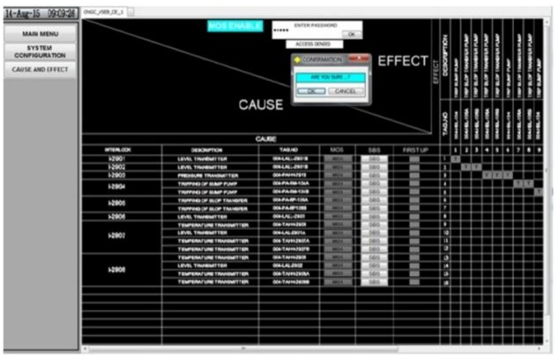

Figure 8: Graphic display of cause and effect matrices

Figure 9: Graphic display of controller and I/O module status

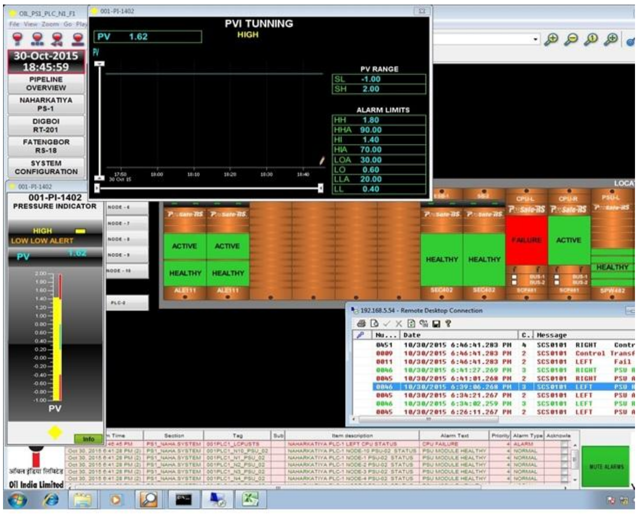

Figure 10: Graphic display of PVI tunning

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