

## A Modular Control Package for Automation of Indus-2 Low Conductivity Water (LCW) Plant

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### ABSTRACT

A comprehensive, modular control package "PANI" has been developed and deployed for automation of LCW plant of Indus-2<sup>1</sup>. The Plant automation utilises LabVIEW<sup>®</sup> based GUI and application development while VME controllers are used for front-end equipment interface. The safety interlocks are implemented in hardware. Control software is designed in modular fashion for easy maintainability, configuration and troubleshooting. PID controllers and load managers using Modbus<sup>®</sup> communications have also been integrated for complete plant automation. The overall system is described with emphasis on software features.

### INTRODUCTION

Low Conductivity Water (LCW) is used as the cooling agent in accelerators for cooling various systems and components, e.g., power supplies, magnets, vacuum chambers, radiation absorbers etc. A control system is required to control the production, cooling, distribution and monitoring of low conductivity water and supervising the plant operation with all the necessary features like alarming, logging and providing a user friendly GUI for easy operation, maintenance and up gradation of overall system. Indus-2 LCW plant control system is of three layer architecture with "PANI" LCW control package developed in LabVIEW<sup>®</sup> running in windows environment on PC at layer-1 which communicates with PID temperature controllers and Maximum demand controllers on ModBus<sup>®</sup> and with layer-2 on TCP/IP. Layer-2 is the supervisory layer with OS9 modules running on VME bus having Motorola 68040 based controller card, this layer collects data and sends signals to one Equipment Controller (EC) in LCW plant area and four ECs in the ring tunnel equipment gallery using ProfiBus<sup>®</sup>. Layer-3 is the equipment control layer where there are different input and output cards connected with various devices such as pump starters, temperature transmitters, pressure transmitters, temperature switches, pressure switches, level transmitters, level switches, hand valves, electrically operated valves, pressure regulating valves, flow transmitters and flow switches. There are approximately 850 status, 500 analog and 130 control signals connected to different input and output cards at layer-3, distributed over almost entire area of Indus-2 ring, power supply hall, LCW plant, RF hall and Transport Line-3 tunnel.

A closed loop feedback control algorithm is implemented at layer-1 to control inlet & outlet temperature, flow rate, conductivity, quantity and pressure of the circulating low conductivity water.

### SOFTWARE FEATURES

A modular approach is adopted so that the package can be upgraded conveniently from time to time, to include signals from different subsystems as their commissioning goes on one by one. The control package "PANI" is designed for accommodating the changes made at lower layers at different times in card configuration and protocols. GUI presents data in plant mimic form as well as in tabular form. Password protected logon modes are provided for user and administrator operations. A debug facility is provided for debugging of the individual device operations. Error messages coming from lower layers and EC status are provided at layer-1 for easy and fast fault diagnostics of system. Client GUI can be opened on remote PCs for remote operation of the Plant from main control room as well as from any other PC on network with password authentication. A separate interlock window is provided to pictorially represent the interlock status as well as the contribution of the individual devices towards interlock status. Facility is provided for reading the complete plant configuration in the form of Excel spreadsheet for verification. Different editor windows are provided for editing the configuration files for configuring the device parameters, start up sequence, alarm limits, control

limits, control actions, association of control actions with events and user profiles. Control module is designed to maintain a self-record of configuration changes and maintenance and repair work. Slave module on the second PC provides the redundancy for master PC failure.

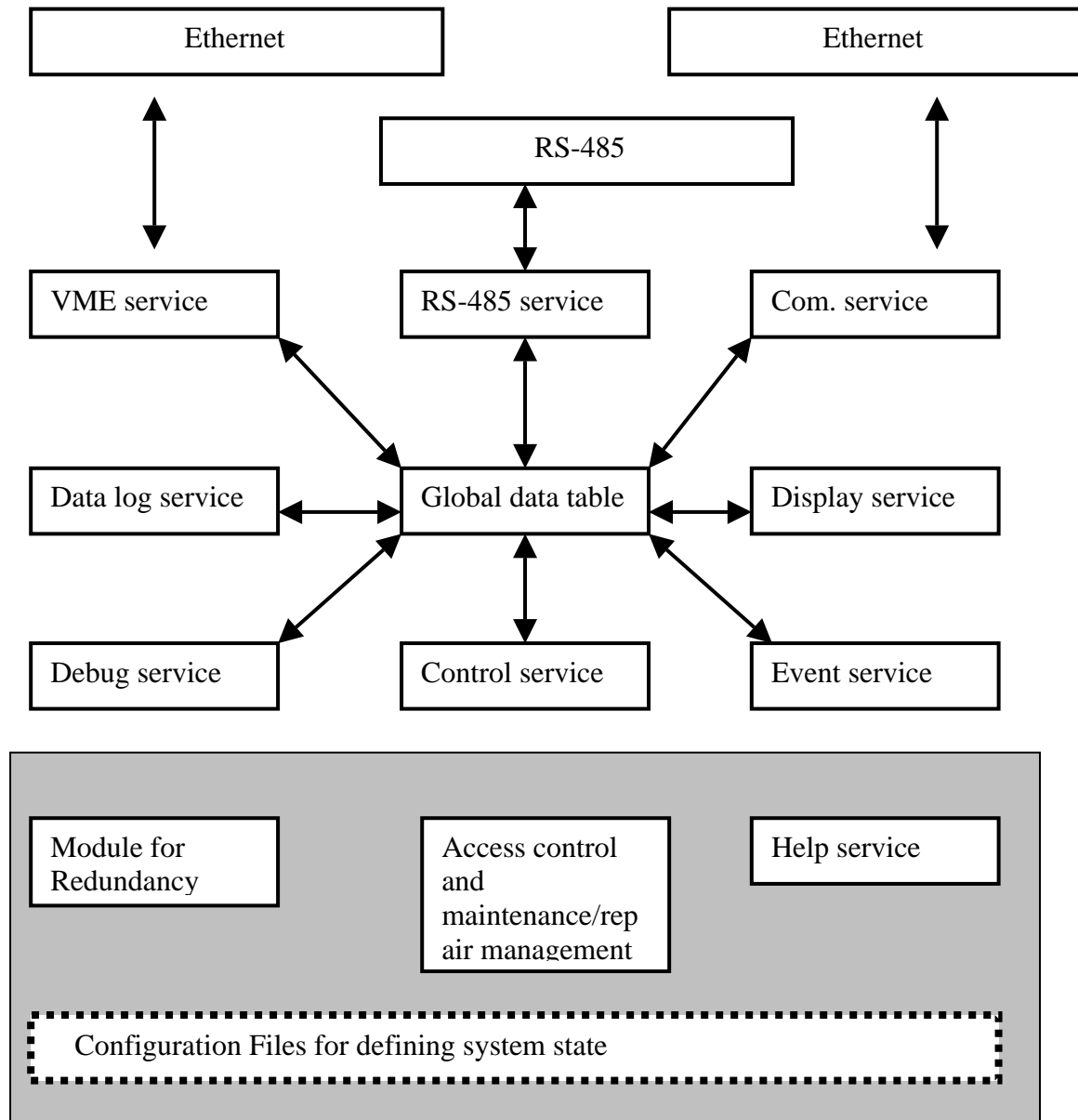


Fig 3.1 Block diagram of "PANI" control module.

### SOFTWARE ARCHITECTURE

A Modular approach is adopted here. Complete software is divided into 10 services as shown in fig 3.1. Multitasking facility of LABVIEW® is exploited here to run multiple services simultaneously such as alarm handling, control actions, data logging and monitoring. A service is grouping of tasks related with the implementation of some common goal. We have tried to keep the services independent of each other as far as possible. Inter-service data flow is using global data file and TCP/IP sockets. Different functions served by services are as follows.

### *VME service:*

Its functions are to acquire data from layer-2 (supervisory layer)[1] through Ethernet, by using client server based architecture. It segregates different types of data (digital and analog), extracts status signals and maps them to different Digital IN devices, scales and maps different analog data to devices and passes this processed data to other services. This service passes the control commands (issued from control services and other services) to layer-2 and ensures the command action by following the command response protocols with lower layer (layer-2). This service also checks for the failure and timeout conditions for any command and passes this information to error message queue for further action by other services. Devices such as electrically operated Valves take about 17 to 20 seconds of time for change of state from open to close state and vice versa. So, the verification for the command action in sequential manner will delay the loop by 20 seconds for each valve. This will slow down the whole process. This problem is overcome by associating a "timeout object" with each command. Object lives for the period equal to the delay needed in response of the feedback device. The object sends an error message in error message queue if the feedback device fails to respond in time or the response does not match with the reference state specified in the device configuration file. Authenticity check and mapping of command string to the commands coming from other services are done here in order to make other services completely independent of protocols and command string format adopted at layer-2. VME configuration editor is provided for configuring the remote port number, local port number, VME server TCP/IP address and loop delay.

### *Control service:*

This service is for implementing a closed loop feedback system to control the Inlet/outlet temperature, flow-rate, conductivity, quantity and pressure head of the circulating low conductivity water. This service also takes care for safety interlock failure and tripping of devices. This service takes control events from the active control table generated and prepared by event service one by one and finds out the control action from control configuration file and lists out the group of actions to be performed on devices (relays to be switched on/off) and it does the following for each action stated in the above list of actions.

1. It lists out pre-action conditions for devices to be checked.
2. It lists out the reference states for the feedback devices and feedback device numbers.
3. It lists out the delay between consecutive commands and the sequence of commands

Using the above lists it does the following

1. It checks for the pre-action conditions and prepares action report; in case condition is passed it sends the command to VME service one by one in the prescribed sequence.
2. It checks for the feedback condition by reading the feedback device state corresponding to each command after the prescribed delay period and it prepares a report of this and appends it to the action report.

This cycle goes on until all the commands stated in the action, and all the actions associated with the corresponding control event are served. Action report is logged to the action log file along with the owner of the action, start time and PC IP address from where the action is initiated. In case of error in report this is sent to error message queue, action report is also sent to a control message queue from where one can see the sequence of individual commands. Every action initiated is logged in the action log file for diagnostic purpose as well as for tracing the action record in the initial commissioning stage. The control actions are configurable and the plant configurations towards the control actions can be verified through the action tables generated by excel table sub service.

### *Debug service:*

This service comprises of a debugger window for testing the functioning of individual devices at the time of commissioning & fault diagnosing. Its functions are reading and writing on the selected device. In the debugger window all the devices (status read, analog read, control write) are grouped in a table. Clicking on the group opens the contents and shows the devices present in that group along with their device names and their present read back values. The read back values are continuously updated. For writing on a device one has to simply select the device to be operated and then click on

update. Writing on devices using debug window directly writes the command on to the device, bypassing the software interlock check. One can define a test group and collect devices under this group for testing purpose. This service also contains device editor, interlock editor, control editor, action editor, start up editor, and logon editor. All these editor windows are for editing the configuration files for the system. All of these editors provide data in the form of dropdown lists grouped in the form of device groups to make the configuration process easy and fault free. Devices and action groups defined at one place can be used at other places by simply picking it from the list; thus avoiding the chances of error because of misspelling. Special editors are provided in place of conventional editors so that data can be stored in a form, which can be easily read and converted in LabVIEW data formats in order to speed up the execution. This service contains one excel table generating sub service which generates system state defining tables in excel spreadsheet file format which can be printed and used for verification purpose.

#### *Event service:*

This service generates and prepares active event tables for alarm events and control events. Event conditions are configurable for limits and enabled state. This service also handles the alarm generation, viewing and printing. Active alarm window of pop-up type is provided for active alarm logging and handling. Logged alarms can be viewed using a separate alarm window. Control event table is used by control service for initiating the control actions.

#### *Data log service:*

Its functions are selecting data for logging, selecting log-rate, plotting of data (up to 10 parameters can be selected for plotting simultaneously on the same graph for comparison purpose. Both online and stored data can be plotted), handling data log file generation, viewing and printing of data log file. Data is also logged in common database for accelerator data.

#### *Access control service:*

Provides password protected logging in two modes- mode 1 as “Administrator” with full control and mode 2 as “User” with limited controls. In administrator mode, logon is allowed only after one supplies the authentication password as well as the complete information about the purpose of logon as administrator. One is supposed to supply completely and correctly all the information regarding changes to be done in configuration files, addition or removal of devices, disabling of interlocks at the time of maintenance and creating new user profiles. By viewing the maintenance log file one can find out all about the new changes implemented and can always revert to the initial state if needed.

#### *Display service & Help service:*

This service comprises of a GUI for plant operation. It shows a toolbar on the top of the window from where one can select different working area windows. Plant signals are accommodated in three windows (primary loop, secondary loop, DM loop) and field signals are accommodated in two windows (SRS ring area, Power supply area). Representation is provided in two forms - tabular form (shown in fig 3.3), where complete data is represented in the form of tables and in the plant mimic form (shown in fig 3.2), where user gets plant representation with the help of device pictures, and flowing water path is depicted by change in color of pipes. Occurrence of alarm causes the corresponding indicator to blink on screen to call attention of the operator. Information about controls and indicators are provided on tool tip. A separate alarm window also pops up to show all active alarms. Two windows are provided for communication with four PID temperature controllers and two maximum demand controllers. On the top write corner of the screen animated icons of VME service, event service, control service, com. service and RS-485 service are shown to show the healthy state of these services. Service failure is shown by a non-animated (frozen) icon. A separate action window is provided for user commands and one has to supply login name and password along with a command. Error message queue and control action queue can be enabled for viewing actual implementation of the command. Help service provides help for users, administrator and application developers. Help is structured in the forms of frequently asked questions, problems & remedy, plant starting & stopping procedures, device tables and about using editor windows.

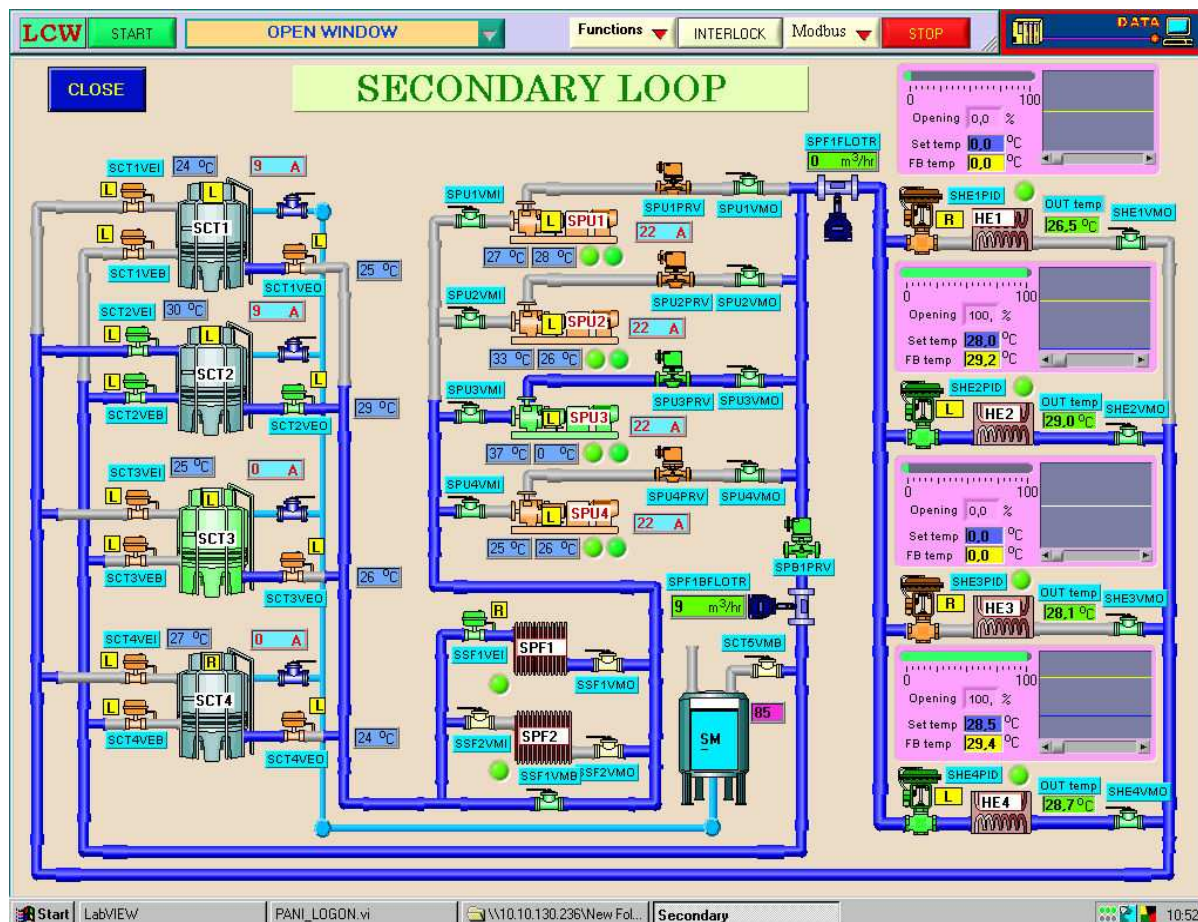


Fig 3.2 GUI service, mimic window for secondary loop

#### Com service:

Communication service provides data over network between client and main application using data socket protocol. This service also serves as server for remote action command coming from remote PC over Ethernet. Each remote action command is checked with a login name and password. This service filters out invalid and unauthentic commands.

#### RS-485 service:

This service is for communication with PID temperature controllers and maximum demand controllers over RS-485 using Modbus protocol. This service is needed, as there are six devices to be operated using single RS485 port so port spooling is needed. This service accepts inputs as device number, start address, no of bytes, type of command, and port no. It performs read and write operation-using Modbus protocol and returns the incoming string.

#### Module for redundancy:

This module is for providing software redundancy for PC failure. The module comprises of two parts, the master part and the standby part. Both of these parts communicate with each other and keep on notifying each other about their presence. Main PC part continuously updates the configuration folder and global file folder from main PC to standby PC. In case standby PC does not get flag change from main PC in 3 seconds, it launches the complete application "PANI" on the standby PC. In case main PC starts refreshing the flag, standby PC stops all the services and intimates this to main PC. Main PC on receipt of intimation from standby PC starts the application "PANI" on itself and the second PC goes into standby mode.



Fig 3.3 GUI service, Tabular window for SRS ring area

## DISCUSSION

This module is already in operation and we are working to add some more functionality to this like providing zooming on the selected area, providing online plant data using Internet browser so that other groups if needed can utilize the data, providing TCP/IP address based filtering for the action commands and encrypting the password before sending it along with command, providing facility for auto calibration of devices through software.

## REFERENCES

- [1] Pravin Fatnani et.al. "INDUS-2 control system" PCaPAC99, Tskuba, Japan.