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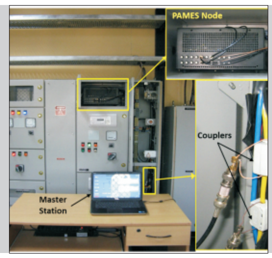
BARC NEWSLETTER

Radiation Shielding Windows

CONTENTS



Radiation Shielding Windows for Metallic Hot Cells

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Abstract

Remote operations in radioactive hot cell require Radiation Shielding Windows (RSWs) to facilitate direct viewing to obtain high visual acuity and depth perception during operations. Molybdenum-99 is an important isotope because of its daughter isotope, Technetium-99m (^{99m}Tc), which is the most widely used medical radioisotope for diagnostic purposes. A Hot Cell Facility for production of Fission Moly-99 (^{99}Mo) is in the advanced stage of completion at Board of Radiation & Isotope Technology (BRIT), Mumbai. As RSWs for the hot cells could not be imported due to embargo, Technology Development Division (TDD) of Nuclear Recycle Group (NRG) was entrusted with the responsibility to take up Design, Development, Manufacturing and installation of three large-sized RSWs for this Project and the entire work has been completed successfully.

Keywords: Hot Cell, Radiation dose, Radiation Shielding Windows (RSW), Viewing angles, Light transmission, Stabilized glasses, Anti-reflection, Streaming.

Introduction

A facility for production of Fission Moly-99 for medical applications is being set up by Board of Radiation & Isotope Technology (BRIT) to pursue Department of Atomic Energy's commitment to deploy radiation technologies for societal benefit. ^{99}Mo is one of the most important isotopes, because of its daughter isotope, ^{99m}Tc (Technetium-99m), which is the most widely used medical diagnostic radioisotope. Most of the industrial-scale ^{99}Mo processes are based on the fission of U-235. The facility consists of three Hot Cells with reprocessing and separation equipments with the state-of-the-art technology. The operational radiation dose inside the Hot Cells ranges from 8.8 x 10^6 µSv/hr (~880 R/hr) to 1.98 x 10^8 µSv/hr (~20,000 R/hr). The Hot Cells are constructed using thick MS shielding plates with provision of cutout (without steps) for Radiation Shielding Windows for each Cell. Remote operations in Hot Cells with the aid of Master Slave Manipulators (MSMs) require Radiation Shielding Windows (RSWs) to facilitate high visual acuity & depth perception.

As the RSWs could not be imported due to embargo, Technology Development Division (TDD) of Nuclear Recycle Group (NRG) independently carried out work related to Design, Development, Manufacturing and Installation of three RSWs for MS Hot cells having cut-out sizes of 900 (W) x 800 (H) x 520 (Thk) (RSW1), 800 (W) x 500 (H) x 450 (Thk) (RSW2) and 800 (W) x 500 (H) x 350 (Thk) (RSW3) for this project of national importance.

Design & Manufacturing of RSWs

Two variants of RSWs, mainly Dry RSWs and Oil Filled RSWs, are being used for the hot cells based on the type of facility and functional aspects of RSWs such as ease of maintenance and RSW Performance parameters. However, we have opted for Dry type RSWs filled with nitrogen gas for Fission Moly Production (FMP) facility. Since FMP hot cells are constructed from thick MS shielding plates, it was challenging to design the RSWs with available glass slabs having densities in the range of 2.5 g/cc – 5.2 g/cc and in limiting the overall thickness of the RSWs to facilitate the operation of MSMs as specified by the end users.

Even before taking up the design of RSWs, construction of Hot Cells was completed, including the installation of inner SS containment boxes. Therefore, no constructional modifications were possible. The projection of RSWs outside the hot cells was also restricted to facilitate the operation of Master Slave Manipulators. The Technology Development Division commenced the design with the available sizes and densities of RSW Glass Blocks in BARC. Multiple design iterations were carried out to optimize design parameters like effective shielding, extreme viewing angles and light transmission parameters in all three RSWs. In view of very high radiation dose on the hot side of RSWs, utmost care has been taken by providing a

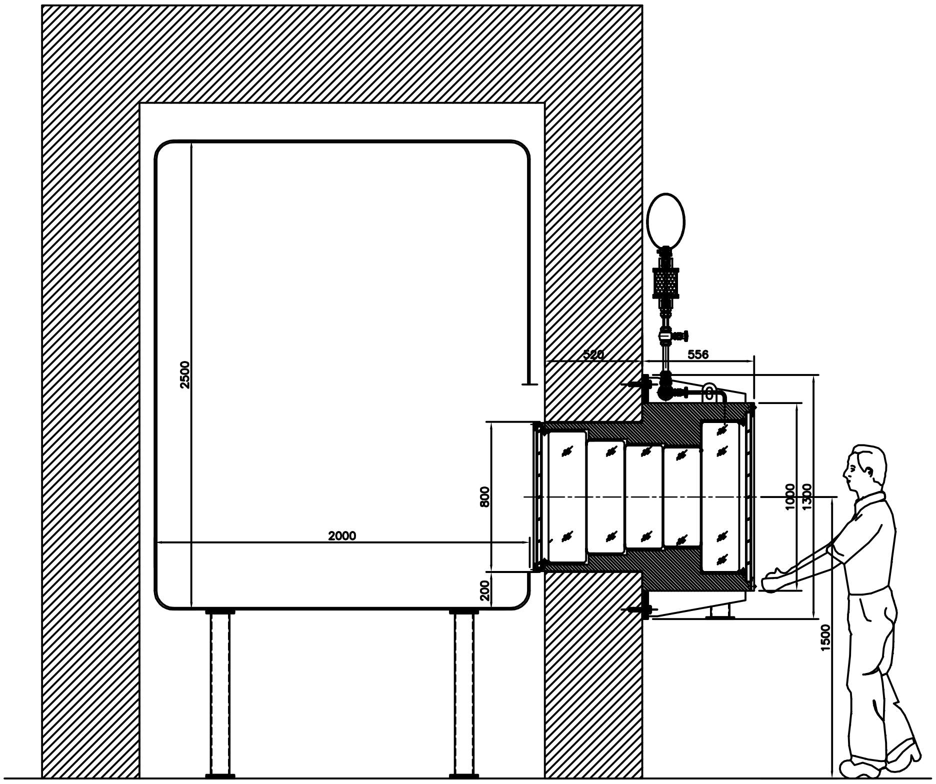

Fig.1: Typical sectional view of Hot Cell & RSW

Fig. 2: RSWs undergoing final Inspection & Testing

combination of Carbon Steel, high density concrete and Lead (Pb) to overcome the streaming of radiations due to constructional features of RSWs. **Fig. 1** shows the sectional view of Hot Cell and RSW.

Various types of radiation resistant and optically compatible glasses are used in the construction of RSWs. This range includes ceria-stabilized glass blocks of 2.5 gm/cc, stabilized/unstabilized glasses of 3.6 gm/cc and high density glasses of 4.77 gm/cc. While the low density glasses are borosilicate glasses with no Lead in their composition, the medium and high density glasses contain varying amounts of Lead to give the glasses the desired optical and radiation resistant properties. Glass slabs with anti-reflection coating have also been used at appropriate locations in order to reduce the reflection losses from the glass surfaces.

While designing the RSWs, key technical aspects such as Radiation Shielding adequacy, Radiation Stability of the Glass Blocks, requirement of Viewing Angles of the facility, Light Transmission Efficiency, Leak Tightness of the filled N_2 gas and Overall Thickness of RSWs were taken into account to meet the requirements laid down for the Facility.

Subsequently, all RSWs were manufactured and assembled at M/s. HMT Machine Tools Ltd., Hyderabad, with stringent Inspection and Quality Assurance in order to achieve quality parameters in line with the international standards. All RSWs were tested rigorously with respect to raw material inspection, dimensional tolerances, pneumatic testing of the housing, densities of filler materials, light transmission efficiency, leak tightness of the filled Nitrogen gas and Viewing Angles. **Fig. 2** indicates RSWs lined up for delivery after final Inspection & testing at HMT Works. After passing the stringent inspection criteria, all RSWs were supplied to Fission Moly Project Site on October 15, 2019. Important activities, such as design, preparation of detailed engineering drawings, identification of requisite glass slabs, obtaining the approvals, fabrication of the housings, assembling of RSWs, stage-wise inspection, final inspection, site delivery and installation have been carried out in a record time of one year.

Fig. 3: Installation and Pressure Testing of RSW

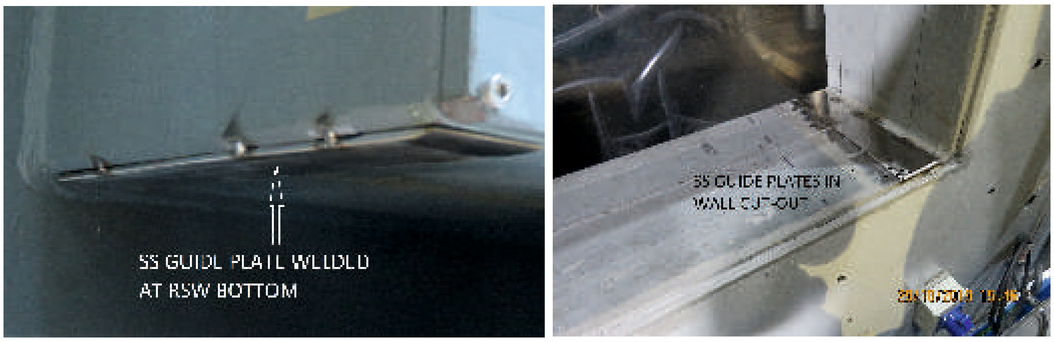

Fig. 4: Provision for SS plates at the bottom of RSW and cut-out arrangement for smooth insertion

Fig.5: Scientific personnel pose for a photo during the installation of three RSWs at FMP Facility, BRIT

Installation of RSWs

The installation and commissioning work of the RSWs was taken up immediately after the delivery of RSWs at the plant site. By the virtue of being heavy and fragile, utmost care was taken during the packing, transportation of RSW Assemblies and also during shifting of RSWs to installation site.

After unpacking, cleaning and pressure test of filled N_2 gas, the RSWs were released for installation (**Fig.3**). To facilitate smooth insertion of RSWs in their corresponding cut-outs, SS plates were welded in the wall cut-outs and at the bottom side of RSWs (**Fig. 4**). Use of innovative techniques such as positioning of studs for progressive uniform insertion, tools and fixtures resulted in safe installation of all RSWs without removal of any existing wall-mounted devices and panels. Each RSW has been fixed with the help of Bolts on its mounting Flange.

Close tolerances of the mounting flanges of RSWs facilitated smooth installation. Minor gaps between RSWs and their cut-outs were filled by thin Lead Sheets to avoid any streaming of Radiation. Installation and commissioning of all three RSWs have been completed as per schedule on October 31, 2019. **Fig. 5** shows the RSWs installed at FMP, BRIT Facility.

Technical Parameters of RSWs

Technical parameters related to the design and performance of RSWs are given in Table 1.

Table 1: Technical Data of three RSWs installed at FMP, BRIT

Sr. No.	Parameter	RSW -1	RSW -2	RSW -3
1	Cut-out Size	900mm X 800mm	800mm X 500mm	800mm X 500mm
2	Cell Wall Thickness (MS)	520 mm	450 mm	350 mm
3	Hot Cell Radiation Dose	20×10^3 R/hr	1×10^3 R/hr	0.8×10^3 R/hr
4	Overall Thickness of RSW	1140 mm	910 mm	675 mm
5	Light Transmission Efficiency @ 589 nm wavelength light	Min. 26 %	Min. 33 %	Min. 40 %
6	Extreme Viewing Angles – Horizontal	Min. 45^0	Min. 45^0	Min. 45^0
7	Extreme Viewing Angles Vertical	Min. 50^0	Min. 40^0	Min. 55^0
8	Inert Gas Purge System	Inert N_2 Gas (Leak Tight)	Inert N_2 Gas (Leak Tight)	Inert N_2 Gas (Leak Tight)
9	Weight of RSWs	4.5 T	3.5 T	3 T

Conclusion

Design, manufacturing and installation of three RSWs resulted in timely accomplishment of an important activity, which otherwise could have severely affected the progress of Fission Moly Project. Further, the indigenous Design and Manufacturing of these RSWs resulted in significant foreign currency savings and reduction in the project cost. Design, manufacturing and supply of these RSWs have also resulted in import substitute for embargo listed items meant for Radiochemical plants. In addition, the validation of in-house design & development of RSWs for this crucial project has enhanced the confidence of engineers and scientists involved in the project.

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We acknowledge the cooperation extended by Shri A. C. Dey, Shri P. Naskar, and the entire staff of FMP, BRIT and HMT officials. We also acknowledge the support extended by Shri K. Agarwal, Former Director, NRG; Dr. C. P. Kaushik, Associate Director, NRG; Shri K. V. Ravi, Chief Executive, NRB; Shri S. Pradhan, Deputy Chief Executive, NRB; Shri H. R. Pimparkar, GM, NRPSED, NRB and Shri Pradeep Mukherjee, Chief Executive, BRIT, in facilitating timely completion of this important activity.

Post-Accident Monitoring of Electrical Systems

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Abstract

The assessment of the extent of damage to the electrical systems soon after an accident is of immense importance as power supply to certain safety systems needs to be restored at the earliest to avoid serious consequences. The state of utter confusion that prevails after an accident can render even a seasoned operator clueless. Precious time may be lost in the assessment of the state of various cooling circuits and the availability of power supply to its components.

Accidents due to external causes such as earthquake, fire, flooding, etc. have the capacity to cripple the electrical distribution networks in Nuclear Power Plants (NPPs) in spite of superior design system. The critical equipment and systems may have undergone extensive design basis analysis and testing to prove the capability to survive an accident. But the survival of the equipment may be of little use in the absence of electric power following an accident.

PAMES is an automated monitoring system that can periodically scan and assess the health of the power cables in an electrical distribution system and presents an overview to the operator to enable timely action before a crippling failure.

Keywords: **PAMES, SLD, TDR, NPP, Non-Intrusive, NDE, FPGA, Power Cable**

Introduction

An on-site electric power distribution system in a Nuclear Power Plant (NPP) essentially comprises of a hierarchy of distribution buses at different voltage levels and configurations–three-phase systems at 6.6kV, 415V; single –phase systems at 240V; and DC at 220V, 48V or 24V. Many of these buses cater to the safety-related electrical loads which need uninterrupted power.

The cables interconnecting the buses and the electrical loads cumulatively run for more than 50km in a typical NPP. The cable raceways are either in the trenches on the plant floor or on the cable trays fixed to the vertical walls or hung from the ceiling. The cables, thus, are the most exposed and are therefore vulnerable elements of the power system from the viewpoint of an accident.

A line-to-line or an earth-fault anywhere in the power system manifests itself with unusually high current in the line or earth conductor respectively leading to the actuation of the protective gear and fault-clearance by the circuit breakers. If such a fault occurs in an energized cable, then it is isolated almost immediately by the protective gear.

Faults due to degraded cable insulation do not cause substantial fault current or create an intermittent fault leading to a trip but vanish once a trip has occurred. Such faults are difficult to detect by conventional methods. Insulation of cable conductors is known to be stressed (and therefore degraded) by high temperature, fire, submergence or mechanical damage. One or more of these stressors can be caused by an accident.

Another issue of specific importance to NPP is that many of the safety system loads are not energized during normal operation but their operation is crucial to safety after reactor shutdown, e.g., pumps of decay heat removal system or Emergency Core Cooling System that are powered only under specific accident conditions. Even dead faults on cables for such loads caused by an accident may lie undetected till they are required to operate.

Thus, the goal of the proposed system is to measure the service-worthiness of Nuclear Power Plant (NPP) cables following localized degradation due to stressors caused by an accident, irrespective of their state of Energization.

As distribution buses are housed in steel enclosures to ensure protection against submergence, fire and mechanical stresses, damage to them is not considered.

Key challenges

The cable condition monitoring system had to be designed to meet the following constraints.

1. In-situ, non-destructive and not requiring disconnection of the cable (s).
2. Required to work irrespective of the state of energization of the cable.

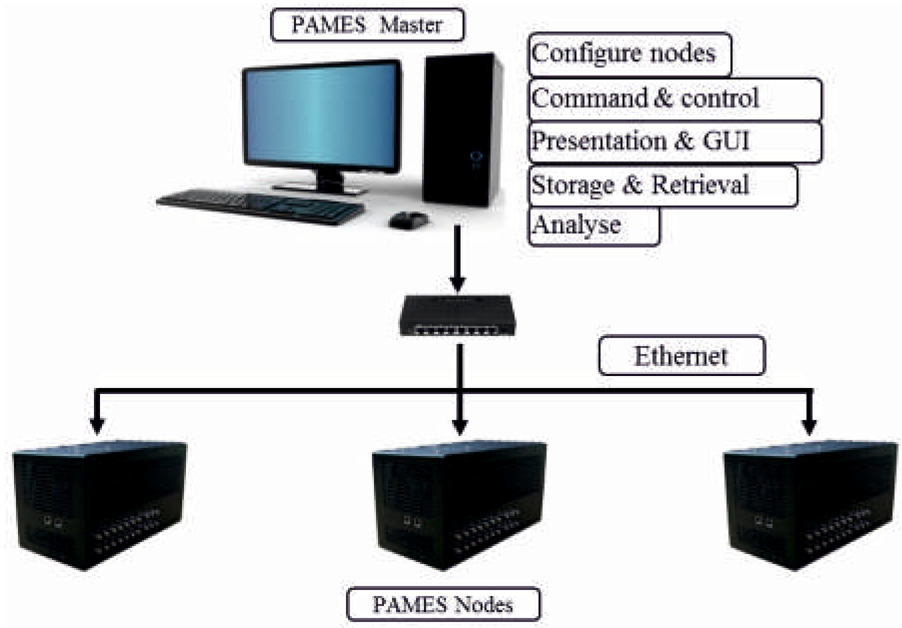

Fig.1: PAMES Architectural View

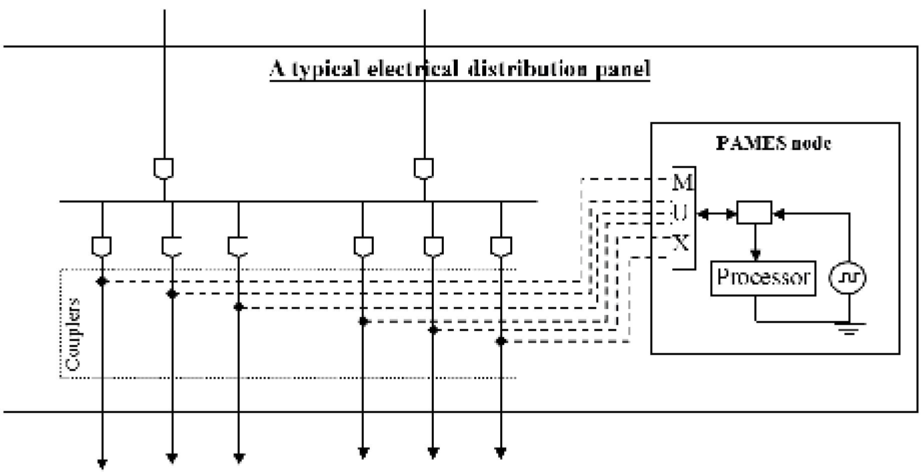

Fig.2: PAMES Node Context Diagram

3. Without requiring any modification of the electrical power system physically or functionally or in any way that alters the electrical system from safety or reliability point of view.

Therefore, the monitoring system must work galvanically isolated from the power system it monitors and protects itself from the power system transients that it is likely to meet. The design also had to consider easy installation and removal from the plant without requiring any disruption of the plant operations.

Architectural view

Fig.1 shows the architectural design of the PAMES system comprising two sub-systems namely, PAMES nodes and PAMES master connected over Ethernet.

PAMES nodes have the necessary instrumentation to generate a diagnostic Time Domain Reflectometry (TDR) pulse of suitable design and receive its response (echo) from the cable core (conductor). It can detect anomalies in the cable core insulation by correlating the diagnostic response signal with the injected pulse. The algorithm in the PAMES node obtains the following diagnostic status information from the diagnostic response signal.

1. The number of anomalies on the cable length (max 3 nos.)
2. The distance of each anomaly from the panel (the pulse injection point)
3. The extent/type of the anomaly

PAMES nodes are housed in the distribution panels and can test the cores (conductors) of the outgoing feeder cables from the panel one-at-a-time. An automatic sequential test operation can be started by a single command (from the master station) that tests the cores of all outgoing cables to obtain the diagnostic status.

The diagnostic status information obtained for the conductor cores is packed in a formatted data frame with a timestamp before transmission to the master station. A pre-fixed number of latest data frames can be stored at the local memory of the PAMES node that can be retrieved later by the master station.

The Ethernet-based network supports bi-directional communication between the PAMES master and the geographically distributed nodes. The communication is deterministic as at a time the connection is formed between the master and one of the nodes in a query-response fashion. Nodes cannot start communication on their own.

The PAMES master is a workstation computer that enables the user to view the status of the electrical system and generate recovery plans. It is to be located in a habitable area near the Main Control Room of a NPP. It is designed to work autonomously without any need for 24x7 manning. Trained supervisors should be able to use the interactive Graphical User Interface (GUI) presentation on the master station to obtain details at the required level.

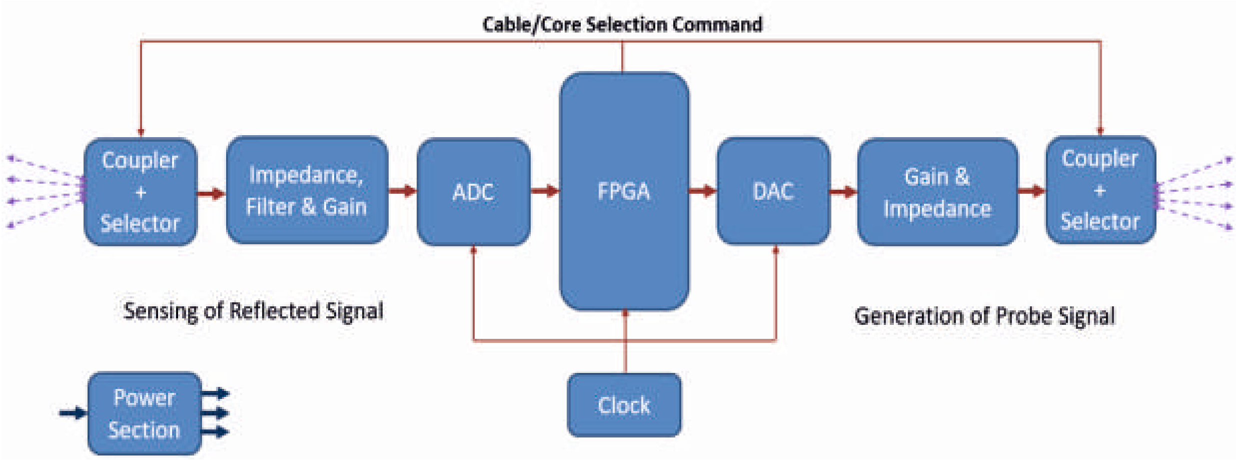

Fig.3a: Schematic Block Diagram

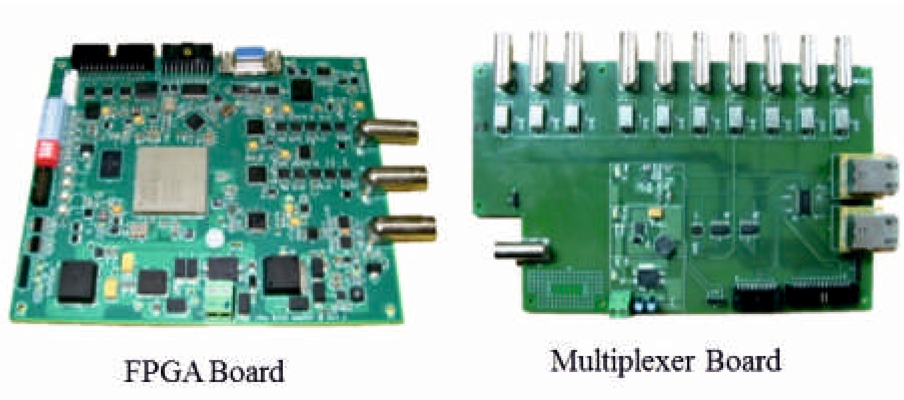

Fig.3b: Hardware modules

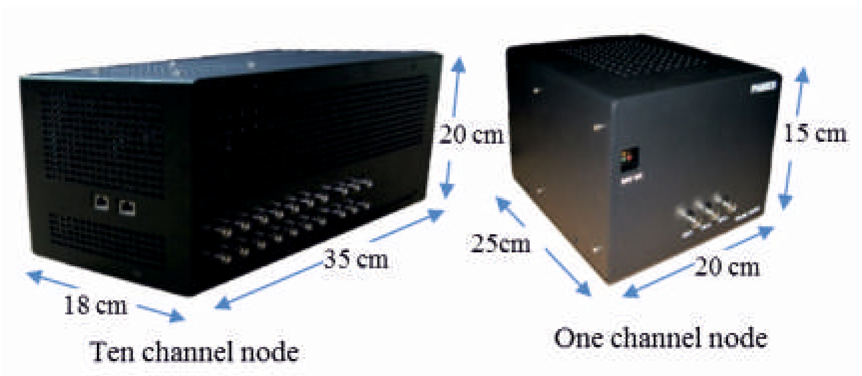

Fig.3c: PAMES nodes

Description of sub-systems

PAMES nodes

The PAMES system will interact with the electric power distribution system of the plant through the PAMES nodes that are housed in the distribution panels. Conductor cores of critical feeder cables can be injected with a TDR signal generated at the PAMES node via magnetic (non-galvanic) coupling.

A PAMES node can test one conductor core at a time and hence the signal from the signal generator is obtained through a multiplexer to the desired core coupler. The time window for receiving the response (echo) from the cable varies with the length of the cable downstream and therefore is a configurable parameter. The multiplexer will hold the connection to a coupler for the pre-configured time before switching to the next. The hardware for PAMES node comprises of two custom-designed modules (boards).

- An FPGA board to generate the probe signal and receive the echo (reflected) signal
- A multiplexer board to select one of ten (10) cable cores for testing.

The FPGA board can generate 1 to 4 cycles of sinusoidal probe signal of 5Vpp in the frequency range of 1MHz to 50MHz. The echo signal is sensed using a 12-bit ADC sampling at 400MSPS. Power line noises are filtered from the echo signal before processing by ADC. It also generates a cable/core selection command to select one of the 10 cable cores for testing.

The multiplexer board connects the probe signal to and receives the echo signal from the target cable core using Radio-Frequency relays.

The PAMES node works with a built-in 24VDC power supply and can communicate with the PAMES master on Ethernet. A schematic block diagram of the PAMES node is given in **Fig. 3a**. The actual photographs of the hardware modules (boards) and the physical outlines are given in **Fig. 3b & 3c**.

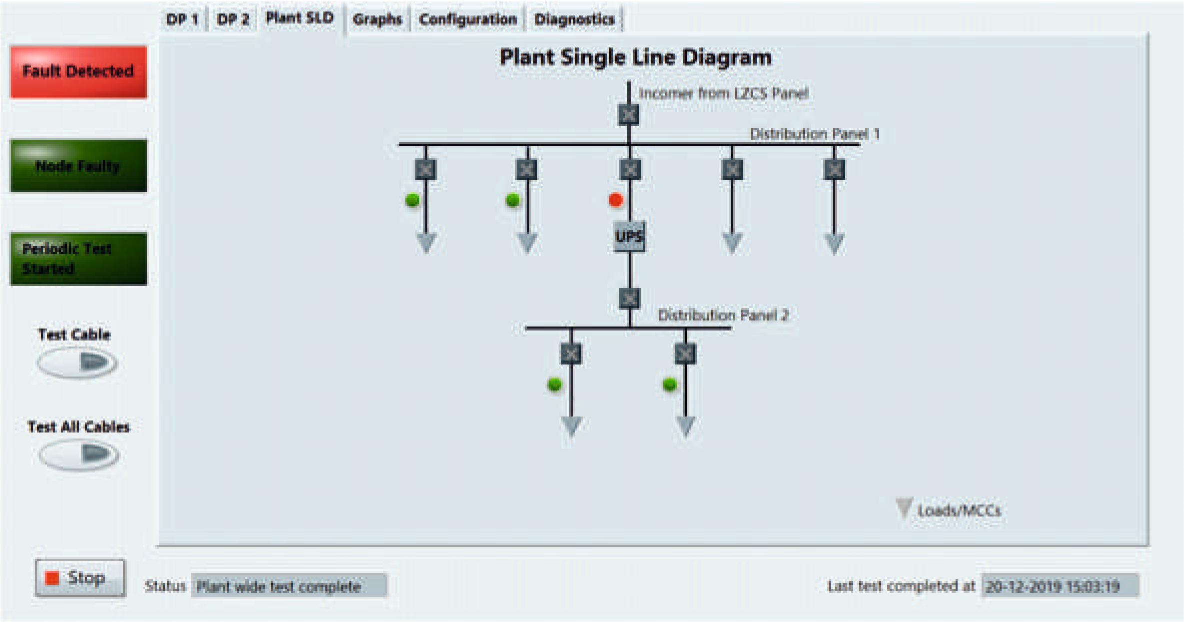

Fig.4a: An overview of PAMES presentation

Fig.4b: PAMES cable level presentation

PAMES master station

The PAMES master station is a supervisory workstation to monitor the health of the cables connected to PAMES.

It is designed to work autonomously in a pre-configured manner and allows manual overriding. Interactive GUI presentation can provide multiple levels of details to the operator on demand. The master station serves the following purposes.

1. Configure the individual PAMES nodes.
2. Initiate diagnostic testing on individual PAMES node one-at-a-time and obtain the diagnostic status information.
3. Map the diagnostic status information onto a graphical presentation of the electrical power distribution network. This should show the location, extent, and type of damage to the cable/conductor core.
4. Store the diagnostic status information on long-term storage (data files).

A demo application was developed to validate the PAMES operation on the electrical system at the PAMES lab.**Fig.4a** shows the overall power system at PAMES lab as Single Line Diagram(SLD). The faulty cable is marked by a red dot. Users can view the details at the level of each distribution panel & further down to individual cable/core level **(Fig. 4b)**.

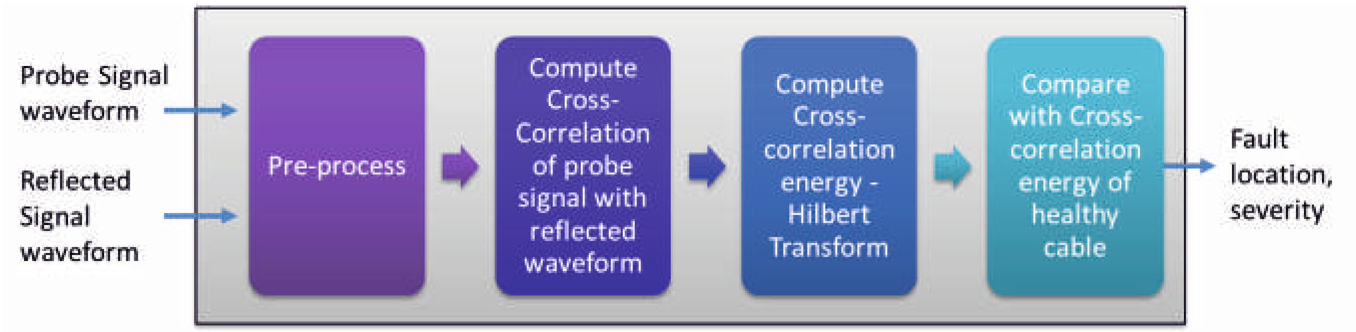

Fig.5: Steps of the Automated Fault Detection Technique

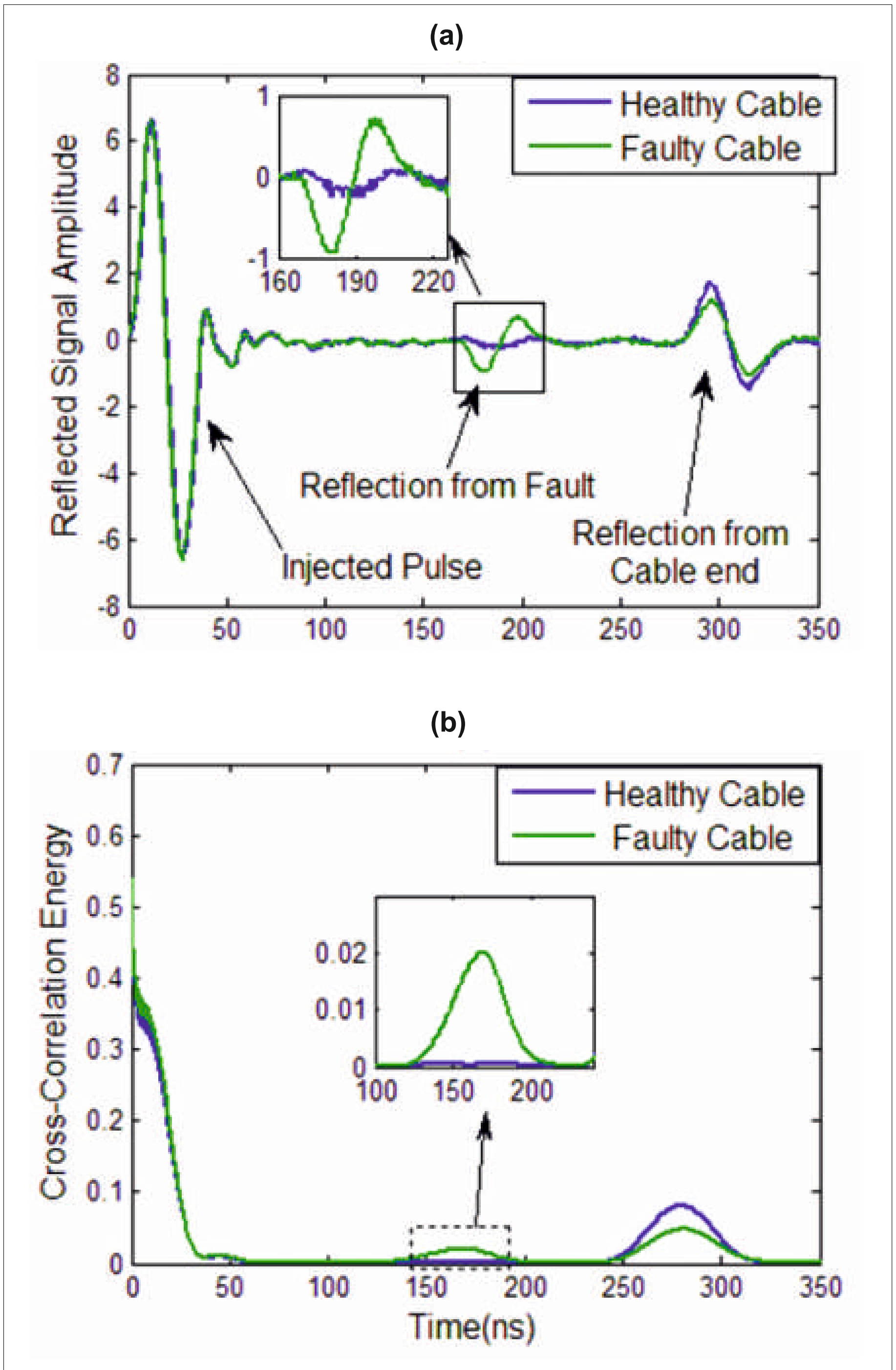

Fig.6: Sine pulse TDR signature (a) and Cross-correlation energy (b) for thermal damage

Signal Couplers

As the system is designed to work with live (carrying load current) cables, galvanic isolation must be provided between the cable conductor and the signal (probe and echo) processing circuitry. Inductive coupler using ferrite core is employed as the signal interface to the live cable in both directions (injection and sensing).

Clamp-on type cylindrical ferrite cores having suitable working frequency band have been used like a 1:1 transformer for injection as well as sensing purpose. Ferrites have an added advantage of blocking the transients at power frequency and its harmonics. There is, however, substantial loss of signal strength due to the inductive couplers and this affects the overall sensitivity of the system.

Fault Detection Technique and Experimental Validation

A matched filter based detection algorithm [1] is used for automated fault detection owing to its property of being the most optimal detector under white noise conditions. The block diagram of the algorithm is given in **Fig. 5**. The technique is experimentally validated on power cables damaged by thermal and mechanical stressors. **Figs. 6, 7** compare the sine pulse TDR response of cables and the Cross-Correlation

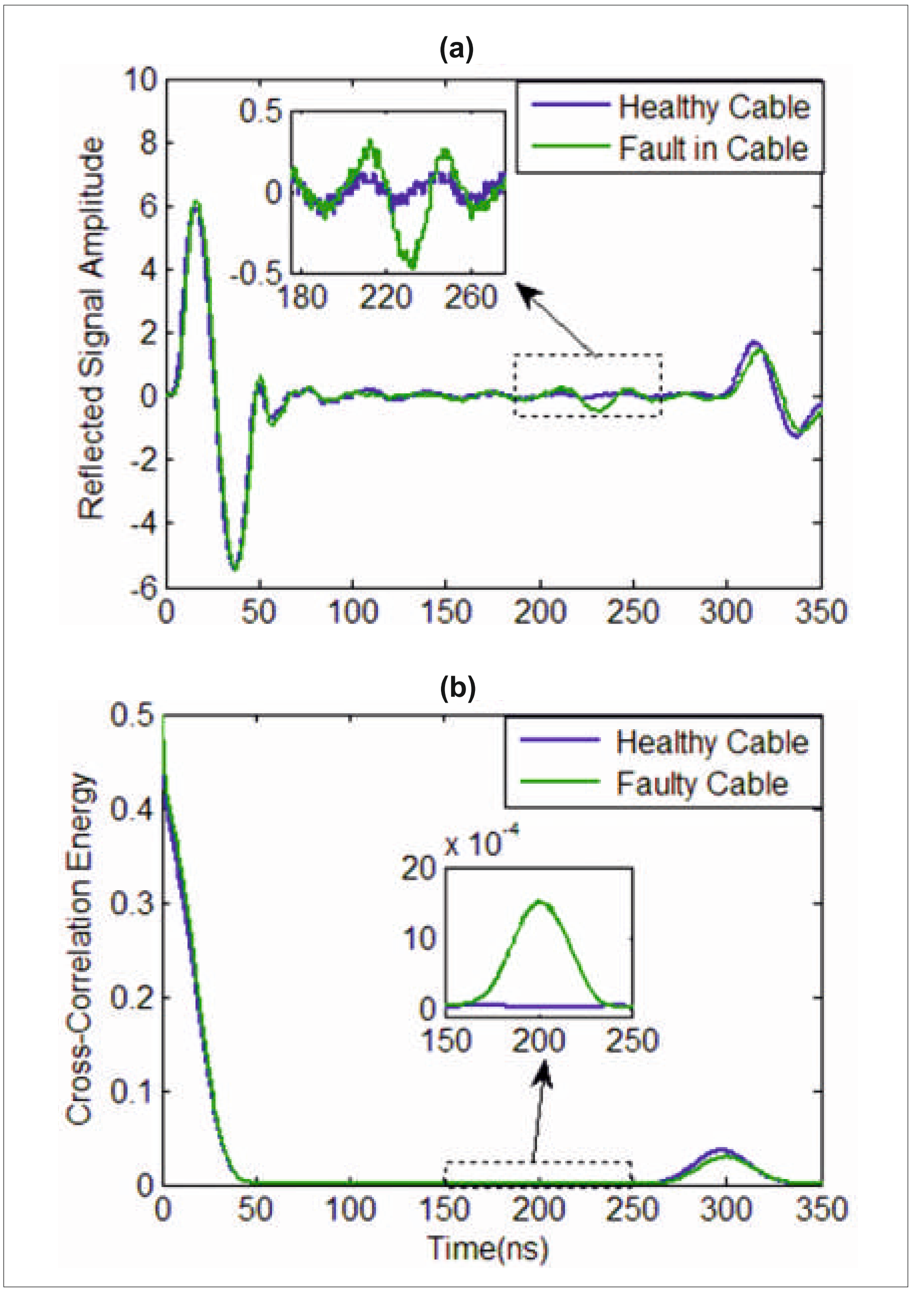

Fig.7: Sine pulse TDR signature (a) and Cross-correlation energy (b) for mechanical damage

energy waveforms for thermal and mechanical damages. The peak in the cross-correlation energy corresponding to the localized fault is indicated in the zoomed part of **Figs. 6(b) and 7(b)**.

Validation

PAMES was validated in a scaled-down electrical power system comprising of two distribution boards – DP-1 with 415V, 50Hz, three-phase supply, and DP-2 with 220V, 50Hz, single-phase supply. **Fig. 4a** shows a single line diagram for the power system. The power supply for DP-2 is generated from DP-1 with a UPS (3ϕ to 1ϕ). DP-1 feeds two blowers via feeder cables of length ~80 meters while DP-2 feeds one blower and one control system rack via feeder cables of ~60 meters. Few spare cables are provided on each DP to carry out damage detection tests. **Fig. 8** shows the image of the Validation Lab at Reactor Control Division (RCnD) in BARC Trombay.

Validation experiments were carried out to broadly establish the following

1. To ascertain the loss of signal from the generation point to the reception point on dead (unpowered) cables. The signal loss depends on the efficiency of coupling and transmission loss on the cables.
2. The power system transients that affect system operation when the cables are powered (not necessarily carrying load current).
3. To find the effect of load current on the PAMES signal, especially the coupler performance.
4. To find the effectiveness of signal blocking (prevent power line noises from the upstream electrical system from entering the cable under test) using ferrite cores.
5. Obtain signature echo signals from cables damaged by mechanical / thermal stressors.

Plant trials

A prototype system was deployed in one of the live feeder cables at Tarapur Atomic Power Station (TAPS) – 2 of Nuclear Power Corporation of India Limited (NPCIL).The PAMES node is connected to the cable using two ferrite core couplers and associated coaxial cables – for signal injection & reception. The couplers house protective circuitry to insulate the PAMES node from the power system transients. The PAMES master GUI software running on a laptop is connected to the node over a serial (RS-232) connection. The master issues a command to the node to initiate testing and obtain the time-series signal resulting from the test. The time-series is displayed on the screen as well as stored in a file.

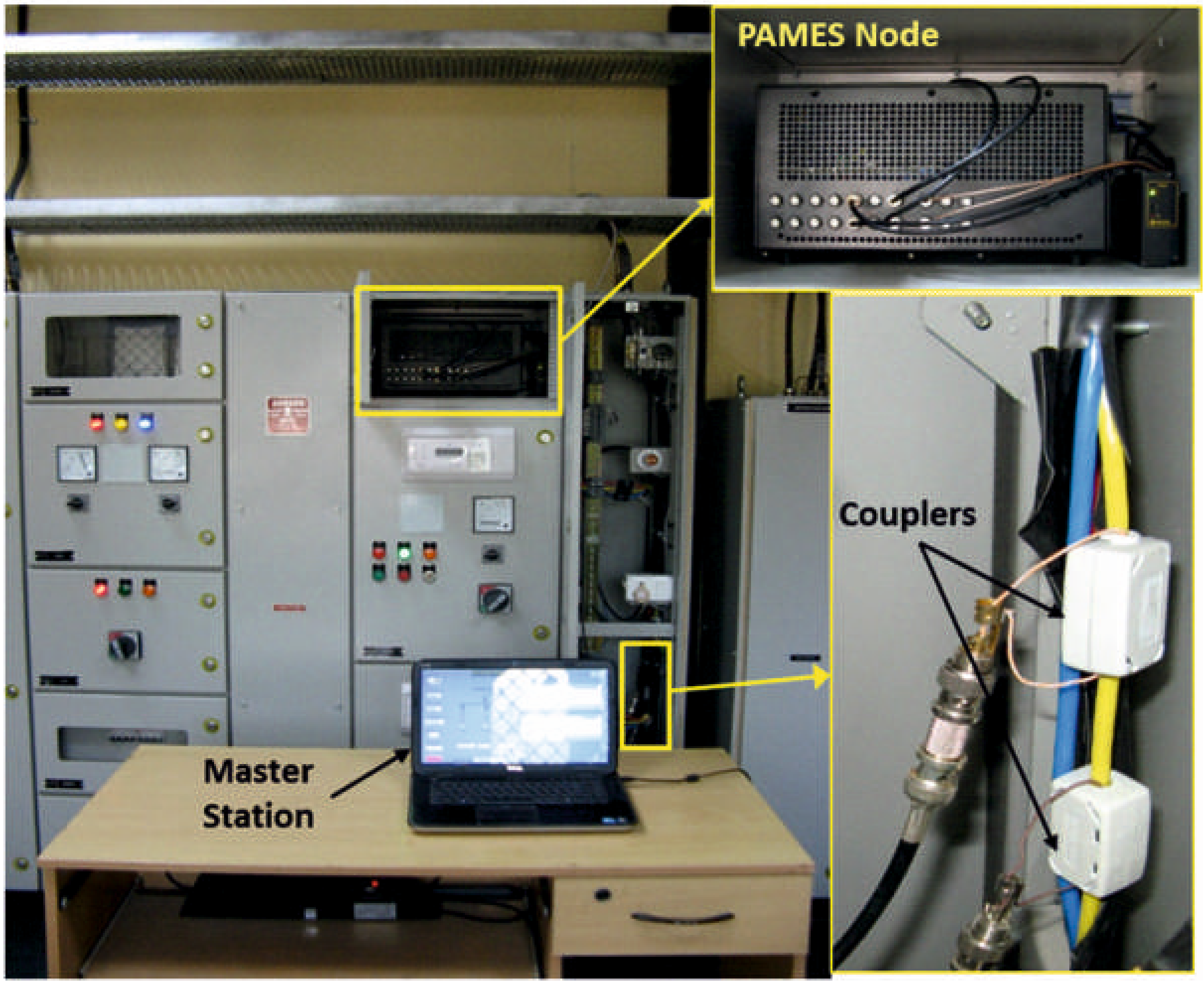

Fig.8: PAMES Lab at Reactor Control Division

Conclusion & Future work

Cable condition monitoring is of immense importance in critical wiring such as NPP electrical systems. Abrupt damage of cable insulation due to an accident is a localized degradation. Exposure to environmental stressors e.g. heat/steam, radiation, corrosive fumes, etc. also gradually degrades the properties of insulation material over a long period. The PAMES system is effective in both cases to determine the location of the degradation provided the affected part is only a fraction of the cable length. Easy clamp-on installation to the cable and ability to work without any service disruption enables the system to be used also as a portable instrument.

Degradation due to water-tree formation is not known to be detected by TDR based techniques. Also, bulk degradation due to ageing and in estimation of remaining useful life (RUL) is another area of active research, particularly concerning NPPs. Broadband Impedance based techniques are being explored globally towards these goals. The authors express strong commitment towards exploring emerging research trends which are relevant to their research, as part of their future endeavors.

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RFID based Data Acquisition and Equipment Monitoring in BARC Radiological Labs

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Abstract

In radiological facilities like RLG & PRAFPUL uninterrupted operation of the utility services is of paramount importance for the radiological safety of the Plant. To ensure the functional requirement of the equipments and to achieve this purpose, round-the-clock shift operation is being pursued for the Plant. During shift operations, the Operator monitors the performance of the equipments by taking rounds in the area as per the surveillance schedule. The important operating parameters are manually recorded in the prescribed form and are reviewed by the shift-in-charge for any abnormalities and further action. In the old system of manual entry, several drawbacks like verifying authenticity of the recorded data, difficulty in tracing the history, generation of required reports etc were difficult and cumbersome. To overcome these deficiencies, a new RFID-based data acquisition-cum-Equipment Monitoring system (EMS) was developed and installed at RLG & PRAFPUL sites. In the new system, the data acquisition in a particular area is recorded on a Tab by authentication through RFID and the data is transferred automatically to a centralized server through a docking facility. The data is utilized for online viewing, generation of reports for management, maintenance history record and system analysis along with several other features.

Keywords: **HHT, Docking units, RLG, EMS, RFID, Tours**

Introduction

RLG and PRAFPUL facilities are handling high radioactive sources and significant quantity of radioactive materials. Smooth and safe functioning of these facilities is dependent on safe operation of safety-related services maintained by Hot Lab Utility & Engineering Services Section (HLU&ESS). To operate and monitor safety related services, stringent, reliable and smart methods and practices had to be adopted for data acquisition and monitoring. Various safety-related services like ventilation system, compressed air system, emergency power supply system, vacuum breathing air system, fire detection and alarm system, radioactive effluents level discharge system etc are being operated, monitored on round-the-clock basis by a team of shift In-charges and operators of HLU&ESS at various locations i.e. RLG 11 KV substation, RLG control room, PRAFPUL control room and S-60 control room. Previously, the above mentioned services were being operated and monitored in conventional methods of manual paper based data acquisition, which have inherent limitations of erroneous & duplicate data, difficulty to trace the history of the equipment, frequent breakdown in systems, under-reporting of actual condition of systems, transferring of responsibilities, difficulty in storing and retrieval of the system data, lack of verifiability of data, no provision of audio/video signals of the systems, difficulty in planning of preventive maintenance.

A new RFID-based data acquisition-cum-plant monitoring system has been developed to overcome the problems persisting with the previous system. The new system is equipped with state-of-the-art digital devices for data acquisition, software application for data processing and report generation, data transferring system and various modules related to operation, maintenance and incident reporting among others. The new system is discussed in detail in the following paragraphs.

System Discussion

The RFID system is installed at four locations i.e. G-18 control room, Filter House control room, PRAFPUL control room and G-60 control room. All these locations are connected through BARC intranet to the centralized server system where the software application is placed. The RFID system installed at these locations is configured and linked to these locations. The data created, updated or recorded at these

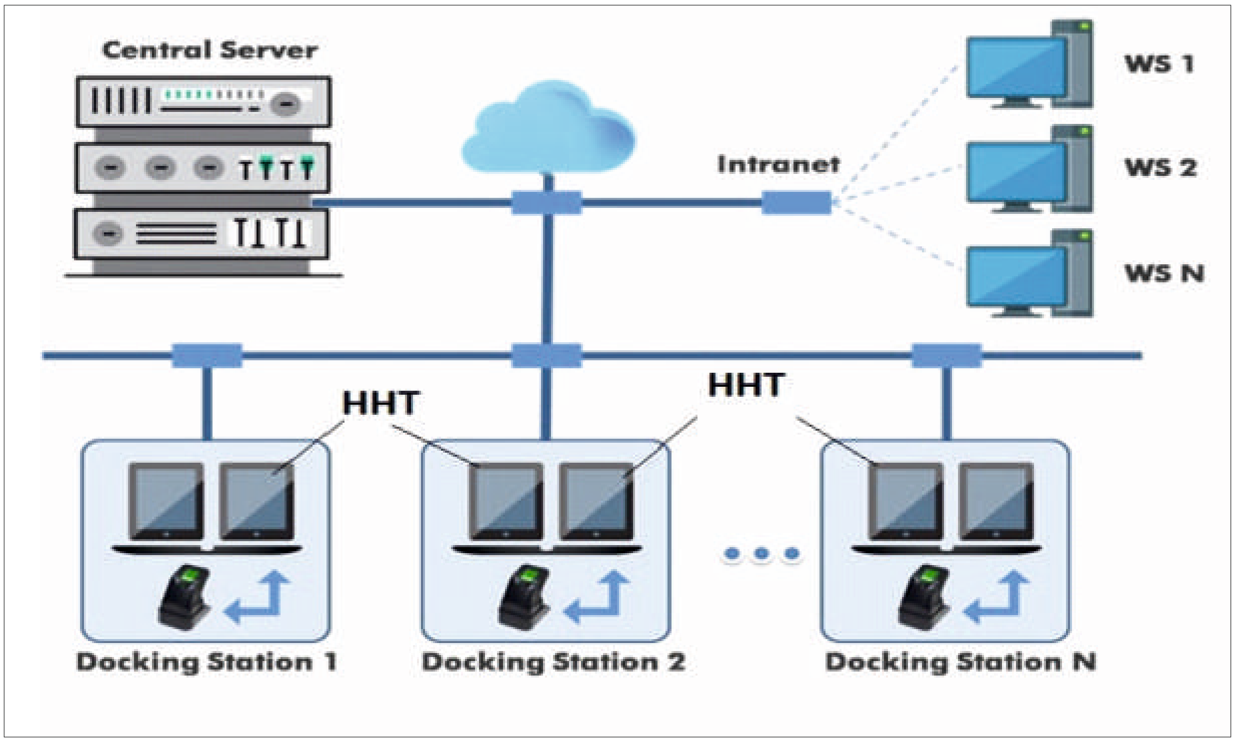

Fig. 1: System Architecture

locations in EMS system is updated in the centralized server, continuously. The entire RFID-based data acquisition-cum-equipment monitoring system comprises the following components to accomplish the intended requirement of equipment data acquisition and monitoring.

1. RIFD Tags
2. Hand-Held Terminal units
3. Industrial grade Work station
4. Docking station for housing & transferring the data of HHT.
5. Centralised Server
6. Customized Application Software

RFID Tag

Radio Frequency Identification Tag (RFID) is an electronic tag used in the system to capture/encrypt information in the form of electronic data. The RFID Tag communicates with the RFID reader through radio frequency waves. It is made up of two components, an antenna to receive radio frequency waves and an IC for processing, storing data, modulating and de-modulating the waves received by antenna. RFID Tags are the identification of the group of equipment for which the data is to be acquired and located in proximity. The RFID used in system stores the login information related to that group of equipment, and works as an access provider for data acquisition and verification of the operator. Each time the RFID reader reads the encrypted information in a particular RFID Tag, it works by identifying the corresponding equipment group associated with the RFID Tag and allows the user to enter the field data into HHT. These RFID Tags are installed at the entire site in such a way that maximum equipment can be covered in a tour. RFID Tags enable administrators to monitor time-stamped data logging and also the identity of the user acquiring the data.

Hand Held Terminal (HHT) Unit

Hand Held Terminal (HHT) is an important device of this system of data acquisition and equipment monitoring. The HHT is a portable device carried by the operator to the site for data acquisition. It is a combination of various devices which enable it to work as a multifunction device. The HHT comprises RFID reader, Human-Machine Interface, application fields with logics, audio & video recording features, a compatible structure with docking unit and diverse communication provision with RFID reader, processing unit, docking unit etc. The HHT is based on customised Android operating system in KIOSK mode on which the user application operates. The HHT communicates with RFID reader through Bluetooth and with the docking unit through a C-type USB communication port. The charging mechanism of HHT is with Pogo Pin connector to ensure durability and better connection. The RFID reader mounted on HHT reads the data stored in RFID tags installed at the site and opens the field parameter of the corresponding

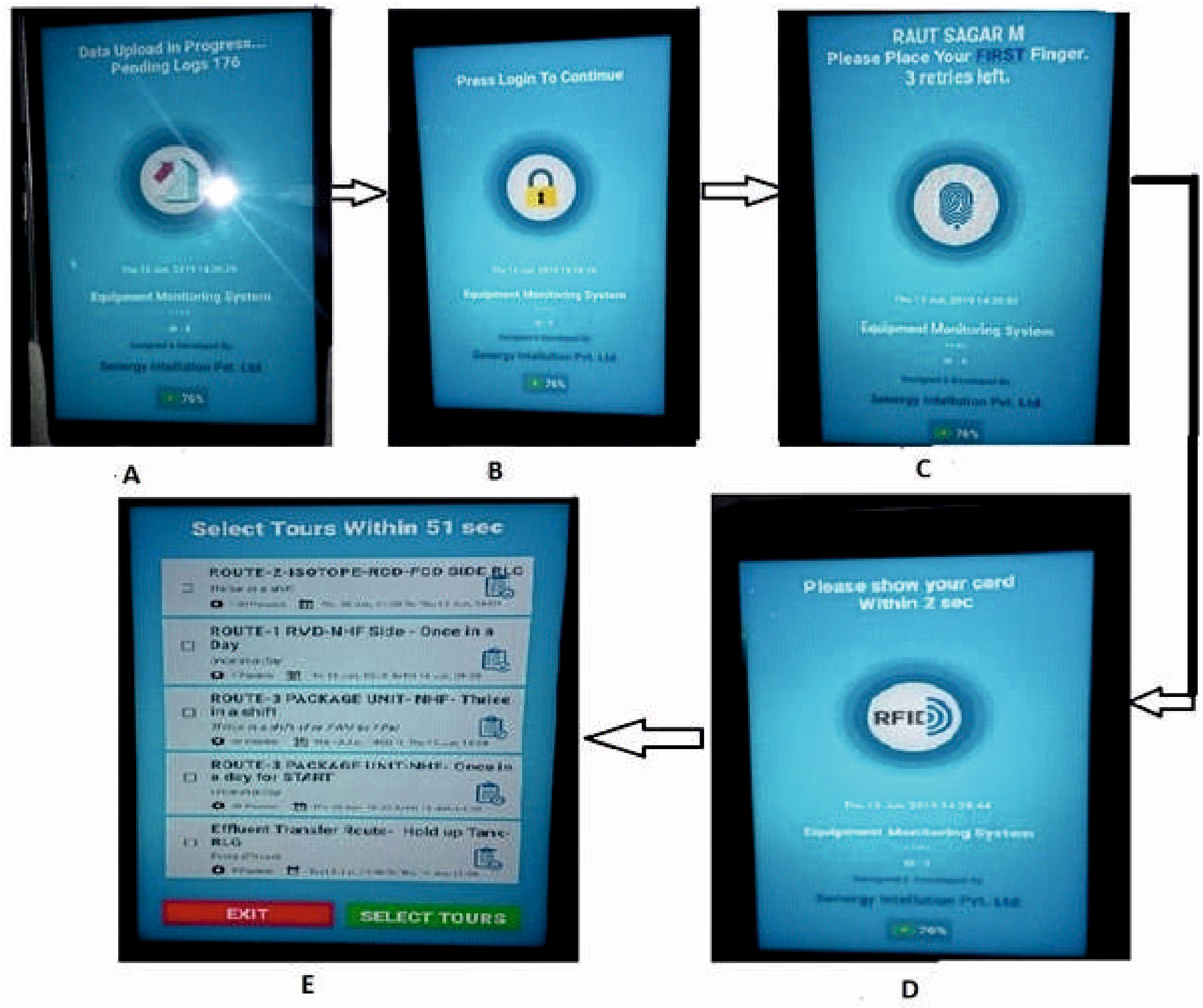

Fig.2: Tour selection

equipment. The software application is meant to provide systematic selection of equipment in a manner called TOUR. When the tour is started, the operator carries the HHT and enters the recorded data in a field opened in HHT. The HHT is provided with minimum storage capacity so that it can store at least one week's data of all equipments in case of the unavailability of the main server or non-availability of the docking unit or the communication link.

Tour selection though HHT

As shown in **Fig. 2**, the HHT initially uploads and updates the data of the previous tour on the server through a docking unit as shown in Step-A. After uploading of data, the HHT is ready for Login and the next tour selection, as shown in Step-B. In the following step, the user will authenticate identity through credential-like biometric data in the form of finger printing and RFID data stored in its ID card as shown in Steps-C, D. After double authentication and user login, the list of tours available for selection is displayed as shown in Step-E. The user will select the desired data of a specific tour. After selection of tour, the required data is uploaded into the HHT from the server followed by a signal to indicate the start of tour.

Workstation

Workstation is a server grade PC console with 24/7 working capability. Here, the work station is used for user interface and for accessing the software application, which also functions like a terminal station to carry out updates, modification etc. in the software application stationed at the server. Users like plant operator, shift In-charge, maintenance In-charge etc access the RFID based system through their Work station. Workstations are located at various locations and are connected through BARC LAN to access the system from any location inside BARC.

Docking station

It is delicately designed and custom-built unit to cater to multi-functions like House-the-HHT, Charge-the-HHT, store the details of tours, communicate with HHT & server,

Fig.3: Docking station housing Hand-Held Terminal (HHT)

to provide HHT login through RFID & Biometric Reader and to transfer the collected data from HHT to the system server and download/updation of recipes from server to HHT. The data is transferred from the docking unit to the server through Ethernet-based LAN. The data communication between HHT and the Docking unit is through USB 3.0. The Docking Unit comprises a fan-less computer with Intel Celeron N2807 2.16 GHz processor. The unit is provided with a dual login-cum-verification module. One is biometric reader for login through ID cards and a biometric reader for login through biometric data-like finger prints. The unit is designed in such a way that it can handle two nos. of HHT, simultaneously. The docking unit works as a link connecting the HHT, centralized server&software application. It has its own software, a Linux-based operating system support. The Docking station is provided with an in-built storage to store data for at least one week and is customized and redesigned multiple times based on the feedback and working experience to minimize maintenance work and plant interruption.

Server System

Server system is being used to store the data generated by the EMS and users. Devices like HHT, docking station etc communicate continuously with the server for the latest up dates, change in data or for synching data for a task. Web-based software application is hosted on the server to provide access from any location in BARC. The server is located at the central location of BARC and storage space is provided through a shared cloud. The server is being accessed through common LAN network i.e. intranet in BARC. The server works on Windows Operating System 2013. Simultaneous data backup provision is also provided in the server on a separate hard disk to avoid loss of data in case of failure of the main hard disk or server.

Software Application

Equipment monitoring software application is an important module of the RFID-based data acquisition-cum-equipment monitoring system. The software is developed based on the type of equipment, type of parameters, frequency of data acquisition and monitoring, location of the equipment, types of systems and its grouping and other inputs like modes of uses, data access etc. The application is created on MySQL application as a backhand interface and HTML as a front-user interface. The application is provided with following modules to achieve the intended function.

Equipment Tour Module

The Tour is actually a group of equipments located spatially at different locations and on a route through which user will start and complete a full cycle of the data acquisition on these equipments. Based on the frequency of data acquisition, the timing of data acquisition is different for different equipments and thus the frequency of tours also varies. Based on the frequency of data acquisition and the set of equipment, tours are defined in two broad categories i.e. Static tours and Dynamic tours. Equipment tour module is meant to create and define various types of tours and manage these tours and for configuring of equipments in the tours.

Different types of tours

a. Static Tours

Static tours typically are fixed and are time independent. Static tours cover fixed nos. of equipments to be monitored and the frequency of any static tour is fixed. Based on the frequency of data acquisition, static tours may be of various types like three times in a shift tour, once in a shift tour, hourly tours etc.

b. Dynamic Tours

The Dynamic tour is conceptualised to cover equipments which don't have a fixed frequency

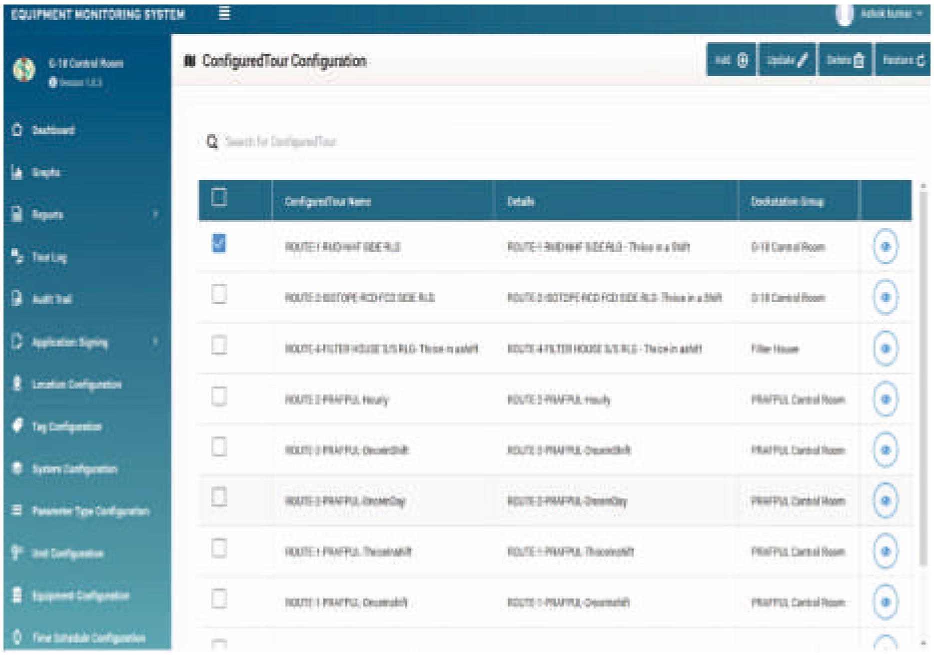

Fig. 4: Details of static tours

of data acquisition, and for special requirement of monitoring the equipment. The dynamic tour is variable in nature. Set of equipment and frequency of data acquisition is variable in these tours. In dynamic tours, parameters of the equipment to be taken under static tours coincide with the timing of dynamic tour thereby allowing it to take the entire data during the tour.

Equipment Master Module

Equipment master module is designed to configure the Equipments, sub equipments, grouping of equipments and systems. The system is defined as a combination of one or more equipment. Equipment is defined as a subset of the system and there may be more than one equipment under a single system. Equipment comprises more than one dissimilar units called sub equipment. Sub equipment can be defined as electrical or mechanical functional unit in which the data is recorded or acquired. Logical grouping, hierarchy and interlinking of equipments, sub equipments& systems is achieved in this module. The hierarchy of systems, equipment and sub equipment is designed in such a way that right equipment and sub equipments are grouped together and fall under the correct tour. The module features option for management of addition, modification and deletion of equipment grouping, linking and features etc. **Fig. 5** shows the typical system and equipment grouping.

Parameter Module

Parameter module is conceptualized to provide various types of parameters and their unit of measurement. The module features modification, addition, deletion etc

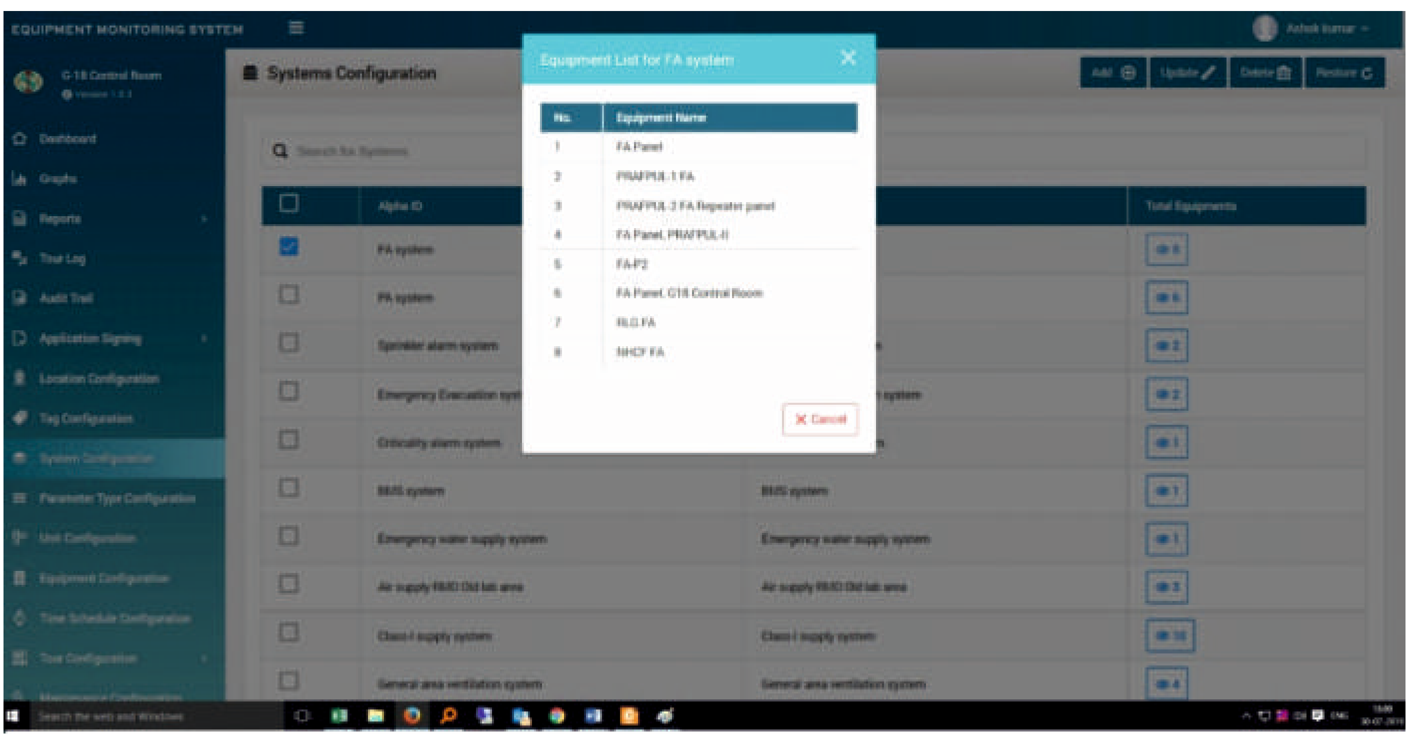

Fig.5: Equipment Master Module with system and equipment

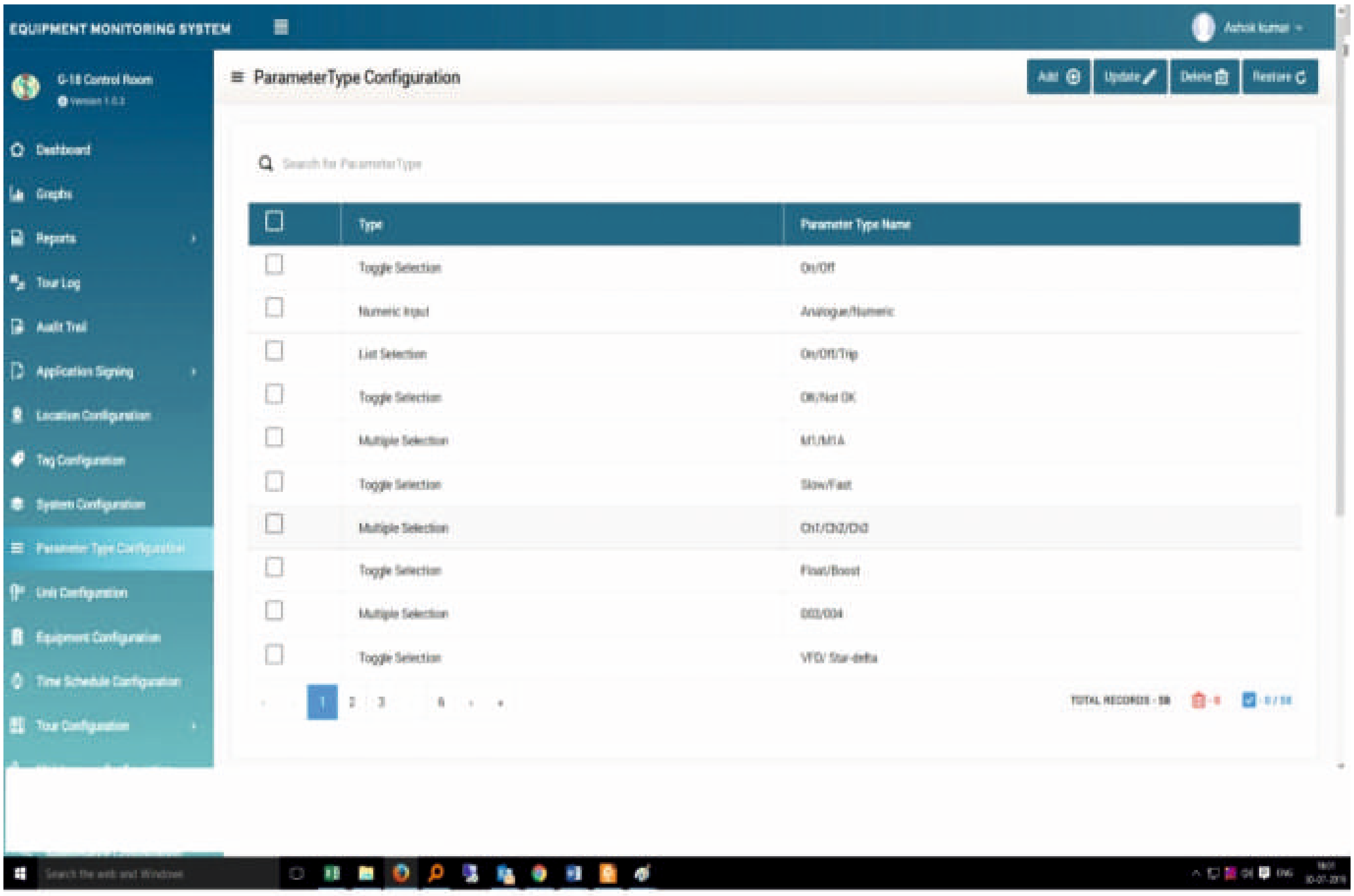

Fig. 6: Parameter module with type of Parameters

of parameters and database. In this module, various parameters are configured like Electrical parameters i.e. current, voltage, phase, power etc, Mechanical parameters i.e. pressure, force, level vibration temperature etc. The corresponding units of all parameters are also configured in this module. Majorly, three categories of parameters are created as shown in **Fig. 6**.

Toggle type parameter

Equipment parameters of this type comprises two fixed states like ON/OFF, Slow/Fast, Under maintenance/Service, Healthy /unhealthy etc. Toggle parameters don't have units of measurement.

Multiple selection parameters

Multiple selection parameters are similar to Toggle but don't have measuring units. And they comprise more than two states like Ch1/Ch2/Ch3, ON/OFF/TRIP etc.

Alpha Numeric parameters

Alphanumeric parameters employ mixed type of parameters like alphabetical character, numerical character and mixed type parameters. It has ampere, volt, pressure etc as the measuring units.

Device Configuration Module

Device configuration module is created for configuring three components of the EMS system i.e. HHT, docking unit and the Docking station group. HHT (Hand Held Terminals) are specifically configured to work within a particular area, and particular docking units like the HHT configured in G-18 control room will work within RLG premises only. But if these settings require changes, then the same can be achieved through this module. The Docking unit and its groups can also be changed and configured for a particular area, and they can be linked to the selected HHT. Addition, deletion and modification of any HTT, docking unit and their location is also achieved through this module as shown in **Fig. 7**.

Maintenance Module

Maintenance Module is designed to make provision for initiating online request, updation of maintenance activities and handover of the maintained system to Operation. To start the maintenance work on any equipment, the maintenance team requests the required equipment with selection of the parameters to be maintained, location and tentative time of maintenance activities etc. Through this module, the Operation team can accept the request or reject

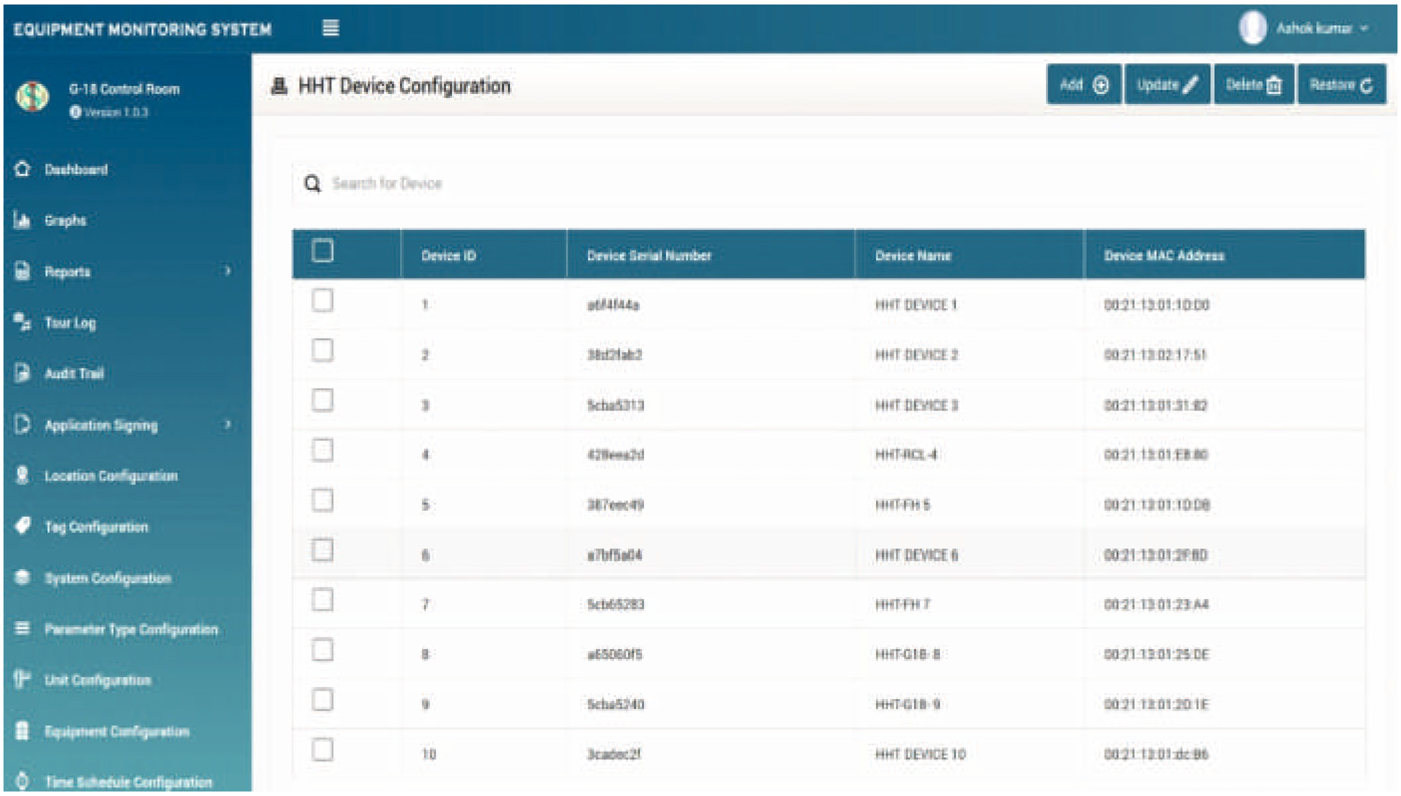

Fig.7: Device configuration Module

it. After acceptance of request, the selected equipment is taken under maintenance. The maintenance team can update the progress of the maintenance activities. After completion of maintenance activities, the system is transferred to operations after carrying out due diligence and acceptance by operation team through maintenance tour created for supervision of maintenance status. The module provides the history of maintenance on any particular equipment taken through this module.

Unusual Occurrence (UO) Module

Unusual occurrence (UO) module provides the way to submit a report in case of any unusual events happening during the shift operation. In this module, a form is created in which the Shift In-charge fills the UO form with the required information like type of incident, root cause of the incident, affected area, equipment & services, action taken etc, and submit the observations for approval by the superiors. Shift Manager and Head of division review the UO and pass their comment, suggest necessary action and approve/disapprove the UO.

Report Module

Report module is created to generate various reports to review the status of various modules. Provision of report generation is provided for Master database, Tour logs, Device Report, Alarm report, operation activity report, maintenance activity report. Master database report is generated for various databases i.e. location master, equipment master, Tag master, system master, user master etc. Tour master report is to know the status of the tours. It will provide the status of tour addition, deletion, modification etc. Device report is for change in the status of the device, their location, zone of operation etc. Alarm report is for the equipments which are under alarm conditions. Alarm report provides status about the type of alarm, identity of the plant staff recording the alarm parameter, time of alarm etc. as shown in **Fig. 8**. Operation and maintenance report module provides the history and status of the activities during a particular period.

Conclusion

RFID-based data acquisition-cum-plant monitoring system is developed to digitise the plant operations by replacing the existing manual (paper based) monitoring system, which is characterised by deficiencies. The new system facilitates and provides new features to manage the plant operations in a smart and efficient way. It also provides for monitoring, operation and data acquisition with a timestamp. It also helps eliminate redundant and false data generated during plant operation. The data available in the digital form helps in generation of various reports and also history of plant equipment and systems. The linkage with maintenance activities provides a time bound and updated status of maintenance work. Digital data

RLG G-18 Control Room				
Equipment wise Alarm History				
Name of equipment -Hold Up Tank				
Generated On: 14 Nov, 2019 14:57Total:16				
Parameter	**Alarm Value**	**Alarm Condition**	**Operator**	**Date Time**
Level	0 MM	<150.0	29873 : SINGH B K	Yes
Level	00 MM	<150.0	23932 : MINZ S M	Yes
Level	0 MM	<150.0	29873 : SINGH B K	Yes
Level	00 MM	<150.0	23932 : MINZ S M	Yes
Level	0 MM	<150.0	22020 : FULZELE A N	Yes
Level	0 MM	<150.0	29873 : SINGH B K	Yes
Level	0 MM	<150.0	16075 : KHALORE N D	Yes
Level	0 MM	<150.0	22020 : FULZELE A N	Yes
Level	0 MM	<150.0	29873 : SINGH B K	Yes
Level	0 MM	<150.0	23932 : MINZ S M	Yes
Level	0 MM	<150.0	29760 : SHETKAR S D	Yes
Level	0 MM	<150.0	22387 : PATIL K R	Yes
Level	0 MM	<150.0	29760 : SHETKAR S D	Yes
Level	00 MM	<150.0	27427 : DHONGADE D R	Yes
Level	2500 MM	>2450.0	27427 : DHONGADE D R	Yes
Level	2500 MM	>2450.0	29873 : SINGH B K	Yes

Fig. 8: Alarm report of hold-up tank

created by the system can also be used for further plant process improvements. Thus, RFID-based data acquisition-cum-equipment monitoring paves way for improving the plant operations and monitoring at RLG & PRAFPUL facilities in a highly efficient, smart and digitalised manner. It will further improve the performance of services rendered by HLU&ESS by reducing the plant breakdown events, mainly resulting from the existing scheme of operation and monitoring procedures.

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Design of Smart Panel for Power and Motor Control Centre in BARC

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Abstract

Modern Power systems are in great demand for centralized monitoring and control functions. There are various ways to connect the power system components to the centralized control stations. This paper elucidates the design of a new power control and motor control centres, which are connected to a centralized control system with minimum use of external interfacing equipments. The power and motor control centre have been designed to even adopt to low voltage switchgear applications in a cost-effective way and these aspects have been discussed in detail. A Low Voltage power Control centre consists of switchgears such as Molded Case Circuit Breaker (MCCBs), Contactors, Meters, Current transformers, contactors and indicators. In a panel there are several incomer and outgoing feeders. Various smart devices are available in the market which can be used for the purpose of monitoring and control from a control room. However, interfacing of these devices with an external system at a later stage becomes complicated. The paper also discusses design aspects in manufacture of smart power or motor control centre panel. Four such panels have been manufactured and installed in BARC Trombay. Importantly, these panels have been connected to centralized monitoring system of the plant with limited use of external hardwires.

Keywords: **PCC, MCC, PLC, MDM, MCCB, DI, DO, AI, RS485, Ethernet, RTU**

Introduction

There is a growing demand for monitoring and control of power systems remotely from centralized control centres. Power and motor control centres are the heart of power distribution centres and the demand for smart power and motor control centres in centralised control is on the rise [4]. Although, smart components are mostly selected for designing panels, however, these are not fully smart. Furthermore, the information required for the centralized control centres is not readily available. To develop a supervisory control and monitoring system, external hardwires are required in a large way. Most often, internal components procured are quite expensive which do not provide adequate information. When a centralized monitoring system is provided with external hardwires such as remote terminal units (RTU), network cards, cabling between multiple RTU, cabling from switchgears components to RTU etc are required [8]. If the components inside the panel are of non-communicable type, the requirement of external hardwires is at its high. Again, if the components inside a panel is of intelligent type, there will be a huge cost escalation, which in some cases may even be greater than the cost of the equipment for which power distribution is being installed. Therefore, panels have been selectively designed to effectively address cost concerns and at the same time also be fully intelligent to readily adopt to centralized control and monitoring station.

Advantage of Intelligent Power Control Centre

1. Engineering will be faster using few components
2. Connection of switchgears field buses with devices becomes easy and it enables savings in wiring within different units
3. It will reduce time for wiring, testing and commissioning
4. Intelligent components will provide pre-warning, which leads to increased availability of equipments
5. Easy identification of defective switchgears
6. External communication and signal cabling will not be required. It will make the installation easier
7. Due to presence of power and control cables in the same cable route or nearby leakage problem arises a lot. Leakages are mostly due to Electromagnetic Interference (EMI) interfaces which becomes difficult to remove. With the smart panels there will be no interference issue due to power cables as there is not external cabling requirement other than only one or two communication cable

8. Interlocking between multiple equipments synchronised to multiple feeders becomes easier.

Selection of Components of Intelligent Power Control Centres

Intelligent panel in generally will be having power system as per the feeder type. However specific features shall be taken for each of the components to make them intelligent. Intelligent panel will be having local as well as remote controllability and monitoring features with additional protection.

MCCBs

Molded Case Circuit Breakers (MCCBs) are being increasingly used as switchgear equipments for low voltage applications. However, for higher current applications, Air circuit breakers are used. Selection of the basic MCCB rests on the feeder size. Various factors which are used are continuous current rating, voltage rating (in generally available in medium voltage 415 V AC only), breaking capacity, making capacity, type of protection required.

The basis selection criteria shall be as per standards of panels. The complete panel is as per IEC standards [1], [2], [3]. If fine adjustments and multiple delays based protection settings are required it is advisable to opt for microprocessor-based protection release. Else, thermal magnetic release would be adequate. If earthing protection for each feeder is required, the release has to be specified for earth fault or leakage as required. Releases are available in market with or without earthing protection. In order to make the feeder intelligent, following are required:

Communicable Release

Communicable release is required for viewing the setting from remote station. The setting can be changed from remote station for these releases. In general, RS485 communication is used for the releases. However there are releases with other field bus option also. Communicable releases are normally available with microprocessor based release. With the help of release protection status, protection set points, trip history will be available. However, actual position feedback of the MCCB will not be available, which shall be taken separately.

Auxiliary contact

In order to get remote status of the MCCB, auxiliary contact shall be taken. This can also be used for interlocking purposes also if required.

Remote ON/OFF facility

There are motorised MCCBs, where the MCCB can be switched ON/OFF from remote location through its closing coil and shunt trip coil which is similar to breaker control to some extent. However, such releases prove to be expensive. In combination with release contactor can be used which may be an economical option. If only remote OFF provision is required, only shunt trip release can be taken. A typical example of remote OFF or electrical OFF condition is a panel with two incomers with separate source and interlocking requirement between these two incomers. The shunt trip coil can be used for interlocking of two incomers so that both are not switched on inadvertently.

Metering Solution

Digital meters are available in market which provide local voltage, current and power information. Ammeters are also available in digital form in various classes of accuracy. In order to make an intelligent panel these meters shall have a communication interface. Meters are available with RS485, Ethernet communication interface. If only one current is to be sensed and to be communicated the Hardwired Hall Effect type current transformers are available which are equipped with a 4 to 20mA transducer.

Drives

If VFD drive is used in the panel it should have communicable features for monitoring purpose. It was observed that if Close loop Proportional Integral and derivative control (PID) loops are better equipped to avoid close loops through communication bus. In such cases, hardwire interface is required for providing external input to drive for speed reference. For DOL and star delta starters, communication functions will be not be available. In such cases, provision for conrol wiring should be made to remotely operate ON/OFF contacts and remote ON/OFF.

Design

A total of 4 intelligent PCC (pls expand 'PCC') panels have been designed ideal for Class IV (PP-1 and PP-2) and Class III (EP-1 and EP-2) power supply systems. Design of PP-1 and PP-2 panel will be discussed herewith. Each panel has 15 feeders. Following is the complete description and brief design features of various feeders. List of feeder and the type of connections are given in a Single Line Diagram (SLD) in **Fig 1**. Complete SLD is not shown in **Fig. 1**. Typical feeders such as incomer, bus coupler, one thermal MCCB based feeder, one microprocessor based feeder, one DOL starter is shown in **Fig. 1**.

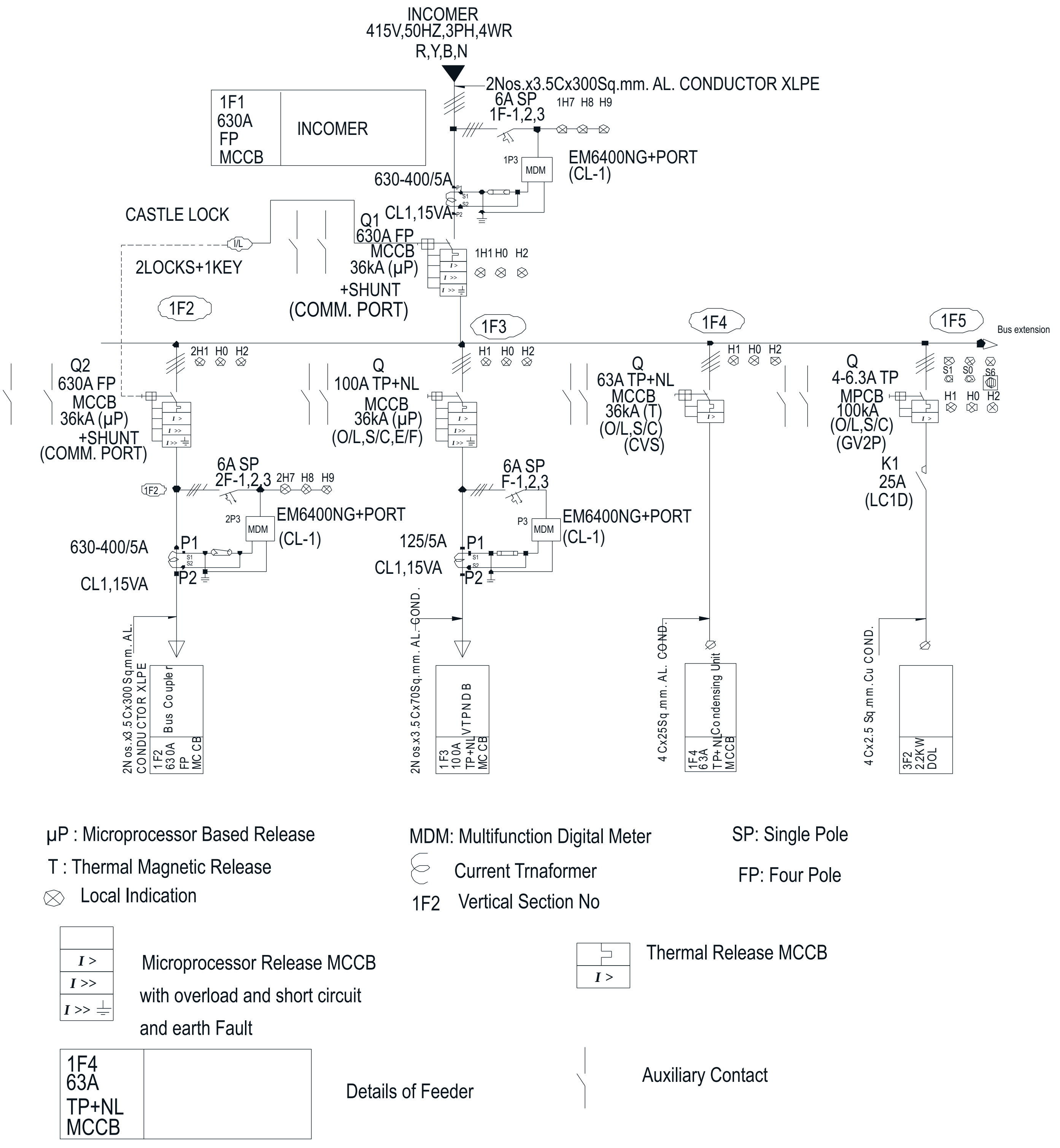

Fig.1: Single Line Diagram of Panel

Incomer

Two incomers are present in each of the panel. Income for PP1 and PP2 panel is 630A MCCB 4 pole, 50 KA breaking capacity, 415 V. Incomer two has been used as a bus coupler between PP1 and PP2 panel. MCCB selected is communicable release type which can provide access to set point adjustment, view of set parameters, tripping history. The communication bus is RS485. A mechanical key interlock for incomer 1 and 2 has been used. Additionally, shunt trip release has been used to enable feeder tripping from remote station either by hardwire or software. Multifunction meter has been used for monitoring voltage, current and power parameters locally as well as at SCADA system. In order to monitor from remote RS485 communication bus has been taken for the Multifunction meter. Following is the full specification and design features of MCCB based incomer feeder.

a. 630A 4P 36KA MCCB MCCB Microprocessor-based release with Rs485 communication
b. Spreader, Phase barrier and extended handle for operation without opening door
c. 240V Shunt release for remote tripping provision
d. Auxiliary contact for MCCB ON feedback for local indication as well as for remote indication
e. Key lock for interlocking with the 2nd incomer
f. Local R, Y B Indication, ON and Trip indication
g. Multifunction digital meter of ` Schneider-make with inbuilt RS485 port
h. Current transformer 630-400/5A
I. Miscellaneous control MCB for metering and indication circuit protection

Outgoing feeders

The panel has outgoing feeders of following types and the design features are described in subsequent paragraphs

Outgoing feeder of rating 100A and above

The feeders are mainly used for ON/OFF purpose and are feeding to distribution boards, rolling machines etc. These equipments draws large amount of power and it is required to monitor the current, tripping history, if any. Hence following components have been used. Total 5 such feeders were taken as per the requirement of the facility.

a. 160/100A 3P+N 36KA MCCB Microprocessor based release with RS485 communication
b. Spreader, Phase barrier and extended handle for operation without opening door
c. Shunt release is not taken as there is no requirement of remote tripping
d. Auxiliary contact for MCCB ON feedback for local indication as well as for remote indication
e. Local ON and Trip indication. RYB indication is not required as it draws power from the same bus as that of an incomer.
f. Multifunction digital meter of Schneider-make with inbuilt RS485 port for getting current measurements on continuous basis as well as for keeping a backup.
g. Current transformer 160-100/5A
h. Miscellaneous control MCB for metering and for protection of indication circuit

Outgoing feeder of rating 32A to 63A

These feeders also cater to ON/OFF purpose and to feed to small lighting and power loads through distribution boards. Unless there is a specific requirement for monitoring the power drawn by the equipment, multifunction digital meter and microprocessor based release is not required. If these feeders are equipped with meter and microprocessor based release, the cost of the feeder becomes very high. With the essential equipments not readily available, the following components have been developed.

a. 32A/ 63A 3P+N 36KA MCCB Microprocessor-based release with RS485 communication
b. Spreader, Phase barrier and extended handle for operating without opening door
c. Auxiliary contact for MCCB ON feedback for local indication as well as for remote indication
d. Local ON and Trip indication.
e. Miscellaneous control MCB for metering and indication circuit protection.

VFD Starter based outgoing feeder

The VFD starter was designed for the exhaust system of the laboratory ventilation. There is a requirement of speed control which is based on exhaust system static pressure measured from the common plenum. The VFD is controlled in a close loop control based on the pressure feedback. Miscellaneous power, torque, current parameters are available from the communication bus of VFD and hence separate additional meter is not required. Additional meter will require additional current transformer which will increase the size of the feeder. In general, VFD has been selected as per the guidelines given in corresponding standards [3] The feeder comprises of the following components

a. 13 - 18A 50KA ROTARY TYPE MPCB GV2P (O/L+S/C)
b. Fault Contact for MPCB for Local as well remote indication
c. 32A (AC3) 3P Contactorwith 1NO + 1NC 230V AC COIL
d. Local and remote selection button, start stop button for local and remote mode.
e. 7.5KW ATV212 Series Schneider-make Variable Frequency Drive communicable type with provision of giving external analog input
f. Local ON and Trip indication.
g. Miscellaneous control MCB for metering and indication circuit protection

Direct On Line starter based feeder

A feeder which is independent of speed control is not required but

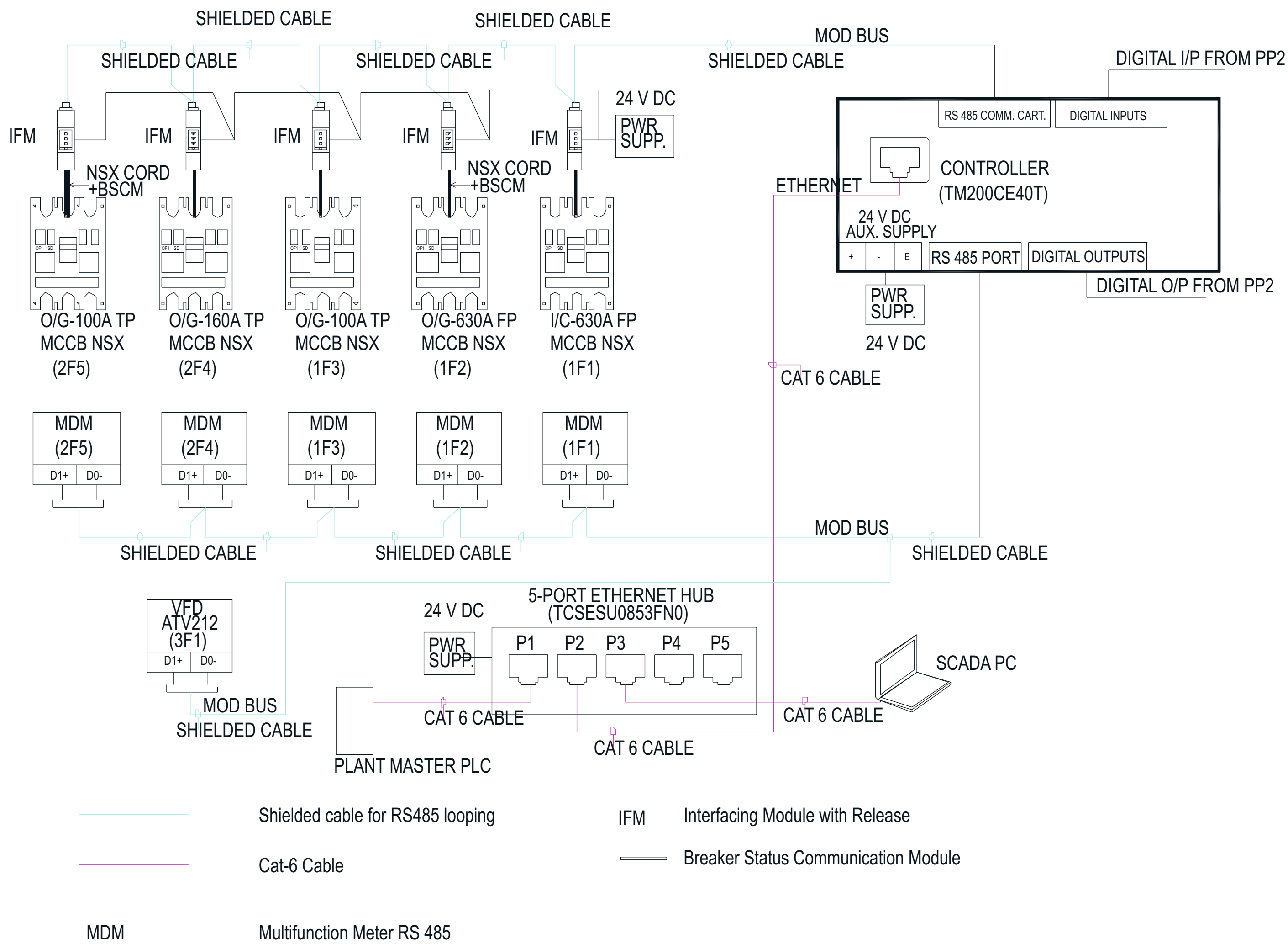

Fig.2: Bus Architecture of various intelligent devices inside the panel

motor has to be driven. For small motor DOL starter can be used based on the capacity of the plant. There is a supply blower which is connected to DOL starter. Being very small motor of 2.2 KW multifunction digital meter, microprocessor based release etc are not required as it will not be economical considering the cost of the motor. However to monitor and control the feeder from remotely as a part of the smart panel following bill of materials are considered

a. 4 - 6.3A 100KA ROTARY TYPE MPCB GV2P (O/L+S/C)

b. Fault Contact for MPCB for Local as well remote indication

c. 25A (AC3) 3P Contactorwith 1NO + 1NC 230V AC COIL

d. Local and remote selection button, start stop button for local and remote mode.

e. Local ON and Trip indication.

f. Miscellaneous control MCB for metering and indication circuit protection

Communication Chamber

The communication chamber (vertical shaped) consists of a small PLC with digital input and output channels and RS485 communication port. Individual feeders have been kept provision for connection to PLC either through digital input and output channel or through communication bus. The feeders are connected to the PLC as per the following arrangements Communication bus architecture is given in **Fig. 2**. Typical digital input connection (2 Nos.) to PLC section is shown in **Fig. 3**. The connections shown are for thermal MCCB feeder and one motor feeder of DOL type. The data of various feeders are available through the ethernet port of PLC in modbus TCP/IP format for centralized monitoring and control. The communication architecture followed in the distribution network has been studied [5], [6]. The network for field and supervisor control level has to be separate. In the design architecture, Rs485 has been chosen for field-level interfacing as it is an open protocol and commonly available in most of the protective and energy management equipments. Supervisor control and monitoring systems are generally given in industrial PC based interfaces which

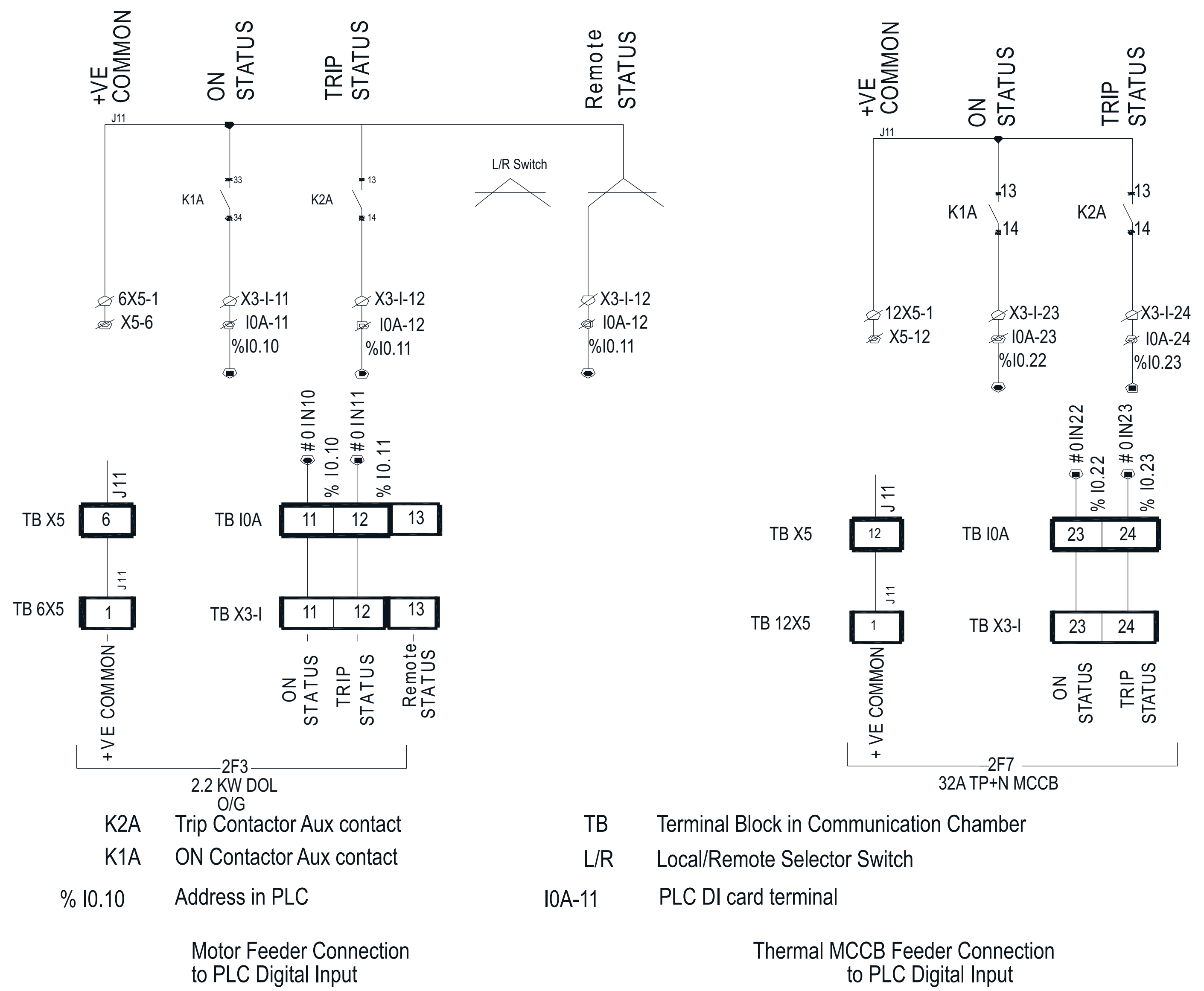

Fig.3: Digital Input connections for non-intelligent feeders

mostly support ethernet communication. The RS232 type interfaces do not provide adequate speed and diagnostic features thereby making them least attractive. Ethernet communication is highly preferred as monitoring and control stations can be easily duplicated with proper security measures.

Incomer feeder connection to communication chamber

The incomer MCCB feeder potential free contact for ON position and trip position feedback is connected to digital input channel. Shunt trip coil is connected through the digital output channel. Digital output channel is isolated from direct connection by using solid state relay driven from the digital output channel contacts. Microprocessor-based release and multifunction digital meter is connected in RS485 loop which is directly connected to RS485 port of the PLC. In PLC program release and meter data, which are essential for monitoring of power systems, the systems are configured with sequential addressing. Although, there is a mechanical interlock between the two incomers, PLC programming ensures that the two feeders do not trigger ON simultaneously.

Outgoing feeder of rating 100A and above connection to communication chamber

The MCCB potential free contact for ON feedback and trip feedback is connected to digital input channel. Microprocessor based release and meter data is addressed in PLC with the help of communication loop (RS485).

Outgoing feeder of rating 32A to 63A

The MCCB ON and trip feedback data is carried to the PLC via digital input channel. Since the current data is not important for these feeders, no other parameter is fed to the PLC.

Fig.4: Pp1 panel

Fig.5: Pp1 Communication Chamber

VFD Starter based outgoing feeder connection inside communication chamber

This feeder is digital-input-and-output-channel intensive. The MPCB ON and trip feedback, Local/Remote selector switch status feedback (for checking whether the drive is controlled locally or from remote) is connected to the digital input channel. Instruction for 'Start' and 'Stop' are given through digital output channel of PLC. VFD internal parameters such as voltage, current, torque, speed setting, mode etc. are addressed in PLC programming through RS485 common loop. The VFD is operated in auto-mode based on pressure feedback at the duct. VFD analog input terminal is connected to the pressure transmitter and programming is done in PLC with a PID controller. There are two options available. Transmitter can be connected either to the VFD or through the PLC. As PLC based PID is more user-friendly to configure and its response is faster PLC based PID is used.

Direct On Line starter based feeder connection in communication chamber

The feeder MPCB ON and trip feedback, local/remote selector switch status is connected to digital input channel. Start and stop command is given through PLC digital output channel.

The measurement of flow of current, which is of no great importance for this feeder, is usually not taken. However, if required, current transformers that offer 4 to 20mA direct output can be connected to PLC.

Manufacturing, installation and commissioning of panels

A total of 4 smart panels were designed for Class IV system (2 nos.) and Class III System (2 nos.). Manufacturing has been done with the help of external agency as per the custom design specifications. The panels have been tested, commissioned and connected to plant SCADA system (**Figs. 6 to 8**) in the newly established Radiological Plant of BARC. Intelligent panel image is shown in **Fig 4**. The communication chamber consists of small PLC, power supply module, relay module whose image is given in **Fig. 4**. As the plant had UPS power available communication chamber is fed from UPS power. There are products available where redundant power can also be used to provide power to communication chamber both from the panel own power as well as from an external power supply. The various feeders data is monitored in a SCADA system and the pictures are given in **Fig 6 to 8**. In **Fig.6** a part of the monitored screen

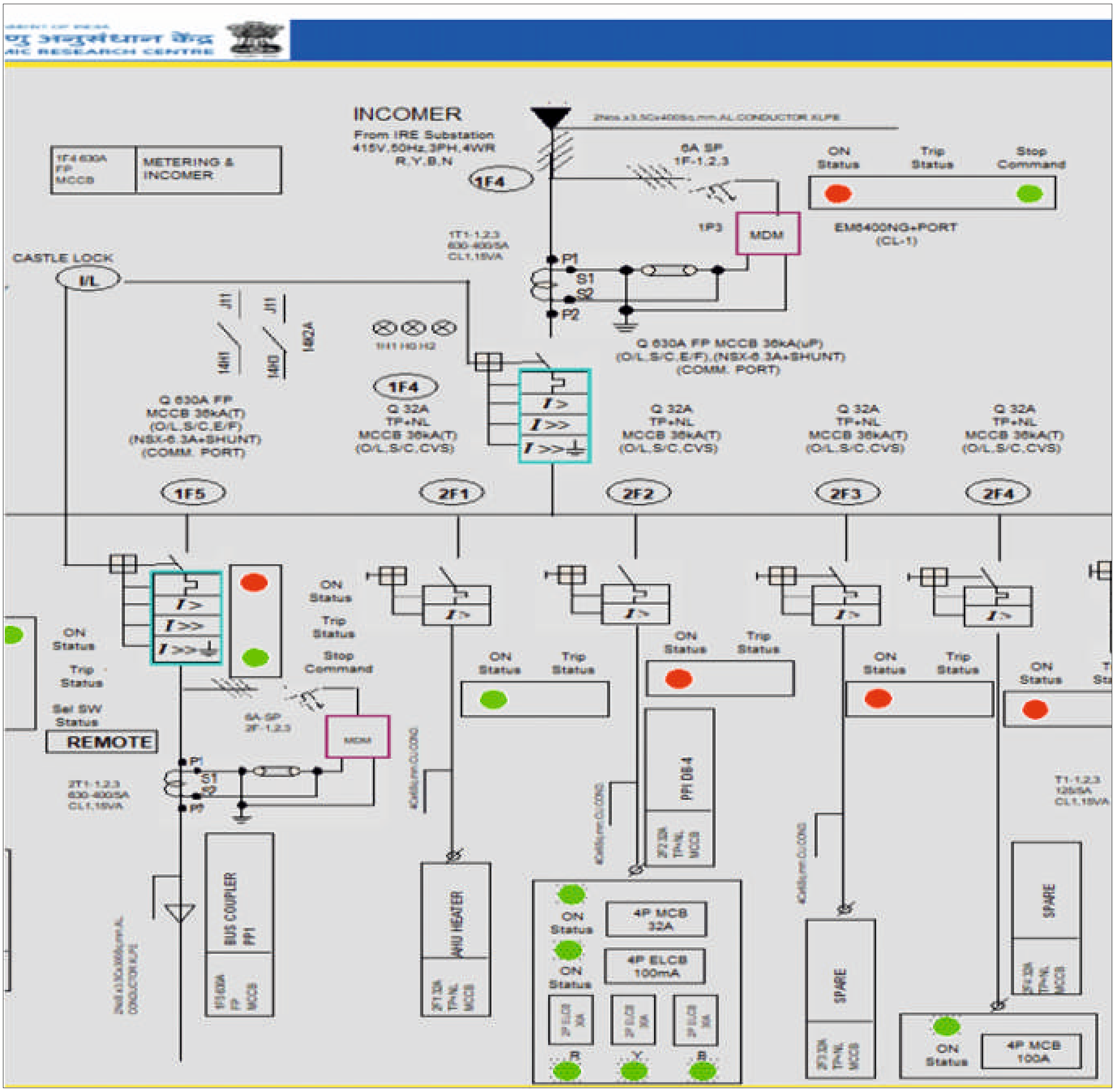

Fig.6: A section of SCADA screen developed with the help of Smart Panel highlighting microprocessor (uP) based incomer, bus coupler and thermal MCCB feeder

pertaining to microprocessor (uP) based incomer and bus coupler section and thermal MCCB feeder based OG section is shown. There are 4 fully built power panels ideal for Class IV and III system. There is a Class II system also. The whole power system is monitored in a SCADA system with minimal external hardwires. There are feeders such as glove box exhaust, laboratory exhaust, laboratory supply system which are used in main and standby configuration. The Main system and Standby system present in different panels have been successfully interlocked in an external PLC system. In SCADA, the user interfaces have also been designed in such a way that only one system operates at a given point of time. In the event of failure of one system, the other system gets triggered automatically. Thanks to smart panels, implementation of logics and monitoring of panels remotely is no more a complicated task.

Discussion

Design panels are conventionally monitored through local indicating lamps and meters and protective gear status. SCADA systems are introduced with additional external interfacing devices outside the panel to make them compatible with the SCADA system. This is done through separate distributed RTUs at multiple places [8]. Panels are also most of the

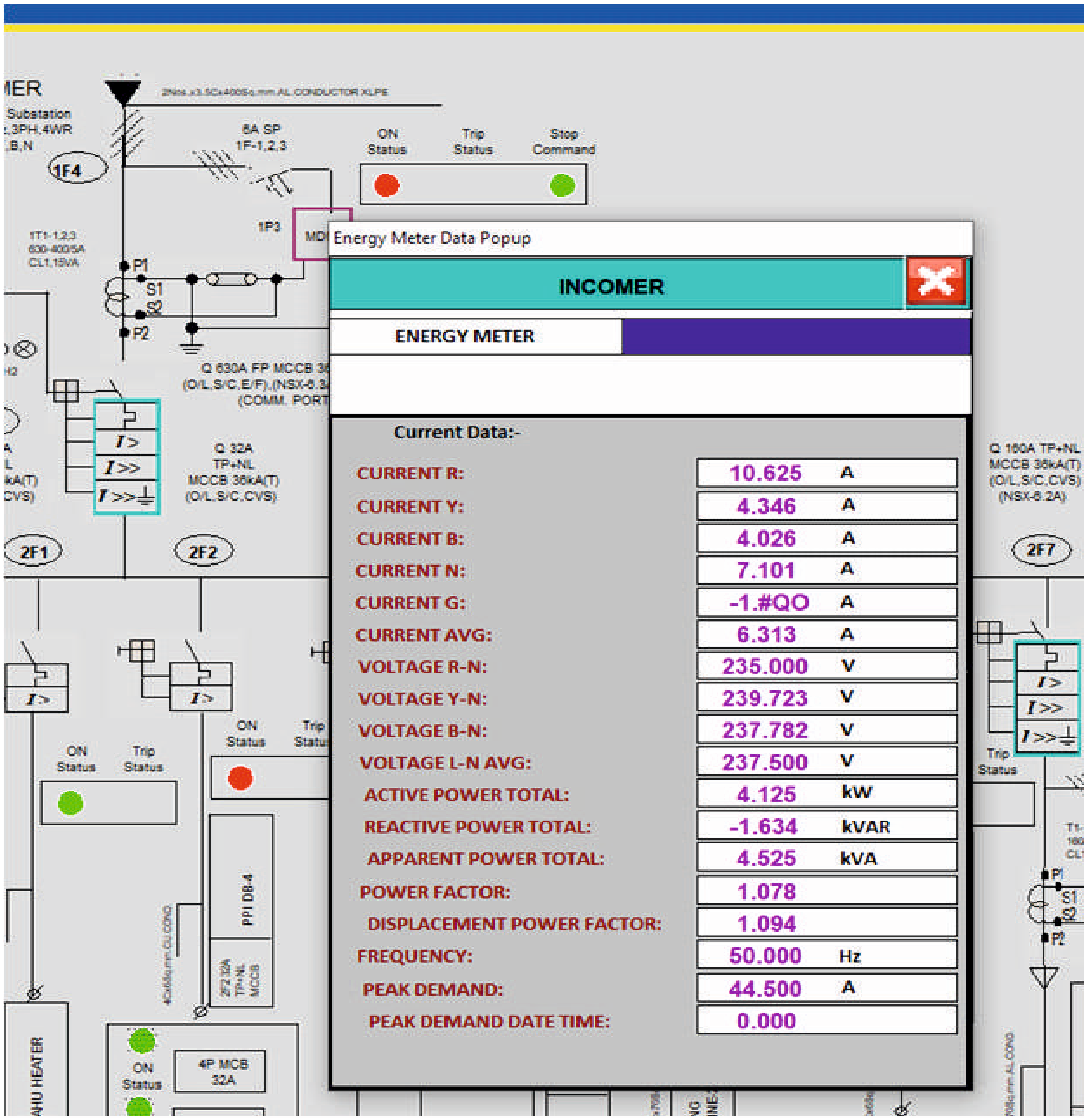

Fig.7: Incomer Meter Current Status monitored and recorded in SCADA screenfeeder

time designed with latest communicable devices. However, when they are connected to a SCADA system, it becomes tedious to connect each of these devices to SCADA due to their different bus architectures, requirement of additional cables to be installed from each of the devices to SCADA or to an external PLC or RTU. In order to get ON and Trip feedback, local, remote switch status separate cables are required which makes the cable alley of the panel very shabby. Due to presence of power and control cables in the same cable route or in the vicinity, leakage problem arises. Leakages are mostly due to EMI interfaces, which are difficult to remove. The four smart panels are designed with the feeder types required for the specific plant. The rating of the panel and type of the feeders may be different. In general, three to four types of feeders are used such as incomer, outgoing on/off type feeder, motor feeder with DOL or star delta and motor feeder with VFD. The protection switchgears may be different depending upon the size of the panel. There will be slight changes in the design if Air circuit breakers are used. However, MCCB based PCC panels are being widely used and in such cases, a similar smart chamber may be designed to monitor and control the panel and other equipments with minimum external cabling. External cabling for grouping of data should preferably be

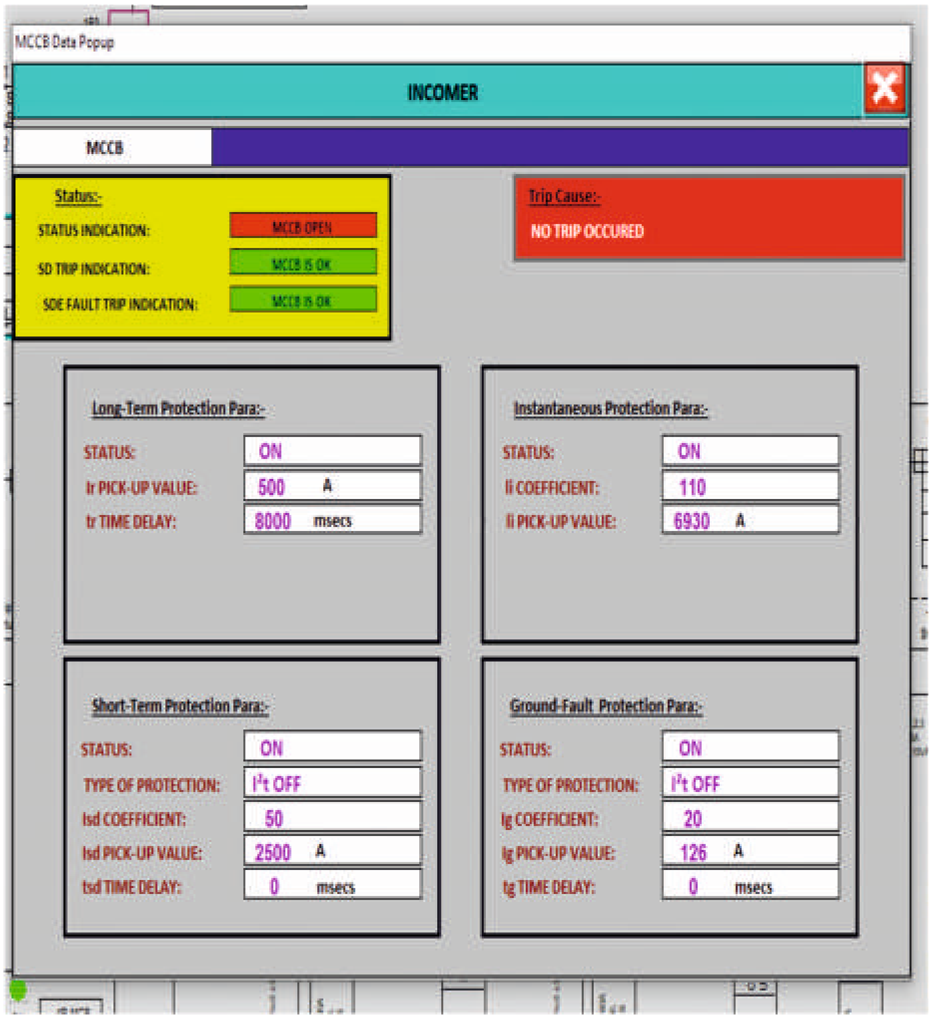

Fig.8: Incomer microprocessor (uP) based Release status as monitored/recorded in SCADA screen

avoided to get rid of EMI issues which may lead to leakage voltage at control cable terminals. While using multiple MCC panels, sequential operation of equipments is taken up through various equipments fed from multiple panels; a common external hub or ethernet switch can be used to control the equipments from external PLC or SCADA without any additional cabling. Sequential operation, interlocking becomes easier with smart panels.

Conclusion

The smart panels have been designed, manufactured, installed and commissioned successfully. The complete power system of the plant comprising of 4 panels have been charged and monitored from two remote control rooms. The smart design is cost-effective also as few components have been taken non-intelligent type but converted all the information in digital format inside the panel. All the components used are widely available in the market. Importantly, the panels were installed in a very limited space. Also, smart design has led to limited use of wiring and space.

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BARC Commissions state-of-the-art Drinking Water Facility in Maharashtra

To address growing requirement for clean drinking water in villages, BARC has implemented a state-of-the-art drinking water facility at Somthana Village in Maharashtra's Nanded district.

The 1000 litres-per-hour reverse osmosis (RO) based drinking water facility was an outcome of the DAE sanctioned project 'Deployment of Water Purification Technologies in 50 Villages in India'.

The facility in Nanded district would effectively treat high levels of nitrate (140-150 ppm) and high salinity (1200-1400 ppm) in ground water to supply clean and safe drinking water of Indian Standard 10500 quality to the village of 2500 households.

Villagers of Somthana pose for a photograph with Dr. (Smt.) Sadhana Mohan, Associate Director, ChEG, BARC during the inauguration of the drinking water facility.

Under a pay-and-use model, villagers pay a highly affordable Rs. 5/- for every 20 litres of water drawn from the facility. The revenue accrued from this arrangement would cover expenditure incurred against regular operation and maintenance of the facility. The reject water from the facility is redirected for cattle use, non-potable applications and ground water recharge.

Computational Chemistry Symposium

To encourage wide-ranging scientific and technical consultations among the researchers involved in making use of molecular modelling in various fields of science and technology, BARC Chemical Engineering Group organised the maiden symposium on Computational Chemistry.

The three-day DAE-BRNS symposium on Computational Chemistry (DAECCS-2019) held in DAE Convention Centre in Anushaktinagar, saw participation from 295 scientists and researchers from both India and abroad from various DAE units, national laboratories and universities, who leveraged the opportunity to deliberate on latest advances and

Dr. (Smt.) Sadhana Mohan, Associate Director, Chemical Engineering Group, speaking at the first DAE-BRNS symposium on Computational Chemistry (DAECCS-2019).

deliberate on latest advances and future trends in the fast expanding domain. The list of dignitaries at the event includes Dr. A.K. Mohanty, Director, BARC; Prof. E.D. Jemmis, Honorary Professor, IISc, Bangalore; Prof. Srikumar Banerjee, Chancellor, HBNI, Mumbai; Shri R.K. Garg, Former Director, Chemical Engineering Group, BARC and Prof. Swapan K. Ghosh, Dean, Centre for Excellence in Basic Sciences (CEBS), DAE, Mumbai.

At the event, a total of 37 invited lectures were delivered and 132 papers were presented covering all important applications of computational chemistry in science and technology. An exhibition of various hardware/software developed for the cutting edge computational chemistry research was arranged at the symposium venue.

During the valedictory function, the Symposium's Organising Committee (OC) led by Dr. (Smt.) Sadhana Mohan, Associate Director, Chemical Engineering Group, BARC; Shri K.T. Shenoy, Chairman of OC; Musharaf Ali, Convener of OC and Dr. A.K. Singha Deb, Secretary, DAECCS-2019 expressed satisfaction over the growth and quality of computational chemistry and smooth conduct of the event.

BARC Industrial Safety Awards

Towards promoting high safety standards in day-to-day operations of various facilities, BARC has introduced Industrial Safety Award Scheme in three categories - Operating Plants & Industrial Units, R&D Labs and Engineering Projects under construction.

From the list of entries received under this scheme, Industrial Hygiene and Safety Section (IHSS), HS&EG, BARC, evaluated the safety-related aspects, including Safety Performance Statistics and Safety Management Indicators such as Incident Rate, Safety Related Significant Event reported, Injury Index, Safety Culture, Safety Inspections/Surveys, Emergency Preparedness and Safety Training. The awards were handed over to the respective winners by Director BARC in presence of Chairman DAE.

The Director's Safety Shield 2018 was accorded to

1. Waste Immobilization Plant (WIP), WMD, NRG, Mumbai in the category Operating Plants & Industrial Units.
2. Sludge Hygienisation Research Irradiator, SHRI facility, RTDD, RC&IG, Vadodara and Detritiation Facility for Heavy Water Research Reactors (DFHRR) & Upgrading Plant (UGP), HWD, Mumbai in the category R&D Labs.
3. Kalpakkam Nuclear Recycle Project Construction (KNRPC), NRB, Kalpakkam in the category Operating Plants & Industrial Units Engineering Projects under construction.

Dr. A. K. Mohanty, Director, BARC giving away the Safety Shield to Smt. Neelima Singh Tomar, Head, TSS, WMD and Shri Sunil Solankar, Safety Coordinator in presence of Shri K.N. Vyas, Chairman DAE and C.G. Karhadkar, Associate Director, Reactor Group, BARC.

Dr. P. K. Pujari, AD, RC&IG and Shri Naresh Kumar, O-I-C, SHRI Facility, Vadodara receiving the Safety Shield from Director BARC.

Shri V.P. Haridas, Plant Superintendent, UGP and Shri G. K. Nath, Safety Coordinator of HWD receiving the Safety Shield from Director BARC.

Shri K V Ravi, Chief Executive, NRB, Shri I V N S Kamaraju, Project Manager, KNRPC, NRB-K and Shri Biplab Das, Safety Officer, NRB receiving the Safety Shield from Director BARC.

Central Complex at BARC

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