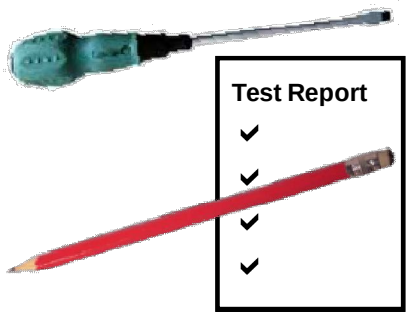
Commissioning until now

- Always on the critical path
- Manual, step-by-step procedure
- Labor intensive
- Requires
  - Screw driver
  - Check sheet
  - Pencil
  - Multimeter
  - Oscilloscope
- Connect one device at a time
- Disconnect after testing



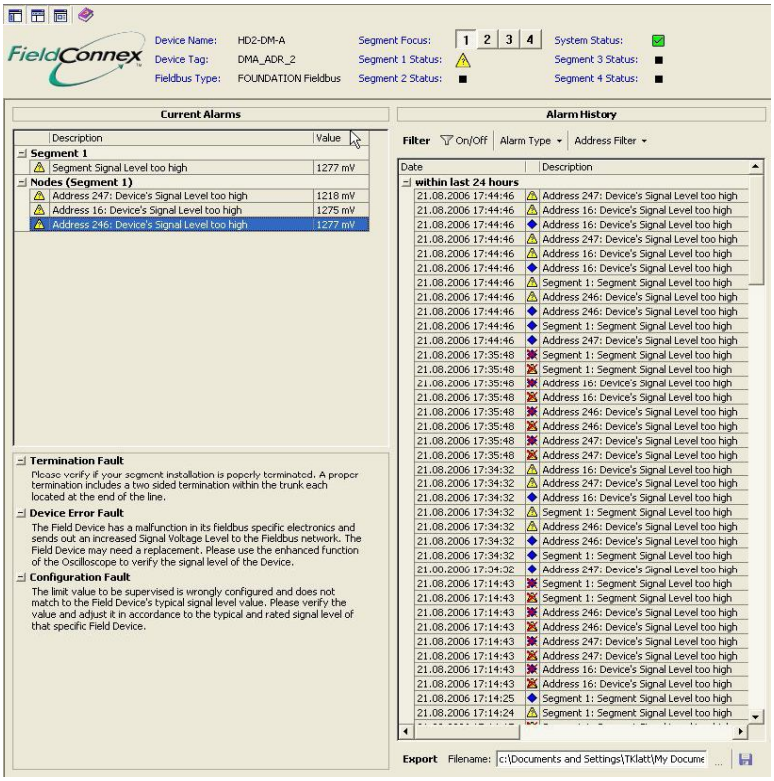
Simple Commissioning Steps with ADM

- Verify address setting
- Wire up devices in the right location
- Check shielding
- Activate communication
- Use automated work procedures
  - Testing
  - Documentation
- All devices at once
- Wiring remains undisturbed!

Commissioning Wizard

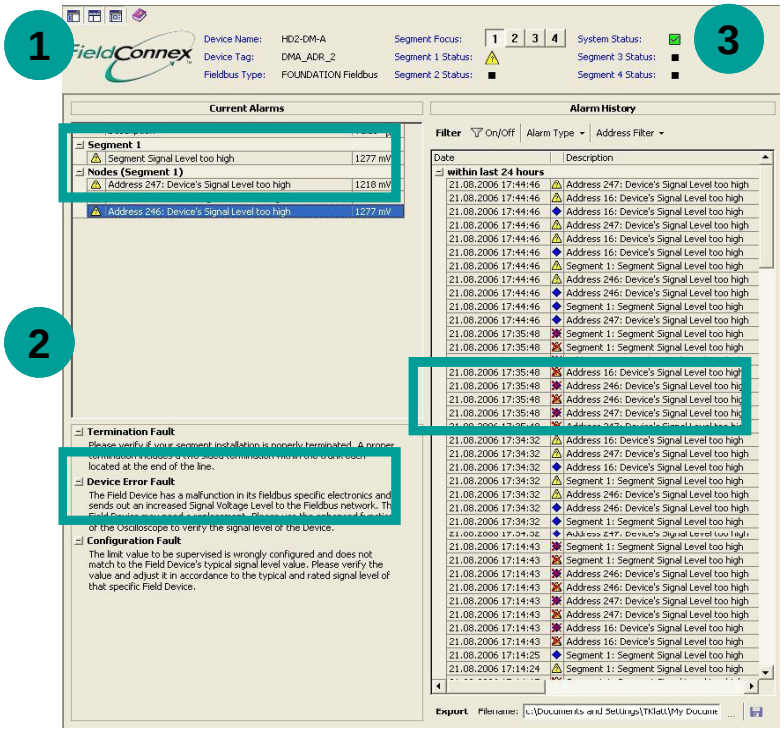
ADM in PRM, Jump to Diagnostic Menu

- **Diagnostic Manager is launched by a right click in the network view of a specific ADM representation**



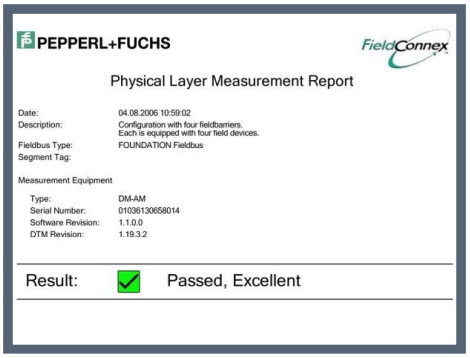
Diagnostic Menu

- **ADM delivers actionable information for fast fault finding**
  - 1 Active messages
  - 2 Actionable information with solution guideance based on expert knowledge
  - 3 History with timestamps When the failure…
    - … occured
    - … disappeared
  - Export function for external analysis and storage

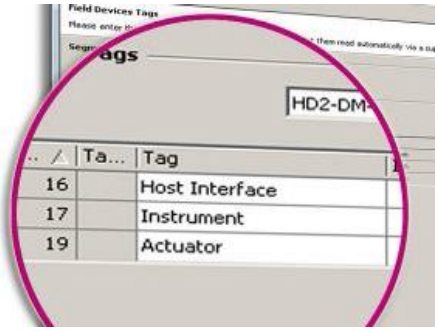


Commissioning Wizard

- **With Expert System Support**
  - Takes snapshot
  - Identifies wiring erros
  - Ensures compliance with AG181 and IEC 61158-2
  - Recommends limits for ADM messages
  - Stores limits in non-volatile memory



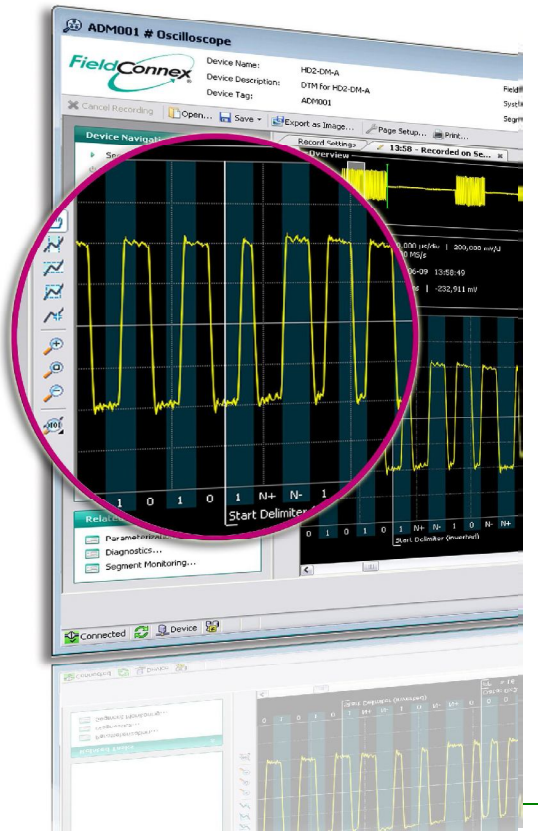
- **Automatic Tag Readout**



- **Creates baseline report:**
  - Snapshot of all measurements
  - Complete documentation

Built-in fieldbus oscilloscope

- **ADM provides expert tools for fast fault finding**
  - For diagnosing complex scenarios
  - For the fieldbus expert
  - With fieldbus specific triggers
  - Captures up to 10 shots in a row



Full Integration – Simplifies your work

- **Simplify configuration processes**
  - Select segments and configure entire plant automatically
  - Only a few mouse clicks
- **Simplify operations processes**
  - Asset Management native op guide messages
  - Summary alarms alert without nuisance
- **Simplify maintenance processes**
  - Integrated at Asset maintenace systems
  - Fieldbus physical layer is now a manageable asset
  - Detailed information for proactive planning of plant upkeep

Summary

- **Using DART Foundation fieldbus in projects are**

- **Faster and easier to design**
- **Reduced time in validation**
- **Higher accuracy (digital data throughout)**
- **Reduced components**
- **Less prone to failures**
- **Greater flexibility while selecting hazardous area concepts based on the project needs**
- **Diagnostics are integrated and reduces design and commissioning time**

Thank You

FUEL HANDLING CONTROLS IN PRESSURISED HEAVY WATER REACTORS

Presented By:

Nitin Rimza

Executive Engineer

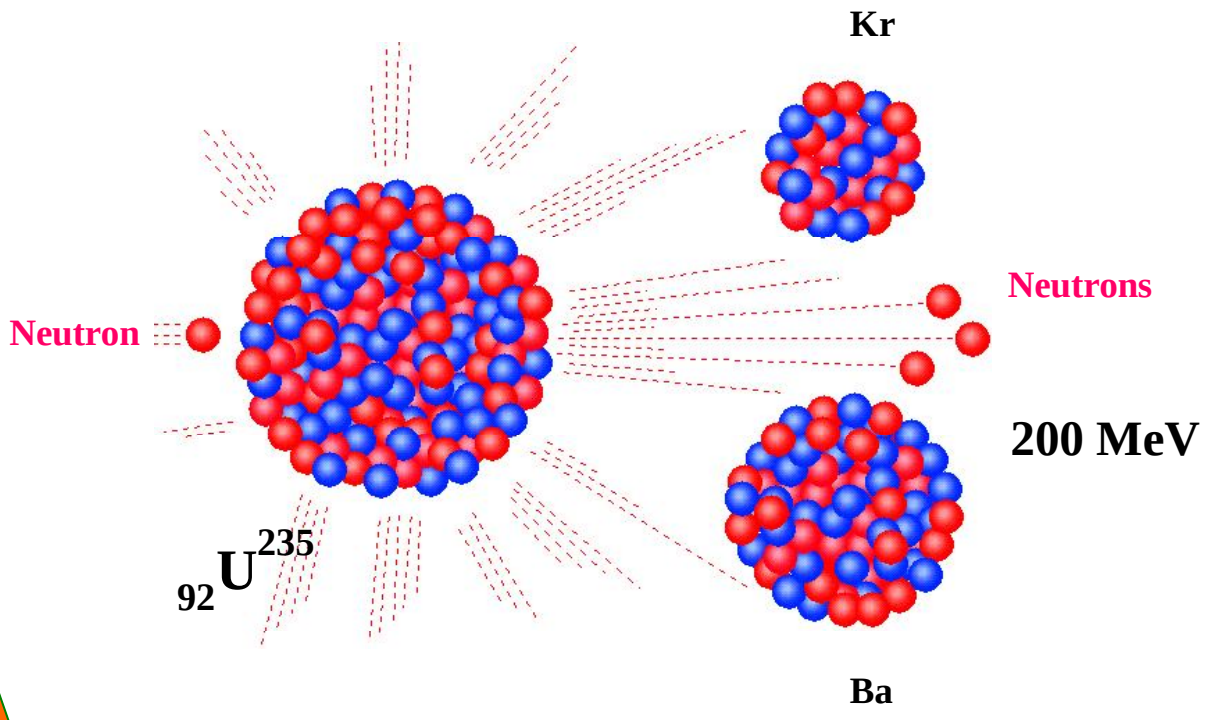
NPCIL

PRESENTATION OUTLINE

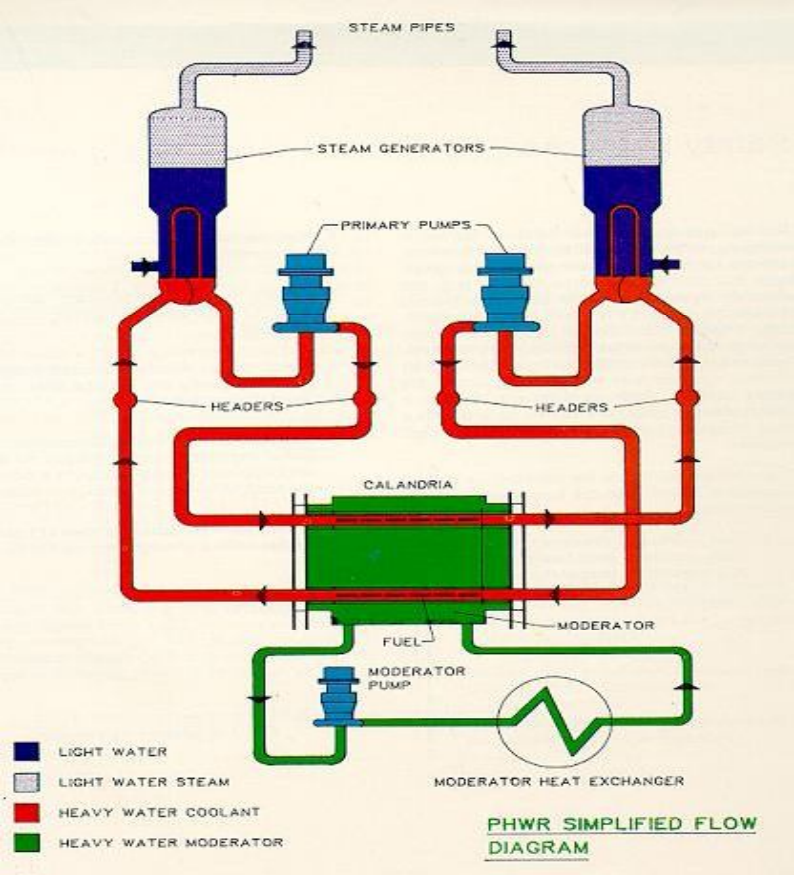
- Pressurised Heavy Water Reactors
- Fuel Handling System Overview
- Refuelling Operation
- Fuel Handling Control system
  - Key Features
  - Digital I&C System
  - Software Organization
  - Diagnostics
  - Built-in Safety
  - Manual & Safety Logic
  - Main Control Room Panel
- Future Plans

Pressurized Heavy Water Reactor (PHWR)

Nuclear Fission



PHWR

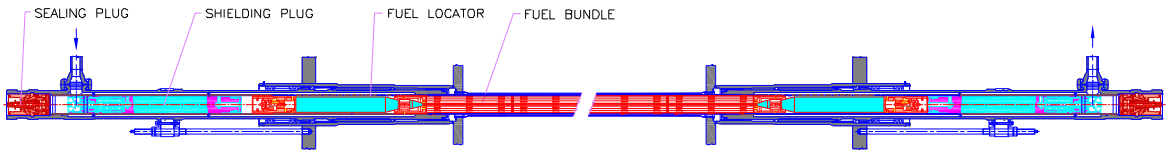

STEAM PIPES
STEAM GENERATORS
PRIMARY PUMPS
HEADERS
HEADERS
CALANDRIA
MODERATOR
FUEL
MODERATOR PUMP
MODERATOR HEAT EXCHANGER
LIGHT WATER
LIGHT WATER STEAM
HEAVY WATER COOLANT
HEAVY WATER MODERATOR
PHWR SIMPLIFIED FLOW DIAGRAM

PHWR

Natural Uranium fuel bundles

PHWR

- Fuel bundles contained in coolant channels
- In 700 MWe PHWR 392 channels and 12 bundles in each channel
- Long string of bundles free to move inside channel due to drag force of coolant flow and held in position by shield plug



COOLANT CHANNEL ASSEMBLY

PHWR

- Coolant channels arranged in square lattice grid in Calendria

- Low excess reactivity of Natural Uranium necessitates regular refuelling for sustained operation of reactor.

FUEL HANDLING SYSTEM (FHS)

Responsible for:

- Storage and Transfer of New Fuel
- Refuelling of Channels and
- Transfer and Storage of Spent Fuel

- Very dynamic system having intricate robotic mechanism
- Operated using Electric and Fluid power with D_2O, H_2O, Oil and Air

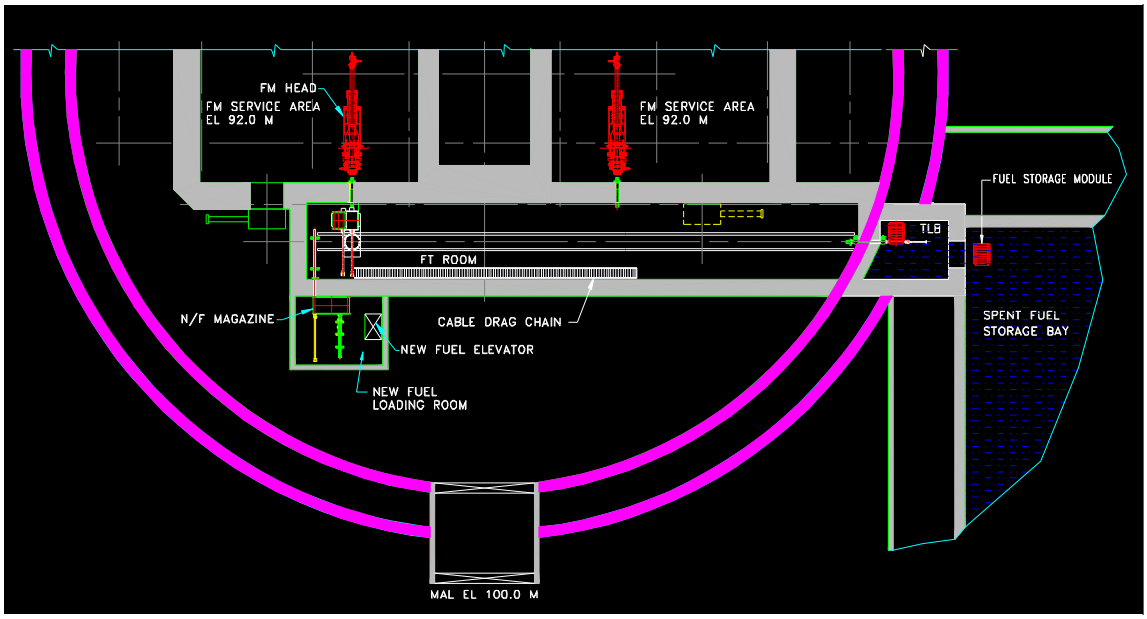
- FHS operate in a predefined sequence

FUEL HANDLING SYSTEM (FHS)

Divided into three sub-systems:

- Fuelling Machine (FM) system
- Fuel Transfer (FT) system
- Auxiliary system

FUEL HANDLING SYSTEM (FHS)

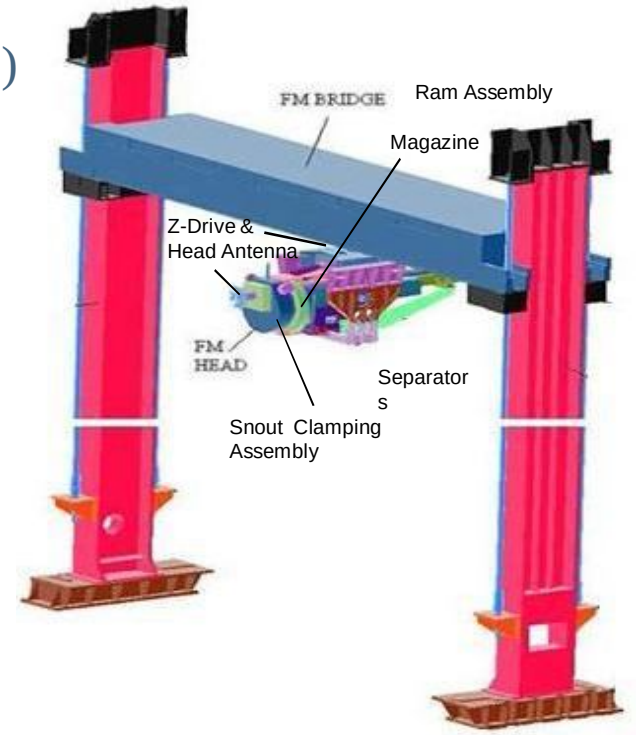


Two functionally identical FMs at North and South side of Calendria

FUEL HANDLING SYSTEM

The Fuelling Machine (FM) system sub-assemblies:

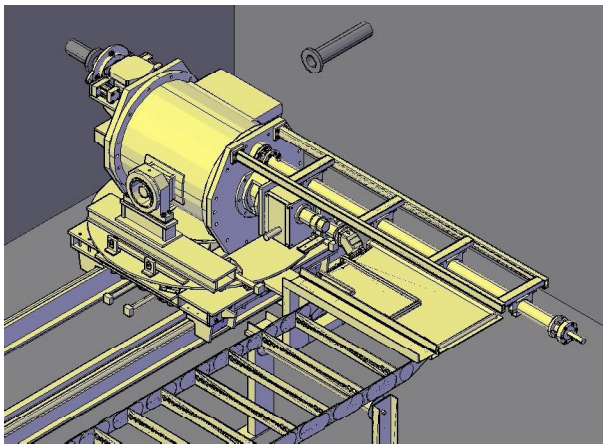
- Bridge and Carriage (X & Y)
- Z-drive and Head Antenna
- Leveling and Centralizing
- Snout Clamping assembly
- FM Magazine
- Ram assembly
- Separators
- Guide Sleeve & lock

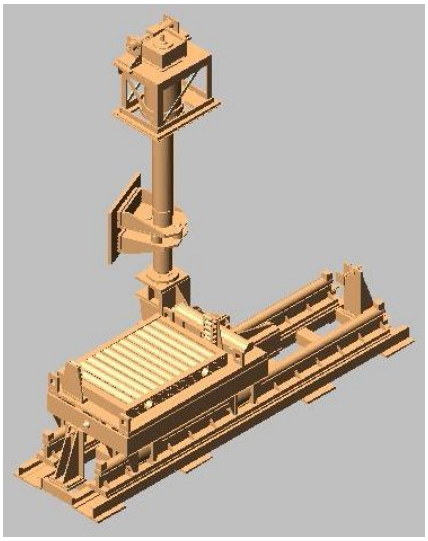


FUEL HANDLING SYSTEM

Fuel Transfer (FT) system sub-assemblies:

- New Fuel Magazine (NFM)
- Mobile Transfer Machine (MTM)
- Tray Loading Machine (TLM)

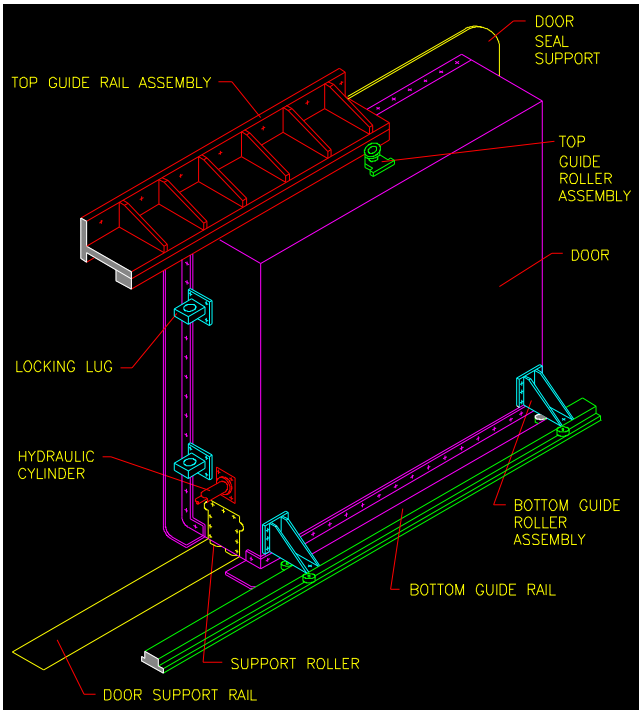




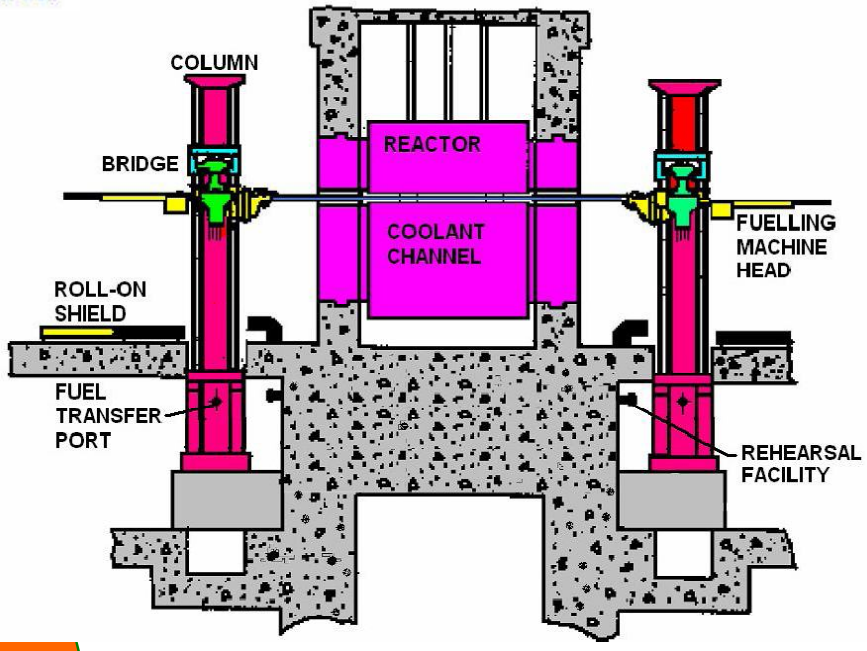
FUEL HANDLING SYSTEM

Auxiliary system sub-assemblies:

- Roll-On Shield
- Sealing and Shielding Doors for FM Vault and Service area, FT room etc



REFUELLING



- North & South FMs are clamped onto channel
- Upstream FM loads New fuel & Downstream FM receives spent fuel
- FT system loads new fuel into FM and transfer spent fuel from FM to TLB

FUEL HANDLING CONTROL (FHC) SYSTEM

- Fuel Handling Control system carry out Fuel Handling operations by control of :
  - o Process Pressure (e.g. Magazine pressure etc)
  - o Drive Force (e.g. Forces of Rams etc)
  - o Drive Position (e.g. Position of drives etc)
  - o Direction (e.g. Advancing/Retracting of cylinders etc)
  - o Speed (e.g. High/Low speed of MTM etc)
  - o Level (e.g. Levels of storage tanks etc)

FHC SYSTEM

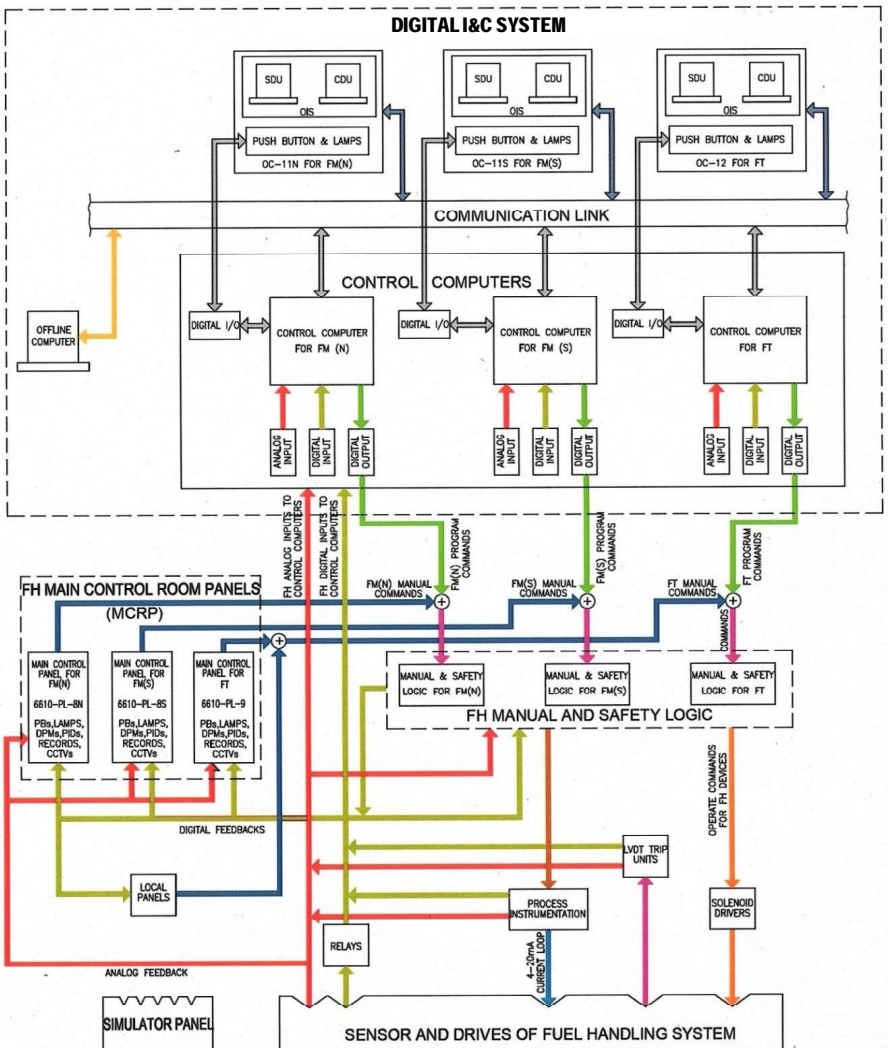
KEY FEATURES

- Fully automatic operation using custom built Digital I&C system developed in-house
- On-line and Off-line diagnostics to check healthiness of hardware and integrity of software
- Ensured safety of operation by checking safety interlock logic
- Ability to carry out all FH operations with manual backup during unavailability of Digital I&C system
- 2/2 logic for improving reliability of operation
- Operator friendly Interface
- Use of state-of-the-art FPGA to reduce complexity and improve maintainability
- Remote viewing CCTV system

FHC SYSTEM

FHC System Comprises of:

- Digital I&C System
- Operator Console (OC)
- Manual & Safety Logic (M&SL)
- Main Control Room Panel (MCRP)

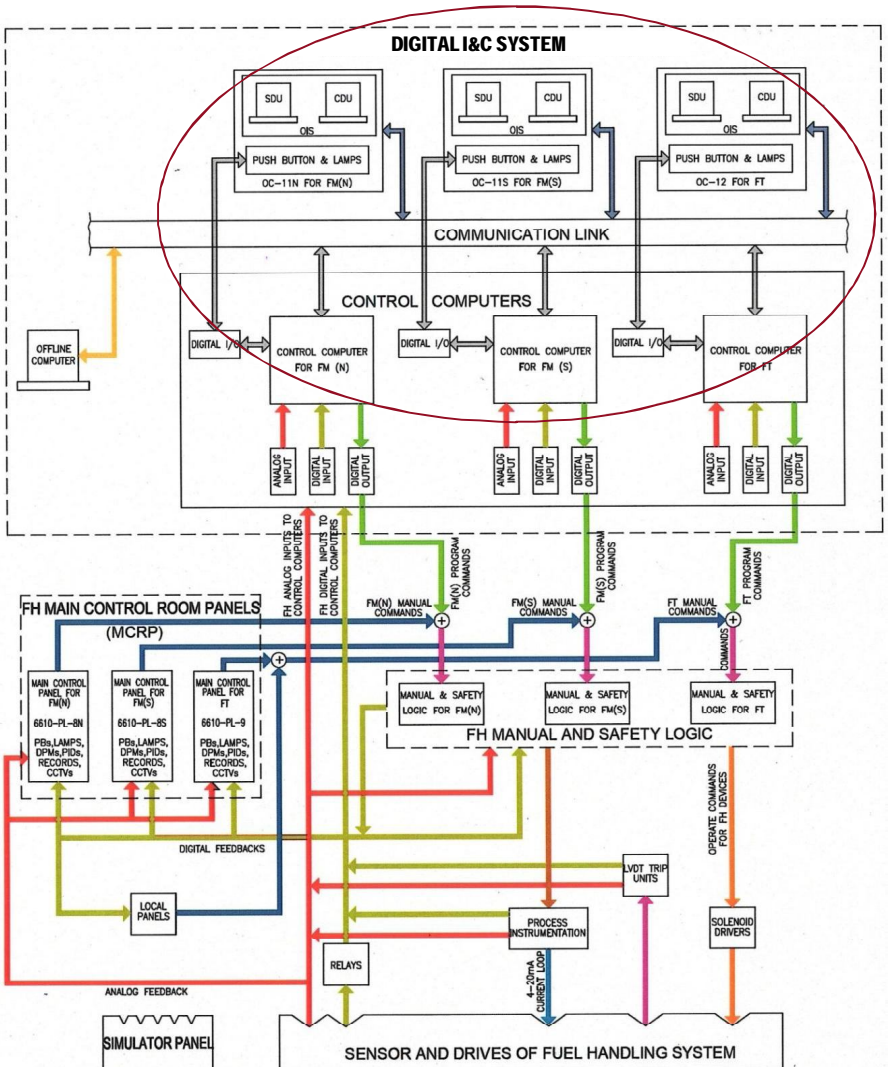


Legends:

- DIGITAL INPUT
- DITITAL OUTPUT
- ANALOG INPUT

SENSORS used in FHC

- Potentiometers
- LVDTs
- Proximity switches
- Micro switches
- Reed switches
- Commutator switches
- Pressure, Flow, Level & Temperature Switches and Transmitters etc.

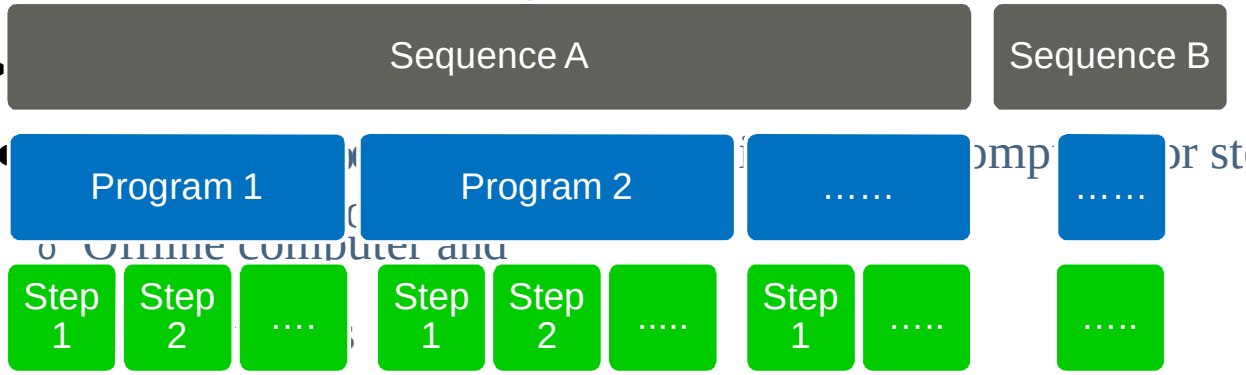


Legends:

- DIGITAL INPUT
- DITITAL OUTPUT
- ANALOG INPUT

DIGITAL I&C SYSTEM

- Complete refuelling sequence involves more than 1200 varied and complex operations with highly precise movements
- Used for Auto mode of operation
-



- Total 22 sequences and 30 programs.
- As many as 14 programs in each sequence and As many as 54 steps.in each program

DIGITAL I&C SYSTEM

- Safety Interlock Logic to ensure safety of operation
- Logic design according to functional and operational safety requirements of devices
- Three control computers communicate with Offline computer and with each other through dual LAN.
- Field interfacing through Analog & Digital Inputs and Outputs

  Each control computer consists of approximately 420 digital inputs, 62 analog inputs and 240 digital outputs
- Output commands routed through M&SL

SOFTWARE ORGANIZATION

Depending on application, software is organized as Online software and Offline software

Online software:

- Programs for control and monitor FH operations
- Calibration table for Auto positioning of drives at predefined positions
- Cycle based with cycle time of 50 msec
- During each cycle the control computer read inputs, execute step logic, check interlocks and set/cancel commands

Offline software:

- Utilities for testing and transfer/storing of online software modules
- Diagnostics of computer hardware

DIAGNOSTICS

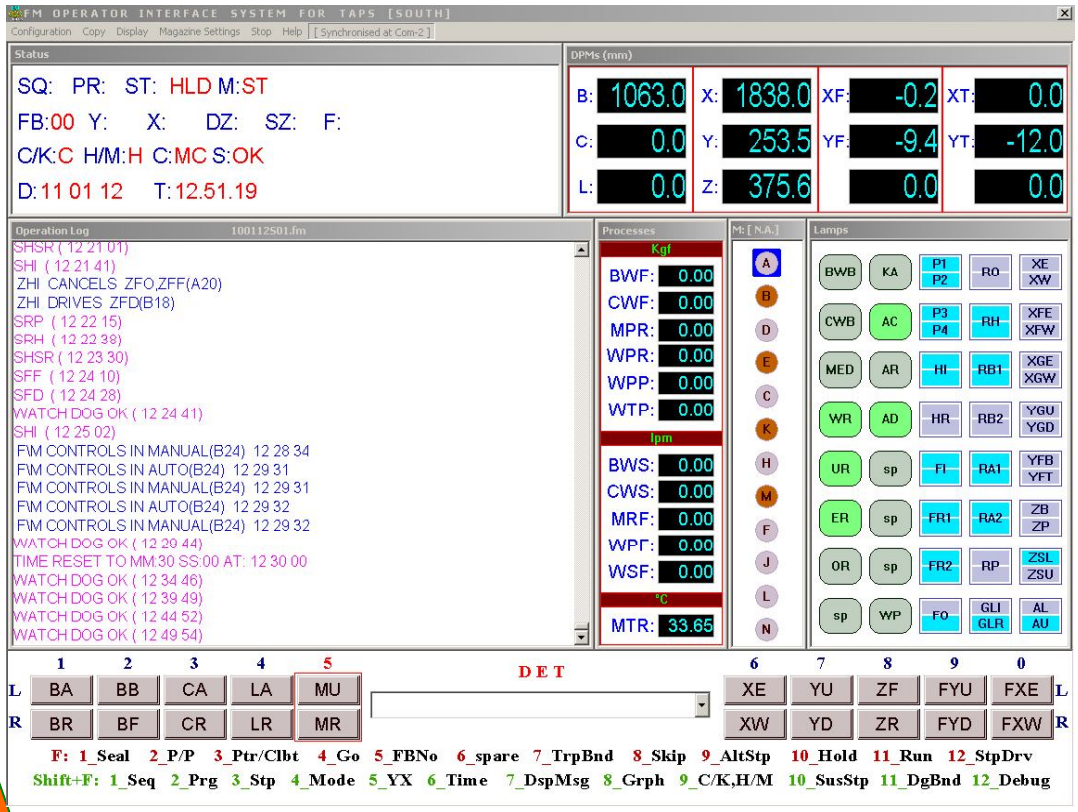
Online and Offline diagnostics to check healthiness of the system

Diagnostics for Software and Hardware of system

DIAGNOSTICS

- Software integrity check during each cycle through external hardware (Watchdog timer)
- Detection of any fault generates a contact type output to trip the FHC system and force all outputs to bring the system in fail safe state
- Checks for corruption in calibration data of various drives, in case any corruption is detected further Auto-positioning is not allowed
- Checks for functionality of Computer hardware
- Modular design of hardware facilitates easy fault identification and quick replacement of faulty module

DISPLAY UNITS



DISPLAY UNITS

Two display units are provided:

- Control Display Unit (CDU)
- Status Display Unit (SDU)

DISPLAY UNITS

CONTROL DISPLAY UNIT

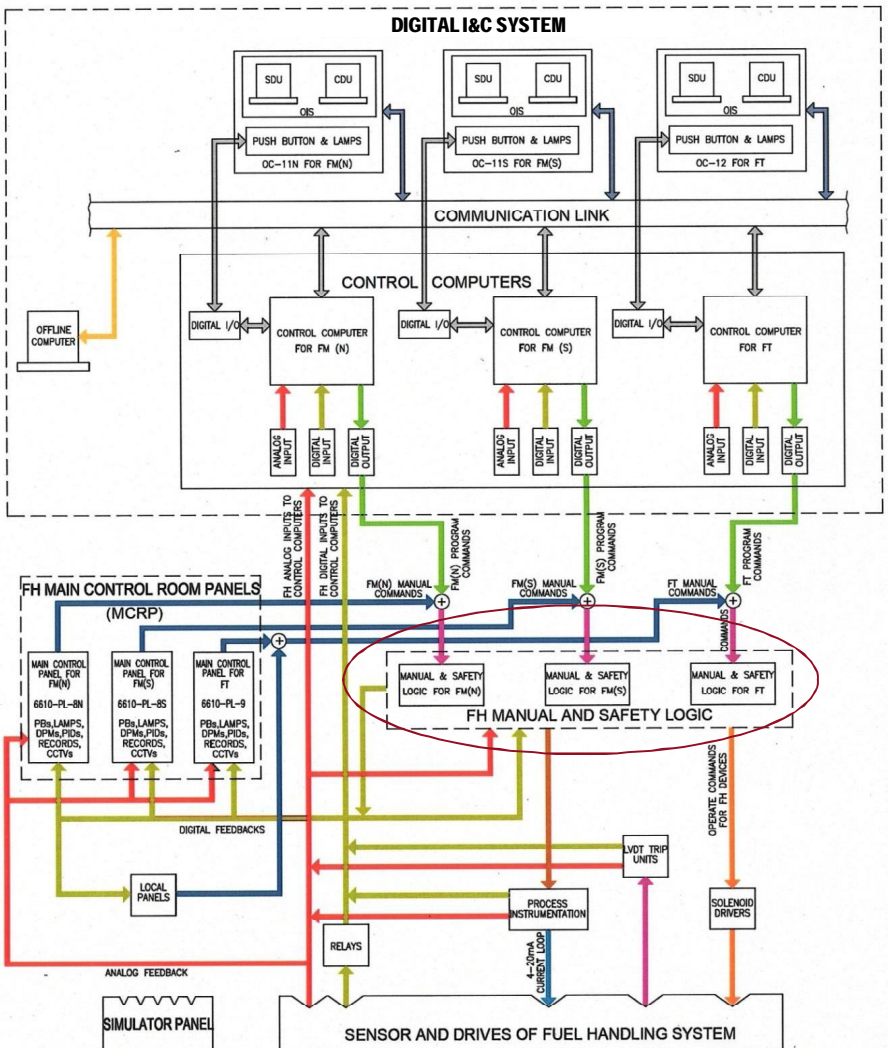
- Initiate FH operation sequence in Auto mode.
- Display of various information like:
  - Program messages
  - Diagnostics messages
  - Calibration values
  - Logic statements
  - Non-availability of permissive/feedbacks etc
- Maintains log of all operations performed and messages displayed during auto mode

STATUS DISPLAY UNIT

- Displays additional information to assist the operator such as Status of various drives and actuators

OFFLINE COMPUTER

- Execution of offline diagnostics
- Loading of online software
- Storing of calibration table
- Modifications in Application software etc.



Legends:

- DIGITAL INPUT
- DITITAL OUTPUT
- ANALOG INPUT

MANUAL AND SAFETY LOGIC (M&SL)

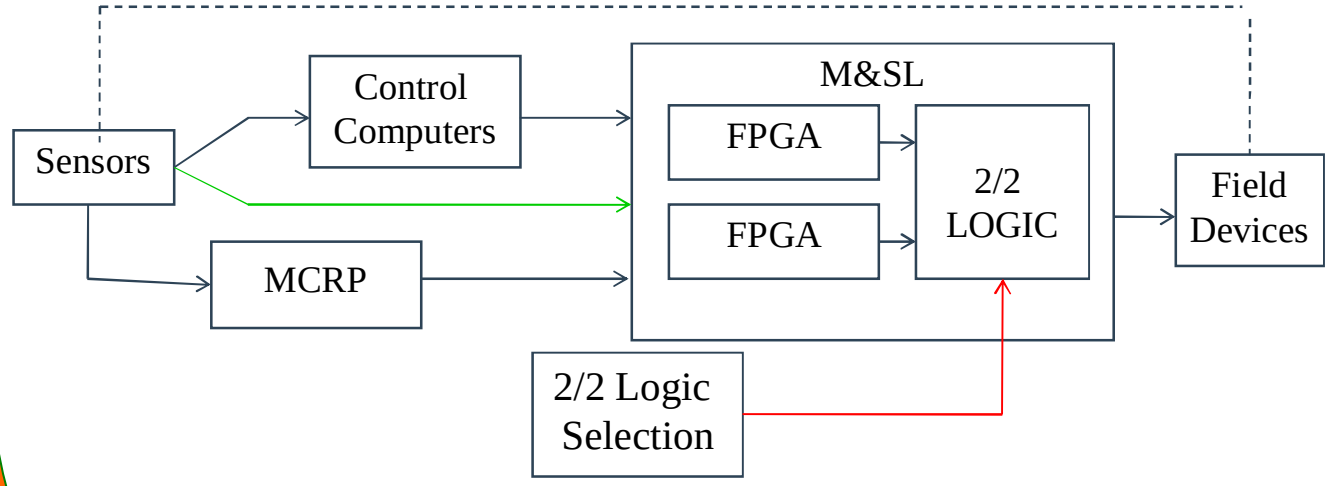
Major functions:

- To check safety interlocks using hardwired logic
- To facilitate operation using Manual backup during unavailability of Digital I&C system to bring the system in safe mode
- To provide auto initiated actions

MANUAL AND SAFETY LOGIC

nplemented using Field Programmable Gate Arrays

Periodic diagnostics embedded to check healthiness of logic



Control computer outputs routed through M&SL

2/2 logic to ensure that failure of single component will not issue wrong commands

Provision to bypass single channel

MAIN CONTROL ROOM PANEL

tons

g Lamps

& Digital

ers

rs

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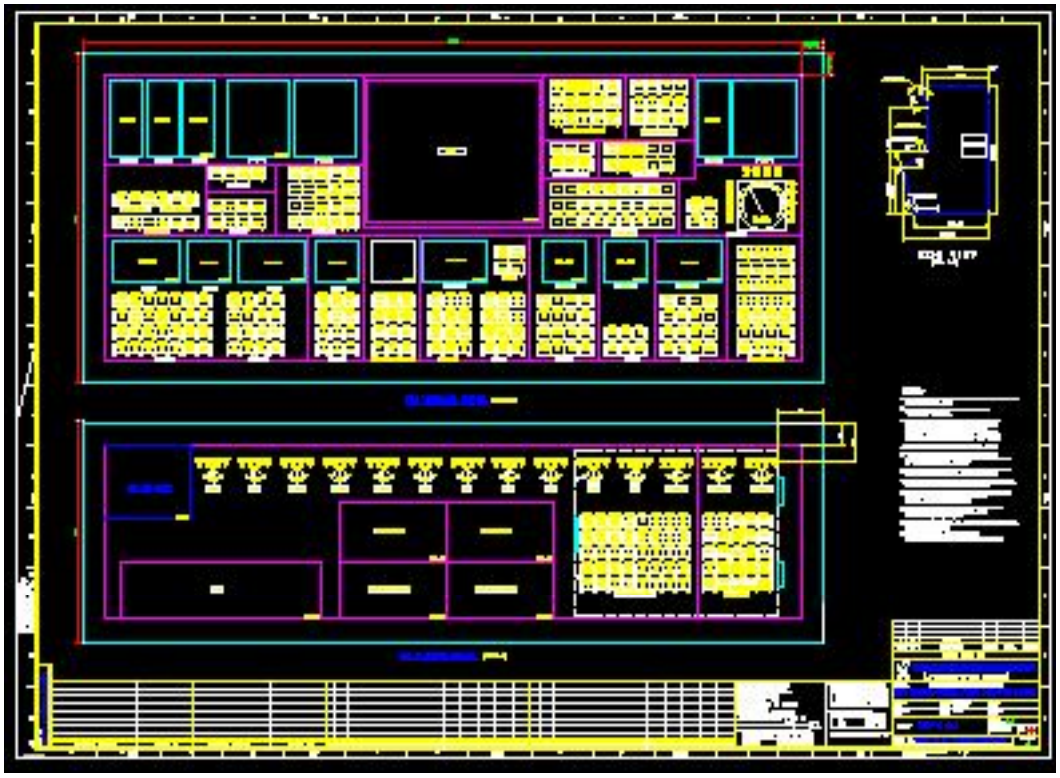
MAIN CONTROL ROOM PANEL



BUILT-IN SAFETY

- Interlock logic implementation in both software and hardwired
- 2/2 logic to ensure no false command is issued
- Redundant sensors, cables and power supplies
- Physical diversity provided for laying of redundant cables
- Alarm windows for operator's attention in case of abnormalities and failure
- High system availability by proper selection of components
- Auto initiated actions

FUTURE PLANS

- Animation of Fuel Handling operations
- Incorporation of intelligence for Off-Normal Procedures
- Monitoring healthiness of devices

THANK YOU

Reactor Control and Protection System of VVER-1000

Nabanita Pyne, SEE(C&I)

K. Nathani, DCE (C&I)

S.K.Sen, ACE(C&I)

Nuclear Power Corporation of India Limited, Mumbai

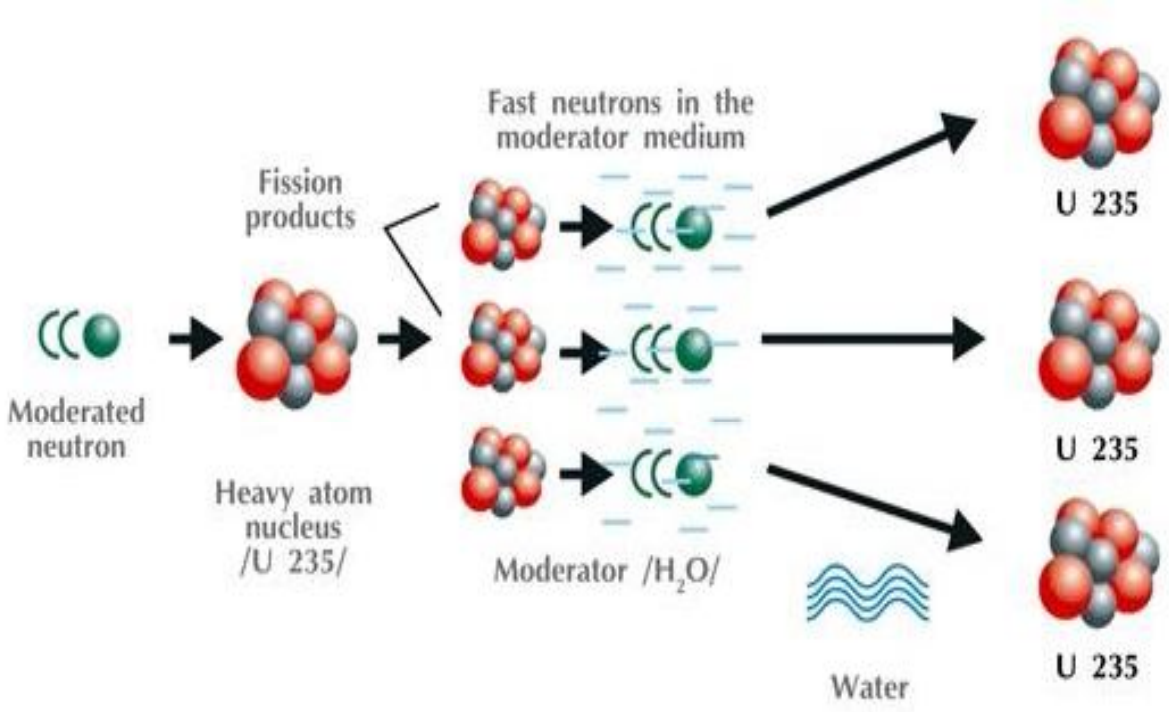
ISA(D)POWAT-INDIA 2012, Delhi , Jan 13th -14th, 2012

OVERVIEW

- Nuclear Heat Generation Basics
- Role of C&I in VVER-reactor
- Reactor Control and Protection System of VVER-reactor
  - Design Philosophy
  - System Architecture
- Final Control Element
- Conclusion

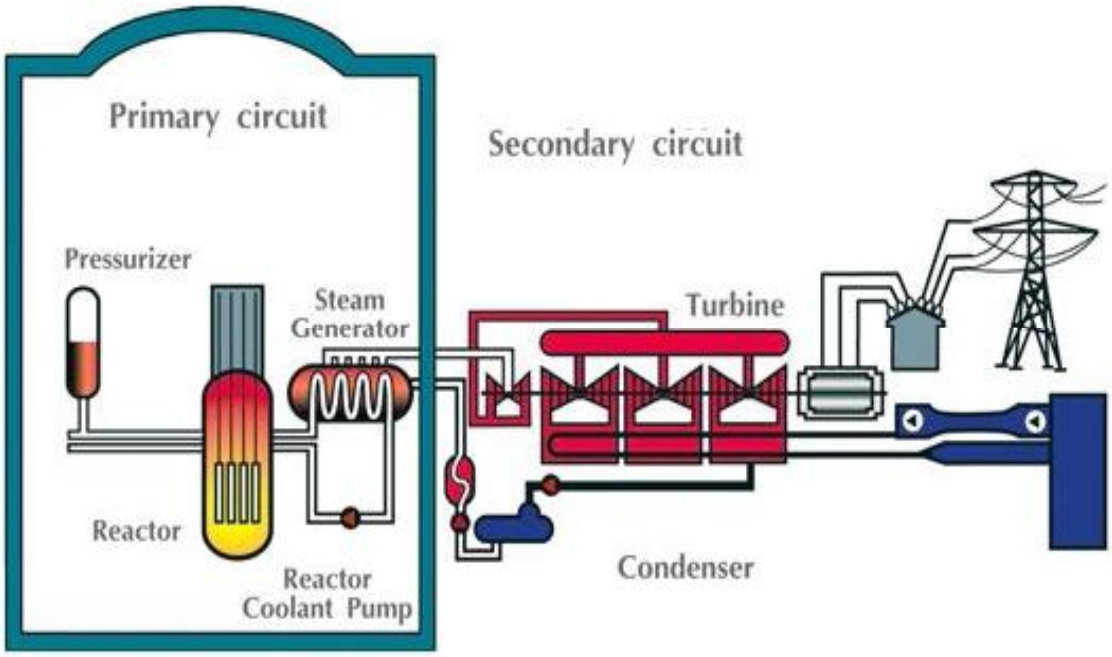
NUCLEAR HEAT GENERATION: BASICS

- Nuclear Reactors generate power using heat released by a process called nuclear fission.



NUCLEAR HEAT GENERATION: BASICS (contd.)

- VVER- 1000 uses light water as coolant and moderator and enriched Uranium (about 2.2 to 4.4% U^{235} max.) as fuel. Control rods are used as device for reactivity control.



ROLE OF C&I IN VVER- REACTOR

- C&I of VVER reactor acts as the neuro system of the power plant and plays a vital role in achieving safe, reliable and efficient operation of the reactor. It ensures reactor safety under all circumstances with high degree of reliability and availability. Design of C&I is evolved based on the principle of defense in depth.
- **Defense in depth:**

layers of Protection

Plant Control System

+

Preventive Protection System

+

Reactor Protection System

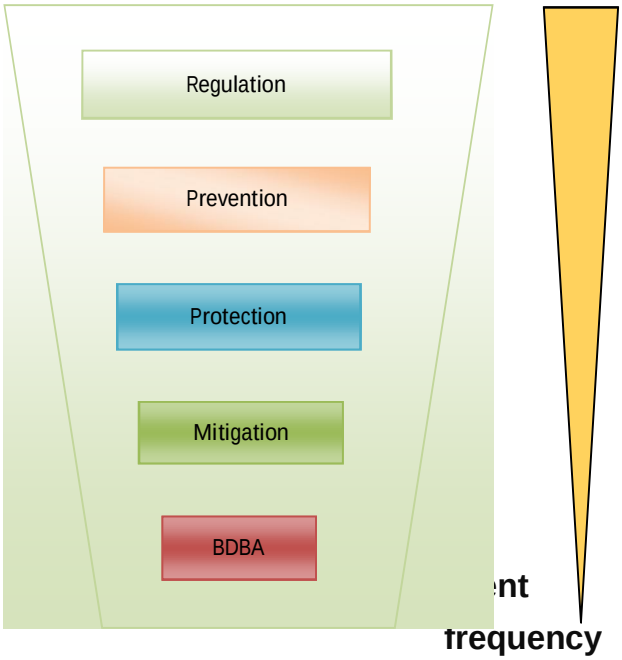
+

Engineered Safety Feature

+

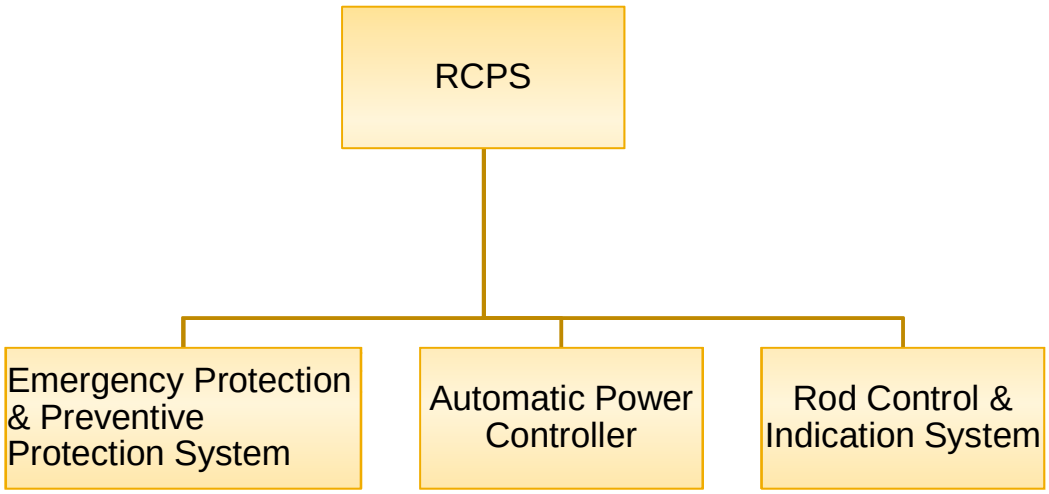
Severe Accident

Precaution/coping



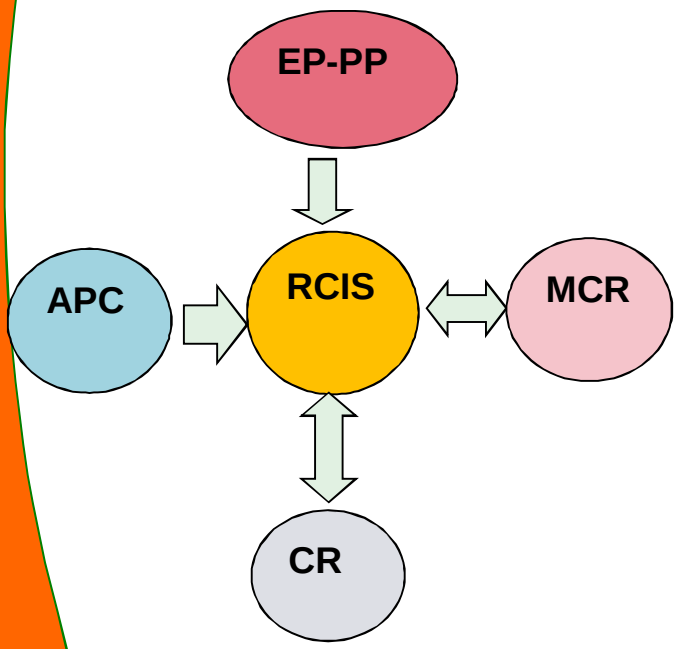
REACTOR CONTROL AND PROTECTION SYSTEM

- Reactor Control and Protection System (RCPS) is one of the most significant C&I system for VVER reactor. It consists of following subsystems belonging to different layers of protection, used to perform control and safety functions.



REACTOR CONTROL PROTECTION SYSTEM (contd.)

Subsystems



Major function

- Flux & process monitoring, tripping of reactor (EP), hold back (PP2), set back (PP1) and step back (APP)
- Control of Reactor Power as per demand (N,T & C mode)
- Interface for EP-PP, APC, MCR with CR.

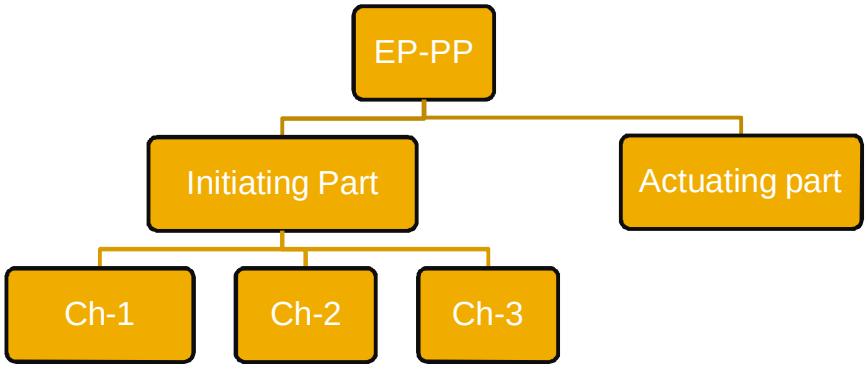
EMERGENCY PROTECTION – PREVENTIVE PROTECTION (EP-PP) SYSTEM

Design Philosophy

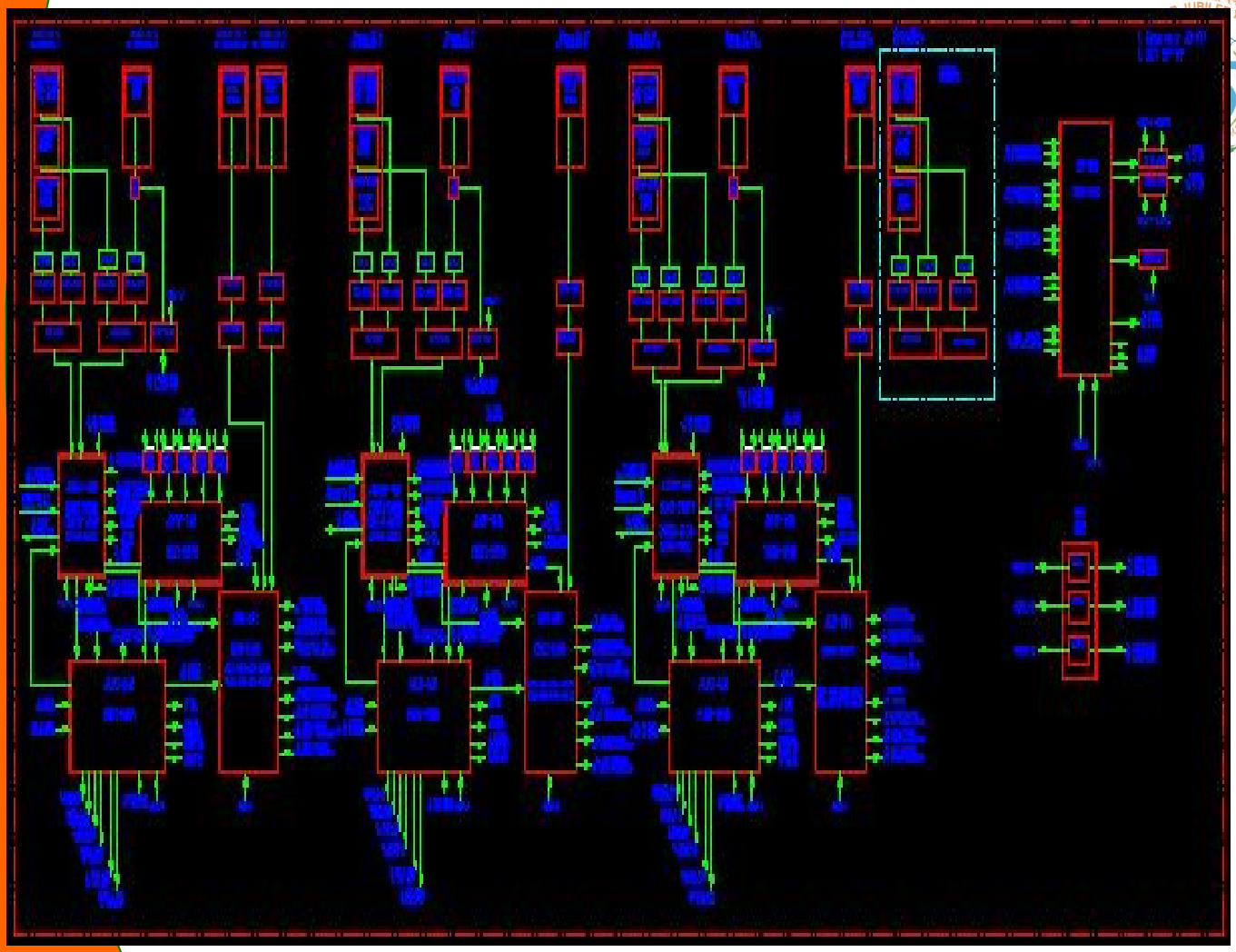
- It is a hardwired system having 2 independent sets of 3 channels with limited software.
- Each channel is functionally independent and kept physically separated.
- It monitors neutron flux/ process parameters for generation of reactor trip (EP), step back (APP), setback (PP1) and holdback (PP2) signals.
- All the field inputs are converted to frequency for transmission to processing circuit.
- Signal generation is performed on 2 out of 3 logic for each parameter.
- Design involves fail-safe logic.
- Proper galvanic/optical isolation is provided for shared signals
- Provision for manual tripping of reactor is available
- System can be tested online without disturbing reactor operation.

SYSTEM ARCHITECTURE

- Each set of EP-PP system is logically divided in two parts.



- Each channel of Initiating part constituents following parts:
  - Sensors
  - Signal processing and comparator system
  - Signal logic processing equipment
  - Display system



SYSTEM ARCHITECTURE ->SENSORS (contd.)

- Separate sensors are provided for each neutronic & process parameter for each channel of EP. Sensors are common for EP and PP.
- Different types of neutron detectors of different range are used to monitor neutron flux over wide power range with overlapping of minimum one decade.

Name of range	Type of detector	Limits of power monitoring
Source range, SR	Boron Counter	10^{-8} to 10^{-4} % of Nnom
Initial range, IR	Fission Chamber	10^{-6} to 10^{-1} % of Nnom
Working range, WR1	Ionization chamber	10^{-2} to 150 % of Nnom
Working range, WR2	Fission Chamber	1 to 150 % of Nnom

- To monitor process parameter, thermocouple, pressure transmitter, level transmitter etc are used

SIGNAL PROCESSING AND COMPARATOR SYSTEM

- Sensor signals are fed to CU for conversion(V/I- >f).
- Frequency signal are processed and compared with set point in Signal Processing and comparator system
- On exceeding set points, It will generate discrete signal for reactor trip, PP1, PP2 and APP function

SIGNAL LOGIC PROCESSING EQUIPMENT

- Receives discrete signal from all 3 channels of signal processing and comparator system
- Realizes 2 out of 3 voting on binary output signals for each and every trip parameter.
- The output is final EP or PP command at channel level and actuating part.

SAFETY LOGIC FOR EP-PP INITIATING PART