# Control & Instrumentation – User's Perspective

Care
Integrity
Excellence
Collaboration
Trust
Respect

## From Decade of Progress to Era of New Possibilities

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12th April, 2013

TATA POWER
Lighting up Lives!

## Introduction

- Rapidly changing schedules, Varying fuel qualities, Strict Evironmental requirements – Role of Automation Critical
- Production reliability, Operational efficiency and Bottom line profitability.
- Progress of Control System – Proprietary based to totally integrated
- Vastly increased computing power of controllers
- DCS an integral part of the corporate IT infrastructure
- Advanced Application Tools - Volumes of data to useful information
- Leveraging the capabilities of control system

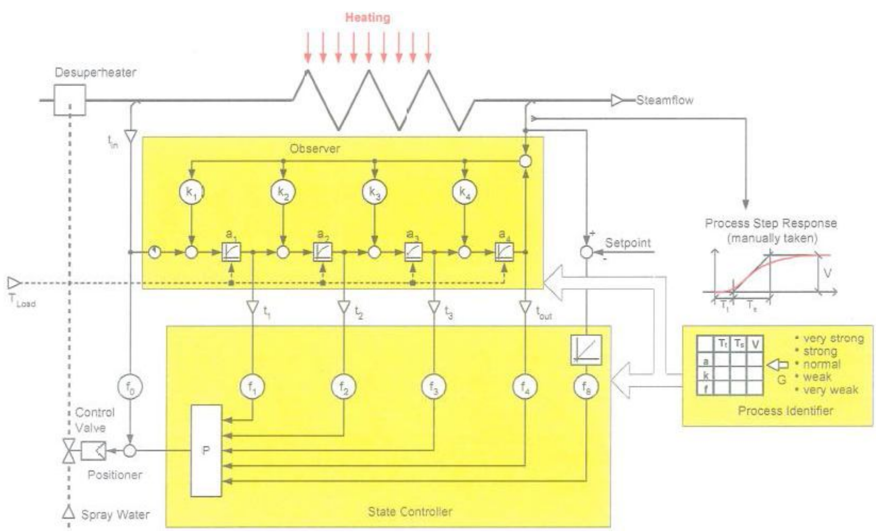
# Control & Instrumentation – The Journey

**Progress** → **Possibilities**

- Advanced Control Concepts
- Alarm Management System
- Unattended and Reduced Attendance Operation
- Cyber security of Plant Control Systems
- Control Loop Performance Monitoring software
- Power Plant Simulator
- Community of Experts

# Advanced Control Concepts

- Limitation of PID Controllers - Nonlinear process & Large Time Constants
- Superheater Steam temp Control - Large temperature excursions - Plant life reduction and creep life damage on boilers
- Process Model calculates the intermediate control states
- HP Bypass control Valve
  - Model Predictive Control
- Exploiting Margins
- Correction before Error



## Alarm Management

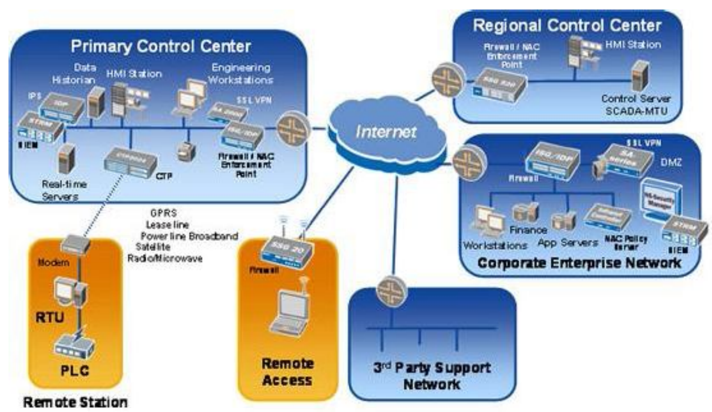
- Alarm flood and nuisance alarms - Adverse effect on process efficiency
- Alarm system - Operator's attention for timely assessment and action
- Blocking of alarms from an out-of-service plant/equipment
- Grouping of Multiple process alarms
- Suppression of major event alarm – Fail safe action
- Rationalization of all multiple alarms initiated directly to the root cause
- Blocking of Downstream alarms
- Rate of Rise philosophy or Some other concept for spurious alarms
- Alarm Management System - Root Cause Analysis Tree

# Unattended and Reduced Attendance Operation

- Pocket pager by the roving operator for alarms & message
- Control Room physically unattended but fully in effective control
- Operator recall alarms and lights activate for physical presence
- Level of plant protection automatically raised in unattended mode
- Design Principle – Single Pushbutton Operation, Advanced control
- Safety Integrity Level certified systems – Boiler & Turbine Protection
- <u>Operator actions largely interventions, rather than Control & Monitoring</u>

# Cyber Security of Plant Industrial Control Systems

- ❑ Increased connectivity of control system network to corporate networks
- ❑ Normal disconnect - I&C professionals not conversant with IT products
- ❑ Set of security policies and procedures by team of I&C and IT engineers
- ❑ Periodic comprehensive security audit by certified auditor
- ❑ Security features in specification




Cyber security requirements

- Culture not compliance

## Control Loop Performance Monitoring Software

- Software evaluates the control loops - More targeted corrective action
- Diagnosing control problem - Which Loops & Why
- Prioritized list of poorly performing loops based on the criticality
- Maintaining performance and tuning history
- Integration into on-line Heat Rate Calculation Software
- Useful to for less-experienced process control engineers

## Power Plant Simulators

- Training platform for  operators, engineers and plant management
- Operators trained for multitude of possible malfunctions
- Validation of Process equipment design & Control strategy
- Eliminate problems before implementation
- Optimize plants, already in operation.
- Experiment control design changes before implemented in "live" plant

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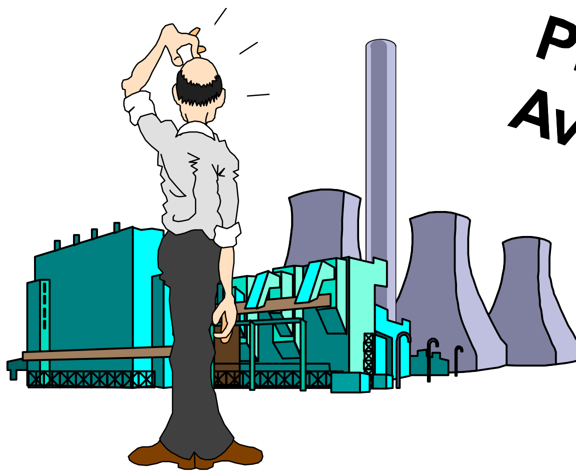
## Community of Experts

- Automation systems - Fast becoming communications channels
- Computers at Power plant - Expertise and software elsewhere
- Performance Enhancing products and services through the portal
- Optimization of plant’s processes as a whole rather than piecemeal
- Community of experts - Collaborate towards the common objectives
- Automation system - The Platform for community

# Thank You

Safety ?

Process Availability ?



Risks ?

Cost saving?

# Controls and Automation in Solar Thermal Plants




**Siddhartha Ghoshal, Director- SE Asia**

# AREVA Group offers one-stop solutions for carbon-free power generation

## World leader in nuclear power and major player in renewable energy

**Bioenergy Power Generation**

More than 100 bioenergy plants built by AREVA worldwide

*2800 MWe*

**Offshore Wind Power Generation**

250 AREVA wind turbines chosen for use in offshore wind parks in Europe

*1200 MWe*

**Concentrated Solar Thermal**

Most cost-effective, utility-scale turnkey concentrated solar power (CSP) solution

***300 MWe in operation/ construction***


**Hydrogen & Storage**

Energy Storage solutions with GreenergyBoxTM and Myrte fuel cell system

*100 kWe*

*Source: AREVA*



AREVA

# AREVA Solar
## Projects track record

- AREVA Solar currently has close to 550 MW of CSP projects in operation, under construction or in advanced development

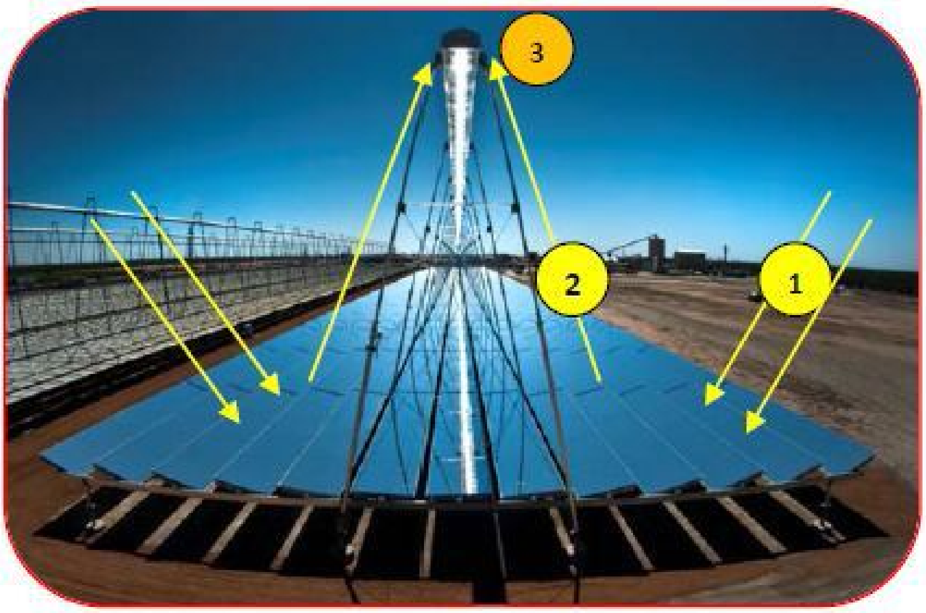
| | | | |
|---|---|---|---|
| Australia | First coal/solar booster prototype | Booster 3 MWe | Prototype |
| Australia | Construction of world's largest coal/solar booster | Booster 44 MWe | Construction |
| USA | First CSP plant commissioned in the USA in 20 years | Stand-alone 5 MWe | Operation |
| USA | High-temperature booster demo for additional applications | Booster 5 MWe | Construction |
| India | Delivery of a large-scale, high-temperature CSP plant | Stand-alone 2x125 MWe | Construction |

**AREVA, one the fastest-growing CSP technology providers**



AREVA

# AREVA's solar technology of choice
# Compact Linear Fresnel Reflector




1 *Sunlight falls on the single-axis, sun tracking reflectors*

2 *Sunlight gets reflected towards the fixed receiver*

3 *In a once-through boiler, the water gets converted to steam directly*

## Each such module is called a Solar Steam Generator – SSG

**1 SSG typically produces upto 20MWth or 5.5MW in India DNI conditions**

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# Specifications sheet
# Standard Solar Steam Generator

| Solar Steam Generator Unit<br>Performances depend on local conditions | |
|---|---|
| Temperature | Up to 485°C (905°F) |
| Pressure | Up to 2,400 psia (165 bara) |
| Thermal Output | Up to 22 MWth |
| Electric Output | Up to 7.7 MWe |
| Water Usage<br>(dry cooling) | 0.3 $m^3$/MWhe<br>80 gal./MWhe |
| Land Use<br>(acres/hectares) | 15.44 acres<br>6.2 hectares |
| MWe per<br>acre/hectare | 0.5 MW/acre<br>1.24 MWe/hectare |
| Grade | East – West = up to 1.6%<br>North – South = <1% |



AREVA

# Controls and Operational Excellence

AREVA Solar

# Topics

- **Controls Features and Architecture**
- **System Automation**
- **Solar Field Operations and Operational Modes**

# CONTROLS FEATURES AND ARCHITECTURE

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# SSG Safety and Protections

- **SSG controls will begin to roll off reflectors when steam conditions approach pressure and temperature limits**
- **SSG controls will trip (roll off all reflectors) when steam conditions exceed pressure or temperature limits**
- **Temperature limits**
  - **Tube Maximum Mean Wall Temperature**
  - **Thermal expansion**
- **Pressure limits**
  - **Pressure safety relief pressures**
    - Set below Maximum Allowable Working Pressure
- **SSG controls will trip when flow rates are too low to ensure that temperatures can be managed**

# SSG Steam Quality Controls

- Exit steam pressure and temperature conditions are controlled by a Model Predictive Controller (MPC) that determines flow rates into and out of the SSG
- Target flow rates are also adjusted based on an estimate of available thermal input power from the sun
- The MPC provides tight steam conditions that account for the challenging process dynamics of direct steam generation
- Control valves manage flow rates into and out of the SSG

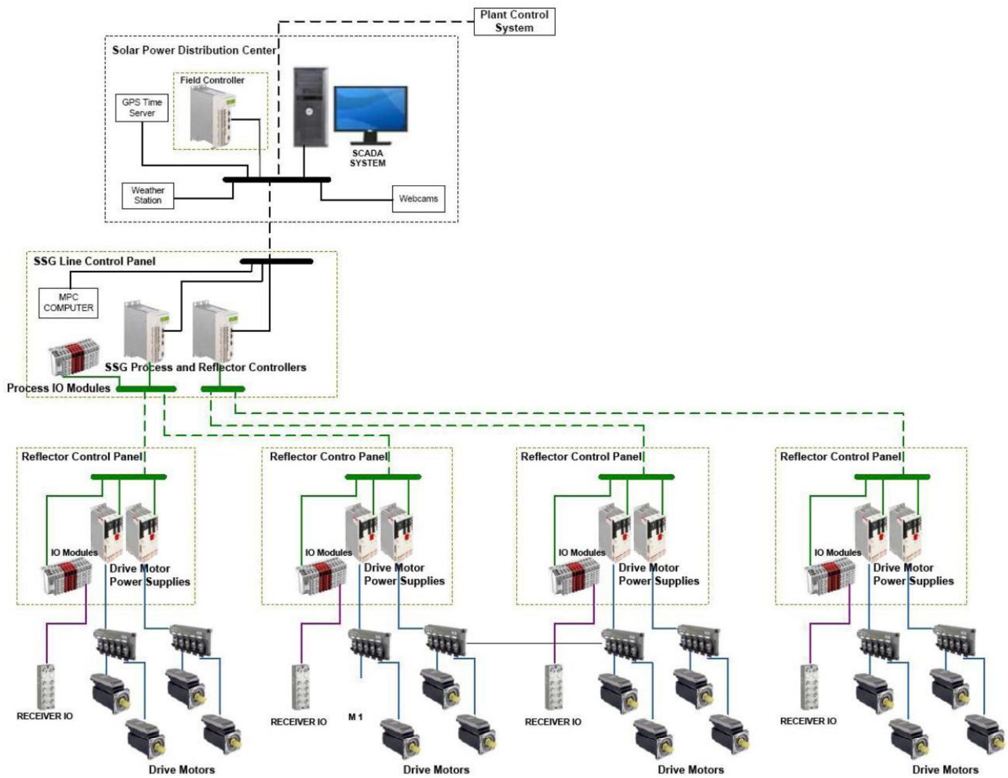
# SSG Reflector Controls

- Reflectors controls focus the solar power on the receiver
- Reflector angle determined based on solar position and SSG design geometry
  - Solar position calculated based on time and location on earth using industry standard algorithms
- Reflector angle accurate to within +/-0.05 degrees
- Reflector angle calibrated with optical field measurement at installation to ensure tracking is correct

# Operator Interface and SCADA

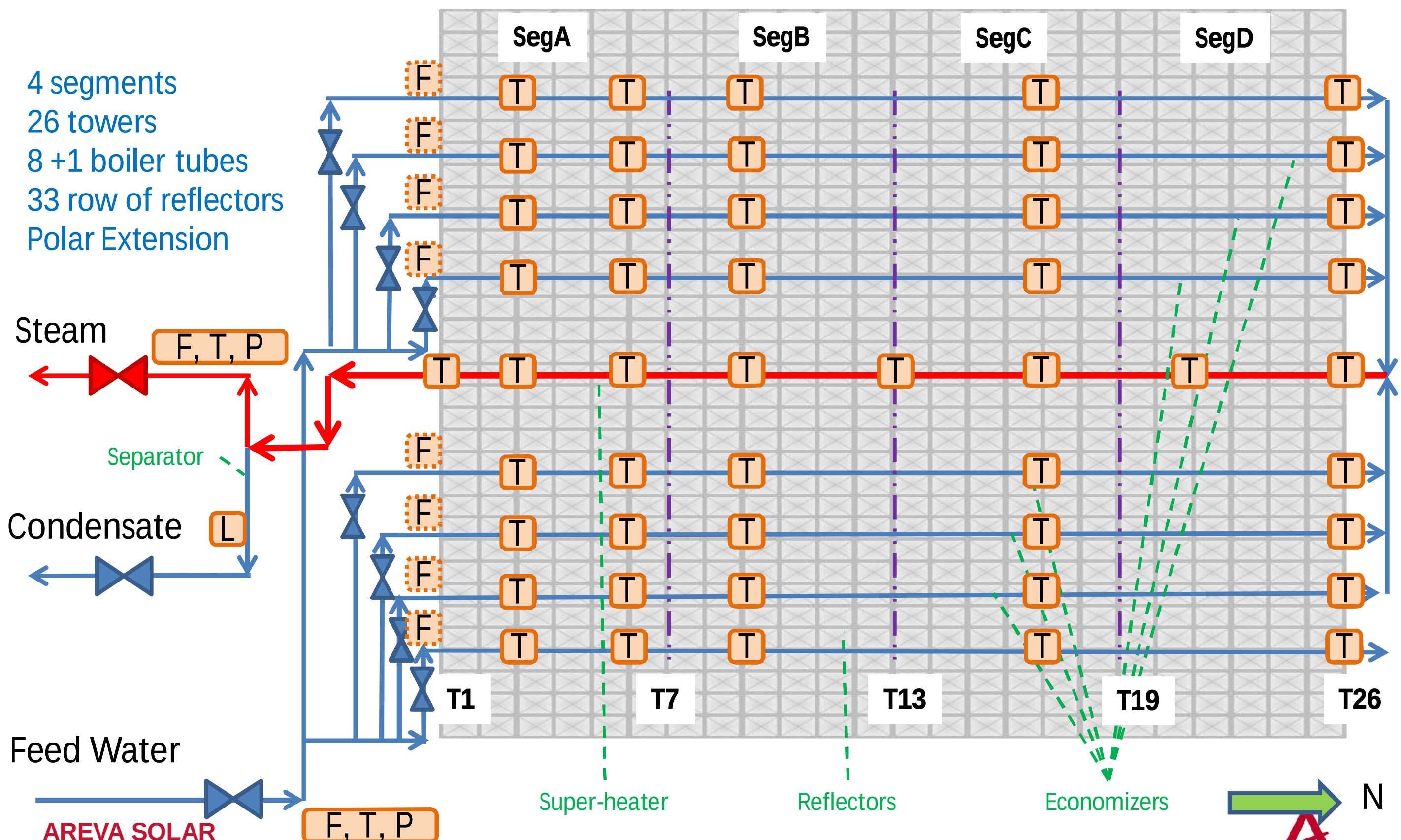
- Solar Field SCADA provides alarm and trip protection notification to operators
- Solar Field SCADA screens provide detailed information for all Solar Field equipment
  - Flow, pressure, temperature, level indications
  - Motors, pumps, and valves
  - Weather station
- Screens allow operators to run systems in manual or automatic control
- Historian included with Solar Field SCADA

# Controls Hardware Architecture

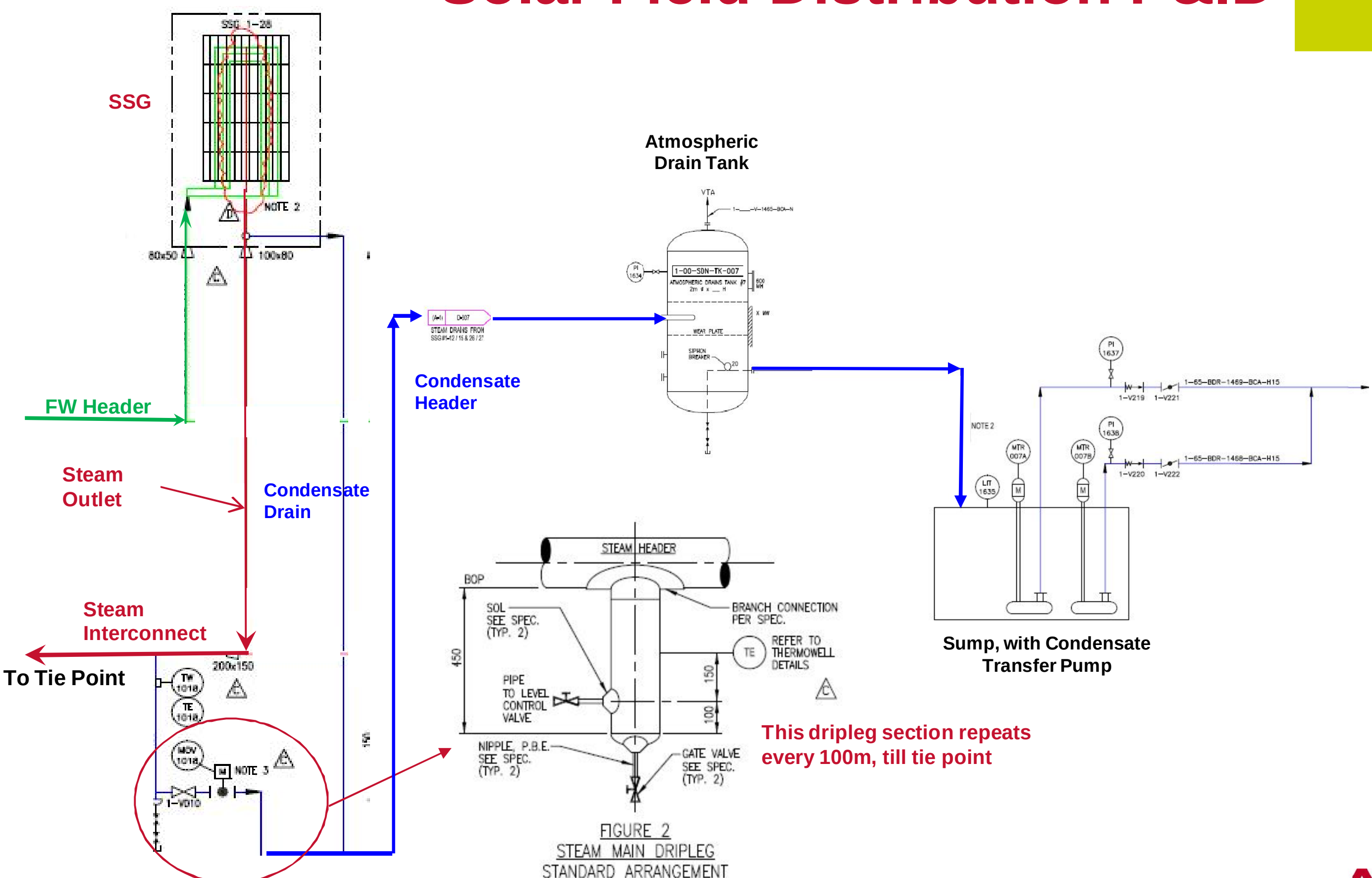


# SSG Simplified P&ID

- 4 segments
- 26 towers
- 8 +1 boiler tubes
- 33 row of reflectors
- Polar Extension



# Solar Field Distribution P&ID

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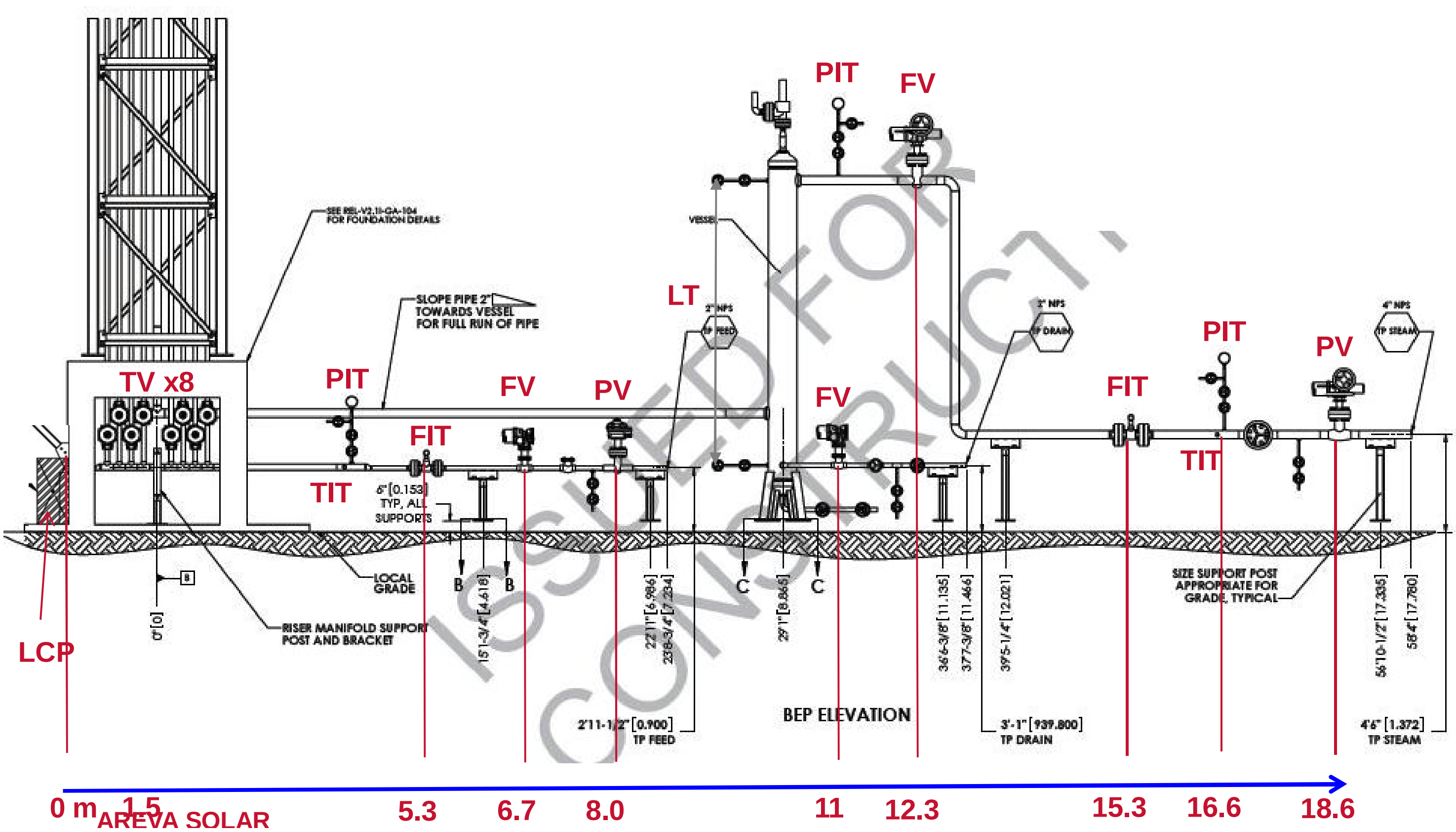
# BEP Valves & Instrumentation

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# CONTROLS SYSTEM AUTOMATION

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# Automation Capabilities

- Goal of automation is to reduce the need for operators to run the SSGs
- Automation is implemented as a supervisory control system that coordinates reflector tracking and steam process management
- Automation includes all phases of daily system operation, from start-up through normal operation and then shutdown

# SSG Start-up

- **Normal automated start-up**
  - **Reflectors roll on in anticipation of sunrise**
  - **SSG exit steam valve manages pressure build and superheat**
  - **Feedwater valves add flow to bring steam conditions to steady state**
  - **BOP coordination**

- **Start-up after extended lay-up**
  - **Same as above, except**
    - Not automated; start-up requires operator attention
    - Nitrogen may need to be vented out the drain system
    - Water inventory in the SSG may need to be added prior to start

# SOLAR FIELD OPERATIONS

# Solar Field Coordination of SSG Controls

- **In normal operation, all available SSGs operate**
  - **When host is at maximum steam capacity, roll off reflectors in SSGs**
  - **Operating more SSGs improves energy capture during start-up and shutdown when host is not at maximum steam capacity**
  - **Operating more SSGs provides faster response and more flexibility to roll reflectors on to compensate for clouds**
- **The Solar Field control system provides setpoint ranges for steam pressure and temperature conditions for each SSG**
- **SSG pressure setpoints are chosen to be above steam header pressure to prevent interactions between SSGs**

# Impact of Clouds at a Power Project

- **Economic optimization of power project favors overbuild of solar field**
  - **Peak solar field steam production is typically ~2x turbine rated capacity**
- **Mid-day operation is typically clipped, especially in summer**
- **Mid-day clouds can be compensated by reducing clipping**
  - **In these circumstances, small clouds do not change turbine load**
- **When available optical power is not enough to fill the turbine, steam header pressure will slide**
- **SSGs will deliver all available power**
  - **Some will have lower flow rates than others depending on the clouds**
- **SSG pressures will drop to maintain flow to the turbine**
  - **Control system will manage pressure reduction to maintain acceptable temperatures**

# SSG Start-up when Field is Already Operating

- **Option 1: Pressurize SSG**
  - **Bypass valve around non-return valve at SSG exit allows steam from the header to pressurize the SSG**
  - **Roll on reflectors during start-up provided receiver temperatures are acceptable**
  - **Begin normal operation once SSG is at operating pressure**
- **Option 2: Vent SSG through drain**
  - **Start-up as normal, except SSG exit pressure and temperature are managed by flowing steam into the drain system or by rolling off reflectors**
  - **SSG steam introduced into common header once correct pressure and temperature conditions achieved**

# Normal, Clipped, and Cloud Interrupted Operation

## Normal Operation

- **Begins when start-up is complete**
- **Controls manages exit steam conditions within an allowable range of pressures and temperatures**
  - Valves at inlet regulate feedwater flow into the SSG
  - Valve at exit regulates steam flow into the steam header

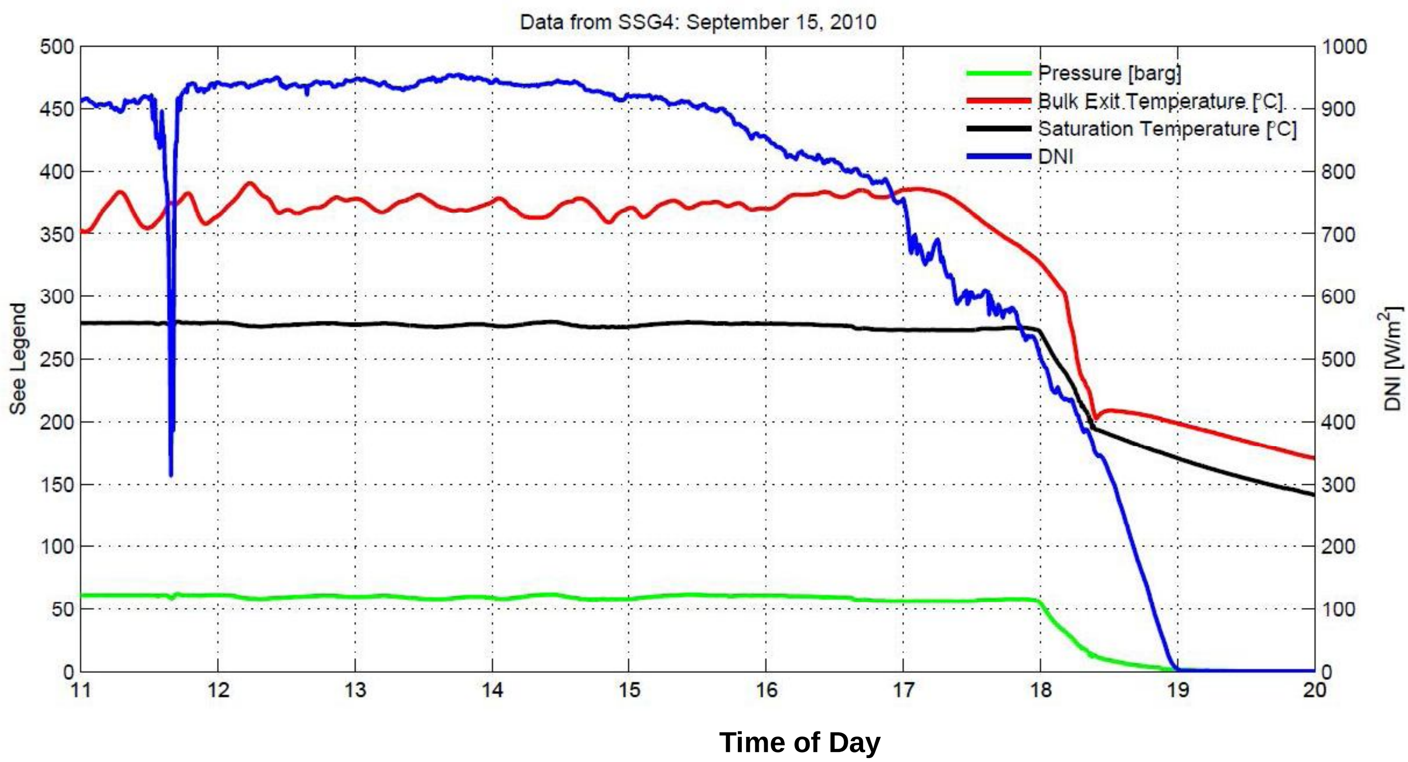
## Clipped Operation

- **Flow out of the SSG can be reduced by rolling off reflectors**
- **Steam conditions maintained by matching optical power to desired flow**

## Cloud Interruption

- **If SSG is clipped, additional reflectors can be rolled on to increase power**
- **If optical power is still not sufficient, flow is reduced**
- **Steam flow can be maintained by allowing SSG pressure to drop**

# SSG Operating Data - Superheat at 370C



# SSG Shutdown

- Flow from SSGs reduces with loss of optical power
- Pressure allowed to drop while maintaining temperature
  - Pressure reduction for boosters limited by host process conditions
- When steam flow drops below minimum level, SSG inlet and exit are isolated
- Reflectors move to stowed position for overnight storage

# Power Block Faults

- **Loss of feedwater pressure**
  - **If feedwater flow drops below the desired flow rate, the SSG will roll off reflectors in proportion with the available feedwater flow rate**
- **Solar steam rejection**
  - **If the host rejects the solar steam, the solar field will trip offline**
    - Option 1: Host can send a trip signal to the solar field
    - Option 2: SSGs see rising exit pressure, trip offline on high pressure
  - **Steam production by the field can be reduced to 0 within 30 seconds**
    - 30 seconds is the time required to adjust each reflector just enough to take optical power off the receiver

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# C&I for Nuclear Power Plants


M Bharath Kumar

Associate Director

NPCIL


# Present NPP Scenario in India

- PHWR Program
  - 19 operating NPPs (capacity  4680 MWe)
  - 4 plants under construction (capacity 2800 MWe)
  - 6 plants (4200 MWe capacity) under launch
- LWR Program
  - 2 plants under construction (capacity 2000 MWe)
  - more to follow

# Present NPP Scenario in India

## I-Stage progress
## PHWR Programme

**Future projects**
**700 MWe & above**

TAPS-3&4
2005-2006

← 220 MWe →

540 MWe

ECONOMY
OF SCALE

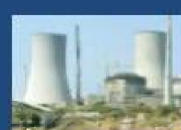
1970s
TECHNOLOGY
DEMONSTRATION

1980s
INDIGENISATION

1980s
STANDARDISATION

1990s
CONSOLIDATION

2000s
COMMERCIALISATION

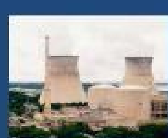


RAPP-3&4

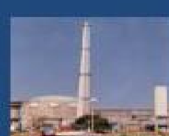
KAIGA-3&4

RAPS-1&2

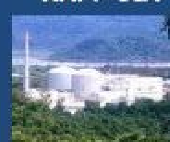
MAPS-1&2



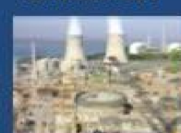
NAPS-1&2



KAPS-1&2

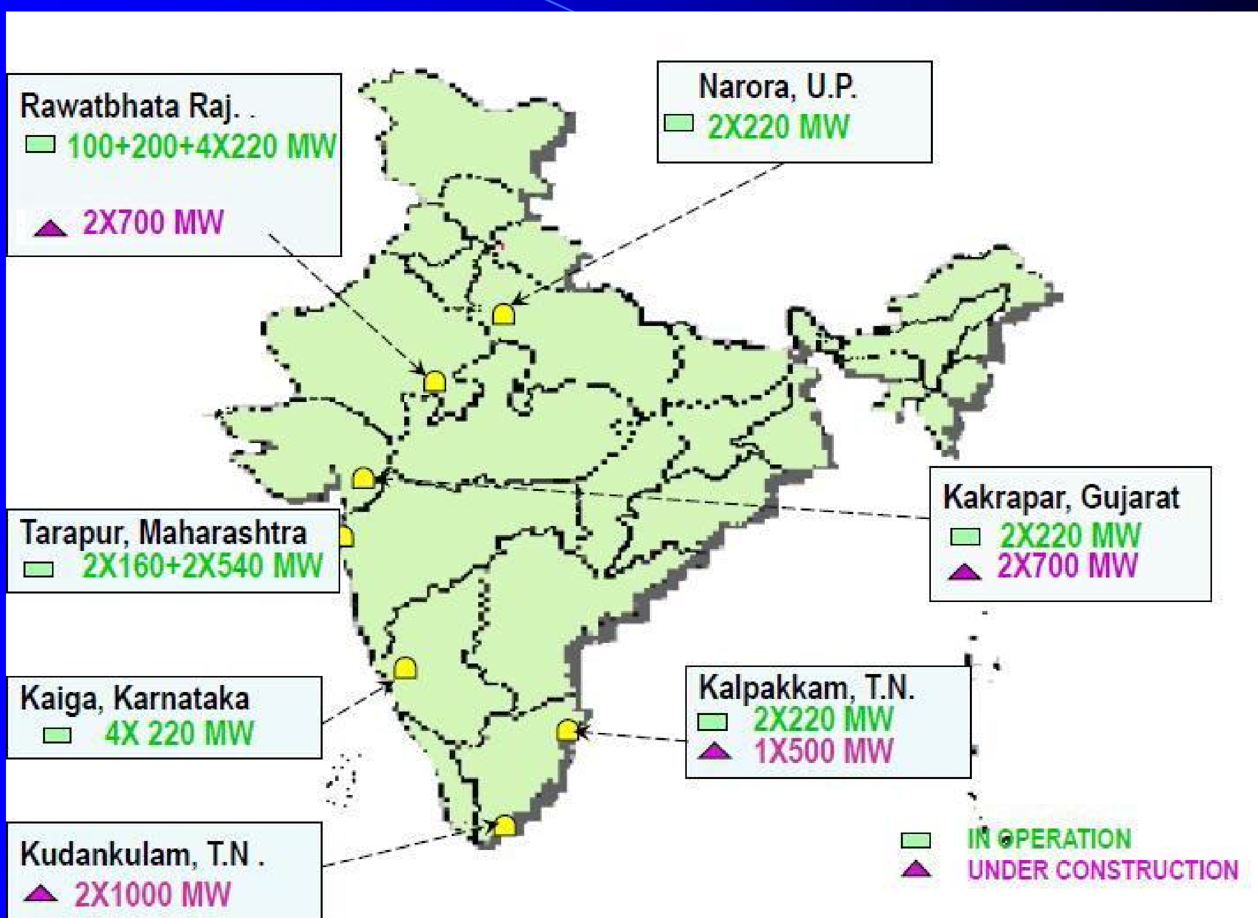


KGS-1&2



RAPP-5&6

# Present NPP Scenario in India



# Codes and Guides

- Safety Codes and Guides --- protection of site personnel, public and the environment from undue radiological hazards.
- These structures, systems, and components shall assure that activities or circumstances that the prescribed limit must not be exceeded.

## Structure Systems & Components

- The integrity of the pressure boundary
- shutdown the reactor and maintain it in a safe shutdown state
- Prevent the accident or to mitigate the consequences of accidents
- Remove residual heat

# C&I Activities

- Design and Engineering
- Development of Systems
- Production of Systems
- Installation & Commissioning
- Operation & Maintenance

# C&I Systems – Functions

- Monitoring
- HMI
- Protection
- Control
  - Shutdown
  - Operations

# C&I Systems – Requirements

- High reliability
- Redundancy
- CCF
- Fault Tolerant…..(FMEA)
- On-line Testability
- Structural Integrity
- Environmental qualification
- Ageing

# C&I Systems – Challenges

- Limited life
  - Obsolescence
  - Changing Technology
  - Refurbishment
  - User interface

# C&I Systems –Issues

- Steady introduction of solid state components with higher levels of integration
- Components – HMC, SMD
- PCBs- Multilayer
- Introduction of computers / microcontrollers/ PLDs / CPLDs/ FPGAs.
- Qualification of Digital C&I
- Cyber security

# Computer Based Systems in Indian NPPs

- Use in safety related applications increased steadily
- Awareness of V&V issues
- Engineering Procedures defined
- Support issues
- Nuclear industry is a conservative industry

# C&I -- Impact of evolution

- Infrastructural & new competency demands lead to outsourcing
- Requirement of providing long term support to electronics systems lead to development being steadily ‘in-sourced’

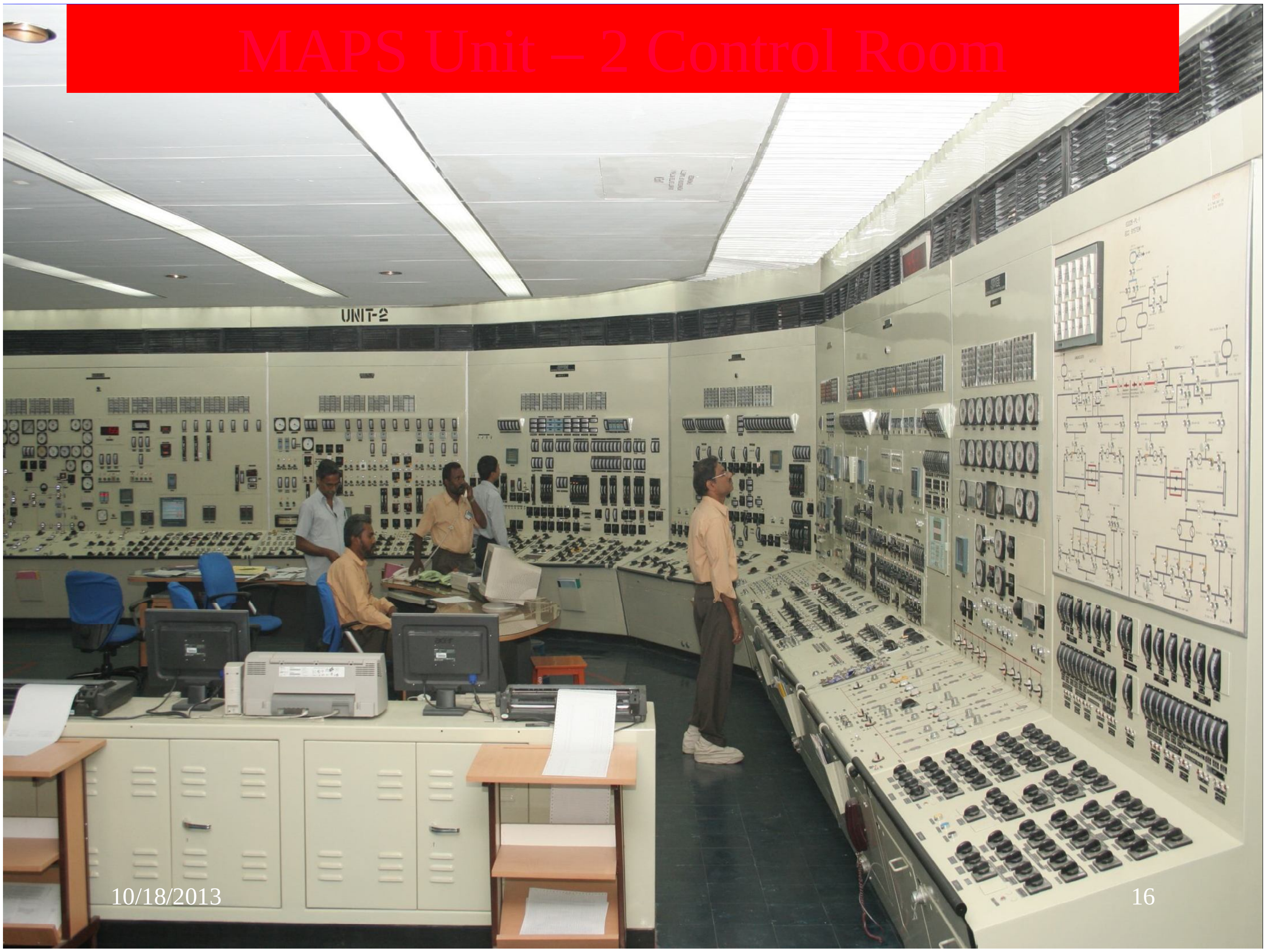
# C&I – in Severe Accident

- Instrumentation  for Monitoring:-
    - The start of severe accident
    - Various stages of core states
    - Arrest the accident progression
    - Hydrogen management

# C&I – in Severe Accident

- Instruments Required :-
    - Pressure Transmitters
    - Temperature detectors
    - Radiation Monitors
    - Hydrogen Detectors
    - Battery operated loop powered indicators

# MAPS Unit – 2 Control Room



SCHEME-2 (3-D VIEW)

THANK YOU

# PV Technologies & Solutions

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