



CANDU Safety

#24 - CANDU 9 Design Overview

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CANDU 9

- λ CANDU 9 - a single unit design with output >935 MWe**
- λ optimized for multi-unit construction**
- λ based on Bruce B and Darlington, integrated 4 unit plants operating in Canada**
- λ single unit features adapted from CANDU 6**
- λ CANDU 9 design improvements based on utility and industry feedback and licensing experience**

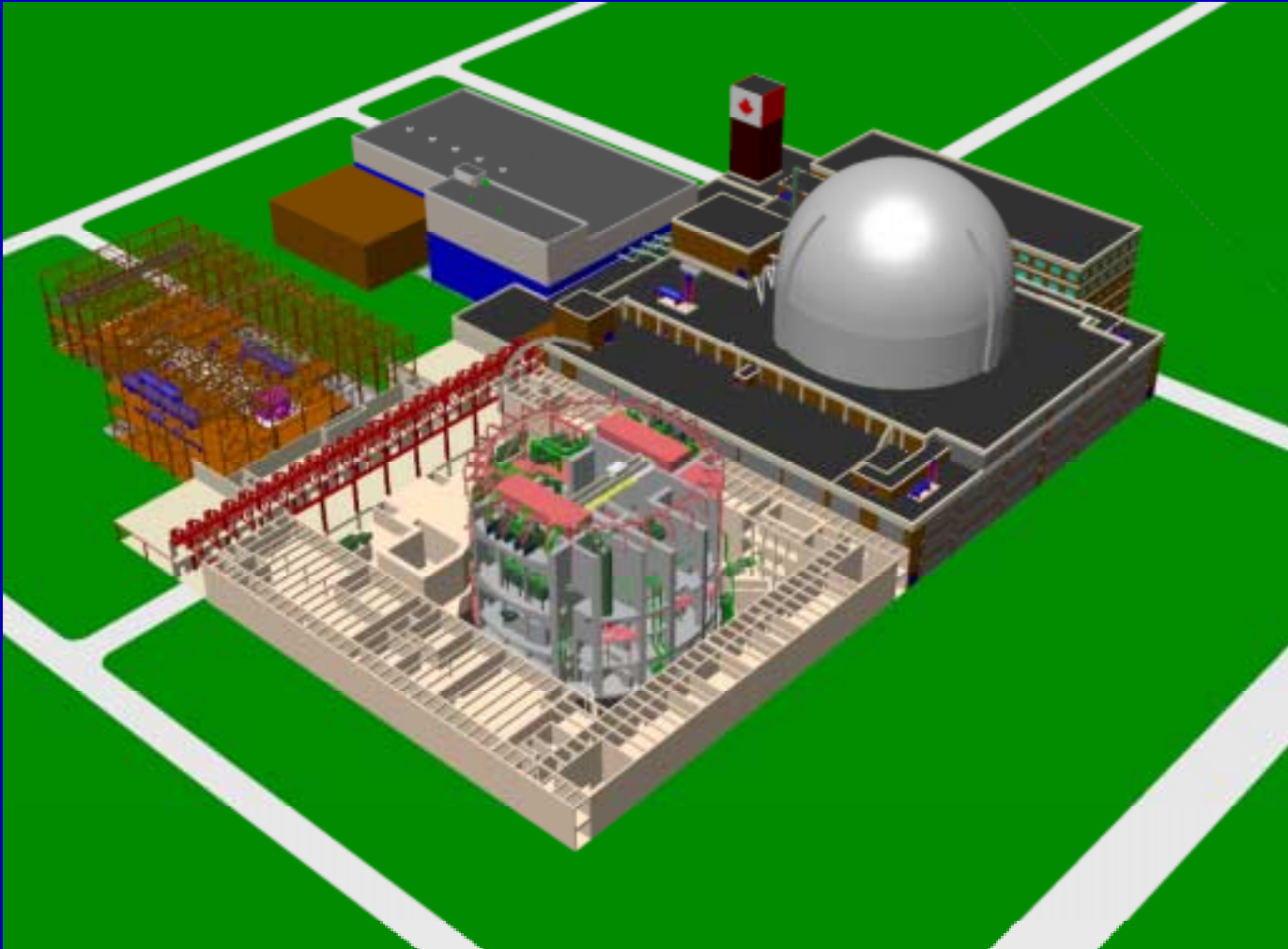


Comparison with operating plants

| | <u>CANDU 6</u> | <u>Bruce B</u> | <u>Darlington</u> | <u>CANDU 9</u> |
|------------------------------|---------------------|---------------------|---------------------|---------------------|
| # of Fuel channels | 380 | 480 | 480 | 480 |
| Fuel Bundle | 37 elements | 37 elements | 37 elements | 37 elements |
| Reactor Coolant Pressure | 9.9 MPa(g) | 9.9 MPa(g) | 9.9 MPa(g) | 9.9 MPa(g) |
| Coolant Outlet Quality | 4% | 0.7% | 2% | 2% |
| Maximum Channel Flow | 24 kg/s | 24 kg/s | 25.2 kg/s | 25.2 kg/s |
| Number of reactor headers | 8 | 6 | 8 | 6 |
| Number of Coolant Pumps | 4 | 4 | 4 | 4 |
| Number of Steam Generators | 4 | 8 | 4 | 4 |
| Steam Generator Surface Area | 3200 m ² | 2400 m ² | 4900 m ² | 4900 m ² |
| Power Output | 715 MWe | 915 MWe | 936 MWe | 945 MWe |



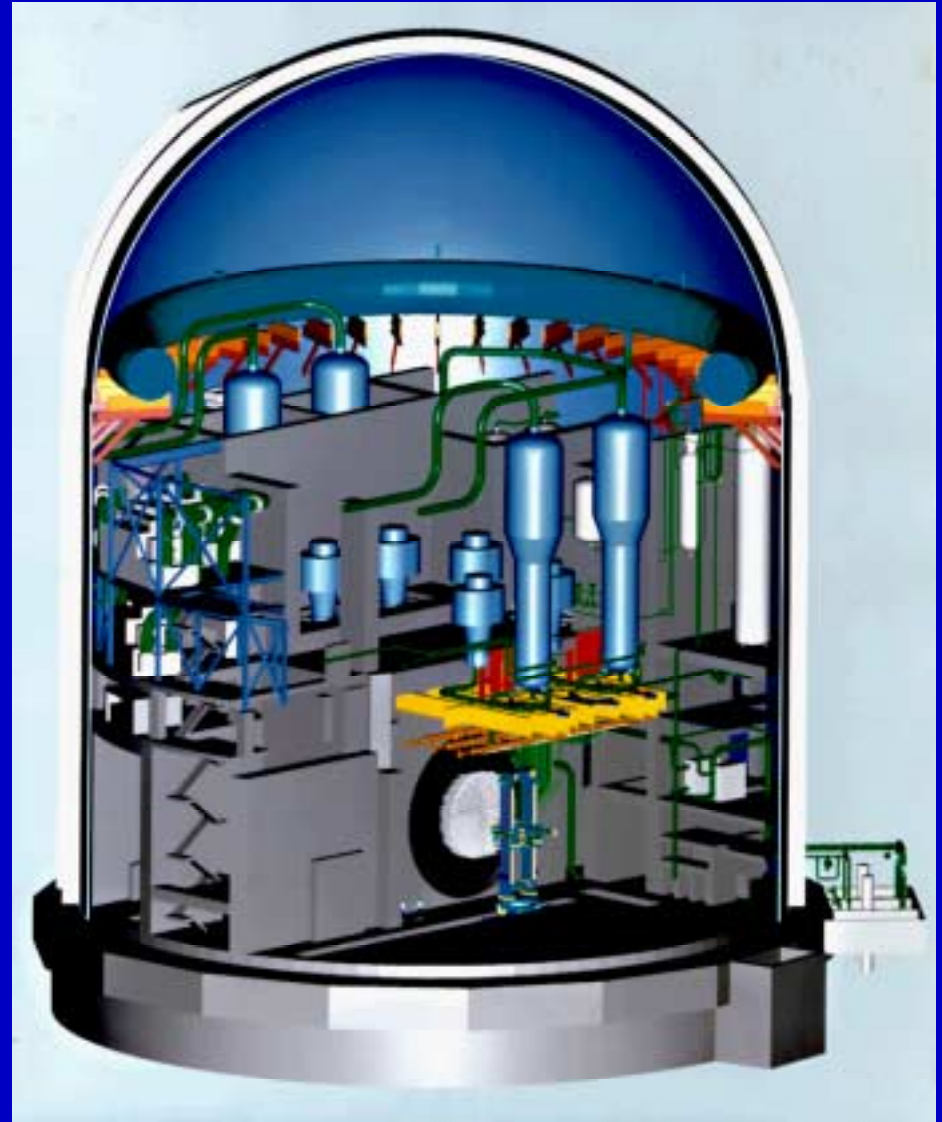
Two Unit Layout





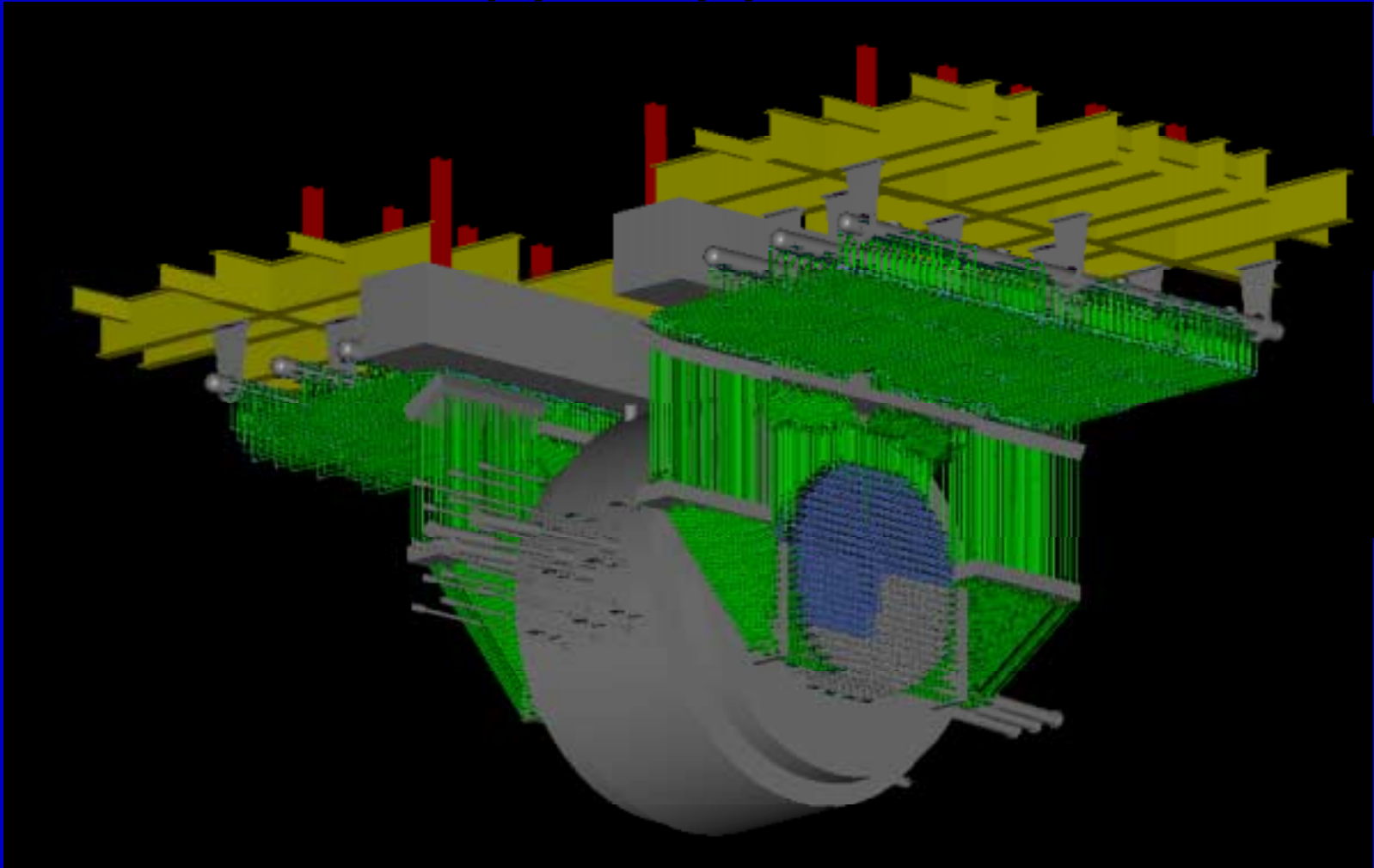
Reactor Building

- λ conventional dry containment
- λ prestressed concrete
- λ steel-lined
- λ no basement
- λ elevated Reserve Water Tank for accidents instead of dousing tank





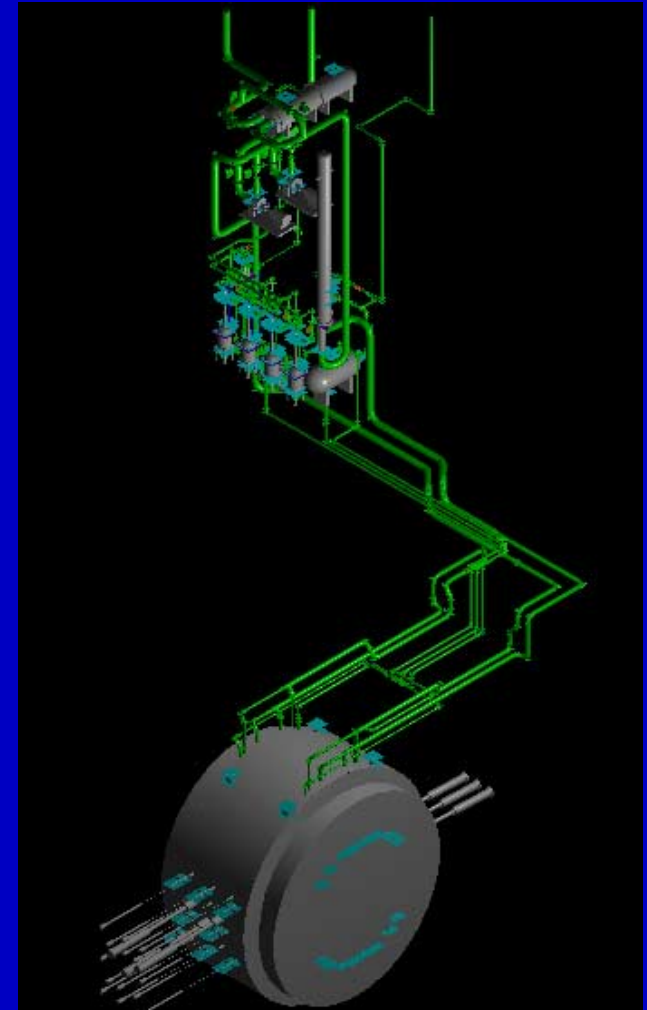
Feeder, header and pipe whip platform





Shield Cooling & End Shield Cooling System

- λ elevated piping so that a leak in a pipe does not drain the shield tank
- λ connection to Reserve Water Tank for severe accidents





Control Centre





Control Centre Layout

λ Main Control Room

- work control area & computer hardware room**
- Technical Support Centre & Emergency Operating Centre**
- seismically qualified - no need for operator to go to Secondary Control Area following an earthquake**

λ Secondary Control Area

- used only in case of inhabitability or hostile takeover of Main Control Room**
- all Group 2 control functions are available in the SCA (shutdown, cool, monitor)**
- seismically qualified**



CANDU 9 Control Centre Mockup





Operability Improvements

- λ separation of plant control and display/annunciation
- λ central overview display
- λ improved displays to suit operational tasks
- λ improved display navigation
- λ advanced computerized annunciation system
- λ common plant-wide parameter database
- λ computerized safety system testing



Evolution of Plant Control and Monitoring

Digital Control Computers

- Display
- Annunciation
- Control Programs



Plant Display System

- Display
- Annunciation



Relay Logic and Analog Controllers

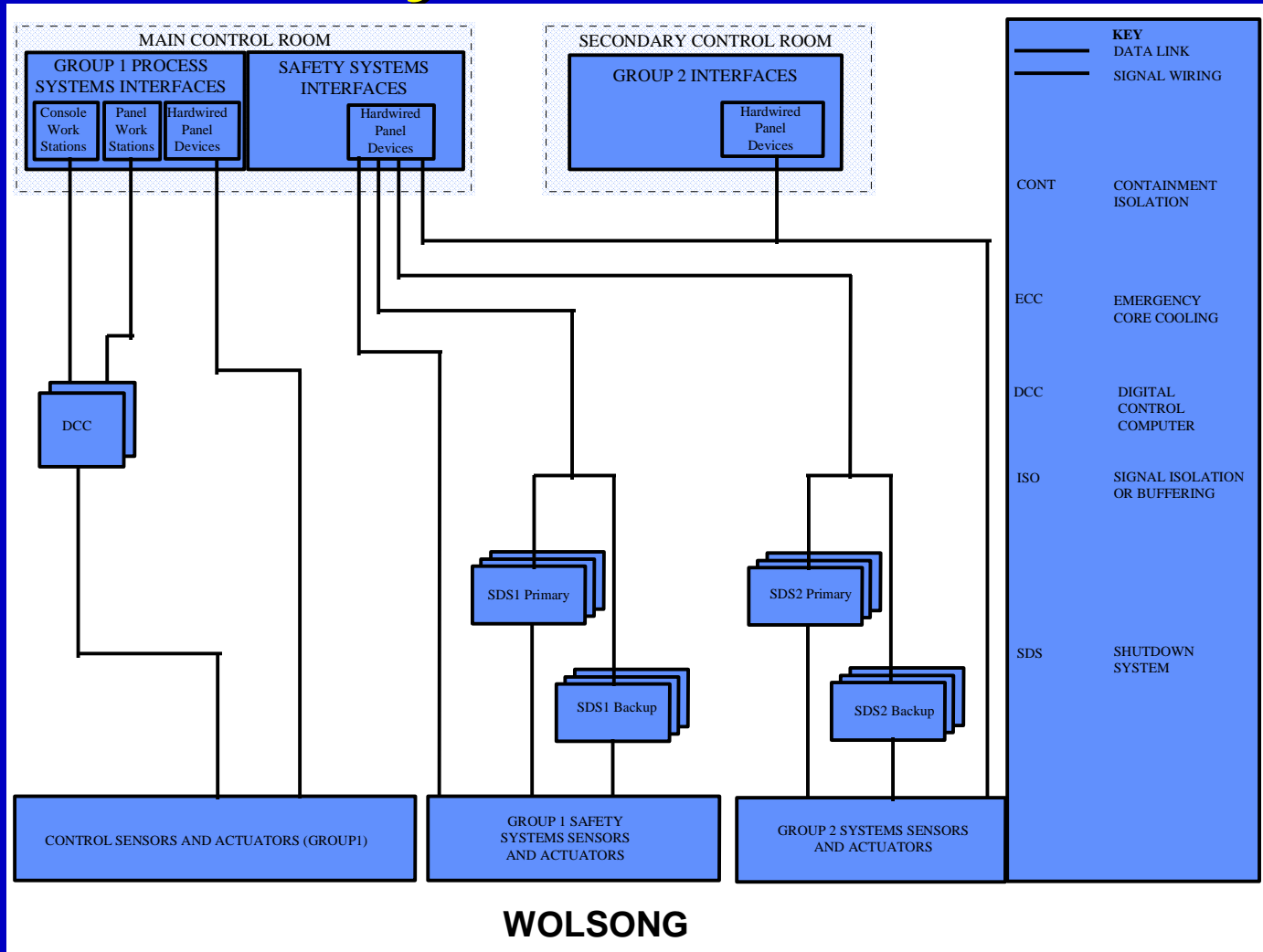


Distributed Control System

- Control Programs
- Relay logic
- Most analog control functions

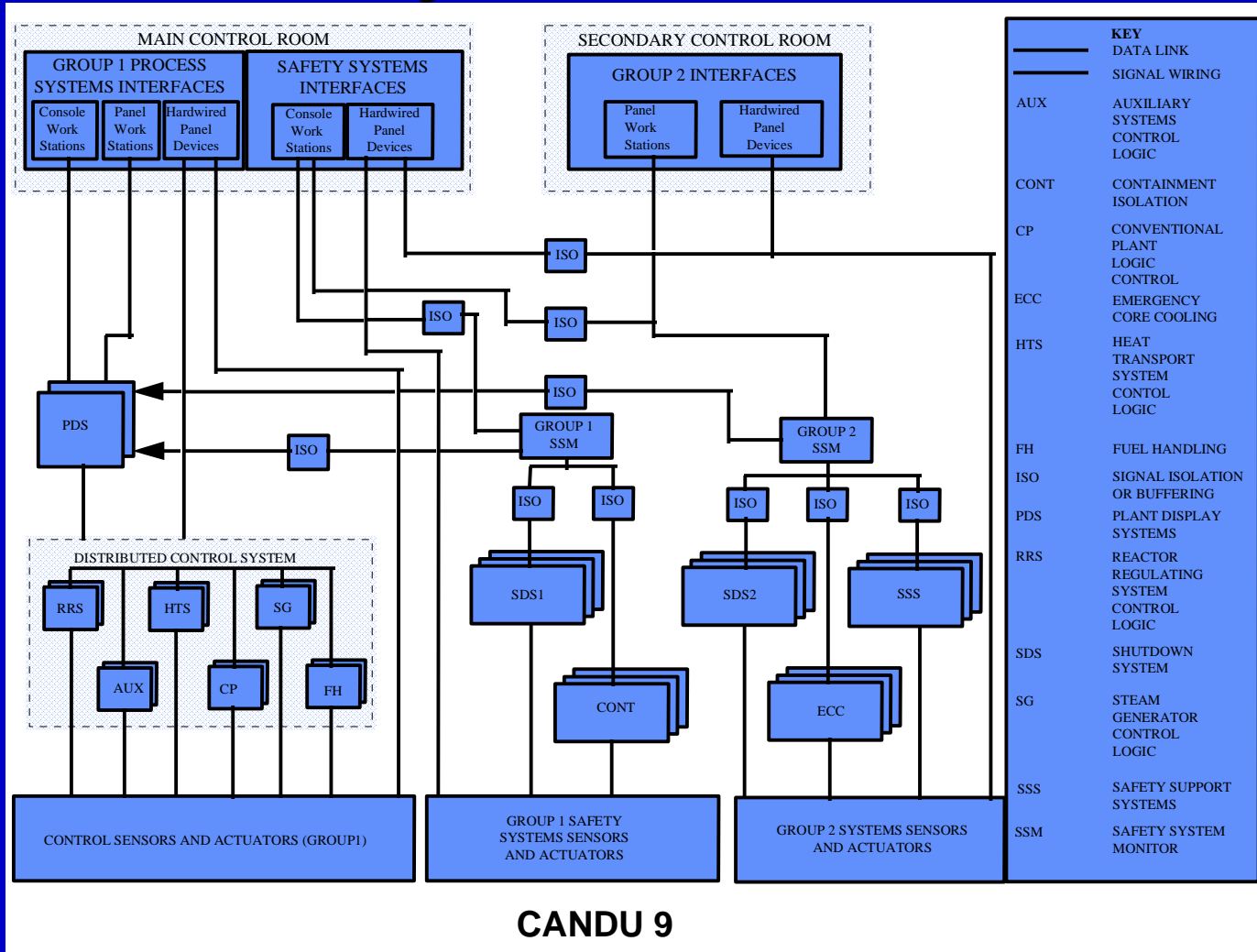


CANDU 6 C&I Systems Overview





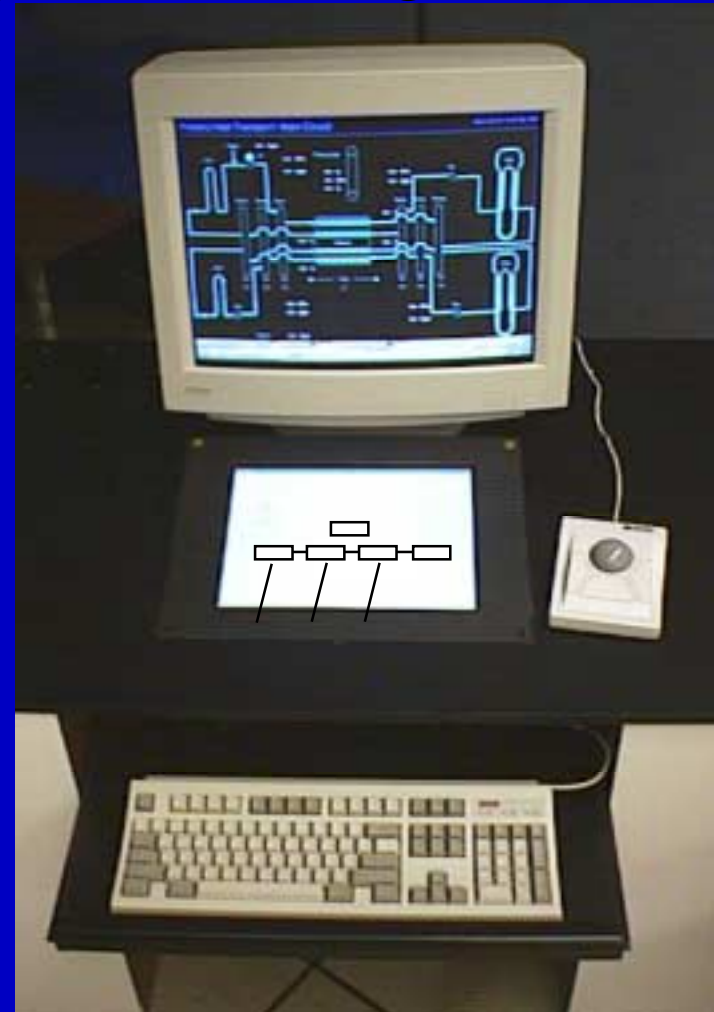
CANDU 9 C&I Systems Overview





Plant Display System - Improved Navigation

- λ two redundant forms of navigation are provided at all times
 - navigation icons within process monitoring and control displays, and
 - direct display selection via 'soft function' keypads





Plant Display System - Improved Navigation

HEAT TRANSFER SYSTEMS

SINKS

SGs Level

SG 1 TBD m
SG 2 TBD m
SG 3 TBD m
SG 4 TBD m

HT SYSTEM

HT Pressure TBD kPa

REACTOR

R Power TBD MW

VALVE LCV203

Issues

- 97-02-15 11:58:00 - Alarm / Health / Maintenance Issue #1
- 97-02-15 11:58:00 - Alarm / Health / Maintenance Issue #2
- 97-02-15 11:57:30 - User entry (created from New Entry button)
- 97-02-15 11:57:00 - Alarm / Health / Maintenance Issue #3
- 97-02-15 11:56:30 - Alarm / Health / Maintenance Issue #4
- 97-02-15 11:56:00 - Alarm / Health / Maintenance Issue #5
- 97-02-15 11:55:00 - Alarm / Health / Maintenance Issue #6
- 97-02-15 11:49:00 - 1104674.9032746576392174567959324562490321456790

Supporting Functions

- System Voltage 13.8 kV
- Gld Seal Valves AUTO/OPEN
- Gld Seal Flow BLOCKED
- Gld Seal Supply 54 °C
- Gld Seal Return 150 °C

Links to other displays

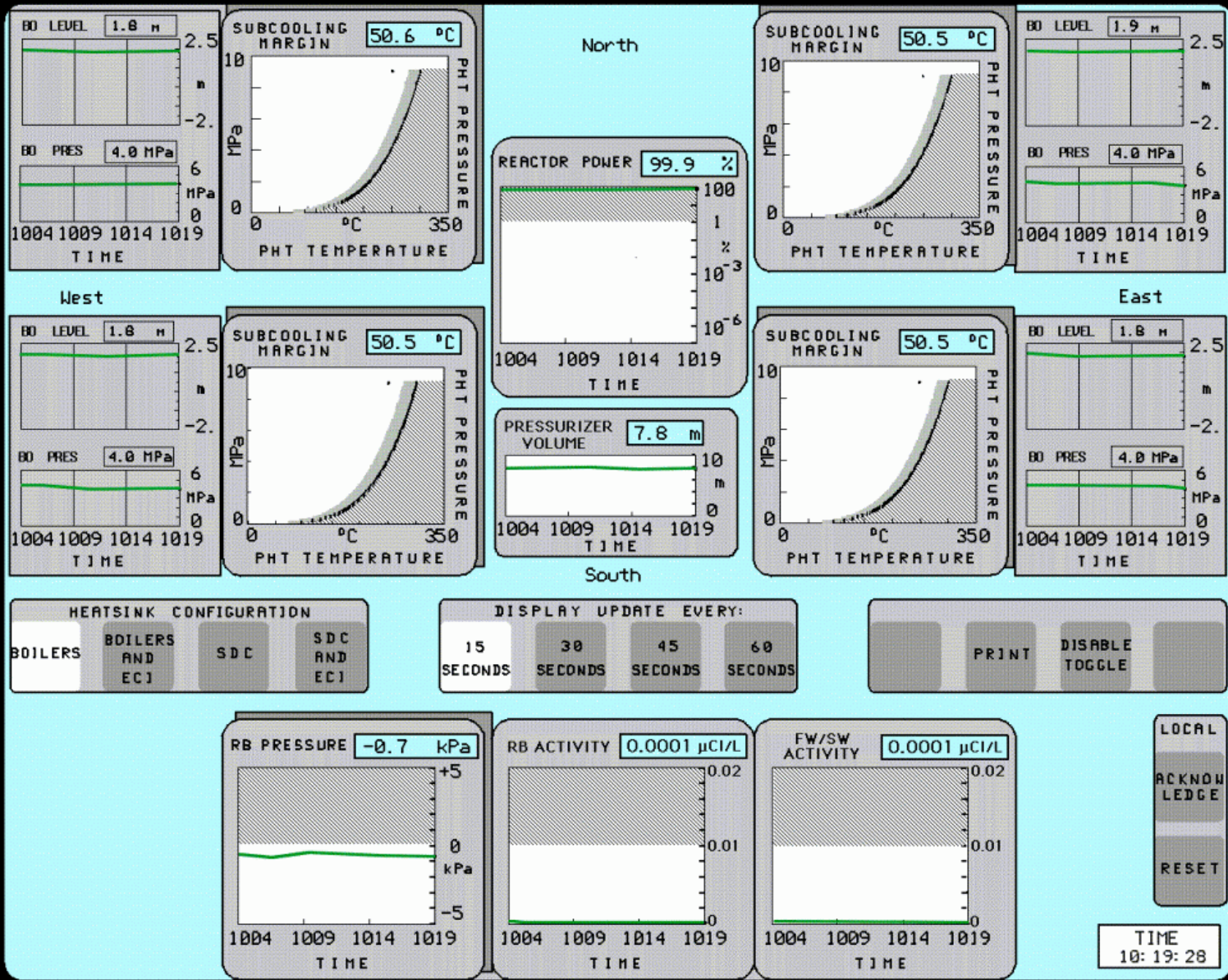
Links to control dialogs

Display System Status Plant Mode 2/14/97 1:30 PM



Critical Safety Parameter Monitor System

- λ system supports overall operational strategy to managing plant upsets and emergencies
- λ CSP display provides
 - functional representation of safety state of the plant
 - high level physical map to key CSP-related systems
- λ CSP monitoring is part of the Safety System Monitor Computer Display





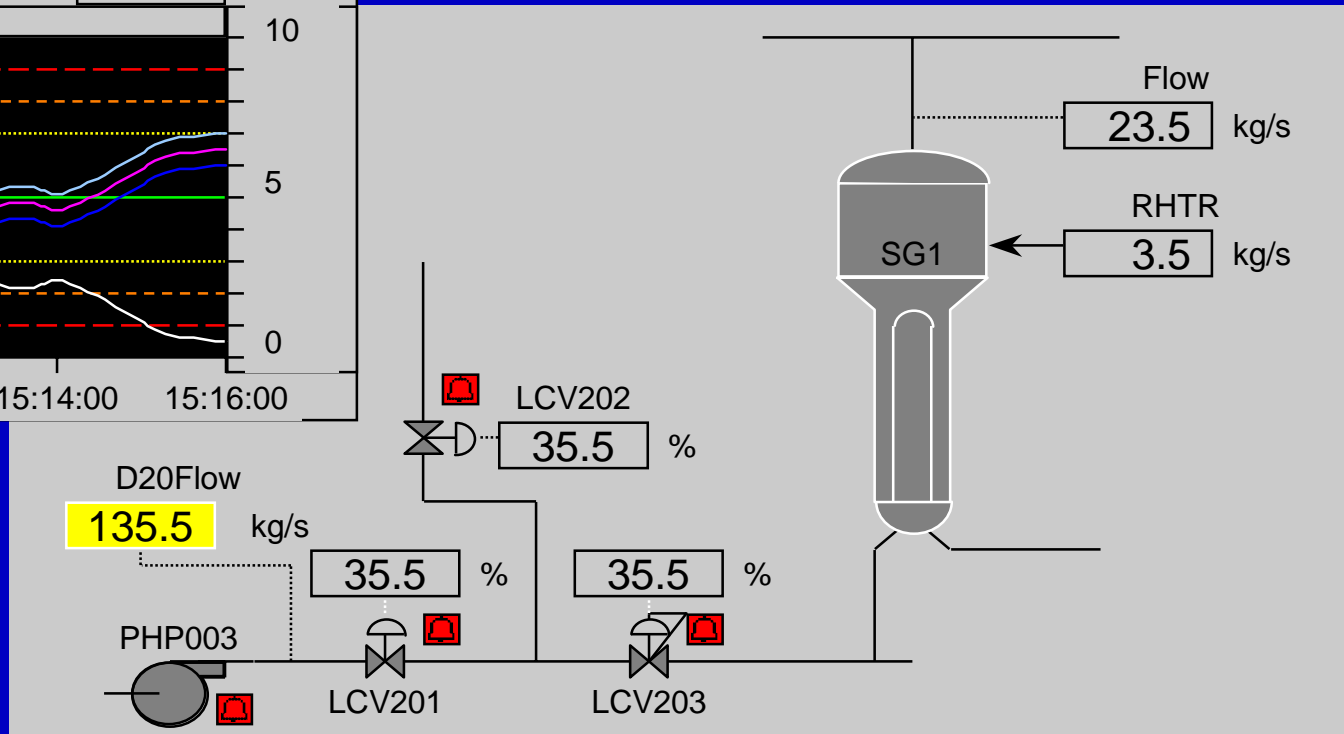
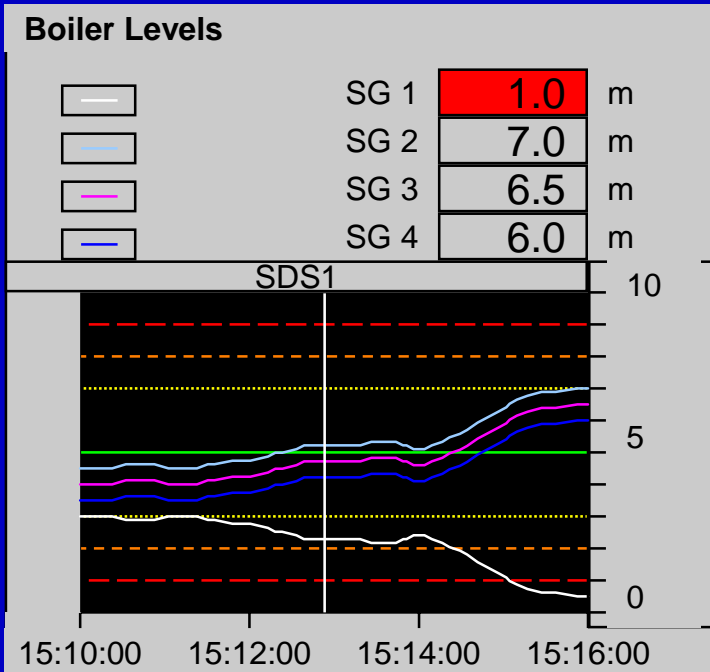
Enhanced Process Monitoring/Control Displays

Faults

- Boiler 1 Lvl Low
- HT Pressure High
- N Condenser 1 Low
- RCW Temp High
- Demin Flow Low

Status

- CSDVs Closed
- Power & Generating
- LZC P2 Running
- N HT Purif Isolated
- Alternate Mode





Advanced Computerized Annunciation System

- λ alarm processing
 - prioritization and conditioning based on plant state
 - alarm coalescing, cause-consequence
 - new types of alarms (expected-but-not-occurred, OP&P violations, rate and margin - advanced warning)
- λ alarm presentation: central displays
 - fault messages ordered and colour coded by priority
 - status messages ordered by time



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Pwr & Blr Turbine & Generating                    5 OF 5 FAULTS
ECIS CHAN K - HT PRESS 7.0 MPA - PUMPS START
GPC ECIS CHAN M-D18,D7 - INJ IMP HT FL 0
GPC ECIS CHAN K-X9 - INJ IMP HT FL 0
GPC ECIS CHAN L-E2,E3 - INJ IMP HT FL 0
TURBINE TRIP - TRIP CHAN 1 ACTS
N GPC ECIS CHAN E-V6 - INJ IMP HT FL 0
N GPC ECIS CHAN M-D7 - INJ IMP HT FL 0

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<- Fault Display

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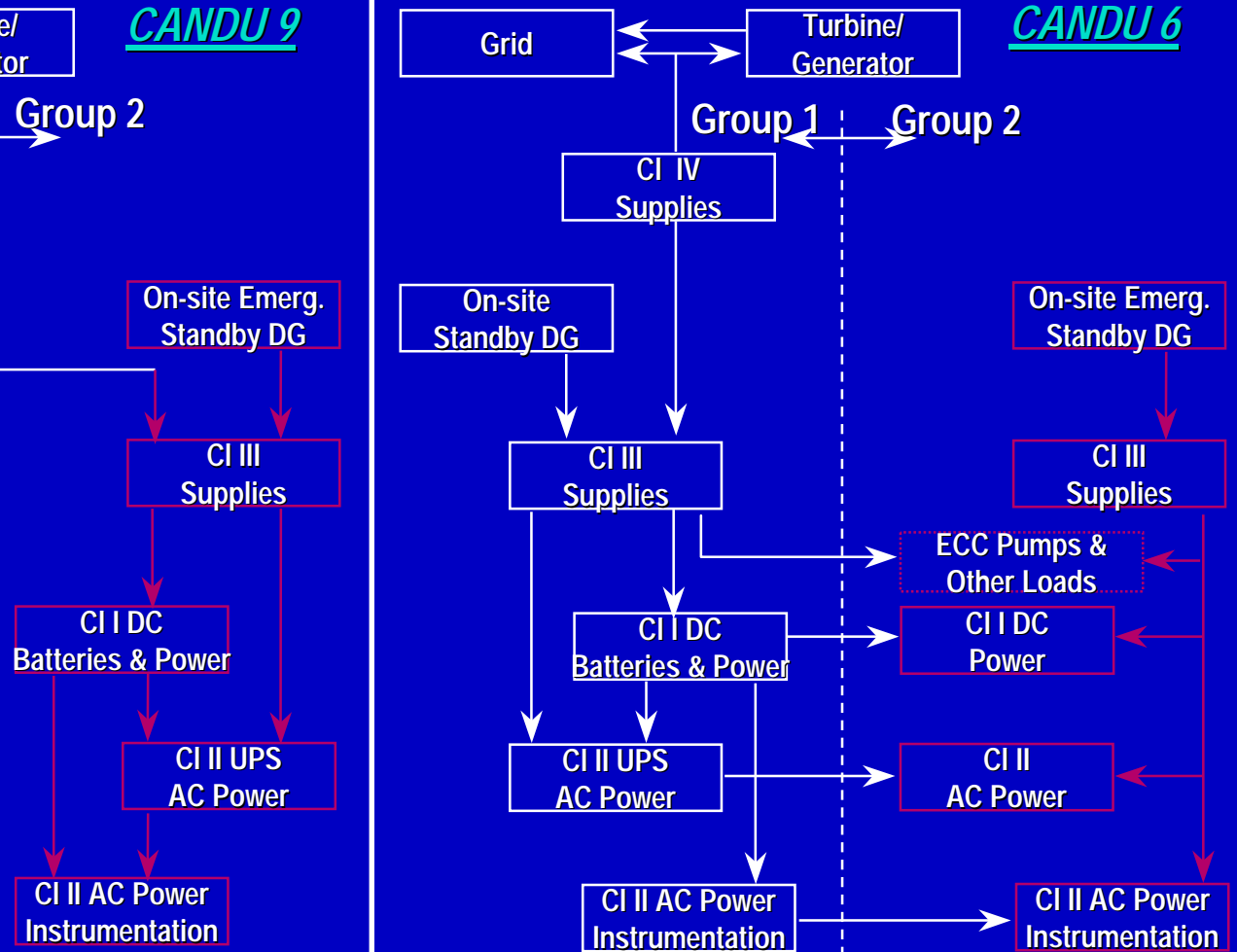
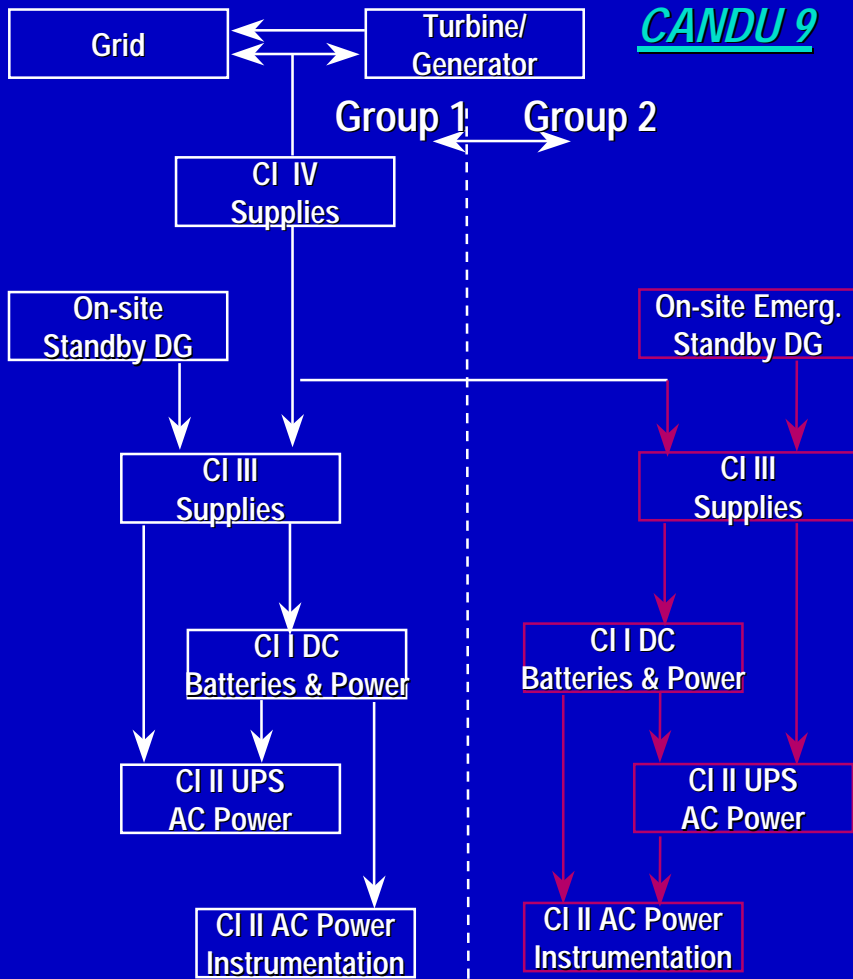
Mode: Pwr & Blr Turbine & Generating
N RRS RCTR SETBACK HI STM GEN PRESS
TT4 LIVE STEAM LIMITER OPERATING
N TT4 LIVE STEAM LIMITER OPERATING
ZeroPwr & ASDVs & TG
RRS RCTR SETBACK HI FLUX TILT
RRS RCTR SETBACK HI LOCAL CHNL PWR
RRS RCTR SETBACK HI ZN PWR
RRS RCTR SETBACK HI STM GEN PRESS
N RRS RCTR SETBACK HI FLUX TILT
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ECIS CHAN M - HT PRESS 7.0 MPA - PUMPS START
ECIS CHAN K - HT PRESS 7.0 MPA - PUMPS START
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RRS RCTR SETBACK HI FLUX TILT
RRS RCTR SETBACK HI LOCAL CHNL PWR
RRS RCTR SETBACK HI ZN PWR

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Status Display ->



CANDU 9/CANDU 6 Electrical Overview Diagrams





Summary

- λ evolutionary improvement approach ensures updated designs without economic risk of new concepts
- λ operating experience reports and database systems are used to determine improvements to CANDU products
- λ major improvements in control centre, and instrumentation and control systems
- λ major improvements in safety (next lecture)