CANDU 9

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

<table>
<thead>
<tr>
<th></th>
<th>CANDU 6</th>
<th>Bruce B</th>
<th>Darlington</th>
<th>CANDU 9</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Fuel channels</td>
<td>380</td>
<td>480</td>
<td>480</td>
<td>480</td>
</tr>
<tr>
<td>Fuel Bundle</td>
<td>37 elements</td>
<td>37 elements</td>
<td>37 elements</td>
<td>37 elements</td>
</tr>
<tr>
<td>Reactor Coolant Pressure</td>
<td>9.9 MPa(g)</td>
<td>9.9 MPa(g)</td>
<td>9.9 MPa(g)</td>
<td>9.9 MPa(g)</td>
</tr>
<tr>
<td>Coolant Outlet Quality</td>
<td>4%</td>
<td>0.7%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Maximum Channel Flow</td>
<td>24 kg/s</td>
<td>24 kg/s</td>
<td>25.2 kg/s</td>
<td>25.2 kg/s</td>
</tr>
<tr>
<td>Number of reactor headers</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Number of Coolant Pumps</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of Steam Generators</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Steam Generator Surface Area</td>
<td>3200 m²</td>
<td>2400 m²</td>
<td>4900 m²</td>
<td>4900 m²</td>
</tr>
<tr>
<td>Power Output</td>
<td>715 MWe</td>
<td>915 MWe</td>
<td>936 MWe</td>
<td>945 MWe</td>
</tr>
</tbody>
</table>
Two Unit Layout
Reactor Building

- conventional dry containment
- prestressed concrete
- steel-lined
- no basement
- elevated Reserve Water Tank for accidents instead of dousing tank
Feeder, header and pipe whip platform
Shield Cooling & End Shield Cooling System

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

- 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

- 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

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

- Display
- Annunciation
- Control Programs

Digital Control Computers

Plant Display System
- Display
- Annunciation

Relay Logic and Analog Controllers

Distributed Control System
- Control Programs
- Relay logic
- Most analog control functions
CANDU 9 C&I Systems Overview

MAIN CONTROL ROOM

GROUP 1 PROCESS SYSTEMS INTERFACES
- Console Work Stations
- Panel Work Stations
- Hardwired Panel Devices

SAFETY SYSTEMS INTERFACES
- Panel Work Stations
- Hardwired Panel Devices

SECONDARY CONTROL ROOM

GROUP 2 INTERFACES
- Panel Work Stations
- Hardwired Panel Devices

DISTRIBUTED CONTROL SYSTEM
- RRS
- HTS
- SG
- AUX
- CP
- FH

CONTROL SENSORS AND ACTUATORS (GROUP1)
- GROUP 1 SAFETY SYSTEMS SENSORS AND ACTUATORS
- GROUP 2 SYSTEMS SENSORS AND ACTUATORS

CANDU 9
Plant Display System - Improved Navigation

- 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

- Links to other displays
- Links to control dialogs
Critical Safety Parameter Monitor System

- System supports overall operational strategy to managing plant upsets and emergencies
- CSP display provides
  - Functional representation of safety state of the plant
  - High level physical map to key CSP-related systems
- 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

Boiler Levels

<table>
<thead>
<tr>
<th>SG</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>7.0</td>
</tr>
<tr>
<td>3</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Flow
- D20Flow: 135.5 kg/s
- LCV202: 35.5 kg/s
- RHTR: 3.5 kg/s
- SG 1: 23.5 kg/s

Boiler Levels

<table>
<thead>
<tr>
<th>SG</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7.0</td>
</tr>
<tr>
<td>3</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>6.0</td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

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

- 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)

- alarm presentation: central displays
  - fault messages ordered and colour coded by priority
  - status messages ordered by time
### Fault Display

| 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-F2,A23 - INJ IMP HT FL 0 |
| TURBINE TRIP - TRIP CHAN 1 ACTS |
| GPC ECIS CHAN M-U6 - INJ IMP HT FL 0 |
| GPC ECIS CHAN M-D7 - INJ IMP HT FL 0 |

### Status Display

<table>
<thead>
<tr>
<th>Mode</th>
<th>Pwr &amp; Blr Turbine &amp; Generating</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>RRS RCTR SETBACK HI STM GEN PRESS</td>
</tr>
<tr>
<td>TT4</td>
<td>LIVE STEAM LIMITER OPERATING</td>
</tr>
<tr>
<td>N</td>
<td>TT4 LIVE STEAM LIMITER OPERATING</td>
</tr>
<tr>
<td>N</td>
<td>ZeroPwr &amp; ASDVs &amp; TG</td>
</tr>
<tr>
<td>RRS</td>
<td>RCTR SETBACK HI FLUX TILT</td>
</tr>
<tr>
<td>RRS</td>
<td>RCTR SETBACK HI LOCAL CHNL PWR</td>
</tr>
<tr>
<td>RRS</td>
<td>RCTR SETBACK HI ZN PWR</td>
</tr>
<tr>
<td>RRS</td>
<td>RCTR SETBACK HI STM GEN PRESS</td>
</tr>
<tr>
<td>N</td>
<td>RRS RCTR SETBACK HI FLUX TILT</td>
</tr>
<tr>
<td>N</td>
<td>RRS RCTR SETBACK HI LOCAL CHNL PWR</td>
</tr>
<tr>
<td>N</td>
<td>RRS RCTR SETBACK HI ZN PWR</td>
</tr>
<tr>
<td>N</td>
<td>RRS RCTR SETBACK HI STM GEN PRESS</td>
</tr>
<tr>
<td>TT4</td>
<td>LIVE STEAM LIMITER OPERATING</td>
</tr>
<tr>
<td>TT4</td>
<td>LIVE STEAM LIMITER OPERATING</td>
</tr>
</tbody>
</table>
CANDU 9/CANDU 6 Electrical Overview Diagrams

CANDU 9

- Grid
- Turbine/Generator
- CANDU 9
- Group 1
- Group 2

CANDU 6

- Grid
- Turbine/Generator
- CANDU 6
- Group 1
- Group 2

On-site Standby DG

- CI IV Supplies
- On-site Emerg. Standby DG
- CI III Supplies
- CI I DC Batteries & Power
- CI II UPS AC Power
- CI II AC Power Instrumentation

ECC Pumps & Other Loads

- CI IV Supplies
- On-site Emerg. Standby DG
- CI III Supplies
- CI I DC Batteries & Power
- CI II UPS AC Power
- CI II AC Power Instrumentation

CI I DC Power

- CI II UPS AC Power
- CI II AC Power Instrumentation

CI II AC Power Instrumentation
Summary

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