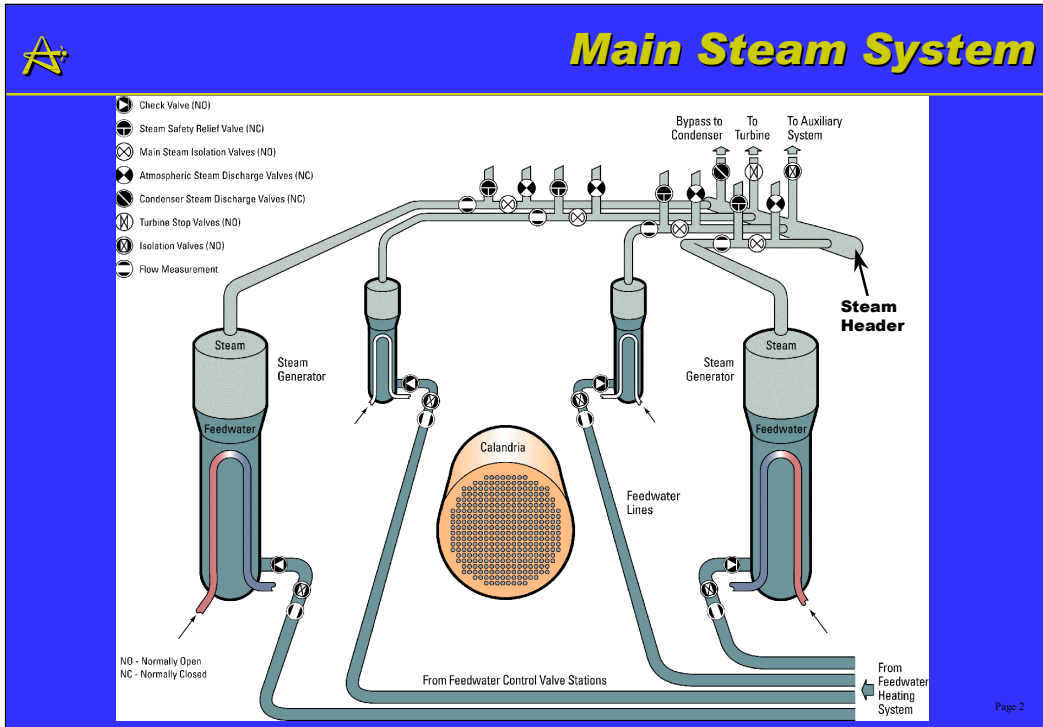




## Main Steam & TIG Systems, Safety



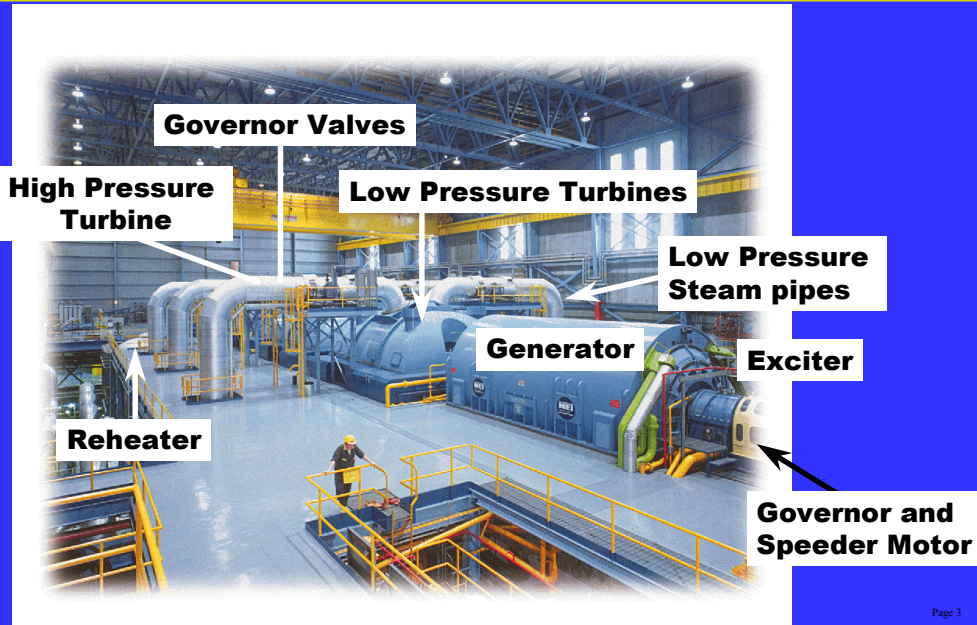
- This steam generator, built for the Wolsong station in Korea, was manufactured in Canada by the Babcock and Wilcox company. In Wolsong 2,3, and 4 a joint venture was formed between Babcock and Wilcox and the Hanjung company of Korea. In each Wolsong unit, Hanjung took a larger share of the total contract.
- Now, Hanjung will build the Qinshan Phase III steam generators in their factory in Korea, with very small help from Babcock and Wilcox.
- These generators are of the vertical U-tube type with integral preheater, and with a recirculation ratio of about 7 and a steam wetness of  $<0.25\%$ . Their weight is about 270 megagrams.
- These generators were put into the reactor building in the horizontal position, then raised up. In the Qinshan construction plan they will be lifted by a large crane over the top of the reactor building wall and then lowered into position. This method will save time in the project schedule.
- The generators are supported on a vertical post located at the bottom, and then braced from the sides by cables and seismic snubbers.



- The main steam system together with the feedwater system, turbine and condenser, are connected to form a closed flow circuit. This circuit contains ordinary water and steam.
- These systems carry heat from the Heat Transport circuit to the turbine operating on a Rankine cycle. This cycle transforms heat energy to rotational energy in the turbine shaft. About 30% of the heat energy is changed to rotational energy, and the rest is rejected to the condenser cooling water.
- Several valves are connected to the main steam pipes. The most important of these are the steam safety relief valves, which protect against overpressure in the vessels. These valves also are equipped with actuators which can open the valves to reduce pressure (and therefore temperature) in the steam generators. This action cools and reduces pressure in the HT circuit in the event of an accident --- this is the same function as performed by the automatic depressurization system (ADS) in a PWR. In a CANDU, this important safety function can be done without opening the HT circuit piping, as must be done in a PWR.
- Main steam isolation valves are needed in case one or more tubes start to leak in a steam generator. Using one of these valves and one feedwater isolation valve, a steam generator can be completely isolated from the circuit.
- Atmospheric steam discharge valves have a capacity of 10% main steam flow are used to control steam pressure during transients following rapid turbine power reduction.
- Condenser steam discharge valves can transfer up to 100% steam flow, bypassing the turbine. This capability can be used to keep the reactor at 60% power or more to limit Xenon buildup and consequent reactor poison shutdown.
- Turbine stop valves are used to prevent transfer of liquid water from the steam generator to the turbine -- which might seriously damage the turbine.
- Flow is measured in both the feedwater and steam piping. Large and small control valves ensure that the water level in each steam generator is correct.



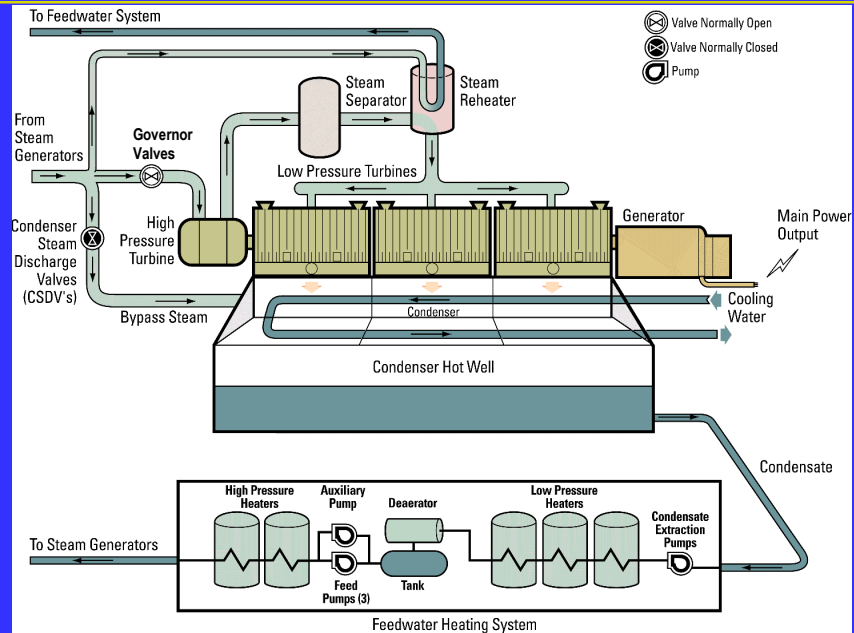
## Point Lepreau Turbine-Generator



- This photograph shows the turbine and generator of the Point Lepreau generating station. This T/G was manufactured in Canada by the Parsons company of the United Kingdom.
- The generator is cooled by hydrogen circulated through both the rotor and the stator windings.
- This T/G generates electricity at 60 Hz. The Qinshan T/G is a 50-cycle machine.



## Turbine - Generator, Feedwater

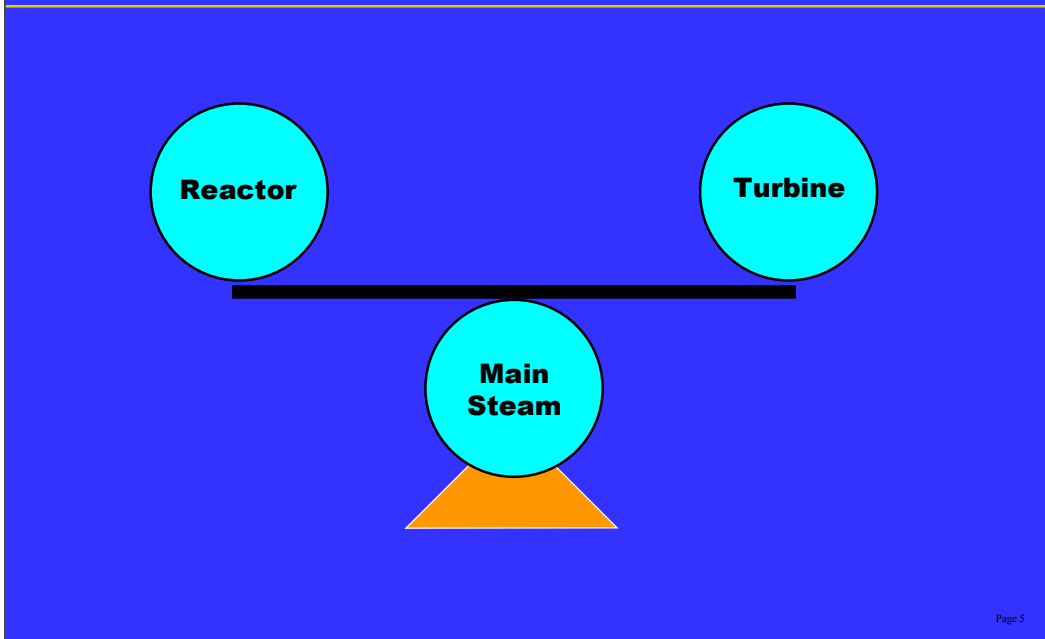


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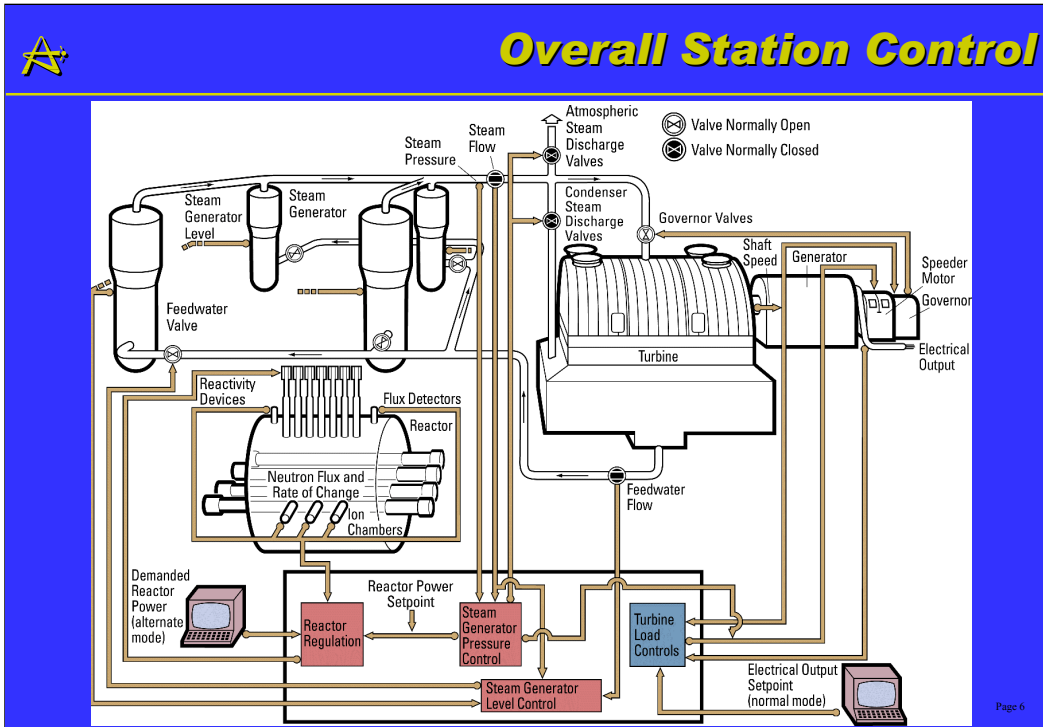
- The main steam flow passes to the governor valves, which are controlled by the governor/speeder motor system to hold the frequency of the electricity sent to the distribution system. The steam then enters the high pressure turbine.
- A very dangerous accident where the turbine speeds up and other controls fail to work is prevented by separate safety devices which are part of the turbine design.
- Some main steam is bypassed to the reheaters to raise the quality of steam entering the low pressure turbines. Water discharged from these reheaters is returned to the steam generators.
- The moisture separators and reheaters are placed in the discharge piping from the high pressure turbine. Steam then passes to three low pressure turbines, and through their several stages to the main condenser.
- Condensate extraction pumps take water from the condenser hot well and deliver it through the low pressure feedwater heaters (which use bleed steam from the turbine to heat this water) to a large tank called the deaerator which removes dissolved gases. The deaerator storage tank holds reserve feedwater.
- Feedwater then is taken by the main feedwater pumps and delivered to the steam generators through the high pressure feedwater heaters.
- This completes the circuit of the 'working fluid' in this system.
- Water in this system must, of course, be of very high purity. The station includes a water treatment plant and chemistry lab for this purpose.



## Station Heat Balance



- This diagram shows the “heat balance” between reactor and turbine.
- This heat balance is easily and quickly detected by the pressure of the main steam. If the reactor power is a little bit too high the steam pressure will rise. If the station is being controlled by the “reactor-follow-turbine” rule, the control action reduces reactor power.
- In the plant is being operated by the “turbine-follow-reactor” rule, then the control action is to open the governor valve a little bit to decrease the steam pressure back to the setpoint.



- This shows a summary of all the station controls.
- The most important circuits are:
  - a) the neutron chain reaction circuit, which releases heat in the fuel
  - b) the primary heat transport circuit, which takes heat from the fuel and sends it to the steam generators
  - c) the steam and feedwater circuit, which takes heat from the steam generators and sends it to the turbine
  - d) the turbine-generator, where heat energy is transformed to electrical energy.
  - e) the electric power circuit, where electrical energy is sent to the user





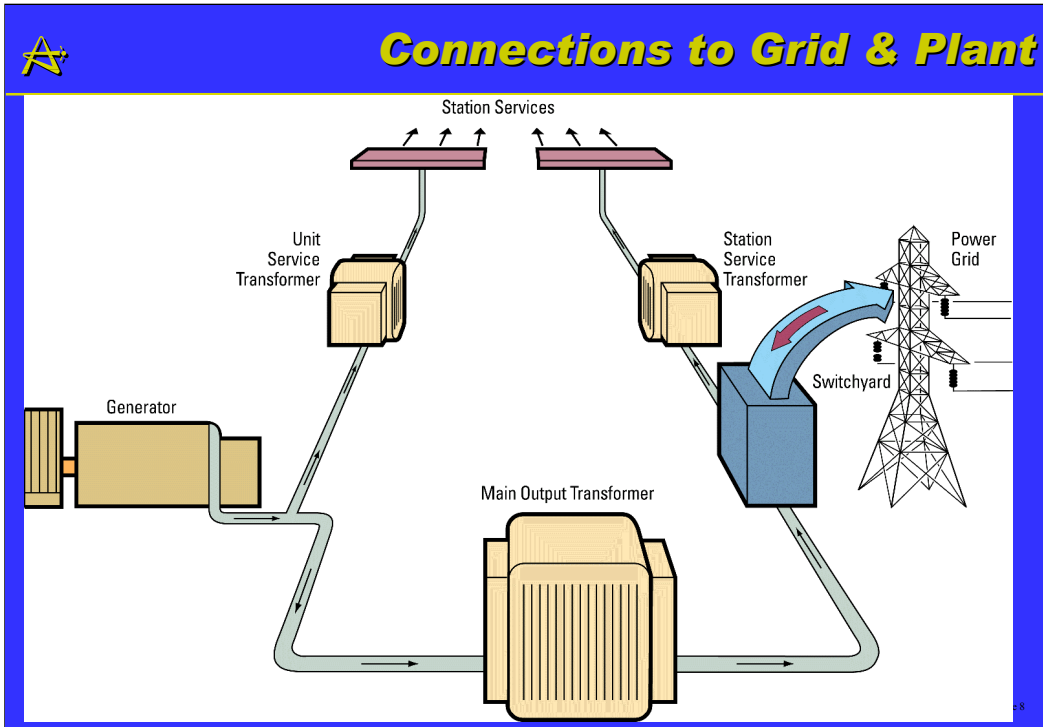
## **Darlington Generating Station**



**4 x 935 MWe CANDU units**

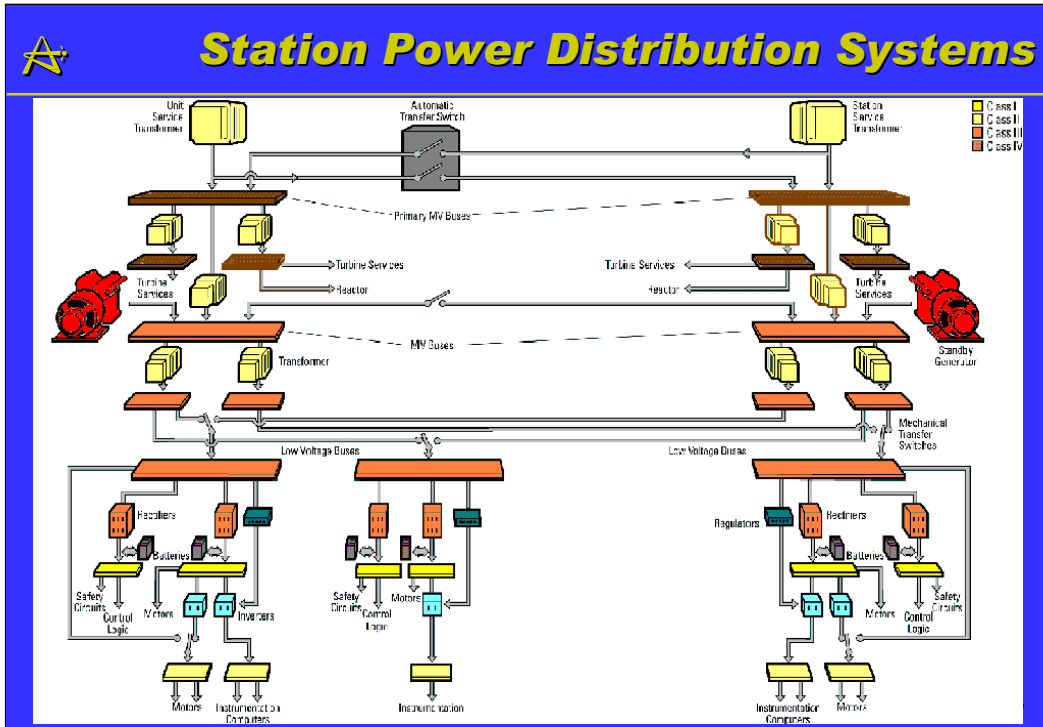
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- This station is the latest of the series of large CANDU stations built by Ontario Hydro in Canada. It has four reactor units, with a common fuelling system and a vacuum containment system instead of the normal envelope containment design such as is used on CANDU 6.
- The principles of operation of all of the CANDU stations are the same; differences are found in the design details.



- The majority of the generator electrical output is sent to the Main Output Transformer, where the voltage is raised from generator voltage (usually 25000 volts) to the grid voltage (usually 200,000 to 500,000 volts).
- The high-voltage output is sent to the switchyard (mostly enclosed in recent designs). The enclosed switchyard uses sulphur hexafluoride ( $\text{SF}_6$ ) as dielectric to reduce its size.
- In the switchyard, a step-down transformer reduces voltage again to 13,800 volts to provide one of the supplies to station electrical services. This transformer is called the “Station Service Transformer”.
- It is important to notice that in some emergency conditions the station becomes a customer for electricity instead of a supplier. This emphasizes the fact that a stable electrical grid is important to safe operation of the station.
- A second “Unit Service Transformer” is connected directly from the generator output to the station electrical loads. Usually, half of these loads are carried by each transformer --- but each one can supply 100% of the loads if needed.

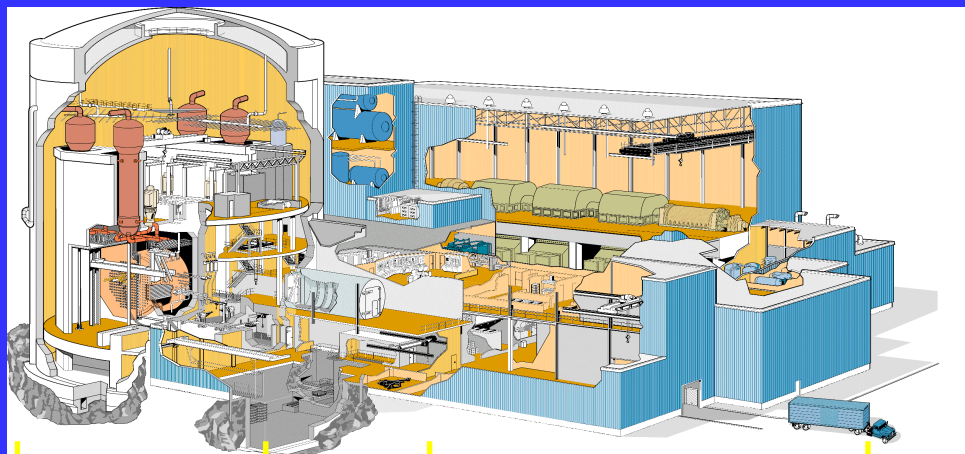




- The top of this diagram shows the station service transformer and the unit service transformer, each connected to a separate electrical “busbar”, or “bus”. A normally-open interconnect allows connection of these buses.
- The highest voltage level serves the heat transport system pumps and some turbine service loads. The buses feeding these systems are colored dark brown. Their classification is Class IV.
- The Class IV buses send power to the lower level Class III buses through a transformer. These buses are used to supply power to most of the station pumps and compressors.
- The Class III buses each are connected to a diesel-driven standby generator which starts automatically if and when the voltage on the Class III bus drops to zero. All equipment connected to the Class III buses can be operated on the standby generator, after a short interruption.
- Each Class III bus also supplies two additional Class III buses, the so-called ‘Odd and Even’ buses. These buses supply three additional Class III buses, connected so that they can be switched between Odd or Even supplies.
- Class I buses (uninterruptible DC power) are supplied from the three Class III buses through rectifiers. In parallel, these buses are connected to batteries which can supply essential loads for several hours. Three of these buses supply power to control logic circuits plus one channel of the safety shutdown systems. Three other buses supply to electrical switchgear and DC motors. They also supply power through inverters to the Class II system.
- The Class II power supplies the station computers, AC instruments, critical motor loads, and emergency lighting.
- In addition to these systems the station is equipped with a separate and independent Emergency Power Supply system which can supply all electrical loads essential for safety, under reactor shutdown conditions.



## The CANDU 6 Power Plant



**Nuclear Steam  
Supply System  
(NSSS)**

**Balance of  
Nuclear Steam  
Plant  
(BNSP)**

**Balance of Plant  
(BOP)**

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- This diagram shows a typical layout of a CANDU 6 single-unit station. Other layouts may be chosen depending on site conditions (especially seismic activity), specifics of equipment supply, and the preferences of the customer.
- When two or more units are supplied simultaneously, the layout is adjusted slightly, and a few peripheral systems, such as the heavy water upgrader, can be shared to reduce overall station cost.
- The station is divided into three major blocks - the nuclear steam supply system (NSSS), the balance of nuclear steam plant (BNSP), and the balance of plant (BOP).



## **The Canadian Safety Philosophy**

- **Developed over more than 50 years**
  - **By direct experience in Canada and the world**
  - **International cooperation and consultation**
  - **Licenses in Korea, Argentina, Romania, Canada**
  - **Construction permit in China**
- **Responsibility and Authority**
  - **The Operator is responsible for plant safety**
  - **Regulator gives operator the authority to operate (licence)**
  - **Licence is renewable at 2-5 year intervals**
  - **Regulator reviews safety performance daily**
  - **Safety systems reliability is measured, reported**
- **Plant Operating Practices**
  - **Operation by established procedures**
  - **Each person is responsible for his/her own safety**

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- The Canadian approach to nuclear safety in design and operation is the same, in all important ways, as in the rest of the world. Specific differences exist because of the unique history of the Canadian nuclear industry.

The most dramatic example of unique history is the very serious accident in the NRX research reactor in 1952. This accident happened mostly because of poor design and poor understanding of safety shutdown requirements. Human error also was a strong factor in this accident.

A second example is the very serious situation in the United States which happened when the nuclear station suppliers and the regulators were found guilty of deception and poor judgment in a number of licensing procedures. This event led to extreme application of rule-based regulation, a practice which continues today. Today's NRC is slowly correcting this serious and very costly error.

- The most important principle of safety is that the operator must have the authority, and must accept his responsibility, to operate safely within the limits of the authorization given by the regulatory agency on behalf of the people.
- In Canada, licenses are renewed at 2-5 year intervals. This practice gives the regulator more effective authority to regulate operational safety. On-site inspectors are located at each station to monitor day-to-day operation. They have authority to order station shutdown.
- A very important principle of personal safety in the plant (both industrial safety in general and radiation safety in particular) is that each individual is held responsible for his or her own safety. Experts are employed to assist and advise.



## Canadian Safety Philosophy - 2

- **“Process systems” operate the station**
  - mostly automatic - operator monitors operation and does tests
  - these systems also protect the workers and the plant equipment
- **Separate and independent “Special Safety Systems” protect the public**
  - protection is their only job. They are independent of the process systems that run the station
- **Combination of probabilistic and deterministic safety criteria**
  - measured system reliability must meet standard
  - defence in depth for highest reliability

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- The idea of using completely separate and independent process and safety systems came directly from the NRX accident, which showed that under some conditions the goals of station operation and station safety are in conflict. The obvious case is one where the senior management wants more electrical energy from the station than the amount that can be produced safely.
- Special safety systems are designed, built, and tested against reliability and performance standards.
- The safety assessment and regulatory acceptance criteria use a combination of probabilistic methods and deterministic methods. For example, a shutdown system is evaluated by its measured unavailability (must be  $<10^{-3}$  /yr.), but it is unacceptable, in a regulatory proceeding, for the licensee to claim a value less than this limit in making a safety argument.