ROLE OF PROJECT DESCRIPTION IN AN ENVIRONMENTAL ASSESSMENT REPORT FOR A NUCLEAR POWER PLANT PROJECT

by

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Abstract

The environmental assessment (EA) process is a decision-making tool for gathering information regarding the natural environment (biophysical environment, i.e., air, water, land, plants, birds and mammals), as well as the social and economic environment. The purpose of an EA is to identify and understand the likely effects of proposed projects on these environments and to mitigate potential adverse environmental effects to help promote sustainable development. The Canadian Environmental Assessment Act(1) is the legal basis for defining federal environmental assessments that are to be conducted by the "Responsible Authority" (RA), that is, the federal government department responsible for ensuring that an EA is conducted. The RA, which is the Atomic Energy Control Board (AECB) if the project deals with radioactive materials, determines which EA process applies and what the schedule will be for conducting the EA. Moreover, the RA administers the EA review process, co-ordinates review of the EA by other agencies, ensures that regulatory requirements are complied with, and decides on the acceptability of the EA. The AECB also determines the scope of the project and the factors to be considered in the assessment, and provides guidance to the proponent on how to structure the EA report to be submitted to the AECB for review and decision.

The description of the proposed project is an essential part of every environmental assessment. This description includes an overview of the project, including its purpose; a description of the facilities and services at the proposed site; major project activities, including waste management systems; and the potential radiological and non-radiological emissions from such activities. An adequate description of the project is necessary in order to allow all potential environmental effects of the project to be identified. Such a description has recently been written as part of a draft environmental screening report for the Pickering A Return-to-Service (PARS) project.

This paper describes a generic methodology for preparing a project description for environmental assessment of a CANDU 6 nuclear generating station (NGS). The methodology is similar to that used for PARS, but it is CANDU-6-specific and applies to a CANDU 6 NGS.

1. Introduction

Environmental assessment (EA) is a review process aimed at protecting the environment from harmful developments. It is a project-planning tool designed to help decision-makers achieve the goal of sustainable development. The most common definition of sustainable development was introduced by the World Commission on Environment and Development in 1987 as

> "In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations".

Canada's Parliament provides a variation on that definition, "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." However, most observers agree that "sustainable development" cannot be defined or used as a measuring stick to make judgment about a given decision or practice, but it is rather a sense of direction, an agreement to give greater importance to the environmental effects of our actions[1].

Yet in spite of this collective opinion, an EA clearly provides a systematic approach for identifying the environmental effects of proposed projects and allows decision-makers the option to modify plans so that adverse effects can be minimized or eliminated. Consequently, it helps to promote projects that are better designed and more environmentally friendly.

A "project", under subsection 2(1) of the *Canadian Environmental Assessment Act*[(1)] (the Act), means, in relation to a physical work, any proposed construction, operation, modification, decommissioning, abandonment, or other undertaking in relation to that physical work, or any proposed physical activity not relating to a physical work that is listed in the *Inclusion List Regulations*[2] of the Act. The project's proponents and federal authorities are provided with guidance on preparing project descriptions for the projects that may require an assessment under the Act.

The project description is an essential part of an EA report. It gives an overview of the proposed project, including its purpose; it describes the facilities and services at the proposed site, the major project activities, including information on waste management systems, and potential radiological and non-radiological emissions from such facilities and activities. Such a project description has recently been written for a draft environmental screening report for the Pickering A Return-to-Service (PARS) project.

The main objective of the project description is to identify and characterize the details of each undertaking that has a potential to interact with and result either directly or indirectly in a likely change to or disruption of the surrounding environment. For a new nuclear power project, this

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[1] Dr. Stuart L. Smith, Chair, National Round Table on the Environment and Economy, "Sustainable Development and Nuclear Energy", Carlton University, Ottawa, Ontario (October, 1999).

[2] List set out in regulation that specifies physical activities not in relation to physical works, which are subject to environmental assessment because of their potential to cause significant adverse environmental effects.

identification and characterization are needed for the different phases of a project, such as construction and commissioning, operation, and decommissioning. Each interaction with the environment is the result of an activity associated with one of the phases, and the EA is discussed in terms of each of these activities. The environment includes land, water and air, all organic and inorganic matter, and the ecosystems in which they interact.

An adequate description of the project is necessary to allow all potential environmental effects of the project to be identified. This paper describes a methodology for the preparation of a project description for the EA of a nuclear generating station (NGS). The methodology is similar to that used for PARS, but it is CANDU-6-specific and applies to a CANDU 6 NGS.

This paper describes
- the types of environmental assessments,
- the steps involved in the EA process,
- the project description in the EA process and how it fits in the EA report, and
- the preparation of a typical project description for an EA associated with a CANDU 6 NGS.

2. Types of Environmental Assessments

When the Act was proclaimed in 1995, a new independent agency, the Canadian Environmental Assessment Agency (CEAA) was established to administer the federal environmental assessment (EA) process and to ensure that opportunities are provided for public participation in this process.

All projects are to receive an appropriate degree of environmental assessment. The degree depends largely on the scale and complexity of the likely adverse effects of the project and public concerns. There are four types of environmental assessments under the Act:

- screening,
- comprehensive study,
- mediation, and
- panel review.

Environmental screenings account for approximately 99% of all federal projects assessed. Since 1995 more than 25,000 federal EAs have been conducted, and 99% of which were at the screening level; 46 proposed projects have undergone a comprehensive study (23 are still underway as of the end of 1999), and five projects have undergone review by a panel, and another four panel reviews were underway at the end of 1999[(2)].

A screening systematically documents the potential environmental effects of a proposed project and determines the need to eliminate or minimize (mitigate) any adverse effects; if adverse effects cannot be justified, or if there is sufficient public concern, then modifications to the project plan, or further assessment through mediation or a panel a review, may be recommended. It applies to both small-scale projects as well as larger projects. To improve the efficiency of the process, small-scale projects may be assessed through the use of a class screening. Examples for screening studies for relatively complex projects include waste management area for above-ground and bulk storage of low-level waste, the construction of a new four-lane highway, construction and operation of a hydro-electric development.

Large-scale and environmentally sensitive projects usually undergo a more intensive assessment called a comprehensive study. The Comprehensive Study List regulation identifies projects in this category. Examples for completed comprehensive studies include proposal to decommission a military base near Truro, Nova Scotia (RA is National Defense), development of a hazardous waste disposal site in Thunder Bay, Ontario (RAs are Environment Canada, and Fisheries and Oceans Canada).

Mediation approach to environmental assessment is a voluntary process in which an impartial mediator appointed by the Minister of the Environment helps interested parties resolve issues surrounding a project. This approach is used when interested parties are few and consensus is possible, but has never been used yet.

Panel reviews enable more involvement of the public (a large number of groups and individuals with different view points) by allowing them to present information and express concerns. Panels have subpoena powers to enforce the attendance of spoke persons and to have required information provided. The concept for the disposal of Canada's nuclear waste has undergone a panel review process.

A public registry is established by the RA to ensure public access to information relating to the environmental assessment of a project. Public participation is one of the goals of the Act, with increased opportunities for mandatory public input into an EA for all types of environmental assessments.

3. Steps in an EA Process

Once it is established that the Act applies to a project, the following steps are followed.

1. Determining the Track of the EA
   There are four EA categories as explained in Section 2. The RA determines the scope of the assessment (see item 2), ascertains factors to be considered, manages the EA process, and ensures that the EA report is prepared. The RA determines which of the four EA categories, i.e., screening, comprehensive study, mediation or panel review, applies to the project.

2. Scope of the EA
   Under the Act, the project's activities and the scope of the specified factors included in the assessment are determined by the RA.

   For instance, a final scoping document (with public input) was issued in January 2000 by the AECB for the EA of the PARS project[(3)]. The AECB has determined (pursuant to Section 18(1) of the Act) that a "screening" must be conducted for that project and that a screening report must be prepared.

3. Preparation of the EA report
   The RA delegates preparation of the EA report to the proponent (e.g., Ontario Power Generation Inc. for the PARS). For screening, the report describes the project, existing natural, social, and economical environments and results of the studies of the environmental effects on the natural, social, and economical environment. The report also identifies measures taken to eliminate or reduce such effects. The mitigation measures to be implemented must be technically sound, economically feasible, and cost-effective.

   The following shows typical sections in a screening report(3) including the description of the project which allows for a reasonable consideration in the screening of the environmental effects of the project.

   - executive summary,
   - introduction,
   - application of the Act,
   - scope of the project,
   - factors to be considered in the screening,
   - purpose of the project and description of the project,
   - assessment of study areas and time frames (spatial and temporal boundaries),
   - description of the existing environment (i.e., baseline)
   - identification, consideration and mitigation of environmental effects (normal operation, malfunctions and accidents, environmental events, cumulative effects),
   - significance of residual effects,
   - monitoring and follow-up programs,
   - public and stakeholder consultation program,
   - decommissioning planning,
   - references, and
   - glossary.

4. Review of the EA Report
   Public and government review of the EA report, also peer review, are required.

5. Decision by the RA
   The RA makes a decision on approval of the EA.

6. Follow-up Programs
   As must address the need for a follow-up program to monitor and verify the accuracy of the project's EA and to determine the effectiveness of the implemented mitigation measures.

4. Content of a Typical Project Description in a Screening EA Report

Usually, the description of the project elaborates on those items identified in the project scope that the RA has defined. A typical scope identifies facilities that are involved in the project's proposal and the undertakings that are to be conducted in relation to those facilities. An adequate description of the project is necessary to allow all potential environmental effects of the project to be identified. A typical project description in an EA report for a NGS includes the following elements.

- description of activities for site investigation and preparation;
- description of construction and management activities, and work force requirements;
- description of commissioning phases (Phase A, Phase B, Phase C and Phase D) activities;
- description of the routine operations and maintenance activities, including buildings and structures that house the nuclear and non-nuclear portions of the facility;
- important components of the facility designed specifically to isolate the project from the surrounding environment, or to prevent, stop, or mitigate the emissions from malfunctions and accidents;
- important components of the facility and their environmental qualification requirements for equipment age and wear to ensure environmental performance and reliability;
- estimated inventories of radioactive and other hazardous materials in the operation of the project, including their storage locations and storage methods;
- sources, types, and quantities of generated radiological and non-radiological wastes;
- on-site collection, handling, storage, and disposal of generated radiological and non-radiological wastes;
- predictions of emissions (both gaseous and liquid) from the project under normal operating conditions; and
- a description of the relevant organizational management structure, staff qualification requirements with emphasis on safety and environmental management programs.

5. Methodology to Prepare a Project Description of a CANDU 6 Plant

A CANDU 6 plant, with a gross electrical output in the range of 725 MW(e), is a modern and proven CANDU plant. There are eight CANDU 6 units in operation (two in Canada, four in the Republic of South Korea, one in Argentina and one in Romania) and three CANDU 6 units under construction. The CANDU 6 reactor is ideally suited to utilities with medium-sized electrical grids and moderate grid expansion rates. Through the economies of replication and sequential construction, multiple CANDU 6 stations provide operational flexibility and economical electricity production to utilities with larger electrical grid demands.

As the vendor of the CANDU 6 reactor, AECL uses a basic subject index to classify all equipment and components in the plant. The index can be used as a basis to identify and describe systematically those systems associated with the daily operation of the facility. The index is shown in Table 1. To align this approach more closely with the expectations of an EA, the site layout and buildings and structures (first two items in Table 1) can each be described separately, and the remaining divisions associated with reactor operations can be divided into the following three major groups:

- nuclear Steam Supply System (NSSS);
- balance-of-plant (BOP) components including main steam systems, feedwater system, turbine generator system, and electric power system;
- other auxiliary systems, including radioactive and non-radioactive waste management systems;

The major systems under these three groups are shown in Table 2. After the site layout and buildings are described, the next step is to describe these three systems. Once their operational characteristics are known and activities associated with their operation and maintenance are established, then those activities that have potential environment effects during construction, commissioning, operation, and decommissioning phases for the project can be determined.

Sections 5.1 to 5.9 briefly describe the sub-sections that would be included in a project description section of an EA report for a NGS.

5.1. *Site and Improvements*

The nuclear power plant (NPP) site, its location, its access routes, existing services, security and maintenance requirements, and proposed improvements are first described in the project description. This section also includes a description of the site construction and commissioning activities and staffing requirements. Figure 1[(4)] shows the general site layout of a CANDU 6 plant.

5.2. *Buildings and Structures*

The buildings and structures section of an EA report includes a description of the buildings and structures, and the equipment and systems housed inside them. The major buildings and structures include the reactor building, service building, turbine building, cooling water structures, auxiliary service structures, and ancillary structures (e.g., heavy-water upgrader).

The reactor building—which is a pre-stressed concrete containment structure that has internal reinforced concrete walls and a reinforced concrete calandria vault—shields workers and the public from radiation during reactor operation and in the event of a reactor accident. The reactor building houses the nuclear reactor, heat transport and moderator systems and their auxiliaries, the fuel handling system and its auxiliaries, other auxiliary systems and their instrumentation.

The pressure inside the reactor building is slightly below atmospheric to control any spread of airborne contamination. Any air exhausted from the reactor building is passed through filters before being released to the environment. The exhaust air in the main stack is monitored. There are also containment isolation monitors that isolate the reactor building's atmosphere from the environment upon detection of radioactivity in the exhaust air over a given set point, and thereby keep radioactive releases to a minimum.

The service building houses nuclear facilities, which can be located outside the reactor building. Usually, the service building houses mechanical workshops, laboratory facilities, change rooms, and the main control room. The new-fuel storage areas, irradiated fuel storage bays, decontamination areas, the emergency core-cooling system equipment, and the main control room are also located in the service building.

The turbine building consists of a turbine hall, auxiliaries bay, and two single storey annexes. The electrical power distribution equipment is located in the auxiliaries bay. The water treatment plant and diesel generators are located at grade level in the annexes. There are overhead travelling cranes in the turbine hall for maintenance of the turbine generator and some of its auxiliaries.

The pumphouse, which has a reinforced concrete substructure, contains the condenser cooling water pumps, raw service water pumps, fire water pumps, screens, and racks and screen wash pumps. A steel-framed superstructure provides housing for the pumps' motors.

5.3. Nuclear Steam Supply System (NSSS)

The nuclear components of a CANDU 6 reactor are designed to produce nuclear heat and the steam used in electric power generation. This is accomplished with negligible impact to the atomic radiation workers, the public or the environment. The design of the facilities is such that radiological exposure of operating staff and the public is well below the limits recommended by the International Commission on Radiological Protection. Figure 2 shows major components of the NSSS, i.e., the reactor, the heat transport system (HTS), the moderator system, and the fuel handling system. Figure 3(4) shows the NSSS and its interface with the balance-of-plant (BOP) systems.

Reactor

The reactor consists of a stainless steel horizontal cylinder (calandria) closed at each end by end shields. The end shields support the 380 fuel channels that span the calandria and provide personnel shielding. The calandria is located inside a water-filled, steel-lined concrete structure (reactor vault) that provides radiation shielding to personnel, and the water provides thermal shielding for the concrete structure. The calandria contains heavy-water moderator at low pressure and temperature, and reactivity control devices and their guide tubes.

A fuel channel consists of a Zr-2.5% Nb pressure tube that contains heavy-water coolant at high temperature and pressure, and 12 fuel bundles. Nuclear heat produced by fission is carried by the coolant to the steam generators. Each fuel bundle (~ 0.5 m long) comprises 37 fuel elements, arranged in concentric rings (one element in the centre, and three rings around it containing 6, 12 and 18 elements respectively). Each fuel element is a stack of uranium dioxide pellets completely enclosed by a zirconium fuel sheath. The pressure tube is contained inside a zirconium calandria tube that is in contact with the heavy-water moderator on the outside. The gap between the calandria and pressure tube is filled with carbon dioxide gas that is circulated by the annulus gas system.

Fission products produced in fission are contained within the Zircaloy-4 fuel sheath. Gaseous fission products can only be released into the coolant after a fuel sheath has failed. However, the fuel defect rate is low for CANDU fuel bundles, < 0.1%. Because of the failed fuel location and delayed neutron monitoring systems, a fuel defect is detected promptly and the failed fuel is removed from the core. Many of the fission products that escape into the coolant after such a fuel failure are removed by the purification system.

Heat Transport System (HTS) and Its Auxiliaries

Figure 4[4] shows schematically the HTS auxiliaries, i.e., HTS heavy-water purification system, shutdown cooling (SDC) system, pressure inventory and control system. Also shown is the heavy-water collection system that can be described under the heavy-water management systems. The heat that is produced by fission in the natural-uranium fuel, is carried by the coolant in the fuel channels to the steam generators where it is transferred to light water to produce steam. The important radionuclides produced in the HTS and present in its auxiliaries are ^{3}H, ^{14}C, ^{41}Ar, fission-product noble gases after a fuel-element failure (xenon and krypton isotopes) and relatively short-lived induced activities (^{16}N, ^{19}O, and ^{17}F).

Moderator System and Its Auxiliaries

Figure 5[4] shows the main moderator system and its auxiliaries, i.e., moderator heavy-water purification system, heavy-water collection system, and cover gas system. Neutrons produced by fission are slowed down by the heavy-water moderator, which is circulated through the calandria and the external circuits for cooling and purification. The important radionuclides produced in the moderator and consequently in its auxiliaries are ^{3}H, ^{14}C, ^{41}Ar, activation products, and the short-lived induced radioactive isotopes in the heavy water (^{16}N, ^{19}O and ^{17}F).

Fuel Handling System

Figure 6[4] shows the fuel handling system used to refuel the reactor during operations. The new-fuel storage area, new-fuel charging area, fuelling machines, irradiated fuel bays—which includes the discharge bay, reception bay, and the storage bay—are also shown in this figure. The fuel bay for failed fuel, which is also shown in Figure 6, has been eliminated from CANDU 6 plants built after Wolsong 2 because low fuel failure rates (<0.1%) made a separate storage location unnecessary.

The important radionuclides associated with the fuel handling systems are tritium, fission-product noble gases (occur after failed fuel conditions) and traces of fission products and corrosion products that are removed by the irradiated fuel bay purification system.

Other Auxiliary Systems

The other auxiliary systems include the biological shield cooling system, the annulus gas system, and a liquid zone control system (LZCS). Helium gas is used in the LZCS, and carbon dioxide is used in the annulus gas system. Argon-41 is produced in both systems because both these gas systems contain argon impurities. Carbon-14 is also produced in small quantities in the annulus gas.

Reactor Regulating System

The reactor regulating system is an integrated reactor control system comprising neutron and thermal power measurements, reactivity control devices, and a set of computer programs, which are all coordinated to perform the following three main functions:

- monitor and regulate total reactor neutron power to satisfy the station load demands,
- monitor and control neutron flux shape in the reactor, and

- monitor important plant parameters and reduce reactor power at an appropriate rate if any parameter is outside operational limits.

The reactivity control devices in this system include the light-water zone controllers, adjusters, moderator poison addition and removal, and mechanical control absorbers. The regulating system instrumentation includes ion chambers and in-core flux detectors.

Safety Systems

The safety systems consist of the two shutdown systems (SDS1 and SDS2), emergency core-cooling system (ECCS), and containment system. The purpose of the shutdown systems is to quickly terminate the reactor's operation by dropping shutoff rods into the core (SDS1) or by injecting poison (concentrated gadolinium nitrate solution) into the moderator inside the calandria through six horizontal tubes (SDS2). The solution is contained in six poison tanks, as shown in Figure 7[(4)].

The ECCS provides light water to the HTS to compensate for the heavy-water coolant lost in a postulated loss-of-coolant accident. The system recirculates the water collected in the reactor building floor to the reactor to maintain fuel cooling.

Finally, the containment system provides a sealed envelope around the reactor's systems if an accidental release of radioactivity should occur from these systems. The containment is formed by a reinforced epoxy-resin lined, post-tensioned concrete structure. It includes an automatic dousing system that releases a spray of light water to condense any steam discharged, air coolers, airlocks, and an automatically initiated containment isolation system for button-up (isolation of reactor building atmosphere from the environment).

Heavy-water Management Systems

The CANDU 6 reactor design includes systems to recover and upgrade heavy water that has escaped as liquid or vapour from the heavy-water-filled systems. Most of the heavy-water leakage is recovered via the heavy-water vapour recovery system or the active drainage system. The plant systems are designed to collect and recover the heavy water as quickly as possible by the minimum downgrading with light water. The recovered heavy water is removed and transferred to the clean-up and upgrading systems. Figure 8[(4)] shows schematically the heavy-water supply system, upgrading system, and the separate heavy-water collection, vapour recovery, clean-up and deuteration/de-deuteration systems serving the heat transport and moderator systems.

5.4. Balance-of-Plant

The balance-of-plant (BOP) is the conventional portion of a NGS and it complements the NSSS. In CANDU 6 plants, the BOP starts at an imaginary line called the K-line that separates the Turbine Hall from the Service Building. Figure 3 shows the interface between the NSSS and BOP. Steam, which is produced in the steam generators located in the reactor building, is transferred to the turbines and the generator located in the Turbine Building. In the turbine, the thermal energy of steam is converted to mechanical energy by the turbines. In the generator, mechanical energy created in the turbine is converted to electrical energy, which is transferred to the grid. The Turbine Building and Pumphouse are the main areas housing the BOP systems.

The main components of the BOP are steam turbines (high-pressure and low-pressure turbines), turbine generator, condenser, moisture separator reheater, feedwater heaters (high and low pressure), feedwater pumps, raw service water system pumps, recirculated water system pumps, and condenser cooling water system pumps.

Turbine Generator System

This system consists of a turbine generator unit and associated condensing and feedwater heating systems. Figure 9[(4)] shows the steam turbines, the generator, the condensing system, and the feedwater heating system.

Steam that is produced in the steam generators enters into the high-pressure turbine and its water content increases as it expands at this stage. The steam passes through steam separators for water removal, then goes through reheaters and then passes through the low-pressure turbines, into the condenser where the steam condenses to water. The water is returned to the steam generator via the feedwater heating system.

Electric Power Systems

Figure 10[(4)] shows schematically the electric power systems. The mechanical energy created by the turbine is converted into electrical energy in the generator. The main output transformer steps up the generator output voltage to the same level as the switchyard transmission voltage. The transformer is equipped with all necessary accessories and protective equipment.

During normal operation, power for the station's services is supplied by both the unit service transformer and the system service transformer. Either transformer can provide total service load in the event of a failure of one supply.

There are two Standby Diesel Generators per unit, located outside the turbine building. In the event of failure of Class IV[3] power sources, the generators start automatically. They are tested at regular intervals.

Feedwater and Main Steam System

The water is supplied to the steam generators (SGs) secondary side via the feedwater heating system. The chemistry of the feedwater to the SG is controlled by demineralization, de-aeration and pH control. This system is shown in Figure 9. A blowdown system is provided for each SG to control the concentration of the dissolved impurities in the secondary side, and to provide for chemical wash of the SG for removal of the non-soluble and/or non-suspended species to control the accumulation of the sludge build-up on the tube sheet inside the SGs.

Cooling Water Systems

Cooling water is provided to various systems in the plant by the following systems:

[3] The station services power supplies are classified in order of their level of reliability requirement. There are four classes (from Class I to Class IV) that range from uninterruptible power to that which can be interrupted with acceptable consequences.

- The Raw Service Water System (RSW), which is an open system, that cools the recirculated cooling water (RCW) heat exchangers, and various cooling equipment if Class IV power is lost.
- Recirculated Cooling Water System (RCW) is a closed loop that cools the moderator system heat exchangers and pumps, heat transport system pumps, local air coolers (LACs) in the reactor building, Emergency Core-Cooling System (ECCS) heat exchangers when required, and biological shield cooling system heat exchangers.
- The emergency Class III standby diesel cooling water system that supplies sea or lake water when the diesel generators are operating and the RSW is not available.
- Condenser Cooling Water (CCW) System is an open loop that supplies required sea or lake water to condense the exhaust steam from the Low-pressure Turbine.

Pumphouse

The Pumphouse is a reinforced concrete substructure containing the condenser cooling water pumps, raw service water pumps, fire water pumps, screens, and racks, and screen wash pumps. The pump motors are inside a steel framed structure. Roof hatches allow for installation and maintenance of the pumps.

Water Treatment Plant

The water treatment plant (WTP), which treats (purifies) water for use in various systems, consists of a pre-treatment system and a demineralized system.

Sewage Treatment Plant

Sewage is collected from buildings on site and directed to the site sewage treatment plant. The waste produced is sludge from the settling tanks. The sludge is removed periodically and is transferred by a tanker to an off-site disposal facility.

Oil Storage Tanks

The aboveground and underground oil storage tanks are provided on site to fuel various pieces of equipment, including the standby generators and the auxiliary boiler.

5.5. *Radioactive Waste Management Systems*

Radioactive waste produced in an NPP can be divided into three groups: solid, liquid, and gaseous waste.

Radioactive Solid Waste Management

The radioactive solid waste can be divided into two main groups, i.e., maintenance waste (low-level waste, which can be further divided into compactible, non-compactible or non-processible, and incinerable waste categories) and purification waste (intermediate-level waste, such as ion-exchange resins and filters). The low-level waste (excluding incinerable waste) is stored on-site in the radioactive solid waste storage facility (RSWSF). The spent resin is stored in the concrete storage tanks (with stainless steel liners) located in the service building basement.

Radioactive Liquid Waste Management

The radioactive liquid waste is collected by the radioactive liquid waste management system. These wastes are divided into 2 categories: The low-activity waste that can be discharged to the condenser cooling water duct without treatment (provided that discharge limits will not be exceeded at the outfall) and high-activity waste that is treated in the decontamination facility consisting of an ion exchanger and a filter unit, prior to discharge. The tank contents are sampled and radioactivity contents are determined before pump-out. Discharges are monitored by the liquid effluent monitor that can stop pump-out automatically if the pre-set limits are exceeded. The liquid effluent releases are monitored in two categories: tritium and activated corrosion products.

Radioactive Gaseous Waste Management

All active or potentially active gases, vapours, or airborne particulates that occur in the station are monitored and filtered before their release to the atmosphere. In particular, active gases that have been vented from the primary systems are released to the active ventilation system only after removal of the heavy water (by the heavy-water vapour recovery systems) and hold-up to permit decay of short-lived radionuclides. Also, the off-gas management system treats fission-product noble gases and thus reduces their amounts released to the environment.

The gaseous emissions are monitored in 5 categories: particulate, radioiodine and noble gases (by the gaseous effluent monitor continuously), and ^{3}H and ^{14}C (continuously sampled by the samplers and the samplers are measured periodically in the health physics laboratory).

5.6. Non-radioactive Waste Management Systems

Three types of non-radioactive wastes are generated: solid, liquid, and gaseous waste.
The solid waste consists of sludge, domestic garbage, and resin. The sludge is transferred off-site by tanker; domestic garbage is collected and removed periodically by truck to an off-site landfill; used resins are regenerated and reused to the extent possible. Operating experience shows that the resins used, for example, in WTP, are changed every 5 to 10 years.

The liquid waste consists of water collected from various drains and plant systems, oils and chemicals. The water is neutralized if required and disposed of according to the local regulations. Oils are collected in drums for off-site storage, treatment, and disposal. Chemicals from maintenance facilities and laboratories, for example, are stored in drums for disposal.

Gaseous waste comprises periodic steam discharges to the air from steam valves, and emissions from diesel generators when they are used intermittently. The diesel generators provide emergency power to the site, ensuring that electrical power is available at all times in order to operate the station's essential safety systems.

5.7. Safety and Environmental Programs

In an EA, this section may include a description of the organizational management structure and staff qualification requirements with emphasis on safety and environmental management capability. This section mainly includes programs such as occupational health and safety, radiation protection, on-site monitoring, emergency response, security and safeguards, and off-site environmental monitoring programs to assess the effect of station's operation.

5.8. Malfunctions and Accidents

Malfunctions and accidents are the result of a procedural, process system or equipment failure. Although the release of contaminants is relatively minor, it could involve the potential release of radioactive and non-radioactive substances to the environment.

The project description discusses those physical barriers that would mitigate any effects of the malfunction or accident that results in the release of radioactivity from one of the plant systems. These physical barriers include the fuel sheath, the HTS piping, and the reactor building structure. The shutdown systems, the emergency core-cooling system, the ventilation system, and the dousing system would also mitigate the effects of a radioactive release. In the plant, employees are alerted by audible and visual alarms. Emergency response procedures are initiated with priority given to protection of the public, the station's staff, and the plant.

The description of malfunctions and accidents, their likely environmental effects and whether these effects require further assessments are included in a separate section of the EA report, i.e., not in project description.

5.9. Preparation of an Activity Matrix

An activity matrix is developed to list those activities that involve the transfer of radioactive and non-radioactive contaminants (solid, liquid, and gaseous) to the environment during construction, commissioning, operation, and decommissioning stages of the NGS. This matrix serves as a precursor to the main-effects matrix, which is used to evaluate each activity. Activities usually cover siting, construction, commissioning, routine operation, potential malfunctions and accidents, and decommissioning (abandonment) phases.

Once these project activities are identified by the EA process, then they will be considered for subsequent evaluation of their likely associated effects and any mitigation measures, if required.

While preparing such an activity matrix, the interface of the NSSS, BOP, and auxiliary systems with the environment is identified. For instance, the NSSS contains radioactive contaminants that could reach the environment. However, all these systems are housed in the reactor building or service building, and consequently they do not have a direct interface with the outside environment. Radioactive contaminants from the NSSS will only reach the environment through the radioactive waste management systems. Any leakage from the NSSS in gaseous form (mostly from the pressurized HTS) is recovered by the heavy-water vapour recovery dryers and the amount that is not recovered is directed to the main stack via the active ventilation systems after it has passed through filters. The radioactive liquid that leaked from these systems is also collected in the heavy-water collection systems and is then cleaned up and upgraded for re-use in the heavy-water filled systems. Liquid waste is collected in the liquid waste management system.

The safety systems (shutdown systems, ECCS, and containment system) operate after an accident has occurred to reduce or prevent contaminants from reaching the environment via the gaseous and liquid pathways. Consequently, during normal operation none of these systems or their associated activities interface with the outside environment.

The radioactive waste management systems are designed to manage solid, liquid, and gaseous radioactive wastes produced at an NGS as a result of operation of the NSSS. These systems have a direct interface with the outside environment. The solid radioactive waste is collected, segregated into radioactive and non-radioactive categories; radioactive waste is stored in the solid radioactive waste management facilities, and the non-radioactive waste is shipped off-site for disposal. The liquid waste is collected by the liquid radioactive waste management system and is treated, if required, by the liquid waste decontamination facility before discharge. The discharges to the sea, lake, or rivers are monitored so that operational targets and regulatory limits are not exceeded. The gaseous radioactive waste management systems consist of the heavy water vapour recovery systems, various filtered ventilation exhausts, and the off-gas management system which treats noble gases. The discharges via the stack are continuously monitored so that operational limits and regulatory targets are not exceeded.

The non-radioactive waste management systems collect, handle, and dispose of non-radioactive wastes in solid, liquid, and gaseous categories. Any gaseous wastes will be discharged via inactive ventilation systems. The non-radioactive aqueous waste will be collected by the inactive drainage system and discharged to the waters. The non-radioactive solid wastes are managed as described above. Consequently, the activities associated with the operation of the non-radioactive waste management system also have an interface with the outside environment.

6. Conclusions

The project description not only explains how the systems in an NGS operate, what radioactive and non-radioactive contaminants the station produces, and the mitigation measures in place to limit environmental emissions below operating targets and regulatory limits, but also identifies whether activities associated with the station operation may have an effect on the environment.

These activities need to be considered because of their potential to affect the environment. Thus, the project description is central to an EA report because it links with the subsequent sections of the report.

It is realized that most of the nuclear systems have no interface with the environment. Only some of the service systems have interface with the environment (e.g., the raw service water system, the reactor building ventilation system and the service building ventilation systems). Furthermore, many of these interfaces are associated with the conventional (non-radioactive) substances.

7. References

1. Government of Canada.1992, "Canadian Environmental Assessment Act, Statutes of Canada", 1992, Chapter 37, Third session, Thirty-fourth Parliament, 4-41 Elizabeth, 1991-2, Bill C-13, assented to 23rd June 1992.

2. Government of Canada.1999, "Review of the Canadian Environmental Assessment Act - A Discussion Paper for Public Consultation", issued by the Canadian Environmental Assessment Agency, (December 1999).
3. Atomic Energy Control Board (AECB). 2000, "Scope of the Environmental Assessment for the Proposed return to Service of the Pickering Nuclear Generating Station A", (January 31, 2000), Ottawa, Ontario.
4. R. S. Hart, "CANDU Technical Summary" (October 1997).

Table 1: Basic Subject Index Divisions and their Descriptors for a CANDU 6 Plant

BSI No.[4]	Division	Description
10000	Site and Improvements	The Nuclear Power Plant Site ≅ Site investigation ≅ Site access system ≅ Site security ≅ On-site transportation facilities
20000	Buildings and Structures	Buildings and other structural work associated with the physical plant and station facilities ≅ Reactor building ≅ Service building ≅ Turbine building ≅ Cooling water structures ≅ Auxiliary service structures ≅ Ancillary structures
30000	Reactor, Steam Generator and Auxiliaries	Equipment and activities necessary for steam generation in an NPP ≅ Reactor ≅ Moderator system ≅ Heat transport system ≅ Auxiliary systems ≅ Fuel transfer and storage ≅ Steam generator and steam and water systems ≅ Fuel ≅ Heavy-water management systems
40000	Turbine, Generator and Auxiliaries	Equipment and activities related to the conveyance of steam, the generation of electricity and the return of the steam condensate ≅ Turbine-generator ≅ Condensing systems ≅ Feedwater and auxiliary steam ≅ Auxiliary systems
50000	Electric Power Systems	Activities, systems and equipment related to all electric power systems within the confines of an NPP ≅ Main station connections ≅ Standby emergency generators ≅ Station services primary distribution system ≅ Station services secondary distribution system ≅ Uninterruptible power supply systems ≅ Lighting and building service systems
60000	Instrumentation and Control	Instrumentation and control systems and equipment that are used to monitor, record, annunciate, and control all power plant functions ≅ Site instrumentation ≅ Building and structures ≅ Reactor, steam generator and auxiliaries ≅ Turbine-generator and auxiliaries ≅ Electric power systems ≅ Control centre equipment ≅ Common processes and services ≅ Safety systems
70000	Common Process and Services	All common non-nuclear processes and services required for the operation of an NPP ≅ Water systems ≅ Auxiliary process systems ≅ Heating, cooling, and air conditioning systems ≅ Miscellaneous common services ≅ Compressed gas and vacuum services ≅ Material handling ≅ Maintenance facilities and equipment ≅ Miscellaneous equipment ≅ Radioactive waste management
80000	Construction Plant	Temporary and semi-permanent facilities and services that may be required during the construction of an NPP ≅ Operation and maintenance ≅ Site management and engineering

[4] BSI for "General Project" is excluded from this list.

Table 2: Major Components of the NSSS, BOP and Other Systems in a NGS Project Description Section of an Environmental Assessment Report

Category	Major Systems
Buildings and Structures [BSI: 20000]	ι Reactor building, ι Service building ι Turbine building ι Pumphouse
Nuclear Steam Supply System (NSSS) [BSI : 30000]	ι Reactor ι Heat transport system and auxiliaries ι Moderator system and auxiliaries ι Fuel handling system and auxiliaries ι Other auxiliary systems ι Reactor regulating system ι Safety systems ι Heavy-water management systems
Balance of Plant (BOP) [BSI: 40000, 50000, 70000]	ι Turbine generator system ι Electrical power systems ι Cooling water systems ι Pumphouse ι Water treatment plant ι Sewage treatment plant ι Oil storage tanks
Waste Management Systems [BSI: 70000]	ι Radioactive waste management ι Non-radioactive waste management
Safety and Environmental Programs (organizational structure for personnel involved in such programs are also included)	ι Organizational and management structure ι Occupational health and safety programs ι Radiation protection program ι On-site monitoring ι Fire protection ι Emergency response ι Security and safeguards ι Environmental and other monitoring programs
Malfunctions and Accidents	ι Mitigation measures in design against malfunctions and accidents

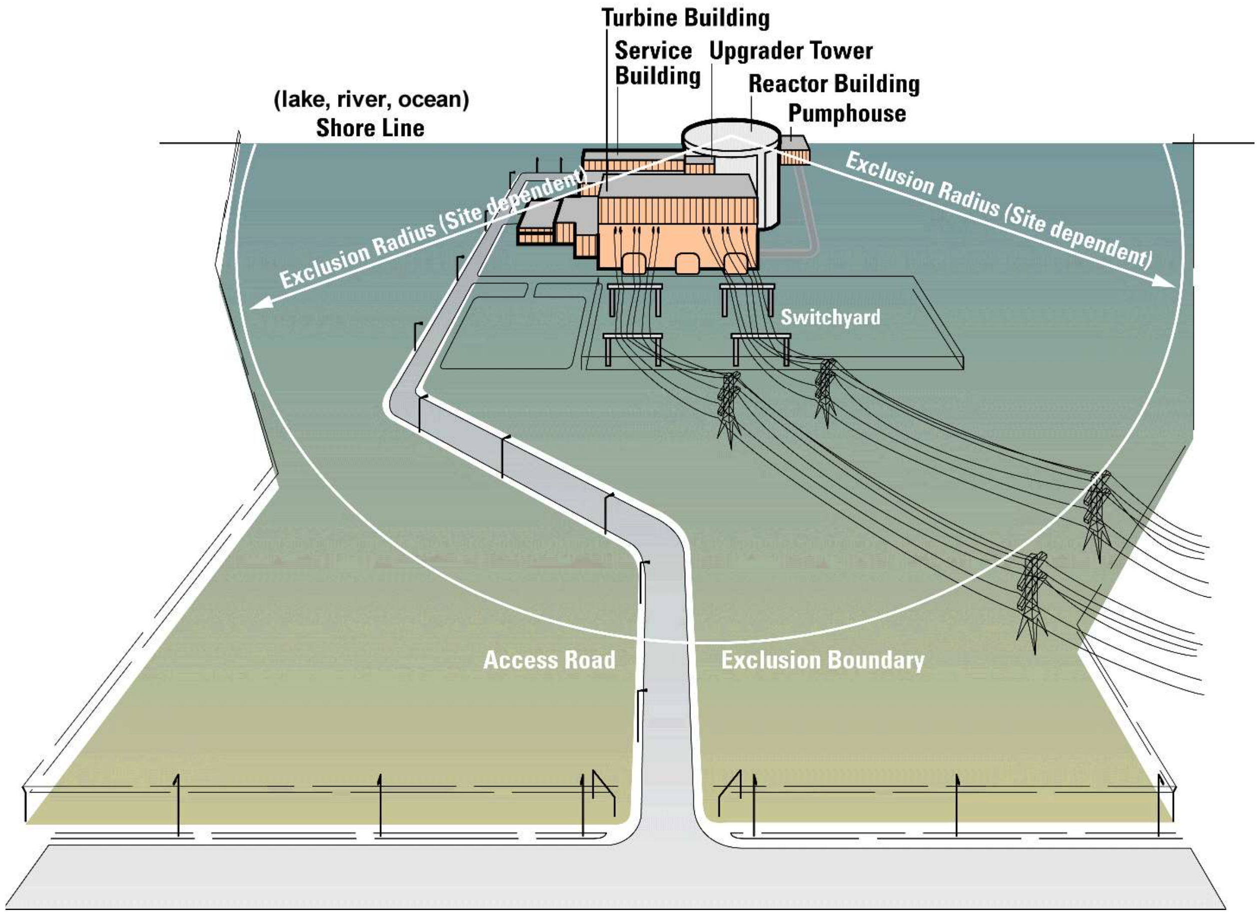

Figure 1: General Site and Plant Arrangement for a CANDU 6 Nuclear Generating Station

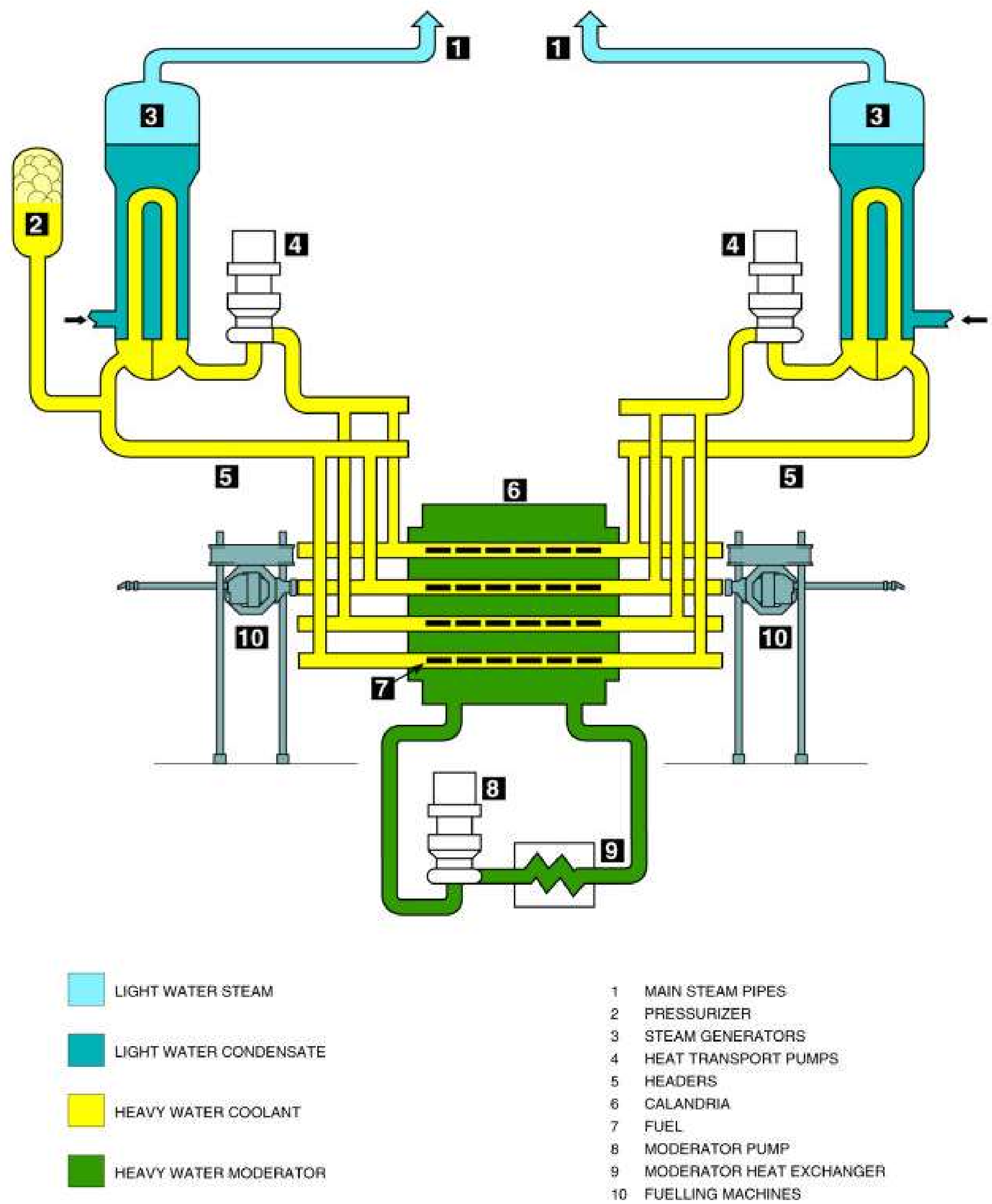

Figure 2: Major Components of the Nuclear Steam Supply System

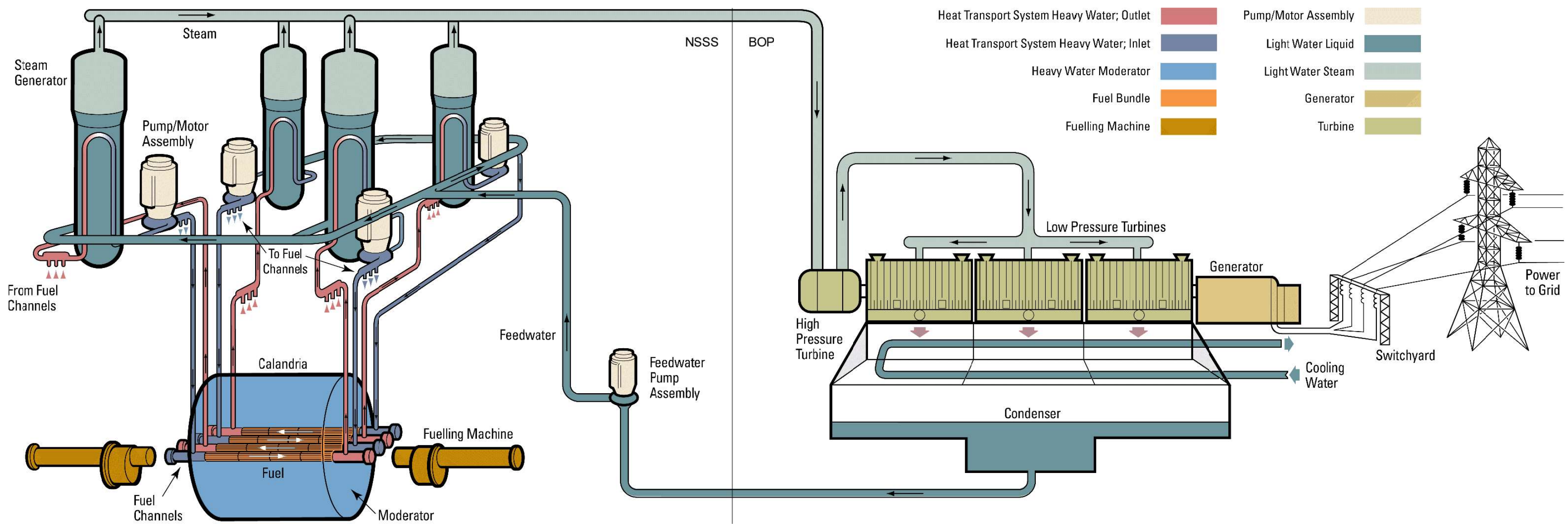

Figure 3: A Typical Station Flow Diagram Showing Interface Between the Nuclear Steam Supply System and Balance-of-Plant

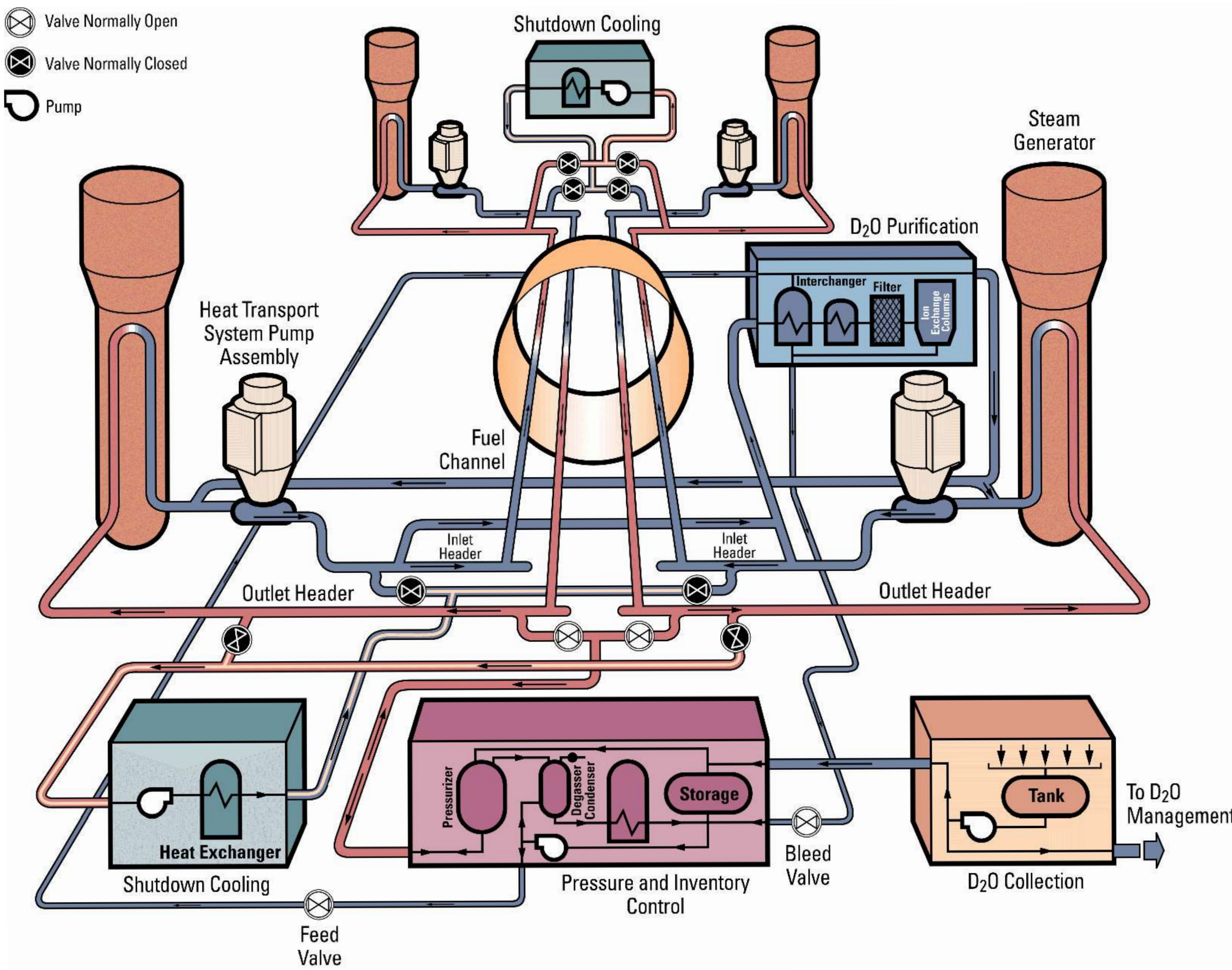

Figure 4: The Heat Transport System and Its Auxiliaries

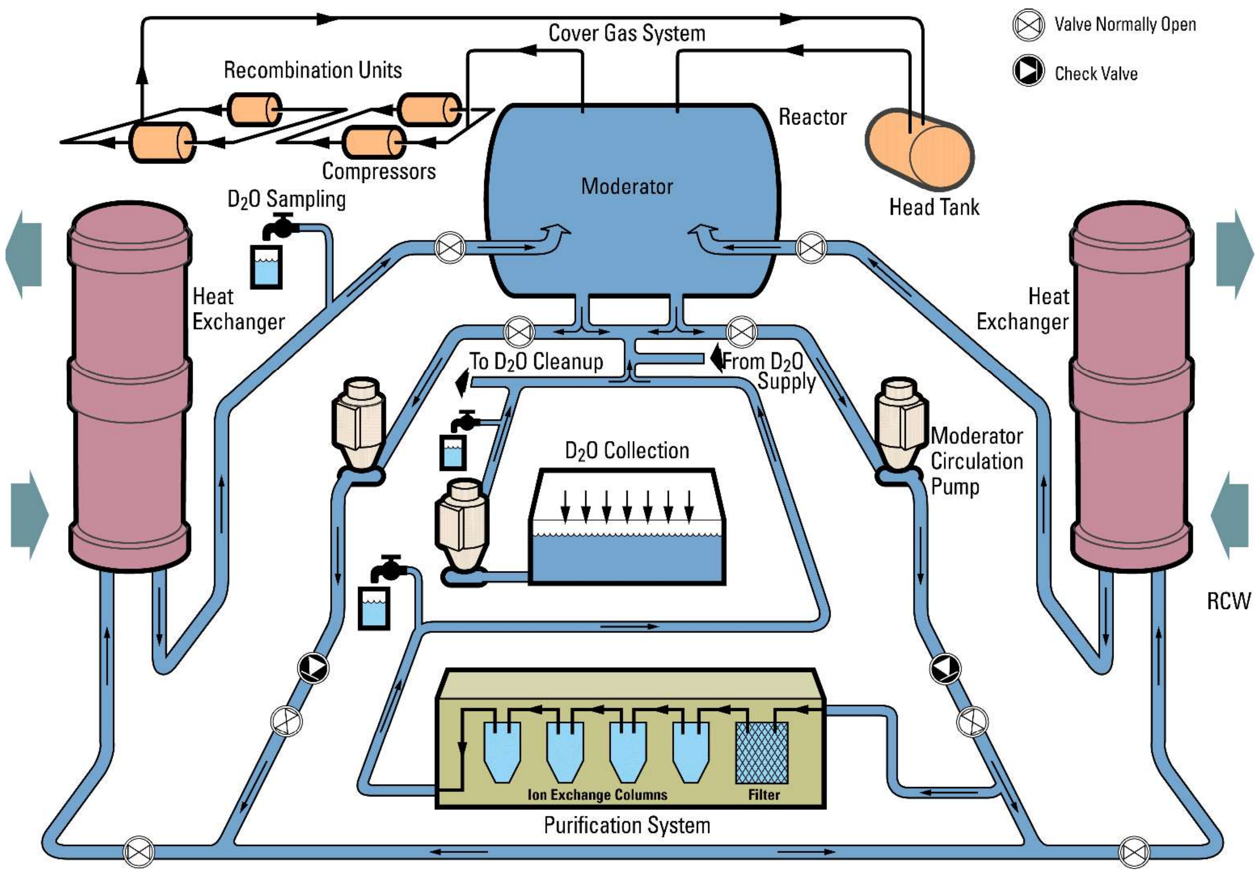

Figure 5: The Moderator System and Its Auxiliaries

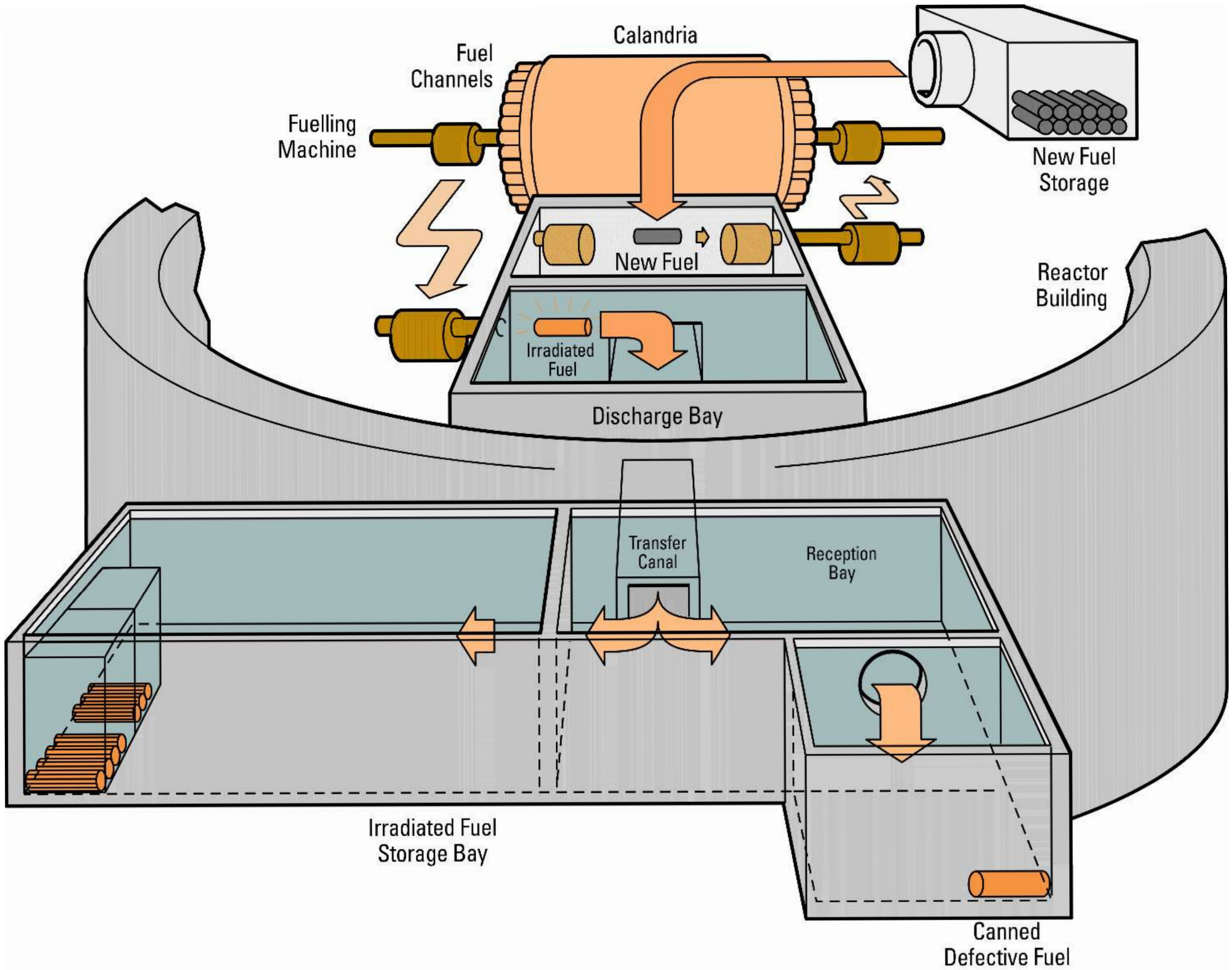

Figure 6: The Fuel Handling System

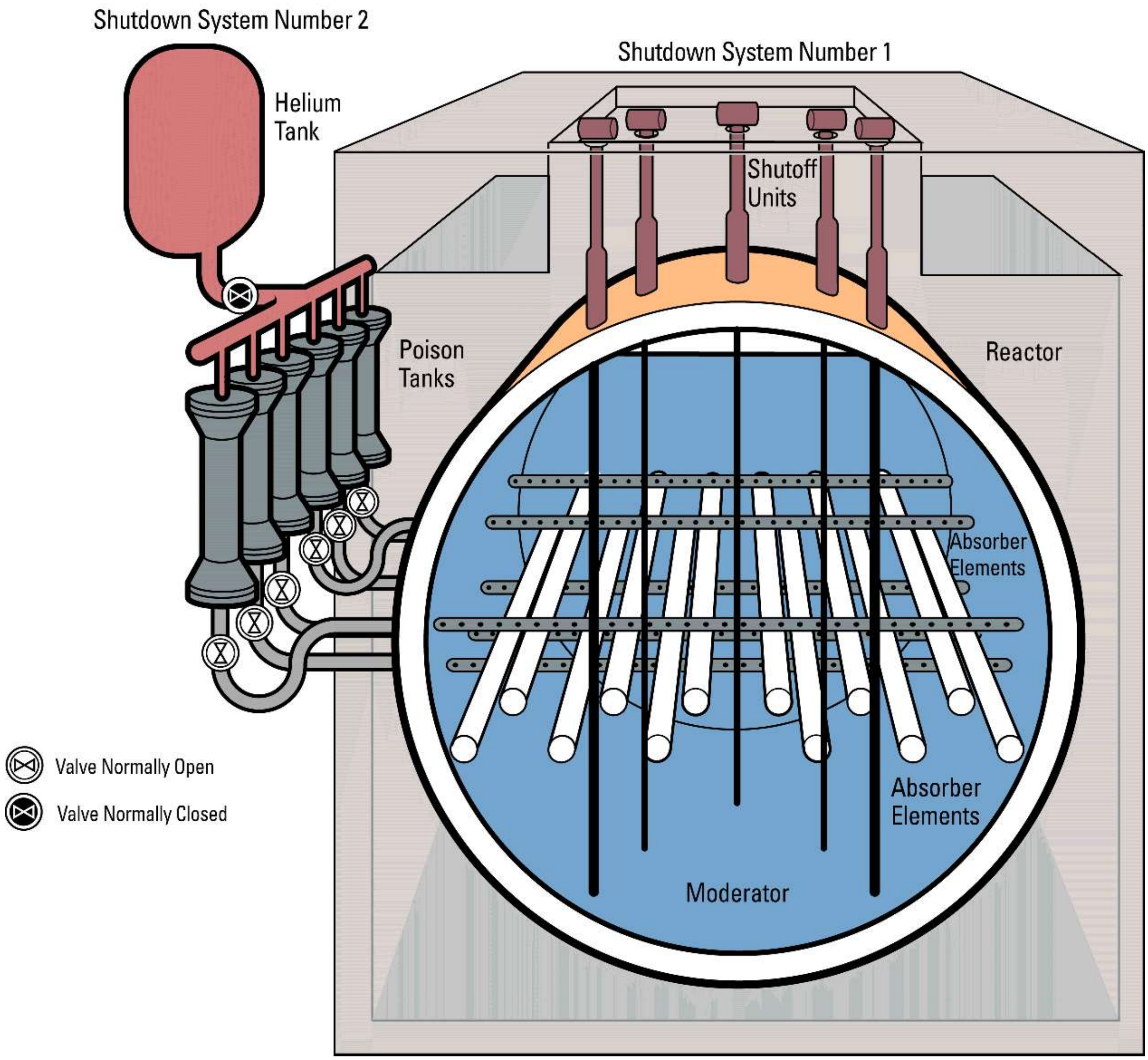

Figure 7: Shutdown Systems of a CANDU 6 NGS

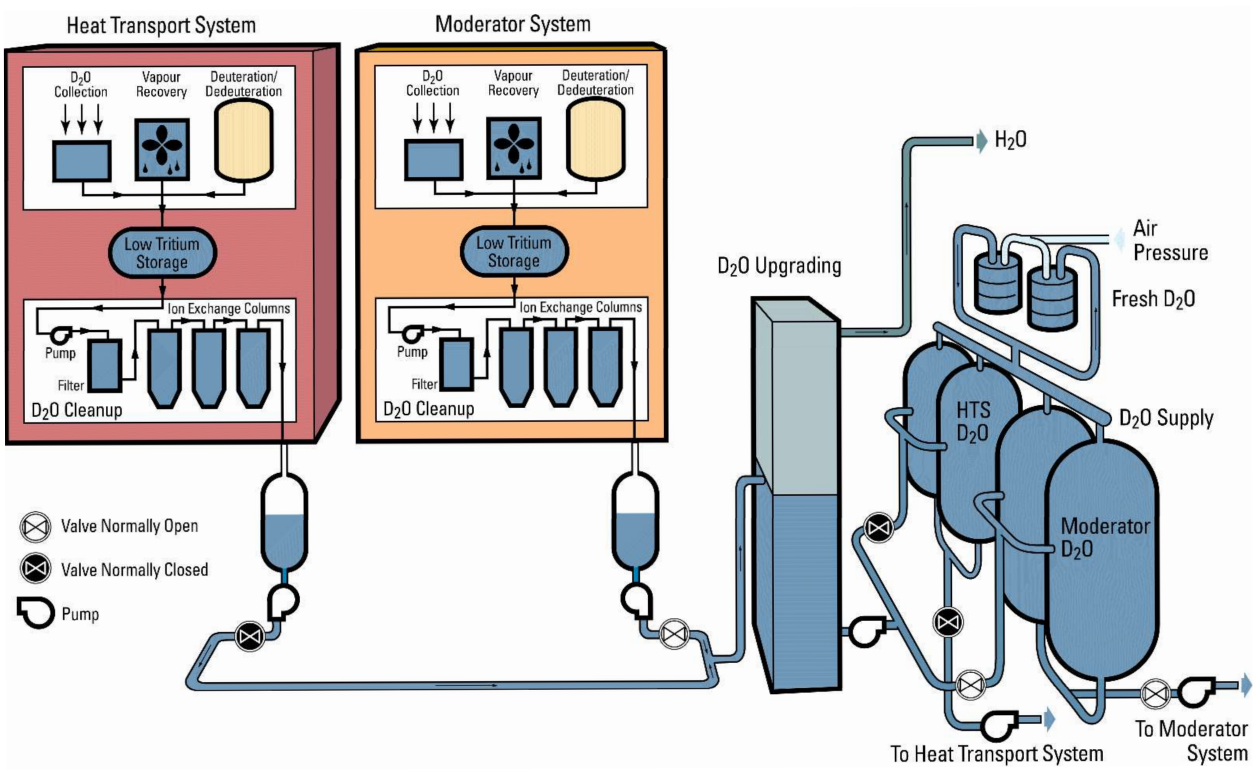

Figure 8: The Heavy-water (D_2O) Management Systems

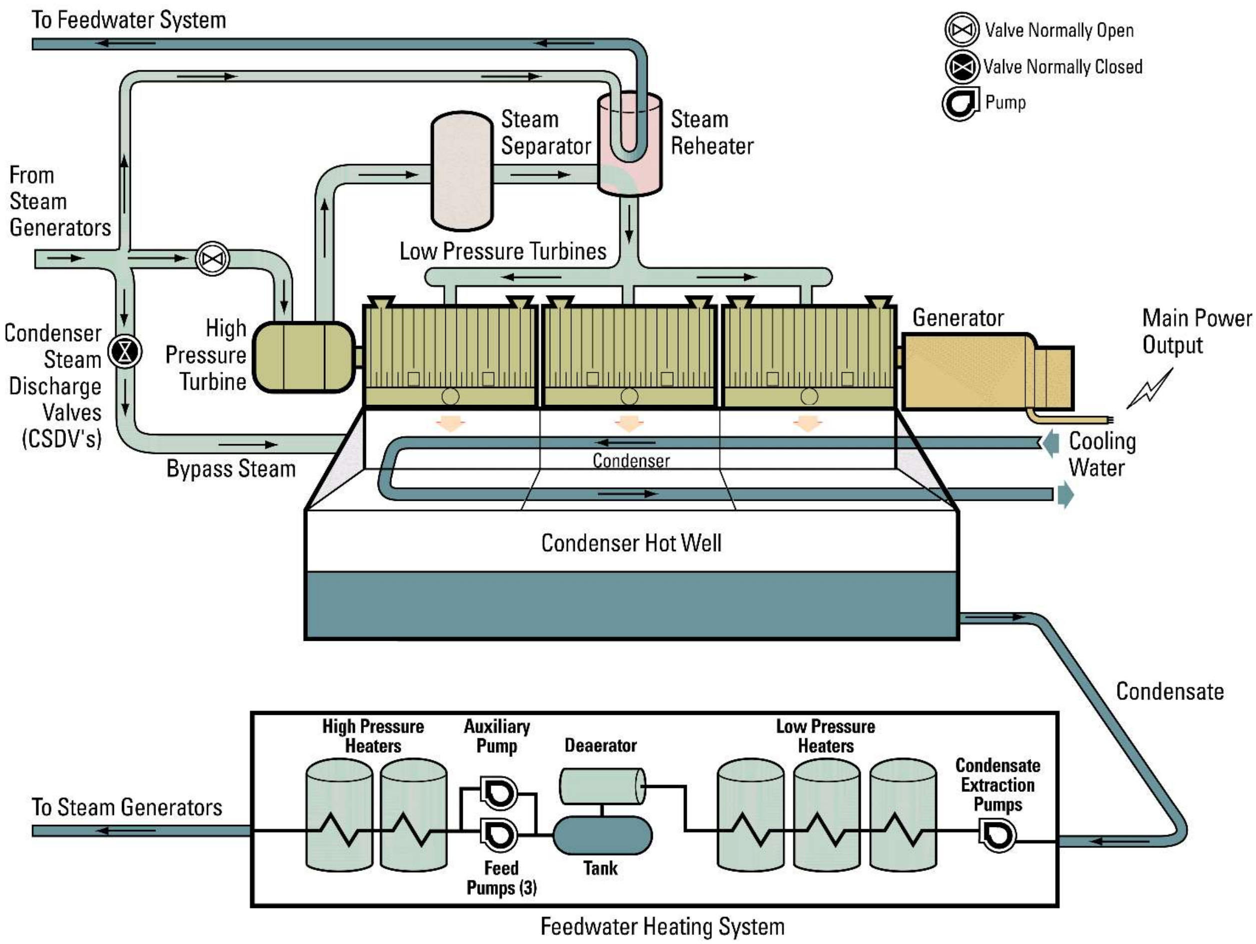

Figure 9: The Turbine Generator System (Steam Turbine, Generator, Condensing Steam and Feedwater Heating System)

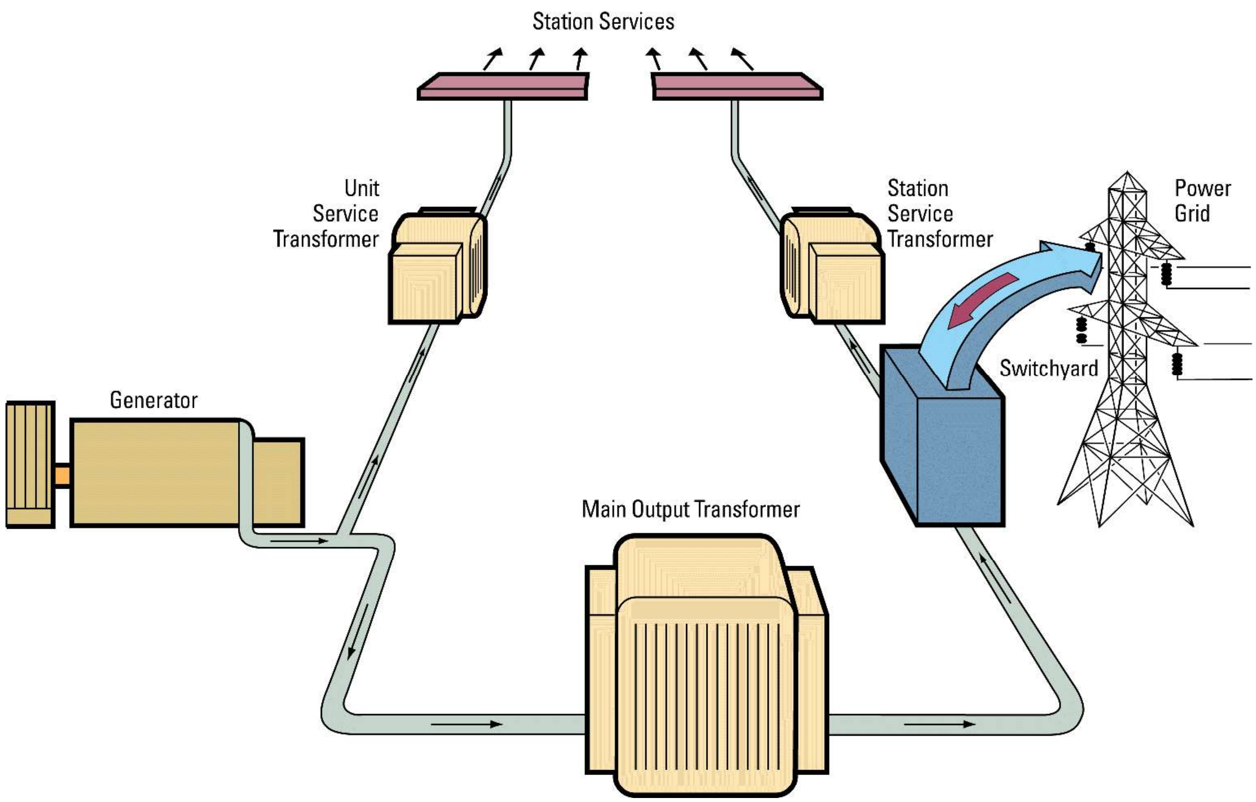

Figure 10: The Electric Power System (Showing the Turbine Generator, Main Transformer, Unit Service Transformer, System Service Transformer and Power Grid)