4 Nuclear Power Plants

4.1 Technology Description

Nuclear power plants are thermal power plants similar to those burning fossil fuels. The main difference lies within the source of heat used to generate steam. In conventional power plants fossil fuels are burned in the boiler to generate high pressure steam that is used to drive the turbines which produce electricity. Nuclear power plants use the heat released by the continuous nuclear fission of atoms in the nuclear reactor. Fission is the process of splitting the nucleus of uranium atoms in certain elements.

There are several types of nuclear reactors. The most common is the pressurized water reactor (PWR) and the less numerous boiling water reactor (BWR). Both types use water as coolant and moderator. Since water normally boils at 100°C, they have robust steel pressure vessels or tubes to enable the higher operating temperature.

Figure 4-1: Simplified schematics of nuclear power plants

Basic fuel is usually uranium dioxide (UO₂), low enriched (3% to 4%) with the uranium isotope-235, arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies which are submerged in the reactor core. The heat value of the nuclear fuel is very high compared to that of fossil fuels. For comparison, the
heat value of hard coal is 29.3 MJ/kg ce (coal equivalent), while that of uranium dioxide is 3,888,000 MJ/kg (based on UO₂ enriched to 3.5% and 45,000 MWd/t burnup in light water reactors, see also 4.1.4).

4.1.1 Main components

The main components of a nuclear reactor are the pressure vessel, the moderator, control rods, the coolant, the containment and the steam turbine generator.

The Pressure vessel is usually a robust steel vessel containing the reactor core and moderator/coolant. The moderator is a material in the core which slows down the neutrons released from fission so that the chain-fission can take place. It is usually water, in certain types of reactors it may be heavy water or graphite.

The Coolant is a fluid circulating through the core to transfer the heat from it to the steam generator. In light water reactors, the water moderator functions also as primary coolant. Power reactors moderated and cooled by water are called light water reactors – LWR. In BWRs, there is a secondary coolant circuit where the water becomes steam.

The Control rods are made with neutron-absorbing material and are inserted or withdrawn from the core to control the rate of reaction, or to halt it.

The Containment is the structure around the reactor and associated steam generators which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any serious malfunction inside. It is typically a meter-thick concrete and steel structure.

The Steam generator, (essentially a heat exchanger – HEX) is part of the cooling system of PWR (not in BWR) where the high-pressure primary coolant, bringing heat from the reactor, is used to make steam for the turbine, in a secondary circuit. Reactors may have up to four 'loops', each with a steam generator.

4.1.2 Nuclear reactors on the market

Several generations of reactors are commonly distinguished. Generation I reactors were developed in the 1950-60s; they are not in operation any more. They mostly used natural uranium fuel and graphite as moderator. Most reactors still in operation are of Generation II. They typically use enriched uranium fuel and are mostly cooled and moderated by water. Generation III are the advanced reactor developments of the second generation with enhanced safety. However,

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13 WNA – World Nuclear Association, Nuclear power reactors
14 WNA – World Nuclear Association, Advanced nuclear power reactors