Practices and Solicitations of Nuclear Reactor Competitive Energy Market with Enriched Uranium

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Abstract: *The nuclear energy generation has raised in technology and engineering since 1976 and today nuclear energy engineering is in high demand to look forward to the future of energy generation. Electricity generation is in the process of generating electrical power from the different resources of energy available in nature case today every appliance is running by feeding electrical energy. So it is a big challenge how the world generates this access amount of energy with the low-cost generation, no dependency on fossil fuel, free carbon emissions, switching the use of non-renewable energy to renewable energy resources which is eco-friendly and clean to run the technology. The world energy need significantly increasing in the future since the demand is increasing about twice as overall energy use and respectively to rise by more than half in the year 2040. Generally, nuclear energy provides over 10% of world energy. And 14% in developing countries. So almost all organizations suggest is increasing the production base up the nuclear generation, therefor related to this task the nuclear reactor is the operational unit which mostly bases on reactor performance. The studies are going on to design such a reactor that uses both the natural and enriched uranium with a high degree of safety and high controllability of reactor performance against natural disasters, maintaining and moderating the fission chain reaction in the combustion chamber, and proper nuclear waste management. This research had been done to understand the nuclear reactor, various technologies based upon the nuclear reactor.*

Keywords: Reactor, Nuclear Energy, Uranium.

1. INTRODUCTION

A atomic power plant is type of thermal-based power generation which the heat sources is a nuclear reactor where the heat is used to generate the steam and generated steam is responsible to drive the turbine in desired speed respectively the shafts of turbine and generator is interconnected and electricity is produced, nuclear power plants are considered as baseload plant where the fuel is a minor part of the price of production and cannot be easily forwarded, their operations, preservation, fuel cost is low so makes as the baseload power supplier as compare to other types of power plant. The nuclear power plant is working on the course of atomic fission to generate electricity by exhausting atomic reactors in combination through the Rankine cycle, where the temperature generated by the reactor converts water to the steam which rotates the turbine and generator. Nuclear base power generation feeds 11% of the world energy need which the largest producers. Nuclear reactors are the most important and functional apparatus of nuclear power where nuclear fission is produced in the form of a controlled chain reaction. Or said to be a controlled chain reaction system supplying nuclear energy-based up burning of nuclear fuel like U^{235}, U^{233} or Pu^{239} in the furnace and produce useful products like heat, neutron, and radioisotope. Commonly there are two types of reactors used in the atomic power plant which is pressurized water reactor (PWR) and boiling water reactor (BWR), a pressurized water reactor as unpretentious as water-cooled and moderated thermal reactor taking an unusual core design, using both natural and highly enriched fuel. Where in the boiling water reactor the only enriched fuel is used, the construction and arrangement of boiling water reactor is simple as compare to pressurized water reactor.

2. NUCLEAR REACTOR FOR CURRENT ENERGY SCENARIO

Atomic reactors are devices aimed to maintain a chain reaction generating a steady flow of neutrons created by the fission of nuclei. There are many kinds of nuclear reactor what is shared to them all is that which produce thermal energy which is converted to the mechanical energy by turning of the turbines and converted to the electrical energy by the generator provided the desired lead center.

The fission of weighty atomic nuclei in which the communal one among the all are U^{235} produces heat that is transmitted to a fluid that actions as a coolant. Throughout the fission procedure bond energy is unrestricted and this first converts obvious as the moving energy of fission products produced and that of the neutrons being released. Since these elements undergo intense declaration in the dense nuclear fuel the stored energy turns into heat energy.

According to fig.1, any reactors are consist of control rods, moderators, core, heat exchanger, fuel rods, which can be discussed in brief further. Every reactor is operated under certain controlled operations in which the controlling of reactors against natural disasters and the uncontrolled fission chain reaction is the biggest challenge facing the technology regarding nuclear energy production.

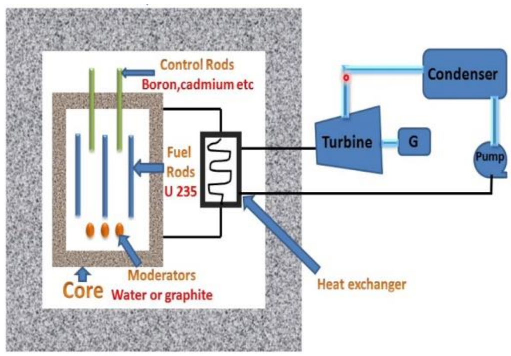

Fig.1: Nuclear reactor diagram

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2.1 Descriptions of reactor types

2.1.1 Pressurized water reactor

Pressurized water reactor in the simplest form is light water cooled and moderated thermal reactor which having an unusual core design, using both natural and highly enriched fuel, the principal parts of the reactor are.

(i) Pressure vessel
(ii) Fuel elements
(iii) Reactor containment
(iv) Reactor thermal shield
(v) Control rods
(vi) Reactor pressurizer

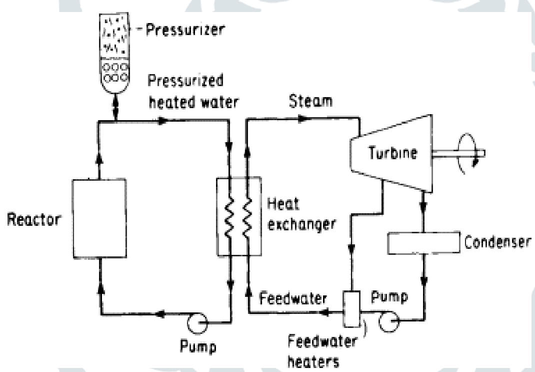

Fig.5: PWR

The component of the secondary system of the pressurized water plant is a simile to those in a normal steam station.

According to layout, the PWR is having two circuits of water, one primary circuit which passes through the fuel core and is radioactive. The primary circuit produces steam in a secondary circuit which consists of a heat exchanger or the boiler and the turbine. Such the system the steam is the turbine is not radioactive and no need for shielding. Pressure in the primary circuit should be high so that the boiling of water takes place at high pressure. A pressuring tank keeps the water at 100kg/cm^3 so that collects in the dome. as more steam is forced into the dome by boiling. The pressure rise and pressurizes the entire circuit. Pressure y be reduced by providing cooling coil or spraying water on the steam.

2.1.2 Boiling water reactor

In a boiling water reactor, only enriched fuel can be used. As compared to PWR the arrangement is simpler the plant can be safely operate using natural convection with the core force circulation the safe operation of the reactor the pressure in the forced circulation must be maintained constant irrespective of the load demand. In the case of the part-load operation of the turbine, some steam is by-passed.

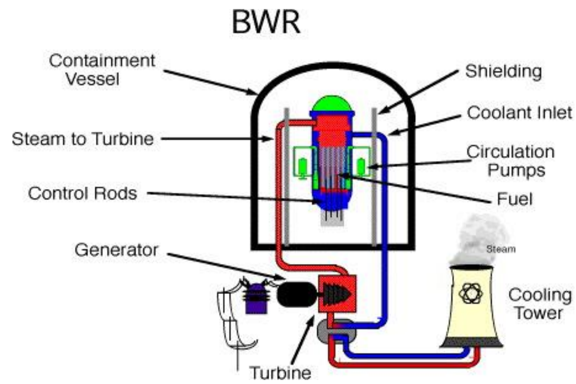

Fig.6. BWR

3. CANDU (Canadian-deuterium-uranium) reactor

CANDU is a thermal nuclear reactor in which heavy water 99.8% deuterium oxide is the moderator, coolant and neutron reflector. This reactor was developed in Canada and being named and CANDU used extensively in this company. As few CANDU reactors are operating or under construction in some other country also.

In this reactor, the natural uranium (0.7% U^{235}) is used as fuel and heavy water as the coolant. This reactor is more economical to those countries which they can produce enriched uranium which enriched uranium is very costly.

CANDU reactor differs from the light water reactor in that in the latter the same water serves as a coolant and moderator, wherein the CANDU reactor the coolant and moderator are kept separate. Consequently unlike the pressure vessel of an LWR the CANDU reactor vessel, which contains the relatively cool heavy water moderator, does not have to withstand high pressure. Only the heavy water coolant has to be pressurized to inhibit boiling in the reactor core.

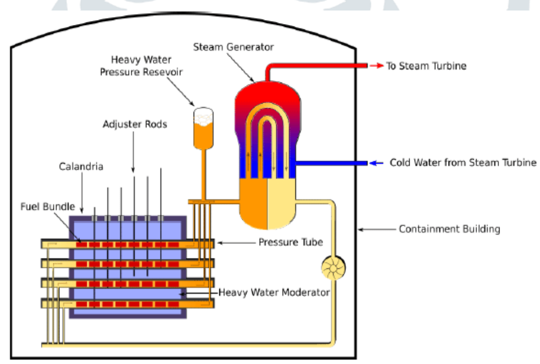

Fig.7. CANDU reactor

3.1 Descriptions of CANDU Technology

Types of vertical systems incorporated in the CANDU reactor.

Several strong neutrons absorb Reactor vessel and core:

The reactor vessel is steel in a cylinder shape with a horizontal axis the length and diameter of the cylinder are 6m to 8m respectively. The vessel is penetrated by some 380 horizontal channels called pressure tubes because they are designed to withstand high internal pressure.

The channels contain the fuel element and the pressurized coolant flows along the channels and around the fuel element for removing the heat generated by fission. Coolant flows in the opposite direction with adjacent channels. The high pressurize 10MPa and high temperature 370 coolants leaving the reactor core enters the steam generator. About 5% of fission heat is generated by fast neutrons escaping into the moderator and this is removed by circulation through a separate heat exchanger.

(i) Fuel:

The fuel in the CANDU is normal fuel uranium oxide as small cylinder pellets. These pellets are packed in a corrosion zirconium alloy tube nearly 0.5 long and 1.3 cm in diameter to perform a fuel the relativity short rods are combined in bundles of 37 rods and 12 bundles are replaced such end to end to each other to each pressure tube. The total fuel in the core is about 97000kg. the CANDU reactor is unusual in that refueling in conducted while the reactor is on an operation.

(ii) Control:

- There are various rods of cadmium which are used mainly for reactor shut-down and start-up.
- There are other less strongly absorbing rods control the power variation during reactor operation and to produce an approximately uniform heat distribution throughout the core

In an emergency the shutdown rods would immediately drop into the core, followed if necessary by the injection of a gadolinium nitrate solution into the moderator.

(iii) Steam system:

- The respective ends of the pressure tubes are all connected into inlet and outlet headers.
- The high-temperature coolant leaving the reactor passes out the outlet header to a steam generator of conventional inverted U tube and is then pumped back into the reactor by way of the inlet header.
- Steam generated at a high temperature of 265'C.

There are two coolant outlet headers. On at each end of the reactor vessel, corresponding to the opposite direction of coolant flow through the core, each inlet header connected to a separate steam generator and pump loop, A single pressurizer maintain the consistent coolant system pressure. The reactor vessel and the steam generator system are enclosed by a concrete containment structure. A water spray in the containment would condense the steam and reduce the pressure that would result from a large break in the coolant circuit.

Advantage of CANDU reactor:

a- Heavy water used as a moderator, which has a higher multiplication factor and low fuel consumption.
b- Enriched fuel is not required.
c- The cost of the vessel is less as it has not to withstand high pressure.
d- Less time is needed (as compared to PWR and BWR) to construct the reactor.
e- The moderator can be kept at low temperature which increases its effectiveness is slowing down neutron.

Disadvantage:

a- It requires a very high standard of design, manufacture, and maintenance.
b- The cost of heavy water is very is high.
c- There are leakage problems.
d- The size of the reactor is extremely large as power density is low as compared with PWR and BWR.

3.2 Gas-cooled Reactor

In such a type of reactor the coolant used can be air, hydrogen, helium or carbon dioxide generally inert gases are used such as helium and carbon dioxide. The moderator used is graphite. The problem of corrosion is reduced much in such reactors. This type of reactor is safer especially in case of accidents and the failure of circulating pumps. The thickness of a gas coolant reactor shield is much reduced as compared to the other types of reactors.

There are two principal types of gas-cooled reactors developed for central station service and these are:

(i) The gas-cooled graphite moderator reactor (GCGM)
(ii) The high-temperature gas-cooled reactor(HTGC)

Both types are graphite-moderated. The former (GCGM) uses natural uranium fuel while the latter (HTGC) employs highly enriched uranium carbide mixed with thorium carbide and clad with graphite.

The coolant pressure and temperature in GCGM are about 7 bar 336'C respective, for HTGC, their figures are 15 to 30 bar and 700 to 800'C.

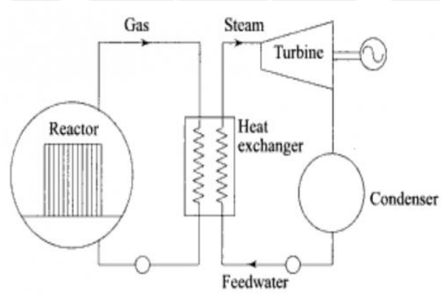

Fig.8: Gas coolant reactor

Advantage:

- The processing of the fuel is simpler.
- No corrosion problem.
- As a result of low parasitic absorption, it gives a better neutron economy.
- Graphite remains stable under irradiation at high temperatures.
- The use of carbon dioxide as a coolant eliminates the possibility of an explosion in the reactor which is always present in the coolant plant.
- The uranium carbide and graphite can resist high temperature and therefore the problem of limiting the fuel element temperature is not as series as in other reactors.

Disadvantage:

- Fuel loading is more elaborated and costly.
- Power density is very low therefore large vessel is required
- Since the critical mass is a high large amount of fuel loading is initially required.
- If helium is used as instead of carbon dioxide the leakage of gas is a problem.
- The more power required the more coolant it is used.
- The control is more complicated due to the low negative coefficient as helium does not absorb a neutron.

3.3 Liquid Metal Cooled Reactor

The sodium graphite reactor is one of the typical liquid metal reactors. In this reactor, sodium works as the coolant and graphite work as a moderator. Sodium boils at 880'C under atmospheric pressure and freezes at 95'C hence sodium is then melted by the electric heating system and be pressurized to about 7 bar. The liquid sodium is circulated by the circulation pump. The reactor will have two coolant circuits or loops.

(i) The primary circuit has liquid sodium circulate through the fuel core and gets heated by the fashioning of the fuel. This liquid sodium gets cooled in the intermediate heat exchanger and goes back to the vessel.

(ii) The secondary circuit has an alloy of sodium and potassium in liquid form. This coolant takes heat from the intermediate heat exchanger and gets heat from the sodium of the primary coolant circuit the liquid sodium and potassium then passes through a boiler which is a once-through type having tube only the steam generated from this boiler will be superheated. Feedwater from the condenser enters the boiler. The heat sodium and potassium passing through the tubes gives it to heat to water thus converting it into steam. The sodium and potassium liquid in the second circuit is pumped back to intermediate heat exchanger thus make a closed circuit.

The reactor vessel primary loop and intermediate heat exchanger it shielded for radioactivity, the liquid metal be handled under the cover of inert gas. Such as the helium to prevent content with air while chagrining of draining the primary and secondary circuit loops.

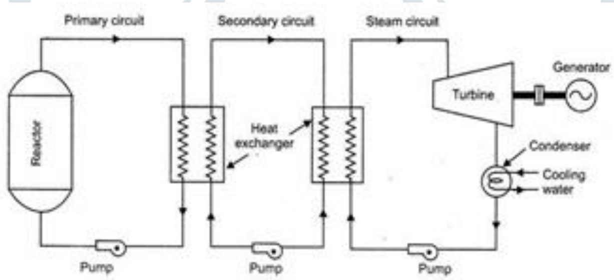

Fig.8: Liquid metal coolant reactor

Advantage of SGR:

- The sodium as coolant does not pressurize.
- High thermal efficiency at a low cost.
- The low-cost graphite as a moderator
- Purity at high temperature.
- Excellent heat removal.
- High conversion ratio.
- Superheating of steam is possible.
- The neutron absorption cross-section of sodium is low.
- The size of the reactor is small

The disadvantage of SGR:

- Sodium reactor violently with water and actively with air
- Thermal stresses are the problem
- The intermediate system is necessary to operate active sodium from the water.
- The heat exchanger must be leakproof.
- It is necessary to shield the primary and secondary systems with the concrete block.
- The leak of sodium is very dangerous as compared with other coolant medium used.

3.4 Breeder Reactor

It is simplest from a fast breeder reactor to is a small vessel which is the necessary amount of enriched plutonium that is kept without using a moderator. A fissionable material that absorbed neutron surrounds the vessel. The reactor core cooled by liquid metal. Necessary neutron shielding is provided by the use of lights water, oil or graphite additional shielding is provided for gamma rays (it worth nothing that when U^{235} is fission it produce heat and additional neutron ifU^{235} is kept in the reactor part of the additional neutrons available after reaction with U235 convert U238 into fissile plutonium

Advantage of Breeder technology:

- The moderator is not required.
- High breeding is possible.
- The small core is sufficient
- The parasite absorption of fuel is achieved.
- High burn-up of the fuel is achieved
- The absorption of the neutron is low.

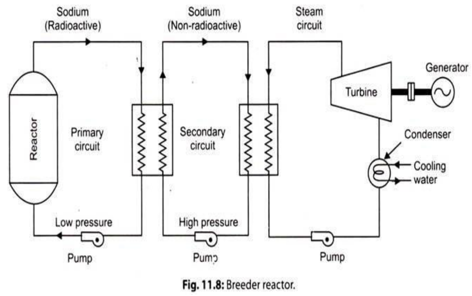

Fig.9: Breeder reactor

The disadvantage of a breeder reactor:

- Require highly enriched fuel.
- It is necessary to provide safety against meltdown.
- The neutron flux is high at the center of the core.
- The specific power of the reactor is low.
- There is a major problem with banding sodium.

4. CONCLUSION

Atomic power plants use atomic fission which is the process of splitting double atoms. And nuclear fusion the procedure of merging atoms into one particle has the latent to be safer but nuclear fusion has not yet been advanced to operate in a large power plant for generation of electricity. Nuclear energy originates from uranium, a nonrenewable source that must be excavated. Every 18 to 24 months the reactor of the power plant necessity shut down to eliminate its spent uranium gasoline, which suits radioactive waste. Atomic power plants generate about 20% of U.S. electricity. Nuclear energy is existence used in more than 30 countries around the world. The contests for today's electricity production can be resolved by generating and employing nuclear energy. The studies are going on to find out the better performance of the nuclear reactor under several phenomena which safety, using natural and enriched fuel, the strength of core against the rays, cooling problem, and effect of natural disaster on the reactor. The latest technologies on reactor types can be listed CANDU reactor, breeder reactor, liquid metal cooled reactor are some of the reactor types which can use both natural and enriched fuel as well as plutonium as fuel for generating the steam.

PWR is the greatest corporated type of atomic reactor representing around (60%) of all nuclear power reactors in the domain, PWRs are successively in countries such as the United States, France, Japan, Russia, and China. These reactors use U^{235} of a normally 3%-4.5% upgraded.

The breeder reactor is the kinds which can use enriched plutonium as fine as the natural uranium (0.7% U^{235}) and enriched uranium (3-4.5% U^{235}) the worth of this reactor is that which is smaller as equaled to the all other machineries also the cost of plutonium is cheaper as of the uranium (natural and enriched type) so the using such machinery is economically.

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