2) In the shielding of cables copper or aluminum sheaths are used, providing a high noise security for the low frequency range from 1 MHz to 30 MHz.

3) Symmetrical cable design is used. Bare stranded copper conductors, located in the outer layers of the cable, are used as a grounding.

Nowadays in Russian Federation the work by the creation of such a type of a cable is at the beginning stage. There is not enough information about using the systems of a variable-frequency drive, the methods and criteria of the resistance to overloads, the ways and means of the protection to a corona discharge. In the course of the project is planned to develop cable products, adapted to work in the VFD with the pulse-width modulation, as well as the recommendations for its using.

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Basic design and common types of nuclear reactors

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This article reviews the construction of the existing nuclear reactors. Due to the fact that in many countries approximately 20% and even more of the generated energy is nuclear energy, the development of nuclear energetics is a priority today.

1. The fission process

Before considering the question about the basic design and common types of nuclear reactors we need to review the physical principles of generating heat and electrical energy by a nuclear power station. Given enough fissile material, such as ^{235}U, fission leads to the production of a self-sustaining chain reaction in which the neutrons arising from a given fission cause another fission reaction, which in turn causes another one and so on. Each fission reaction produces two or three neutrons and with an average of about 200 MeV energy. Since only one neutron is required to cause fission, others are available in excess.

One should note that there are supercritical systems, neutrons progressively increase the rate of fission, which is basic of atomic bombs. However, in a nuclear reactor excess neutrons are often absorbed rather than used to produce more fissile material. In addition, thermal or slow neutrons (kinematic energy of less than 10 eV) are used to support the controlled chain reaction. Absorbing excess neutrons often occurs by control rods and slowing down occurs by the moderator.

2. The components common to most types of nuclear reactors

To begin with, in the core, the **fuel** (uranium, plutonium or thorium) undergoes fission so that a lot of heat is released.

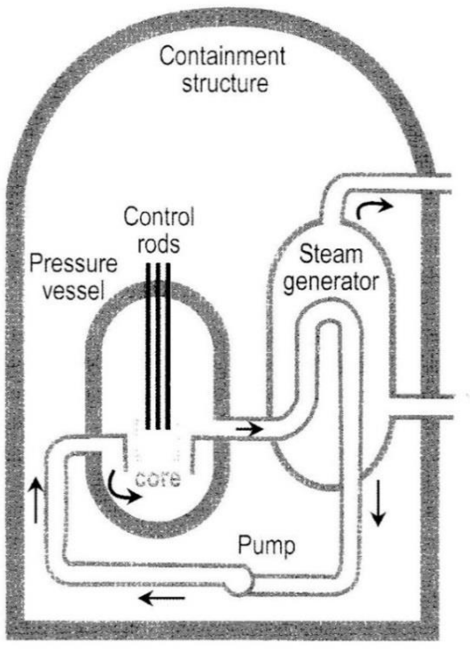

Figure 1. A schematic diagram of nuclear reactor.

Usually it is pellets of UO_2 inserted into tubes to form fuel rods, which are arranged into fuel assemblies in the **reactor core**. A schematic diagram is represented by Figure 1. The next component is the **control rods** made of cadmium, hafnium or boron which are to regulate the rate of the reaction, and therefore heat yield, by absorbing the excess neutrons. The core is immersed in the **moderator** (water or heavy water) and is enclosed in a very thick steel **pressure vessel**. For instance, in a pressurized-water reactor the water, under high pressure, serves both as a coolant and a moderator. In addition, a coolant is a liquid or gas circulating through the core to transfer the heat to a heat exchanger (**steam generator**) where water in a separate circuit is turned into steam, which rotates turbine to produce electrical energy [1.P.28] The process of fission, heat generating and water turning into steam occurs in a big concrete and steel **containment structure**. This component protects the core from outside intrusion and the space around it from radiation.

3. Common types of nuclear reactors.

A pressurized water reactor (PWR) is the most common type of reactors in the world. The reactor of this type was originally designed to drive nuclear submarines.

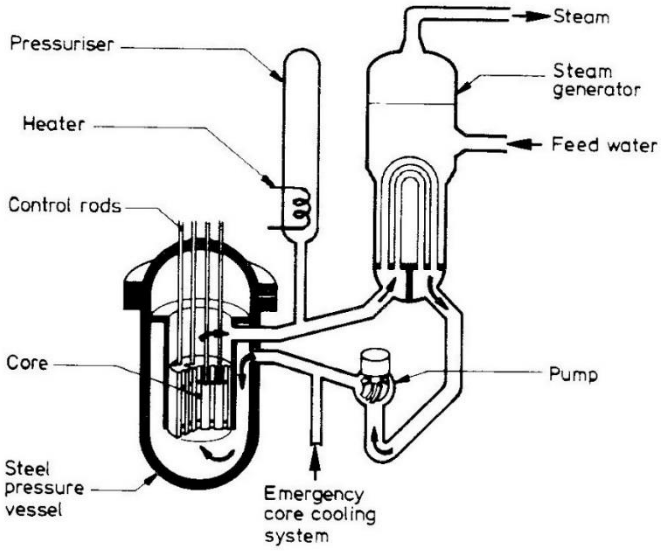

Figure 2. A schematic diagram of PWR.

Electrical energy is generated in the following way: water at typically 150 bars is pumped into a pressure vessel, which contains the reactor core. The water passes downwards through an annulus between the reactor core and the pressure vessel and then flows up over the fuel elements. Then it goes through a series of pipes, which pass to the steam generator. The light water coolant also acts as a moderator for this kind of reactor.

In the steam generator, the hot water from the reactor passes through vertical U-tubes, and water at lower pressure is fed into the steam generator shell and contacts the outside of the U-tubes. Steam is generated approximately at 70 bars, passed from the steam generator into the turbine, and further to the condenser, after the condensate returns to the steam generator through feed preheater. PWRs have typically two, three or four coolant loops. The fuel elements have the form of uranium oxide pellets mounted in a tube made of zirconium alloy. The tubes are mounted in bundles [2.P.43].

From the construction of a PWR, one can conclude advantages and disadvantages of it. The first advantage is the capital cost, which is considerably less than of other types due to the fact that the great reduction of size of the core enormously increases volumetric power density and core rating. The second advantage is that a lot of PWRs can be constructed off-site under factory conditions.

The most significant disadvantage that needs to be addressed is the problem of corrosion on the secondary side of the steam generator. According to some experts this problem can be easily prevented by design improvement. However, the most existing reactors are still prone to the corrosion problems.

A boiling water reactor (BWR) is another type of nuclear reactors (Figure 3), it does not have a steam generator. Water at a pressure of about 70 bars passes through the core, and about 10% of it is converted to steam. Then the steam is separated near the core to move to the steam turbine. The steam from the turbine passes through a condenser, and then the condensate is returned to the bottom of the reactor vessel by a pump system. The fuel elements have form similar to that in PWR and the core power density in a BWR is about half of that in a PWR [3.C.133].

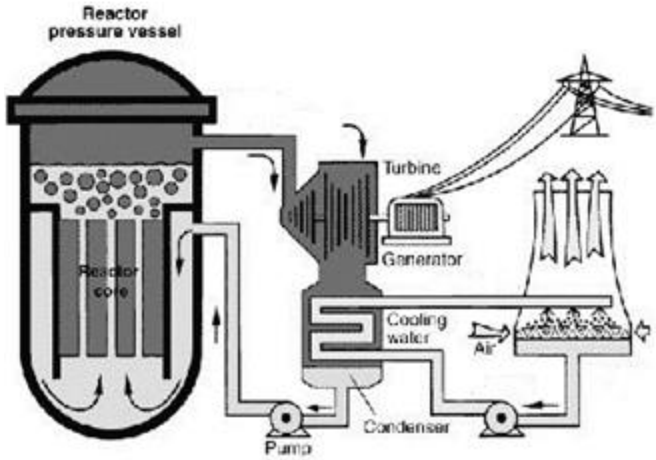

Figure 3. A schematic diagram of BWR

Considering the construction of the BWR one should note here that the most important advantage of this reactor type is the elimination of the steam generator, which has been one of the most troublesome features of the PWR.

Despite the great advantage, the BWR has a few drawbacks. The first one is that a coolant passes through the core where corrosion products may be activated by the reactor neutrons to produce radioactive isotopes, which will circulate around the system. The second problem is that the coolant may transport a small amount of radioactive substances leaking from damaged fuel elements, including rare gases xenon and krypton. So, the reactor must be operated with many external components working in radioactive conditions. The last problem is cracking of stainless steel pipework due to corrosion under the highly stressed conditions. This is similar to the steam generator problems in PWRs. It can be addressed by using a different design approach. **A pressurized heavy water reactor «CANDU» (PHWR) is the type of reactor in which** heavy water is used as a moderator. One cannot deny that PWRs and BWRs require considerable enrichment of the uranium in order to overcome the relatively high absorption of neutrons by the light water coolant. The disadvantages can be overcome by using heavy water as a moderator and either the heavy water or the boiling water as the coolant. If heavy water itself is used as a coolant, it is possible to operate with natural uranium. This is adopted in the Canadian-designed CANDU (Canadian deuterium-uranium) reactors.

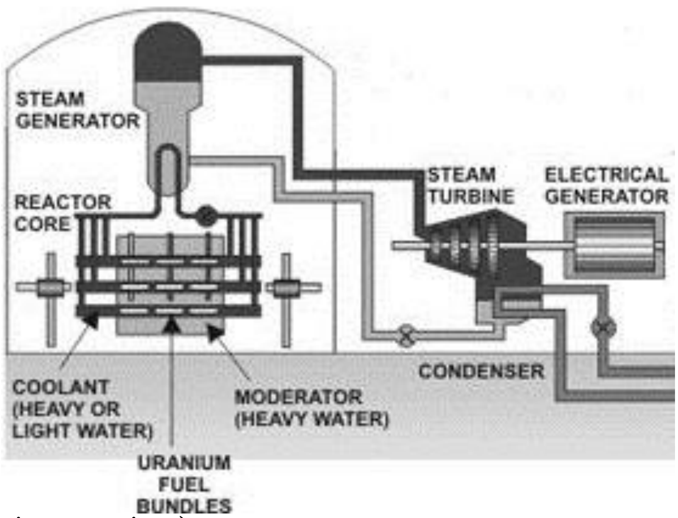

Figure 4. A schematic diagram of CANDU reactor.

CANDU reactors, similarly to BWRs and PWRs, have the massive thick-walled pressure vessel. However, the fuel elements are placed in horizontal pressure tubes constructed from zirconium alloy. These pressure tubes pass through a calandria filled with heavy water at low pressure and temperature. In the CANDU reactor, heavy water coolant is passed over the fuel elements at a pressure of approximately 90 bars. It then passes to a steam generator, which is very similar to that used in PWR. CANDU reactors have not experienced the same steam generator problems as the PWRs. Experts suppose that it happens possibly because of the lower operating temperature [2.P.48].

The fuel elements consists of bundles of natural UO_2 pellets clad in zirconium alloy cans; individual bundles are about 50 cm long, about 12 of such bundles are placed into each pressure tube. Another fact about CANDU is that the average volumetric power density in the core is approximately one-tenth of that in a PWR.

Although the CANDU has operated with remarkable success, difficulties have been experienced with hydrating of the zirconium alloy pressure tubes. Even though it has a lower fuel cost, CANDU needs considerable amounts of expensive heavy water, which makes its capital cost higher. For this reason the CANDU reactor is less demanded than the PWR and the BWR.

Conclusion

It is undeniable that science has been developing fast nowadays. Progress has influenced the nuclear energy: several new nuclear reactors have been designed and built. These reactors are safer but have higher capital costs, which prevents their large-scale exploitation. Despite this fact, experts are convinced that the number of nuclear power plants will increase in the next 50 years and nuclear power energy will be able to compete with other types of energy.

References:

1. Hore-Lacy I., Nuclear energy in the 21st century. World Nuclear University Press, 2010. 133 p.
2. Hewitt G.F., Coiler J.G., Introduction to nuclear power. London, 2000. 304 p.
3. Антонова А.М., Воробьев А.В. Атомные электростанции: учебное пособие. Изд-во Томского политехнического университета, 2009. 275 с.

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Synchronization of Two Induction Motors

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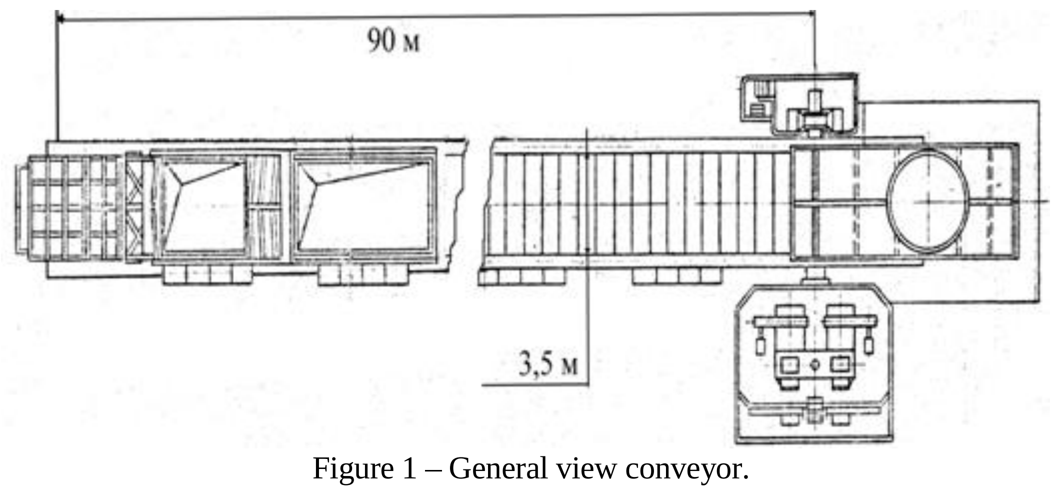

Figure 1 – General view conveyor.

This article is devoted to development of a control system of asynchronous electric motor drive conveyor with two electric motors.