Conference Paper

Project Development of an Underground Nuclear Power Plant on the Basis of the Integrated Ship Reactor, KN-3

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Abstract

In this study, we focused on the development of device module along with the fabrication process in search of alternative energy sources. We tried to show the design basis of underground nuclear power plants. At present, the power supply of remote areas is carried out mainly through gasoline and diesel generators and this leads to high fuel costs and negative impact on the environment. One of the solutions to the aforementioned problems can be the use of modular super low power (50–100 MW) integrated ship reactors.

Keywords: underground nuclear power units, design development, power generation, alternative energy, energy sources

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1. Introduction

The idea of underground placement of nuclear reactors is not new. Underground nuclear power plants (NPP) have not become a rarity since the very beginning of nuclear power development. In the Soviet Union underground blocks of industrial reactors were built in Krasnoyarsk. A number of such power units were built in a land layout. The period of rapid growth in the number of such reactors was abruptly cut off after the accident at the Three Mile Island (TMI) NPP in the USA and especially, after the Chernobyl catastrophe in the USSR. In many countries of the world there is a large number of territories that do not have connections with centralized electric networks. Energy supply of such areas is one of the most difficult tasks. At present, NPPs are used throughout the world as base capacities (varying during the day and depending on the time of the year, electricity needs are provided by other types of power plants). The specificity of the operation of NPPs lies in the fact that their production cycle is practically continuous and does not allow regulating the amount of electricity supplied to the country's power system [1–3].

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Underground NPP setting has some beneficial effects on power industry. In case of underground NPP installation, the high level of protection from external influences can be ensured (hurricanes, aircrafts, bombs, terrorists, etc.). Safety issues are maintained for non-emergency of radioactive substances outside the station as in the case of an accident everything will be located underground. Less funds are needed for physical protection as it is not necessary to guard the entire perimeter of the NPP, but only the entrances to the underground part. Underground NPPs of low power can be placed in abandoned mines or mines, using access roads and infrastructure. Underground NPPs are suitable for mountainous areas (NPPs in the mountains), territories with old mines, or mines.

2. Methods

An underground NPP consists of several components unit. In our study, we focused on the design based on integrated ship reactor of type KN-3. These types of reactors are usually of pressurized water reactor (PWR) kind using enriched uranium-235 fuel to produce 300 MW of power. This kind of power reactor was developed by OKBM Afrikantov. This type of reactor module has significant utilities for power generations. In this connection, construction of underground NPPs with application of ship reactors of KN-3 type with capacity of 50–100 MW is promising. This will make it possible to solve the problem on power supply in the far remote areas, where people have very less access to power generation. Figure 1 shows the arrangement of the main equipment schematically.

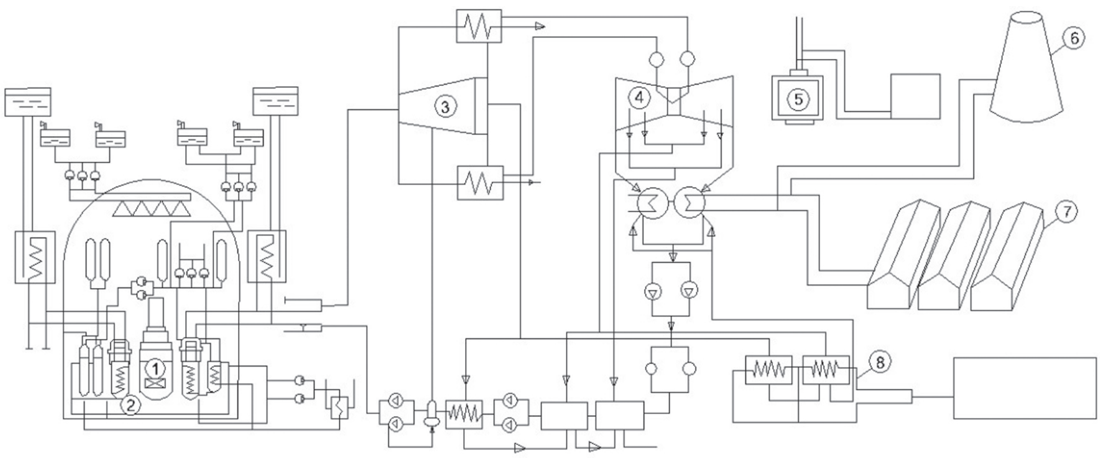

Figure 1: Schematic diagram of reactor settlement: 1 – reactor; 2 – SG; 3 – HP turbine; 4 – LP turbine; 5 – LP turbine top; 6 – hot water pans; 7 – bio complex; 8 – cooling tower.

Most importantly, underground NPP reduces the risk from seismic catastrophe. At least two important facilities are maintained in case of underground NPP compared to the above-ground nuclear power units. First of all, the peak acceleration everywhere below the free surface is lower than it is at the surface. Secondly, the structures on the surface differ in the excavations based on free standing in the interior of a three dimensional solid and reactors can be attached to the wall of shaft to minimize inertial effects [4].

3. Results

According to the opinion of Russian scientists, the construction of a 900 MW underground station is three times shorter than that of a similar NPP; hence, the construction requires much less capital investment. This is due to the peculiarities of the technological solution of their operation. Core design basis has been reported in the Figure 2.

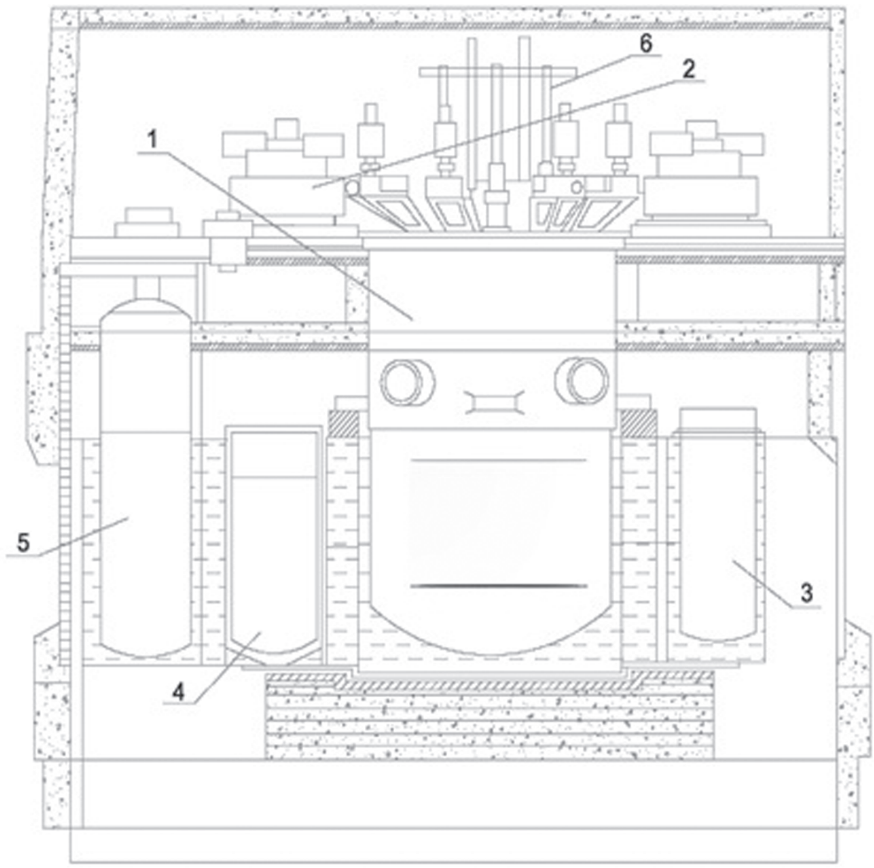

Figure 2: Representation of the reactor core design: 1 – reactor; 2 – electric drive of MCP; 3 – filter primary circuit; 4 – filter refrigerator; 5 – pressure compensator; 6 – CPS drive.

Floating NPP (FNPP) is a series of energetically connected reactors-modules, which are produced entirely in the plant. Such factories exist in Russia, for example, in Saint Petersburg; before they specialized in producing reactors for nuclear submarines. Some changes in the reactor, which are necessary for peaceful operation, are made quite easily. It is important to guarantee the safety priorities for NPP installation. In Figure 3, we showed the five-step safety barriers for reactor unit.

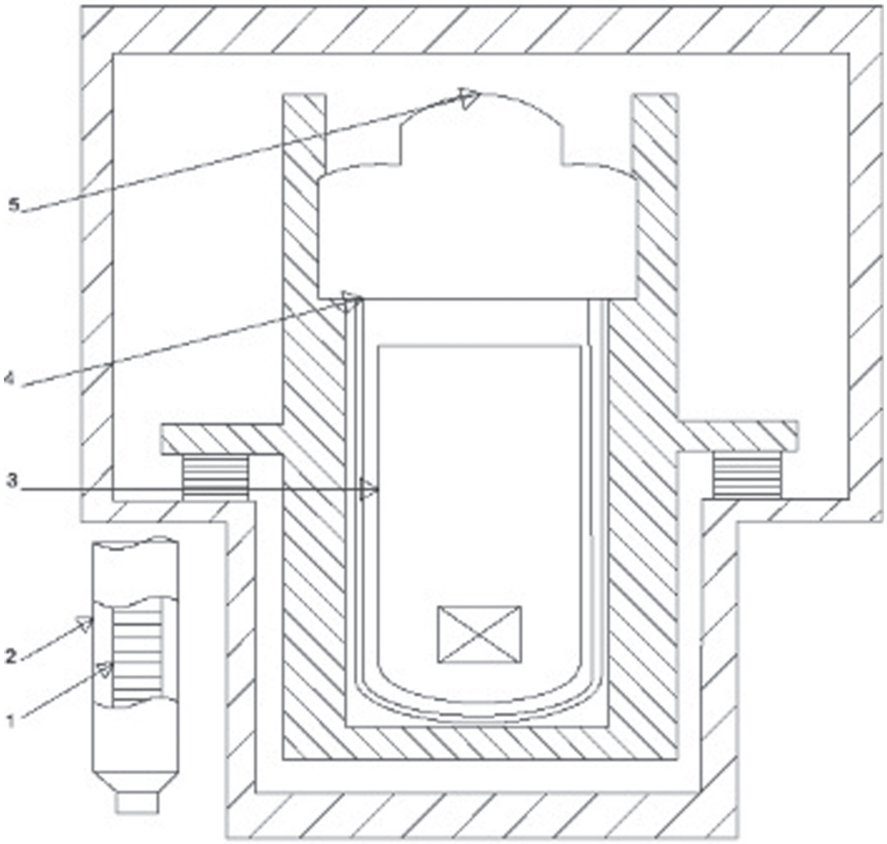

Figure 3: Depiction of protection barriers for reactor unit: 1 – fuel matrix; 2 – TVEL sheath; 3 – reactor vessel; 4 – safety reactor vessel; 5 – protective cap (contact).

Reactor modules are delivered to the site of operation and are simply dropped below the ground to a depth of about 70 meters. To operate the floating NPP, an area of less than 25 hectares is needed, which allows them to be installed almost anywhere. Table 1 presents the aspect of energy policy. When the impact on the FNPP of 32 standard extreme factors was calculated, it turned out that 19 of them (58%) had no influence on the mode of its operation. Among them are hurricanes, tornadoes, earthquakes, and explosions outside the station. Figure 4 demonstrates the main equipment distribution.

The station withstands even of a direct hit of an atomic bomb with a capacity of up to 50 kilotons [5, 6]. In case of bad failure, the chance of accident occurrences reduces due to its underground settlement. Less concrete is needed for the safety barriers, which

Table 1: Aspects of the energy strategy.

Economical	Social	Political
Energy supply of the city	Health of the population	Attention of the RF Government
Energy independence	Ecology	Involvement of the best scientific resources
Wage level	Workplaces	Authority of the Municipal of education in Kushva in the country
Development of new productions	Educational level	International recognition
Reducing the load on environment	Cultural level	Contribution to the implementation
The arrival of the latest technologies	Medical care	

does not allow the cost increase. Watson et al. [7] gave an idea of cost concept in their article stating that the cost penalty of the underground plant is estimated to be less than 10% above a similar surface plant in favorable geologic media. Underground NPPs have also one drawback – they are more expensive, because it is necessary to mount all the equipment not in an open area, but in a rock or in a mountain. The problem of nuclear waste in the case of an underground NPP is less, because all the waste is localized underground. Table 2 presents the perspective comparison of different energy sources.

Table 2: Integral comparison of the different energy sources.

Indicator	Coal	Gas	Wind	Solar	FNPP
Total cost project and source	700 million Rub RAO EAS	270 million Rub MS KUSHVA	–	–	436 million USD Budget RF
Cost of electric power (Rub/kW·h)	1–1.2	0.8–0.9	1.8	3.6	0.7–0.9
Investments in social development of the city (million)	0	0	0	0	46
CO_2 emission (kg/MW·h)	250	190	0	0	0
Annual fuel consumption	600 000 tons	360 000 000 m^3	0	0	28 tons
Installation time, hour	200 000	7 000	50 000	400 000	260 000
Source of budgetary funding	RAO EAS	SVR and MS	MS	MS	RF
Note: *MS-Metropolitan Sector, SVR-Sverdlovsk Region, RF-Russian Federation					

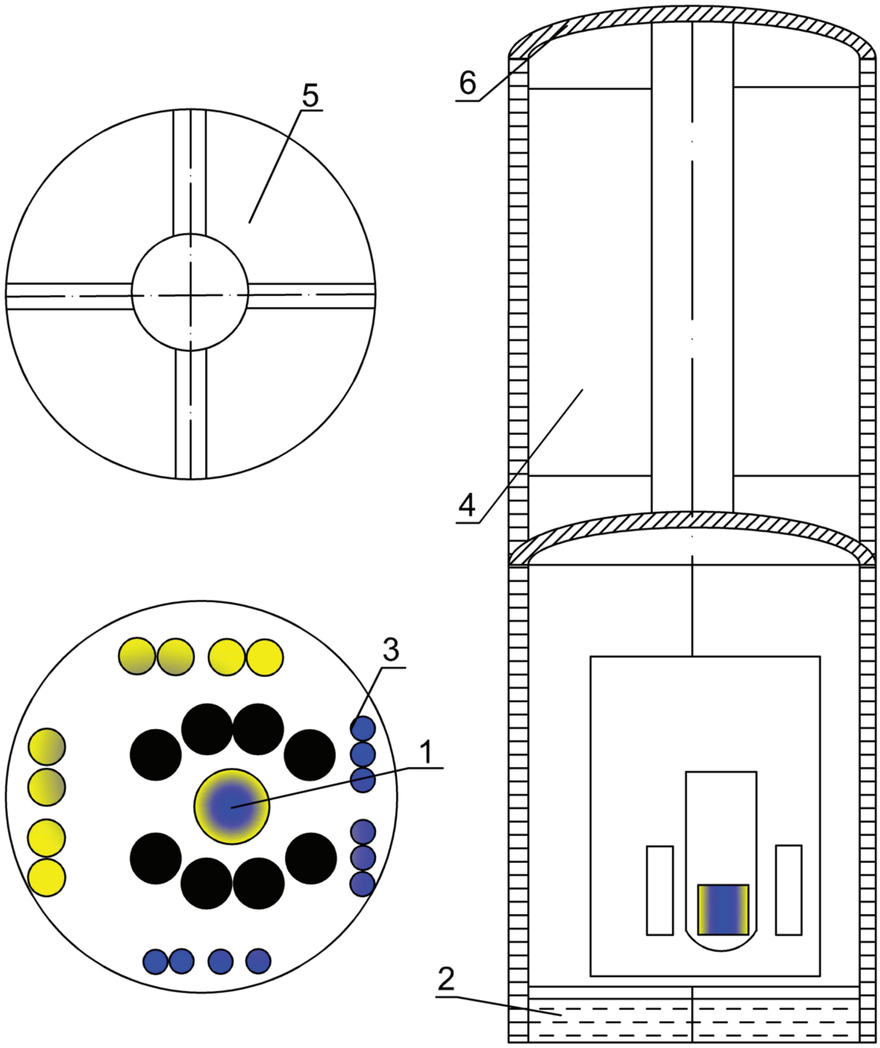

Figure 4: Location of the main equipment of FNPP: 1 – active zone; 2 – exposure pool; 3 – air-tight closure; 4 – pipelines; 5 – reactor cover premises; 6 – hermetic module of nuclear power plant.

4. Conclusion

The design of the reactors allows reliability in sustainable energy consumption. The sluggishness of modern nuclear power plants does not allow reacting quickly to the changes in energy consumption during peak hours. The downtimes of water–water energetic reactor stations are explained by the fuel reset, as well as by routine maintenance to check the reliability of the power units. In case of floating nuclear power plants installed from several reactor modules, the need for shutdown is eliminated, because one module is always in reserve. Recharging and testing of reactors are performed in turn, so that the required power can always be maintained. This allows the underground station with a capacity of 900 MW to produce up to 6 billion kWh annually.

References

[1] Eriksson, O. (2017). Nuclear power and resource efficiency – A proposal for a revised primary energy factor. *Sustainability*, vol. 9, pp. 1–10.

[2] Pinto, S. (1979). *A Survey of the Underground Siting of Nuclear Power Plants*. Swiss Federal Institute for Reactor Research Wurenlingen.

[3] Pashin, V. M., Kopchenov, V. P., Struev, V. P., et al. (1999). Basic provision of technical safety assurance FNPP-300. *Ship Building Technology*.

[4] Varun, P. M. and Fairhurst, C. (2014). Underground nuclear power plants: The seismic advantage. *ISRM International Symposium – 8th Asian Rock Mechanics Symposium, ARMS 2014*, pp. 2797–2803.

[5] Pashin, V. M., Kopchenov, V. P., Struev, V. P., et al. (2000). Initial information to the environmental justification of the pedagogical documentation. *Inv.*, pp. 0402–2445.

[6] Pashin, V. M., Kopchenov, V. P., Struev, V. P., et al. (2000). Preliminary materials on the assessment of the effect of underground nuclear thermal energy on the environment. *Inv.*, pp. 0404–2446.

[7] Watson, M. B., Kammer, W. A., Langley, N. P., et al. (1975). Underground nuclear power plant siting. *Nuclear Engineering And Design*, vol. 33, pp. 269–307.