MEDIUM-SIZED WATER REACTORS FOR UNDEVELOPED REGIONS

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ABSTRACT

In the new century the considerable growth of population and an increase of energy demands are expected. It is important to find optimal ways in solving such problems without the climate warming. The nuclear power having many advantages in comparison with fossil fuel technologies could play the great role in near future.
In the paper the Medium-Sized Pressurized Water Reactors and Boiling Water Reactors for production of electricity, heat and fresh water are considered as a main direction of nuclear power applications in the developing world and particularly in Countries with Small and Medium Electricity Grids.
Mainly an attention is paid on Pressurized Water Reactors designed on the basis of navy technology. Such compact PWR built on special mills and placed on barge as floating NPP could be used in undeveloped regions. Whole plant can be transported to any point of World Ocean and return back to mill after exhaustion of plant potential. It is expected that such reactors with proven design feature, provision of high safety level and proper economic efficiency could be very attractive for isolated regions and developing countries.
Boiling Water Reactors with natural circulation of the coolant, simple chart and easy control could be also interesting for developing countries.

1 ROLE OF THE NUCLEAR POWER IN MEETING THE ENERGY PROBLEMS OF THE DEVELOPING WORLD

1.1 Social and Economic Problems of the Developing Countries

New 21 century was opened by series of awful catastrophes. Destruction of buildings of World Trade Center in New York by terrorist-suicides, gigantic explosion on board of atomic submarine "Kursk", premeditated explosions of dwelling houses in Moscow have displayed new dangers to life. Terrorism now is strategic threat for all countries. Under such conditions the elements of the energetic system have to be considered as a potential source of hazard for industrial and civil objects. Another well-known problem is a danger of climate changes in connection with growth of emissions of greenhouse gases. Such problems as stratification of peoples on a degree of riches, increase confessional contradictions make up also contribution in the burden of complex social and economic global problems of our world.

Since times of Conference in Rio de Janeiro the solution of these uneasy problems is seen in provision of sustainable development of the world at rational use of natural resources and the control over non-proliferation of the weapon of mass destruction. But a mechanics of global environmental control, maintenance of stability of a society to external influences, provision of security from external threats still are not developed in the world community. In particular it is necessary to clarify the role of nuclear power in the solution economic and environmental problems of the world.

From other side, the majority of experts have no doubt, that in XXI century, in process of exhaustion of cheap mineral power resources, the nuclear energy will play more and more important role. Restoration of trust of a society to safe, economically - effective, socially - accepted production of the electric power on nuclear power stations is a business of the near future.

But for realization such possibilities it needs to find the ways of the practical realization of economic potential of nuclear engineering, to solve the problems of non-proliferation, safety and security. The results of our International Conference on the Nuclear Option in Countries with Small and Medium Electricity Grids in Dubrovnik, Croatia might be noticeable in such efforts.

1.2 A State of Small and Medium- Sized Nuclear Reactors (SMRs)

On data IAEA in the world by the end of 2002 441 reactors have been in operation, the accumulated experience has made 10,6 thousand reactor.years. Basically the park of power reactors consists of blocks with the installed capacity more than 300 MWe, placed in various countries basically near to large industrial centers. But enormous territories of developing countries with great mineral potential, a variety of natural and demographic conditions definitely put the question on necessity of development power in such areas, particularly on sites with small systems of energy supply. Therefore use of nuclear power stations with small and medium-sized reactors (SMRs) is considered as the important direction in the decision of power problems of the many countries.

Extensive researches of opportunities of using of small medium-sized reactors in developing countries are carried out in IAEA. Detailed discussions of various concepts of reactors, features of a design, levels of safety, economic prospects of reactors in developing countries are carried out at various meetings.

More than 40 years experience of development of LMR reactors in Russia has shown their big opportunities, has allowed to work off constructive ways and physical methods of achievement of required characteristics of reactors. It is known, that within 60-70 and first half 80th years in the USSR have been constructed some SMR reactors of different type (Table 1 [1]).

Table 1 Nuclear reactors of the low and medium-sized power constructed in the USSR

The name of plant	The type	Capacity of unit MWe/ MWh	Number of unit	The site	Year of start-up
TES-3	pressurized water	1.5/ 11	1	Obninsk	1961
ARBUS	Organic coolant	0.5/ 4	1	Dimitrovgrad	1963
BK-50	boiling-water	50/ 250	1	Dimitrovgrad	1965 in operation
Bilibino	boiling water, graphite moderator	12/ 29	4	Bilibino	1974 in operation

Within 80 and 90th years projects of SMRs nuclear plants for the remote areas have been subjected to the deep analysis and re-making to meet of modern requirements and for the account of safety recommendations of IAEA [2]. However an economic situation in the country and political events of last 15-20 years have not allowed realizing these development

The modern atomic power policy of the Russian Federation is formulated in [3]. In these documents the designing and construction SMRs, including with use of ship technologies, is marked as the important direction of development of nuclear engineering. As specific targets a creation of during 2006-2010 floating combined heat and electricity generation plant (CHEP) in Severodvinsk and ground CHEP for Arkhangelsk are planned. Besides it is supposed to carry out development small NPP the enhanced safety for the remote areas and an infrastructure for their service, a construction of SMRs till 2030, including stationary, floating power and desalination plants.

1.3 Requirements to Small and Medium-Sized Reactors

Developing countries at the development of national economy meet number of difficult problems. There are complexities of crediting of large projects, shortage of qualified personnel and weakness of a technical infrastructure. At consideration of alternatives in development of regions and areas with small electricity grids this specificity determines a set of special requirements to designs of reactor systems of and plants as a whole.
The basic requirement to SMRs is enhanced nuclear safety based on advanced ability to prevent of severe accidents, a high degree of self-protection from dangerous failures of systems and errors of the personnel. Such internal features of plants should be realized due using of natural feedbacks, equipments with passive principles of reaction to indignations, high reliability and tolerance in operation.
Small and medium-sizes reactors should be simple in service and operation, do not demand high qualification of the personnel for their effective utilization. Also important that plants would be ecologically safe at normal operation and at emergencies. For a wide deployment of such reactors they should be well protected against terrorist actions, must be tolerant to external events and should not apply technologies with potential of their use for the military purposes.
The important feature of such installations should be their economic attractiveness based on simplicity of the circuit, small number of capital-consuming elements, cheap transportation and installation of systems, an opportunity of remote control, simplicity of refueling and radioactive waste management. These features should compensate rise of specific cost duet reduction of scale.

The big work on elaboration of requirements to reactors of new generation is conducted in IAEA within the framework of programme INPRO [4].

Shortly SMRs designed as the sources of electricity and the heat have to be:
-inherently safe- be stable, operable, fail-safe, forgive operators errors,
-consist of from transportable components,
-large parts of equipment have to be fabricated on the mills on turnkey base and be delivered on sites by ships, planes or tracks for assembling,
-manageable- be rather simple for control and management, be suitable for remote control and surveillance,
-economical effective,
-to provide a long live of equipment, high burn-up of fuels, be suitable for not very qualified staff,
-to use of proven components and tested equipment,
-accident-resistant,
-able to stop the accident through internal safety features, passive shutdown systems, to reach the stabilisation levels without great overpower, growth the temperatures or pressure,
-the radioactive releases have to be in the strong limits.
Besides such reactors have to be proliferation –resistant.

2 MODERN PROJECT OF SMALL AND MEDIUM-SIZED REACTORS

2.1 Design Approaches for SMRs

Now the whole class nuclear reactors with low and medium power for combined production of electricity and heat with the inherent safety based on use of natural physical laws and adequate methods of designing are offered. These SMRs can produce the electric power, technological heat of various potential in any proportion (including for petrochemical, metallurgical manufacture, desalination, etc.), provide a district heating. Reactor plant can work without refueling of 10-15 years.
Power of SMRs of a similar class (from 1 up to 300 MWe) can cover needs of settlements of any size due to creation of several units on a site.

The reactors should possess the enhanced safety, to allow deterministically to exclude an opportunity of the catastrophic consequences of accidents, not only due failures of safety systems, errors of the personnel or natural events, but also at ill-intentioned actions, influence of explosives (terrorism, a military attack).
The important and determining role in creation of NPPs with immanent safety is played a choice of the coolant of the first circuit. Among various coolants to the greatest degree requirements internally protected NPPs are answered with water under pressure.

2.2 Pressurized Water Reactors for SMRs

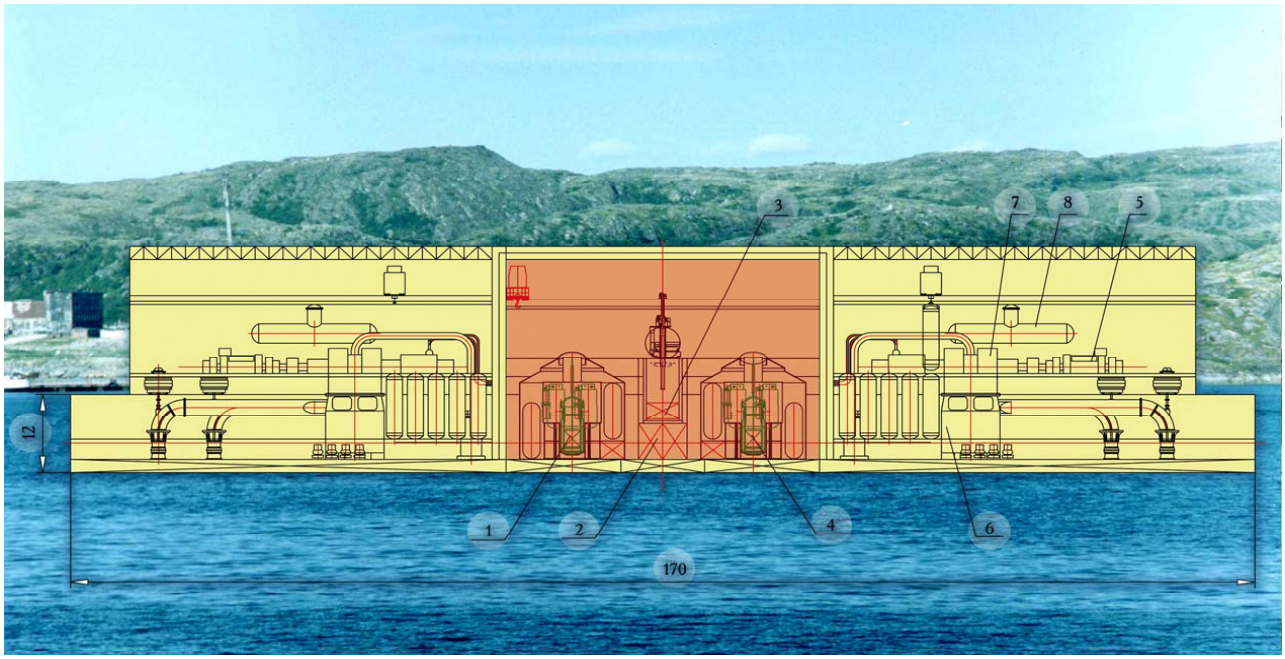
Apparently, a perspective direction at future nuclear power applications in developing countries and the remote regions can become use of the pressurized water reactors, developed on navy technology. As an example of the successful solution of many problems of production of heat and electricity on SNR can serve an actively developed project floating CHP with reactors KLT-40C type. The project of plant with KLT-40C is created on the basis of use more than 30-years experience of development, tests and operation of family of nuclear vessels and ships. Reactors of this type successfully are used on nuclear icebreakers and transport ship "Sevmorput". A procedure of obtaining of the license for construction is now in final stage [5].
Other example of SMRs based on use of navy technology is the project of plant WBER-300 (ВБЭР-300) [6].
All such reactors developed for see transportation, possess the qualities giving to them of advantage in a competition to other nuclear installations by compactness, stability to the shock influences, the proven technology of factory manufacturing practically all components that results in significant reduction of terms of deliveries and commissioning. Besides nuclear plants based on navy design philosophy possess such especially valuable quality, as stability to extreme influences and new threats, including terrorism. Existence of the industrial base and an infrastructure of fleet, experience of designing and operation of units- analogues allow to reduce considerably terms and cost of a construction of power plants.
Use reactors developed on the basis of navy technologies is possible both in a ground variant for CHEP and as power sources for floating nuclear power plants which can be created entirely at the ship-building enterprises and then is delivered in any point of ocean.
The basic characteristics of power units with reactors KLT-40C and WBER-300 are presented in the table.

Table 2. Basic characteristics KLT-40C and WBER-300

The name	KLT-40C	WBER-300
Thermal capacity, MWt	150	850
Pressure in the core of a reactor, MPa	12,5	15,7
Parameters superheated steam Pressure, MPa Temperature, ^{o}C	 3,72 290	 6,38 305

Service life of installation KLT-40 makes 40 years, installations WBER-300 is equal to 60 years.
Cost of constructions of WBER-300 equals 470 million dollars USA.

Block of two reactors WBER-300 can be placed on floating barge. Reactors are situated in the steel containments in central part of vessel. Turbogenerators are placed on both sides.



2.3 Boiling Water Reactors

For many years in the various countries boiling power reactors are used successfully. In Russia almost 40 years a boiling reactor with natural circulation of coolant VK-50 is in operation [7].
Boiling water reactors have a number of features, which make their attractive to regions with low-power supply systems. Many designs of boiling reactor for use in the remote areas are known. As examples projects of plant ВКТ-12 and ВК-300, created in organizations ОКВ “Gidropress” and RDIPE [1]. Для these installations with natural circulation of the coolant, similar NPP BK-50 can serve, simplicity of management is characteristic. High reliability of work of fuel elements results in insignificant radiating loadings for the personnel, population and environment.

3 OPTIMIZATION OF SOLUTION OF POWER PROBLEMS OF REGIONS

In many regions of the world there are places where already now the electric power, heat, fresh water are vital, but reliable power supply is practically impossible and there is no prospect of transfer of energy from energetically provided regions. In such conditions nuclear reactors could be used for production of an electricity, supply of heat and fresh water. An obstacle to this can be only political and economic factors.
As is known, already for a long time ways of providing of steady development of the world are discussed, sharp discussions about a possible role of nuclear power are conducted. Efforts IAEA by an objective estimation of possible power alternatives in national economy of the various countries have great value. Results of the long-term Coordination Project in comparison of various power sources in the various countries (DECADES) in view of economic, social factors and influences on health of people and an environment are submitted in work [8]. In analyses of many experts it is shown, that the nuclear power is a part of optimum strategy of power development of the countries. However it is necessary to expect a sharp competition between various manufacturers of energy. This side of reality is reflected in document IAEA [9] in which growing value of operational expenses in competitive struggle nuclear and traditional energy producers is marked and opportunities of reduction in operational expenses on working NPPs are specified.
It is important to pay attention to necessity of reduction in the insurance payments dependent on probabilities of accidents on NPPs also. A reduction of financial risks is connected directly to achievement of a high degree of safety, development of safety culture and efficiency of actions of operators at control of NPP. It is

known, that about one third of all accidents on nuclear plants arises from the personnel errors. For exception of serious mistakes of operators and reductions in probability of severe accidents are used intellect control systems and effective systems of the help to operators on the basis of new computer technologies.

4 THE CONCLUSION

At the solution of problems of power supply of the remote regions having small electricity grids, it is expedient to use the power reactors created on navy technology having properties of guaranteed safety, ecological compatibility and attractive enough from economic point of view.
Such plants possess sufficient stability to extreme influences and threats. Apparently, such installations could be created on a leasing basis at active support of the interested states.
Nuclear boiling water reactors with natural circulation of coolant also are perspective type of reactors for the remote regions.

REFERENCES

1. Proceedings of the International seminar “ Small power. Results and prospects ”, Moscow, Russia, October, 10-11, 2001.
2. Seminar on Small and Medium Sized Nuclear Reactors, Lausanne, Switzerland, August 24-261987, Nuclear Engineering and Design v.109 (1988), p. 1-397
3. Programme of nuclear power development of the Russian Federation for 1998-2005 and for the period till 2010, Strategy of development of nuclear power of Russia in the first half of the 21st century, Moscow, the Ministry of the Russian Federation for atomic energy, 2000.
4. Guidance for the evaluation of innovative nuclear rectors and fuel cycles, (INPRO), IAEA-TECDOD-1362, IAEA, Vienna 2003
5. Makarov V.I., Pologih B.G., Hlopkin N.S., etc. Experience of creation and operation реакторных installations of civil courts, the Atomic energy, that 89, вып.3, 2000
6. Ponomarev-Stepnoj N.N., Kirushin A.I, Kvasha N.I., etc. Atomic power stations with reactor unit WBER-300 (ВБЭР-300), Magazine of the Nuclear Society of Russia № 6, 2002
7. Osmachkin V.S., Sokolov I.N., A potential of boiling water power reactors with a natural circulation of a coolant, 5-th Regional Meeting on Nuclear Energy in Central Europe, Terme Chatez, Slovenia, September 7-10, 1998
8. Case studies to assess and compare different energy sources in sustainable energy and electricity supply strategies, IAEA-TECHDOC-1370, Vienna 2003
9. Developing an Economic Performance System to Enhance Nuclear Power Plant Competitiveness, Technical Reports Series № 406, IAEA, Vienna 2002