ECONOMIC EFFICIENCY OF "NUCLEAR CELL MARS" WITH REFERENCE TO DIFFERENT REGIONS WITH THE ACCOUNT COGENERATING PRODUCTION

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ABSTRACT

The popular belief in a low economic efficiency NPP with nuclear reactors of small capacity (SNPP) is stipulated by the stereotyped approach to their role as a power source (PS) and absence of a system approach to an estimation of their role and place in economy of regions.

Actually, the specific expenses of installed capacity for SNPP can be some times higher than those for ones with high-power reactors.

As a rule, pay back of the SNPP projects is justified proceeding from only the income of sale produced electric power and heat. Poor economic efficiency of such variant of use forces the developers to consider variants cogeneration of useful production, for example, power-desalination complexes.

But thus it is not taken into account, that only nuclear power source (NPS), due to quality of long-term autonomy can ensure in hard-to-reach regions ecologically safe, practically unbounded on time, reliable energy provision of unique production manufacture, which can be yielded only in a sectional place and due to presence of reliable and ecologically acceptable power supply.

Examples of such exclusive symbiosis of technologies can be enough, especially taking into account the factor of an ecological acceptability, which acquires the increasing weight at definition of competitiveness of the projects.

The factor of uniqueness at technologies combination in a sectional context does not contradict the strategy of seriality small capacity NPS application, as they are irreplaceable for long-time and reliable power supply of the independent removed or hard-to-reach consumers. In this their special applicability and their specific energy niche, which not busy while by any another PS. On land their role is similar nuclear submarines, which thanking NPS have got completely other quality of autonomy in the discharge of underwater kettles.The territory of Russia on the area both variety of resources and manufactures allows to implement different variants and combinations of cogenerated technologies of SNPP energy and production, switching and on the first sight exotic.Thus, the apparent conflict between high specific expenditures of the nuclear power supply projects for the removed consumers and its energy, ecological and social usefulness can be primely authorized by methods of the system economic analysis.The optimum economic rebound is possible at embodying the projects nuclear-power-technological complexes, in which SNPP delivers energy of necessary views, and conjugate manufacture produces production (goods?), which or in itself has high consumer value in different regions (seafoods, gold, mine concentrates etc.), or is extremely necessary for sectional region (foodstuff, motor fuel). It is actual both for again mastered regions, and for the existing occupied items, (since the people in far settlements can not sit without business at all even with heat and at a bright bulb!). The economic efficiency in such case should calculate for the whole isolated region not only in view of expenditures for energy production, but also in view of the incomes of embodying production, yielded with its help. It some kind of "the system" price of a yield and ensuring power source. NPP should correspond to the safety level and the requirements of autonomous operation. Therefore, for power-technological complexes the reactors of other breed are needed. The reactor MARS (ISTC №3012) is one of them.

1 INTRODUCTION AND MAIN CONSIDERATIONS

Serious orientation toward innovation development of economy is a path of Russia to postindustrial world.

From all widely used nowadays power carriers only uranium has no «double application» in other industries as raw material. Besides, organic fuels have also higher export potential.

Uranium is not used for peaceful purposes anywhere, except as fuel in nuclear reactors for heat and electricity production.

The principle of reasonable use of fuel and energy resources is the fact that it is necessary to apply each type of power carrier there, where it is irreplaceable or unique. In other words, organic fuel is for organic synthesis and uranium is for energy production.

Therefore, even pumping of petroleum and gas is more logical to realize not using burning of more than 10 % of pumped raw material, but to do it using a nuclear reactor. In this case nuclear energy is used by its purpose, and organics is used by its. Hence, there is excluded useless burning of organic fuel and ecology degradation of environment.

The available deposits are more and more depleted and it forces miners to another areas: on offshore deposits, into hard-to-reach water-logged and frozen grounds.

Hydrogen power engineering, hydrogen techniques are the technologies of near bright future for mankind not only from a view of manufacturing processes and ecological transport, but also for high power engineering.

It is simple and familiar to get hydrogen from natural gas, as it is made now, certainly, but …! It is not enough that its stores are limited, it is still the only feedstock (together with oil, certainly) for production of organic synthesis.

There is one, practically not limited opportunity to get hydrogen – to get it from water. Hence, we need energy and there is nothing ecological reasonable for it but nuclear energy in the near future.

One more problem of world-wide importance, which can be solved by nuclear power engineering: mankind supplying with sweet water. According to the data of world-wide organizations (UN, UNESCO etc.) the governments and scientific community have realized that drinking water at nowadays consumption, structure of use and contamination can become critical resource "development stability" for regions and industrial agglomerations.

According to UN estimations the one fifth part of Earth population has no normal water supply and this share will be increased proportionally to the population growth. The wilderness and arid regions of Asia and Northern Africa are subjected to this problem.

It is known, that deficit in drinking water, energy, mineral resources can cause conflicts (political and military). It becomes obvious, that shortage of sweet water can cause the same international conflicts, which arise at revision of oil patches.

The quantitative and qualitative estimation of water resource and prediction of its decrease dynamics suppose searching of regulation mechanisms, techniques for its use. The main task to solve these problems is estimation of ENERGY USE in water consumption. Position in principle is: whether it is favorably to use hydrocarbon fuel for water preparation processes, distribution, quality recovery of used water?

The sweet water is the main factor of stable development. In the places, where it is cannot be received from natural springs there is a need of desalination of marine and mineralized underground waters.

Desalination is high energy process, for which different sources of low-grade heat, including solar, or electrical power can be used. The choice depends on cost indexes of desalinated water and fuels availability.

According to our estimations by 2050 in a World it is required to product annually as minimum 35-45 109 m3 desalinated water. The primary energy expenditures for this purpose will make 72-128 million ton of equivalent fuel .

Ecological problems are stand in one row with energy estimation. On global scale they will become isolated on heat balance condition of the planet, i.e. they become boundary conditions, that should not be crossed at any circumstances.

Economical estimation of different ways for water supply problems solution is hardened not by awkwardness, but due to variety of requirements in places of consumption and supply opportunities. For example, ecological and energy efficiency of solar energy (including accumulated in coal, oil, gas) and nuclear power engineering are completely different.

It becomes more obvious that for water desalination problems in any perspective we should orient by restored power sources, in particular solar and nuclear. The last one can be used as restored, in view of known reproduction property of new nuclear fuel in reactors-breedings.

In this field there is a widest field of application for autonomous nuclear power installations.

The nuclear power installations are good because they that can work independently both outside of power grids, and in their composition. The modern developments have a campaign from 10 till 60 years. Thus the power level of nuclear installation can be selected practically in any interval from 1 up to 50 MWe.

The task is to use the unique consumer qualities of nuclear energy sources in full.

It is considered, that SMR are economically unprofitable. It is reasonable without taking into account their qualitative parameters and special consumer purposes. There is opinion about high capital outlays for SMR as compared to high power installations (NPP of power 1000 MWe) and this matching is considered valid. However, there is no similar comparison for cost of kWh spent in watch cells and ordinary irons.

This example is taken specially to show that SMR are considered as «nuclear cells» for remote and semiarid regions.

Most vivid example of adequate application for small reactors is atomic submarine. In this field the advantages of nuclear power installations are shown in full: fuel with high specific energy-conversion efficiency, long service life of nuclear power installation and absence of service materials. The sufficient power of installation gives submarine a long autonomous life and even relative "comfort" for all systems. At the present atomic submarines become dominant of oceans instead of shore diving due to nuclear power installation on the board.

In the near future SMR should have similar role on land.

In Russia there is one of the widest experience in the field of nuclear installations of small power for submarines.

In the world, especially in Russia, there is a lot of territories with decentralized energy supply, where fuel delivery is very complicated and expensive. This fact suppress development of the regions. First of all it concerns regions of Russian North.

The energy sources of long-term service life of the following (fifth) generation of nuclear power reactors have to be used for these regions. These energy sources are SMR of perspective construction (nuclear cell), the development of which is carried out by the experts of RRC KI.

Why are these projects “perspective" and «under development»?

Because the existing installations are not in a category of nuclear cell.

The advantage of small reactors is the possibility of use of another approaches and design solutions that are unacceptable for high-power reactors. Hence, such reactor installations do not require many engineering systems.

Another advantage of SMR is smaller risk of investments.

The reactors of such class are already patentable on international level. It means, that other power sources with such level of self-sufficiency, reliability, mobility, safety, efficiency do not exist yet.

Technical and economic assessment carried out for, for example, KLT-40, that product electric power and heat (even together with desalination complex) show a long time of payback for such designs.

Let’s use methods of «system approach" to economics of small nuclear power engineering.

Let's consider a deleted region, where the inhabitants have hard life. However, in this place there is a resource basis of mineral, ore raw, etc., which can be used for manufacturing of unique products, but it can be implemented only if there is energy source, in particular, NPP.

In this case economics of such isolated region should be evaluated not separately (electrical power -heat-products), but jointly. Such cogeneration of unique products will change in considerable economical indexes. It should be noted, that the production in this place could not be realized without the help of NPP.

But NPP should correspond to the safety level and the requirements of autonomous operation. Therefore, for power-technological complexes the reactors of other breed are needed. The reactor MARS (ISTC №3012) is one of them.

Small Power Reactor on the base of micro-particles fuel elements with molten salt coolant

and gas turbine heat conversion system (MARS-GT).

This inherent safety reactor concept is based on advantages of molten salt coolant and of kernel fuel as:

- one phase, fire-safe coolant with high freezing temperature
- radiation resistance coolant and chemical inert to water and air
- coolant natural circulation
- low pressure under high temperature
- spherical micro-particles fuel elements has three PyC - claddings and SiC one

MARS-GT Power plant has high ecological and economical characteristics due to gas turbine second circuit with air coolant.

The principal part of this concept: reactor lifetime is equal to core lifetime – more 15 years.

MARS-GT designed on the base of experienced in the world techniques: kernel fuel of reactors Peach Bottom and Fort St. Vrain (USA) and more then 30-years Russian experimental validation of HTGR-type reactors (VGR-50, VGM, VG-400).

Characteristics	Data
Thermal reactor power, MW	13,5
Electric power, MW	5,0
Net heat efficiency coefficient , %	37
Coolant temperature inlet/outlet, °Ñ	550/750
Core: diameter/height, m	3,0/3,0
Spheric fuel element diameter, mm	60
Fuel burn up, GWd/t	98
Power density, MW/m3	0,637
Fuel campaign, years	15

As an example, we shall esteem usage of a reactor MARS for wastelesstess of waste-handling of ocean water and with reference to requirements of. Ust-Kamchatsk (Russia).

In coastal areas with a deficit of sweet water on the base of wastelesstess treatment of ocean water, except for sweet water a broad gang chemical products and fertilizers including for hothouse facilities and restoring of desert lands. The examinations held by the Brazilian specialists have shown a reality and practicality of a system approach to an estimate of an economic efficiency nuclear energy-technology complex.

The complete expenditures on a demonstration energy-industrial complex working 30 years will make ~ 30 millions $. The complete income for 30 years of maintenance will make ~ 150 millions $ in the modern prices. The economical indexes for some sorts of commodity manufactured energy-technology complex in a settlement on 500-1000 inhabitants are reduced in tab.

With reference to requirements of. Ust-Kamchatsk (Russia) the integrated annual volume of production of hydrogen on collapse of energy of reactors MARS evaluated. Usage of electrolytic baths of different types at expenditure 50 millions кw hour/year of "free energy" allows turn out 8-10 millions нм3 of hydrogen. A sectional amount it is enough for substitution 2-3 thousand т of gasoline for a urban transport.

Table 1. Technological parameters energy-technology of the module with installation wastelesstess of waste-handling of ocean water

Production	Application	Annual production	Price, $	Profit in year, million $
Electricity	domestic, industrial and agricultural	7000 000 kWh	0.08	0.56
Sweet water	potable water and engineering for an industry and agriculture	1100000 $м^3$	1	1.1
Sodium salt	a food and chemical industry	25000 т	50	1.25
Sulphate of a sodium	production of a glass and mineral fertilizers	4000 т	60	0.24
Carbonate of magnesium	alloys of magnesium special ceramics, electroinsulators and brick	5000 т	300	1.5
Sulphate of calcium	building materials	1200 т	40	0.048
Potash fertilizers	microfertilizers, restorers of soil, manufacture of simulated soils, zeolites for intensive agriculture	4000 т	60	0.24
The total annually / for 30 years, million $		4.938 / 148.14		

Examples such cogenerative of energy-technological complexes in deleted or hard-to-reach regions (apart from domestic security by a heat and electrical power) can become:

- Trusses of a seafood on coast(littoral) of northern seas having in high potential of bioefficiency (to provide illumination, preheating, production of forages);
- Desalination complexes with a complete salvage of return brines for production chemical products and mineral fertilizers for support agriculture on reclamate and dewed infertile soils;
- Production of hydrogen on placers and ore deposits for needs of the transport, ore cleaning and waste-handling;
- Oil still plant on unpromising, from a point of view of customary techniques, fields of heavy hydrocarbons, not accessible without special primary waste-handling in place .;
- Etc.

2 CONCLUSIONS

The majority of the specialists does not doubt of necessity of wide area implementation of kernel power engineering in fuel and energy now any more. It is no doubt and that to it the special structure with an infrastructure for global safety (closure of all cycles) should be provided.

It is necessary a question how to begin to realize this scale and indispensable structural in modern Russian "market" requirements (and market generally), when the large and long-term enclosures of resorts in energy quadrant are indispensable, but for the state them are not present; other investors miss and it is necessary to take into account a pitiable state of the basic machine-building enterprises?

The exit again is, and it consists of making a web NPP low-power, the instant necessity for which one is felt already for a long time and in many northern and eastern locales of our country and many locales of a world. On system nuclear power engineering of low powers it is possible to simulate and "calibrate" structure large nuclear power engineering .

This « the heavy flywheel » is possible to attempt to move off from the rest at the expense of a reasonable application concerning small efforts in the special critical points. And such “points "of application" can become isolated industrial complexes on the basis cogeneration of energy and commodity.

So, on a pioneering stage of implementation small NPP in market requirements, when it is necessary to demonstrate not only them « physical necessity », but to demonstrate "by money" competitive strength, it is necessary to try to find such "«points" on a map, in which one nuclear power installation of low-power will allow to realize « industrial breakthrough » (engineering, technological, social and etc.}. I.e. it is necessary to give in "point" energy, and with its help production by useful and indispensable for “here -and-now" commodity or unique, having warranted demand in other regions.

Such line of the nearest development nuclear power engineering really is escaping of many existing as of today inconvenient situations, such, as:

- The hazards (financial, radiation and man-caused) from small NPP are incomparably lower, than in case of large generating sets and « the club of the investors » can be added up even and from the private persons or regional legal persons (at the suitable solution of questions of the property);
- For atomic power engineering and machine-building branch it will be the factor of saving of a material and technical base, techniques, regular personnel and research and development potential of branch in adding up requirements of stagnation of atomic engineering of major powers.
- It "small-scale" model (point of growth) for test and architecture hereinafter of complete structure atomic power engineering of major powers and scales.

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