DEVELOMENT OF NUCLEAR ENERGETICS IN LATVIA

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RESEARCH IN THE USE OF NUCLEAR ENERGY

The first serious investigations in nuclear physics started at the Institute of Physics, Latvian Academy of Sciences, in the early 1950-ties. Both theoretical and practical tasks were solved which were “secret topics” at that time. The results obtained during the research were not applied directly in nuclear energetics.

At the end of the 1950-ties the Latvian scientists gained remarkable achievements in the application of radioactive isotopes and nuclear radiation. In 1958 the USSR Council of Ministers gave a permission to build a typical research nuclear reactor (IRT) in the vicinity of Riga. It agreed with the initiative of Igor Kurchatov (Head of the Moscow Institute of Atomic Energy) about extensive construction of scientific reactors, as a result of which six IRT reactors were erected on the territory of the USSR, and four IRT reactors abroad.

The site for building a nuclear reactor in Latvia was chosen at Salaspils – at the distance of 20 km from Riga. A sanitary zone was created around it with a 1 km radius. In 1959 the staff of the Institute of Physics increased with new specialists engaged in the construction of the reactor and its preparation for work. The IRT nuclear reactor (its authors were specialists from the Moscow Institute of Atomic Energy) was of the “basin type” with a 1000 kW_{th} heating capacity; afterwards its heating capacity was increased to 2000 kW_{th} but, after reconstruction in 1974, – to 5000 kW_{th}. The reactor had in its core 40 kg of uranium enriched to 10% with ^{235}U isotope. After reconstruction uranium was used with 90% ^{235}U isotope enrichment. The Salaspils reactor was launched on September 26, 1961. This was done by a team of experts from the Institute of Physics under the guidance of Y.Babulevich, an I.Kurchatov’s team-mate. He had been present at the start of the first nuclear reactor

(F-1) in Moscow in 1946. The notability of the work performed by Latvian scientists at the Salaspils nuclear reactor is characterised by the fact that Presidents of the USSR Academy of Sciences M.Keldysh and A.Alexandrov, as well as the leading nuclear physicist Academician I.Kokoin, visited the reactor in the 1960-ties.

As a consultant engaged at the Salaspils nuclear reactor was E.Stumburs, an expert in fast neutron reactors from Obnitsk (Russia), a Latvian by nationality. He was chief engineer of the first reactor BN-2 of such a type, launched in Europe in 1956. In the field of nuclear energetics the Salaspils physicists were engaged in the measurements of the neutron spectra at Kola, Armenian and Novovoronezh NPPs. On the 10 horizontal and 15 vertical canals of the Salaspils reactors, mainly scientific investigations were conducted in nuclear physics, radiation chemistry and radiobiology. A thermo luminescence dosimeter TELDE was created, the production of radioactive medical preparations (technetium ^{99}Tc) was carried out, and other practically used things.

The Salaspils nuclear reactor was applied for training specialists both in the USSR and within the framework of international programmes. Here, under the guidance of Latvian experts, knowledge in the maintenance of nuclear reactors was extended to specialists from the countries which had purchased IRT reactors from the USSR: North Korea (in 1965), Iraq (in 1966) and Libya (in 1981). Approximately 50 000 tourists have visited the reactor during its period of operation.

After the Chernobyl accident in 1986 the Salaspils reactor continued operation, the commission from Moscow did not detect any serious deficiency in its performance. The reactor continued working till its stoppage in 1998. On the whole, it had had been active for 37 years and consumed 12.3 kg of the uranium ^{235}U isotope.

UNIQUE EQUIPMENT OF NUCLEAR ENERGY

The radiation loop – a source of gamma rays

One of the most unique devices of the IRT nuclear reactor was the radiation loop created by Latvian specialists – a source of gamma rays with the radioactivity of 7×10^{14} Bq. An alloy of liquid indium with gallium and tin was used as a source of gamma rays in it. As it is known, the gamma radiation does not leave any permanent radioactivity in the radiated materials, therefore it is convenient for physical and technological processes. A possibility appeared to employ the familiar radiochemical processes, such as polyethylene polymerisation, polymer concrete production, sterilisation without raising temperature, and implementation of other processes, in an industrial extent.

Successful application of the radiation loop provided a possibility to work out a project for the radiation reactor (10 MW_{th}) with the gamma radioactivity of 4×10^{17} Bq in which large-scale radiation with the gamma rays could be conducted. This project remained on the level of ideas and was not implemented. Further analysis showed that it is expedient to create a radiation loop at the NPP. Together with the specialists from Moscow a project was developed for the extension of the 3rd unit of Ignalina NPP by a radiation contour. A radiochemical production plant could be created at the RBMK water-graphite nuclear reactor of the canal type of Ignalina NPP with a 4×10^{18} Bq gamma-ray activity. The radiation loop would not lower the output of electric energy of the NPP, and its efficiency would be high because neutrons which are absorbed in the biological protection could be used to activate the radiation contour. This energoradiation-chemical production plant was not implemented because in 1988 the building of the 3rd unit of Ignalina NPP was stopped.

The critical test bench

On September 15, 1966 the critical assembly RKS-25was started in Salaspils (its capacity 25 W_{th}). It was developed and built by Latvian specialists (E.Tomsons, V.Gavars, A.Dinduns, and V.Bute). The nuclear fuel of the reactor IRT was used in the active zone, which initially contained uranium enriched to 10% with ^{235}U isotope and a graphite reflector but later on it consumed uranium enriched to 90% with ^{235}U isotope and a beryllium reflector. The operation of RKS-25 continued till the year 1991. During the work of the assembly thirty various combinations of the critical mass were created and investigated including the core with a massive graphite reflector and the reactor canals, which was a model of the core of the RBMK reactor.

By means of the critical assemblyRKS-25 the optimal structure was found out for the radiation loop generators including also a loop connected with the nuclear reactor of the 3rd unit at Ignalina NPP. The most significant work performed on the critical assembly was the unique liquid metal regulator of the nuclear reactor intended for the use in nuclear reactors in a weightless state in space. There were also investigated rotary cylindrical regulators of nuclear reactors.

PARTICIPATION IN INTERNATIONAL PROJECTS

Participation in the projects of nuclear fusion

Since the 1970-ties the Latvian scientists have taken active part in the investigations on nuclear *fusion*. A support for these studies was provided by L.Artsimovich, Academician-Secretary of the Physics and Astronomy Department, the USSR Academy of Sciences who was then engaged in the problems of controlled reactions of nuclear *fusion* synthesis.

Liquid metal limiters were designed at the Institute of Physics for the plasma control (Professor O.Lielausis) and metal corrosion in the liquid lithium-lead alloy was studied in a strong magnetic field. A technology was worked out for the production of a lead-lithium alloy and its application in the reactor systems of nuclear fusion (J.Freibergs).

Research has been completed at the Faculty of Chemistry, the University of Latvia, on tritium emission from the beryllium materials of the nuclear fusion reactor, and it was found that lithium-containing alloys are perspective materials for the reproduction of tritium and its transfer in nuclear fusion reactors (Academician J.Tīliks). Use is made of non-structured ceramic balls of lithium orthosilicate to produce tritium in the nuclear fusion reactors. The impact of powerful magnetic fields was investigated on the radiolysis of the blanket ceramics and tritium emission.

An extensive range of investigations were conducted at the Salaspils reactor in order to create radiation-resistant insulation materials for the nuclear fusion reactors including Tokamak T-15.

Detectors of a principally new type are being developed at the Institute of Solid State Physics, the University of Latvia, for the control of plasma parameters (Professor A.Šternbergs), as well as methods for optical investigation of the plasma contents (Professor I.Tāle). Theoretical studies are carried out on the plasma stability and operation of gyrotrons (equipment for initial heating of plasma).

The LU Institute of Physics and the LU Institute of Chemical Physics continue their collaboration in the world's greatest scientific research project – the development of the International Thermonuclear Experimental Reactor (ITER). Active involvement of the Latvian scientists in the European Union's nuclear fusion programme EFDA (European Fusion Development Agreement) began in the year 2001. An association was created of four scientific organisations AEUL (Association of EURATOM and University of Latvia), which is an official member of the EURATOM.

Participation in the projects of the 4th generation NPP

Since the 1960-ties research work developed in Latvia at the Institute of Physics, the Latvian Academy of Sciences, on magnetic hydrodynamics (MHD). There were studied the electromagnetic properties of liquid metals – sodium, mercury, the indium-gallium alloy and other liquid metals. The further investigations were directed at the development of alkali metal pumps and at the possibilities to use them for the transportation of the liquid metal in nuclear reactors with the liquid metal cooling.

Experiments of theoretical character were prepared and carried out. One of the most outstanding was the *MHD–dynamo* experiment, in which self-excitation of the magnetic field in the MHD systems was directly proved for the first time in the world (in 1999). The pioneers of this work were I.Kirko, O.Lielausis, A.Gailītis and E.Platacis.

Applied investigations are going on at the Institute of Solid State Physics, the University of Latvia, on the use of liquid metal technologies for the fourth generation nuclear reactors. Application of the liquid metal is most effective in the units which are subject to great radiation and temperature loads. The use of MHD technologies pertains to nuclear reactors, lead-cooled fast neutron nuclear reactors (LFR) and sodium-cooled fast neutron nuclear reactors (SFR). New constant magnet MHD pumps have been developed. Studies have been carried out in the simulation of the mercury flow in the MYRRHA accelerator in the IPUL equipment.

The LU Institute of Physics is involved in three international projects on nuclear energetics: with France (CP ESFR), Sweden and Denmark (ESSS), as well as with Japan (IFMIF). The Latvian experts in magnetic hydrodynamics at Salaspils conduct successfully the simulation of the nuclear energetic equipment and elements.

PROPOSALS FOR BUILDING NPPs IN LATVIA

The NPP construction projects in Soviet Latvia

Due to the deficiency of natural energy resources in the north-western part of the former Soviet Union and more extensive application of nuclear energy, the USSR State Plan Committee recurrently proposed Latvia to build an NPP.

In the late 1960-ties and early 1970-ties the USSR Designing Institute at the Ministry of Energetics and Electrification started looking out for possibilities to locate NPPs on the banks of various lakes in Latvia – Rāzna, Lubāna, Usma, and others. After discussions with various-profile scientists in the Latvian State Plan Committee the proposed variants were declined. At the same time the government of Lithuanian SSR agreed to build Ignalina NPP on its territory. So provision of the region with electricity was solved for the nearest period, and the construction of a NPP in Latvia was not started.

In 1975, when planning the perspective provision of the north-western region of the country with electricity and considering the long building time of a NPP, the USSR Ministry of Energetics and Electrification repeatedly suggested that the government of Latvian SSR should use nuclear energy and reserve possible building sites for the future NPP. After reviewing the previous and some new variants, it was decided to make a detailed inspection of a possible site for the PNN on the shore of the Baltic Sea. According to the existing regulations, a buffer zone had to be reserved around the NPP with a 3 km radius in which no residential buildings could be located. Its location on the shore of the sea would reduce the evacuated area. The government of Latvian SSR did not respond to this proposal since it had solved the problem of electricity provision by agreeing to build Daugavpils HPP, and the construction of the NPP was temporarily suspended.

The designers returned to the search of a site for the NPP in 1980. Three variants were offered for a concrete choice on the Kurzeme seaside of the Baltic Sea:

- 8 km south from Pāvilosta (30 km from Liepāja)
- 5 km north from Pāvilosta
- at Pape, which is situated 24 km from Liepāja and 28 km from the border with Lithuania.

In 1981 the government of Latvian SSR gave a principal consent to reserve two variants of a construction site for the NPP. The local district administration, too, agreed to the location of the NPP in Liepāja District. The USSR Ministry of Energetics and Electrification envisaged building an NPP in Latvia with a 3000 MWe electric capacity. The Latvian State Plan Committee pointed out during the discussion of this proposal that the republic does not need such great generating capacities. The implementation of the project would require building high-capacity electric lines across the territory of Kurzeme and solution of how to store radioactive waste. It would be necessary to build a village not far from the NPP for 33 thousand residents and ensure their employment.

During the 1980-ties, the increase in the consumption of electric energy in the USSR, including Latvia, was considerable, on the average, 5% a year. It was expected that till the year 2010 the consumption of electricity in Latvia will rise to 15 TWh a year. In that time the electric power plants existing in Latvia produced only 40% of the required electric energy. Therefore a decision was made to build a new NPP with the first power generating unit launched in 2003. The NPP was designed with four power generating units and a 4000 MWe total electric capacity. They had to be water-water nuclear reactors VVER 1000. The estimated amount of the produced electricity was 22.5 TWh a year. The total number of the NPP operating staff – 2100 persons. The estimated building indices:

the time of designing and preparation	6 years
the construction time of the first unit	6 years
the total construction time	12 years
the number of workers engaged in construction	15 thousand

A little later the USSR Ministry of Energetics and Electrification announced the government of Latvian SSR that the construction of a larger NPP must be envisaged on the reserved sites with a 6000 MWe total electric capacity.

Two historical events stopped the implementation of the NPP construction plans: „perestroika", which had started in the USSR, and the Chernobyl NPP accident. After the accident, which occurred in 1986, the residents of Liepāja District and the neighbouring Kretinga District in Lithuania voiced a protest, the prospecting work was interrupted and the construction of the NPP suspended.

Plans for the construction a district heating nuclear power plant

In the period when nuclear energetics flourished power generating units AST-500 (with the net capacity of 500 MW_{th}) were designed in the Soviet Union, and intended to provide cities with heat (without producing electricity). In the early 1980-ties the USSR State Plan Committee suggested to provide also Riga with heat using such a power generating unit. On the territory of the USSR the construction of heat generating sources AST-500 had already started to provide with heat the cities of Gorky, Odessa, Voronezh, Arkhangelsk, Kharkov and Minsk. The construction site of the district heating nuclear power plant providing Riga with heat was chosen at

Baloži, which is situated 12 km south from the centre of Riga. The designing work started in 1985. The Chernobyl NPP accident put an end to these projects. Implementation of all the AST-500 projects in the Soviet Union, including Riga, was interrupted.

PROVISION OF LATVIA WITH ELECTRICITY FROM THE NPPs

Closure of Ignalina NPP in Lithuania

Up till now, in order to provide Latvia with electricity, 30 – 40% of electric energy is imported. In these purchases the amount of electricity produced at Ignalina NPP in Lithuania constituted about 10% of the electric energy consumed in the country. But in 2010 the operation of Ignalina NPP has to be stopped, as provided by the agreement signed in 2004 when Lithuania entered the European Union. It should be remarked that a part of electricity imported from Russia is also produced at NPPs. Summing up the amounts of electricity purchased from Lithuania and Russia which are produced at NPPs, we obtain approximately 1 TWh electric energy a year. In this way we can conclude that the provision of Latvia with electricity is ensured till now by approximately 150 MWe electric capacities generated at NPPs located in other countries.

Latvia could practically ensure the 7.5 TWh consumption of electricity during the last years by means of its already existing electric power plants. The medium output of the Daugava HPPs is 2.8 TWh a year. The Riga district plants (DHPs) could produce up to 5.0 TWh of electric energy a year. However, the Riga DHPs are basically used in the winter period to produce heat electric energy being generated as a by-product. In summer, when the consumption of heat decreases, it is not profitable to produce electricity at the DHPs; it is cheaper to buy it on the Baltic market. In accordance with the EU Directive 2003/54/EC, free wholesale trade in electric energy is open in the Baltic States in which Latvia, Lithuania, Estonia, as well as Russia take part. The Latvian Transmission System Operator (TSO) „Augstsprieguma tīkls" is able to ensure all the necessary flow of electric energy, including the transit. The closure of Ignalina NPP will influence these flows only partly since this NPP supplied electric energy not only to Latvia but also to Belarus and Russia.

Cooperation between Latvia, Lithuania and Estonia in electricity provision has been stable. The TSOs of the Baltic states have joined into the BALTSO association and, since July 2009; have completely merged into the European association ENTSO-E. Besides, there is created an association BRELL of the Byelorussian, Russian, Estonian, Latvian and Lithuanian energy systems.

Provision of Latvia with electricity

In 2008 there was the highest electric load (1410 MWe) and the highest consumption of electricity (7.5 TWh) recorded in Latvia during the recent years. There were hydropower plants (HPPs) with a 1500 MWe electric capacity, district heating plants (DHPs) operating on gaseous fuel (800 MWe), wind power plants (WPPs) (26 MWe), and biomass, biogas plants (25 MWe). The decrease in the gross domestic product (GDP) in the year 2009 caused also a lower demand for electric energy in contrast to the previous year.

The demand for electricity will rise in the future; a need will appear to build new electric power plants. The basic guidelines of the Latvian power industry envisage that it is necessary to promote the development of national electric power plants so that they could completely cover the consumption after the year 2015. In the near future there might be increased generating capacities using natural gas (they have the shortest construction time). Latvia has a voluminous storage facility of natural gas (2.2 billion m^3); therefore the risks about gas supplies, in comparison with the other countries of the region, are small. The construction of Renewable Energy Power Plants (REPP) will continue. The potential of the renewable energy resources will partly cover the demand for electric energy in Latvia. By using the biomass resources and biogas it will be possible to produce additional 0.5 TWh of electricity. The potential of wind energy is estimated at 1.2 TWh but the production of electricity cannot be prognosticated.

It is expected that in Latvia, in contrast to the average consumption in the EU countries, the increase in the electric energy will be more rapid because there is a considerably lower specific consumption per one inhabitant. Now this index for Latvia is 3500 kWh/person but the average index for the EU countries is 6500 kWh/person. In this connection one can expect in Latvia in a more distant period till 2025 – 2030 increased consumption of electric energy up to 12 – 13 TWh/year.

New base electric power plants must operate on the territory of Latvia after 20 years ensuring additional 5–7 TWh output of electric energy with simultaneous diversification of the imported energy resources that are required for their performance.

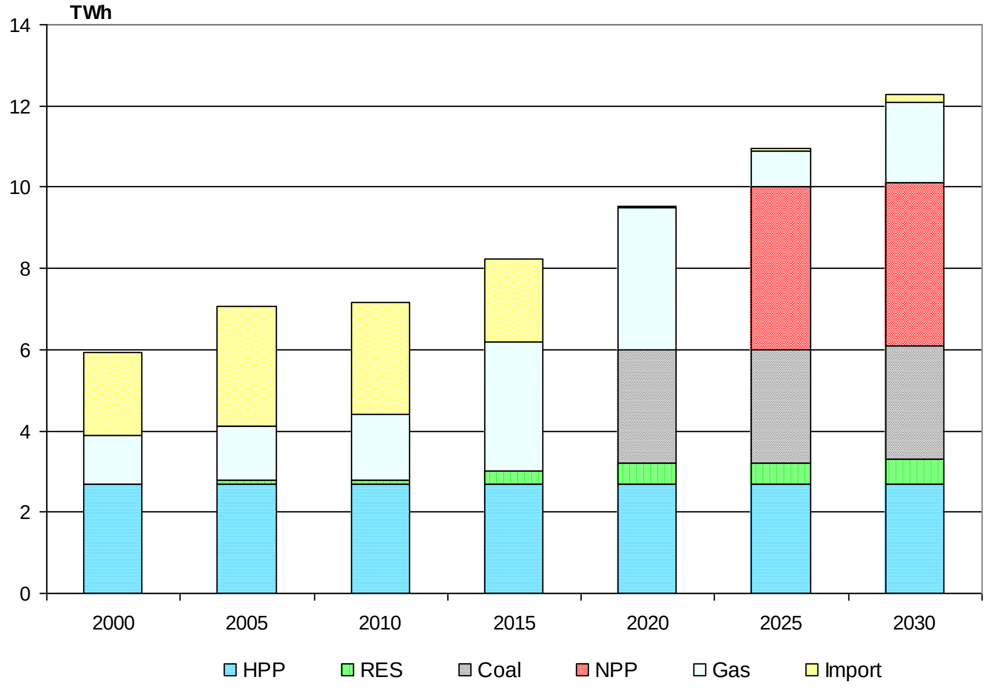

Fig.1. Provision of electric energy in Latvia

Taking into account the fact that society is not ready yet to accept the construction of NPPs, it is anticipated that the first plant to be built might be a coal power plant. But, already, after the year 2015 one will have to consider extension of the base capacities. The most expedient for this purpose would be NPPs. These electric power plants start proving their superiority more and more in the production of electricity in the countries which are short of their own energy resources. The NPPs are economically profitable and their main advantage is non-pollution of atmosphere with harmful emissions. The construction has started and it is planned to build more than 10 NPPs in the Baltic region and around it.

The possible Latvian NPP

Wide use of the 3rd and 3rd+ generation NPPs has started in the world. The capacity of one power generating unit of the NPP has reached the 1600 MW level, which is profitable for large energy systems. When choosing the capacity of a new power generating unit, Latvia has to take into account the necessary reserve of the energy system for its safe performance. The conducted analysis showed that the aggregates generating power in the Baltic region and exceeding 800 MW need additional reservation. The Baltic states are connected with the other EU countries by means of only one line (ESTLINK with Finland having a 350 MW capacity). The power reserve can be ensured from the side of Russia with which there is a synchronous link. However, this would not comply with the guidelines of the Latvian power engineering.

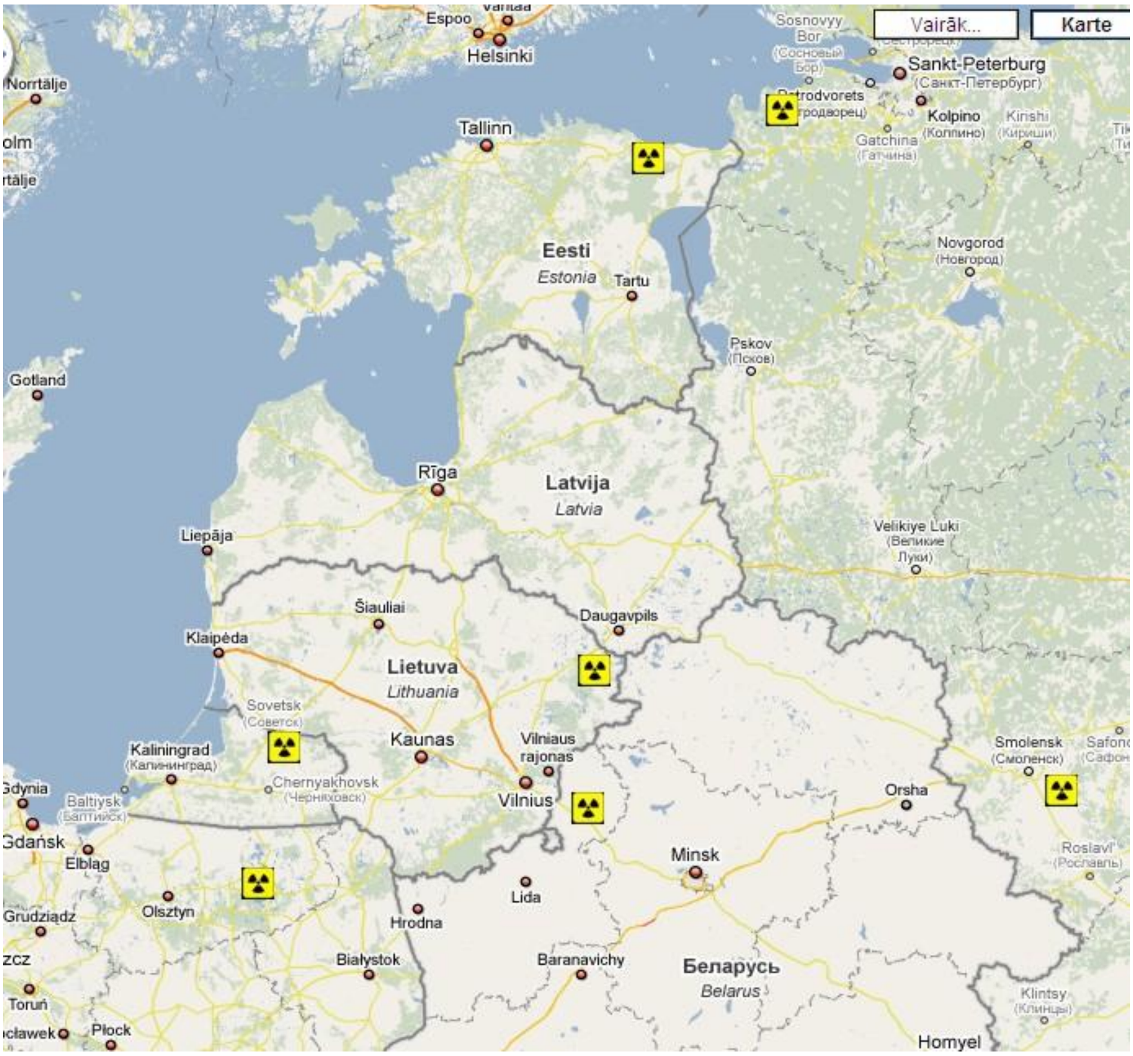

Fig.2. The NPPs to be built and planned in the Baltic region

Among the 3rd generation reactors offered in the world the most acceptable for the Latvian NPP is reactor EC-6 of a Canadian company AELC with a 700 MW capacity and reactor AP–600 of a US Westinghouse company with a 600 MW capacity. After the year 2020, due to successful development of new NPPs, several 4th generation

NPPs would be acceptable for Latvia, their capacities not exceeding 800 MW. The 4th generation NPPs will have a greater safety and will fulfil fuel reproduction.

The choice for the location of the NPP on the territory of Latvia may present certain problems. Its choice might start after the Latvian Saeima (Parliament) has approved the application of nuclear energy for the production of electricity. Taking into account experience in the choice of the location, the new NPP could be situated in Kurzeme, near the shore of the Baltic Sea. There is no large base electric power plant in the western part of Latvia. The main wind parks of electric power plants are going to be located in this region. It is planned to create here also a closed ring of a 330 kV transmission network for switching in additional capacities.

Alongside the development of an NPP project, it will be necessary to solve the management problems of the spent fuel. The geological structures of Latvia are different from the structures in the countries of Northern Europe; therefore it will not be possible to use their experience. Intense development of other technologies is going on in this field in the world with an aim to simplify safe disposal of the nuclear waste, which will facilitate the solution of this problem.

When starting the project of the Latvian NPP, it should be clear from the very beginning about the participation of the private and state capital in the project. One must gain society's approval of this project. Successful resolution of the organisational and technical problems will be a guarantee for the erection of a new Latvian NPP.

CONCLUSIONS

1. Already during the 1950-ties the scientists and engineers of Latvia were involved in the research on extensive application of nuclear energy in power engineering;
2. Unique equipment of nuclear reactors have been created: a radiation loop, a source of gamma rays, a critical assembly, liquid metal pumps, and regulators for nuclear reactors;
3. In the 1970-ties the Latvian scientists were engaged in international projects and continue work in the projects of reactors of nuclear fusion and the 4th generation nuclear power plants;

4. Since the 1980-ties, electric energy is used to provide Latvia with electricity which is imported from the NPPs in the neighbouring countries (Lithuania and Russia).
5. Considering the deficiency of energy resources and restrictions on emissions, it will be possible to ensure reliable provision of Latvia with electricity only by applying nuclear energy.

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