NUCLEAR ENERGY AND PUBLIC AWARENESS

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ABSTRACT

The Hungarian government signed an intergovernmental agreement with Russia in 2014 on the construction of two new units at the site of the currently-four-unit Paks Nuclear Power Plant. This decision – based on the National Energy Strategy adopted in 2011 – maintains the capacity of the Hungarian nuclear based electricity production for the next decades. Public acceptance of a new nuclear construction, which is determined by the public awareness, is a key point of the success of the project. It is essential to educate environmentally and socially conscious youth, but also to provide them with the necessary technical knowledge to ensure that the next generation can have a well-based judgement of energy-related issues instead of an emotional approach. The presentation gives an overview about the Paks 2 project and the possible methods of information and education of the next generation concerning the energy policy including the new nuclear units.

INTRODUCTION

The Paks Nuclear Power Plant (Paks NPP) has an inevitable role in the Hungarian electricity system: it has a share of more than 50% in the domestic electricity generation, and a 36% share in the electricity supply of Hungary. There are four Russian designed nuclear units operating at the Paks site with a total electric output of 2000 MW. The units started commercial operation in the '80s, so they are reaching their originally planned 30-years lifetime in this decade. After a comprehensive preparatory program, the units are now in the lifetime extension licensing process, as a result of which they would be able to operate for a further 20 years (having their lifetime extended from 30 to 50 years). However, even after the lifetime extension the units will be shut down between 2032 and 2037, so there is an urgent need to ensure their replacement capacities.

The idea of constructing new units at the Paks site has been on the agenda since the '80s. The site itself is suitable for hosting two further units and has the necessary infrastructure for the construction; moreover, it is the most explored and best-known potential site in Hungary. In addition, the surrounding population supports the project, recognizing the positive economic effects of the construction on the region.

Following several years of preparatory work of the project, the Hungarian government signed an intergovernmental agreement with Russia on 14 January, 2014. The intergovernmental agreement (IGA) includes the construction of two pressurized water reactors with a capacity of at least 1000 MW each at the Paks site. Regarding the financing of the project, the IGA lays down that the Hungarian state would get an interstate loan from Russia.

After the announcement of the IGA, intensive negotiations started between the parties about the exact technical, legal and financial details of the cooperation. As a result of these negotiations, three contracts (the so-called Implementation Agreements) were signed by the Hungarian Paks 2 Development Ltd. – the future licensee of the new units – and the Russian JSC NIAEP company on 9 December, 2014. The Implementation Agreements covered the engineering, procurement and construction details (EPC contract), the operation and maintenance support and the nuclear fuel supply. The basis of these agreements is a set of a significant number of safety-related, technical and legal requirements defined by the Hungarian party. These requirements ensure that a state-of-the-art, Generation 3+ nuclear power plant will be built at Paks, with the reasonably highest possible safety level.

ELECTRICITY – DEMAND AND SUPPLY

One of the most important challenges to be solved by our society is the secure energy supply. We can read different expert statements and analyses about the ideal energy sources. However, it is obvious, that there are some misunderstandings and misinterpretations of natural and technical facts among laypeople in the subject of electricity supply.

Electricity is one of the most important products in our life. Unfortunately, unlike other everyday goods, electricity cannot be stored in industrial scales. Of course, there are several solutions for the small-scale electricity storage – e.g. batteries – but the possibilities are very limited in large dimensions. Among the exceptions the pumped-storage hydroelectricity shall be mentioned, which is a high-efficiency, proven method for a short term electricity storage.

The most important feature of the electricity system is the consequence of restricted storage possibilities, which means that the balance of the generated and consumed electricity shall be maintained in each moment for the whole electricity system. The quality of this special product (i.e. the electric energy) in the electricity grid can be described by the frequency. It is 50 Hz in Europe, and the system operators and even the power plants have to keep this 50 Hz frequency very precisely to maintain not only the quality, but the stability, or even functionality of the whole system. If the frequency increases or drops beyond certain limits, the electricity system will collapse, causing a severe supply problem as well. Keeping the electricity system between the required frequency limits needs lot of efforts. So-called primary, secondary and tertiary reserves – i.e. dedicated power plants – shall be ensured for the electricity system to cope with the unforeseen demand or generation fluctuations. The different reserve types are responsible for the different levels of electricity grid control.

If the electricity production and consumption get unbalanced, the frequency of the system deviates from the nominal value. For example if a power unit gets shut down because of technical reasons or if the increase of the electricity consumption (e.g. in the morning hours) cannot be fully covered by operating power plants the frequency decreases. Immediately after the decrease of the frequency the primary reserves are necessary: these power plants are running and parallelized with the 50 Hz system, so if there is a load increase, these primary reserves can be started or their power can be increased to supply the necessary electricity to the grid (immediate intervention). The secondary reserves can interact with the system within few minutes – these are shut down power plants (or ones operating at low power), which are able to get started very quickly after the frequency change. The tertiary reserves are usually shut down power plants, used for the mid-term balancing of the electricity grid. To keep the system operating, very precise planning and high availability of the power plants is necessary.

Having a look at the daily change of the electricity demand (this is the so-called load curve, see Fig.1.), different daily load curves can be observed, depending on the season, on workdays / holidays, or on special weather conditions. Even an important and very popular sport event or TV program can influence the load curve. Their common feature is that there is a minimum in the electricity consumption in the pre-dawn hours, when the electricity demand is only about 60-70% of the peak load. The value of the daily peak load in Hungary is about 4000-6300 MW – larger in winter season and on workdays, lower at summer weekends. However, with the increasing deployment of air-conditioning, the summer electricity load is approaching or even exceeding the winter demand peaks, as it is well-known for example in the USA.

The shape of the load curve depends on the value and time point of the peak load, which can occur during working hours or in the evening. In some cases, even two peaks with very similar height can be observed. We can make a difference between the typical load curve with the help of two animals: the load curve with one load peak is similar to the back of an elephant, whereas the two-peak curve is similar to a two-humped camel.

The knowledge of the shape and values of the load curve is essential for the planning of the generating capacities. The constant part of the demand (i.e. below the minimal demand) can be supplied with cheap, continuously operating power plants, these are the so-called baseload power plants – typically the nuclear power plants are in this category. Baseload plants are necessary for the secure, inexpensive electricity supply. The load-following power plants are responsible for the supply of the foreseeably fluctuating part of the load – these are typically the flexible fossil-fuel-fired power plants, mostly gas-, but recently often coal-fired power plants. In the short, high-electricity-demand periods, peaking power plants are used, which can be started very quickly, but usually with high generating prices – these are typically gas turbines.

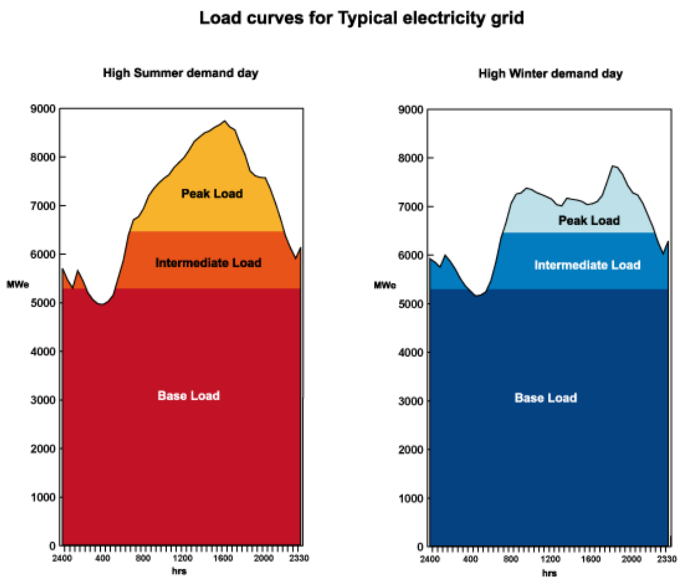

Fig.1. Typical daily load curves (Source: World Nuclear Association) [1]

ROLE OF RENEWABLE ENERGY SOURCES IN ELECTRICITY GRID STABILITY

Considering the renewable energy sources, a difference shall be made between the weather-dependent and the continuously operating power plants. Plants with continuous operation (as large hydroelectric power plants or biomass-fueled plants) can act as part of the baseload generation. The pumped-storage hydroelectric plant is a typical peak-load plant – the upper water reservoir can be filled up in the demand valley time period with cheap electricity coming from baseload power plants, and the energy can be recovered in peak-load periods.

However, the situation is totally different in case of the weather-dependent renewable sources, as wind power or solar power. The forecast of the electricity generation from these sources is very complicated, causing difficulties in the electrical grid control.

Germany, on the road of its energy transition to the clean renewable sources is a good example for the difficulties caused by the weather-dependent energy sources. (The German energy policy aims the total phase-out of nuclear power plants until 2022 and sets out a target for 80% share of renewable sources in the German electricity consumption by 2050.). The daily peak load in Germany nowadays is about 60-70 000 MW. There is an installed wind based production capacity of more than 40 000 MW and solar (photovoltaic, PV) capacity of roughly 38 000 MW – so these renewables would be able in theory to cover the demand by themselves. However, the real feed-in from the renewables is much smaller; the PV panels can generate only daytime, and the wind power plants are not able to generate continuously either. Additional to that we have to mention that the wind feed-in never reaches 100% of wind production capacity.

In Fig.2, the electricity production in Germany is shown in January of 2014. It can be clearly seen, that the baseload power generation comes from large hydro, biomass, nuclear and lignite-fueled power plants. The generation from the wind power plants is uncontrollable and weather-dependent, so the necessary production-side control takes place with coal-fired and natural gas fueled power plants.

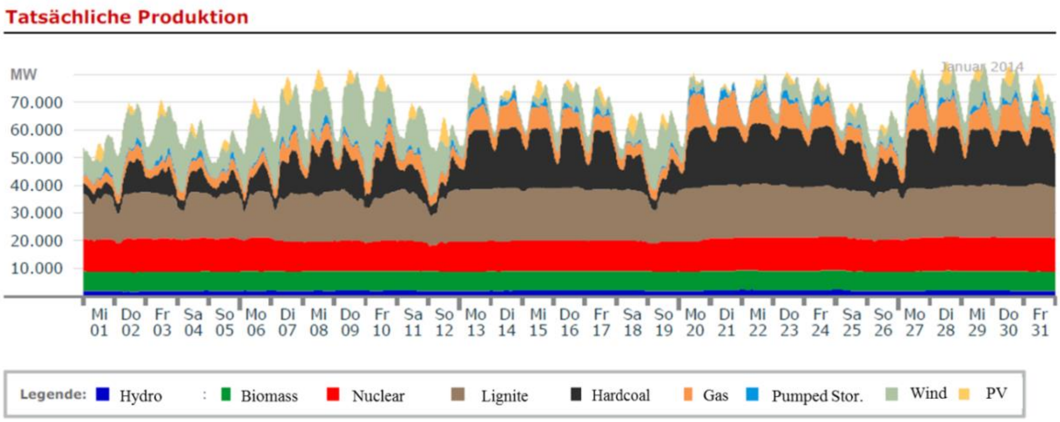

Fig.2. Electricity generation in Germany in January 2014 [2]

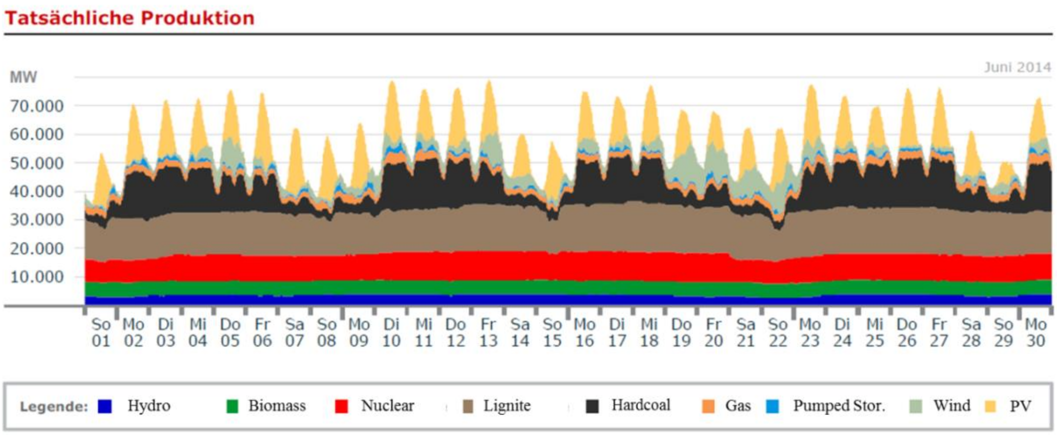

Fig.3. Electricity generation in Germany in June 2014 [2]

Fig.3. shows the electricity generation for another month, for June of 2014. In summer, daytime feed-in from solar panels is much higher than it was in winter, as it can be observed

in the figure – combined with a very low but fluctuating wind generation. The role of the natural gas was almost negligible in the electricity generation in that month, however gas played important role in short-term balancing.

The result of the large renewable production can be observed in Fig.4, which shows the data for a selected week in August 2014. The grey sector is the electricity generated by the conventional (i.e. nuclear plus fossil-fired) power plants. The green part shows the wind production, and the yellow humps represent the solar generation. There are some periods, when the feed-in from wind is over 20 000 MW, but there are long hours when the feed-in from wind is negligible. The sudden changes of the wind production can cause serious grid control problems – the necessity of keeping the frequency stable is the main rule, so the high rate of wind power requires large capacity of reserve power plants, which makes system operation even more expensive and technically more complicated.

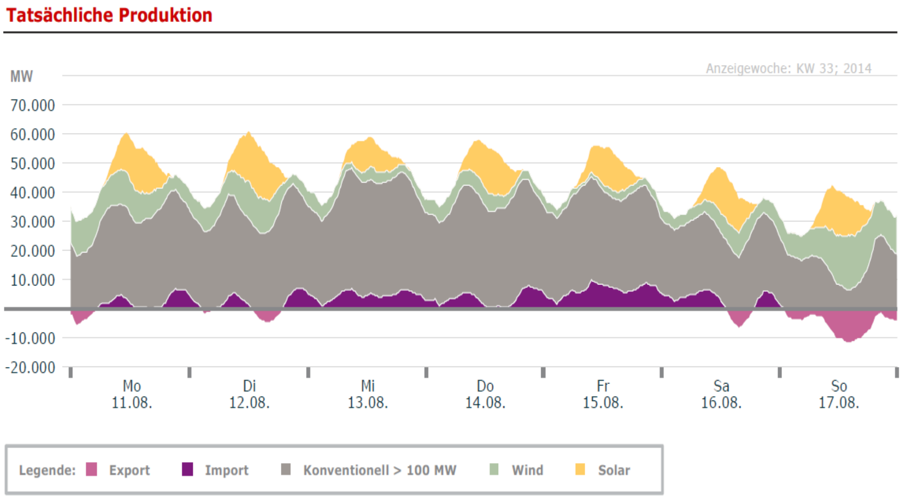

Fig.4. Electricity production in Germany from renewable sources, August 11-17, 2014 [2]

According to the figure, the daily peak production of conventional power plants varies from 30 000 to 50 000 MW, and the export-import balance varies from -10 000 MW (export) to +5000 MW (import). The large changes in the generation can cause forced (not planned and not contracted) export to the neighboring countries, causing grid instability in these countries as well. An extreme consequence of the unforeseeable production changes is the presence of negative electricity prices as it happened at the end of August 2014: in some cases of sudden renewable overproduction – combined with a drop in grid loads – the operators of the baseload power-plants cannot shutdown their units for few hours therefore they had to pay for taking over the electricity generated by them. In the events on the weekend of August 17^{th} 2014 between 12:00 and 16:00 the spot price of electricity has been climbing down to minus (!) 60 EUR per MWh. These are definitely symptoms of a distorted market which is characterized by high subsidies of renewables. This distortion materializes in a market environment where electricity markets are not giving real, long-term price signals and seriously endanger the future investment in dispatchable power plants that ensure electricity supply security. This development, namely the lack of new investment in dispatchable power plants, a worsening future supply security is clearly against the most important energy policy objective of Europe.

It is unclear at this moment how these issues can be resolved. However this is evident that stable, controllable power plants are henceforward necessary to ensure reliable electricity system operation, security of supply and system safety. Large capacity of power plants is inevitable which are independent from weather conditions and are available in all seasons. By the selection of future energy mix we have to consider many different factors including economics and targets for combating climate change.

ROLE OF NUCLEAR POWER PLANTS IN THE ELECTRICITY SYSTEM

Now, at the beginning of 2016, there are 442 nuclear power reactors in operation worldwide, with a total net installed capacity of 383 GW, covering about 11-12% of the annual global electricity production. After the Fukushima accident (2011) some countries decided to phase out nuclear power plants – for example Germany, as mentioned earlier. However, at the moment 66 nuclear units are under construction, and many countries are planning to maintain or expand their nuclear generation capacity.

According to the forecast of the International Energy Agency (IEA, see Fig.5), after the post-Fukushima stagnation of the nuclear industry, the total installed capacity of the nuclear power plants will increase in the next decades, mainly because of the fast nuclear expansion in China and other developing countries. However, in the EU the sustainment of the nuclear capacities is forecasted until 2040 (see Fig.5).

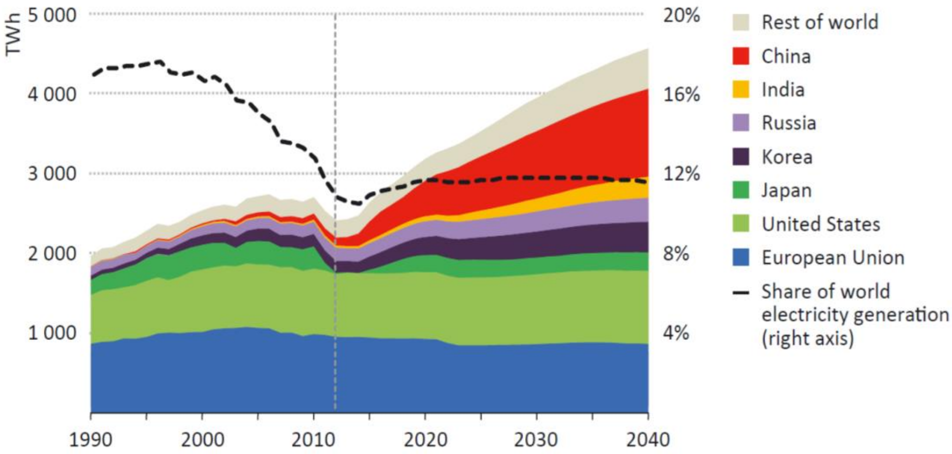

Fig.5. Installed capacity of nuclear power plants until 2040 according the World Energy Outlook [3]

The member states of the European Union have the right to choose their own energy mix, including the mix of primary energy sources in their electricity production (the combination of the applied electricity generation methods), as far as they are consistent with the energy policy goals of the EU. These goals – to increase the competitiveness, to ensure affordable electricity prices, to enhance supply security of the Union and to help the battle against the climate change – can be met with the use of nuclear energy as a part of the energy mix. Nuclear power plants can operate without emitting carbon-dioxide, and also their CO2-emmission during the whole life-cycle (per kWh) is in the order of the emission of renewable sources (wind, PV). The security of the energy supply can be improved as well, because fresh (unused) nuclear fuel assemblies are easy to handle and to stockpile reserves, even for years. The uranium, the raw material for the fuel is available from different, politically stable countries. By given technical and commercial conditions the fuel assemblies can be procured from different fuel vendors. For the transportation of the fresh fuel alternative means e.g. rail and air transport are available, which is much more flexible than gas import through pipeline or electricity import by transborder power-lines.

A special feature of nuclear power plants is the relatively high investment cost, together with low operation-maintenance and fuel costs. As a result, if appropriate financing is available, electricity generated in nuclear reactors is especially competitive with other electricity generation technologies (see Fig.6). Because of the favorable financial conditions of the new Paks units, the levelised cost of electricity of the new units will be even lower than the values of the IEA forecast for Europe.

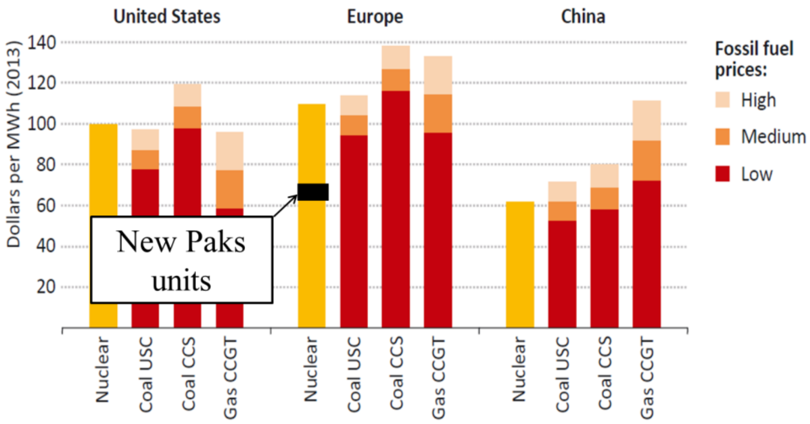

Fig.6. Cost of electricity generation for different sources according the World Energy Outlook [3]

NEW UNITS AT THE PAKS NUCLEAR POWER PLANT

The annual total gross electricity consumption of Hungary is about 44 TWh (2015: 43,75 TWh, see data of MAVIR) with a peak load of about 6500 MW, while the installed capacity in the Hungarian power plants is only 9000 MW and is decreasing. In the next decades, the annual total gross electricity consumption, together with the peak load is expected to increase with a rate of about 1% / year. Combined with the shutdown of old Hungarian power plants, these developments result in a need of about 7300 MW new generating capacity to be built until 2030. The Hungarian energy policy aims to increase the security of electricity supply that makes the construction of new nuclear reactors necessary.

The Hungarian parliament approved the preparation of new NPP construction on March 30, 2009. After this decision in principle of the parliament, the Hungarian electricity utility MVM established the Lévai-project with the task of performing the further preparatory works. In July 2012, the Paks II NPP Developing Company has been established, which is now responsible for the pre-construction and construction works.

On 14 January, 2014 the Hungarian government signed an intergovernmental agreement with Russia on the cooperation in the peaceful use of nuclear energy, including the construction of two new units at the site Paks Nuclear Power Plant. The choice of the Russian supplier can be explained with the very favorable loan conditions and the long experience of the Hungarian institutions in the application of Russian nuclear technologies.

The offered reactor design is the VVER-1200/V491, which is a state-of-the-art pressurized water reactor (PWR) type with 1200 MW gross electric output – the same design has been selected for the Finnish Hanhikivi project. The design can be classified as a Generation III+ reactor, i.e. with improved safety and economic performance compared with the actually operating Generation II reactors. The Generation II and Generation III/III+ reactors use low enriched uranium, which is unsuitable either in fresh or in spent fuel form for production of nuclear weapons. These type of units are designed to fulfill wide range of nuclear safety, nuclear security and also non-proliferation requirements.

For the commissioning of the units altogether about 6000 different permissions are necessary (see Fig.7). The licensing process has already started; recently the site licensing and the environmental licensing processes are underway. Concerning the environmental licensing, the EIA (Environmental Impact Assessment) report was submitted to the competent authority on 19

December 2014. During the spring of 2015, 41 presentations were given during a public information roadshow in the settlements around the site, and a public hearing was also organized in the town of Paks. In the frame of the preliminary international consultation process (began in 2012), the preliminary consultation document (PCD) was sent to 30 countries, among which, 11 countries have been registered to take part in the environmental licensing process according to the Espoo Convention, the biggest part of which took place in 2015. Expert consultations and public consultations were organized in 7 countries by the Ministry of Agriculture; another 4 countries requested written consultations. The EIA – published on the internet – described the expected environmental effects of the construction, operation and decommissioning of the new units. The results showed that the largest impact on the environment would be the heat release from the power plant into the river Danube during the operation; however, this heat load is still tolerable for the flora and the fauna living in the vicinity of the plant. In the international section of the licensing process, the potential consequences of severe nuclear accidents were demonstrated as well.

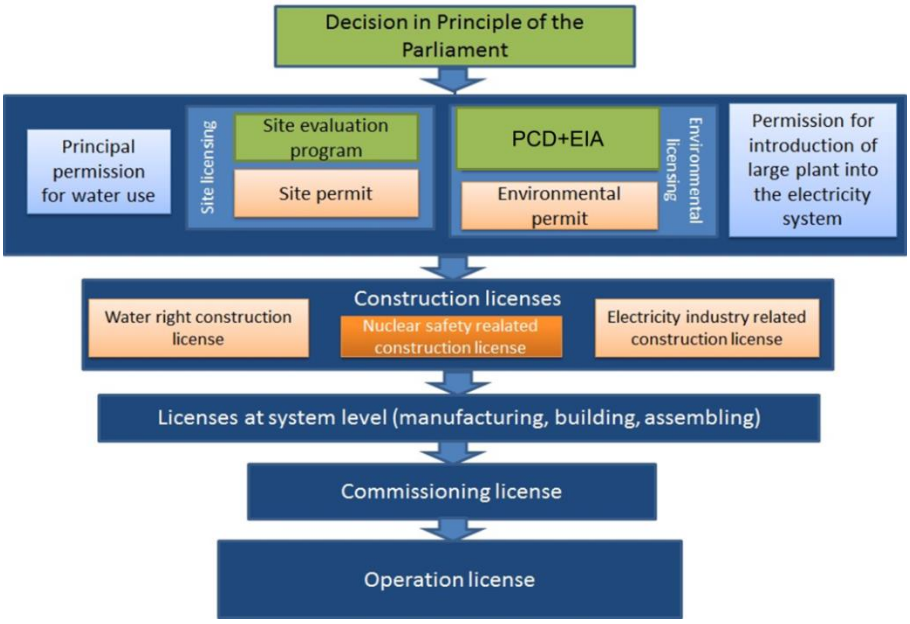

Fig.7. Licensing process for the new units

Concerning the site licensing, the site investigation and assessment program has been already accepted by the Hungarian nuclear safety authority. Based on this program, 3D seismic measurements were performed in August-September 2014 as the first steps of the investigation. The Geological Research Program started in May 2015 with the first geological drilling. The Program includes on-site measurements and laboratory investigations as well with surface and underground research processes.

According to the schedule, the first new unit would start commercial operation in 2025. This requires the start of the construction in 2018. Until this date, the construction licenses should be obtained from the different authorities, requiring hard work in the upcoming years from the licensee and the regulatory bodies as well.

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