Research of the Development Feature and Trends of the World's Nuclear Industry in 2015

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***Abstract*--The paper introduces the current status of the world's nuclear power units in operation and under construction, tracks the nuclear power policies and their changes in the developed and developing countries and predicts the future nuclear power development. It summarizes some features of the world's nuclear power development in recent years as well as some new situations in nuclear power export market.**

Keywords-Nuclear power development; Nuclear power policy; Development trend

I.SUMMARY

In 2015, the prices of bulk energy continued to fall because of continued adjustment and differentiation of the world economy, sluggish recovery, shrank demand in major economies as well as the shift of China's economic development. International crude oil price drops to below $30/barrel in 2016 from the peak value $147/barrel in 2008, and Bohai-Rim steam-coal price also drops to below CNY360/t from the peak value CNY820/t in 2011, and there is no sign of improvement in the prices of bulk energy in the next few years. Thermal power costs continued to decrease and coal-fired power benchmark price was lowered repeatedly. Meanwhile, new energy developed rapidly and both installed capacity and power generation maintained ultrahigh-speed growth at a double-digit rate. With the decreasing power generation cost and the forced pressure on energy saving, nuclear power price and installed capacity suffered unprecedented pressure and International Atomic Energy Agency (IAEA) has lowered the predictive value of global nuclear power capacity in 2030 for many years in a row[1]. Although the number of global nuclear power units starting construction in 2015 was 3 times the number in 2014, nuclear power development was slow and it was difficult to promote new projects, and some countries have shut down several units ahead of their operation license expiration for economic and security reasons. Nuclear power development was almost stagnant in developed countries[2] and nuclear industry maintained a steady development only in developing countries represented by BRICS. The world's nuclear industry continued to maintain low-speed development.

II. GLOBAL NUCLEAR POWER UNIT STATUS

A. Status of Units in Operation

According to the IAEA statistics[3], by the end of 2015, the number of global nuclear power units in operation came to 438 units, having a net increase of 1 unit over that of 2014; the total installed capacity reached 402 GWe, having an increase of 4.705 GWe over the end of 2014. Influenced by the Fukushima nuclear accident, Japan continued to improve its nuclear safety standards and considering the transformation required to adapt to the new safety standards as well as the considerable preparatory work required for the review to restart the NPP, Japan shut down 5 old nuclear power units; UK also shut down a relatively old gas-cooled reactor power plant; Germany continued its nuclear exit program and also shut down 1 nuclear power unit.

B. Status of Units under Construction

By the end of 2015, 71 units were under construction worldwide, having a net increase of 1 unit over that of 2014, and total installed capacity reached 76.356 GWe, increasing by 1.278 GWe. Specifically, in 2015, 9 units started construction on a global scale, 3 times the number of 2014, and 8 units were completed and put into operation.From the perspective of construction progress of nuclear power units, the construction schedule of NPPs in China and South Korea has been controlled fairly, China and South Korea have relatively mature Gen-II+ technology, so the cost is low, the construction period is short and economic efficiency is high.Most of the nuclear power units in construction of other countries experienced significant delays, excessive expenditure, suspension and other circumstances,especially 8 AP1000 units[4], 4 EPR units[5] and some NPP in Japan, India, Brazil,Slovakia ,Ukraine, etc.

III.GLOBAL NUCLEAR POWER DEVELOPMENT AND PLANNING DEVELOPMENTS

Global nuclear power development still experienced winter in 2015 and there was clear differentiation in countries' attitudes towards nuclear power development. In developed countries except for UK, nuclear power development was almost stagnant. Nuclear energy only

developed continuously in developing countries represented by BRICS. IAEA has also continued to lower the forecast for the global nuclear power capacity in 2030 for many years in a row. Although some countries have shut down several units in operation in advance and some countries have slowed down nuclear power development, nuclear energy is still an indispensable and major option in the future global energy structure and the dominant society still recognized the role of nuclear power in the global energy structure, so nuclear power will maintain low and steady development. At present, nuclear power development is gradually getting rid of the shadow of the Fukushima accident, but the future development of nuclear power mainly depends on its own economical efficiency.

A. The Developments of Global Nuclear Power Planning

(1) Nuclear power development was almost stagnant in developed countries, excluding UK.[6]

For economic reasons, the United States successively shut down 5 nuclear power units in advance between 2013 and 2014. Although it did not shut down units in advance in 2015, large US nuclear power operators Entergy and Exelon have considered shutting down more nuclear power units in advance. Although the DOE has invested a lot of money into several identified and stressed technical fields, including advanced nuclear reactors, small modular reactors (SMRs), the continuing compact of low oil price and shale gas still had a negative impact on the development of its large and SMRs. Analysts believed there would be almost no possibility of new large nuclear power projects into the next decade in the United States. Japan was slow in the implementation of the plan to restart nuclear power. In the next future years, perhaps only 7 reactors of the 42 Japanese reactors that can be restarted because stringent nuclear safety standards and relevant laws and regulations have restricted the restart of NPP. South Korea also slowed down the pace of nuclear power development. In the seventh basic plan for power demand (2015-2029) that was issued in 2014, the South Korean government reduced the proportion of nuclear power from 41% of the previous version to 29%, which had only a slight increase over the current proportion of nuclear power, and South Korea does not consider life extension for nuclear power units on expiration.The French government is actively promoting energy restructuring, vigorously developing new energy and reducing the proportion of nuclear power. By 2030, the proportion of nuclear power will be reduced to about 50% from the current 75%. For the next decade, Sweden would shut down 2 units of RinghalsNPP and 2 units of OskarshamnNPP ahead of their operation license expiration for economic reason, and another 6 units which will probably be permanently closed in advance because of the same reason.Germany shut down 1 unit in 2015.Belgium permanently closed 1 unit and restarted 2 units that were shut down in 2013. Canada has no plan to build new nuclear power units in the next few years and it will only extend the life of existing units.

Currently, the UK NPPs in operation gradually face retirement. Under the pressure of demand for energy and climate changes, UK gradually chooses a path that is completely different from Germany abandoning its nuclear program, namely it plans to build 8 new NPPs with the installed capacity of 16 GWe before 2030.

(2) Developing countries represented by BRICS still serve as the main engine to drive the world's nuclear power development.

In India, Modi intended to replicate the successful experience of Gujarat after coming to power, he made efforts to develop infrastructure, emphasized large-scale development of nuclear power and solar power and planned to import 28 light water reactors. Nuclear power capacity will increase to 35.20 GWe in 2025 from 5.80 GWe in 2014, increasing by 5 times.Brazil plans to build 4 new nuclear power units on the basis of two existing units by 2030, with 2 in the northeast and the other 2 in the southeast of the country. They are expected to be put into operation between 2025 and 2030. Brazil is currently contacting with many potential suppliers and it plans to sign a contract with the selected suppliers in 2017 and start construction in 2018.Russia plans to build 9 NPPs with 21 nuclear power units before 2030, including 5 new double-unit NPPs (8 VVER-1200 units and 2 BN-1200 sodium-cooled fast reactors); 10 VVER-1200 units in the existing plants; and 1 BN-1200 sodium-cooled fast reactor. In addition, it plans to build SVBR-100 prototype reactors and it also plans to design 300MWe-level combined heat and power (CHP) plants. However, the Russian economy remains in the doldrums in recent years, some NPPs under construction have taken the initiative to postpone commissioning time and the huge nuclear power planning is under great pressure.6 units started construction in China in 2015. China's nuclear power development has entered a new round of peak. In the next five years, 5 or more units will start construction per year, serving as the main engine of the world's nuclear power development.South Africa plans to build 6 to 8 new nuclear power units before 2030, adding 9,600 MWe to the current installed capacity of nuclear power generation, namely 1,800 MWe. So far, South Africa has approved the launch of the nuclear power project bidding process.

(3) Among the non-BRICS developing countries, Iran, Saudi Arabia, etc. have a huge nuclear power development plan.

After the first NPP was put into operation, Iran vigorously develops nuclear power construction, specifically as follows: it plans to build 2 ACP100 units of China National Nuclear Corporation (CNNC); it plans to build 3 new Russian VVER units at the site of Boushehr plant; and it plans to build 4 VVER units at another site in the country. Iran also reached a Joint Statement of Intent on the Reconstruction of the Heavy Water Research Reactor in Arak in Joint Comprehensive Plan of Action (JCPOA) with China and the United States, and China Atomic Energy Authority and the United States

Department of Energy will be double leader of the Six-nation Working Group on Iranian Nuclear Issues to jointly promote the reconstruction of the heavy water research reactor in Arak.Saudi Arabia plans to build 16 nuclear power units before 2030. Currently, it is also actively contacting with major nuclear power suppliers, including CNNC.

(4) There is also positive development in some nuclear power projects of other developing countries.

For example, Pakistan, Turkey, Kazakhstan, Jordan, Czech Republic, Lithuania, etc. are also carrying out constant contact with potential suppliers and cooperation agreements on relevant projects may be signed within 2 years. The nuclear power projects of Vietnam, the UAE, Argentina and other countries also have a positive progress.

B. Research and Development Status of Global Mainstream Nuclear Power Models

As for large reactors, there hasn't been significant progress in other nuclear power reactor types except for HPR1000 launched by China. After the main pump of the first reactor was returned to factory for maintenance, SanmenNPP, which used AP1000 technology, finally completed the installation of the first pump and the final commissioning of the unit remains to be seen. UK ABWR of GE-Hitachi (GEH) has completed the phase-3 Generic Design Assessment (GDA, 4 phases in all) of the British Office for Nuclear Regulation (ONR) and it is expected to obtain a design acceptance confirmation from ONR in December 2017. In China, State Power Investment Corporation has basically completed CAP1400 equipment manufacturing industry chain, the demonstration project has entered the final part of approval review and it is expected to start construction in the first half of 2016[7]. Especially, after National Energy Administration made a match, China National Nuclear Corporation (CNNC) and China General Nuclear Power Corporation (CGN) jointly set up Hualong International Nuclear Power Technology Co., Ltd. to promote the integration and export of Hualong technology. The first 4 HPR1000 demonstration units have started construction and the maturity and economical efficiency of the units remain to be verified by demonstration projects.

As for SMRs, at present, about 45 kinds of SMRs are developing in the world, about half of the reactor types will be built in the next 10 years and 3 kinds of SMRs will be put into operation in the next 4 years, namely Russian KLT-40S, China's high temperature gas-cooled reactor and Carem-25 of Argentina. Currently, these 3 kinds of reactors are under construction and Russian KLT-40S is expected to be put into operation in 2016. Technically, several SMR models that are studied by the United States are more advanced. However, due to the impact of decreasing natural gas price and slow growth in power demand, most SMRs that are studied by the United States are experiencing a financial crisis, Babcock & Wilcox has slashed R & D budget for mPower and Westinghouse has suspended the research and development of SMRs, but the research and development activities of Nuscale and Holtec SMR are steady. UK began to actively promote the research and development of SMRs while vigorously promoting the construction of large reactors. So far, UK's Nuclear Advanced Manufacturing Research Center (NAMRC) has signed an agreement with Nuscale to jointly promote the research and development of 50 MWe-level SMRs. The SMART of South Korea has obtained the design license from Nuclear Safety and Security Commission (NSSC) of South Korea. Korea Electric Power Corporation (KEPCO) has signed a memorandum of understanding with Saudi Arabia in 2015 and it will build 2 SMRs for Saudi Arabia in the future. In addition, Korea Atomic Energy Research Institute (KAERI) announced that it had carried out passive safety simulation and verification tests for the reactor cavity cooling system of the ultra-high temperature reactor (VHTR) developed by it. VHTR demonstration unit is expected to start construction in 2020 and it is expected to be put into commercial operation in 2025. In China, the overall design for CNNC's ACP100S and CGN's ACPR50S has been completed and demonstration reactors will start construction at the end of 2016 according to schedule. Additionally, CNNC has signed a memorandum of understanding with Iran and it will export ACP100S SMRs to Iran.

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