CHAPTER 13

COMMITMENT AND LEARNING IN INNOVATION

The Case of the First 500 kV Transformer Made in Viet Nam

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In the early 1990s a shortage of electric power generation capacity in the southern provinces of Viet Nam seriously hindered the economic development of the whole country. The long S shape of Viet Nam with its three distinct regions (North, Central, and South), each with its own separate electrical system, made it impossible to match surplus generating capacity in the North with consumer demand in the South. A proposal to construct a 500 kilovolt (kV) transmission line 1,500 kilometres (km) long from the North to the South was considered and approved by the Vietnamese government. The high voltage minimizes the energy lost by transmitting over such a long distance, making the project economically viable. The line was constructed in record time—only two and a half years—and began operation in May 1994. It immediately resolved the problems of electricity shortages in the South. In the following years, the 500 kV transmission network was expanded and now plays a substantial role in harmonizing the supply of electricity in the country.[1]

The strategic importance of 500 kV transformers in Viet Nam

Transformers capable of handling 500 kV step up and step down the voltage at connections between the 500 kV network and the remainder of the network. A malfunction in a 500 kV transformer can lead to power loss for an entire region for a long period. Repair can take several months; replacing the transformer would also take time and money. For these reasons, 500 kV transformers are considered to be critical equipment for the security of the line and for the entire electrical power system.

In Viet Nam, 500 kV transformers from a number of manufacturers have been used. The original 500 kV power line constructed in the 1990s had five transmission stations, each equipped with a 500 kV transformer supplied by a French manufacturer.[2] Since beginning operation in 1994, the 500 kV transmission line has been expanded several times, each time with different vendors and different 500 kV transformers. Because it is a highly sophisticated piece of equipment, only a limited number of countries (including China, France, Germany, the Republic of Korea, the Russian

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Federation, and Switzerland) can manufacture 500 kV transformers, and prices are high.[3]

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The challenges of designing and manufacturing 500 kV transformers locally

The operation of 500 kV transformers creates super-high-voltage electric fields. These transformers also need to be able to survive voltages up to 1,550 kV in the event of a lightning strike or short circuit, so the equipment must have precisely positioned and engineered electric field shields. The higher the capacity of the 500 kV transformers, the more shields are needed and the more sophisticated the design has to be. Even a small fault in design or manufacture can lead to the failure of the entire system. According to an interview in 2018 with Chief Designer Nguyet, a foreign company with a research and development (R&D) team of eight staff with post-doctoral degrees and 34 engineers failed three times before succeeding on their fourth attempt to design and manufacture a 500 kV transformer.[4] The design of the number of shields, their shape and size, and their arrangement in the structure of the apparatus are all critical: on one hand this allows the transformer to function well and on the other hand it allows the system itself to be easily manufactured. Because the designs of 500 kV transformers are companies' proprietary information, designing the first 500 kV transformer locally was a major challenge. In addition, the capacity of 450 MVA (3 × 150 MVA) of the targeted 500 kV transformer created additional challenges because the required number of electric field shields for this capacity are much higher (21 in this machine compared with only 2 in the transformer in Yali).[5]

Manufacturing presented another challenge. The problem was how to adjust and upgrade existing manufacturing facilities so that such a complex, high-precision 500 kV transformer could be constructed with minimum costs for upgrading the facility.

The process of accumulating knowledge

Dong Anh Electrical Equipment Corporation - Joint Stock Company (EEMC) is a local Vietnamese company that specializes in the manufacture and repair of electric transformers of all kinds. Many of its technical staff members have been trained in top technical universities in Viet Nam and overseas. Some have had experience working in leading research and manufacturing organizations in the Russian Federation, which has given them valuable practical knowledge as well. In Viet Nam, this company's technical staff are considered leading experts in the field.[6]

Having had many opportunities to repair imported transformers made by various manufacturers, and with a good theoretical foundation, gradually EEMC's staff increased their understanding of the functional features of transformers and the theoretical and practical basis for their design and manufacture. In 1994, EEMC successfully developed the first locally made 110 kV transformers. This was a great achievement at that time and helped EEMC win the trust of the top business and government leaders. The firm was then given a contract to develop a 220 kV transformer. Nguyen Thi Nguyet, the project's chief designer, reported that while developing the 220 kV transformer a proposal to spend US$1 million to buy a design from a foreign firm was considered, but that proposal was not approved and EEMC went on to make the 220 kV transformer without foreign assistance.[7] By the early 2000s, EEMC had become a leading local supplier of this equipment.

In 2005 the company encountered a unique learning opportunity when the single-phase 500 kV transformer with a capacity of 72 MVA at the Yaly Hydropower Plant needed repair. The equipment had been manufactured in Ukraine, and it would have taken 16 months to repair if it had been sent back to the original manufacturer. EEMC proposed making the repair in Viet Nam, but it was awarded the contract only after agreeing to complete the repair within three months. EEMC successfully repaired that first transformer and proceeded to repair other low-capacity 500 kV transformers in subsequent years. Experience and knowledge learned while repairing other manufacturers' equipment gave EEMC the confidence to design and manufacture its first 500 kV transformer locally.

The project: To design and manufacture the first 500 kV transformer in Viet Nam

In 2008 EEMC requested, from the Ministry of Industry and Trade and the Ministry of Science and Technology, a 15 billion Vietnamese dong (VND) grant to be matched by its own investment of 62.338 billion VND for the design and manufacture of a 500 kV transformer.[8] Because of the strategic importance of 500 kV transformers in the Vietnamese power system, the grant was approved. In addition, EEMC had access to the national high-voltage laboratory, which has the capability of testing electrical equipment up to 500 kV; the laboratory is located just next to its factory. The project formally began in November 2009 and finished in October 2010. In November 2011, the first locally made 500 kV transformer was installed and began operation in the Nho Quan transmission station in Ninh Binh. The 500 kV transformer strictly followed International Electrotechnical Commission (IEC) 60076:2000 standards for a power transformer.[9] The high-voltage national laboratory in Hanoi and various laboratories of the Quality Assurance and Testing Centre 1 of the Directorate for Standards, Metrology and Quality carried out necessary testing for 19 key specifications of the transformer. The testing verified that the transformer functioned correctly and met the design specifications.[10]

According to the R&D team that designed and manufactured the first locally made 500 kV transformer, the design work was a process of creative problem solving. The team had extensive knowledge of 220 kV transformers and some knowledge of lower-capacity 500 kV transformers from repairing them. However, designing a 500 kV transformer with a higher capacity (one with 3 × 150 MVA) was something new and required a design grounded in first principles. Starting with the basic structure observed in similar equipment in China, the team first developed a design concept with an asymmetric structure, then the physical design, and finally the detailed design.[11]

The team received support during the design process from a Russian consultant whom the chief designer of the team had met at Yali when both EEMC and the original vendor were invited to the site to assess the damage to the broken 500 kV transformer and submit a proposal for its repair. Each time the team came up with a specific design, the consultant reviewed it and suggested improvements. Having more than 40 years of experience in the field and having developed software for calculating various parameters of 500 kV transformers, he proved to be an important resource for the team.[12]

To develop a working physical design of the 500 kV transformer, the team developed a small-scale prototype with similar technical features to test various aspects of the design as well as to collect data for establishing the relationship between key parameters.[13] As mentioned earlier, one of the most difficult issues encountered in designing a 500 kV transformer is the complex and precise arrangement of electric field shields. Another related problem is determining how to design such complex equipment so that it can be manufactured in already-existing production facilities that require the least expensive upgrading and also have low operational costs. For each of these issues, a creative solution was required.

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Through the accumulated knowledge of EEMC, the commitment and hard work of the team, and the support of the foreign consultant, the 'learning-by-doing' process and creative problem solving bore fruit. The final EEMC design was considered by the Russian consultant to be very effective and efficient.[14]

In terms of manufacturing, the large size, complex structure, and precise arrangement of 500 kV transformers normally require advanced, sophisticated manufacturing facilities that were too costly for EEMC to acquire. The only available solution was to upgrade the existing 220 kV transformer factory to manufacture the 500 kV unit.

The electric wire used in the 500 kV transformer needs to be wrapped with insulating paper and the process must take place in a perfectly clean environment. EEMC adopted new technology allowing simultaneous wrapping with 21 layers of insulating paper in a closed chamber. After the successful application of the process to 500 kV transformers, the technique was also used to enhance the quality and reliability of the 220 kV transformers with improvements to various design and capacity elements.

Wiring around the huge magnetic cores of the 500 kV transformer also required a new solution. EEMC developed an innovative wiring machine to work with standing magnetic cores. The adjusted machine had a higher capacity than the previous one and was able to wire around magnetic cores that were around 3.5

metres high. This innovative solution was completely original to EEMC.

The large size of a 500 kV transformer means that a huge quantity of thin magnetic steel plates is required. These plates need to be carefully positioned and rotated without altering their relative placement, among other positioning requirements. Commercially available equipment for this task was very expensive, so EEMC managed to modify the smaller equipment used for manufacturing the 220 kV transformer to enable it to handle the much larger elements used in the magnetic core of the of 500 kV one. This was an important incremental innovation in this project.[15]

Policy recommendations and takeaways

The successful design and manufacture of the first 500 kV transformer raised the confidence of scientists and engineers in Viet Nam in the electrical equipment sector. With this advance, Viet Nam entered the club of the few countries in the world that can design and manufacture such large transformers.[16] In Asia, only Japan, China, the Republic of Korea, India, and now Viet Nam have this capability. With the option of manufacturing locally, Viet Nam has improved its bargaining power in negotiating with international vendors in the 500 kV transformers market. The price of 500 kV transformers has dropped about 20% to 30% of previous prices since 2010.[17] Moreover, the security of the national power system has strategically improved, and the project has been successful in expanding Viet Nam's 500 kV lines over time.[18]

The knowledge acquired in during the course of the project has increased local capacity for maintaining and repairing such sophisticated equipment. The technologies and innovations developed for this project are now used to design and manufacture higher-quality 110kV and 220kV transformers, helping Viet Nam manufacturers to maintain their dominance with this range of products in the local market.

Viet Nam's completion of the project that researched, designed, and manufactured a three-phase 500 kV 3 ×150 MVA transformer was a great technological achievement.[19] The project's success proved that with the right commitment, local scientists and engineers can make extraordinary advances and contribute significantly to the economy. However, its economic success was not so clear, which raises the question of industrial policy related to this project. After the first 500 kV transformer, EEMC found it difficult to win contracts for future ones. So far EEMC has made only three 500 kV transformers. Once EEMC entered the market, foreign vendors—especially those from China—responded with price cuts on their own products. Since 500 kV transformers are usually only one piece of equipment in a larger bidding package, without joining with other vendors EEMC found it difficult to win contracts.

The inconsistency between the policy that supports local R&D efforts to make 500 kV transformers and the bidding policy that works in favour of large and financially powerful international vendors will need to be corrected, otherwise the success of the 500 kV transformer project with all its invaluable knowledge will soon fade away. Many tacit lessons learned and much knowledge generated from this project are in danger of being lost if they are not codified quickly and enhanced further. Knowledge management at both the firm and national level is not currently being sufficiently considered, and some measures must be taken to correct it.

Notes

1 Tran Viet Ngai, 2014.

2 Tran Viet Ngai, 2014.

3 MoST and MoIT, 2010.

4 Nguyet (Chief Designer), interviews, 2018.

5 Nguyet (Chief Designer), interviews, 2018.

6 EEMC management, interviews, 2017 and 2018.

7 Nguyet (Chief Designer), interviews, 2018.

8 Tran Manh Huong (EEMC Technology Department), personal communication, 2018.

9 The International Electrotechnical Commission (IEC) 60076:2000 standards provide technical specifications for power transformers. See https://fenix.tecnico.ulisboa.pt/downloadFile/845043405448082/IEC%20 60076-1%202000.pdf for further information.

10 MoST and MoIT, 2010.

11 Nguyet (Chief Designer), interviews, 2018.

12 Nguyet (Chief Designer), interviews, 2018.

13 EEMC management, interviews, 2017 and 2018.

14 Nguyet (Chief Designer), interviews, 2018.

15 MoST and MoIT, 2010.

16 As of 2011, according to EEMC's Technology Department, the 12 countries capable of manufacturing 500kV transformers were China, France, Germany, India, Italy, Japan, the Republic of Korea, the Russian Federation, Switzerland, Ukraine, the United States of America, and Viet Nam.

17 EEMC management, interviews, 2017 and 2018; Nguyet (Chief Designer), interviews, 2018.

18 MoST and MoIT, 2010.

19 MoST and MoIT, 2010.

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