A review of HVDC in China

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By 2018, about 60% of the installed capacity of HVDC schemes worldwide will be in China (in only 20% of the number of schemes). By necessity, China has become the leader in HVDC, with a strong emphasis on developing its own country's capabilities.

The result is that Chinese HVDC firms are now globally competitive on complete HVDC schemes, with ±800 kV and 6400 MW schemes being standard. Chinese firms are also at the forefront of the development of HVDC technology with the testing of 1100 kV valves as well as fault based maintenance methodology.

The Chinese power grid is also extremely complex and HVDC and FACTS (Flexible AC Transmission Systems – SVCs, Series compensation, Statcom, etc.) devices are required to improve overall grid stability.

Eskom and Hydoelectric Cahora Bassa (HCB) recently undertook a fact finding mission to China to review the status of the HVDC market in China by visiting HVDC sites and suppliers.

Fig. 1: Eskom and HCB executives at NR electric visitor centre.

China's electricity market

By 2020, China's maximum demand is expected to reach 1272 GW. There are large distances between the economic power generation locations and the load centres. Therefore China needs develop solutions to transmit large amounts of power over large distances.

As a result, China has voltage levels up to 1000 kV AC and ±800 kV DC and is busy testing the 1100 kV voltage level. Due to the total power requirement and long distances involved, China has rapidly become a world leader in HVDC.

Table 1 summarises the HVDC projects in China and the world to date and those planned to 2018.

Fig. 3 shows the map of the planned HVDC and UHVDC projects planned in China.

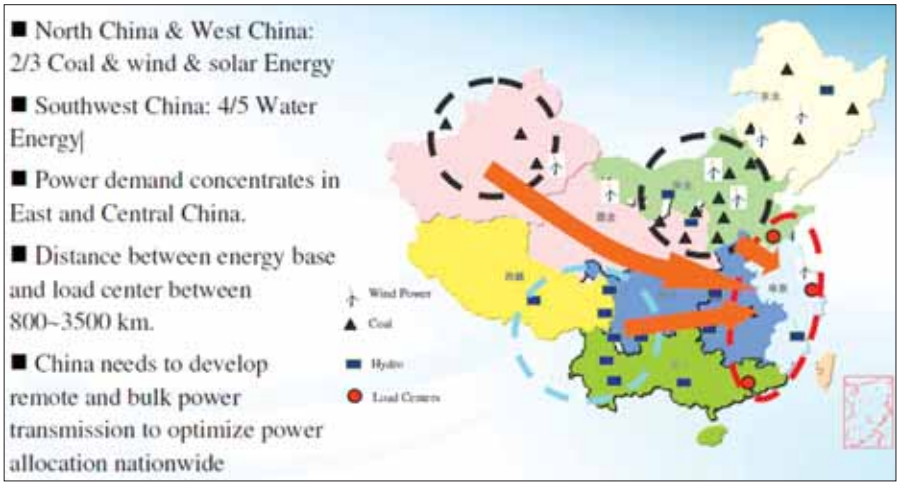

Fig. 2: China generation vs. load centre map.

The fact that China will have more than 60% of the installed HVDC capacity in only 20% of the number of schemes demonstrates the need for higher technology for the higher average scheme power. Most schemes to date have been ±500 kV 3000 MW, but upcoming schemes will be mostly ±800 kV 6400 MW and there will be a number of 1100 kV projects in the future.

Research and development and supplier development

In order to support the research in key technologies, State Grid (SGCC) has established a world class test and research platform, which is taking the lead in comprehensive R&D capabilities. Key local suppliers have also got significant R&D facilities, such as Xi'an Electric (XD) and NR Electric (NR), with well staffed R&D centres and a number of national level high voltage test facilities.

The Chinese government implemented a policy that for European based HVDC OEMs, such as ABB and Siemens to be able to take part in the early HVDC projects in China (in the early 90s), they needed to partner with local Chinese companies and transfer skills and technology to them.

Most (more than 90%) of the thyristors used in HVDC schemes in China are manufactured by PERI (Power Electronics Research Institute) in Xi'an. PERI are

	China				Total World	
	Installed capacity		Schemes		Capacity	Schemes
	GW	%	#	%	GW	#
Existing up to 2011	42,3	41%	17	15%	102,7	117
Planned 2012 to 2018	77,4	84%	14	48%	92,3	29
Total to 2018	119,7	61%	31	21%	194,9	146

Table 1: HVDC projects.

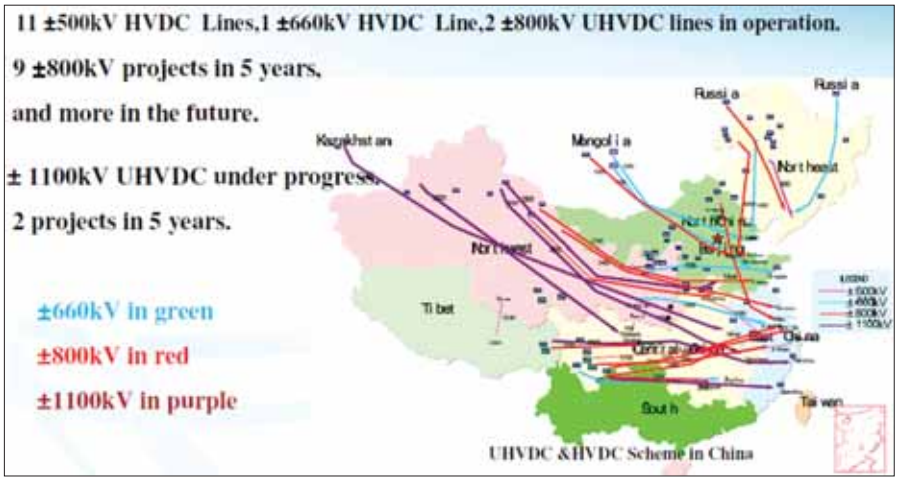

Fig. 3: Map of planned HVDC schemes in China.

Reliability Index	Xiangjiaba – Shanghai Project	Conventional HVDC Project
Converter forced outage rate	≤ 2 times / (converter ▪ year)	–
Monopole forced outage rate	≤ 2 times / (pole ▪ year)	≤ 5 times / (pole ▪ year)
Bipolar forced outage rate	≤ 0.05 times / year	≤ 0,1 times / year
Energy unavailability	≤ 0,05%	≤ 0,5%

Table 2: Reliability statistics.

the most established and technically advanced thyristor manufacturer in China. They have co-operated with ABB and Siemens on thyristor development since 1998 and both ABB and Siemens use thyristors manufactured by PERI for all their projects in China. PERI reportedly took the lead in the development of the 6" thyristor. Their market share in China is estimated at 70% for general thyristors, 90% for 6" thyristors and 100% for LTT thyristors.

The 800 kV HVDC systems have been designed for high reliability. There are double series connected converters based on a modularised and symmetrical design. There are 46 operational patterns available in total. The control and protection system uses real time operation system based control with advanced logic "2 from 3". In this way, SGCC has been able to obtain the reliability statistics given tin Table 2.

China XD group

Xi'an Electric (also known as China XD group) has developed its capabilities from its early co-operation with international OEMs, to be the leading supplier of UHV AC and DC primary equipment, including system design, converter transformers, DC smoothing reactors, converter valves and other equipment. XD's converter valves has been used in many HVDC systems in China and they are busy testing the 1100 kV valve. XD has 3 national level HV test and research companies in the group up to ±1100 kV DC. The XD Group ranks 1 among the Top 100 Chinese Electrical Equipment Enterprises. Most Chinese HVDC projects split the converter transformers between two manufacturers due to the sheer size of the order. XD Transformers is the largest manufacturer of special transformers in China, and has rich experience and accomplishments in DC power transmission equipment manufacturing. XD transformers manufactures transformers up to 1000 kV and 1000 MVA, including converter transformers and has contributed to all of the HVDC projects in China with more than 167 converter transformers and 38 smoothing reactor sets.

Fig. 4: Photo of Eskom and HCB executives considering the details of the XD manufactured valves.

NR electric

NR is ranked number 3 out the global top 5 Control and Protection providers (Newton Evans 2006). NR is a control and protection solution provider with over 20 years experience and has about 45% market share in China, six subsidiaries and four service centres outside China, and their products have been sold in 60 countries.

Since co-operating with ABB initially on HVDC, NR's more than 400 engineers in R&D have developed their own next generation technology, including their UAPC platform, which now forms the basis of their whole range of protection relays and power electronics solutions. NR has completed eight new HVDC scheme control and protection systems, two system refurbishment (replacement of control and protection systems) from old BBC and Siemens systems and are busy with four new systems. NR have found that they are able to refurbish the control and protection system without a corresponding change to the hardware technology for the valves; and their control and protection systems work well with the ABB, Siemens and ED valve, which are fairly similar in nature.

NR is also a leading contributor to the power system stability in China with their FACTS devices (series compensation (SC), SVCs, etc.) and power stability control systems (PSCS) which have been adopted by both SGCC and China Southern Grid (CSG). PSCS has been found to be superior to the alternatives of SPS and WAMS, because it is real time and has much faster response and operating times. The result is that while China's power gird probably the most complex, it is also probably the most stable. NR has also supplied one of the largest utility SVCs in China at the 50 kV Guilin substation. This SVC has a 240 Mvar thyristor controlled reactor (TCR) and 180 Mvar fixed capacitor filter banks (FC). NR has also developed a voltage source converter (VSC) system, that forms the basis of its VSC-HVDC (HVDC Lite), Statcom Static Var Generator and photovoltaic (PV) Inverter.

Fault exploring based maintenance

China has evolved is maintenance strategy from time based maintenance before the 90s, to condition based maintenance (CBM) (90s to present) and is busy piloting fault exploring based maintenance (FBM). Compared to CBM, FBM does not completely rely on the early warning signals from device monitoring equipment; it pays more attention to the

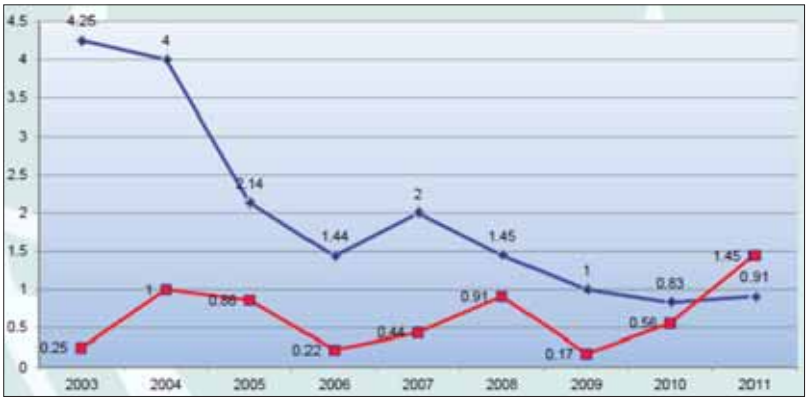

Fig. 5: Reducing incidence of forced block times.

correctness and optimality of the software programs and reference values of control and protection systems. FBM emphasizes improving the operation reliability through specialised production employees' active and day-to-day investigations of the possible troubles of all of devices in substations. Most faults in HVDC schemes are forced blocks from the control and protection scheme. The hidden problems of the control and protection system can often not be found by CBM, however FBM and innovations in the control and protection system can effectively reduce the forced blocks caused by the control and protection system. FBM has been carried out in the 10 SGCC HVDC transmission systems for several years. The excellent operation indexes of HVDC transmission systems in SGCC indicate that FBM can improve the operational reliability of HVDC transmission systems. The average forced block times of mono pole or unit was reduced from 3,25 to 0,81, and that of bi pole or unit was reduced from 0,75 to 0. Forced energy unavailability is determined by forced block times and forced restoration duration. Compared to HVDC projects in other countries, HVDC projects in China have less forced block times but longer restoration duration per forced block. An important principle for dealing with HVDC forced block in SGCC is that the true fault reason must be found before restoration. The longer restoration duration per forced block in China is caused by elaborate fault analysis after forced block. By doing comprehensive investigations into true fault reason, SGCC and its supplier partners, such as NR, are able to improve the control and protection system to reduce the possibility of that type of fault occurring again.

Conclusion

Because of the location of the economic generation zones and load centres, China has had to rapidly adopt HVDC to be able to transmit the power required. China therefore went from having almost no HVDC by 2000 to an expected 60% of the installed capacity by 2018. As a result of this rapid growth, China has been able to enforce the empowerment and development of its local suppliers, facilitate research and development into leading edge HVDC technology and techniques in order to transmit more power over longer distances with higher reliability. HVT provides local sales and service for HVDC and FACTS systems from XD and NR in South Africa serving the Southern African (SADC) market. The cornerstone of our business model is a fully skilled & resourced local Technical Service & Support Centre for all products sold.

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