Grids united

ABB and Tsinghua University are helping interconnect China's grids

Qianjin Liu, Qiang Lu, Christian Rehtanz

Rapidly growing industries in China rely heavily on a stable and continuous power supply. This means China's power grids are coming under increasing pressure. Because the centers of power consumption are often far from the principal generating areas, the interconnection of regional grids and the development of long-distance transmission infrastructure are now priorities for China's utility sector.

There is much more to interconnection than just joining wires. Numerous planning, implementation, monitoring and protection measures must accompany the interconnection if instability and unpredictability are to be avoided.

In coordination with Tsinghua University, ABB is addressing these issues and is helping China's electricity grids interconnect. Thanks to this program, the nationwide exchange of power is fast becoming a reality.

As part of ABB's new corporate research center in Beijing, China, a group has been formed to conduct research and development in the area of power systems engineering. This group has, as its mission, to "contribute to the development of the power technology market through solutions to power systems issues and research on future systems requirements." Initial discussions with ABB customers in China indicated that various system performance shortfalls had been faced regarding the interconnection of the regional power grids. To better understand and alleviate the issues involved, ABB Corporate Research in China has initiated a project with Tsinghua University under the title "Interconnection of China's regional Grids".

As the leading technical university in China, Tsinghua is deeply involved in technical issues connected with the operation and planning of the national power system grid. Tsinghua University is also the site of China's State Key Lab of Power Systems led by Professor Lu Qiang 1, a member of China's National Academy of Sciences. Professor Lu has worked extensively with China's power system and it was he who orchestrated the co-operation with ABB.

The Tsinghua project will identify the key technical issues and then develop the required systems solutions. The initial phase of the project has already been completed and it provides a summary of the historical development of China's transmission grid, and a summary of the problems that have accured as well as a database of the transmission system configuration.

China's power grid[1)]

At present, China has seven interprovincial networks 2, namely: the North China Grid (NCG); Northeast China Grid (NECG); Central China Grid (CCG); East China Grid (ECG); Northwest China Grid (NWCG); South China Grid (SCG) and Sichuan and Chongqing power networks (CYG) as well as four independent provincial grids in Shandong, Xinjiang, Hainan and Tibet. 500 kV has become the backbone structure in most regions except in the northwest, which relies on 330 kV networks.

In China, the major energy sources are located in the west (hydro) and the north (coal). The major load centers are in the east and south. Interconnecting the regional grids is therefore a natural step in the development of China's power systems. Grid planners intend to realize "west to east power transmission, north and south power exchange and nationwide interconnection".

The interconnection of China's regional grids

Interconnecting the regional grids began in 1989 when a 500 kV 1,200 MW HVDC tie line, connecting the Central China Grid with the East China Grid, went live. In 2003 a second 500 kV HVDC transmission line went into operation, increasing the transmission capacity between East and Central China to 4,200 MW. In May 2001, the NECG and NCG achieved synchronous interconnection through a 500 kV AC line, as did Fujian Province and East China in December 2001. The Sichuan and Chongqing power networks and Central China were similarly interconnected in April 2002, and Central and North China in September 2003. In 2004, a 3,000 MW HVDC transmission link was completed between the Three Gorges power plant in Central China and Guangdong in the South China Grid. Numerous other interconnections, both AC and DC, are currently being studied and planned.

Issues encountered

In the area of system security, if the amount of power exchange between regional grids is large, any disturbances on the interconnecting lines significantly affect the frequency and voltage stability of the connected power systems. For example, once the Sichuan and Chongqing Grid (named ChuanYu Grid, CYG), the CCG and the ECG are interconnected, large amounts of power will be transmitted from the CYG to the ECG through the CCG 3. The intertie line between the CCG and the ECG, the Genan DC line, will carry up to 1,200 MW of power. If the Genan DC link is interrupted while the CYG is sending power to the CCG through the Wanlong line intertie 4, the CCG will have surplus power and the frequency will rise. In 2001, the Genan DC link experienced this problem four times when sending large quantities of power to the ECG. Each interruption caused the frequency of the CCG to exceed the upper limit of 50.2 Hz. The most serious incident occurred on June 4, 2001: while the Wanlong line was transmit-

1 Professor Qiang Lu of Tsinghua University.

2 Interconnection of China's regional grids.

NCG = The North China Grid
NECG = Northeast China Grid
CCG = Central China Grid
ECG = East China Grid
NWCG = Northwest China Grid
SCG = South China Grid
CYG = Sichuan and Chongqing power networks

Footnote:

1) The following paragraphs are summarized from a Tsinghua University report from April 2005.

ting 550 MW to the CCG and the Genan DC link was sending 1,040 MW to the ECG, a DC interruption drove the frequency of the CCG to 50.31 Hz. To limit such rises, generator tripping equipment was installed in the Gezhouba hydro plant in 2004 – the main source and starting point of the Genan DC link.

As for voltage stability, the CCG has been encountering low voltage problems in the rainy season when the hydro units are running at full capacity. After interconnection with the CYG, the problem worsened due to the large power being "wheeled – through" the system. The voltages of many critical 500 kV buses need reactive power support from generators located in load centers.

The weak interconnection of regional grids also causes low frequency oscillations between areas. For example, following the interconnection of the NCG and the NECG, a low frequency oscillation was observed on occasions. This was triggered under special conditions when certain important elements in the NCG were out of operation. Similar problems happened to the CYG and the CCG after they were interconnected: the Wanlong line connecting the two regional grids is most vulnerable and sometimes experiences a low frequency oscillation. The most critical situation occurred after the NECG, NCG and CCG were interconnected. According to a report by the state power company, a low frequency oscillation was measured by primary metering units (PMUs) installed at a substation in the CCG. Although many generators are equipped with power system stabilizers – following the interconnection of the NECG and the NCG, more than 60 large capacity generators were fitted – this low frequency oscillation can still be observed.

The transient stability of China's regional grids is also affected by the interconnections. These modify the transient stability limits of many transmission lines. For example, the limit of the Dafang double-circuit line in NCG decreased from 1,580 MW to 1,450 MW. If this line fails, power systems covering Beijing, Tianjin and Tangshan will have to handle up to 1,500 MW of excess power. This unbalanced power will cause a loss of synchronization between the NECG and the NCG. Some studies show that the transient stability of the NECG deteriorated after it was interconnected with the NCG. Temporary remedies are now in place to limit power transmission on the tie lines, and to trip tie lines in emergencies, in order to maintain the transient stability of these two regional grids. In the long term, however, the interconnection backbone will have to be strengthened.

Potential system solutions

HVDC is playing an important role in the interconnection of China's regional grids because of its ability to asynchronously link systems with different nominal frequencies, and its ability to transmit large amounts of power over long distances more economically. As more and more DC transmission projects are installed, the coordination of controls between DC and AC systems grows in importance. In fact because of their ability to rapidly control the transmitted power, HVDC systems can be used to enhance the stability of the AC system, and provide damping for power system oscillations.

FACTS (Flexible AC Transmission Systems) play the principal role in enhancing the controllability and power transfer capability in AC systems. Since the interconnections of China's power networks are relatively weak, this situation is likely to last for some time. It is foreseeable that FACTS controls will play a more important role in China's power networks, increasing the transfer capability and enhancing system security.

FACTS

FACTS covers a number of technologies that enhance the security, capacity and flexibility of power transmission systems. FACTS solutions enable power grid owners to increase existing transmission network capacity while maintaining or improving the operating margin necessary for grid stability.

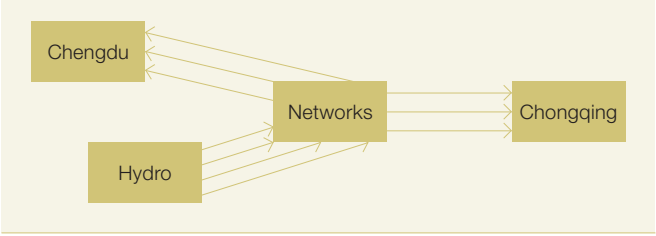
See also: ABB Review 4/2003 pp 21–26 and ABB Review 1/2005 pp 22–25.

Dr. Qianjin Liu
Power Systems
ABB China, Corporate Research Center
qianjin.liu@cn.abb.com

Prof. Qiang Lu
Tsinghua University

Dr. Christian Rehtanz
ABB China, Corporate Research Center

3 The Sichuan and Chongqing Grid (CYG).



4 Power transfer in the CYG, CCG and ECG.