Power System Development and Nationwide Grid Interconnection in China

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Abstract: This paper briefly describes the development of the power systems and the nationwide grid interconnection in China. The purposes of the interconnection, the basic structure, key projects, some technical problems, and the research and development of power system technologies in China are discussed. The nationwide interconnected grid will be basically established in the years 2010-2015 and become one of the largest interconnected power systems in the world. Key issues of the international power grid interconnection between China and North East Asian countries are briefly presented.

Keywords: power system interconnection, long-term planning, HVAC/HVDC, power system technology, International power grid interconnection

1. INTRODUCTION

China's power industry began in 1882, and installed generation capacity reached 1.85GW with an annual generation of 4.3TWh when the Peoples Republic of China was established in 1949. The first 220kV transmission line was put in operation in 1943. During the 1950s and 1960s, provincial power grids were formed gradually. In 1972, the first 330kV transmission line was built to establish a cross-provincial power grid, the Northwest Power Network(NWPN). In 1981, 500kV lines appeared in China's power grid. From the 1980s, China's power industry has stepped into the historical stage of high generating parameters, large units, high voltage, and large power networks. The first interconnection project of regional power grids was commissioned in 1989. It was a DC tie line of +/-500kV, 1200MW from the Gezhouba Hydroelectric Station to the East China Power Network (ECPN). It was designed to transmit hydroelectric power of Gezhouba to ECPN. The Gezhouba Hydroelectric Station is at Yichang City, 40km downstream from the Three Gorges Hydroelectric Station.

Today, China's power industry starts a new stage of cross-regional interconnections striding toward a nationwide interconnected grid for optimizing resources disposition on an even large scope. The construction of the Three Gorges Hydropower Project will further push forward the implementation of the nationwide interconnection program. It is predicted that the nation's total installed capacity will reach 500GW in the year 2010. The first 10-15 years of the 21st century will be a key period to form a nationwide interconnected grid. By the year 2010-2020, a nationwide interconnected grid will be basically established, which will cover major regional and provincial power grids with a total installed capacity of about 750GW by the year 2020.

Following the recent movement of economic globalization and the potential benefits of the international power grid interconnection between China and neighboring countries, feasibility studies have been carried out for certain projects. Some issues have to be studied, considered and solved in order to push forward the realization from a long-term point of view.

2. CURRENT STATUS AND DEVELOPMENT OF POWER SYSTEMS IN CHINA [1-5]

The national economy of China has been developing fast over the past 5-10 years with an annual growth rate around 7-8% each year. The power sector of this country has also been developing rapidly in the same time period. For the power generation sector, the total generation capacity reached 300GW by the end of April 2000. Among the total capacity, about 75% is from thermal power plants, and nearly 24% is from hydro generation. There are two nuclear power plants in operation with total capacity of 2.1GW, 1% of the total capacity in the whole country. It is estimated that the total generation capacity will reach 327GW, and the annual electric production of the whole country in 2001 will be 1430TWh, ranking second in the world. Among the total generation production, about 70% is from coal fired power plants, 20% from hydro, and 10% from others including oil fired and nuclear plants. The annual growth rate of electricity generation will be around 6-6.5% this year.

For the power transmission system in China, the highest transmission voltage level is 500kV AC. The first 500kV transmission line was built in 1981, and the total length of the 500kV lines was 22,400 km by the end of 2000 in the whole country. In the Northwest Power Network the highest voltage level is 330kV, which is different from the other parts of the country. Because of the unbalance of the energy resources distribution in China, the coal mines are located mostly in the Northwest and the hydro potential mostly in the Southwest, while the electricity load centers are in the coastal areas of the East; thus long distance transmissions are needed. The power system stability problem becomes crucial for most power transmission systems. In the year 1990, a +/-500kV long distant HVDC transmission project, from the Gezhouba Hydro Power Plant to Shanghai, was completed and put into operation. This was the first project of this kind in China. Now a new HVDC transmission project, the TSQ project from the Tianshengqiao Hydro Power Plants to Guangzhou with +/-500kV, 1,800MW long distance transmission is just commissioned. The first pole has been operating since the end of 2000. The feasibility studies of other two HVDC projects with 3,000MW each, one from Gueizhou to Guangdong and one from the Three Gorges to Guangdong have been approved. These two projects will be put in operation in 3-4 years.

There are 7 inter-provincial power networks and 5 independent provincial level power networks in operation in the mainland of China. They are East China, North China, Northeast China, Central China, Northwest China, South China, and Sichuan and Chongqing for the inter-provincial networks, and Shandong, Fujian, Hainan, Xinjiang, and Tibet for the provincial level networks. Now the East China Network has been connected with the Central China Network by the above-mentioned HVDC line. It is expected that among the existing networks more interconnections by HVAC or HVDC links will be realized in the future. Among the interconnected projects in China the 500kV AC interconnection between the North China Network and the Northeast China Network has been in operation since the middle of 2001. The others—e.g. Shangdong to North China, Fujian to East China—will be in operation by the end of 2001 or 2002. According to the long-term plan, the first phase of the interconnection of the whole country's power grids will be realized within the next five years.

The Three Gorges development is the backbone project of exploiting the hydro-resources of the Yangtze River. As one of the main parts of the Three Gorges development, the power plants have 26 units of 700MW each, amounting to a total of 18,200MW with annual production of 84.7TWh. There are Left and Right Bank Power Plants, with 14 units in the Left Bank Plant (totaling 9,800MW) and 12 units in the Right Bank Plant (totaling 8,400MW). According to the planned schedule, the first unit will start generation in year 2003, and the installation will complete in the year 2005 for the Left Bank

Plant and in the year 2009 for the Right Bank Plant.

The Three Gorges Project is situated in the central region of the country, close to the load center of the Yangtze River economic development zone. Considering the distribution of the energy resources of the country and the development strategy and analysis of the power demand, it has been concluded that the main areas supplied by power from the Three Gorges are to be Central China, East China, and Chongqing and Sichuan provinces. Thus, the Three Gorges Power System (TGPS) actually will be constituted by the Three Gorges Power Plants, the receiving networks (Central China, East China, Chongqing, and Sichuan), and the transmission system sending power to the receiving networks.

It is estimated from the load forecast and the power system development planning that the maximum load in the year 2010, when the 26 units will be completely installed, will be 52.8GW, 72.1GW, and 24.5GW for Central China, East China and the Sichuan-Chongqing Network, respectively. The grand total installed generation capacity of the whole TGPS will exceed 190,000MW. It can be seen that when the generation capacity of the Three Gorges Project is fully in commission, it will be about 8% of the whole TGPS.

Figures 1, 2, and 3 show the recent regional power grids in China, the regional grid interconnections in 1999, and the regional grid interconnections in 2001-2002, respectively. The Three Gorges Transmission System is shown in Figure 4.

3. PURPOSE AND FUNCTION OF THE NATIONAL GRID INTERCONNECTION [10]

China is vast in territory and rich in energy resources. But distribution of these resources is quite unbalanced geographically. The proven coal deposits are about 900 billion tons; 82% of coal deposits are scattered in the North and Southwest. The exploitable hydropower capacity is 378GW, and average annual electricity is 1920TWh; 67% of hydropower is concentrated in the Southwest. In the meantime, 70% of energy consumption is concentrated in the central and coastal areas of the country. In order to make up the deficits of energy in the central and coastal areas, it is imperative to transmit energy in large amounts and over long distances. Therefore to develop cross-regional power systems interconnection is necessary.

The area along the Yangtze River where the Three Gorges Power System (TGPS) is formed is going to be the center of economic development of the country, as well as an important electric load center. It is necessary to build a strong network along the Yangtze River economic belt, and this will be a natural consequence of the network development. Besides, the southwest hydroelectric power base will be the next mammoth projects after the Three Gorges Power Plant (TGPP), including the 50GW power development and power export from the Jin Sha Jiang projects. This power will be sent to Central China, East China and South China regions though strong transmission systems. Unavoidably, the TGPS will partly undertake the function of forwarding this power from the Southwest. The 500kV transmission lines and network could be difficult in transmitting and receiving such large quantities of bulk power from the Southwest. The idea of higher AC voltage transmission systems or HVDC transmission systems becomes significant for further bulk power transmission.

Besides the exploitation of the huge hydro-power potential mostly in the Southwest, coal-fired electric power plant development in the north and northwest areas in the 21st century will also pose a great amount of transmission requirements which certainly will enhance the power networks' interconnection.

Theoretically, the unified operation of the power networks through tie lines is an effective way for making full use of the energy resources, reducing the necessary total installed capacity, increasing the reliability, and ensuring the supply quality. The most significant benefits are the merging of peaks and the hydro-thermal coordination and cross river-valley compensation.

The territory of China spans several tens of longitudinal and latitudinal degrees, and has climatic differences across the country, which reflects in the merging of peaks and load pattern levelling when connecting the power networks countrywide. Interconnection of the power networks also makes it possible for the hydroelectric stations of different river valleys to make use of hydrological differences and reservoir capacities to adjust their operation regimes to turn spill-over and seasonal output into firm power, thus realizing the advantage of cross river-valley supplementation.

The TGPS may further interconnect with the North China and South China power networks in orde r to alleviate the difficulty of peak regulation of the North China network and to realize the advantage of cross river-valley supplementation with the Hung Shui River of South China.

4. BASIC STRUCTURE OF THE NATIONWIDE INTERCONNECTED GRID [10]

It is predicted that the major phase of the interconnection of power networks of the whole country will be formed by the years 2010-2015. By the years 2015-2020, the nationwide interconnected grid will cover most existing regional and provincial networks in China.

According to the study on energy resources distribution, regional relations, and interconnections, the nationwide interconnected grid will be likely divided into three interconnected sections: the North Section, the Central Section, and the South Section.

The North Section: the North Section will be composed of the NCPN, NEPN, and NWPN, as well as the Shangdong provincial grid. The deficiency of electricity in the NEPN will be mainly supplied by the eastern area of Inner Mongolia. The NEPN and NCPN are being connected to share the interconnection benefits. The NCPN and NWPN will be probably interconnected along with the development of the "Sanxi" thermal power base. Also, it is said that the NEPN will possibly be interconnected with the Russian power system to import electricity. The proposed interconnection with countries in Northeast Asia should be studied and considered in order to share benefits of interconnection.

The Central Section: the Central Section will be mainly composed of the CCPN, ECPN, and CYPG as well as the Fujian provincial grid. This section will be basically established when the first generating unit of the Three Gorges Power Plant is commissioned.

The South Section: the South Section will be composed of the Guangdong, Guangxi, Guizhou, and Yunnan provincial power grids. In the South Section, a large amount of electricity will be transmitted to Guangdong from the west provinces mainly by HVDC/HVAC transmission lines. In the future, the Hainan provincial grid will be interconnected with the Guangdong provincial grid by HVDC marine cable, and Yunan will export electricity to Thailand.

There will be some interconnections between the north and central sections as well as the central and south sections. Interconnection between the north and central sections will mainly achieve compensation between thermal power in the north and hydropower in the center. A few thermal plants in the north will be taken as remote power stations to provide electricity to the center. The interconnection between the north and the center will probably use HVDC in a longer time point of view. The interconnections will appear gradually between the center and south to exchange power so as to obtain trans-valley compensation benefits. And thus these two sections will likely merge into a united south part. Therefore, the developing trend of the nationwide interconnected grid is to form two parts, namely the north part and the south part, after the year 2020.

Before the years 2015-2020, the main purpose of interconnection of regional power grids is transmitting electricity. In details, the interconnection projects from west to east are aimed at transmitting electricity, and the interconnection projects from north to south are respectively aimed at transmitting electricity and exchanging power to obtain interconnection benefits. And it will gradually change its function to achieve comprehensive interconnection benefits, such as load leveling, emergency back up, peak load savings, and improving operation performance of power systems.

In the year 2020, it is planned that the installed capacity of the main power deficiency areas, such as Central China, East China, and South China, will reach 100 to 150GW. And it is difficult to import a large amount of electric power from outside due to the restrictions of the environment and exploiting speed of hydro and thermal power bases, as well as transmission corridors. It is optimistic that the imported power will account for 10-20% of the capacity of the receiving system.

The interconnection projects and suggested transmission schemes between the north and central sections are shown in Table 1.

Table 1 The passageway from North to South [10]

Sending system	Receiving system	Transmission power (MW)	Assumed transmission schemes
South Shanxi*	North Jiangsu	4000	500kV AC with SC
Shanxi	Hubei	3000	±500kV DC
Ningxia	East Hubei	1200-2400	±500kV DC
Shanxi	Sichuan	2400	± 500kV DC
Shanxi	CCPN	About 300	Back-to-back

* Remote thermal plant; the first stage of the project is complete.

Some large hydro power stations will be established before 2020, such as the Xiluodu and Xiangjiaba hydro power stations on the Jingsha River and the Xiaowan, Dachaoshan, and Nuozhadu hydro power stations on the Lancang River. Thus there will be two passageways from the southwest hydropower base to the central load One is to the central section and another is to the south section. The preliminary studied schemes are showed in Table 2.

Table 2 The passageway from southwest to east [10]

Sending system	Receiving system	Transmission power (MW)	Transmission alternatives
Hydro power stations on the Jingsha River (Xiluodu, Xiangjiaba)	CCPN	6000	±600kV DC or UHVAC
	ECPN	10000	±800kV DC or UHVAC
Step Hydropower stations on the Lancang River (Xiaowan, Dacaoshan, Nuozhadu, etc.)	Guangdong	7000-8000	±500kV DC or±600kV DC

Figures 5 through 7 show regional grid interconnections in approximately 2005, 2010, and 2015-2010, respectively. Figures 8 and 9 show hydropower and coal-fired power transmissions in China, respectively.

5. SOME KEY PROJECTS [10]

A 500kV AC transmission line has been constructed to connect the NCPN with the NEPN, and this interconnection is mainly used to supply electricity from thermal power from the NCPN to the NEPN. In the future, the major purpose of the tie line will be sharing interconnection benefits.

When the Three Gorges Project is completed, an interconnected grid will be established and is called the Three Gorges Power Grid (TGPG). The TGPG covers 8 provinces and two metropolitan cities along with the Yangtze River: Sichuan, Hubei, Henan, Hunan, Jiangxi, Anhui, Jiangsu, and Zhejiang Provinces, Chongqing and Shanghai. The supply area of the Three Gorges Hydroelectric Station will probably extend to the NCPN and Southern China. The main purposes of connecting with the NCPN are making most of the Three Gorges Hydropower Station to share the peak load of the NCPN (which is a nearly pure coal-fired power system) and load leveling. So the Three Gorges Project is a turning point for developing the inter-regional power network connection and speeding up establishment of the nationwide interconnected grid. The TGPG will be the heart of the nationwide interconnected grid.

Following the HVDC project from the TGPG to the Southern China Interconnected Network (SCIN). Besides energy transmission, the significant benefit of this interconnection project is also trans-valley compensation between the Yangtze River and the Lanchang and Honghe River s.

Some interconnection projects are being studied. These are interconnection between the NWPN and the CYPG; interconnection between the ECPN and the Fujian Provincial Grid; interconnection between the NCPN and the Shangdong Provincial Grid because of transmitting power from the Wangqu Thermal Power Plant (in Shanxi) to Shangdong; etc. The nationwide interconnected grid will be formed in the foreseeable future. Some of the studied interconnection and transmission projects are shown in Table 3.

Table 3 Some of the Studied Interconnection and Transmission Projects by 2020 [11]

Interconnection Project		Capacity (GW) /Distance (km)	Transmission Candidates
NEPN—NCPN		About 1GW/159	500kV AC/ DC back to back
Hu League (Inner Mongolia) —Liaoning		4.7~10GW/1100	500kV up to 1200kV or DC
The west of Inner Mongolia—JJTPG		Up to 10GW/400~800	500kV(SC), 800kV or 1200kV
South Shanxi—North Jiangsu		3~4/700	500kV AC with SC
Shanxi-Shangdong NWPN-NCPN		2.4~3.6GW/300 1.2GW or more/500~1100	500kV 500kV or 800kV AC or ±500kV DC
Shaanxi—Sichuan		1.8~2.4/650	± 500kV DC
The TGHS	—CCPN	12GW/up to 500	500kV AC
	—ECPN	7.2GW/about 1000	±500kV DC
	—CYPG	Up to 2GW/335	500kV AC
TSQ—Guangdong		3.6GW/ about 900	500kV AC and ±500kV DC
Xiluodu, Xiangjiaba	—CCPN	6GW/1200	±600kV DC or UHVAC
	—ECPN	10GW/2300	±800kV DC or UHVAC
Step stations in Lancang River (Xiaowan, Dacaoshan, Nuozhadu, etc.)—Guangdong		7GW~8GW/1100 ~1400	±500kV DC or ±600kV DC
CCPN—South Interconnected Grid			500kV AC
ECPN—FJPG		-	Being studied
CCPN—NCPN		-	Being studied
Northeast China—Russia		-	Further studies are needed
Yunnan Provincial Grid—Thailand		-	Further studies are needed

6. TECHNICAL PROBLEMS [7-10]

According to the preliminary simulation study, some technical problems should be paid attention even though some of them are only found in special conditions.

The inter-regional interconnection may affect system stability depending on network structure and operating conditions. In some cases, transient stability of systems is improved, but it is found that the transient stability is impaired in the interconnection project between the NEPN and the NCPN.

If there are two or more AC link corridors between two regional power systems, investigation of loop flow, tie-line load flow control, and measures for cascading should be made.

More attention should be paid to the problems of low frequency power oscillation and inadvertent power fluctuation on tie lines. Dynamic stability with low or even negative damping oscillation is a crucial problem in some cases.

For simultaneous faults on UHVAC (more than 1000kV) transmission corridors, the effects on the interconnected power systems are very severe, due to the large transmission power capacities on the corridors. Therefore, countermeasures to prevent the collapse of the interconnected power systems should be taken.

When the inverters are concentrate d in load central, voltage collapse and simultaneous commutation failure of several HVDC systems have been found. So measures, such as reasonably arranging the capacity and location of converter stations, emergency drop of DC power, allocating SVC, etc., should be considered when a large amount of power will be imported by means of HVDC.

Mutual impacts between AC and DC systems in both sending and receiving systems should be studied.

7. THE RESEARCH AND DEVELOPMENT OF POWER SYSTEM TECHNOLOGY

With the rapid development of the power systems and the nationwide grid interconnection, especially with the construction of the TGPP and the TPGG, which started in the last century and carries over to the 21st century, it is essential to adopt advanced science and technology in order to build power systems with the properties of security and reliability, of high technical level, economically sound, flexible in operation, and easy in management. To bring about modernized power systems, the following advanced transmission technologies have been and will further be developed and adopted.

7.1 Enhancement of the transmission capability and stability of the 500kV AC transmission system

As mentioned above, the total length of the 500kV transmission lines in China is near 22,400 km. So far a 500kV-bone network has been built within most inter-provincial grids. With the increase of the transfer requirement, the transmission capability of the 500kV line should be further enhanced. For example, in the case of the TGPG, as the TGPP is located close to the load center, 500kV lines are suitable to send the power to Central China and Sichuan-Chongqing. But it is seriously constrained by the great number of outgoing lines, which make the line corridor seriously crowded. In order to reduce the number of outgoing lines and thus make better use of the line corridor and to enhance the stability limit, measures must be taken to raise the transmitting capability of the 500kV lines. For the overhead lines, studies will be directed to the feasibility of compact line structures, which will reduce the impedance and increase the natural loading of the line. For the power systems, studies will be directed to measures of enhancing stability limits, including fixed and controlled series capacitor compensation and controlled shunt compensation with new types of automatic devices and relay protective equipment. The comprehensive application of these measures should raise the transmission capability of the 500kV system to a new level.

7.2 Applications of long distance and back-to-back HVDC transmission technologies

Besides the existing Gezhouba to Shanghai +/-500kV HVDC transmission line, as mentioned above a new TSQ +/-500kV HVDC line with 1,800MW transfer capacity is now under commission in the South China Grid. And two new HVDC projects have been approved from their feasibility studies. For the TGPS, it is planned that two additional new +/-500kV HVDC transmission lines will be built for transmitting 6,000MW power from the Three Gorges plants to East China. With the existing

Gezhouba to Shanghai +/-500kV HVDC line, a total of 7,200MW of power will be transmitted through HVDC links. We prefer HVDC for its high capability, excellent stability performance, flexible control, and regulation. However, at present, disadvantages like low reliability in the initial phase of operation, complicated control, high requirements for operators, and the risk of inducing sub-synchronous resonance of large turbo-generators plus harmonics pollution etc. are problems to be solved. Particularly, when several HVDC circuits sending power to receiving terminals close each other, how to avoid simultaneous outages of the DC system when a fault occurs on the AC system, and how to take full advantage of the modulation capability of the DC systems to strengthen the AC/DC hybrid system are problems for further research and simulation tests. To enhance the equipment reliability and to improve the design of the converter station and the HVDC lines are also problems for further studies. For the network interconnection, a back-to-back HVDC scheme may have advantages from system operation and economic points of view. Research work should also be undertaken on this aspect.

7.3 Research and Development of Flexible AC Transmission Systems (FACTS) and Its Applications.

The main points of FACTS are application of power electronics and modern techniques of control, implementing flexible control of AC power flow and thus enhancing in large magnitude the transmission capability of existing or new transmission lines, and raising the stability limits. With the extremely rapid development of power electronic technology, this new transmission technology is expected to have bright prospects in future development. The research work and feasibility study of TCSC (Thruster Controlled Series Compensation) has been undertaken in recent years in China for a certain long distance AC transmission system. A TCSC demonstration project will be set up in the South China transmission system in 2001. A prototype ASVG (Advanced Static Var Generator) of 20MVA has been put into operation. For all kinds of FACTS components, through simulation studies and model tests, the design techniques will be well in hand, and the intermediate prototype tests and further demonstrative projects will be carried out to more fully assist the manufacture and operation of the FACTS components.

7.4 New Techniques of Power System Operation and Control

Following the progress of computer applications in the power industry, the technique development and implementation of power system operating and dispatching automation, including SCADA, EMS in the system control center, and local controls, have been rapidly executed since the middle of the 1980s. The control centers of all inter-provincial and provincial power grids have been equipped with advanced computer-based automation systems at present. Looking ahead to the future, the TGPS is large in size and complicated in structure. Its secure and economic operation has important effects on the national economic growth in the Yangtze economic zone.

New techniques of dispatching and operation will be developed for the power system by using the latest computer and information technologies. Dispatching and automation systems at all levels will be developed on the basis of the latest computer hardware and software platforms with consideration of the power market environments. Power system control, together with management information systems, will be established, with a dedicated high-speed digital telecommunications network. Theories of intelligent control with artificial neural networks, expert systems, and fuzzy logic control could be applied. A GPS-based PMU system will be developed and built in the large interconnected power systems for security and stability monitoring and control of the whole system.

7.5 Development of Advanced Power System Analysis Software and Real-Time Power System Simulation

Beginning in early 1970s great effort was made in the development of power system analysis software in China. As a result, the Electric Power Research Institute of China (EPRI China) has developed power system analysis software named Power System Analysis Software Package (PSASP). Since the 1980s PSASP has been working in most of the power systems in China as a powerful tool for system planning, design, and operation. In addition, other software (e.g. BPA power system analysis, EMTP, and EMTDC) has been imported or imported/modified for applications in Chinese power systems.

Based on the new idea of the power system analysis software platform, the function of PSASP is being expanded broadly. For example, the new small-disturbance linear analysis platform can automatically provide the coefficient matrix of whole system's linearized differential equations including inner fixed models and user-defined models. This is very convenient and valuable for secondary development for users, and these data can even be studied further by utilizing some mathematical analysis tool such as MATLAB, EXCEL, etc. On the other hand, the new platform also provides many facilities for developers. For example, based on the small-disturbance linear analysis platform, several application programs such as small-disturbance stability, small-disturbance voltage stability, control system linear design and coordination, etc. can be developed. In the course of development, the reusability technique in Software Engineering will greatly be adopted—which is helpful both to improve the reliability of software development and to decrease the workload of software development.

As another powerful tool for the power system analysis and testing, the real time power system simulation has been extensively applied in China since the 1960s. The physical model type with micro machine simulation facilities is still used for testing of protection relay and automation devices. A modern digital and physical hybrid type simulation laboratory called the Three Gorges Power System Simulation Center (TGPSSC) has been established in EPRI China since 1999. With the simulation work of this center, some key problems of the TGPS have been studied in advance, including problems in system design, construction, commissioning, and operational planning. The center can be also used for testing prototypes of the protection relay and safety automatic devices, and for training high level dispatchers and operational personnel. The TGPSSC will be a powerful tool for analysis and a decision aid for construction and operation of the TGPS. The most recent development in power system simulation is the so-called full digital real time power system simulator. RTDS is one of this kind and has been used in China. A more powerful digital simulation tool, which can simulate large scale power systems with both electromagnetic and electric mechanical system phenomena is being developed in China.

8. ISSUES OF THE INTERNATIONAL POWER GRID INTERCONNECTION BETWEEN CHINA AND NORTH EAST ASIAN COUNTRIES

North East China, which includes Liaoning, Jilin, and Heilongjiang provinces, is a major industrial base for steel, mechanics, energy, chemistry, etc. in China. The major product shares in 1994 are steel 16.8%, iron 14.8%, oil 5.9%, natural gas 26. 5%, and coal 12.66%. This area is also a major electric power industry base in China. From the 1950s through the 1970s the East China power system was the largest in the country. For several years the development of the power industry in this area was facing the problem of low increasing rates compared with other parts of the country. In 1994, the total generating capacity of the three provinces was 24,171MW, and the produced electric energy was 111.7TWh. And in 1999 the above numbers were 32,682MW and 132.4TWh, respectively. The average rate of increase was only 2.93% for produced electricity. Last year (2000) the situation changed with a much higher rate of increase. But still the electric power supply is much larger than the demand in the whole area. This situation has seriously affected power generation development and also the possibility of international grid interconnection with neighboring countries.

From a long-range point of view, the primary energy resources for electric generation in North East China will probably meet with a shortage condition. According to the area 20-30 years planning, the coal for electricity generation should be supplied by West Inner Mongolia and Shanxi province via railway in future years. Of course they can also import energy (coal, natural gas, and electricity) from Russia. It is predicted that the international power grid interconnection will provide remarkable benefits to this area through electric power exchange.

In order to facilitate the procedure of the interconnection, some issues should be studied, considered, and solved: 1) Long range power system planning: the international interconnection must fully accord with the national power grid long range planning. 2) Getting full support from related national governments. 3) International coordinated feasibility studies should be carried out first for certain projects. 4) Technical problems should be studied and solved before project realization. 5) Mutual benefits will be the most important issue for the feasibility of the interconnection.

9. CONCLUSIONS

In 2015-2020, the nationwide interconnected grid will be basically established to transmit electricity from thermal and hydropower bases to central and coastal regions of the country. The construction of the Three Gorges Hydropower Project will further push forward the implementation of a nationwide interconnection program.

The nationwide interconnected grid will cover most existing regional and independent provincial power grids. Total installed capacity will reach 750GW by the year 2020. It will be composed of three sections in the early stage, namely the north, central, and south sections. The central and south sections will likely merge into one.

Power flow is mainly from west to east, and there is power exchange from north to south. It is guessed that the north section will be connected to the center by HVDC.

Some technical problems should be studied and paid attention to, such as transient stability change, loop flow, low frequency oscillation, voltage stability, etc.

North East China, which includes Liaoning, Jilin, and Heilongjiang provinces, is a major industrial base of China. From a long-range point of view, the primary energy resources for electric generation in this area will probably meet with a shortage condition. It is predicted that the international power grid interconnection will provide remarkable benefits to this area through electric power exchange.

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BIOGRAPHY

Xiaoxin Zhou

Prof. Xiaoxin Zhou was born in Shandong, China in 1940. He graduated from the Electrical Engineering Department of Tsinghua University, China and joined the Electric Power Research Institute of China (EPRI China) in 1965. He is currently the Chief engineer of EPRI, a Member of the Chinese Academy of Sciences, Fellow IEEE, Senior Member of CSEE, Chairman of the Beijing PE Chapter of IEEE, and Chairman of the Power System Committee of CSEE. His current research interests are in the area of power system analysis, FACTS, and control.

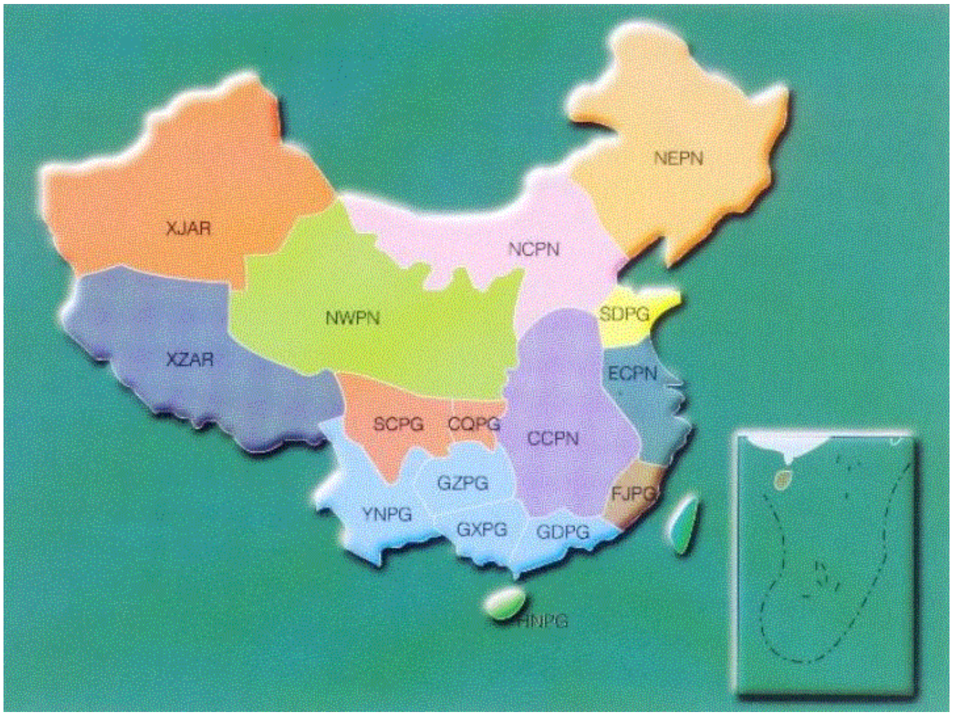

Figure 1 Regional electric power grids in China

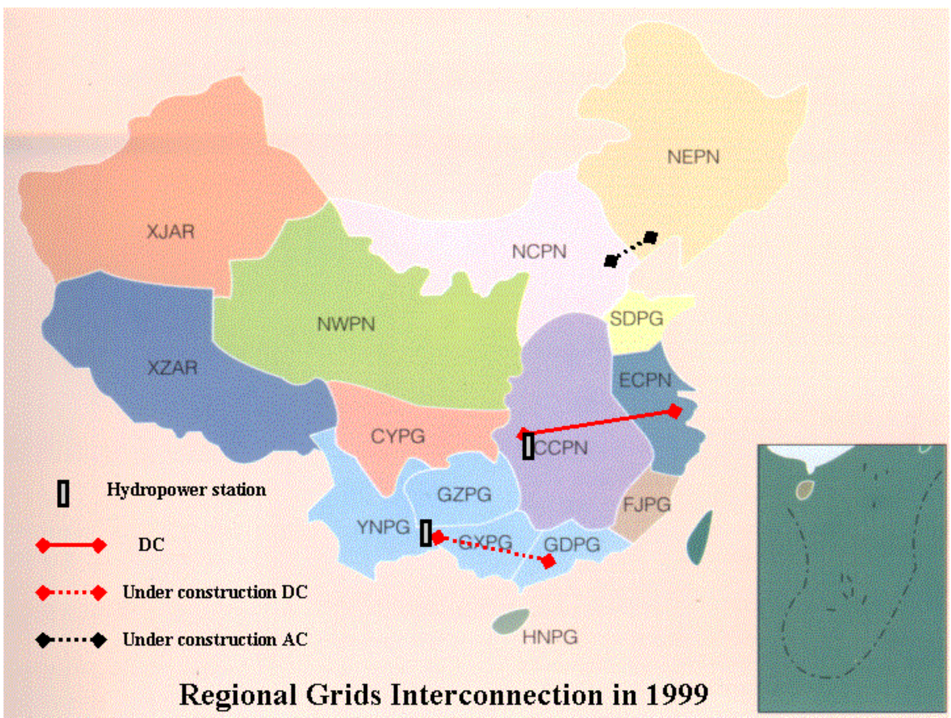

Figure 2 Regional grid interconnections in 1999

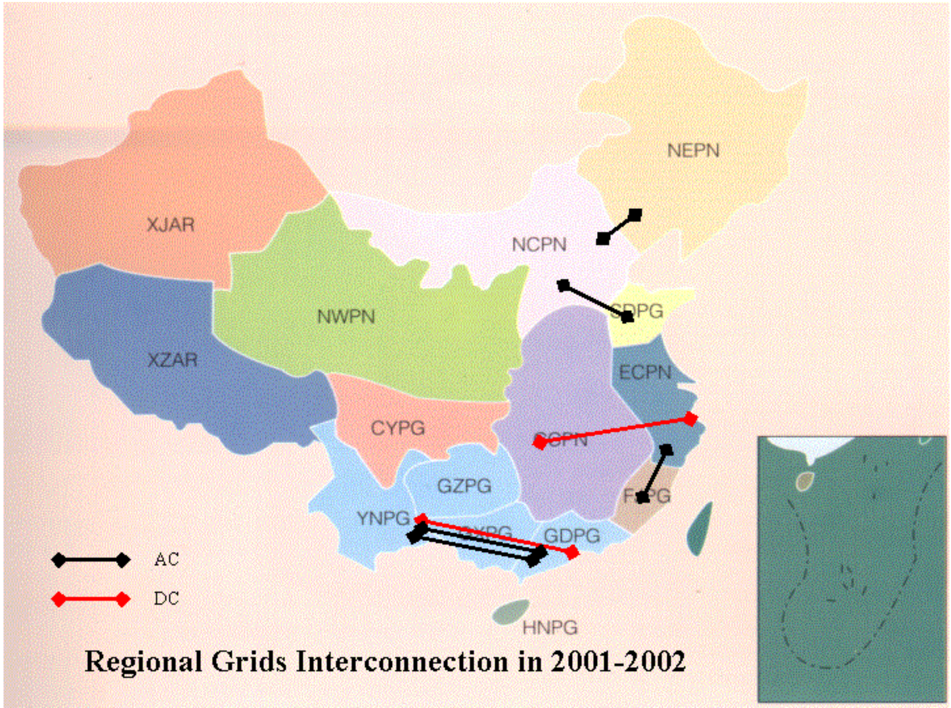

Figure 3 Regional grid interconnections in 2001-2002

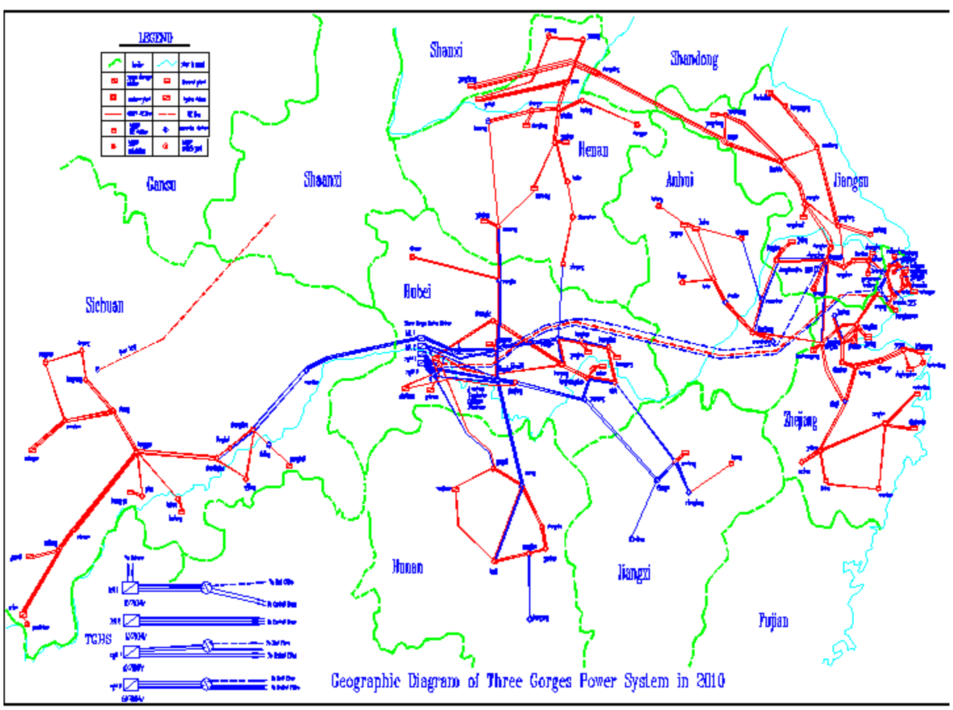

Figure 4 The Three Gorges Power System

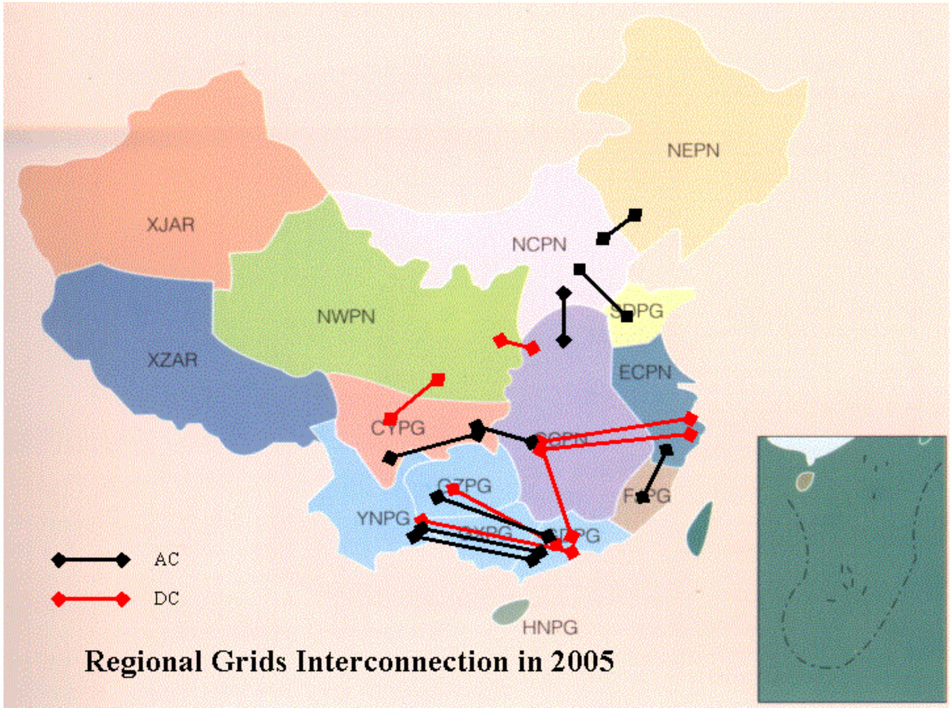

Figure 5 Regional grid interconnections in 2005

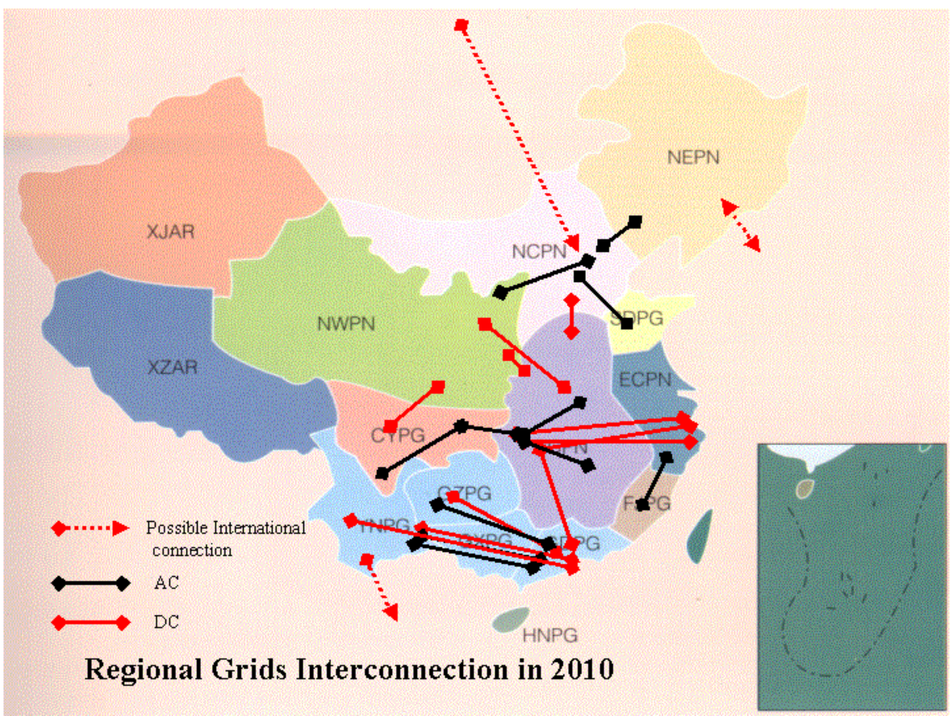

Figure 6 Regional grid interconnections in 2010

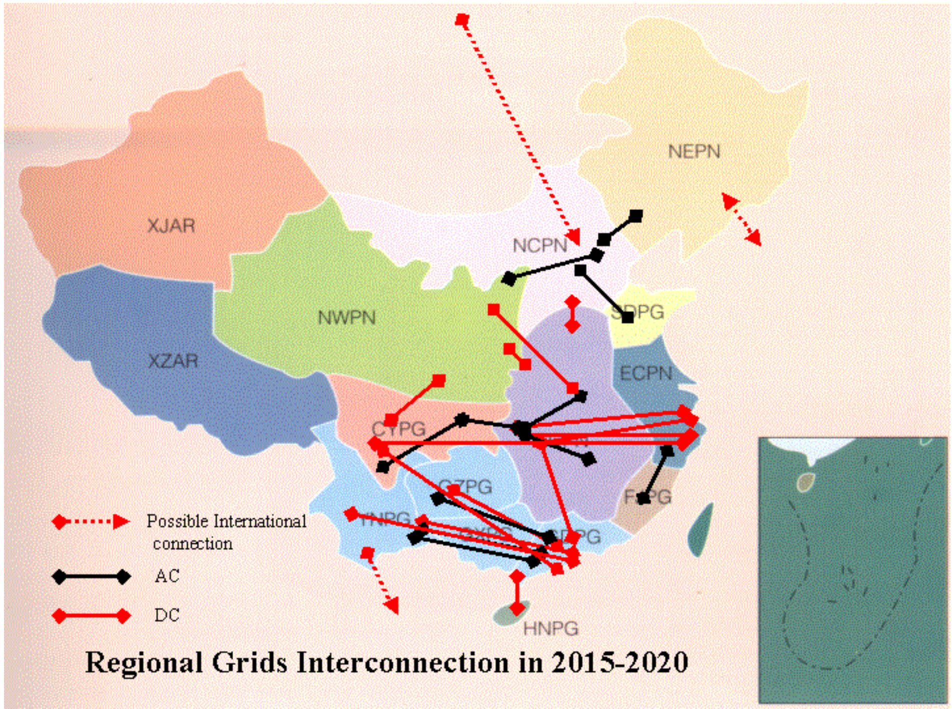

Figure 7 Regional grid interconnections in 2015-2020

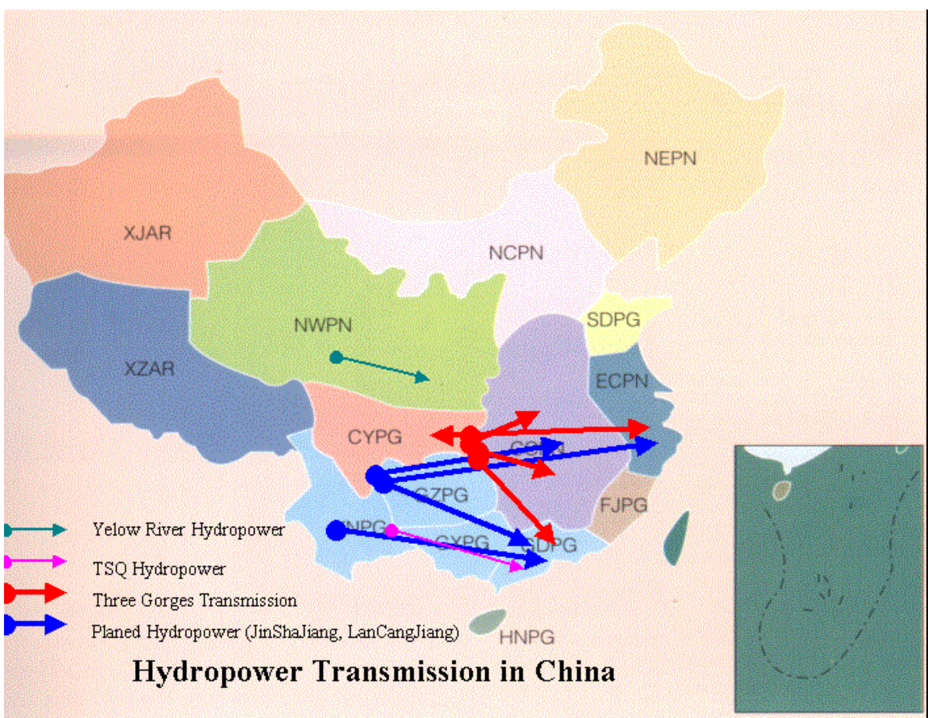

Figure 8 Hydropower transmission in China

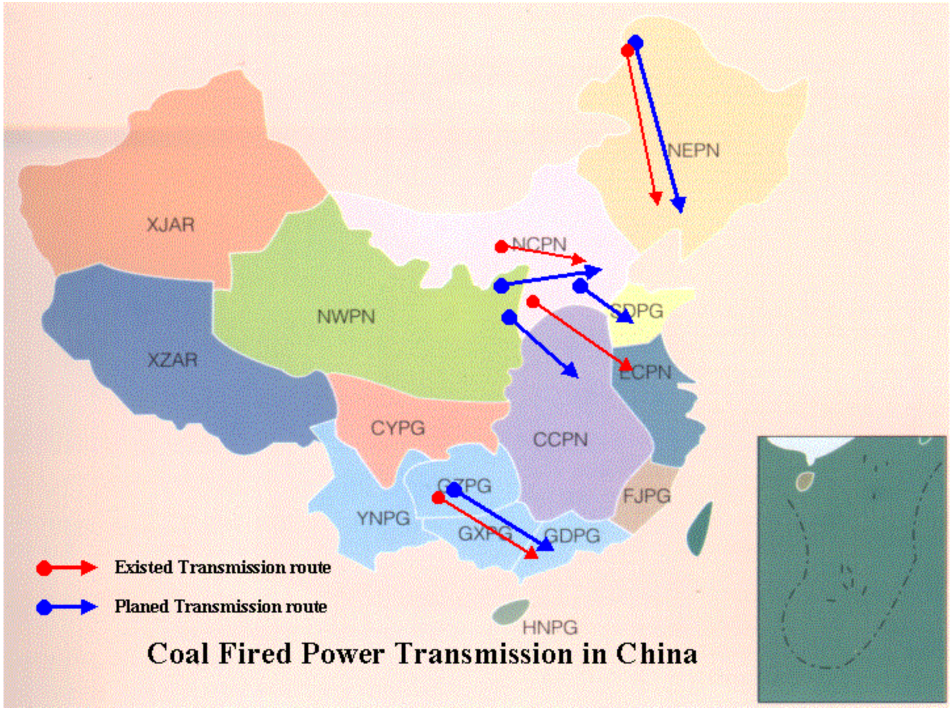

Figure 9 Coal-fired power transmission in China