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CONTENTS

THE ELECTRIC POWER SYSTEM IN CHINA: RAPID DEVELOPMENT CALLS FOR ADVANCED TECHNOLOGIES

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Abstract: Rapid growth of electric power systems in China and the prospects of future development up to year 2010 are briefly reviewed. The rapid growth brings about problems to be resolved by advanced technologies in the fields of electric power generation, power system and power plant control, power system technology, the socialistic electricity market competition. They are outlined in this paper.

Keywords: Growth of electric power, Advanced technologies, Power generation, Power system, Power market, Power generation control, Power system control

1. INTRODUCTION

Since the founding of the People's Republic of China in 1949, the total generating capacity increased from 1.85 GW to 65.87 GW in year 1980, averaging 2.13 GW/yr, and to 102.90 GW in year 1987, averaging 5.29 GW/yr. The funding was solely vertically appropriated from State allocation. The gap between the requirement and appropriation became larger and larger. Electricity shortage became more and more acute as the national economy grew faster and faster under the policy of opening to the outside world. This made the first big restructuring of the electricity enterprise very necessary, in the funding of capital construction of electric power generation. Local investment was welcome and foreign investment was invited with favorable policies and regulations. Beginning from 1988 and onward the development of annual addition of generating capacity exceeded 10 GW and the total installed capacity reached 102.90 GW. In year 1995, the total capacity of 217.22 GW and annual generation of 1006.9 TWh was attained. The rapid increase of electric power generation effectively supported the national economic progress. Power shortage has been greatly lessened, consumers service improved, and the growth of electric power industry has now been standing on its own footing.

The lion's share of the load has been taken by the thermal power in spite of the fact that hydropower resources in China is abundant. Of course, capital construction funding was the prime problem. We will provide in various ways, preferred policies to encourage priority development of hydropower in the coming Five-year Plans, the present 9th-Five (1995-2000) and the next 10th-Five (2001-2005).

At the end of this century, the total installed capacity will be about 300 GW, in which hydroelectric will be 69.02 GW, thermal 228.91 GW, nuclear 2.1 GW and annual generation will be about 1400 TWh. At the end of the 12th-Five (year 2010), the total installed capacity is estimated to be 553 GW, the hydroelectric will come up to 125 GW, its share will be 22.6%, somewhat higher than the previous proportion as the huge Three Gorges Project will fully be in commission. The thermal power will still take the main share, and the nuclear power will only be about 20 GW.

The greatest restructure and deregulation will take

place in the power system from the National Dispatching to the network of the end-users. The electricity consumption structure has already been changing towards the consumers' market. The share of the industrial consumption is decreasing from 81% in 1987 to 75.3% in 1994 while the share of residential consumption is increasing from 5.5% to 9.7%. The policy and strategy of the State will further speed up the process of forming the socialistic market economy. The National Electric Power General Corporation was inaugurated on January 26, 1997 and the purpose is to offer better service to the consumers at higher quality, better reliability and to extend supply of electricity to all households which have not yet access to electricity. The target of power development in year 2000 is 300 GW with annual generation 1400 TWh, and in year 2010 is 500 GW with 2500 TWh annual generation.

With the mammoth Three Gorges Project, 18 GW capacity, likely to be completely in commission during this period, a unified interconnected nation-wide power system will be formed. The problems of such a large-sized power system covering such a big geographical area with diversified composition of generation and consumption units is worth study by the entrepreneurs engineers (trail-blazers).

In connection with the rapid growth of the Chinese power systems, there are many technical problems to be studied and resolved by contemporary scientists and engineers. They are briefly outlined in the following sections. We will start with generation problems in the next section and then on power system and power plant control problems, and advanced power system technologies. Finally the electric power market competition problems and our policies will be touched upon.

2. GENERATION TECHNOLOGY

The greater part of power generation in China has relied upon thermal generation, as was noticed in table 2, and among the thermal generation, coal-fired generation is and will be the dominating supply. (Table 3) Not only the required 794 million tons of coal per year will be a heavy burden on the coal industry and the transportation, but also the emission of particles , CO_2, sulphur and NO_x and the ash discharge will be the serious environmental problems. Evidently, increasing generation efficiency will reduce the total amount of fuel required and environmental protection will be another problem of paramount importance. As the fast growth will double the capacity in less than 10 years, in new additions, the advanced technologies that will be implemented will help greatly improving the situation. Of course, renovation and rehabilitation are also necessary.

The global average of unit coal consumption for power plants is 412 g/kW. For year 2000, the net coal consumption for power generation is expected to be 380/kWh. Measures to be taken are: to install large turbo-generator sets of 300 0r 600 MW subcritical and supercritical units demonstration plant of domestic make will be in operation in year 2000. Development of 1000 MW supercritical unit will be placed on agenda. To actively develop 600 air-cooled units for most of the coal abundant regions, where water is scarce. To develop 300 MW co-generation units for metropolitan cities in the north where district heating is necessary. At the end of 1994, the national percentage of district heating supply (by co-generation) was 9.26%. In year 2000 it is expected to increase to 12-13%, an increase of 15 GW (2.5 GW annually) in years from 1994 to 2000.

Environmental protection is a basic policy in China. On Aug. 29, 1995 the newly revised "Law for the prevention and mitigation of atmospheric pollution in the People's Republic of China" (Atmospheric Law) was published, including SO_2 and NO_x mitigation and clean combustion emission. The coal-fired power plants are classified into 3 categories: (1) Thermal power plants built or applications reviewed and approved for construction before Aug. 1, 1992. (2) Thermal power plants built or applications reviewed and approved for construction during Aug. 1, 1992 to Dec. 31 1996 (3) Constructions on or after Jan. 1, 1997.

We are placing great emphasis on clean combustion technology: CFBC, IGCC, and PFBC-CC. China claims to have the greatest number of small AFBC (Atmospheric-pressure Fluidized Bed Combustion) boilers in the world. On this basis, the development of CFBC (Circulation Fluidized Bed Combustion) technology started recently, with output of 20 t/h, 35t/h, 75t/h, to the 220 t/h in 1990. At present, the number of 220 t/h boilers (to supply 50 MW turbine-generator) under construction is over 10 sets. An imported 100 MW unit with CFBC was put into operation in the first half of 1996. They are good for coal with high sulphur and ash content, low volatile matter and low fusion temperature for ash. A batch of medium capacity CFBC boilers (220 t/h and 410 t/h) mainly for retrofitting the medium and small old power plants and co-generating plants. The CFBC boiler of larger sizes to supply 200-300 MW units is being developed through international cooperation.

Cooperative research work is under way to select the technical approach most suitable for the development of IGCC (Integrated Gassification Combined Cycle). A feasibility study is being made on retrofitting an oil-fired combined cycle unit into

an IGCC,unit of the 100 MW class.

A PFBC-CC pilot station of 15 MW was set in Jia-Wang power plant in Xu-zhou, Jiangsu province. An original 12 MW steam turbogenerator plus the PFBC (Pressurized Fluidized Bed Combustion) and a 3 MW gas turbine were set up. A 100 MW PFBC-CC test unit is being planned to be built as a pilot test unit. The aim is to set up a unit of 300 MW and larger, having thermal efficiency close to that of IGCC unit. Possibly the technology will be matured around 2010.

Natural gas is a good clean fuel for power generation. It is being produced in large quantities in oil fields in the northwest. Plans are in progress also to import it from Russia.

Hydropower is an excellent clean and renewable energy resources. Besides the giant Three Gorges Project of 18.2 GW mentioned above, there are quite several large hydroelectric projects of GW-size, such as Lijiaxia project (2 GW) on the upper reach of the Yellow river in Qinghai province, Tianshengqiao-I project (1.2 GW) on the Nanpan river in Guangxi Autonomous Region, Ertan project (3.3 GW)on the Yalong river in Sichuan province, and Xiaowan project (4.2 GW) in Yunnan province, Gubitan project (2.0 GW) in Guizhou province, Longtan project (5 GW) in Guangxi Autonomous Region, Laxiwa (3.72 GW) in Qinghai province, Pubugou (3.3 GW) in Sichuan province and Gongboxia project (1.5 GW) in Qinghai province and other hydroelectric projects totaling 49.7 GW (including Three Gorges).

Pumped storage hydroelectric power plants are now very important not only for peaking functions to support thermal and especially nuclear generation but also for emergency dispatching. Guangzhou pumped storage project (2.4 GW) on the Liuxi river near Guangzhou and Tianhuangping pumped storage project (1.8 GW) on the Daxi river in Zhejiang province and Ming Tombs (Shisanling) pumped storage project (800 MW). They are important ones, and there are many others.

Mini-hydroelectric power plants play an important role in rural electrification. By the end of 1994, the aggregated installed capacity of medium and mini-hydroelectric power projects was about 7.5 GW.

As clean power production is highly preferred nowadays, wind power, solar power and geothermal power receive much attention for development especially in connection with poverty alleviation program in harsh regions. China is abundant in wind resources. About two-thirds of its territorial surface are wind prevalent zones. The nation wide exploitable and utilizable wind power resources is estimated to be 253 GW. By the end of 1994, more than one million sets of micro type household wind power generator, totaling 20 MW in capacity were installed. The production of such type of wind power generators reached 30,000 sets/year. 18 wind power farms, including wind/diesel and wind/solar and those connected to power systems add up a total capacity of 30.36 MW. The largest one is the Dabancheng wind power farm in Xinjiang Autonomous Region, with an installed capacity of 10.7 MW. The largest single wind power generator is of 500 kW, with an annual average utilization of 3200-3400 hours.

China is also abundant in solar power. Over two-thirds of China's territory has annual sunshine hours of more than 2000. The total amount of annual solar radiation energy is about 930-2330 kWh/sq.m per year and the distribution profile is higher in the western plateau. Solar photocell has been widely used in railway, transportation, communication, broadcast, television, meteorology, agriculture and especially in supplying the household electricity for peasants, herdsmen and fishermen in remote regions and on islands. At the end of 1994, 5 MW of solar photocells were installed and in use, and 14 photocell stations were built, among which, 4 were in Tibet.

The major exploitable and utilizable geothermal resources in China are high temperature geothermal resources, mainly in South Tibet and West Yunnan. In Yangbajing High Temperature Geothermal Power Plant, Tibet, the first 1000 kW generating unit was put into operation in 1977. At the end of 1992 the total capacity of this plant reached 25.18 MW. The Napu double cycle geothermal demonstration power plant with a capacity of 1000 kW has been put into operation, funded by the United Nations. At the end of 1994 the total installed capacity of the geothermal power plants throughout the country was 30.4 MW.

Nuclear power is much needed in coastal areas, where energy resources are not adequate, so that the energy policy encourages appropriately supplementing nuclear power to the speeding up of the development of thermal and hydro power. The construction and stable operation of two nuclear power plants achieved success and massive engineering works of extension to these plants and other nuclear projects are under way. The Qinshan Nuclear Power Station Phase I with an installed capacity of 300 MW is the first industrial demonstrative pressurized water reactor nuclear power plant designed and constructed by domestic technical forces. This plant commenced its construction in December 1991, and went into commercial operation since April 1, 1994. It passed

through a long period of trial operation. The Daya Bay Nuclear Power Project of Guangdong Province (2 × 900 MWe PWR units) was jointly invested and constructed by Guangdong Nuclear Power Investment Co. Ltd. and China Light and Power Company, Hong Kong. The construction started in August 1987, completed and in full commercial operation in May 1994. The Qinshan Nuclear Power Project Phase II consisting of 2 × 600 MWe PWR units is invested jointly by the central and local governments. This project is based mainly on domestic resources, and strives for international cooperation. It means that we will be responsible for engineering, manufacturing, construction and operation of the project and seek foreign consultation and procure some critical equipment abroad. Following the historical breakthrough of nuclear power construction during the 8th Five-year Plan period, which is symbolized by the completion and stable operation of both Qinshan and Daya Bay nuclear power plants, in 1995, the Qinshan NPP generated 2.2 TWh electricity with a load factor of 84% and the Daya Bay NPP 10 TWh, and the government has planned to deploy more nuclear power and associated auxiliary projects in the 9th Five-year Plan period. It is preliminary planned to construct 4 nuclear power projects with 8 reactors and a total capacity of 6.6 GW to be deployed.

3. TECHNIQUES FOR POWER SYSTEM AND POWER PLANT CONTROL

The technique of power system and power plant control started from scratch in the early 1960's with domestic make 'bare computer' (no software whatsoever). Groups of valuable computer application pioneers were trained in this hard way.

Since 1987, power system control applications advanced remarkably and achieved outstanding results. In 1987 there were 60 computerized monitoring systems and 1200 sets of telemechanical devices , mostly domestic make, in operation. They earned much experiences, but the control is practically unsatisfactory. Taking the lead, the four big interprovincial power pools, the Northeast, North, East, and Central China power pools, closely followed by the Northwest power pool were equipped with modern, 1980's computerized monitoring hardware and software system. Some provincial systems quickly followed suit, such as Shandong, Yunnan, Guangdong, Hunan etc. At present, there are more than 700 computerized SCADA systems operating all over the country. They include the National Dispatching Center, all five Pool Dispatching Centers and most provincial dispatching centers. The energy management systems (EMS) imported for the four big pools with technical transfer and relevant training brought about significant technical advancement and groups of qualified and experienced Chinese engineers. In the coming 9th Five-year Plan period (1996-2000), it is expected that power system automatic dispatching in all the pools and about 30 provincial and autonomous regions, about 250 district power bureaus and 300-400 county power bureaus will be in operation. The need of supply of knowledge, hardware and software is immense, and is advancing with time.

As there are so many control centers and so many suppliers of hardware and software, open type programming is very desirable. Open type object-oriented software platform is already implemented in Northeast China. Another system uses a gateway station to link the existing LAN or the main computers to the new system. The trend is toward easy extension and advance.

Power system communication network is the foundation of remote automatic control and management. Formerly, power line carrier (PLC) was most widely used. Since the completion of the first PCM (Pulse Code Modulation) digital microwave channel over 1000 km in length in 1979, several digital microwave trunk channels were built to a total length of over 33,000 km, accounting for 80% of power system communication channels in 1994. Power system satellite communication network has grown rapidly in recent years, and the modernized fiber-optical communication has also developed rapidly. In recent years, while power communication network provided vocal and low speed communication , the construction of DDN (Digital Data Network) is providing automatic information exchange between computers of different speeds and of different types for common sharing of data resources. The State DDN, CEDnet is supplied by N.E.T. of U.S. will link the pools with the National Dispatching as the hub and also all the provincial and autonomous regions. Intranet construction is being considered with a view to using Internet for wider market information exchange.

The outstanding merit of computerized supervisory control of power stations is the safeguard of machines and prevention of failure by early warning of malfunction. For example, the computer controlled start and stop of turbine set at Douhe Thermal Power Plant with monitoring over shaft stress saved a case of imminent shaft breakdown. The value of computerized economic operation at power stations has now been widely recognized by persons in the power sector as illustrated by many successful cases.

At present, the computerized monitoring system for

the thermal power plant can be classified into three classes: (1) Those built around year 1980 using mini-cofnputer of type HN-3000 (Solar-16) or PDP-11 for data acquisition only; (2) Those built in the later part of 1980's either for the domestic 300 MW units or imported 350 MW units using mini-computer of the type HN-3000 or PDP-11 assisted by programmable logic controller (PLC) for specific functions to carry out Closed Circuit Control (CCS) or sequential control (SCS); (3) Those built after 1990 with distributed control using separate PC for specific data acquisition for specific control or monitoring functions, such as temperature control, pulverizing mill control, feed water control and combustion control. The trend is toward integrated, distributed and intelligent control. In order to meet the future requirement of submitting generation bidding of the price and generation for the 24 hours (perhaps in 48 half-hour periods)of the next day, the generation plant has to be equipped with the mechanism and information system of generation pricing as well as generation control according to pool market dispatching. Of course, the introduction of multimedia into the monitoring and control system is now also under consideration. Dispatcher training simulator is now widely used and the technology of multimedia and virtual reality will be helpful in enhancing its functionality.

4. POWER SYSTEM TECHNOLOGY

To meet the growth of the power system capacity, the transmission lines have to be greatly strengthened. As our coal resources are in the north, and the hydropower resources are in the west, while the rapid load growth is along the coast in the south and east, there is the necessity of long-distance transmission of electric power from north to south and from west to east. The first problem under discussion is whether the next higher voltage than the existing 500 kV should be adopted and when. On the problem of power output of 18 GW from Three Gorges Project there were suggestions to use higher voltage than 500 kV. For development of hydro-power further upstream in the south-west, the problem of the next higher voltage is more serious. In the North-west Power Pool 330 kV started to be used in the year 1972. At the end of year 1995 the total length has extended to 5468 km, with 23 substations of aggregated capacity of 8190 MVA, and has offered satisfactory service to the pool. However, looking forward to years beyond 2010, not only the transmission capacity from hydropower in the further west will need a higher voltage, but also the short circuit current at 330 kV will be too heavy. So, the next higher voltage of 750 kV is welcome in many discussions.

The new technology of Flexible A.C. Transmission System (FACTS) has received much attention in China, as a very promising technique for future application, and some cooperative develop-ment works are being carried on. Some research institutes in the Ministry of Electric Power and some universities are undertaking research work on Static Var Generator (SVG, in the name of ASVG) and Unified Power Flow Controller (UPFC), and a FACTS experimental laboratory has been setup. There are five sets of static var compensator in satisfactory operation on the 500 kV Northeast Power Pool. A set of thyristor controlled series capacitor (TCSC) is under cooperative construction and will be installed at the output switchyard of Yi-ming thermal power plant of Northeast Power Pool. Adjustable speed a.c. excited generation, non-linear static excitation system and flexibilized short circuit limiter are under study. In connection with the study on the future retail competition in the electric power market CUSTOM POWER, a FACTS technology for the customer level, has received great interest, and research work will undoubtedly set out before long.
In order to strengthen the existing transmission lines, particularly the transmission corridors which are more and more difficult to obtain, it is necessary to make best use of the limited line route. Much research work has been expended on the compact-structured transmission line whose bundle conductors have some novel configuration such that the whole bundle occupies a smaller space, more compact, resulting in much smaller supporting tower and smaller natural impedance, that means better use of the corridor with higher transmission capability. Two 220 kV test projects were cons-tructed, the An-Lang line in North China, near Beijing, and a stretch of the Gongan-Shishou line in Hubei province. The aim is to obtain experience and information for the construction of demonstration projects of 500 kV lines

As networks are interconnected, we are troubled by low frequency oscillations all over the country. Generators of various types of fast acting excitation system on different sides of the tie line cause this kind of low frequency oscillation due to negative damping which eventually result in failure of system stability. Power system stabilizers, commonly called PSS, are found to be effective means of preventing such oscillations. A supplementary excitation properly introduced into the excitation system provides damping and stabilizes the system. For long distance transmission lines, transient stability is mostly the limit of power transfer. Series compensation has been found to be effective in enhancing the stability.

Rural electrification, as was mentioned above, is very important in the Anti-poverty campaign.

Through more than 40 years of construction, rural electrification has now reached a preliminary scale. By the end of 1994 the total capacity of county and township generating units amounted to 32,090 MW, generating 98.9 TWh for the year. The installed capacity of mini-hydroelectric power units amounted to 15,770 MW, generating 54.3 TWh and small thermal power units amounted to 8180 MW, generating 38 TWh and diesel oil generating units 8060 MW, generating, 6.5 TWh and other renewable power sets 80 MW, generating 0.1 TWh. This (98.9 TWh) was only a small portion of the total electricity consumption, 336.0 TWh, of counties and smaller communities, for the year 1994. The main portion was supplied by the local power systems. The main target of rural electrification towards the end of this century is to enhance the quality of service by upgrading and renovation of the rural network and supporting the anti-poverty program in giving access to electricity to houses in difficult and harsh places so that electricity will be available to all houses. By the end of 1994, there were still 17 counties and approximately 100 million rural population not yet served with electricity across the whole country. They are at the difficult inaccessible locations, on the mountains or in the desert, or on the islands. Services to these places are hard nuts to crack, but it is determined to achieve this final success.

5. ELECTRIC POWER MARKET COMPETITION

As was mentioned in the INTRODUCTION, the first big restructure in the electric power industry, the method of funding was very successful. The long standing power shortage in China has been alleviated by rapid growth of electric power through funding from various channels instead of only vertically through the government. The next big move will be towards the electric power market, competitive market of the wholesale level and also of the retail level. The power system and power plant control will be revolutionized. The first step evidently will be on the wholesale level, where generating units will bid their electricity selling price together with available amount of power for , say, half-hour period, of the next day. And the distributors, or retailers, will provide their application for demands of the next day. The Dispatcher (or the Independent System Operator, ISO, the broker) will design the schedule, and execute it, making on-line decisions, including his supervision on the bilateral contract between the direct two-way transactions. For the existing conditions in China, possibly only a few power generating units can do the bidding properly without much experimentation, not only to their own satisfaction but also acceptable to the pool and to the consumers. Hence, a simulated market experiment is very necessary, to find out problems specific to China, beyond those we learned from Europe, America. Australia and other places.

The work needs to be done for the retail market is even more important, as this directly brings the power suppliers in contact with the end users. All the pricing and market activities should be transparent to the consumers, so that the consumers according to the preferred pricing setup in the market optimize his electricity consumption which will automatically implement the demand side control of the load to the advantage of the pool. This not only needs novel intelligent metering interface with the consumer but also a good information network. It is evident that the market will need a good information network for control and management, including pricing, settlement, transaction, billing and recording and fast response and coordinated actions in case of emergency. All these will be carried out on the information network, with electronic signals, electronic messages, electronic mails, electronic records, electronic documentation and electronic billing and selling with electronic money. There is vast amount of challenges and opportunities for scientists and engineers to offer their wisdom for these future problems.

But what is most important for the market is impartiality and fairness of the persons concerned, not only in pricing acceptable to both parties, but also in all transactions, all must be based on friendship and cooperation between the parties concerned. The ISOs must be upright and fair persons with high moral caliber. Particularly in emergency, his/her decision might not be the best, but from the bottom of his/her heart. Ethical culture is the most important thing for the market.