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Operation challenges for fast-growing China's hydropower systems and respondence to energy saving and emission reduction

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ABSTRACT

During the past two decades, in particular the past decade, there has been a rapid rate of development of hydropower in China. It is foreseeable that the same rate of development will be maintained in the next decade. The total installed generation capacity of hydropower in China has now surpassed 200 GW and ranks first in the world. The unprecedented rate of expansion, development scale, emergence of large number of hydro plants with high head and huge capacity, and electric power transmission have led to significant changes in management and operation of large-scale hydropower systems which have become one of the significant factors in constraining the security and economic operation of power grid in China. This article gives an overview of the China's hydropower, analyses the new challenges that it faces, highlights the key scientific and technological issues that need to be solved, and pinpoints that the solution of these problems will be the key to the realization of energy saving and emission reduction by China in 2020.

Contents

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1. Introduction

Hydropower's low cost, near-zero pollution emissions and ability to quickly respond to peak loads make it a valuable energy source. In past years, hydropower occupied about 15% of Chinese total electricity generation and about 22% of total installed capacity. Now it is the most widely used renewable resource for electric power generation in the China. According to the proposed "Twelve 'Five Year' Electrical Plan in China" that will be released soon, hydropower will be placed in the first priority amongst all types of development of electricity generation and it is recognized as the most stable and reliable approach to reduce the proportion of non-fossil energy to one-time energy consumption in China to 15% in 2020 and 40–45% carbon emission.

Up to the end of 2010, 213.4 GW of hydropower generation capacity in China, with approximately 22.2% of total generation capacity, has been reached, which is the result of rapid development of hydropower and power grid during the past two decades, in particular the past decade. It is foreseeable that the same rate of development will be maintained in the next decade. The hydropower installed capacity will reach 330 GW in 2020. More than 45,000 hydropower plants exist in China, which include about 400 ones with more than 50 MW generation capacity, 85 ones with more than 300 MW and 32 ones with more than 1000 MW. The largest hydropower plant in the world, the Three Gorges with the total capacity of 22.4 GW and an annual production of 84.7 trillion Wh, is a typical example.

At present, the total generation capacity has reached 962.19 GW in China, about 73.4% of generation capacity is from thermal power plants, 22.2% from hydropower plants, a very small percentage from other energy. About 70% thermal plants are using coal for electric power generation in China. However, about 82 of coal deposits are concentrated in the north and southwest regions. About 70% of hydro resources are in 5 southwestern provinces, cities or autonomous regions, including Sichuan, Yunnan, Tibet, Guizhou, Chongqing, and Guangxi. However, the majority of electricity consumption is required in the eastern and the southern coastal regions as well as some part of the central region. Long distance and large scale electric power transmission is necessary for effective utilization of hydropower resources. In the past 10 years, the total length of high-voltage transmission lines of 35 kV and above increased by 69%, and total substation storages increased by 2.3 fold. 750 kV UHV AC, 1000 kV UHV AC and ±800 kV UHV DC have been put into operation successfully. By the end of 2009, the total length of high-voltage transmission lines of 220 kV reached 399,400 km. Now, most of regions are connected by interconnected national grids. The power systems of China have the capacity of transporting a massive amount of electricity over the geographic span of huge country. The operation and management of hydropower systems in China are characterized by large scale, trans-basin, trans-province, and trans-region. The operation and management of large-scale hydropower systems have become one of the significant factors in constraining the security and economic operation of power grid in China. The challenges to the operation management of the large scale hydropower systems are tremendous. New problems, which have direct impacts and relations to the attainable efficiency of the hydropower systems comprising the commissioned plants as well as those large-scale plants under construction, have emerged and become the technical bottleneck in operation and management of systems of hydropower stations in China.

2. An overview of China's hydropower

China is endowed with large hydro potential. The exploitable hydro capacity is 542 GW and the corresponding annual generating production 2470 trillion Wh, ranked first in the world. The development process of hydropower in China has lasted for 100 years or so. Tables 1 and 2 respectively list the top 20 countries in the world in terms of total installed capacity of hydropower and generation by the end of 2007. The two tables show that China ranked first from both two indexes. Table 3 shows the total installed

Table 1
Ranking of country (top 20 in the world) in terms of hydropower installed capacity (2007, unit: GW).

Rank	Country	Capacity (GW)	Rank	Country	Capacity (GW)
1	China	145.26	11	Venezuela	14.597
2	USA	77.885	12	Italy	13.573
3	Brazil	76.871	13	Switzerland	13.465
4	Canada	73.439	14	Turkey	13.395
5	Russia	46.062	15	Mexico	13.143
6	India	35.209	16	Spain	13.025
7	Norway	27.832	17	Argentina	9.94
8	Japan	21.824	18	Columbia	8.525
9	France	20.829	19	Austria	8.429
10	Sweden	16.592	20	Paraguay	8.13

Table 2
Ranking of country (top 20 in the world) in terms of hydropower generation (2007, unit: trillion Wh).

Rank	Country	Generation	Rank	Country	Generation
1	China	486.7	11	France	57.6
2	Brazil	370.3	12	Paraguay	53.2
3	Canada	364.7	13	Columbia	41.4
4	USA	247.5	14	Austria	35.6
5	Russia	175.3	15	Turkey	35.5
6	Norway	132.6	16	Switzerland	34.9
7	India	122.6	17	Italy	32.5
8	Venezuela	83.0	18	Argentina	30.2
9	Japan	73.3	19	Vietnam	29.6
10	Sweden	65.5	20	Pakistan	28.4

Table 3
Total hydropower installed capacity in GW and generation in trillion Wh.

Year	Capacity	Annual generation	Year	Capacity	Annual Generation
1949	0.36	1.20	1980	2031.8	58.21
1950	0.36	1.32	1981	21.93	65.55
1951	0.38	1.49	1982	22.96	74.40
1952	0.39	1.83	1983	24.17	86.36
1953	0.53	2.55	1984	25.60	86.78
1954	0.61	3.20	1985	26.42	92.37
1955	0.70	3.40	1986	27.54	94.48
1956	0.91	4.71	1987	30.19	100.23
1957	1.02	4.82	1988	32.70	109.18
1958	1.22	4.11	1989	34.58	118.45
1959	1.62	4.36	1990	36.05	126.35
1960	1.94	7.41	1991	37.88	124.84
1961	2.33	7.41	1992	40.68	131.47
1962	2.38	9.04	1993	44.89	151.60
1963	2.43	8.69	1994	49.06	166.79
1964	2.68	10.60	1995	52.18	186.77
1965	3.02	10.41	1996	55.58	186.92
1966	3.64	12.62	1997	59.73	194.56
1967	3.84	13.14	1998	65.07	204.30
1968	4.39	11.50	1999	72.97	212.93
1969	5.05	16.01	2000	79.35	243.13
1970	6.24	20.46	2001	83.01	261.11
1971	7.80	25.06	2002	86.07	274.57
1972	8.70	28.82	2003	94.90	281.33
1973	10.30	38.90	2004	105.24	330.99
1974	11.82	41.44	2005	117.39	396.40
1975	13.43	47.63	2006	128.57	416.70
1976	14.66	45.64	2007	145.26	486.70
1977	15.77	47.65	2008	172.60	565.55
1978	17.28	44.63	2009	196.29	571.68
1979	19.11	50.12	2010	213.40	