Energy Policy 61 (2013) 104–113

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Development of China's pumped storage plant and related policy analysis

Zeng Ming [a], Feng Junjie [a], Xue Song [a,*], Wang Zhijie [a], Zhu Xiaoli [a], Wang Yuejin [b]

[a] School of Economics and Management, North China Electric Power University, Beijing 102206, China
[b] Beijing Electric Power Transmission and Transportation Company, Jibei Electric Power Company Limited, State Grid Corporation of China, Beijing 102401, China

HIGHLIGHTS

- Analyze development of China's power structure and system load situation.
- Analyze development of pumped storage plant in China.
- Summarize regional planning and layout of pumped storage plant in China.
- Analyze related policy.

ARTICLE INFO

Article history:
Received 14 March 2012
Accepted 18 June 2013
Available online 18 July 2013

Keywords:
Pumped storage plant
Development status
Policy analysis

ABSTRACT

With the rapid development of the Chinese economy and society, differences in the electric power system load between the peak and valley values are increasing, and inefficient small capacity coal-fired plant units must be involved in load adjustment because gas units and pumped storage units that act as peak-load units are lacking. In addition, due to concerns about energy saving and emissions reduction, clean energy sources are rapidly being developed and deployed. This presents a significant challenge for the construction and planning of peaking power solutions in China. Pumped storage plants provide a means of reducing the peak-to-valley difference and increasing the deployment of wind power, solar photovoltaic energy and other clean energy generation into the grid. Pumped storage plants represent the most mature approach among the peaking power sources and thus are one of China's major investments for the future. This paper presents China's current development of pumped storage plants, their role in the electric power system, the management models for pumped storage plants and the electricity price patterns utilising them. Here, we also analyse China's future plans for pumped storage plants, including the influencing factors and related policies.

1. Introduction

In July 2011, the National Energy Board released a report titled "The notification of the National Energy Board on further improving the construction of pumped storage plant" (National Development and Reform Commission http://www.sdpc.gov.cn). The report describes the increasingly high demand for electric power system security and reliability and the need for more rapid deployment of pumped storage plants in response to China's rapid economic development and the adjustment of the energy structure.

China's electricity structure is coal-based, with combined heat and power plants (CHP) accounting for a large proportion of the coal-fired capacity in Northern China (Wang and Chen, 2010). In addition to coal-based power, hydropower is a significant source of energy, with run-of river hydropower being the predominant type (Yuan and Lin, 2010). These sources do not address the long-standing problem of a peaking capacity shortage. With large-scale development of clean energy sources, such as wind power which is variability, the need for peaking capacity in the system increases greatly (Zeng et al., 2013). This need is exacerbated by the anti-peaking characteristics of wind power (in general, electricity demand during the day is more than that at night and the Chinese government use centralized heating by the CHP in winter, however in China the wind power generation more at night or in winter) (Ding et al., 2012). Concurrently, the rapid social and economic development in China has increased the

* Corresponding author. Tel./fax: +86 10 51963851.
E-mail address: xuesongbjhd@163.com (X. Song).

0301-4215/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.06.061

peak-to-valley difference in power systems. Ensuring the security and stability of China's power system presents a significant challenge. Grid-connected wind turbines have been limited to in the regions of Western Inner Mongolia, Eastern Inner Mongolia, Xinjiang and Jilin, which restricts the sustainable development of clean energy in China. In addition, to ensure the security and stability of the power system, power rationings are common in some places in China during peak-load periods. Thus, rapid application of energy storage technology is crucial to meet the future system peak demand in China.

Currently, pumped storage, compressed-air energy storage and chemical energy storage are the primary large-scale energy storage technologies. Compared with compressed-air energy storage and chemical energy storage, pumped storage offers certain advantages, such as low investment (3000–5000 yuan per kilowatt) and long service life. The use of natural gas peaking plants is not a good option because of the lack of significant natural gas reserves and infrastructure (Development Research Center of the State Council, 2009). Also coal gasification technology is immature and there is no large-scale development of shale gas (Zhang et al., 2013). For these reasons, on the current technical level pumped storage plants are now the most reliable, economical, and mature energy storage technology with a long life cycle and large capacity in China. Pumped storage plants pumping to the upper reservoir during valley load, then turning on the water to the lower reservoir to generation during peak load. Pumped storage plants have several advantages (Hino and Lejeune, 2012): (1) Pumped storage plants with flexible start/stop and fast response speed. (2) Pumped storage plants are able to track load changes and adapt to drastic load changes. (3) Pumped storage plants can modulate the frequency and maintain voltage stability. So pumped storage plants are useful tools in electricity system (Nazari et al., 2010; Mitteregger and Penninger, 2008). First, they can serve as emergency and standby power supplies or provide black start service in the electric power system to improve the security and stability of the electric power system. Second, they can decrease the peak-to-valley difference in the system with their function of peak shaving and valley filling, then improving the stability of grid frequency and voltage and ensuring the quality of electric power. Third, the excess electricity during peak load (at night) which price is low can be transferred as high-value electricity during peak load (daytime) which price is high by pumped storage plants, that would improve the efficiency of nuclear power, high efficiency coal-fired units, wind power (Yan et al., 2011). Fourth, pumped storage plants can reduce the impact from renewable energy (i.e. wind power, solar power) to power system through smoothing their generation output and reducing their variability.

As pumped storage plays an important role in load regulation, promoting grid-connected clean energy and maintaining the security and stability of the electric power system, it will be China's primary peaking power source in the future (Zhang et al., 2013). Section 2 of this paper reviews China's current electric power system's development from electricity structure and electric power system load. Section 4 describes the development of pumped storage plants in China includes their role, status, management model and electricity price pattern. Then analysis the regional planning and layout of pumped storage and related policies respectively in Section 4 and Section 5. And the last section is conclusion.

2. The development of China's electric power system

2.1. Electricity structure

During China's *Eleventh Five-Year Plan* (2005–2010), the installed capacity of grid-connected wind power grew from 1.06 MW s at the end of 2005 to 29.58 MW s at the end of 2010, i.e., a cumulative net increase of 28.52 MW s, an average increase of 5.7 MW s per year and an annual growth rate of 94.75% (http://www.chinaero.com.cn/). However, the intermittent nature of wind power significantly affects the system's security and stability (Louka et al., 2008). China's land-based wind resources are primarily distributed in underdeveloped areas, such as the Northwest, Northeast and North, which cannot make full use of the wind power and thus limit the development of wind power. Wind power must be distributed over long distances through the high-voltage grid. The costs and technical challenges posed by long-distance energy transmission restricts the development of both wind power and solar power. In April 2010, China promulgated the Renewable Energy Law (Revised Version) (www.npc.gov.cn/), which mandates the development of energy storage technologies (Zhang et al., 2013). Appropriate construction of pumped storage plants is the most effective tool for guaranteeing the security, stability and economic operation of the electric power system and for solving the bottleneck for the development of large-scale wind power and other clean energy sources.

China's total installed generation capacity at the end of 2010 was 966.41 MW s (Fig. 1), 4.4% of which was generated by nuclear power, wind power and photovoltaic power. China's total electricity generation in 2010 was 4227.8 GW h (Fig. 2), only 3.1% of

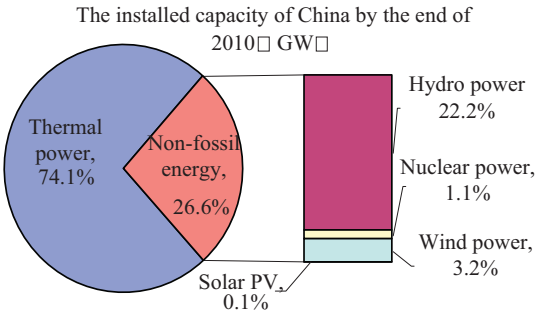

Fig. 1. Total installed capacity by the end of 2010.

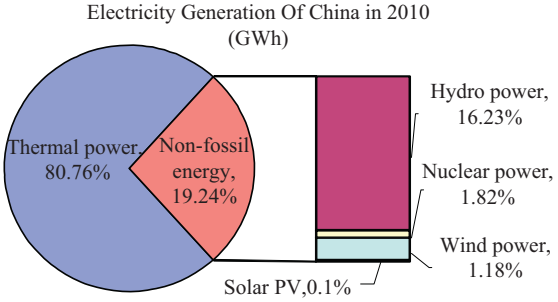

Fig. 2. Total electricity production in 2010.

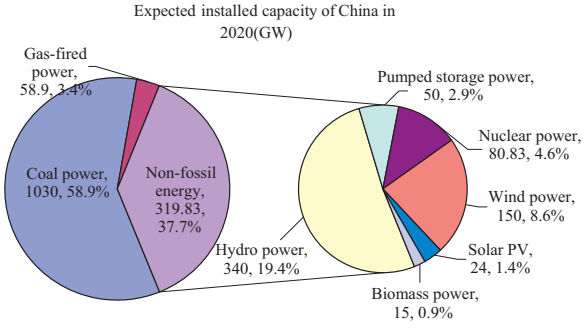

Fig. 3. Total installed capacity in 2020.