THE DEVELOPMENT OF PUMPED HYDROELECTRIC STORAGE AND RENEWABLE ENERGY IN CHINA AND NORWAY

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Abstract

Pumped hydroelectric storage (PHS) is an important means for regulation and energy storage in electric grid. Today it could effectively promote the development of clean and renewable energy. The installed capacity of PHS over the past years in China with that of developed countries was compared. The main characteristics of the electric system in China's different regions, the current status of PHS in these regions, and the planning targets of capacities of PHS together with the wind power in 2020 were analyzed. For the planning of PHS, one of the most important missions is to support the development of wind power. In parallel, however, the development of photovoltaic (PV) power is also very fast in some regions of China. As the same with wind power, PV power is also a kind of intermittent energy. Therefore, these regions should also develop PHS to increase the grid-connected PV power generation. Similar with China, Norway has very long coastline. It is well known that Norway has plenty of wind energy potential near the North Sea. It is necessary to delivery Norway's offshore wind power to the European continent when exploring it. Norway should also install some PHS in the southern area, and some advices for the construction of PHS project are given. In addition, Norway can make use of the fjord or suitable coastal topography to construct a trail station of seawater PHS project combined with wind power station as a set of green battery in electric systems.

1 The comparison of PHS in China and other countries

Pumped hydroelectric storage (PHS) can provide supports to an electricity system through services such as network frequency control, grid stabilization, reserve energy, and integration of variable renewables. The Gangnan PHS Station in Hebei province, built in 1968, is the first PHS project in China. It has only one unit, and the installed capacity is 11MW [1]. Since the 1990s, PHS has been developed rapidly, and the installed capacity of PHS in China had reached 16.9 GW up to the year of 2010 [2].

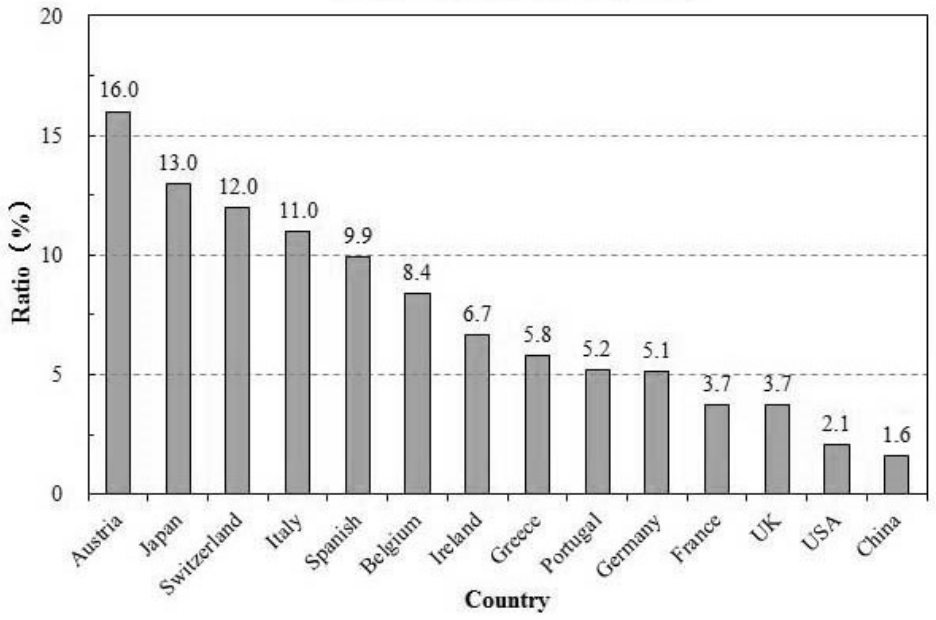

Figure 1 The ratio of PHS installed capacity to the total electric installed capacity

There are two main kinds of PHS projects in China, one is combined with conventional hydropower, and the other one is pure PHS power station. China has led the world in the development of many technologies of PHS in the world. The largest installed capacity of a PHS power plant in China has approached 2.4 GW [3], and the hydroelectric generating unit has reached 300 MW [3], and the designed water head of Xilongchi Pumped Storage Power Station is 640m [4].

Generally speaking, the ratio of the PHS installed capacity to the total installed capacity should be 10% in an electric system. As shown in figure 1, the ratio of 1.6% in China is much less than the other developed countries [2-6]. The Chinese government should accelerate the construction of PHS projects.

2 The relationship of PHS and intermittent power in China

The development of renewable energy is mainly to reduce the amounts of carbon dioxide emission. At the 2009 United Nations Climate Change Conference held in Copenhagen, the Chinese Government announced the target of cutting carbon dioxide emissions per unit of gross domestic product by 40-45 percent of the 2005 level by 2020. Secondly, non-fossil energy consumption accounts for 15% of primary energy in 2020. Therefore, the government encourages to the development of hydropower, wind power, and photovoltaic power.

In recent years, it has made tremendous growth of wind and solar generation in response to the favorable policies. It is well known that wind power and photovoltaic power are intermittent energy. And the safety, stability and economic operation of electric system will be affected when connected on the grid. So the variability of wind and solar generation increase the need for energy storage, including physical and chemical energy storage. Currently, large capacity storage of intermittent power can only relay on PHS, because hydropower pumped storage is the only commercially proven technology available for grid-scale energy storage. Developing additional PHS, particularly in areas with recently increased wind and solar capacity, would significantly improve grid reliability while reducing the need for construction of additional fossil-fueled generation.

As mentioned above, the main purpose for the development of PHS is to accommodate wind power penetration. Figure 2 shows the planed installed capacity of PHS as well as the wind power in the main regional power grid in China [2].

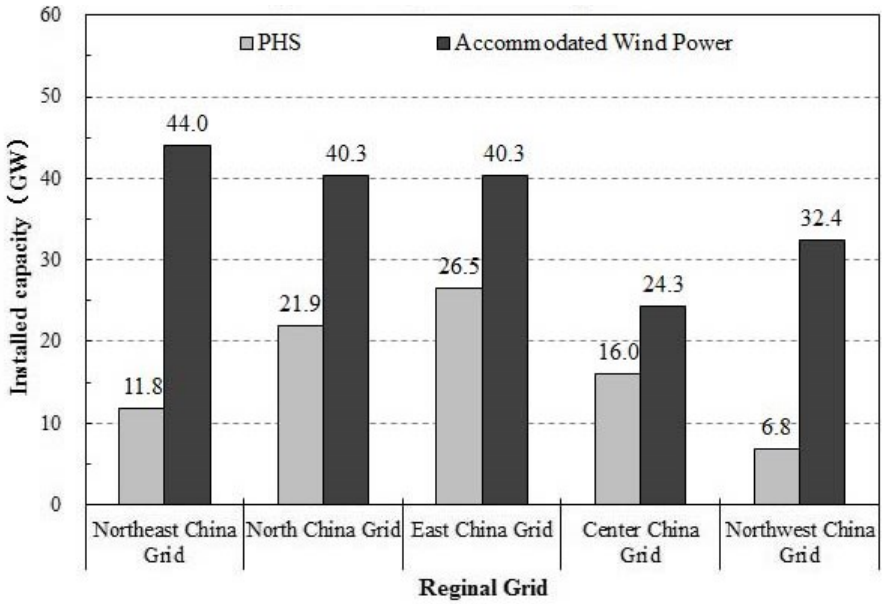

Figure 2 Development plan 2020 of PHS and accommodated wind power in regional China grid

The Northeast China Grid, the North China Grid and the East China Grid are rich in wind energy. As the proportion of hydropower is very small in the electricity grid, many PHS projects are planned in these regions[2]. The Center China Grid, of which the famous Three Gorges Hydropower Station located in, is rich in water resources. However, due to the limits of flood control, the traditional hydropower cannot play an important role for regulating intermittent power. At the same time, considering the "West-East electricity transmission project" and the developed economy of this center China, some PHS projects are also planned [2]. These planning ideas are reasonable and necessary. It is noted that the accommodated wind power will reach up to 32.4 GW in the

Northwest China Grid in 2020, while the planning of PHS is only 6.8 GW. This capacity is not enough for the reasons below.

Wind energy resources (mainly in Gansu province) and solar energy resources are very rich (mainly in Qinghai province) in this region, and the development of PHS is mainly for the need of wind power penetration. However, Qinghai province is currently accelerating the development of photovoltaic power generation. For the randomness and instability of photovoltaic power generation, high quality hydropower was also need for regulating. Although the hydropower in the upstream Yellow River is mainly located in Qinghai province, the power generation must subordinate to the water regulation, therefore, Qinghai province should develop PHS power stations.

3 The necessity for the development of PHS in Norway from a Chinese point of view

Norwegian electricity is mainly generated from hydropower, accounting for 95% or more (higher proportion in history) of total electric power, thus, only a small part for the conventional thermoelectric and wind power. Theoretically, there is no need for PHS development in Norway, because the excellent performance of hydropower regulation can be well adapted to the load. Hydropower accounting for the large part can adjust well to the wind power, which occupies a very low percentage. However, nearly all the countries in the world are embarked actively on the development of renewable energy sources, especially in Europe. Up to 2011, there are six European members in the top ten countries of the world in the wind power development, namely, Germany, Spain, France, Italy, UK and Portugal. There is no doubt that developing the offshore wind power is an important direction, which is an important step to achieve the goal of the European Renewable Energy taking 20% of total energy by 2020 [7]. Actually, the North Sea is just a richest area of wind resource.

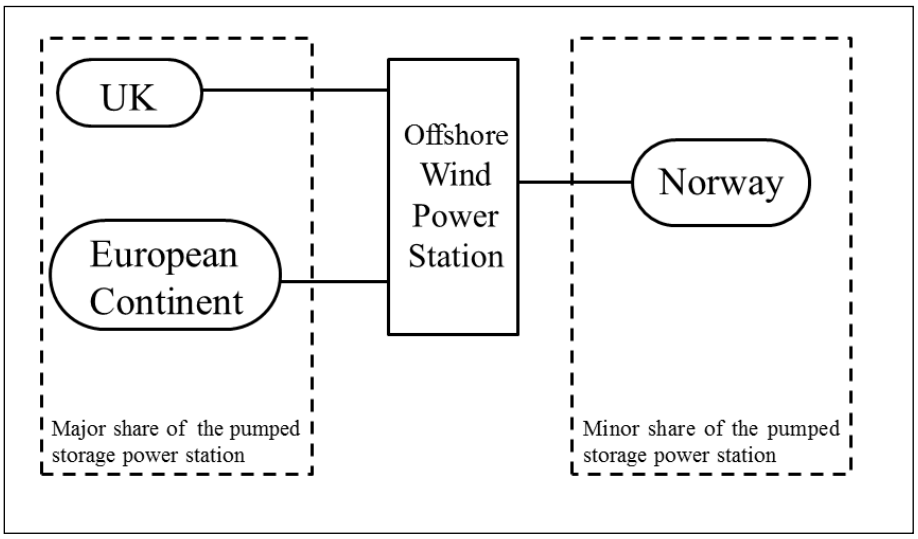

Figure 3 Offshore wind power and PHS power station in Europe

According to the traditional concept, the PHS power station should be built near load centers, which can ensure the safe operation, economic transmission and convenient management. Since Norwegian traditional hydropower is sufficient to supply its domestic demand, the offshore wind power should mainly be conveyed to European continent and UK. Thus, Norway is not a load center, so the PHS station should not be located in Norway. However, according to the research of China's relevant departments, in order to "improve the operating conditions of EHV transmission system and enhance the economic situation of transmission" [2], a small part of pumped storage capacity should be built in the vicinity of the wind farm in China. Similarly, there should be a small part of the pumped storage capacity built in Norway correspondingly. (Offshore wind power plant is supposed relatively close to Norway). So, most pumped storage capacity should be established in European Continent and in UK (Fig. 3). In this case, the construction of PHS power station in Norway can not only provide peak load electricity for itself, but also the power can be sent to the European continent for peaking regulation. As well known, the Norwegian coastline and mountainous topography conditions, in particular Norwegian bedrocks being mostly made up of hard rock make it more convenient to construct underground PHS plant [8]. In addition, good rock condition is favorable for seepage control. Permeability coefficient of reservoirs may be

much smaller, even localized permeability coefficient might be relatively large due to fissures or faults, which is easy to deal with. However, China has made great efforts on the handling of the reservoir seepage.

There are two ways to build PHS power station in Norway. The first is to increase the pumps on the basis of traditional hydropower, using the original power plant generating units, forming so-called mixture station, which involves almost no environmental issues (more easily to be accepted by the Norwegian citizen). The second is to build a new pure PHS power station at the right place. For the first approach, there could be some different schemes from the economic and technical points of view.

4 The suggestions for constructing tentative seawater PHS power station

Norwegian fjord regions or near coast areas may be the most desirable places to build seawater PHS power stations. The world's first seawater PHS power station, which is an experimental power plant, was built in 1993 in Kunigami, Okinawa, Japan. It has only one 30MW reversible turbine unit with effective head of 136 m [9, 10].If such places happens to have offshore wind resources, it can be considered to build a pilot seawater PHS power station. This kind of direct use of wind power will create superior quality green battery pack.

The purpose constructing green battery packs is to study the problems existing in converting the intermittent power into the stable power, the suitable proportion of pumped storage capacity to wind power station in the pack. Hydrodynamic problems can be studied simultaneously, such as the problem of water dynamics coupling power output, as well as potential environmental problems. It will bring about many benefits to construct seawater PHS project in Fjord or coast area, e.g., sea directly using as low reservoir.

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