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Concept study of wind power utilizing direct thermal energy conversion and thermal energy storage

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ABSTRACT

Present wind power is intermittent and cannot be used as the baseload energy source. Concept study of wind power utilizing direct thermal energy conversion and thermal energy storage named Wind powered Thermal Energy System (WTES) is conducted. The thermal energy is generated from the rotating energy directly at the top of the tower by the heat generator, which is a kind of simple and light electric brake. The rest of the system is the same as the tower type concentrated solar power (CSP). The cost estimation suggests that the energy cost of WTES is less than that of the conventional wind power, which must be supported by the backup thermal plants and grid enhancement. The light heat generator reduces some issues of wind power such as noise and vibration.

1. Introduction

Considerable amount of installation of the renewable energies to the power network arises lots of issues since the most of the renewable energies are intermittent [1]. This paper describes a novel idea named wind heat power (WTES), which is proposed for the first time, to solve the network issues.

The concentrated solar power (CSP) attracts attention because of its dispatchability. Some plants can operate continuous power generation of 24 h a day [2]. The thermal energy storage already became the second largest energy storage system in the USA after hydro. Solana, which became online since 2013, has the huge energy storage of 1680 MW-h. The sum of the thermal energy storage will become almost double in 2015 [3]. The proposals employing this practical thermal energy storage are gradually increasing [4–6]. The use of energy storage is also studied from various aspects [7,8].

Utilization of this thermal energy storage and employment of light and low cost heat generator are the key points of WTES. Typical configuration of WTES of “thermal specialized type” is shown in Fig. 1. The rotating energy is converted to the thermal energy at the top of the tower directly. The rest of the system is the same as the tower type CSP [9]. The produced thermal energy is transferred to the base utility by the heat transfer fluid (HTF) and produces steam to drive the turbine generator when required. The total energy cost of renewable energies is mainly estimated by the following points.

a) Efficiency
b) Capacity factor
c) System cost

WTES has the potential to become the most reliable and an economic power source when those are considered. The present situation of the renewable energies' installation conditions in various regions is analyzed and the merit of WTES is described in this paper.

2. Analysis of present network

2.1. Subjects of present power network

Several countries have already introduced considerable amount of renewable energies and maintain their power network in various methods [10]. The published documents issued by governments and organizations those who have responsibility to the stable power supply are studied.

Abbreviations: WTES, wind heat power; CSP, concentrated solar power; HTF, heat transfer fluid; CCGT, combined cycle gas turbine.

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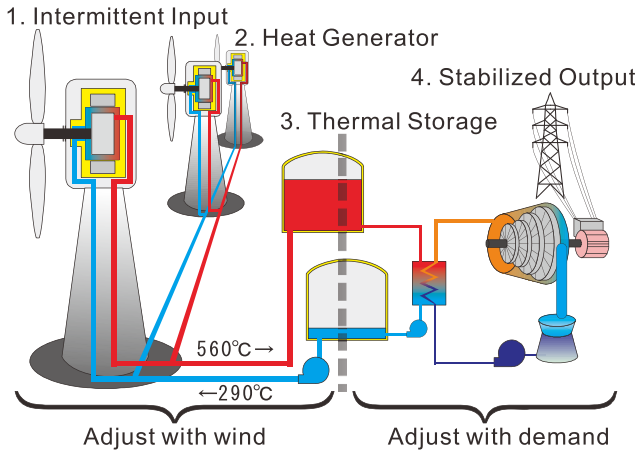

Fig. 1. Configuration of wind heat power (WTES), thermal specialized type.

2.2. Present situations of Spain and Denmark

The power network of Spain is almost isolated from the European network. Spain's wind power capacity was 2.4 GW in 2000 and it was increased to 24.8 GW in 2010. They introduced combined cycle gas turbine plants (CCGT) from 0 GW to 25.2 GW in this period [11]. It seems that their demand can be handled without renewables as shown in Fig. 2 [12].

It is said that the over 20% of the energy is supplied by the wind power in Denmark. Intimate study shows that Denmark manages their energy within Nordic energy market. Their capacity of the wind increased considerably and the capacity of the thermal plant is also slightly increased despite the amount of energy consumption in 2010 stays the same as that of the 1980. Some study claims that the energy consumption of the wind power in Denmark remains only 4% and the rest of the 16% is exported to nearby countries with low price [13].

2.3. Present status and plan of Germany [14].

German Energy Agency called dena assumes that Germany's energy consumption will decrease by 8% from 2008 to 2020. The percentage of the renewables will occupy 30% of the total electricity energy capacity in 2020 as shown in Fig. 3. The total installed capacity is increased to 25% under this condition although the total energy consumption is decreased as noted above.

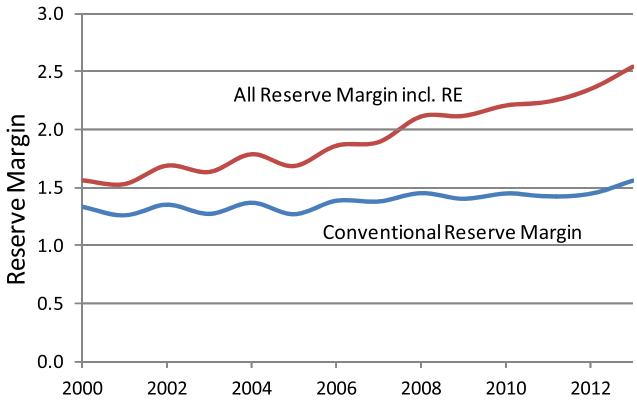

Fig. 2. Change of electricity capacity [12].

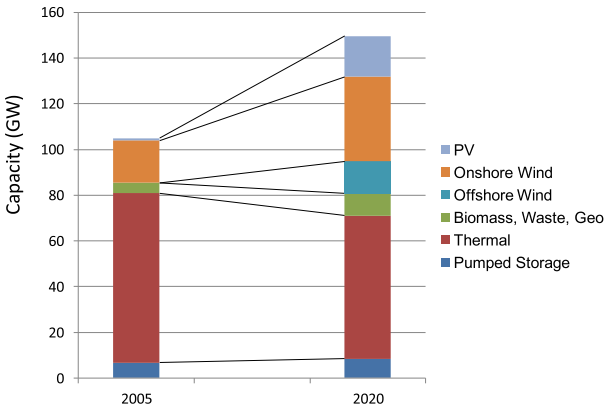

Fig. 3. Planned and installed capacity in Germany [14].

Some suggest that the output of the renewable energies becomes stable when the renewable energy sources from wide area are connected. Observed wind power of the entire German wind power shown in Fig. 4 proves this condition is not applicable to the time span of a day [15]. The conventional thermal plant must compensate the shortage of the electricity.

Another study claims that the new reserve such as CCGT is not required when the wind power is introduced in the power network by 20% [16]. Replacement of the power station, however, is necessary if the existing power stations have low output adjustability. Demand side management is not so prospective since not so many loads can wait for several days [17].

Some study shows that 90% of the backup capacity is required to introduce wind to the power network [18]. This study claims that around 20–30% of the generated power should be curtailed when the optimum network configuration is assembled. The efficiency of the backup thermal plant decreases 8% because of the intermittent operation. The total carbon dioxide reduction is slightly spoiled by this intermittent operation. DOE's simulation of 20% penetration of the wind shows 16% reduction of the carbon dioxide emission [19]. It is concluded that considerable amount of the adjustable output thermal plants are required. It should be pointed out that the frequent start-up, shutdown and adjustment of the thermal plant output make the maintenance cost increase and plant lifetime short [10].

2.4. Other means to integrate renewables

dena investigated the various systems such as pumped hydro and battery to integrate the renewables to the present network.

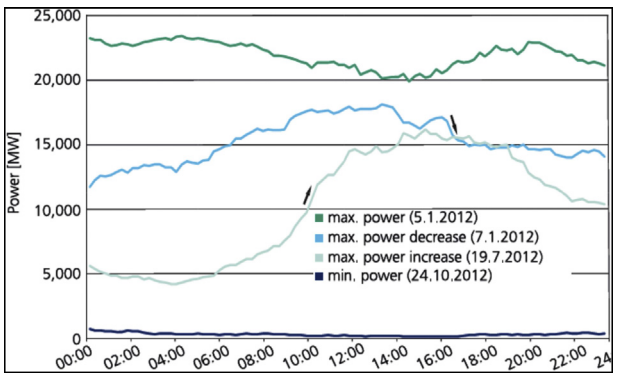

Fig. 4. Extreme Days of German Wind Power in 2012 [15].