The Maximum Potential Analysis of Wind Plant Development Based on Power Storage’s System Self-adaptive Tracking Control

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Abstract. Wind plant had a great influence on the power grid operation because of the volatility to the power supply layout. Moreover, the power system cannot consume all generated power when it exceeded the demands. However, the power storage device would change the wind plant output curves, and then the more new energy power could be utilized. How to analyse the maximum potential was an important matter to energy planning and power system development. The analysed results could decide the trends of energy supply structure in the future. In this paper, the reasonable generation scale arrangement was discussed considering the energy resources, land planning, ecological requirements, and the power storage system tracking control principle was proposed to optimize power output.

1. Introduction

Since 2010, the non-hydro renewable energy mainly contained photovoltaic (PV) and wind electricity generation were growing rapidly for policy guidance in China. The percentage of fossil-fired energy decreased for the 21st century due to renewable energy explosive growth [1]. As the report by EPPEI, the total energy consumption of China in 2018 was 4.64 billion SCE, an increase of 3.3 percent over the previous year. The proportion of clean energy in the total consumption had risen to 22.1%, and the proportion of non-fossil energy in the total consumption arrived at 14.3%. The growth was largely driven by wind plant and solar PV, which saw annual average growth rates of 21% and 43% between 2010 and 2018, the proportion of wind energy and PV in consumption arrived at 2.4% and 1.2% respectively. The capacity of electrical plants was 1.9 billion kilowatts, the combustible fuel plants accounted for 60.2% of total gross electricity production, nuclear plants 2.4%, hydroelectric plants 18.5%, PV 9.2% and wind 9.7%. The annual capacity of China in 2018 was 7 trillion kilowatt-hour, the combustible fuel plants accounted for 60.2% of total gross electricity production, nuclear plants 2.4%, hydroelectric plants 18.5%, solar PV 9.2% and wind 9.7%. The capacity of wind plant in 7 provinces surpassed 10 million-kilowatt, those were Neimenggu, Xinjiang, Hebei, Gansu, Shandong, Shanxi and Ningxia. After almost ten years rapidly developed, the scale of non-hydro renewable energy plant in China ranked first. [2]

However, the scale of renewable energy in a zone could not increase forever, one reason is that the space is limited to develop the new energy generation. How to assess the maximum potential for a
province was a significant thing which that decided the future energy supply structure. The problem would discuss in this paper considering to various external constraints. And the self-adaptive tracking control technology was used to improve the wind power output characteristic, those could increase the maximum capacity of wind plant.

2. Physics Restriction
There were several physics restrictions determining the scale of the wind plant, such as land planning, ecological requirements and energy distribution.

2.1. Resource condition
Windmills used turbines to convert rotational energy into electricity that can reliably flow into to a grid. The wind power resource was a decisive factor of the development. The even wind speeds represented the level of wind power, generally, the 6m/s wind speed in 50 meters to 100 meters was identified as potential wind developing zone, which was supposed that the wind power density surpass 300W/m². Nowadays, a low speed turbines was manufactured to enlarge developing zone, and the wind power density exceed 200W/m². The areas with average wind speed was lower than 5m/s were unfit to develop the wind plant. The parameters of wind rose, intensity of turbulence, air mass density and wind shear were the important factor to assess the capacity of wind resources. Therefore, the resource condition was the basis to initiate development work on setting wind farms, the high quality wind resource area would be developed preferentially.

2.2. Land planning
The non-hydro renewable energy plants belonged to low power density generation, therefore, the plants ought to occupy large area of land. Legal land procedures was the first condition to develop plants.

Land used corresponds to the functional dimension of areas: areas used for residential, industrial or commercial purposes, for farming or forestry, for recreational or conservation purposes, etc. The land use was different to land cover which corresponds to a (bio) physical description of the earth's surface, the land cover enabled various biophysical categories to be distinguished - basically, areas of vegetation (trees, bushes, fields and lawn), bare soil, hard surfaces (rocks, buildings), wet areas and bodies of water (watercourses, wetlands). Distinctions between land use and land cover had impacts on the development of classification systems, data collection and information systems in general.

The effect of land planning was marking the socio-economic description, it might be possible to infer land use from land cover and conversely. But situations were often complicated and the link was not so evident. Contrary to land cover, land use was difficult to observe. For renewable energy development, the land use should be construction land, commercial land or industrial land, the basic farmland, forest land and basic grassland were forbidden to build up the power plants.

2.3. Ecological requirements
The wind energy development should impact the ecological environment during construction period and operation period. Since 2017, a guideline on an ecological “red line” declared certain regions under mandatory and rigorous protection. The ecological red line refers to spatial boundaries and administrative limits for the implementation of strict protection with regard to natural ecosystem services, environmental quality and security and natural resources utilization. The purpose of the ecological red line was to safeguard the ecological security on a national and regional level, maintained in the sustainable development of economy and society, and guarantee the health of the public.

By the end of 2020, according to the document, China should have clearly defined the “red line.” This strategy will cover regions with important ecological functions, including water and soil conservation, biodiversity maintenance as well as windbreak and sand-fixation, along with ecologically fragile regions which are prone to soil erosion, desertification and salinization. By the end
of 2020, the demarcation of the border and calibration of the regions should be completed and an ecological protection “red line” system will be basically established. By 2030, the layout of the ecological protection “red line” will be further optimized, effectively implemented, the ecological function of the regions promoted, and national ecological safety guaranteed. The wind developing position have to out of the red line, the scale of wind plants is limited.

2.4. Power demands
The power demands decided the consumption of electricity. Owing to the power keep balance in time, the power demands were required equaling to power generation output, but the wind power output was random, excessive development of wind power might result in some wind power abandon. The main reason was that electricity cannot store formerly. However, the power storage system increased greatly in recent years, the previous limit will be lighten in condition of the power storage developing.

3. Power Storage system

3.1. Structure of power storage
Power storage system contained power conversion system (PCS), battery pack (BP) and battery Management System (BMS), and it was shown in Figure.1. The PCS included a converter for converting an AC power from a power grid to a DC power for controlling charge power, a DC capacitor for smoothing the DC power output from the converter, an inverter for converting the DC power smoothed by the DC capacitor to an AC power for controlling discharge power. The BMS had a unit for detecting battery condition and control each battery working status. The BP was electricity storage unit which may be Li ion, flow cell or other mode. In conclude, PCS was the core control section because of connecting the battery pack and power grid and controlling power storage system work, the power system dispatching center sends the AGC order to PCS for control the power storage system.

3.2. Application of power storage
Power storage system had function as storing electrical power or thermal energy to make the power system become flexible. Power storage was complements the intermittency of renewable energy produced by wind or solar power generation system. That stabilizes the output of renewable energy by charging & discharging irregular and intermittent power which was generated by wind system. Power storage can manage the local peak demand in a smart way, deferring the point of necessary investment for transmission and distribution network, and it will supply power frequency control and voltage control to maintain stable power system. Moreover, energy storage based on lithium ion battery provides reliable and fast frequency response without being subject to fuel prices and with zero emissions.[3-6] Power stored during off-peak time can be used during on-peak hours so that home/commercial owners can cut peak demand and electricity cost. Power storage integrated with wind energy can maximize consumption of new energy by using electricity stored off-peak. Due to transmission constraints, currently, the ever-increasing portion of wind generation was being curtailed.
Energy storage was the best option for reducing renewable power curtailment, relieving transmission congestion, and achieving full utilization of renewable energy sources.

4. Self-adaptive Tracking Control technology
The power storage system should change the curves to make the power system generations output being mate to the power demands one, there are two ways to achieve to harmonize, one was smooth the wind power output, the another was storing during off-peak time and used during on-peak time. The operation mode of power storage system was the basis of power demand, others power generation, wind power output and battery storage change. The structure of self-adaptive tracking control mode were proposed, the principle was shown in Figure.2, and the process was shown in Figure.3.

![Process of self-adaptive tracking control mode](image)

Based on self-adaptive tracking control process, the collect information contained the power demand this time which might be several seconds marked as \( t \), power plants output in last time, the power storage system capacity and those state of charge (SOC).

The optimizing target was the cost of power system being the least, the cost contains peak load regulation cost of power plants, line loss and storage system cost. The operating constraints included power grid capacity, power system voltage and frequent, plants ramp rate, storage capacity and SOC.
5. Maximum potential of wind plant
The area Ningxia province was 66400 square km, the capacity of wind plant in the area was 11.01GW in 2018, and the maximum potential of wind plant would obtain through census. The maximum potential were analysed considering in each restraints, the area conformed to all comprehensive restraints is 4040 square km, and the wind plant capacity in there is 20.2GW. However, the maximum load of the zone will be 24.4GW in 2030, according to the limit of abandon the wind rate was 5%, the operation state in the power system with storage system are simulated based on the self-adaptive tracking control mode in 2030, the potential based on power demand was 17.6GW, and the maximum potential got to 20.2GW in condition of 2GW power storage device, the comprehensive results were shown in Table.1.

| Restriction                        | Potential of wind                  |
|------------------------------------|------------------------------------|
| Resource condition                 | 36GW(25200square km)               |
| Land planning                      | 27.1GW(7200square km)              |
| Ecological requirements            | 26.0GW(5200square km)              |
| comprehensive restraints           | 20.2GW(4040square km)              |
| Power demand without storage       | 17.6GW                              |
| Power demand with 0.5GW/2GWh storage| 18.4GW                              |
| Power demand with 2GW/8GWh storage | 20.2GW                              |

6. Conclusion
The restriction of wind plant development was analysed in this power. The self-adaptive tracking control technology was proposed to analyse the influence of power storage devices, the power demand character and wind electricity generation curve were investigated. The measures referring to the storage technology to increase installed wind capacity were studied. The maximum potential of wind plants was obtained. Those could provide the basis to make the energy developing strategy.

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