Research on Unified Cognitive System of Renewable Energy Utilization Rate

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Abstract. China's requirements of renewable energy utilization rate target have greatly promoted vigorous development of renewable energy industry and rapid increase of its scale. But with further increase of renewable energy' proportion, strictly maintaining this target will bring negative effects. This paper refers to public knowledge of hydropower development, proposes and defines three utilization rates of renewable energy, respectively are theoretical utilization rate, technical utilization rate, economical utilization rate. Based on a power system operation simulation model, this paper also gives an example of three utilization rates, and makes analysis from the perspective of sharing responsibility between renewable energy and traditional energy.

Keywords: renewable energy; utilization rate; economical utilization.

1. Introduction

For China, in order to promote clean and low-carbon transition, "Clean Energy Consumption Action Plan (2018-2020)" was proposed in 2018, which clearly defined utilization rate of wind power and photovoltaic power should above 95% and abandonment rate should below 5% [1]. In recent years, requirements of renewable energy utilization rate target have greatly promoted vigorous development of renewable energy industry and rapid increase of its scale, especially wind power and solar power. But with further increase of renewable energy' proportion, strictly maintaining this target will bring negative effects [2-4].

Referring to public knowledge of hydropower development [5], as shown in Table 1, this paper updates and proposes three utilization rates of renewable energy, respectively are theoretical utilization rate, technical utilization rate, economical utilization rate. These three utilization rates and the unified cognitive system of renewable energy utilization rate they constituted, will unify the industry's cognition of development and utilization of renewable energy, so as to achieve a more scientific utilization target and guide development of renewable energy industry.

Table 1. Referring to three statistical methods of hydropower resources and proposing three cognitive methods for renewable energy utilization rate

Three statistical methods of hydropower resources	Three cognitive methods for renewable energy utilization rate
Theoretical hydro energy reserves: theoretical calculated value of hydropower resources	Theoretical utilization rate
Technical available hydro energy resources: hydropower resources amount that can be developed and utilized under current technical conditions	Technical utilization rate
Economical available hydro energy resources: hydropower resources amount with economic development value	Economical utilization rate

2. Analysis model and method

Renewable energy absorption is about power system operation, so model involved in this paper is mainly power system operation simulation model. The objective function of power system operation simulation model is to minimize system operating cost in simulation period. System operation cost includes operation cost and start-stop cost of thermal power unit, operation cost and mode conversion cost of CCGT unit, and start-stop cost of hydropower unit and pumped storage unit. Operating costs of wind power, solar power and nuclear power are relatively low, so not considered in objective function.

$$\min \sum_t^T \left[\sum_{n_{co}} \left(c_{n_{co}}^{ope}(t) + c_{n_{co}}^{s-up}(t) + c_{n_{co}}^{s-do}(t) \right) + \sum_{n_{cc}} \left(c_{n_{cc}}^{ope}(t) + c_{n_{cc}}^{trans}(t) \right) + \sum_{n_{hy}} \left(c_{n_{hy}}^{s-up}(t) + c_{n_{ny}}^{s-do}(t) \right) + \sum_{n_{ps0}} \left(c_{n_{ps}}^{s-up}(t) + c_{n_{ps}}^{s-do}(t) \right) \right] \quad (1)$$

in which, T is total number of simulation periods; t is period number of simulation periods; nco, ncc, nhy and nps is the number of thermal power, CCGT, hydropower and pumped storage units respectively; $c_{n_{co}}^{ope}(t)$, $c_{n_{co}}^{s-up}(t)$ and $c_{n_{co}}^{s-do}(t)$ are respectively operation cost, start-up cost and shutdown cost of thermal power units; $c_{n_{cc}}^{ope}(t)$ and $c_{n_{cc}}^{trans}(t)$ are respectively operating cost and mode conversion cost of CCGT units (including start-stop cost); $c_{n_{hy}}^{s-up}(t)$ and $c_{n_{ny}}^{s-do}(t)$ are start-up cost and shutdown cost of hydropower units respectively; $c_{n_{ps}}^{s-up}(t)$ and $c_{n_{ps}}^{s-do}(t)$ are respectively start-up cost and shutdown cost of pumped storage units.

Unit operation constraints details of thermal power units, CCGT units, hydropower units, nuclear power units, wind power units, solar power units and pumped storage units can be found in Ref [6] and Ref [7], we won't explore it in this paper.

3. Concepts of three utilization rates

3.1 Theoretical utilization rate

Theoretical utilization rate is utilization rate under renewable energy theoretical absorption space [8], as shown in Figure 1, and also the maximum utilization rate that can be achieved. Theoretical utilization rate is a simple calculation from annual power generation balance. For a system without internal network constraints, renewable energy absorption only needs to meet dynamic balance of power generation and consumption, therefore, space under "load plus outgoing transmission power" curve is system regulation space, that is, the theoretical renewable energy absorption space. Under theoretical utilization rate, renewable energy will "all should be absorbed", which is equivalent to making traditional energy undertake unlimited absorption responsibility.

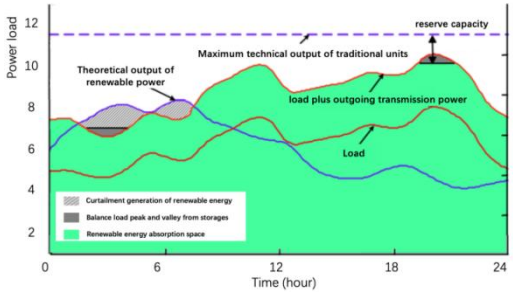

Figure. 1 Diagram of renewable energy absorption space.

When development scale of renewable energy is not that large, theoretical annual renewable power generation is smaller than renewable energy maximum absorption space, and now theoretical utilization rate is 100%. With gradual increase of renewable energy proportion, theoretical annual power generation of renewable energy gradually exceeds renewable energy maximum absorption

space, and theoretical utilization rate can be calculated by Formula (2). In other words, if renewable energy proportion gets large enough, the maximum utilization rate of renewable energy cannot reach 100% in any case.

$$\text{Theoretical utilization rate}=\frac{\text{renewable energy maximum absorption space}}{\text{renewable energy theoretical annual power generation}} \quad (2)$$

3.2 Technical utilization rate

Technical utilization rate is utilization rate under renewable energy absorption space after considering current technical level, and can be calculated by power system operation simulation model mentioned in Chapter 2 considering correlation between operating state of each moment. Under technical utilization rate, all regulation measures should be applied to their maximum within the range of development potential and operating characteristic parameters, and without considering economic cost, that is, all regulation parameters in power system operation simulation model are set to 0. At this time, traditional energy sources undertake limited responsibility, but because of high costs, this division of responsibility is unfair.

In contrast, subject to structural characteristics and technical characteristics of regulation means, some regulation needs cannot be met, therefore technical utilization rate must not be larger than theoretical utilization rate.

In a short period of time, when proportion of PV installed capacity is too large, if there is no sufficient scale of daily regulation energy storage, then PV's output at noon will not be integrated, but considering theoretical utilization rate, this PV's output can be shift from peak to valley. In a long period, if there is no long-cycle regulation energy storage of sufficient scale, then some renewable energy needs to be integrated across weeks, even months and seasons, cannot be met.

3.3 Economical utilization rate

Economical utilization rate is utilization rate considering renewable energy absorption space after the current technical level and its technical economy, and can be calculated as a planning result to promote the lowest power supply cost of whole society. Under economic utilization rate, each regulation measures should be used up and applied to the fullest extent considering its economic cost. At this time, responsibility of traditional energy is limited, and in the global perspective, this division of responsibility is more fair.

In contrast, subject to technical economy of regulation means, some regulation needs cannot be met, therefore, economical utilization rate must not be greater than technical utilization rate. For example, for CSP power generation with good regulation characteristics, considering its current cost is still high, in the calculation of technical utilization rate, CSP power will be fully applied, and in the calculation of economic utilization rate, CSP power will be partially applied or not applied.

4. An example of three utilization

Below is a small example to show the difference between theoretical utilization rate, technical utilization rate and economical utilization rate, as shown in Figure 2. When scale of renewable energy is not too large, all three utilization rates can reach 100%. As scale of renewable energy increases, economical utilization rate will first fall below 100%, then technical utilization rate, and finally theoretical utilization rate.

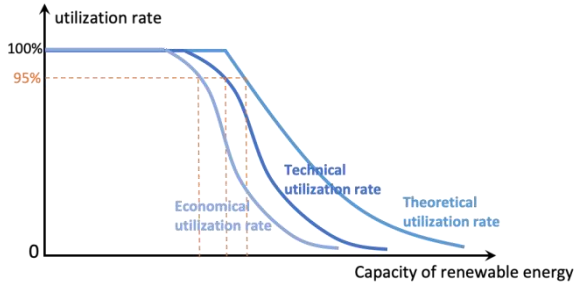

Figure. 2 Diagram of renewable energy absorption space.

Combined with China's renewable energy consumption targets, according to different utilization rates considerations, allowed scale of renewable energy integrated to grid is different. And the scale corresponding to theoretical utilization rate is greater than technical utilization rate and greater than economical utilization rate. This corresponds to government's determination to promote development of renewable energy, especially wind power and solar power, that is, how much development responsibility government expects traditional energy and whole society to help renewable energy to undertake.

5. Suggestions

Focusing on utilization rate of renewable energy, the key is to fairly distribute responsibilities of traditional energy and renewable energy in the optimal combination of traditional energy and renewable energy, which requires government, upstream and downstream enterprises and users to strengthen exchanges, recognize laws, build consensus, work together, seek countermeasures in practice, resolve contradictions, and promote the development of renewable energy to a new level.

Firstly, after accomplishment of carbon peak goal in some western provinces, theoretical utilization rate of renewable energy will be reduced to below 95% if outside the power system measures are not taken into account. Therefore, it is necessary to increase publicity of different utilization rate concepts of renewable energy, guide the society to widely understand and gradually form a consensus that "renewable energy cannot be 100% integrated", and avoid unlimited responsibility of traditional energy.

Secondly, for different regions, further deepen the difference between technical utilization rate and economical utilization rate, identify and select technology categories that are more economical to improve utilization rate, and accelerate relevant demonstration applications.

Lastly, in the near future, for national utilization targets, it is necessary to plan scale of renewable energy development according to economical utilization rate to avoid causing too large power system costs brought by renewable energy. In the medium and long term, utilization rate assessment target should be released in a planned and step-by-step manner, and the generalized absorption measures should be promoted for the development of market self-drive.

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