Analysis of power market simulation methods under the background of re-electrification

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Abstract. The world is experiencing a new round energy transition from fossil energy to clean energy. To many countries, continuously upgrading electrification level and accommodate more wind power and solar power to achieve re-electrification roadmap, will be a trend and the only way of these countries’ energy transition. In this paper, challenges brought by large-scale wind power and solar power to power system operation are analyzed from the aspects of accommodation, fluctuation characteristics, prediction error, power electronics characteristics and pulling down system marginal cost. Also, key issues of power market simulation methods, such as co-considered day-ahead market and real-time market by use of Security Constrained Unit Commitment (SCUC) model and Security Constrained Economic Dispatch (SCED) model respectively, co-optimized energy and ancillary service market and added rotational inertia verification in SCUC model, are studied.

1. Introduction

With the increasing prominence of worldwide energy crisis and environmental crisis, a new round of energy transition is being conceived and developed, which will promote strategic transition of human energy utilization from fossil energy to clean energy, and construct a new energy system to cope with major challenges such as environmental pollution and greenhouse gas emissions. To many countries, the key of energy transition is large-scale development and utilization of wind power and solar power, expansion of scale and scope of electric energy, and improvement of energy use efficiency. Therefore, continuously upgrading electrification level to achieve the key re-electrification roadmap, will be a trend and the only way of these countries’ energy transition.

Under the background of re-electrification, the biggest challenge is connecting large-scale wind power and solar power to power grid efficiently. Therefore, power market mechanism and its simulation methods should adjust to wind power and solar power accommodation, and also safeguard the fairness of power market. In this paper, challenges brought by large-scale wind power and solar power to power system operation are analyzed from the aspects of accommodation, fluctuation characteristics, prediction error, power electronics characteristics and pulling down system marginal cost. Also, key issues of power market simulation methods, such as co-considered day-ahead market and real-time market by use of Security Constrained Unit Commitment (SCUC) model and Security Constrained Economic Dispatch (SCED) model respectively, co-optimized energy and ancillary service market and added rotational inertia verification in SCUC model, are studied.
2. Challenges brought by large-scale wind power and solar power connecting to power grid

Compared with conventional energy, wind power and solar power are inexhaustible, clean and pollution-free, which will not have a negative impact on the environment at an extent. At the same time, wind power and solar power are generally uncontrollable, which bring many challenges to maintain power system operation safely and stably after connecting large-scale wind power and solar power to power grid.

2.1. Accommodation efficiently

Take China as an example, in the past decade, the installed capacity of wind power and solar power have become the largest in the world. Restricted by factors such as uncoordinated power generation planning and power grid planning, insufficient cross-regional transmission lines and peak regulation capacity, and also imperfect market mechanisms, appearance of pretty low utilization rate of wind power and solar power has been prominent since 2010. In recent years, through efforts of all parties in the society, establishment of auxiliary service market mechanisms and the inter-provincial trading mechanism have made utilization of wind power and solar power in a good way.

Given that wind power and solar power will continue to develop in the future and replace coal as the biggest power generation in the medium and long term, challenge of maintaining reasonable utilization of wind power and solar power will continue to exist.

2.2. Fluctuation characteristics

The output of wind power and solar power is volatile, especially wind power. The output power of wind turbine has strong uncertainty, the maximum daily fluctuation can reach 80% of the installed capacity, and presents certain reverse peak regulation characteristics. At present, the accuracy of digital weather forecast technology in wind speed prediction is low, especially in day-ahead generation plan. Moreover, wind power output is greatly affected by the weather, which directly leads to the uncertainty of wind power output far greater than that of load, directly affecting the unit combination, output arrangement and standby arrangement of conventional units.

2.3. Prediction errors

Due to inherent characteristics of wind power and solar power, such as wind speed and wind direction, output of wind power and solar power is highly uncertain. In addition, power generation also has certain uncertainties, such as wind speed change caused by the start and stop of wind turbines, working condition adjustment, structure and incentive.

The above characteristics of wind power and solar power jointly cause the uncertainty of its output. Existence of these uncertainties leads to great difficulty in output prediction, which is reflected in the error of wind power and solar power prediction from the result.

2.4. Power system electronization

In recent years, electronic components have been widely used in power system, especially "low inertia" wind power and "zero inertia" solar power, their proportion will be further expanded in the future, showing the characteristics of high proportion of electronization.

Rotational inertia is an important index to measure anti-disturbance capability of power system. A traditional power system is mainly composed of conventional units, with sufficient rotational inertias and strong ability to deal with faults. As conventional units are replaced by a large number of wind power and solar power units, resulting in continuous decrease of overall rotational inertias of power system and continuous deterioration of the anti-disturbance capability.

2.5. Pulling down system marginal cost

Since marginal costs of wind power and solar power is low, and even can be quoted negatively, large-scale participation of wind power and solar power in the market will reduce clearing price of power
market. In extreme cases, market clearing price can be zero or negative, which affects market earnings of thermal power generation.

In Germany, for example, large-scale generation of renewable energy leads to a sharp drop in the wholesale market price of power. Conventional power is in a state of low profit or even loss, and future investment intentions are reduced. According to statistics, the price of electricity at peak load in Germany has been reduced from 80 euros/MWh in 2008 to 38 euros/MWh in 2013. RWE, a German energy firm, lost 2.8 billion euros in 2013. Many traditional power plants have applied to shut down.

3. Practices of wind power and solar power participating in power markets
As the early development pioneer of renewable energy, the United States and Northern Europe have successful experiences and the way of renewable energy participating in power market worth learning.

What related to wind power in Nordic power market includes day-ahead energy market, real-time energy market, wind power enterprises need to forecast and report their outputs and prediction error will lead to unbalance. Wind power participates in day-ahead energy market and profit of wind power enterprises is determined by spot price. In real-time balance market, if the unbalance is contrary to the system unbalance, wind power enterprises will be exempted from punishment and settle according to spot price. If the unbalance is the same as the system unbalance, the enterprise will be punished and settled at real-time market clearing price.

Power markets in the United States mostly base on a double settlement of day-ahead future market and real-time spot market, in power markets like Midcontinent Independent System Operator (MISO), Electric Reliability Council of Texas (ERCOT), California Independent System Operator (CAISO) and New York Independent System Operator (NYISO), renewable power suppliers can directly participate in real-time spot market, usually offer zero tariff to become price recipient and settle with real-time market clearing price.

4. Analysis of power market simulation methods to cope with re-electrification challenges
To cope with challenges brought by large-scale wind power and solar power connecting to power grid under the background of re-electrification, considering main practices of wind power and solar power participating in power markets, there gives three power market simulation methods.

4.1. Co-considered day-ahead market and real-time market by use of SCUC model and SCED model respectively
For a long time, system operator should make generation plan of the next day, including load prediction, units start and stop plan, generation output and transmission lines plan, etc., so as to reduce pressure of real-time dispatching. In real-time power system operation, system operator only has to
deal with imbalances caused by various reasons. Co-considered day-ahead energy market and real-time energy market fully draws on these operating experiences, clearings and settlements of these two markets are respectively.

Day-ahead market runs computer program based on SCUC model according to units bidding, load quotation and bilateral trading plans, calculates generation schedule and day-ahead market price for each hour of next day, and then makes settlements for the day-ahead market. Real-time market is also known as balance market. According to actual operating conditions of power system, SCED software based on security constraints is operated every 5 or 15 minutes to conduct real-time generation scheduling and calculate real-time electricity price. Real-time market settlement is conducted based on the deviation between real-time scheduling results and day-today plans and real-time electricity price. Day-ahead market price and real-time market price are node marginal price (LMP), including energy price, blocking cost and network loss cost.

4.2. Co-optimized energy and ancillary service market
Reserve and frequency modulation capacity occupy generating capacity, so ancillary service market is inseparable from energy market.

Co-considered day-ahead market and real-time market, jointly market clearing optimization of ancillary service market and energy market use the same market optimization program. Similar to energy market, ancillary service market is cleared in day-ahead market and real-time market respectively, among which, what clear in real-time market is a deviation between ancillary service plan and day-ahead market plan.

4.3. Added rotational inertia verification in SCUC model
Generally, power system simulation model with very short time scales (second and millisecond) is needed to verify transient power system frequency stability. However, for power system planning, it is necessary to consider the power operation on a more macroscopic and larger time scale. Therefore, a simple method that can judge whether system’s rotational inertia meets the stability requirement is needed in power operation of minute level and hour level use for power planning.

After that, a certain power planning scenario can be applied, that is, whether total rotational inertia of thermal units, hydropower units and nuclear power units in this scenario meets system’s requirement under N-1 failure. Therefore, whether this power planning scenario meets the stability requirements of power system can be judged.

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References
[1] Xie K. (2017) Electricity market, operation and regulation: US practice. China electric power press, Beijing.
[2] Zhu J.Z. (2019) Methods of electricity markets operation in multi-energy environment. China machine press, Beijing.
[3] Ma X.W., Song H.L., Hong M.G., etc. (2009) The security-constrained commitment and dispatch for Midwest ISO day-ahead co-optimized energy and ancillary service market. IEEE Power & Energy Society General Meeting.
[4] Wang C.X., Li Q.H. (2016) Renewable energy integration experiences abroad and implications to China. China energy, Commun., 38(8): 33–37.