The research on simulation model and application of new energy generation

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Abstract. Facing the rapid development of renewable energy which is represented by wind and photovoltaic power generation, the installed capacity of renewable energy in the power system is increasing with each passing day. While the proportion of wind and photovoltaic power in the total installed power supply of the system is small, the power system is able to fully accept wind power and photovoltaic grid-connected power generation; However, when wind power and photovoltaic reach a certain scale, the intermittency and volatility of their output make their influence on the system not negligible, so it is necessary to study the acceptance capacity of renewable energy. In this paper, based on many innovative energy sources which are connected to the power grid in a certain region, the corresponding model is established, and the risk analysis of different innovative energy links correlating with the power grid and the optimization operation research are carried out.

1. Introduction

With the application of wind power generation, CPV and other distributed power production to the grid more and more widely, we must take into account its negative impact on the whole power system. On account of the seasonal, intermittent and other natural specialties of wind energy, wind power generation itself has volatility and uncontrollability. In addition, voltage, harmonics and other aspects also bring novel threats to the stable operation of the power system[1-3].

There are many methods to study the capacity of new energy consumption, among which the optimization manner and the producing simulation pattern are the main two types. In the optimization method, the economic optimum or maximum volume of new energy may be taken as the objective function to meet various constraints in the operation of the power scope to carry out the absorption of renewable energy; Stochastic production simulation method is used to evaluate the absorption capacity of renewable energy by simulating the reliability of actual production. Both methods have their advantages and disadvantages[4-6].
In this paper, based on the analysis on the influencing factors of new energy given, by using the probability density function model for power grid, the grid in one region of forecast load and contain wind power and photovoltaic power planning as a result, the production simulation method to evaluate the region's new energy given ability, the advice is given on the basis of the evaluation to improve the area absorption of renewable energy.

2. Stochastic model of distributed new energy

2.1. Simulation of photovoltaic power production

In the power production field containing photovoltaic power one, due to the relatively high cost of photovoltaic power production system, in order to maximize the usage of solar energy resources and the pursuit of maximum output of photovoltaic system, the appropriate installation Angle is usually selected according to the local longitude and latitude, or the corresponding tracking system is configured. In order to study the risks brought by photovoltaic power generation access to distribution network operation, it is necessary to determine the output energy of photovoltaic production unit at first, and its output power is closely related to solar light intensity, so it is also required to study the random distribution of solar light intensity. [7,8] The solar illumination intensity in a short time (a few hours) is approximate to Beta distribution, and the probability density function for Beta distribution is,

$$f(r) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} \left(\frac{r}{r_{\text{max}}}\right)^{\alpha-1} \left(1 - \frac{r}{r_{\text{max}}}\right)^{\beta-1}$$  \hspace{1cm} (1)

Where, $\alpha, \beta$ is distribution shape parameter respectively, $\Gamma$ is the Gamma function; $r$ and $r_{\text{max}}$ are the practical light magnitude, the maximum light magnitude separately. For the photovoltaic power supply in the system, its Beta distribution parameters can be obtained according to the average light intensity and variance in a certain period of time, and the relationship is as follows:

$$\alpha = \mu\left[\frac{\mu(1-\mu)}{\sigma^2} - 1\right] \hspace{1cm} \beta = (1-\mu)\left[\frac{\mu(1-\mu)}{\sigma^2} - 1\right]$$  \hspace{1cm} (2)

The output result of solar cells is not only involved in solar radiation intensity, but also related to photoelectric transfer productivity and photovoltaic array area. After the probability distribution of light intensity is obtained from the above formula (1), the output power $P_M$ and the maximum output power of the photovoltaic cell can be obtained $P_{M\text{ max}}$,

$$P_M = rA\eta \hspace{1cm} P_{M\text{ max}} = r_{\text{max}}A\eta$$  \hspace{1cm} (3)

Where, $A$ is the area of the photovoltaic cell, $\eta$ is the photovoltaic transfer productivity of the battery. When the likelihood intensity distribution function of light is known, the likelihood intensity distribution function of photovoltaic cell output electricity can be obtained through equations (1) and (2), which also follows the Beta distribution, as shown in the formula,

$$f(P_d) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} \left(\frac{P_d}{P_{M\text{ max}}}\right)^{\alpha-1} \left(1 - \frac{P_d}{P_{M\text{ max}}}\right)^{\beta-1}$$  \hspace{1cm} (4)

According to the definition of moment, the v-order origin moment of Beta distribution can be obtained by following expression. According to the relationship between the origin moment and the
semi-invariants, the semi-invariants of the active power of photovoltaic energy production can be available as,

$$a_v = \frac{a(a + 1)(a + 2)\ldots(a + v + 1)}{(a + \beta)(a + \beta + 1)(a + \beta + 2)\ldots(a + \beta + v + 1)}$$  \hspace{1cm} (5)

When the photovoltaic energy production system is bonded into the distribution network, the grid-connected inverter generally ensures that the power factor of its output power is 1, that is, the system does not absorb reactive power, so we can regard the photovoltaic power generation system as a PQ node with zero reactive power output in power flow calculation.

2.2. Simulation of wind power generation

When studying the risk assessment calculation of distributed power supply and other related issues, the first step is to decide the output volume of the wind generator. The active power output of the wind generator depends on the wind velocity and varies with the change of wind velocity, so does the reactive power imbibed by the generator. Therefore, it is necessary to study the random distribution of wind velocity before determining the output power of wind generator.

The output power of the fan system depends on the normal operation of the unit and the velocity of the wind. There are many simulation models for wind speed probability distribution, such as Weibull distribution, three-reference Weibull distribution, Rayleigh distribution, lognormal distribution and so on. A large number of studies have shown that the Weibull distribution model is most suitable for simulating the actual wind speed. Assuming that the probability distribution of wind velocity obeys the two-reference Weibull distribution, the likelihood density function[9,10] is:

$$f(v) = \frac{k}{c} \left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k}$$  \hspace{1cm} (6)

The cumulative probability distribution function is:

$$F(v) = 1 - e^{-\left(\frac{v}{c}\right)^k}$$  \hspace{1cm} (7)

Where, \(v\) is wind velocity; \(C\) and \(k\) are two references of Weibull distribution; \(C\) is called scale parameter; \(K\) is called the shape parameter.

The actual output of a wind turbine depends on the speed of the wind, and the turbine does not work at all speeds. If the wind speed is too high, the fan cannot work. If the wind speed is too small, the fan cannot start running normally.

The relationship between the actual output of the fan and the wind speed can be expressed by the output characteristic curve of each fan. There is an approximate piecewise function between the output result of the wind turbine and the wind velocity as follows,

$$P_{\text{wind}} = \begin{cases} 0, & v < v_{ci} \\ \frac{P_r v - v_{ci}}{v_r - v_{ci}}, & v_{ci} \leq v \leq v_r \\ \frac{P_r v}{v_r - v_{ci}} - \frac{P_r v_{ci}}{v_r - v_{ci}}, & v_r \leq v \leq v_{co} \\ 0, & v > v_{co} \end{cases}$$  \hspace{1cm} (8)

Where, \(v\) is wind velocity, \(v_{ci}\) is fan inlet wind velocity, \(v_r\) is rated wind velocity, and \(v_{co}\) is fan outlet wind velocity. \(P_{\text{wind}}\) is the output power of the fan, and \(P_r\) is the rated output power.

Wind turbines operated in the distribution network usually do not output reactive power, and the power factor is generally kept constant through parallel compensators. In power flow calculation, wind
turbines are generally treated as PQ nodes, and the reactive power of wind turbines can be expressed as,

\[ Q = P \tan \phi \]  

In the formula, \( \phi \) is the power factor angle, and it is generally in the fourth quadrant, that is, the fan absorbs reactive power. Therefore, the density function of the probability distribution of reactive power is,

\[ f(Q_{\text{wind}}) = \frac{k}{ac} \left( \frac{Q_{\text{wind}} - b}{ac} \right)^{k-1} \exp\left(-\left(\frac{Q_{\text{wind}} - b}{ac}\right)^{k}\right) \tan \phi \]  

2.3. Simulation mode for power load

The load is predicted and there is some uncertainty. Because the operation of the system is affected by many uncertain factors, there will be some errors in load forecasting, which should be taken into consideration when establishing the load model. Therefore, the probability distribution of the load can be calculated through the statistics of the load status in the cycle, and the uncertainty of the load can be reflected through the method of probability.

The load probability model can be divided into discrete model and continuous model. The discrete load can be represented by a series of discrete data, including the load power value of each discrete point and its corresponding probability. Through the collection of a large number of data and analysis, it is shown that for continuous load, the uncertainty of load can usually be represented by the normal distribution approximation[11,12].

Assuming that the expected value and variance of the active and reactive power of the load are \( \mu_p \), \( \sigma_p^2 \), and \( \mu_Q \), \( \sigma_Q^2 \), respectively, the likelihood density functions of the active and reactive power are,

\[ f(P) = \frac{1}{\sqrt{2\pi\sigma_p}} \exp\left(-\frac{(P - \mu_p)^2}{2\sigma_p^2}\right) \]  

\[ f(Q) = \frac{1}{\sqrt{2\pi\sigma_Q}} \exp\left(-\frac{(Q - \mu_Q)^2}{2\sigma_Q^2}\right) \]  

3. Application results and discussion

3.1. Application for Simulation of photovoltaic power production

According to the situation of photovoltaic power production in a certain area, take the date with good weather conditions and large photovoltaic output as the typical output of photovoltaic in this region, and then simulate according to the theory in Section 2.1. According to www.ip138.com, on April 8, 2018, the weather in this area was fine, with a temperature of 21-12 ° and a wind direction of 3-4 degrees from southwest to south. The photovoltaic output curve of photovoltaic phase one on that day is shown in the left figure of Figure 1. Taking this day as a typical output, the simulation results show that the \( \alpha \) and \( \beta \) of photovoltaic output model in this area are \( \alpha = 0.5774 \) and \( \beta = 0.3408 \),
respectively. The cumulative likelihood density and probability distribution function curve of beta distribution obtained from the simulation of $\alpha$ and $\beta$ are shown in the right figure of Figure 1.

![Figure 1. Photovoltaic output curve and Beta distribution curve.](image1)

3.2. Application for Simulation of wind power generation

The left one of Figure 2 shows the wind speed data of Shanghai 24 hours a day in April 2018. The data is from the website http://www.wunderground.com/. According to the historical data of wind speed, among the Weibull parameters, the scale parameter $c=3.00$, the shape parameter $k=2.02$, and the right one of Figure 2 is the probability density curve obtained by $c$ and $k$. From these two parameters, the wind speed is simulated by Weibull method, and then the wind power output is calculated according to equation (11).

![Figure 2. Wind speed curve and probability density curve.](image2)

4. Conclusion

This paper presents the stochastic model of new energy output, including the probability model of wind turbine, photovoltaic output and load. Its effectiveness in describing the probability distribution and cumulative probability density of the randomness of new energy output is demonstrated.
In this paper, the proposed model is innovative in terms of photovoltaic power generation simulation, according to the light intensity within a certain period of time, the mean and variance, the Beta distribution parameters can be found in the aspect of wind power one; according to the probability density function of wind speed and the output power of wind turbine and wind speed, using the knowledge of probability and statistics, the probability distribution of the output active power is calculated, the model is made more flexible and can be quickly solved. This will be establishing an effective modeling basis for distribution network risk assessment with the distributed power.

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