Evaluation of Power Quality and Reliability of Distributed Generation in Smart Grid

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Abstract. With the continuous development of new energy power generation technology, the access capacity of distributed photovoltaics continues to increase, and its impact on the power quality of the distribution network is gradually increasing. The access of distributed power sources brings many problems to the system planning, power quality, and relay protection of the power grid. From the perspective of power quality, this paper analyses the power quality problems caused by the grid-connected distributed power sources and the commonly used improvement methods, and expounds the role of microgrid technology in the hybrid access of multiple distributed power sources to the grid. At the same time, it expounds the technical hotspots of harmonic research on distributed new energy access to the power grid from the aspects of harmonic measurement, harmonic source location and responsibility assessment, harmonic resonance and its instability, and puts forward the future large-scale distributed new. The new harmonic research trend after energy integration provides a theoretical reference for the study of harmonic problems in the distributed new energy grid.

Keywords: Distributed Generation, Smart grid, Power quality, Harmonic measurement, Harmonic source location.

1. Introduction

With the increasing environmental pollution and the continuous depletion of traditional fossil energy such as coal and oil, it is imperative to replace traditional energy with clean and renewable energy. Photovoltaic power generation has many advantages such as green environmental protection, high efficiency, sufficient resources and no geographical restrictions, and has gradually attracted people's attention. In recent years, due to the strong support of the country and the gradual maturity of photovoltaic power generation, the installed capacity of domestic photovoltaic power generation has exploded. Distributed photovoltaic power generation has a series of impacts on the power quality of the distribution network due to its intermittent and random characteristics and the application of a large number of power electronic devices. When the connected capacity of distributed photovoltaic is large, the reliability of power supply and power quality of users will not be guaranteed. Therefore, it is necessary to analyse the maximum access capacity of distributed photovoltaics [1].
Due to the increasing demand for electricity from social development and technological progress, the limitations of traditional power development, and the increasing importance of society on environmental protection, the application of distributed new energy power conforms to social development. However, the incorporation of new energy power into the power grid has caused a series of problems. As a result, the related equipment of power users cannot be used normally, resulting in changes in voltage, current, and voltage frequency, resulting in a decrease in power quality of the power grid and affecting use. Therefore, for new energy generation technologies with distributed characteristics such as wind power and photovoltaic power generation, rely on science and technology to improve the application of distributed power, reduce the impact of distributed power output on the grid integration, and reduce the impact of intermittent power generation devices on the grid interference.

2. Distributed power quality monitoring system

In order to make up for the shortcomings of the existing technology, a power quality monitoring system for smart grid is proposed, as shown in Figure 1. The distributed monitoring system includes a distributed power quality online and offline node detection module, a network communication module, a distributed database integrated management module, and a power quality monitoring system integrated management module.

![Figure 1. Distributed power quality monitoring system for smart grid.](image)

2.1. Distributed power quality online and offline node detection module

Distributed power quality offline node detecting means for implementing basic functions of the distributed detection signal underlying intelligent power grid. The module includes a parallel analogy to digital conversion module, parallel signal processing module, the analogy acquisition terminal module, control module embedded type, self-calibration module. Analog acquisition terminal module includes a voltage sensor, a current sensor and associated signal conditioning circuit, for converting an arbitrary voltage and current in the power system as a standard electrical signal, and each signal into parallel analogy to digital converter to multiplex module. Parallel analogy to digital conversion module comprises a plurality of parallel sheet D conversion chip, programmable logic devices and a clock distribution module, configured to input the electric signal standard analogy to digital conversion and pre-processing, and transmitted to the parallel signal processing module [2]. By modulo four up sampling chip interleaving, it can be guaranteed under the premise of the sampling rate times the sampling accuracy. As shown in picture 2.
2.2. System monitoring circuit design

2.2.1. Voltage and current detection. In the power grid system, the voltage and current signals are monitored. This system mainly adopts the DC sampling method, which needs to collect the U, V, W three-phase voltage and four-phase current signals. In Figure 3, PT is a current type voltage transformer, A Phase input voltage through the current limiting resistor R1 makes the rated current of the PT primary 2mA, and the secondary will produce the same current [3]. Through the operational amplifier (LF353N), through the value of the feedback resistor R2, the required voltage output can be obtained at the output.

2.2.2. Frequency tracking circuit design. The main function of the frequency tracking circuit is to be able to maintain synchronization with the grid voltage and avoid spectrum leakage. After the phase voltage is stepped down by the transformer, it passes through the two diodes D1 and D2, and then sends it to the operational amplifier to convert the sine signal into a square wave signal. The function of the resistor R7 is to generate a positive feedback, accelerate the jump process of the amplifier, and obtain a more accurate synchronization signal. Figure 4 shows the frequency tracking circuit.
3. Distributed power grid-connected power quality and reactive power compensation strategy

3.1. Detection method based on instantaneous reactive power theory

There are also many algorithms based on this theory. The accuracy of the detection results of these algorithms is relatively high, and the detection speed is very fast, and the real-time performance is relatively ideal. However, it mainly detects harmonics in three-phase power systems, and further research and expansion are needed for single-phase systems. Figure 5 shows the spatial position relationship between coordinate system \((\alpha, \beta)\) and coordinate system \((d, q)\). The \((d, q)\) coordinate system rotates with the current vector \(I\) at a synchronous angular frequency \(\omega\). The angle between \(I\) and the \(d\) axis is \(\theta_s\), and the angle between the \(d\) axis and the \(\alpha\) axis is \(\phi\). The projection calculation method of the current vector \(I\) in the two coordinate systems is as follows.

\[
\begin{align*}
    i_d &= i_d \cos \phi + i_q \sin \phi \\
    i_q &= i_d \sin \phi + i_q \cos \phi
\end{align*}
\]

(1)

The transformation from the two-phase vertical stationary coordinate system \((\alpha, \beta)\) to the two-phase vertical rotating coordinate system \((d, q)\) is

\[
\begin{bmatrix}
    i_d \\
    i_q
\end{bmatrix} = \begin{bmatrix}
    \cos \phi & \sin \phi \\
    -\sin \phi & \cos \phi
\end{bmatrix} \begin{bmatrix}
    i_\alpha \\
    i_\beta
\end{bmatrix}
\]

(2)

![Figure 5](image-url)
3.2. Analysis of the UPQC control strategy coordinated with the same phase voltage compensation and parallel current compensation

The compensation device always compensates for the amount of change during compensation, thus ensuring the stability of the original value. Compensation for voltage and current in this device requires corresponding control strategies. In previous studies, the PWM control strategy includes sinusoidal PWM (SPWM) control and space vector pulse width modulation (SVPWM) control. The former uses SPWM waves to decompose the original waveforms, and then replace them with equivalent rectangular waves; the latter is a new control method emerging in recent years, and its principle is analysed and studied on the basis of voltage vector rotation. When rotating, it will form a ring, and the switch of the switch tube will generate a magnetic flux circle when it is opened and closed. There are also many voltage compensation strategies. Different compensation methods can achieve different compensation effects and have different manufacturing costs [4]. Therefore, choosing a suitable compensation strategy can achieve the ideal state and reduce the manufacturing cost. Voltage compensation mainly includes complete compensation, in-phase compensation, and minimum capacity compensation:

1) The complete compensation method can compensate the voltage drop of the system to the original voltage within a certain range, including the amplitude and phase angle of the voltage. This compensation method also has disadvantages: when the disturbance in the system is too large, the voltage will also change greatly. At this time, the compensation ability of this method is reduced, and it is difficult to compensate the flicker voltage to exactly the same voltage as the original one. In addition, the load has a certain anti-interference ability, so it is not necessary to make full compensation in this case. Of course, not all faults in the power grid are temporary faults. Permanent faults are also relatively common. In this case, the method of complete compensation cannot be achieved, so this method is not widely used in practical applications [5].

2) The minimum energy compensation requires the least energy, and the voltage advance method is used for compensation. When the compensation voltage is ahead, the angle between the compensated voltage and current will become smaller, increasing the active power, and because the load requires a certain amount of energy, the output power of the converter will decrease. This method will increase the power factor and reduce the manufacturing cost of the compensator. However, since this method changes the voltage phase for compensation, as with full compensation, when there is a large interference, the phase change exceeds the compensation range, this method will not work, and a "phase shift" phenomenon will occur after compensation. In addition, it also needs to provide a large enough output voltage to ensure its work.

4. Power quality assurance measures for new energy power into the grid

(1) In improving the power quality of new energy power into the grid, fast response equipment, that is, dynamic reactive power compensation equipment, is generally used, which can be divided into net value reactive power compensation equipment and active filter equipment, and power quality control equipment. In the distribution grid, especially in the medium and high voltage, the factors that cause voltage fluctuations are directly related to the load of the grid and the maximum short-circuit capacity allowed in the grid. Therefore, under the condition of unchanged short-circuit capacity, reactive power compensation becomes an effective method to restrain voltage fluctuations [6]. This method is most suitable for wind power generation that absorbs reactive power and simultaneously emits active power.

(2) According to the relevant research on reactive power compensation and voltage stability in wind power grid access, facilities with flexible AC transmission methods can be applied to wind power generation in order to better improve the stability of equipment use. When there is too much reactive power in wind power generation and sudden changes in wind speed near the generator set, the faults generated in the system are studied and found that applying SVC and static synchronous compensator to wind power generation can effectively stabilize wind power the effect of voltage and transient stability.
3) Reform the grid structure to increase the short-circuit capacity limit of the circuit in the public connection of the grid and use the appropriate line X/R to realize the voltage fluctuation and flicker control generated by the wind turbine. When the line X/R value relative to the line impedance angle is between 60° and 70°, the voltage fluctuation and flicker value generated are the smallest. For the harmonic processing method generated by the electronic switch in the power grid, an increase filter or a flattening device is generally used to achieve the purpose of filtering harmonics [7].

4) In order to resolve the conflict between the power grid and distributed new energy, reduce the impact on the main grid when selecting grid access, and to improve the stability and reliability of the power system, microgrid technology can be used, which can be used scientifically and effectively. Deal with various problems arising from the mixed access of distributed power sources into the network.

5. Conclusion
As a competitive power generation method, distributed power generation plays an increasingly important role in modern power systems. This article introduces the impact of three kinds of distributed power sources on power quality, summarizes methods to improve power quality, and discusses the role of microgrid technology in the hybrid access of multiple distributed power sources to the power grid, combining the current traditional power grid to smart grid the development trend, discussed the research direction of power quality of distributed power microgrid under the framework of smart grid.

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