Analysis of Harmonic Active Power Characteristics of Distributed Photovoltaic and Wind Power Grid-Connected

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Abstract. This paper analyzes the active power characteristics of common harmonics and ultra-high harmonics of distributed photovoltaic and wind power grids, and explores their different effects on energy metering, which has great guiding significance for achieving more fair and reasonable metering schemes. For the harmonic acquisition data of a wind power grid-connected point, the data characteristic analysis method is used to quantitatively analyze the harmonic characteristics, summarize the variation characteristics of the harmonic energy of the new energy grid-connected, and compare the different characteristics of the common harmonic and the super-high harmonic active power. Provide methodological guidance for the study of its predictive analysis of the impact of energy metering.

1. Introduction
The new energy grid-connected power inverter will inject a large number of wide-frequency domain harmonics and a little number of ultra-high-order harmonics into the power grid. As a result, the error of energy metering increases. For large-scale wind farms and photovoltaic power plants, due to the unified management of the harmonics before the centralized grid connection, the harmonic content at the grid points is small, and there is little error in the energy metering. However, according to the measured data, the harmonic content of the distributed photovoltaic and wind power grid-connected points is large. At this time, harmonics will have a non-negligible influence on the energy metering. Among them, the ultra-high harmonics are new problems in the current harmonic analysis, and research on this subject at home and abroad has just begun. According to power quality standards, defined 2-150 kHz Harmonics is ultra-high harmonics. This paper will quantitatively analyze its active power characteristics and compare it with ordinary harmonics to obtain different effects on energy metering, so as to realize a fairer and reasonable measurement scheme for new energy grid-connected.

2. Analysis of harmonic active power characteristics
The new energy grid-connected harmonic active power has strong volatility, which is affected by the external objective climate and the harmonics generated by the inverter and the grid side background harmonics, which will produce complex harmonic characteristics. At present, the research on the influence of traditional harmonic sources (such as steel mills, electric locomotives, etc.) injected into the grid harmonics on energy metering is more in-depth. In order to achieve fair metering, many traditional harmonic source metering points use fundamental wave metering. It can be seen that it is quite necessary to study the characteristics of harmonic active power and study its influence on energy.
metering. Moreover, the analysis of the existing active power characteristics, most of which are qualitative description and analysis, quantitative analysis is relatively small, and at home and abroad, the research on ultra-high harmonics is still insufficient. In this paper, it analyzes the harmonic characteristics of ordinary harmonics and super-high harmonics, and studies the characteristics of absolute and relative values. It mainly uses statistical calculation analysis to obtain the variation characteristics of active power, which lays a theoretical foundation for analyzing the prediction analysis of the influence of harmonics on electric energy measurement.

The data in this paper comes from a wind power grid connection point. During the quantitative processing, according to the relevant standards, the ordinary harmonics can be taken 2-7 times, and the super high harmonics can be taken 40-45 times for preliminary comparison. The harmonic characteristics are mainly analyzed for the following three aspects:

2.1. Harmonic active power level time variation characteristics
As a volatility power source, the new energy of the grid is changing at all times and cannot be equal to the general power station. Therefore, for the data collected, the time of normal harmonic and super high harmonic active power is analyzed on the time scale. Change the distribution characteristics to understand their respective changing characteristics. The specific results are as follows:

![Figure 1. Level time variation characteristic](image-url)
Based on the above results, the following conclusions can be drawn:

(1). Ordinary harmonics
The negative characteristic is exhibited on the time scale, and the peak value is large, and the rate of change is low, wherein the even harmonic has a small change rate with respect to the odd harmonic and the peak value is small.

(2). Super high harmonics
The change is frequent and the rate of change is high but the value is small, and the positive value is obtained by statistical mean on the time scale. The even harmonic has a small but relatively sharp peak relative to the odd harmonic.

2.2. Harmonic active power fluctuation variation characteristics
When the new energy grid-connected active power is injected into the grid, the concern is the output value that may occur in the next period of time when the current output value is known, and the hopping characteristics are analyzed to play a role in the analysis of the impact on the energy metering. In addition, in order to effectively solve the problem of system injection of fluctuating power, the existing practical and effective method is to configure the energy storage components to suppress the fluctuations. In order to cost-effectively configure the energy storage components, quantitative analysis of fluctuations characteristics of power have great significance. According to the above objectives and requirements, the following expression can be defined to reflect the fluctuation characteristics of the normal harmonic and the super high harmonic active power:

\[ \Delta P = P_N - P_{N-1} \]  

The specific results are as follows:
Based on the above results, the following conclusions can be drawn:

(1). Ordinary harmonics
On the time scale, each harmonic has a similar trend, but the even harmonics are less sharp than the odd harmonics. Such similar variation characteristics provide a theoretical basis and inspiration for exploring the predictive analysis of the effects of ordinary harmonics and super-high harmonics on energy measurement.

(2). Super high harmonics
On the time scale, each harmonic has a similar trend compared with the harmonics of ordinary harmonics, but the frequency of change is higher and the amplitude is smaller. It can be seen that external objective factors mainly a ffect fluctuations and affect harmonic changes.

2.3. Harmonic active power state transfer characteristics
The active power output from the new energy grid is randomly uncontrollable. It is not only affected by environmental change factors, but also related to the network side network topology of the grid-connected point, which largely determines the degree of influence of the output harmonic energy metering. Therefore, it is necessary to study the transition between different output forces at different time scales, that is, to explore the transition probability distribution characteristics of active power between different states. This method is of great significance for studying the influence of ordinary harmonics and super-high harmonics on energy measurement. The analysis steps are as follows:
According to the above data and the results obtained in 2.2.1 and 2.2.2, the ordinary harmonics and the super-high harmonics have great differences in absolute values, and the distribution characteristics are also different. Therefore, in order to uniformly reflect the state transition characteristics, it is normalized and processed into data between intervals [0, 1]. There are many different forms of normalization, and the following formula is used here:

$$
\hat{x} = \frac{x - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}}
$$

(2)

And based on the above analysis results, the active power level time variation characteristic has different characteristics from the fluctuation quantity variation characteristic. The time variation characteristics of the active power level reflect its variation on the time scale, while the fluctuation variation characteristics reflect the objective characteristics that determine the variation characteristics of the fluctuation. Therefore, in order to effectively analyze the characteristics of ordinary harmonics and super-high harmonics, state transition characteristics are analyzed separately for level-time changes and fluctuations, and the variation characteristics are summarized. The analysis results are as follows:

1. Harmonic active power level change state transition characteristic

Figure 3. The calculation method of state transition probability matrix
Figure 4. Harmonic active power level change state transition characteristic

According to the above results, it can be intuitively found that there is a significant difference in the level variation characteristics of the ordinary harmonics and the super high harmonics on the time scale. It can be observed from the figure that the even harmonic active power state transition matrix of ordinary harmonics exhibits an independent ‘anonymous’ characteristic, and the relationship between adjacent elements is weak. However, the value of the diagonal element in the odd harmonic active power state transition matrix is greater than the value of the element near the two sides, and the farther away from the diagonal, the smaller the element value. The matrix curve shows the ‘ridge’ feature and the connection between adjacent data is relatively tight. The ultra-high harmonic active power state transition matrix exhibits a ‘high intermediate low’ characteristic on both sides, indicating that the high-order harmonic has a high probability of transition between peaks.
(2). Harmonic active power fluctuation state transition characteristics

![Figure 5. Harmonic active power fluctuation state transition characteristics](image)

According to the above results, it can be intuitively found that the variation characteristics of the fluctuations of the ordinary harmonics and the super-high harmonics on the time scale are also significantly different. It can be observed from the figure that the state transition matrix of even harmonic active power fluctuations in ordinary harmonics exhibits ‘Y’ characteristics, and the odd harmonics have similar characteristics in the overall trend. The ultra-high harmonic active power state transition matrix exhibits a ‘cluster’ characteristic as a whole, and the overall trend is approximately the same. The state transition characteristics of ordinary harmonics and super-high harmonic active power
fluctuations have no obvious difference in parity characteristics. It indicates that the state transition characteristics of fluctuations mainly depend on objective external factors, and this conclusion is consistent with above.

3. Conclusion
In this paper, the harmonic characteristics of distributed photovoltaic and wind power grid are introduced. The level-time variation characteristics, fluctuation characteristics and state transition characteristics of active power are introduced respectively, so as to realize the quantitative analysis of harmonic active power characteristics. Because distributed photovoltaic and wind power generation are volatility power supplies, their output grid-connected harmonics are not only affected by objective factors, but also related to the grid-connected environment. Therefore, this chapter analyzes the relevant characteristics of a measured data, and compares the common harmonics with the ultra-high-order characteristics to analyze the differences between them. Since each characteristic has a quantitative parameter index system, the analysis of the grid-connected harmonics is not only based on the intuitive perceptual knowledge. The quantitative indicators of each characteristic provide a reasonable solution for distributed photovoltaic and wind power grid-connected energy measurement on valuable parameter data and theoretical guidance. At the same time, through the above analysis, it is known that the influence of ordinary harmonics and super-high harmonics on energy measurement has great predictability, which can provide theoretical guidance for its research.

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