

Research on Harmonic Summation Coefficient of New Energy Grid

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Abstract. The third type of technical report of the International Electrotechnical Commission puts forward the harmonic voltage summation method. However, it has been found that the harmonic superposition coefficient of special load electrified railways has some discrepancies with the national standard, and the particularity of wind power and photovoltaic power generation. Therefore, it is also necessary to study the harmonic superposition coefficient suitable for wind power and photovoltaic power generation. First of all, we deduced the mathematical formula of harmonic superimposition under the condition of unknown phase, and got the relationship between the square of the total harmonic amplitude and each superimposed component. Then, by using a large number of measured data of harmonics of wind power and photovoltaic power generation, the method of numerical statistics is used to solve the expectation of the phase difference cosine of the superposed components. Finally, the harmonic superposition coefficients of wind power and photovoltaic power generation under different harmonic frequencies are summarized.

1. Introduction

In recent years, all countries in the world are competing to develop green and renewable energies. Wind energy and solar energy are greatly favored by their unique advantages. Large-scale wind farms and photovoltaic power stations connected to the grid, will inevitably have a significant impact on the stability of the power system and power quality [1-2]. The mainstream of wind power and photovoltaic power generation systems using a large number of power electronics, will produce harmonics, adversely affect the power grid and hazards [3-10]. With the power system requirements for power quality getting higher and higher, the impact of wind power access to the power grid will become a research hotspot and difficulty. The third type of technical report of the International Electro-technical Commission puts forward the harmonic voltage summation method [11-12]. However, the summation index proposed in this report may not be suitable for the superimposition of harmonics on the power system side after the new energy is connected to the grid. In this paper, a large number of measured harmonic data statistics and calculations are given for the new energy grid harmonic superimposed coefficient.



2. Measurement methods

In order to calculate the harmonic current summation coefficient of the new energy grid, we measured the harmonic data at the following parallel points: traditional loads and wind farms, photovoltaic power plants and wind farms, different photovoltaic power generation, electrified railways and wind farms, traditional loads and photovoltaic power stations.

Using the test instrument FLUKE1760, export data for the voltage, current, active power, reactive power and power factor. Calculate the harmonic summation coefficient requires the phase angle difference, and the instrument's derived data is the power factor. The following is the phase angle difference calculation method:

Step 1: Use the power estimation method to give the dominant harmonic source hypothesis. The dominant harmonic source is determined by the power curve. If the active power is greater than zero in most cases, the system side is the dominant harmonic source, whereas the user side is the dominant harmonic source.

Step 2: Calculate the phase difference. The phase difference is divided into two cases:

1) If the estimated system side is the dominant harmonic source, the reference direction of the harmonic voltage and the harmonic current is the correlation reference direction, and the phase angle difference of the harmonic current ahead of the harmonic current is estimated as follows:

When $P > 0$ and $Q > 0$, then $0^\circ < \varphi < 90^\circ$, take the inverse of the absolute value of the power factor.

When $P > 0$ and $Q < 0$, then $-90^\circ < \varphi < 0^\circ$, find the absolute value of the power factor inverse cosine, and then take the opposite number.

When $P < 0$ and $Q > 0$, then $90^\circ < \varphi < 180^\circ$, 180° minus the power factor absolute value of the cosine.

When $P < 0$ and $Q < 0$, then $-180^\circ < \varphi < -90^\circ$, the power factor absolute value of the cosine minus 180° .

2) If the reference side is the dominant harmonic source, the reference voltage of the harmonic voltage and the harmonic current is the non-correlation reference direction, the phase angle difference of the harmonic current ahead of the harmonic current is estimated as follows:

When $P < 0$ and $Q < 0$, then $0^\circ < \varphi < 90^\circ$, take the inverse of the absolute value of the power factor.

When $P < 0$ and $Q > 0$, then $-90^\circ < \varphi < 0^\circ$, the absolute value of the power factor is negated.

When $P > 0$ and $Q < 0$, then $90^\circ < \varphi < 180^\circ$, 180° minus the power factor absolute value of the cosine.

When $P > 0$ and $Q > 0$, then $-180^\circ < \varphi < -90^\circ$, power factor absolute value of the cosine minus 180° .

After calculating the phase difference corresponding to each measurement time, the two lines of the synchronous measurement can calculate the harmonic summation coefficient by the phase difference of the two lines. As the two lines of harmonic measurement is synchronized, the instrument measurement time is synchronized by the view, so the same time the phase difference can be considered the same time the true value. The harmonic summation coefficient is twice the cosine of the phase difference at the same time. The following will show the measured data calculated by the harmonic summation coefficient frequency distribution histogram.

3. The summation coefficient of plants wind farms and photovoltaic power

First, the synchronous test of wind power generation and photovoltaic power generation is carried out. The summation coefficients of these two harmonic sources are plotted as the frequency distribution histogram as follows:

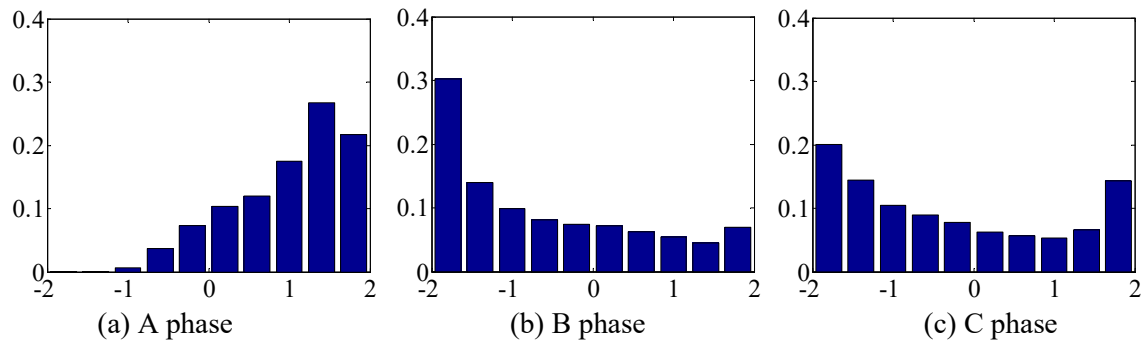


Figure 1. Histogram of 3rd harmonic summation coefficient of wind farms and photovoltaic power.

Figure 1 (a), (b) and (c) were A phase, B phase, C phase harmonic summation coefficient. From the two groups of wind power generation and photovoltaic power generation of the third harmonic summation coefficient of the frequency distribution of the histogram, wind power generation and photovoltaic power generation of the third harmonic distribution is not concentrated in the $[-2, 2]$ range can be taken. So, the third harmonic summation coefficient does not have the statistical law, it is recommended to refer to the national standard in the value.

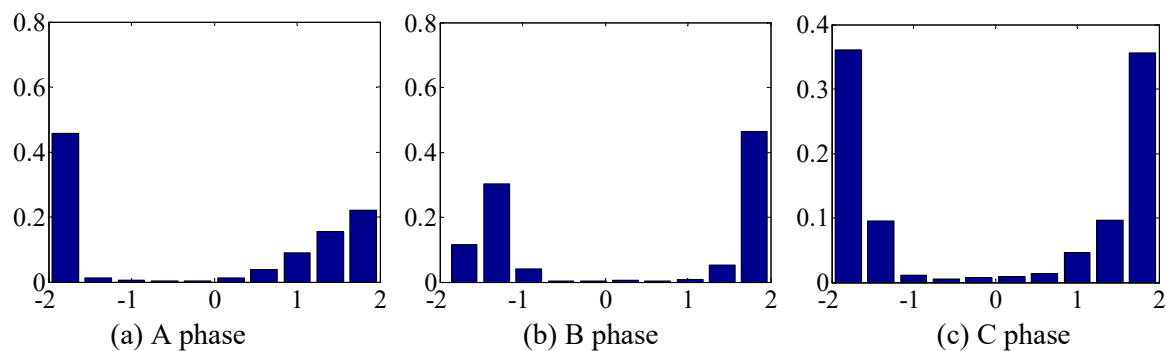


Figure 2. Histogram of 5th harmonic summation coefficient of wind farms and photovoltaic power.

In Fig. 2, (a), (b) and (c) are the harmonic summation coefficients of phase A, phase B and phase C respectively. Figure (a) shows that wind power generation and photovoltaic power generation fifth harmonic summation coefficient A phase concentration in the $[-2, -1.8]$ range. However, from (c), the value of the C-phase of the fifth harmonic summation coefficient of wind power generation and photovoltaic power generation is at both ends and can not be taken to a representative value. It can also be seen in Figure (b) that the frequency of any one section is greater than 0.5 and can not take a representative value. From the frequency distribution histogram of the fifth harmonic summation coefficient of wind power generation and photovoltaic power generation, the distribution of the fifth harmonic of wind power generation and photovoltaic power generation is not concentrated, so the fifth harmonic summation coefficient does not have statistical law.

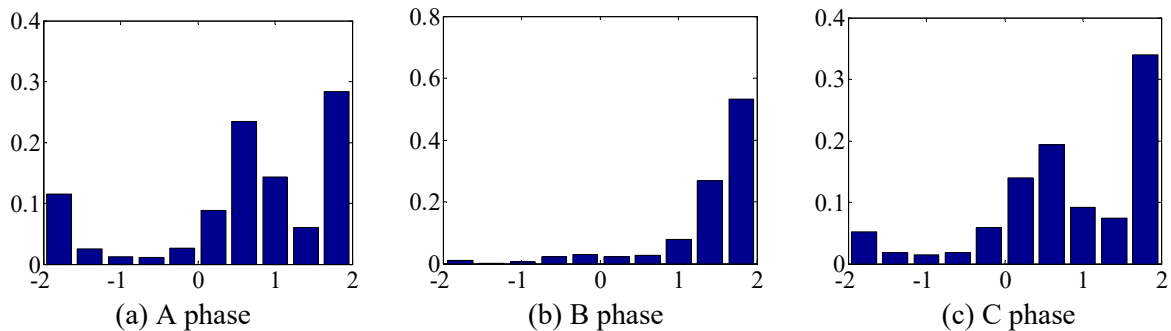


Figure 3. Histogram of 7th harmonic summation coefficient of wind farms and photovoltaic power.

Figure 3 in (a), (b), (c) were A phase, B phase, C phase harmonic summation coefficient. From the frequency distribution histogram, it can be seen that the distributions of the 7th harmonic of wind power generation and photovoltaic power generation are not concentrated, and there is no consistent trend. There is no representative range of values. Therefore, the 7th harmonic summation coefficient does not have the statistical law, it is recommended to refer to the national standard.

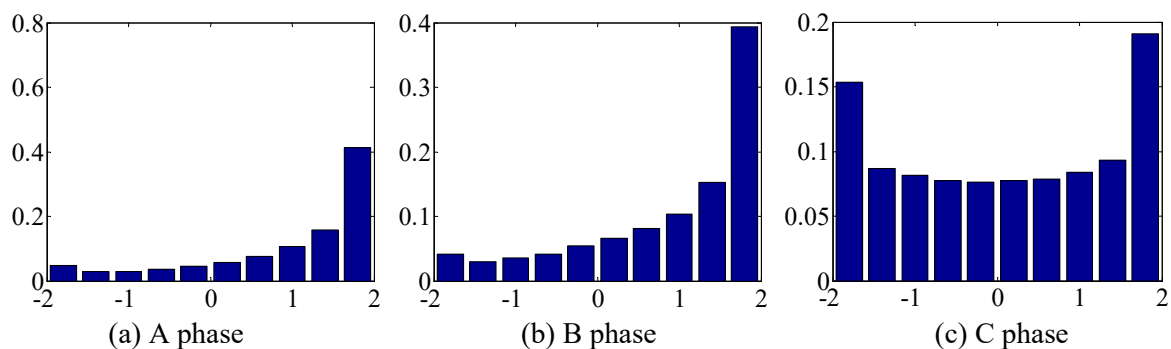


Figure 4. Histogram of 9th harmonic summation coefficient of wind farms and photovoltaic power.

Figure 4 in (a), (b), and (c) were A phase, B phase, C phase harmonic summation coefficient. From the frequency distribution histogram, the distribution of the 9th harmonic of wind power and photovoltaic power generation is not concentrated, and the frequency of the interval is similar, and the distribution is more uniform. So the 9th harmonic summation coefficient does not have statistical law, it is recommended to refer to the national standard in the value.

The same process to deal with 2~19 times the harmonic summation coefficient, from the distribution of the harmonic summation coefficient of view, wind power and photovoltaic power generation and the harmonic summation coefficient is not the appropriate value, it is recommended to refer to the national standard.

4. The summation coefficient of wind farms and traditional loads

Measure the harmonics of wind power and the traditional load and plot the 3rd, 5th, 7th, 9th harmonic summation coefficient into the frequency distribution histogram as follows:

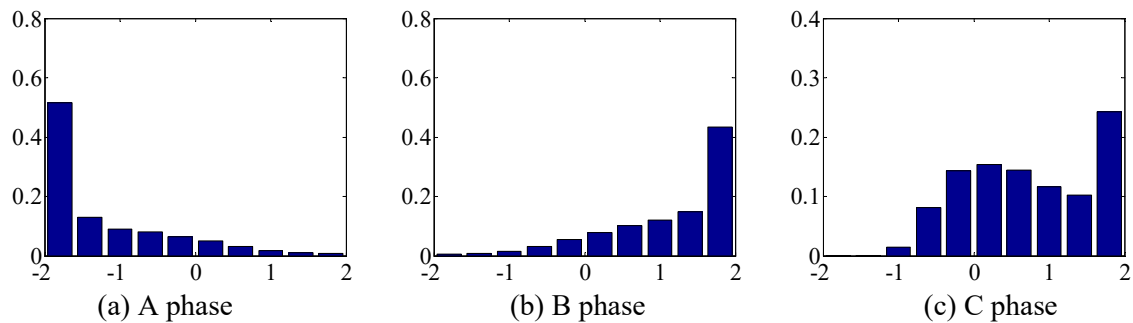


Figure 5. Histogram of 3rd harmonic summation coefficient of wind farms and traditional loads.

In Figure 5, (a), (b), and (c) are the harmonic summation coefficients of phase A, phase B and phase C, respectively. Wind power and traditional load harmonic summation coefficient distribution are not consistent trend, we can see the wind power and the traditional load of the third harmonic summation coefficient is not the appropriate value.

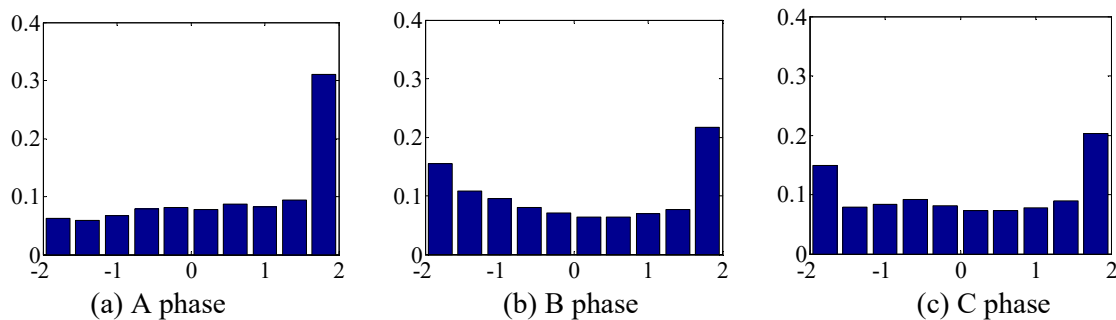


Figure 6. Histogram of 5th harmonic summation coefficient of wind farms and traditional loads.

Figure 6 shows that the five-harmonic summation coefficient distribution of wind power and traditional load is very uniform. In view of its distribution is not particularly obvious law, wind power and traditional load 5th harmonic summation coefficient is not suitable for the value, it is recommended to refer to the national standard value.

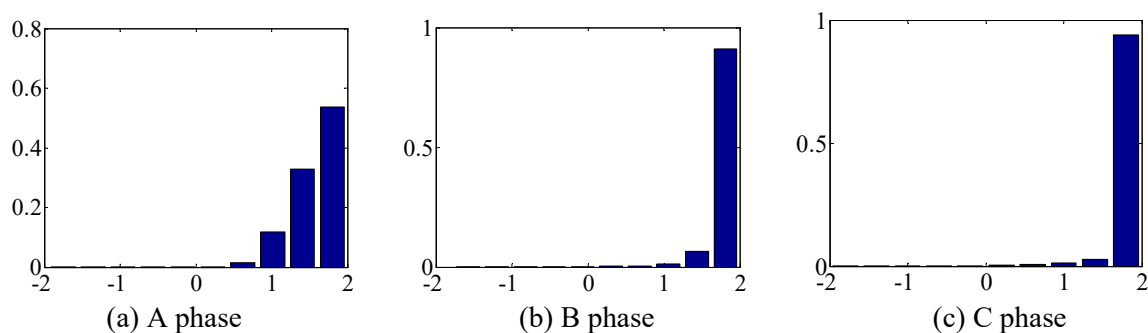


Figure7. Histogram of 7th harmonic summation coefficient of wind farms and traditional loads.

Figure 7 shows that the distribution of 7th harmonic summation coefficient of wind power and traditional load is more dispersed. Although the value on the right side of Figure 7 is more, but the confidence of any value is not large, the accuracy of the results is not high, so there is no suitable value as the harmonic summation coefficient.

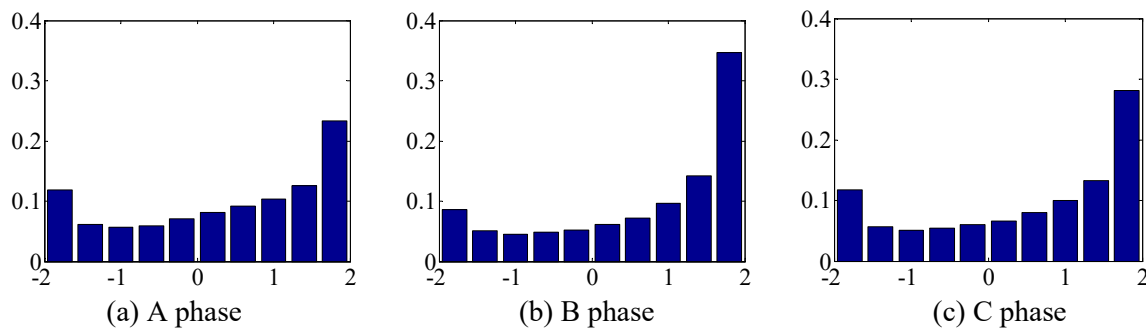


Figure 8. Histogram of 9th harmonic summation coefficient of wind farms and traditional loads.

In Figs. 8, (a), (b) and (c) are the frequency distribution histograms of the harmonic summation coefficients of phase A, phase B and phase C, respectively. As can be seen from the above figure, in addition to the right side of the interval frequency is high, the left side of the value distribution is still very uniform. The 9th harmonic summation coefficient of wind power and the traditional load of is not a great confidence as a reference, it is recommended to refer to the national standard value.

Also deal with the 2nd-19th the harmonic summation coefficient. From the distribution of harmonic summation coefficients, the harmonic summation coefficients of wind power generation and traditional load do not have suitable values, and there is no high confidence value as the reference value of harmonic summation coefficient in the range of values. Suggestions refer to the national standard.

5. Summary

In order to analyze the characteristics of the harmonic summation coefficient of the new energy power generation and other loads, we carried out a large number of harmonic data tests in the load category. And the measured data to calculate the harmonic summation coefficient work, and finally draw the frequency distribution histogram to observe the distribution of the situation. From the harmonic summation coefficient distribution situation, the new energy power generation and other load harmonic summation coefficient is not suitable value. Since there is no confidence value in the range of values as a reference value of the harmonic summation coefficient, it is recommended to refer to the values in the national standard.

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