The Research of Harmonic Coincidence Factor Applicable to National Standard

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Abstract. With the development of power system**,** it is more necessary to research the distribution of harmonic current limits. In order to relieve the strict harmonic current limits, we compare GB/T 14549-1993 with IEC 61000-3-6, and introduce the concept of harmonic coincidence factor. This paper introduces the method to calculate the harmonic coincidence factor largely and discuses the necessities and rationalities of the harmonic coincidence factor through theoretical analysis. Finally, the recommended values is shown in Table 3

1. Introduction

With the continuous development of society and the progress of science and technology, nonlinear loads in power system, such as the increase of rectifier, inverter, electric railway, single non-linear load capacity is also increasing, current and voltage waveform distortion caused by the harmonic pollution problem trend in severe, and the nonlinear load in the power grid must be limited.

Nonlinear load input power grid harmonic limit value assignment problem, many experts and scholars at home and abroad has been in research, harmonic limit value distribution of the main problems is if harmonic limits too strict, it will bring unnecessary investment; and if harmonic limits too loose, it will reduce electric energy quality of the power grid, and threat to network and user with electrical safety. Our country uses GB/T14549-1993, and the standard is correct undoubtedly. But with the increase of nonlinear loads, limitations are also becoming increasingly prominent, meanwhile the harmonic limit values are too restrictive, one of the reasons is the national standard does not consider the harmonic coincidence factor. So I think it is necessary to introduce the concept in the national standard.

Then we will explain the distribution method of harmonic limits in national standard and IEC and get the coincidence factor applying to national standard by contrast.

2. The Harmonic Current Limits Algorithm of National Standard and IEC

2.1 The Harmonic Current Limits Algorithm of National Standard

Harmonic current limits can be determined by random vector addition. If a PCC is connected to n nonlinear load harmonic sources, the total load is

$$\mathrm{S}_t = \sum_{i=1}^{n} S_i$$

Where S_t is overall load, S_i is the protocol capacity of the ith user.

The injection of PCC total harmonic current vector is

$$\mathrm{I}_h = \sum_{i=1}^{n} I_{hi}$$

In the formula, I_{hi} means the ith harmonic injection level vector,I_h means the total harmonic injection level vector of a PCC, and I_h can be calculated by the following formula.

$$\mathrm{I}_h = \mathrm{I}_{\mathrm{hp}}(S_k/S_{k0})$$

Where S_k is the minimum short-circuit capacity at the PCC, S_{k0} is the reference circuit capacity and I_{hp} is the hth allowable harmonic current corresponding to the reference circuit capacity.

If I_{hi} is a random vector and I_{hi} has zero mean value in quadrature component, according to the central limit theorem, the volumes of random vector I_h and I_{hi} obey Rayleigh distribution, the variance of I_h and I_{hi} is directly proportional to the square of St and Si. By this way, the expression of harmonic current limit goes that

$$I_{hi} = I_h\sqrt{S_i/S_t}$$

Considering the distribution characteristics of I_{hi} more generally, simulating harmonic current limits by using Monte-Carlo model can get another expression

$$I_{hi} = I_h(S_i/S_t)^{1/\alpha}$$

In this formula, α is harmonic superposition index, as shown in Table 1.

Table 1 Harmonic superposition exponent proposed by national standard

h	3	5	7	9	11	13	>13
α	1.1	1.2	1.4	2.0	1.8	1.9	2.0

2.2 The Harmonic Current Limits Algorithm of IEC

IEC and GB are almost similar, the difference is that the harmonic superposition index value is different, also introduced the harmonic coincidence factor. The expression delimited by IEC of harmonic current limit is

$$I_{hi} = I_h[S_i/(F_{HV}S_t)]^{1/\alpha}$$

In the formula, F_{HV} means harmonic coincidence factor. The value of harmonic superposition index is shown in Table 2.

Table 2 Harmonic superposition exponent proposed by IEC

h	3	5≤h≤10	h＞10
α	1.0	1.4	2.0

By comparison, we can find that IEC standard and national standard of harmonic calculation of harmonic current limits are different, they are described briefly below.

(1) IEC substitutes "the capacity of power supply equipment" for "modified network available power";

(2) The alpha value is different;

(3) The concept of harmonic coincidence factor is introduced in IEC.

Through the above analysis, it can be found that compared with the national standard, the harmonic current limits determined by IEC is more relaxed for users, and more reasonable. However, the IEC standard has not presented how to determine the value ofF_{HV}, and it takes a lot of difficulties for the application.

3. The method for determining harmonic coincidence factor

The harmonic coincidence factor F_{HV} is introduced in the technical documents of IEC 61000-3-6, but it does not specifically introduce the method for calculating high voltage load harmonic coincidence factor at the same time, just give the recommended range and the range of harmonic coincidence factor is from 0.4 to 1. As we all known, the harmonic coincidence factor is not only related with the harmonic sources emission characteristics, but also the number of bus harmonic source. If the number of harmonics at the PCC is bigger, the harmonic coincidence factor is smaller. On the other hand, the number of harmonics at the PCC is smaller; the harmonic coincidence factor is closer to 1.

Experts and scholars generally believe that the calculation of harmonic limits is strictly in accordance with the harmonic current standard. In the long-term practice，we find that the harmonic current limits come larger than they actually should be if we use formula (1). This consciousness helps us to ascertain the minimum value of harmonic coincidence factor. After we apply harmonic coincidence factor, the values of harmonic current limits should not larger than the values calculated by formula (1).Therefore, when the harmonic coincidence factor, the following inequation should be set up

$$I_{hi} = I_h[S_i/(F_{HV}S_t)]^{1/\alpha} \leq I_h\sqrt{S_i/S_t}$$

Through simplification, we can get

$$F_{HV} \geq (\frac{Si}{St})^{1-\alpha/2}$$

Reference [3] gives the recommended formula used to calculate the harmonic coincidence factor of IEC as follows

$$F_{HV} = \left[1 + (\frac{S_i}{S_t})^{1-\alpha/2}\right]/2 \quad (2)$$

For the national standard, to determine the suitable harmonic coincidence factor, it should meet the following equation

$$I_h[S_i/(F_{HV1}S_t)]^{1/\alpha 1} = I_h[S_i/(F_{HV2}S_t)]^{1/\alpha 2} \quad (3)$$

Where F_{HV1} is the harmonic coincidence factor proposed by IEC, $\alpha 1$ is harmonic superposition exponent proposed by IEC, F_{HV2} is the harmonic coincidence factor proposed by national standard, $\alpha 1$ is harmonic superposition exponent proposed by national standard.

By (3) we can get the harmonic coincidence factor applied to national standard

$$F_{HV2} = (\frac{S_i}{S_t})^{1-\alpha 2/\alpha 1} {F_{HV1}}^{\alpha 2/\alpha 1} \quad (4)$$

Put (2) into (4), we can get the following formula

$$F_{HV2} = (\frac{S_i}{S_t})^{1-\alpha 2/\alpha 1}\{\left[1 + (\frac{S_i}{S_t})^{1-\alpha 1/2}\right]/2\}^{\alpha 2/\alpha 1} \quad (5)$$

To facilitate the analysis, assuming that the capacities of n distorted high voltage loads are equivalent, that is to say $S_i/S_t = 1/n$. Putting it into (5) goes

$$F_{HV2} = (\frac{1}{n})^{1-\alpha 2/\alpha 1}\{\left[1 + (\frac{1}{n})^{1-\alpha 1/2}\right]/2\}^{\alpha 2/\alpha 1} \quad (6)$$

By querying the tables 1 and 2, it is not difficult for us to calculate the harmonic coincidence factor with different harmonic number and different load number. The different values of the harmonic coincidence factor with different harmonic number and different number of users of distorted high voltage is shown in the following table 3.

Table 3 Different values of the harmonic coincidence factor

Fhv \ n / h	1	2	3	4	5
3	1	0.9004	0.8596	0.8371	0.8229
5	1	0.8323	0.7508	0.6992	0.6623
7	1	0.9061	0.8596	0.8299	0.8085
9	1	1	1	1	1
11	1	0.933	0.896	0.8706	0.8513
13	1	0.9659	0.9466	0.933	0.9227
>13	1	1	1	1	1

The range of harmonic coincidence factor given in Table 3 and the value range given by IEC is different because alpha values are different, and that is not a contradiction. By observing the data in Table 3 we can find when the load is less than the number 7, the harmonics coincidence factor are range from 0.6 to 1 and with the increase of the number of load, the coincidence factor decreases, this is also in good agreement with the actual situation.

Significantly, the result of 9^{th} harmonic coincidence factor is larger than 1. However, it is obvious that the harmonic coincidence factor should be smaller than 1, so the final value of 9^{th} harmonic coincidence factor becomes 1.

Taking the 3th harmonic for example, Table 4 gives the relationship between the coincidence factor and the number of load

Table 4 Relationship between the coincidence factor and the number of load

n	1	2	3	4	5	6	7	8	9	10
Fhv	1	0.9	0.86	0.837	0.823	0.813	0.806	0.801	0.798	0.795

4. Conclusions

This paper introduces the national standard GB/T 14549-93 and IEC 61000-3-6 technical documents' algorithm in calculating the limit value of harmonic current, and introduces the harmonic coincidence F_{HV} according to IEC 61000-3-6, and discusses the value of harmonic coincidence F_{HV} amply. Finally the way to calculating harmonic coincidence is given at the end of the paper. The limitation of this method lies in there is no word to discuss the characters of different loads, but only give a method to calculating. We must do statistical analysis based on a large number of measured data if we want to get an accurate harmonic coincidence. However, in the context of not familiar with load characters, by using this method, there is no doubt that distributing national standard harmonic limits will be looser and engineering application will be more convenient.

References

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