Research on Thermal Fault of Neutral Line Caused by Harmonic Current and Fire Problem

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Abstract: The proportion of non-linear loads is increasing due to the large number of electric equipment. Therefore, the load property in the low-voltage distribution system has undergone a profound change. Even under the effect of three-phase sinusoidal excitation, non-sinusoidal distortion will occur in the three-phase phase line current, and the harmonic current will be generated, thereby involving a plurality of new aspects, such as the safe operation of the electrical equipment and the electric fire protection. In particular, the problem of the thermal fault and fire of the neutral line needs to be studied carefully, and an effective solution is put forward.

1. Introduction

At present, with the rapid development of the economic construction and the improvement of the living quality, the power utilization equipment of the office building and the residential building is greatly increased, and the increase of the proportion of the non-linear load is especially prominent. For example, various lighting devices with ballasts, computers, fax machines, photocopiers, color TV sets, air conditioners, and switching power supplies are non-linear loads. Therefore, the proportion of the non-linear load in the low-voltage power distribution system obviously increased. The load property has changed deeply, and the load current has non-sinusoidal distortion. Then, the harmonic current is generated, thereby involving new problems such as safe operation and electrical fire protection of the electrical equipment. For example, special attention should be paid to the practical problems, such as neutral line overload, wire break and fire, and the research should be carefully studied, so as to provide an effective solution for the problems in engineering design, construction installation and operation maintenance.

2. Harmonics of non-sinusoidal distortion current and its hazards

It is well known that when the sinusoidal voltage is added to the linear load, the sinusoidal current of the same frequency will be generated. In other words, when the sinusoidal voltage is applied to the linear load, it will not produce non-sinusoidal distortion current, so it will not produce harmonic current. However, when the sinusoidal voltage is added to the nonlinear load, it will produce non-sinusoidal distortion current or harmonic current. According to Fourier analysis, we can obtain a set of non-sinusoidal distorted currents which are approximately represented by the superposition of sine wave series. It includes constant component, fundamental component and high order harmonic component. Usually, the high order harmonic components are divided into odd harmonics and even harmonics. In low voltage distribution system, the distortion current waveform of non-sine is almost equal in positive and negative half cycles, so in harmonic analysis, there are no constant components and even harmonics, and the rest are odd harmonics.

The amplitude of three-phase equilibrium current is divided into positive sequence three-phase current, negative sequence three-phase current and zero-sequence three-phase current according to the order in which A, B and C three-phase appear. For three-phase harmonic current, there is also the problem of phase sequence. The phase sequence of positive sequence harmonics is the same as

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that of fundamental wave. For example, 7th, 13th, 19th are positive sequence harmonics. The phase sequence of negative sequence harmonics is opposite to the fundamental phase sequence, such as 5th, 11th, 17th are negative sequence harmonics. Zero sequence harmonics do not form phase sequence and have nothing to do with fundamental phase sequence.3th,9th,15th are zero-sequence harmonics. Whether it is positive sequence harmonics or negative sequence harmonics, the vector sum of them in the neutral line is zero, and the zero sequence current flows through the neutral line and the value is large, which is much higher than the phase line current. The above analysis of non-sinusoidal distorted current will help us to discuss the following problems.

3. The new component of neutral current and its thermal fault

The harm caused by harmonics is various, and sometimes it is not easy to be found, such as:

(1)Three-phase induction motor burns out.

(2)Three-phase four-wire distribution line neutral line overload, overheating, burning line.

(3)The original circulation of transformer with △－Y connection mode causes overheating to burn out transformer.

(4)Circuit breaker misaction and so on. The thermal fault and fire caused by harmonic current in the neutral line of low voltage distribution system is focused on, and other problems of harmonic pollution are not involved.

3.1 Three-phase unbalanced linear load

It is known that when the three-phase sinusoidal voltage is applied to the three-phase unbalanced linear load, each phase will produce unbalanced three-phase current. Therefore, there is an unbalanced current in the neutral line, that is, how to master and control the unbalanced current of the neutral line by $N=A+B+C \neq 0$, which not only considers the load of the distribution line, but also considers the technical and economic rationality in the engineering design. Therefore, in the relevant technical specifications, it is proposed that the load distribution of each phase of three-phase lighting line should be balanced, and the load current of the maximum and minimum phase in each distribution panel should not exceed 30%. Considering that there is unbalanced current in the neutral line, the neutral line section is generally chosen to be equal to the phase line section, which actually leaves a certain margin. It should be pointed out that for three-phase balanced linear load, the linear current should be equal to zero, which is a special case. That is $N=A+B+C \neq 0$

3.2 Three-phase unbalanced nonlinear load

According to the previous analysis, the effective values of zero-sequence current of each phase are not equal in the three-phase unbalanced nonlinear load, and the phases of INA, INB, INC are different from each other. The effective value of zero-sequence current in the neutral line can be approximately expressed as the generational sum of the effective value of zero-sequence current of each phase under the condition that the unbalance degree is not serious. At the same time, because only zero-sequence current passes through the neutral line, positive sequence current and negative sequence current are divided into zero vector sum on neutral line. The effective value of this zero-sequence current will be reduced to a new component of the neutral current. This is an important feature of three-phase unbalanced nonlinear load and is the basis for our research. It should also be pointed out that for three-phase balanced nonlinear load, because the effective values of zero-sequence current of each phase are equal to each other, that is to say, the effective value of zero-sequence current of neutral line should be the algebra sum of the three, or three times of the effective value of one-phase zero-sequence current. That is, the effective value of zero sequence current still exists in $I_N=3I_{NA}=3I_{NB}=3I_{NC}$, or neutral line at this time, rather than in the case where the neutral line current of three phase balanced linear load is equal to zero, which is a big difference. Therefore, according to the theoretical results of three-phase balancing linear load in the past circuit theory, it has become powerless to solve the problem of three-phase unbalanced nonlinear load.

In the case of both three-phase linear load and three-phase nonlinear load in low-voltage distribution system, it should be fully considered that the load properties and their composition have undergone profound changes. Therefore, in three-phase four-wire or two-phase three-wire distribution lines, the cross section of N-wire should be selected reasonably. Otherwise, the overload problem of N-wire will also occur when the cross section is too small, which may not attract enough attention. According to the relevant technical specifications:

(1) In the circuit with gas discharge lamp as the main load, the N line section should not be smaller than the phase line section.

(2) The N line section of the three phase four wire or two phase three wire distribution lines supplied by thyristor or computer should not be less than 2 times of the phase line section, and should be carried out seriously in the engineering design and construction installation.

3.3 Thermal failure of neutral line and hazard of fire

There are three-phase unbalanced non-linear loads in the low-voltage distribution system. It results in a voltage displacement on the load-measured neutral point, a serious loss of balance of each phase voltage, where a phase voltage is higher than the rated voltage. The various electrical equipment connected to is burned down at a higher voltage than the rated voltage.

3.4 Case analysis

The effective values of each phase voltage are equal to each other when the three-phase voltage is balanced, and the phase difference is 120°. When the neutral line breaks the neutral point voltage displacement, the three-phase voltage loses its balance, the effective values of each phase voltage are different from each other, and the phase difference is not equal. At the same time, the high voltage of a certain phase brings serious adverse consequences. The cases found in the test will be analyzed, hoping to attract everyoneundefineds attention.

Case 1: At 5: 00 p.m. on June 9th, 2000, a residential building with 16 stories in Beijing. Except for the first floor, most of the household appliances in the other odd floors were burned down .Fortunately, there was no electrical fire. At that time, it was found that the three-phase voltage had been out of balance, and the three-phase voltage was 300V, 225V and 196V, respectively. Therefore, it was preliminarily determined that the neutral line was broken. Then the voltage imbalance is found from the first layer to the third layer or even the high level, so the temporary line is connected from the first layer to the third layer on the N line terminal of the shunt box, and the above voltage imbalance phenomenon disappears again. Finally, it is found that the contact surface of the three-layer N-wire terminal screw overflows under the action of the neutral line is large current, the contact resistance increases, so that the neutral line cannot become a good conductive path, and there is a similar phenomenon of almost neutral line breaking.

Case 2: In the evening of September 17th, 2016, the Political Consultative Conference of the Chinese Peopleundefineds Political Consultative Conference (CPPCC) held a celebration of the 50th anniversary. The test site 4 # distribution box, the maximum line current is 87A, and the neutral current is 174A far higher than the phase line current. The infrared thermometer is used to measure the temperature of the outer skin of the neutral rubber cable, and it is found that the temperature is up to 98 ℃, which exceeds the specification of 65 ℃ of the technical specification, and it can directly observe the phenomenon of softening and color change of the wire skin, and is in the dangerous state of igniting the insulating material. It is preliminarily determined that this is due to the use of silicon controlled dimming, which is a non-linear load for the load property. Due to the insufficient cross section of the neutral line, the phenomenon that the neutral line is seriously overloaded and the cable scale is ignited is caused. And then the two ends of the original neutral line are connected with a large temporary line with a larger cross section, and the neutral line overload phenomenon disappears immediately.

Case 3: Fushun Power supply Company Auditorium held a "July carol" concert and carried out electrical fire prevention test on June 19th, 2018. It was found that the load of the main circuit breaker DZ158100A of the computer lamp distribution box was as follows: the current of phase A is

24.5 A, the current of phase B is 24.8 A, the current of phase C is 17.8A;the current of N line is 54A. The results show that the N-line current is 2.2 times higher than that of A phase current, which is due to the nonlinear load of computer lamp. Therefore, the N line section must be more than 2 times larger than the phase line section in order to meet the requirements. In fact, this consideration has been made in the design.

4. Non-sinusoidal distortion current measurement and instrument selection

For a three-phase unbalanced nonlinear load low-voltage distribution system, Not only the current of the phase line should be measured, but also the current of the neutral line. First of all, the section of the wire should meet the requirements of carrying flow, especially the neutral line. In the low voltage distribution system with nonlinear load, it is often found that the neutral line current is larger than the phase line current, or even much larger. This is a normal phenomenon, but sometimes there is a problem of small neutral line section. Secondly, the neutral line is particularly important for all the connection parts of the low voltage distribution system mentioned above to be firm and reliable, the contact is good, and the phenomenon of wire breakage should be prevented.

Finally, how to measure the non-sinusoidal distortion current of low voltage distribution system with nonlinear load is discussed. In essence, it is the question of which type of instrument is selected to measure the non-sinusoidal distortion current and effective value. For many years, average response instrument have been using to measure the effective value of sinusoidal quantity. For example, magnetoelectric instruments, full-wave rectifier magnetoelectric instruments and ordinary clamp ammeters, but this average response instrument cannot measure the effective value of harmonic current caused by nonlinear load. If measured by this similar table, the measured value is much lower than the actual value (some data show that it is more than 20%). Of course, this is related to the content of harmonics. For the measurement of harmonic current effective value due to non-sinusoidal distortion caused by nonlinear load, the average response instrument of current square should be adopted, such as electromagnetic or electric instrument. At present, it is more suitable for digital clamp ammeter with current true effective value (abbreviation ARMS), which can accurately measure the true effective value of harmonic current with non-sinusoidal distortion. Because the accuracy of the measurement results will have a great impact on the fault diagnosis, and even make the wrong judgment.

5. Conclusions

(1) With the increase of electrical equipment, the nonlinear load ratio increases. The harm caused by harmonic current should be paid enough attention to.

(2) The thermal fault and fire problem of neutral line should be eliminated from the aspects of design, construction, maintenance and so on. For example, the influence of harmonics should be considered in the selection of neutral line section. The connection part of neutral line should be firm and reliable, and the contact should be good. Then, the line will not be damaged. The protection of neutral line and the problem of current measurement in inspection should be dealt with scientifically and effectively.

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