Reasons Analysis and Solutions of Existing Hazards of Three-phase Imbalance

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Abstract: This paper briefly states that the imbalance of three phases is mostly caused by the imbalance within elements, line parameters or load asymmetry of three phases. The cause and mechanism of wire fault and ground fault are expounded emphatically. At the same time, it demonstrates the solution to the three-phase imbalance, and it points out that the construction of distribution network should follow the principle of "small capacity, multiple distribution points, short radius". The necessity of power supply for low voltage cluster wire is demonstrated. Multi-point grounding is avoided and zero line power loss is reduced; It also points out precautions for installing three-phase imbalanced intelligent regulator.

1. Introduction

Three-phase imbalance is an important indicator of power quality. Most of the imbalance is caused by asymmetric three-phase elements, line parameters or loads. Because there are many factors affecting the three-phase load balance, the three-phase voltage and current are easily unbalanced at the power supply point, and the lines loss will affect the motor adversely at the power supply point. Then, the normal operation of the motor will be jeopardized. For ordinary users, the increase of imbalance in three-phase voltage will cause the burning loss of household appliances, while the decrease of voltage will affect the normal use of appliances.

2. The reason analysis of imbalance in three-phase

2.1. Unreasonable distribution of three-phase load

Most of the staff don't know the concept of three-phase load balance, so they do not control the three-phase load balance when connecting the electricity. It causes the imbalanced three-phase load to a large extent.

Secondly, most of the circuits are integrated with power and lighting in China. When single-phase electrical equipment is used, the efficiency of power consumption will be reduced. The differences emerging aggravates the imbalance in three-phase load of distribution transformer.

2.2. Continuous change for power load

The cause of unstable power load includes the demolition area, movement of table or the increasing number of users. Load is instable in temporary electricity and duty summer season (It is required to deal with the summer load increasing in the grid work, three-phase imbalance and the low voltage problem. For load is segmentation and phase modulation, the reduced electricity needs in summer need to be reset back in winter).

2.3. Various faults

2.3.1. Broken line

If one phase is disconnected but not to be grounded, or one phase of circuit breaker and isolating switch is not connected, the fusing of the voltage transformer will cause asymmetric three-phase parameters. When the circuit of the upper voltage level is broken by one chase, the lower voltage

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level will be reduced by three phases. One is lower and the other two are higher, but their voltage values are similar. When the line is broken at this level, the broken phase voltage is zero, and the unbroken phase voltage is still the phase voltage.

2.3.2. Ground fault

When one phase of the line is broken and single-phase is grounded, the voltage value doesn't change after grounding, although the three-phase voltage imbalance is caused. Single-phase grounding is divided into metallic grounding and non-metallic grounding. For metallic grounding, the fault phase voltage is zero or close to zero, and the non-fault phase voltage increases by 1.732 times, and then remains unchanged. For nonmetallic grounding, the ground phase voltage is not zero but decreases to a certain value, while the other two phases increase by less than 1.732 times.

2.4. Resonance

2.4.1. The fundamental frequency resonance

For fundamental frequency resonance, its characteristic is similar to single-phase grounding. When one phase voltage drops, the other two phase voltage rise, which makes it difficult to find the fault point. The check result of special users indicates that it isn't ground reason. The reason may be resonance.

2.4.2. Frequency resonance

The other is frequency division resonance or high frequency resonance. Its characteristic is three-phase voltage increasing at the same time. In addition, the bus removal part of fault lines or single-phase earth disappears. For example, a ground signal, and a phase and two phases or three phases voltage are more than line voltage. Voltage meter pointer is to an end and moves slowly at the same time, or three-phase voltage rises over line voltage in turn. This kind of situation is caused usually by resonance, as is shown in Fig.1 and Fig.2.

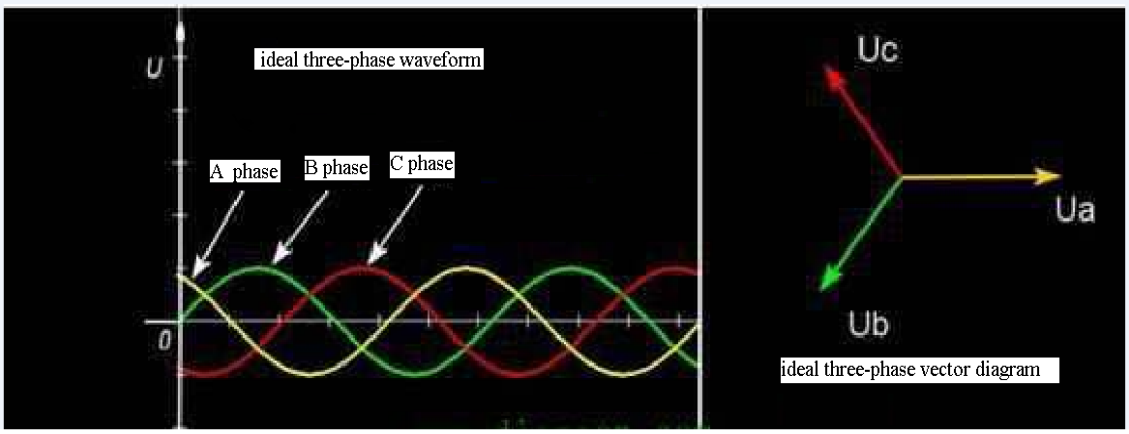

Fig.1 Ideal three-phase waveform

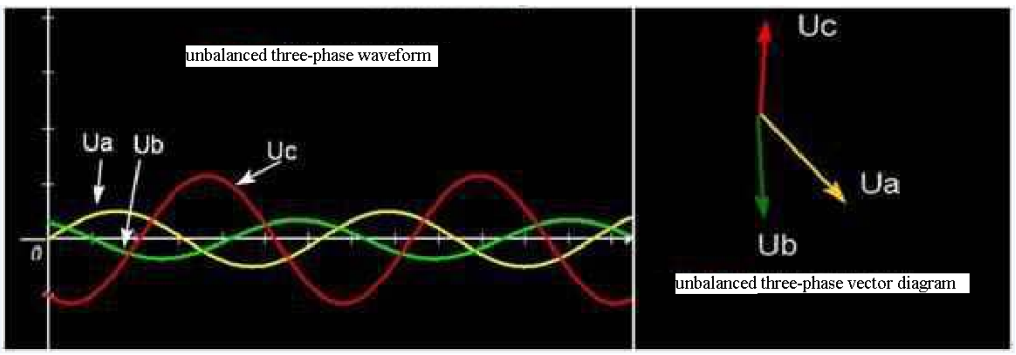

Fig.2 Imbalanced three-phase waveform

3. Harm of three-phase imbalance

3.1. Increasing the power loss of line

When the low voltage grid is supplied by three-phase four-wire system, imbalance of three-phase load is inevitable due to the single-phase load.

When the three-phase load is imbalanced, the neutral line will go through current. The more serious the imbalance is. the greater the current flowing through the neutral line will be. In this way, the neutral line has losses, and it is proportional to the square of the current flowing through it, which increases the losses of the grid line.

3.2. Increasing power loss of distribution transformer

When the three-phase load is imbalanced, the transformer is in asymmetric operation. The loss of transformer increases (including no-load loss and load loss). According to the regulations of transformer operation, the neutral current of transformer in operation should not exceed 25% of rated current of ow-voltage side of transformer. In addition, imbalanced operation of three-phase load will lead to excessive zero-sequence current of transformer. If zero-sequence current exists in transformer during operation, zero-sequence flux will be generated in its iron core (there is no zero sequence current in high side), It forces zero sequence flux only to tank wall and steel members as channels, but steel members permeability are lower. When zero sequence current goes through steel members, it will produce hysteresis, eddy current loss, unbalanced distribution of steel members and local temperature fever, even burning the transformer. At the same time, the zero sequence current deposit will increase with the changeable loss.

3.3. Reduction of distribution transformer

In distribution transformer, the winding structure is designed according to the load balance operation condition. The performance of the winding is basically the same, and the rated capacity of each phase is the same. The maximum allowable output of the distribution transformer is limited by the rated capacity of each phase. If the transformer is operated under imbalanced three- phase load, the phase with light load will have surplus capacity, reducing the output of the transformer. The degree of output reduction is related to the imbalance of three-phase load. The larger the three-phase load imbalance is, the more the distribution output decreases. As a result, the distribution transformer runs under imbalanced three-phase load, and its output capacity can't reach the rated value. Correspondingly, its reserve capacity is reduced, as well as its overload capacity. If the distribution transformer runs under the overload condition, it is very likely to get hot, and even causes the distribution transformer to burn loss.

3.4. Affecting the safe operation of electrical equipment

The distribution transformer is designed according to the three-phase load balance operation condition. The resistance, leakage reactance and excitation impedance of each phase winding are basically same. When the distribution transformer runs under the three-phase load balance, its three-phase currents are basically equal, and the voltage drop of each phase inside the distribution transformer is basically the same. What’s more, the three-phase voltage output of the distribution transformer is also balanced. If the distribution transformer runs under imbalanced three-phase load, the output current of each phase is not equal, and the three-phase voltage drop inside the distribution transformer is not equal, which t will inevitably lead to imbalanced three-phase output voltage of the distribution transformer. At the same time, when the distribution transformer runs under imbalanced three-phase load, the three-phase output current is different, and the neutral line will go through current. Thus, the neutral line produces an impedance voltage drop, which leads to the neutral point drift and the voltage changes of each phase. The voltage of the load phase decreases, while the voltage of the lightly loaded phase increases. Power supply under the condition of voltage is imbalance. As a result, it is easy to cause the burnt out of the user's electric equipment with a phase connection high voltage, while the user's electric equipment with a phase connection low voltage may not be used. Therefore, the imbalanced operation of three-phase load will seriously

endanger the safe operation of electrical equipment.

3.5. Motor efficiency reduction

When the transformer is running under imbalanced three-phase load, it will cause imbalanced three-phase output voltage. Since the imbalanced voltage has three voltage components, namely positive sequence, negative sequence and zero sequence, when the imbalanced voltage is input into the motor, the negative sequence voltage generates a rotating magnetic field which is opposite to the rotating magnetic field generated by the positive sequence voltage and plays a braking role. But the positive sequence magnetic field is much stronger than the negative sequence magnetic field. Thus, the motor still rotates in the direction of the positive sequence magnetic field.

The braking action of negative sequence magnetic field will reduce the output power and efficiency of the motor. At the same time, the temperature and reactive power loss of the motor will increase according to the imbalance degree of three-phase voltage. Therefore, it is very uneconomical and unsafe to operate the motor under the condition of imbalanced three-phase voltage.

4. Three - phase imbalance solution

4.1. Paying attention to plan and strengthening communication

The low voltage distribution network planning is appreciated. The communication with local government planning departments work is strengthened. And distribution network construction is avoided disorderly, especially while avoiding a band-aid in the low voltage distribution network. The low voltage distribution network construction owns power supply area and renovation. Reasonable partition divided with variable points closest to the load center, fan type power supply and power supply are avoided. The construction of the distribution network follows "the stationing, small capacity, short radius" with location principle.

4.2. Power supply for low-voltage cluster wire

On the low voltage three phase four wire system, the conditional distribution area using 3 or 4 core cable or with low voltage bundle conductor to the client should be actively strived. Construction of low voltage line is maximum to avoid the emergence of single partial phase. Three-phase load in low pressure loading forms single-phase electric meter in A. B. C three-phase as far as possible. Single-phase electric only articulated on A phase or two phase is avoided, and load partial phase is caused in the end of the line.

4.3. Multi-point grounding to reduce zero line power loss

Multi-point grounding is adopted in the zero line of low-voltage distribution network to reduce the power loss of zero line. At present, due to the imbalanced three-phase load distribution, it resulted in the current. The zero line in accordance with the procedures for zero line current should not exceed 25% of the phase line current in actual operation, since the zero line conductor cross section is fine with big resistance and the same length of the phase line. Its zero line current is so large on the conductor that it can cause certain percentage of the energy loss. So, public advocate zero use multipoint grounding in low voltage distribution network, the loss of zero power is reduced, the zero line current of the load imbalance is avoided in presence of voltage seriously and personal safety, and through the multipoint grounding, fever reasons such as the zero line of broken strands is reduced.

4.4. Installing three-phase imbalanced intelligent regulator

When distribution transformer carries out imbalanced current compensation, it should meet the following principles:

(1) It should be noted that current governance should have two contents, one is compensating the power factor, and the other is adjusting the three-phase current imbalance, these determine the reactive power needed for compensation.

(2) The treatment method of full capacity should be adopted to distinguish from inductance compensation in the actual construction of the project, and serious over-compensation is avoided.

(3) It is necessary to consider that the load will change with time. Based on this characteristic, the compensation amount should also be appropriately adjusted according to the change of load.

5. Conclusions

Urban residents and rural power supply system is in the low-voltage three-phase four-wire system: Because most of the electricity users are single-phase load or single-phase and three-phase load mixed, and the load size and using time are different. Therefore, the imbalanced current of three phases in the power grid exists objectively, and the imbalanced state of electricity consumption is irregular and can't be predicted in advance. It leads to imbalance of the three- phase load for the low voltage power supply system in long-term. For imbalanced three-phase current, the power sector has few effective solutions other than to distribute the load as reasonably as possible.

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