

Three-Phase Unbalanced Treatment Scheme Based on High-Speed Power Line Carrier

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Abstract. Most of the low-voltage distribution networks are three-phase four wire systems. Because of the quantity and dispersion of single-phase power users, the three-phase load unbalanced problem exists in a large number of low-voltage stations. With the continuous increase of power consumption level of the majority of power customers, the three-phase load unbalanced has become increasingly prominent in low-voltage station area. In this paper, the mechanism of three-phase unbalance generation and the defects of traditional treatment methods are introduced. On this basis, a three-phase unbalanced treatment scheme for low-pressure station area is proposed. The scheme can test out three-phase imbalance of low-voltage substation area quickly and accurately, and adjust the load phase sequence in real time without power failure through the intelligent commutation switch system, so that three-phase load in the station area lies a comparatively balanced condition. The scheme can cut down the loss of transformer and line caused through unbalanced three-phase load e in nicely. And it can restrain single-phase overcurrent, and solve the problem of terminal low voltage treatment.

1. Introduction

There are lots of single phase, asymmetric, nonlinear and impact loads in medium and low voltage distribution system. Because of the lack of incipient grid design and planning, there will be lots of single-phase loads concentrated in one or two phases. The unbalanced load will make the distribution system to be in a three-phase imbalance, which will lead to the imbalance of three-phase voltage and current in the distribution [1].

Because of the nonuniform distribution of load and the inconsistent load nature, the reactive power of low-voltage power supply system is insufficient and the load is unbalanced. Especially in the developed areas, the performance is more obvious. Insufficient reactive power and load imbalance have become two major problems in distribution systems.

2. Definition of three-phase unbalance

2.1. Three-phase unbalanced hazard

At present, for the low-voltage power grid in China, the three-phase four wire system is generally adopted, and the distribution transformer is Yyn0 wiring. Due to lots of single-phase loads and different timing of electricity consumption, the triphase unbalanced working of the distribution



transformer is unavoidable [2]. The asymmetry of triphase voltage or current can bring lots of harm to the equipment of generation, transmission, distribution and consumption.

- Increase in loss of line

When a current is passed through the wire, power loss will occur on the wire due to the resistance of the wire. The greater the imbalance, the greater the line loss.

- Increased active loss of distribution transformers

The existing 10/0.4kV low-voltage distribution transformers are mostly Y/yn0 connections. When the load on the secondary side is unbalanced and there is a zero-sequence current, and the primary side has no neutral lead, the zero-sequence current cannot flow. When the zero-sequence magnetic flux is large due to the large zero-sequence current, because of the neutral drift is too large, the saturation of iron core is caused by the high voltage of some phases, and the iron loss increases sharply.

- Reduced distribution transformer output

The design and manufacture of the transformer capacity is determined on the basis of the three-phase load balance state. The structure and performance of the three-phase winding are the same. The maximum permissible output is limited by the rated capacity of each phase, in which the rated capacity of each phase is the same. When there is three-phase load imbalance, the permissible maximum output can only be within the limit of the maximum one phase of the three-phase load not exceeding the rated capacity, and the light load phase is rich, so that the output of the transformer is reduced. The reduction degree of transformer output is related to the degree of balance. The greater the degree of imbalance, the greater the degree of reduction. It has an impact on the full utilization of transformer equipment capacity.

- Affect the motor output power and increase the winding temperature

Unbalanced three-phase load will make the three-phase voltage asymmetric, and then there will be reverse rotating magnetic field in the stator of induction motor. The motor works under the combined action of forward and reverse rotating magnetic fields. The rotation direction of the motor will not change because the positive sequence rotating magnetic field is higher than the negative sequence. But the reverse sequence impedance of the rotor is small, so the reverse sequence current is large. The reverse sequence magnetic field and current can produce more braking moment, and then the motor output power will be cut down, the winding temperature will be risen, thus endangering the safe operation of the motor.

2.2. Three-phase unbalanced traditional governance method

- Adjust the load by changing the line manually

This method has the highest utilization rate, however its human investment is large. It is necessary to cut off the user's power supply, and it is difficult to adapt to the change law of load in long term.

- Interphase capacitance compensation

By means of interphase parallel capacitors, the reactive power is compensated to the two phases at the same time, and the active power is transferred when it compensates reactive power on the basis of Wang's theorem. The cost of cost of manufacture is small, and it does not influence the user's power supply when the system fails. However, it also has disadvantages, such as over compensation due to small active power regulation, low utilization rate of capacitor because only single-phase flow between each item. It can only solve the imbalance of distribution transformer side, and the line remains unbalanced, so line loss can't be cut down.

- Power electronic three-phase load automatic regulation equipment

The SVG and APF are used to detect the harmonic component, unbalanced component and reactive component of the load through the detection technology, and the inverter technology is used to generate the harmonic, unbalanced and reactive components that need to be compensated[3]. It can deal with the problems of voltage fluctuation, reactive power, harmonic and three-phase unbalanced load. But the cost of this method is high. It can only achieve the approximate balance of three-phase current at the low-voltage side of the transformer, not the load balance in essence.

3. Structure of intelligent commutation switch system

The intelligent commutation switch system is a set of 380V / 220V low-voltage distribution system suitable for three-phase four wire system, which is used to control the three-phase imbalance in the low-voltage distribution station area [4][5][6]. It can quickly and accurately detect the three-phase imbalance of the low-voltage distribution system, and then make the three-phase load in the station area in a relatively balanced status to adjust the single-phase load through the three-phase intelligent phase change switch system without power failure in real time. The system can availablely cut down the loss of line and transformer caused through three-phase unbalanced load, and suppress the terminal low voltage, single-phase overcurrent and many security risks caused by the three-phase imbalance.

The intelligent commutation switch system adopts the way of power carrier to communicate. The intelligent master switch serves as the master, and the intelligent reversing switch serves as the slave. The communication module uses an HPLC carrier module, the main control switch uses an HPLC routing module, and the reversing switch uses a high-performance liquid chromatography single-phase carrier module for communication. The HPLC carrier technology has the characteristics of strong expansibility, high communication performance and fast speed, and can load various network applications. Moreover, its cost does not increase much compared to the narrowband carrier. Therefore, it has the superiority of cost performance [7][8].

3.1. System composition

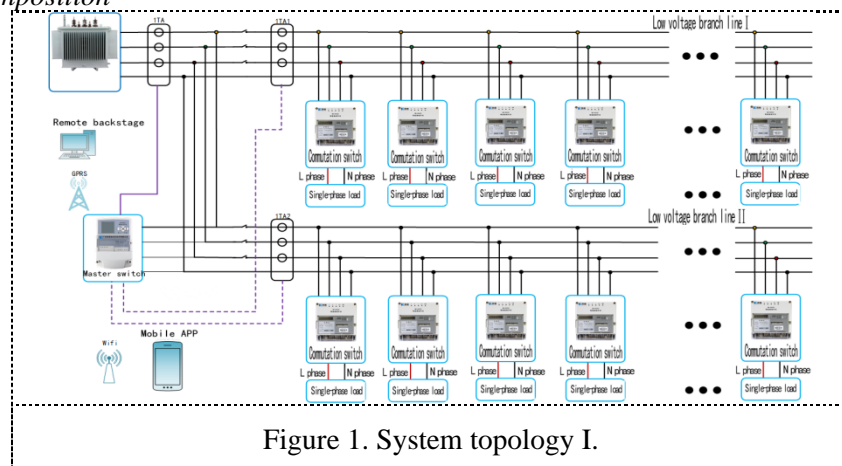


Figure 1. System topology I.

The system is composed of an intelligent commutation terminator which is in charge of automatic commutation control and load monitoring, a certain number or amount commutation switching units which are in charge of carrying out load commutation. The intelligent commutation terminator monitors the three-phase current of the distribution low-voltage outlet in actual time. If the three-phase load imbalance of the low-voltage side is over-limit within a certain monitoring period, the intelligent commutation terminal reads the real-time data of each load branch current and phase sequence of the distribution low-voltage outgoing line and all the commutation switch units, and it performs optimization calculation to issue an optimal commutation control command, and each commutation switch unit shall be commutation according to the specified commutation process.

3.2. System functions

- Automatically balance three-phase load. it monitors the three-phase imbalance degree in actual time and adjust the three-phase load automatically on the basis of the imbalance degree. Its commutation time is less than or equal to 20ms. It will not interrupt the power supply of users, cause the reset and restart of common electrical appliances, and will not cause damage to electrical appliances.
- Reduce transformer loss. It makes the transformer operate symmetrically and effectively reduces the loss of transformer.

- Reduce line loss. it effectively reduces the current of neutral line, thus reducing the loss of neutral line and phase line.
- Solve the problem of low pressure and overvoltage. it solves the problems of low voltage and over-voltage caused by the three-phase imbalance, so as to avoid burning the electrical equipment due to over-voltage or affecting the normal operation of the electrical equipment due to low voltage.
- Protect the safe operation of the low-voltage distribution network. It can avoid the heating and old damage caused by the excessive neutral current for a long time, and avoid the hidden danger of the burning of the distribution equipment such as the transformer.

3.3. System advantage

- Maintenance-free and management-free. After the system is put into operation, there is no need for special personnel to maintain and manage, so as to save human and material resources and improve efficiency.
- It automatically commutates without interrupting the user's power supply and human participation; its commutation time is less than 20ms, which will not cause power interruption.
- The system has reliable hardware latching technology and phase-to-phase short-circuit prevention technology, as well as preventing multiple phase sequences from being connected at the same time and intelligently preventing phase-to-phase short-circuits through multiple software algorithms.
- Its switching components do not consume electricity, and the power consumption of the device is small; it uses a permanent magnet relay mechanism to operate without pressure, and its device operating power consumption is less than 8W.

4. Technical principle

4.1. Principle of balance

4.1.1. Principle overview

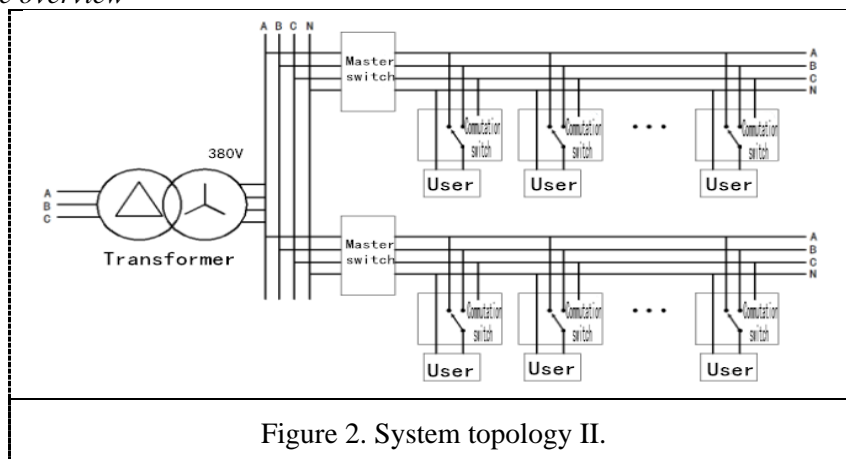


Figure 2. System topology II.

A main control switch is installed at the beginning of each branch, which is responsible for monitoring the three-phase unbalance information and issuing an adjustment command. a commutation switch is installed at the front end of the user along the branch line, which can monitor the load information of its own loaded circuit, and the corresponding commutation operation is performed according to the commutation command issued by the main control switch.

4.1.2. Intelligent networking

The commutation switch adopts the power carrier mode for communication, the master control switch uses the HPLC routing module, and the commutation switch uses the HPLC single-phase carrier module, which improves the communication efficiency and reliability.

Each master switch is only responsible for communicating with its commutation switch of the same branch. A branch constitutes a subsystem, in which the main control switch is the host and the commutation switch is the slave.

In view of the mode of multi-master switch common network, the system developed a unique intelligent networking mechanism - preemptive time-sharing communication mechanism, which avoids the conflict and interference of carrier communication between different branches and realizes the intelligent networking function [9].

4.2. Principle of no-power-down commutation

The essence of non-power-down commutation is to complete the phase sequence switching in a very short time, the basis of the realization is as follows:

- Action element

The permanent magnet relay is used as the action element of the commutation switch. Based on the characteristics of permanent magnet relay, such as strong carrying capacity, small power consumption, fast over speed, small loss, reliable operation and low cost, the commutation switch realizes the function of non-power-down commutation. In the process of commutation, it will not lead to the interruption of power supply for users, which ensures the quality of power supply.

Through a large number of theoretical research and actual measurement verification, 30 ms power down time will not lead to power down of non load sensitive electrical equipment, and the commutation switch commutation time is less than 20ms, thus meeting the application requirements.

- Zero-crossing commutation

In order to ensure the life of the switch, zero-crossing switching technology is used to minimize the damage of switching to the operating elements. The zero-crossing cutting technology is based on the principle of "current zero crossing cut-off, voltage zero crossing input", which can achieve the effect of extremely small impact and extremely small arc.

4.3. Principle of commutation algorithm

When the main control switch detects that the imbalance degree of the station branch exceeds the set value, the balance logic algorithm is started. The system is based on the principle of balanced algorithm of mathematical recursive logic. When the main control switch detects that the imbalance degree of its own branch exceeds the set value, the balance logic algorithm is started. The power load of each user is different, and the imbalance degree of each branch is not the same. Based on the principle of mathematical recursive logic algorithm, the system combines the balance demand and the load size of each phase change switch to carry out logical combination operation and solve the optimal strategy.

The principle of the balance algorithm based on the branch balance strategy is as follows. After the master switch in each branch calculates the optimal strategy, it will command the commutation switch in the branch to perform the corresponding commutation operation, thereby achieving the balance of the branch. Each branch in the station reaches a three-phase equilibrium state, which can achieve three-phase balance of the transformer.

5. Conclusion

The main conclusions of this paper are as follows:

- The product basically conforms to the technical principles and requirements that should be followed in the design, production and selection of the national power grid three-phase load unbalance automatic adjustment device (commutation switch type). The advantages are as follows:

- Three-phase balance is realized based on the power supply phase of the switching terminal single-phase load, and the three-phase unbalance problem is solved from the cause of the three-phase unbalance.
- The three-phase balance of distribution transformer and line is realized, and the line loss is effectively reduced.
- The phase switching does not affect the user's power consumption.
- Communication based on HPLC carrier has the advantages of high signal performance, fast speed and strong expansion ability. The equipment has been piloted in many places, and the three-phase unbalanced treatment effect is obvious

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