Design of Three Phase Load Unbalance Automatic Regulating System for Low Voltage Power Distribution Grids

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Abstract. In the three-phase four wire system of the low voltage side for the distribution grid, the phenomenon of asymmetrical and uneven single phase load were very common, causing unbalance in certain network. When unbalance exists, the system will have a larger line loss and the unbalanced loads can result in efficiency reduction of power energy and voltage quality decline. And then the safety and stabilization of power system in the low-voltage distribution grid will be directly affected. Therefore, based on the problems above, combined with the characteristic of the low voltage distribution grid in the three-phase four wire system, a three phase load unbalance automatic regulating system for low voltage distribution grid is designed. The system is composed of intelligent phase change controller and phase commutation switch. Based on the relevant theoretical analysis and experimental research applied in the system, the results show that this system can reasonably reduce load imbalance, improve power system performance, economic and social benefits.

1 Introduction

With the rapid development of power system, the three phase unbalanced problem of low voltage distribution grid is becoming more and more prominent. The reason is that the operation of the three phase four wire system issued in the low voltage distribution grid. The supply network is three-phase power load with single-phase life mix of electricity power. In this case, single phase loads occupies a large proportion in the whole power supply system.

Currently, the phenomenon of asymmetrical and uneven single phase load exists widely in the low voltage distribution grid systems in our country. The unbalanced three-phase load is not only related to the user load characteristic and the time of use, but also related to the load distribution of the power system. Distribution grid structure is complex, and the three-phase load is random variation, so the distribution transformer three-phase unbalance phenomenon is difficult to avoid. The serious unbalanced state will affect the quality of power supply. And then the line loss was increased and the reliability of power supply was reduced.

The traditional ways to solve this problem are mainly circled with artificial phase modulation, intelligent phase adjustment and additional unbalanced compensation device. OTTO R A proposes to transform the unbalanced three-phase load to balanced state through an ideal compensation grid in parallel with three-phase load. Feifeng J uses static var compensator to compensate the load balancing device; Dongdong G gives a three-phase load automatic balancing device. The single-phase load redistribution of low-voltage power to reduce the unbalanced three-phase load is used. These methods are not very convenient. The means are relatively deficient and the investment is inefficient. So these methods can not solve the unbalanced problem fundamentally, the actual effect is not ideal. This paper designs a method of 380V intelligent environmental protection three-phase unbalanced control switch to solve the problem.

2 The Operation Principle Of Automatic Regulating System

The three-phase unbalanced automatic regulating system adopts advanced power electronics technology, which can automatically balance the current of three phases through intelligent control mode. Computed tomography (CT) monitoring is used to determine the bus side current of each phase, and then calculate and determine the commutation strategy. By changing the online phase switch load, the larger lateral load were turn out a small part of the load to the current phase to reduce three-phase imbalance. The reliability of power grid operation can be realized well.

The three phase unbalance automatic regulation system is mainly composed of the intelligent commutation terminal and a number of phase switching units. The schematic diagram is shown in Figure 1.

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Unbalanced three-phase automatic regulating system is mainly installed in the same distribution area. The intelligent commutation terminals were installed in the low-voltage distribution transformer outlet side, it were used to collect the distribution transformer' voltage and current, power indicator information. The dispersed scattered commutation switch was arranged on the inlet end for each residential user, it was used to check user's electricity information. This data will be used as a reference of real-time distributed load.

The commutation switch and the intelligent commutation terminal are communicated through wireless LORA technology, which is easy to expand the maintenance. Each user's current information was uploaded to the intelligent terminal phase through the power line. The transformer current and commutation switch current were calculated and analyzed. Then switch optimization phase of each intelligent phase was obtained. Finally, distribution during the three-phase load was completed and the three-phase imbalance level was reduced. Commutation switch adopts thyristor patrolled contactor structure of double crystal phase. The phase change process doesn't consume power, and has fast switching speed.

An automatic control system of three-phase was proposed in this paper was proposed. Real-time detection and processing of three-phase current was treated through the external current transformer. Determining if the system is in an unbalanced state, then all current of commutation switch were send to the intelligent terminal and calculated the equilibrium needed for each phase change value. The control signal was sent to a reversing switch and thyristor and magnetic latching relay were driven. In order to achieve a relative balance, we need to make unbalanced current from the current phase transfer to small current phase. The commutation switch combines the advantages of thyristor and magnetic latching relay. The composite switch with thyristor and magnetic latching relay is used as a commutation driver. The thyristor is cut off by zero switching at the moment of input and removal, and the magnetic latching relay is switched on. Due to thyristor switching through zero, it has no inrush characteristic and short conduction time will not cause heat. Magnetic holding relay has no impact and spark at the moment of suction and disconnection. It has no impact on power grid, and is an ideal three-phase imbalance control switch.

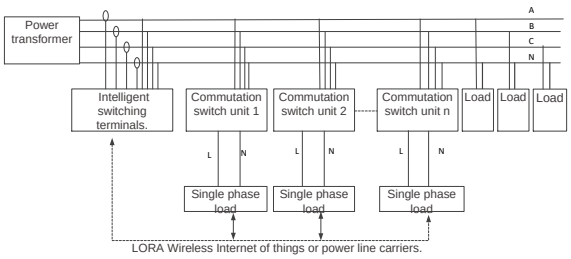

Figure 1. Schematic diagram of a three phase unbalance automatic regulation system.

3 Three-Phase Unbalanced Automatic Regulating System Control Strategy

3.1 Commutation Switch Unit

The phase switch unit is the basis of the realization of three-phase unbalanced automatic regulating system. In order to realize the dynamic adjustment process of three-phase load with stable phase change, it is necessary to adopt the fast moving, inrush current and the static switch without electric arc, and the user's power supply reliability is not affected. The commutation switch unit of this system is composed of a magnetic holding relay and thyristor in parallel, so the load can be freely switched between A, B and C to meet the control requirements. The thyristor switch has the characteristics of no mechanical contact and no switching arc and it does not affect the continuous normal use of the load. It is an ideal fast load switch. At the same time, the purpose of a magnetic holding relay in parallel at both ends of the thyristor static switch is to eliminate the voltage drop in the process of the thyristor switch and reduce the power loss of the equipment.

When the phase switch unit receives the commutation command, it is switched to the corresponding phase according to the specific command of the phase change. The thyristor is in parallel with the magnetic holding relay. As shown in Figure 2, the switch of the thyristor and the two switch coils of the magnetic holding relay are controlled by the CPU. If the process is from phase A to phase B, firstly, switching the thyristor of phase A and simultaneously disconnect magnetic hold A relay of phase A, then after a while disconnect the thyristor of phase A. After phase calculation of the timer, when the voltage of phase B of zero, the thyristor of phase B is driven, finally, magnetic hold relay of phase B is driven and after a while thyristor of phase B is disconnected. The other phases are in the same order, as shown in figure 3. So the thyristor only works in commutation process. The current in normal working process flows through magnetic latching relay. This is to solve the long time heating problem of the thyristor. It prolongs the electrical switching life of the mechanical switch and improves the reliability, commutation time is within 7ms.

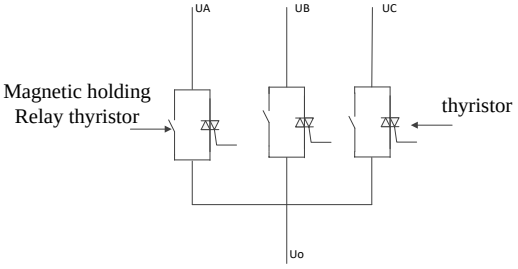

Figure 2. Structure diagram of commutation switch.

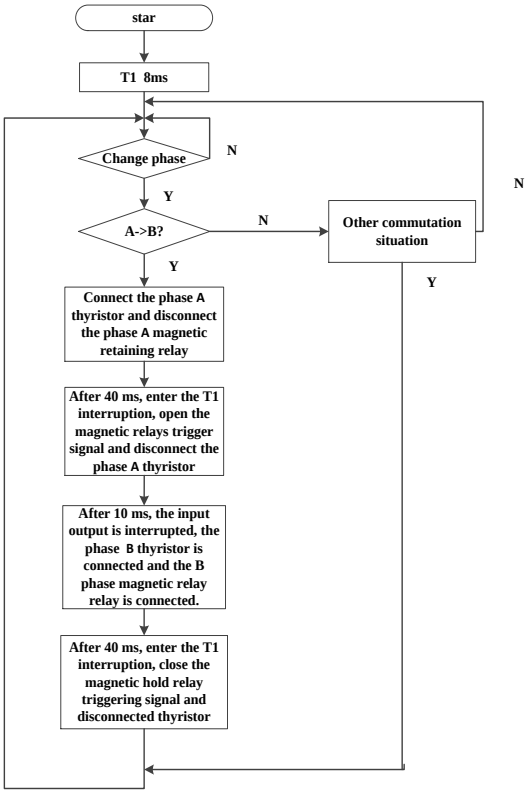

Figure 3. Commutation module flow chart.

3.2 Intelligent Commutation Terminal Commutation Control Strategy

It is the key issue in the three-phase unbalanced automatic regulating system. The distribution transformer terminal calculates the three-phase unbalance rate according to the collected current. When the calculated value is larger than the set three-phase unbalanced threshold, it will control the dispersed installed commutation switches.

3.2.1 Adjust Criterion

In actual engineering application, the intelligent terminal phase was not real-time detected of three-phase load state and the operation. In general, the average time of the load was calculated by calculating the average load average of a certain time, with a minimum time of 10 min or an integer multiple, which can be flexibly configured according to the actual demand and field load fluctuation. At the time of adjustment, the criterion for determining whether the regulation needs to be adjusted or not is mainly the system's imbalance rate of more than 15%, and minimum number of switches in the automatic phase switching devices in the phase change process is the basis.

3.2.2 Load Transfer Principle

In the three-phase imbalance regulation, the basic principle was considered as the same distribution area and known as the current phase and load information of all commutation switches, making the motion switch quantity at least was realized the optimal load transfer. When the load is transfer, load of the biggest commutation switch is priority select to adjust.

The actual load current was acquired through wireless communication. After judging the load imbalance in the transformer station, the number of commutation switches and the current magnitude of each phase are recorded from the recorded data. Then, Sort these data from the smallest to the largest, and remove the switch phases that are larger than the commutation threshold. Then the three-phase unbalance ratio was calculated based on the average current detected, and the phase with the largest and the smallest current was found. If the unbalance ratio is greater than the threshold and the maximum number of phase-mounted commutation switches is 0, the maximum current of the commutation switch current is switched to the minimum current phase. The average current corresponding to each phase is also subtracted or added to the corresponding current, and then the simulated unbalance ratio after the commutation is calculated according to the new average current. If the unbalance ratio is within the specified range or the number of phase-change switches with the maximum current phase is 0 or has been changed 10 times, then the commutation process is exited, otherwise, the previous commutation step is continued.

3.2.3 System Level Control Strategy

Three-phase unbalance load control system focuses on how to generate reasonable strategy according to the actual running situation and optimal load switching scheme. Choosing the appropriate switch is combined computed to achieve the optimal load adjustment in the minimum number of switching action, which made the system to realize the new three-phase load balancing. The flow chart of the control strategy is shown in Figure 4.

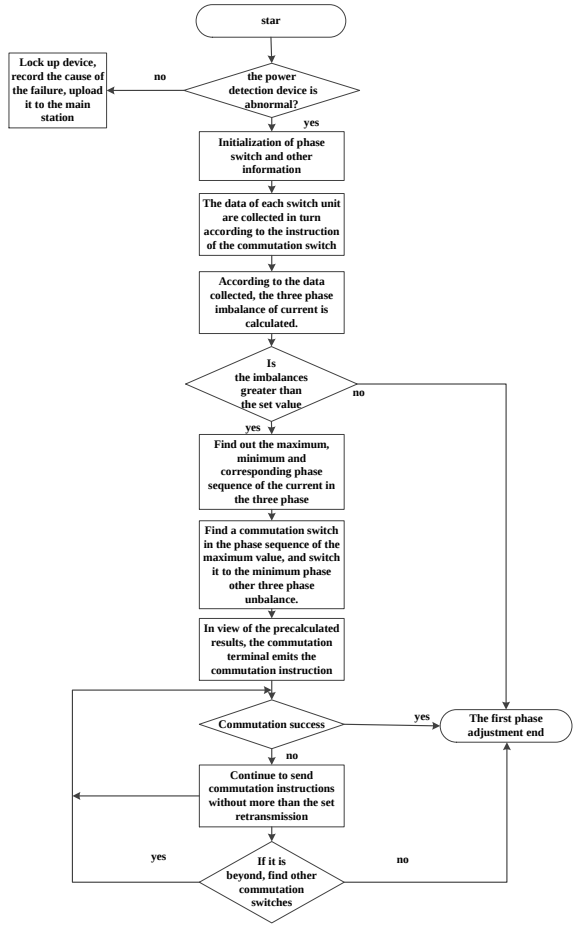

Figure 4. Flow chart of commutation control logic.

4 Experimental Research And Result Analysis

The experimental process can be divided into two parts. Firstly, the phase change operation of the single phase switch unit is tested, and the instantaneous waveform was analysed to verify the feasibility of the phase change operation. The three-phase unbalanced load regulating system are testing and monitoring of three phase unbalanced situation of the export side. The system balance scheme was analysed through the data of experimental. we can verify the correctness of the algorithm.

4.1 Single Phase Switch Switching Test

The effective value of 380V three-phase power is connected to the inlet end of the air switch, which is powered by the air switch to the phase switch, and the load side is connected to the 70A load as the user load. In the experiment, commutation control is done by the computer station. At a time when the instruction issued commutation, the commutation switch receives the commutation command and makes judgment immediately. If meet the commutation operation, it will be in switch operation immediately. Test system composition is shown in Figures 5 and 6. The thyristor waveform, load voltage waveform and magnetic holding relay current waveform are shown in Figure 7. Channel CH1 represents the thyristor current waveform, channel CH2 represents the load voltage waveform, and channel CH3 represents the magnetic latching relay current waveform. As you can see from the result of the experiment wave-forms in the graph, the commutation process are shorter and smoother, it can finish phase operation in half a cycle. Commutation process does not affect users of electricity.

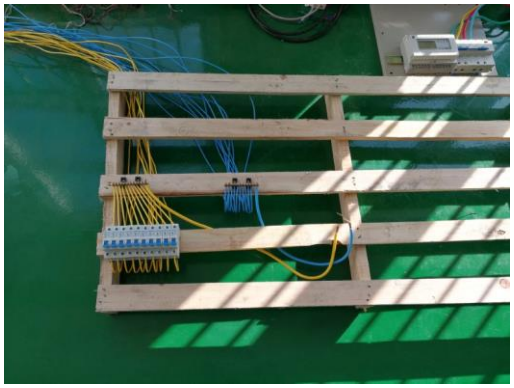

Figure 5. Test system composition A.

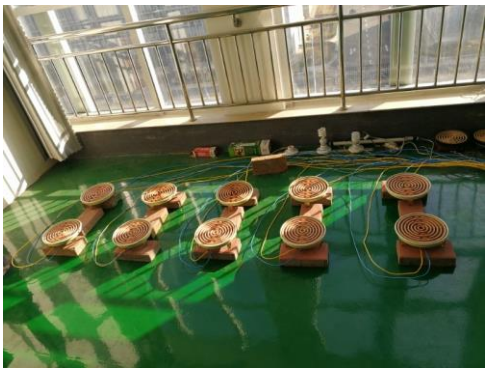

Figure 6. Test system composition B**.**

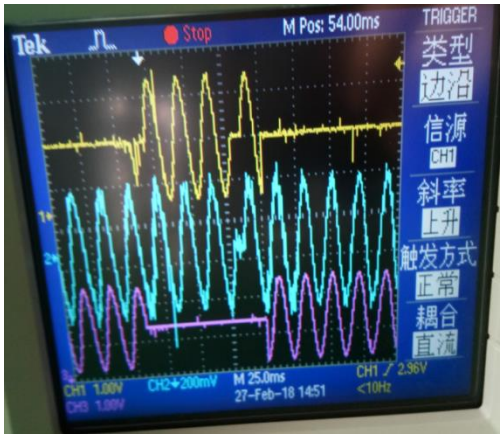

Figure 7. Switching waveform of commutation switch.

4.2 Experiment of Load Control System

In view of the three-phase unbalance problem, a simple simulation system is carried out. The intelligent

commutation terminal and three phase commutation switches are installed under the same transformer station, and the voltage and current of the transformer outlet side are collected. The test results are shown in Table 1:

Table 1. Experimental data of the load control system.

Pre commutation unbalance rate	40.1%	22.4%	15.1%	14.9%
Pre commutation Ia/A	1.60	1.61	1.10	1.08
Pre commutation Ib/A	0.21	1.83	1.65	1.81
Pre commutation Ic/A	1.56	0.78	1.55	1.54
Post commutation unbalance rate	20.2%	11.3%	6.9%	6.8%
Post commutation Ia/A	1.06	1.61	1.62	1.63
Post commutation Ib/A	0.77	1.10	1.29	1.29
Post commutation Ic/A	1.56	1.56	1.55	1.55

As can be seen from the above data, after the automatic commutation, unbalance rate of the system is decreased significantly. The system is completed to solve the problem of distribution grid three-phase imbalance, and sharply reduce the low voltage distribution grid line loss. The system is improving voltage regulation in real time and stabilizing system voltage, so power distribution quality is improved.

5 Conclusions

The three-phase imbalance has not only adverse effects in the distribution grid, but also can affect the safe and stable operation of the whole power grid. Because the three-phase balance is one of the base of the stable operation in power grid. Through the study of the three-phase unbalance, we can stabilize the operation of the power grid and reduce the loss of electric energy to ensure the safe use of all kinds of electrical appliances. Therefore, it has very important practical significance for the research of three-phase imbalance.

In this paper, unbalanced load in low voltage distribution grid in our country are analysed and researched, and the three-phase unbalanced load control system was developed. The system composition, working principle and control strategy have carried on the simple analysis. Through theoretical analysis and practical experiments test, the application of three-phase unbalanced load control system is showed. It is certified reducing the three-phase current unbalance and improving power quality as well as reduce labour costs. The three-phase unbalanced load control system has obvious effect on the three-phase unbalanced governance and achieves good social and economic benefits. At the same time, the system has advantages such as low cost, strong real-time performance, good balance effect, and uninfluenced load power supply, which is suitable for application in power system.

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