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The application of reactive power compensation technology in electrical automation engineering

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Abstract. In recent years, with the rapid development of China's social economy and the continuous improvement of science and technology, the power industry has begun to develop in the direction of electrical automation. And the reactive power compensation is of great significance for China's electrical automation. In this paper, based on the application of reactive power compensation technology in electrical automation, firstly, the key technology of reactive power compensation was introduced. Secondly, the way for realizing the application of reactive power compensation technology was discussed. Finally, the application measure of reactive power compensation technology in electrical automation was put forward, so as to provide some reference for the reactive power compensation technology in electrical automation.

Key words. Electrical automation, reactive power compensation technology, application.

1. Introduction

Reactive power compensation technology is developed recently in China, according to adjust the electronic power supply system, the maximum power grid power is achieved, and its utilization is improved. In this process, the power supply transformer and transmission line consumption is minimized, so as to improve the power efficiency in the whole electric automation, and continually improve the power supply environment [1]. With the continuous improvement of the level of electrical automation, the non-linear and unstable changes in electrical equipment increase the reactive power of the transmission line to a certain extent. While in electrical automation, the rational use of reactive power compensation technology cannot effectively improve the energy efficiency of electrical equipment, while the reactive efficiency in the automation process can be reduced, at the same time, to a certain extent, the stability and reliability of the electrical equipment operation can be improved [2]. From the current actual situation to see, China's power operation

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mode is divided into three kinds: low-voltage network, medium-voltage network and high-voltage network. In these three power operation modes, the medium-voltage network is relatively stable, and compared to high-voltage network, the low-voltage network unstable. And then, how to ensure the stability of low-voltage network and high-voltage network becomes an important issue that is urgent to be solved in the power industry [3]. Through the use of reactive power compensation technology, the stability of low-voltage network and high-voltage network has been significantly improved. Reactive power compensation technology can effectively reduce the loss of network operation and improve the utilization rate of power resources, thus increasing the capacity of power supply equipment, and effectively controlling the voltage of distribution system and power supply system in electrical automation [4]. Then, the application of reactive power compensation technology in the process of electrical automation can better maintain the stability of the power grid, thereby reducing the damage of the break current to the internal components caused in the electrical automation process, which has a good improvement role [5].

2. State of the art

2.1. The development situation and realization way of reactive power compensation technology in electrical automation

In essence, the reactive power compensation technology is mainly used to improve the high power factor of electrical automation, according to the fundamental way by combining with the current filtering technology, to achieve the purpose of harmonic compensation, and reducing the negative sequence. From the development of reactive power compensation technology at this stage, China has made considerable achievements in the research work of this technology [6]. In recent years, according to apply the reactive power compensation technology to the problem of harmonic control, to a large extent, a role in improving the power factor is played, so that the ultimate purpose of filtering or counteracting the harmonics in electrical automation is achieved.

Under the normal circumstances, in the electrical automation, the application of the effective way of reactive power compensation technology can be divided into the following several. Firstly, the simple filter design, which can be achieved by installing a fixed capacitor and reactor, but before designing this filter, the actual power should be considered, so as to ensure that the reactive power compensation technology can improve the power factor and reduce the negative sequence. Secondly, the design of vacuum circuit breaker, which has the characteristics of small investment and easy operation, however, due to at the time of closing, the vacuum circuit breaker will bring high-voltage withstand pressure for the capacitor, resulting in that dynamic compensation effect is affected. Thirdly, the hybrid voltage regulator, that is, the device consists of the fixed filters, capacitors and reactors, etc.; in general, it is to use the bus bar voltage of the regulated step-down transformer to adjust the filter or reactor voltage, so as to achieve the purpose of reactive power change. In addition,

theoretically speaking, through the thermistor on-off regulation, tap-changer no-load regulation, the electrical life will not be limited [7].

2.2. The problems of reactive power compensation technology in electrical automation

Line wear problem. Because of the restriction of the development of China's actual uncompensated compensation technology, in a large number of use processes, the current in China's electrical automation circuit is transferred in a variety of high-voltage transformer, then, through the transmission line, the current is conveyed to middle and low voltage substation with the indirect help of external machines and lines, so it is conveyed to the electricity enterprises or units that have different demands step by step [8].

Effect of harmonic content on the capacitor, in the operation of electrical automation, the capacitor in the reactive power compensation technology has a certain degree of anti-harmonic ability, and if the harmonic content in the circuit exceeds the national standard, then, the capacitor life will suffer certain impact, and it will be greatly shortened, or even appears in serious problems, resulting in that the capacitor cannot work, and the overall operation of the system is affected, which brings running errors and troubles for the whole system.

Reactive power compensation capacity configuration is unreasonable. The application of reactive power compensation technology in the field of electrical automation in China is still in a primary stage, for the reactive power compensation technology, in all relevant operations, such as the configuration coordination, it is inevitably that there will be loopholes, which causes that in the process of electric automatic operation, the power factor is too low at high load, or the phenomenon of compensation will often occur when the load is low, and this seriously affects the quality of electrical automation application [9].

2.3. Significance for applying the reactive power compensation technology in the development of electrical automation

At the same time of the rapid development of China's economy, the scientific and technological fields have also secured big development, especially the development in the field of electrical automation. Whether it is in the substation or the high-speed rail traction system, the degree of application of the electrical automation is very high. However, there is a more serious problem in the application of electrical automation technology, that is, the load problem of conventional single-phase electric traction, the variation of the load is very complex, which results in the unnecessary power increase, and then, it will affect the utilization rate of electrical automation system, which is not conducive to improving the overall efficiency. For the application of reactive power compensation technology in electrical automation, its advantages can be divided into the following points: Firstly is to provide stable support for the electrical automation system, this can not only stabilize the entire system's voltage, but also greatly improve the entire power grid quality and safety,

at the same time, the regulator can also be configured properly, so as to improve the transmission capacity of the whole system. Secondly, the partial electrical appliances will produce overheating, and the main cause of the problem is due to the existence of high harmonics, then, the use of reactive power compensation technology can avoid that better [10]. The working principle is to set the static reactive power compensator in the electrical automation system, thereby improving the voltage load in the power grid, and avoiding the phenomenon of overheating temperature, so as to protect the capacitor. Thirdly, if we meet the case of three-phase load imbalance, the reactive power compensation technology can be used, and this can balance the power. Besides, the rational application of reactive power compensation technology in electrical automation technology can effectively improve the stability and anti-interference of the electrical system.

3. Methodology

3.1. The principle of reactive power compensation

Reactive power compensation, which is referred to as reactive power compensation, it plays a role of improving the power factor of the power grid in the power supply system, reducing the power supply transformer and transmission line loss, improving the power efficiency and the power supply environment. Therefore, in the power supply system, reactive power compensation device is in an indispensable and very important position. The reasonable choice of the compensation device can minimize the loss of the power grid and improve its quality [11]. On the contrary, if the choice or use is improper, it may cause the increase of the power supply system, voltage fluctuations, harmonics and many other factors.

Power output power includes two parts: Firstly is the active power: direct consumption of electricity, the electrical energy is transformed into mechanical energy, heat, chemical energy or sound energy, according to use these work, this part of the power is known as active power; secondly is the reactive power: electricity consumption, this is only to change the electrical energy into another form of energy, which is the essential condition for the electric device to be able to work, furthermore, this energy can conduct the periodic transformation with the electric energy in the power grid, which is called as reactive power (such as the occupied electric energy for the electromagnetic components to establish the magnetic field, the occupied electric energy for the capacitor to establish the electric field) [12].

3.2. The significance of reactive power compensation

Compensating the reactive power can increase the proportionality constant of active power in the power grid.

Reducing the design capacity of power supply equipment, reducing the investment, for example, when the power factor $\cos\varphi = 0.8$ increases to $\cos\varphi = 0.95$, the capacitor that takes 1 kvar can save equipment capacity 0.52 kW; conversely, for the original equipment, increasing 0.52 kW is equivalent to increase the power

supply equipment capacity. Therefore, the new construction and alteration of the engineering should take full account of reactive power compensation, so that the design capacity can be reduced, thereby reducing investment.

Reducing the line loss, the formula for calculating the change of power factor is shown in Fig. 1.

$$\Delta P\ (\%) = 1 - \frac{\cos\theta}{\cos\varphi} \times 100\,\%\,. \tag{1}$$

It can be derived from (1), that $cos\varphi$ is the power factor after the compensation, $cos\theta$ is the power factor before the compensation, then: $cos\varphi > cos\theta$, Therefore, after increasing the power factor, the line loss rate is reduced, besides, reducing the design capacity and the investment, increasing the transmission ratio of active power in the power grid, and reducing the line loss directly determine and affect the economic benefits of power supply enterprises [13].

3.3. Function of reactive power compensation technology in electrical automation

The continuous advancement of electromechanical integration and the application of electrical automation have greatly accelerated the development speed of power system. The reactive power compensation technology system of electrical automation is shown in Fig. 1, and its function is shown in Table 1.

Table 1. Function of the reactive power compensation technology of the electrical automation

1	When the three-phase load appears in the unbalanced conditions, the reactive power compensation technology can balance the three-phase apparent power, which plays an important role in improving the overall performance and anti-interference of power system.
2	Because the power network composed of a large number of power transmission lines can be divided into three modes: high, medium and low. In most cases, the flow voltage of the high-voltage network and low-voltage network is very unstable, and then, the use of reactive power compensation technology can improve the stability and reliability of the electrical automation system, so that the power system can greatly improve the transmission quality in more secure conditions. Moreover, in actual use, the corresponding regulator can be equipped with, and then, according to cooperate with the reactive power compensation technology, the overall performance of the system operation is improved, and the system's anti-interference is enhanced.
3	Application of reactive power compensation technology in electrical automation can improve the power factor of the power grid and its load, and reduce the capacity of each part of the electrical equipment as much as possible, thus saving the operating costs and energy consumption.
4	In addition, the reactive power compensation technology can also configure the corresponding static vary compensator for the system, on the one hand, it can regulate the voltage of the power grid in the operation of electric automation; on the other hand, it can also provide safety guarantee for the cable and capacitor in the operation of electrical automation, so as to prevent the local heating failure caused by the high-frequency harmonics.

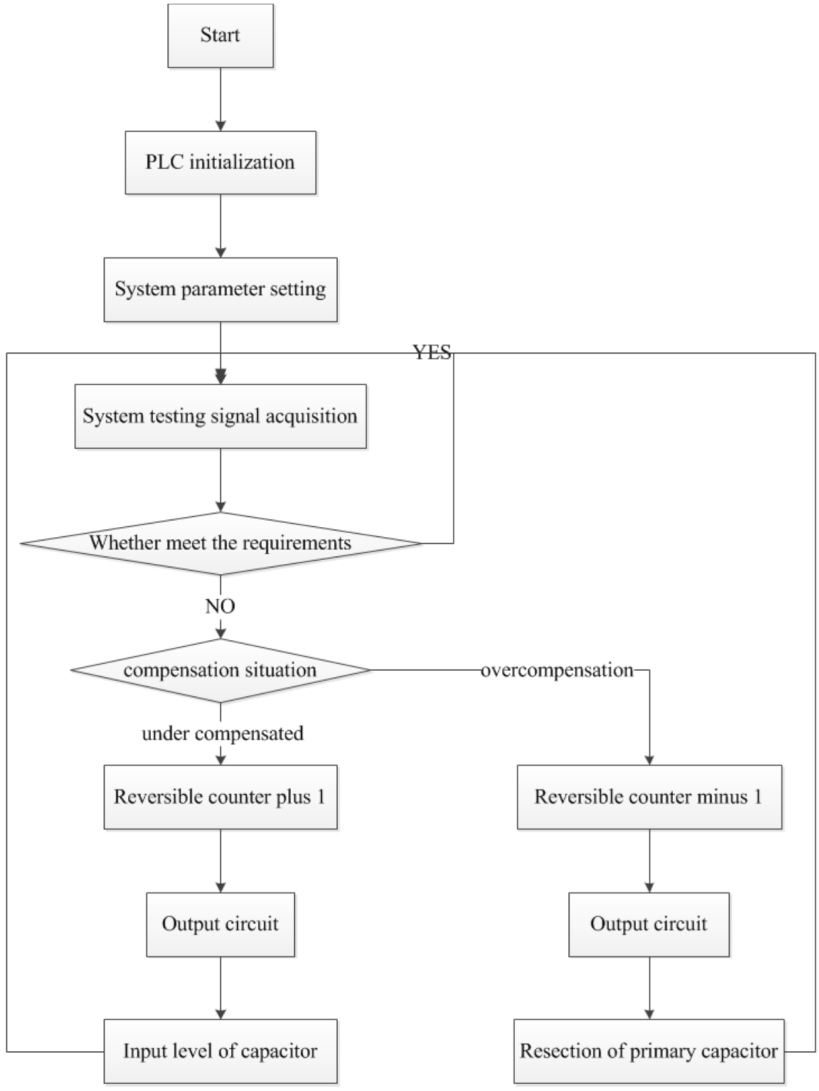

Fig. 1. Reactive power compensation system of the electrical automation

3.4. The key technology of reactive power compensation

Power factor was introduced as follows in this paper. The so-called power factor mainly refers to the proportion of the active power supplied by the apparent power of the transformer and the line in the power network. In the operation of power network, the power factor should be increased as much as possible. Because the bigger the power, the better it is. If the power factor is large, most of the active power can be supplied by the apparent power of the power equipment. Therefore, the transmission of reactive power and the loss of active power are reduced [14].

The power factor of the power supply equipment can be improved and the quality of the voltage can be guaranteed by improving the power factor of the users within a reasonable range. In this case, when Q is 0, the power factor is 1. Therefore, in order to reduce the reactive power consumption of power equipment, it is necessary to improve the power factor.

The method of compensating reactive power of shunt capacitor is as follows. The adjustment of reactive compensation voltage: the removal and input of shunt compensation capacitor will have certain influence on the voltage change of transformer load side. Therefore, the quality of the voltage can be improved by the removal and input of the capacitor. Firstly, the capacitor input is adjusted to the load side voltage of the transformer, which is shown in formula (2). The adjustment of the voltage measured by the transformer when the capacitor is cut out is shown in formula (3).

$$U_{\mathrm{H}} = \sqrt{\sum_{n=2}^{\infty} U_n^2}, \quad I_{\mathrm{H}} = \sqrt{\sum_{n=1}^{\infty} I_n^2}\,, \tag{2}$$

$$U_{\mathrm{h}} = \sqrt{\sum_{k=1}^{25} X_k I_k}\,. \tag{3}$$

Here, U_{h} is harmonic voltage limit, X_k is the impedance of the kth harmonic, ${}_I k$ is the current of the kth harmonic.

3.5. Design method of reactive power compensation technology in electrical automation

Table 2 summarizes the design method of reactive power compensation technology in electrical automation.

3.6. Solving measures of the reactive power compensation technology in the application of electrical automation

Strengthening the management of the user side, according to strengthen the energy saving and management of the user side, the users can be fully aware of the importance of reactive power compensation technology in electrical automation, and then set up a consciousness of correctly treating the relationship between reactive power compensation technology and power loss, so that to a large extent, the loss of electrical energy in transmission lines can be reduced from the internal part.

Determining the actual capacity of substation reactive power compensation, in determining the actual capacity size of the substation reactive power compensation, people should be fully aware of the actual situation in different regions, and besides, there are differences in the regulation of substation [15]. On this basis, the reactive power compensation technology is used to conduct the reactive power compensation for the low load, transformer of the transformer substation. And the latest technology, equipment and technology, the reasonable compensation capacity of power industry are used. In addition, it is necessary to strengthen the skill training of staff,

and try to reduce and prevent the occurrence of reactive power back phenomenon.

Table 2. Design method of reactive power compensation technology in electrical automation

Method	Concrete content
The method of combining the thyristor adjustment reactor phase with the stable filtering equipment	Through the method of combining the thyristor adjustment reactor phase with the stable filtering equipment, the inductive current of the inflow loop can be influenced at the time of adjusting the saturation degree of saturation reactor, so as to enable the extra capacitive power in the parallel filter to achieve a balance. At the same time, because the filter can be put into irregularly, to a certain extent, the use of thyristors is reduced, and the processing speed of the system is greatly guaranteed, but the drawback will be generated by filtering.
Method of combining with a stable filter, the capacitor adjustment pressure and capacitor	Before using this method, it is necessary to adjust the bus voltage of the two sides of the transformer low voltage, so as to connect the filter on the low-voltage bus or the voltage on reactor, and achieve the purpose of changing reactive power. However, in terms of the present situation, the technical level for achieving the combination of stable filter, capacitor adjustment pressure and capacitor is not mature and perfect enough.
Method of combining with the stable filtering harmonic device and controllable saturation reactor	Series reactors and anti-parallel thyristors can play a role of balancing and paralleling the compensating current of the additional capacitive reactive power of filter, so as to meet the requirements of the power factors. Relatively speaking, this technology has several advantages: high investment time, easy to operate, fast adjustment speed, and does not produce resonance and other advantages, while because this technology has higher technical requirements, the risk is higher, the cost is relatively expensive and other factors, resulting in that this technology cannot be well applied.

Effectively compensating the low-voltage side of the distribution network capacitor group, in this regard, it is necessary to pay attention to the reduction of the power and electric power caused by the transformer and line passing through the reactive current transmission, while for the common transformer unit that its load is relatively large, it is necessary to consider whether setting the capacitor bank at the side of low-voltage distribution network, and then to implement the effective compensation.

4. Result analysis and discussion

4.1. Cyclic switching test of simplified structure of reactive power compensation system

Intelligent low-voltage reactive power compensation system simplified architecture consists of two intelligent compensation capacitor integrated modules, and the two integrated modules are equipped with two three-phase capacitors that the capacity is 5 kVAr. After power-on, firstly is to set the ID number of the capacitor

and the corresponding capacity; then, it is to set one of them as the main controller mode, and the other is the non-controller mode. The experimental results of connecting the reactive power compensation system into the power grid are shown in Table 3.

Table 3. Experimental results of simplified structure of reactive power compensation system

	Three-phase voltage U (V)	Current value I (A)	Apparent power S (KVA)	Reactive power Q (kVAr)	Power factor $\cos\varphi$
Before compensation	211	106	22	15.3	0.73
After compensation	217	78	16.8	5.4	0.95

It can be found that, firstly, the thyristor conduction, that is corresponding to the first capacitor, the capacitor is put into the grid, indicating to compensate 5 kVAr of amount of reactive power; and after a period of time, the thyristor conduction, that is corresponding to the second capacitor, the capacitor is put into the grid, then, there is no capacitor to be put into. After the three-phase motor's operation is stopped, the first capacitor is first removed, then, followed by the second capacitor, indicating that the desired effect of the recirculation is achieved.

4.2. Optimized switching test for standard architecture of reactive power compensation system

Intelligent low-voltage reactive power compensation system standard architecture consists of a reactive power compensation controller and two intelligent compensation capacitor integrated modules, and among them, the capacity of one integrated module is 5 kVAr three-phase capacitor and 10 kVAr three-phase capacitor; then, another integrated module has 20 kVAr three-phase capacitor and 40 kVAr three-phase capacitor. According to connecting this set of reactive power compensation system to the power grid, the experimental results after operation are shown in Table 4.

Table 4. Experimental results of the standard architecture of reactive power compensation system

	Three-phase voltage U (V)	Current value I (A)	Apparent power S (KVA)	Reactive power Q (kVAr)	Power factor $\cos\varphi$
Before compensation	211	106	22	15.3	0.73
After compensation	218	82	17.6	4.9	0.96

Through the experiment, it can be found that after the compensation capacitor of the reactive power compensation system, the power factor of the power grid is

compensated from the original 0.73 to 0.96, and the voltage value is increased from 211 V to 218 V. After the capacitor is put into the power grid, the reactive power value is reduced a lot, and the quality of the power grid is highly improved.

5. Conclusion

In electrical automation, the use of reactive power compensation technology not only enhanced the coordination and integrity of the entire system, but also played a key role in improving its stability, at the same time, it also provided the conditions for the use and utilization of the resources and energy of the whole system more effectively, which played an important role in ensuring that the equipment could be safely used in the electrical automation system. Then, according to discuss the development status, ways of realization, design method of reactive power compensation technology in the electrical automation, as well as the problems in the application process, a reasonable and effective way to solve these problems was found, so that the efficiency of electronic automation was further improved, and the loss of power energy during transmission was reduced. Moreover, in order to further promote the reform and development of electrical automation industry, it is necessary to strengthen relevant technical personnel's research and development efforts, and strengthen the improvement of technology and equipment, then solve the problems existing in the application of reactive power compensation technology in electrical automation.

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