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Study on New Type Magnetic Saturation Transformer Based on PDF Theory

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Abstract. With intermittent energy grid connected, the requirements of transformer and reactive power compensation are developed. A novel combination technique of controllable reactor and magnetic saturation transformer is proposed in this paper. The optimal control target is implemented by combining the advantages of controllable reactor and magnetic saturation type transformer to suppress flicker of voltage effectively. The corresponding mathematical representation and the equivalent circuit are presented.

Keywords: magnetic saturation transformer, controllable reactor, reactive power compensation, voltage control

1 Introduction

The extensive use of wind energy, solar energy and other large-scale intermittent power supply brings some difficulties of the grid control and safe operation. The main performance is one of the reactive power and the frequent changes greatly. It not only causes voltage drop in quality, but also brings great hidden danger to the security and stability of power system. In the background, it is a pressing matter of the moment of to seek the effective control of voltage and the compensation of reactive power while wind power, solar energy and other units connected to grid.

With the continuous expansion of grid scale and reactive power consumption of various electrical equipments, the problems of lacking of reactive power and voltage fluctuation are increasingly prominent. With intermittent energy grid connected, the requirements of transformer and reactive power compensation equipment technical are increased day by day [1-6]. Reference [3] proposes a new kind of hybrid genetic algorithm, which is composed of simple genetic algorithm and simulated annealing. Simulated annealing method is used to renew individual character. So the diversity of group is increased and the local optimum can be avoided. It can enhance stability of wind obviously.

Reference [7] proposes PI control method for a controllable reactor meets the needs of voltage control in power systems while its implementation in projects is easy. References [8-9] propose mathematical model and physical model through the application of controllable reactor in power system and selection methods. These

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methods have played a certain role in control the voltage stability, but some methods have limitations and difficult to be achieved.

Static Var Compensator (SVC) is one of the most commonly used equipments for reactive power compensation. SVC has a significant role in improving the stability of system. One of the main functions is that stabilize of the system voltage. Traditional SVC have their defects respectively. For example, thyristor controlled reactor produces large harmonic and needs to add additional filter. Moreover, in the working, the thyristor needs to bear all of the working voltage and current. At present, the domestic and foreign still cannot manufacture high voltage grade SCR. In order to improve the ability of SCR to withstand high voltage, a lot of SCRs are used in series, but the driver and insulation conditions are hard to guarantee [10-11].

According to the problems caused by methods of the traditional reactive power compensation in the process of intermittent energy connected with grid, a novel combination technique of controllable reactor and magnetic saturation transformer is proposed in this paper. These problems contain large harmonic contents, big loss, poor power quality, high investment cost and large amount of electrical equipment maintenance. The traditional transformer and reactor are used independently, and that not only causes the large equipment investment, but also brings certain difficulty to the operation and maintenance work, and the control of voltage and reactive power is poor. However, these disadvantages can be avoided by the combination technique of controllable reactor and magnetic saturation transformer. Magnetic conductor and winding of the hybrid controllable magnetic saturation of the transformer are rational distribution to reach the purpose of reducing the power loss and effectively suppress harmonics. Taking the wind power as an example, in the process that combination technique of controllable reactor and magnetic saturation transformer is applied to intermittent power connected with grid, combination technique of controllable reactor and magnetic saturation transformer can track to the change of the power of wind turbines fast.

2 Combination of controllable reactor and magnetic saturation transformer

This paper presents a combination technique of controllable reactor and magnetic saturation transformer, and this concept of combination embodies in the following aspects: The first combination is the function of the controllable reactor and the function of transformer. The second combination is a variety of control winding, working and compensation winding and phase shift winding. The last combination is a reactor, a capacitor group, DC power and AC power. This paper proposes the new concept of 'combination' to solve many problems of intermittent power grid-connected operation effectively. These problems include the high harmonic caused by traditional ways of reactive power compensation, loss of large, poor power quality, high investment cost and large amount of electrical equipment maintenance. Because the response time of the magnetic valve controllable reactor is usually in the 15 power frequency cycle that is about 0.3s, which is far less than the requirements of suppressing flicker.

This method is proposed for the magnetic valve controllable reactor and transformer hybrid control strategy, and it has very high prospective and innovative.

There are many characteristics of magnetic valve controllable reactor. It can change the voltage through the grid voltage and self winding, and obtain control power by thyristor components rectification. It does not need additional excitation. The working winding and control winding are organically combined together by the magnetic valve controllable reactor. This helps to reduce the power loss, and the structure is simplified .

The core section of the magnetic valve controllable reactor has a decrease. In the work scope of the reactor, only a small core section is saturated, and this is equal to a 'magnetic valve'. Due to the special structure of magnetic valve controllable reactor, therefore, it has smaller harmonic, the volt ampere characteristics of approximation linear, the smaller loss and fast response speed.

3 The working principle and structure of hybrid controllable magnetic saturation transformer

The novel combination technique integrates transformer, reactor, capacitors and other equipment. In fact, it is a special type of transformer. This transformer is equal to a reactive power. For the combination technique of controllable reactor and magnetic saturation transformer, there is a big difference from the conventional transformer and controllable reactor. These differences can be reflected in columnar iron core of transformer and its distribution of the winding. When the combination technique of controllable reactor and magnetic saturation transformer is applied to the wind farm reactive power voltage regulator, it is the transformer, and is also a controllable reactor at the same time.

In the process of reactive power compensation, the hybrid transformer and parallel capacitor group are used together. When the magnetizing current is zero, hybrid device works in the state of transformer. When the magnetizing current of hybrid device is a rated value, it works in the state of the controllable reactor. Under normal circumstance, the magnetizing current is between of zero and a rated value, so it has the function of transformer and controllable reactor.

For the winding distribution, the coil is hybrid winding. At the same time, it represents the primary winding of transformer and the reactor working winding are the secondary coil winding, and they reflect the function of transformer secondary winding, control winding and phase-shifting winding.

The whole device is composed of the three-phase same modules which connect with each other. Each phase has a magnetic conductor with two columns, and each conductor column was divided into two parts. The primary winding is composed of two coils, and the coil winding on the iron core 1 and 2, respectively. Then the coil connected with the AC power supply, produces circulatory flux in the magnetic conductor. Secondary winding consists of four branches, which are connected with four star structures respectively. One end is connected to the terminal *a*, *b*, *c*, and the other end is led out by the neutral point.

4 The equivalent circuit and its equation of hybrid controllable magnetic saturation transformer / reactor

Through the above analysis, the equivalent circuit of primary winding is the same to the transformer. However, the equivalent circuit of the secondary winding is relatively more complicated. According to Kirchhoff's law and the equivalent circuit, the equation can be established as following:

$$\begin{cases} L_{\sigma A}\, pi_A - L_{\sigma B}\, pi_B + p\Psi_A - p\Psi_B = u_A - u_B - i_A(R_A + R_{Am}) + i_B(R_B + R_{Bm}) \\ L_{\sigma B}\, pi_B - L_{\sigma C}\, pi_C + p\Psi_B - p\Psi_C = u_B - u_C - i_B(R_B + R_{Bm}) + i_C(R_C + R_{Cm}) \\ pi_A + pi_B + pi_C = 0 \end{cases} \quad (1)$$

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Further the corresponding equivalent magnetic circuit and the equation can be established, and the working state of controllable hybrid transformer is analyzed..

5 Conclusion

Through the above analysis and argumentation can draw that the combination technique of controllable reactor and magnetic saturation transformer is integrated with the functions of transformer and reactor. This technique has overcome the disadvantages of traditional method that large investment, maintenance difficulties and the poor of reactive voltage control. Through the reasonable distribution of magnetic conductor and the winding of controlled hybrid magnetic saturation of transformer, the purposes of reducing the voltage loss and harmonic suppression are reached.

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