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The Direct Current Control Method of STATCOM and It's Simulation

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***Abstract*-This paper introduced the working principle of STATCOM, uses the method of direct current control of triangle carrier wave to detect both the harmonic and the basic reactive power. Used the Matlab to build the model of STATCOM, The simulation and experimental results verified the feasibility and effectiveness of this method, and good tracking performance, and accurately, fast and steady compensation effect.**

Keywords-STATCOM; direct current control; instantaneous reactive power; MATLAB

I. INTRODUCTION

With the rapid development of industry, the requirements of electric power quality are becoming stricter, how to improve the reliability, controllability and rapidity of modern power system has become a urgent problem to be solved[1]. Static Synchronous Compensator (STATCOM) is the central device of modern Flexible AC Transmission Systems, compared with the traditional reactive power compensation device, STATCOM has the advantage of fast response, absorb reactive continuous, harmonic current, low loss, small size, etc. Therefore, STATCOM has become an important development direction of reactive power and harmonic compensation device's research [2,3].

There are many researches on the control design of STATCOM. The literature [4] analysis the direct current control method of voltage outer, the current inner structure static Var generator and simulate the control method. The literature [5] give the reason and the solution of high voltage across the capacitor when device emits pure capacitive reactive power, Simulation gives the simulation waveform of the system emits inductive and capacitive reactive current and the voltage across the capacitor under the control of direct current method. The literature [6] which application of instantaneous power detection theory to collect real-time power decoupled into active and reactive component, using the relation of the power and switch quantity to control active and reactive power through the simulation verified the effectiveness of control. The simulation results can be further improved.

This paper studies the working principle of STATCOM, According to the triangular carrier direct current control method to build Matlab simulation model validation and study, verify its effect of control and compensation.

II. THE WORKING PRINCIPLE OF STATCOM

In short, The basic principle of STATCOM is self commutated bridge circuit through the reactor or directly parallel to the grid, a properly adjusted bridge circuit in AC side output voltage amplitude and phase, or directly control the AC current, can make the circuit to absorb or emit to meet the requirements of the reactive current, achieve the purpose of dynamic reactive power compensation. According to the structure of STATCOM, it can be divided two types: voltage bridge type circuit and the current bridge type circuit. In fact, due to the reasons of operational efficiency, practical uses is mostly voltage bridge type circuit, so STATCOM specifically refers to Using self commutation voltage bridge circuit as a dynamic reactive power compensation device. Device main circuit structure as shown in Figure 1, Power switch devices use the switch device IGBT which have the capacity of self-switching-off .

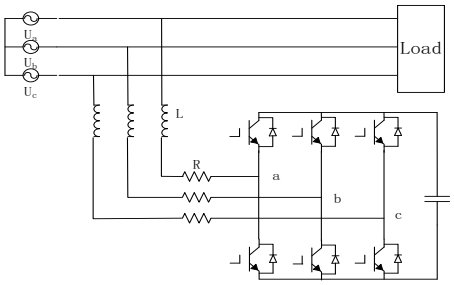
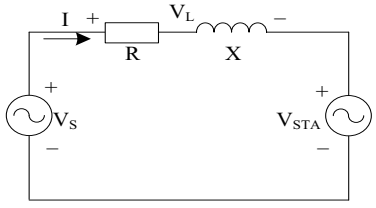


Figure 1. The main circuit structure of STATCOM

By the STATCOM working, it transforms DC side voltage into the output voltage of AC side with the electrical network frequency, which is equivalent to a voltage type inverter, It is equivalent to an amplitude and phase controlled AC voltage source here [7]. The actual phase equivalent circuit and phase diagram as shown in Figure 2, taking into account loss of the circuit, It can be considered the loss as resistance which connect reactor. The grid voltage and the output AC voltage of STATCOM is V_S and V_{STA}, the voltage of reactance is V_L, the reactor equivalent impedance is R, inductive reactance is X, electric current is I.



(a) The actual phase equivalent circuit

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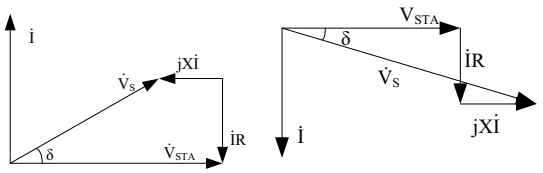


(1) current lead (2) current lags

(b) the working principle of phase diagram

Figure 2. Phase equivalent circuit and phase diagram

As Figure 2 showed, the phase difference of the voltage V_S and current I is not 90°, it is smaller than 90° with a δ angles, grid provides power to supplement the circuit loss, when $V_{STA} > V_S$, current leads the voltage, STATCOM is equivalent to a continuous adjustable capacitor, It is a capacitive mode of operation, absorb reactive power; when the $V_{STA} < V_S$, current lags the voltage, STATCOM is equivalent to a continuously adjustable inductance, It is perceptual mode and absorb reactive power.

III. STRATEGY OF STATCOM DIRECT CURRENT CONTROL

The control method of STATCOM has two kinds: current indirect control and direct control[8] , current indirect control takes STATCOM as a voltage source, through the control of AC voltage wave phase and amplitude which produced by the inverter side to indirect control of AC side current. By adjusting the phase difference δ of the output voltage and the system voltage, or in combination with the control pulse width θ to compensation system; Direct current control uses track PWM technology on current instantaneous value to feedback control. As a result of indirect current control method is relatively simple, the control precision is not high, slow response speed, and the direct current control method response is fast and control precision is high, so It can achieve the effect which the indirect control can not achieve, therefore, this article adopts the direct current control method.

Figure 3 is the block diagram of the instantaneous reactive and harmonic current detection method, in which I_a, I_b, I_c is a three-phase load currents, U_{dcref} is DC side voltage reference value, U_{dc} is the detected DC side voltage. firstly, transform I_a, I_b, I_c into α-β phase coordinates through abc three-phase coordinate, so get i_p and i_q, The process compose of a phase voltage U_a and through the lock link PLL acquisition to get the sine and cosine signals which has the same phase voltage as a phase. In order to obtain the harmonic current and reactive power signal, disconnect the reactive channel i_q (and $i_q=0$), and the DC control signal and the filtered signal are compared with active i_p as active channel signal i_p*, after inversing coordinate into abc three-phase coordinates, calculate the fundamental active current signal.

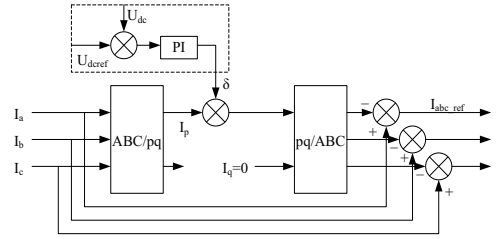


Figure 3. Instantaneous reactive and harmonic current detection

Tracking PWM control technology can use the hysteresis comparison method, it also can be used triangle wave comparison[9,10], In the link of modulation, switch frequency varies with the compensation current in the hysteresis modulation, which causes the great pulsating current and switching noise, while using the triangle wave modulation method, switching frequency is equal to the triangular carrier frequency, pulse current is small, and the output voltage of less harmonic content. Based on the above advantages, this paper adopts the triangular wave comparison.

Triangle wave comparison control compared the detected deviation between the current actual value and reference value with the high frequency triangular carrier phase pulse, the pulse as the inverter switching device to control signal, resulting in the inverter output to obtain the desired current waveform, the control process is shown in figure 4.

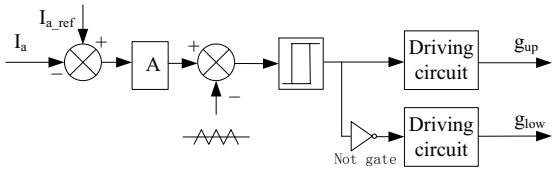


Figure 4. Triangle wave comparison

Figure 4 shows the control mode is different to the use of other triangular wave as carrier wave of PWM control, it does not directly command signal compared with a triangular wave, but through the deviation of the command current and compensation current to the amplifier A and then compared with a triangular wave. Amplifier A often uses proportional integral amplifier. It is composed of a control system which can make the deviation signal control at minimum.

The triangular carrier direct current control method which can realize the simultaneous compensation of reactive power and harmonic, and the DC side voltage control can make the DC side voltage to remain stable, so as to achieve a stable, accurate compensation effect.

IV. MODELING AND SIMULATION ANALYSIS

In this paper, using MATLAB 7.1 Simulink component library to build the simulation model of the line voltage is 220V/50Hz STATCOM, As shown in Figure 5, the model mainly comprises of a power module, a load module, detection module and control module. The load module is composed of two parts, a part is a rectifier load, simulation

of harmonic current; another part is the reactive load, the reactive power change of the load simulation in the network which set in 0.1s.

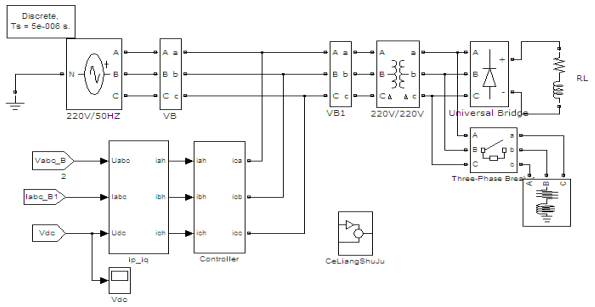
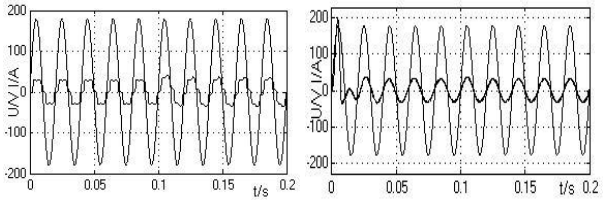


Fig 5. Direct current control MATLAB simulation model

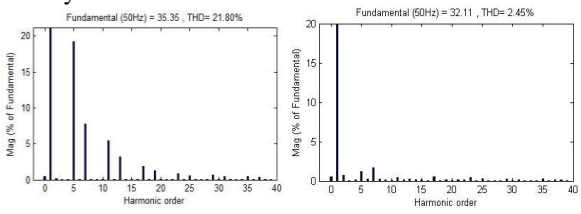
Figure 6 is the voltage and current waveform before and after compensation of phase A. From the Figure (a) can be seen, before the compensation rectifier load harmonics are relatively obvious, reactive load input also caused the current changes in 0.1s. Figure(a) is the voltage and current waveforms of after compensation, compensation system tends to be stable in 0.02s. When the system access a reactive load caused fluctuations in 0.1s, the compensation device respond quickly and achieve good compensation effect. Figure (b) the former 0.02s fluctuations are caused by the impact. when the device just input.



(a) before compensation (b) after compensation

Figure 6. The A phase voltage and current waveform

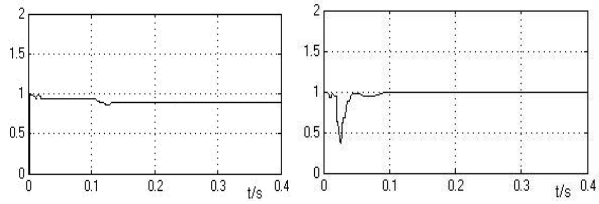
Figure 7 analysis A phase harmonic current spectrum before and after compensation, The figure shows that current distortion rate was 21.80% before the compensation, It is more serious. While the current distortion rate can reduce to 2.45% after the compensation, current quality improved obviously.



(a) before compensation (b) after compensation

Figure 7. The A phase harmonic current FFT analysis

Figure 8 is the power factor changes of A phase circuit before and after compensation, Figure (a) compare with Figure (b), the power factor of A phase circuit is basic for 1 after compensate stably. So STATCOM has good compensation performance on reactive power.



(a) before compensation (b) after compensation

Figure 8. The A phase power factor

Figure 9 is the current tracking effect of the compensation process, compared the reactive current with the detected instruction signal. From the figure can be seen, the reactive current of the device emits and the command signal basically are coincident in 0.01s, It achieve to a precise and fast tracking performance.

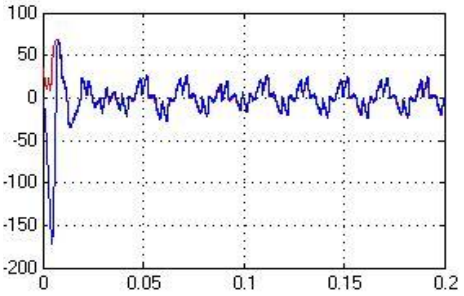


Figure 9. Current tracking effect of the compensation process

Figure 10 is the DC side capacitor voltage waveform, after compensation stably, the DC capacitor voltage can be stabilized to a set value, It still can stable to the set value rapidly when the load is suddenly thrown.

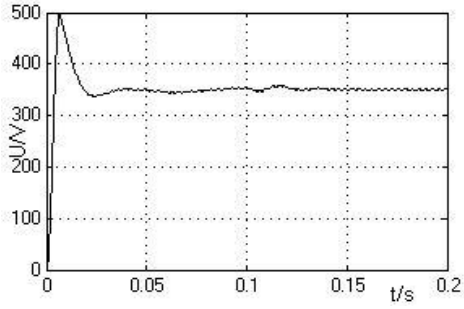


Figure 10. The DC side capacitor voltage waveform

V. CONCLUSIONS

This paper analysis the basic working principle of STATCOM as well as the triangle wave modulation direct current control method, using the MATALB simulation software to build simulation model, a detailed analysis of the STATCOM rectifier load circuit of reactive and harmonic compensation characteristics. The simulation results show that, STATCOM adopts direct current control strategy of

reactive power and harmonic current fast tracking effect, the system reactive power and harmonic has good compensation characteristics.

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