Voltage Stability Control Strategy of Rural End substation Based on SVG

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Abstract. A method of voltage stabilization based upon Static Var Generator (SVG) was proposed in this paper to solve the prominent problems of high energy loss and low terminal voltage of country electrical network in Chaoyang (Lingcheng electric line, 66kV). Relying on the control strategy and the selection of closed loop control amount and regulator, as well as the closed-loop current control of SVG, it is possible to make the output status of SVG change with the actual situation of the system and thus stabilize the voltage of power system.

Introduction

STATCOM（Static Synchronous Compensator）or SVG（Static Var Generator）means that self-commutated power semiconductor bridge converter is used to install dynamic var compensation. STATCOM is the static var compensation device with the best performance. The basic principle is directly to connect self-commutated bridge circuit with power grid in parallel by electric reactor. Appropriately adjusting the phase of bridge circuit exchange output or directly controlling AC side electricity can make the circuits absorb or send out the reactive current meeting requirements, which realizes dynamic var compensation.

Voltage Stabilization Control Strategy

Voltage stabilization control of SVG. The output reactive power of SVG can be controlled by the oblique line according to the change of system voltage. The reactive power is sent rapidly during transient state of power grid (response speed <20ms）,which can maintain the stabilization of power grid.

For the control, the difference between SVG and the traditional SVG is as follows. In SVG, the control signals which are output by outer and closed loop adjuster are used as reference value Bref of equivalent susceptance of SVG, and the signal is used to control and regulate SVG to the required equivalent susceptance. In traditional SVG, the control signals which are output by outer and closed loop adjuster are regarded as the reference value of reactive current (or reactive power) which is generated by compensator.
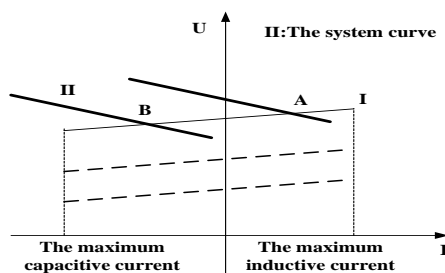

Figure 1　U-I feature curve

The features of SVG voltage-current are shown in Figure 1. We can see that when the voltage of power grid reduces, and the voltage-current feature of compensator reduces, SVG can adjust the amplitude and phase of converter exchange side voltage, to keep the provided maximal reactive current $I_{L\max}$ and $I_{C\max}$ invariable. And it is only limited by current capacity of

power semiconductor device. For traditional SVC, the provided maximal current is restricted by the impedance feature of paralleled electric reactor and capacitor. Therefore, it reduces with the reduction of voltage. Therefore, the operation range of SVG is greater than that of traditional SVG. The operation range of traditional SVC is a triangular area, and the operation range of the practical new SVG is the rectangle area, which is the characteristic of SVG which is better than SVC. The linear range controlled by SVG is the control area of SVG voltage changes with SVG current, in which the current or reactive power can change from capacitive area to inductive area. The actual reactive compensation device is generally not designed to have voltage-current feature of level, but is designed to have the feature of slope (as shown in Figure 1). The design has the following advantages.

(1)Achieving the nearly same control objectives can greatly reduce the specified reactive power of SVG.

(2)It prevents from that SVG is too frequent to achieve the limitation value of reactive power.

(3)Reactive output power of several paralleled reactive compensators is easy to be distributed.

The slope of V-1 feature curve means that the adjustment ratio is defined in the linear control area of compensator, so the formula of the slope KSL is

$$K_{SL} = \frac{\Delta V}{\Delta I} \Omega \qquad (1)$$

In the formula, ΔV ——voltage amplitude increment(V);

ΔI ——current amplitude increment (A).

Per unit value of slope is

$$K_{SL} = \frac{\Delta V / V_r}{\Delta I / I_r} (\text{p.u.}) \qquad (2)$$

In the formula, Vr and Ir——the rated value of SVG voltage and current.

When $\triangle I = Ir$,

$$K_{SL} = \frac{\Delta V(when I_r or Q_r)}{V}(p.u)$$
$$= \frac{\Delta V(when I_r or Q_r)}{V} 100\% \qquad (3)$$

Q_r —— the rated reactive power of SVG.

Therefore, the slope can be defined as the percentage of the voltage to the rated voltage when SVG outputs the maximal reactive power. The maximal reactive power value is the greater of maximal inductive reactive power and maximal capacitive reactive power, the reason for which is that the rated reactive power of SVG corresponds to the greater reactive power. The slope generally keeps in the range of 1％～10％, and the typical value is 3％～5％. It is necessary to add a specific slope in V-1 feature curve.

Reference current calculation. Reference current calculation includes voltage phase detection, direct voltage control, current amplitude setting and amplitude phase synthesis.

The function of phase detection is to rapidly and accurately detect the phase of three-phase voltage. Meanwhile, when system voltage is balanced or not balanced, phase detection algorithm should rapidly separate positive sequence component from negative sequence component.

Direct voltage control module consists of three PI adjusters which make feedback adjustment on three-phase direct voltage. And the output is adding the angle of phase displacement to system voltage phase. In chained SVG, phase displacement angle δ is the most important controlled quantity. When SVG output is different from reactive power, with the change of current, the loss power of installation changes.

Only changing the active power of δ regulating system in SVG can achieve the balance of active power and keep direct voltage constant. Therefore, it is proper to select direct voltage constant as the adjusting objective of phase displacement angle.

The functions of current amplitude setting is to compute the amplitude to be output by

three-phase converter according to the reactive reference value of upper controller. In order to make the control method apply to the conditions that system voltage is balanced or imbalanced, three-phase amplitude should meet

$$\frac{I_{ab}}{V_{ab}} = \frac{I_{bc}}{V_{bc}} = \frac{I_{ca}}{V_{ca}} \qquad (2\text{-}4)$$

V_{ab}, V_{bc}, V_{ca} is the amplitude of three-phase system voltage. On the other hand, the total power of STATCOM output should be equal to reference value Q^*. And the following formula can be used to computer the amplitude of three-phase reference current.

$$I_{ab} = 2V_{ab}Q^* /(V_{ab}^2 + V_{bc}^2 + V_{ca}^2)$$
$$I_{bc} = 2V_{bc}Q^* /(V_{ab}^2 + V_{bc}^2 + V_{ca}^2) \quad (2\text{-}5)$$
$$I_{ca} = 2V_{ca}Q^* /(V_{ab}^2 + V_{bc}^2 + V_{ca}^2)$$

Amplitude phase synthesis module synthesize the stated current amplitude and phase into a sine alternating quantity, and it is the reference value to be traced by STATCOM output current. And the phase of current reference value includes the following parts. Phase angle $\omega t + \varphi$ of system voltage, it can be achieved by the detection of phase detection module. The representation system infuses phase displacement angle δ with reactive power in installation, which is generated by direct voltage control module. Current is in the lead /lags behind phase angle of system voltage, $\pm \pi / 2$. According to the requirement of system absorbing and sending reactive power, when it sends reactive power, the current should be in the lead of voltage $\pi / 2$. And when it absorbs reactive power, it lags behind $\pi / 2$.
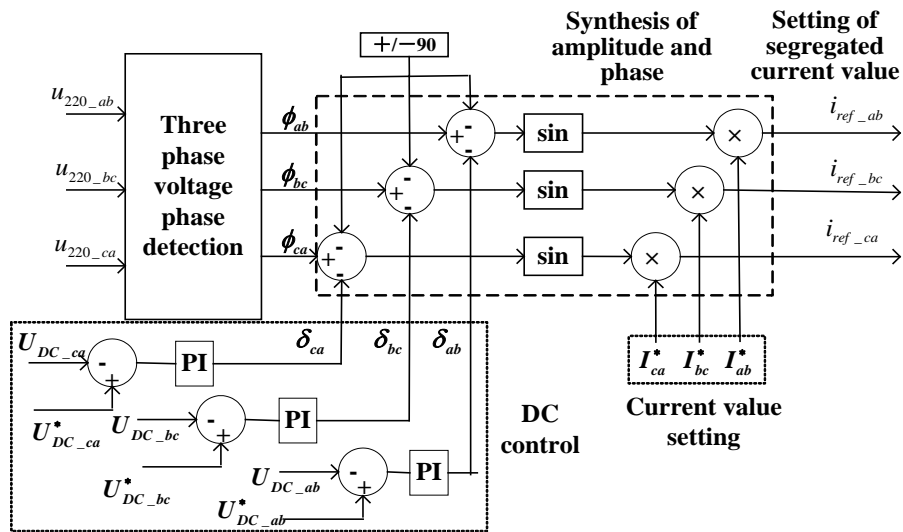

Figure 2 Low voltage strategy

Low voltage and voltage control. At the moment of low system voltage (for example, when there is malfunction), the control logic of SVG locks SVG. Under the situation, if SVG continues to work and voltage adjuster works, SVG will generates great capacitive output, which makes great voltage at the moment of clearing faults. Figure 2 shows the model frame of low-voltage strategy. Vmeas means per unit value of busbar voltage of high voltage side SVG, and UVmin and UVmax means the upper limit and lower limit of low voltage.

When three-phase has faults, and three-phase rectification voltage is lower than threshold voltage Uvmin(it is generally 0.6pu), the following actions are forbidden.

——voltage adjuster is ineffective.

——electric susceptance adjuster is forbidden.

When voltage rises to the second constant value again UVmax(0. 69pu, it is higher than the first

constant value U). After presetting the delay (about 30ms), the suppression is canceled. After presetting the delay for about 170ms, electric susceptance resumes to work. Low -voltage strategy generally ensures that it can works effectively when three-phase has faults rather than during one-phase fault. The difference of two faults is completed by selecting threshold voltage.

If the voltage is high, the control system sends inductive reactive power to system, and control the resection of the near paralleled capacitor group or the investment of electric reactor group, which makes the voltage in the state which is close to or less than 1pu. If the voltage is higher than 1.15pu, SVG sends tripping signal after 1 second.

When system voltage is greater than the allowable value, and SVG output has achieved the extreme of the inductive reactive output, it detects the state of capacitor in the station. If there is online capacitor group, a group of capacitors are cut. If system voltage is low (system operates under stable condition), and SVG output has achieved the limit of capacitive reactive output, the state of capacitor is detected. If there is no online capacitor group, it controls the system to send the order of switching in, and the capacitor group is invested. If the system voltage is still lower than the stated value after investment, online capacitor group is continued to be invested until system voltage is in the allowable range or the capacitor is completely invested.

In order to ensure the safety of system and not influence the lifetime of capacitor group, the order of switching in is not received in 12 hours.

Voltage Stabilization Control Effect

Based on the above voltage stabilization control strategy, SVG equipment operates the rural grid substation of Zhaoyang at the end of 66 kv line——the voltage stabilization control waveform of Daoerdeng substation is shown in Figure 4 (the system voltage stably operates under the situation of 10.6kV).
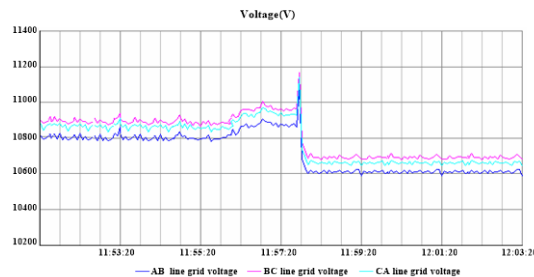
(a) Investing inductive current and reducing system voltage to 10.6kV
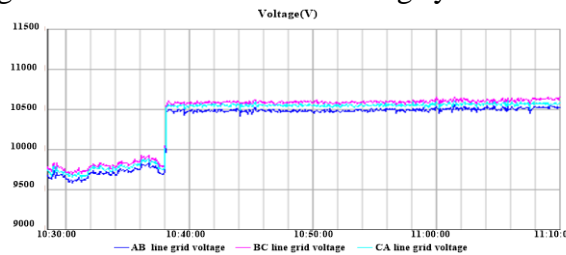
(b) Investing capacitive current and reducing system voltage to 10.6kV
Figure 4 Voltage waveform of SVG operating on Daoerdeng substation

Conclusions

The paper proposes a voltage stabilization method based on SVG. The paper mainly analyzes from control strategy, selection of outer and closed ring feedback control quantity and adjuster. The current closed ring of SVG is controlled to make the output state of SVG changes with the change of actual situation of SVG, to achieve the objective of stabilizing system voltage.

From SVG voltage stabilization control waveform of Daoerdeng substatio--rural grid substation in Zhaoyang, we can see that based on the above voltage stabilization strategy, for the problems of great line loss and low voltage of end users of 66kv line in Zhaoyang rural grid, SVG not only can

stably control voltage, but also can improve the quality of electric energy according to the actual situation of system.

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