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Voltage and Reactive Power Control Considering the Increment of Adjustment of Transformer Substations

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Abstract: The increment of adjustment of transformer substation is always ignored with the traditional voltage and reactive control in transformer substation. Especially when the adjustment to the tap of transformer or the group of reactive compensation equipment is occurred near the critical value, the oscillation is easily generated. To overcome the default, the traditional method is improved in this paper. Because the increment that generated by adjustment of voltage and reactive power can change the value of reactive power of reactive compensation equipment and the voltage value which transformer supplies, the voltage and reactive control adopts the method that considers the increment of adjustment of transformer substation. With calculating the taps of transformer and the value of reactive power, the rapid and accurate adjustment can be implemented.

Key words: Voltage and reactive control, Increment of adjustment, transformer substation

INTRODUCTION

The voltage and reactive control is an important method to guarantee safety and economy operation of power system. As the load fluctuation, it is always frequent to adjust the voltage and reactive in transformer substation. If to do that by man, at one hand, it will increase the burden of the operator on duty; at another hand, it is hard to adjust in reason. According to the standard of power enterprise and the request of do at the Best, the certified ratio of system voltage should be above 99% at percent of pass, the power factor of system should be above 90% at percent of pass. The aim of the voltage and reactive controlling should be:

- To keep the voltage of power supply eligible;
- To keep the stability of electric network and the balance of reactive;
- If the voltage is acceptable, the loss of power should be the least.

The traditional method of voltage and reactive control does not consider the interrelationship of the voltage and reactive in the control, and not consider the change trend of the voltage. When the operating point is at the border of inside and outside, the control system may consider it is inside, so do not do anything; it also may consider the voltage or the reactive is outside, so give the command to change the taps of transformer or switch the group of capacitors, and at the dynamic change of load it may give wrong command to operate. It will lead the frequent switch in the taps of transformer and the groups of capacitors. The surge of adjustment will happen. This case is prohibited in the fact operation.

Otherwise, the reason that the voltage is beyond permission may be rapid change of reactive; also may be the change of voltage of the high-tension side; and the change will be a time-continuing process. If the reason is that the change of voltage of the high-tension side, and the operating point is at the border of reactive, it will lead to the wrong switch of the group of capacitors. If the operating point is also at the border of voltage, it will lead to the wrong adjustment to the taps of transformer. If we adjust to the taps of transformer when the shortage of reactive is heavy, it will lead to the negative voltage regulation effect, and make the voltage more instability[1].

Aiming at shortcoming of the existing methods for adjustment of the reactive voltage, an improve method is given in this paper. This method considers the increment generated by adjustment of voltage and reactive power. When taps of transformer is adjusted, the value of reactive power of reactive compensation equipment is correspondingly changed. When the reactive power of reactive compensation equipment is adjusted, the voltage value that transformer supplies is also correspondingly changed. By reckoning in adjustment increment of the taps of transformer and the value of reactive power, the control of voltage and reactive can be optimized, and a

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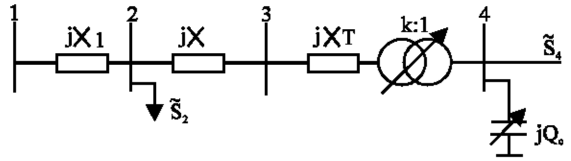

Fig.1: The main system chart of the synthesis control of reactive voltage

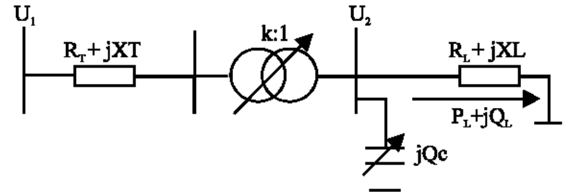

Fig.2: The circuit of the integration- governing reactive voltage in transformer substation

proper controlled quantity of the reactive voltage gotten quickly.

The Traditional Voltage and Reactive Synthesis Control in Transformer Substations: The traditional voltage and reactive control method is always to measure the voltage and reactive of the system, then determine how to switch the taps of the transformer and the groups of the capacitors[1,2]. But this method dose not consider the effect on switching capacitors to the voltage and changing voltage to the reactive power, the voltage and the power factor of the system adjusted have some deviation to the result that we hope.

We suppose there is a four-node simulation of power supply system as shown in Fig.1, the classification of voltage is 110kV. The resistance values of the line and the transformer are reduction to the high-voltage side. The transformer voltage rate is 110/11kV. When the voltage of the third node is 102kV, the load of the fourth node is 24+j17MVA. We suppose that the change of the voltage request the fourth node's voltage to be above 10.5kV, the power factor of the third node should be above 0.9. According to the traditional voltage and reactive control method, the transformer voltage rate should be 9.625, the voltage of fourth node should be 10.6kV; the given reactive should be 6Mvar, the output power factor should be 0.909.

But the changes of voltage have effect to the size of the load, if also have the effect to output of the reactive power compensation equipment. The output of the reactive power compensation equipment is direct ratio the square of node-voltage. The switch of the reactive power equipment also has effect to the node-voltage. When the reactive of transformer and line change, the voltage drop of the transformer and line will also change. The change will have an effect on the node-voltage. So it is flaw to adjust to the voltage and reactive isolated.

Determine the rate of voltage regulation and the capacity of the reactive power compensation: When the voltage of the transformer substation or the reactive of system has changed, the voltage of the low-voltage side of the transformer and the power factor of system should keep.

As shown in Fig.2, the transformer is expressed as the connection of resistance branch and the perfect transformer in series.

By the traditional reactive voltage control method, there are:

$$U_1 = kU_2 + \frac{P_L R_T + (Q_L - Q_C)X_T}{kU_2} \quad (1)$$

$$Q_C = mQ_{CN} \quad (2)$$

Q_{CN} means the rated capacity of a group of reactive power compensation equipment;

m means the groups of reactive power compensation equipment;

k means the voltage rate of the transformer.

The input voltage U_1 and the load power P_L+jQ_L of the transformer substation can be measured. In the Eq. 1 and 2, they are quantities known. The rate of the transformer (k) and the groups of reactive power compensation equipment (m) are quantities unknown.

When the voltage rate of transformer is determined by regulating the position of tap switch of the transformer with load, the voltage rate's solution space can be known, and it is denoted discrete numerical value. When the groups of capacitors (m) are determined by switching capacitors with load, the solution space can also be known and denoted discrete numerical value.

The different values of k and m are substituted into Eq. 1 and 2, the solution of U_2 and Q_c can be gotten rapidly. According to the request of the system to U_2 and cosφ, the proper value of k and m can be chosen.

But, if the adjustment increment is not considered, namely operators put these results into actual control, the adjustment effect is not perfect.

At the lower part, the adjustment increment will be considered, and used to modify the result above.

Supposed that the module value of load is Z_c, phase angle is φ, then:

$$R_L = Z_L \cos\varphi \quad (3)$$

$$X_L = Z_L \sin\varphi \quad (4)$$

$$Z_L = \frac{U_{2N}^2}{\sqrt{P_L^2 + Q_L^2}}, \quad \varphi = \arctan\frac{Q_L}{P_L}$$

Supposed that the voltage increment aroused by the reactive change of system after adjustment is $\triangle U_2$, then:

$$U_2^{'} = U_2 + \Delta U_2 \tag{5}$$

In the Eq. (5), U_2 means the voltage value not considering the increment after adjustment, U_2' means the voltage value considering the increment. So the power increment of load is:

$$\Delta Q_L = \frac{U_2^{'2}}{R_L^2 + X_L^2} X_L - Q_L \tag{6}$$

$$\Delta P_L = \frac{U_2^{'2}}{R_L^2 + X_L^2} R_L - P_L \tag{7}$$

The increment of the output reactive of the parallel capacitors is:

$$\Delta Q_C = U_2^{'2} \varpi C - Q_C \tag{8}$$

$$Q_C = U_2^2 \varpi C_C$$

Supposed that the reactive increment of system after adjustment is $\triangle Q$, then:

$$\Delta Q = \Delta Q_L - \Delta Q_C \tag{9}$$

After considering the increment, the voltage of high-voltage side of transformer is:

$$\Delta U_2 = \frac{\Delta P_L R_T + \Delta Q X_T}{U_2} \tag{10}$$

$\triangle U_2$ can be calculated in Eq. 10.

After considering adjustment increment of the reactive voltage, there are:

$$U_1 = k' U_2^{'} + \frac{(P_L + \Delta P_L) R_T + (Q_L + \Delta Q) X_T}{k U_2^{'}} \tag{11}$$

$$Q_C + \Delta Q_C = m' Q_{CN} \tag{12}$$

In Eq. 11 and 12, the rate of the transformer (k') and the groups of reactive power compensation equipment (m') can be calculated. Action of adjustment increment of the reactive voltage is alternate and multiple, but first time is the most strong. Generally, getting k' and m' from Eq. 11 and 12 need only one time.

APPLICATIONS

The emulate parameter of transformer substation equipment is:

Table 1:The data that meet the demand of integration-governing

k k,	m m,	U_2 BM	 AM	$\cos\varphi_1$ BM	 AM
9.25	0	10.987	10.987	0.907	0.907
9.25	1	11.022		0.908	
9.25	0		10.987		0.907
9.375	0	10.840	10.817	0.907	0.907
9.375	2	10.909	10.886	0.909	0.909
9.375	5	11.010		0.911	
9.375	4		10.991		0.911
9.5	0	10.698	10.685	0.907	0.907
9.5	2	10.765	10.751	0.909	0.909
9. 5	6	10.898	10.886	0.912	0.911
9.5	8	10.963	10.955	0.912	0.912
9.625	2	10.625	10.619	0.909	0.909
9.625	6	10.756	10.749	0.912	0.911
9. 75	3	10.522	10.521	0.910	0.910
9. 75	6	10.619	10.615	0.912	0.911
9.875	8	10.546	10.546	0.912	0.912

The transformer parameter: SFZ9-40000/110, $Y_0/\triangle$-11, voltage rate: 110±1.25%/11KV,

The resistance that reduction to high-voltage side: 0.93+j31.76Ω;

The capacitors parameter: 1Mvar, 8groups.

The transformer voltage rate's solution space is:

(9,9.125,9.25,9.375,9.5,9.625,9.75,9.875,10, 10.125,10.375,10.5,10.625,10.75,10.875,11}

The capacitor group's solution space of reactive power compensation equipment is:

{0, 1, 2, 3, 4, 5, 6, 7, 8}.

Supposed that load of the transformer on rated voltage is 27+j10MVA, the bus voltage at the high-voltage side is 105kV, the bus voltage requested at the low-voltage side is between 10.5kV and 11kV, the power factor requested at the low-voltage side is greater than 0.9.

From table 1, it is shown that if the adjustment increment of the reactive voltage is not considered, the solution set in Eq. (1) and (2) may be beyond voltage criterion, but if the adjustment increment is considered, the solution set in Eq. (11) and (12) is not beyond voltage criterion. For example, from the second and 5th line's values in Table 1, it is shown that if Eq. (1) and (2) are applied, the voltage of transformer low-voltage side (11.022kV and 11.010kV) is not eligible, but if Eq. (11) and (12) are applied, the voltage of transformer low-voltage side (10.987kV and 10.991kV) it is eligible. The increment has more effect to the voltage at low-voltage side of transformer, and less effect to the power factor. The reason is that the change of voltage has effect both to the consumed power of load and the reactive output of compensation capacitors, and all these effects reflect at power factor is smaller.

CONCLUSIONS

If reactive compensation equipment is switched simply, the increment can not be considered. When the reactive voltage is integration governing, if the increment is not considered, adjustment error will lead to. So if the voltage and reactive control adopts the method considering the increment, the result is more meet the need of practical operation, and avoids adjustment oscillation. The adjustment results can be calculated rapidly by acquisition real-time values of system, if it can meet the need of real-time calculation.

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