Effect of Capacity Imbalances of 500 kV Standby Transformer on Its Current

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***Abstract*—To avoid the economic loss caused by transformer failure, power companies will reserve a certain number of standby transformers. Reasonable choice of the number and capacity of transformer can effectively increase economic efficiency. In this paper, when the capacity of 500kV standby transformer is not equal to the original transformer capacity, the variation rule of zero sequence current is researched. And an example is illustrated. The following suggestions are given. First, the medium voltage side of capacity imbalance of standby transformer should keep splitting operation. Second, try to keep same variable ratio of each phase of capacity imbalance transformer. Third, when capacity imbalance of standby transformer is operating, all side currents should smaller than rated currents. Finally, capacity of reactive power compensation equipment, that band to the low voltage winding of capacity imbalance of standby transformer, is not more than 160MVar.**

Keywords- Transformer capacity imbalances; Standby transformer; Circulation current; Zero sequence current

I. INTRODUCTION

Power Grid Company would suffer great economic loss caused by power transformer fault. To avoid it, the reliability of transformer should be improved, and timely online monitoring of transformer insulation system should be implemented. In addition, a certain number of standby transformers should be reserved, which can timely replacement fault transformers to ensure the continuity of power supply. As 500kV transformer is an important node in the grid, ensure its reliability and continuity is significant [1-2]. Usually, 500kV transformer is composed of three single-phase transformer units. When one phase fails, the standby phase transformer can replaced it. However, the capacity of 500kV transformer of power companies is not entirely consistent [3-6]. If the capacity between standby transformer and accident transformer are not equal, what affect would the capacity of 500kV power transformer on the current imbalance? Within short-term of the transformer accident maintenance, can we adopt unbalanced capacity transformer to run?

were calculated with examples.

In this paper, effect of capacity imbalances of 500 kV standby transformers on its zero sequence current is researched. And an example is illustrated. Finally, some suggestions about the run of capacity imbalances of 500 kV standby transformer are given.

II. GENERATION OF UNBALANCED CURRENT

500kV have two kinds of capacities, which are 750 MVA and 1000 MVA (the capacities of single-phase transformer are 250 MVA and 334 MVA). If we use single-phase transformer with 334 MVA take place single-phase transformer with 250 MVA that was failure, there is zero sequence current caused by capacity imbalances of 500 kV standby transformers (see Fig.1).

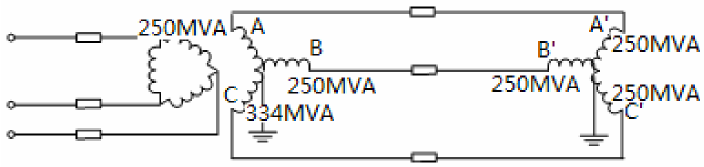

Fig.1 generation of unbalance current

Transformers parallel operation should meet the following conditions:

1）Rated voltage of the respective transformer should be equal, namely, the transformer turns ratio should be equal.

2）The respective transformer should belong to the same connection group.

3）In per unit value of the respective transformer short-circuit impedance should be equal.

4）Maximum capacity of the transformer in parallel with the minimum capacity of not more than 3:1 ratio.

III. UNBALANCED ZERO SEQUENCE CURRENT CALCULATION OF 500KV TRANSFORMER

As 500kV JS and SBQ transformer station an example, calculate zero sequence current caused by capacity imbalances of 500 kV standby transformer with one 334 MVA single-phase transformer and two 250 MVA single-phase transformer.

Tab.1 2# 500kV transformer parameters of JS substation

Run No.	Rated capacity MVA	Voltage ratio	Impedance voltage (%)		
			High - Medium	High- Low	Medium- Low
2# A	250	525/√3/230/√3±8×1.25%/35	12.22	43.54	28.68
2# B	250	525/√3/230/√3±8×1.25%/35	12.79	43.42	28.56
2# C	250	525/√3/230/√3±8×1.25%/35	12.78	43.48	28.71

Tab.2 1# 500kV transformer parameters of SBQ substation

Run No.	Rated capacity MVA	Voltage ratio	Impedance voltage (%)		
			High - Medium	High-Low	Medium-Low
1# A	334	525/√3/230/√3/±2×2.5%/36	16.47	60.29	39.15

If the A phase of 750MVA group transformer fault, use 334MVA single phase transformer replace it and calculate zero sequence current of this capacity imbalances of 500 kV transformers. Rated current of B and C phases are

$$I_{bN}=I_{cN}=\frac{S_{bN}}{U_{bN相}}=\frac{250000}{\frac{525}{\sqrt{3}}}=824.8\text{(A)}$$

The equivalent leakage reactance of 334MVA single-phase transformer high-voltage side is

$$\text{U}_{k1}\%=0.5(\text{U}_{k1-2}\%+\text{U}_{k1-3}\%-\text{U}_{k2-3}\%)=0.5$$

$$(16.47+60.29\text{-}39.15)=18.8$$

$$\text{X}_a=\frac{\text{U}_{k1}\%}{100}\frac{U_{aN}^2}{S_{aN}}=\frac{18.8}{100}\frac{525^2}{334}=155.1(\Omega)$$

The equivalent leakage reactance of 250MVA single-phase transformer high-voltage side is

$$\text{U}_{k1}^{'}\%=0.5(\text{U}_{k1-2}^{'}\%+\text{U}_{k1-3}^{'}\%-\text{U}_{k2-3}^{'}\%)=0.5$$

$$(12.22+43.54\text{-}28.68)=13.54$$

$$X_b=X_c=\frac{\text{U}_{k1}^{'}\%}{100}\frac{U_{bN}^2}{S_{bN}}=\frac{13.54}{100}\frac{525^2}{250}=149.3(\Omega)$$

From $S=\frac{U^2}{X}$, we can see that capacity is inversely proportional to electrical resistance. Let k A, B, relative to the capacity of the distribution coefficient, there are

$$k=\frac{S_a}{S_b}=\frac{X_b}{X_a}=\frac{149.3}{155.1}=0.963 \qquad (1)$$

Therefore, When B, C phase to the rated capacity, A phase capacity is

$$S_a=kS_{bN}=0.963\times 250000=240750\ \text{(kVA)}$$

Transformer load was set as $\beta=\frac{S}{S_N}$, so

$$\beta_a=\frac{240750}{334000}=75\%,\quad \beta_b=\beta_c=100\%$$

$$\beta=\frac{240750+250000\times 2}{334000+250000\times 2}=88.8\%$$

At this time, a phase current is

$$I_a=\frac{S_a}{U_{aN相}}=\frac{240750}{\frac{525}{\sqrt{3}}}=794.27\text{(A)}$$

zero sequence current I_0 is the sum of vectors of I_a、I_{bN} and I_{cN}. See Fig.2.

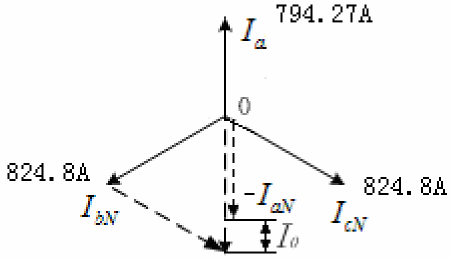

Fig.2. current vector diagram of 500kV group transformer

The result of calculation is

$$I_0=824.8-794.27=30.53\ \text{(A)}$$

As with load, the capacity allocations of A, B and C phases are not only associated with the winding resistance, but also with the line impedance, load impedance and power structure. It is not a definite value. So, it needs that building a model of unbalanced capacity group transformer, and uses it in the actual power grid simulation.

IV. SIMULATION AND ANALYSIS

A. *Simulation conditions*

The simulating calculation does not consider the power imbalance, transformers body imbalances, power loss and core saturation.

According to the 500kV single phase auto transformers survey of Sichuan power grid, the transformer high-pressure side voltages of SBQ, SM, LW substations are different from that of 334MVA 500kV standby transformer. Therefore, as a simulation case, we build a group transformer simulation model that is composed of one 334MVA single phase transformer, which parameters are just like the transformer's of SBQ substation (see tab.2), and two 250MVA single phase transformers, which parameters are just like the transformer's of JS substation (see tab.1). Then take this group transformer as one transformer of SBQ substation and calculate zero sequence current when run separately in the medium voltage side. There are two the simulation conditions. One is that the voltage ratios of those two capacities transformers should as equal as possible. The other is that the medium voltage of those two capacities transformers should as close as possible.

B. *Simulation results*

In simulation adopt standby transformer on SBQ substation. B phase is standby single phase transformer. Firstly, set voltage ratio according to the parameters in Tab. 2. Then calculate zero sequence current when run separately in the medium voltage side according to the two simulation conditions.

The simulation results are shown in Tab.6. The capacity of adjacent transformer is 250MVA/250MVA/250MVA. The load of two transformers medium voltage side of SBQ substation is equal. There is no-load on low voltage side voltage winding.

Tab.3 Simulation results of SBQ substation

substation	capacity (MVA)	rated current		
		HV side	MV side	LV side
Transformer of SBQ	250	787.3	1789.3	2222.2
Standby transformer	334	1102	2515	2222

From Tab.3, we can see the imbalance currents of no load conduction are almost equal, which are 73A in HV side and 212A in LV side. On rated load, when the voltage ratios are close for those two transformer, zero sequence currents of HV, MV and LV are 65A、40A and 212A. When the medium voltage are close for those two transformer, zero sequence currents of HV, MV and LV are 83A、47A and 197A. The current increments of zero sequence circulating currents are basically unchanged with the increase of load.

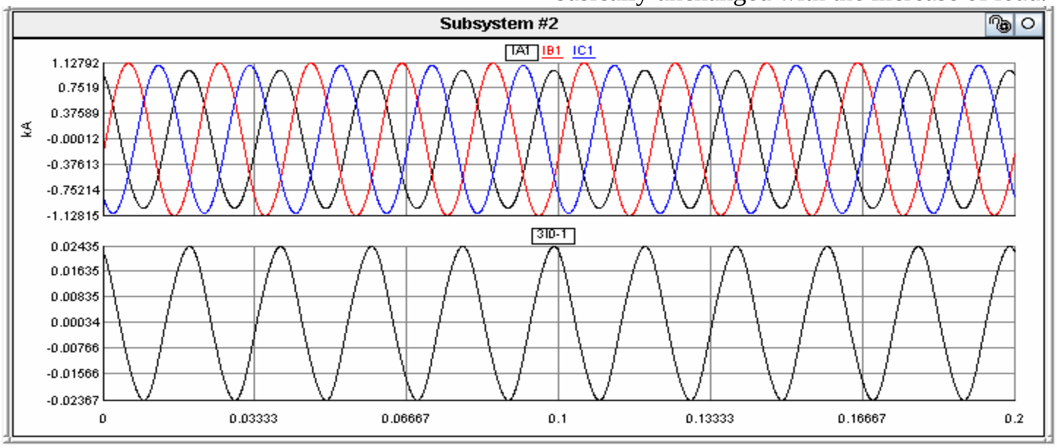

Fig.3 phase current and zero sequence current in transformer HV winding of SBQ station with rated load and closely voltage

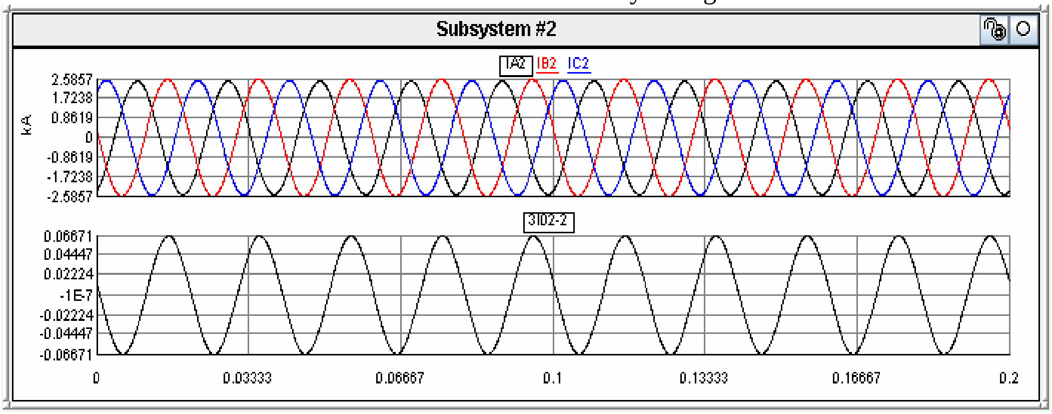

Fig.4 phase current and zero sequence current in transformer MV winding of SBQ station with rated load and closely voltage

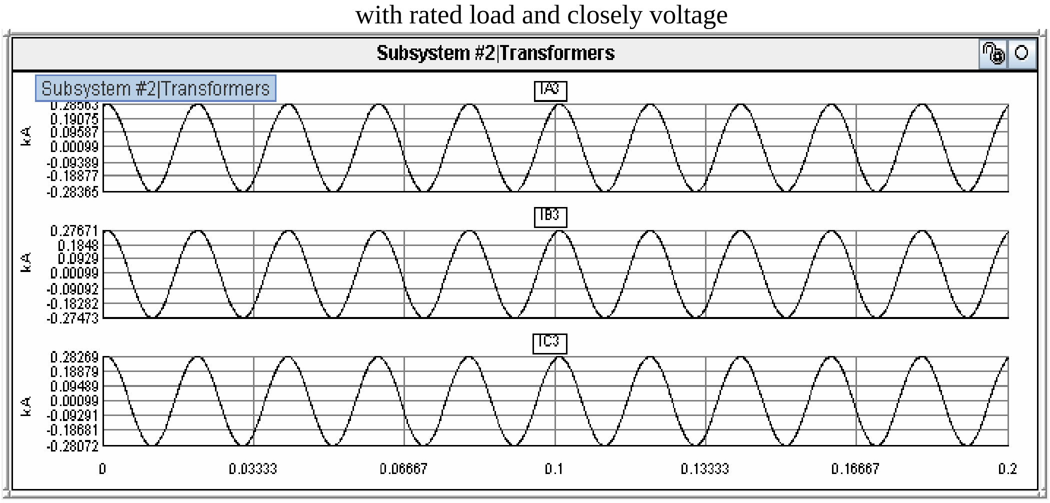

Fig.4 zero sequence current in transformer LV winding of SBQ station with rated load and closely voltage

V. CONCLUSION

When using 334MVA single phase transformer as 500kV standby transformer of SC power grid, although effect of the standby transformer on short-circuit voltage is greater, the equivalent impedance transformer load impedance than that of transformer body is larger. So, the three-phase current transformer high voltage side and medium voltage sides are in the basic balance, and HV, MV bus voltages are balance. There is 26-200A of the zero-sequence circulation current in low voltage winding. Take JS substation as an example, after adopting capacity imbalance of standby transformer, the zero sequence currents in HV, MV windings are little, respectively 9A and 2A. There is 26A of the zero-sequence circulation current in low voltage winding. If the load is increase, vary of voltage and zero-sequence current in low voltage winding is very little.

Though above simulating calculation, the following suggestions is given, to restrain the zero sequence current caused by capacity imbalances of standby transformer. First, the medium voltage side of capacity imbalance of standby transformer should keep splitting operation. Second, try to keep same variable ratio of each phase of capacity imbalance transformer. Third, when capacity imbalance of standby transformer is operating, all side currents should smaller than rated currents. Finally, capacity of reactive power compensation equipment, that band to the low voltage winding of capacity imbalance of standby transformer, is not more than 160MVar.

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