Identification of Transformer Parameter based on Least Square Method

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Abstract

Because of the connection mode of the transformer, separately write loop equation, the eliminate the affection of the circulation and the public flux linkage in the triangular side winding. This way does not need to change the TA configuration of the triangle side.The direct use of the triangle constructed line current transformer winding resistance and inductance parameter identification algorithm. The simulation is carried out by EMPT. The results show that the parameter identification algorithm is stable, not affected by the load fluctuation and the change of the power factor. This identification accuracy is high precision.

Keywords

Transformer; least square method; parameter identification.

1. Introduction

Among the many transformer protection methods, method of differential protection count for the most.There are two aspects of transformer main protection requirements, the first to prevent the external short-circuit current imbalance, second to prevent the inrush current caused by false action. The principle of differential protection based on the current and the two current leaving the network. Each phase of the primary and the secondary current transformer as unbalanced current transformer differential protection source, but in the transformer over excitation work,the excitation current exceeds the rated current of the transformer, which is bound to result in differential protection of the wrong action. Even very likely, transformer end power when short circuit interruption of external circuit of transformer a sudden pressure recovery, or in no-load transformer closing suddenly,the short-circuit current and inrush current are equal, in such a large current imbalance, will inevitably lead to differential protection. As a result, these shortcomings lead to differential protection can not meet the main protection of speed, so that fault is magnified.

References [1-4] proposed increases and the manufacturing process of improvement in the capacity of transformer, the EHV transmission line length, and the increase in system capacity and equipment increased, the secondary harmonic brake reliability issues have become increasingly prominent, in order to solve this problem, the majority of experts were a lot of research, put forward some solution method, and also made some progress, literature [6] Hao country et al proposed a new principle of transformer circuit equilibrium equation of transformer protection based on the, jumped out of the traditional differential protection principle of ideas, to circumvent the magnetizing inrush current and fault current flow of discriminant, has opened up new ideas of transformer protection, has good application prospects. In the paper, [1] is used to judge whether the transformer is fault by the admittance parameters in the equivalent circuit, and the reference [6] and [7] are used to realize the protection of the transformer by constructing the protection criterion using the transformer circuit equation.

In this paper, a method of identifying transformer inductance and resistance parameters by least square method with forgetting factor is derived. In no need of a given triangle side of the phase currents, but features based on the side of the triangular loop three-phase equal, elimination of the loop equations of nonlinear term and circulation, using dynamic forgetting factor least square method quickly and easily realize parameter identification of transformer, into the loop variable pressure protector lay the foundation.

2. Basic principles

The equivalent circuit of the double winding one-way transformer is shown in Figure 1. The electromagnetic relationship between the original and the secondary side of the transformer is always established for the normal operation and the external fault of the double winding single phase transformer.

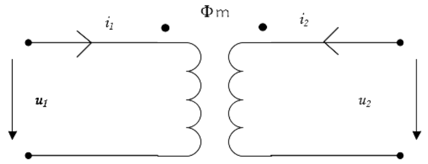

Fig. 1 Equivalent model of double winding

According to the reference direction provided in Figure 1, the winding circuit equation:

$$\left.\begin{aligned} u_1 &= i_1 r_1 + L_1 \frac{di_1}{dt} + N_1 \frac{d\varnothing_m}{dt} \\ u_2 &= i_2 r_2 + L_2 \frac{di_2}{dt} + N_2 \frac{d\varnothing_m}{dt} \end{aligned}\right\} \tag{1}$$

In this equation: u_1,u_2,i_1,i_2 is primary and secondary winding voltage and current; r_1,r_2,L_1,L_2 is the primary winding and the secondary winding resistance and leakage inductance, N_1,N_2 for the original, secondary side winding turns; $\varnothing_m$ for the original, secondary side winding mutual flux.

Under the condition of normal operation, inrush current and external fault, the mutual inductance magnetic flux calculated by the formula (1) should be the same, and the equation of the primary and secondary side winding circuit (2) is obtained, and $K= N_1/N_2$:

In the new theory, both the voltage and current can be obtained through the mutual inductor, so the precision of both sides of the resistance and inductance value can directly influence the accuracy of the new principle.

$$\int_0^{t_1}\left(u_1 - i_1 r_1 - L_1\frac{di_1}{dx}\right)dt - K\int_0^{t_1}\left(u_2 - i_2 r_2 - L_2\frac{di_2}{dx}\right)dt = 0 \quad (2) \tag{2}$$

In the power system, the transformer connection mode based on double winding connection of the transformer as an example, as shown in Figure 2, for the convenience of analysis, a transformer ratio is 1, and the error ratio regardless of the voltage transformer and the current transformer.

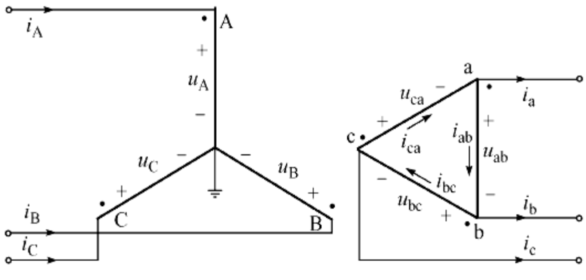

Fig. 2 Connected three-phase transformer

As shown in Figure 2, in order to I, u expressed the instantaneous value of voltage and current, Y side with A, B, C, secondary side with a, b, c,and it means the winding outlet current. Y side A phase loopequation is:

$$u_A = R_A i_A + L_A \frac{di_A}{dt} + \frac{d\Psi_{Aa}}{dt} \tag{3}$$

As it shown in equation (3) L_A and R_A are leakage inductance and resistance of Y side A phase; Ψ_{Aa} is common flux linkage for A phase and a phase winding.

Secondary side a phase loop equation is:

$$u_{ab} = R_{ab} i_{ab} + L_{ab} \frac{di_{ab}}{dt} + \frac{d\Psi_{Aa}}{dt} \tag{4}$$

L_{ab} and R_{ab} respectively present leakage inductance and resistance of side a phase winding. Elimination of the original, secondary side winding mutual flux linkage Ψ_{Aa}, then:

$$u_A - R_A i_A - L_A \frac{di_A}{dt} = u_{ab} - R_{ab} i_{ab} - \frac{di_{ab}}{dt} \quad (5)$$

According to the relationship between side current and phase winding currents :

$$\begin{cases} i_a = i_{ca} - i_{ab} \\ i_b = i_{ab} - i_{bc} \\ i_c = i_{bc} - i_{ca} \end{cases} \quad (6)$$

When the secondary side is empty , assume that:

$$i_{ab} = i_{bc} = i_{ca} = i \quad (7)$$

Take the formula(7) into the formula(5),

$$u_A - R_A i_A - L_A \frac{di_A}{dt} = u_{ab} - R_{ab} i - L_{ab} \frac{di}{dt} \quad (8)$$

In the same way:

$$U_B - R_B i_B - L_B \frac{di_B}{dt} = u_{bc} - R_{bc} i - L_{ab} \frac{di}{dt} , \quad (9\text{-}10)$$

$$u_C - R_C i_C - L_C \frac{di_C}{dt} = u_{ca} - R_{ca} i - L_{ca} \frac{di}{dt}$$

Combining equation (6) ~ (8), at the same time, in the primary winding make $R_1=R_A=R_B=B_C$, in the secondary windings $R_2=R_{ab}=R_{bc}=R_{ca}$, then

$$\begin{aligned} &(L_{bc} - L_{ca})u_A + (L_{ca} - L_{ab})u_B + \\ &(L_{ab} - L_{bc})u_C - (L_{bc} - L_{ca})u_{ab} \\ &-(L_{ca} - L_{ab})u_{bc} - (L_{ab} - L_{ba})u_{ca} = \\ &(L_{bc} - L_{ca})R_1 i_A - (L_{ca} - L_{ab})R_1 i_B - \\ &(L_{ab} - L_{bc})R_1 i_C + (L_{bc} - L_{ca})L_A \frac{di_A}{dx} + \\ &(L_{ca} - L_{ab})L_B \frac{di_B}{dx} + (L_{ab} - L_{bc})L_C \frac{di_C}{dx} \end{aligned} \quad (11)$$

In order to reduce the number of parameters to be identified , let the $e_1=L_{ab}-L_{bc}$,$e_2=L_{bc}-L_{ca}$,$e_3=L_{ca}-L_{ab}$, so then e2/e3,e1/e3,(e2/e3)LA,LA,(e1/e2)LA, are considered as unknown to identify,so that LA,LB,LC take into formula(10),and then set e1,e2,e3 as unknown parameters.

$$\begin{aligned} &e_2 u_A + e_3 u_B + e_1 u_C - e_2 L_A \frac{di_A}{dt} - \\ &e_3 L_B \frac{di_B}{dt} - e_1 L_C \frac{di_C}{dt} = e_2 u_{ab} + e_3 u_{bc} + \\ &e_1 u_{ca} + e_2 R_1 i_A + e_3 R_1 i_B + e_1 R_1 i_C \end{aligned} \quad (12)$$

By Solving the equations e_1, e_2, e_3 are gotten, then solve the formula (13):

$$\begin{cases} e_1 = L_{ab} - L_{bc} \\ e_2 = L_{bc} - L_{ca} \\ e_3 = L_{ca} - L_{ab} \end{cases} \quad (13)$$

$$\begin{aligned} &e_2 \left[u_A - L_A \frac{di_A}{dx} - u_{ab} - R_1 i_A\right] + e_3 \left[u_B - \right. \\ &\left. L_B \frac{di_B}{dx} - u_{bc} - R_1 i_B\right] + e_1 \left[u_C - L_C \frac{di_C}{dx} - \right. \\ &\left. u_{ca} - R_1 i_C\right] = 0 \quad (14) \end{aligned} \quad (14)$$

So L_{ab}, L_{bc}, L_{ca} can be obtained.

3. simulation experiment and its results

The voltage and current of the transformer are generated by the electromagnetic transient simulation program EMTP, and the three-phase Y and the D transformer are connected by 3 single phase transformers. Parameters of the transformer set: rated voltage of 330 kV / 110 kV, supply voltage shifting of 30 degrees, former vice winding resistance and leakage inductance for:

$$R_A = R_B = R_C = 0.94\ \Omega$$
$$R_{ab} = R_{bc} = R_{ca} = 0.285\ \Omega$$
$$L_A = L_B = L_C = 1540\text{mH}$$
$$L_{ab} = L_{bc} = L_{ca} = 51\text{mH}$$

Produce waveform as shown in figure3:

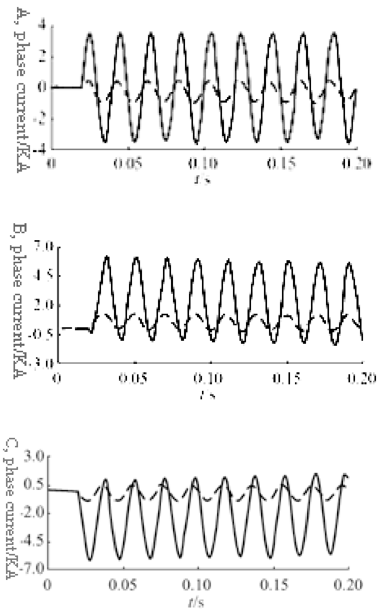

Fig 3 three-phase current

Figure 3 shows that the inrush current waveform during no-load deviates from the horizontal axis, then a slow recovery. Using EMTP generated voltage and current waveform data, 400 points per cycle of sampling, parameter identification. The error of the identification results is less than 1%, and the estimated value is stable after convergence and no oscillation.

Table 1 simulation data leakage inductance calculation

parameter	Set value /mH	Estimated value /mH	error/(%)
LA	1540	1 538.048 7	-0.31
LB	1540	1 538.852 7	-0.07
LC	1540	1 540.685 3	0.04
Lab	51	51.164 8	0.32
Lbc	51	50.852 7	-0.29
Lca	51	51.206 4	0.40

The identification results are shown in table 1. As seen from the table 1, using the least square algorithm to identify the leakage inductance parameters, the error of the results is less than 0.4%.

4. Conclusion

(1) presents a transformer resistance, inductance parameter online identification method, the method for delta winding configuration TA difficult characteristics, does not change the TA configuration, solve the connection of three-phase transformer resistance and inductance calculation problem, can get transformer online dynamic resistance and inductance values.

(2) the parameter identification algorithm is stable and reliable, and the transformer operating conditions (including load size and power factor) will not affect the results of parameter identification.

(3) error parameter identification mainly by the identification algorithm of excitation current, delta winding loop compensation and phase error, and the real-time data is read when the transformer and data sampling error of the measurement system, when the identification parameters are applied in the occasions of high precision and can compensate the error term.

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