PRECISION MEASUREMENT OF CAPACITANCE TO GROUND IN NEUTRAL COMPENSATING NETWORK AND ONLINE MONITORING OFCAPACITANCE TO GROUND IN NEUTRAL ISOLATED NETWORK

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The capacitance to ground (3Co) of the network is an important basic data for a neutral non-effectively grounding network. Timely and accurately know well of it can give full play in the effect of fault management.

Currently, there are many ways to handle the 3Co of the system. But some of them are not really perfect and some of them even contain important defects.

In this paper, we analysis the inadequate points in some currently used measuring methods and in the calculating algorithm. And on such bases we introduced the new calculating method which is more effective.

1. Precision Measurement of Capacitance to Ground in Neutral Compensating Network

1.1 CURRENTLY MEASURING METHODS AND ITS INADEQUATE POINT

There are currently to have the function to measuring the capacitance to ground online in the automatic follow-up tuning type arc suppression coil (or say Peterson coil). The method is: by the tuning test we can have two resonance curve I and II, as shown in Fig. 1. It represents the status information of under-compensation and over-compensation respectively. And then we can use the data I_{L1}, U_{01} and I_{L2}, U_{02} from the curve I and II to calculate the capacitive current of the network by the equation (1):

$$I'_C = \frac{I_{L2} - \frac{U_{01}}{U_{02}} I_{L1}}{1 - \frac{U_{01}}{U_{02}}} \qquad (1)$$

Where I_{L1}, U_{01} and I_{L2}, U_{02} are the inductive current and the displacement voltage of the neutral point respectively.

According to the results of many field tests, the calculating results gained from calculation have relative large dispersive.

For to reduce such dispersive, they always carry out repeated tests and take the arithmetic mean as the final results.

$$I_C = \frac{\sum_1^n I'_C}{n} \qquad (2)$$

Where n —times of calculate use the equation to calculate the capacitance current I'_C.

The diversity of the results will reduced or say the error may be restrict in a rather small extent after using such measures. But it is too troublesome to do so.

The capacitive to ground of the network can be expressed according to equation (2) as:

$$3C_0 = \frac{\mathrm{I_C}}{\omega \mathrm{U}} \qquad (3)$$

1.2 Improvement of the measuring method

The high diversity appears in the results is due to the expression in the nominator of equation (1) is inadequately reasonable. In the measuring test we can control the diversity and calculation error by increase the difference value between U_{01} and U_{02}.

The most fundamental measures is using the data from the curve I and II to calculate by equation (4), where it change the "-" to "+" in the numerator and nominator of equation (1), i.e.

$$I_C = \frac{I_{L2} + \frac{U_{01}}{U_{02}} I_{L1}}{1 + \frac{U_{01}}{U_{02}}} \qquad (4)$$

Then, according to equation（4）we can have the capacitance to ground of the network.

$$3C_0 = \frac{\mathrm{I_C}}{\omega \mathrm{U}} \qquad (5)$$

theoretical analysis and tests in the network. Two points must pay attention during measuring: the first is the two data group must avoid to measuring near the resonance point; and the second is there must take a suitable anti-damping measures to prevent resonance especially during the changing from over-compensation to under-compensation.

In the system using more than one arc suppression coil, one of them can temporary switch off for to put the system changing from over-compensation to under-compensation. The 3Co can calculate directly from the two zero sequence data under over-compensation state and under-compensation state.

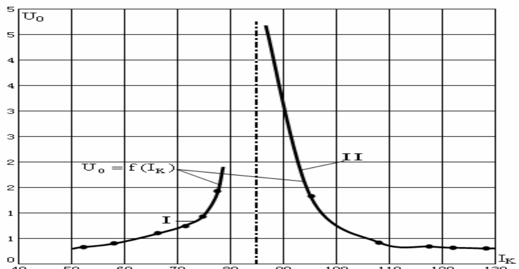

Fig.1 Relation between the displacement voltage of neutral point and the compensate tuning value
I—under-compensation；II—over-compensation

2. ONLINE MONITORING OF CAPACITANCE TO GROUND OF NEUTRAL ISOLATED NETWORK

There are relative high proportions of the distribution networks in our country to be the neutral isolated networks. Follow the rapidly development of the network, the 3Co also rapidly increased. To avoid the influence of the arcing ground over voltage, the electric power administration in China had a regulation to limit the 3Co, i.e. the capacitive current to ground in the neutral isolated system must keep not greater than 10A, it means the 3Co must lower than 5.5μf; otherwise the system must change to neutral compensating ground. The utilities had to measure the capacitance to ground periodically, which is once a year commonly, to know the change of it in time.

2.1 Measuring method currently used

There are many methods currently used, the direct ground method, signal injection method, bias capacitance method etc., but the bias capacitance method is mainly used. In the bias capacitance method a capacitance to ground (i.e. so called bias capacitance).is connected temporary on one phase of the network and form a vector value of neutral displacement voltage. The capacitance to ground can gain through a special calculation. This method is always undergoing off line. Though the bias capacitance method is safer than another two methods but the traditional method still contains some un-sufficiency, i.e.:

- It need to have the same value bias capacitance connect on three phases successively, and to get the final 3Co by take the average value gained in the three phases;
- The calculation is under the hypothesis that "two of the three phases have the same capacitance to ground" and it is not exactly true. The error caused must be corrected.
  The traditional equation used is：

$$3C_0 = \frac{U'_A}{U_A - U'_A}\Delta C \qquad (6)$$

where，ΔC is the bias capacitance，U_A 、U'_A is the voltage of phase A before and after the ΔC is connected。

2.2 THE NEW METHOD TO MEASURE THE CAPACITANCE TO GROUND

Here we introduce a new algorithm structure to calculate. The new method have following peculiarities：

- The bias is only needed to connect on one phase and no any restrict on connect to whether phase；
- It is not necessary to give the hypothesis that "two of the three phases have the same capacitance to ground"；
- It is favorable to measure under online。

2.2.1 Theoretical foundation

In the neutral isolated distribution network, neglect the conductance to ground of the network, the neutral unsymmetrical voltage $\dot{U}_0$ can express as：

$$\dot{U}_0 = -\frac{\dot{E}_1 c_1 + \dot{E}_2 c_2 + \dot{E}_3 c_3}{c_1 + c_2 + c_3} = -\frac{c_1 + a^2 c_2 + a c_3}{c_1 + c_2 + c_3} E_1 \qquad (7)$$

where，$\dot{E}_1$、$\dot{E}_2$、$\dot{E}_3$ are the potential of the three phases of the network，C_1、C_2、C_3 are the capacitance to ground of the three phases, where C_1 is the maximum one, and take it as the reference phase；according to the positive sequence ，C_2、C_3 is the capacitance to ground of the following first and second phase.

Added a △C on the C_1， as shown in Fig.2，Thus，$\dot{U}_0$ change to the form as shown in (8)：

$$\dot{U}_{01} = -\frac{c_1 + \Delta c + a^2 c_2 + a c_3}{c_1 + \Delta c + c_2 + c_3} E_1 \qquad (8)$$

From equation（7）we can have:

$$c_1 + a^2 c_2 + a c_3 = -\frac{c_1 + c_2 + c_3}{E_1}\dot{U}_0 \qquad (9)$$

Substitute（9）into（8），then

$$\dot{U}_{01} = -\frac{-\frac{c_1 + c_2 + c_3}{E_1}\dot{U}_0 + \Delta c}{c_1 + \Delta c + c_2 + c_3} E_1 = \frac{(c_1 + c_2 + c_3)\dot{U}_0 - \Delta c E_1}{c_1 + c_2 + c_3 + \Delta c}$$

Solve to have

$$3C_0 = c_1 + c_2 + c_3 = \frac{\dot{U}_{01} + E_1}{\dot{U}_0 - \dot{U}_{01}}\Delta c \qquad (10)$$

We can have capacitance to ground of the network $3C_0$ only needed to measure the vector $\dot{U}_0$、$\dot{U}_{01}$ and the reference vector E_1

If there are some restrict in the field that it is not possible to connect △c on the C_1, then you can connect to C_2 or C_3, but the relative calculating equation must change to (11) or (12):

$$3C_0 = c_1 + c_2 + c_3 = \frac{\dot{U}_{02} + a^2 E_1}{\dot{U}_0 - \dot{U}_{02}}\Delta c \qquad (11)$$

$$3C_0 = c_1 + c_2 + c_3 = \frac{\dot{U}_{03} + a E_1}{\dot{U}_0 - \dot{U}_{03}}\Delta c \qquad (12)$$

2.2.2 Engineering practice

During practice, you must first determine the phase in the network that the capacitance to ground is maximum (i.e. the phase with minimum phase voltage), and define it as the phase '1' in the equation. Than another two phases are defined according to the clockwise principle as phase '2' and '3'.

There are two ways for selection to connect the Δc . The one way is connect the Δc directly to the one phase of the high voltage circuit by using a vacuum switch.. This is an easiest way and not necessary to convert the bias capacitance and can directly substitute into the equation for3Co. Another way is couple the bias capacitance to the network through a special manufactured transformer.

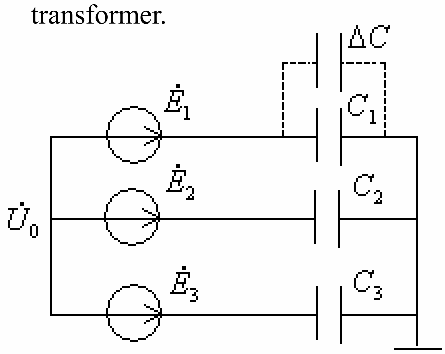

Fig 2 Principle diagram of the △c added to C_1

3. Conclusion

In this paper, we analysis the traditional methods in calculation of the capacitance to ground and on its base we introduced a new calculation method to solve the four difficulties problems which peoples pay close attention to it, i.e.:

- It gives the calculation of grounding fault resistance (R_f) for un-effectively grounding network (neutral isolated network and neutral compensating grounding network) an indispensable relative data;
- To provide the parameters of zero sequence network for the reasonable tuning of the compensating networks;
- To provide the scientifically basis for the increase of capacities for compensating networks ;
- To provide the decision making basis for to change the neutral isolated grounding to neutral compensating grounding 。

4. ACKNOWLEDGEMENT

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