Info Letter No. 18

Transient relay for high resistance, intermittent and recurrent earth faults (Part 2)

Static earth fault

Figure 3 can also be used for the determination of static earth faults. In an isolated network the entire capacitive current of all outputs flows through the point of failure. The relays in the healthy outlets measure a capacitive zero current and the relay in the faulty output measures an inductive zero current. With a stationary earth fault, the value of the inductive zero current is the same as in the previous section, the value of the zero current of the healthy outputs at the back of the relay.

In compensated networks, the situation changes. In this case, the current overlaps through the Petersen coil and reduces the capacitive current through the point of failure. In an ideal matching network, the capacitive current through the failure point is fully compensated. From Figure 3, it is evident that, in this case, the relay in the faulty output also measures a capacitive zero current as well as the relays in the healthy outputs. Therefore, in a compensated network the inductive nature of the zero current is no longer an indication of a faulty output.

Through the use of Petersen coil, the current can be reduced to on a small active current, which is usually in the range of 2 % to 3 % of the total capacitive phase-earth current.

Overlay

At the first ignition of the arc, the superposition of three operations begins.

The following figures show two different earth faults for a compensated 20 kV network with three outputs and a capacitive current of 108 A and 5 A overcompensation. The network corresponds to the configuration in Figure 3. The low resistance earth fault has a value of 10 ohms, and the high-resistance earth faults have a value of 2000 Ohms. The recording was made with a sampling rate of 10 kHz.

The high frequency discharge oscillation is greater in the case of a low-resistance earth fault.

In the case of the high resistance fault, the zero voltage in the steady state reaches only 40%.

TRANSIENT RELAY

Conventional transient relay

The conventional transient relay evaluates the charging process for the directional decision concerning the earth fault. If the zero sequence voltage u_0 exceeds a set threshold offset, a narrow window is used for measuring the zero current i_0. The direction decision is made by comparing the sign of i_0 with the sign of u_0 during this test window.

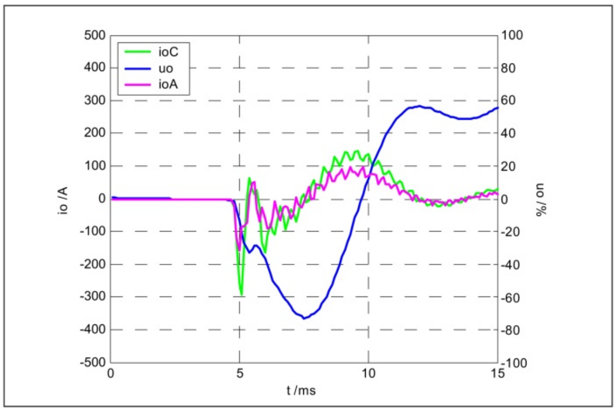

***Figure 5** Two healthy outputs with a low resistance earth fault*

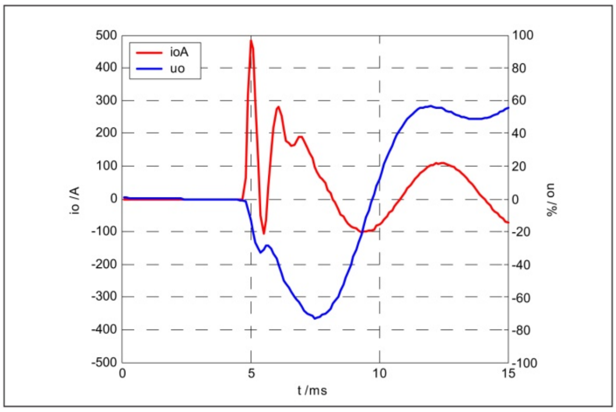

***Figure 6** Faulty output with a low resistance earth fault*

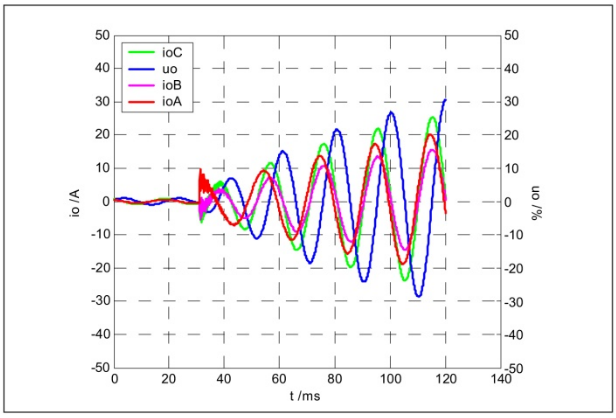

***Figure 7** High resistance earth fault*

The earth fault is in the direction of the output when the sign of i_0 does not correspond to the sign of u_0. If the signs are the same, the fault is in the direction of the busbar.

When the ignition is at the time u_{1E} = 0 V, there is no discharge oscillation.

The charging oscillation is present in all cases and can be evaluated by the transient relay.

TRANSIENT RELAY with qu algorithm

In the previous section, it was shown that the two common wires are charged by the earth fault on the network voltage. This charging process can be measured via the zero system.

As an example, the charge of healthy output B of the network from Figure 3 can be described by equation (2).

$$u_0(t) \quad u_0(t_0) \quad \frac{1}{C_{eqB}} {}_{t_0}^{t} i_{0B}(\quad) d \qquad (2)$$

Now, t_0 can be chosen so that $u_0(t_0) = 0$.

The new digital relays use signal processors, which include sufficient memory and have a sampling rate of 10 kHz or more. These properties enable the relay to now use values from the past for the evaluation. This makes it possible to go back into the past from one of the zero crossings of u_0 and from this time carry out the integration of the zero current i_0 up to the triggering point.

The result of the integration process shows that the curve of the integrated zero current i_0 differs from the curve of u_0 only by a factor C_{eqB} which corresponds to the zero-equivalent capacitance of output B. The integration of i_0 corresponds to the current charge q_0 of the output.

If these conditions are shown in a diagram, wherein the integral of i_0 on the y-axis, and the zero voltage u_0 on the x-axis is applied, we obtain a straight line with slope C_{eqB}. This representation is referred to as a qu diagram.

In case of an output with an earth fault, this ratio is no longer valid. The sum of the charging currents of the healthy outlets flows from the faulty output. The result of the integration of i_0 is no longer proportional to the zero voltage.

These ratios are shown in Figure 8 for the two healthy outputs B and C and the faulty output A.

Figure 9 shows the qu-diagram for an earth fault with a fault impedance of 2000 ohms. The corresponding time histories for i_0 and u_0 are shown in Figure 7.

The detection of a transient earth fault can be reduced to a decision as to whether the curve is a straight line in the qu diagram or not.

Figure 10 shows the qu diagram for a recurring earth fault. The two healthy outputs produce two straight lines. The faulty output produces a curve deviating from the straight line.

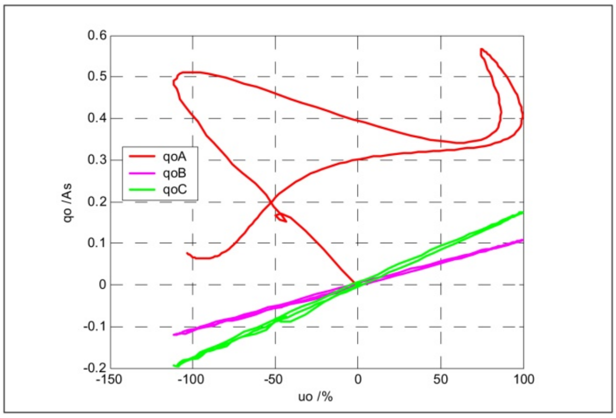

Figure 8 *qu diagram of a low resistance fault*

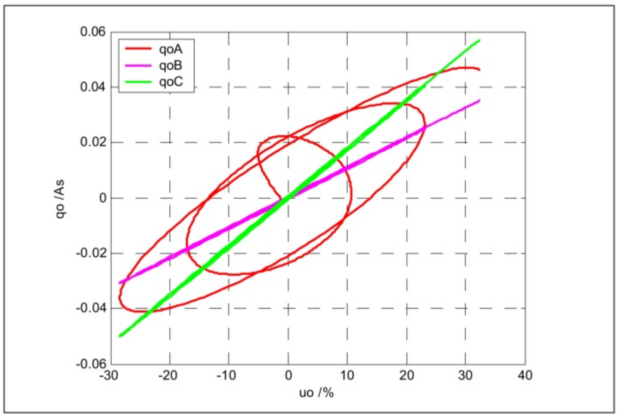

Figure 9 *qu diagram of a high resistance fault*

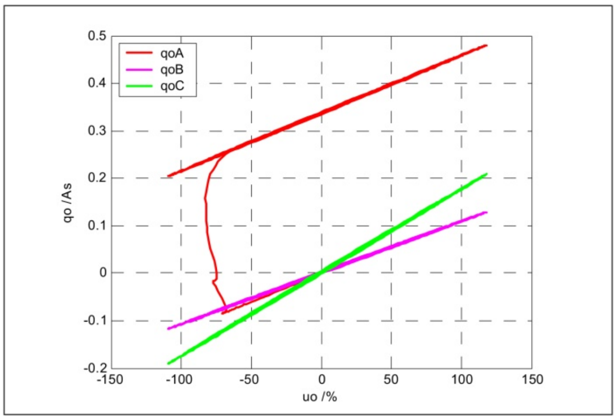

Figure 10 *qu diagram of a recurring earth fault*

With the new qu algorithm, it is now possible to unambiguously determine the earth fault direction, even during an intermittent fault in the isolated network, as well as during a recurring earth fault in the cable network.

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The series will be continued.
We will gladly supply missing Info Letters at any time!

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