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CONTENTS

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SYSTEM OF SIGNAL INJECTION AND EXTRACTION FOR PROTECTION AND INSULATION MONITORING IN MEDIUM VOLTAGE NETWORKS

Simple overcurrent criterion is most often used for detection and elimination of ground faults in radial industrial medium voltage networks. Since in Poland medium voltage networks work with non-effectively grounded neutral point, the ground fault currents can reach very low values, especially under high resistance faults. Such faults cannot be detected by any protection. Therefore, new methods to detect ground faults and to control the insulation in medium voltage network are of great importance. In the paper the idea for monitoring insulation parameters of the system, based on the simultaneous use of two different signals of non-industrial frequency, injected into the controlled network, is presented and discussed.

1. INTRODUCTION

European Union legislation and the actions of electricity market regulators in European countries issue a challenge to subjects in the field of power engineering that are connected with the increase of reliability and continuity of energy supply, energy efficiency increase, etc.

Energy supply continuity is strongly related to the reliability of the medium voltage (MV) distribution networks. Therefore, the increase of the reliability of MV networks is a key problem of any country, particularly due to strong energy dependence of each other.

The most common faults in MV networks are the single-phase faults to the ground (about 60–70%). The main reason for the ground faults appearance is the degradation of cable line insulation due to many factors like overvoltages and environmental hazard.

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Of course it is impossible to avoid the ground faults completely, but there are some ways to reduce their occurrence to prevent deterioration of insulation and reduce hazard level for people. The continuous monitoring of insulation parameters should be carried out. There are cases of lack of response of power system protection during low-current ground faults. It all makes the need of research for new methods of insulation monitoring and modernization criteria for the protection operation.

Therefore, the development of the system of signal injection and extraction for network protection and insulation monitoring in MV network is an important issue not only scientifically, but also industrially [1–3].

2. GROUND FAULTS IN NON-EFFECTIVELY GROUNDED MEDIUM VOLTAGE NETWORK

When protecting lines and MV equipment against ground faults the most commonly used criterion is simple overcurrent criterion. Signal from the zero-sequence current filter goes to relays, such as Ferranti CT (for cables) or Holmgreen system (for overhead lines). Starting current value I_{0r}, set on protection, must be rebuilt from the capacitive currents of own line and from the error currents of zero-sequence current filters.

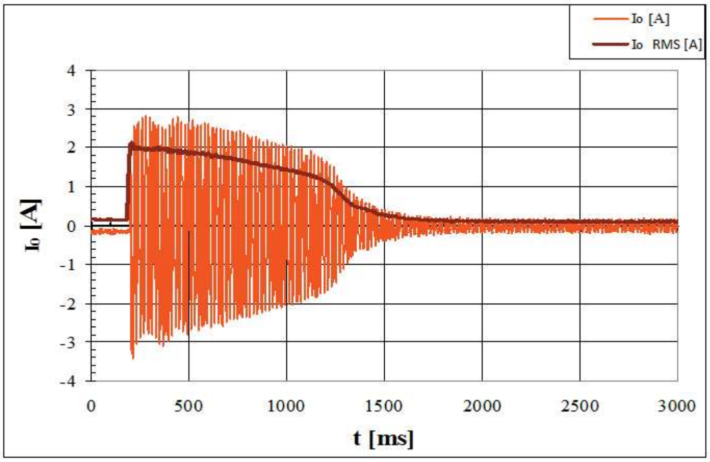

Fig. 1. A signal waveform (error) at the output of current transformer to measure zero sequence current during switching the pump motor of 400 kW power [1]

Figure 1 shows the selected error current waveform of Ferranti CT, registered in the isolated 6 kV network during starting of an asynchronous motor with nominal power of 400 kW driving a pump (without ground fault).

Phase current at the beginning of the motor start was approximately 200 A. Under these conditions the signal appearing at the current transformer output for measurement of the zero sequence current must be interpreted as an error signal.

As it results from the waveform of zero sequence current I_0 shown in Figure 1, an rms value in the initial period of motor start, exceeds 2A and goes to values close to zero after the time above 1.2 seconds. Consequently, when setting up this starting values the above error currents from the Ferranti CT should be taken into account. Such a low value of starting currents may cause a standard protection unable to detect a low-current faults (high-resistance). As an example of this situation might be the fault shown in Fig. 3. In the same power station, a fault was made by placing the cable on the surface of the earth on the one side connected to a selected phase, as shown in Fig. 2.

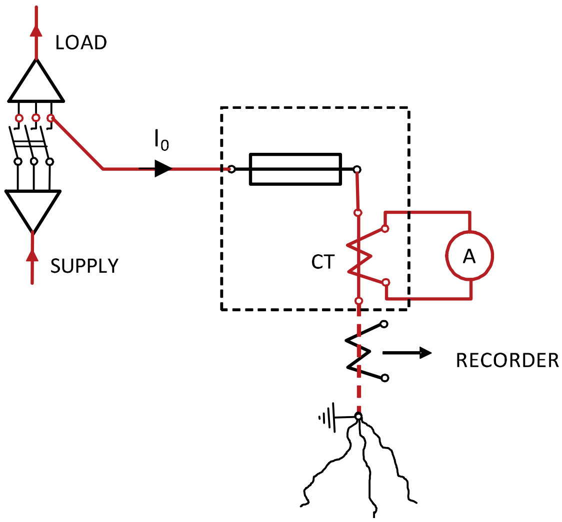

Fig. 2. Scheme of measurement system for a single-phase resistive ground faults

Figure 3 shows the waveform of zero sequence current I_0 as a function of time, where it could be seen an envelope curve of fault current that allows the evaluation of the fault phenomenon waveform. R_{ms} value of the fault current for t = 0 was about 1.5 A and in the steady state does not exceed 0.3 A.

As it results from the shown waveform, the current value in steady state is considerably lower than the starting value setting in protection. This means, that with this setting the protection is not able to detect the resistive ground fault of the line.

According to above mentioned, research is being conducted on various other detection methods of low-current ground faults or deterioration of the cable insulation [1, 4, 5]. One of these methods could be the system injection into MV network of signals with a frequency differing from the rated network frequency.

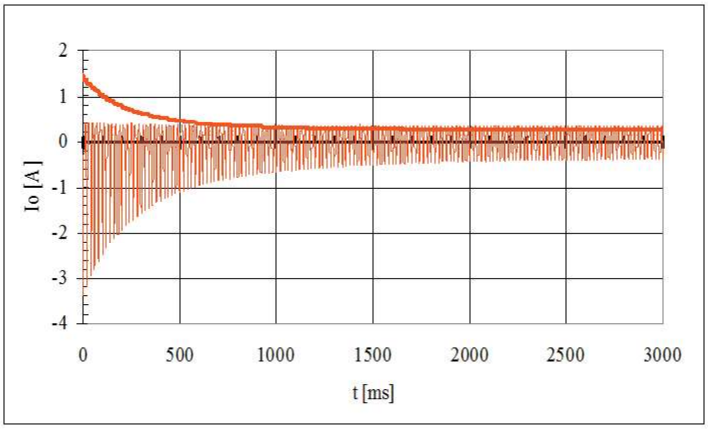

Fig. 3. The waveform of zero sequence current I_0 at the time of resistive ground faults [1]

3. SYSTEM OF CURRENT INJECTION INTO THE MEDIUM VOLTAGE NETWORK

For selective and continuous monitoring of insulation parameters a method based on the simultaneous use of two signals of non-industrial frequency injected into a controlled network was developed. A scheme of such a system is shown in Fig. 4.

Many techniques are known with use of current signals injection both AC and DC. In contradistinction from other methods, a concept of simultaneous use of two signals of non-industrial frequency allows to define separately resistance R and capacity C, not only the impedance Z as in case of one signal injection.

The most optimal construction scheme of any microprocessor system is the design of a modular principle of the system [6].

The microprocessor system, that implements the method of continuous monitoring of insulation components values of distribution network in normal operating conditions consists of the following functional blocks:

- the block of signal injection;
- the block of signal extraction and processing;
- the block of matching and external commutation;
- micro-computer;
- the block of control and signalization.

The essence of this method is following: two signals of unequal and non-industrial frequency are injected into a controlled network relative to ground. The block of current injection into a controlled network may be implemented by means of special transformer included in a network neutral point or via arc suppression reactors with the secondary windings connected to the signal generators.

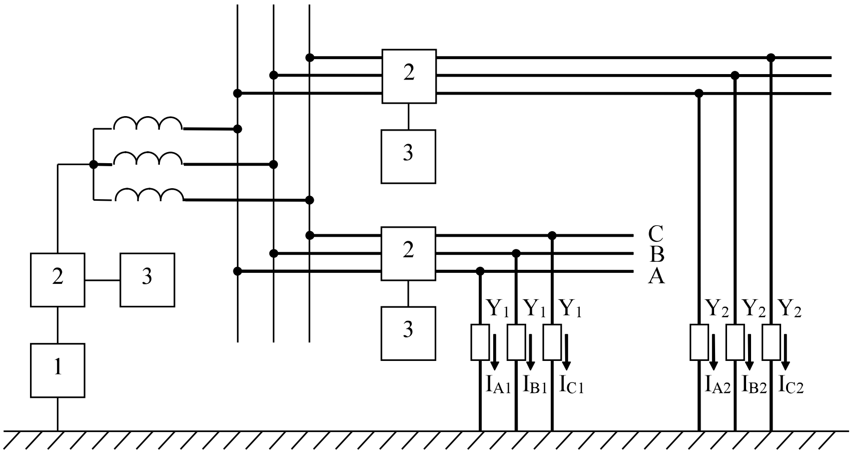

Fig. 4. System of signal injection into the network:
1 – the block of signal injection,
2 – the block of signal extraction and processing, 3 – micro-computer

In controlled sections (connection or line) and at a place of source connection are installed the devices of extraction and processing of appropriate signals, the function of such block could be executed by current and voltage measurement transformers.

For signals injected into a network accepted frequency values are 100 and 200 Hz. This choice is justified by almost complete absence of even harmonics in the network that strongly reduce a measurement error. Depending on the location of measuring current transformer it is possible to measure insulation parameters of particular connection or the whole network.

At the block of signal extraction and processing required frequencies are extracted and converted into digital form then are sent to a calculation unit.

After the simulation calculations in an appropriate computer program, signals are generated, that corresponds to the value of insulation parameters in controlled sections of the power supply system.

Methodology for determination of current parameters is as follows:

complex admittance:

$$\underline{Y} = \frac{1}{R} + j\omega C = \frac{1 + j\omega CR}{R}, \tag{1}$$

and respective impedance:

$$\underline{Z} = \frac{1}{\underline{Y}} = \frac{R}{1 + j\omega CR} = \frac{R(1 - j\omega CR)}{1 + \omega^2 C^2 R^2}. \tag{2}$$

Therefore, the complex current flowing through the resistance:

$$\underline{I} = \frac{U}{R}(1 + j\omega CR) \tag{3}$$

or RMS value:

$$I = \frac{U}{R}\sqrt{1 + \omega^2 C^2 R^2}\ . \tag{4}$$

In case of having two signals, we get the following equation:

$$I_1 = \frac{U_1\sqrt{1 + \omega_1^2 C^2 R^2}}{R}, \tag{5}$$

$$I_2 = \frac{U_2\sqrt{1 + \omega_2^2 C^2 R^2}}{R}, \tag{6}$$

where:

I_1, U_1, ω_1 – current, voltage and frequency of the first signal;

I_2, U_2, ω_2 – current, voltage and frequency for the second signal.

From the formulas (5) and (6) resistance value can be expressed as:

$$R^2 = \frac{U_1^2}{I_1^2 - U_1^2\omega_1^2 C^2}, \tag{7}$$

$$R^2 = \frac{U_2^2}{I_2^2 - U_2^2\omega_2^2 C^2}\ . \tag{8}$$

Therefore, for R = const, we can find C:

$$C = \frac{1}{U_1 U_2}\sqrt{\frac{U_2^2 I_1^2 - U_1^2 I_2^2}{\left(\omega_1^2 - \omega_2^2\right)}}\ . \tag{9}$$

Similarly, when C = const we can find R:

$$R = U_1 U_2\sqrt{\frac{\omega_2^2 - \omega_1^2}{U_2^2 I_1^2\omega_2^2 - U_1^2 I_2^2\omega_1^2}}\ . \tag{10}$$

Thus capacitive current can be calculated for the given value of network capacity. An important advantage of the proposed method is versatility for monitoring of fast-changing insulation parameters relative to ground for both the whole network and a given connection [7].

By using the micro-computer this method can be used for:

- operative assessment of insulation resistance and capacitance level for the whole network and each of the connections of distribution or industrial networks;
- measurement of inductance value of an arc-extinguishing coil (compensation device);
- automatic adjustment of compensation device in resonance with the capacity of distribution or industrial network;
- selective signaling of damaged section of the network or protection against ground faults in power supply system regardless of the configuration and neutral point operation mode.

4. CONCLUSIONS

Ground faults, especially under high-resistive condition (e.g. at the simple criteria, based only on the value of ground fault current I_0), cannot be detected in many cases and cleared by power system protection. It is very dangerous for people near the fault location due to possibility of occurrence of full touch and step potentials.

All the time it doing the research of new methods and criteria for the better detection and disconnection of ground faults as well as insulation condition detection. One of these methods is presented in the article, it is based on the simultaneous use of two signals of non-industrial frequency injected into a controlled network. This method allows the selective detection of damaged network section or protection against ground faults in power supply system, regardless of the configuration and neutral point operation mode.

The use of systems that during normal operating conditions of controlled network could detect and localize possible states threatening with a failure allows not only prevention of accidents and people injuries but also avoidance of the costs associated with clearing of the failures.

REFERENCES

[1] HABRYCH M., MIEDZIŃSKI B., WANG XIN, *Applicability of a Hall Sensor in directional ground fault protections of MV cable networks with no-effective earthing*, M. Habrych, B. Miedziński, Xin Wang, Elektronika ir Elektrotechnika, 2016, Vol. 22, No. 5, pp. 26–31.

[2] HÄNNINEN S., *Single phase earth faults in high impedance grounded networks. Characteristics, indication and location*, Technical Research Centre of Finland, Espoo 2001.

[3] ŁUKOWICZ M., *New method of data transmission delay estimation for feeder differential protection*, Present Problems of Power System Control, Vol. 1, 2011, pp. 92–103.

[4] MARCINIAK L., *Wavelet criteria for identification of arc intermittent faults in medium voltage networks*, Proc. of the IS „Modern Electric Power Systems, MEPS '10", paper 09.1, Wrocław, Poland, 2010.

[5] LEI LI, ZHONG Li, *Additional low frequency signal measurement method of insulation resistance about mine cable*, Conference: International Symposium on Computer, Consumer and Control (IS3C), Natl. Chin Yi Univ. Technol, Xian, Peoples Republic of China, Date: Jul. 4–6, 2016, pp. 891–894.
[6] SHKRABETS F., MISYATS Ye., KYRYCHENKO M., *The structure of continuous insulation monitoring system in the 6–10 kV grids in mining enterprises*, The Efficiency and Quality of Industrial Enterprises Power Supply: VI International Scientific and Technical Conference, Publishing Office PSTU, 2008, pp. 401–404 (in Russian).
[7] SHKRABETS F., TSYPLENKOV D., KOVALEV A., KYRYCHENKO M., *Insulation parameters of distribution grids: control and management*, Electrical Engineering and Electromechanics, Issue 1, 2010, pp. 49–51 (in Russian).