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Improving protection against single-phase earth faults in networks with isolated neutral

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ABSTRACT: This article discusses a single-phase circuit in three-phase electrical networks of all voltage classes.

KEYWORDS: selective protection, highly sensitive protection, resonant-grounded neutral, higher harmonic components.

I.INTRODUCTION

A single-phase earth fault is the most common type of damage in three-phase electrical networks of all voltage classes.

In electric networks of 6–10 kV, enterprises operate, as a rule, with isolated or compensated neutral, the values of single-phase earth faults (SEF) are small, they do not exceed 20–30 A. Therefore, networks of these voltage classes are traditionally called networks with a low fault current to the ground. However, SEFs pose a great danger to the equipment of electric networks and to people and animals located near the place of the SEF. In this regard, the Rules for the technical operation of power plants and networks require in some cases to quickly automatically turn off the SEF, and in others, immediately proceed to determine the connection with the SEF and then turn it off.

To date, nobody has managed to create selective (selective) and highly sensitive protection against SEF suitable for all types of networks with a low earth fault current. Indeed, it is difficult to create universal protection against SEF for such different types of electrical installations as overhead and cable lines, generators and electric motors, for such different grounding modes of the neutral points of the network as "isolated neutral", "resonant-grounded neutral" or "resistive-grounded neutral "(neutral, grounded through a limiting active resistance - resistor).

II. METHODOLOGY

Particular difficulties in performing selective protection against SEF arise in networks of 6 (10) kV with a resonant-grounded neutral, where the damage current of the industrial frequency is completely compensated by the current of the extinguishing reactor and therefore cannot be used as a source of information for protection. Additional difficulties arise when it is necessary to selectively determine the connection with SEF in complex electric networks, in the absence of a cable insert on the connection needed to install a zero-sequence current transformer, with the often changing primary circuit of the protected network and in other cases.

Earth fault currents, in addition to capacitive, inductive and active components of industrial frequency, can contain higher harmonic components, some of which appear only during the transition period when an earth fault occurs and is determined by the parameters of the earth fault loop. Another part of the higher harmonics currents continues to flow through the arc during the entire time of its burning. These currents are due to the presence of harmonic components in electromotive force (e.m.f.)generators, as well as electromotive forces of various harmonics due to saturation of the

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magnetic transformers of power transformers and rapidly changing uneven loads, when arc processes are used in consumer technology (mercury-rectifier installations of industrial enterprises and electric traction, electric arc furnaces, etc.).

In the earth fault current, the fifth harmonic component most often prevails. At the same time, sometimes the seventh harmonic component appears, but smaller in magnitude.

With rapidly varying non-uniform loads in the windings of network transformers, unbalanced electromotive forces (e.m.f.) of self-induction of higher frequencies arise, under the influence of which charges and discharges of the phase capacities relative to the earth, and therefore, the current flows through the damage site.

As a result of resonant phenomena, currents of the burning frequency of the grounding arc are usually distinguished. Currents due to these unbalanced e.m.f., often represent the eleventh or thirteenth harmonic components, or both together. Summing up, they create a current of the twelfth harmonic component, the beat frequency of which is equal to the industrial frequency.

Prior to earth fault, in addition to the load currents, a capacitive current i'_c flows in the damaged phase, ahead of the phase voltage of a three-phase symmetric system. Earth fault is a cut of voltage, as a result of which e.m.f.the mutual induction of the windings of the transformers supplying the network, change their direction by the value of the voltage cutoff.

At the neutral of the network, the voltage Uo is oscillatoryly set, which is inverse to the voltage of the damaged phase, and the voltages at the non-damaging phases acquire linear voltage values.

Capacitive current i'_c transfers to earth fault current, which in steady state has a direction opposite to i'_c if the network operates with isolated neutral or under compensation, or has the same direction as i'_c when the network is operating in overcompensation.

The first half-wave of the transient component of the earth fault current is purely capacitive in nature and therefore is always directed in the direction that coincides with the direction of the shear voltage in the damaged phase and is 90 degrees ahead of the voltage fluctuation. On neutral and on undamaged phases, the direction of which also coincides with the direction of the voltage cutoff on the damaged phase.

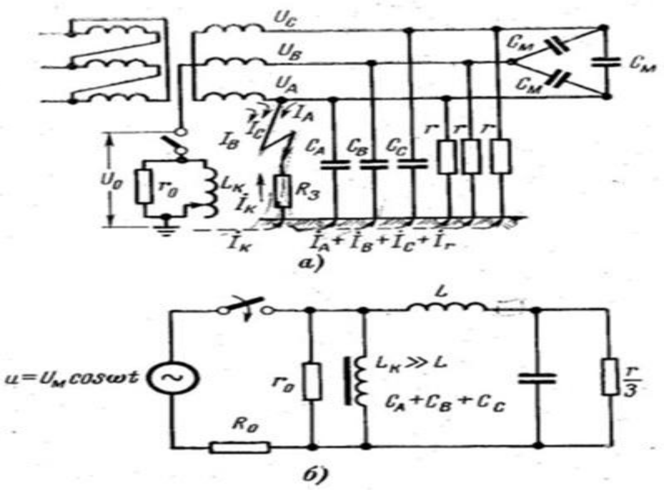

Fig. 1.Equivalent circuits of a network operating with isolated neutral and with compensation of capacitive currents.a - three-phase; b - zero sequence.

Evaluation of the main components of the earth fault currents (capacitive tc and inductive ik) arising during the transition period when one phase of the network is shorted to ground can be made in accordance with the equivalent circuits shown in Fig. 1. The three-phase circuit (Fig. 1, a) is converted into a simplified zero-sequence circuit (Fig. 1, b), which is a

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parallel connection of the parameters of the network R, L, C and the concentrated inductance of the arc suppression apparatus LK to the zero-sequence voltage. The main current paths are shown by thick lines.

Immediately from the moment of earth fault occurrence until the oscillation current iosc occurs, a current flows through the grounding arc due to the wave discharge of the damaged phase and the establishment of the total initial voltage at the interfacial capacitances Cm and capacitances of intact phases to the ground .

At the moment of phase closure to earth, a transient occurs, in which the currents and voltage of the zero sequence change according to a complex law and can significantly exceed the established values. Under these conditions false alarms are possible. Therefore, when substantiating protection against single-phase earth faults, it is necessary to consider and take into account currents and voltage of the zero sequence in transient conditions.

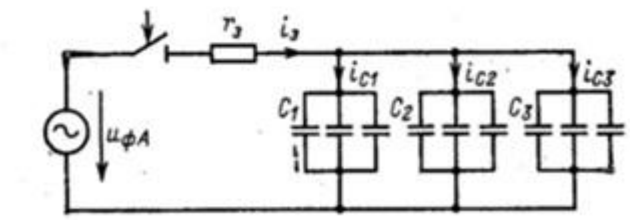

Fig. 2.Scheme for calculating zero sequence currents during transients.

III. EXPERIMENTAL RESULTS

Currently, 6–10 kV electric networks, in the light of the concept of creating an intelligent power system, are also of great importance when used as a connecting link for Micro Grid technologies. In connection with their widespread use in industrial enterprises, in the system of auxiliary needs of power plants, in city networks, they will largely determine the reliability of Micro Grid facilities with non-traditional energy sources. A known drawback of these networks is the frequent damage to electrical equipment due to the high level of overvoltage during arc faults to earth, as well as the difficulty of providing selective operation of relay protection, especially at a low level of phase-to-earth fault currents.

Improving the reliability of these networks is constantly being paid attention by both research and operating organizations and manufacturers of electrical equipment. This is how the introduction of high-resistance and low-resistance grounding of the network neutral, modern microprocessor protection, surge arresters such as arrester. Work is underway on the study of transient processes in these networks using both modern digital recorders and mathematical modeling methods. However, despite this, the reliability of these networks remains insufficient.

Therefore, the development of principles for constructing automatic control systems for objects based on the Smart Grid concept and improving the reliability of 6-10 kV networks in case of fault protection by improving methods for mathematical modeling of these networks, resistive neutral grounding, limiting overvoltage and increasing the sensitivity and selectivity of relay protection is an urgent task .

IV. CONCLUSION

Effective protection against SEF allows to reduce the dangerous impact on the equipment of 6-10 kV networks of the effects that occur during the SEF. This, in turn, will increase the reliability of the engines, cables and other network elements and will extend their life. Safety is also increased for people and animals that may be in the zone of incidence of the overhead power line wire.

In some cases, the necessary efficiency can be achieved using non-directional overcurrent protection of the zero sequence.

This primarily refers to resistive-grounded networks and installations with small capacitive currents. If, for example, we are talking about protecting the cable network of the auxiliary needs of a power plant in which a grounding resistor is installed, and an active resistor current of about 35-40 A flows in the SEF place and the capacitive currents of individual

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connections do not exceed several amperes, many can be used here successfully from known non-directional current protection devices.

The second case of this kind is intra-workshop networks at enterprises where an arcing reactor can be installed, but there are a large number of connections with a small capacitive current. It is difficult to carry out effective selective protection without a grounding resistor. By installing such a resistor with a current of 10-15 A, we get the opportunity to install a simple zero-sequence current protection on most connections.

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