Impact of the Operating Mode of Neutral in 35 kV Power Grids on the Arc Overvoltages and Voltage Measuring Transformers

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Abstract – has been analyzed possible methods of earthing of neutrals in 35 kV power grid. Among the most common injuries in these electrical system are arc circuits, that is why the dependence of overvoltage multiplicities on the nature of earth arcing and on the method of earth arrangement of electrical system neutral. Given that in 35 kV power grids may arise ferroresonant processes, operation of voltage measuring transformers has been researched during unstable earth arcing.

Key words – power grid, arc overvoltage, digital model, insulated neutral, resonant-earth neutral, overvoltage ratio, resistance-earth neutral, voltage transformers.

I. Introduction

Power grids with a voltage of 35 kV are distributive networks. They are one of the longest on the total length [1], so their work largely depends on the reliability of consumers’ electricity supply, which is now very topical due to the constant deterioration of the technical condition of electrical networks and stable growth of energy consumption.

According to [2] Power grids with a voltage of 35 kV in the mode of arrangement of neutral earthing can be divided into: power grids with insulated neutral, power grids with neutral earthing through a ground-fault neutralizer (resonant-earth or compensated neutral), power grids with neutral earthing through resistance (high-resistance or low-resistance) and power grids with combined earthing.

One of the weighty reasons of failures in 35 kV power grids are internal overvoltages that arise at following electromagnetic processes: arc, ferroresonance and switch. This case requires research and determination of limit multiplicities of overvoltage at specified electromagnetic transients and development of recommendations for the coordination of insulation.

Significant risk to the electrical equipment of electrical networks of 6-35 kV are overvoltages during the earth arcing in the occurrence of single-phase earth fault. These processes are dangerous by frequency of occurrence in the power grids, by their duration and overvoltages magnitude.

During unstable earth arcing is the saturation of magnetic system of the measuring voltage transformers, which can lead to the development of ferroresonance processes, significant growth of currents of primary windings of voltage transformers and their thermal damage.

II. Rated Model

We perform all researches using digital simulation based on the model of electrical network with a voltage of 35 kV, developed in the software package RE [3] (Fig.1). This model reproduces in 35 kV power grids, which includes power transmission lines, buses, power triple-wound transformer 110/35/10 kV and voltage measuring transformer. Resistor and inductor are connected to the neutral of medium voltage winding of power transformer in parallel via switching elements, which, respectively, simulate the earth resistor and ground-fault neutralizer.

In Ukrainian the 35 kV power grids are operated voltage measuring transformers types 3HOM-35 (ZNOM-35), HAMH-35(NAMY-35) and HTH-35 (NTN). Voltage transformer model type 3HOM-35 (ZNOM-35), is shown in Fig.1, and voltage transformer models type HAMH-35(NAMY-35) and HTH-35 (NTN-35) – in Fig.2. Rated models of voltage transformers are formed in accordance with the scheme of connection of their windings and passport data in consideration of characteristics of the magnetic circuit magnetization.

The magnitude of arc overvoltages is determined by the nature of earth arcing during single-phase earth fault.

The real picture of arcing depends on many factors, the main of which are: magnitude and nature of current earth fault, disruptive pressure at the injury site after arc extinction, cooling conditions [4, 5]. The closest to real operational conditions is the nature of arcing on the theory of N.N. Beliakov and C.M. Dzhuvarla [6], according to which arc tries to extinguish at each passage of current through zero. However, extinction of the arc occurs only if the first voltage peak at the injury site is less than \(0.4U_{lim}\). For unipolar regular arc each subsequent breakdown occurs approximately after the period of industrial frequency, when the voltage on the damaged phase reaches the peak value. For bipolar...
regular arc each subsequent breakdown occurs in approximately half of the period of industrial frequency, for amplitude value achieving by a voltage.

According to the above mentioned algorithm were investigated single-phase earth fault with unipolar arcs, when the arc gap breakdown happened at one polarity of renewable voltage, and bipolar symmetric and asymmetric arcs, when the arc gap breakdown happened both along the positive and negative polarities of renewable voltage.

III. Analysis of Arc Overvoltages

For all possible methods of arrangement of earth mode of electrical system neutral, the magnitude of arc overvoltages has been investigated for two natures of earth arcing: unipolar and bipolar.

All the researches are performed for different values of the capacitive current earth fault from 1 A to 15A. For network with compensated neutral, the value of inductance of the earth reactor has been designed for capacitive current earth fault 7A. Therefore, studies that were conducted with this ground-fault neutralizer for the values of capacitor current 1 – 6.9 showed the process of overcompensation of the current earth fault, and in the range 9 – 15 A – process of undercompensation of capacitive current earth fault.

Also regarding capacitive current earth fault 7 A was calculated: the value of active resistance of 3040 Ohm for network earthing via a high resistance resistor, and the value of resistance 6735 Ohm, which is connected in parallel to ground-fault neutralizer in network with a combined neutral earthing.

The results of calculation are shown in Fig.3. Typical voltages digital diagram during the unstable arcing are shown in Fig.4 (high-resistive neutral earthing) and Fig.5 (resonant neutral earthing).

As you can see from the obtained results, the highest overvoltages multiplicities occur in the mode of overcompensation of the capacitive current in the network with compensated neutral: 2.47 for unipolar arc and 2.32 for bipolar arc. The least multiplicities of arc overvoltages we can observe at the full compensation of capacitive current, and at combined neutral earthing for unipolar arc 1.9 and 1.78 for bipolar arc.

Of course, as seen in Fig.3 and 5, the lowest overvoltages and the easiest arcing nature are to be observed during the power grids operating with resonant neutral earthing at almost perfect resonance compensation
adjustment. To achieve this mode in actual use is extremely difficult because of the need for almost continuous variable control of the inductance of the earth reactor.

IV. Analysis of Measuring Voltage Transformers

The unstable arcing at single-phase earth fault may lead to significant growth (in hundreds and thousands of times) of current in primary windings of voltage transformers. Since the earth arcs can burn for long periods of time, such current growth causes thermal damage of the windings of voltage transformers.

A research was conducted of the influence of earthing mode of the network neutral, the value of the capacitive current of earth fault and type of voltage transformer on the current value that will flow in primary windings of the measuring voltage transformer at unstable arcing. The results are shown in Fig. 6-8.

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**Fig. 6.** The dependence of the current magnitude in primary winding of the voltage transformer type 3HOM-35 (ZNOM-35) on the magnitude of capacitive current and the method of network neutral earthing

**Fig. 7.** The dependence of the current magnitude in primary winding of the voltage transformer type HAMH-35 (NAMY-35) on the magnitude of capacitive current and the method of network neutral earthing

**Fig. 8.** The dependence of the current magnitude in primary winding of the voltage transformer type HAMH–35(NAMY-35) on the magnitude of capacitive current and the method of network neutral earthing
The research results show that the highest currents flow in the primary windings of the voltage transformer type 3HOM-35(ZNOM-35) at the power grids with insulated neutral – 4.59 A if unipolar arc and 2.16 A if bipolar arc. The lightest operating conditions of TH 3HOM-35 (ZNOM-35) during the earth arcing to be characterized by the electrical network operation mode with a combined neutral earthing.

A similar pattern is observed for voltage transformer type HAMI-35(NAMY-35). For this voltage transformer increase of the current of primary windings to 2.2 A is possible in the mode of the insulated neutral. For this voltage transformer an optimal is an operation in networks with resonance and combined neutral earthing, regardless of the setting of compensation of capacitive current earth fault. In these networks during the unstable earth arcing currents of the primary windings of voltage transformer type HAMI-35(NAMY-35) will not exceed values of 0.09 A.

The lowest values of the currents in primary windings can be observed in the voltage transformer type HTH–35(NTN-35). In it, almost regardless of the method of neutral earthing, currents do not exceed 0.08 A, which is not destructive value from the point of view of the thermal stability of the windings, which is 0.1 A for almost all voltage transformers.

In Fig. 9 it is shown a digital diagram of currents of primary windings of voltage transformer type 3HOM-35 (ZNOM-35) during earth arcing.

Fig. 9. Typical digital diagrams of currents of primary windings of voltage transformer 3HOM-35 during earth arcing and insulated network neutral

Conclusions

1) Method of arrangement of neutral earthing mode significantly affects the nature of burning and development of overvoltages in 35 kV power grids.

2) The highest overvoltage multiplicities occur in the mode of overcompensation of the capacitive current in the network with compensated neutral: 2.47 for unipolar arc and 2.32 for bipolar arc. The least multiplicities of arc overvoltage occur at full compensation of capacitive current and fine tuning of ground-fault neutralizer, as well as at the combined earthing of neutral 1.95-1.99 for the unipolar arc and 1.78 and 1.9 for bipolar arc;

3) During unstable arcs the highest currents flow in the primary windings of the voltage transformer type 3HOM-35 (ZNOM-35) in the power grids with insulated neutral – 4.59 A if unipolar arc and 2.16 if bipolar arc.

4) The lowest values of currents in primary windings can be observed in the voltage transformer type HTH–35 (NTN-35) regardless of the method of power grids neutral earthing, so this voltage transformer is not damaged during the arc earth fault.

References


