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RESEARCH OF ADAPTIVE RELAY PROTECTION AGAINST SINGLE-PHASE EARTH FAULTS IN 6-35 KV POWER GRIDS

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Abstarct. This article shows the results of a study of relay protection against single-phase earth faults. The originality of the study lies in a completely new approach to identifying the fault feeder by the constant component in the zero sequence current. Further research is currently underway. In the article there is a review of one of the received patents for the invention of the Republic of Kazakhstan.
Keywords: single-phase earth fault, networks with DGR, isolated neutral, protection algorithm, constant component, zero sequence current.

Introduction. Improving the efficiency of networks with a voltage of 6 - 35 kV is one of the important tasks associated with the need to increase the reliability of power supply to consumers, due to the fact that most of the electricity is distributed to consumers through networks of this voltage class.

The most common type of damage in 6 - 35 kV networks are single-phase earth faults (SPEF), which are not accompanied by large currents. However, very often these damages are the root cause of accidents, accompanied by significant economic damage and posing a danger to the lives of operating personnel.

It is known that short-circuit currents are many times higher than the currents of normal operating modes. This is a consequence of the closure of the phases between themselves or the phase and the earth. Such accidents are a common occurrence for energy companies.

According to statistics, to date, SPEF occurs from the following factors, such as:

– wear of cables with a service life exceeding the warranty period;
– the practical absence of relay protection against SPEF;
– vulnerable to overvoltage insulation of cable lines with insulation made of cross-linked polyethylene;
– fan shutdowns of feeders after the appearance of the 1st SPEF.

Thus, the improvement and implementation of relay protection from SPEF is an urgent problem of energy enterprises.

Studies are being conducted in various countries aimed at preventing or minimizing the emergency consequences of single-phase earth faults, and these studies are aimed at improving both neutral grounding modes and protections against single-phase earth faults.

Currently, current and current directional protection devices are used to protect against SPEF in 6 - 35 kV networks with isolated neutral with increased safety requirements and in power plant networks. However, they do not fully meet modern requirements: current protections such as RTZ-50, RTZ-51 do not have the necessary sensitivity in short-range networks (since it is necessary to detach from its own capacitive connection current), and directional protection such as ZZP-1 and ZZP-1M may unnecessarily trigger when eliminating external single-phase earth faults.

Research conditions and methods. The research methodology sets the following tasks:

- analysis of known algorithms and relay protections against earth faults;
- justification of directional relay protection against ground fault based on a direct current algorithm;
- calculation of electrical circuit parameters;
- experimental studies;
- development of recommendations for the introduction of selective directional relay protection against ground faults in 6-35 kV power grids.

According to [1,2], the main and most common algorithms for relay protection against SPEF are the following.

1. Algorithm for the maximum effective value of the fundamental harmonic of the zero sequence current in the connections. For networks with isolated neutral, especially with a small number of outgoing feeders, the scope of application is very limited.

2. The algorithm for the SPEF transient process is based on determining the sign of the instantaneous power of the zero sequence in the initial stage of the transient process. Provides fixation of short-term self-removing insulation breakdowns. However, the duration of the transition phase on which the signal signs need to be fixed is 0.5-2.0 ms, which reduces reliability.

3. The algorithm for the direction of the power of the zero sequence is the most obvious and adequate, since the source of the zero sequence is located right at the point of the SPEF. But it is difficult to use the algorithm in practice, which is explained by large angular errors and non-identical characteristics of existing zero-sequence current transformers (ZSCP), especially with arc SPEF and in the low-current region [3,5].

4. The algorithm for the sum of the higher harmonics in the zero sequence current works satisfactorily in centralized relative metering devices for branched networks containing a large number of ferromagnetic equipment (transformers, arc-extinguishing reactors, etc.). But for individual absolute measurement devices, it is almost impossible to calculate the setpoint by the level of harmonics. Therefore, they are ineffective due to the instability of the composition and the level of higher harmonics in the zero sequence current.

5. The algorithm for the magnitude of the harmonics of the superimposed current provides the greatest selectivity in compensated networks. Requires a special superimposed current source. The most appropriate application is in networks that already have such a source, for example, for controlling arc-extinguishing reactors. Limited use in complex branched power grids [4].

The analysis of the presented relay protection algorithms shows a number of their shortcomings that limit their use.

Research results. To solve the higher tasks , the following relay protection is proposed:

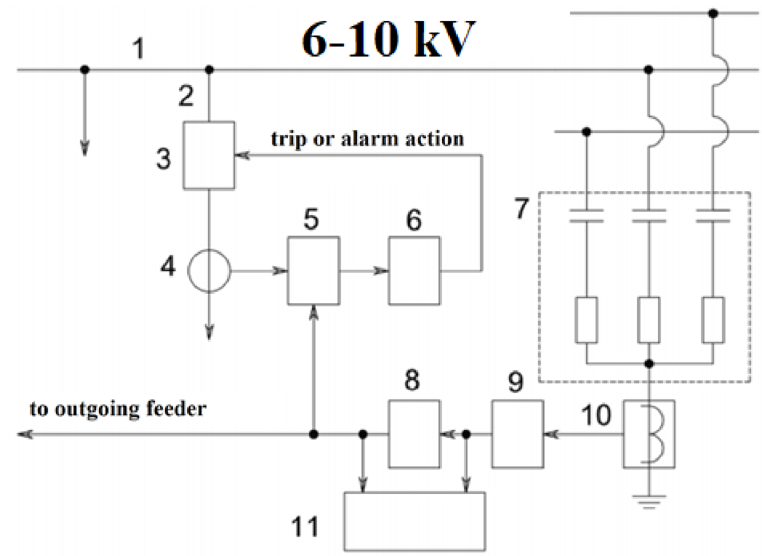

Figure 1. Device diagram

The figure shows a block diagram of a single-phase earth fault protection device in electrical networks, where:

1 – the power grid,
2 – outgoing feeder,
3 – switch,
4 – zero sequence current (ZSC) sensor
5 – phase–detecting module,
6 – actuating relay,
7 - RC extinguisher,
8 – voltage relay,
9 – matching unit,
10 – current transformer,
11 – signal recorder

In the power grid (1), each of the outgoing feeders (2) contains a switch (3), a ZSC sensor (4) connected by a secondary winding to the input of the phase-detecting module (5), the output of which is connected to an executive relay (6), a control switch (3). At the same time, common to all outgoing feeders (2) connected directly to the power grid (1) is an RC extinguisher (7) connected by inputs to the power grid (1) and outputs connected to a common point, grounded through a current transformer (10). Moreover, the secondary winding of the current transformer (10) is connected by means of a matching unit (9) with a signal recorder (11) and a voltage relay input (8) having a time characteristic, the outputs of which are connected to the input of the phase-determining module (5) and the input of the signal recorder (11).

The proposed invention works as follows.

In the normal operation of the power grid (1) without switching overvoltages and SPEF, the outgoing feeders (2), with the switch on (3), provide power supply to consumers, and the ZSC sensors (4), RC extinguisher (7) and current transformer (10), built from unbalance currents, are energized in their original state. Also in readiness to function in the event of switching overvoltages or SPEF are the phase-determining module (5), the executive relay (6), the voltage relay (8), the matching unit (9) and the signal recorder (11).

The occurrence of switching overvoltages in the power grid (1) is accompanied by the fact that a current pulse appears in the RC extinguisher (7) and the current transformer (10), which is then converted into a voltage pulse in the matching unit (9). Since the duration of the switching overvoltage does not exceed, as a rule, 10 ms (one half-wave of the fundamental harmonic), and the setpoint of the delay time in the voltage relay (8) significantly exceeds the specified duration, the signal about the resulting switching overvoltage is only recorded in the signal recorder (11) and does not manifest itself in other elements of the device.

The appearance of the SPEF in the power grid (1) leads to the fact that in the RC extinguisher (7), which is, in essence, an intact outgoing feeder, as well as through the capacitances in intact feeders, a zero-sequence current appears, which, passing through the current transformer (10) and its secondary winding, is then converted into in the matching block (9) in the voltage of the zero sequence Uo. At the same time, its phase coincides, by definition, with the phase of the current from the ZSC sensor (4) of the intact feeder. Then, the Uo signal exceeding the setpoint in the voltage relay (8), determined by the current unbalances in the RC extinguisher (7), and with a delay for the duration of the transient process at the SPEF, usually by 20-40 ms, enters the phase-detecting module (5). Simultaneously and synchronously with this process, a signal from the ZSC sensor is received (4) and is compared in the phase-determining module 5 with the phase of the signal Uo. At the same time, their mutual antiphase state indicates a damaged feeder and the signal generated in this way from the phase-detecting module (5) comes to the executive relay 6 with subsequent action on the signal or on disconnection by the switch (3) of the damaged feeder. Moreover, the Uo signal is also sent to the signal recorder (11), which records the fact of the SPEF in the power grid (1).

Discussion of scientific results. A comparative analysis of the proposed device with the prototype shows the following:

1. The use of an RC extinguisher (7) as a voltage sensor of the zero sequence Uo is based on its absolute similarity with intact outgoing feeders of the power grid (1), the currents in the ZSC sensors of which coincide in phase with the specified voltage of the zero sequence Uo. At the same time, the use of an RC extinguisher (7), one per bus section of the power grid, instead of a high-voltage three-phase rectifier, which is installed on each outgoing feeder, greatly simplifies and reduces the cost of protection against SPEF in power grids.

2. The rationale in the proposed device for the additional function of limiting and registering switching overvoltages that occur in the power grid (1) for a number of reasons lies in their manifestation primarily in the RC extinguisher (7). At the same time, compared with nonlinear surge limiters, which have a very high level of operation, the RC extinguisher (7) limits even insignificant switching overvoltages and dangerous higher harmonics. This ensures an increase in the reliability of the device and the power grid as a whole.

3. The introduction of a signal recorder (11) into the device makes it possible to record in time the facts of the occurrence and limitation of switching overvoltages. This helps in the subsequent analysis to identify sources of overvoltage in order to take preventive measures to prevent overvoltage and improve the reliability of the power grid.

4. The increase in the level of electrical safety created by the proposed device consists in the fact that the current transformer (10) creates a galvanic isolation between the high-voltage power grid (1) with the RC extinguisher (7)

connected directly to it and, accordingly, the remaining low-voltage elements of the device.

Conclusion. The presented analysis confirms the increase in the efficiency of power supply when using a simple and inexpensive to implement device for protecting power grids from SPEF with advanced functionality for limiting and registering emerging switching overvoltages and ensuring the safety of the power grid, and also proves the novelty and significant advantages of the proposed device compared to the prototype for all types of SPEF. On the basis of the above, it should be noted the importance of researching new protection systems against SPEF in 6-35kV networks. Therefore, this work is devoted to the research of a new high-performance protection in 6-35 kV networks.

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6-35КВ ЭЛЕКТР ТОРАПТАРЫНАҒЫ БІР ФАЗАНЫҢ ЖЕРГЕ ТҰЙЫҚТАЛУЫНАН БЕЙІМДІ РЕЛЕЛІК ҚОРҒАНЫСТЫ ЗЕРТТЕУ

Аңдатпа. Бұл мақалада электр тораптарынағы бір фазаның жерге тұйықталуынан релелік қорғанысты зерттеу нәтижелері көрсетілген. Зерттеу жаңалығы зақымдалған фидерды нөлдік реттілік тогындағы тұрақты құраушысы бойынша анықтауға негізделген абсолютті жаңа тәсілдемеде. Қазіргі таңда одан әрі зерттеу жұмыстары жүргізілуде. Мақалада осы зерттеу негізінде алынған Қазақстан Республикасының өнертабысқа патенттерінің біреуі сипатталған.

Тірек сөздер: бір фазаның жерге тұйықталуы, ДСР бар тораптар, ажыратылған бейтарап, қорғаныс алгоритмі, тұрақты құраушы, нөлдің реттілік тогы.

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ИССЛЕДОВАНИЕ АДАПТИВНОЙ РЕЛЕЙНОЙ ЗАЩИТЫ ОТ ОДНОФАЗНЫХ ЗАМЫКАНИЙ НА ЗЕМЛЮ В ЭЛЕКТРОСЕТЯХ 6-35КВ

Аннотация. В данной статье показаны результаты исследования релейной защиты от однофазных замыкании на землю. Новизна исследования заключается в абсолютно новом подходе к выявлению фидера повреждения по постоянной составляющей в токе нулевой последовательности. На данный момент ведутся дальнейшие исследования. В статье идет ознакомление с одним из полученных патентов на изобретение Республики Казахстан.

Ключевые слова: однофазное замыкание на землю, сети с ДГР, изолированная нейтраль, алгоритм защиты, постоянная составляющая, ток нулевой последовательности.