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V.I. Dmitrichenko[1] (orcid – 0000-0002-8624-0894) - main author,
N.T.Omirzakov[2] (orcid – 0000-0003-4319-0724),
M.K. Ermagambetov[3] (orcid – 0000-0001-7840-9728),
M.A. Zhetpisov[4] (orcid – 0000-0002-6589-7352)

[1]Cand. tekhn. sci., docent,[2,3,4]master's student
NJSC «Almaty University of Power Engineering and Telecommunications»,
Almaty, Kazakhstan,
e-mai: omirzakov_4598@mail.ru

COMBINED RELAY PROTECTION AGAINST EARTH FAULTS IN POWER GRIDS 6-10 KV

Abstract. This article discusses the problems that arise during the SPEF in networks with an isolated neutral. The main problem lies in the occurrence of overvoltage, inoperability of overvoltage protections and in the absence of available and selective overcurrent protections. Selective non-directional overcurrent protection is widely used, however, in networks with weakened insulation, it is inapplicable due to the high level of overvoltage and insufficient sensitivity with incommensurate own capacitive currents of feeders. This is proved by calculations using the example of Substation-47 of JSC "AZhK", and the solution to the problem by replacing selective non-directional overcurrent protection with individual directional protections for each feeder is justified.

Key words: single phase earth fault, overvoltage, selective non-directional current protection, determination of damaged feeder, selectivity condition, relay protection.

Introduction. According to statistics, about 80-90% of accidents in distribution power grids occur in cable lines (CL), from single-phase earth faults (SPEF), arising in most cases from overvoltage (OV) and, to a lesser extent, from mechanical damage and moisture ingress [1]. The functioning of these networks, the occurrence in them and the course of emergency processes, as well as the provision of protection against accidents, depend mainly on the neutral grounding modes [2, 3]. The main electrical equipment that provides the neutral mode (neutral-forming transformers, arc suppression reactors, neutral resistors) are designed to limit overvoltages and capacitive currents that occur during SPEF and are the most dangerous for power grids [4, 5]. Nonlinear overvoltage arresters (NOVA), RC absorbers of higher harmonics, shunting of SPEF, etc. are also used [2, 6, 7].

However, the final function of identifying, localizing and disconnecting emergency connections in power grids is performed only by relay protection (RP). At the same time, for each neutral mode of the power grid and the electrical equipment used, there are distinctive conditions and requirements, the consideration of which provides an opportunity to determine the damaged feeder (DF) and further actions of the relay [2, 8].

Research conditions and methods. The primary basis for DDF operations and relay protection actions are devices with certain functions, which are usually called algorithms.In the event of the SPEF, they receive signals from the corresponding measuring equipment installed in the power grid and in each outgoing feeder, convert them and feed them directly to the relay protection elements. The main and most common algorithms for relay protection against SPG, according to [2, 8, 9], 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 is very limited.

2. The algorithm for the transient process of the SPEF is based on determining the sign of the instantaneous power of the zero sequence at the initial stage of the transient process. Provides fixation of short-term self-eliminating insulation breakdowns, however, the duration of the transient process section, on which it is necessary to fix the signs of signals, is 0.5-2.0 ms, which reduces reliability.

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

4. The algorithm for the sum of the higher harmonics in the zero sequence current (ZSCT) works satisfactorily in centralized relative metering devices for branched networks containing a large amount of ferromagnetic equipment (transformers, arc suppression reactors, etc.). But for individual absolute metering devices, it is almost impossible to calculate the setpoint from the harmonic level. Therefore, they are not very effective in conditions of instability of the composition and level of higher harmonics in the zero sequence current.

5. The algorithm for the magnitude of the injected current harmonics provides the highest selectivity in compensated networks. Requires a dedicated source of injected current. It is most expedient to use in networks that already have such source, for example, to control arc suppression reactors. The use in complex branched power grids is limited.

As follows from the analysis of the presented algorithms, the most problematic from the standpoint of the functioning of relay protection against SPEF is the isolated neutral mode. For such networks, an algorithm is mainly used for the maximum effective value of the fundamental harmonic of the zero sequence current, and the protection is called selective zero sequence non-directional current protection (SNCP).However, according to [2], even for the most sensitive digital protection against SPEF, the sensitivity condition is fulfilled in cases where the intrinsic capacitive current of the protected feeder does not exceed 17% of the total capacitive current of the network. This is due to a very serious drawback of relay protection against SPEF, since the zero sequence current transformer of the damaged feeder does not react to its own capacitive current, but records the total capacitive current of the intact feeders. Therefore, in this mode of the neutral of the network with SNCP, additional algorithms are forcedly applied, namely, directional relay protection, they create superimposed currents or include a resistor in an artificially created neutral of the power grid. And this requires the installation of additional special, including high-voltage, equipment [2, 7, 8, 9].

Research results. Thus, the presented analysis of systems and devices for relay protection against SPEF allows us to conclude that the most problematic are power grids with isolated neutral. For these networks, in most cases, the known RP algorithms are either completely unacceptable, or involve the installation of additional complex equipment and devices.In addition, they are characterized by a high probability of protection failure in operation due to the instability of the composition and level of zero sequence currents [2, 7]. This is the basis for formulating a conclusion about the urgency of this problem for 6-10 kV power grids.

It is proposed to solve the task of ensuring the reliability of the relay protection against SPEF, in which the SNCP cannot function on some of the outgoing feeders, is proposed to be solved by the example of the existing problematic 10 kV power grid (substation №47) in “AzhK” JSC in Almaty.The outgoing feeders in this network were initially equipped with the SNCP of MICOM, but some of them were not put into operation for the reasons presented in our work. Figure 1 shows the design diagram of one of the outgoing feeder sections, made by cable lines (CL), mainly with outdated, weakened paper-oil insulation. In addition, part of the cable line is made with modern cross-linked polyethylene insulation, which is also very vulnerable to overvoltages during SPEF. The specified grid is with isolated neutral (uncompensated), i.e. does not contain an arc suppression reactor.

Calculations of the SNRP, as you know, are made according to two conditions of setpoint current selection [2, 9]:

- a failure condition at an external SPEF (on another feeder) by detuning from the protected feeder's own capacitive current;
- the triggering condition (sensitivity coefficient).

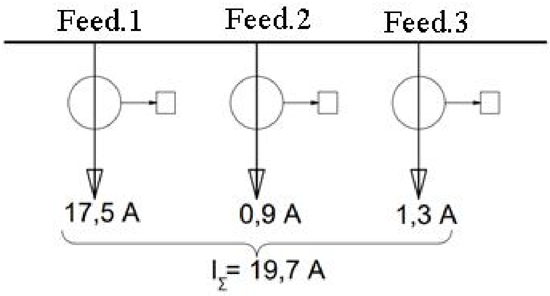

Figure 1. Distribution scheme of capacitive currents on the substation section

Calculations for outgoing feeder 1[2]:

$I_{с.з.}$= 1,2 x 1,3 x 17,5 = 27,3 A (1)

where:

- $I_{с.з}$ - tripping current;
- 1,2 – reliability factor;
- 1,3 – throw factor (for modern digital relay protection MICOM type is 1.2 - 1.4);
- 17,5 – own capacitive current of feeder 1.

K_s = (19,7 – 17,5)/27,3 = 0,08 < 1,25 (2)

where:

- K_s – sensitivity factor;
- 19,7 – total (total) capacitive current of the network.

Insofar as $K_ч$ = 0,08 < 1,25, then the selectivity condition for feeder 1 is not met [2].

Calculations for outgoing feeder 3:

$I_{с.з.}$= 1,2 x 1,3 x 0,9 = 1,4 A (3)

K_s = (19,7 – 0,9)/1,4 = 13,4 > 1,25 (4)

The selectivity condition for feeder 3 is fulfilled and this feeder is reliably protected by the installed SNCP of type MICOM.

Calculations for outgoing feeder 5:

$I_{с.з.}$= 1,2 x 1,3 x 1,3 = 2,0 A (5)

$K_s = (19,7 – 1,3)/2,0 = 9,1 > 1,25$ (6)

The selectivity condition for feeder 5 is also fulfilled and this ensures reliable protection of the installed SNCP of type MICOM.

Thus, for feeder 1 with its own capacitive current of 17.5 A, the existing SNCP cannot be used due to the insufficient value of the sensitivity coefficient.

For such cases, individual (for each feeder separately) RP are used based on the injected current or resistive grounding of the neutral, shunting of the SPEF, as well as injecting current [2, 7, 9]. However, these measures are very costly and greatly complicate the power grid.

In addition, they are beginning to use centralized relay protection against SPE, using several algorithms. In these protections, the damaged feeder is determined by the largest value of the parameter of each of the algorithms [1, 2]. However, centralized protection is very complex, expensive, requires highly qualified personnel for operation, and involves a complete reconstruction of relay protection at existing substations.

Discussion of scientific results. To eliminate the indicated disadvantage of SNCP, it is most preferable to replace individual SNCP with insufficient selectivity with individual directional zero-sequence protection.

The principle of operation of directional zero sequence protection is based on the fact that the direction of the current in the damaged feeder is opposite to the direction of the currents in the undamaged feeders. In this case, the phase-sensitive protection element (power direction organ) reacts to the change that has appeared and generates a signal about the SPEF on a specific feeder [2].

Such protection of the ZZN type is serially manufactured at the Cheboksary electrical equipment plant (Russia), is widely used and reliable in operation.

Advantages of individual directional relay protection against SPEF:

- the possibility of using in power grids containing any number of feeders with insufficient selectivity of SNCP;
- sufficient noise immunity;
- relatively low cost.

Conclusion. Based on the analysis of damage statistics in 6-10 kV power grids of "AZhK" JSC, Almaty, an increase in the damage rate of cable lines with outdated weakened insulation was established.

The low efficiency of overvoltage protection, as well as the disadvantages of relay protection against SPEF in the indicated power grids, are noted.

Calculations have been performed and presented to assess the selectivity and sensitivity of SNCP, showing the limited use of this protection against SPEF in a number of cases due to insufficient sensitivity.

The necessity of increasing the selectivity and reliability of relay protection against SPEF with insufficient sensitivity by replacing it with individual directional relay protection has been substantiated.

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В.И.Дмитриченко, Н.Т.Омирзаков, М.К.Ермагамбетов, М.А.Жетписов

НАО «Алматинский университет энергетики и связи», Алматы, Казахстан

КОМБИНИРОВАННАЯ РЕЛЕЙНАЯ ЗАЩИТА ОТ ЗАМЫКАНИЙ НА ЗЕМЛЮ В ЭЛЕКТРОСЕТЯХ 6-10 КВ

Аннотация. В данной статье рассмотрены проблемы, возникающие при ОЗЗ, в сетях с изолированной нейтралью. Основная проблема заключается в появлений перенапряжении, неработоспособность защит от перенапряжения и в отсутствии доступных и селективных защит по току. Широкое применение имеет токовая защита селективная ненаправленная, однако в сетях с ослабленной изоляцией она неприменима из-за высокого уровня перенапряжения и недостаточной чувствительности при несоизмеримых собственных емкостных токах фидеров. Это доказывается расчетами на примере ПС-47 АО «АЖК», и обосновано решение проблемы с заменой отдельных защит ТЗСН на индивидуальные направленные защиты для каждого фидера.

Ключевые слова: однофазное замыкание на землю, перенапряжение, селективная ненаправленная токовая защита, определение поврежденного фидера, условия селективности, релейная защита.

В.И.Дмитриченко, Н.Т. Өмірзақов, М.К.Ермағамбетов, М.А.Жетпісов

КЕАҚ «Алматы энергетика және байланыс университеті», Алматы, Қазақстан

6-10 КВ ЭЛЕКТР ЖЕЛІЛЕРІНДЕГІ ЖЕРГЕ ТҰЙЫҚТАЛУДАН ҚҰРАСТЫРМА РЕЛЕЛІК ҚОРҒАНЫС

Аннотация. Бұл мақалада оқшауланған нейтраль желісінде бір фазаның жерге тұйықталуы кезінде пайда болатын мәселелер қаралған. Негізгі мәселе мынада: асқын кернеудің пайда болуында, асқын кернеуден қорғаныстың жұмыс жасауға қабілетсіздігінде және қолжетімді, іріктемелі жерге тұйықталулардан тоқтық қорғаныстың жоқтығында. Кең таралған іріктемелі бағытталмаған тоқтық қорғаныс оқшаулағыш қасиеті әлсіреген желілерде жоғары асқын кернеу және бөліну желілерінің меншікті сыйымдылық тоқтарының шамаласпайтындығынан жеткіліксіз сезімталдығы себебінен қолдануға жарамсыз. Бұл АҚ «АЖК» –ның №47 қосалқы станциясының мысалында жасалған есептермен дәлелденген және бұл мәселені бағытталмаған іріктемелі тоқтық қорғанысты әрбір бөліну желісінің жеке бағытталған тоқтық қорғанысына ауыстыру арқылы шешу жолдары негізделген.

Тірек сөздер: бір фазалы жерге тұйықталу, асқын кернеу, бағытталмаған асқын токтан қорғаныс, зақымдалған қоректендіргішті анықтау, іріктемелік шарттары, релелік қорғаныс.

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