ANALYSIS OF LIMITING EARTH FAULT CURRENTS IN HIGH-VOLTAGE POWER NETWORKS USING A PETERSEN COIL"

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Annotation: This article provides detailed information about the Petersen coil used to minimize ground fault currents in electrical networks. The Petersen coil compensates for ground fault currents in medium and high voltage networks, enhancing network stability and safety. The article discusses the coil's operating principle, key characteristics, and methods for calculating technical parameters. It is noted that the use of this coil helps protect electrical equipment from overvoltage, maintain insulation levels, and reduce energy losses within the network. Additionally, the analysis of its significance in electrical systems and its role in modern energy infrastructure is presented.

Keywords: Petersen coil, ground fault, electrical networks, equipment protection.

Annotatsiya: Ushbu maqolada elektr tarmoqlaridagi yer bilan qisqa tutashuv oqimlarini minimallashtirish uchun qo‘llaniladigan Petersen induktivlik g‘altagi haqida batafsil ma’lumot berilagan. Petersen g‘altagi o‘rta va yuqori kuchlanishli tarmoqlarda yerga nisbatan qisqa tutashuv toklarini kompensatsiya qilishga xizmat qilib, tarmoq barqarorligi va xavfsizligini oshiradi. Maqolada g‘altakning ishlash prinsipi, asosiy xususiyatlari va texnik parametrlarini hisoblash usullari muhokama qilingan. Ushbu g‘altakdan foydalanish elektr jihozlarini o‘ta kuchlanishlardan himoyalash, izolyatsiya darajasini saqlash va tarmoqdagi energiya yo‘qotishlarini kamaytirishga yordam berishi takidlangan. Shu bilan birga, maqolada elektr tizimlaridagi ahamiyati va zamonaviy energiya infratuzilmalaridagi roli tahlili keltirilgan.

Kalit so‘zlar: Petersen g‘altagi, yerga tutashuvi, elektr tarmoqlari, jihozlarni himoyalash.

Аннотация: В данной статье представлена подробная информация об индуктивной катушке Петерсена, используемой для минимизации токов замыкания на землю в электрических сетях. Катушка Петерсена служит для компенсации токов короткого замыкания на землю в сетях среднего и высокого напряжения, повышая устойчивость и безопасность сети. В статье обсуждаются принцип работы катушки, её основные характеристики и методы расчета технических параметров. Указывается, что использование этой катушки помогает защитить электрическое оборудование от перенапряжений, сохранить уровень изоляции и снизить потери энергии в

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сети. Также проведен анализ её значения в электрических системах и роли в современной энергетической инфраструктуре.

Ключевые слова: катушка Петерсена, замыкание на землю, электрические сети, защита оборудования.

Introduction

Today, the reliable and safe transmission of electrical energy is considered a critical requirement of power networks. In electrical systems, faults to ground such as single-phase (65%), double-phase (20%), and three-phase (5%) short circuits can cause disruptions or damage to electrical equipment [1]. To address this issue, technologies for compensating earth fault currents are widely applied. One such technology is the Petersen coil. This device ensures stable operation of the network by balancing earth fault currents at resonance frequency in power systems operating at voltages from 35 kV to 220 kV.

This article provides an in-depth analysis of the limitation of single-phase earth fault currents using Petersen coils and explores their effectiveness in electrical networks. Furthermore, it discusses calculation methods of their technical characteristics and their application in modern energy systems.

Earth fault currents are considered harmful and dangerous to electrical equipment. When a Petersen coil is connected to the system, it operates at resonance frequency and minimizes the flow of ground currents. As a result, the magnitude of harmful fault currents is significantly reduced. In this way, the Petersen coil enhances the stability and safe operation of power networks.

The advantages of Petersen coils include the following:

- Reduction of earth fault currents;
- Improvement of voltage stability in the power network;
- Enhancement of safety levels and protection of electrical equipment [2].

These coils are typically used as protective devices in high-voltage networks and can be operated in conjunction with automated control systems. The inductance (L) of the Petersen coil can be calculated using the following expression (1):

$$L = \frac{1}{\omega * I_n}; \qquad (1)$$

where:

L – inductance of the Petersen coil (H)

ω - angular velocity, i.e. (**ω** = *2 *π* * *f*),

f - network frequency (50 Hz)

I_n - earth fault current (A).

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The inductance value calculated using expression (1) enables the compensation of earth fault currents by the coil.

The earth fault current in general power systems typically exhibits a nearly pure capacitive nature, which can reach dangerously high levels. When a supply reactor of a certain inductance is connected into the fault loop, the earth fault current is neutralized or damped—meaning it is significantly reduced.

Due to the fact that grounding capacitances vary with changes in system load (such as the connection and disconnection of lines), the Petersen coil must also be adjustable. Therefore, at selected points in the power system, grounding connections of transformer neutral points utilize plunger-type coils or tapped coils that are connected to the grounding line.

Since the short-circuit current includes an active component caused by line resistances, full compensation is not possible. This active component typically accounts for approximately 10% of the fault current and is characterized as the unbalanced residual current of the earth connection [3].

If the electric arc occurs at the fault location in an overhead power supply system, it will extinguish automatically when the residual current is sufficiently low. In such cases, disconnection of the partially affected network may not be necessary. This highlights the technical and economic significance of neutralizers in overhead lines and mixed systems consisting of both overhead lines and cable networks.

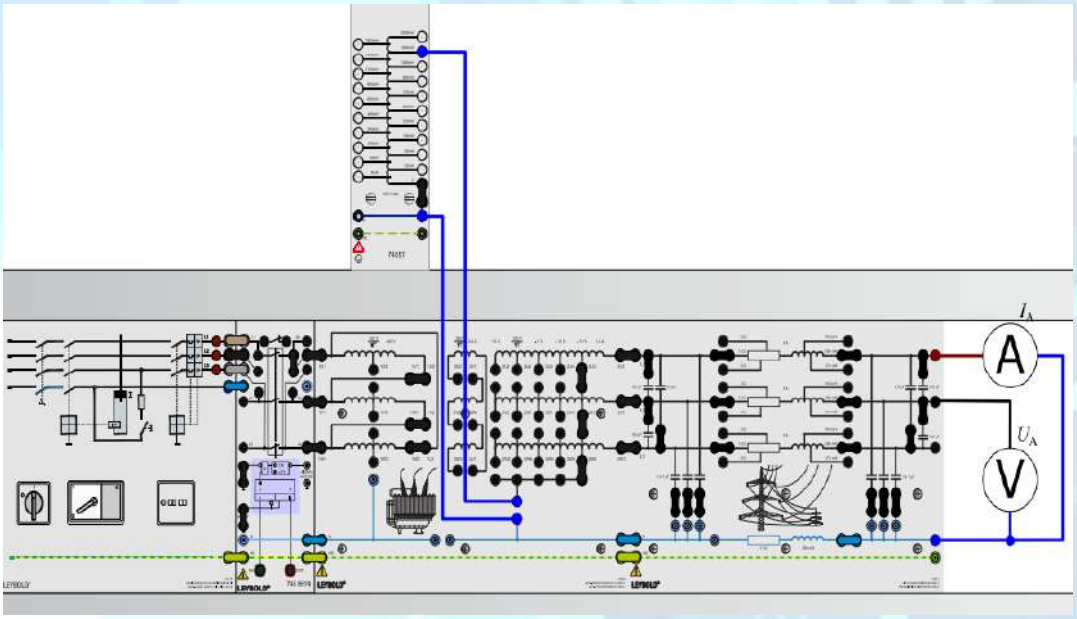
In purely cable networks, arc extinction under fault conditions is not feasible; only the limitation of fault current is possible. However, this approach still reduces the risk of fault propagation within the system.

In this grounding method, one or several neutral points are grounded either directly or through a low-resistance resistor. This type of grounding is commonly applied in high-voltage (110 kV) cable networks as well as in extra-high-voltage (220 and 380 kV) overhead and cable transmission networks. In Europe, direct grounding of the neutral point is more commonly used [4].

The main advantage of this method lies in the low ground fault factor, meaning that during an earth fault, the voltage of the unaffected phases increases only slightly. This provides an insulation advantage for both the line and the connected transformers. However, in the event of a single-line-to-ground fault, the current can be very high—potentially reaching the level of a three-phase short-circuit current. To clarify this scenario, such fault currents are referred to as **earth short-circuit currents**, which differ from fault currents in other grounding methods. These types of faults must be eliminated as quickly as possible using network protection devices.

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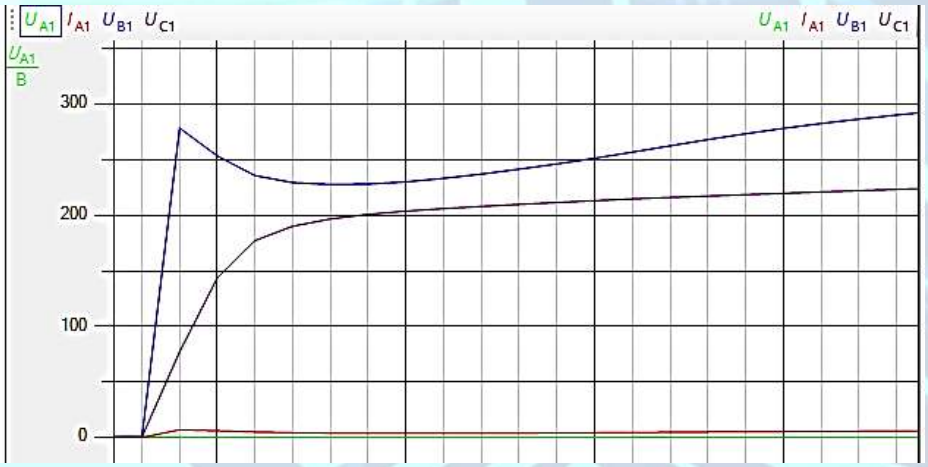
In the laboratory stand of the electrical network system, a voltage of 1 V is considered equivalent to 1 kV. Accordingly, a voltage of 220 V represents 220 kV.Various inductance values of the Petersen coil—specifically 720, 1125, 1445, 1680, and 1805 mH—were selected and applied under conditions of single-phase earth fault. The resulting variations in current magnitude and line voltages were analyzed.



a)

Figure 1. Laboratory setup of the electrical network system.

Initially, when the inductive coil with an inductance of 720 mH was connected to the system, the results are as shown in Figure 1.



b)

Figure 2. Graph of short-circuit current and line voltage variation when a Petersen coil with an inductance of 720 mH is connected to the network.

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Figure 3. Graph of short-circuit current and line voltage variation when a Petersen coil with an inductance of 1445 mH is connected to the network.

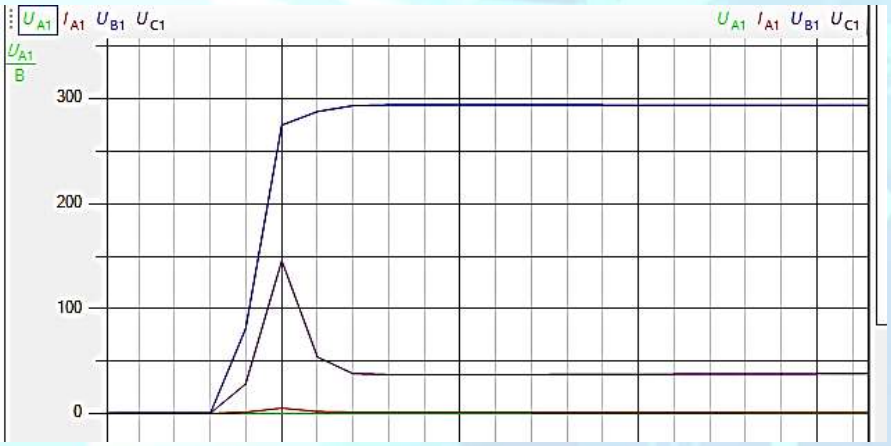


Figure 4. Graph of short-circuit current and line voltage variation when a Petersen coil with an inductance of 1805 mH is connected to the network.

Table 1

Petersen Coil Inductance L (mH)	720	1125	1445	1680	1805
$I_{q.t}$ (kA)	0,121	0,057	0,027	0,03	0,36
U_A (kV)	0,3	0,3	0,3	0,3	0,3
U_B (kV)	251,7	319,7	303,6	297,5	294,1
U_C (kV)	213,4	60,6	30	30,3	38

Figure 7 illustrates the curve of the residual earth fault current as a function of the inductance of the compensation coil.

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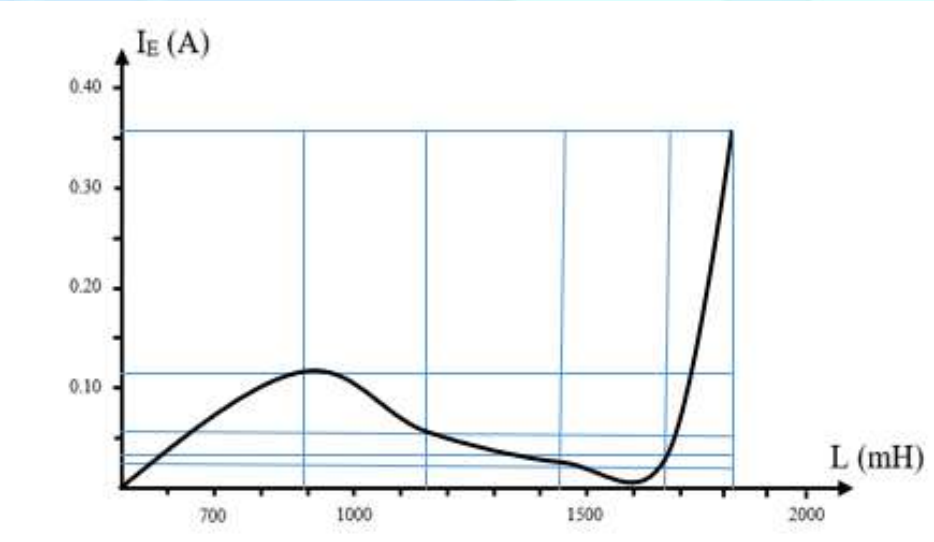


Figure 5. Graph of current magnitude as a function of inductance.

Conclusion:

The Petersen coil has proven to be highly effective and reliable in limiting earth fault currents in medium- and high-voltage power networks. In this study, the inductance of the coil was applied and analyzed to minimize short-circuit currents occurring in the network. The research findings indicate that in a 220 kV electrical network, the single-phase-to-earth fault current was reduced by up to 20 times when a Petersen coil with an inductance of 1445 mH was used.

Furthermore, the coil significantly decreases the earth fault current, thereby reducing fire hazards and the risk of insulation damage. Given that the Petersen coil is available in various sizes and parameters that meet technical requirements, it can be widely applied in electrical networks.

The optimization of the Petersen coil enhances its role as an effective safety measure in electrical power transmission systems, providing additional reliability and operational stability.

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