https://doi.org/10.33271/nvngu/2025-1/055

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IMPACT OF POWER ELECTRONICS DEVICES ON LEAKAGE CURRENT IN MINE ELECTRICAL SYSTEMS: A CASE STUDY IN VIETNAM

Purpose. To determine the impact of power electronic devices on leakage current in underground mine AC power network. The research results allow choosing appropriate leakage protection method to improve electrical safety in underground mining.

Methodology. This study uses analytical methods and modeling methods on Matlab/Simulink software to determine, analyze, and evaluate the working current and leakage current in the mine power network containing power electronic devices.

Findings. A mine power network model containing inverter and electric motor was built by analytical method and simulated using Matlab/Simulink with model parameters $U = 1{,}140$ V, $C = 0.19$ uF/phase, $R = 168$ kΩ/phase. The research results show that, with a leakage resistance of 1 kΩ, the leakage current value in the AC network with a frequency other than 50 Hz after the inverter (467 mA) is 1.52 times higher than the leakage current value in the AC network with a frequency of 50 Hz before the inverter (307 mA), and at the same time, many high-order harmonic components appear in the 50 Hz AC network with THD = 1.77. In addition, the research results also show that the leakage current in the AC network before and after the inverter depends less on the insulation resistance of the DC network but depends mainly on the insulation of the AC network, the leakage resistance and the operating frequency of the AC network.

Originality. Leakage current in AC power network containing power electronic devices in mining in Vietnam is studied. The research results show that when using a mine power network with an inverter, the leakage current on the AC side after the inverter has a larger value than the leakage current of the AC side before the inverter.

Practical value. The research results allow choosing the appropriate leakage protection method to improve electrical safety in underground mining.

Keywords: *electrical safety, power electronic devices, leakage current, underground mining*

Introduction. The characteristics of underground mining in Vietnam are narrow mining space, high humidity in mining up to 98 ± 2 % and dangerous environment of explosive dust and gas. Therefore, mining always creates electrical safety hazards. Ensuring electrical safety in underground mining is one of the top tasks [1, 2]. Currently, to ensure safety in mining, a series of solutions are being implemented: the power network is an isolated neutral network; grounding with resistance not exceeding 2Ω; limits on power supply radius and the number of connected devices; the power network is equipped with an electric leakage protection relay [1, 3].

In mining in Vietnam today, RLR-660/1140PN leakage protection relays made in Vietnam or JY82 devices made in China are basically used. These leakage protection relays are designed and manufactured to work in mine power networks with sinusoidal signals at 50 Hz frequency [4]. The advent of semiconductor and control technology has revolutionized the mining industry, introducing a plethora of power electronic devices like rectifiers, inverters, and soft starters. While these devices offer significant benefits in terms of energy efficiency and operational flexibility, they also introduce a new challenge: the generation of non-fundamental frequency current components within the mine power network. The use of these power electronic devices causes the current in the mine power network to appear current components other than 50 Hz [5]. The appearance of these current components other than 50 Hz will lead to unreliable operation of the leakage protection devices currently used in mining, leading to safety risks [6, 7].

Many studies have shown the influence of frequency converters on leakage currents in industrial power networks in general and underground mine power networks in particular [8]. In the study [9, 10], they studied the effect of high frequency current in the range of 50 Hz to 150 kHz on the operation of Residual Current Devices (RCDs); the results of the study showed that type A and AC RCDs have increased fundamental tripping current (50 Hz) in the presence of HF components, which poses a potential safety hazard. In the study [11–13], the influence of high-order harmonics on electrical equipment in mining was studied, the research results showed that high-order harmonics negatively affect the operation of mine electrical equipment.

Research [14, 15] presents considerations on leakage protection measures operating in underground coal mine network systems containing loads including inverters. The possibility of failures in the leakage protection has been demonstrated in the case of reduced leakage protection in the DC circuit. In the study [16], simulations have shown that the cable branch of the inverter is characterized by an unacceptably high probability of fatal electric shock. In the study [17], the mathematical model of the cable branch of the inverter as part of the substation power network was improved with a single-phase grounding. As a result of the numerical simulation for a specific case of the network, it was determined that the occurrence of a short circuit to ground due to the human body in the cable branch of the inverter is characterized by an unacceptably high probability of fatal electric shock.

In the study [18], it was shown that the normal leakage current fluctuation has a great influence on the fixed threshold of leakage protection. To solve this problem, this paper proposes an adaptive leakage protection method based on the back propagation (BP) neural network of the sparrow search algorithm (SSA). In the study [19] new approaches and development technologies adapted to the voltage fluctuation leakage current protection system used in the isolated neutral system are proposed. The protection device control algorithm is developed using fuzzy logic, which allows adjusting the threshold of the protection device when the network parameters change. In the study [20], the method for detecting insulation degradation of mine cables is studied, especially the technology of additional low-frequency signal sampling of power cables.

In case of fault, the fault current is no longer sinusoidal and the response of the human body to multi-frequency currents has been studied considering the perception threshold for the test waveform defined in IEC 62423 [21]. A novel concept of multi-level leakage protection system is proposed to accommodate the shortcomings mentioned in the current leakage protection system used in underground low voltage distribution network [22].

Through the above analysis, it can be seen that the use of power electronic devices generates harmonics, increases losses on equipment, causes errors in measuring devices, etc. and also causes many other factors that lead to the mistaken impact of leakage protection devices in the power network, causing unsafety in mining. However, previous studies have not mentioned the evaluation and survey of the value of leakage current in the mine power network using power electronic devices according to the insulation parameters of the power network, which leads to not suitable setting of leakage relay, causing unsafety in mining. Therefore, the survey and assessment of the leakage current value to calculate and adjust the leakage protection value will improve safety in mining. The content of the article analyzes the influence of power electronic devices on leakage protection in the mine power network with the characteristic parameters of the mine power network in Vietnam. The research method is shown on the basis of theory and simulation, the research results will provide recommendations to improve leakage protection in the mine power network to ensure safety in mining. Part 1 of the paper presents an overview of the related issues. Part 2 presents the network parameters and the model for determining leakage current in a mine network containing converters. Part 3 presents the results of a study on the influence of converters on leakage current. The final part is the conclusion of the study.

Leakage current in mine power network containing conversion devices. ***Insulation parameters of underground mine power network.*** Leakage current in mine power network depends on the insulation parameters of the power network. To determine the insulation parameters of underground mine power network, the three-voltmeter method is often used. Its outstanding advantages are simple measurement techniques and measuring instruments. In general, the schematic diagram of the measuring device using the three-voltmeter method to determine the insulation resistance value of the power network is shown in Fig. 1.

From Fig. 1, the effective conductance and capacitance of the network relative to ground are determined by the formula:

$$G_\Sigma = \frac{1}{R_A} + \frac{1}{R_B} + \frac{1}{R_C} = \frac{1}{R}; \quad C_\Sigma = C_A + C_B + C_C. \tag{1}$$

Assuming the source voltage is symmetrical, when adding an additional resistor R_f, the voltage vector graph of the network is depicted in Fig. 2.

From the vector graph, the neutral displacement voltage $\dot{U}_N$ can be calculated according to the phase voltages $\dot{U}_A, \dot{U}_B, \dot{U}_C$. The equation of a circle with center at points A, B, C and radii U_A, U_B, U_C has the form

$$\left(x - \frac{U_d}{\sqrt{3}}\right)^2 + y^2 = U_A^2; \quad \left(x + \frac{U_d}{2\sqrt{3}}\right)^2 + \left(y + \frac{U_d}{2}\right)^2 = U_B^2; \quad \left(x + \frac{U_d}{2\sqrt{3}}\right)^2 + \left(y - \frac{U_d}{2}\right)^2 = U_C^2. \tag{2}$$

Hence

$$x = \frac{U_B^2 + U_C^2 - 2U_A^2}{6U_f}; \quad y = \frac{U_B^2 - U_C^2}{2\sqrt{3}U_f},$$

where U_f is phase voltage; U_d is line voltage; x, y are the coordinates of the phase shift point N.

Therefore

$$\dot{U}_N = \frac{U_B^2 + U_C^2 - 2U_A^2}{6U_f} + j\frac{U_B^2 - U_C^2}{2\sqrt{3}U_f}. \tag{3}$$

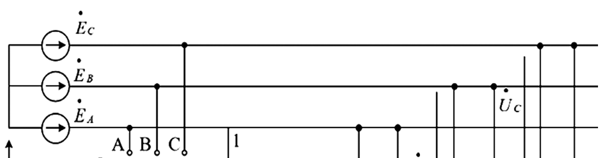


Fig. 1. Schematic diagram of insulation parameter measurement using the three-voltmeter method

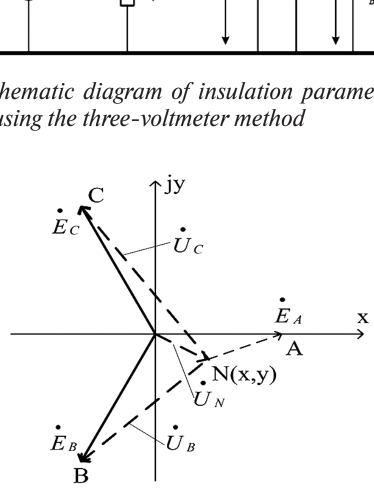


Fig. 2. Voltage vector graph when adding additional resistor R_f

Phase voltages $\dot U_A, \dot U_B, \dot U_C$ can be calculated as follows

$$\dot U_A = U_f - \dot U_N = \frac{2U_A^2-(U_B^2+U_C^2)}{6U_f}+U_f + j\frac{U_C^2-U_B^2}{2\sqrt{3}U_f}; \quad (4)$$

$$\dot U_B = a^2U_f - \dot U_N = \frac{2U_A^2-(U_B^2+U_C^2)}{6U_f}-\frac{1}{2}U_f + j\left[\frac{U_C^2-U_B^2}{2\sqrt{3}U_f}-\frac{\sqrt{3}}{2}U_f\right]; \quad (5)$$

$$\dot U_C = aU_f - \dot U_N = \frac{2U_A^2-\left(U_B^2+U_C^2\right)}{6U_f}-\frac{1}{2}U_f + j\left[\frac{U_C^2-U_B^2}{2\sqrt{3}U_f}+\frac{\sqrt{3}}{2}U_f\right]. \quad (6)$$

When phase A is short-circuited to ground

$$\dot I_{An} = \dot U_A \cdot Y_\Sigma. \quad (7)$$

When R_f is added, the short circuit current is equal to

$$\dot I_{An} = \dot U'_A \cdot (Y_\Sigma + Y_f), \quad (8)$$

where, $\dot U'_A$ is phase A voltage relative to ground when adding additional resistor R_f; $Y_\Sigma = G_\Sigma + j\omega C_\Sigma$ – total admittance of the electrical network insulation relative to ground; $Y_f = \frac{1}{R_f} = g_f$ – additional admittance connected to phase A of the network.

Because the short-circuit current in the two cases is constant, (7) and (8) lead to

$$\dot U_A \cdot Y_\Sigma = \dot U'_A \cdot (Y_\Sigma + Y_f) \rightarrow Y_\Sigma = \frac{\dot U'_A \cdot Y_f}{\dot U_A - \dot U'_A}. \quad (9)$$

The total insulation conductance and total insulation susceptance of the network relative to ground are calculated as follows

$$G_\Sigma = \mathrm{Re}\left(\frac{\dot U'_A \cdot Y_f}{\dot U_A - \dot U_A}\right);$$

$$b_\Sigma = \omega C_\Sigma = I_m\left(\frac{\dot U'_A \cdot Y_f}{\dot U_A - \dot U'_A}\right). \quad (10)$$

Assuming

$$\dot U_A = a + jd;$$

$$\dot U'_A = a' + jd', \quad (11)$$

where

$$a = \frac{2U_A^2-(U_B^2+U_C^2)}{6U_f}+U_f;$$

$$a' = \frac{2U_A'^2-\left(U_B'^2+U_C'^2\right)}{6U_f}+U_f;$$

$$d = \frac{U_C^2-U_B^2}{2\sqrt{3}U_f};$$

$$d' = \frac{U_C'^2-U_B'^2}{2\sqrt{3}U_f}.$$

Substitute $Y_f = \frac{1}{R_f}$ and (11) into expressions (10), and get the result

$$G_\Sigma = \frac{1}{R_\Sigma} = \frac{a'(a-a')+d'(d-d')}{R_f\left[(a-a')^2+(d-d')^2\right]};$$

$$C_\Sigma = \frac{ad'-a'd}{\left[(a-a')^2+(d-d')^2\right]R_f}. \quad (12)$$

Total insulation admittance of the network relative to ground is

$$Y_\Sigma = G_\Sigma + j\omega C_\Sigma. \quad (13)$$

From formulas (12, 13) determine the insulation parameters of the isolated three-phase neutral network as the basis for determining the leakage current of the underground mine power network.

General model of the mine power network containing converters. The underground mine power network model containing the converters to supply power to AC and DC loads is shown in Fig. 3 [13].

Fig. 3 shows that in a mine power network containing converters, the power network will include three types of current components: 50 Hz alternating current before the inverter (BI), direct current (DC) and alternating current with a frequency other than 50 Hz after the inverter (AI). A general replacement diagram for an underground mine power network containing converters is shown in Fig. 4 [6].

In the diagram in Fig. 4, the symbols are represented as follows. The insulation resistance and phase capacitance to ground of the power network before the inverter (BI) are represented by the symbols R_A, R_B, R_C, C_A, C_B, C_C. The insulation resistance and phase capacitance to ground of the network after the inverter (AI) are represented by the symbols R_{Af}, R_{Bf}, R_{Cf}, C_{Af}, C_{Bf}, C_{Cf}. *The insulation resistance* and capacitance between the positive (+) and negative (–) poles relative to ground of the direct current (DC) network are represented by the symbols R_+, R_-, C_+, C_-; U_f is the secondary phase voltage of the area transformer; U_0 is the average value of the three-phase bridge rectifier voltage.

Suppose that when there is a leakage in the AC power network, the leakage current i_a from the BI network is divided into two current components i_{a1} and i_{a2}, which are the leakage current components to the AC and DC power networks. Similarly, the leakage current i_b from the AI network is the current i_{b1} and i_{b2} to the DC and AC power networks. To determine these current components, it is necessary to determine the insula-

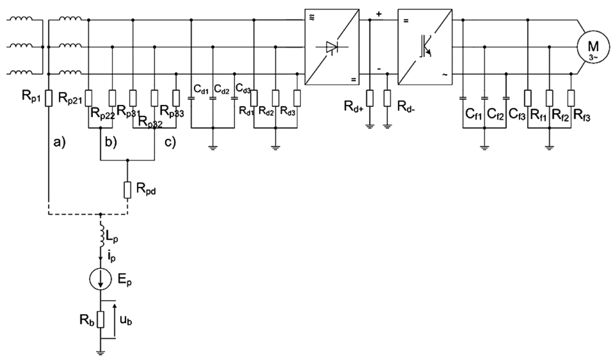


Fig. 3. The mine power network with converters

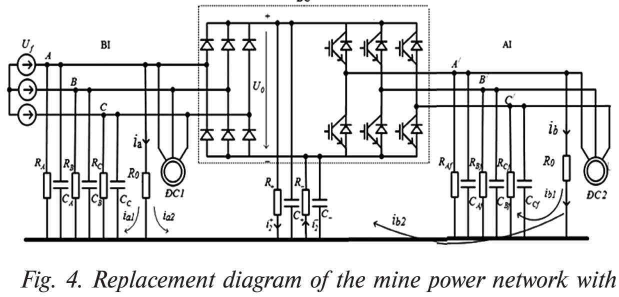


Fig. 4. Replacement diagram of the mine power network with converters

tion resistance parameters of the network and the voltage of the phases relative to ground in the mine power network.

Determination of leakage current in the mine power network with converter.

a. Leakage current on the 50 Hz AC power network side (BI).

With the isolation parameters of the power network determined as (12, 13), if there is an electric leakage before the inverter (BI) through the leakage resistor R_0, the corresponding leakage current i_a is divided into two components: the leakage current component i_{a1} closes the loop to the 50 Hz AC power network, the leakage current component i_{a2} closes the loop to the DC power network (Fig. 4). The leakage current i_a before the inverter is determined according to formula [6]. The root mean square value of the AC and DC components is determined:

- the AC component leakage current is determined by the formula

$$I_{a1} = U_f \frac{\sqrt{R^2 + X_C^2}}{\sqrt{R^2 R_0^2 + X_C^2 (R + R_0)^2}},$$

where R is resistor; X_c – electrical reactance; U_f – phase voltage of the power grid;

- leakage current to the DC network consists of two components: leakage current component towards the positive grid I_{a2}^{+} and leakage current component towards the negative grid I_{a2}^{-} of the AC network, determined by the formula

$$I_{a2}^{+} = \frac{1.17U_f}{R_0(R + R_+) + RR_+} R;$$

$$I_{a2}^{-} = \frac{1.17U_f}{R_0(R + R_-) + RR_-} R.$$

Total DC leakage current is determined

$$I_{a2} = 1.17U_f \left(\frac{1}{R_0(R + R_-) + RR_-} - \frac{1}{R_0(R + R_+) + RR_+} \right) R.$$

The root mean square value of leakage current on 50 Hz power network side before inverter (BI) is calculated by formula (15)

$$I_a = \sqrt{I_{a1}^2 + I_{a2}^2};$$

$$I_a = U_f \sqrt{\frac{R^2 + X_C^2}{R^2 R_0^2 + X_C^2 (R + R_0)^2} + 1.17^2 R^2 \left[\frac{1}{R_0(R + R_-) + RR_-} - \frac{1}{R_0(R + R_+) + RR_+} \right]}. \quad (15)$$

From expression (15), it can be seen that the leakage current in the network before the inverter (BI) depends not only on the resistance and reactance of the network (BI) but also on the insulation resistance of the DC network. When the DC network is symmetrical ($R_+ = R_-$), the leakage current then only has an AC component

$$I_a = I_{a1} = U_f \frac{\sqrt{R^2 + X_C^2}}{\sqrt{R^2 R_0^2 + X_C^2 (R + R_0)^2}}. \quad (16)$$

From formula (16), it can be seen that in a DC power network with symmetrical resistance, the leakage current of the power network depends only on the voltage, insulation parameters and leakage current value of the power network.

b. Leakage current on AC power network with frequency other than 50 Hz.

Similarly, when leakage occurs in the power network after the AI inverter through the leakage resistor R_0, the leakage current i_b consists of two components i_{b1}, i_{b2} respectively closing the loop towards the 50 Hz AC power network and the DC power network (Fig. 4), the leakage current i_b is determined according to the formula [6]. The root mean square value of the AC and DC current components is determined according to the formula

$$I_{b1} = U_f' \frac{\sqrt{R_f^2 + X_{Cf}^2}}{\sqrt{R_f^2 R_0^2 + X_{Cf}^2 (R_f + R_0)^2}}; \quad (17)$$

$$I_{b2} = \frac{2.34U_f}{R_- R_+ R_f + R_- R_+ R_0 + R_- R_f R_0 + R_+ R_f R_0} R_+ R_f.$$

Root mean square value of leakage current of power network with frequency other than 50 Hz after inverter is calculated by formula (18).

From formula (18), it can be seen that the leakage current after the external inverter depends on the parameters of the power network after the inverter and also depends on the resistances R_+ and R_- of the DC power network. When the DC power network is symmetrical ($R_+ = R_- = R_{dc}$), the leakage current then only has an AC component and is calculated by formula (19).

$$I_b = \sqrt{I_{b1}^2 + I_{b2}^2};$$

$$I_b = \sqrt{\frac{U_f'(R_f^2 + X_{Cf}^2)}{R_f^2 R_0^2 + X_{Cf}^2 (R_f + R_0)^2} + \frac{(2.34U_f R_+ R_f)^2}{R_- R_+ R_f + R_- R_+ R_0 + R_- R_f R_0 + R_+ R_f R_0}}; \quad (18)$$

$$I_b = \sqrt{\frac{U_f'(R_f^2 + X_{Cf}^2)}{R_f^2 R_0^2 + X_{Cf}^2 (R_f + R_0)^2} + \frac{(2.34U_f R_f)^2}{(R_{dc} R_f + R_{dc} R_0 + 2R_f R_0)^2}}. \quad (19)$$

From formula (19), it can be seen that, in general, the leakage current in the power network after the inverter depends not only on the parameters of the power network after the inverter but also on the insulation of the DC circuit R_{dc}. In the ideal case, the insulation of the DC network is extremely large ($R_+ = R_- = R_{dc} = \infty$), then the leakage current component of the power network after the inverter is determined by the formula

$$I_b = U_f' \frac{\sqrt{R_f^2 + X_{Cf}^2}}{\sqrt{R_f^2 R_0^2 + X_{Cf}^2 (R_f + R_0)^2}}. \quad (20)$$

According to formula (20), it can be seen that in the most ideal case, meaning the case where the insulation resistance of the DC power network is extremely large, the leakage current value in the network depends on the voltage, resistance, reactance of the power network after the inverter and the leakage current value of the power network.

Results and discussion. The mine power network model to evaluate the impact of converters on leakage current in the mine power network is built based on the power network parameters suitable for mining in Quang Ninh region of Vietnam corresponding to the model values: $U = 1{,}140$ V, $C = 0.19$ uF/phase, $R = 168$ kΩ/phase. The simulation model is built on Matlab – simulink software as shown in Fig. 5.

In the case of a DC power network with ideal insulation ($R_+ = R_- = \infty$), the current and voltage characteristics of the 50 Hz frequency power network before the inverter and the other 50 Hz frequency power network after the inverter supplying the working motor are given in Figs. 6 and 8.

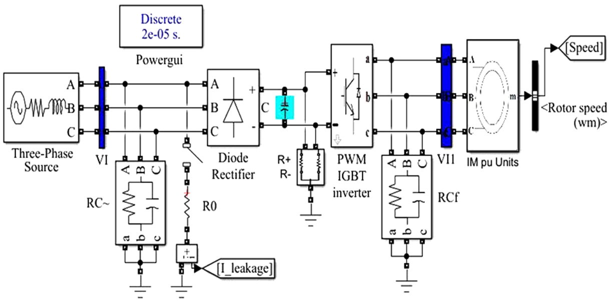
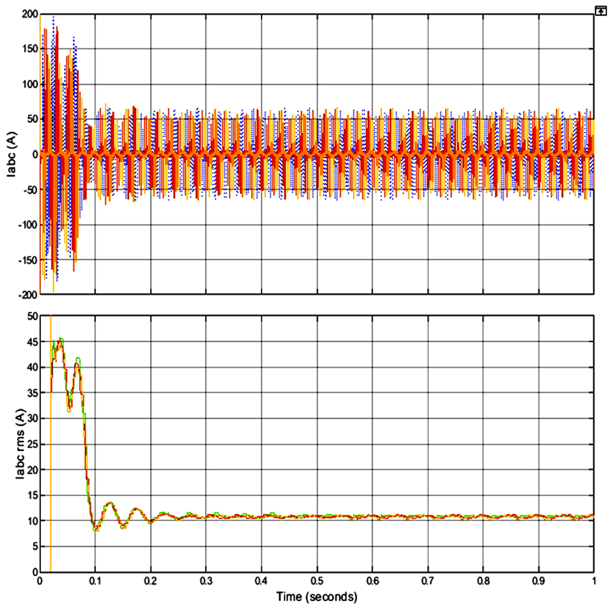
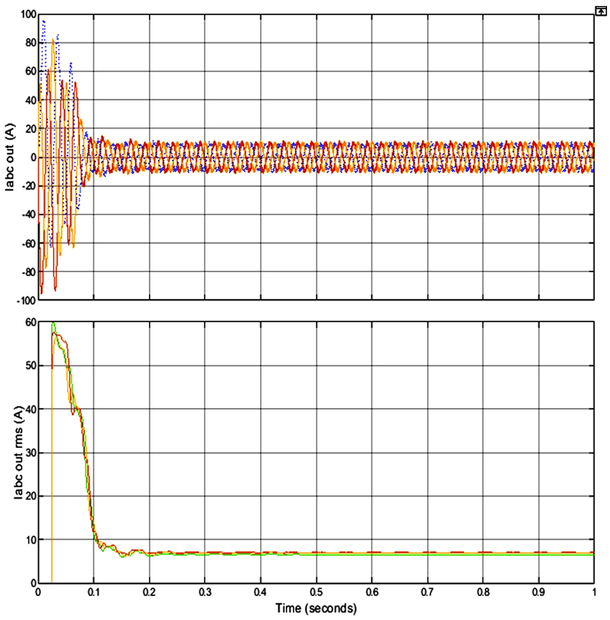


Fig. 5. Mine power network simulation model with converters

The results in Fig. 6 show that when using power electronic devices in the mine power network, the current appears with many high-order harmonic components, leading to a distorted current that is no longer sinusoidal. The level of distortion is characterized by using the total harmonic current coefficient



a



b

Fig. 6. Network current before the inverter (a), after the inverter (b)

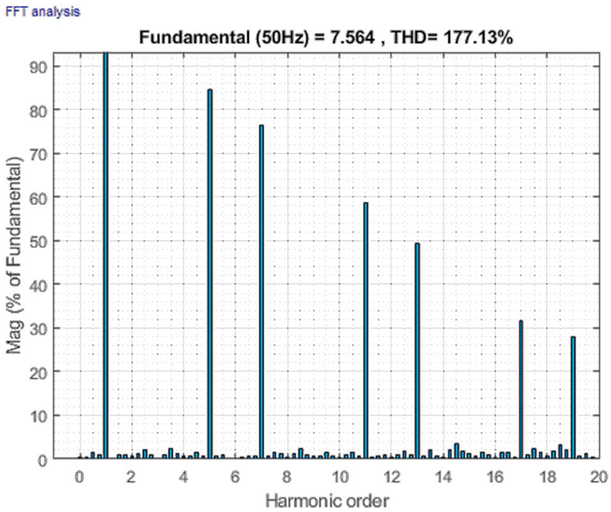
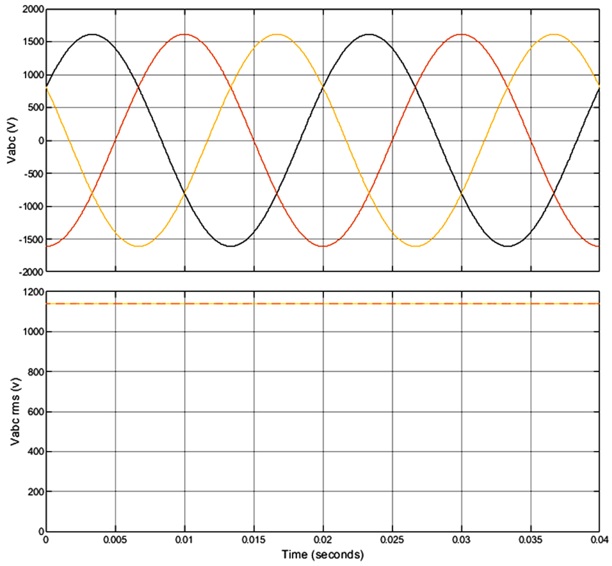


Fig. 7. FFT analysis of network current before the inverter



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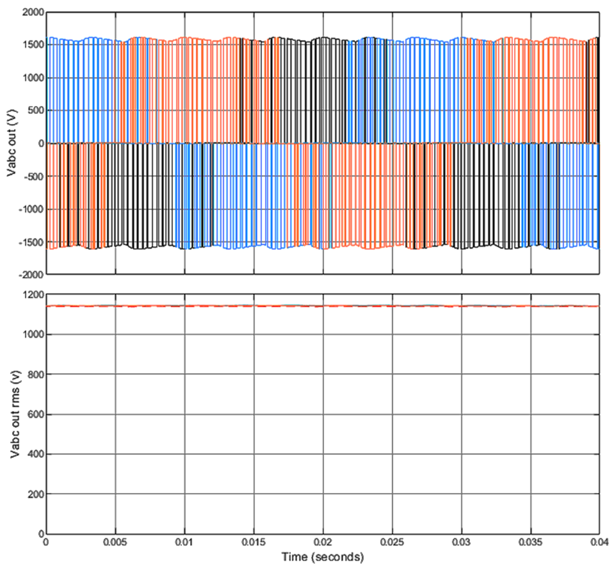


b

Fig. 8. Network voltage before the inverter (a), after the inverter (b)

THD [23, 24]. FFT analysis of network current before the inverter is shown in Fig. 7. The result of the analysis of the total harmonic distortion of the 50 Hz AC power network has a value of 1.77. With THD = 1.77, it not only increases the loss in the power network and electrical equipment, but also causes measurement errors of measuring devices and causes confusion in the protective devices, especially the leakage protection in the mine power network.

In the case of a DC power network with ideal insulation ($R_+ = R_- = \infty$), there is electric leakage through the leakage resistance $R_0 = 1$ kΩ on the 50 Hz AC power network before the inverter and the other 50 Hz AC power network after the inverter. The results of the leakage current survey of the power network before the inverter and after the inverter are shown in Fig. 9.

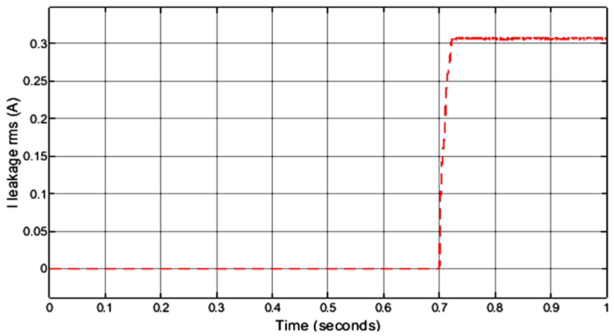
The results in Fig. 9 show that the leakage current value in the AC network before the 50 Hz frequency inverter is i_a = = 307 mA, the leakage current value in the AC network with a frequency other than 50 Hz after the inverter is i_b = 467 mA. Thus, it can be seen that in a condition of the power network when there is an electric leakage on the AC network with a frequency other than 50 Hz after the inverter, the leakage current increases to 1.52 times the leakage current of the AC network before the 50 Hz frequency inverter, which causes unsafety in mining as well as the mistaken impact of the electric leakage protection in the mine power network.

In case the insulation of the DC power network is degraded, the insulation of positive pole (R_+) and negative pole (R_-) are degraded differently. Suppose the initial insulation resistance of the positive pole and the negative pole are the same $R_+ = R_- = 500$ kΩ, then the insulation resistance of the negative pole (R_-) is degraded to 100 kΩ, then the leakage current of the 50 Hz AC power network before the inverter and the other 50 Hz AC power network after the inverter depends on the insulation of the DC network as shown in Fig. 10.

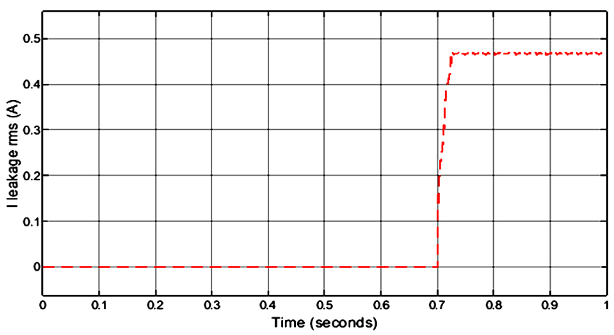
The results in Fig. 10 show that after a leakage occurs, after a period of 0.02 and 0.025 s, the leakage current will stabilize in the case of leakage before the inverter and after the inverter. During this time, the leakage current on the BI side fluctuates more strongly than the leakage current on the AI side. The stable values of the BI and AI network leakage currents are basically unchanged at 307 and 467 mA respectively, and the leakage current of the network after the inverter is still 1.52 times larger than the leakage current before the inverter as in the case of the DC network with extremely large insulation. Consequently, it becomes evident that the leakage current magnitudes within both the BI and AI networks exhibit a reduced sensitivity to the insulating condition of the DC network. Instead, these currents are primarily influenced by the inherent leakage resistance (R_0) and the prevailing operating frequency of the mine network. This observation underscores the critical role of these factors in shaping the overall leakage current profile and highlights the need for effective monitoring and control strategies to ensure electrical safety in mining environments.

Through the above analysis, it can be seen that the frequency of the converter greatly affects the leakage current value. Power electronic devices, integral components of modern mine power networks, are frequently adjusted to synchronize their operating frequencies with the specific demands of various mining equipment. Adjusting the frequency of power electronic devices will lead to changes in the value of leakage current in the mine power network. The intricate relationship between the operating frequency and leakage current presents a compelling avenue for further research. By meticulously analyzing the impact of frequency variations on leakage current levels, researchers can develop innovative leakage protection strategies tailored to enhance electrical safety in underground mining environments. Such advancements would not only safeguard personnel and equipment but also contribute to the overall reliability and sustainability of mining operations.

Conclusions. Nowadays, with the development of material technology and semiconductor technology, power electronic devices are increasingly used in underground mining power networks. The use of power electronic devices changes the leakage current, causing many high-order harmonic components in the power network, causing confusion of

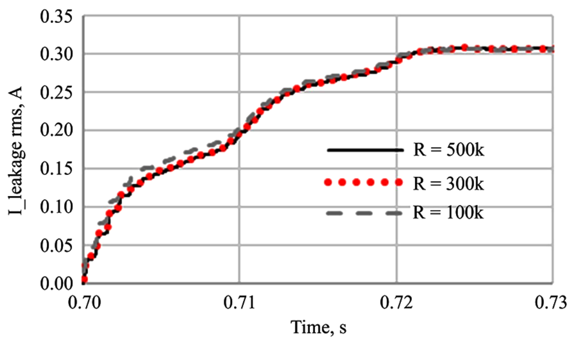


a

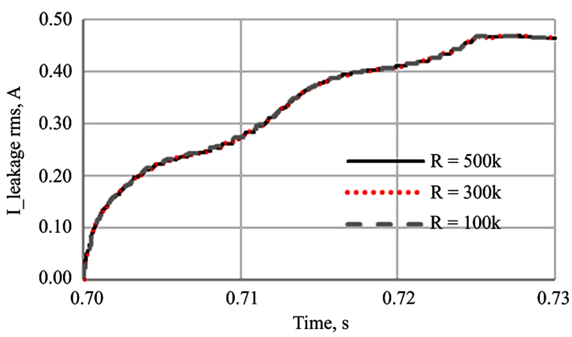


b

Fig. 9. Effective value of leakage current:
a – before the inverter; b – and after the inverter



a



b

Fig. 10. Leakage current before the inverter (a) and after the inverter (b) changes the DC insulation resistance

leakage protection devices in the power network, causing unsafety in mining.

The research results with the model parameters $U = 1{,}140$ V, $C = 0.19$ uF/phase, $R = 168$ kΩ/phase showed that when using power electronic devices, the leakage current value after the inverter is 1.52 times higher than the leakage current value before the inverter, respectively $i_a = 307$, $i_b = 467$ mA and many high-order harmonic components appear in the power network (THD = 1.77), which increases the loss as well as the mistaken impact on the leakage protection device in the underground mine power network. In addition, the research results also showed that the leakage current in the AC power network depends mainly on the insulation of the AC power network, the leakage resistance and the operating frequency of the AC power network.

The research results were validated through both analytical modeling and comprehensive simulations performed on the MATLAB-Simulink platform. The findings provide invaluable scientific insights that can inform the selection of optimal leakage protection methods, thereby significantly improving electrical safety standards in Vietnam's underground mining industry. By employing strategies driven by this research, mining operations can mitigate risks, protect personnel, and ensure uninterrupted operation of critical electrical infrastructure for sustainable development.

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Вплив силових електронних пристроїв на струм витоку в шахтних електросистемах: приклад В'єтнаму

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Мета. Визначити вплив силових електронних пристроїв на струм витоку в підземній шахтній електромережі змінного струму. Результати дослідження дозволяють вибрати відповідний метод захисту від витоків з метою підвищення електробезпеки підземних гірничих робіт.

Методика. У цьому дослідженні використовуються аналітичні методи й методи моделювання за допомогою програмного забезпечення Matlab/Simulink для визначення, аналізу та оцінки робочого струму та струму витоку в шахтній електромережі, що містить силові електричні пристрої.

Результати. Модель шахтної електромережі, що містить інвертор і електродвигун, була побудована аналітичним методом і змодельована за допомогою програмного забезпечення Matlab/Simulink із параметрами моделі U = 1140 В, C = 0,19 мкФ/фаза, R = 168 кОм/фаза. Результати досліджень показують, що при опорі витоку 1 кОм значення струму витоку в мережі змінного струму з частотою, відмінною від 50 Гц, після інвертора (467 мА) в 1,52 рази перевищує значення струму витоку в мережі змінного струму із частотою 50 Гц до інвертора (307 мА), і, у той же час, в мережі змінного струму 50 Гц з'являється багато гармонійних складових високого порядку з коефіцієнтом нелінійних коливань THD = 1,77. Крім того, результати досліджень також показують, що струм витоку в мережі змінного струму до і після інвертора менше залежить від опору ізоляції мережі постійного струму, але залежить, в основному, від ізоляції мережі змінного струму, опору витоку та робочої частоти мережі змінного струму.

Наукова новизна. Досліджено струм витоку в електромережі змінного струму, що містить силові електронні пристрої в гірничодобувній промисловості В'єтнаму. Результати дослідження показують, що при використанні шахтної електромережі з інвертором струм витоку на стороні змінного струму після інвертора має більше значення, ніж струм витоку на стороні змінного струму до інвертора.

Практична значимість. Результати дослідження дозволяють обрати відповідний метод захисту від витоків для підвищення електробезпеки при підземному видобутку корисних копалин.

Ключові слова: *електробезпека, силові електричні пристрої, струм витоку, підземні розробки*

The manuscript was submitted 01.10.24.