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Articles

Study on the Influence of Converters on Current in Mine Electrical Network: A Case Study of a Mine in Vietnam

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Abstract

Inverters, soft starts, and power converters are all common in Vietnam's mining industry today. The usage of these devices in the mine electrical network produces other current components with frequencies other than 50Hz, which have undesired repercussions during operation. The results for the leakage current of the electrical network show that at the time of leakage before the inverter, the leakage current of the electrical network increases with a pulse coefficient k_{xk} = 2.2 times and the current after the inverter fluctuates strongly and takes about 0.2s to return to zero, which leads to the mistaken operation of the leakage protection relay in the mine electrical network.

The research results provide the basis for calculating and selecting appropriate electrical equipment to improve safety in underground mining.

Keywords: current, inverter, mine electrical network.

1. Introduction

Currently, in mining, many power electronic devices, including frequency converters, are used to improve the working efficiency of machines. In addition, according to the results in research (Kim, 2018; de Paula et al., 2015), it is shown that in the future, when the mine capacity increases and the mining depth increases to ensure and improve the efficiency of power supply, mining enterprises will use more and more of these types of devices. The conversion equipment is usually a rectifier to convert AC into DC, an inverter to convert DC into AC, or both to provide reasonable voltage for the loads in the electrical network (Do, 2018).

Using converters has many benefits such as: increasing power quality, reducing harmonics, reducing voltage flicker during switching, reducing cable costs, reducing motor and cable heating. In addition, converters can also provide DC power to DC motor load devices. Using single inverters or external inverter stations causes harmonic problems, increases equipment losses, etc. and also causes many other factors that lead to the mistaken impact of leakage protection devices in the electrical network, causing unsafe mining operations (Zhao et al., 2016).

Many research projects have shown the influence of frequency converters on leakage currents in industrial electrical networks in general and underground mine electrical networks in particular.

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In the study (Wymann et al., 2015; Nguyen et al., 2007; Beleiu et al., 2020) 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 (Ngo, Do., 2022; Do, Ngo, 2021; Marek, 2017; Pontt et al., 2009) studied the effect of high-order harmonics on electrical equipment in mining, the results of the study showed that high-order harmonics negatively affect the operation of mine electrical equipment.

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 confusing effects of leakage protection devices. The content of the article analyzes the impact of converters on current in the mine electrical network. The research results are the basis for calculating the selection of suitable electrical equipment to improve safety in underground mining 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 electrical network to ensure safety in mining.

2. Discussion and results

Mine power network model containing conversion equipment

The underground mine electrical network model containing converters to supply power to AC and DC loads is shown in Figure 1 (Kim, 2018).

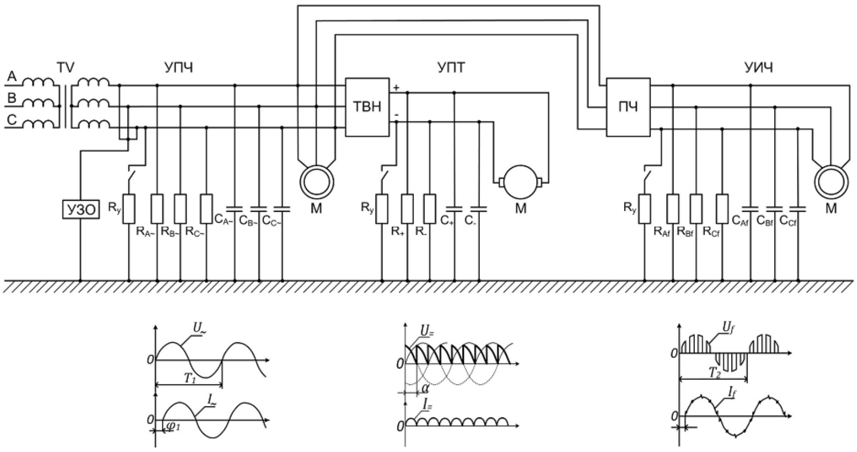

Fig. 1. Mine electrical network containing conversion equipment

Figure 1 shows that in a mine electrical network containing converters, the electrical network will include three types of current components: 50Hz alternating current component before the inverter (BI), direct current component (DC) and alternating current component with a frequency other than 50Hz after the inverter (AI). The general replacement diagram for an underground mine electrical network containing converters is shown in Figure 2 (Nguyen et al., 2023).

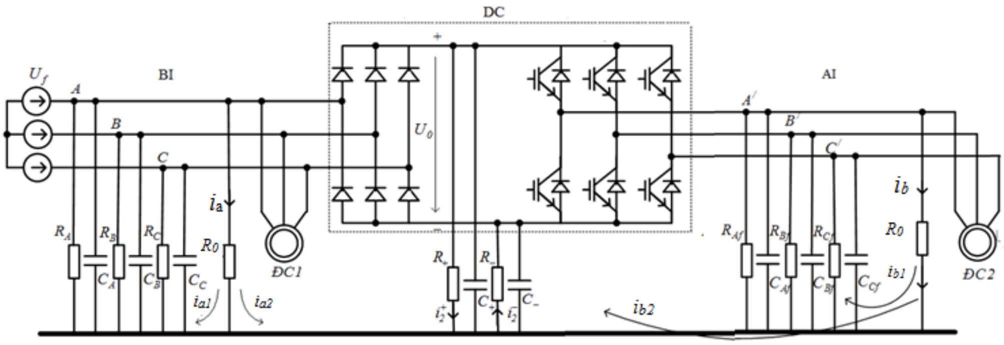

Fig. 2. Schematic diagram of the mine electrical network replacement containing conversion equipment

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

The simulation model for general research is suitable for the underground mine electrical network in Vietnam using inverter on Matlab-simulink software as shown in Figure 4, AC network insulation resistance R=150k Ω/phase, AC voltage frequency 50Hz, network voltage U=1140V, in Figure 3.

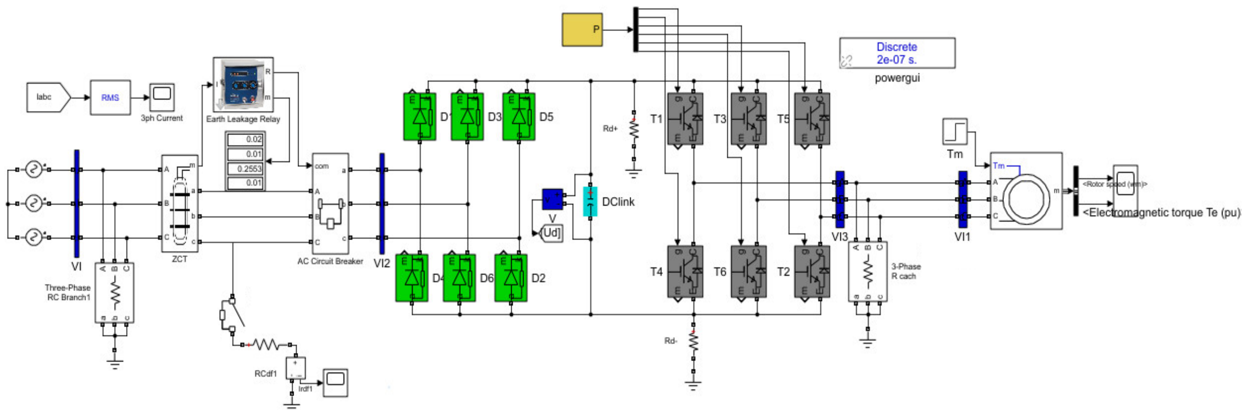

Fig. 3. Simulation model of mine power network using inverter

Based on the research model in Figure 3, the influence of the converter on the current in the mine electrical network is studied. During the research process, the leakage current in the electrical network when leakage occurs before the inverter with a 300k leakage resistor Ωat 0.8s is also studied. The survey results on voltage, current and leakage current before and after the inverter are shown in Figures 4 to 8.

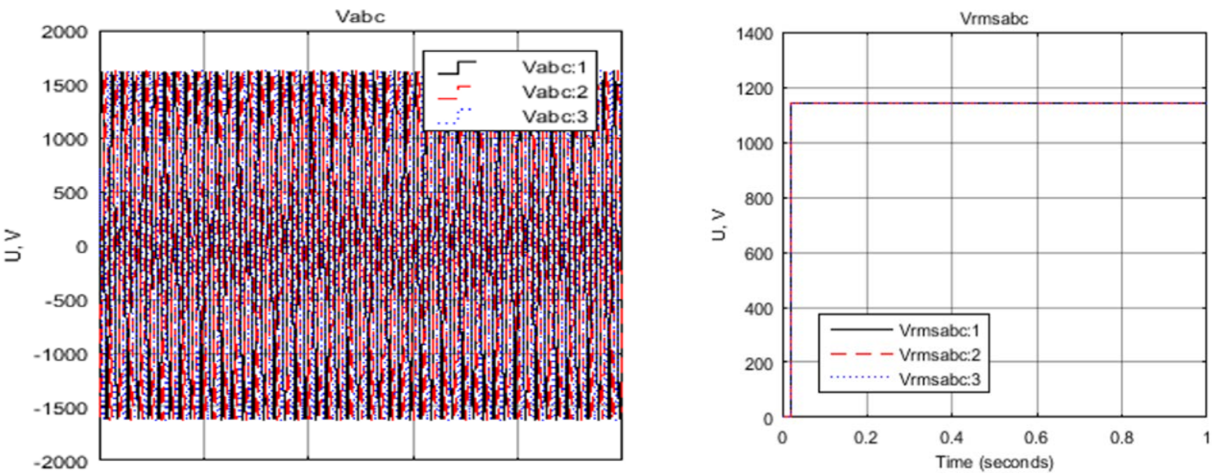

Fig. 4. Voltage before inverter

Results in Figure 4 and Figure 5 show that the supply voltage and the electrical network have a sinusoidal shape with an amplitude of 1140V. However, with the participation of the inverter in the mine electrical network, the current in the electrical network is no longer sinusoidal, in addition to the 50Hz frequency current, there are many other current components of 50Hz. When an electric leakage occurs at 0.8s, the current amplitude before the inverter does not change much.

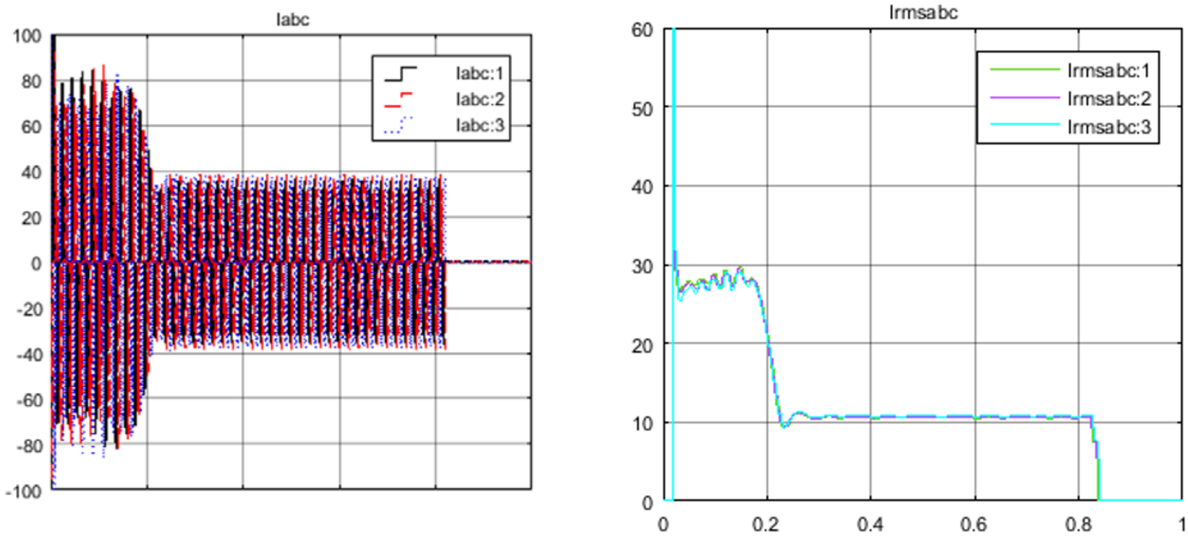

Fig. 5. Current before the inverter

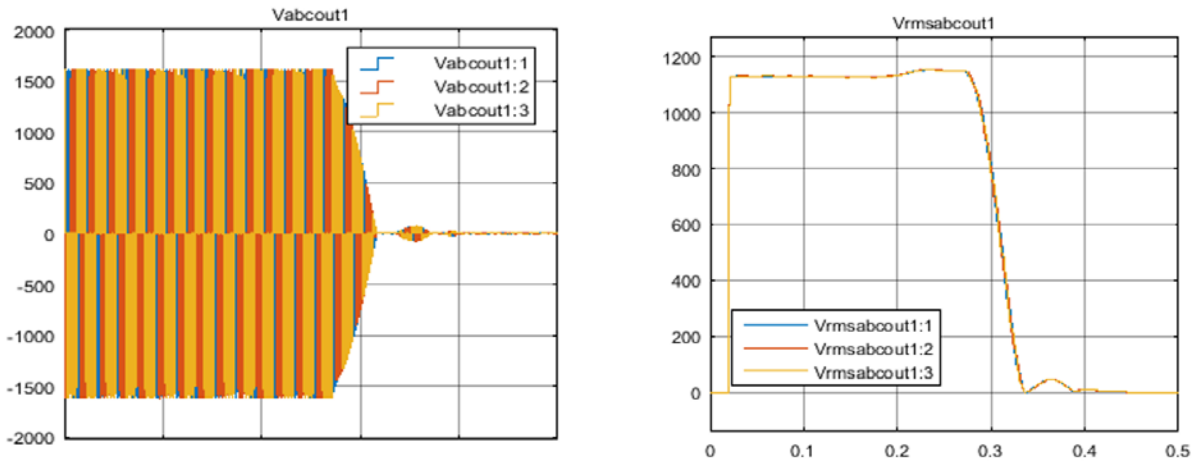

Fig. 6. Inverter output voltage

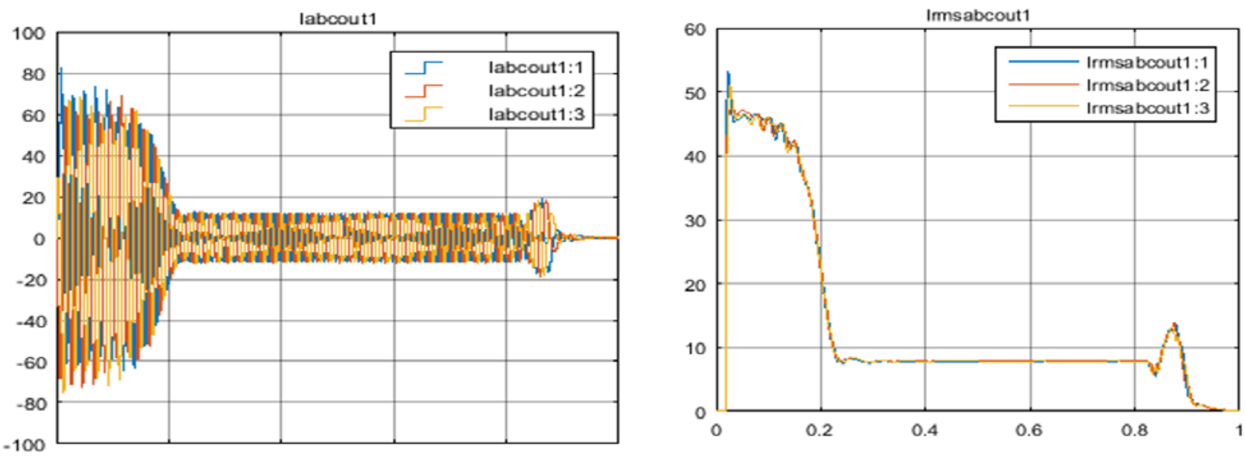

Fig. 7. Output current from the inverter

The research results in Figure 6 and Figure 7 show that after the inversion process to convert into AC voltage, the current amplitude after rectification suddenly increases with a peak amplitude of up to 52A after a period of 0.2s, the current stabilizes at an amplitude of 9A. After the electric leakage occurs at 0.8s, the current after the inverter fluctuates strongly and takes about 0.2s to return to zero.

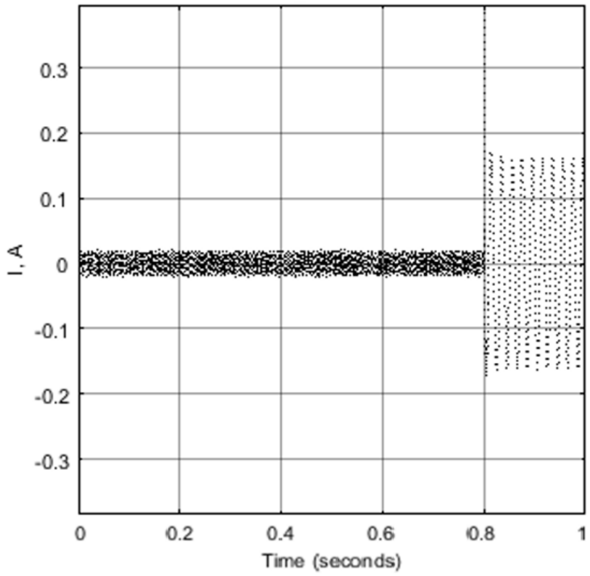

Fig. 8. Leakage current of the power network

The results for the leakage current of the electrical network in Figure 8 show that when a leakage occurs, the amplitude of the leakage current increases suddenly with a pulse current value of up to 0.4A and then stabilizes at an amplitude of 0.18A. Thus, it can be seen that at the time of leakage before the inverter, the leakage current of the electrical network increases with a pulse coefficient k_{xk} = 2.2 times the normal leakage current amplitude, which leads to the mistaken operation of the leakage protection relay in the mine electrical network.

3. Conclusion

Converters such as inverters, soft starters, and power converters are commonly used in mining in Vietnam today. In the future, when mining capacity increases and mining depth increases to improve power supply efficiency, mining enterprises can switch to using inverter stations. The use of these devices in the mine electrical network, in addition to the 50Hz alternating current component, also includes current components with frequencies other than 50Hz. These current components can cause confusion with the leakage protection relay. To improve operational efficiency in mining, it is necessary to have measures to limit the impact of this current component caused by power electronic devices.

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