Improving the operation of earth fault relays by auto earthing-connection at earth fault situations in 6kV mining grid of Quang Ninh

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Abstract. Single phase earth-fault in MV grids usually causes overvoltage that harm to human being and electric equipments. In 6kV mining grids of Vietnam, earth fault which is majority incident accounts 55% to 73% of the total faults. When earth fault occurs many grids' eco-technical parameters will be affected. Moreover, the overvoltage and earthing current can lead to serious electric shock accidents caused mainly by stepping-overvoltage or touching-overvoltage. One of earthing relays requirements is to trip in minimum time duration in order to reduce the magnitude of earthing currents and overvoltage. Base on the simulation in Matlab, the paper suggests a prior connection diagram that allows an auto earthing-connection for improving the better performance of relays. The utilization of the diagram will help to decrease the tripping time of relays, reduce the amplitude of internal overvoltage as well as enhance the safety for human being in case of earthing incidents.

1 Introduction

In the Quang Ninh 6 kV electrical network, one-phase earthing is the majority failure, accounting for $61 \div 85\%$ of all types of incidents [1]. This incident significantly affects to the normal operation of electrical network as well as apparatus in the mines. In mining 6 kV grids, to ensure the electrical safety, it is impossible for operators to directly contact with parts grounding to earth. It is also impossible to have contacting voltage, step voltage and induction voltage. Therefore, it is necessary to eliminate immediately the earthing point from grid as well as decrease the amplitude of earthing current. One of the most effective solution is to automatically connect the earthing point by a small resistor in order to reduce internal over voltage and decrease the effecting time on human body.

2 Theory and the simulation results

Based on the theory of earthing phenomena in isolating neutral [3,5], the incident earthing current will depend on grid's parameters and short-circuiting the connection diagram describing the method mentioned above is shown in Figure 1.

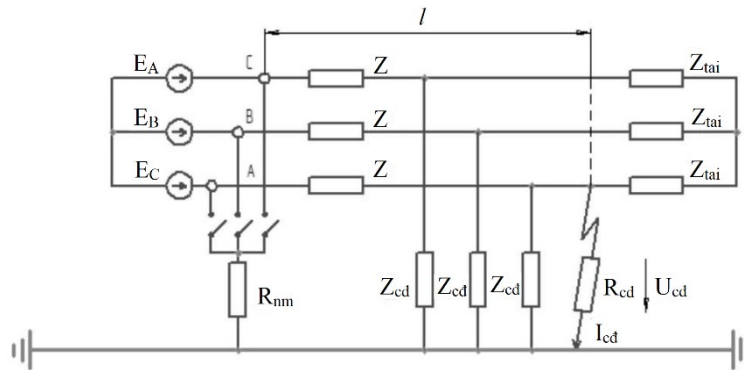
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Fig. 1. Connection diagram of earthing circuit with a short-circuiting resistor.

In Figure 1: Z-line impedance from the source to the earthing point;

R_{nm}-Short-circuiting resistor;

R_{cd} – Earthing resistor;

Z_{cd}-Insulation resistance of phase to earth;

l- the length of conductor to earthing point;

I_{cd}-Earthing current;

U_{cd} – Voltage across the earthing resistor;

E_A, E_B, E_C – electromotive force of source;

Z_{tai} – Load impedance.

Earthing current is determined by:

$$I_{cd} = U_f \frac{3Z_{tai}Z_{nm} - ZZ_{cd}}{\left(R_{cd} + \frac{1}{3}Z_{cd}\right)Z^2 + \left(\frac{R_{cd} + Z_{cd}}{Z_{cd}}(Z + 3Z_{nm}) + 2R_{cd} + Z_{cd}\right)ZZ_t \ (3Z_{nm}R_{cd} + Z_{cd}(Z_{nm} + R_{cd}))(Z + Z_{tai})}$$

(1)

Because insulation resistance of phase to earth is much bigger than other impedance, therefore the equation (1) could be shorten as equation (2):

$$I_{cd} = \frac{U_f \left(3Z_{tai}Z_{nm} - ZZ_{cd}\right)}{Z_{cd}Z\left(\frac{1}{3}Z + Z_{tai} + \left(R_{nm} + R_{cd}\right)\left(1 + \frac{Z_H}{Z}\right)\right)}$$

(2)

From equation (2) some following relations could be obtained:

+ The relation of voltage across the earthing resistor and short-circuiting resistor.

+ The relation of earthing current and short-circuiting resistor and earthing resistor.

As mentioned in [2], the value of earthing current depend significantly on capacitance and insulating admittance of each phase to earth. Two these latter quantities are expressed by (3):

$$C_f = 0,00041 + 0,00399N_{BA} + 0,0079N_{ĐC+MX} + 0,01259L_{Tk.qđ} + 0,19559L_{C.qđ}, \mu F$$

$$G_f = 1,07801 + 0,07271N_{BA} + 0,10825N_{ĐC+MX} + 0,17192L_{Tk.qđ} + 2,24998L_{C.qđ}, \mu S$$

$$(3)$$

Formulate a simulating diagram as figure 2 with the values of components as: C_f =0,021µF/phase, R_f =327,99kΩ/phase, Rd = 2,662Ω, Ld = 0,0047Ω; Stt = 969,1 kVA, Rt = 35,521Ω, Lt = 0,065Ω.
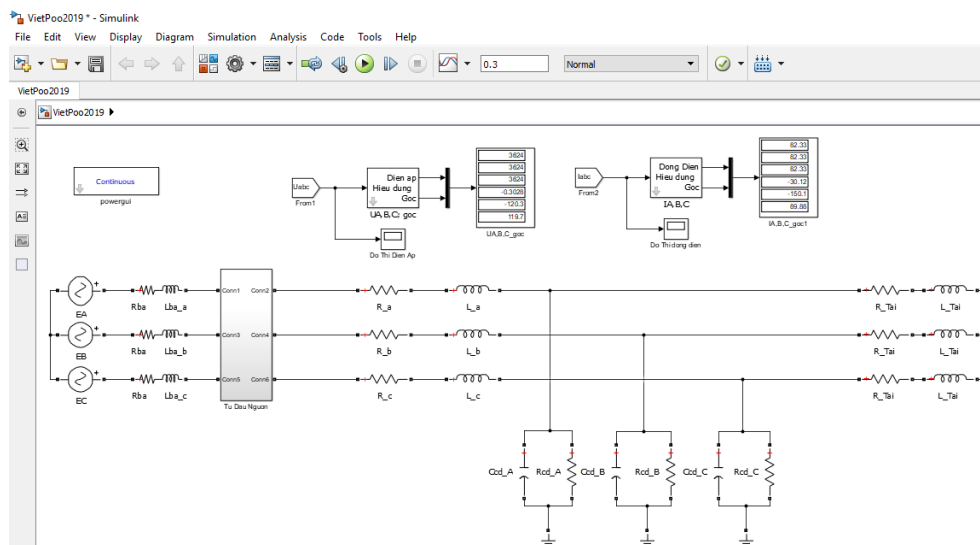

Fig. 2. Simulation diagram of 6kV grid expressing earthing incident.

Figure 3 shows the simulation of 6kV grid with earthing phenomena containing the automatically connection of short-circuiting resistor at t=0,1s.
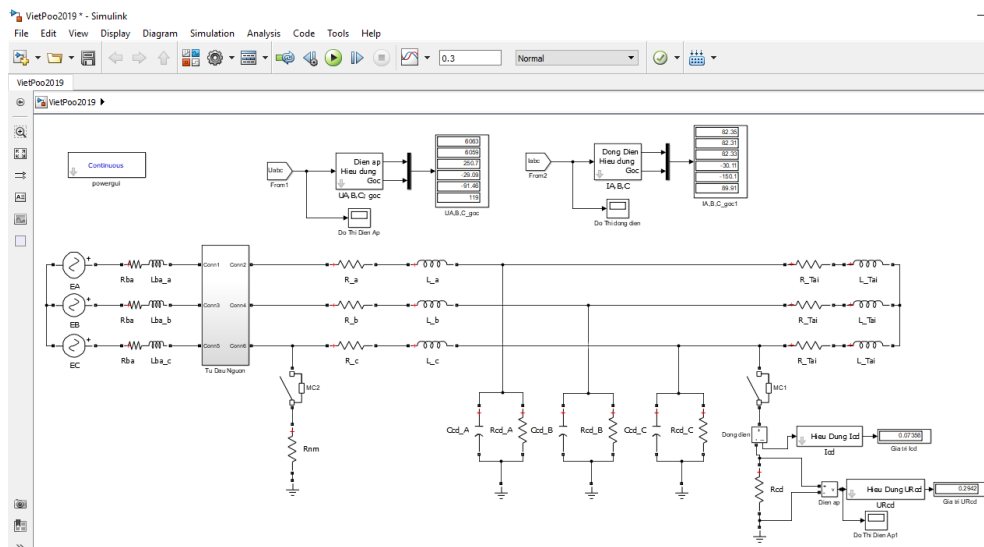
Fig. 3. Simulation diagram of 6kV grid with short-circuiting resistor R_{nm}.

By utilizing a short-circuiting resistor at t=0,1s, the amplitude of over voltage is reduced greatly, the waveform of earthing over voltage (blue curve) is shown in figure 4.
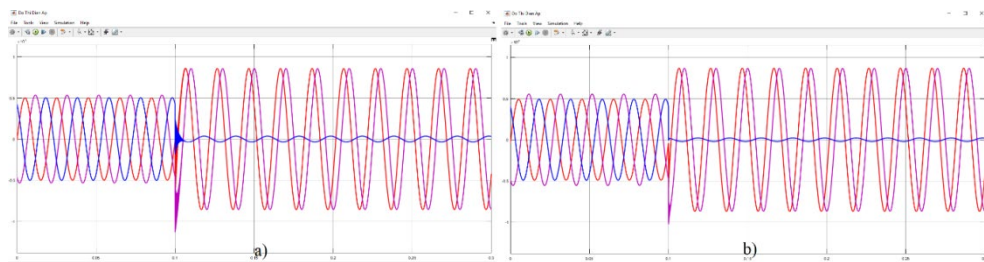

Fig. 4. Earthing voltage wave-forms without a short-circuiting resistor (a) and with a short-circuiting resistor (b). The resistor is short-circuited at t=0,1s.

Implementing some other simulation with different value of R_{nm}, the series value of earthing over voltage depending on value of R_{nm} are form as curve in figure 5. The series value of earthing current depending on value of R_{nm} are form as a curve in figure 6.
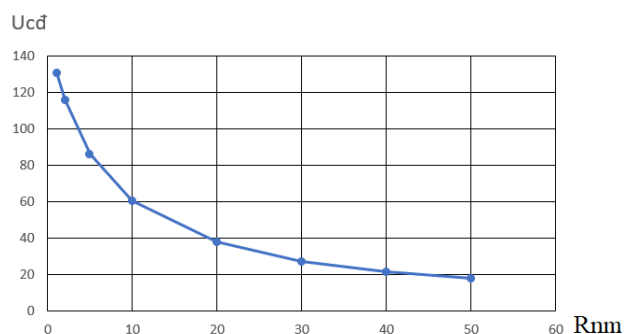
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Fig. 5. Diagram showing the relation of earthing over voltage and short-circuiting resistor at R$_{cd}$ = 4Ω.
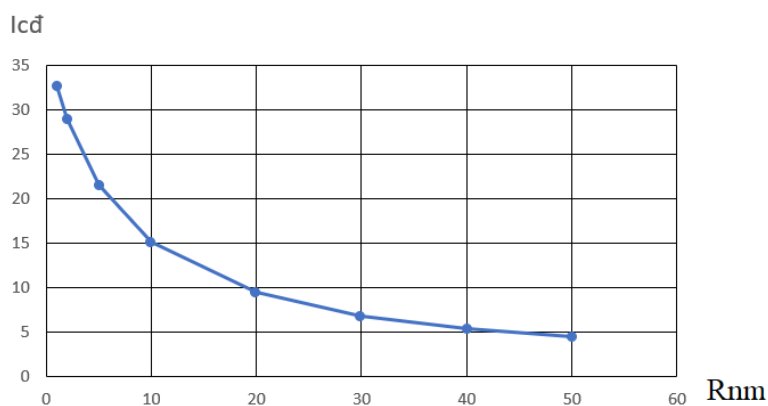
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Fig. 6. Diagram showing the relation of earthing current and short-circuiting resistor at R$_{cd}$ = 4Ω.

3 Conclusion

The above simulations show that: By utilizing a short-circuiting resistor at earthing point of 6kV grid, the following advantages could be deducted:

+ The amplitude of earthing over voltage is reduced significantly. In figure 5, the earthing voltage is only one seventh (nearly 20V) if R$_{nm}$ = 50Ω.

+ The earthing incident current is also decreased effectively when the value of short-circuiting resistor is big enough. In figure 6, this current reduced from nearly 35A (without any short-circuiting resistor) to 5A (with short-circuiting resistor R$_{nm}$ = 50Ω).

Obviously, when the over voltage is reduced, its influence on equipment insulation is also decreased. The amplitude of earthing current is reduced, the possibility of appearing arcing current on 2 other phases is also decreased. This advantage is enhanced significantly the reliability of power supply.

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