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RESEARCH ON BUILDING FOR DEPENDENCE OF INSULATION PARAMETERS OF THE 6kV GRID WITH THE ENVIROMENT AND STRUCTURAL PARAMETERS OF OPEN-PIT MINES IN THE QUANG NINH AREA

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Abstract:
Medium voltage insulation indicators depend on many factors such as environment, length of feeders, numbers of transformers and motors connected on the grid. The values determined by experimental measurements will be used to build up maths distributions. Base on these results, an experimental equation will be formed for determining capacitance and impedance of 6kV grid to ground in QuangNinh open pit coalmines.

Keywords: A One-Phase Earth Fault; An Insulated-Neutral Grid; An Insulation Parameter; A Sensitive Earth Fault Relay.

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1. Introduction

Building a 6kV grid model of open-pit mines in the Quang Ninh area, used to investigate the transient process in switching of short-circuit switches in fault phases so as to ensure safety when there occursingle-phase earth faults, need take into accountthe effect of insulation resistance,the capacitance, loads, compensate capacitors and potention transformers.

The insulation resistance and capacitance of the 6kV open-pit minegrid in the Quang Ninh area depend on the operating environment such as temperature,humidity,... and the structural parameters of the grid. Based on the measured datas, it is possible to determinethe dependenceof the environment and the open-pit mine 6kV grid's structure such as: the supply line length, the number of low-voltage transformers, the number of high- voltage motors.Therefore,this results are the basic factors for the grid modeling.

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2. Research On Selection Of Measuring Methods To Identify Insulation Parameters Of Open-Pit 6kv Mine Grids In The Quang Ninh Area

2.1. Elementary Theory

Research on the analysis and comparision of measurable methods enable to choose a three- volt meters method for determination the capacitance (C) and the conductance(G) of the grid to the ground. This method has the outstanding advantage, such as no creation artificial short-circuit causing insecurity, in complex measurable techniques and instruments. Although calculations are complex, it is extremely convenient to program by a computer. The principle diagram is shown in Figure 1[1,4].

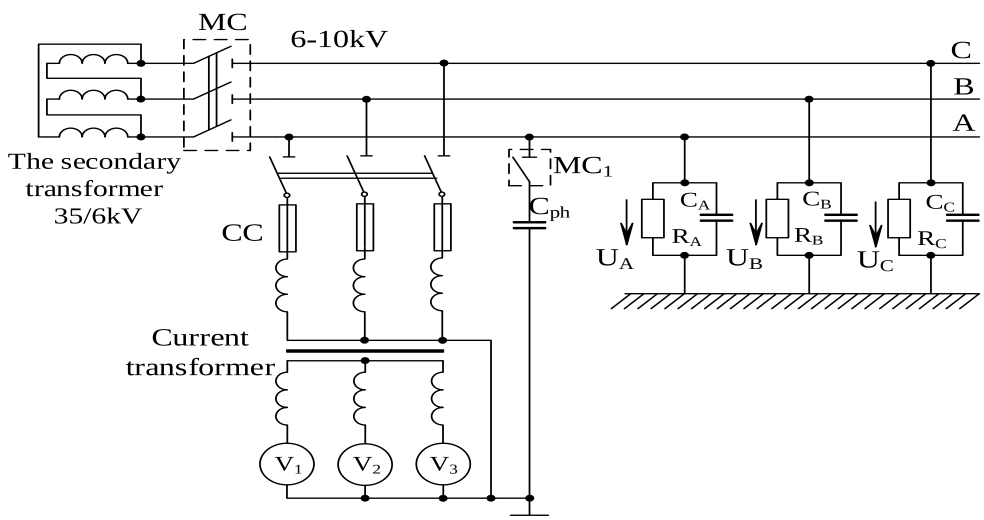

Figure 1: The diagram illustrates determination of the capacitance **(**C**)** and the conductance (G) of the grid to the ground by the 3-volt meters method

$\dot{U}_A, \dot{U}_B, \dot{U}_C$ - the complex number of voltage of phase to ground;
R_A, R_B, R_C, C_A, C_B, C_C–the resistance and capacitance of phase to ground;
C_{ph}–the auxiliary capacitance;

MC_1–the circuit breaker in order to put C_{ph} into the grid.

The number of essential measurementsto ensure the adequateaccuracy [5]:

$$n = N - \frac{\Delta\sqrt{N^3}}{q} = 44 - \frac{0{,}05\sqrt{44^3}}{2{,}58} = 38$$

Whereas: n – the number of essential measurements
N – the number of feeders
Δ –the selective accuracy (choose Δ =0,05 in order to ensure accuracy with high probability)

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q- the certain standard is the confidence probability function. If consider that the value (q) corresponds to the probability value

if P = 0,95 then q = 1,96

P = 0,99 then q = 2,58

If $\dot{U}_A, \dot{U}_B, \dot{U}_C$ - vectors of phase-to-ground voltage before connecting to Cph.

$\dot{U}'_A, \dot{U}'_B, \dot{U}'_C$, - vectors of phase- to-ground voltage after connecting to Cph

With $\dot{U}_A = a + jb; \quad \dot{U}'_A = a' + jb'$

whereas: $a = \dfrac{2U_A^2 - U_B^2 - U_C^2}{6.U_f} + U_f$; $a' = \dfrac{2U'^2_A - U'^2_B - U'^2_C}{6.U_f} + U_f$

$$b = \frac{U_C^2 - U_B^2}{2.\sqrt{3}.U_f}; \qquad b' = \frac{U'^2_C - U'^2_B}{2.\sqrt{3}.U_f};$$

Suppose there has a phase- earth fault on phase A, the complete earth fault current of phase A before and after connecting to Cph:

$$\dot{I}_{cđ} = \dot{U}_A.Y_{cđ} = \dot{U}'_A(Y_{cđ} + Y_f) => \dot{Y}_{cđ} = \frac{\dot{U}'_A.Y_{ph}}{\dot{U}_A - \dot{U}'_A} \text{ with } Y_{ph} = j\omega C_{ph}:$$

$$Y_{cđ} = \frac{(a' + jb').j\omega.C_{ph}}{(a - a') + j(b - b')} = \frac{(j\omega.C_{ph}.a' - \omega.C_{ph}.b')[(a - a') - j(b - b')]}{(a - a')^2 + (b - b')^2}$$

$$= \frac{(a'.b - b'.a).\omega.C_{ph}}{(a - a')^2 + (b - b')^2} + \frac{j[a'.(a - a') + b'.(b - b')].C_{ph}.\omega}{(a - a')^2 + (b - b')^2} = G_{cđ} + j\omega.C_{cđ}$$

$$=> G_{cđ} = \frac{(a'.b - b'.a).\omega.C_{ph}}{(a - a')^2 + (b - b')^2}; \; C_{cđ} = \frac{[a'.(a - a') + b'.(b - b')].C_{ph}}{(a - a')^2 + (b - b')^2}$$

infer: $G_{cđ} = \mathrm{Re}\left[\dfrac{\dot{U}'_A.Y_{ph}}{\dot{U}_A - \dot{U}'_A}\right] = \dfrac{(a'.b - b'.a).\omega.C_{ph}}{(a - a')^2 + (b - b')^2}$

$$\omega C_{cđ} = \mathrm{Im}\left[\frac{\dot{U}'_A.Y_{ph}}{\dot{U}_A - \dot{U}'_A}\right] = \frac{[a'.(a - a') + b'.(b - b')].C_{ph}}{(a - a')^2 + (b - b')^2}$$

To ensure accuracy, it is necessary to select the auxiliary capacitance (Cph) so that the ground-phase voltages fluctuate minimum, about (10-20) %. $U_{fđm}$. The values of the auxiliary capacitance connected to each feeder is detemined by the simulation model, shown in fig 2. According to the simulated results, applied to 6kV feeders of open-pit mines in the QuangNinhregion, Cph can be selected as follows: CaoSonC_{ph}=0,62µF; CocSauC_{ph}=0,32µF; ĐeoNaiC_{ph}=0,4µF; NuiBeoC_{ph}=0,36µF; HaTuC_{ph}=0,46µF.

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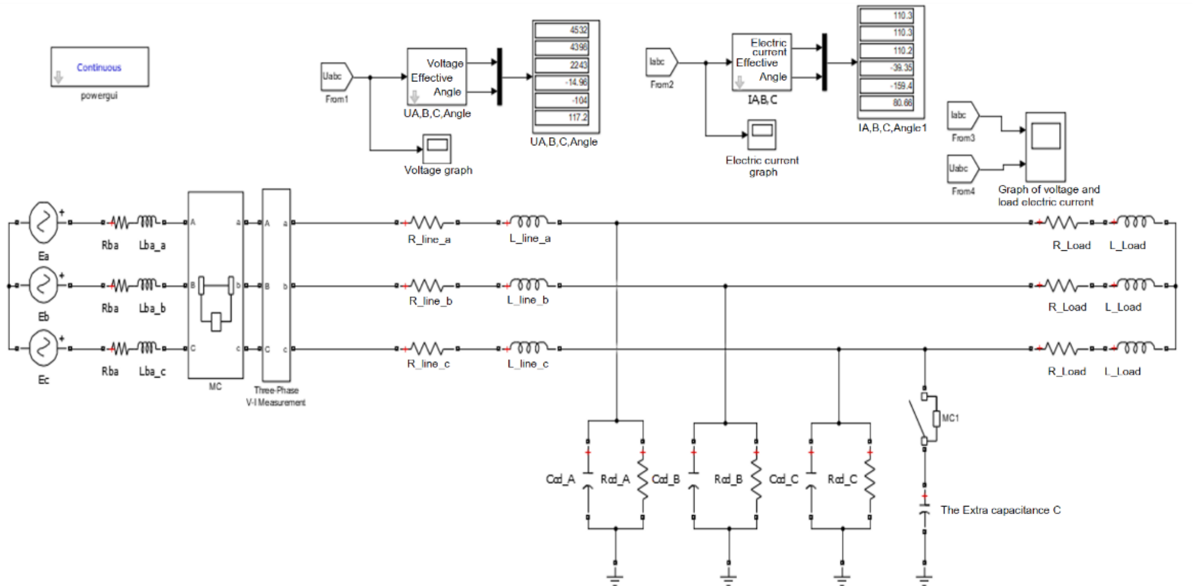

Figure 2: The simulation diagram identifies Cph connected to phase A so that voltage fluctuates in the range (10-20) %

Based on the measured datas, it is possible to identify G_{cd} and C_{cd}. The results are listed in Table 1.

Table 1: The measured results of open-pit mines in the QuangNinh area

Order	Temp, ^{0}C	Humidity, %	The Converted Overhead line length L_{dqd}, km	The Converted Cable length L_{cqd}, km	The number of high-voltage motor, unit	The number of transformer, unit	The capacitance, C_f, μF	The conductance $G_f.10^{-6}$, Simen
1	17,2	80	15744	2027,8	0	6	0,506	7,010
2	16,5	75	11330	797,1	4	4	0,255	4,451
3	21,2	84	4274,5	1045	3	5	0,302	3,794
4	23,3	84	5665	1727,6	4	5	0,434	5,301
5	28,7	83	3399	1298,3	4	5	0,340	4,186
6	29,4	82	7261,5	1562,9	3	7	0,431	5,312
7	28,6	85	2303	2034,8	0	9	0,383	5,308
8	28	88	7210	1223,8	3	4	0,340	4,483
9	27,5	84	1545	874,6	5	5	0,293	3,263
10	25,5	77	9064	2241	5	8	0,505	6,154
11	23,4	81	9167	1114,1	4	5	0,346	4,733
12	19	85	4326	1062,8	4	4	0,303	3,859
13	17,2	80	1380,1	471,7	2	8	0,153	2,464
14	16,5	75	1946,7	1045	4	4	0,175	3,472
15	21,2	84	2343,3	551,8	2	5	0,198	2,569
16	23,3	84	3168	267	1	4	0,156	2,056
17	29,4	82	2414,9	320,4	2	5	0,156	2,180
18	28,6	85	3554,8	160,2	1	4	0,132	1,852
19	28,6	85	4481,5	1012,8	2	2	0,261	3,590
20	28	88	2012,5	1094,7	3	3	0,261	3,422

21	27,5	84	1851,3	222,5	1	8	0,132	2,019
22	25,5	77	4172,5	842,5	4	1	0,069	3,279
23	23,4	81	3124,4	436,1	1	8	0,152	2,742
24	19	85	1449,6	231,4	1	6	0,132	1,856
25	17,2	80	4635	890	2	3	0,199	3,377
26	16,5	75	8001	1096,8	1	7	0,159	4,389
27	21,2	84	3090	1105,6	1	3	0,117	3,431
28	23,3	84	2575	1068	2	4	0,219	3,434
29	29,4	82	4096	480,8	1	2	0,128	2,445
30	28,6	85	8090	590	1	6	0,165	3,470
31	28,6	85	4635	879	1	4	0,219	3,331
32	28	88	2500	679	2	5	0,219	2,811
33	27,5	84	6328	1312,5	1	6	0,224	4,451
34	25,5	77	3355	1101,4	2	4	0,230	3,609
35	23,4	81	6185	1468	1	4	0,247	4,579
36	19	85	6314	1112	1	5	0,219	4,044
37	17,2	80	3409,3	605,7	1	5	0,168	2,736
38	16,5	75	2369	207,6	0	8	0,078	1,985
39	21,2	84	3449	195	1	3	0,078	1,915
40	23,3	84	6193,4	177,6	0	10	0,176	2,625
41	29,4	82	3038,5	417,3	1	9	0,148	2,592
42	28,6	85	2636,8	348	1	9	0,120	2,413
43	28,6	85	5097	225	1	9	0,113	2,569
44	28	88	5057,3	464,1	0	7	0,146	2,771
45	27,5	84	6296,4	177,6	0	12	0,098	2,759
46	25,5	77	4839,5	582,3	1	7	0,175	3,028
47	23,4	81	4550,1	318	1	8	0,120	2,728
49	19	85	6474	846	1	5	0,250	3,609
50	17,2	80	1300,4	506,5	2	13	0,134	2,808
51	16,5	75	6059	807	3	9	0,252	3,889
52	21,2	84	5547	1112,5	2	4	0,284	3,956
53	23,3	84	4302	890	3	9	0,375	3,768
54	29,4	82	4096	480,8	1	2	0,147	2,445
55	28,6	85	5562	768,5	1	6	0,242	3,398
56	28,6	85	4267	222,5	2	11	0,134	2,645
57	28	88	4302	89	4	9	0,100	2,473
58	27,5	84	6421,5	1312,5	1	6	0,229	4,465
59	25,5	77	2454	222,5	1	6	0,100	1,991
60	23,4	81	3272	890	3	2	0,203	3,199

2.2. Identification of the Insulating Parameters of The Open-Pit Mine 6kV Grid

2.2.1. Frequency of the Capacitance (C_f) and the Insulating Conductance (G_f)

Identify the number of capacitance intervals [4]: k = 1 + 3,22. lg(n) = 1 + 3,22. lg (60) = 6,9, select 7 intervals with $\Delta C = 0,0728, \mu F$

Applying the Frequency function in Excel calculates the frequency of capacitance and conductance parameters with a given intervals and building the frequency of capacitance and insulating conductance as shown in Figure 3.

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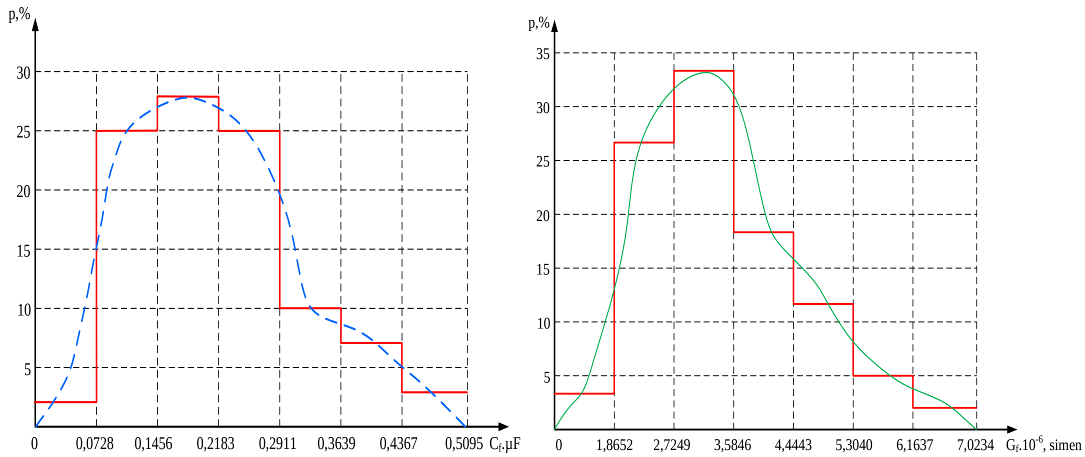

Figure 3: frequencyof the capacitance C_f and the insulating conductance G_f of phases to ground

The diagramillustrates that the frequency of insulation capacitance C_f and insulating conductance G_f has only one peak, closingto the standard form. Therefore, it is reasonable to examine the insulating parameters of the open-pit mine grids in the Quang Ninh area by months of the year.

2.2.2. Testing the Normal Distribution of The Capacitance and The Insulating Conductance

According to the results of the capacitance C_f and the conductance G_f measurement, the testing of the compatibility between the experimental distribution and the theoretical distribution, based on the distribution standard $\chi 2$ [2], is carried out. The characteristic parameters which arerepresented by the line graph of the theoretical standard distribution density function (dash-dottedline) and the experimental distribution function (solid line) are calculated by using the Descriptive Statistics tool in Excel (Figure 4).

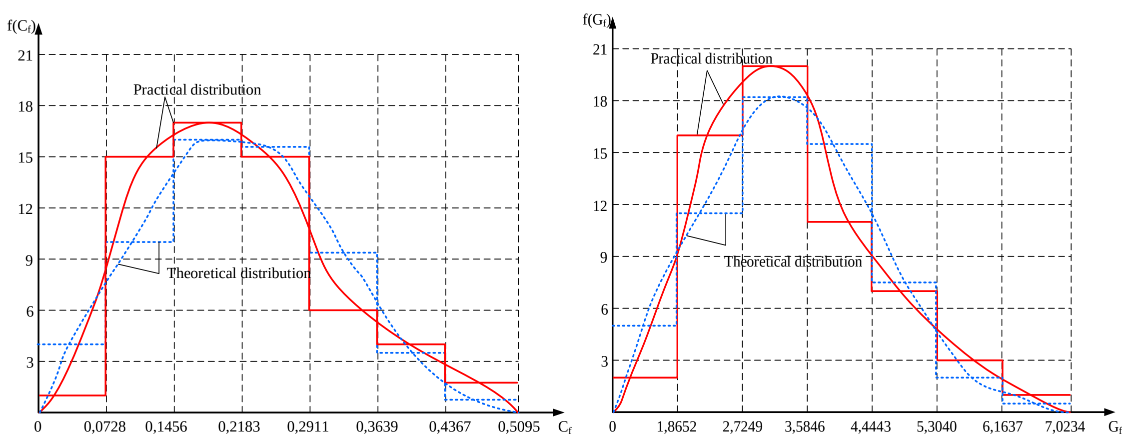

Figure 4: The standard distribution function of the capacitance and conductance density of open-pit mines in the QuangNinh area

After testing the standard distribution of the capacitance Cf and the insulating conductance Gf found that it is reasonable to investigate the dependence of the capacitance Cf and the insulation conductance Gf of phases to ground with environmental parameters (temperature, humidity) and the structure of grid during the year.

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3. Building Dependence of insulating Capacitance C_f And Insulating Conductance G_f with Environment and Structural Parameters of Open-Pit Mine 6kv Grid

Based on the calculated results (Table 1), the least squares method is an effective and resonable to build the relationships between the conductance G_{cd} and insulating capacitance of phase to ground with parameters of environment (temperature, humidity) and the grid structure (the grid conversion length, the number of low-voltage transformers, high-voltage motors).

Selecta regression model with parametersa$_0$, a_1, a_2, a_3, a_4, a_5, a_6, b_0, b_1, b_2, b_3, b_4, b_5, $b_6$from the equations:

$$C_f = a_0 + a_1.D_a + a_2.T_d + a_3.N_{BA} + a_4.N_{đc} + a_5.L_{Tk.qđ} + a_6 L_{C.qđ}$$
$$G_f = b_0 + b_1.D_a + b_2 T_d + b_3.N_{BA} + b_4.N_{đc} + b_5.L_{Tk.qđ} + b_6 L_{C.qđ}$$

Whereas: C_f, G_f - the insulating capacitance and conductance of phase to ground;

$L_{Tk.qđ}$; $L_{C.qđ}$- the converted length of overhead line and cable to cross- sectional area S = 50mm^2; D_a - The humidity of the environment; T_d–the temperature of the environment; N_{BA}- the number of low-voltage transformers connected to the grid; N_{DC} -the number of high- voltage motors connected to the grid.

To predict multiple linear regression model uses Regression, allowing multiple linear regression with a maximum variable of 16, in Excel's Data Analysis Tool, [3].

Through the results of the variance testing of C_f and G_f measurements and the regression results of C_f and G_f, the equations indicating the dependent relationship are received as follows:

$$C_f = -0,45706 + 0,00555.D_a - 0,0005.T_d + 0,00594.N_{BA} + 0,01839.N_{đc} + 7,95.10^{-6}.L_{Tk.qđ} + 0,00015 L_{C.qđ}, \mu F$$
$$G_f = 0,5298 + 0,006064.D_a - 0,0042.T_d + 0,05288.N_{BA} + 0,064474.N_{đc} + 0,000144.L_{Tk.qđ} + 0,001686.L_{C.qđ}, S$$

4. Conclusion

- Building dependence of insulating capacitance Cf and insulating conductance Gf phase to ground with environment and structural parameters of open-pit mine 6kV grid
  $$C_f = -0,45706 + 0,00555.D_a - 0,0005.T_d + 0,00594.N_{BA} + 0,01839.N_{đc} + 7,95.10^{-6}.L_{Tk.qđ} + 0,00015 L_{C.qđ}, \mu F$$
  $$G_f = 0,5298 + 0,006064.D_a - 0,0042.T_d + 0,05288.N_{BA} + 0,064474.N_{đc} + 0,000144.L_{Tk.qđ} + 0,001686.L_{C.qđ}, S$$
- In the experimental formulas , besides the grid's structural effects (the supply line length, the number of transformers and high-voltage motors), it also takes into account the impact of open-pit mine environment such as humidity and temperature, environmental temperature of the year
- Based on the experimental relationships, it is possible to simulate the actual working status of the grid in order to give necessary conclusions ensuring safety when operating open-pit mine grid as well as accuracy and efficiency calculation, calibration of the single-phase earth-fault protection.

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