Workability Conditions Determination of Network Distribution with Overhead Lines Power Transmission with the 6-35 kV

Vasiliy Kutin, Marina Kutina, Artem Kovalov and Sergyi Maksimov

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Vasiliy Kutin[1,*], *Marina* Kutina[1], *Artem* Kovalov[1], and *Sergyi* Maksimov[2]

[1]Vinnytsia National Technical University, Khmelnitsk highway, 95, Vinnytsya, 21021, Ukraine
[2]Scientific and technical center «Instrument-mikro», Oktyabrskaya street ,68, Kvasnikovka village, Engelsky district, Saratov region, 413138, Russia

Abstract. The principal of identification of isolation workability in relation to a ground was proposed. It is based on the electrosafety criteria usage and a minimum current flow to a ground. The conditions of workability of isolation of distribution network is calculated in look of changes of isolation workability restrictions in relation to regulations and standards. A mathematical model for the calculation of isolation workability in a look of a relation of workability indicators to the isolation parameters according to a ground. By analyzing the adequacy it as set that introduced formed models assumptions result in the appearance of a method error to 3,5 %.

1 Introduction

For the workability conditions determination of any object or system two ways can be used the first way for the object diagnostics (OD) wish mostly overhead homogeneous structure of elements, that have a small amount of parameters that can be directly calculated first are theoretically researched for the selection of items of a technical condition (TC). Based on certain criteria's that should be necessarily previously noted, the analysis of possible of OD should be held by its control. Data that forms a diagnostic model of OD forms the workability conditions of OD. The checking of informative evaluation of a chosen complex of controlled items should be done.

According to another approach the previously chosen controlled items are used, that can describe TC of diagnostic object. Then for the DO the amount of experimental researches is made for the setting of sensitivity impact on a chosen complex of items on a technical condition of an object. The next stage contains she mathematical model of a change description of TC and then statistical reference of data basis being formed or neuron network that gives the opportunity of identify object TC according to the result of chosen items control. Given method is used in cases, that theoretically can`t explain the ability of controlled items to show TC through the difficulty of DO. Specifically, the workability conditions of DO can be formulated on the basis of analysis of theoretically formulated model or can be get experimentally [1].

The most unreliable part of network distribution is a overhead power lines (OPL)[2-4]where in a from of isolation the glass, porcelain and recently polymeric isolators are used. Isolators OPL are by direct impact of aggressive environment, which reveals in a look of a contamination of isolators top by dust, salt compounds that while hydrated cause the formation of leading on the top of isolator in accordance with current flow to the ground. [5-10]

The determination of isolation workability in conditions of exploitation is more complicated because of the absence of precise quantitative methods of impact factors evaluation that worsen the isolation condition. That factors are the aging isolation process, hydration, contamination, mechanical impact, overstrain, corrosion etc. That`s why for the TC isolation control is practically used by average electrical items: neutral bias voltage, the tangent of the dielectric loss angle, common active resistance in relation to a ground, current and resistance zero sequence, phase conductivity according to a ground. [11-12].

To solve the calculation problem of isolation workability IW it is proposed to take precise and understandable for the isolation workability IW calculation. As such criteria safety operation conditions of isolation equipment from current flow to the ground that that form through the defects of isolation damages should be used as such criteria.

The aim of the study is the determinations of conditions of isolation workability of network distribution in relation to a ground by the technical conditions evaluation of isolation through the safety criteria`s and a minimum loss of electrical current from the current flow to the ground.

2 Research result

To gainthe set goal the following algorithms is proposed. The first step is to explain the criteria`s for the isolation workability conditions determination that should the multiple TC isolation divide into two submultiples of workable condition and unworkable condition.

The second stage is to determine the workability conditions. DN isolation to a ground should be looked upon as a whole integral object of technical condition that is described as the group parameter change-active phase conductance DN in relation to a ground. The item selection of technical isolation condition should be ground on correspondence analysis the whole items complex, that in one way or another characterize the processes of isolation technical conditions change through the chosen criteria`s of TC isolation evaluation: safe usage DN and economical functioning. [13].

The main reason of isolation DN TC change is from isolated neutral is damage in relation to a ground, that`s why it is known that technical condition of sub phases isolation does not largely influence on its common TC. And its influence can be unnoticed. The phase unity in relation so a ground (C_a, $C_в$, C_c) depends on constructive network parameters and that's why their numbers are considered as constants. Small increase of common volume is observed only by isolator top hydration. Active isolation conductance in relation to a ground (q_a, q_b, q_c) can be changed in a rather wide range of significations. These changes characterize the process of formation of isolation damages. It`s main reason is the formation of shunting connections within network phases and ground.

Two boundary processes of TC are isolation change determined:

1. Symmetrical increase of active conductance's of isolation phases in relation to a ground, as a result of hydration and contamination of isolators top.
2. Non - symmetrical major increase of active conductance of certain phases in relation to a ground, as a result of appearance of shunting connections in them with the ground.

As we know [14] there is a standard in Ukraine in accordance with which current that can flow through a human body is restricted by the number 50 Hz, a magnitude no more than 6MA within the continuous protection work from the single-phase earth closure that is no more than 1s.by calculating the voltage and current though a human body it is modeled in electrical chain by a resistor with the resistance in a continuous protection act from SPEC to 1s - kOhm, more 1s – 6 kOhm. So, for the explanation of safety criteria of operation, indicator of isolation damage, that has a connection with the isolation damaging process and current through a human body that appears in the process should be introduced. Such an indicator can be current in shunting connection, created by a person with his touch to a current conducting part of electro setting. For the explanation of the choice of a taken indicator a special model of appearance of isolation damages should be built and considered. [15].

According to another criteria, it`s obvious that, the main way of economical functioning of network distributions is losses in the process of transmission of electroenergy. The instant characteristic is active power of electroenergy loss of the current flow to the ground (ΔP_{iz}). It can be considered as a way of economical functioning of isolation DN and according to the indicators of workability in a use of this criteria.

As an explanation of electrosafety criteria let`s look at the case when human touch appears in grounded parts of electrosetting (body, carcass, metallic construction). (Fig. 1),

where r_a, r_b, r_c,- active isolation phase resistance DN;

C_a, C_b, C_c - volumes of certain phases in relation to a ground;

r_1, L_1 – parameters of transformer substitute scheme of voltage (TV), isolation control;

Z_N– equivalent resistance load ;

r_l–human body resistance, (r_h =6 *kOhm*[16]),

R_g – grounded equipment resistance,

r_d– additional transitional resistance.

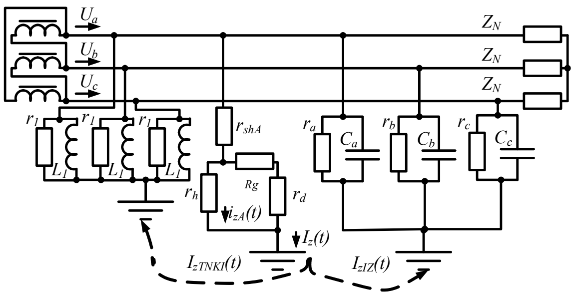

Fig. 1. Backup scheme for the description of a process of shunting connection appearance and human touch to the grounded elements electrosetting

For the modelling of the most unfavorable case let`s consider that isolation damage happens in electrosetting with the simplest way of grounding. And additional transitive resistance of current flow to the ground is approximately the same as the wire that fell on the ground [17]and thus in the place of spread on the ground it approximately eques 100 Ohm for the raw soil. For the most unfavorable case let`s consider that the damage appears simultaneously in 2 different phases and human touch happens in a most damaged place of an isolation and current (i_{zA}), flows in a human body and it should not be more than 6 mA.

For that conditions limit values of workability conditions of an isolation can be calculated as:

$$\begin{cases} I_{zA} = U_A \dfrac{g_{shA} \cdot g_h}{g_{shA} + g_h + g_g} \leq 6 \cdot 10^{-3}\text{A}; \\ I_{zB} = U_B \dfrac{g_{shB} \cdot g_h}{g_{shB} + g_h + g_g} \leq 6 \cdot 10^{-3}\text{A}; \\ I_{zC} = U_C \dfrac{g_{shC} \cdot g_h}{g_{shC} + g_h + g_g} \leq 6 \cdot 10^{-3}\text{A}. \end{cases} \tag{1}$$

where U_A, U_B, U_C – voltage phase A, B,C in relation to a ground (active items);

g_{shA}, g_{shB}, g_{shC} – shunting connection transmission appeared damages in certain phase;

g_l- human body transmission that equally ($g_h = 1/ r_h – 1/(6{\cdot}10^3)$) ;

g_3 = ground transmission that is calculate das (g_g = *1/* R_g *+1/* r_a, where R_g – nominal resistance of grounded gear, that should not be more than 10 Ohm; r_d– additional transmission resistance of a ground).

Shunting connection transmission if for different can be calculated in a way of measuring in active phases in relation to a ground in the primary time moment (r_{a0}, r_{b0}, r_{c0}), for example, after putting to a work of electrosetting and its current repairmen and also these resistances calculation in any time moment (r_a, r_b, r_c) and their further comparison with the primary numbers and formulas:

$$\begin{cases} g_{shA} = 1/r_a - 1/r_{a0} - 1/r_S\,; \\ g_{shB} = 1/r_b - 1/r_{b0} - 1/r_S\,; \\ g_{shC} = 1/r_c - 1/r_{c0} - 1/r_S\,, \end{cases} \qquad (2)$$

where r_s – symmetric reduce of isolation resistance in relation to a ground as a result of hydration of isolators top in a time of atmospheric precipitations that can be calculated as:

$$r_s = Min(r_{a0} - r_a);\ (r_{b0} - r_b);\ (r_{c0} - r_c)\,. \qquad (3)$$

Stream usage in shunting connecting in a way of technical condition isolation item and a formation on a basic of these conditions of isolation workability (1) lets restrict the isolation workability condition multiples, based on equipment usage conditions.

Voltage in phases in a relation to a ground also depends on the isolation parameters

$$\begin{cases} U_A = I''\sqrt{\left[g_b + g_c + \frac{\omega}{\sqrt{3}}(C_c - C_b\right]^2 + N}; \\ U_B = I''\sqrt{\left[g_a + g_c + \frac{\omega}{\sqrt{3}}(C_a - C_c\right]^2 + M}; \\ U_C = I''\sqrt{\left[g_b + g_a + \frac{\omega}{\sqrt{3}}(C_b - C_a\right]^2 + K}; \\ I'' = \dfrac{1{,}5\cdot U_f}{\sqrt{(g_a+g_b+g_c)^2 + (\omega(C_a+C_b+C_c) - B_L)^2}}; \\ N = \left[\frac{g_b - g_c}{\sqrt{3}} + \omega(C_b + C_c) - \frac{2B_L}{3}\right]^2; \\ M = \left[\frac{g_c - g_a}{\sqrt{3}} + \omega(C_a + C_c) - \frac{2B_L}{3}\right]^2; \\ K = \left[\frac{g_a - g_b}{\sqrt{3}} + \omega(C_b + C_a) - \frac{2B_L}{3}\right]^2, \end{cases} \qquad (4)$$

where U_f– network distribution phase voltage;

ω- angle frequency DN;

C_A, C_B, C_C– volumes of certain phases in relation to a ground;

g_A, g_B, g_C– active transmission network phases in a relation to a ground;

B_L – sum reactive transmission of all inductive elements set to DN in a relation to a ground (transformer volume winding to the isolation control ZNOM , NTMI type and also arc extinguishing reactors and resonant grounding neutral devices): ($B_L = 3/\omega(L_{TNKI\Sigma 1} + L_{DGR} + L_{PRZN})$), thus, the winding induction TNKI is considered as linear items (for the state work regimes in a network).

Take (4) in an equation (1) we get mathematical model for the workability calculation using mentioned above criteria's.

Using safety criteria's of usage of mathematical model for the isolation workability calculation looks as:

$$\begin{cases} I_{gA} = I''\cdot g_{shA}\cdot g_h/(g_{shA} + g_h + g_g)\cdot\sqrt{G_{A'} + G_{A''}}; \\ I_{gB} = I''\cdot\dfrac{g_{shB}\cdot g_h}{g_{shB} + g_h + g_g}\cdot\sqrt{G_{B'} + G_{B''}}; \\ I_{gC} = I''\cdot\dfrac{g_{shC}\cdot g_h}{g_{shC} + g_h + g_g}\cdot\sqrt{G_{C'} + G_{C''}}; \\ G_{A'} = \left[g_b + g_c + \frac{\omega}{\sqrt{3}}(C_c - C_b\right]^2; \\ G_{A''} = \left[\frac{g_b - g_c}{\sqrt{3}} + \omega(C_b + C_c) - \frac{2B_L}{3}\right]^2; \\ G_{B'} = \left[g_a + g_c + \frac{\omega}{\sqrt{3}}(C_a - C_c\right]^2; \\ G_{B''} = \left[\frac{g_c - g_a}{\sqrt{3}} + \omega(C_a + C_c) - \frac{2B_L}{3}\right]^2; \\ G_{C'} = \left[g_b + g_a + \frac{\omega}{\sqrt{3}}(C_b - C_a\right]^2; \\ G_{C''} = \left[\frac{g_a - g_b}{\sqrt{3}} + \omega(C_b + C_a) - \frac{2B_L}{3}\right]^2. \end{cases} \qquad (5)$$

The power of electroenergy loss from the current flow to the ground can be calculated using the information about power and active transmission network phases in a relation to a ground

$$\begin{cases} \Delta P_{iz\Sigma} = \Delta P_{izA} + \Delta P_{izB} + \Delta P_{izC}; \\ \Delta P_{iz\Sigma} = U_A^2\cdot g_a + U_B^2\cdot g_b + +U_C^2\cdot g_c. \end{cases} \qquad (6)$$

A gotten number of power loss in isolation ($\Delta P_{iz\Sigma}$) is compared to normative (ΔP_{iz}^{norm}), that can be calculated, having such technical data about a network as a type (OL or CL) common length L, nominal volume and cable type preferable, according to a described method in [18]:

$$\Delta P_{iz\Sigma} \le \Delta P_{iz}^{norm}. \qquad (7)$$

Thus, over normative power isolation can be calculated as restriction on its number for the formation of the workability conditions. Thus, the taken restrictions can be separated for different phases:

$$\Delta P_{izA} \le \Delta P_{iz}^{norm}/3\,;$$
$$\Delta P_{izB} \le \Delta P_{iz}^{norm}/3\,;$$
$$\Delta P_{izC} \le \Delta P_{iz}^{norm}/3.$$

According to a method [18], there are few states of environment, where the researches has been alone (LvivORG-RES) and has been got the normative isolation power loss numbers. They are: 1) rain, wet snow, drizzle; 2) fog; 3) dew, no precipitation. So, for the calculation of isolation workability DN calculation should first calculated normative power loss in isolation for those three states of environment and only after that compare the factial number of power loss in isolation with the normatives for the certain hydration level of environment that should be controlled. Using the economical criteria's of mathematical model functioning for the isolation workability calculation looks:

$$\begin{cases} \Delta P_{izA} = I'''(N' + M'); \\ \Delta P_{izB} = I'''(N'' + M''); \\ \Delta P_{izA} = I'''(N''' + M'''); \\ I''' = \dfrac{2{,}25 \cdot U_f^2 \cdot g_a}{(g_a + g_b + g_c)^2 + (\omega(C_a + C_b + C_c) - B_L)^2}; \\ N' = \left[g_b + g_c + \dfrac{\omega}{\sqrt{3}}(C_c - C_b\right]^2; \\ M' = \left[\dfrac{g_b - g_c}{\sqrt{3}} + \omega(C_b + C_c) - \dfrac{2B_L}{3}\right]^2; \\ N'' = \left[g_b + g_c + \dfrac{\omega}{\sqrt{3}}(C_a - C_c\right]^2; \\ M'' = \left[\dfrac{g_c - g_a}{\sqrt{3}} + \omega(C_b + C_c) - \dfrac{2B_L}{3}\right]^2; \\ N''' = \left[g_b + g_c + \dfrac{\omega}{\sqrt{3}}(C_b - C_a\right]^2; \\ M''' = \left[\dfrac{g_a - g_b}{\sqrt{3}} + \omega(C_b + C_c) - \dfrac{2B_L}{3}\right]^2. \end{cases} \tag{8}$$

As we see, the main part in describing the change process of isolation DN technical phase are the active transmission network phases in a relation to a ground (g_a, g_b, g_c). They are the only numbers in correlations (7) and (8), that change in a developing damaging process, because later we will consider them as diagnostical items for the isolation workability calculation.

Given the above, the diagnostic model for the method of determining the efficiency of insulation can be represented as a four-pole network with the input signal – phase voltages of the distribution network, and output: in the first case (using the criterion of operational safety) – currents flowing to ground through the shunt connection (Fig. 2.a); in the second case (when applying the criterion of economy of functioning) – the power of electricity losses from currents flowing to ground (Fig.2.b).

Fig. 2. Diagnostic model for determining the efficiency of insulation

a) –when applying the criterion of operational safety; b) - when applying the criterion of economy of functioning; in the diagram (W_I) is the transfer function when used as an output signal of the current in the shunt connection, (W_P) – is the transfer function when used as an output signal of the power of electricity losses from currents flowing to ground.

Determination of operability can be obtained from the relationship between the transfer functions (W_I) and (W_P), since both the currents in the shunt and the power of electricity losses from currents flowing to ground depend on the phase voltages of the network relative to ground:

$$W_I = |W(i\omega)| \cdot \frac{g_{shX} \cdot g_l}{g_{shX} + g_l + g_z}; \quad Wp = |W(i\omega)|^2 \cdot g_x \tag{9}$$

Where (x) is the index of the corresponding phase of the network; (*W(iω)*) is a complex of the transfer function, when the phase voltage (x) of the network relative to ground is used as the output signal.

As can be seen, both transfer functions have a common component: a complex of transfer functions (*W(iω)*). To simplify the problem of constructing a characteristic equation, we will further use it as a diagnostic model.

Let's define the transfer function for the received diagnostic model and the characteristic equation for carrying out check of correctness of a choice of indicators of efficiency of isolation.

Complexes of transfer functions at consideration of various phases of a network is going to be identified by the formula:

$$W_X(i\omega) = \frac{\dot{U}_X}{U_f}.$$

To simplify the calculations in further research, we will consider only networks with isolated neutral, in which there are no inductive elements that have a connection to ground, ie. ($B_L=0$).

$$W_A(i\omega) = \frac{\sqrt{3}\left[(g_b + i\omega C_b)e^{i30^0} + (g_c + i\omega C_c)e^{-i30^0}\right]}{(g_a + g_b + g_c) + i\omega(C_a + C_b + C_c)};$$

$$W_B(i\omega) = \frac{\sqrt{3}\left[(g_c + i\omega C_c)e^{i30^0} + (g_a + i\omega C_a)e^{-i30^0}\right]}{(g_a + g_b + g_c) + i\omega(C_a + C_b + C_c)};$$

$$W_C(i\omega) = \frac{\sqrt{3}\left[(g_a + i\omega C_a)e^{i30^0} + (g_b + i\omega C_b)e^{-i30^0}\right]}{(g_a + g_b + g_c) + i\omega(C_a + C_b + C_c)}. \tag{10}$$

In ratios (10) the expressions for the complexes of the voltages of the network phases relative to the ground were obtained by using the formula for the bias voltage of the neutral (U_0) in complex form and analysis of the backup scheme of a three-phase network with isolated neutral, shown in Fig.2.

To move from a complex to the operator form of the record (operational method is used: ($i\omega \rightarrow p$)) open the complexes in the numerator of expressions (10) and multiply the numerator and denominator on the conjugate denominator complex. As a result, we get:

$$W(p) = \frac{\sqrt{3}(a_3p^3 + a_2p^2 + a_1p + a_0)}{(g_a + g_b + g_c)^2 + \omega^2(C_a + C_b + C_c)^2}, \quad (11)$$

where a_0, a_1, a_2, a_3 - coefficients of the characteristic equation.

For getting the characteristic equation, it is necessary to equate the numerator of expression (11) to zero.

$$a_3 \cdot p^3 + a_2 \cdot p^2 + a_1 \cdot p + a_0 = 0 \quad (12)$$

For phase A the coefficients of the characteristic level

$$\begin{cases} a_3 = -\left[\frac{1}{2 \cdot w} \cdot (C_b - C_c) \cdot (C_a + C_b + C_c)\right]; \\ a_2 = \frac{1}{2 \cdot w} \cdot (C_b - C_c) \cdot (g_a + g_b + g_c) - \\ -\left[\frac{1}{2 \cdot w}(g_b - g_c) + \frac{1.5}{\sqrt{3}}(C_b + C_c)\right](C_a + C_b + C_c); \\ a_1 = -\frac{1.5}{\sqrt{3}} \cdot (g_b - g_c)(C_a + C_b + C_c) - \\ -\left[\frac{1}{2 \cdot w}(g_b - g_c) + \frac{1.5}{\sqrt{3}}(C_b + C_c)\right](g_a + g_b + g_c); \\ a_0 = \frac{1.5}{\sqrt{3}}(g_b + g_c)(g_a + g_b + g_c); \end{cases} \quad (13)$$

For phases B and C the coefficients of the characteristic equation are similar to expressions (13) with the only difference that instead of the factors ($g_b \pm g_c$) and ($C_b \pm C_c$) for phase B there will be factors ($g_c \pm g_a$) and ($C_c \pm C_a$), and for phase C – ($g_a \pm g_b$) and ($C_a \pm C_b$).

To check the correctness of the choice of insulation performance indicators (diagnostic indicators) we will study the sensitivity of the roots (poles) of the characteristic equation (13) to change of diagnostic indicators (parameters of isolation of phases – active conductivities of isolation of the distributive network concerning the ground). With the help of this study, you can qualitatively assess the degree of influence of the selected diagnostic indicators on the technical condition of the object of diagnosis, namely the isolation of the distribution network concerning the ground. In the final result we should receive confirmation of correctness of a choice of set of diagnostic indicators and the information for their ordering according to degree of influence. For the convenience of research, a real distribution network of overhead power lines with a voltage of 10 kV with a total length of 70 km was taken.

Based on its technical data, the normative power of insulation losses for all three environmental conditions was determined according to the method [18] by the formula:

$$\Delta P_{iz\_i}^{norm} = I_{iz}^2 \cdot R_i \cdot T_i \cdot \frac{L}{100},$$

where I_{iz} - specific square value of the ground fault current (given in tabular form in [18] for air distribution networks of different voltage classes) for the corresponding i-th level of ambient humidity, A/ 100km;

R_i - the specific value of the equivalent active resistance of the insulation relative to the ground for the i-th level of humidity, Ohm 100km;

T_i - duration for a year of weather with the i-th level of humidity, hours (from the reference of the hydrometeorological center);

L – is the total length of the distribution network.

For given distribution network: $\Delta P_{iz_{100\%}}^{norm} = 23377\ W$; $\Delta P_{iz_{80-100\%}}^{norm} = 17910\ W$; $\Delta P_{iz\_<80\%}^{norm} = 6643\ W$.

Initial conditions of the study:

1. At the initial moment of time, the active insulation of the network phases relative to the ground is symmetrical (*$r_{A0}=r_{B0}=r_{C0}=100$ kOmh*). Accordingly, we introduce the concept of the normal value of the active conductivity of the phase insulation relative to ground, which is equal to ($g_n=10^{-5}$ *Sm*). Any current value of active conductivity, the effect of which on the poles is investigated, can be represented as the sum of the normal value and the current value of its deviation ($g_i=g_n+\lambda_i$).

2. Capacities of isolation of phases concerning the ground are symmetrical, are ($C_a=C_b=C_c=C_f=0.5$ *mcF*) and remain unchanged.

3. When studying the effect of a diagnostic indicator on the poles, it is believed that all other indicators remain unchanged.

4. The extreme change of the diagnostic index is considered to be the permissible deviation of the active conductivity (λ_i), in which the active conductivity in the phase of shunting (phase A) is equal to the active conductivity of the phase whose change is investigated (phase B or C), at critical performance of working conditions (6) and (7) It is believed that the damage occurred simultaneously in two phases and gained maximum development, up to the limit of the efficiency of the insulation.

5. For working conditions (6) and (7) the simulation is carried out and the limits of change of active conductivities are determined for the given initial conditions:

- for performance conditions (7) in the study of the effect of active conductivity of phase B – ($\lambda_B=5.39\cdot10^{-5}$); of phase C – ($\lambda_C=6.692\cdot10^{-5}$);
- for performance conditions (6) in the study of the effect of active conductivity of phase B: ($\lambda_{B\ 100\%}=4.118\cdot10^{-4}$, $\lambda_{B\ 80-100\%}=2.992\cdot10^{-4}$, $\lambda_{B<80\%}=8.766\cdot10^{-5}$) ; of phase C: ($\lambda_{C\_100\%}=4.118\cdot10^{-4}$, $\lambda_{C\_80-100\%}=2.992\cdot10^{-4}$, $\lambda_{C\_<80\%}=8.766\cdot10^{-5}$);

With a symmetrical increase in the conductivities of all three phases simultaneously: ($\lambda_{sym\_100\%}=2,238\cdot10^{-4}$, $\lambda_{sym\_80-100\%}=1,691\cdot10^{-4}$ $\lambda_{sym\_<80\%}=5,644\cdot10^{-5}$);

Since the capacitances of the phases are symmetric, the characteristic equation will be quadratic and will have the following roots:

$$x_1=\frac{g_a+g_b+g_c}{C_a+C_b+C_c}=\frac{g_n}{C_f};$$
$$x_2=\frac{-\frac{1{,}5}{\sqrt{3}}\cdot(g_b+g_c)}{-\frac{1{,}5}{\sqrt{3}}\cdot(g_b+g_c)+-\frac{1{,}5}{\sqrt{3}}\cdot(C_b+C_c)}=-\frac{g_n}{C_f}. \quad (14)$$

Given the above initial conditions, we write the expressions of the characteristic equation for three cases:

1. In the study of the impact g_a:

$$-3\sqrt{3}C_f^2x^2+\sqrt{3}\Lambda C_f x+3\sqrt{3}g_n^2+\sqrt{3}\Lambda g_n=0. \quad (15)$$

2. In the study of the impact (g_b):

$$\left(3\sqrt{3}C_f^2-\frac{3C_f}{2w}\Lambda\right)\left[\frac{\Lambda^2}{2w}+\left(\sqrt{3}C_f+\frac{3g_n}{2w}-\frac{3\sqrt{3}C_f}{2}\right)\Lambda\right]x+$$
$$+3\sqrt{3}g_n^2+\frac{5\sqrt{3}g_n}{2}\cdot\Lambda+\Lambda^2=0. \quad (16)$$

3. In the study of the impact (g_c);

$$\left(\frac{3\Lambda C_f}{2w}-3\sqrt{3}C_f^2\right)x^2+\left[\left(\frac{-\Lambda^2}{2w}\right)+\left(\sqrt{3}C_f-\frac{3g_n}{2w}-\frac{3\sqrt{3}C_f}{2}\right)\Lambda\right]x+3\sqrt{3}g_n^2+\frac{5\sqrt{3}g_n\Lambda}{2}+\Lambda^2=0 \quad (17)$$

To assess the sensitivity of the poles to diagnostic indicators and to organize them according to the degree of influence, we will use the method of determining the norm of the vector of relative sensitivities [1].In general, the norms of the vectors of relative sensitivities of the poles (in the form of dependence on the deviation λ) to change the relevant diagnostic parameters will take the form:

in the study of the impact (g_a):

$$Ta(\Lambda)=\text{const}=$$
$$=\sqrt{\left[\frac{\sqrt{3}C_f\cdot x_1+\sqrt{3}g_n}{6\sqrt{3}C_f\cdot g_n\cdot x_1}\right]^2+\left[\frac{\sqrt{3}C_f\cdot x_2+\sqrt{3}g_n}{6\sqrt{3}C_f\cdot g_n\cdot x_2}\right]^2}, \quad (18)$$

in the study of the impact (g_b):

$$Tb(\Lambda)=$$
$$=\sqrt{\frac{\left[\left(\frac{-3C_f}{2w}\right)\cdot x_1^2+\left(\frac{\Lambda}{w}+\frac{3g_n}{2w}-\frac{\sqrt{3}C_f}{2}\right)\cdot x_1+2\Lambda+\frac{5\sqrt{3}g_n}{2}\right]^2}{-6\sqrt{3}C_f\cdot g_n\cdot x_1}+\frac{\left[\left(\frac{-3C_f}{2w}\right)\cdot x_2^2+\left(\frac{\Lambda}{w}+\frac{3g_n}{2w}-\frac{\sqrt{3}C_f}{2}\right)\cdot x_2+2\Lambda+\frac{5\sqrt{3}g_n}{2}\right]^2}{6\sqrt{3}C_f\cdot g_n\cdot x_2}}, \quad (19)$$

in the study of the impact (g_c):

$$Tc(\Lambda)=$$
$$=\sqrt{\frac{\left[\left(\frac{3C_f}{2w}\right)\cdot x_1^2+\left(\frac{-\Lambda}{w}-\frac{3g_n}{2w}-\frac{\sqrt{3}C_f}{2}\right)\cdot x_1+2\Lambda+\frac{5\sqrt{3}g_n}{2}\right]^2}{-6\sqrt{3}C_f\cdot g_n\cdot x_1}+\frac{\left[\left(\frac{3C_f}{2w}\right)\cdot x_2^2+\left(\frac{-\Lambda}{w}-\frac{3g_n}{2w}-\frac{\sqrt{3}C_f}{2}\right)\cdot x_2+2\Lambda+\frac{5\sqrt{3}g_n}{2}\right]^2}{6\sqrt{3}C_f\cdot g_n\cdot x_2}} \quad (20)$$

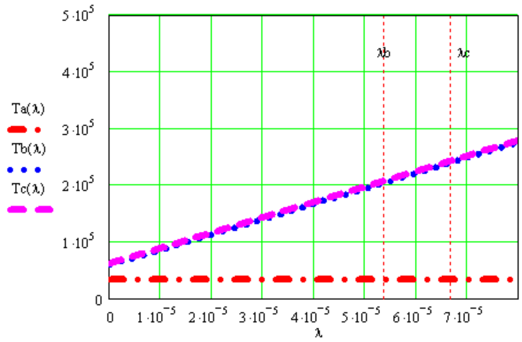

Fig. 3. Dependences of norms of vectors of relative sensitivities on deviation: a- is general schedule of dependencies

The norm of the vector of relative sensitivity to change (g_a) is a constant value, and is equal to (T_a=3.333·10^-4). This is explained by the fact that the dependence of the roots of the characteristic equation from (g_a) has a linear character (compiled to consider the possibility of damage in phase A), and therefore at differentiation for definition (T_a) as a result a constant will be received. The norms of the vectors of relative sensitivities to the change of (g_b) and (g_c) are functions of the deviation (λ). Graphs of dependencies are going to be built for a visual assessment of sensitivity for each diagnostic indicator, Figure 3.Thus, as a result of the conducted researches it is established that influence of all three conductivities of phases on poles (roots of the characteristic equation) has approximately one order of magnitude, and influences (g_c) and (g_b) are almost identical that it is possible to observe in fig.3 (curves of the dependence of the norm of the sensitivity vector on the deviation for phases B and C are almost coincide). Therefore, the set of diagnostic indicators was chosen correctly and the diagnostic model is appropriate.

3 Conclusion

The main reason isolation damage is appearance of shunting connecting's within conductive part and a ground in electrical distribution network with the voltage 6-35 kV. In this case there are 2 processes-smooth symmetrical reduce of active isolation resistance of isolation phases as a result of hydration work on the isolator top and non-symmetrical harsh reduce of isolation active resistance of separated phase in a relation to a ground as a result of shunting connecting appearance. Isolation workability conditions calculation of distribution network in a look of restriction of isolation workability items change in relation to a ground, based on official documents and standards should carry out the current reduce through shunting connection with the electrosafety criteria's and active power loss in isolation from current flow to a ground with the economical criteria of minimum electroenergy loss.

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