STUDY ON THE INFLUENCE OF THE STAR CONNECTION NEUTRAL ON THE ELECTRICAL TRANSFORMERS WINDINGS ON ELECTRIC-SECURITY AND ON THE ELECTRICAL NETWORK

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ABSTRACT: Electrical networks producing electricity transmission and distribution , of the National Power System are dependent on electrical power transformers ,on the voltage level at which the conversion of electricity produced or distributed is made and on the treatment of neutral . The work took as reference the treatment of neutral and its influence on the human body when accidentally touching a phase entering in three-phase power system configuration .
KEY WORDS: electrical networks, electric-security

1.INTRODUCTION

The paper aims to conduct a case study on the treatment of neutral and its influence on the security against the current passing through the human body to phase touching.At the development of the paper, work was started from electrotechnics notions of balanced three-phase electrical systems , namely unbalanced star and delta connection of alternative current and was intended setting the expression that can determine the amount of electric current passing through the human body at the touch of phase for three different cases . Electrotechnics notions used in this paper were limited to [2] :complex admittance form for alternative current ;total insulation admittance against earth phases ;the relation between conductance and electric admittance ; phasor diagram of phase voltage to earth in three-phase power system with electric power, according to the rotation controller ;zero voltage setting .

The case study of the work was limited to three specific situations in the treatment of neutral electrical networks based on who can establish conclusions on the electrical security and the insulation of electrical networks and operation and maintenance personnel practicing under thereof .

Study three different situations , namely neutral grounding in three-phase power system with electric power are:

- isolated neutral systems of the star transformers ;
- systems capacitive leakage current compensation ;
- systems direct binding neutral earth star connection **.**

The amount of electric current that would pass through the body by putting voltage, is the main factor that determines the risk of electric shock. Current passing through the human body is determined mainly by touch voltage , which in turn depends essentially on neutral mode of power supply transformer star [1] .

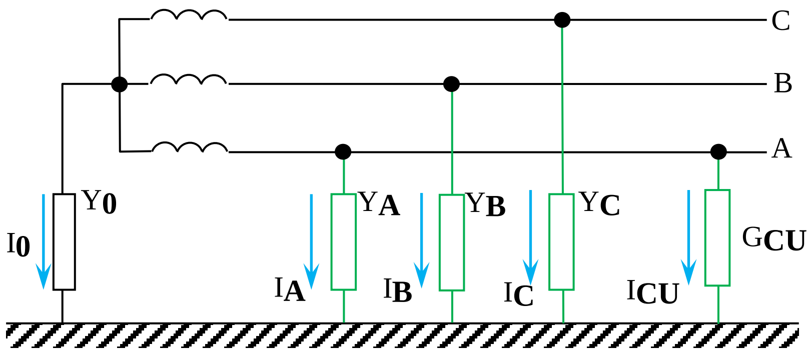

Fig.1. Equivalent circuit of three-phase electric power system .

Figure 1 shows the equivalent circuit for the most general case of three-phase electrical system with a neutral admittance Y0 star to earth , total admittance insulation, Y_A , Y_B , Y_C corresponding phases A, B and C to ground and the conductance G_{CU} of the man who touches a phase A of the system. For total insulation admittance from the ground phase it can be written [1,2] :

$$Y_A = G_A + jB_A;$$

$$Y_B = G_B + jB_B; \qquad Y_C = G_C + jB_C$$

where:

-G_A.G_B,G_C insulation conductances of the corresponding phases A, B and C to the ground;

-B_A,B_B,B_C proper capacitive susceptibles insulation of the corresponding phases A, B and C to ground .

Conductances and susceptibles of insulation to the ground are equal to:

$$G_A = \frac{1}{R_A};\ G_B = \frac{1}{R_B};\ G_C = \frac{1}{R_C}$$

And

$$B_A = \omega C_A;\ B_B = \omega C_B;\ B_C = \omega C_C$$

where:

-R_A,R_B,R_C insulation resistance of the corresponding phases A, B and C to the ground;

-C_A,C_B,C_C appropriate capabilities phases A, B and C to ground ;

G_{CU} conductance of the human body is : $G_{CU} = \frac{1}{R_{CU}}$

where R_{CU} is the resistance of the human body .

With G_{CU} human body is noted the concentrated monophased duct leakage by the resistance R_{CU} . The phasor diagram (Figure 2) [1] with $\underline{U}_A$, $\underline{U}_B$, $\underline{U}_C$ are are ranked the corresponding phase voltage vectors A, B and C to ground before reaching the phase of human A (before the onset of active concentrated leak conductance G_{CU}) .

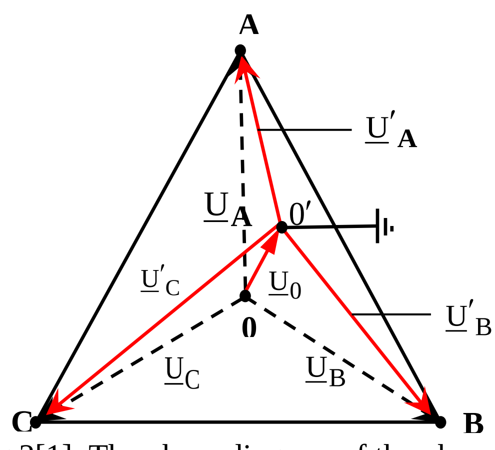

Fig.2[1]. The phase diagram of the phase voltages to the ground in system three phase power supply

Through $\underline{U}'_{A},\underline{U}'_{B},\underline{U}'_{C}$ are ranked The phase voltage vectors corresponding to A, B , C after reaching Phase A man (after the appearance of concentrated active leakage conductance G_{CU}) and with $\underline{U}_0$ - voltage neutral star. From the phasor diagram follows that [1] :

$$\underline{U}'_{\mathbf{A}} = \underline{U}_{\mathbf{A}} - \underline{U}_{\mathbf{0}} \quad ;$$

$$\underline{U}'_{\mathbf{B}} = \underline{U}_{\mathbf{B}} - \underline{U}_{\mathbf{0}};\ \ \underline{U}'_{\mathbf{C}} = \underline{U}_{\mathbf{C}} - \underline{U}_{\mathbf{0}}. \quad (1)$$

$$\underline{I}_{A} = \left(\underline{U}_{A} - \underline{U}_{0}\right)Y_{A};\ \underline{I}_{B} = \left(\underline{U}_{B} - \underline{U}_{0}\right)Y_{B};\ \underline{I}_{C} = \left(\underline{U}_{C} - \underline{U}_{0}\right)Y_{C};$$

$$\underline{I}_{0} = \left(0 - \underline{U}_{0}\right)Y_{0} = -\underline{U}_{0}Y_{0}.$$

According to Kirchhoff's first theorem it shows that [1] :

$$\underline{I}_{\mathbf{A}} + \underline{I}_{\mathbf{B}} + \underline{I}_{\mathbf{C}} + \underline{I}_{\mathbf{CU}} + \underline{I}_{\mathbf{0}} = 0 \ ,$$

and after substituting in this expression sum for the currents we get:

$$\left(\underline{U}_{\mathbf{A}} - \underline{U}_{\mathbf{0}}\right)Y_{\mathbf{A}} + \left(\underline{U}_{\mathbf{B}} - \underline{U}_{\mathbf{0}}\right)Y_{\mathbf{B}} + \left(\underline{U}_{\mathbf{C}} - \underline{U}_{\mathbf{0}}\right)Y_{\mathbf{C}} + \\ + \left(\underline{U}_{\mathbf{A}} - \underline{U}_{\mathbf{0}}\right)G_{\mathbf{CU}} - \underline{U}_{\mathbf{0}}Y_{\mathbf{0}} = 0 \ .$$

From this relation it is determinated the $\underline{U}_{\mathbf{0}}$ voltage dependence of the star nular[1]:

$$\underline{U}_{\mathbf{0}} = \frac{\underline{U}_{\mathbf{A}}Y_{\mathbf{A}} + \underline{U}_{\mathbf{B}}Y_{\mathbf{B}} + \underline{U}_{\mathbf{C}}Y_{\mathbf{C}} + \underline{U}_{\mathbf{A}}G_{\mathbf{CU}}}{Y_{\mathbf{A}} + Y_{\mathbf{B}} + Y_{\mathbf{C}} + Y_{\mathbf{0}} + G_{\mathbf{CU}}} \quad (3)$$

After representing $\underline{U}_{\mathbf{A}};\ \underline{U}_{\mathbf{B}};\ \underline{U}_{\mathbf{C}}$ by phasor operators a and a^2($a = (-\frac{1}{2} + j\frac{\sqrt{3}}{2}; a^2 = -\frac{1}{2} - j\frac{\sqrt{3}}{2})$: $\underline{U}_{\mathbf{A}} = U;\ \underline{U}_{\mathbf{B}} = a^{\mathbf{2}}U;\ \underline{U}_{\mathbf{C}} = aU$ the relation (3) is transformed into:

$$U_{\mathbf{0}} = U\frac{Y_{\mathbf{A}} + a^{\mathbf{2}}Y_{\mathbf{B}} + aY_{\mathbf{C}} + G_{\mathbf{CU}}}{Y_{\mathbf{A}} + Y_{\mathbf{B}} + Y_{\mathbf{C}} + Y_{\mathbf{0}} + G_{\mathbf{CU}}} \quad (4)$$

The searched current $\underline{I}_{CU}$ passing through the human body (by concentrated flow duct G_{CU}) shall be determined as [1] :

$$\underline{I}_{\mathbf{CU}} = \underline{U}'_{\mathbf{A}} \cdot G_{\mathbf{CU}} = \left(\underline{U}_{\mathbf{A}} - \underline{U}_{\mathbf{0}}\right)G_{\mathbf{CU}}. \quad (2)$$

Analogous relation (2) we can write:

If is substituted (4)in(3) is obtained [1]:

$$I_{\mathbf{CU}} = UG_{\mathbf{CU}}\frac{Y_{\mathbf{B}}\left(1 - a^{\mathbf{2}}\right) + Y_{\mathbf{C}}\left(1 - a\right) + Y_{\mathbf{0}}}{Y_{\mathbf{A}} + Y_{\mathbf{B}} + Y_{\mathbf{C}} + Y_{\mathbf{0}} + G_{\mathbf{CU}}} \ . \quad (5)$$

Studies show that susceptables and conductances of insulation of the three phases to the ground in three phase electrical systems most often are about equal .

Therefore it is acceptable $Y_A=Y_B=Y_C=Y$, and (5), after it replaces $a^{\mathbf{2}} = -\frac{1}{2} - j\frac{\sqrt{3}}{2}$ and $a = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$ it will get the form [1] :

$$I_{\mathbf{CU}} = UG_{\mathbf{CU}} \cdot \frac{3Y + Y_{\mathbf{0}}}{3Y + Y_{\mathbf{0}} + G_{\mathbf{CU}}} \ . \quad (6)$$

2. SETTING THIS CURRENT INTENSITY FOR THE THREE NEUTRAL GROUNDING SITUATION

Star neutral regime of the system for the electricity supply of the consumers from a particular technological flow chart it is chosen from a technical and economic analysis . But for the applicability of one or another system , the most important criterion for electrical securiatea in handling the electrical equipment .

The most unfavorable system from the point of view of the risk of damage due to the electric current it isnecessary to achieve by the man simultaneously up to two phases of the three-phase system .

Thus,the touch voltage is equal to the line voltage and independent of the transformer neutral star system and the amount current flowing through the body resistance of 600Ω is considerable (0.63 A at U_n = 380 V , 1.1 A to U_n = 660V) [1] .

The value of this current exceeds the fibrillation current limit several times and with high probability can cause deadly diseases . In systems with direct binding of neutral star person that has broken ground wire and touched one phase,it determines the touch , similar to phase voltage ,and the current passing through the body is dangerous (0.37 A at U_f = 220 V and 0.63 A at U_f = 380V) [1] .

2.1. Systems with the transformers neutral isolated

In the system of the transformer star with isolated neutral $Y_0 = 0$. When the I_{CU} current passing through the human body it can be determined according to the relation [1] :

$$I_{CU} = UG_{CU} \cdot \frac{3Y}{3Y + G_{CU}} \qquad (7)$$

The systems with isolated neutral of the transformer star can be divided into two groups:

- insignificant capacity systems from the ground ;
- significant capacity systems from the ground ;

In systems with insignificant capacity to ground $C \approx 0$ and therefore, $B = \omega C << G$ due to which it is recognized $Y = G$. As a result (7) it takes the form [1] :

$$I_{CU} = UG_{CU} \cdot \frac{3G}{3G + G_{CU}} ,$$

and after replacement of the $G_{CU} = \frac{1}{R_{CU}}$ and $G = \frac{1}{R}$ for I_{CU} **we** will get [1]:

$$I_{CU} = \frac{3U}{3G_{CU} + R} . \qquad (8)$$

Electric power systems with negligible capacitive to the ground are the ones , including power transformer , the power supply to the total length which does not exceed 20 to 30 m and not more than 1 ÷ 2 electrical components .

Actual power systems with isolated neutral of the transformer star have significant capacity to ground . In this case, after the replacement of the $Y = G + j\omega C$ in rel (7) and performing the necessary mathematical transformations to obtain the I_{CU} [1] :

$$I_{CU} = 3UG_{CU} \cdot \sqrt{\frac{G^2 + \omega^2 C^2}{(3G + G_{CU})^2 + 9\omega^2 C^2}} . \qquad (9)$$

If we substitute $G_{CU} = \frac{1}{R_{CU}}$ and $G = \frac{1}{R}$ we will obtain[1]:

$$I_{CU} = \frac{U}{\sqrt{R_{CU}^2 + \frac{R\left(R + 6R_{CU}\right)}{9\left(1 + R^2\omega^2 C^2\right)}}} . \qquad (10)$$

2.2. Capacitive current compensation system with drain

Equivalent circuit of the system with capacitive leakage current compensation is presented in Figure 3 [1] . In this and in the following formulas are neglected the resistance of the arc extinguishing reactor as very small .

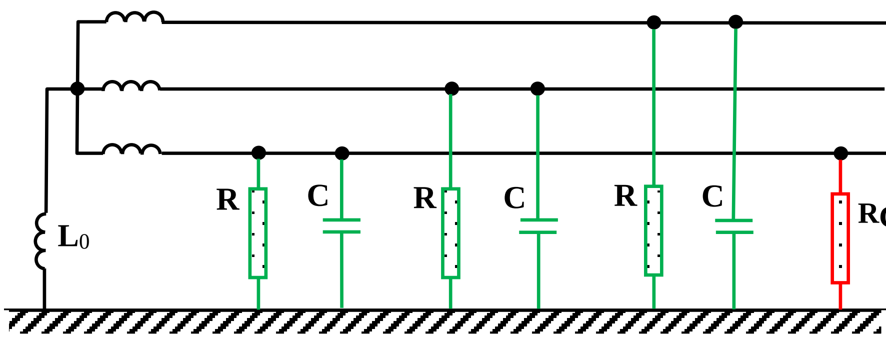

Fig.3. Equivalent circuit of the power supply system with capacity compensation to ground

Independent of the size of R_{CU} the leakage current obtains the minimum value at full capacity compensation. I_{CU} expression (7) can be presented as follows [1] :

$$I_{CU} = UG_{CU}\frac{3(G+j\omega C)-j\frac{1}{\omega L}}{3(G+j\omega C)-j\frac{1}{\omega L}+G_{CU}} = UG_{CU}\frac{3G+j\left(3\omega C-\frac{1}{\omega L}\right)}{3G+G_{CU}+j\left(3\omega C-\frac{1}{\omega L}\right)}$$

Full compensation of capacitive leakage current would be obtained at the resonance extinguishing reactor of the electric arc ,at[1] :

$$3\omega C-\frac{1}{\omega L}=0$$

and so on :

$$L=\frac{1}{3\omega^2 C}$$

In the case of total compensation of capacitive leakage current for the current I_{CU} expression is restricted to (8) as the minor system capacity to ground (C = 0).

2.3. Systems with direct connection to a neutral ground

In this case $Y_0 = G_0 >> Y$, due to we can admit that $Y \cong 0$. Then (6) it will take the form[1]:

$$I_{CU} = UG_{CU}\frac{G_0}{G_0+G_{CU}} = \frac{U}{R_0+R_{CU}}$$

Because $R_0 << R_{CU}$, we can admit $R_0 \cong 0$ and expression for I_{CU} will be[1]:

$$I_{CU} = \frac{U}{R_{CU}}$$

3. CONCLUSIONS

By comparing the three basic systems that have different regime of neutral from the point of view of electrical safety we can determine both advantages and disadvantages.

1.The basic disadvantages of the system with direct grounded of the neutral star from the point of view of electrical safety and networks electrical insulation of distribution of electricity can be formulated as [1] :

a) the size of the current, passing through the human body to achieve one of electrical system phase is essential , this current does not depend on the insulation resistance to ground of the other two phases , so the insulation condition does not has protective role ;

b) single-phase ground fault current , is the single-phase ground fault current , which is very high , it causes dangerous voltages even if the protective grounding of electrical equipment appropriate .

Neutral directly grounded star systems has some essential advantages of exploitation. The most important one is that putting ground phase (short circuit) that appear, are decoupled from the current maximum protection . It works safely, quickly and in proper adjustment is selective , ensuring easy decoupling of network damaged node . The conductor, it creates opportunity out power supply network for both consumers of the single-phase and three-phase .

2.The basic advantages of the system with insulated neutral star transformers are [1] :

a) the amount of current that passes through the human body to achieve one phase electrical system , depending on the insulation resistance to ground for the other two phases ; the satisfactory insulation resistance and the minor ability to ground (or partial or complete clearing) current , which passes through the entry 's body voltage can be harmless size . The insulation resistance to ground electrical systems mining plays a protective role ;

b) the current implementation phase grounded electrical systems up to 1000V voltage is insignificant , it is not dangerous in terms of thermal in networks insulation of electrical equipment .

The main disadvantages of the star isolated neutral system are [1] :

a)at faulty or missing protection that continuously controls the condition of the insulation and at its dangerous reduce or at ground penetrations it automatically disconnects power supply , commissioning phase usually occurs down there very long ; it can cause rupture and in other phases because their voltage to ground rise $\sqrt{3}$ times , and consequently lead to two or three-phase with resulting adverse consequences short circuits; in the presence of uncoupled ground fault of one of the phase reached by man to another phase leads to a big danger of problems , because the human body for a long time is under achieve equal to the line voltage ;

b) permanent automatic insulation control is achieved with relatively complex equipment , the operation of which in most cases is non-selective , so after the decoupling voltage automatic protection of the entire electrical system supply instead breakthrough in networks with complicated configuration is found difficult and this often leads to long-term shutdown of the production process . .

3. Capacitive current compensation system leakage due to large inductive reactance compensation coil retains the advantages and disadvantages of the system given the star's isolated neutral transformer . Security qualities of the system with the isolated neutral star transformer and of the system capacity compensation can be guaranteed only with the condition, that is achieved permanent control of insulation status and of automatically disconnecting of the protection to the emergence implementation phase to ground or to reduce isolation under minimum undangerous set .

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