Calculation Model and Analyses of Grounding of the Fence on Medium Voltage Stations

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Abstract - **Groundings of transformer stations (TS) in power networks with neutral point grounded by small resistively, in the case of single pole fault to ground, may to find on high potential. In such a case considerable potential differences can be registered between some points into and around transformer station and to come to high touch and step voltages. In this paper results of analysis of particular case are introduced, TS MV/MV (medium voltage) 35/10 kV 'Omorane2', near by Veles, which is make to find optimum way for grounding of the fence to satisfied safety criteria's, given in rules and recommendations. The analysis have for purpose not just to answer of the problem which is already described, thus to give some general thinking and recommendations in the general case.**

Keywords - **grounding, fault to ground, analysis, step and touch voltage, fence of TS, safety criteria's**

I. INTRODUCTION

Metal fence of TS HV/MV, TS MV/MV longer time is object of different treatment in projecting practice in relation at type of grounding and abstinence of dangerous step and touch voltages. In this problem it is general approach is one of the following ways:

- fence is grounded with galvanic connection of more places on general grounding grid of TS, figure 1a.
- through special grounding placed from external side of fence on distance of 1 m which can be in galvanic relation with grounding grid, so-called common grounding, or galvanic separated from it, figure 1b.

In first case external electrodes of grounding grid of TS MV/MV usually follows fence of external side on distance of 1 m. with that occupied area is increased with grounder and resistance is decreased of shared parts, but potential of fence is going to be equivalent with grounding grid voltage. Safety criteria's will be satisfied if gradients of potential of both sights of fence are controlled with help of modeling of potential. But that is possible just in case of low specific resistively on the bottom point ρ, low current of near grounded connection and so on, so in more practical those terms are not fulfilled. In some rube it can be founded some recommendations by which this problematic are examined and in itself includes the way of grounding of neutral point of network.

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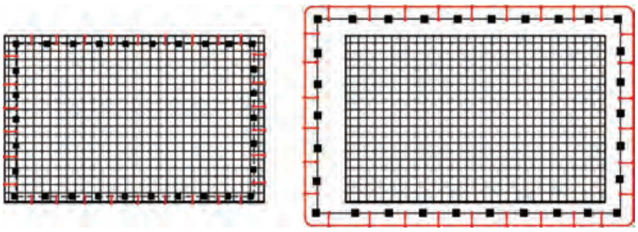

Fig. 1. a) without b) with special grounding placed from external side of fence on distance of 1 m

II. REVIEW TO RECOMMENDATION FOR GROUNDING OF MV TS

According to (10), in phase of projecting of TS 35/10 kV or 35/20 kV it doesn't needs preview or account for grounding, so the project needs just to predict grounding according this recommendation. Therefore it is need connecting of grounding grid of TS 35/10 kV, TS 35/20 kV with annular grounding grid of fence, i.e. it is needed to be used common grounding. Motion of network with isolated neutral point can go on with capacity current of fault to ground is not to be increased more than 10 A in 35 kV network, i.e. 20 A in 10 kV network. Grounding of neutral points of MV networks (35 kV, 20 kV, 10 kV) is obliged when currents of fault to ground will achieve two times higher values than stated above.

Systems of grounding of TS are dimensioned in accordance touch voltage so they are not allowed to over cross voltages shown according phase (1):

$$U_{doz} = \begin{cases} 1000V & T \le 0{,}075s \\ \dfrac{75}{T}V & 0{,}075s < T \le 1{,}153s \\ 65V & T \ge 1{,}153s \end{cases} \quad (1)$$

where T is duration of fault to ground.

According the same recommendation, safety criteria's of touch voltage will be satisfied if total impedance of grounding has value:

$$Z_u \le \frac{k_d \cdot U_d}{r \cdot I_k} \quad (2)$$

k_d - attitude of voltage on grounding grid of TS and touch voltage.

U_d - allowed voltage according relation (1)

r - reductive factor of MV overhead line who give a current of TS

I_k - total allowed current of fault to ground of medium voltages network.

In accordance, literary (10) for isolation network when fault to ground has stabile character this values are: $k_d = 2$, $U_d = 65$ V, $I_k = 20$ A. If TS gives current over overhead line the reductive factor amount is r = 1. Replacing this values in (2) it gives that safety criteria's will be satisfied only if total impedance of grounding has value lower of 6,5 Ω.

According the same recommendation, if network is with grounding natural point over low impedance amplifier with limitation of current of fault to ground on 300 A, total resistance (impedance) of system of grounding on TS 35/10kV or 35/20 kV should be in relation (2) $Z_u \le 0{,}7\Omega$ if it is TS 35/10 kV or TS 35/20 kV connected to the overhead line 35 kV, $k_d = 3$, (r=1). In case not to be satisfied over headed condition, it needs, time of disconnection on fault to ground on collectors 35 kV in TS 35/10 kV or TS 35/20 kV to be original for most 0,5s with it disturb to be fraught criteria for security of touch voltage thereated without prove with accountings or measurement or decrease value of voltage grounding on security grounding (for example: with adding of vertical grounding grids, adding for one more annular grounding grid, etc., in order to satisfy overhead term.

According the same recommendation at taking out of grounding to install contour (annular) round fundament grounding grid that is connected with it on more places of distance 1m from wall of building on depth of 0,8 m.

III. MODEL FOR EVALUATION OF THE WAY OF GROUNDING ON FENCE

Often in practice the question is estimated for each other influence on grounding grid for different near placed objects. The answer may be appropriate useful at analyses of secure and work grounding grid of TS MV/LV, at appointment of different metal installation or cable of metal conductive layer near to the grounding grids in basement of housing objects like in case at evaluation is annular grounding grid to fence to be galvanic separate from main grounding grid or linked. And in case of galvanic separated grounding grid of fence of grounding grid of TS it get some potential of fault in TS as a result on that what is found in potential funnel on active grounding grid, (of TS 35/10). Characteristics of both grounding grids can be calculate over below-mentioned mathematics model, based on well-known Maxwell's relation. For two grounding grids *a* and *b* with n_a and n_b rectilinear electrodes besides (4), (7) import:

$$\begin{bmatrix} [U_a] \\ [U_b] \end{bmatrix} = \begin{bmatrix} [r_{aa}] & [r_{ab}] \\ [r_{ba}] & [r_{bb}] \end{bmatrix} \cdot \begin{bmatrix} [I_a] \\ [I_b] \end{bmatrix} \qquad (3)$$

$[U_a],[U_b]$ - vector of voltages on electrodes of grounding grids with dimensions $n_a \times 1$, $n_b \times 1$

$[I_a],[I_b]$ - vector of current of taking away on electrodes on grounding grids, with dimensions $n_a \times 1$ i.e. $n_b \times 1$

$[r_{aa}],[r_{bb}]$ - square symmetrical matrix with dimensions $n_a \times n_a$ i.e. $n_b \times n_b$. On main diagonals with own resistivities on electrodes on grounding grids, and the others members are mutual resistivities of electrodes from the first (second) grounding grid.

$[r_{ab}],[r_{ba}]$ - rectangular matrix with $n_a \times n_b, n_b \times n_a$ members which presents mutual resistivities of elements from grounding grid *a* with elements from grounding grid *b*.

At calculation of own and common resistivities to be taken apprehend into consideration and their links on relation of plain on their own discontinuity (land area), one or endless number in dependence on that if the ground is homogeneous or is not homogeneous, and is calculate by method of medium potential literature [2],[3].

During calculation can be omitted failure of voltage because are small on electrode with smaller length and to take in consideration that all elements are on the same potential, i.e.:

$$[U_a] = [1_a] \cdot U_a \text{ and } [U_b] = [1_b] \cdot U_b \qquad (4)$$

In the last relation it showed two single vectors with same dimensions like the vectors of voltages. Parameters of two near galvanic separates grounding grids and its mutual influence are analyzed in conditions when from some of them shunt current into fault to ground I_z, for example from grounding grid *a*, in case fundamental grounding grid. Run a grounding *b*, annular of fence, doesn't have current of fault to ground.

$$I_z = [1_a]^T \cdot [I_a] \qquad (5)$$

$$[1_b]^T \cdot [I_b] = 0 \qquad (6)$$

From overhead relation emanate:

$$\begin{matrix} U_a \\ U_b \end{matrix} \begin{bmatrix} [1_a] \\ [1_b] \end{bmatrix} = \begin{bmatrix} [r_{aa}] & [r_{ab}] \\ [r_{ba}] & [r_{bb}] \end{bmatrix} \cdot \begin{bmatrix} [I_a] \\ [I_b] \end{bmatrix} \qquad (7)$$

From relations (5) and (6) follows:

$$\begin{bmatrix} [1_a]^T & [0_b] \\ [0_a] & [1_b]^T \end{bmatrix} \cdot \begin{bmatrix} [I_a] \\ [I_b] \end{bmatrix} = \begin{bmatrix} I_z \\ 0 \end{bmatrix} \qquad (8)$$

Relations (7) and (8) can be with one common matrix equations:

$$\begin{bmatrix} [r_{aa}] & [r_{ab}] & -[1_a] & [0_a] \\ [r_{ba}] & [r_{bb}] & [0_b] & -[1_b] \\ [1_a]^T & [0_b]^T & 0 & 0 \\ [0_a]^T & [1_b]^T & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} [I_a] \\ [I_b] \\ U_a \\ U_b \end{bmatrix} = \begin{bmatrix} [0_a] \\ [0_b] \\ I_z \\ 0 \end{bmatrix}$$

(9)

Which solution will be:

$$\begin{bmatrix} [I_a] \\ [I_b] \\ U_a \\ U_b \end{bmatrix} = [C] \cdot \begin{bmatrix} [0_a] \\ [0_b] \\ I_z \\ 0 \end{bmatrix} \qquad (10)$$

where $[C] = \{c_{ij}\}$, inverse matrix on square matrix in relation (9) with dimensions $(n_a + n_b + 2) \times (n_a + n_b + 2)$ and $[0_a],[0_b]$ zero vector with dimensions $n_a \times 1$, $n_b \times 1$.

The systems relations (10) can be presented in progressing form:

$$I_a(k) = c_{kj} \cdot I_z \qquad I_b(k) = c_{ij} \cdot I_z$$

$$U_a = c_{jj} \cdot I_z \qquad U_b = c_{j+1j} \cdot I_z \qquad (11)$$

where $k = 1,2,...n_a$ i.e. $k = 1,2,...n_b$ appropriately, $i = k + n_a$ $j = n_a + n_b + 1$

For own self grounding resistively of first grounding at existing of second and mutual grounding resistively of both groundings import:

$$R_a = \frac{U_a}{I_z} = c_{jj}\, ; \quad R_{ab} = \frac{U_b}{I_z} = c_{j+1j} \qquad (12)$$

Further it can calculate the potential of any point *M* of land area like value of potentials which are given as a result of currents on taking away from both groundings:

$$\varphi_M = [r_{aM}] \cdot [I_a] + [r_{bM}] \cdot [I_b] \qquad (13)$$

where $[r_{aM}],[r_{bM}]$ is matrix on mutual resistively at all electrodes from both groundings and their links and point *M*.

If groundings are galvanic linked in that case total current on fault to ground is addition of currents on take away in earth over electrodes on both groundings, and potential of both groundings are equivalent, so equations (4), (5), (6), are modificated. Two galvanic linked grounding grids can be solved so as one grounding. Potential who is occur on one grounding like result on current of fault in near to it grounding can be calculate according to relations, literature [9], and at that the mistake not to be bigger then some %. On this way are avoid matrix equations and potential of passive grounding grid is calculate like potential in its brunt or live medium value potential calculated in middle points of electrodes in annular.

IV. Example and Analyses

In base on shown model, who can be generalized like in [7],[8], from sight on authors is made computer program by which help is analyzed the problem of grounding of fence of TS 35/10 kV Omorane, near to Veles. In this example networks on 35 kV and 10 kV sights are with isolation neutral point while network 0,4 kV is directly grounded. All 10 kV drain are airy, and intake is round the same so with one over ground lead. Transformer station is predict to work with isolated natural point with possibility in future to ground, with what it will used medium secure. Because it doesn't exists concrete predictions in which time interval in future can be show need to grounding of neutral point, dimensioned and presentation of grounding is done for real conditions in 35 kV and 10 kV network, but it is tested the variant when network will be grounded over small resistively. Grounding of TS is done by technical recommendation no. 7. The building in which is located complete TS (patch board, command room etc) is predict to have fundamental grounding grid, presented with FeZn clatter 30x4 mm. Fundamental grounding grid is predict on 3 places to be connected with external grounding grid, presented with copper cable Cu 50 mm of distance of 2 m from external wall of object and on depth 0,8 m, because immediately to the fence is made a pavement with width 1 m. Internal of building is present line for equivalence of potential with FeZn clatter 25x3 mm. on which are connected metal construction of 35 kV and 10 kV cells, and all metal parts. Line for equality of potential in object is connected with fundamental grounding grid, grounding grid for modeling of potential and zero point 0,4 kV from transformer station of home needs (with cable PPOO 1x16 mm^2), and lighting rod installation.

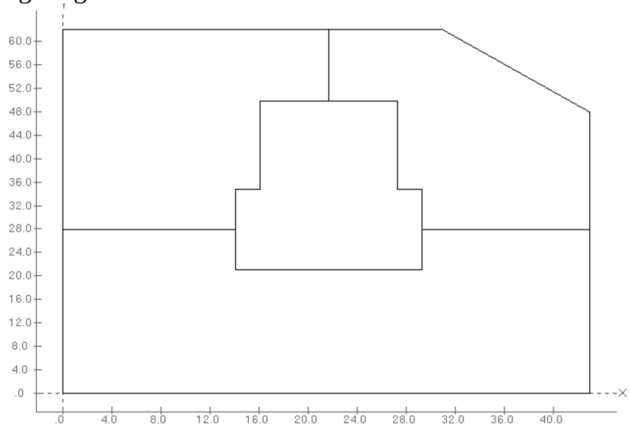

Fig. 2. View of fundamental grounding grid and on grounding of fence of TS 35/10 kV Omorane 2 - Veles

Specific resistively of fundamental in and around transformer station is $\rho = 200\Omega$ m.

By analyzing the grounding resistively groundings on TS in two cases (when they are galvanic linked and separated), grounding grid of TS, no. 1, and grounding on fence, no. 2, like and potentials who will find two groundings at fault to ground of 10 kV sight, U_1, U_2. Also it's calculating touch voltages which are the largest on corner of fence, followed diagonal, from internal and external sight of fence, U_{dv}, U_{dn}. At it is inspect next 4 cases:

1. network is insulate, groundings galvanic separated
2. network is insulate, groundings galvanic linked
3. network is fault to ground over small resistively, groundings galvanic separated
4. network is fault to ground over small resistively, groundings galvanic linked

Results of calculating are shown in table 1:

TABLE 1: CHARACTERISTICS OF THE GROUNDINGS 1 AND 2

case	1	2	3	4
$R(\Omega)$	5,37	2,23	5,37	2,23
U_1 (V)	107,38	44,61	1610,70	669,15
U_2 (V)	23,21	44,61	348,15	669,15
$U_2 / U_1 (\%)$	21,61	100,00	21,61	100,00
U_{dv} (V)	5,01	11,63	75,15	174,45
U_{dn} (V)	6,36	18,40	95,40	276,00
$U_{dv} / U_2 (\%)$	21,59	26,07	21,59	26,07
$U_{dn} / U_2 (\%)$	27,41	41,24	27,41	41,24

It shows that in case of insulate network term (2) is satisfied in both cases. But if network is ground over small resistively then grounding resistively is higher of limited 0,7 Ω. From table we can see that in cases 2 i.e. 4, grounding resistively is smaller as potential of main grounding grid. However in that case both groundings are proceed on the same potential which is potential of fence and is larger than in cases 1, 3. Like result on that step and touch voltages from internal and external side are larger than in cases when groundings are galvanic separated. This is important in case 4 when they are linked and network is grounded. In that case we get touch voltages higher from limited. If resistively of people body in best case man can be exhibit of voltage of 31,25 % lower from value showed in table 1. For critical case, at touch of external sight of fence this values for cases 3 i.e. 4 will be 119,9 V i.e. 189,75 V.

So in conditions of work with insulate neutral point, terms for secure by recommendation are satisfy in both cases and that is almost indifferent is annular grounding of fence and grounding grid of TS will be galvanic linked or not. But at eventual crossing of network with grounded neutral point safety criteria's is much easier to be satisfied if groundings galvanic are separated. In this case duration of fault is limited on 0,5 sec. Allowed touch voltage, internal and external of installation for this time by recommendation, relation (1), is 150 V. From here we can give conclusion that in cases of work with grounded natural point safety criteria's are satisfy internal of fence, which is not case out of fence. To be satisfy this conditions in this case its need specific resistively of fundamental around TS to go on, or to add one more ring or vertical elements in poll in annular grounding of fence or drain of TS to do with cables with funeral external layer like on example. IPO 13 which shows that are excellent groundings.

V. CONCLUSION

The analyses shows that projectants working on this problematic shall not roundly to hold to recommendation so they should do some calculating. It shows that technical recommendation no. 7. consistently imports if network is with insulate neutral point. In that case it benefits together grounding. But in eventual crossing of work on neutral point fault to grounded over small resistively, (for which in our country in this moment is convoy comprehensive action), if it proceeded consistently of recommendation, safety criteria's can from most higher step and touch voltages not to be satisfied. In case like this, safety criteria's can be satisfied much easier if galvanic are separated from grounding of fence, from grounding grid of TS HV/MV, TS MV/MV.

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