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Automation of Calculation of Resistances of Grounds

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Abstract: Methodology of calculation of specific electric resistance of soil is presented depending on his temperature and humidity, using fuzzy logic. A formula is presented for determination of humidity of soil depending on a water-table from data of geological survey center. Dependence of temperature is found on the depth of soil and season, got on the basis of the use of theory of heat conductivity of Fourier and these weather-stations. The program allowing to automatize the calculation of specific electric resistance of soil and resistance of earthing devices offers.

Key words: Specific electric resistance of soil · Temperature · Humidity · Soil · Program · Earthing devices

INTRODUCTION

The reliable functioning of electric options and safety of their exploitation is in a great deal determined by correct organization of the system of grounding [1-2]. For the decline of resistance of earthing devices and errors of calculations it is necessary to use the model of earth maximally close to her real stratified structure with the specific electric resistance [rpo] and in thick every layer. [rpo] changes in wide limits depending on the temperature *t* and humidity *v* and type of soil. Well-known formulas and seasonal coefficients, recommendable the rules of device of electric options on that it is possible to expect [rpo], give only the approximate picture of his change from the above enumerated parameters, that entails complication of construction of device of grounding and increase of amount of metal for his making.

Analysis of well-known works [2-10] for determination of parameters of grounds shows that in them a value [rpo], is entered measured by traditional methods and is corrected by means of correction coefficients taking into account a climatic zone and humidity, or the range of his values gets out. Besides for realization of most algorithms substituting of the real multi-layered structure of earth is executed by double-layer. It leads at determination of parameters of grounding to the very approximate results.

Therefore the task of calculation [rpo] remains actual and works proceed on her decision.

In this article job of authors performances are expounded on determination [rpo] on the basis of the use of fuzzy logic [11-12].

Basic Part: Fuzzy logic allows to describe unclear concepts and knowledge, operate these knowledge and to do unclear conclusions. Results are here assumed some washed out or indefinite. It provides effective drawing of vagueness and inaccuracies of the real world tools [13-23]. The presence of mathematical facilities of reflection of such initial information allows to build a model adequate to reality. Using of unclearness for the construction of conditional expressions allows formally to plug in them the knowledge of experts, expressed by the verbal categories of type "moistly", "dryly", "strongly moistly" etc. There is not a clear border between concepts "moistly" and "dryly", the unclearness of task of corresponding great number shows up exactly herein.

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For every type of soil the system of the washed out rules is determined: «If ($v \in A_i$) then y=$\eta_i(v)$», where A_i - unclear subset, i.e. unclear interval for the variable v with the function of belonging $\mu_i(v)$. A function of belonging is some subjective measuring of unclear belonging of element v to the set great number. If $\mu_i(v)$ = 1, that an element clearly belongs to this great number, if $\mu_i(v)$ = 0, that - does not belong.

The built model looks like

$$\rho = \sum_{i=0}^{N} \mu_i(v) \cdot \eta_i(v), \quad (1)$$

$$\eta_i(v) = b_0 \cdot b_1^v \quad (2)$$

where $\mu_i(v)$ - regressive dependence got experimentally, for example on setting presented in [9], N - an amount of intervals.

It is necessary for determination [rpo]:

- Experimentally determined [rpo] at a temperature 20°C at a limit amount of values of parameter "humidity" of the examined type of soil;
- The amount of intervals gets out and on the basis of the obtained experimental data the parameters of regressive dependences (b_0, b_1) are determined for every unclear interval of the system of the washed out rules of A_i, where i=1,2;
- On a formula (2) a value $[rpo]_{20}$ is calculated soil at the set humidity;
- A value [rpo] for the set positive temperature is determined on a well-known formula $\rho_t = \rho_{20} e^{-0,022(t-20)}$ [24].

For example, for sand [9] at t>0:

$$\rho_{\Pi} = \left[6,8 \cdot 0,4^v \cdot \mu_1(v) + 1,5 \cdot 0,9^v \cdot \mu_2(v)\right] \cdot e^{-0,022(t-20)} \text{(kOm*m)} \quad (3)$$

We will mark that is different types of sands : coarse-grained to fine-grained.

To use the got dependence(3) for planning of earthing devices, we worked out other formulas for determination of temperature and humidity of soil.

For determination of humidity of soil below 1m is used formula:

$$v_{sand} = (v_{MAX} - k_h \cdot h_{\Gamma B}) \cdot \mu_1(h_{\Gamma B}) + v_{MIN} \cdot \mu_2(h_{\Gamma B}) \quad (4)$$

where $h_{\Gamma B}$=|h-$h_{y\Gamma B}$| - distance from a water-table, h – depth on that v is determined, $h_{y\Gamma B}$ – depth of being of subsoil waters, v_{MAX} - maximal moisture-capacity of soil, v_{MIN} - humidity of the natural bedding of soil, k_h - coefficient built at the use of least-squares method taking into account the height of the capillary raising of soil (for sand - 0,5m, for sandy loam– 1m, for a loam - 1,5m, for clay - 2,5m), characterizing it barrage ability, $\mu_1(h_{\Gamma B})$ and $\mu_2(h_{\Gamma B})$- accessory functions from $h_{\Gamma B}$ if we are "nearby" with ground waters or is "far".

For example, for sand $v_{sand} = (18 - 27 \cdot h_{\Gamma B}) \cdot \mu_1(h_{\Gamma B}) + 4,5 \cdot \mu_2(h_{\Gamma B})$. Reliability of a formula is confirmed with results of experiments and data of meteorological stations of Pavlodar and Novosibirsk.

Temperature of soil is defined on [25]

$$t = t_{\Pi} - \frac{t_{\Pi\max} - t_{\Pi\min}}{2} \cdot \left(\frac{0,2}{t_{\Pi\max} - t_{\Pi\min}}\right)^{\frac{h}{h_{\Pi}}} \cdot \cos\left[\frac{2\pi}{365}(g - 20 \cdot h)\right], \quad (5)$$

where h - depth (m) from a soil surface, t_{Π}, h_{Π} – temperature and depth of "a layer of a constant of t", for example for Pavlodar t_{Π}=8°C и h_{Π}=15м, g - number of days (from 0 to 365), $t_{\eta max}$ and $t_{\eta min}$ – the maximum and minimum average monthly t of a surface of soil in a year for this district. Check of adequacy of a formula was carried out for two regions of Russia and Kazakhstan average and one southern latitude: Kaliningrad, Pavlodar and Stavropol.

The main outcome of work is development of recommendations for calculations of resistance of the grounding conductors, necessary for safety of people:

- Calculation of temperature of soil on (5) for which it is necessary to know amplitudes $t_{\eta max}$, $t_{\eta min}$, temperature and depth of constant annual temperature. These data undertake in a meteorological station. The error of calculation doesn't exceed 10% that gives a calculation error [rpo] 5%.
- Calculation of humidity of soil on (4) where level of ground waters which gives the prospecting center is specified only. As a result an error on humidity not higher than 20% for dry and 10% for damp soil. It in calculations [rpo] gives an error not higher than 15% and 7%, respectively.

- Definition [rpo] on (3) with use of the data obtained earlier for each layer of earth with a sufficient accuracy for practice, after all the is more precisely defined [rpo] soil, the parameters of grounding devices at power plants will be better chosen.
- Final result – the grounding resistance, a choice of parameters of grounding devices according to standard requirements.

Calculation Example [rpo]:

- There are geological exploration data: sand, month April (g=105), h=3m depth, level of ground waters $h_{ГВ}$=7m, ($t_{\eta max} - t_{\eta min}$ =30°C, t_l=8°C and h_l=15m for the Pavlodar region).

Temperature of soil pays off on (5) $t = 8 - \frac{30}{2}\cdot\left(\frac{0,2}{30}\right)^{\frac{3}{15}}\cdot\cos\left[\frac{2\pi}{365}(105-20\cdot 3)\right]$ =3°C, humidity on (4) v_{sand} = (18 – 27.$h_{ГВ}$). 0+4,5.1=4,5%, [rpo] on (3) $[rpo]_{sand}$=(6•0,3^{4,5}•0,01+1,5•0,7^{4,5}•0,99)•e$^{-0,022(3-20)}$=435Om•m.

- There are geological exploration data: sand, month September (g=257), depth h=2,5m, level of ground waters $h_{УГВ}$=2,5м, ($t_{\eta max} - t_{\eta min}$=30°C, t_l=8°C and h_l=15m for the Pavlodar region).

Temperature of soil pays off on (5) $t = 8 - \frac{30}{2}\cdot\left(\frac{0,2}{30}\right)^{\frac{2,5}{15}}\cdot\cos\left[\frac{2\pi}{365}(257-20\cdot 2,5)\right]$ =13°C, humidity on (4) *vsand* = (18 – 27.0). 1+4,5.0=18%, [rpo] on (3) $[rpo]_{sand}=(6\bullet 0,3^{v}\bullet\mu_1(v)+1,5\bullet 0,7^{v}\bullet\mu_2(v))\bullet\alpha$= =(6•0,3^{18}•0+1,5•0,7^{18}•1)•e$^{-0,022(13-20)}$= 2,8 kOm•m.

For automatic calculation of parameters of grounding devices the program realizing above than listed methods was created. It gives out the calculated values of temperature, humidity and specific electric resistance of soil, their change within a year, considers climatic, hydrogeological (multiple layers of soil) features of a site of building.

Basic data: quantity of layers and type of soil, its thickness, month, level of ground waters, t_l, h_l, g, $t_{\eta max}$, $t_{\eta min}$. For example, in Fig. 1 the interface where the user establishes values of basic parameters of model (quantity of layers of earth – 3, its sort is presented, for example, "sandy loam", "clay", "sand", thickness of the first, second and third layers 2m, 1m and 2m, chooses a time span of year - "July" and receives temperature, humidity and required values [rpo].

The offered program allows to build dependence [rpo] from t and soil v at any time years for each layer (Fig. 2) and to choose or specify the worst option of value [rpo]. From Fig. 3 it is visible, at increase in humidity of soil [rpo] decreases in spring and autumn months (curves 1, 2). With increase in a depth of grounding devices [rpo] it is stabler. Therefore grounding conductors deeply dug in soil including vertical, carry out the task better, than horizontal, laid near a soil surface.

The received program calculates resistance of simple and difficult artificial grounding conductors (Fig. 4,a and Fig. 4,b), but can be applied as in addition to other programs which dismiss more difficult designs of grounding devices. Calculation [rpo] is carried out when pressing "calculation [rpo]" button with application above the described methods. For calculation of resistance of grounding devices the type of a grounding conductor is specified and its parameters are entered

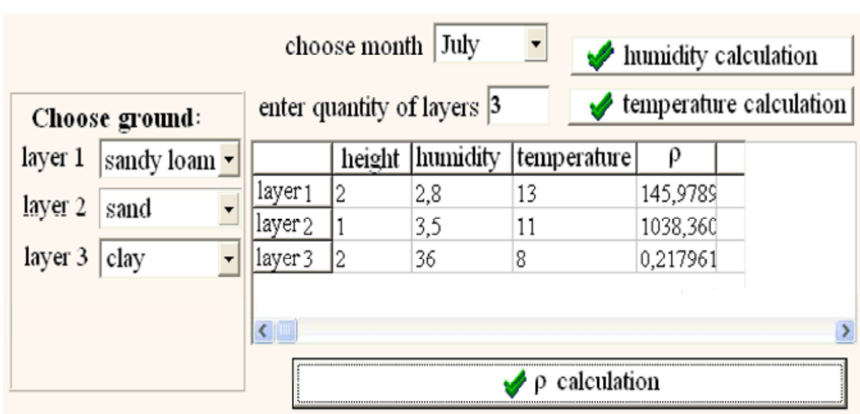

Fig. 1: Panel of determination of basic values.

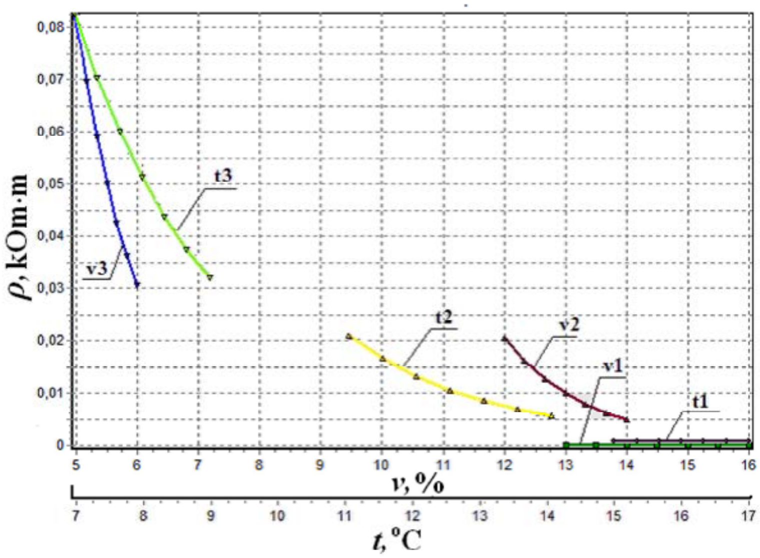

Fig. 2: Schedules of change of specific resistance of soil depending on temperature and humidity of layers (t1, t2, t3 and v1, v2, v3 – temperature and humidity of the first, second and third layers).

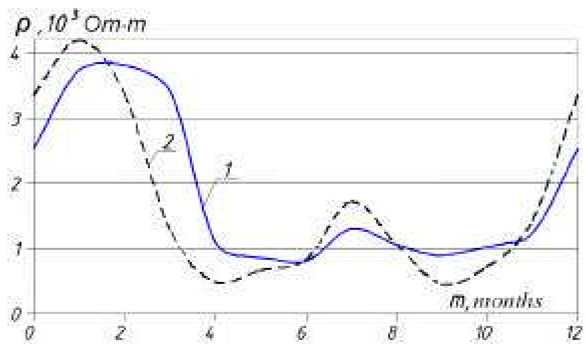

Fig. 3: Comparison received on dependences [rpo] sand within a year for depth 0,7m (a curve 1) with widely known data (a curve 2) from [26] and with experiments on [9].

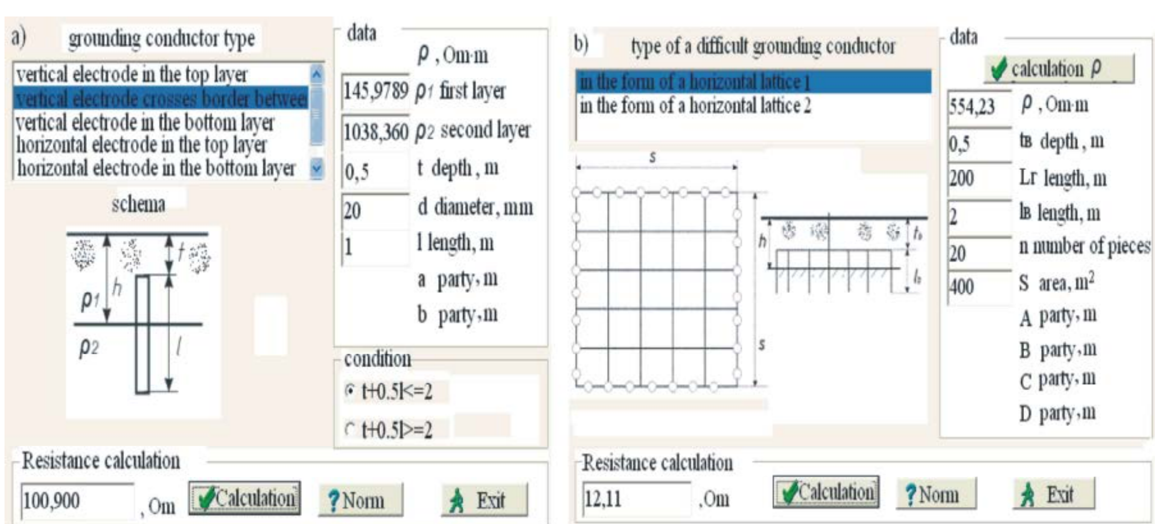

Fig. 4: Calculation of resistance of grounding devices in multilayered soil: a) for simple, b) difficult grounding conductors.

when pressing “Calculation” button. At a choice of the “Norm” button there is a window with standard values of resistance of a grounding conductor.

The most effective use of the program is carried out at design and reconstruction of grounding devices since these processes demand repeatedly repeating computing operations. The program allows to simplify work with the reference materials necessary for performance of calculation and also to realize alternative design.

CONCLUSIONS

The offered formulas for calculation of specific electric resistance, temperature and humidity of soil give the chance to receive their values for each layer at any time years.

The formula for determination of humidity of soil from level of ground waters with a margin error not higher than 20% for dry and 10% for damp soil on the basis of data of the prospecting center is received.

The offered dependence of temperature of soil on its depth and season allows to define it with a margin error 4-15% on the basis of these meteorological stations.

The developed program allows to automate calculation of electric characteristics of grounding devices at their design and reconstruction, gives the chance to approach as much as possible earth model to its real layered structure taking into account climatic conditions and to calculate the specific resistance of soil and resistance of grounding conductors is more exact, than it becomes now.

REFERENCES

1. Lipatkin, V.A., D.E. Stennikov and S.L. Shishigin, 2011. Specific Features of Designing the Grounding Device for a 110 kV Substation in Soil with a Rock Bed. Electrical Technology Russia, 8: 23-29.
2. Averbukh, M.A. and V.V. Zabusov, 2009. Calculating the parameters of Grounding Devices using Fuzzy-Sets and Fuzzy Logic Theory. Electrical Technology Russia, 7: 2-4.
3. Task Force F0A of the IEEE / PES Substations West Coast Subcommittee. Current North American assessment and refurbishment practices of substations grounding systems. IEEE Transactions on Power Delivery. 2005. 20(3): 1886-1889.
4. Güemes, J.A. and F.E. Hernando, 2004. Method for calculating the ground resistance of grounding grids using FEM. IEEE Transactions on Power Delivery., 19(2): 595-600.
5. Nahman Jovan and Ivica Paunovic, 2006. Resistance to earth of earthing grids buried in multi-layer soil. Electrical Engineering, 88(4): 281-287.
6. Khan, Y., N.H. Malik, A.A. Al-Arainy, M.I. Qureshi and F.R. Pazheri, 2010. Efficient use of low resistivity material for grounding resistance reduction in high soil resistivity areas. TENCON, IEEE Region 10 International Conference, pp: 620-624.
7. Guemes-Alonso, J.A., F.E. Hernando-Fernandez, F. Rodriguez-Bona and J.M. Ruiz-Moll., 2006. A practical approach for determining the ground resistance of grounding grids. IEEE Transactions on Power Delivery - IEEE TRANS POWER DELIVERY, 21(3): 1261-1266.
8. Jinliang He *et al*, 2005. Decreasing Grounding Resistance of Substation by Deep-Ground-Well Metho. IEEE Transactions on Power Delivery, 20(2): 738-734.
9. Zaytseva, N.M., D.S. Zaytsev and M. Ya. Kletsel, 2008. Dependences of Soil Electrical Resistivity on Moisture Content and Temperature. Electrical Technology Russia, 9: 30-34.
10. Zakker, Sam, Seyedeh Somayeh Hoseini, Morteza Ahmadi, Mostafa Ahmadi and Nader Javadi Far, 2011. Effect of Multilayered Ground System on Substation’s Surface Potential Distribution in Short Circuit Conditions Using Quasi Static Image Method and Method of Moments. World Applied Sciences Journal, 12(10): 1708-1714.
11. Zadeh, L.A., 1965. Fuzzy sets. Information and Control, 8: 338-353.
12. Zadeh, L.A., 1978. Fuzzy Sets as a Basis for a Theory of Possibility, Fuzzy Sets and Systems, 1(1): 3-28.
13. Kobersi, Iskandar Souleiman, Valery Ivanovich Finaev, Siham Abdulmalik Almasani and Kaid Wadii Ahmed Abdo, 2013. Control of the Heating System with Fuzzy Logic. IDOSI Publications, World Applied Sciences Journal, 23(11): 1441-1447.
14. Iliev, Oliver L., Ahmad Zakeri, Pavle Sazdov and A.M. Baytelieva, 2013. A Fuzzy Logic Based Approach for Integrated Control of Protected Cultivation. IDOSI Publications, World Applied Sciences Journal, 24(5): 561-569.

15. Ataei, Esfandyar, 2013. Application of TOPSIS and Fuzzy TOPSIS Methods for Plant Layout Design. IDOSI Publications, World Applied Sciences Journal, 24(7): 908-913.
16. Naz, Munazza and Muhammad Shabir, 2013. Fuzzy Soft Sets and their Algebraic Structures. IDOSI Publications, World Applied Sciences Journal 22 (Special Issue of Applied Math): 45-61.
17. Naz, Munazza, Muhammad Shabir and Muhammad Irfan Ali, 2013. On Fuzzy Soft Semigroups. IDOSI Publications, World Applied Sciences Journal 22 (Special Issue of Applied Math): 62-83.
18. Rajkumar, S., 2013. Assortment Of Uncertainty And Randomness With Fuzzy Logic In Deception Detection For Employee Database Management System Using Hotchpotch Techniques. IDOSI Publications, World Applied Sciences Journal, 21(6): 854-857.
19. Larimi, Mohsen Asghari, 2013. On $(\in,\in Vq_k)$-Intuitionistic Fuzzy Ideals of Hemirings. IDOSI Publications, World Applied Sciences Journal 21 (Special Issue of Applied Math): 54- 67.
20. Niknam, Taher, Javad Olamaie and Reza Khorshidi, 2008. A Hybrid Algorithm Based on HBMO and Fuzzy Set for Multi-Objective Distribution Feeder Reconfiguration. World Applied Sciences Journal, 4(2): 308-315.
21. Mesgari, M.S., A. Pirmoradi and G.R. Fallahi, 2008. Implementation of Overlay Function Based on Fuzzy Logic in Spatial Decision Support System. World Applied Sciences Journal, 3(Supple 1): 60-65.
22. Aghataher, R., M.R. Delavar, M.H. Nami and N. Samnay, 2008. A Fuzzy-AHP Decision Support System for Evaluation of Cities Vulnerability Against Earthquakes. World Applied Sciences Journal, 3(Supple 1): 66-72.
23. Karimi-Davijani, H., A. Sheikholeslami, H. Livani and M. Karimi-Davijani, 2009. Fuzzy Logic Control of Doubly Fed Induction Generator Wind Turbine. World Applied Sciences Journal, 6(4): 499-508.
24. Karyakin, R.N., 2002. Grounding devices of electroinstallations. Directory. Power service, pp: 320.
25. Kletsel, M. Ya., N.M. Zaytseva and B.B. Isabekova, 2011. Determination of temperature of soil on depth of grounding conductors. Electrical Technology Russia, 7: 19-24.
26. Dolin, P.A., 1984. Safety measures bases in electroinstallations: Manual for higher education institutions. M: Energoatomizdat, pp: 448.