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DETERMINATION OF DIRECTION TO RECONSTRUCTION OF GROUNDING SYSTEM

Purpose. In paper the most efficient and economical way for bringing the grounding system of power facilities into compliance with requirements of normative parameters was determined. *Methodology.* The determination was based on the comparison of the calculated values of touch voltage and length of additional electrodes for reconstruction of grounding system by two ways. To calculate the software based on the method of point current source which located in the three-layer soil, method of guidance potential, Gauss method and the method of ordinary least squares was used. *Results.* For three possible cases amount of material and labor costs for the reconstruction and modernization of the grounding system while maintaining the equipotent grounding system and allowable touch voltage was defined. *Originality.* For the first time the effectiveness the reconstruction of grounding system for requirements of touch voltage, not to her of resistance, both in terms of electrical safety and in terms of material and labor costs proved. *Practical value.* The implementation of results saves a national scale funds for modernization and reconstruction of existing grounding systems of power facilities. References 3, tables 8, figures 6.

Key words: grounding system, electrical safety, reconstruction, material and labour costs.

На основании расчетного эксперимента проанализированы возможные случаи несоответствия заземляющих устройств нормативным требованиям и способы их реконструкции по требованиям к напряжению прикосновения и сопротивлению. Определена эффективность указанных направлений реконструкции как с точки зрения электробезопасности, так и материально-трудовых затрат. Библ. 3, табл. 8, рис. 6.

Ключевые слова: заземляющее устройство, электробезопасность, реконструкция, материально-трудовые затраты.

Introduction. Substations (SS) operated in Ukraine, most were designed for the requirements of the permissible value of resistance of grounding device (GD). Since these energy facilities were built over 30 years ago, it has undergone significant changes. GD influenced corrosion processes, replacement and reconstruction of high-voltage equipment and so on. Therefore, at this time you need to choose the best option of GD modernization according to one of its normalized parameters (NP). To bring the current GD in line with current regulations [1] uses electromagnetic diagnostics (EMD) of the state of GD [2] which aims to determine the NP of GD and development of recommendations on reconstruction and modernization of GD.

Reconstruction of GD of electrical installation for voltage above 1 kV in power grids with dull grounded neutral, as well as the design can be done in two ways [2]: according to the requirements of the GD allowable resistance values or the permissible touch voltage. Existing investigations [3] have repeatedly noted that in some cases of GD realization according to its resistance can not guarantee the electrical safety of staff and provide a valid value of touch voltage. But this time estimate material and labor costs, taking into account the values of NP to select the optimal arrangement direction of GD is not performed.

The goal of the work is determining the optimal direction of reconstruction and modernization of electrical grounding device of electrical installations of voltage above 1 kV working in a network with dull grounded neutral.

Materials of investigation. We consider two methods of reconstruction of existing grounding device: the first one – the requirements for its resistance, the second one – the requirements to touch voltage. Analysis of the development of recommendations by these two ways to perform the reconstruction of GD we carry out on the example of electrical substation of voltage class of

110 (150) kV. It was considered three options:

1) before the reconstruction of exceeding the permissible touch voltage observed in 50% of the equipment after the reconstruction of both the first and second contact means voltage does not exceed the permissible value;

2) before the reconstruction of exceeding the permissible touch voltage observed on all equipment to ensure acceptable touch voltage in the reconstruction of both the first and second insulating layer methods used in the field of surgical equipment maintenance;

3) before the reconstruction of contact voltage and impedance GD do not exceed the allowable values and during the reconstruction of the first and second method required only made constructive recommendations.

We consider these options in detail:

1) After the reconstruction of two ways of contact voltage does not exceed the permissible value.

We execute analysis on the example of existing substation, the results of which EMD state GD are shown in Fig. 1, 2. This thick solid black line marked grounding located underground. The real name of the research facility is changed to conditional – SS No. 1.

Initial data for determining NP of GD were: real circuit GD SS No. 11, in use, the electrical characteristics (ECH) of ground (electrical resistivity (ER) I layer – 42.65 Ω -m, II layer – 25.37 Ω -m and thickness of the first layer – 0.82 m), the value of current single-phase short circuit (SC) – 1.957 kA. It should be noted that the implementation of reconstruction GD exceeding the allowable contact voltage (65 V at the time of operation of reserve protection with more than 1.0) was observed in 50% of the equipment where possible operational switching (namely: BI T-1, BI T-2, S T-1, S T-2 and SC-1), while the resistance value GD does not exceed the allowable value of 0.5 Ω .

2) For permissible touch voltage in the reconstruction of both the first and the second insulating layer methods used in the field of surgical equipment maintenance.

We execute analysis on the example of existing substation, the results of which EMD state GD are shown in Fig. 3, 4. This thick solid black line marked grounding located underground. The real name of the research object changed to conditional – SS No. 2.

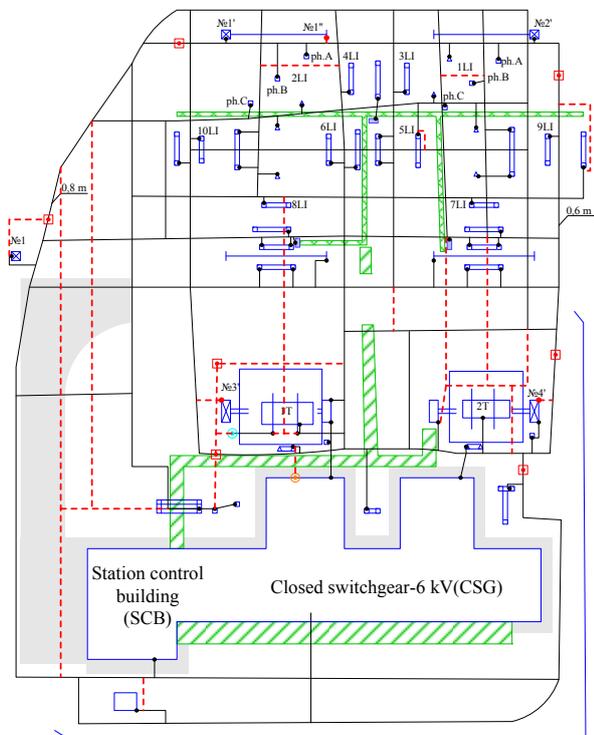


Fig. 3. Circuit of the GD of the SS No. 2 complied with the permissible resistance value

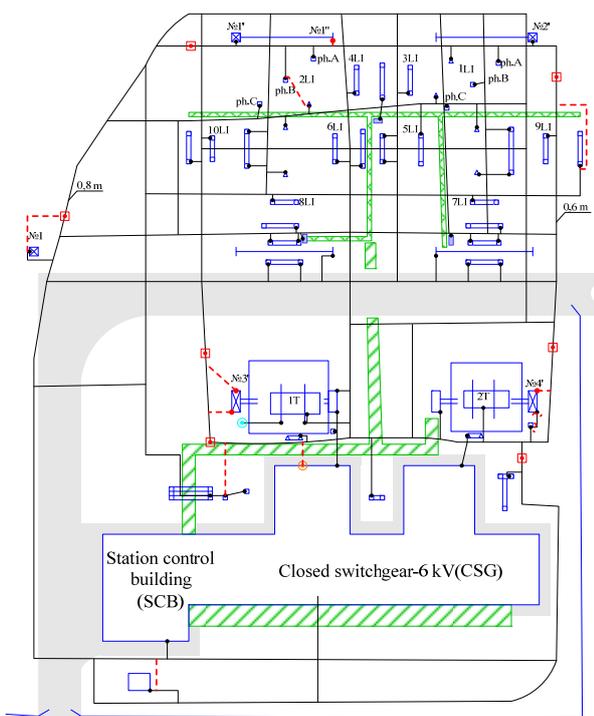


Fig. 4. Circuit of the GD of the SS No. 2 complied with the permissible touch voltage value

Initial data for determining NP GD were: real circuit GD SS No. 2, in use, ECH ground (ER layer I – 33 Ω·m, II layer – 4.6 Ω·m and thickness of the first layer – 1.97 m, the value of current single-phase circuit – 10.784 kA. It should be noted that the implementation of reconstruction GD exceeding the allowable contact voltage (65 V at the time of operation of reserve protection 0.1 s) was observed on all equipment where possible rapid switching, although the resistance value of GD does not exceed the permissible 0.5 Ω.

Fig. 3 shows the GD of the substation with introduced recommendations necessary to bring embodiment of the GD to the requirements of its resistance GD (additional HG are indicated by dotted line).

Fig. 4 shows the GD with the recommendations necessary to bring it into compliance with the allowable voltage to ground.

We compare the value and variation (see Table 3) of touch voltage for both versions of the GD.

From Table 3 we can see that the voltage of contact for both methods of reconstruction exceeds the permissible value of 65 V. Therefore the use of the insulating layer required for the reconstruction of both methods in the field of equipment maintenance, thus reducing to acceptable U_t .

Table 3

Equipment name	Values of U_t , V		Deviations of U_t from mean value, %	
	GD with requirements for R_G	GD with requirements for U_t	GD with requirements for R_G	GD with requirements for U_t
1LI ph. A	195.5	208.5	16.2	8.4
1LI ph. B	137.4	198.4	-18.3	3.2
1LI ph. C	134.5	155.8	-20.1	-19.0
2LI ph. A	152.7	217.3	-9.3	13.0
2LI ph. B	191.9	185.9	14.0	-3.3
2LI ph. C	196.6	214.0	16.8	11.3
3LI	173.4	189.1	3.0	-1.7
4LI	180.8	200.7	7.4	4.4
5LI	127.5	174.2	-24.2	-9.4
6LI	185.7	203.4	10.4	5.8
7LI	155.7	168.3	-7.5	-12.5
8LI	171.3	198.8	1.8	3.4
9LI	190.2	201.9	13.0	5.0
10LI	162.7	175.8	-3.3	-8.6

Variations in the contact pressure will be roughly the same for both cases.

In this case, when performing the first reconstruction GD way of material and labor costs for the construction of additional HG (see Table 4) will be significantly higher (more than six times). For improvement include operational service in both cases used without metal reinforcement plate with a total impedance of 3500 Ω.

3) Touch voltage does not exceed the permissible values, and during reconstruction included only the necessary constructive recommendations.

We execute analysis execute on the example of existing substations, the results of which EMD state GD are shown in Fig. 5, 6. This thick solid black line marked grounding located underground. The real name of the research object changed to conditional – SS No. 3.

Table 4

Name and type of works		GD with requirements for R_G	GD with requirements for U_t
Laying additional HG in soil of 3 group, m		199	32
Laying additional HG in soil of 5 group, m		78	12
Fulfillment of punctures under roads or pass on the asphalt-concrete massive	Amount	8	1
	length, m	63	3
Number of places of stacking plates without reinforcement with the area of 1 m ² , pieces		16	16

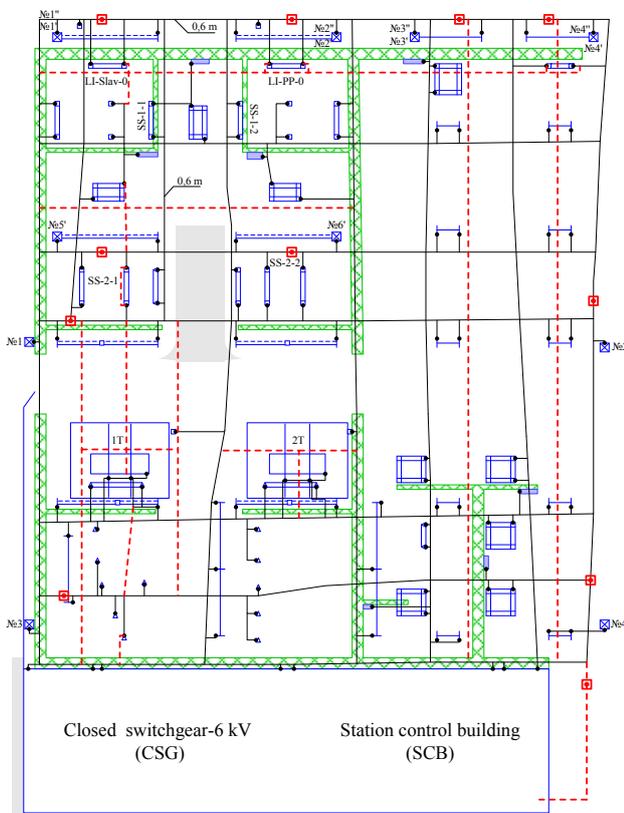


Fig. 5. Circuit of the GD of the SS No. 3 complied with the permissible resistance value

Initial data for determining the NP were: the real circuit of GD SS No. 3 (see Fig. 5), which is in operation, ECH ground (ER I layer – 12.1 Ω·m, II layer – 15.1 Ω·m, the first layer thickness – 1.15 m), the value of current single-phase circuit – 3.798 kA. It should be noted that the implementation of reconstruction touch voltage does not exceed the permissible value (65 in operation at the time of backup protect more than 1.0 s) on all equipment. GD resistance value was also lower than the allowable 0.5 Ω.

Fig. 5 shows the GD of the substation with introduced recommendations necessary to bring embodiment of the GD to the requirements of its resistance GD (additional HG are indicated by dotted line).

Fig. 6 shows GD with recommendations necessary to bring it into compliance with the allowable voltage to ground. As seen from the circuit, GD installation requires only vertical grounding connections and lightning at SCB. We compare the value and variation U_t (see Table 5) for both versions of the GD.

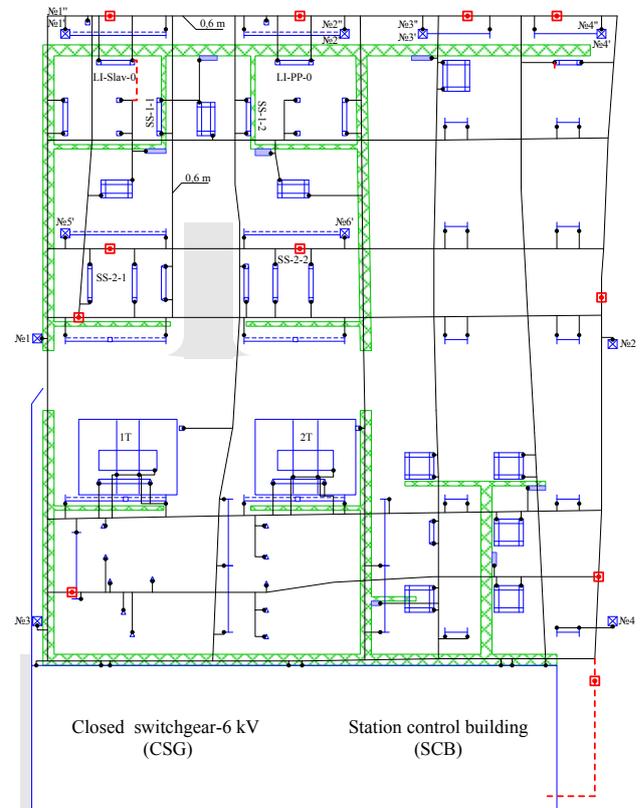


Fig. 6. Circuit of the GD of the SS No. 3 complied with the permissible touch voltage value

Table 5

Equipment name	Values of U_t , V		Deviations of U_t from mean value, %	
	GD with requirements for R_G	GD with requirements for U_t	GD with requirements for R_G	GD with requirements for U_t
LI-Slav-0	26.2	35.1	13.7	14.3
SS-1-1	23.9	28.2	3.8	-8.1
LI-PP-0	21.7	37.9	-5.8	23.5
SS-1-2	25.2	28.5	9.4	-7.2
SS-2-1	18.7	30.2	-18.8	-1.6
SS-2-2	22.5	24.3	-2.3	-20.8

From Table 5 follows that of contact voltage as in the first and in the second mode of execution does not exceed the permissible value of 65 V. Also, variations in the U_t will be approximately the same for both cases. In this case, when performing the first reconstruction GD way of material and labor costs for the construction of additional HG (see Table 6) will be almost 8 times higher.

It should be noted that the reconstruction of the GD by requirements for R_G reduces resistance value GD only 3-6% compared to GD reconstruction the requirements to touch voltage (see Table 7).

Table 6

Name and type of works		GD with requirements for R_G	GD with requirements for U_t
Laying additional HG in soil of 3 group, m		321	38
Laying additional HG in soil of 5 group, m		125	16
Fulfillment of punctures under roads or pass on the asphalt-concrete massive	Amount	5	-
	length, m	28	-

Table 7

Substation name	R_G before GD reconstruction, Ω	R_G after GD reconstruction, Ω :	
		with requirements for R_G	with requirements for U_t
SS No. 1	0.309	0.235	0.251
SS No. 2	0.088	0.083	0.087
SS No. 3	0.133	0.119	0.123

According to the Standard ДСТУ Б Д.1.1-1-2013, the analysis of the cost of reconstruction of GD in two directions for the object (see Table 8) to the cost of construction of HG in the soil of different groups, and arranging the insulating layer in the event necessary, on-site equipment maintenance.

Table 8

Substation name	Cost of the GD reconstruction, thousand UAH:	
	with requirements for R_G	with requirements for U_t
SS No. 1	42.504	8.915
SS No. 2	29.423	4.640
SS No. 3	45.781	5.168

Thus, cost-effectiveness of reconstruction and modernization of existing power facilities GD with requirement for allowable contact voltage is proven.

Conclusions.

1. Implementation of the GD with requirements for its resistance does not guarantee electrical safety of the electrical maintenance personnel in case of emergency, i.e. the resistance value of the GD does not allow one to judge the suitability of the GD for further use.

2. Reconstruction of existing GD should be carried out according to the requirements to touch voltage that will

ensure electrical safety of service personnel and reliability of operating the equipment in all modes of electrical installations.

3. Implementation of modernization and reconstruction of the GD in the direction of providing acceptable touch voltage has high economic efficiency: the average savings in the reconstruction of power facilities of voltage classes of 110 kV and 150 kV is about 33 thousand UAH for each object.

The authors during the period 2015 – 2016 have developed recommendations for modernization and reconstruction of the GD as required for touch voltage of 10 substations of the voltage class of 150 kV and 20 substations of voltage class 110 kV. That said introduction of the indicated direction of reconstruction allowed even for a fairly small number of substations saving more than 1 million UAH for Ukrainian energy sector.

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