Installation of Gravel in the Switchyard Area of the Substation with Dusty Sandy Soil Reduces Step Voltage and Touch Voltage

I Gusti Ngurah Janardana[1], I Wayan Arta Wijaya[2]

[1,2] Departement of Electrical Engineering, Faculty of Engineering
Udayana University, Bukit Jimbaran
Bali, Indonesia
janardana@unud.ac.id

Abstract: The thickness of the gravel layer in the substation area is often ignored, even though it can increase the resistance of the officers' feet. The gravel layer at the switchyard location must comply with IEEE Std 80-2013 standards. The aim of this research is to determine the thickness of gravel in the switchyard equipment grounding system on dusty sandy soil to eliminate the stress gradient between equipment and equipment, equipment and soil and the stress gradient on the ground surface itself. The method used in this research analysis is descriptive quantitative. The results show that with increasing thickness of gravel, the step voltage and touch voltage decreasesbut a gravel thickness of 15 cm has the best value.

Keywords— Earthing, Thickness of Gravel, Dusty sandy soil

I. INTRODUCTION

Each soil texture has a different earth resistance value and causes the need for different types of earthing as[1].. Well as resulting in different step voltage and touch voltage, ultimately resulting in differences in the thickness of gravel needed in that soil texture. The specific aim of this research is to determine the thickness of gravel in the switchyard of the substation on a sandy soil texture so that the step voltage and touch voltage to standards. It is hoped that the results of this research can be used as a reference for installing gravel in substation areas on dusty sandy soil.

II. LITERATURE REVIEW

2.1 State-of-the-Art Review

1. Hard clay soil showed that the touch voltage in the dry condition was 153.5615 volts and the wet condition was 152.0702 volts, the step voltage in the dry condition was 188.5057 volts and the wet condition was 182.8265 vol[2]
2. The results of research on grounding in slightly wet sandy soil showed that the touch voltage value was 223.51 Volts, the step voltage value was 1188.69 Volts[3].

2.2 Current Through the Human Body

The fault current path that passes through the human body is as shown below [4].

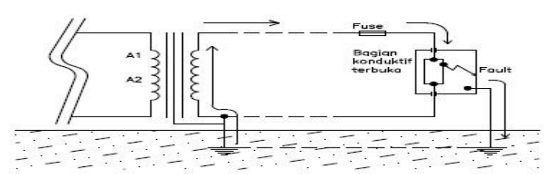

Figure 1. Fault Current Path[4].

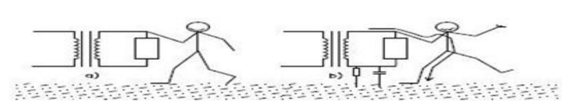

Figure 2. System without Grounding[4].

2.3 Permitted Touch Voltage

The magnitude of the touch voltage criteria and the allowable interruption duration

2.3.1 Touch Voltage

The reduction factor is calculated by the equation:

C_(s 0.08)=1-(0.09 (1-ρ/ρ_s))/(2h_s+0.09) (1)

Touch voltage is calculated by the equation: (2)

Where :

$$E_{t\ 70} = [1000 + 1{,}5\rho_s\ C_s]\ \frac{0{,}147}{\sqrt{t}} \quad (3)$$

2.4 Step Voltage

The voltage that arises between the two legs of a human standing on the ground where a fault current is flowing to the ground without touching the equipment is called step voltage [6],[7]:

$$E_{l\ 50} = [1000 + 6\ C_s.\rho_s]\ \frac{0{,}116}{\sqrt{t_s}} \ldots\ldots\ldots\ldots\ldots(4)$$

III. RESEARCH METHODS

3.1 Location and Time of Research

The research location was carried out in several sandy soil textures in the Bali area from December 2022 to August 2023.

3.2 Research Design

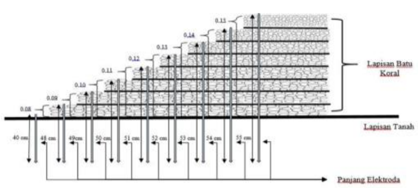

Figure 4. Electrode Length and Gravel Thickness

3.3 Research Flowchart

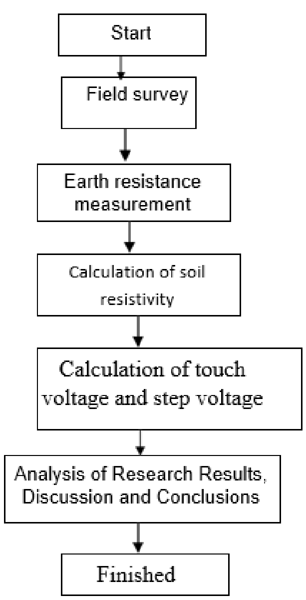

Figure 4. Research Flowchart

The following is an explanation in Figure 4:

Activity 1. Get started

Preparation of research materials.

Activity 2. Field survey,

Determine the research location for dusty sandy soil.

Activity 3. Measurement

Measurement of soil resistance, and measurement of gravel resistance with a coral thickness.

Activity 4. Calculation of soil resistivity

Calculate the Rho (soil type resistance) of dusty sand and the addition of gravel with variations in gravel thickness of 8 cm – 15 cm respectively based on measurement data to be able to calculate the allowable step stress and contact stress.

Activity 5. Calculation of step voltage and touch voltage

Calculate the allowable touch voltage and step voltage based on the thickness of the gravel to obtain the thickness of the gravel that is best installed for grounding the substation on dusty sandy soil.

Activity 6. Analysis, discussion and conclusions.

IV. RESULTS AND DISCUSSION

4.1 Touch Voltage Analysis

The allowable touch voltage can be calculated based on the thickness of the gravel layer in dusty sandy soil.:

C_(s 0,08)=1-(0,09 (1-ρ/ρs))/(2h_s+0,09)

So that with a thickness of 0.08 meters of coral,

$$C_{s\ 0{,}08} = 1 - \frac{0{,}09\left(1-\frac{41{,}45}{15{,}07}\right)}{2x0.08+0{,}09}$$

$$C_{s\ 0{,}08} = 1{,}64$$

Using the same formula, a gravel thickness reduction factor value of 8 cm to 15 cm is obtained. The soil resistivity of dusty sandy soil in dry conditions is 41.45 ohm-meters. The soil resistivity value when given gravel is found to vary depending on the thickness of the gravel. The results of the touch voltage based on the thickness of dusty sandy soil gravel in dry conditions are as follows:

$$E_{t\ 70} = [1000 + 1{,}5\rho_s\ C_s]\ \frac{0{,}147}{\sqrt{t}}$$

$$E_{t\ 70} = [1000 + 1{,}5\ x\ 15{,}07\ x\ 1{,}64]\ \frac{0{,}147}{\sqrt{1}}$$

$E_{t\ 70} = 152{,}45$ Volt.

The touch voltage value for a coral rock thickness of 8 cm to 15 cm for dusty sandy soil in dry conditions is as shown in the table below.

TABLE 3

TOUCH VOLTAGE CALCULATION RESULT VALUE SOIL AND GRAVELDRY, CORAL THICKNESS 8-15 cm

No	ρ soil (Ohm-m)	ρ Coral (Ohm – m)	Coral Thickness (m)	Reduction Factor	Touch Voltag e (V)
1	41,45	15,07	0,08	1,64	152,45
2	41,45	15,07	0,09	1,58	152,25
3	41,45	13,82	0,10	1,66	152,05
4	41,45	12,56	0,11	1,67	151,62

5	41,45	11,30	0,12	1,74	151,33
6	41,45	11,30	0,13	1,68	151,18
7	41,45	10,04	0,14	1,80	150,98
8	41,45	10,04	0,15	1,72	150,80

In wet conditions, the resistivity of gravel is 27.63 ohm-m, calculation of the reduction factor:

Coral stone thickness of 8 cm was obtained,

$$C_{s\,0,08} = 1 - \frac{0{,}09\left(1-\frac{27{,}68}{12{,}56}\right)}{2x0.08+0{,}09}$$

$$C_{s\,0,08} = 1{,}44$$

So,

$$E_{t\,70} = [1000 + 1{,}5\rho_s\, C_s]\,\frac{0{,}147}{\sqrt{t}}$$

$$E_{t\,70} = [1000 + 1{,}5\ x\ 12{,}56\ x\ 1{,}44]\,\frac{0{,}147}{\sqrt{1}}$$

$$E_{t\,70} = 155{,}987 \text{ Volt}$$

The results of the touch voltage calculation for wet soil and coral rock conditions yielded the following results:

TABLE 4
TOUCH VOLTAGE CALCULATION RESULT VALUE SOIL AND WET CORAL STONE CORAL STONE THICKNESS 8 cm-15 cm

No	ρ soil (Ohm – m)	ρ Coral (Ohm – m)	Coral Thickness (m)	Reduction Factor	Touch Voltage (V)
1	27,63	12,56	0,08	1,44	150,99
2	27,63	12,56	0,09	1,41	150,90
3	27,63	11,30	0,10	1,45	150,61
4	27,63	11,30	0,11	1,42	150,54
5	27,63	10,05	0,12	1,47	150,26
6	27,63	8,79	0,13	1,55	150,00
7	27,63	7,54	0,14	1,65	149,74
8	27,63	7,54	0,15	1,62	149,69

4.2 Step Voltage Calculation

The allowable step voltage is based on the thickness of the gravel in dusty sandy soil. Coral stone thickness of 8 cm was obtained,

$$C_{s\,0,08} = 1 - \frac{0{,}09\left(1-\frac{\rho}{\rho_S}\right)}{2h_s+0{,}09}$$

So with a coral stone thickness of 0.08 meters we get,

$$C_{s\,0,08} = 1 - \frac{0{,}09\left(1-\frac{41{,}45}{15{,}07}\right)}{2x0.08+0{,}09}$$

$$C_{s\,0,08} = 1{,}64$$

The results of step voltage with a gravel thickness of 8 cm for dusty sandy soil in dry conditions are as follows:

$$E_{s\,70} = [1000 + 6\rho_s\, C_s]\,\frac{0{,}157}{\sqrt{t}}$$

$$E_{s70} = [1000 + 6\ x\ 41{,}45\ x\ 1{,}64]\,\frac{0{,}157}{\sqrt{1}}$$

$$E_{s70} = 221{,}035 \text{ Volt}$$

TABLE 5
CALCULATION RESULTS STEP VOLTAGE OF SOIL AND CORAL STONE DRY WITH VARIATIONS IN THICKNESS CORAL STONE 8 cm – 15 cm

No	ρ soil (Ohm – m)	ρ Coral (Ohm – m)	**Coral Thickness** (m)	**Reduction Factor**	(Step Voltage(V)
1	41,45	15,07	0,08	1,64	221,035
2	41,45	15,07	0,09	1,58	218,692
3	41,45	13,82	0,1	1,66	221,816
4	41,45	12,56	0,11	1,67	222,206
5	41,45	11,30	0,12	1,74	224,930
6	41,45	11,30	0,13	1,68	222,597
7	41,45	10,04	0,14	1,80	227,282
8	41,45	10,04	0,15	1,72	224,159

The step voltage in wet soil and gravel conditions is calculated with a reduction factor based on the thickness of the coral rock from 8 cm to 15 cm with the equation:

$$C_{s\,0,08} = 1 - \frac{0{,}09\left(1-\frac{\rho}{\rho_S}\right)}{2h_s+0{,}09}$$

So for a coral stone thickness of 8 cm we get,

$$C_{s\,0,08} = 1 - \frac{0{,}09\left(1-\frac{27{,}68}{12{,}56}\right)}{2x0.08+0{,}09}$$

$$C_{s\,0,08} = 0{,}44$$

Results for step voltage with a coral stone thickness of 8 cm in dusty sandy soil in wet conditions:

$$E_{s\,70} = [1000 + 6\rho_s\, C_s]\,\frac{0{,}157}{\sqrt{t}}$$

$$E_{s70} = [1000 + 6\ x\ 27{,}63\ x\ 1{,}44]\,\frac{0{,}157}{\sqrt{1}}$$

$$E_{s70} = 194{,}479 \text{ Volt.}$$

TABLE 6
CALCULATION RESULTS STEP VOLTAGE SOIL CONDITIONS AND WET CORAL STONE VARIATIONS IN THICKNESS 8 cm-15 cm

No	ρ soil (Ohm – m)	ρ Coral (Ohm – m)	Coral Thickness (m)	Reduction Factor	(Step Voltage(V)
1	27,63	12,56	0,08	0,08	1,44
2	27,63	12,56	0,09	0,09	1,41
3	27,63	11,30	0,10	0,10	1,45

4	27,63	11,30	0,11	0,11	1,42
5	27,63	10,05	0,12	0,12	1,47
6	27,63	8,79	0,13	0,13	1,55
7	27,63	7,54	0,14	0,14	1,65
8	27,63	7,54	0,15	0,15	1,62

4.3 Discussion

Based on the research results, it can be concluded that a gravel thickness of 15 cm produces a touch voltage value = 150.80 volts (dry soil and gravel conditions) and 149.69 volts (wet soil and gravel conditions) and the smallest and best step voltage with a value = 224.159 volts (dry soil and gravel conditions) and 199.164 volts (wet conditions) when compared to a gravel thickness of 8 cm to 14 cm, the best thickness of gravel to be installed in a substation on dusty sandy soil is equal to 0.15 meters whether the soil and coral are wet or dry.

V. CONCLUSION

A gravel thickness of 8 cm to 14 cm has a good touch voltage or step voltage value, a gravel thickness of 15 cm has the best value in wet or dry soil and gravel conditions in dusty sandy soil. This has an impact on the proper and safe functioning of the grounding system for equipment and people around it.

REFERENCES

[1] Agung, J. 2015. Perancangan Sistem Pengetanahan Peralatan di Gardu Induk PLTU IPP (Independent Power Producer) Kaltim 3. Malang : Universitas Brawijaya.

[2] Suciawan, IPN. Janardana, IGN, Wijaya, IWA. 2021. Pengaruh Ketebalan Batu Koral Pada Tanah Lempung Dan Tanah Berpasir Terhadap Tegangan Langkah Dan tegangan Sentuh. Jurnal SPEKTRUM; Volume 8 No. 1 Maret 2021.

[3] Mahadewi, KM., Janardana, IGN., Wijaya, IWA., 2019. Analisis Tegangan Langkah dan tegangan Sentuh Serta Perencanaan Sistem Pembumian Pada Pembangunan Substation VVIP. Di Bandara Internasional I Gusti Ngurah Rai Bali. Journal SPEKTRUM Volume 6, No. 1 Maret 2019. Jimbaran : Program Studi Teknik Elektro Universitas Udayana.

[4] Suartika M. 2017. Sistem Pembumian (Grounding) Dua Batang Sistem Pengaman Tenaga Listrik. Bali: Universitas Udayana Bali.

[5]] IEEE Standard 80 - 2000. (2013). Guide For Safety In Ac Substation Grounding. New York

[6] Tanjung, A. 2015. Analisis Sistem Pentanahan Transformator Distribusi di Universitas Lancang Kuning Pekanbaru. ISSN: 1693-2390 Jurnal Sains, Teknologi dan Industri, Volume 12 (2). Pekanbaru: Jurusan Teknik Elektro Fakultas Teknik Universitas Lancang Kuning.

[7] Kamal, J, Abduh, S. 2018. Perancangan Sistem Pentanahan Gas Insulated Switchgear 150 kV Pulogadung dengan Finite Element Method. JETri, Volume 15 (2). Jakarta: Jurusan Teknik Elektro Fakultas Teknologi Industri Universitas Trisakti.

[8] Latif, A. 2016. Probabilitas Tegangan Sentuh dan Tegangan Langkah di Lokasi Rencana Gardu Induk 500 kV Antosari. Bali: Universitas Udayana.