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Annual Conference on Science and Technology Research (ACOSTER) 2020, 20-21 June 2020, Medan, Indonesia


Accepted papers received: 20 January 2021

Published online: 12 February 2021

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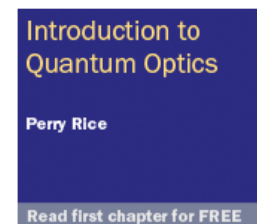
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To cite this article: R Syafruddin *et al* 2021 *J. Phys.: Conf. Ser.* **1783** 012075

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Transient Voltage Programming in Electric Power Grounding System

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Abstract. Liner equations with n variables can be solved if there are n equations, the matrix is formed $n \times n$ square matrix, using the inverse matrix method. In this research, the linear equation used comes from the rod and mesh grounding system method, which is solved by the finite element method to calculate the grounding impedance, from the results of other research researchers. Here the researcher wants to inform in this study how to solve the linear equation with a calculation program. And the research results are plotted in Cartesian coordinates $V = V(t)$. The results of this calculation program can be used to estimate how much the transient voltage is in the ground rod / mesh in the place where the electrical power system substation will be built when lightning strike with an amplitude of 34 kA/switching with a current of 34 kA/step with a current of 34 kA crash it. To adjust the transient voltage by adjusting the length of the finite element, required in accordance with the applicable safety level, while the subsequent arrangement can by increasing the number of mesh or increasing the length of the mesh.

1. Introduction

1.1 Background

This research is motivated by the Liner Equation of the Finite Element Method (FEM) electric power grounding system, which produces a linear equation in the form of a multiplication matrix as follows:

$$[V_i] = [Y_{ik}] \times [I_k]$$

Here there are two types of grounding systems that will be calculated, namely grounding in the form of rods and grounding in the form of mesh^{[1] [2] [3] [4] [5] [6]}.

1.2 Formulations

Formulations for the earth rod the admittance matrix is obtained :

$$Y_{i,j} \neq 0$$

$$Y_{i,j+1} \neq 0$$

$$Y_{i+1,j} \neq 0$$



other = 0
 for i = interger
 $Y.V(t) = i(t) + b(t - h)$

Y is the admittance, V (t), i.e. the voltage, i (t) current, and b (t-h) the previous current.
 Rod grounding substation system, $\rho = 11.78 \Omega\text{-m}$, segment $n = 9$, $l = 6\text{m}$ / stem, $i_{\max} = 34\text{kA}$, step, lightning $1.2 / 50 \mu\text{s}$, swithing $350/2500 \mu\text{s}$ as table 1.

Table 1. Admittance of rods $\rho = 11.78 \Omega\text{-m}$, $n = 10$, $l = 6\text{m}$ / rod, $i = 2$, ..., $n-1$, $j = 2$, ..., $n-1$, other $Y_{i,j}$ is zero Ω

No.	$Y_{1,1}$ [Ω]	$Y_{n,n}$ [Ω]	$Y_{i,i+1}$ [Ω]	$Y_{i+1,i}$ [Ω]	$Y_{i,i}$ [Ω]
1	0.3466515	0.3466515	-0.1695675	-0.1695675	0.5162189

And formulations for earthen mesh, an admittance matrix is obtained:

$Y_{i,i} \neq 0$
 $Y_{i,i+1} \neq 0$
 $Y_{i,i+7} \neq 0$
 $Y_{i+1,i} \neq 0$
 $Y_{i+7,i} \neq 0$
 other = 0
 for i = interger
 $Y.V(t) = i(t) + b(t - h)$

$$\begin{bmatrix} Y_{1,1} & \cdots & Y_{1,7} \\ \vdots & \ddots & \vdots \\ Y_{7,1} & \cdots & Y_{7,7} \end{bmatrix} \times \begin{bmatrix} V_1 \\ \vdots \\ V_7 \end{bmatrix} = \begin{bmatrix} i_1 \\ \vdots \\ i_7 \end{bmatrix} + \begin{bmatrix} b_1 \\ \vdots \\ b_7 \end{bmatrix}$$

To accelerate the convergence process, the inverse matrix process is multiplied by the accelerator matrix [A k, j].

Y is the admittance, V (t), i.e. the voltage, i (t) current and b (t-h) the previous current [1].

Mesh grounding substation system, $\rho = 11.78 \Omega\text{-m}$, segment $n \times n = 49$, $l = 20\text{m}$ / wicker rod, $i_{\max} = 34\text{kA}$, step, lightning $1.2 / 50 \mu\text{s}$, swithing $350/2500 \mu\text{s}$ as table 2.

Table 2. Admittance grid $\rho = 11.78 \Omega\text{-m}$, $n \times n = 7 \times 7 = 49$, $l = 20\text{m}$ / rod of grid, $i = 2$, ..., $n-1$, $j = 2$, ..., $n-1$, other $Y_{i,j}$ is zero Ω

No.	$Y_{1,1}$ [Ω]	$Y_{n,n}$ [Ω]	$Y_{i+1,i}$ [Ω]	$Y_{i+7,i}$ [Ω]	$Y_{i,i+1}$ [Ω]	$Y_{i,i+7}$ [Ω]	$Y_{i,i}$ [Ω]
1	1.4689566	1.4689566	-0.4874932	-0.4874932	-0.4874932	-0.4874932	1.9564498

2. Research Method

2.1 Algorithm

Algorithm for calculating the switching voltage of the rod and mesh grounding system^{[7] [8] [9] [10] [11]}.

Rod grounding system

Step 1: divide the ground rod into finite elements whose length $L = 6\text{ meters}$ and the number of 9 elements and the number of each vertex

Step 2: calculate the parameters for each finite element using formula 3.1 and formula 4.3 from the rod grounding system data

Step 3: make the resistive equivalent circuit of the rod grounding system as shown in Figure 4.7.b, and calculate the parameters of the circuit.

Step 4: from the equivalent circuit in step 3, calculate the Y admittance matrix. Calculate the inverse of the Y matrix. take $k = 0$.

Step 5: $k = k + 1$. compute the previous source of the equivalent circuit at time $t = (k-1)h$ using the formula 4.38

Step 6: calculate the amount that should be injected at time $t = kh$. calculate the amount of current $i(kh) + b((k-1)h)$.

Step 7: solve the voltage equation: $e(kh) = Y^{-1} (i(kh) + b((k-1)h))$.

STEP 8: whether kh is greater than t_{max} YES Stop, DO NOT go back to step 5.

Mesh grounding system

Step 1: the length of the finite element is equal to the side length of the mesh $L = 20$ m and each vertex is numbered 1 to 49 according to Figure 4.8.a.

Step 2: calculate the parameters for each finite element using formula 3.1 and formula 4.3 from the mesh grounding system data.

Step 3: create a resistive equivalent circuit for the mesh grounding system as shown in Figure 4.8.b, and calculate the parameters of the circuit.

Step 4: from the equivalent circuit of step 3, calculate the admittance matrix Y of the mesh grounding system. Calculate the inverse of the Y matrix. Take $k = 0$

Step 5: $k = k + 1$. Calculate the previous source current from the equivalent circuit at time $t = (k-1)h$ using the formula 4.38

Step 6: calculate the amount of current injected at $t = kh$. calculate the amount of current $i(kh) + b((k-1)h)$

Step 7: solve the voltage equation: $e(kh) = Y^{-1} (i(kh) + b((k-1)h))$.

STEP 8: whether kh is greater than t_{max} YES STOP, DO NOT go back to step 5.

2.2Flowchart

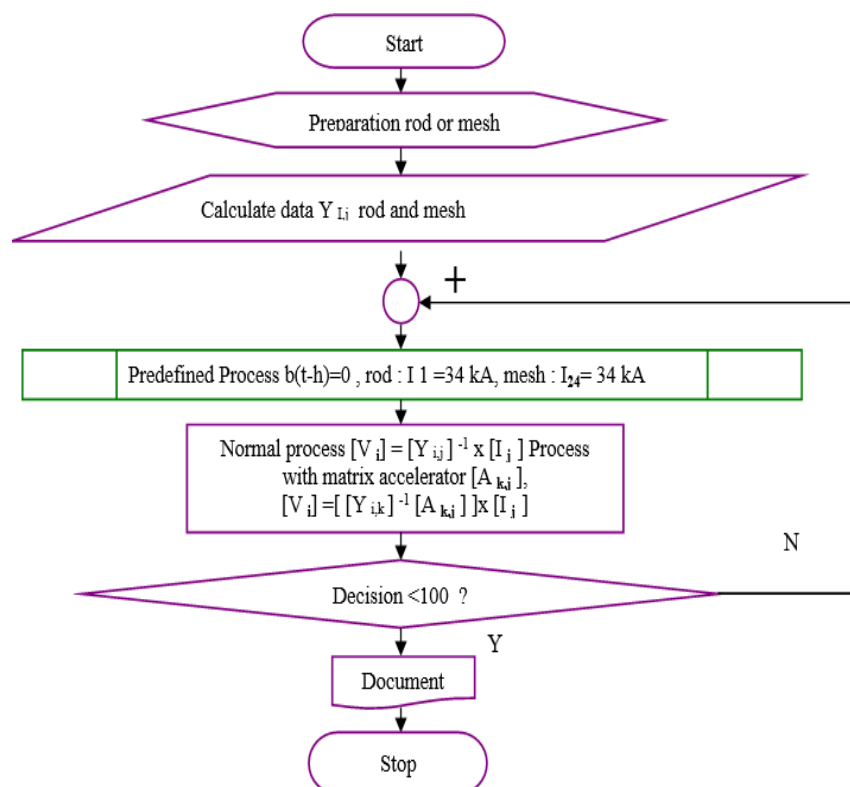


Figure 1. Flowchart

3. RESULTS AND DISCUSSION

3.1 Results

From the results obtained, it can be used to predict the planning requirements, the form of the grounding system needed if you want to build in a location that has soil density ρ in different units $[\text{ohm} / \text{m}]$ [12] [13] [14].

The results of the execution program, only use the inverse matrix equation to find the transient voltage in the rod or mesh grounding system, to speed up program execution is necessary to use a matrix accelerator called the matrix eigen value $[A_{k,j}]$, where the equation is as follows: $[V_i] = [[Y_{i,k}]^{-1} [A_{k,j}]] \times [I_j]$. By using the last equation within a few minutes the equation with the dimensions $[V_{49}] = [[Y_{49,49}]^{-1} [A_{49,49}]] \times [I_{49}]$ can be finished in execution.

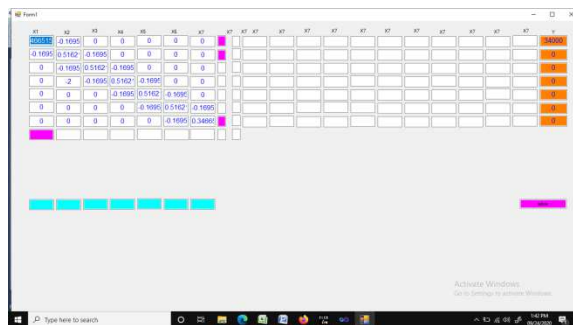


Figure 2. Admittance, Current, “...” C#

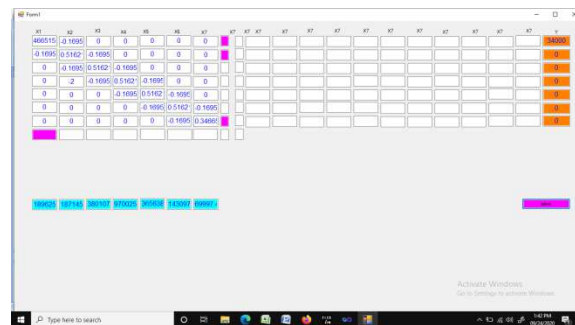


Figure 3. Admittance, Current, Voltage C#

Following are the results of the switching voltage programming for Cigareleng GI, Bandung, West Java, Indonesia:

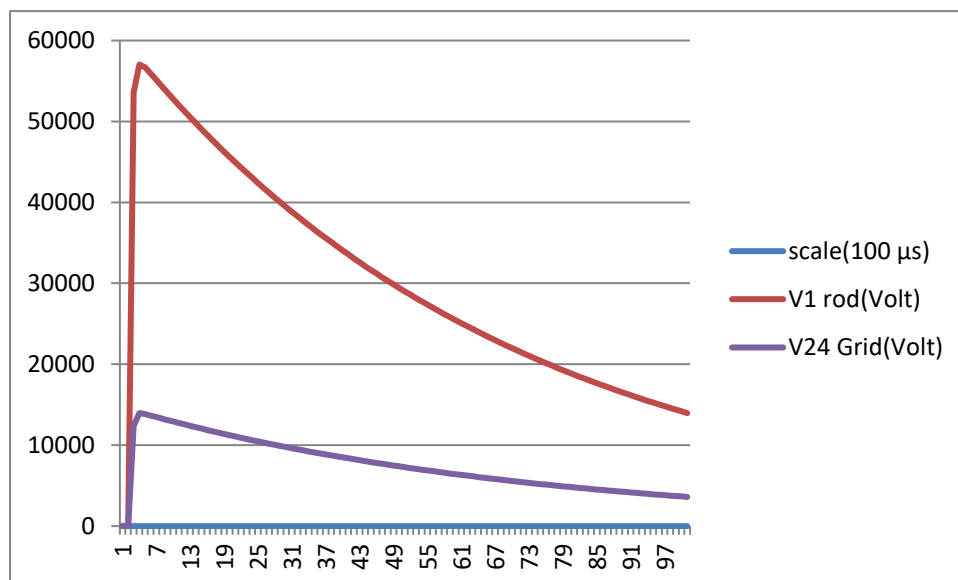


Figure 4. Voltage transient

3.2 Discussion

If the transient voltage is still greater than desired, it is sufficient for the system to be used to increase the number of n mesh for the same area or to add n steps by increasing the length for grounding of the

rods, or both for grounding rods and mesh in parallel so that the transient voltage decrease to 50% of the original calculated transient voltage.

4. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusions

Transient voltage programming in electric power grounding system can be used to predict the planning requirements for transient voltage, when you want to build in a location that has soil density ρ units [ohm / m] in different value.

4.2 Suggestions

It is recommended that if the transient voltage is still greater than desired, it is sufficient for the system to be used to increase the number of n mesh for the same area or to add n steps by increasing the length for grounding of the rods, or both for grounding rods and mesh in parallel.

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