Modeling Of Generator Neutral Grounding Through Distribution Transformer Using Lab View Graphical User Interface

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Abstract. Computation of the generator neutral grounding system through a distribution transformer can be done through manual calculations. A lot of data is used in calculations so that the possibility of recurring calculations. This is very difficult and causes a large difference in the calculation results. Therefore, a computer-based computing system is needed to overcome problems like this. Several papers have been developed on the calculation of the voltage capacity through medium grounding, the length of the electrodes attached to the ground of the generator, one-phase faults to the ground, and zero sequence current disturbances. Therefore, this paper discusses modeling using the LabView Graphical User Interface (GUI) application to create it easier to design neutral grounding for equipment. As an implementation, modeling using Std. C62.92.2TM-2017 data and the results of the generator neutral grounding design can be easy, faster, and more accurate.

1. Introduction

In general, the grounding system can be divided into two that is neutral grounding and non-neutral grounding. The Neutral grounding system is used in generators and transformers [1]. The neutral grounding is divided into two categories including the neutral point grounding of the equipment and the grounding equipment body. The grounding system is a grounding system with a neutral point that is grounded. The system is intentionally connected to the ground, either through impedance or directly (solidly) to avoid accidents or losses due to fault currents to the ground. The equipment grounding system is safe by connecting the protected equipment body or installation with a neutral conductor which is grounded in such a way that in the event of insulation failure there will not be a high touch voltage until the operation of the overcurrent safety device.

The generator is a very important component so that the continuity of generator operation must be maintained properly so that the supply of electrical energy does not decrease due to interference with the generator. In general, the importance of the role of the generator demands that a generator must have a reliable neutral grounding system. The grounding system is a conductive connection system that connects the system equipment body and installation with the ground so that it can protect humans from electric shock and protect installation components from the dangers of overcurrent.

Types of generator neutral grounding are mentioned in Std.C62.92.2TM2017 and Std. C37.101-2006 including [2]:

1. Effectively Grounding
2. Low Resistance Grounding
3. Low Reactance Grounding
4. High Resistance Grounding
5. Resonant Grounding
6. Undergrounding Generator

The neutral grounding system of the generator through a distribution transformer is where the primary end of the transformer is connected to the secondary of the generator, and the secondary of the transformer is connected to a resistor. The secondary resistor is usually selected for single-phase ground fault at the generator terminals, the power loss of the resistor equal to or greater than the reactive volt-ampere voltage in the zero-sequence capacitance of the transformer windings connected to the generator terminals. The purpose is that if there is a fault at the secondary end of the transformer, the disturbance will be eliminated using high resistance grounding which is connected through the secondary of the transformer. The neutral grounding system of the generator through a distribution transformer uses high resistance grounding to limit the single-phase fault current to ground with a maximum fault current limitation in 3-25 amperes.

Previous studies have shown analysis and computation systems on types of generator neutral grounding using computer-based applications medium voltage generator grounding-type that calculates the voltage capacity on the neutral grounding of a single-phase synchronous generator using MATLAB software. Lab View Graphical User Interface has been used to model of substation grounding grid design was published in [3]. Analysis of the generator grounding system configuration by determining the length of the electrodes on the wind turbine to obtain different soil resistivity values using the CDEGS application [4]. The effect of zero sequence load currents on the generator neutral ground using a low resistance grounding-type simulated using a transient electromagnetic program (PSCAD/EMTDC) [5].

2. Generator Neutral Grounding

Various variations and types of generator grounding are associated with the generator system configuration. Within the sub-variations of the various grounding systems are discussed for the configurations usually used. The types and variation of generator grounding are discussed in this part [6] [7].

2.1 Resistance grounding

Grounded with resistance, the neutral of the transformer or generator is connected to the ground through a resistor. Ordinary grounding resistance may be high or low; the difference is based on the magnitude of the ground fault current that occurs, either on low ground or on high ground which is designed to limit the transient voltage to 250% of the system voltage.

2.1.1 Low Resistance Grounding. A neutral grounding system with low grounding resistance protects the power transformer and generator from single-phase fault currents to the ground. The low-resistance ground of the generator is connected to the ground via a resistor. The resistor limits the fault current to the ground by 200-400A. Low resistance grounding with a resistor of 100A is generally applied to industrial systems with a time limit of about 10s. While as the 400A resistor is used in distribution systems that use overhead conductors.

2.1.2 High Resistance Grounding. Ground with high grounding resistance is usually a low ohm value resistor connected to the secondary of the distribution transformer with the primary winding of the transformer connected from the generator neutral to the ground. The current through the primary grounding and transformer for single-phase to ground faults at the generator terminals is usually limited to between 5-15A, depending on the size of the generator and the zero-sequence capacity for grounding circuits operating at generator voltages.
2.2 Grounding of the neutral generator through a distribution transformer

Grounding using a distribution transformer with a primary voltage value equal to or greater than the line to neutral voltage value of the generator with a secondary voltage rating of 120 V or 240 V. The distribution transformer must have sufficient overvoltage so that phase-to-ground faults do not occur with the engine operating at an initial voltage of 105%[8]. The neutral grounding of generators scheme is shown in Figure 1.

![Figure 1. Grounding with a distribution transformer [6]](image)

Generator grounding through high resistance is limited that the phase-to-ground fault current to a maximum value of about 3 - 25 amperes in the primary side. Where the ground resistance value is very small and the ohmic value on the primary side becomes a very high resistance value.

Steps to determine parameters related to generator grounding through distribution transformer. Determine the capacitance impedance:

\[
\begin{align*}
    C_0 &= (C_{\text{gen}} + C_{\text{sb}} + C_{\text{tr}} + 2C_{\text{aux}} + C_{\text{mb}} + C_{\text{vt}}) \mu \text{F} \\
    X_{c0} &= \frac{1}{\omega (C_{\text{gen}} + C_{\text{sb}} + C_{\text{tr}} + 2C_{\text{aux}} + C_{\text{mb}} + C_{\text{vt}})} \Omega
\end{align*}
\]

Where:

- \(X_{c0}\) or \(C_0\): Capacitance Impedance \((\mu \text{F})\)

Capacitance to ground reactance \((X_{cg})\) can be determined by equation:

\[
X_{cg} = \frac{X_{c0}}{3\phi}
\]
\[ R_n = X_{cg} \text{ or } R_n \leq X_{cg} \]

Transformer ratio:

\[ N = \frac{v_{\text{gen}}}{v_{\text{sec}}} \quad (4) \]

A 24,000 - 240 V distribution transformers is used to ground the generator to neutral. Therefore, the secondary resistor must be calculated so that the effective neutral resistance is equal to \( R \).

\[ R_{\text{sec}} = \frac{R_n}{n^2} \quad (5) \]

The maximum neutral voltage is assumed to be the phase-to-ground voltage.

\[ I_{\text{sec max}} = \frac{v_{\text{sec}}}{R_{\text{sec}}} = \frac{v_{\text{gen}}(L-L)}{\sqrt{3}} \times \frac{1}{N} \times \frac{1}{R_{\text{sec}}} \quad (6) \]

Resistor current to primary, can be calculated by:

\[ I_{\text{primary}} = IR \quad (7) \]

The power rating (Pr) of a resistor can be calculated by:

\[ P_R = I^2 + R \quad (8) \]

The transformer thermal rating is calculated using the full voltage of the transformer, the equation is as follows:

\[ \text{KVA} = V_{\text{sec rated}} \times I_{\text{sec max}} \quad (9) \]

The KVA and Isec max values are the values of the current through the neutral of the equipment during ground faults. The ground of the transformer can be rated in a short time.

\[ \text{Duration of overload} = \frac{\text{KVA}}{\text{multiple of rated KVA}} \quad (10) \]

Ground fault current:

\[ I_f \geq 3I_{\text{co}} \]

\[ I_f = \sqrt{I_{\text{prim}}^2 + (3I_{\text{co}})} \quad (11) \]

Where :
- \( X_{\text{co}} \): capacitance Impedance (μF)
- \( X_{\text{cg}} \): capacitive reactance of system ground (μF)
- \( R_n \): neutral resistance (Ω)
- \( N \): turn ratio
- \( P_R \): power rating (Kw)
- \( 3I_{\text{co}} \): system charging current (Kva)
- \( I_f \): Ground Fault Current (A)
3. Research Methods

The development of a generator neutral grounding application using the LabView GUI computer-based application. This research was designed to follow the following steps including identifying and preparing all the required data, formulas, constants, and data tables used. Test each formula and option used with the data and standards provided. Make comparisons with previous data and do analysis.

**Table 1. Data generator**

| Equipment                         | Phase Capacitance-To-Ground (Co) |
|----------------------------------|----------------------------------|
| 24 Kv Generator ($C_{gen}$)      | 0.23 μF                           |
| Surge Bank ($C_{sb}$)            | 0.125 μF                          |
| Unit Transformer ($C_{tr}$)       | 3667 μF                           |
| Auxiliaries Transformer ($C_{aux}$) | 1092 μF                         |
| Isolate Phase Bus ($C_{mb}$)      | 4413 μF                           |
| Voltage Transformer ($C_{vt}$)    | 1173 μF                           |

**Table 2. Voltage Data**

| System voltage (Kv) | charging current |
|---------------------|------------------|
| 4800.2 - 2          |                  |
| 6000.1 - 2          |                  |
| 2.4002 - 5          |                  |
| 4.1602 - 5          |                  |
| 13.8005 - 10        |                  |

**Table 3. Permissible overload duration data for distribution transformers**

| Duration of overload | Multiple of rated Kva |
|----------------------|-----------------------|
| 10 s                 | 10.5                  |
| 60 s                 | 4.7                   |
| 10 min               | 2.6                   |
| 30 min               | 1.9                   |
| 2 hour               | 1.4                   |
4. Result And Discussion

4.1. Test results

The results of the generator neutral grounding application design based on the LabView GUI are shown in Figure 2. The first process is to enter the data needed to use this LabView application, the second adjusts the required settings. Adjustments are made simultaneously with the execution process. Then run the program in run continue mode. Then check all the indicators and steps that are still messy. The data used in the generator neutral grounding system for calculations are taken from IEEE std. C62.92.2TM-2017 in table 1.2.3. Data changes or option settings can be made while the program is running.

Input data in the interface as shown in Figure 1 and adjust to the required options. Then run the program in continuous run mode and check the results whether it meets the predetermined standards or not. Marked on the response of the indicator at run time.
4.2. Result of calculation
There are several modeling steps carried out in designing, namely as follows:

4.2.1. Step 1. The first step is to calculate the total capacitance impedance (Xco) to determine, capacitive reactance (Xcg) to the ground from the three phases. Then calculate the neutral resistor (Rn) by determining the turn ratio (N) on the ground through the transformer to be able to determine the value of the current resistor (Rsec). The results of the applications are compared with the actual results of the calculated data in the IEEE. This calculation uses equations (1) to (6).

4.2.2. Step 2. As long as the ground fault continues, the current will flow in the secondary resistor, the calculation uses equation (7) to determine the power rating of the resistor (Pr) on the transformer and calculates the transformer thermal rating at full voltage position with equations (9) to (10).

The ground through a transformer can be rated in a short time. The factor of overload in the short time allowed for a distribution transformer used for neutral grounding can be calculated by equation (11).

4.2.3. Step 3. Calculating the current on the primary side to calculate and compare the results of the charging current system with the ground fault current written in the form Ig ≥ 3Ico. Then it is compared with the actual results from the IEEE. The calculation uses equations (12) to (14).

4.3. Comparison Results of Design and Actual
The results of the comparison of the generator design and actual neutral grounding system:
### Table 4. Comparison of design and actual

| Parameter                                | Design  | Actual |
|------------------------------------------|---------|--------|
| Generator                                | 24 Kv   | 24 Kv  |
| Capacitance Impedance (Xco)              | 7247 Ω  | 7239 Ω |
| Capacitance Reactance (Xcg)              | 2415 Ω  | 2413 Ω |
| Turn Ratio (N)                           | 100     | 100    |
| Resistor Sekunder (Rsec)                 | 0.2413 Ω | 0.2313 Ω |
| Arus Sekunder (IsecMax)                  | 5737 A  | 574 A  |
| Power Rating Transformator (Pr)          | 7.94 Kw | 79.6 Kw|
| Rating Thermal Transformator             | 137760 Kva | 138 Kva |
| System Charging Current (3Ico)           | 3.29 A  | 3.1 A  |
| Arus Primer (Ip)                        | 3.5 A   | -      |
| Ground Fault Current (Ig)               | 6.79 A  | 8.12 A |

#### 4.4. Discussion

From table 4 it can be seen that the results of the two calculations show almost the same results and have a difference of below 1%. The calculation through the LabView GUI application has very small errors. This proves that the LabView application is suitable and accurate to use in performing complex calculations without any errors. The results of the actual and design calculations have a slight difference in numbers, this is because there is a rounding of numbers in the application to 6 digit numbers.

#### 5. Conclusion

The neutral grounding design of the generator via a distribution transformer using the application is easier, faster, and more accurate by calculating the required data. Calculations using the application are easier to execute and change data even when the execution mode is running. This application can be used as a research instrument for a broader equipment neutral ground analysis system.

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