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Grounding Transformers

Grounding is clearly one of the most important aspects of electrical design, but it steadfastly continues to be misinterpreted and misunderstood. Millions of dollars in liability and loss can be attributed to ground-fault arcing; thus, grounding-related issues should top the checklists of any electrical contractor.

Grounding Transformers:

Simply put, a grounding transformer is used to provide a ground path to either an ungrounded "Y" or a delta connected system. Grounding transformers are typically used to:

1) Provide a relatively low impedance path to ground, thereby maintaining the system neutral at or near ground potential
2) Limit the magnitude of transient over voltages when re-striking ground faults occur
3) Provide a source of ground fault current during line-to-ground faults
4) Permit the connection of phase to neutral loads when desired

If a single line-to-ground fault occurs on an ungrounded or isolated system, no return path exists for the fault current, thus no current flows. The system will continue to operate but the other two un-faulted lines will rise in voltage by the square root of 3, resulting in overstressing of the transformer insulation and other associated components on the system by 173%. MOV lightning arresters are particularly susceptible to damage from heating by leakage across the blocks even if the voltage increase is not sufficient to flash over. A grounding transformer provides a ground path to prevent this.

Large multi-turbine wind farms provide an example of the use of grounding transformers for fault protection on ungrounded lines. In many wind farms the substation transformer provides the sole ground source for the distribution system. When a ground fault on a collector cable causes the substation circuit breaker for that cable to open, the wind turbine string becomes isolated from the ground source. The turbines do not always detect this fault or the fact that the string is isolated and ungrounded; thus the generators continue to energize the collector cable, and the voltages between the un-faulted cables and the ground rise far above the normal voltage magnitude as described above. A grounding transformer placed on the turbine string provides a ground path in the event the string becomes isolated from the system ground.

Construction:

Grounding transformers are normally constructed either with

1) A ZigZag (Zn) connected winding with or without an auxiliary winding or
2) As a Wye (Ynd) connected winding with a delta connected secondary that may or may not be used to supply auxiliary power

The geometry of the Zig-Zag connection is useful to limit circulation of third harmonics and can be used without a Delta connected winding or the 4- or 5-leg core design normally used for this purpose in distribution and power transformers. Eliminating the need for a secondary winding can make this option both less expensive and smaller than a comparable two-winding grounding transformer. Furthermore, use of a Zig-Zag transformer provides grounding with a smaller unit than a two-winding Wye-Delta transformer providing the same zero sequence impedance.

Wye connected grounding transformers, on the other hand, require either a delta connected secondary or the application of 4 or 5 leg core construction to provide a return flux path for unbalanced loading associated with this primary connection. Since it is often desirable to provide auxiliary power from the grounding transformer secondary winding, this benefit can sway the end user to specify a two-winding grounding transformer in lieu of a Zig-Zag connection. The current trend in wind farm designs is toward the Wye connected primary with a delta secondary.

It is important to understand that both Zig-Zag and two-winding grounding transformers can be provided with the ability to provide auxiliary power, and this can be either a Wye or Delta connected load.

A solidly grounded system using a grounding transformer offers many safety improvements over an ungrounded system. However, the ground transformer alone lacks the current limiting ability of a resistive grounding system. For this reason, neutral ground resistors are often used in conjunction with the grounding transformer to limit neutral ground fault current magnitude. Their ohm values should be specified to allow high enough ground fault current flow to permit reliable operation of the protective relaying equipment, but low enough to limit thermal damage.

How to Specify a Grounding Transformer

The basic parameters required for quoting a grounding transformer are:

1) **Primary Voltage** - This is the system voltage to which the grounded winding is to be connected. Don't forget to specify the BIL also. In some cases the BIL will be dictated by equipment considerations, such as 150 kV BIL ratings on 34500 volt wind farms because of the limitation on dead front connectors.

2) **Rated KVA** - Because the grounding transformer is normally a short time device, its size and cost are less when compared with a continuous duty transformer of equal kVA rating. For this reason, grounding transformers are often not sized by "kVA" but by their continuous and short time current ratings. Regardless of how you rate it, the grounding transformer must be sized to carry the rated continuous primary phase current without exceeding its temperature limit. This load includes the magnetizing current of the core, the capacitive charging current for the cables, and any auxiliary load if applicable. The higher this value, the larger and more costly the transformer will be. Typical continuous current values can be as low as 5 amps to as high as a few hundred. Be sure to include any auxiliary loading requirements.

3) **Continuous Neutral Current** - The continuous neutral current is defined as three times the phase to current, or in other words, the zero sequence current. This is usually considered to be zero if the system is balanced. However, for the purposes of designing a grounding transformer, it is a value that is expected to flow in the neutral circuit without tripping protective circuits (which would force the current to be zero) or the leakage current to ground that is not a symmetrical function. Again this value is needed to design for thermal capacity of the grounding transformer.

4) **Fault current and duration** - This value is needed to calculate the short time heating that results from a fault on the system and should be determined from an engineered system study. Typical values for this range from a few hundred amps to a few thousand amps with duration times expressed in seconds and not cycles. For instance, a value of 400 amps for 10 seconds is typical. The fault duration is a critical parameter for the transformer designer. Where protection schemes use the grounding transformer for tripping functions, a relatively short time duration is specified (5 -10 seconds). On the other hand, a continuous or extended neutral fault current duration would be required when the grounding transformer is used in a ground fault alarm scheme.

5) **Impedance** - The impedance can be expressed as a percentage or as an ohm value per phase. In either case it should be chosen so that the un-faulted phase voltages during a ground fault are within the temporary over-voltage capability of the transformer and

associated equipment, such as arresters and terminal connectors. Because of this description, the values can vary from as low as 8% to almost 100%. This value must come from the system designer.

6) **Primary winding connection** - Specify the type of primary connection, either Zig-Zag or grounded Wye.

7) **Secondary connection** - specify the secondary voltage and connection when applicable.

   Specify the size of auxiliary loading to be connected for either Zn or Wye connected primary windings.

   If the option is to have a two winding transformer with no secondary load, advise if the delta winding can be "buried" (that is not brought out) or if only one bushing is to be brought out for grounding to the tank or testing.

8) **Basic overall construction features** - note the following features as they apply to each transformer...

   - Compartmental Padmount transformer with integral tamperproof compartment or substation design
   - Outdoor or indoor
   - Fluid type- mineral oil, silicone, Envirotemp FR3
   - Connectivity -dead front, live front, spade terminals, location of terminals - cover or sidewall , exposed or enclosed, etc
   - Temperature rise is assumed to be 65'C
   - Site elevation or environmental concerns
   - Special paint as required

9) **Neutral Ground Resistors** - The rated voltage of the NGR should be equal to the line to ground voltage of the grounding transformer. The current rating and duration should match the grounding transformer ratings. Remember to set the current rating high enough to be above the cable charging current and grounding transformer magnetizing current.