Tertiary Winding Design in wye-wye Connected Transformers
Scope of Presentation > Tertiary vs. Stabilizing Winding?

- Tertiary vs. Stabilizing Winding?
- Need for Stabilizing Windings
- Need for Tertiary Windings
- Some options – no tertiary?
- Concern – protected tertiary?
Autotransformer Windings

Inter-connection (Auto) Transformers

HV & MV windings are “power windings”, delivering converted power to the network. Does delta-connected tertiary provide a power function?

Delta connected TV winding provided for local loads and the suppression of harmonics.
Is it a Tertiary or a Stabilizing Winding?

• Stabilizing Winding
  
  • “Delta-connected, aux wdg” solely to stabilize wye-wye
  • Not intended for connected loads, reactors, house pwr
  • Buried -or- temp external connections, only for testing

• Tertiary Winding
  
  • Similar to stabilizing (delta-connected, aux)
  • Can be used for connected loads, reactors, house power
  • Winding connections brought out (bushings)
  • Thermal, loading & impedance considerations
  • Exposure to external bus faults – short circuit problematic
Shunt Reactors
MV connection via Tertiary

Reactor Application: Var supply on the cheap
Reactor Type - Oil-filled (direct connect) or Dry-type (MV tertiary)
When tertiary windings used → Transformer cost (& complexity) increased

- Added material - tertiary winding, leads, bushings
- Increase of winding diameter & weight
  Also, winding losses will increase
- Increase in tank dimension, core weight & oil volume

Are Tertiary Windings still needed?
1. Transformer stabilization in case of wye unbalance (neutral loading)

2. Influencing zero sequence impedance of transformer and of the system (relaying considerations)

3. Compensation of transformer’s third harmonics (legacy core steel vs. modern low-loss designs)
Reasons for using Tertiary Windings

1. Auxiliary power supply and/or creating access for reactive power compensation
2. Assure the interchangeability of transformers
1. Stabilization of wye-wye transformer operation in case of starpoint loading

Starpoints are loaded during unbalanced faults, either continuously or short time
1. Stabilization of wye-wye transformer operation in case of starpoint loading

Sum of ampere-turns per transformer limb is no longer zero.

Uncompensated Ampere-turns have same phase & magnitude in all three limbs.

Zero-sequence magnetic field & flux in core limbs (has same orientation in all three limbs).
1. Stabilization of wye-wye transformer operation in case of starpoint loading

Unbalanced flux induces zero sequence voltages in transformer windings.

Level of transferred voltage depends on networks’ grounding condition.

High Zo may cause relaying trips of healthy system (i.e. HV gets activated during unbalanced fault on LV side of the transformer).
1. Stabilization of wye-wye transformer operation in case of starpoint loading

Flux’s return path is most favorable in case of 5-limb, single phase and shell form cores. Zero sequence currents will produce a high flux. Therefore induced zero sequence voltage will be much higher than for 3-limb transformers.
1. Unbalanced fault w/help of delta-connected stabilizing winding

Sum of ampere-turns is zero on each limb.

Zero sequence flux is deleted by stabilizing winding.

Induced zero sequence voltages are minimized. Additional eddy loss does not occur.
1. Stabilization of the transformer operation in case of starpoint loading

A stabilizing winding may not be required if neutral loop for zero sequence current is closed & zero sequence impedances of the supplying network are low enough.

The degree of compensation without stabilization depends on total zero sequence impedance in the primary system.
2. Influence of stabilizing winding on zero sequence impedance (relaying concerns)

![Diagram of transformer connection]

\[
Z_0 = 3 \frac{U}{I} \quad [\Omega]
\]

<table>
<thead>
<tr>
<th>Transformer connection</th>
<th>Number of limbs</th>
<th>Zo/Z1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yy(d)</td>
<td>1, 3, 5</td>
<td>1 .. 2.4</td>
</tr>
<tr>
<td>Yy</td>
<td>1</td>
<td>10 .. 100</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3 .. 15</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10 .. 100</td>
</tr>
</tbody>
</table>
2. Stabilizing winding Influence on the zero sequence impedance

Transformers with solidly grounded neutrals

- Ground current involves zero sequence during phase-ground faults.
- $I_0$ must have minimum magnitude & predictable with good accuracy.
- When stabilizing winding used, transformer’s zero sequence impedance will be linear and of low value.
- Wye-wye connections w/o stabilization *can* used > if a multiple path to ground is available via station’s other transformer’s neutrals
- Ideally, transformer’s contribution to system’s zero sequence must be analyzed before deciding if a stabilizing winding is needed.
3. Compensation of 3rd Order Internal Harmonics

Harmonics are generated in transformer cores due to nonlinearity of core’s magnetizing curve.

3rd order voltage harmonic cannot flow between phases.
3. Compensation of 3rd Order Harmonics

Magnetizing current is nowadays in the range of 0.03 to 0.15% of the rated current.
With modern reduction of no load currents, influence of third harmonics generated by transformers has less relevance.
Is tertiary winding needed for auxiliary power supply or reactive power compensation?

• A separate source for auxiliary power may be more economical.

• In the case of a brought-out tertiary, winding must be designed for rated load (thermal) and especially for withstanding short circuit currents which flow during bus faults.

If sized for thermal load only, tertiary would be massively under-sized!!

ANSI C57 requires windings to be self-protecting >

  Mechanical over-sizing of tertiary required

  1/3 MVA rating?

  Available system impedance & calc?

Tertiary reactors?
Concern for excessive fault currents in tertiary windings

Tertiary reactors?

Air-core, oil-immersed current-limiting reactor (typical)

For brought-out tertiary application w/exposure to high short-circuits.
Additional Risks when Tertiary Windings are used

- Transferred lightning and switching voltages
- Capacitively transferred 60 Hz voltages during unbalanced faults

*It is recommended, that the three terminals of the winding are not left floating. Capacitors or surge arresters shall be used.*

- Very high 3-phase short circuit current w/tertiary bushings.

If only stabilizing function is needed, buried tertiary is recommended.

In general there is no additional benefit for testing, so 3 stabilizing bushings not needed.
Considerations for the use of Tertiary Windings

1. Stabilization of the transformer operation in case of starpoint loading
   • Can unbalanced loading occur continuously?
   • Is the amount of load unbalance significant?
   • What is the effect of the transferred zero sequence voltage?

2. Influencing the zero sequence impedance of the transformer and of the system
   • What is the required zero sequence impedance of the system?
   • What are the requirements for the protection design?

3. Compensation of third harmonics
   • Is there any negative impact of the 3rd harmonic current to other equipment?

4. Auxiliary power supply and/or creating access for reactive power compensation
   • Is it worth to invest so much for auxiliary power supply?
   • Tertiary access for compensation equipment may be ineffective.

5. Assure the interchangeability of transformers
   • Do all tertiaries need to be equivalent?
Siemens US – Transformers Contact

James McIver
Principal Application Engineer
E T TR US
6860 Bermuda Road, STE 100
Las Vegas NV 89119
USA

Mobile: (702) 241-0157
E-mail: james.mciver@siemens.com

Siemens.com/transformers