Selection Criteria for Large Power Transformers in Power Plant Application

by

SANJEEV BHATIA

BECHTEL (I) PVT. LTD.

sbhatia@bechtel.com
## Comparison between ANSI/IEEE and IEC Standards

<table>
<thead>
<tr>
<th>Design Particular</th>
<th>IEC</th>
<th>ANSI/IEEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories of Transformers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• kVA basis</td>
<td>CAT 1: up to 3150 kVA</td>
<td>CAT 1: 15 – 500 kVA</td>
</tr>
<tr>
<td></td>
<td>CAT 2: 3151 – 40000 kVA</td>
<td>CAT 2: 501 – 5000 kVA</td>
</tr>
<tr>
<td></td>
<td>CAT 3: Above 40000 kVA</td>
<td>CAT 3: 5001 – 30000 kVA</td>
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<td></td>
<td></td>
<td>CAT 4: Above 30000 kVA</td>
</tr>
<tr>
<td>• Voltage basis</td>
<td>No categorization</td>
<td>Class 1: 69 kV and below</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class 2: 11 kV thru 765 kV</td>
</tr>
<tr>
<td>kVA rating</td>
<td>• Value of apparent power input to the transformer at rated voltage</td>
<td>• Output power at rated secondary voltage</td>
</tr>
<tr>
<td></td>
<td>• Includes the losses of the transformer</td>
<td>• Excludes the losses of the transformer</td>
</tr>
<tr>
<td>Design Particular</td>
<td>IEC</td>
<td>ANSI/IEEE</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Volts/Hz capability</td>
<td>Capable of sustaining maximum of 105% rated Volts/Hz continuously without damage</td>
<td>Can sustain 110% Volts/Hz at no-load</td>
</tr>
<tr>
<td>Direction of Power Flow</td>
<td>No specific requirement on direction of power flow</td>
<td>Shall be for step-down operation unless specified otherwise</td>
</tr>
<tr>
<td>Tolerance applicable to nominal impedance:</td>
<td>For 2 winding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+/- 7.5% when impedance is &gt;=10%</td>
<td>7.5% if impedance voltage is &gt; 2.5%</td>
</tr>
<tr>
<td></td>
<td>+/- 10% when impedance is &lt; 10%</td>
<td>10% if impedance voltage is &lt;= 2.5%</td>
</tr>
</tbody>
</table>
### Design Particular

<table>
<thead>
<tr>
<th></th>
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<th>ANSI/IEEE</th>
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</thead>
<tbody>
<tr>
<td>- For 3 winding</td>
<td>+/- 10% for one specified pair</td>
<td>+/- 10%</td>
</tr>
<tr>
<td></td>
<td>+/- 15% for second specified pair</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient air temperature</td>
<td>Monthly average ambient temperature over a year shall not exceed 30 degC, and yearly average shall not exceed 20 degC</td>
<td>Average temperature for any 24 hour period shall not exceed 25 degC for water cooled and 30 degC for air cooled</td>
</tr>
<tr>
<td>Short Circuit Withstand</td>
<td>Number of shots for short circuit withstand current is 3 (all shots fully offset). Duration of shots is 2 seconds</td>
<td>Number of shots for short circuit withstand current is 6 (first two shots are fully offset). Duration of shots is at least 0.25 seconds</td>
</tr>
<tr>
<td>Design Particular</td>
<td>IEC</td>
<td>ANSI/IEEE</td>
</tr>
<tr>
<td>-----------------------------------------</td>
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</tr>
<tr>
<td>Reference temperature for load losses</td>
<td>75 degC</td>
<td>85 degC</td>
</tr>
<tr>
<td>Dielectric testing</td>
<td>For Lightning Impulse test, testing with chopped wave is not mandatory</td>
<td>Chopped wave test is mandatory</td>
</tr>
</tbody>
</table>
Selection Criteria for Generator Step-up (GSU) Transformer Rating

GSU Transformer needs to be rated in such a way that it does not limit the output of the associated Turbine and Generator in all the possible operating conditions, including the required reactive power import or export with the utility system.

Major factors which determine the GSU Transformer MVA rating are:

- Turbine output
- Reactive power
- Auxiliary power requirement
- Impedance of GSU transformer
Selection Criteria for Generator Step-up (GSU) Transformer Rating

• MVA rating of GSU transformer is normally selected based on the gross Generator output

• Based on the plants’ auxiliary distribution philosophy, MVA rating of GSU transformer can be optimized as per net power export to utility. If the auxiliary power is tapped off, the net power export from GSU would be gross generator output minus plant auxiliary power requirement

• As per ANSI:
  ➢ power transformers are output rated – can deliver rated MVA at any tap (if output voltage and Volts/Hz do not exceed 105%, power factor is above 0.8, and frequency is at least 95% of the rated frequency)
Selection Criteria for Generator Step-up (GSU) Transformer Rating

• Selected MVA rating is specified at 24-hour average ambient temperature of 30 deg C and maximum ambient temperature of 40 deg C

• As per IEC:
  - Specified MVA rating is input power. Capable of sustaining a maximum of 105% rated Volts/Hz continuously
  - With respect to temperature - cooling air at inlet of cooling should not exceed 40 deg C, 30 deg C monthly average for hottest month, and 20 deg C yearly average
Sample Calculation – GSU Transformer sizing for Steam Turbine Generator (as per IEEE)

- Auxiliary power demand to be computed
- Input to GSU Transformer = (Generator output – aux power)
- As per efficiency, losses in MW is determined
- Reactive power loss is determined based on % impedance
- As per I/P and losses, transformer output rating can be determined
- Different cases for various assumed Transformer output can be tried, unless assumed output matches with calculated output
Sample Calculation – GSU Transformer sizing for Steam Turbine Generator (As per IEEE)

- Above sequence of calculation to be run for complete power factor range of Generator (0.9 lag, unity, and 0.95 lead) – the maximum calculated rating is used to determine GSU Transformer rating

- Ambient temperature and site elevation to be considered for final MVA rating of Transformer:
  
  - ANSI standard condition for transformers are 30 degC max average 24-hour ambient, 40 degC maximum ambient, and maximum elevation of 3300 feet

  - Computed transformer rating can be adjusted for other temperature and elevation conditions
    - For every degC above 24-hour average ambient temperature of 30 degC, transformer needs to be de rated by 1%
    - For every degC below 24-hour average ambient temperature of 30 degC, transformer can be up rated by 0.75%
GSU Transformer sizing for Gas Turbine Generator and Steam Turbine Generator in Combined Cycle Plant

• For Steam Turbine Generator - Generator is normally sized for specific Turbine output

• For Gas Turbine, and Steam Turbine Generator in combined Cycle plants - Generators are selected as per standard frame size

• For optimum selection, GSU transformer for Gas Turbine and Steam turbine Generator in combined cycle plants can be sized as per Turbine maximum output capacity
Important parameters for GSU Transformer

- **Impedance**
  - should meet steady state, transient, and dynamic stability requirement
  - should limit short circuit duties within design values
  - should be able to provide acceptable voltage regulations

- **Transformation Ratio**
  - significant for proper reactive power sharing and
  - for generator operation well within the operating voltage range
  - typically low voltage ratings are 95% to 100% of the generator voltage rating
  - while the high-voltage ratings are 100% to 105% of system rated voltage

- **Highest High-Voltage Winding Tap Voltage Rating**
  - Transformer should be able to operate at maximum system voltage at which
    transmission system is expected to operate
  - Highest transformer tap should not be selected more than 5% below the
    maximum system voltage (as transformer can deliver rated output at 5% above
    rated secondary voltage)
Selection of Parameters for Unit Auxiliary Transformer

- **Voltage Ratio and Tap Range**
  - Primary UAT winding voltage rating to match with rated generator voltage

- **Impedance**
  - First priority should be to keep the impedance at lowest value to provide the adequate voltage regulation for bus
  - Fault current limitation must be considered while impedance selection

- **MVA Rating**
  - Should be selected based on the maximum expected auxiliary load corresponding to highest expected output of generator
Conclusion - Summary of parameter selection

- Select highest high-voltage tap ratings as 5% below the maximum expected system voltage
- Choose transformation ratio equal to 95% of system maximum expected voltage divided by generator rated voltage
- Estimate impedance as manufacturer’s standard value
- Estimate MVA rating
- Review the impedance for stability and short-circuit requirements
- Review MVA rating estimate