TRAINING on dry-type transformers
Presenters

**Carlos García.**
Industrial Engineer – Master in Business Administration.
25 years in the market of electrical equipment, including transformers, switchgears, substations. Worked in sales positions and management positions in ABB and other companies. In TMC since Apr-2018, currently as Sales Manager for North America.

**Jhonatan Hernández.**
Electrical Engineer – Master in Business Administration.
9 years of specific experience in technical and sales positions in Oil and Dry Transformers sector for multinational companies. Currently as Bid Manager for North America in TMC.
<table>
<thead>
<tr>
<th><strong>TRANSFORMERS MANUFACTURED AND SOLD</strong></th>
<th><strong>YEARS OF EXPERIENCE</strong></th>
<th><strong>SQ.M PRODUCTION FACILITY AROUND THE WORLD</strong></th>
<th><strong>EMPLOYEES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>+35,000</td>
<td>30</td>
<td>37,000+</td>
<td>380</td>
</tr>
</tbody>
</table>
Training Agenda

• The general concepts
• Product Portfolio
• Production Process
• Technical Concepts
• Accessories
• Applications
• Basic Maintenance
Dry-type transformers

The general concepts
What is a transformer

In almost every place where a human being is, there is a need for a transformer to change the energy from one voltage level to another.

• Shopping malls
• Hospitals
• Buildings
• Railway stations

• Airports
• Industries
• Ships
• Power plants
Type of transformers

Oil type and dry-type

- Mainly for outdoors installation
- Maintenance needed

- Mainly for indoors installation; outdoors installation is also possible
- No maintenance needed

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>OIL TRAFOS</th>
<th>DRY TYPE</th>
<th>CAST RESIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammability</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Self-extinguishing in case of electric damage</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Necessity of fire fighting measures such as oil</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>bunds and fireproof structures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hygroscopcity of insulating materials</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Contribution to environmental pollution</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Strip windings and optimal resistance to short</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>circuit phenomena</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance stability to short circuit phenomena</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Energizing special procedures</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Maintenance</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Environmental pollution risk due to liquid losses</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Insensitivity towards humid, saline and tropical</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>environments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location close to load with savings on transmission</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>losses, cabling, civil works and management costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability without maintenance and installation</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>without specifically specialized labour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capability to stand high, immediate and short</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>overloads thanks to reduced current density and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high thermal factor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dry-type transformers

**Advantages**

**Safety for people and property**
- No fire hazard
- Nonflammable and self extinguishing
- No special safety features required

**Ecological and environmentally safe**
- Environmentally conscience manufacturing (process and materials)
- Able to be installed closer to the point of consumption, reducing load cable losses
- No risk for leakage of insulation fluids, no ground or water contamination

**Maintenance free**
- Virtually maintenance free
Dry-type transformers

How it looks like

Dry type transformers, components:
- Steel magnetic core

- Copper/Aluminum windings and insulation resin material to build the coils

- 2 coils per phase for primary and secondary winding
Standard and special solutions

Different applications for dry type transformers
TMC Transformers
Experts on any kind of dry type transformers
Product portfolio

Technologies
Experts on any kind of dry type transformers

**Technologies**

**Cast-resin transformers**
- Vacuum cast technology
- Available both for primary and secondary
- Availability for cooling channels in both windings
- All coils manufactured in home

**VPI - VI**
- Vacuum pressure impregnated
- Vacuum impregnated
- Sealed borders available
- All coils manufactured in home
Experts on any kind of dry type transformers

**Product portfolio**

**Medium voltage cast-resin transformers**
- 150 kVA to 25000 kVA
- Class F or H
- AN, AF, AFWF, AFAF
- Up to 52 kV
- Distribution transformers
- And specials up to 48 pulses

**Low voltage transformers and reactors**
- 150 kVA to 5000 kVA
- Air natural, air forced or water forced
- Up to 1.1 kV
- All types of enclosures
CAST RESIN

Key Points & Advantages

Distribution and special transformers

- Cast insulation system up to 25MVA and 52kV
- Winding material in aluminum or copper
- Combination of cast resin and foil winding offers the ultimate in terms of dielectric performance and short circuit withstand
- Axial air-cooling channels cast into coil for improved cooling for ratings >5MVA
- 155° or 180° thermal class
Medium voltage transformers

- Medium-voltage VPI distribution and special transformers with power up to 25MVA and voltages up to 34.5kV
- Winding material in aluminum or copper
- Processed in vacuum chamber: resin initially introduced under vacuum and then placed under positive pressure to improve impregnation
- 155°, 180° or 220° thermal class
- Flame retardant materials
VPI

Key Points & Advantages

Low voltage transformers

- Low-voltage special and distribution VPI transformers with normal or reduced losses and according to customer specifications, up to 10MVA and with insulation class up to 1.1kV
- Winding material in aluminum or copper
- Processed in vacuum chamber: resin initially introduced under vacuum and then placed under positive pressure to improve impregnation
- 155°, 180° or 220° thermal class
- Flame retardant materials
TMC Transformers

VPI-VPE-VCC description

VPI: The windings are vacuum-pressure impregnated VPI, they are vacuum dipped into polyester resin (no filler, no moulds) and cured inside the oven.

VPE: The windings are vacuum-pressure encapsulated VPE, they are vacuum dipped with epoxy resin (no filler, no moulds) and cured inside the oven.

VCC: Vacuum cast coil means windings filled with epoxy resin under vacuum and the thermal class is 180 °C. The VCC windings are casted in moulds with epoxy resin (quartz +resin).

Pros & cons VPI-VPE vs VCC:

<table>
<thead>
<tr>
<th></th>
<th>Dimensions</th>
<th>Weight</th>
<th>Thermal class</th>
<th>Pollution resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VCC</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>VPI/VPE</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
Technical concepts

Standard Distribution Transformers
Dry type transformers

Main applicable standard for dry type transformers

IEEE Std C57.12.01™-2020
(Revision of IEEE Std C57.12.01-2015)

IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers

Scope

1.1 Scope

This standard describes electrical and mechanical requirements of single and polyphase ventilated, non-ventilated, and sealed dry-type distribution and power transformers or autotransformers, with a voltage of 601 V or higher in the highest voltage winding. This standard applies to all dry-type transformers, including those with solid-cast and/or resin encapsulated windings except as follows:

a) Instrument transformers
b) Step and induction-voltage regulators
c) Arc-furnace transformers
d) Rectifier transformers
e) Specialty and general-purpose transformers
f) Mine transformers
g) Testing transformers
h) Welding transformers
Dry type transformers

Insulation levels

According to IEEE C57.12.01, as a minimum, the standard «S» value of insulation level must be used.

- Example: Primary voltage 13.8 kV
- Insulation level: 15 kV
- Low Frequency Voltage Insulation level: 34 kV
- Minimum Basic Lighting Impulse Insulation Level: 60 kV

| Nominal L-L system voltages | Low-frequency voltage insulation level | Basic lightning impulse insulation levels (BIL ratings) in common use kV crest \( t \) 
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(kV rms)</td>
<td>(kV rms)</td>
<td>(kV rms)</td>
<td>10</td>
</tr>
<tr>
<td>1.5</td>
<td>1.2</td>
<td>4</td>
<td>S</td>
</tr>
<tr>
<td>3.5</td>
<td>2.5</td>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>6.9</td>
<td>5.0</td>
<td>12</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>8.7</td>
<td>20</td>
<td>S</td>
</tr>
<tr>
<td>17</td>
<td>13.0</td>
<td>34</td>
<td>S</td>
</tr>
<tr>
<td>20</td>
<td>18.0</td>
<td>40</td>
<td>S</td>
</tr>
<tr>
<td>27</td>
<td>23.0</td>
<td>50</td>
<td>S</td>
</tr>
<tr>
<td>37</td>
<td>34.5</td>
<td>70</td>
<td>S</td>
</tr>
<tr>
<td>49</td>
<td>46.0</td>
<td>95</td>
<td>S</td>
</tr>
<tr>
<td>73</td>
<td>69.0</td>
<td>140</td>
<td>S</td>
</tr>
</tbody>
</table>


S = Standard values

1 = Optional higher level where exposure to overvoltages occurs and improved protective margins are required
2 = Optional lower levels where protective characteristics of applied surge arresters have been evaluated and found to provide appropriate surge protection.
Dry type transformers
DOE Efficiency

<table>
<thead>
<tr>
<th>KVA</th>
<th>20-45 BIL</th>
<th>45-95 BIL</th>
<th>&gt;= 95 BIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2016</td>
<td>%DIF</td>
</tr>
<tr>
<td>15</td>
<td>97.5</td>
<td>97.5</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>97.9</td>
<td>97.9</td>
<td>0</td>
</tr>
<tr>
<td>45</td>
<td>98.1</td>
<td>98.1</td>
<td>0</td>
</tr>
<tr>
<td>75</td>
<td>98.33</td>
<td>98.33</td>
<td>0</td>
</tr>
<tr>
<td>112.5</td>
<td>98.49</td>
<td>98.52</td>
<td>0.03</td>
</tr>
<tr>
<td>150</td>
<td>98.6</td>
<td>98.65</td>
<td>0.05</td>
</tr>
<tr>
<td>225</td>
<td>98.73</td>
<td>98.82</td>
<td>0.09</td>
</tr>
<tr>
<td>300</td>
<td>98.82</td>
<td>98.93</td>
<td>0.11</td>
</tr>
<tr>
<td>500</td>
<td>98.96</td>
<td>99.09</td>
<td>0.13</td>
</tr>
<tr>
<td>750</td>
<td>99.07</td>
<td>99.21</td>
<td>0.14</td>
</tr>
<tr>
<td>1000</td>
<td>99.14</td>
<td>99.28</td>
<td>0.14</td>
</tr>
<tr>
<td>1500</td>
<td>99.22</td>
<td>99.37</td>
<td>0.15</td>
</tr>
<tr>
<td>2000</td>
<td>99.27</td>
<td>99.43</td>
<td>0.16</td>
</tr>
<tr>
<td>2500</td>
<td>99.31</td>
<td>99.47</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Efficiency values are at 50% of nameplate rated load and at a reference temperature of 75°C.

One of the exceptions for Distribution Transformers per DOE 2016 are those with special impedance. Normal Impedance percentages for Dry Type Distribution Transformers as defined in 10 CFR 431 are as listed in the following Table.

---

Normal Impedance Range for Dry Type Transformers
Per Federal Regulations 10 CFR Part 431 Subpart K Table 2

<table>
<thead>
<tr>
<th>Single Phase</th>
<th>Three Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>Impedance (%)</td>
</tr>
<tr>
<td>15</td>
<td>1.5-6.0</td>
</tr>
<tr>
<td>25</td>
<td>1.5-6.0</td>
</tr>
<tr>
<td>34.5</td>
<td>1.5-6.0</td>
</tr>
<tr>
<td>50</td>
<td>1.5-6.0</td>
</tr>
<tr>
<td>75</td>
<td>2.0-7.0</td>
</tr>
<tr>
<td>100</td>
<td>2.0-7.0</td>
</tr>
<tr>
<td>167</td>
<td>2.5-8.0</td>
</tr>
<tr>
<td>250</td>
<td>3.5-8.0</td>
</tr>
<tr>
<td>333</td>
<td>3.5-8.0</td>
</tr>
<tr>
<td>500</td>
<td>3.5-8.0</td>
</tr>
<tr>
<td>667</td>
<td>5.0-8.0</td>
</tr>
<tr>
<td>833</td>
<td>5.0-8.0</td>
</tr>
<tr>
<td>1000</td>
<td>5.0-8.0</td>
</tr>
<tr>
<td>2500</td>
<td>5.0-8.0</td>
</tr>
</tbody>
</table>
Dry type transformers

Thermal class and temperature rise in windings

Considering class 180°C:

- If max. ambient temperature is 40°C, it is considered a temperature rise in windings of 115°C.
- If max. ambient temperature is 50°C, it is considered a temperature rise in windings of 105°C.

- A 80K temperature rise is highly requested in Distribution Transformers Market in USA.

TMC temperature limit for VCC transformers: 180 °C
TMC temperature limit for VPI transformers: 220 °C

---

Table 9—Limits of temperature rise for continuously rated dry-type transformer windings

<table>
<thead>
<tr>
<th>Insulation system temperature class (°C)</th>
<th>Winding hottest-spot temperature rise (°C)</th>
<th>Average winding temperature rise by resistance (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>155</td>
<td>115</td>
<td>95</td>
</tr>
<tr>
<td>180</td>
<td>140</td>
<td>115</td>
</tr>
<tr>
<td>200</td>
<td>160</td>
<td>135</td>
</tr>
<tr>
<td>220</td>
<td>180</td>
<td>150</td>
</tr>
</tbody>
</table>

* Higher average winding temperature rise by resistance may apply if the manufacturer provides thermal-design test data substantiating that temperature limits of the insulation are not exceeded.
Experts on any kind of dry type transformers

Distribution transformers

Eco or Standard distribution transformers
Short or long series
Any kind of accessories or technical solutions
Experts on any kind of dry type transformers

**Distribution transformers**

**Distribution dry type transformers**

**Standard IEEE / DOE Efficiency**

Transformers are usually IP00 (Core and Coil)

Optional, typical enclosures Nema1, Nema 2 (INDOOR) or NEMA 3R (OUTDOOR)

Air natural (AA) or standard air forced cooling (FA)

Accessories: Temperature sensors, temperature monitoring device, lifting lugs, wheels
Custom design for special applications
Experts on any kind of dry type transformers

Special dry type transformers are needed
Special applications
Customized designs
Strong team of expert designers behind
Experts on any kind of dry type transformers
Tailor made for the most demanding applications

Multi-pulses dry type transformers

- Up to 36 kV insulation level
- Up to 20 MVA
- Up to 48 pulses
- VPI or vacuum cast technology.
- Aluminum or copper Conductors
- Special cooling systems when required.
- Customer tailor-made solutions.

3750 kVA, primary voltage 11 kV, secondary windings 15 x 1250 V
Special top box for guiding air forced cooling
Transformer recently delivered
Custom design for special applications

Certifications
Technical concepts

Railway Substation Transformers
Railway Substation Transformers

Applicable Standards - Cycle loads

**IEEE 1653.1, 1653.2**

Source:

**IEEE 1653.1-2016**: IEEE Standard for Traction Power Rectifier Transformers for Substation Applications up to 1500 V DC Nominal Output.

**IEEE 1653.2-2020**: IEEE Standard for Uncontrolled Traction Power Rectifiers for Substation Applications up to 1500 V DC Nominal Output.

---

7.3.4 Extra heavy traction service

The standard rating of a rectifier unit for extra heavy traction service is as follows (refer to Figure 5, which can also be found in the former NEMA Pub. No. R19):

a) 100% rated load amperes continuously until constant temperatures have been reached by all parts of the rectifier unit, followed by 150% of rated load amperes for two hours and a superimposed cycle of overloads consisting of five periods of one min each at 300% of rated load amperes, followed by one period of 450% of rated load amperes for 15 s at the end of the two-hour period. These periods shall be evenly spaced throughout the two-hour period as indicated in Figure 5.
Railway Substation Transformers

Applicable Standards - Cycle loads

**EN 50329, IEC 62695:** Railway applications - Fixed installations - Traction transformers  
(Europe – Canada)

<table>
<thead>
<tr>
<th>Duty class</th>
<th>Id.</th>
<th>p.u. of $I_{F}$</th>
<th>p.u. of $I_{N}$</th>
<th>Initial condition</th>
<th>Duration</th>
<th>Cool period</th>
<th>Typical application</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>1</td>
<td>1</td>
<td>Cont</td>
<td></td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>IA</td>
<td>a</td>
<td>1</td>
<td>0.9</td>
<td>Cont</td>
<td>3 120 s</td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>1.7</td>
<td>1.494</td>
<td>a</td>
<td>480 s</td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>IB</td>
<td>a</td>
<td>1</td>
<td>0.873</td>
<td>Cont</td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>2.2</td>
<td>1.903</td>
<td>a</td>
<td>300 s</td>
<td>3 300 s</td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>IC</td>
<td>a</td>
<td>1</td>
<td>0.651</td>
<td>Cont</td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>2.7</td>
<td>1.961</td>
<td>a</td>
<td>300 s</td>
<td>1 500 s</td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>a</td>
<td>1</td>
<td>0.668</td>
<td>Cont</td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>3.7</td>
<td>2.446</td>
<td>a</td>
<td>180 s</td>
<td>1 620 s</td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>IE</td>
<td>a</td>
<td>1</td>
<td>0.652</td>
<td>Cont</td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>4.4</td>
<td>3.067</td>
<td>a</td>
<td>120 s</td>
<td>1 480 s</td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>IP</td>
<td>A</td>
<td>1</td>
<td>0.909</td>
<td>Cont</td>
<td></td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>3</td>
<td>2.876</td>
<td>a</td>
<td>120 s</td>
<td>3 s</td>
<td></td>
<td>a.c. systems</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>a</td>
<td>1</td>
<td>0.827</td>
<td>Cont</td>
<td></td>
<td></td>
<td>mass rapid transit trolley buses</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>1.5</td>
<td>1.240</td>
<td>a</td>
<td>2 h</td>
<td>3 h</td>
<td></td>
<td>mass rapid transit trolley buses</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>2</td>
<td>1.854</td>
<td>a</td>
<td>60 s</td>
<td>1 800 s</td>
<td></td>
<td>mass rapid transit trolley buses</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>a</td>
<td>1</td>
<td>0.823</td>
<td>Cont</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>b</td>
<td>1.5</td>
<td>1.234</td>
<td>a</td>
<td>2 h</td>
<td>3 h</td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>c</td>
<td>3</td>
<td>2.468</td>
<td>a</td>
<td>60 s</td>
<td>1 800 s</td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>VII</td>
<td>a</td>
<td>1</td>
<td>0.825</td>
<td>Cont</td>
<td></td>
<td></td>
<td>light railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>b</td>
<td>1.5</td>
<td>1.238</td>
<td>a</td>
<td>2 h</td>
<td>3 h</td>
<td></td>
<td>light railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>c</td>
<td>4.5</td>
<td>3.716</td>
<td>a</td>
<td>15 s</td>
<td>1 800 s</td>
<td></td>
<td>light railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>VIII</td>
<td>a</td>
<td>1</td>
<td>0.814</td>
<td>Cont</td>
<td></td>
<td></td>
<td>mass rapid transit trolley buses</td>
<td>cumulative</td>
</tr>
<tr>
<td>c</td>
<td>1.5</td>
<td>1.221</td>
<td>a</td>
<td>2 h</td>
<td></td>
<td></td>
<td>mass rapid transit trolley buses</td>
<td>cumulative</td>
</tr>
<tr>
<td>IXA</td>
<td>a</td>
<td>1</td>
<td>0.755</td>
<td>Cont</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>b</td>
<td>2</td>
<td>1.628</td>
<td>b</td>
<td>60 s</td>
<td>3 h</td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>IXB</td>
<td>a</td>
<td>1</td>
<td>0.658</td>
<td>Cont</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>b</td>
<td>1.5</td>
<td>1.177</td>
<td>a</td>
<td>2 h</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>JP</td>
<td>a</td>
<td>1</td>
<td>0.912</td>
<td>Cont</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>b</td>
<td>1.2</td>
<td>1.095</td>
<td>a</td>
<td>2 h</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>c</td>
<td>3</td>
<td>2.276</td>
<td>b</td>
<td>60 s</td>
<td>3 h</td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>CIN</td>
<td>a</td>
<td>1</td>
<td>0.6</td>
<td>-</td>
<td>304 min</td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>b</td>
<td>2</td>
<td>2</td>
<td>a</td>
<td>60 min</td>
<td></td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
<tr>
<td>c</td>
<td>3</td>
<td>3</td>
<td>b</td>
<td>2 min</td>
<td>300 min</td>
<td></td>
<td>mainline railways</td>
<td>cumulative</td>
</tr>
</tbody>
</table>

**Key:**
- cont: pre-heating period, injection of current until steady-state temperatures of windings at $I_{F}$ are reached
- $t_{h}$: service current in basic load condition
- $I_{b}$: overload current $b$
- $I_{c}$: overload current $c$
- $I_{r}$: rated current
- $t_{h, b}$: cool down period at current $I_{F}$ after overload at current $I_{b}$
- $t_{h, c}$: cool down period at current $I_{F}$ after overload at current $I_{c}$
- $t_{r}$: duration of overload current $I_{r}$
- $t_{c}$: duration of overload current $I_{c}$
- $\Delta t$: duration of the load cycle consisting of overloads and cool down periods
Railway Substation Transformers

6 - 12 Pulse Rectifiers

**6 pulse rectifier**

Transformer (if included) and cabling simple

Current quite distorted $I_{thd}$
32% to 48% (depending on network impedance)

**12 pulse rectifier**

Transformer and cabling more complicated

Current slightly distorted $I_{thd}$
8% to 12% (depending on network impedance)
Railway Substation Transformers

6 - 12 Pulse Rectifiers

6 pulse rectifier

12 pulse rectifier
Railway Substation Transformers

**Special 12P configuration: 24 Pulse effect in MV.**
Dry-type transformers

Accessories
Dry type transformers

Standard accessories

Rating plate

Lifting Lugs

Pulling Eyes
Dry type transformers

Off load Tap Changer

- The industry standard is having an off load regulation
- Common tapping ratio is ±2 x 2.5%. (5 taps)
- Up to 7 taps is possible but have a price impact
- Tap changer are marked on the HV face in the coils
Dry type transformers

**Standard accessories**

- Bi-directional wheels
- Earthing Terminals
Dry type transformers

Power and cooling – Air natural / air forced

- Normally the rating is AA (air natural), and given in kVA
- In some cases, FA (air forced cooling) is required
  - Extra power can be from +20% up to +40%. Typically +30%
  - Example 2500/3250kVA AA/FA
- The following accessories will be included:
  - Fans
  - Control Fan Box
Dry type transformers

**Standard accessories**

PT100 sensor

PT100 sensor box
INTELLIGENT TRANSFORMER MONITOR

Operators can easily compare the winding with the highest temperature to pre-selected relay temperatures.
Dry type transformers

**Temperature Monitoring Units**

Digital Thermometer connected up to 4 separated PT100 Sensors to measure the temperature in windings

1. Pt100 sensors (white-red-red)
2. Supply 24-240Vac/dc 50/60Hz

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relays (FAN-ALARM-TRIP-FAULT)</td>
<td>3</td>
</tr>
</tbody>
</table>

UL certification
Dry type transformers

Temperature Monitoring Units

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Pt100 sensors (white-red-red)</td>
<td>3)</td>
</tr>
<tr>
<td>2)</td>
<td>Supply 24-240 Vac/dc 50/60Hz</td>
<td>4)</td>
</tr>
<tr>
<td>5)</td>
<td>Modbus RTU RS485 output</td>
<td></td>
</tr>
</tbody>
</table>
Dry type transformers

Temperature Monitoring Units

Monitoring Unit with Ethernet Comm
Dry type transformers

Protection devices in MV side

1. NEMA 3 box with protection devices (fuses, disconnector switch or disconnector switch with fuses) attached to the enclosure.

2. NEMA 3 marshalling box attached to the enclosure to locate terminal strips; with option to locate also the temperature monitoring unit.
Dry type transformers

Protection devices in MV side

Fuses (only) inside box

Disconnect Switch for Primary Side

Fused Disconnect Switch for Primary Side
Dry type transformers

Enclosures – NEMA Ratings

**NEMA 1** enclosures are typically used for protecting controls and terminations from objects and personnel. This style of enclosure, while offering a latching door, does not have a gasketed sealing surface. **NEMA 1 enclosures are used in applications where sealing out dust, oil, and water is not required. (INDOOR)**

**NEMA 2** enclosures are intended for indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.

**NEMA 3** enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, sleet, and external ice formation.

**NEMA 3R** enclosures are typically used in outdoor applications for wiring and junction boxes. This style of enclosure provides protection against falling rain, sleet, snow, and external ice formation. Indoors they protect against dripping water. This style of enclosure does not have a gasketed sealing surface. Some models have hasps for padlocking.

**NEMA 3S** enclosures are intended for outdoor use primarily to provide protection against windblown dust, rain, sleet, and to provide for operation of external mechanisms when ice laden.

**NEMA 4** enclosures are used in many applications where an occasional washdown occurs or where machine tool cutter coolant is used. They also serve in applications where a pressurized stream of water will be used. **NEMA 4 enclosures are gasketed and the door is clamped for maximum sealing.**

**NEMA 4X** enclosures are made of stainless steel, aluminum, fiberglass, or polycarbonate. **NEMA 4X enclosures are used in harsh environments where corrosive materials and caustic cleaners are used. Applications include food, such as meat/poultry processing facilities, where total washdown with disinfectants occur repeatedly, and petro-chemical facilities, including offshore petroleum sites.**

**NEMA 5** enclosures are intended for indoor use primarily to provide a degree of protection against settling airborne dust, falling dirt, and dripping non-corrosive liquids.

**NEMA 6** enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against the entry of water during occasional, temporary submersion at a limited depth.

**NEMA 6P** enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against the entry of water during prolonged submersion at a limited depth.

**NEMA 11** enclosures are intended for indoor use primarily to provide, by oil submersion, a degree of protection to enclosed equipment against the corrosive effects of liquids and gases.

**NEMA 12** enclosures are intended for indoor use to provide a degree of protection against drips, falling dirt, and dripping non-corrosive liquids. **NEMA 12 enclosures are most commonly used for indoor applications of automation control and electronic drives systems, including packaging, material handling, non-corrosive process control, and manufacturing applications. Gasketed doors seal the enclosure’s contents from airborne contaminants and non-pressurized water and oil.**

**NEMA 12K** enclosures with knock-outs are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dripping non-corrosive liquids other than at knock-outs.

**NEMA 13** enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and non-corrosive coolant.
### Dry type transformers

#### Enclosures – IP Ratings

<table>
<thead>
<tr>
<th>NEMA Type</th>
<th>IP23</th>
<th>IP30</th>
<th>IP32</th>
<th>IP55</th>
<th>IP64</th>
<th>IP65</th>
<th>IP66</th>
<th>IP67</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3R</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### IP (Ingress Protection) Ratings Guide

1. **SOLIDS**
   - Protected against a solid object greater than 50 mm such as a hand.

2. **WATER**
   - Protected against vertically falling drops of water. Limited ingress permitted. Duration 10 minutes.

3. **SOLIDS**
   - Protected against a solid object greater than 12.5 mm such as a finger.

4. **WATER**
   - Protected against a spray of water up to 60 degrees from the vertical. Duration 3 minutes, shall have no harmful effect.

5. **SOLIDS**
   - Protected against a solid object greater than 2.5 mm such as a screwdriver.

6. **WATER**
   - Protected against water splashed from all directions. Duration 5 minutes, shall have no harmful effect.

7. **WATER**
   - Protected against water jet from all directions. Duration 5 minutes, shall have no harmful effect.

8. **WATER**
   - Protected against severe rain and washing jets. Duration 5 minutes, shall have no harmful effect.

9. **WATER**
   - Protected against partial submersion in water. No harmful effect.

10. **WATER**
    - Protected against heavy rain and powerful jets. No harmful effect.

11. **WATER**
    - Protected against total immersion under water. No harmful effect.

12. **WATER**
    - Protected against total immersion in water under pressure for long periods.

13. **WATER**
    - Protected against the effects of immersion in water between 10cm and 1m for 30 minutes.

14. **WATER**
    - Protected against the effects of immersion in water between 10cm and 1m for 30 minutes.

15. **WATER**
    - Protected against the effects of immersion in water between 10cm and 1m for 30 minutes.
Dry type transformers

Enclosures

Indoor (Nema 1, Nema 2)
Dry type transformers

**Enclosures**

*Outdoor* (Nema 3R)
Dry type transformers

Enclosures details

Cable access panel at the bottom

Anticondensation heater inside the enclosure
Dry-type transformers

Basic Maintenance
Basic Maintenance

Site Environment Evaluation

Based upon this qualitative assessment a regular maintenance program can be established. A general visual inspection must be done in order to establish the effective status of the environment; the criteria for this assessment should be based upon:

- Excessive dust
- Presence of traces of electrical discharges (visual marks)
- Presence of abnormal color of the coils
- Traces of rust
- Sample check of the tightening torque on to the HV – LV bar connections

From the data collected during the inspection the following diagram could be applicable in order to define a minimum Maintenance scheduling applicable to the transformer/s.
Basic Maintenance

Excessive dust
Basic Maintenance

Presence of Traces of Electrical Discharges (Visual Marks)
Basic Maintenance

**Presence of Abnormal Colour of the Parts**
Basic Maintenance

Traces of rust
Basic Maintenance

Maintenance Scheduling Matrix

Other Cases:
In case of a particular environment other scheduling could be applicable, in example in presence of: Water spray – Sea water spray, Aggressive-Chemical environment, Heavy dust, Sand.

*The Scheduling showed is only an example of maintenance matrix, a different matrix can be applied depending on the specific conditions of each particular project.*
Basic Maintenance

Basic annual maintenance plan

• General Visual inspection

• Clean all surfaces, especially the conducting parts, by means of dry cloth and an industrial vacuum cleaner. It is not recommended to use a high-pressure air line to blow the dust away. Do not use solvents or any kind of liquid (especially on the coils)

• Clean all ventilation grills / openings

• Check and if necessary, re-tighten all bolts on the magnetic core clamping assembly, on the HV and LV connections, on the HV tapping or series / parallel links, and on all earth connections. The appropriate tightening torque must be applied

• Check the condition of all painted surfaces. This applies to the core, the enclosure and other structural metallic parts. Remove traces of rust, if any, by means of wire brush. When necessary, apply locally two coats of new paint. Only a temperature resistant (155 °C - 180°C - 220°C) and insulating paint should be used

• Check the operating settings and correct function of the thermal protection device (Temperature Monitoring Unit)

• Perform a Winding Insulation resistance test
Questions

Carlos Garcia – Sales Manager North America – c.garcia@tmctransformers.com
Jhonatan Hernández – Bid Manager North America – j.hernandez@tmctransformers.com
Bryan Herity – Area Sales Manager Northeast – b.herity@tmctransformers.com
Contacts

TMC Transformers USA Inc.
874 Walker Road, Dover
Kent 19904
Production plant:
1 Evercare Way, Waynesboro
GA 30830

marketing@tmctransformers.com
www.tmctransformers.us