THREE-PHASE TRANSFORMERS

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The equipment described in this document is not intended to be used in connection with any application requiring fail-safe performance, unless the application design includes appropriate redundancy. This exclusion includes, but is not limited to, the direct operation of any life support system or any other system whose failure could lead to serious injury, death, environmental damage or mass destruction.
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1. **INTRODUCTION TO TRANSFORMERS**

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors—the transformer's coils (windings). The transformer's coils are usually wound around a metal centerpiece – the core. Passing alternating current (ac) through the first or primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the secondary winding. This varying magnetic field induces an ac voltage in the secondary winding. This effect is called inductive coupling.

Figure 1 illustrates a simple, ideal transformer. Ac current passing through the primary coil creates a varying magnetic field. The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron, so that most of the magnetic flux passes through both the primary and secondary coils. If a load is connected to the secondary winding, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. In an ideal transformer, the induced voltage in the secondary winding \( V_S \) is in proportion to the primary voltage \( V_P \), and is given by the ratio of the number of turns in the secondary \( N_S \) to the number of turns in the primary \( N_P \) as follows:

\[
\frac{V_S}{V_P} = \frac{N_S}{N_P}
\]

By using the appropriate ratio of turns, a transformer can increase an ac voltage by making \( N_S \) greater than \( N_P \), or decrease ac voltage by making \( N_S \) less than \( N_P \).
1.1 Galvanic isolation transformers

A galvanic isolation transformer is a transformer used to supply electrical power from an ac source to some equipment or device while isolating the powered device from the power source. In power electronics, this is usually done to suppress electrical noise in sensitive devices, and to minimize or eliminate any dc component in the voltage supplied to the load device. Transformers are often required for medical devices, for safety purposes.

Suitably designed isolation transformers block interference caused by ground loops. Isolation transformers with electrostatic shields are used for power supplies for sensitive equipment such as computers or laboratory instruments.

Isolation transformers are usually built with special insulation between the primary and secondary windings, and is tested, specified, and marked to withstand a high voltage – typically in the 1000 to 5000 volt range – between windings, and between each winding and ground.

There are generally two types of isolation: one that relies on protective earth ground and one that relies on double or reinforced insulation. A transformer that relies on protective earth ground uses a basic isolation between the primary and the safety shield and shield to secondary. This shield has to be thick to be able to meet required tests in the safety standard. If the isolation fails, the electrical path goes directly to ground, providing safety.

A transformer that relies on double or reinforced insulation has no safety shield. Instead, the insulation used in the coil is much thicker. These transformers are designed so that all layers of the insulation can pass the thickness and high potential voltage tests required. If one insulation layer breaks, the next layer will be able to provide the required safety.

1.2 Transformer standards

Various national and international safety agencies have published standards relevant to the design, construction and testing of transformers. A partial list of those standards follows.

Standards published by the International Electrotechnical Commission (IEC) include:

- IEC 60076 Power transformers
- IEC 60905 Loading guide for dry-type power transformers
- IEC 61000 Electromagnetic compatibility (EMC)
- IEC 61558 Safety of transformers, reactors, power supply units

Standards published by Underwriters Laboratories (UL):

- UL 5085 Standard for Low Voltage UL 5085
- UL 544 Medical and dental equipment

Canadian Standards Association (CSA)

- C22.2 NO. 66.1-06 Low-voltage transformers

There exist a number of regional, national, and local deviations from the abovelist ed standards. For example, in the U.S., the city of Los Angeles requires the use of tamperproof thermal protection and nonflammable materials in transformers, due the region's high seismic activity.
1.3 Three-phase transformers

A transformer for use with 3-phase power is constructed by winding three single phase transformers on a single core.

1.3.1 Delta and Wye connections

In a three-phase transformer, there is a three-legged iron core as shown below. Each leg has a respective primary and secondary winding.

![Figure 2: A 3-phase transformer core](image)

As can be seen, the three-phase transformer actually has 6 windings (or coils) 3 primary and 3 secondary. In power applications, these windings are usually connected in one of two configurations: Delta or Wye.

In a Delta connection, there are three phases and no Neutral. An output Delta connection can supply a three-phase load.

In a Wye connection, there are three phases and a Neutral. An output Wye connection enables the transformer to supply a three-phase voltage (say 3x400 Vac) and also a voltage for single-phase loads, namely the voltage between any phase and Neutral (in this example 230 Vac). The Neutral point can also be grounded to provide greater safety.

When circumstances permit, most industry professionals prefer to use the Delta input Wye output connection for connecting a 3-phase transformer connection in power distribution applications.

If the transformer secondary supplies large amounts of unbalanced loads, the delta primary winding provides a better current balance for the primary source.

The Delta-Wye connection is used to create a common output neutral, when no such neutral exists in the line. This type of connection also suppresses noise from the line to the secondary.
Figure 3: Three primary windings in Delta and three secondary windings in Wye
2. **GAMATRONIC’S ISOLATION TRANSFORMERS**

### 2.1 Features

- Gamatronic offers a wide selection of 3-phase isolation transformers. Standard models are available in a range from 6 to 150 kVA, larger and smaller units are available on request.

- On customer request, Gamatronic can supply transformers capable of accepting a range of input voltages and supplying any one of multiple output voltages: for example, 200 / 220 / 240 Vac. The voltage setting is modified by a switch or by a simple rewiring performed by the customer.

- Standard input and output voltages for the isolation transformers are 3x400 Vac, 50 Hz. Other voltages and frequencies are available on request.

- When appropriate, the transformers are equipped with one or more fans for cooling.

- Temperature sensors for each phase of the transformer are available as an option. In the event that one or more sensors detect a temperature over a specific threshold, the transformer automatically disconnects from the input supply.

- Gamatronic's isolation transformers are usually housed in a metal cabinet. The transformer's input and output terminals are protected from operator access during normal operation. The cabinet includes a protective earth connection.

- Optionally, the cabinet includes four rubber wheels. The two front wheels have stoppers which, when deployed, prevent the cabinet from rolling.
2.2 Two examples of typical isolation transformers

Figure 4 and Figure 5 are generalized examples of typical isolation transformers.

Figure 4: Generalized transformer schematic, Delta-Wye configuration
Figure 5: Generalized transformer schematic, Wye-Wye configuration
2.3 Installation instructions

To install a Gamatronic 3/3 Delta-Wye or Wye-Wye isolation transformer.

1. Verify that the circuit breaker on the feed board for the transformer input line is rated for at least 10 \times I_{nominal}, to eliminate the influence of current transients.

2. Ensure that the feed cables are voltage free before beginning installation and that the feed circuit breaker will remain in the OFF position.

3. Verify that the transformer's input circuit breaker is in the OFF position.

4. Connect the transformer's input ground cable to the building ground system.

5. Connect the input line from the feed board to the transformer's input terminals.

6. Connect the transformer's output phases to the load, including the ground terminal.

7. Switch ON the transformer circuit breaker(s).
3. **TECHNICAL SPECIFICATIONS**

15–250 kVA Isolation Transformers, 3x400 Vac, 50 Hz

*Table 1: Gamatronic’s transformers: general specifications *

<table>
<thead>
<tr>
<th><strong>GENERAL SPECIFICATIONS</strong></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Power capability</td>
<td>15 to 250 kVA. Higher on request.</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC 60076</td>
</tr>
<tr>
<td></td>
<td>IEC 61558-1, class I</td>
</tr>
<tr>
<td>Enclosure protection classification</td>
<td>IP20. Higher on request.</td>
</tr>
<tr>
<td>Terminals</td>
<td>Screw or stud. Flying leads on request.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>INPUT / OUTPUT</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage ¹</td>
<td>3x400 Vac</td>
</tr>
<tr>
<td>Frequency ¹</td>
<td>50 Hz.</td>
</tr>
<tr>
<td>Connection types ²</td>
<td>Wye-Wye</td>
</tr>
</tbody>
</table>

* All specifications subject to change without notice.

Notes:
1. Additional input and output voltages and frequencies available.
2. Other topologies also available; e.g., Delta-Wye, Delta-Delta.
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Table 2: Technical specifications for transformers of various sizes *

<table>
<thead>
<tr>
<th>NOMINAL TRANSFORMER POWER (kVA)</th>
<th>6</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>150</th>
<th>250</th>
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<tbody>
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<td>Efficiency (%)</td>
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<td>96.85</td>
<td>97.21</td>
<td>97.3</td>
<td>97.5</td>
<td>97.82</td>
<td>97.85</td>
<td>97.98</td>
<td>98.02</td>
<td>98.2</td>
<td>98.29</td>
<td>98.38</td>
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<td>Iron type</td>
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<td>EI 300</td>
<td>EI 300</td>
<td>EI 400</td>
<td>EI 400</td>
<td>EI 400</td>
<td>EI 500</td>
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<tr>
<td>Winding**</td>
<td>AL</td>
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<td>AL</td>
<td>AL</td>
<td>AL</td>
<td>AL</td>
<td>AL</td>
<td>AL</td>
<td>AL</td>
<td>Cu</td>
<td>Cu</td>
<td></td>
</tr>
<tr>
<td>Cabinet height (mm)</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>500</td>
<td>600</td>
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<td>Cabinet depth (mm)</td>
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<td>350</td>
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<td>400</td>
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<tr>
<td>Transformer net weight (kg)</td>
<td>45.4</td>
<td>72.7</td>
<td>92.4</td>
<td>101.7</td>
<td>128.9</td>
<td>185.1</td>
<td>198.1</td>
<td>231</td>
<td>261.2</td>
<td>384.4</td>
<td>410.1</td>
<td>568.2</td>
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</table>

* The data in this table are for reference only. The actual data may vary, depending on system configuration.

** AL stands for aluminum winding wire.

Cu stands for copper winding wire.