
APPLICATION NOTE
ISOLATION TRANSFORMERS

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


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SUMMARY

Transformers can do more than transferring electrical energy from one voltage to another. Separation transformers, isolation transformers, and extra isolation transformers play a major role in the protection of people and equipment.

They come in different types and power ranges, from a few VA to a few MVA. Although they are generally more expensive than autotransformers or transformers with conventionally separated windings, they can be very useful in many ways, for example:

-  To protect individuals against electrical shock
-  To avoid losing power after a first insulation fault
-  To protect sensitive equipment from electrical noise
-  To create a star point for equipment

This application note discusses the working principles of isolation transformers, their advantages, and their various application domains.

INTRODUCTION

A transformer is an electrical device that transfers electrical energy from one circuit to another using induction. A current in the primary windings creates a varying magnetic flux in the transformer's core and thus creates a varying magnetic field in the secondary windings. Apart from some special cases, there is no connection between the input (the primary windings) and the output (the secondary windings).

In many cases, the property of transferring electrical energy will be used to obtain a higher or lower level of voltage.

The induced voltage in the secondary windings is in direct proportion to the primary voltage and is determined 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:
$$U_s/U_p = n_s / n_p$$

Electrical transformers can be configured as single-phase or three-phase; oil-filled or dry type devices. They are used for many different applications, including control, distribution, instrumentation, current transformation and power transformation among others. There are also many different mounting possibilities.

The special case where there is a connection between primary and secondary windings is called an autotransformer. There is only one winding, and a part of this winding is common to both the primary and the secondary circuits.

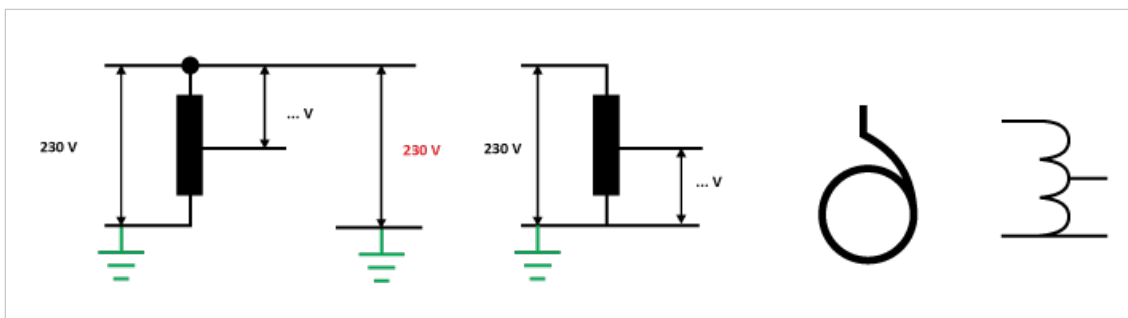


Figure 1 – Autotransformer

The autotransformer will generally be used as a voltage conversion of the local supply to another voltage value that is required for a particular piece of equipment (step-up or step-down).

Although there are some benefits in the use of an autotransformer, it is obvious that there are also many drawbacks. A major one is the fact that there is no isolation for disturbances or interferences coming from the primary.

ISOLATION TRANSFORMERS

Usually electrical transformers are used to transform voltage from a higher level to a lower voltage or vice versa. They do little to attenuate the passage of noise or transients from the primary to the secondary.

Transformers can also be used to change the impedance of the electrical circuit to reduce the short-circuit current or to provide a galvanic insulation between two systems.

In theory, the definition of 'isolation transformer' applies to any transformer where there is no direct connection between the primary and the secondary windings. In other words: all transformers which are not autotransformers. The windings are connected only by the magnetic flux in the core.

Nevertheless, when there is only a basic separation between the primary and secondary windings, we will speak of a separation transformer.

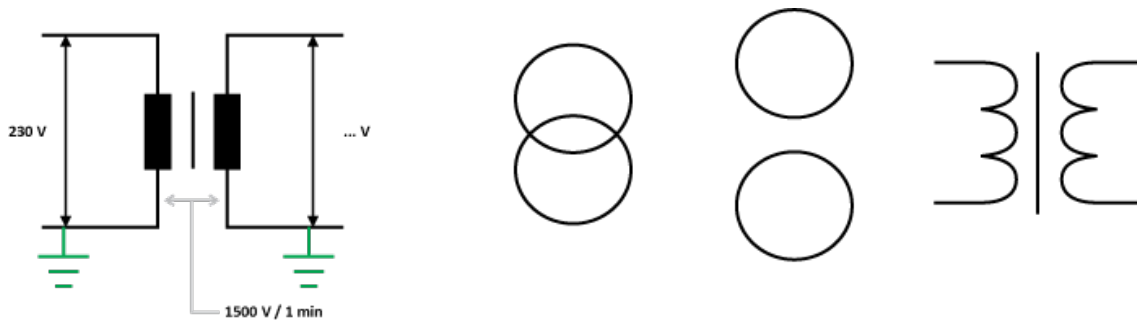


Figure 2 – Separation transformer

The insulation between the primary and the secondary windings provides a degree of protection against electric shock that is equivalent to a basic insulation.

Reminder: basic insulation is the insulation required for ensuring the appropriate operation of the equipment and of the electrical installations and for the fundamental protection against electric shock.

This separation will limit the risk in the event of accidental simultaneous contact with the exposed conductive part and the live parts (or metals parts that can become live in the event of an insulation fault).

Taking the insulation between the primary and the secondary windings a step further, we get to the isolation transformers.

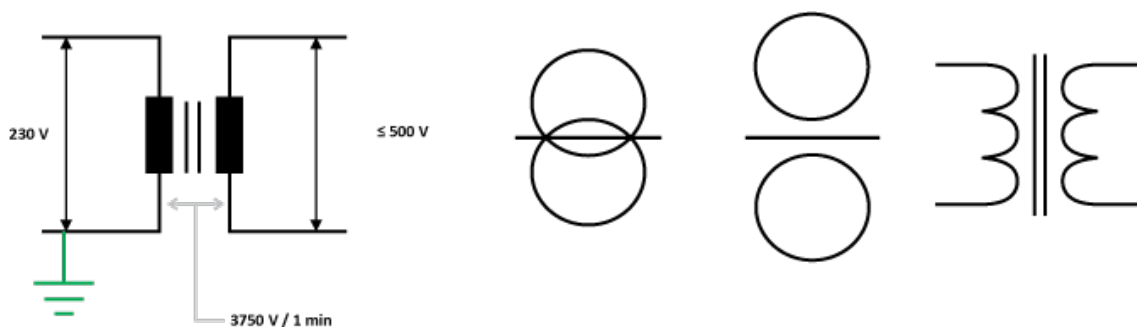


Figure 3 – Isolation transformer

The insulation between the primary and the secondary windings provides a degree of protection against electric shock equivalent to that of double insulation.

This separation will limit the risk in the event of accidental simultaneous contact with the exposed conductive part and the live parts (or metals parts that can become live in the event of an insulation fault).

Reminder: double insulation is the insulation in which provision is made for separate supplementary insulation in addition to basic insulation. It is determined by type tests.

When the no-load secondary voltage of the isolation transformer is limited to U_L , where U_L is the Safety Extra Low Voltage (SELV) Limit, then we have a 'safety transformer.'

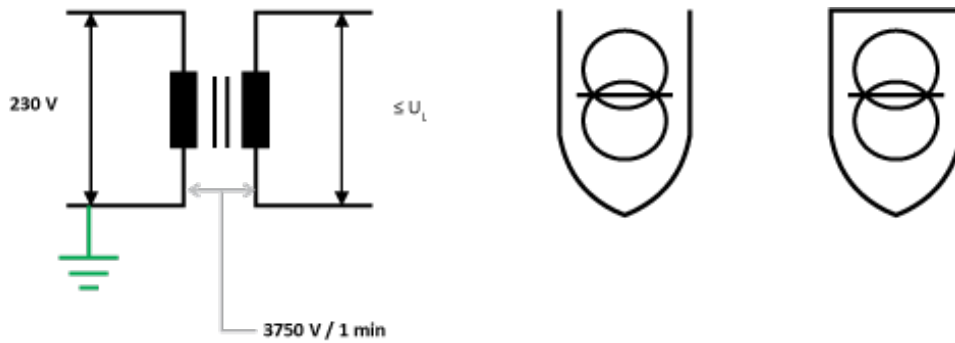


Figure 4 – Safety transformers

ADVANTAGES OF ISOLATION TRANSFORMERS

Isolation transformers can be used to protect people against the dangers of electric shocks. Isolation transformers can block transmission of DC signals from one circuit to the other, but allow AC signals to pass. They will also block interference caused by ground loops. Isolation transformers with electrostatic shields are used for power supplies for sensitive equipment such as medical equipment, computers or precision laboratory measurement instruments.

There are two ways to introduce the equivalent of double isolation:

- E0
E1
 By putting a metallic safety shield (usually copper) between the primary and secondary windings and connecting it to the ground (protective earth). This can also be another winding or a metal strip surrounding a winding. If the isolation breaks, the electricity flows to the ground, providing the required safety. The shield will attenuate or filter voltage spikes and will greatly reduce the coupling of common-mode noise by decreasing the capacitive coupling.
- E0
E1
 By using reinforced insulation. This type of insulation is made up of multiple layers. All layers must pass tests required by established standards. If one layer breaks, the next layer provides the required safety.

Normally, these transformers have a lower leakage current than those that use a shield.

Electrical noise:

Common mode: between ground and the current carrying conductors, including the neutral

Normal mode: between two current carrying conductors, including line to neutral

Isolation transformers will mostly be used in a one-to-one ratio (the primary voltage rating equals the rated secondary voltage value). The two windings will have the same number of turns. There might be a slight difference in the number of turns to compensate for voltage drops; otherwise, the secondary voltage would be slightly less than the primary voltage.

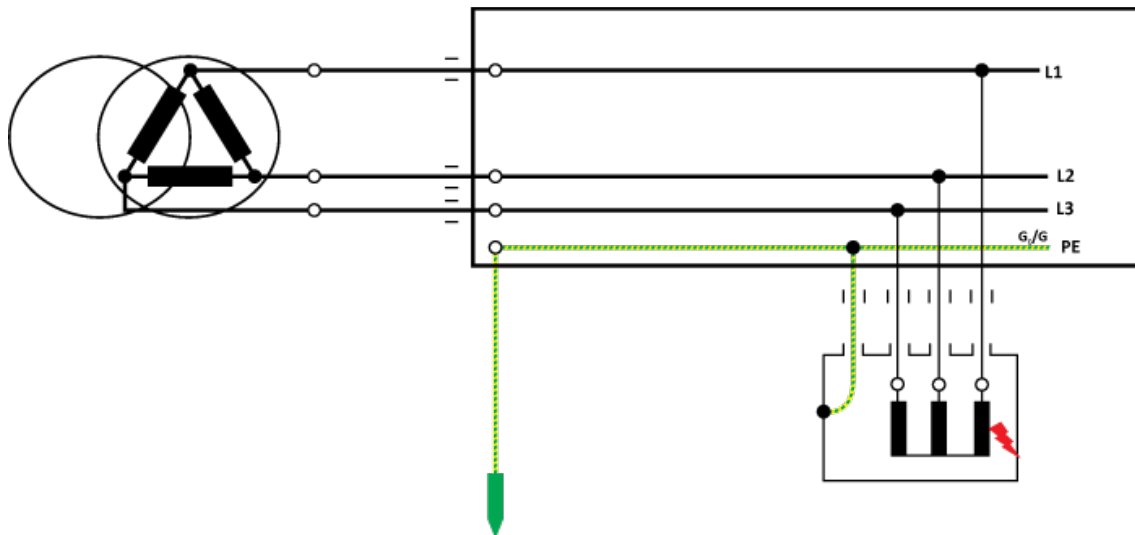
APPLICATIONS

Let us look at a few cases where the use of an isolation transformer is a possibility or even recommended

Isolation transformers will be mainly used to protect people from electric shock and as a power supply for sensitive equipment (computers, medical equipment, laboratory equipment, et cetera).

Isolation transformers are often used to isolate the machine or equipment from the rest of the electrical installation, to **avoid loss of power** in the case of a first insulation fault.

Since there is no return path to the source (the secondary winding of the transformer), in the event of a fault, there will be no fault current flowing and no overcurrent protective device will cut off the supply. Apart from being harmless to persons touching the conductive parts, a first fault will not cause any danger but will also not cut off the supply.



Another application of the isolation transformer is to create a star point in grids that do not have such a point.

Quite a few applications need the neutral point for controlling purposes. When installing such a machine in a grid without star point, the obvious remedy is to install an isolating transformer.

HUMAN SAFETY—PREVENTION OF ELECTRICAL SHOCK

The normal use for isolation transformers is to produce a zone of supply that has no reference to earth. The majority of electric shocks are those involving contact with a live conductor while standing on, or touching an earthed surface.

PROTECTION BY SAFETY ISOLATION OF CIRCUITS

The electrical isolation of circuits is intended to avoid electric shock that may result from contact with exposed conductive parts liable to be made live in the event of a fault in the basic insulation of the live parts of this circuit.

The circuit is supplied by means of a Class II isolation transformer.

The rated voltage of the secondary circuit of the isolating transformers is not more than 500 V.

The circuit supplied in this way does not have any common point with another circuit nor any point connected to earth.

The range of the load circuit is such that the product of the voltage by the length of the wiring systems is not more than 100,000 volt metres and that the total length of the circuit does not exceed 500 metres.

The exposed conductive parts of electrical machines and appliances used in the circuit are intentionally not connected with earth, or with the exposed conductive parts of machines and appliances supplied by other types of circuits.

If several electrical machines or appliances are connected to the same circuit, their exposed conductive parts are connected to a protective conductor that is not connected to earth.





When the circuit supplies socket outlets, these incorporate a protective contact. These contacts with the different sockets are arranged so that the exposed conductive parts are at the same potential, connected to each other and to the exposed conductive part of any generator, without being earthed.

In flexible cables, the protective cover that is used as a bonding conductor is inside the same sheath as the live conductors.



ELECTRICAL SEPARATION

Part 4-41 of IEC 60364 'Low voltage installations — Protection against electric shock' specifies essential requirements regarding protection against electric shock, including basic protection (protection against direct contact) and fault protection (protection against indirect contact) of persons and livestock.

The following protective measures are generally permitted:






-  Automatic disconnection of supply
-  Double or reinforced insulation
-  Electrical separation for the supply of one item of current-using equipment
-  Extra-low-voltage (SELV and PELV)

Electrical separation is a protective measure in which:



-  **Basic protection** is provided by basic insulation of live parts or by barriers and enclosures, and
-  **Fault protection** is provided by simple separation of the separated circuit from other circuits and from earth

Normally, this protective measure shall be limited to the supply of one item of current-using equipment supplied from one unearthed source with simple separation.

Where more than one item of current-using equipment is supplied, the following requirements shall be met:

-  The exposed-conductive-parts of the separated circuit shall be connected together by insulated, non-earthed equipotential bonding conductors. Such conductors shall not be connected to the protective conductors or exposed-conductive-parts of other circuits or to any extraneous-conductive-parts.
-  All socket-outlets shall be provided with protective contacts which shall be connected to the equipotential bonding system.
-  Except where supplying equipment with double or reinforced insulation, all flexible cables shall embody a protective conductor for use as an equipotential bonding conductor.
-  It shall be ensured that if two faults affecting two exposed-conductive-parts occur and these are fed by conductors of different polarity, a protective device shall disconnect the supply.
-  It is recommended that the product of the nominal voltage of the circuit and length of the wiring system should not exceed 100,000 Vm, and that the length of the wiring system should not exceed 500 metres.

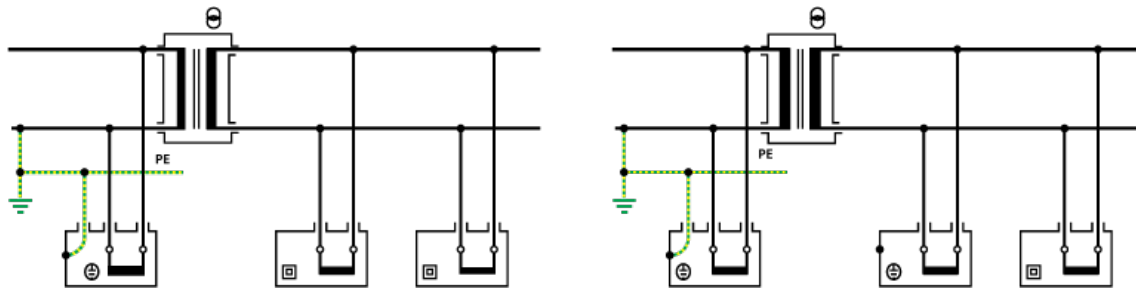
Requirements for fault protection:

-  The separated circuit shall be supplied through a source with at least simple separation, and the voltage of the separated circuit shall not exceed 500 V.
-  Live parts of the separated circuit shall not be connected at any point to another circuit or to earth or to a protective conductor.

- PO B1** To ensure electrical separation, arrangements shall be such that basic insulation is achieved between circuits.
- PO B1** The parts of flexible cables and cords liable to mechanical damage shall be visible throughout any part of their length.

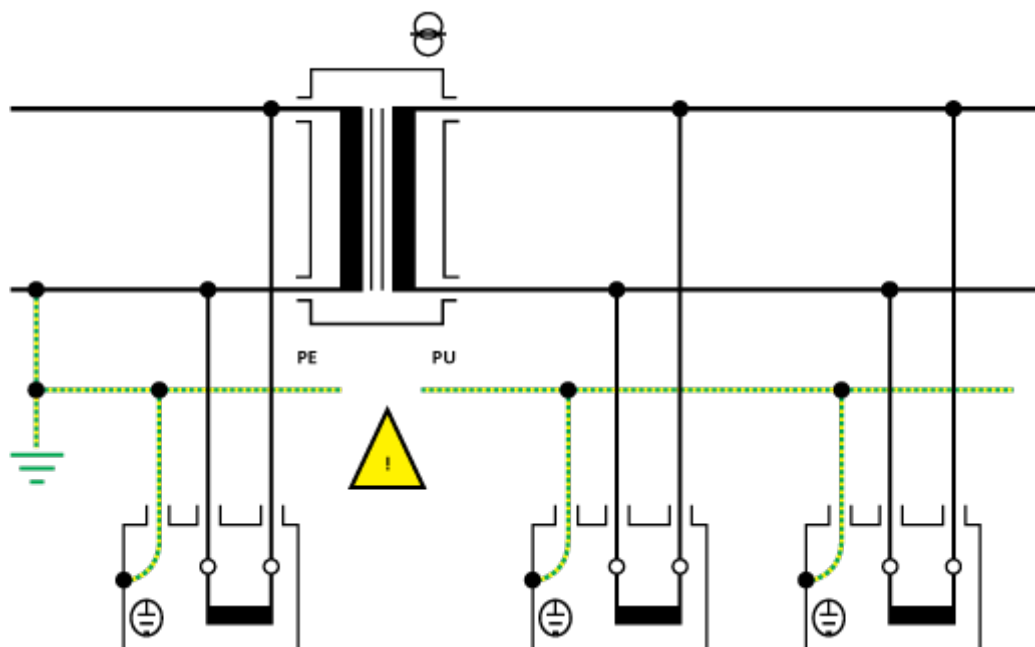
The protection by electrical separation or safety isolation can be very useful for the supply of portable and handheld equipment.

The secondary of the isolating transformer will be floating. The current leakage path to ground is eliminated, which helps eliminate the shock hazard.



When there is an insulation fault in a Class I machine or appliance, a person touching the enclosure under tension, (even touching a live wire), will not be subjected to a shock as there is no current path back to the transformer.



When using more than one Class 1 machine or piece of equipment, an unearthed equipotential bonding should be established. This is a means of avoiding the risk of harmful pathophysiological effects on a person in contact with simultaneously accessible exposed conductive parts in the event of two faults existing simultaneously.



MEDICAL TRANSFORMERS

For the safety of the patient in hospitals, all diagnostic or therapeutic medical equipment (medical electrical devices and non-medical electrical devices in the patient's environment and/or areas for medical use) should be completely isolated from the supply line (double and strengthened isolation). Complete patient/operator safety is assured by medical isolation transformers with very low leakage current. (IEC 60601-Medical electrical equipment; IEC 61558-2-15 'Safety of Power Transformers, Power Supply Units and Similar - Part 2-15: Particular Requirements for Isolating Transformers for the Supply of Medical Locations'.)

Medical transformers are designed:

-  To isolate the patient and/or the operator from an electric shock
-  To protect the equipment from power surges or faulty components (see below)

Isolating transformers are used to provide a safer patient environment by minimizing the potential hazards caused by touch voltages and by ensuring that under single fault conditions there is still continuity of supply.

The output of the isolating transformer is not connected to earth and so provides better protection from potentially lethal shock hazards by removing the low impedance earth return path.

It should be noted that isolating transformers alone are not intended to protect against micro-shock and must be used in conjunction with circuit integrity monitoring devices and equipotential earth bonding.

Toroidal transformers are ideal for the use in a medical environment because they are compact, can be completely encapsulated, have low stray-fields and are therefore less likely to cause radiated electromagnetic disturbances.

A monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed-conductive-parts or to earth. This device shall initiate an audible and/or visual signal that shall continue as long as the fault persists.

If there are both audible and visible signals, it is permissible for the audible signal to be cancelled. Nevertheless, the visual alarm shall continue as long as the fault persists.

It is recommended that a first fault be eliminated with the shortest practicable delay.

PROTECTION OF SENSITIVE EQUIPMENT

Many appliances induce high levels of interference back into their power supply. If the equipment must be protected from this noise, isolation transformers can be used for their supply.

Extra isolating transformers are an advanced version of the isolation transformer with a different construction method and a different method of shielding.

They will have less capacitance coupling and more noise attenuation.

They are effective for isolating sensitive equipment from any kind of power disturbance, from voltage transients, from spikes, from DC leakage, from shocks, et cetera.





They will be used for the supply of sensitive equipment like computers, medical instrumentation, digital communication systems, laboratory instruments, CNC machines, audio and video recording equipment, supply of variable-frequency (variable speed) motor drives, et cetera.

Secondary neutral to ground bonding virtually eliminates common mode noise, providing an isolated neutral-ground reference for sensitive equipment.

If there is multiple shielding used, it can reduce the interwinding capacitance to below 0.005 pico-farad and increase DC isolation to over 1,000 Mega-ohm.






It acts as an efficient low pass filter and suppresses line transients, spikes, and galvanic leakage to protect sensitive equipment.

Advantages:

-  High noise attenuation level even in high frequency application
-  Reduced coupling capacitance
-  Suitable for higher harmonic area installation
-  Longer life of the transformer because of less heat dissipation

CONSTRUCTION—CORES

The most common transformer is the laminated type. However, the more expensive toroidal type has many advantages:





-  Smaller in size for a given power level
-  More efficient than the laminated types, particularly at partial load and under no-load conditions
-  Lower weight
-  Lower external magnetic field
-  No audible noise

Apart from the price, there is another drawback: they are limited in power capacity, they have a higher inrush current, and they are less robust.




CONCLUSION

We have seen that transformers can be more than just static devices that transfer electrical energy. Separation transformers, isolation and extra isolation transformers play a major role in the protection of people and equipment.

They come in all ranges, from very small (a few VA) to quite large (a few MVA), and although more expensive than autotransformers or transformers with simple separate windings, they are an easy way to solve problems that could arise concerning:

-  Protecting individuals from electrical shock
-  Avoiding losing power in the case of a first insulation fault
-  Protecting sensitive equipment from electrical noise
-  Creating a star point for equipment that require it

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