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Transformer Basics Information Guide



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520 Furnace Dock Road . Cortlandt Manor, New York 10567 . Phone: (914)788-8877 Fax: (914)788-8866

Created By: Jim Herrick / Michael Shaw

Approved By: Peter Herrmann



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Transformer Definition

An electric device consisting essentially of two or more windings, wound on a common core, which by electromagnetic induction transfers electric energy from one set of windings (primary) to another set of windings (secondary). In addition to the “basic” transformer design, there are other specialty configurations, such as, Buck/Boost, which are described in Types & Uses.

While the voltage and current usually change (from primary to secondary), the frequency of the energy remains unchanged.

Transformers only work on alternating current (not direct current).

The voltage change is determined by the ratio of turns of wire around the core, between the primary and secondary windings.

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1. Normal Types & Uses

Isolation only

Does not change voltage. It does, however, provide isolation from the facilities electrical system, which eliminates much of the buildings electrical “noise” on the output.

Step down

Changes a higher voltage to a lower voltage, such as 480V to 208V, and provides isolation.

Step up

Changes a lower voltage to a higher voltage, such as 240V to 480V, and provides isolation.

Note: In most cases the transformers (describe above) that provide isolation also incorporate a grounded “Faraday Shield”, between the primary and secondary windings, to reduce the transmittance of high frequency “noise”. Although shielding is generally included, it should be specified.

Buck/Boost

Normally used when only a small change in voltage is required (20% or less), such as 208V to 240V (Boost) or 240V to 208V (Buck). This type system does not provide isolation, but is more cost effective if isolation is not required. A Buck/Boost transformer is also referred to as an “Auto Transformer”. On an “Isolation transformer” there is no direct electrical connection between the primary and secondary (Only magnetic / inductive), such is not the case with a Buck/Boost unit, therefore there is no isolation.

2. Multiple Taps

In order to accommodate various input voltages, some transformers may be equipped with multiple taps on the primary. These taps are sized for standard voltages (220, 230, 240....etc.), or they can be only slight variations to adjust for consistent over or under voltage at a particular location. These taps are most commonly provided as a percentage of the primary voltage, such as 2-1/2% and 5% (up or down from nominal).

(Primary Voltage/Tap Voltage Setting) X Expected Secondary Voltage = Actual Output Voltage

For Example: Given a 480V to 208V Delta > Wye, with an input voltage of 460V and a tap set for 480V would yield: $(460/480) \times 208 = 199.33V$. In order to yield 208V this tap setting would be insufficient. You would have to use a tap setting that was lower, such as 456V.

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3. Reverse Connected

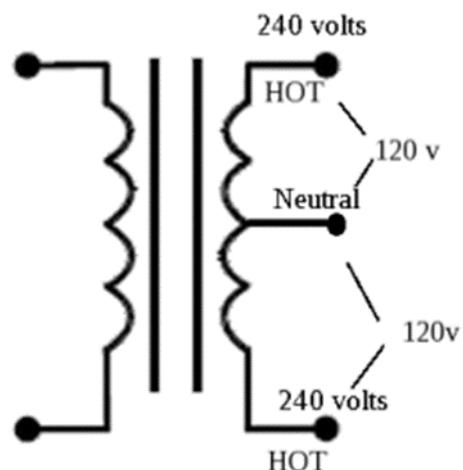
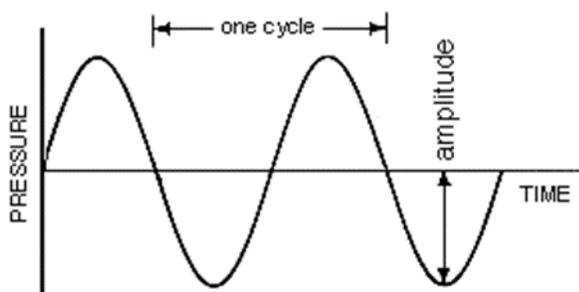
Most transformers can be “reverse connected” which means the same transformer can be wired to be a “step-up” or “step-down, depending on how it’s installed. This reversing capability must be allowed and specified by the manufacturer.

 If a transformer connection is rearranged from step up to step down or step down to step up, careful attention must be paid to the neutral/ground bonding which can only be on the output side of the transformer.

4. Metering

Although not absolutely required, it is recommended that an integral meter panel be installed in, or adjacent to, the transformer enclosure. This will allow constant monitoring of system performance, and let you know if the required voltage is present and that the system is not being overloaded.

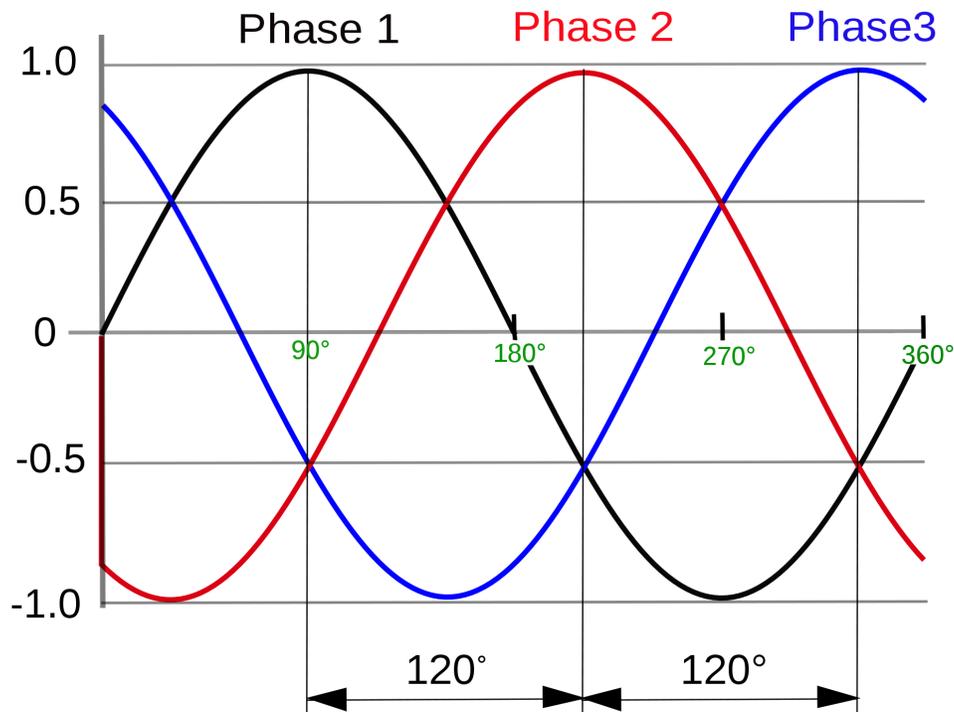
5. Single Phase



A transformer that is fed, on the primary winding, by a single alternating voltage, which can be represented by a single sine wave. The secondary winding can be “split” or “tapped”, to produce multiple voltages, such as, 120/240V.



6. Three Phase



A transformer that is fed, on the primary windings, by three equal alternating voltages, the timing of which are 120 degrees “out of phase” with each other. A typical application would be 480V input with 120/208V output, where the grounded conductor (neutral) on the 120V output is common with all three lines (Phases).

A three phase transformer can be constructed either by connecting together three single-phase transformers, thereby forming a so-called three phase transformer bank, or by using one pre-assembled, three phase transformer which consists of three pairs of single phase windings mounted onto one single laminated core.

The advantages of building a single three phase transformer is that for the same kVA rating it will be smaller, less expensive, and lighter than three individual single phase transformers connected together because the copper and iron core are used more effectively.

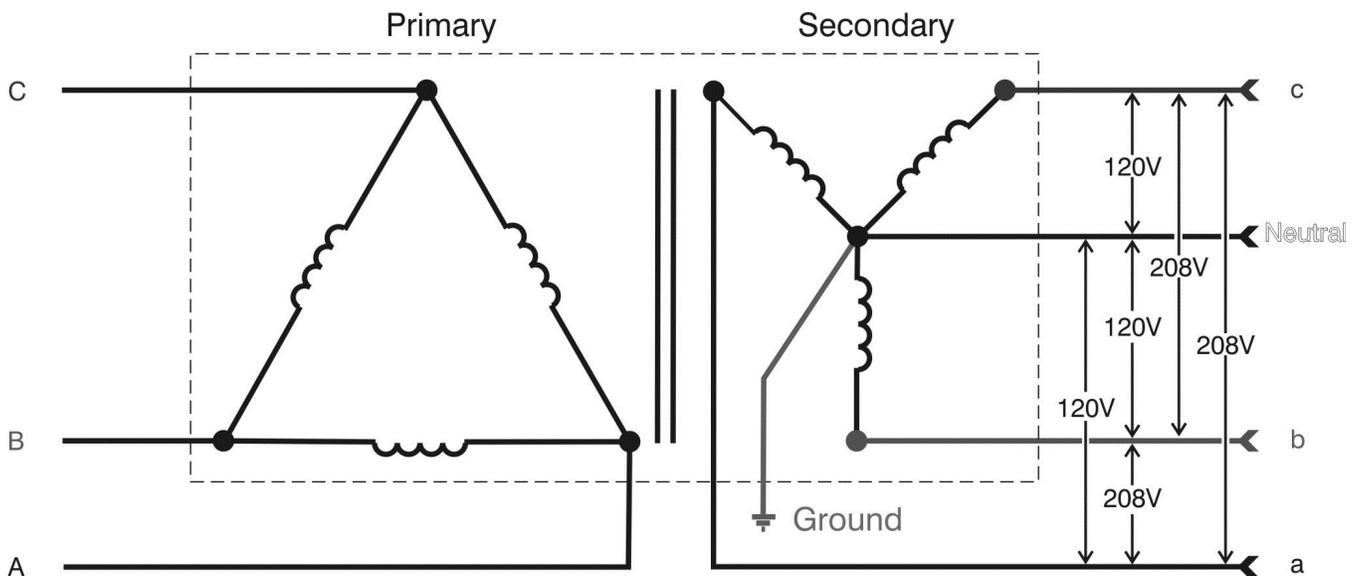


7. Delta / Wye (3-Phase)

There are two types of circuits used to maintain equal load across the three hot wires in a 3-phase system—Delta and Wye. The Delta configuration has the three phases connected like a triangle, whereas the Wye (or “star”) configuration has all three loads connected at a single neutral point. In most cases Delta systems have four wires—three hot and one ground. Wye systems have five wires—three hot, one neutral and one ground. While both Delta and Wye systems can measure 208VAC (on the secondary) between any two hot wires, Wye systems also measure 120VAC between any hot wire and neutral. In other words, it’s the neutral wire of the Wye system that provides two different voltages for powering both 3-phase (208V) and single-phase (120V) devices.

Types

The most common 3-phase configuration is: Delta > Wye, (Depicted below),





7. Delta / Wye (3-Phase) (Continued...)

In addition, there are other configurations available, such as:

Delta > Delta, used when a neutral is generally not required on the secondary. If a secondary neutral is provided, it is termed a “High Leg” system, since one of the legs (referenced to ground), would be in excess of 200V. It is not recommended that a neutral be provided with a Delta secondary, since the “High Leg” can cause equipment damage if not connected properly.

Wye > Wye, in this case a neutral is not required on the primary, however this is a more expensive configuration, without any benefit other than being able to rearrange input and output. (As described in Section 3)

Wye > Delta, This configuration is not recommended, due to its instability with unbalanced loads and it contributes to additional harmonic content.

8. Hertz (Hz)

Also termed “Cycles per Second” or “Frequency”. With relation to sine waves, it’s the time it takes for one complete cycle. In North America the frequency is 60Hz, in most of Europe it’s 50Hz.

Transformers must be specified at which frequency they will be used.

A transformer that is rated at 50Hz will also operate at 60Hz, however the inverse is not true:

A 60Hz rated transformer cannot operate at 50Hz, unless de-rated at least 20% to allow for excessive heating effects.



This is **NOT** recommended and these applications require a transformer rated for 50hz/60hz.

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9. International Considerations

Different countries have different standard voltages depending on the location. In most of Europe the standard voltages include 380V & 415V, but this may vary considerably. It is difficult, if not impossible, to get a transformer with all the possible voltages you may encounter, and additionally more difficult to get one that has both North American and European voltages on the same transformer.

In some cases a “custom wound” transformer can be manufactured, but it is generally cost prohibitive.

10. What Transformers **Can't** Do

Correct Voltage Fluctuations: Transformers are “proportional” devices. The input / output ratio remains the same regardless of the variations in input voltage. As an example: a 2:1 ratio transformer with a 240V primary, will produce 120V on the secondary. If the primary voltage is changed to 250V, the secondary voltage would be 125V.

Change Frequency: Whatever frequency is on the primary will appear on the secondary.

Produce More “Power”: In simple terms, power is defined as “WATTS”. Watts are Volts X Amps. In this case, Volts and Amps are “inversely proportional”, which means if you gain Volts you’re going to lose Amps; if you gain Amps you’re going to lose Volts. As an example:

With a secondary of 100A @240V, the required primary amperage would be 200A @ 120V.

No power (Watts) was gained: $100A \times 240V = 24,000W$ [same as] $200A \times 120V = 24,000W$.



10. What Transformers **Can't** Do (Continued...)

Change single phase to 3-phase: A Single phase transformer primary can be supplied by 2 of the line conductors, of a 3-phase system, however the output (secondary) will be single phase.

3-phase outputs require 3-phase inputs.

11. KVA

To put it simply, VA (Volt Amps) is directly related to Watts. 1 KVA is equal to 1000VA. In most cases transformers are rated in KVA, This is one of the most important parts of the transformer specification.

KVA is determined by the connected load of your equipment. The primary KVA and the secondary KVA are exactly the same. As an example:

100A @ 120V = 12,000VA or 12KVA [same as] 50A @ 240V = 12,000VA or 12KVA.

KVA calculations for 3-Phase transformers is not quite as simple, and will be explained in section 15.

12. Separately Derived Neutral / Ground Bond

One of the important functions of an isolation transformer is that it establishes a new neutral / ground bond point.

This is referred to as a “Separately Derived System”. There are only two places that a neutral and ground are permitted to be connected together, (1) In the main service panel and (2) at the source of a separately derived system. This new bond eliminates any “noise” on the neutral, ground, and to some extent the line conductors, from entering the power provided by the transformer and subsequently getting into equipment connected to the secondary of the transformer.



13. Overload (Over-Current) Protection

Primary: Overload protection or Circuit Breaker (CB) is always required. It may be sized no less than 100% of the current draw on the primary and no more than 125%, unless there is overload protection on the secondary. If such is the case, the primary CB may be increased up to 250%.

For Example: If there were a overload protected 400A feeder on the input side (primary) connected to a 100A rated transformer primary, a primary CB would be required in the transformer, since this arrangement could “possibly” feed this 100A transformer with 400A. This would be 400%, exceeding the 250% maximum allowed. If however, a transformer had a 200A rated primary, the primary CB would not be required, since the 250% would not be exceeded.

Secondary: Overload protection is not always required, however, if the primary CB is sized more than 125%, then secondary protection is required, sized no more than 125% of the maximum secondary capacity. Secondary protection can take the form of several (no more than 6) CBs, as long as the total amperage of all the CBs (added together) does not exceed 125% of the secondary capacity.

Location: The primary and/or secondary overload protection does not have to be in a common enclosure with the transformer. As a typical example, a “house breaker” can serve as primary protection, as long as the percentages, described above, are followed and the primary disconnect is within 50 feet & in sight of the transformer location or the disconnect is lockable.

Note: On **Portable Systems** If you are unsure of what you’re going to encounter in the field, it is advisable to purchase a transformer system with primary and secondary protection, mounted in the transformer enclosure. In most cases the additional cost is justified.



Conductors: The above overload protection requirements apply to transformers only, and not to the conductors that feed the transformer, or conductors going out to the load circuits. Requirements for the protection of conductors are not covered in this document.





14. Load Balancing

When connecting load equipment, on the secondary of a transformer, it is best to “balance” the total load among the individual phases. You most likely cannot balance loads exactly, however, balanced (or nearly balanced) loads help prevent over-heating and reduces electrical stress on the transformer. It is possible to overload individual phases without exceeding to the total KVA capacity of the transformer.

15. Sizing a Transformer

From an “end users” point of view, the following information is required before starting any calculations:

1. Is the system single or 3-phase?
2. What is the frequency (Hz)?
3. What is the voltage (line to line, not line to neutral) of the “house power” (primary)?
4. What voltage is required for your load equipment (secondary)?
5. What is the maximum total load (Amps) of your connected equipment (secondary)?

With the above information, the KVA of the transformer can be calculated (below).



15. Sizing a Transformer (Continued...)

IMPORTANT NOTES: The Volts and Amps, used in the calculations below, can be either the Primary **OR** the Secondary, but not both (Don't mix them). Remember, The KVA is the same in the Primary and the Secondary. The "Volts" are the Line to Line, **NOT** the Line to Neutral.

Single Phase Calculations:

$$\text{Volts X Amps} / 1000 = \text{KVA}$$

Example:

$$208\text{V X } 100\text{A} = 20,800\text{VA} / 1000 = 20.8\text{KVA.}$$

Three Phase Calculations:

$$\text{Volts X Amps X } 1.73 / 1000 = \text{KVA}$$

Example:

$$208\text{V X } 100\text{A X } 1.73 = 35,984\text{VA} / 1000 = 35.984\text{KVA}$$

After determining the KVA, select a "standard" size transformer that is no less than the KVA required.



NOTES