

BUCK BOOST TRANSFORMERS

INTRODUCTION

Buck-boost transformers are small, dry-type transformers used to increase or decrease voltage from 5% to 20%. Typically, a buck-boost transformer serves a specific load that requires a different voltage than the facility distribution system voltage. Buck boost transformers are configured as two types: either isolation type or autotransformer type. Each type is discussed below.

ISOLATION TRANSFORMER

Isolation transformers are constructed and connected such that the primary and secondary windings are both physically and electrically unconnected or isolated. Rather, the primary and secondary windings are magnetically coupled. The primary winding magnetically induces voltage in the secondary winding. Figure 1 is a schematic diagram of an isolation transformer.

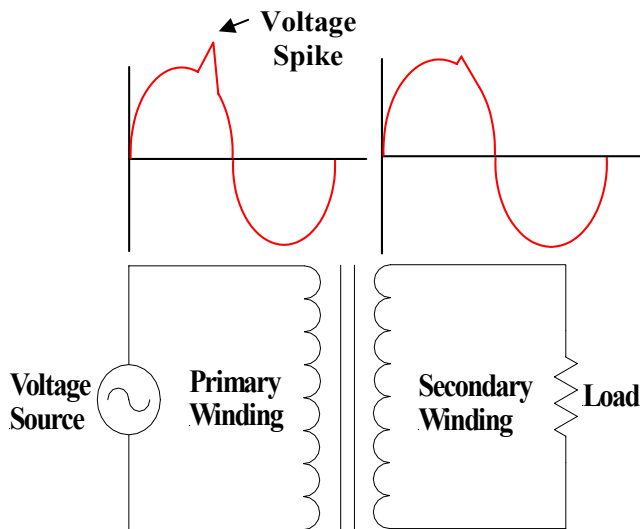


FIGURE 1 - Isolation Transformer

Isolation between the line (primary winding) and the load (secondary winding) often is wanted. Because there is no electrical connection between the line and load, the transformer acts as a filter. Therefore, voltage spikes and other transient disturbances originating on one side of the transformer (load or line) are greatly reduced before transferring to the opposite side.

AUTOTRANSFORMER

An autotransformer is a self-induced transformer. Meaning, a single winding is used as both the primary and the secondary. Figure 2 show a schematic diagram of an autotransformer. Note that both the primary and the secondary windings are the same. The voltage is changed depending on where the connection is made.

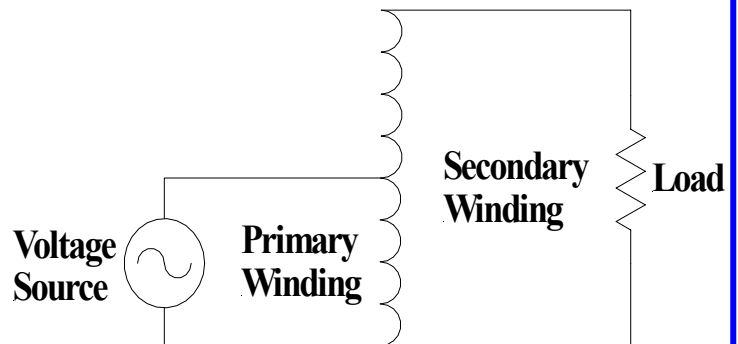


FIGURE 2 - Step-Up Autotransformer

Autotransformers have several advantages over isolation transformers. First, autotransformers are highly efficient, typically in the range of 95% to 98%. Isolation transformers are less efficient because the primary winding is separate from the secondary winding therefore more magnetizing energy is required to induce electricity. Second, auto-

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transformers contain only one winding thereby reducing the cost.

The disadvantage of autotransformers is the inability to buffer the voltage spikes across the transformer. A voltage spike occurring on the primary will be transferred to the secondary at nearly the full magnitude.

In addition, autotransformers are either step-up (boost) or step-down (buck). Figure 3 is schematic diagram of a step-down autotransformer. Note the secondary winding has fewer windings than the primary.

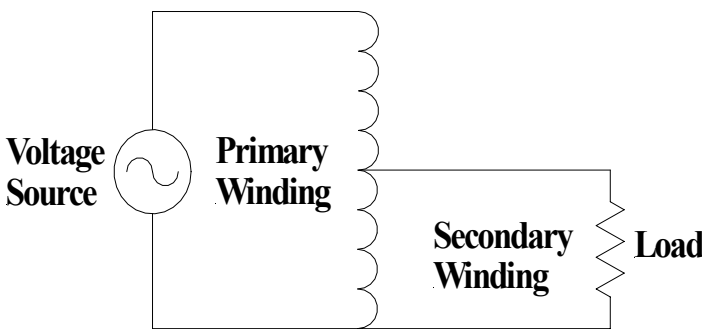


FIGURE 3 - Step-Down Autotransformer

TRANSFORMER PRICIPLES

Without getting into too much detail, the operating principle all transformers use is the continually expanding and collapsing (or alternating) electrical field causing a magnetic field in the secondary winding. This induced magnetic field in the secondary winding creates a voltage. This basic operating principle is common to all transformers.

Even if no electrical load is connected to secondary winding, a small amount of current flows through the primary windings. This current, known as **excitation current**, is used to magnetize the secondary windings. The excitation current is analogous to the extra horsepower needed to move a car at rest to over come inertia.

TRANSFORMER CALCULATIONS

The relationship between the primary and secondary windings is the ratio of the number of turns. This is a direct

proportion. For example, a transformer supplied with 120 volts on the primary with 100 primary winding turns will have a secondary voltage of 90 volts if the secondary windings use 75 turns.

In mathematical form: where **N_p** is the number of primary windings, **N_s** is the number of secondary windings, **E_p** is the primary electrical voltage, and **E_s** is the secondary voltage.

$$\frac{N_p}{N_s} = \frac{E_p}{E_s}$$

$$\begin{aligned} E_s &= E_p \times N_s \div N_p \\ &= 120 \text{ Vac} \times 75 \div 100 \\ &= 90 \text{ Vac} \end{aligned}$$

Most transformers are configured with multiple connection points, or taps, on the secondary windings. This gives flexibility to choose the needed secondary voltage simply by changing the tap connection rather than installing a new transformer.

Figure 4 show a transformer with multiple taps. In this example, connecting between tap A and tap D creates a secondary voltage of 346 volts.

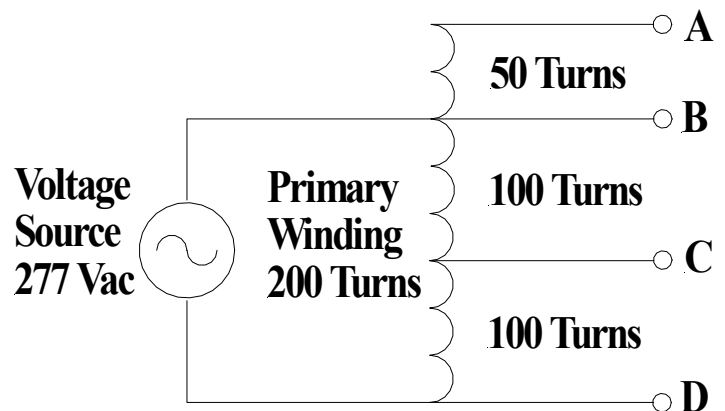


FIGURE 4 - Multi-Tap Autotransformer

Connect Between Taps A and D

$$\begin{aligned} E_s &= E_p \times N_s \div N_p \\ &= 277 \text{ Vac} \times (100 + 100 + 50) \div 200 \\ &= 346 \text{ Vac} \end{aligned}$$

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Connection between tap B and tap C creates a secondary voltage of 138 volts.

Connect Between Taps B and C

$$\begin{aligned} E_s &= E_p \times N_s \div N_p \\ &= 277 \text{ Vac} \times 100 \div 200 \\ &= 138 \text{ Vac} \end{aligned}$$

Lastly, connection between taps A and B creates 69 volts in the secondary.

Connect Between Taps A and B

$$\begin{aligned} E_s &= E_p \times N_s \div N_p \\ &= 277 \text{ Vac} \times 50 \div 200 \\ &= 69 \text{ Vac} \end{aligned}$$

BUCK BOOST TRANSFORMERS

Why are buck boost transformers used in electrical distributions systems? Typically two reasons:

1. Buck boost transformers are simple, economical way to supply a non-standard voltage to specific equipment
 - For example, a commercial building with a 208/120, four-wire distribution system often requires a 240-volt, single-phase source for the air conditioning system. Rather outfit the building with a separate 240-volt source, it is more economical to install several boost transformers each air conditioning unit.
 - An existing building with a 120 volt, single-phase distribution system may require 277-volt single-phase power for a lighting retrofit. A boost transformer will create the new 277-volt power.
 - Converse to the above example, an existing building with a 480/277-volt, three phase distribution system may require 120 volt single phase power for lighting. A boost transformer creates the new 120-volt power from the single.

2. Correct voltage drops due to long conductor leads

- Should long electrical cable cause an unacceptable voltage sag, the depressed supply voltage is boosted to supply the proper voltage to the electrical loads. However should the voltage fluctuate due to load changes, a boost transformer will not cure the problem and maybe a safety issue. If the transformer is sized to correct a deep voltage sag and the sag is intermittent, transformer supply over voltage condition is present.

BUCK BOOST CONNECTION

Buck boost transformers have the ability for connection as isolation type or autotransformers. The transformers, as shipped, have several primary windings and several secondary windings. The windings are externally connected to achieve the needed duty.

If a primary winding is connected to a secondary winding, the transformer is in an autotransformer configuration. If the windings are not cross connected, meaning no primary winding lead is connected to a secondary winding lead, the transformer is configured as a isolation transformer.

CODE REQUIREMENTS

Per the National Electric Code (NEC) 450.4 an over current device rated at not more than 125% of the rated full load input current of the autotransformer. Figure 5 is an example of the required over current protection. A two-pole over current device is required. If only a single pole device is located on a single incoming 208-volt line, the full 208 volts can be supplied across the 32-volt second-

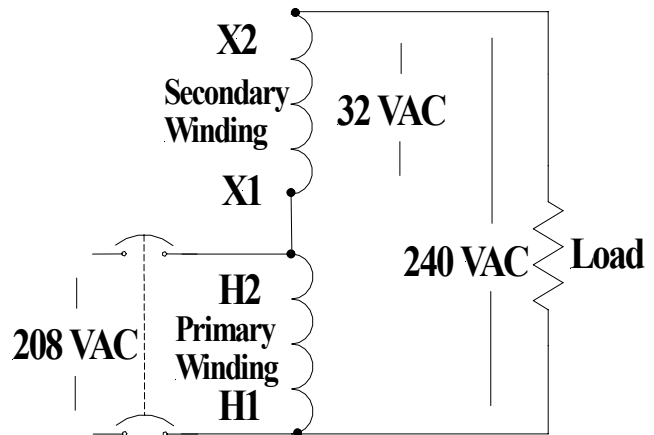


FIGURE 5 - Autotransformer Protection

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dary windings even when the device is open. Therefore, all ungrounded input conductors require over current protection.

A buck boost transformer can operate a load larger than the kVA rated listed on the transformer input nameplate. Therefore, over current protection must be sized for the actual full load rating. Because the secondary windings are the only part of an autotransformer that transform voltage and current. The current draw on the secondary side is calculated based the secondary voltage.

Using Figure 6 and assuming the input nameplate rating on the transformer is 1 kVA and the output kVA rating is 6.kVA for this configuration (note both the input and output kVA ratings are given by the transformer manufacturer). The over current protection must be sized for 125% of the maximum current as calculated below.

$$\begin{aligned} \text{Maximum Secondary Amp} &= \\ \text{Nameplate kVA} \div \text{Secondary Voltage} &= \\ 1000 \text{ VA} \div 32 \text{ Vac} &= \mathbf{31.25 \text{ Amps}} \end{aligned}$$

OR

$$\begin{aligned} \text{Over current Device Rating} &= \\ \text{Output kVA} \div \text{Primary Voltage} &= \\ 6500 \text{ VA} \div 208 \text{ Volts} &= \mathbf{31.25 \text{ Amps}} \end{aligned}$$

$$\begin{aligned} \text{Required Over Current Protection} &= \\ \mathbf{31.25 \text{ Amps} \times 125\%} &= \mathbf{39 \text{ Amps}} \end{aligned}$$

THREE PHASE APPLICATIONS

For three phase buck boost applications several transformers are needed. Table 1 summarizes allowable supply and output combinations.

INPUT Line Side	OUTPUT Load Side	ACCEPTABLE?
3 Wire Delta	Wye - 3 or 4 Wire	⊘ DO NOT USE
3 Wire Open Delta	Wye - 3 or 4 Wire	⊘ DO NOT USE
Wye - 3 or 4 Wire	3 Wire Closed Delta	⊘ DO NOT USE
Wye 4 Wire	Wye 3 or 4 Wire	☑ OK
Wye - 3 or 4 Wire	3 Wire Open Delta	☑ OK
3 Wire Closed Delta	3 Wire Open Delta	☑ OK

TABLE 1 - Acceptable Three Phase Configurations