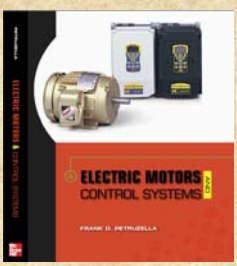


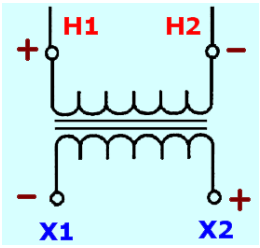
Chapter 3

Motor Transformers and Distribution Systems

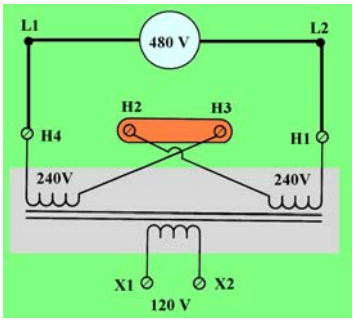
PART 3 Transformer Connections and Systems

TRANSFORMER POLARITY

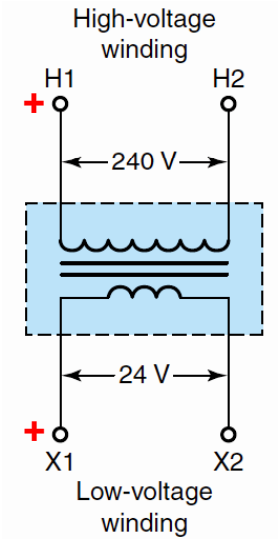
Transformer *polarity* refers to the relative direction or polarity of the induced voltage between the high voltage and low voltage terminals of a transformer.



An understanding of transformer polarity markings is essential in making three-phase and single-phase transformer connections.

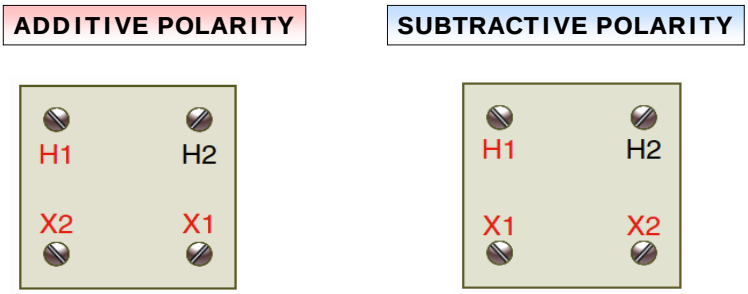


On power transformers the high-voltage winding leads are marked *H_1 and H_2* and the low-voltage winding leads are marked *X_1 and X_2.*

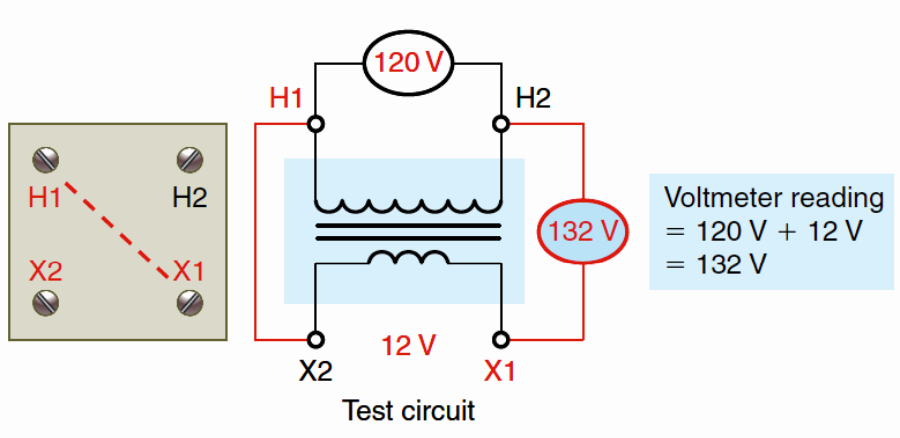


By convention, *H_1* and *X_1* have the same polarity, which means that when *H_1* is instantaneously positive, *X_1* also is instantaneously positive.

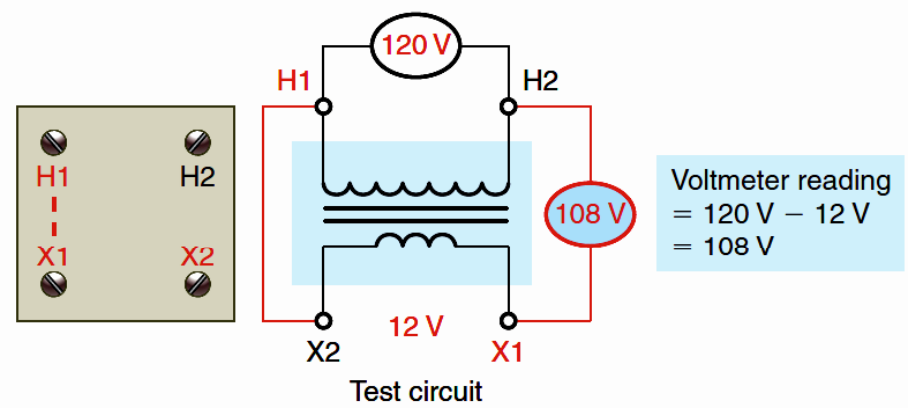
In practice, the four terminals on a single-phase transformer are mounted in a standard way so the transformer has either *additive* or subtractive polarity. Additive and subtractive polarity depends on the location of the H1 and X terminals.



A transformer has an *additive polarity* when terminal H1 is diagonally opposite terminal X1.



A transformer has a *subtractive polarity* when terminal H1 is adjacent to terminal X1.

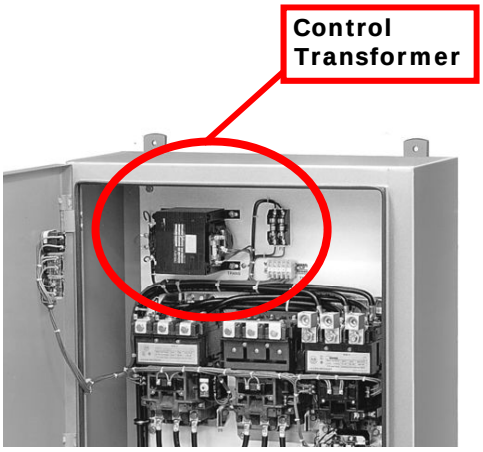


Battery operated transformer polarity checker

Transformer connection diagram

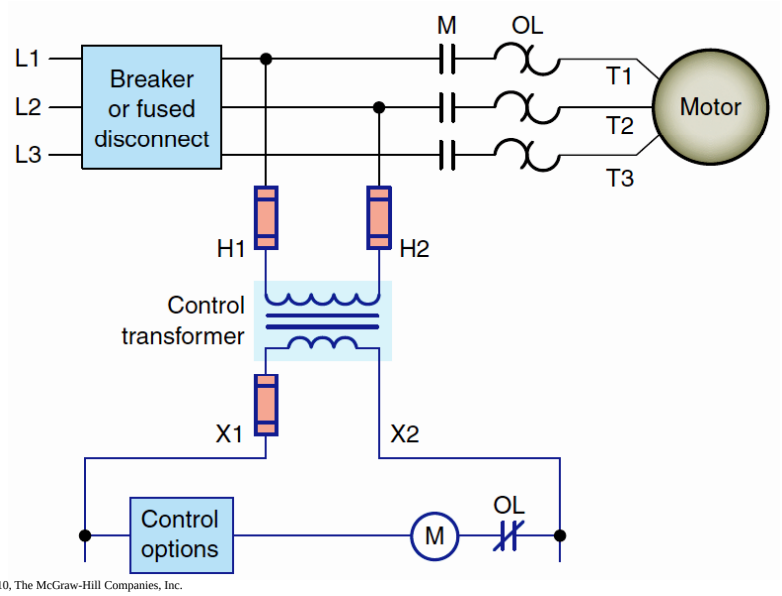
SINGLE-PHASE TRANSFORMERS

Motor *control transformers* are designed to reduce supply voltages to motor control circuits.

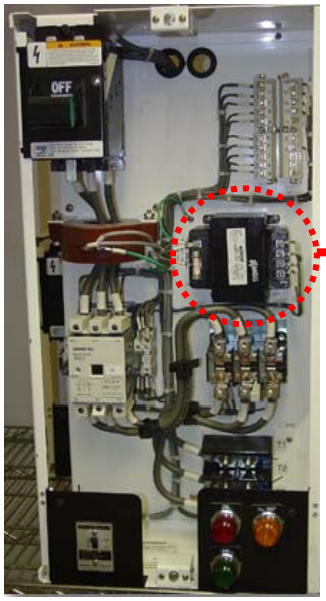


Step-down **control transformers are installed when the control circuit components are not rated for the line voltage.**

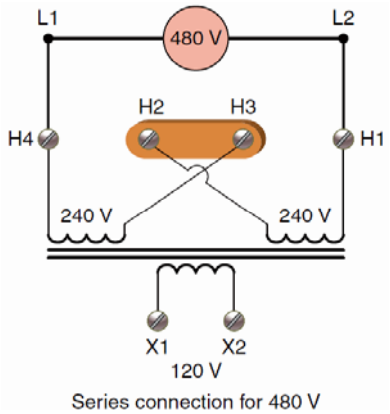
Motor control transformer wiring.



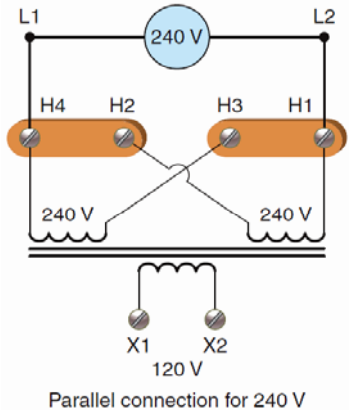
Multi-tap primary **control transformers allow reduced control power from a variety of voltage levels to meet a wide array of applications.**



Dual voltage 480 V and 240 V transformer primary connections.

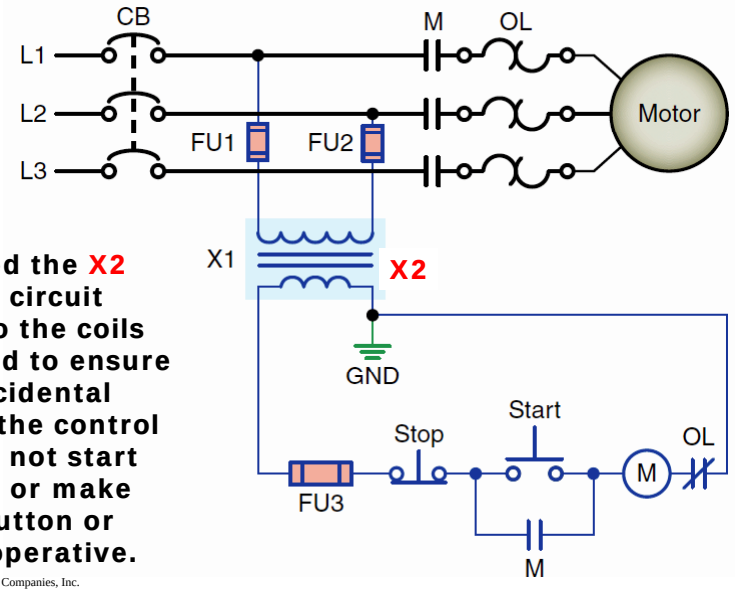


Series connection for 480 V



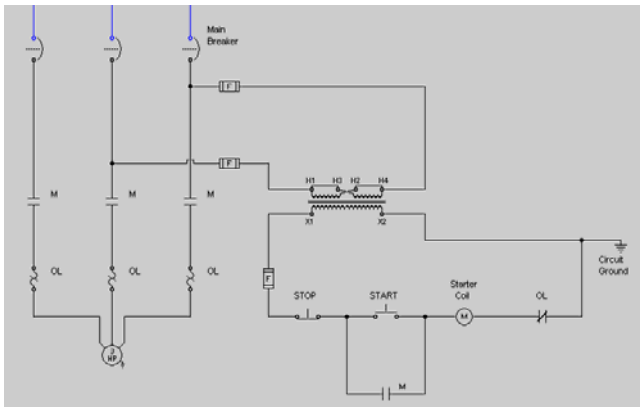
Parallel connection for 240 V

The control transformer secondary can be grounded or ungrounded.

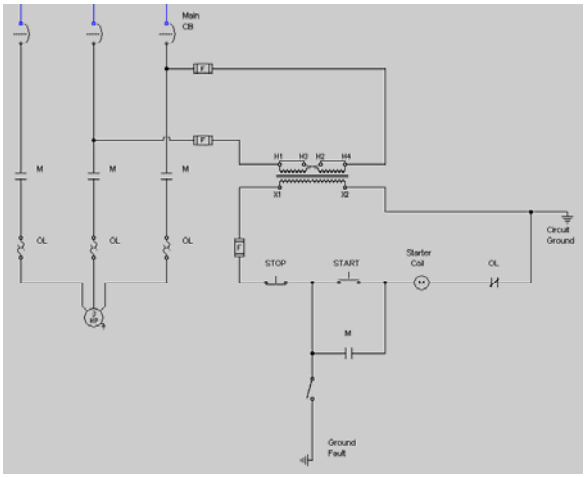


If grounded the X2 side of the circuit common to the coils is grounded to ensure that an accidental ground in the control circuit will not start the motor, or make the stop button or control inoperative.

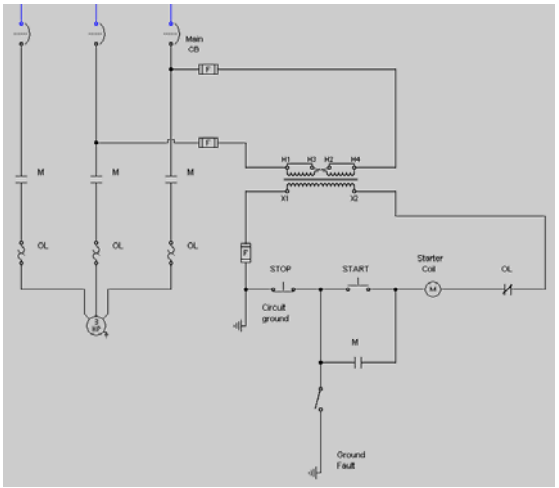
Properly Grounded Control Transformer



Properly Grounded Control Transformer With Ground Fault Condition

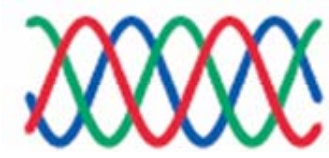


Improperly Grounded Control Transformer With Ground Fault Condition



An additional requirement for all control transformers is that they be protected by fuses or circuit breakers. Depending on the installation, this protection can be placed on the primary, secondary, or both sides of the transformer.

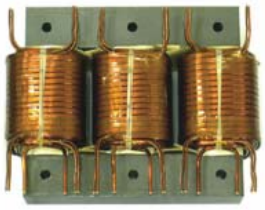
Large amounts of power are generated and transmitted using high-voltage *three-phase systems*. Transmission voltages may be stepped down several times before they reach the motor load.

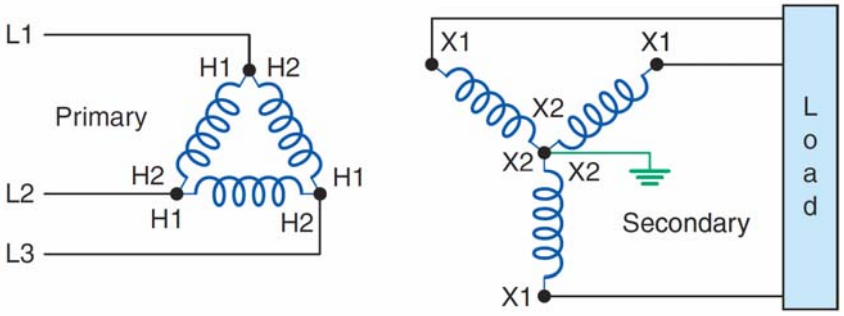


Three-Phase Waveform

Three-Phase Transformer

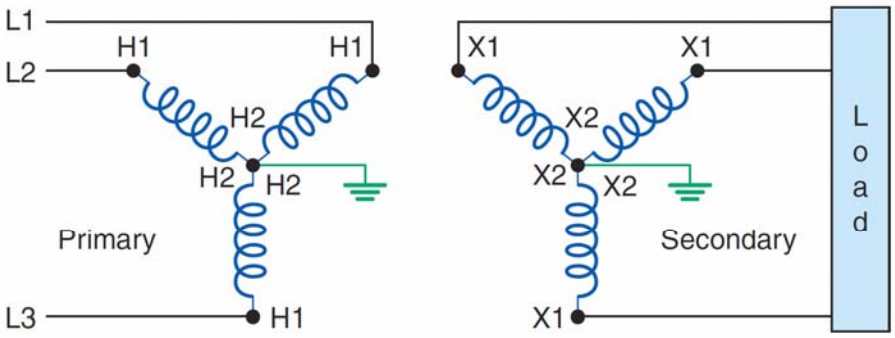
Three-phase transformation is accomplished using three-phase *Wye- or Delta* -connected transformers or a combination of the two.





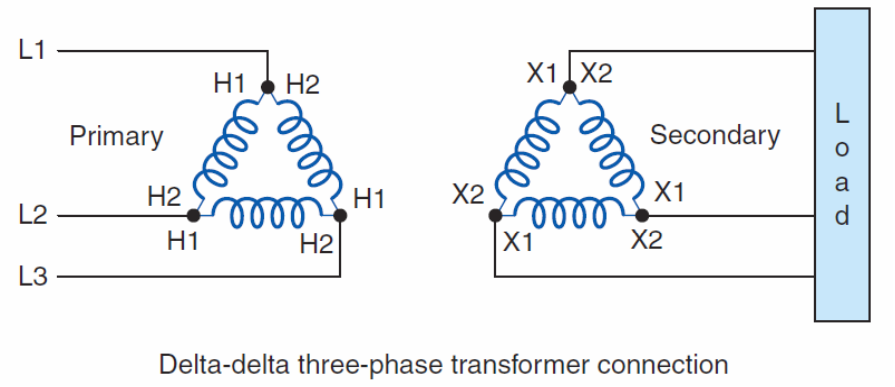
Delta-wye three-phase transformer connection

Three-phase Wye and Delta transformer connections are named after the way the windings are connected inside the transformer.



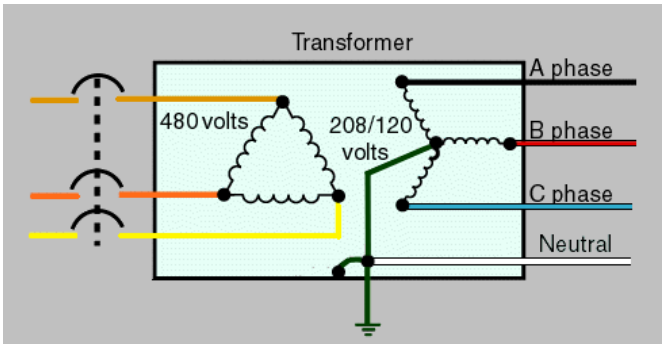
Wye-wye three-phase transformer connection

Polarity markings are fixed on any transformer and the connections are made in accordance with them.

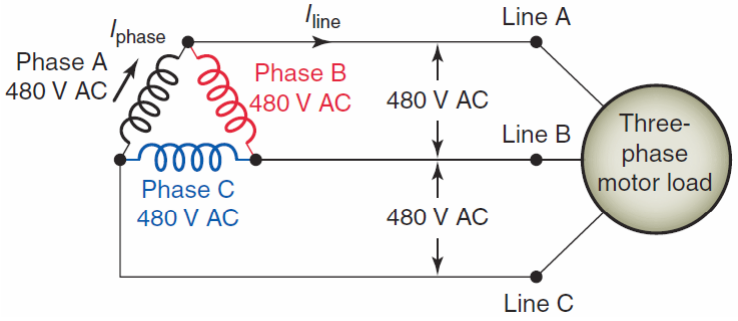


Delta-delta three-phase transformer connection

Two types of secondary distribution systems commonly used are the three-phase *3-wire system* and three-phase *4-wire system*. In both, the secondary voltages are the same for all three phases.



4-Wire Distribution System

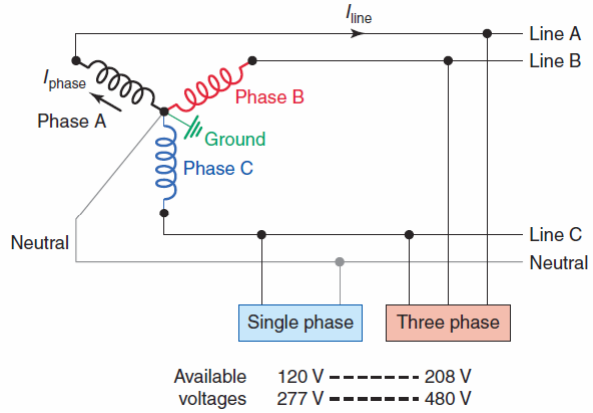


3-Wire Delta Transformer Connection

- The phase voltage (E_{phase}) of the transformer secondary is always the same as the line voltage (E_{line}) of the load.
- The line current (I_{line}) of the load is equal to the phase current (I_{phase}) of the transformer secondary multiplied by 1.73.

$$\text{kVA (transformer)} = \frac{I_{line} \times E_{line} \times \sqrt{3}}{1{,}000}$$

- The constant 1.73 is the square root of 3 and is used because the transformer phase windings are 120 electrical degrees apart.



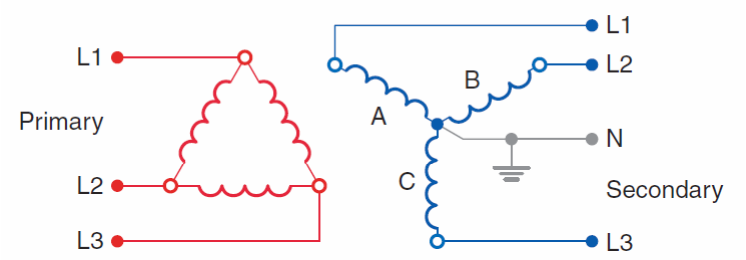
4-Wire Wye Transformer Connection

- The phase-to-phase voltage is equal to the phase-to-neutral voltage multiplied by 1.73.
- The line current is equal to the phase current.

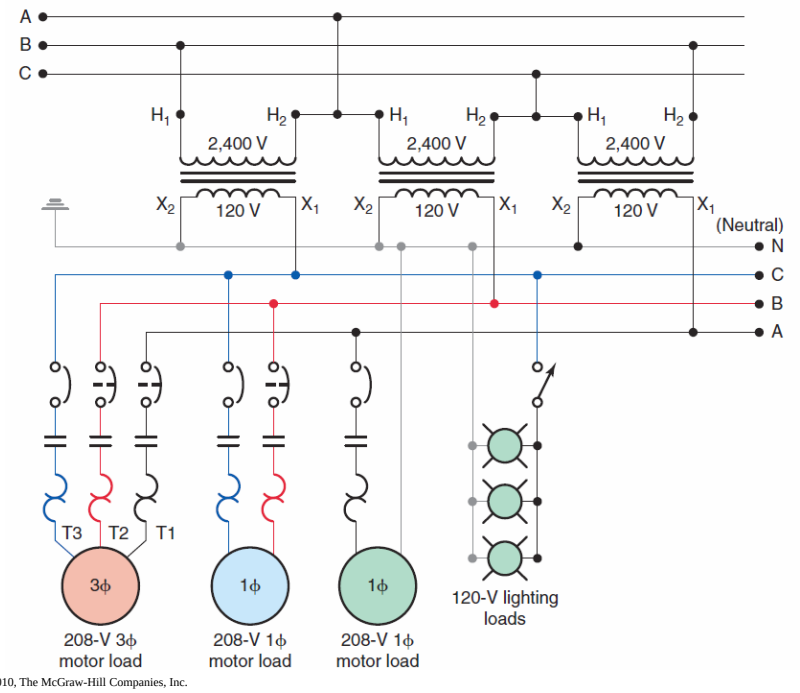
$$\text{kVA (transformer)} = \frac{I_{line} \times E_{line} \times \sqrt{3}}{1{,}000}$$

- Common arrangements are 480Y/277 V and 208Y/120 V.

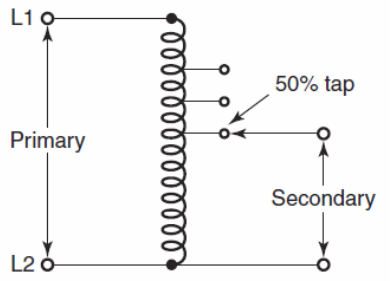
Delta-to-Wye Transformer Configuration



- The secondary provides a neutral point for supplying line-to-neutral power to single-phase loads.
- The neutral point is also grounded for safety reasons.
- Three-phase loads are supplied at 208 V, while the voltage for single-phase loads is 208 V or 120 V.



The *autotransformer* is a transformer consisting of a single winding with electrical connection points called *taps*.



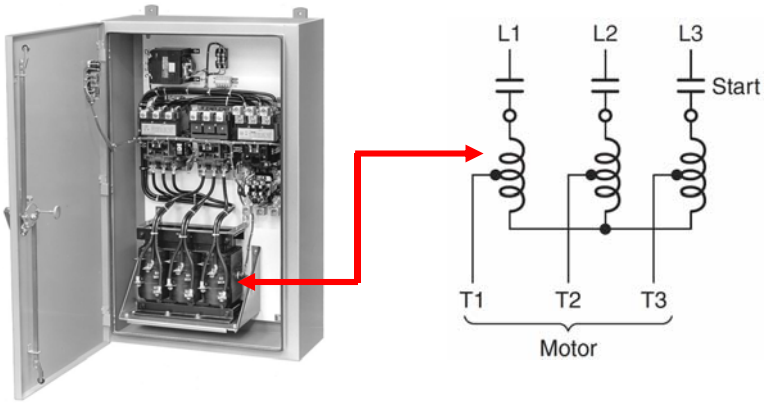
- Each tap corresponds to a different voltage.
- There is no electrical isolation between the input and output circuits.
- The autotransformer is typically lighter and less costly than a two-winding transformer.

A ***variable autotransformer*** is one in which the output connection is made through a sliding brush. Variable autotransformers are widely used where adjustable AC voltages are required.

Three-Phase

Single-Phase

An *autotransformer motor starter* reduces inrush motor current by using a 3-coil autotransformer in the line just ahead of the motor to step down the voltage applied to the motor terminals.

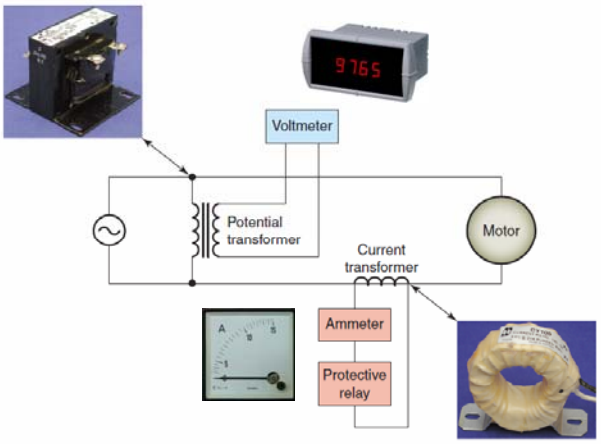


On starting the motor is connected to the reduced voltage taps on the autotransformers. Once the motor has accelerated, it is automatically connected to full line voltage.

INSTRUMENT TRANSFORMERS

Instrument transformers **are small transformers used in conjunction with instruments such as ammeters, voltmeters, power meters, and relays used for protective purposes**

These transformers step down the voltage or current of a circuit to a low value that can be effectively and safely used for the operation of instruments.

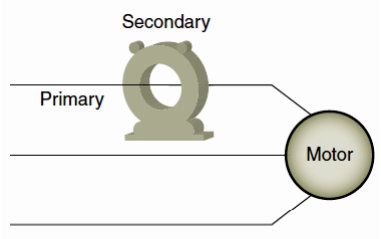


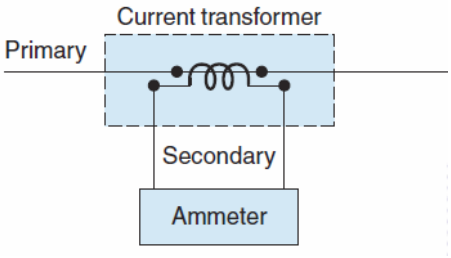
A potential (voltage) transformer operates on the same principle as a standard power transformer. The main difference is that the capacity of a potential transformer is relatively small as compared with power transformers.

Potential transformers have typical power ratings of from 100 VA to 500 VA. The secondary low-voltage side is usually wound for 120 v.

A *current transformer* is a transformer that has its primary connected in series with the line. When the primary has a large current rating, the primary may consist of a straight conductor passing through the core.

The secondary winding consisting of many turns designed to produce *5 ampere* when its *rated current* is flowing in the primary.





A current transformer supplies the instrument and/or protective device with a small current that is proportional to the main current.

The secondary circuit of a current transformer should never be *opened* when there is current in the primary winding. If the secondary is not loaded, this transformer acts to *step-up the voltage to a dangerous level,* due to the high turns ratio. Therefore, a current transformer should always have its secondary shorted when not connected to an external load.