Potential Transformers White Paper

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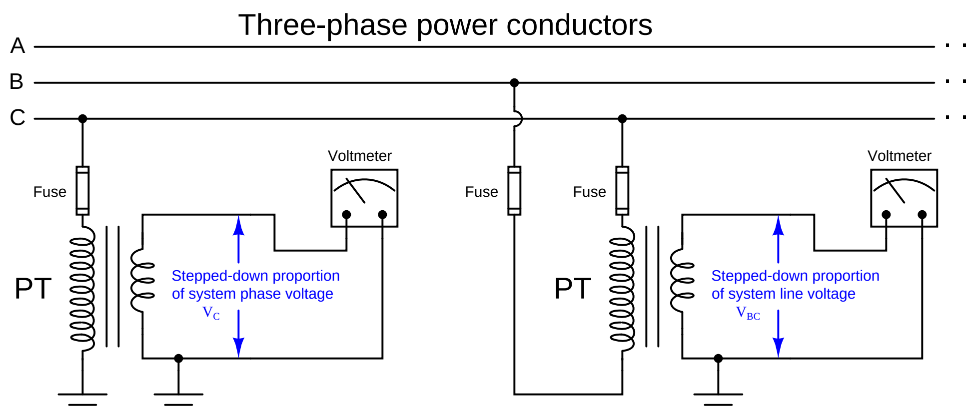
25.6.1 Potential transformers

Electrical power systems typically operate at dangerously high voltage. It would be both impractical and unsafe to connect panel-mounted instruments directly to the conductors of a power system if the voltage of that power system exceeds several hundred volts. For this reason, we must use a special type of step-down transformer referred to as a *potential transformer* to reduce and isolate the high line voltage of a power system to levels safe for panel-mounted instruments to input.

Shown here is a simple diagram illustrating how the high phase and line voltages of a three-phase AC power system may be sensed by low-voltage voltmeters through the use of step-down potential transformers:



Potential transformers are commonly referred to as "PT" units in the electrical power industry. It should be noted that the term "voltage transformer" and its associated abbreviation VT is becoming popular as a replacement for "potential transformer" and PT.

When driving a voltmeter – which is essentially an open-circuit (very high resistance) – the PT behaves as a voltage source to the receiving instrument, sending a voltage signal to that instrument proportionately representing the power system's voltage.

The following photograph shows a potential transformer sensing the phase-to-ground voltage on a three-phase power distribution system. The normal phase voltage in this system is 7.2 kV (12.5 kV three-phase line voltage), and the PT's normal secondary voltage is 120 volts, necessitating a ratio of 60:1 (as shown on the transformer's side):

Any voltage output by this PT will be $\frac{1}{60}$ of the actual phase voltage, allowing panel-mounted instruments to read a precisely scaled proportion of the 7.2 kV (typical) phase voltage safely and effectively. A panel-mounted voltmeter, for example, would have a scale registering 7200 volts when its actual input terminal voltage was only 120 volts. This is analogous to a 4-20 mA indicating meter bearing a scale labeled in units of "PSI" or "Degrees Celsius" because the 4-20 mA analog signal merely represents some other physical variable sensed by a process transmitter. Here, the physical variable being sensed by the potential transformer is still voltage, just at a 60:1 ratio greater than what the panel-mounted instrument receives. Like the 4-20 mA DC analog signal standard so common in the process industries, 115 or 120 volts is the standard potential transformer output voltage used in the electrical industry to represent normal power system voltage.

This next photograph shows a set of three PTs used to measure voltage on a 13.8 kV substation bus. Note how each of these PTs is equipped with *two* high-voltage insulated terminals to facilitate phase-to-phase (line voltage) measurements as well as phase-to-ground:

Another photograph of potential transformers appears here, showing three large PTs used to precisely step the phase-to-ground voltages for each phase of a 230 kV system (230 kV line voltage, 133 kV phase voltage) all the way down to 120 volts for the panel-mounted instruments to monitor:

A loose-hanging wire joins one side of each PT's primary winding to the respective phase conductor of the 230 kV bus. The other terminal of each PT's primary winding connects to a common neutral point, forming a Wye-connected PT transformer array. The secondary terminals of these PTs connect to two-wire shielded cables conveying the 120 volt signals back to the control room where they terminate at various instruments. These shielded cables run through underground conduit for protection from weather.

Just as with the previous PT, the standard output voltage of these large PTs is 120 volts, equating to a transformer turns ratio of about 1100:1. This standardized output voltage of 120 volts allows PTs of any manufacture to be used with receiving instruments of any manufacture, just as the 4-20 mA standard for analog industrial instruments allows "interoperability" between different manufacturers' brands and models.

A special form of instrument transformer used on very high-voltage systems is the *capacitively-coupled voltage transformer*, or CCVT. These sensing devices employ a series-connected set of capacitors dividing the power line voltage down to a lesser quantity before it gets stepped down further by an electromagnetic transformer. A simplified diagram of a CCVT appears here, along with a photograph of three CCVTs located in a substation: