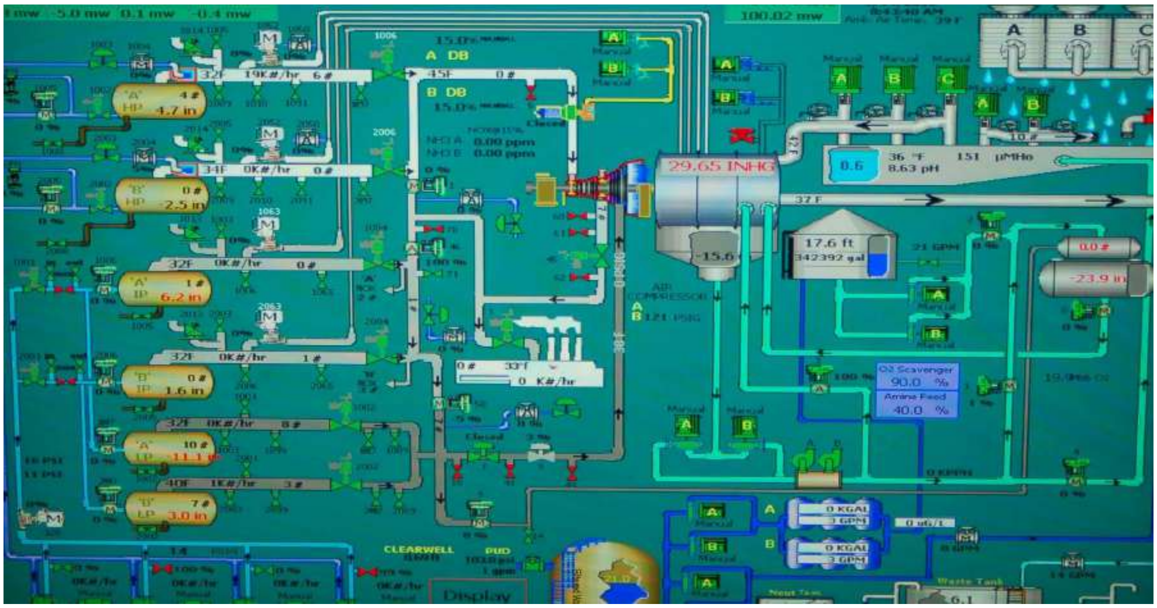
Current transformers



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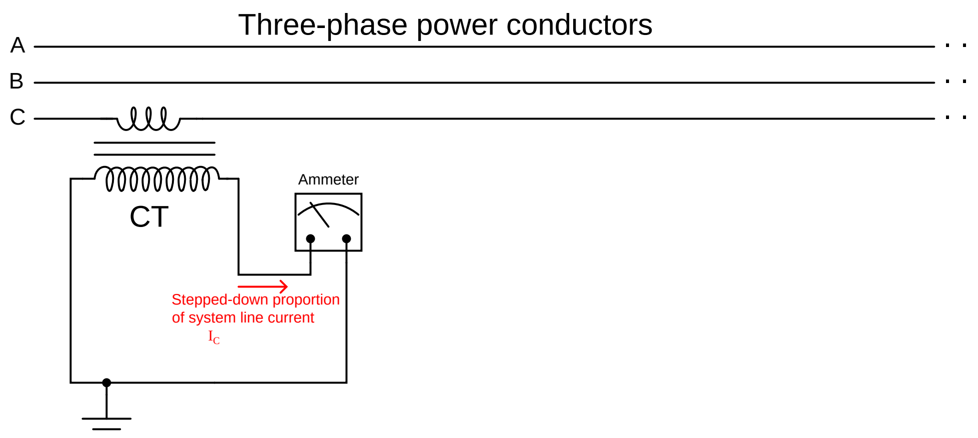
25.6.2 Current transformers

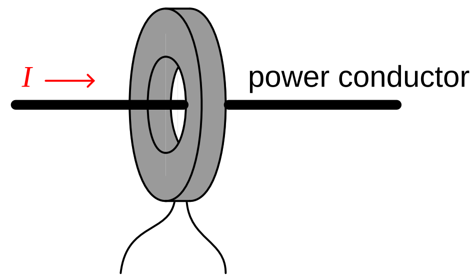
For the same reasons necessitating the use of potential (voltage) instrument transformers, we also see the use of *current transformers* to reduce high current values and isolate high voltage values between the electrical power system conductors and panel-mounted instruments.

Shown here is a simple diagram illustrating how the line current of a three-phase AC power system may be sensed by a low-current ammeter through the use of a current transformer:

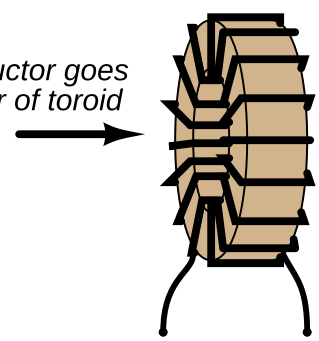


When driving an ammeter – which is essentially a short-circuit (very low resistance) – the CT behaves as a current source to the receiving instrument, sending a current signal to that instrument proportionately representing the power system's line current.

In typical practice a CT consists of an iron toroid[25] functioning as the transformer core. This type of CT does not have a primary "winding" in the conventional sense of the word, but rather uses the line conductor itself as the primary winding. The line conductor passing once through the center of the toroid functions as a primary transformer winding with exactly 1 "turn". The secondary winding consists of multiple turns of wire wrapped around the toroidal magnetic core:



A view of a current transformer's construction shows the wrapping of the secondary turns around the toroidal magnetic core in such a way that the secondary conductor remains parallel to the primary (power) conductor for good magnetic coupling:



With the power conductor serving as a single-turn[26] winding, the multiple turns of secondary

[25] A "toroid" is shaped like a donut: a circular object with a hole through the center.

[26] This raises an interesting possibility: if the power conductor were to be wrapped around the toroidal core of the CT so that it passes through the center *twice* instead of *once*, the current step-down ratio will be cut in half. For example, a 100:5 CT with the power conductor wrapped around so it passes through the center twice will exhibit an actual current ratio of only 50:5. If wrapped so that it passed through the CT's center three times, the ratio would be reduced to 33.33:5. This useful "trick" may be used in applications where a lesser CT ratio cannot be found, and one must make do with whatever CT happens to be available. If you choose to do this, however, beware that the current-measuring capacity of the CT will be correspondingly reduced. Each extra turn of the power conductor

wire around the toroidal core of a CT makes it function as a step-up transformer with regard to voltage, and as a *step-down* transformer with regard to current. The turns ratio of a CT is typically specified as a ratio of full line conductor current to 5 amps, which is a standard output current for power CTs. Therefore, a 100:5 ratio CT outputs 5 amps when the power conductor carries 100 amps.

The turns ratio of a current transformer suggests a danger worthy of note: if the secondary winding of an energized CT is ever open-circuited, it may develop an extremely high voltage as it attempts to force current through the air gap of that open circuit. An energized CT secondary winding acts like a current source, and like all current sources it will develop as great a potential (voltage) as it can when presented with an open circuit. Given the high voltage capability of the power system being monitored by the CT, and the CT turns ratio with more turns in the secondary than in the primary, the ability for a CT to function as a *voltage step-up* transformer poses a significant hazard.

Like any other current source, there is no harm in short-circuiting the output of a CT. Only an open circuit poses risk of damage. For this reason, CT circuits are often equipped with *shorting bars* and/or *shorting switches* to allow technicians to place a short-circuit across the CT secondary winding before disconnecting any other wires in the circuit. Later subsections will elaborate on this topic in greater detail.

adds to the magnetic flux experienced by the CT's core for any given amount of line current, making it possible to magnetically saturate the core if the line current exceeds the reduced value (e.g. 50 amps for the home-made 50:5 CT where the line passes twice through the center of a 100:5 CT).

Current transformers are manufactured in a wide range of sizes, to accommodate different applications. Here is a photograph of a current transformer showing the "nameplate" label with all relevant specifications. This nameplate specifies the current ratio as "100/5" which means this CT will output 5 amps of current when there is 100 amps flowing through a power conductor passed through the center of the toroid:

The black and white wire pair exiting this CT carries the 0 to 5 amp AC current signal to any monitoring instrument scaled to that range. That instrument will see $\frac{1}{20}$ (i.e. $\frac{5}{100}$) of the current flowing through the power conductor.

The following photographs contrast two different styles of current transformer, one with a "window" through which any conductor may be passed, and another with a dedicated busbar fixed through the center to which conductors attach at either end. Both styles are commonly found in the electrical power industry, and they operate identically:

Here is a photograph of some much larger CTs intended for installation inside the "bushings[27]" of a large circuit breaker, stored on a wooden pallet:

The installed CTs appear as cylindrical bulges at the base of each insulator on the high-voltage circuit breaker. This particular photograph shows flexible conduit running to each bushing CT, carrying the low-current CT secondary signals to a terminal strip inside a panel on the right-hand end of the breaker:

Signals from the bushing CTs on a circuit breaker may be connected to *protective relay* devices to trip the breaker in the event of any abnormal condition. If unused, a CT's secondary terminals are simply short-circuited at the panel.

[27]High-voltage devices situate their connection terminals at the ends of long insulators, to provide a large air gap between the conductors and the grounded metal chassis of the device. The point at which the long insulator (with a conductor inside of it) penetrates the housing of the device is called the *bushing*.

Shown here is a set of three very large CTs, intended for installation at the bushings of a high-voltage power transformer. Each one has a current step-down ratio of 600-to-5:

In this next photograph we see a tiny CT designed for low current measurements, clipped over a wire carrying only a few amps of current. This particular current transformer is constructed in such a way that it may be clipped around an existing wire for temporary test purposes, rather than being a solid toroid where the conductor must be threaded through it for a more permanent installation:

This CT's ratio of 3000:1 would step down a 5 amp AC signal to 1.667 milliamps AC.

This last photograph shows a current transformer used to measure line current in a 500 kV substation switchyard. The actual CT coil is located inside the red-colored housing at the top of the insulator, where the power conductor passes through. The tall insulator stack provides necessary separation between the conductor and the earth below to prevent high voltage from "jumping" to ground through the air: