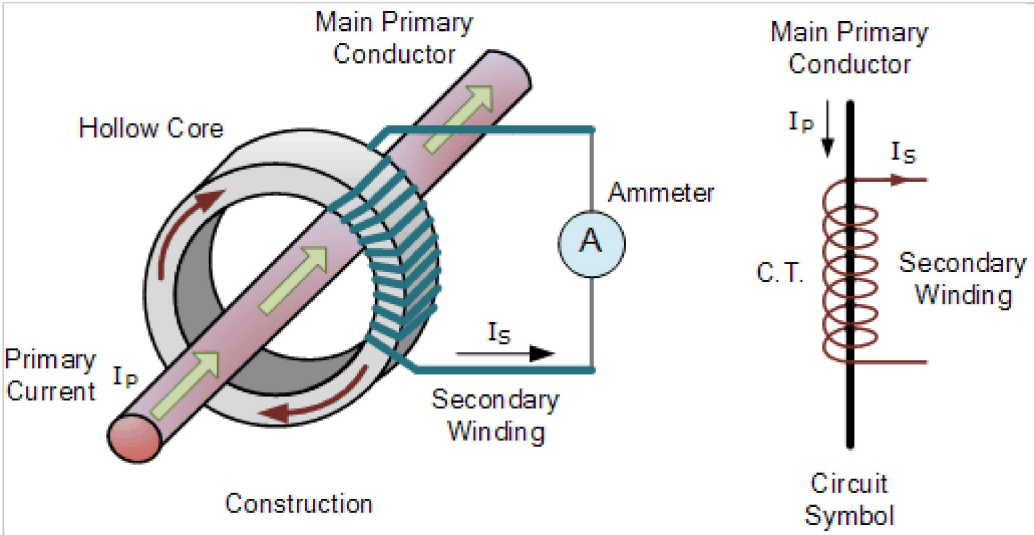


The Current Transformer

Current Transformers produce an output in proportion to the current flowing through the primary winding as a result of a constant potential on the primary

The **Current Transformer** (**C.T.**), is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. *Current transformers* reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

Typical Current Transformer

Unlike the voltage or power transformer looked at previously, the current transformer consists of only one or very few turns as its primary winding. This primary winding can be of either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole as shown.

Due to this type of arrangement, the current transformer is often referred too as a “series transformer” as the primary winding, which never has more than a very few turns, is in series with the current carrying conductor supplying a load.

The secondary winding however, may have a large number of coil turns wound on a laminated core of low-loss magnetic material. This core has a large cross-sectional area so that the magnetic flux density created is low using much smaller cross-sectional area wire, depending upon how much the current must be stepped down as it tries to output a constant current, independent of the connected load.

The secondary winding will supply a current into either a short circuit, in the form of an ammeter, or into a resistive load until the voltage induced in the secondary is big enough to saturate the core or cause failure from excessive voltage breakdown.

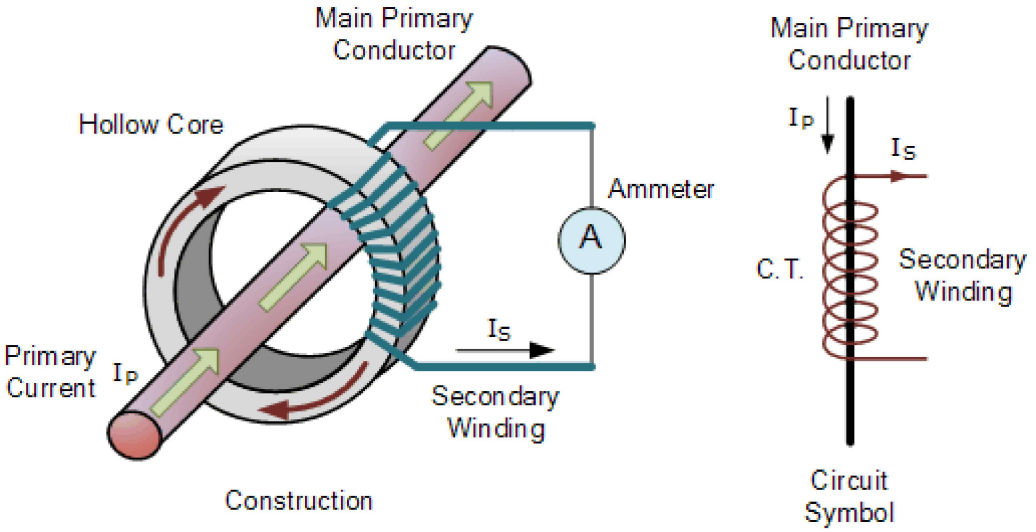
Unlike a voltage transformer, the primary current of a current transformer is not dependent of the secondary load current but instead is controlled by an external load. The secondary current is usually rated at a standard 1 Ampere or 5 Amperes for larger primary current ratings.

There are three basic types of current transformers: **wound**, **toroidal** and **bar**.

- Wound Current Transformer – The transformers primary winding is physically connected in series with the conductor that carries the measured current flowing in the circuit. The magnitude of the secondary current is dependent on the turns ratio of the transformer.
- Toroidal Current Transformer – These do not contain a primary winding. Instead, the line that carries the current flowing in the network is threaded through a window or hole in the toroidal transformer. Some current transformers have a “split core” which allows it to be opened, installed, and closed, without disconnecting the circuit to which they are attached.
- Bar-type Current Transformer – This type of current transformer uses the actual cable or bus-bar of the main circuit as the primary winding, which is equivalent to a single turn. They are fully insulated from the high operating voltage of the system and are usually bolted to the current carrying device.

Current transformers can reduce or “step-down” current levels from thousands of amperes down to a standard output of a known ratio to either 5 Amps or 1 Amp for normal operation. Thus, small and accurate instruments and control devices can be used with CT’s because they are insulated away from any high-voltage power lines. There are a variety of metering applications and uses for current transformers such as with Wattmeter’s, power factor meters, watt-hour meters, protective relays, or as trip coils in magnetic circuit breakers, or MCB’s.

Current Transformer



Generally current transformers and ammeters are used together as a matched pair in which the design of the current transformer is such as to provide a maximum secondary current corresponding to a full-scale deflection on the ammeter. In most current transformers an approximate inverse turns ratio exists between the two currents in the primary and secondary windings. This is why calibration of the CT is generally for a specific type of ammeter.

Most current transformers have a the standard secondary rating of 5 amps with the primary and secondary currents being expressed as a ratio such as 100/5. This means that the primary current is 20 times greater than the secondary current so when 100 amps is flowing in the primary conductor it will result in 5 amps flowing in the secondary winding. A current transformer of say 500/5, will produce 5 amps in the secondary for 500 amps in the primary conductor, 100 times greater.

By increasing the number of secondary windings, Ns, the secondary current can be made much smaller than the current in the primary circuit being measured because as Ns increases, Is goes down by a proportional amount. In other words, the number of turns and the current in the primary and secondary windings are related by an inverse proportion.

A current transformer, like any other transformer, must satisfy the amp-turn equation and we know from our tutorial on double wound voltage transformers that this turns ratio is equal to:

$$\text{T.R.} = n = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

from which we get:

$$\text{secondary current, } I_S = I_P\left(\frac{N_P}{N_S}\right)$$

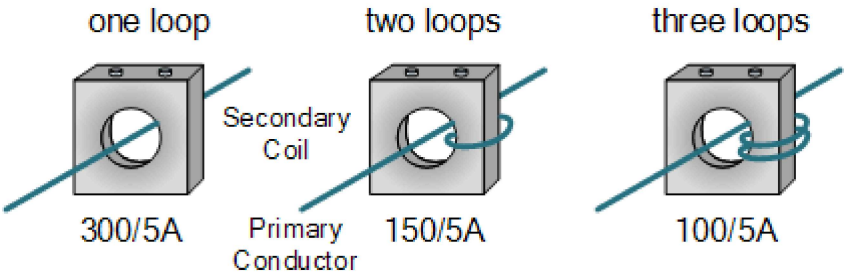
The current ratio will sets the turns ratio and as the primary usually consists of one or two turns whilst the secondary can have several hundred turns, the ratio between the primary and secondary can be quite large. For example, assume that the current rating of the primary winding is 100A. The secondary winding has the standard rating of 5A. Then the ratio between the primary and the secondary currents is 100A-to-5A, or 20:1. In other words, the primary current is 20 times greater than the secondary current.

It should be noted however, that a current transformer rated as 100/5 is not the same as one rated as 20/1 or subdivisions of 100/5. This is because the ratio of 100/5 expresses the “input/output current rating” and not the actual ratio of the primary to the secondary currents. Also note that the number of turns and the current in the primary and secondary windings are related by an inverse proportion.

But relatively large changes in a current transformers turns ratio can be achieved by modifying the primary turns through the CT’s window where one primary turn is equal to one pass and more than one pass through the window results in the electrical ratio being modified.

So for example, a current transformer with a relationship of say, 300/5A can be converted to another of 150/5A or even 100/5A by passing the main primary conductor through its interior window two or three times as shown. This allows a higher value current transformer to provide the maximum output current for the ammeter when used on smaller primary current lines.

Current Transformer Primary Turns Ratio



Current Transformer Example No1

A bar-type current transformer which has 1 turn on its primary and 160 turns on its secondary is to be used with a standard range of ammeters that have an internal resistance of 0.2Ω. The ammeter is required to give a full scale deflection when the primary current is 800 Amps. Calculate the maximum secondary current and secondary voltage across the ammeter.

Secondary Current:

$$I_S = I_P\left(\frac{N_P}{N_S}\right) = 800\left(\frac{1}{160}\right) = 5A$$

Voltage across Ammeter:

$$V_S = I_S \times R_A = 5 \times 0.2 = 1.0\,\text{Volts}$$

We can see above that since the secondary of the current transformer is connected across the ammeter, which has a very small resistance, the voltage drop across the secondary winding is only 1.0 volts at full primary current.

However, if the ammeter was removed, the secondary winding effectively becomes open-circuited, and thus the transformer acts as a step-up transformer. This due in part to the very large increase in magnetising flux in the secondary core as the the secondary leakage reactance influences the secondary induced voltage because there is no opposing current in the secondary winding to prevent this.

The results is a very high voltage induced in the secondary winding equal to the ratio of: Vp(Ns/Np) being developed across the secondary winding. So for example, assume our current transformer from above is used on a 480 volt to earth three-phase power line. Therefore:

$$T.R. = n = \frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$\therefore V_S = V_P\left(\frac{N_S}{N_P}\right) = 480\left(\frac{160}{1}\right) = 76{,}800V \text{ or } 76.8kV$$

This high voltage is because the volts per turns ratio is almost constant in the primary and secondary windings and as Vs = Ns*Vp the values of Ns and Vp are high values, so Vs is extremely high.

For this reason a current transformer should never be left open-circuited or operated with no-load attached when the main primary current is flowing through it just as a voltage transformer should never operate into a short circuit. If the ammeter (or load) is to be removed, a short-circuit should be placed across the secondary terminals first to eliminate the risk of shock.

This high voltage is because when the secondary is open-circuited the iron core of the transformer operates at a high degree of saturation and with nothing to stop it, it produces an abnormally large secondary voltage, and in our simple example above, this was calculated at 76.8kV!. This high secondary voltage could damage the insulation or cause electric shock if the CT's terminals are accidentally touched.

Handheld Current Transformers

There are many specialized types of current transformers now available. A popular and portable type which can be used to measure circuit loading are called "clamp meters" as shown.

Clamp meters open and close around a current carrying conductor and measure its current by determining the magnetic field around it, providing a quick measurement reading usually on a digital display without disconnecting or opening the circuit.

As well as the handheld clamp type CT, split core current transformers are available which has one end removable so that the load conductor or bus bar does not have to be disconnected to install it. These are available for measuring currents from 100 up to 5000 amps, with square window sizes from 1″ to over 12″ (25-to-300mm).

Then to summarise, the **Current Transformer, (CT)** is a type of instrument transformer used to convert a primary current into a secondary current through a magnetic medium. Its secondary winding then provides a much reduced current which can be used for detecting overcurrent, undercurrent, peak current, or average current conditions.

A current transformers primary coil is always connected in series with the main conductor giving rise to it also being referred to as a series transformer. The nominal secondary current is rated at 1A or 5A for ease of measurement.

Construction can be one single primary turn as in Toroidal, Doughnut, or Bar types, or a few wound primary turns, usually for low current ratios.

Current transformers are intended to be used as proportional current devices. Therefore a current transformers secondary winding should never be operated into an open circuit, just as a voltage transformer should never be operated into a short circuit.

Very high voltages will result from open circuiting the secondary circuit of an energized current transformer so their terminals must be short-circuited if the ammeter is to be removed or when a CT is not in use before powering up the system.

In the next tutorial about Transformers we will look at what happens when we connect together three individual transformers in a star or delta configuration to produce a larger power transformer called a *Three Phase Transformer* used to supply 3-phase supplies.

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449 Comments

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Submit

- *Balaji Naik*

  Good knowledge shared to us.

  Posted on September 24th 2024 | 4:16 am
  Reply
- *Mukerem Getahun*

I liked it

Posted on September 11th 2024 | 6:56 pm
Reply

- *Francis Owusu*

I am very impressed by this content and I am looking forward for more relevant content keep it up

Posted on September 10th 2024 | 3:51 pm
Reply

- *Romeo Austria*

thanks for more information and knowledge shared to us.

Posted on July 30th 2024 | 11:52 pm
Reply

- *Paul*

No matter how old you are – there is always someone smarter.
Great article, in fact, series.
My project!!!
I have a boat. Everything is 120 VAC wired. There is nothing 240 VAC.
The hot and neutral of each of the following power sources are separated/ kept separate, isolated per breaker panel.
A) 2 x 30 amp x 120 VAC shore power inlets OR 1 x 60 amp x 120 VAC generator (rotary switch used to switch hot and neutrals).
B) 1 x 60 amp x 120 VAC inverter.
C) 1 x 30 amp x 120 VAC inverter.
D) The AC panel has 120VAC analog RMS volt meter and a 100 amp x 120 VAC analog ammeter.
I did not know that donut shaped CT transformers needed to be shorted when not in use.
My question?
I would like to check each power source for volts and amps using a 4 position rotary switch and 4 CT transformers (1 at each output wire).
What kind of a switch is required to not only keep each power source isolated but also ground out each non selected CT ???
Could you supply a part number. Maybe a wiring diagram.

Thankyou
Paul.

Posted on February 07th 2024 | 11:00 pm
Reply

- *Lawrence Yawson*

This was was really excellent.

Posted on December 26th 2023 | 3:19 pm
Reply

- *charly*

perfect

Posted on November 14th 2023 | 12:26 pm
Reply

- *Anup kumar Dey*

CT calculation 400kv,220kv ,132 kv Transformer Capacity 315mva,30Mva

Posted on October 28th 2023 | 3:13 am
Reply

- *HILAL*

Can we we use ct of30/5 instead of 10/5.Plz clear my confusion.

Posted on September 30th 2023 | 2:00 pm
Reply

- *Wayne Storr*

  For a 10/5 CT, the transformer ratio is 2:1. In other words, there is 2 amperes in the primary winding for each ampere in the secondary winding. If the ammeter indicates 5 amps, the actual current in the primary is twice this secondary current, or 10 amps.

  For a 30/5 CT, the transformer ratio is 6:1. Then if the ammeter reads 5 amps, the actual current in the primary is 6 times the secondary current, or 30 amperes. Then if your maximum original primary current is 10 amperes, the ammeter will indicate 1.67 amperes.

  Posted on October 01st 2023 | 8:14 am
  Reply

- *Engr Nabeel*

  I have a question . What is the purpose of k in knee point voltage of current transformer formula and why we use its value 2 for finding knee voltage

  Posted on September 14th 2023 | 5:46 am
  Reply

- *Kamran Shah*

  How to convert AC Current to DC DC Current. (Ac 200Amp CT to Dc 200Amp CT)

  Posted on July 20th 2023 | 2:32 pm
  Reply

- *Fatosh B*

  Are you sure about the part that ends with: “For this reason a current transformer should never be left open-circuited or operated with no-load attached when the main primary current is flowing through it just as a voltage transformer should never operate into a short circuit. If the ammeter (or load) is to be removed, a short-circuit should be placed across the secondary terminals first to eliminate the risk of shock.”

  You calculation of the secondary voltage as 76.8 KV is based on mis-information. The mis-information is that the primary voltage is 480 volts which is not correct. The primary voltage will be about 0.1 volts (depeding on the current flow) and thus the secondary voltage will be about 0.1 * 160 = 16 volts when the secondary is open circuited and a high current flows in the primary circuit.

  Posted on July 01st 2023 | 10:18 am
  Reply

- *Birhanj*

  Please ,send to this email full information about ct

  Posted on June 03rd 2023 | 3:17 am
  Reply

- *Munyaradzi Nyakabwi*

  State three reasons why current transformers are often used in metering systems of large installation

  Posted on May 12th 2023 | 10:22 pm
  Reply

- *Solomon yakob*

  Good recall of past lesson…

  Posted on May 09th 2023 | 8:07 am
  Reply

- *Alice Banda*

  How to set the correct CT ratio ot 800/5 in the power factor.

Posted on February 28th 2023 | 11:24 am
Reply

- *Stephen kwame tieku*

  How to connect current transformer

  Posted on February 21st 2023 | 5:09 am
  Reply

- *R C Desai*

  I want why CT coil rating of 100/5 rate (Cost) is higher than 200/5.

  Posted on January 30th 2023 | 7:02 am
  Reply

- *Wayne*

  This is a highly informative article… Much appreciation to your efforrs Sir 👍

  Posted on January 04th 2023 | 6:24 am
  Reply

- *Robert James Dalga*

  If you placed two or more ct's over a current carrying conductor (right next to one another) should they all read the same amount of current flowing thru the conductor or could there be some sort of interferrence resulting in different readings among the ct's?

  Posted on October 23rd 2022 | 4:33 pm
  Reply

  - *Wayne Storr*

    The relationship between the primary and secondary currents of a Current Transformer (CT) is dependent on its magnetic circuit produced by a rectangular or rounded core. The CT's primary circuit generally consists of a straight conductor through the center of the core window, with the magnetic flux generated by the current flowing through the conductor uniformly distributed around the core. Stray flux from adjacent or side-by-side positioned unshielded CT's will have some affect due to mutual inductance. But the effect of external stray flux produced by high-current bus-bars and cables adjacent to the CT, or other sources of magnetic fields close to a CT may greatly affect its accuracy. Also, the accuracy of a Current Transformer will depend as well on the impedance of the connected burden. Sufficient spacing's around the CT's will avoid errors.

    Posted on October 24th 2022 | 9:08 am
    Reply

Close