TechTopics No. 122

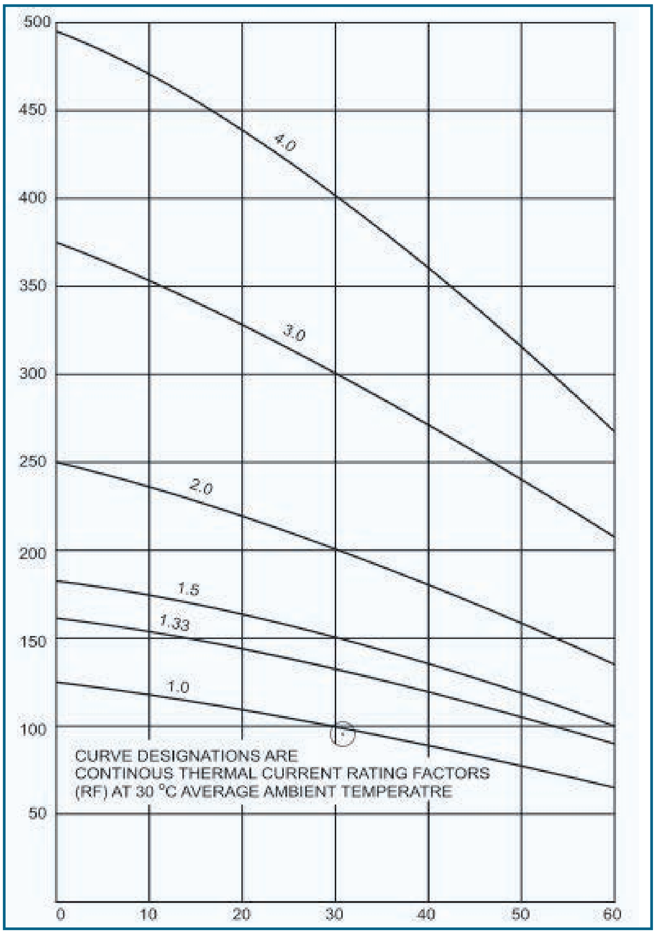
Current transformer thermal-rating factor

Current transformers have a thermal-rating factor, as specified in the instrument transformer standard, IEEE Std C57.13. Due to the number of questions Siemens receives about the thermal-rating factor (TRF), it appears there is confusion what the practical meaning of the TRF is.

IEEE Std C57.13 provides a thermal-rating factor curve for current transformers to give the permissible loading for the current transformer as a percentage of rated primary current when the current transformer is in various ambient temperatures. The figure shown is from IEEE Std C57.13. Percent of rated primary current is shown on the vertical axis and ambient temperature (in °C) is shown on the horizontal axis.

The standard rating basis of all current transformers is that the current transformer must be capable of carrying 100-percent rated current without exceeding 55 °C average winding temperature rise while in an ambient of 30 °C, thus a maximum allowable average winding temperature of 85 °C. In the curve shown, note that a CT with TRF of 1.0 (the lowest curve) intersects 100-percent of rated primary current at an ambient temperature of
30 °C.

Current transformers are available in several values of TRF, depending on rated primary current, such as 1.0, 1.33, 1.5, 2.0, 3.0, and 4.0. As applied in metal-enclosed and metal-clad switchgear or outdoor air-insulated circuit breakers, the higher values of TRF are generally not available due to space and other constraints in the overall equipment.



The standard recognizes that many current transformers are used in conditions of ambient temperature quite different from 30 °C. At the same time, IEEE Std C57.13 maintains a strict upper limit on average winding temperature of 85 °C.

In metal-enclosed and metal-clad switchgear and outdoor air-insulated circuit breakers, the rated maximum external ambient temperature is 40 °C, and the temperature rise of the air inside the enclosure is considered as 15 °C. As a result, the maximum ambient temperature inside the enclosure for the purposes of current transformer operation is considered as 55 °C, and the allowable temperature rise with 55 °C ambient is 30 °C, maintaining the upper limit on average winding temperature of 85 °C.

So, looking at the TRF curve again, for an ambient temperature of 55 °C, the following capabilities of CTs with various TRFs are seen as:

TRF	Capability (%) @ambient		55 °C / 30 °C percentage
	30 °C	55 °C	
1.0	100	74	73.9
1.33	133	98	73.9
1.5	150	111	73.9
2.0	200	148	73.9
3.0	300	222	73.9
4.0	400	295	73.9

The values for capability at 55 °C ambient, and the ratio of capability at 30 °C versus 55 °C ambient, were not read from the TRF curve. Instead, they were calculated based on the fact that the TRF curve is really just a representation of heating based on the square of the current. Therefore:

$$\frac{I_{\text{in 55 °C ambient}}}{I_{\text{in 30 °C ambient}}} = \sqrt{\frac{\text{30 °C allowed rise}}{\text{55 °C allowed rise}}} = 73.9\%$$

When application of CTs at the ambient inside switchgear or outdoor air-insulated circuit breakers is considered, a CT with a TRF of 1.33 is needed to be able to carry almost 100-percent of the rated current for the circuit breaker.

In practice, most of the current transformers that Siemens uses have a TRF of 2.0 (installed in switchgear, 148-percent) for ratios up to about 1,200:5, and 1.5 for higher ratios (installed in switchgear, 111-percent). Thus, the CT capability, as installed in the switchgear or circuit breaker matches the capability of the circuit breaker with which it is used.

The capability of the current transformer for currents above its rated primary current, as an example, 1,200 A rated primary current for a CT with 1,200:5 ratio, does not increase the capability of the circuit breaker or switchgear unit in which it is installed. If the circuit breaker or switchgear is rated for a continuous current of 1,200 A, the combination of the 1,200:5 ratio CT and the switchgear or circuit breaker configuration is limited to 1,200 A (for this example).

Consider another example of an 800:5 CT with TRF of 2.0 (installed in switchgear, 148-percent) in a switchgear compartment rated 1,200 A. For this example, the CT would be capable of 1,184 A, so the switchgear or circuit breaker combination would be limited to 1,184 A, instead of the switchgear rating of 1,200 A. To obtain the higher capability of 1,200 A, a higher-ratio CT (e.g., 1,000:5) would need to be used.

Some might be tempted to request a TRF of 4.0, on the expectation that a much smaller ratio CT (e.g., 600:5) could be used at 2.95 x 600 A = 1,770 A, or almost 1,800 A as installed in switchgear. As long as the resulting current is equal to or less than the continuous current capability of the switchgear, this would be true. So, if the switchgear compartment and circuit breaker were rated 2,000 A, loading to 1,770 A would be permitted. However, if the switchgear and circuit breaker were rated only 1,200 A, the load would need to be restricted to 1,200 A, even though the CT capability would suggest more.

It should be recognized that with a TRF of 4.0, the resulting CT secondary wire (in the CT secondary winding itself, and in the switchgear CT circuit), and all connected devices, would have to be dramatically larger (and more costly) than normal. In addition, the voltage drop on secondary wiring would be much higher, which would be highly undesirable. Thus, high TRF values should not be requested. High TRF values mean that the CT winding secondary wire size must increase, and considering that the overall size of the CT is normally fixed by the switchgear or enclosure design, the extra space for CT secondary winding wire would have to be taken from the space allotted for core steel, reducing the relaying accuracy of the CT.

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Siemens Industry
7000 Siemens Road
Wendell, North Carolina 27591

For more information, please contact our Customer Support Center.
Phone: +1 (800) 333-7421

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