ALLEN-BRADLEY

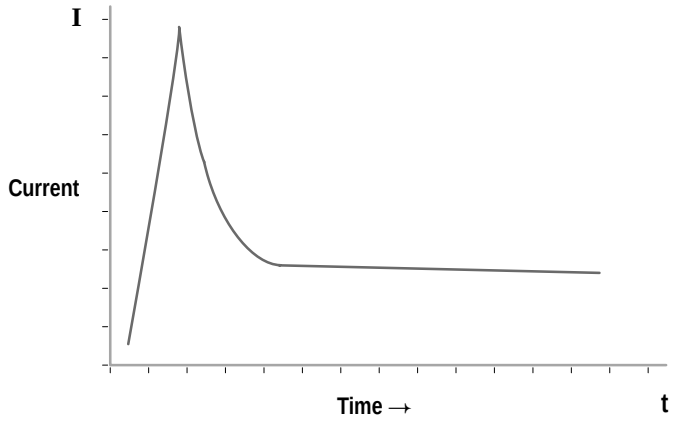
Using Circuit Breakers to Protect Transformer Circuits

Application Note

This document describes how transformer inrush current can cause nuisance tripping of standard trip circuit breakers during start up or application of power. Recommendations for selecting a high inrush compensated circuit breaker are provided.

Transformer Inrush Current

A transformer can generate an almost infinite current spike on start up trying to overcome the saturation of its core. The large current draw is limited only by the resistance of the windings and the inductance of the circuit.



Nuisance Tripping

The inrush spikes are of short duration (1/8 to 1/4 of a cycle). The standard trip circuit breaker, having a quicker reaction time, sees the spike as a short circuit and trips the circuit.

Intermittent nuisance trips may occur depending upon where the transformer core inductance resides at the time power is applied. The amount of core saturation and its location on the hysteresis loop influences the amount of current drawn at startup. This is why a circuit breaker may only trip periodically on start up.

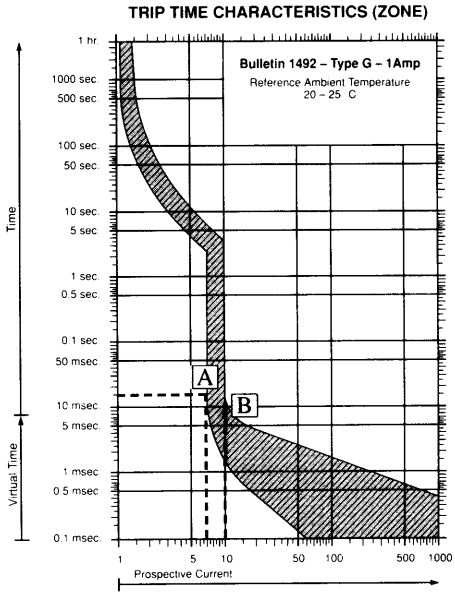
Trip Characteristics

Standard

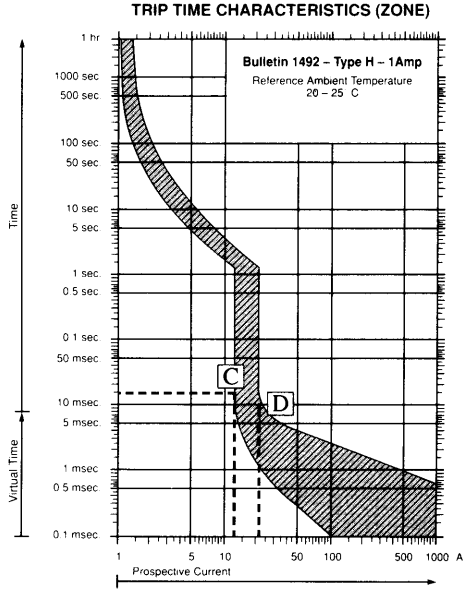
A standard trip characteristic has a time delay to compensate for inrush currents on startup. This trip characteristic works well for relays, solenoids and coils. These devices have typical inrush currents of 6-10 times their rated current when power is applied. A standard trip circuit breaker allows 6-10 times the rated current to be drawn by these load devices for 1 cycle (approximately 20 ms).

For example, a 1 Amp rated circuit breaker allows 6 amperes to be drawn by the load for a period of 20 milliseconds without tripping the circuit open [A]. The same 1 Amp circuit breaker must trip at 10 amperes [B]. Refer to graph.

In = rated current
Int = non-tripping current at 1 hour = 1.05 In
It = trip current (within 1 hour) = 1.35 In



Standard Trip Characteristic



Inrush Compensated Characteristic

Inrush Compensated

An inrush compensated circuit breaker allows for a greater inrush current spike but still reacts quickly to a short circuit or overload condition.
A typical high inrush current compensated breaker allows 12 to 20 times its rated current to be drawn for 1 cycle (20 ms).

For example, a 1 Amp rated circuit breaker must hold the 12 time rating (12 amperes) for a period of 1 cycle (20 ms) [C] but must trip at 20 times the rating (20 amperes) [D]. Refer to graph above. The inrush compensated breaker does not affect the rating of the breaker. Inrush compensated breakers react to an overload the same as standard breakers. In addition, both standard and high inrush rated circuit breakers react the same to short circuit/ fault conditions.

To achieve high inrush compensation using a standard trip breaker requires the current rating to be increased to 2 Amps in the above example (2 x 6 = 12 amperes inrush). This increase reduces the overload protection (by 50 %) as compared to the 1 Amp device.

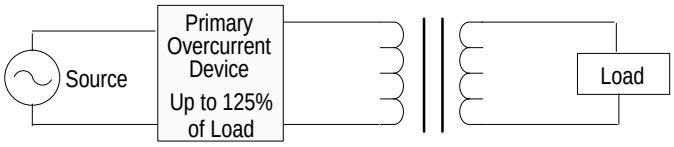
Selecting a Circuit Breaker For Transformer Protection

Circuit breaker protection for the primary side of the transformer can be sized per NEC (National Electrical Code) Article 450-3(b)(2) which states:

> ”All transformers of 600V, nominal, or less, shall be protected by an individual overcurrent device on the primary side . . .”

Article 450-3(b)(2) defines guidelines for sizing an overcurrent protection device. The correct sizing of a transformer primary winding depends upon whether or not the secondary windings have an overcurrent device.

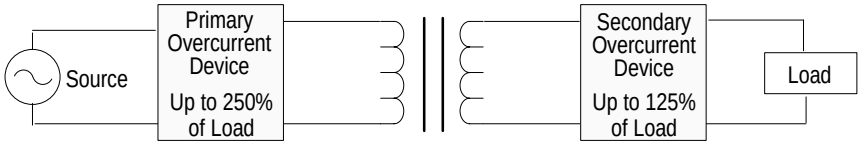
Overcurrent Device on Primary Winding Only



A primary overcurrent device can be sized at, but not more than 125% of the rated transformer load if the secondary side is not protected.

In this application, the primary overcurrent device protects the load as well as the transformer primary windings.

Overcurrent Devices on Both Primary and Secondary Windings



An overcurrent device on the primary side can be rated at, but not more than 250% of the rated transformer load, if the secondary side of the transformer has an overcurrent device rated at but not more than 125% of the rated transformer load.

In this application, the primary overcurrent device is protecting the transformer primary windings only.

Example Applications

By applying the recommendations of the NEC code and high inrush rated circuit breakers, you can apply circuit breakers to a transformer primary application without nuisance tripping while still achieving maximum short circuit and overload protection.

Application Without Secondary Overcurrent Device

A standard single phase transformer may have a rated current load of 2 amperes. Without a secondary overload device, the circuit breaker for the primary windings can be sized to 125% of 2 amperes or 2.5 amps. The NEC code allows you to use the next size available or a 3 Amp circuit breaker. Using a high inrush breaker allows a starting inrush of 12 times 3 amperes or 36 amps to be drawn for approximately 20 milliseconds.

Application With Secondary Overcurrent Device

If an overcurrent device is applied to the secondary windings of the transformer in the above example, the maximum ratings of the primary breaker can be increased. The same 2 ampere transformer can now be protected by a device that is rated up to 250% of the rated load or a 5 Amp circuit breaker. Applying a high inrush compensated circuit breaker allows for 12 times the current rating (able to hold a 60 ampere inrush current for 1 cycle [E]). See graph below.

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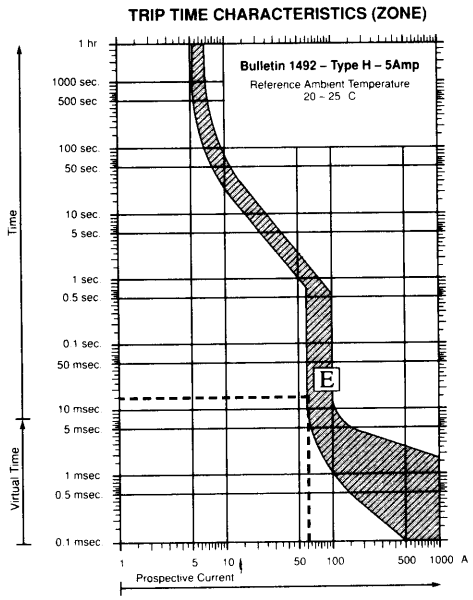
It = trip current (within 1 hour) = 1.35 In



5A Inrush Compensated Trip Characteristic

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