

Inrush Current

Technology Brief

Introduction

Energy shortages around the country, especially in California, have increased the urgency to install high efficiency motors in plants. While they consume less electricity than their older, less efficient counterparts, they are more likely to trip the circuit protector when they're started. The trips are caused by the initial start up current - or inrush current - which can be several times greater than their operating or steady-state current. In a three-phase motor, for example, inrush current generally lasts between 75-150 milliseconds with a current spike between 500% and 1200%. While short lived, this surge can create problems.

The most annoying consequence of inrush current is appropriately called a "nuisance trip" of the circuit protector. If the protector is not designed to handle the amount of inrush current that is present, the device can trip upon energizing the circuit or during circuit operation.

Excessive inrush current may also shorten the life of switches and circuit protectors. Switches are most susceptible since the current spike occurs as the contacts are closed, causing the contacts to become pitted. In severe cases, the excess current can weld switches.

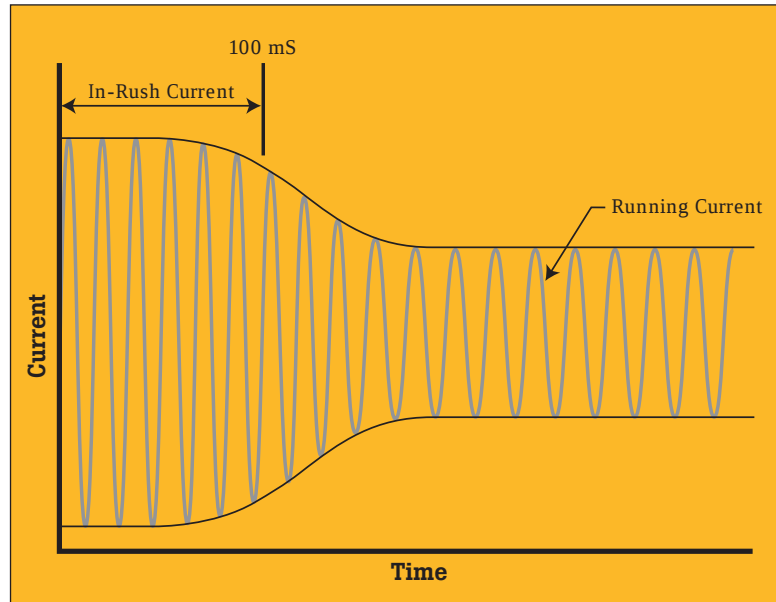


Figure 1. Motor starting current.

Because of this, precise measurement of inrush current is more than just a convenience; it's a critical element of motor installation. Fluke has designed a new set of tools that has the ability to accurately measure inrush current. The Fluke 330 series of clamp meters uses a proprietary algorithm and high-speed digital signal processing to filter out electronic "noise" and capture the starting inrush current as the circuit protector sees it.

Nuisance tripping

While conducting customer research for the new Fluke 330 series, one of the issues explored was nuisance tripping of circuit breakers or overload heaters by motors. Customers said the ability to accurately measure inrush current would be a useful feature.

Why does the display show a value higher than the rating of the circuit breaker?

Inrush current can be 4-to-12 times the normal running current depending on the type of motor. For example, if the running current of a motor is eight amperes and the starting current multiplier is five times the running current, the Fluke 330 Series clamp meter displays a reading of about 40 amperes, even though the circuit breaker is rated for 20 amperes.

The reason the breaker or overload unit does not trip is because both of these devices operate on a time versus current curve that indicates how much current for how long a period they will pass without opening the circuit. If the running current is too close to the continuous rating of the circuit breaker then the motor will usually cause the breaker to trip on starting almost all of the time.

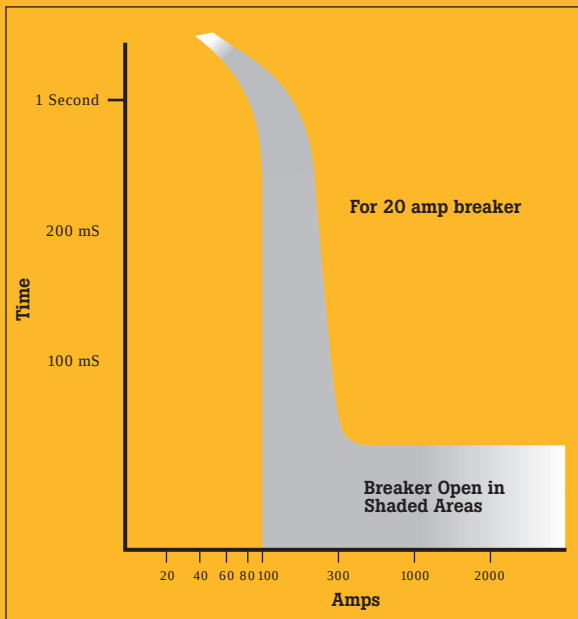


Figure 2: Breaker clearing time for 20 amp breaker.

When considering how to implement this capability in the 330 series, Fluke examined existing methods that have been used to perform this function, such as peak hold, max hold, and min/max hold. It became clear that these methods were inadequate since none of them gave readings that accurately depicted the current the circuit protector experienced. Fluke decided to look at what happens when the motor goes through its startup and how the current draw profile affects circuit breakers and overload units.

After researching motor startup current profiles, Fluke developed the inrush function used in its 330 Series Clamp Meter as a highly accurate method to measure actual startup current. One of the most common problems with previous methods of measuring inrush was that the measurements weren't necessarily synchronized with the motor start-up, so measurements were not only inaccurate but unrepeatable as well.

In order to avoid this pitfall, the 330 Series' inrush function is triggered by rising current in the start-up phase. The technician first "arms" the inrush function of the clamp meter. The meter is then triggered by the inrush current. Once triggered, it takes a large number of samples during a 100 millisecond period and then digitally filters and processes the samples to calculate the actual starting current. This results in a highly accurate, synchronous indication of the start current not previously available in a clamp meter.

Peak, Min/Max, and Inrush

It's important to understand that different brands of clamp meters will use different terms to describe the same measurement. In addition, the actual operation of the feature may be significantly different from what the name would imply. While there is too wide a variation across brands to detail in this space, the following are the terms Fluke uses.

Analog peak

The earliest Fluke handheld instrument to have a highest value capture feature was the 8024A digital multimeter (DMM). It had an analog peak hold circuit (labeled "Peak Hold"), which captured the highest peak value that lasted for 10 milliseconds or longer, regardless of when it happened in time. From a strict definition point of view, this was a correctly labeled feature since it did capture the actual peak value, but it didn't necessarily measure the inrush current.

Digital Min/Max

Newer generations of Fluke DMMs, like the Fluke 27, had a min/max function (more correctly labeled digital min/max). It looks at a portion of the a to d cycle to obtain its value, which happened at a fixed rate based on the system clock. However, it made its measurements when it wanted to, which in many cases did not coincide with the startup event, so it could miss the event partially or completely.

The Fluke 87 was the first handheld instrument to have both a 1 millisecond analog peak and 100 millisecond digital min/max, allowing for measuring of relatively short or medium long events. Again, the 100 millisecond min/max suffered the same limitations as the earlier model 27; the measurements were not synchronous with the occurrence of an event.

The first Fluke clamp meter to have a max hold feature was the Fluke 36. Although this was implemented as an analog track and hold, in ac the Fluke 36 looked at the output of the ac analog rms converter. That significantly slowed the response rate so that the 36 was only useful for events that lasted several hundred milliseconds or longer. Unfortunately this was too slow for short-term events, like inrush current.

Min/max on the Fluke 337 Clamp Meter is a digital min/max — similar to the one on the Fluke 27 — and it is updated every time the display updates. Its sampling window opens for about 100 milliseconds every 400 milliseconds and takes a number of readings, and updates the min or max registers as appropriate. This type of min/max is most useful for longer-term events, such as those occurring on heavily loaded or long wire run circuits, to record more regular voltage drops or load increases, but is not ideal for inrush measurements.

Inrush on the Fluke 43B vs. the Fluke 330 Series

Fluke has inrush functions on other products, such as the Fluke 43B Power Quality Analyzer, but while they share the same name, they are different.

The 330 Series takes a large number of samples precisely at the beginning of the starting current for a 100 millisecond period and then digitally filters and processes the samples to calculate the actual starting current.

In contrast, when "inrush" is selected from the Fluke 43B menu, it digitally captures the current (amps) waveform. A cursor can then be used to pick out the instantaneous amps value at any point of the sampled amps waveform.

The Right Tool for the Job

New high efficiency motors require better tools to evaluate and fix the consequences of their high inrush current. The Fluke 330 Series of clamp meters is designed to capture inrush current accurately and, most importantly, synchronously, providing readings that accurately depict what the circuit protector experiences. Using the right tool for the job allows you to protect your plant's equipment investment and avoid some of the annoying problems inherent with installing new motors.

Glossary of terms

a to d converter	Analog to digital converter. An electronic hardware device that converts analog signals to digital signals.
Analog peak	The highest peak value measured that lasted some specified time period, usually measured in milliseconds.
Circuit breaker	A circuit wiring and device overload protection device in a single-phase system.
Digital min/max	The measurement of the minimum and maximum values (e.g. voltage, current or resistance) over a specific period of time.
Inrush current	A transient condition, generally lasting 75-150 milliseconds that occurs during motor start-up.
Overload units	Devices in motor start control units, such as heater coils, overload trips, thermals, etc. There are a number of different phrases used worldwide to refer to these devices.

Additional resources

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