FLUKE®

Making accurate inrush current measurements

Application Note

It is estimated that 65 percent of the electrical energy consumed in the United States goes to electric motors and that more than 78 percent of the electricity consumed by industry is used to power electric motors. If all the motors sold in this country met the energy efficiency goals set by the Consortium for Energy Efficiency, companies would save 23.3 billion kWh, worth about $1 billion. Add to that the energy shortages around the country and it's no wonder the urgency has increased to install high-efficiency motors in plants.

While high-efficiency motors consume less electricity than their older, less efficient counterparts, they are much more likely to trip the circuit protector when 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. While all motors draw inrush current, it is much greater in high-efficiency motors. In a three-phase motor, for example, inrush current generally lasts between 75-150 milliseconds with a current spike between 500 and 1200 percent. 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.

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 set of tools that has the ability to accurately measure inrush current. The Fluke 335, 336 and 337 Clamp Meters use a proprietary algorithm and high-speed digital signal processing to filter out electrical "noise" and capture the starting current as the circuit protector sees it.

Nuisance tripping

While conducting customer research for the Fluke 330 Series Clamp Meters, one of the issues explored was nuisance tripping of circuit breakers by motors. Customers said the ability to accurately measure inrush current would be extremely useful.

When considering how to implement this capability in the 330 Series, Fluke engineers examined existing methods that were supposed to perform this function, such as peak hold, max hold, and min/max hold. It became clear that past approaches were inadequate since none of them gave readings that accurately depicted what the circuit protector experienced. Fluke decided to look at what happens when the motor goes through its start-up and how the current draw profile effects circuit breakers or overload units.

After researching motor start-up current profiles, Fluke implemented the inrush function as a better way to measure start-up 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 would be inaccurate or unrepeatable.

In order to avoid this pitfall, the 330 Series' inrush function starts precisely when the inrush current starts. 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 ms period and then digitally filters and processes the samples to calculate the actual starting current. This results in a more accurate, synchronous indication of the start current than previous clamp meter instruments.

Why does the display show a value higher than the rating of the circuit breaker?
Inrush current can be four-to-twelve times the normal running current depending on the type of motor. For example, if the running current of a motor is 8 A and the starting current multiplier is five times the running current, the Fluke 330 Series Clamp Meter display should read about 40 A, even though the circuit breaker is rated for 20 A.

The reason the breaker or overload unit does not trip is because both of these devices have 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.

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, have a min/max function (more correctly labeled digital min/max). It looks at a portion of the analog-to-digital conversion to obtain its value and is based on the meter's system clock. So, it takes measurements when it wants to, which, in many cases, do not coincide with the startup event and could miss the event partially or completely.

The Fluke 87 was the first handheld instrument to have both a 1 ms analog peak and 100 ms digital min/max, allowing for measuring of relatively short or medium to long events. Again, the 100 ms 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 down the response rate so that the 36 was only useful for events that last several hundred milliseconds or longer. Unfortunately this was too slow for short-term events, like inrush current.

Min/max on the 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 ms every 400 ms and takes numerous readings, updating 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 PQA 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.

Again, the 330 Series takes a large number of samples precisely at the beginning of the starting current for a 100 ms 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 43B communicates the inrush as a high-speed graph of current over time rather than a single reading.

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 335, 336 and 337 Clamp Meters are designed to capture inrush current accurately and, most importantly, synchronously and provide 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.

FLUKE®

Safety first

As a company, Fluke Corporation is focused on safety in all its products, and has sought industry-wide protection measures to help ensure safe working conditions and product specifications for electrical technicians. Fluke aggressively promoted its Electrical Safety Program, an educational campaign aimed at raising awareness of industrial electrical hazards and product standards. Taking the lead on safety issues in the handheld test tool industry, the Fluke program helps educate users on how to identify which products meet industry standards and pass independent tests, and promotes safe work practices for front-line electricians, technicians and troubleshooters. Fluke's safety campaign is a continuing program through which the company offers educational seminars and videotapes outlining dangers in the workplace, and how to avoid injury from misapplying products in hazardous environments.

Glossary

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 specific 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 40-150 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

Fluke Corporation
www.fluke.com

IEEE
www.ieee.org

Fluke. *Keeping your world up and running.*

Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa (31 40) 2 675 200 or
Fax (31 40) 2 675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com/

Printed in U.S.A. 9/2002 2041766 A-ENG-N Rev A