EDITORIAL

What's in *Your* Toolkit?

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If you're like me, you've spent a lot of time carrying a digital signal analyzer (DSA) and various things to feed it. I'd like to suggest you add to that compliment of accelerometers, pressure sensors, force gauges, impedance heads and microphones a clamp-on current probe.

What exactly is a clamp-on current probe? It is a noninvasive sensor that measures the electrical current (amperage) dynamically flowing though a conductor. The probe has a plier-like jaw that is opened to admit an insulated current-carrying conductor then closed to surround it for measurement. There is no need to break the conductor's insulating sheath and no need to interrupt power to make the attachment. It's a safe and simple way to measure current, particularly for the non-electrician. These probes come in two types: AC only and AC/DC responsive. Both are extremely useful to a machinery diagnostician.

The AC-only probe is basically a transformer. The plier jaws are made of laminated soft iron. When closed around a wire, the jaws form a low-reluctance magnetic core in the wire's magnetic field. A wire coil is wound around this iron lamination. The wire coil (of N turns) is the transformer's secondary or output winding. The single wire passing through the probe acts as the transformer's single-turn input or primary winding. A current of A amperes flowing through the clamped wire induces a current of A/N in the secondary coil (assuming it is closed by a low impedance).

This output current is directly usable by DVMs and other power monitors featuring current inputs. However, such probes (with a sensitivity expressed in mA/A) are not generally useful with a DSA or vibration data collector. By closing the secondary coil with a low-value precision resistor, a voltage output results (with sensitivity in mV/A). Some units provide switch-selectable closing resistors for multiple sensitivity (and full scale) choices. Since it operates like a transformer, this type of current sensor is not sensitive to DC. However, AC probes are rugged, require no batteries or external power and can be very compact.

An AC/DC probe uses a similar laminated iron jaw structure and a Hall-effect sensor. Instead of winding a coil around the jaw, this magnetic core is interuppted by a thin substrate coated with gallium arsenide (GaAs), indium antimonide (InSb) or indium arsenide (InAs). A DC current i is passed through this film perpendicular to the laminated iron core. When a magnetic flux B passes through the iron and the sensor, a voltage proportional to iB is developed between the edges perpendicular to those through which the constant current is applied. This output is termed the *Hall Voltage*.

Figure 1. Small clothespin-style AC probe.

Figure 2. Typical battery-powered, multi-range AC/DC probe.

Hall probes contain a battery or require external power. They contain circuitry to regulate the constant DC-reference current, i and an instrument amplifier to provide a low-impedance image proportional to the Hall Voltage. Multiple output ranges are frequently provided as is a "zeroing" button, causing a DC bias to force the output to zero volts (with no wire in the jaws). AC/DC probes tend to be larger and more expensive than AC-only probes of similar amp rating and jaw size. But they measure a current's DC level, which can be invaluable when working on cars, aircraft, boats and other vehicles as well as for use in processing plants.

A current probe can give you new analytic insight into mechanical performance of many things. Consider a simple but common example: You are analyzing a machine driven by an induction motor. You detect an anomalous acceleration signature from the housing. Analysis of this signature would be far simpler if you knew the motor's exact operating speed – but this system has no tachometer installed. You only know the motor's nominal RPM (60 f_{shaft}) from its nameplate; this is not precise enough for your needs.

You clamp your current probe around one of the wires powering the induction motor and measure a low-frequency spectrum. You look around the power-line frequency (60 Hz here, 50 Hz there) and observe two symmetrically disposed peaks around the line frequency. These peaks are the pole-pass or twice slip sidebands separated from the line frequency f_{line} by $\pm f_{pole\ pass} = \pm 2S\, f_{line}$ (Hz), where S is the non-dimensional slip. Use your DSA's cursors to measure $f_{pole\ pass}$ and evaluate the shaft rotational speed (in Hz) as $f_{shaft} = (2f_{line} - f_{pole\ pass})/P$, where P = integer($120f_{line}$/RPM) is the number of motor poles.

A sensitive (10 mV/mA, 50 mA full-scale) AC/DC probe is suitable for "eavesdropping" on a 4-20 mA process loop. A properly operating process loop will exhibit a DC current between 4 and 20 mA. A broken loop will pass 0 mA, and anything significantly exceeding 20 mA indicates a loop hardware problem. The actual current level allows you to estimate the percent of full-scale pressure, flow or other process variable monitored by the loop. When examining a vehicle, it is frequently useful to know when an electrical component (such as a fan) turns on or off. An AC/DC current probe can provide this information. If the wiring harness does not provide a convenient place to snap the probe on, consider replacing the component's fuse with a short length of wire and clipping the probe around this jumper.

A probe with a jaw larger than the conductor diameter can be an advantage. This allows the clamp to encircle multiple conductors; the probe then measures the sum of all currents passing through it. So if your probe is not sensitive enough for the problem at hand, try looping the conductor through the jaws multiple times. The mV/A sensitivity increases in proportion to the number of turns that pass through the jaws. If you need 100 mV/A and your probe only provides 20 mV/A, wrap five turns together and clamp around the loop formed – problem solved.

You can also use two conductors where the current is known to flow in opposite directions to measure the difference in the flowing currents. For example, if you clamp a sensitive AC probe around the two wires feeding a single-phase load or the three wires feeding a three-phase load, the resulting measurement is the installation's leakage current (which should be zero). Should you (using an AC/DC probe) be interested in a small AC signal that is "buried" by a DC bias, you can use a battery or other DC source (and possibly multiple turns) to "buck" the bias, allowing a higher mV/A setting to be used for more resolute study of the AC component.

I've used my clamp-on probes to study induction and brush-commutated motors and their loads. I have also used them to probe the inner workings of electrodynamic shakers and their payloads.

No, you probably won't reach for a current probe every day, but when you do you will learn something the less prepared analyst might overlook. S/V

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