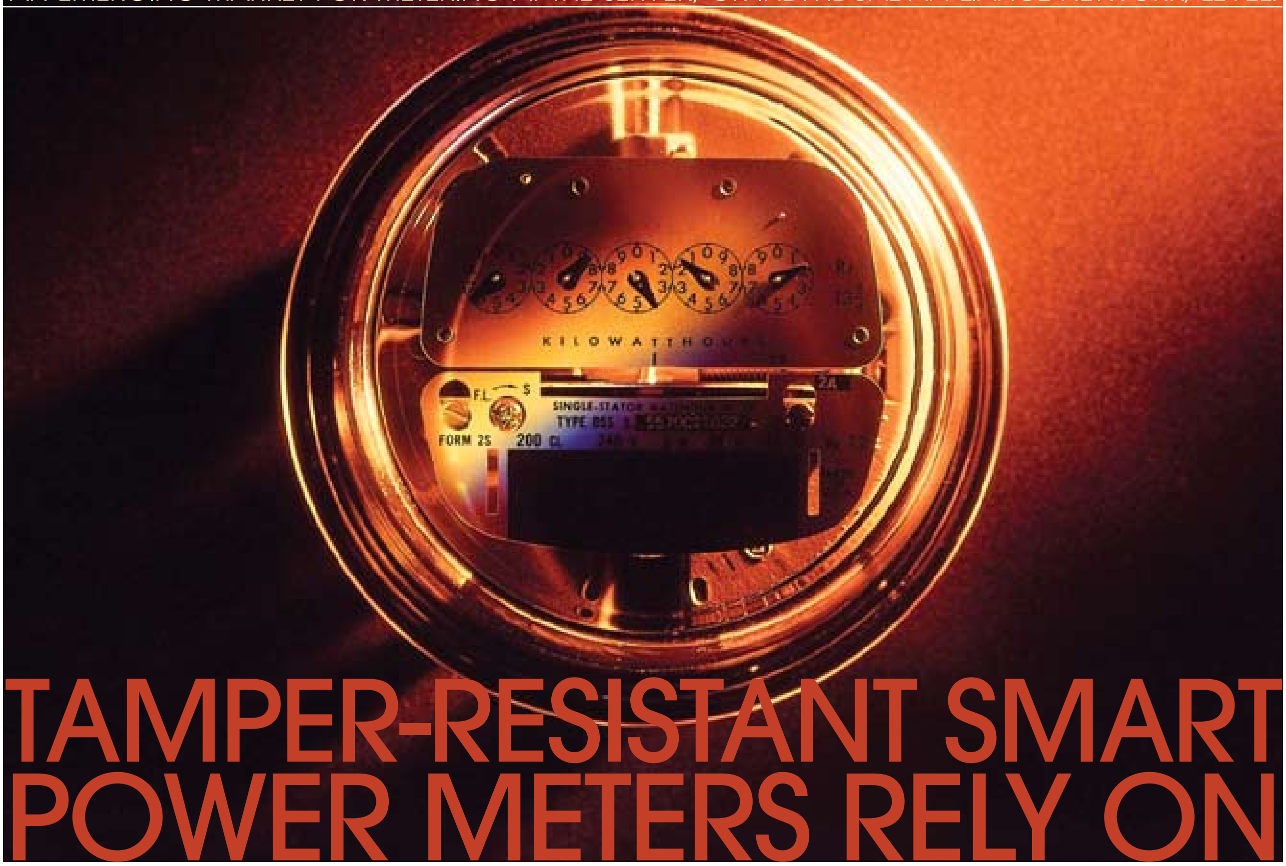
UTILITIES ARE PUSHING TO REPLACE OLD ELECTROMECHANICAL METERS WITH MICROCONTROLLER-BASED SMART METERS THAT, IN ADDITION TO THEIR INTELLIGENCE AND COMMUNICATION ABILITY, ARE ALSO TAMPER-PROOF. THERE IS ALSO A GROWING MARKET FOR INDIVIDUAL SMALL POWER METERS AND AN EMERGING MARKET FOR METERING AT THE SERVER, OR INDIVIDUAL-APPLIANCE-NETWORK, LEVEL.



TAMPER-RESISTANT SMART POWER METERS RELY ON ISOLATED SENSORS

BY MARGERY CONNER • TECHNICAL EDITOR

Most residences and commercial buildings in the United States currently use an old-style electromechanical utility power meter to track electricity use. The meters are reliable and cheap but hopelessly inadequate for use by a power-distribution system that requires accurate, repeatable power metrics as well as wired or wireless communications—in other words, the coming Smart Grid electrical-power-distribution system.

The Smart Grid depends on smart meters with sophisticated communication capabilities to monitor energy usage and allow residential and business consumers alike to make informed choices about how much energy to use and when to consume it. The Smart Grid faces difficulties, though. Although, at the federal level, Washington has passed legislature such as the 2007 energy bill and the 2009 stimulus plan, utilities actually deploy power on a state-by-state basis. California and Texas are the states most aggressively moving toward smart metering in preparation for the Smart Grid (**Reference 1**).

Regardless of whether the Smart Grid in some form will proceed at the national level smoothly and seamlessly, enough individual utilities are purchasing and installing electronic power meters to make this market significant. Look at the important applications of the past 20 years: cell phones, computers, large-screen TVs. They make their mark because they have a market in the hundreds of millions. Utility-installed power meters have a similarly powerful market. Every house and commercial building requires one. Utility companies could replace 500 million meters worldwide over the next 10 years.

Smart power meters comprise a microcontroller with onboard ADC and DAC, a sense component for both voltage and current, an ac/dc-power converter, battery backup, and wireless or wired communication capability (**Figure 1**).

Power-meter ICs are available from companies including Texas Instruments, On Semiconductor, Maxim, Analog Devices, Teridian, and Ev2. These ICs are essentially microcontrollers that track power-usage information as well as information back from the utility. They can perform some DSP calculations on voltage waveform and quality, communicate the information to a display, and store the information to be sent. Although the term *smart meter* indicates that the microprocessor is the central component, antitampering precautions make selection of the current-sensing component and even power backup important decisions for smart meters.

There are three main types of current-sensor technology for power meters: current transformers, Rogowski coils, and resistive shunts. The technology you use depends on whether the power distribution is multiphase or single-phase. Most homes worldwide use only one phase from the generator coming to the wiring of the house. The US residential market uses a split-phase distribution that delivers 120V ac and as much as 240V ac to residences and requires a current transformer as the isolated voltage/current sensor. Commercial and some residential deployments in northern Europe use three-phase, but homes are usually single-phase. In general, when sensing voltage and current to determine power usage in metering, you use a shunt resistor on single-phase distribution systems and a current transformer or Rogowski coil in a split- or three-phase system, because measuring the voltage across different phases can exceed the voltage tolerance of semiconductor devices.

The most popular isolated sensors are current transformers, Rogowski coils, and Hall-effect sensors, roughly in order of popularity (**Figure 2**). A current transformer has an iron core and is susceptible to tampering with a large permanent magnet. A magnet next to the transformer can saturate the core so that the sensing coil can't pick up the ac field in the power line. A Rogowski coil has an air core and consists of a coiled piece of wire that wraps around the power line. Unlike an iron core, the air core doesn't saturate in the presence of a large permanent magnet. However, it's susceptible to other tampering methods, such as the presence of a large inductive field that couples into the coil and over-

AT A GLANCE

- Implementing the Smart Grid requires utility meters with electronic intelligence, tamper-proof electronics, and backup power.
- Magnetic and inductive fields do not affect shunt-based current sensors, as they do current transformers and Rogowski coils.
- Current transformers and Rogowski coils are inherently isolated sensors.
- Backup power sources allow power meters to record and transmit power-outage data when ac power is unavailable.

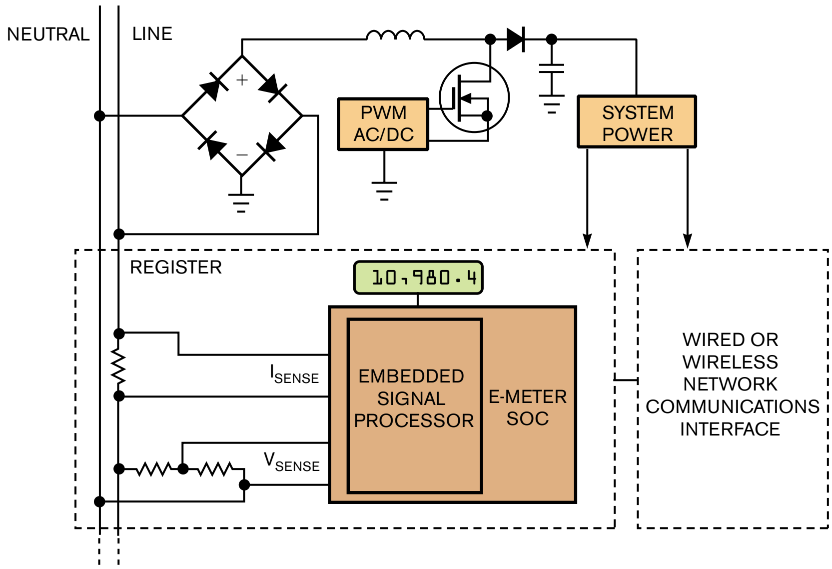


Figure 1 Smart power meters comprise a microcontroller with onboard ADC and DAC, a sensing component for both voltage and current, an ac/dc-power converter, battery backup, and wireless or wired communication capability.

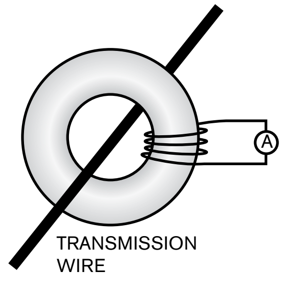
whelms the ac current the coil is meant to sense.

Hall-effect sensors rely on a semiconductor device to sense the magnetic field caused by the alternating line current. But their readings can vary with temperature and are not always linear over a wide range of current. This problem is more significant in the US market, in which meters are rated as high as 200A, than in, say, India, where meters measure 20 or 40A. "Linearity becomes important in a market like the United States," says Kourosh Boutorabi, Teridian's vice president and general manager of the meter-products-business unit. "The requirement by utilities is for meters to have 0.2% error. Tolerances in the rest of the world are closer to 1% error. If you're consuming more power, then more loss in measuring is more important, and accuracy in measuring is more important."

Hall-effect sensors have advantages, too, he says. "Although they are not as accurate as [current transformers], they are cheaper." A Hall sensor can be pushed against [the power line] with no physical interconnection." With a current transformer, you have to manually assemble the power line and the sensing coil.

Most power meters worldwide are single-phase and use a simple shunt resistor as a current-sensing element. Cathal Sheehan, product-marketing manager for Bourns' resistive-products division, characterizes shunts as simple, inexpensive, and unaffected by the magnetic and inductive fields that befuddle magnetic and inductive sensors.

Mark Strzegowski, energy-metering-products-marketing engineer at Analog Devices, agrees that shunts provide no isolation between multiple phases, so you need to provide the isolation elsewhere. The company's approach is to use a shunt resistor with an isolating planar transformer it bases on the company's iCoupler technology for the isolating component: The iCoupler and shunt resistor combined are still cheaper than the cost of a current transformer or Rogowski coil, and they still preserve measurement linearity. "One of the things important to consider in selecting a current-sensing technology is the performance that the customer is looking for," says Strzegowski. "There has been a trend in the market toward wider dynamic ranges and also adding more measurements. You need to accurately measure 100A current all the way down to 100-mA current, with the same level of accuracy, since 0.1% is a typical accuracy spec."



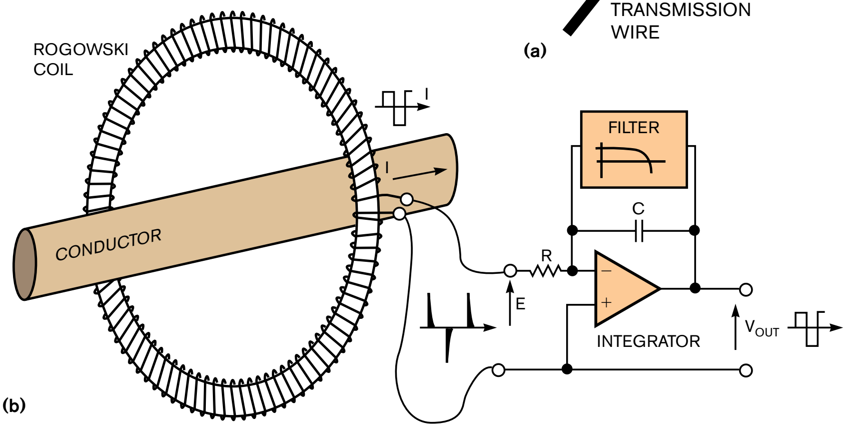


Figure 2 A current transformer's iron core is susceptible to tampering with a large permanent magnet. When you place it next to the transformer, the magnet can saturate the core so that the sensing coil can't pick up the ac field in the power line (a). Rogowski coils have an advantage over current transformers because they employ air cores (b).

Shunts have inherent problems with heating: Although their response is fairly linear, they can't handle some of the largest loads because of their self-heating effect. Likewise, current transformers typically have a small phase distortion that requires compensation, especially when applications require more sophisticated measurements, such as reactive- and harmonic-energy measurements. In general, single-phase power-distribution meters have shunt resistors for sensors, and three-phase meters have current transformers.

Silvestro Fimiani, product-marketing manager at Power Integrations, argues that, in addition to its being tamperproof, efficiency in a power meter is important, especially because there is the potential in the near future to install or replace more than 100 million power meters worldwide. "Over the life of the meter, you can waste as much as $20 in energy costs due to inefficient power usage in a meter," he says. "This [amount] can be as great as the cost of the meter." Fimiani may be a relatively lonely voice in the wilderness of smart meters calling out for power efficiency: Few other vendors are concerned with meter efficiency, possibly because the purchaser of meters, usually a utility, is not the entity that pays for the meter's power consumption. That cost is invisible but passes on to the consumer.

The components in a power meter should consume little power not only for the sake of cost savings and efficiency, but also to make sure that the meter operates efficiently when battery-powered. It's strange to think of a power meter's relying on battery power, but smart meters must be able to continue to operate even when there is a power outage.

The importance of battery backup in power meters depends on the region. In the United States, for example, if the power is down, there's nothing to measure, so there's little need to have the meter awake. Strzegowski of Analog Devices points out that, in India, however, some specifications require that there must be two batteries in the system. One powers meter reading and information storage for 24 or 48 hours and keeps the display alive. The other retains the meter information for as long as two years to prevent meter tampering. It removes the meter from the power line so that there is no voltage available to the meter electronics, but power is still flowing in the line.

Battery backup for power meters is often in the form of a lithium-thionyl battery, which has a self-discharge rate in the nanoamp region and a shelf life that exceeds 10 years. Tadiran is the largest manufacturer of these batteries in the United States. The battery alone is enough to back up data in the meter but not to burst data out in a wireless communication. One approach is to use the battery to trickle-charge a supercapacitor. Pierre Mars, vice president of applications engineering at supercapacitor manufacturer Cap-xx, explains how government regulations affect the meters: "Even though the meter is connected to the mains and there is abundant power, the meter cannot use it to transmit data," he says. "One example is where I live in Australia, where the rules are [that] the meter cannot draw more than 2W of the user's power, so they need to use a [supercapacitor] to provide the burst power for GSM [global-system-for-mobile] communications transmission, which requires up to 6W for 0.6-msec bursts, with average power less than 0.75W." Mars notes that, if the government had written the rules in terms of energy used, rather than limiting peak power drawn, there would have been no problem.

In addition, supercapacitors provide adequate transmitting power for "last-gasp" transmissions, in which, in the event of a power failure, the supercapacitor backs up power to enable a transmission, alerting the meter that the power has failed.

Worldwide, power lost to tampered meters varies widely by region: The United States probably loses less than 4% to tampering, whereas India reports losses of greater than 10%, and losses in some Latin American countries can reach 20%. The search for a tamper-proof power meter is another reason to move toward smart power meters. One of the simplest and most common ways

GOOGLING YOUR POWER STATS

There is a truism in managing resources: You can't improve anything you can't measure. Google.org, the philanthropic side of Google, says, "We believe that everyone deserves access to their energy information to make smarter choices about energy use." So, Google is developing software that allows everyone to display their home power usage right on the Google home page (Reference A, Figure A).

The only catch is that the Google PowerMeter depends on the user's having a smart power meter. Currently, there are about 40 million smart power meters worldwide, but power utilities are planning to add 100 million more within a few years.

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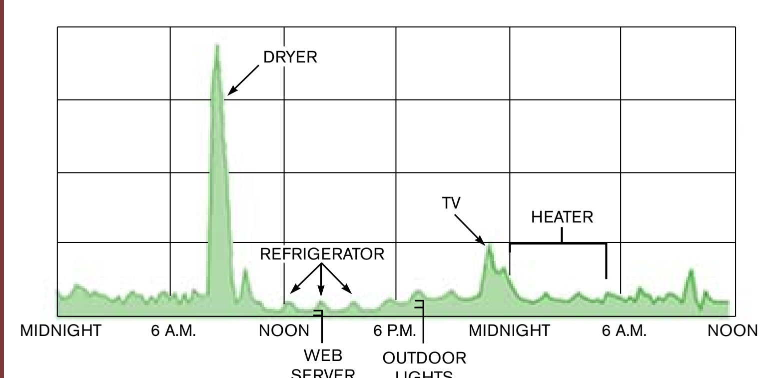

Figure A Google's PowerMeter software, currently in prototype, will receive information from utility smart meters and provide that information to homeowners on the Google home page. The information includes total energy consumption and energy consumption by time of day.

to tamper with a power meter is through the sensor.

Why are antitampering methods important in the United States? At increasingly high electricity rates, a 4% loss is enough to get the utilities' attention. But, even more important, stolen power is the most common power source for illegal marijuana "grow houses." The power bill for such houses in urban areas can easily hit $10,000 a month, and stealing power from nearby power lines is a convenient way to get it. Neither nearby residents nor utilities are in favor of grow houses, so using smart meters is potentially an effective way to curb the activity. However, any activity that implies that a large organization, such as the government or a utility, is monitoring personal activities is a concern to some people (see **sidebar** "Googling your power stats.")

The rising cost of power has made fine-tuning of power metering for nonutility applications, too. Dave Heacock, senior vice president of TI's high-volume analog and logic business, says that server farms sometimes ask their front-end ac/dc-power-supply vendors to include power metering so that the farms can charge their customers according to their usage: The power they use at peak usage time will be subject to a higher rate. "Users [will] start to think, 'I'm going to do all my credit-card transactions at midnight when power costs less,'" Heacock says.

Tolerances for such an application will probably not be as tight as for a utility power meter: Heacock suggests representative tolerances for such metering devices are 2% for loads greater than 20% of full load, dropping down to 5% accuracy at 5% of full load. The reason for the relatively loose tolerance, he explains, is they don't want to add appreciably to the cost of the solution. EDN

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FOR MORE INFORMATION

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