# Electric Utilities Can Protect Revenue Through New Advances in Smart Meter Electronics

*By John Pitrus*

## Idea in Brief

Various trends are driving an increase of electricity theft worldwide. The rate of theft does not seem to be very large; however, the cumulative effect on utilities is significant. Electricity meter standards bodies like IEC and ANSI have developed requirements intended to prevent meter tamper and minimize electricity theft. But the standards are not always effective, and sophisticated users can circumvent the safeguards.

A convergence of innovative technologies is driving better electricity meter design and stronger protection from a common form of theft. The innovative technologies are precision converters and chip scale transformers. The method of theft is tampering with a smart meter by using an external magnet such that the meter undercounts or stops working altogether. When these technologies are leveraged, semiconductor vendors can offer integrated circuits for energy measurement applications that combine:

- Precision analog-to-digital converters
- Digital isolation for data channels
- Isolation for dc-to-dc power conversion

The resulting energy measurement ICs are small and inexpensive and offered in a single low profile package that ultimately enables a new class of smart meters that are completely immune to magnetic tamper. Electric utilities that begin deploying smart meters with these underlying technologies will see a decreased rate of electricity theft and an increase in their long-term revenue.

## The Problem

Some of you are probably already familiar with shoplifting, or the act of deliberately stealing products from a store where merchandise is displayed for sale. Most shoplifters tend to be amateurs; however, there are individuals and organized groups who make their living from shoplifting and tend to be more sophisticated. Shoplifting penalties are typically lower than general theft and oftentimes it's difficult for retailers to apprehend and prosecute shoplifters. Some retailers in the U.S. report that shoplifting has a significant effect on their bottom line, and that about 1% of all inventory disappears to thieves. This may seem like a low percentage, but some have estimated that shoplifters cost all U.S. businesses over $25 million a day.

In many respects, electricity theft is a lot like shoplifting. Some thieves are individual consumers who learn how to steal from their utility through the Internet, while others are sophisticated enterprises involved in illegal drug cultivation. The costs to utilities associated with pursuing suspected energy crimes are often far higher than the revenues recovered. Also, laws and regulations only establish a limited obligation on utilities to combat electricity theft. In the U.S., the industry consensus is that electricity theft costs utilities between 0.5% and 3.5% of annual gross revenues. Again, this level of theft rate seems low, but in one year it can amount to over 1 TWh of generated electricity or over $100 million in lost revenues. In other countries with weaker governance, the rate of electricity theft is estimated to be as high as 20%. Two important differences between the shoplifter analogy and electricity theft are 1) the commercial establishment is a single local utility company instead of a group of different retailers, and 2) the pool of potential criminals is much larger and more distributed than consumers who shop at local retailers. In other words, the potential for economic harm is concentrated at the utility and the beneficiaries are widely dispersed and challenging to catch.

Two recent trends have contributed to the emergence of electricity theft as a serious worldwide problem. First, many utilities started off as state owned monopolies where efficiency and profits were not the highest priority. During the last several decades, many governments have privatized energy infrastructure and improved energy policy so that utilities must operate efficiently and optimize profits. As a result, utilities have a greater incentive to address the problem of electricity theft and protect their revenue. Second, electricity prices have been rising primarily because of cost increases for raw materials used during electricity generation (oil and coal).

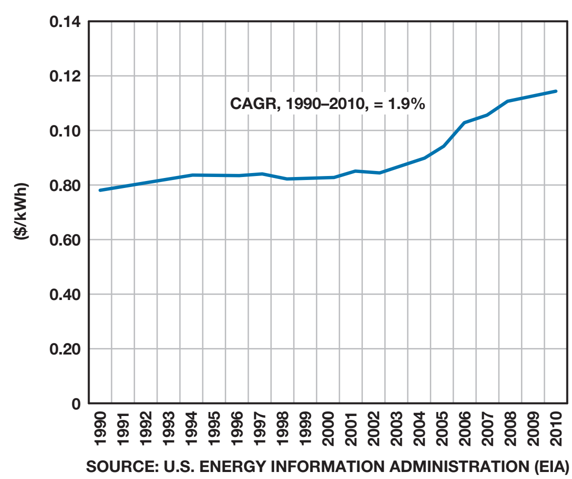


*Figure 1. Average price of electricity in the U.S.A.*

For example, during the last two decades in the U.S., average electricity prices have increased by about 2% annually, from $0.078 per kWh in 1990 to $0.114 per kWh in 2010. Poor macroeconomic conditions have compounded the situation because during times of economic hardship, some consumers and businesses are more inclined to steal electricity.

## How Stakeholders Cope with Theft: Technical Standards for Smart Meters

Utility companies all around the world have known about electricity theft for years and have established a variety of technical requirements for electricity meters that are intended to prevent meter tamper and minimize electricity theft. For example, the International Technical Commission, which is the official body that creates international electricity meter standards, developed a specification for static electricity meters defining accuracy classes of 0.2 and 0.5. Document IEC 62053-22 has an entire section that describes "influence quantities" that can impair meter accuracy. It includes items that may occur during a tamper event, such as reversing the sequence of the phase voltages, applying an external ac or dc magnetic field, or applying electromagnetic RF interference. More specifically, IEC 62053-22 states that for a Class 0.2 meter, an external ac magnetic field with a strength of 0.5 mT can cause an error no larger than 0.5% from the true measured value. It also defines what the test requirements are and describes all of the reference conditions needed to confirm the meter is complying with the specification.

The American National Standard Institute has also developed a similar specification that defines electricity meter tamper events and establishes how meters must maintain correct operation and accuracy. Document ANSI C12-20-2002 contains a section that addresses conditions that can coincide with meter tamper, such as applying an external magnetic field or subjecting a meter to external electromagnetic RF interference. The allowable error limit for the ANSI specification is ±1.0% deviation from the true measured value.

In addition to these baseline standards, many countries add specific requirements that address the energy theft problem. In India, a regional specification defines 25 unique tamper schemes that a meter must detect. A regulation in Germany establishes a very challenging dc magnetic immunity limit: an electricity meter must maintain its accuracy even when a 1.2 T magnet is applied on all housing surfaces of the meter. Many other countries have additional tamper requirements intended to supplement IEC or ANSI meter standards. In summary, industry stakeholders are well aware of the problem, and they are investing significant effort developing technical standards as a way to minimize electricity theft.

## The Convergence of Innovative Technologies

Before describing new technologies, it's important to understand the fundamental building blocks of a smart electricity meter. The figure below shows five blocks within a smart meter signal chain: 1) input sensors that transduce a large input signal level to something small, which will be compatible with the rest of the system; 2) an analog-to-digital converter that creates a bit stream for further processing; 3) isolation, which is required in many specific meter standards and regions; 4) a system microcontroller that computes all of the energy measurement quantities (for example, watt, I rms, V rms, VAR, etc.); and 5) a communications processor so that energy measurements and control instructions can be exchanged between the back office of a utility and the point of consumption.

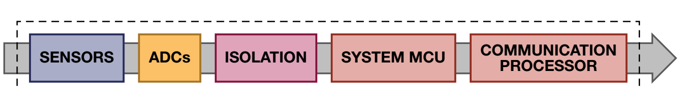


*Figure 2. Smart meter signal chain.*

Two common approaches for polyphase meter design differ depending upon how isolation is implemented in the system. One design approach uses current transformers for the input sensors because they provide galvanic isolation, and they are good for measuring a wide range of input currents.

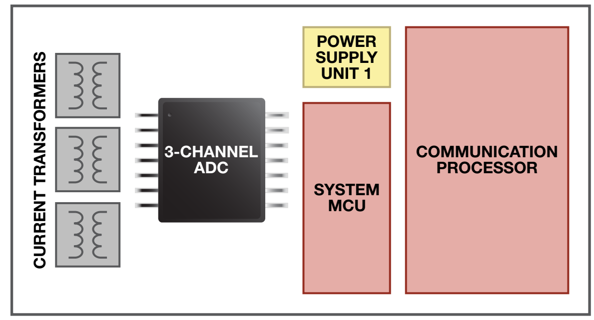


*Figure 3. Polyphase smart meter: current transformers provide isolation.*

A second design approach uses optocoupler technology, which can be small and inexpensive.

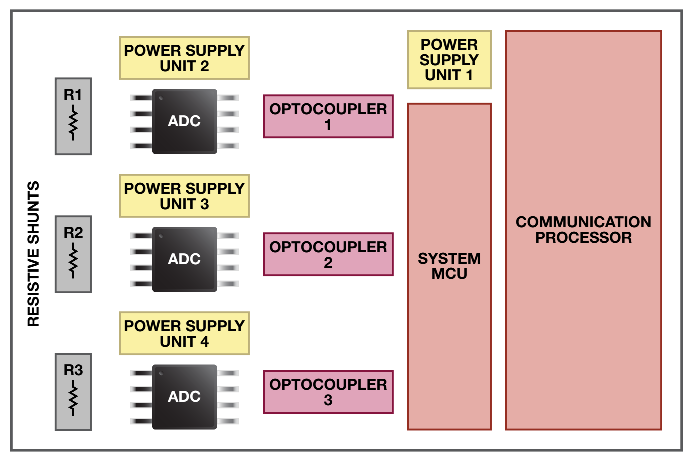


*Figure 4. Polyphase smart meter: optocouplers provide isolation.*

With this background, let us return to the convergence of new technologies. The first innovation is chip scale transformer technology that now makes it possible to isolate not only data channels but also the power domain, such that the system can be completely separate. The other important point to understand is that chip scale transformer technology has achieved very small size and very high manufacturing reliability such that it can be combined with other smart meter blocks, all within the same IC package. The result is a new polyphase smart meter architecture, shown below.

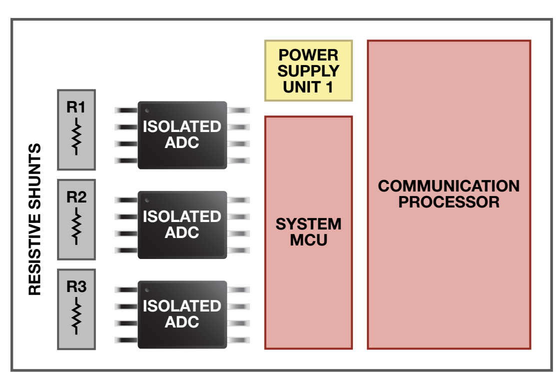


*Figure 5. Polyphase smart meter: isolated ADCs provide isolation.*

When semiconductor suppliers leverage chip scale transformer technology and advanced converter technology within the same IC package, smart meter systems achieve a new level of integration, performance, and reduced overall cost. Most important is the fact that it is relatively easy to tamper with a CT by placing an external permanent magnet close by, ultimately causing the smart meter to undercount or stop working altogether. This common method of electricity theft is completely eliminated so that utilities no longer suffer from lost revenue. With the new level of integration available today, it is no longer necessary to use external current transformers as the sensor type for smart meters. Not only are CTs prone to tamper, they are also large, heavy, and expensive—particularly if they are dc tolerant.

How do smart meters with isolated ADCs compare with ones that use external optocoupler technology? The biggest benefit is that with isolated ADCs, the system becomes much more reliable because there are fewer components. Note that the optocoupler design illustrated in Figure 4 requires at least six extra components. Three are power supply units for each of the three phase currents (PSU2-PSU4), and three are discrete optocoupler ICs that provide galvanic isolation for each of the three phase currents (OC1-OC3). Eliminating the extra components within a smart meter makes it easier to manufacture, and also improves long-term reliability. The later point is important since smart meters must operate properly in the field and maintain their accuracy in harsh environments for years. When smart meters incorporate isolated ADCs, component count goes down while long-term reliability goes up, and this ultimately translates into lower operating expenditures for the utility.

## Conclusion

Electricity theft is an increasingly vexing problem for utilities. However, a convergence of innovative technologies is driving better electricity meter design and stronger protection from theft using an external magnet. As discussed in this paper, precision converters and chip scale transformers can be combined within the same IC package to enable a new class of smart meters. These smart meters of the future are completely immune to magnetic tamper. Electric utilities that begin deploying smart meters with isolated ADC technology will see a decreased rate of electricity theft and an increase in their long-term revenue.



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