Technical Article

Advances in Smart Electricity Meter Field Diagnostics

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Introduction

After more than one hundred years of energy transportation with minimal technological variation, electricity distribution networks have recently seen a dramatic transformation. In a world dominated by technological evolution, the energy sector has evolved to include renewable energy sources such as wind and solar. We have new challenges such as the bidirectional flow of energy, intermittence in generation from renewable sources, distribution of electrical power, and noise emission on power lines, resulting in potential network stability issues. To guarantee continuous and quality service to end customers, energy distribution companies are incorporating smart meters to allow for real-time network diagnostics and immediate fault detection. This technology provides utility companies and end users with a multitude of benefits. This article illustrates smart meter fundamentals and advancements in field diagnostics.

The Smart Electricity Meter

The smart electricity meter is a fundamental component of the energy distribution network. In addition to monitoring energy consumption, a smart meter can collect data on the quality of the power supplied. For example, it can measure the reactive energy, the total harmonic distortion, the harmonic content, the presence of voltage surges and transients, and changes in frequency, all of which are indicators of the state of the network. But how does an electricity meter work?

Figure 1 shows a block diagram with the main components, both for a single-phase system and for a 3-phase system electricity meter.

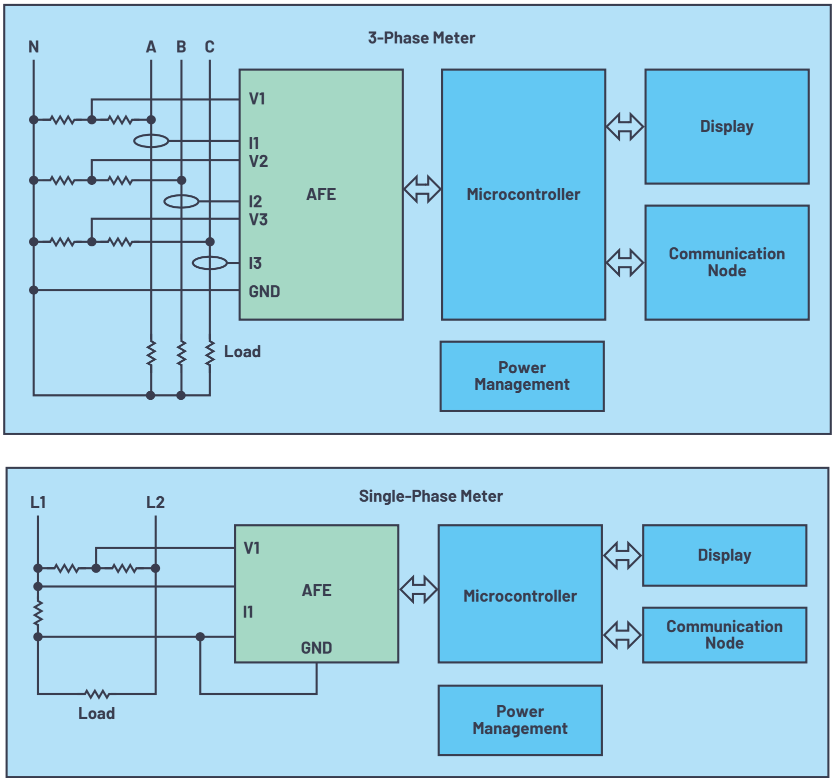

Figure 1. Block diagrams of single- and 3-phase smart electricity meters.

In a smart meter, the basic electrical qualities are derived from the voltage and current measurements. These measurements are processed by a special analog front end (AFE) and supplied to the microcontroller, which displays them or makes them available for the communication node for remote transmission. A power management unit completes the structure.

The Sensors to Measure Voltage and Current

One critical aspect of an electricity meter is the measurement of current. Unlike voltage measurement, which may present only small deviations from the nominal value, the current has a very wide dynamic range, from a few milliamps up to hundreds of amps, and it must be measured with the utmost precision over the entire range. While a simple resistive divider, and more rarely a transformer, is used for voltage measurement, the sensors used to read the current can vary. Generally, the following four types of sensors are used: the shunt, the current transformer (CT), the Rogowski coil, and the Hall effect sensor. Each of these sensors has advantages and disadvantages. For example, the shunt, widely used in domestic meters, is economically advantageous and practical. The biggest drawback of the shunt is Joule effect heating, which limits its use at high currents.

In comparison, the current transformer supersedes the limitations of the shunt in terms of maximum current and is intrinsically isolated, which is highly advantageous. The CT comes in the form of a toroid, and its primary winding is represented by the conductor, in which the current that you want to measure flows through the ring. The secondary winding is wound on a ferromagnetic material, and the number of turns establishes the transformer turns ratio. Compared with the shunt, the CT has a higher cost and a larger footprint. A significant limitation of a current transformer is its ferromagnetic core, which, if saturated, seriously compromises the operation of the smart meter. Saturation can result from a DC offset in the AC, a high current peak, or an external magnetic field such as that generated by a permanent magnet. Because of this limitation, systems that use the current transformer must provide shielding or other protection mechanisms to avoid tampering.

Hall effect sensors have excellent frequency response and can measure high intensity currents. However, these advantages are mitigated by high temperature drift, which requires system calibration at several points for the required precision to be obtained.

Like the current transformer and the Hall effect sensor, the Rogowski coil is intrinsically isolated. The Rogowski coil is an inductor mutually coupled with a conductor through which the current to be measured flows. The magnetic coupling takes place via the air core and therefore does not introduce the typical saturation problems of ferromagnetic materials. The peculiarity of the Rogowski coil is that the signal generated by the sensor is proportional to the derivative of the current and thus requires an integrator to reconstruct the original signal.

To achieve a wide dynamic range and high linearity, and for the ability to measure very high currents, current sensing with a Rogowski coil requires the use of a stable integrator. Additionally, the Rogowsi coil is particularly susceptible to external fields that allow manipulation of the power measurement through the end user.

Introducing *m*Sure Technology for the Next Generation of Smart Meters

A smart meter must be able to perform its function accurately for a relatively long period of time, which can exceed 10 years. A good design and the stability of the silicon electronic components make it possible to maintain high levels of accuracy for many years. However, environmental events such as lightning, a current spike, or a voltage transient can permanently alter the performance of the sensors. Without an advanced diagnostic system, such effects are difficult to detect, if at all. *m*Sure®, a new meter diagnostics technology developed by Analog Devices, makes it possible to check the status of the measurement chain in real time and to protect against the environmental effects at the sensor. *m*Sure technology is immune to environmental effects and can detect manipulations through diagnostics.

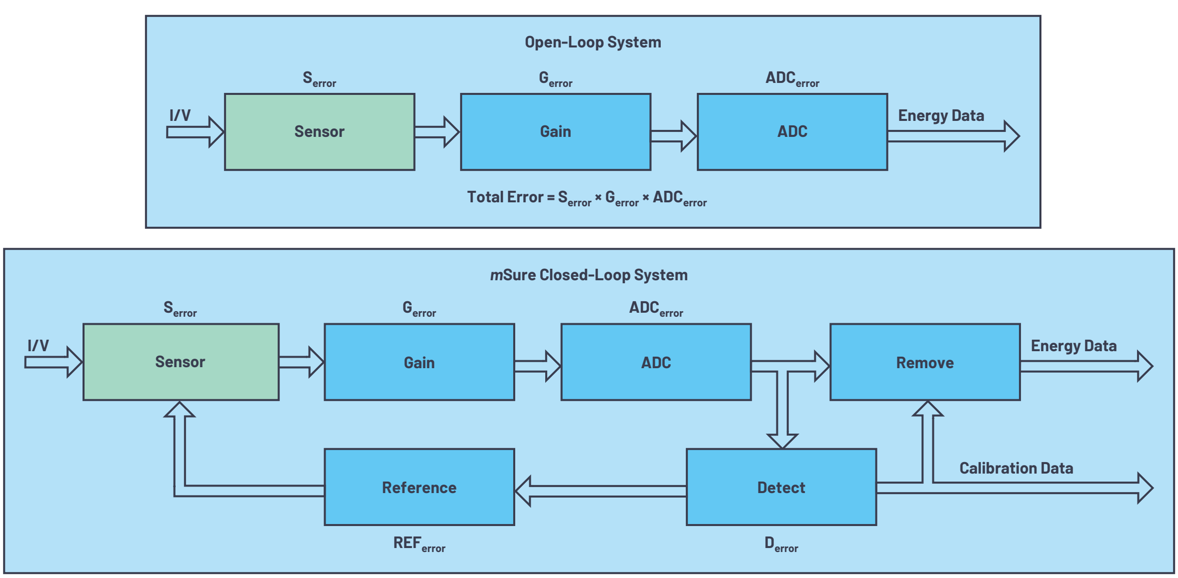

Figure 2. A comparison between open-loop and closed-loop systems with mSure technology.

The operating principle of *m*Sure technology is illustrated in Figure 2. A standard meter works in open loop without a feedback path. The currents and voltages are converted by sensors, there is a processing chain that adds a gain, and, finally, there is an analog-to-digital conversion with the extraction of data directly in the digital domain. Each component contributes to the total error; end-of-line calibration is used to compensate for the initial error and ensure that the meter stays within the specifications for a specific accuracy class.

For a standard meter, once installed in the field, the only way to test its accuracy is to physically remove it for laboratory testing. A less intrusive alternative is to verify the performance of a production batch, but this is costly. In contrast with a standard meter, a meter equipped with *m*Sure technology allows real-time accuracy verification in the field through a more complex, closed-loop system, as shown in Figure 2. The closed-loop system includes the addition of a reference block that generates a stable and very precise signal to be injected on the sensor. This signal crosses the whole measurement chain and is picked up from the detection block. The entire signal chain is monitored in real time, capturing any errors (like gain, drift, etc.), and allowing for continuous calibration to adjust for these errors. Additionally, one of the greatest advantages of *m*Sure technology is the detection of fraud. Since most tampering consists of altering the gain of the measurement chain, *m*Sure can instantly detect this change, unlike an open-loop system.

*m*Sure is nonintrusive and can be activated while the meter is running. To ensure an accurate reading, an appropriate block detects and deducts an *m*Sure device's contribution to the final energy measurement. The accuracy of the meter thus depends on the accuracy of the reference block. The reference has, by definition, a better accuracy compared to the sensor used in the system.

It is possible to activate an autocalibration function at any time. The calibration data is composed of the gain of the current and voltage measurement chains. *m*Sure technology can extract this data with high precision without having to resort to expensive calibration benches. Self-calibration starts by connecting the meter to a voltage source. The presence of a load is optional.

Once a smart meter is equipped with *m*Sure technology and installed in the field, you can check the accuracy of the meter continuously or at predetermined time intervals. If a meter has an accuracy drift, it is possible to correct the calibration data so that the energy count is accurate. So far, government regulations do not allow the calibration data to be changed in the field for standard meters. With *m*Sure technology, the utilities will be able to intervene promptly where needed and, in case of extended intervention, will have an accurate estimate of the difference in energy.

The ADE9153B and ADE9322B are *m*Sure®-enabled energy metering ICs with sensor monitoring and self-calibration for the next generation of smart meters from Analog Devices.

Energy Analytics Studio

The *m*Sure portfolio comes with Energy Analytics Studio (EAS). EAS is the cloud analytics service that supports *m*Sure technology, verifying the health of each meter (health monitoring) and, ultimately, protecting revenues. The *m*Sure Manager software, which runs on the system microcontroller, reports data related to meter parameters. The reporting frequency can be established by the operator. *m*Sure Manager allows you to check the status of a single meter, all meters belonging to a certain geographical area (for example, those that have been subject to some extraordinary weather event), or all the meters belonging to a certain production batch.

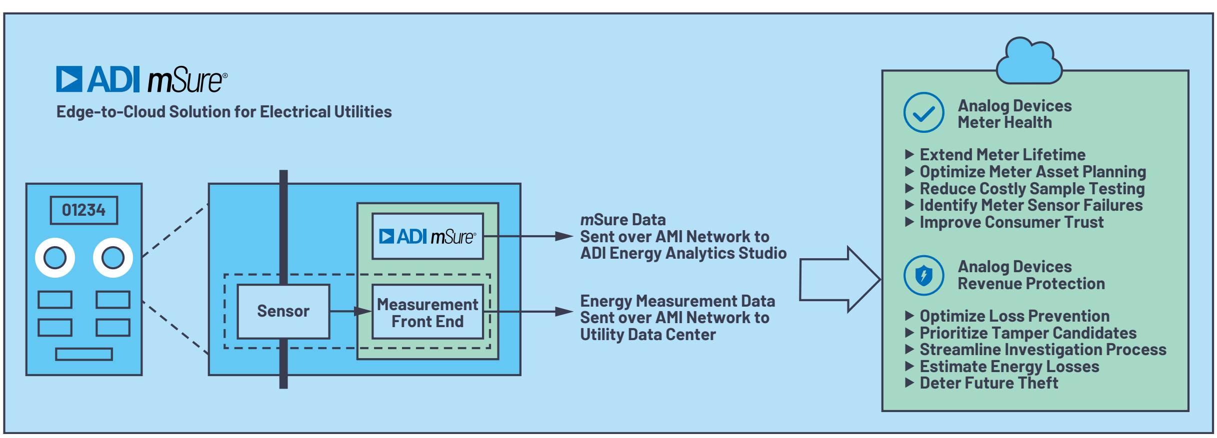

Figure 3. Edge-to-cloud solution for electric utilities.

Conclusion

Innovative *m*Sure technology enables the real-time diagnostics of electricity meters in the field. Combined with Energy Analytics Studio, it can monitor meter health, eliminating the necessity for interventions to cases of actual failure, and prevent fraud. The result is economic savings for the utilities by limiting losses through optimal meter management, while ultimately lengthening the average service life of the meters.

About the Author

Cosimo Carriero joined Analog Devices in 2006 as a field applications engineer, providing technical support to strategic and key accounts. He holds a Master of Science in physics from Università degli Studi of Milan, Italy. Past experiences include INFN, the Italian Institute for Nuclear Physics, defining and developing instrumentation for nuclear physics experiments, collaboration with small companies, developing sensors and systems for factory automation, Thales Alenia Space, as a senior design engineer for satellite power management systems. He can be reached at cosimo.carriero@analog.com.

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