BOURNS®

# Maximizing Smart Grid Resilience: Advanced Circuit Protection for Smart Meter Longevity

## WHITE PAPER

## Introduction

The proliferation of Advanced Metering Infrastructure (AMI) is foundational in the efforts to modernize electrical grids globally, enabling real-time energy management and resource integration. At the heart of this infrastructure transition is the smart meter. These sophisticated electronic devices operate directly on the volatile utility line and are connected to sensitive digital components.

When compared to mechanical electricity meters that were first debuted in the late 1800s, the smart energy meters of today far improve the capabilities offered to consumers and utility companies with real-time monitoring, accurate billing, and proactive maintenance. It is these advanced capabilities that are key in evolving the electrical grid ecosystem toward a more sustainable and efficient future.

Smart energy meters utilize a permanent power line connection with current sensing technology and communication modules for day-to-day monitoring. As a consequence of being connected directly to the power grid with sensitive metering electronics, they are highly susceptible to overvoltage and overcurrent threats such as lightning, switching events, and grid faults. Without effective protection, smart meter failures can compromise data integrity, necessitate expensive service calls, and may seriously erode network reliability.

This paper details a comprehensive multi-stage protection, sensing, and power delivery strategy that employs various Bourns® specialized circuit protection and passive components. It guides designers with an overview of the smart meter operational architecture, along with its power interfaces, metrology needs, and communication requirements. This paper illustrates that by deploying high-energy protection and precision components, smart meter manufacturers are able to meet or significantly surpass industry standards, helping them ensure decades of reliable performance for their utility and consumer customers.

*Figure 1.* | *Smart energy meters are typically found on the exterior of buildings and located on the AC mains line*

## Smart Meter Operational Architecture

A smart meter is an intricate system for measuring, processing, and transmitting energy data.

It relies on three interactive subsystems: the primary power interface, the metrology or measurement core, and the digital/ communication stage.

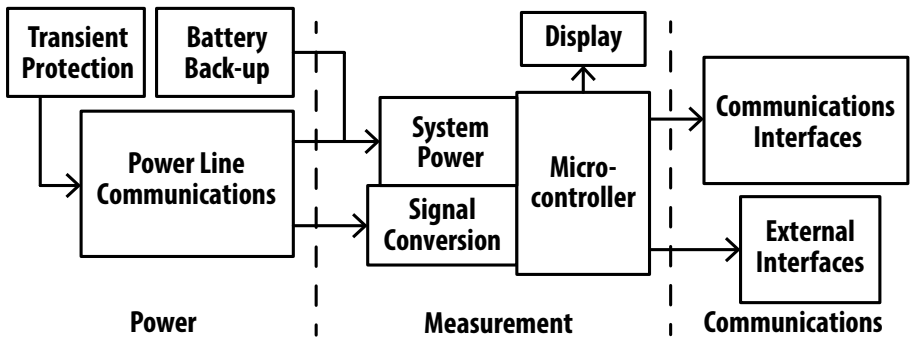


*Figure 2.* | *A breakdown of a typical smart meter design showing the three main sections: Power, Management, and Communications*

## The Primary Power and AC Interface

The primary power and AC interface is the meter's initial point of electrical entry. It connects directly to the power grid's AC mains conductors for both power consumption and voltage sampling. As the most exposed power section, it faces the highest energy threats, including lightning surges and sustained overvoltage events from grid imbalances. Components in this area must be properly rated to outlast typical life expectancies found within consumer-grade applications, hence a lifetime of 25 years is required here.

As such, the primary defense must be a robust, high-energy handling solution that is comprised of both overcurrent and overvoltage protection components. Designers will be faced with several technologies when designing for front-end AC mains overvoltage protection. For the front-end design, a varistor or Gas Discharge Tube (GDT) are typically chosen to be the primary protection devices against overvoltage. Bourns offers several overvoltage protection solutions as listed in Table 1.

*Table 1.* | *Table showing multiple Bourns® overvoltage protection technologies and their trade-offs*

| Technology | Type | Pros | Cons |
|---|---|---|---|
| Gas Discharge Tubes (GDTs) | Crowbar | • Very high-surge current capacity (up to 100 kA)<br>• Long lifetime | • Slower response time<br>• Not ideal for AC lines without series components |
| Varistors | Clamp | • Fast response (10–25 ns)<br>• Low cost<br>• Handles large surges | • Wears out with repeated surges<br>• Leakage increases over time<br>• Clamping voltage rises with surge current |
| TVS Diodes | Clamp | • Very fast response<br>• Excellent clamping<br>• High reliability<br>• Low cost | • Low surge levels<br>• Can be damaged if rating exceeded |
| Power TVS Diodes (PTVS) | Clamp | • Very fast response<br>• Excellent clamping<br>• High reliability | • Higher cost at high surge levels<br>• Can be damaged if rating exceeded |
| GMOV™ / IsoMOV® Hybrid Protectors | Hybrid | • Combines MOV and GDT benefits in a single compact component, avoiding the need for two discrete parts<br>• Long life<br>• Medium clamping speed | • Moderate surge capacity (up to 10 kA)<br>• Slightly larger footprint<br>• Clamping voltage rises with surge current |

In particular, the Bourns® IsoMOV® hybrid protectors offer a compact, robust surge suppressor solution that integrates a high-energy MOV and a GDT into a single device. This integrated combination provides a significant advantage in long-term reliability.

Another option that provides great AC mains overvoltage protection is the Power Transient Voltage Suppressor (PTVS) Diodes. These diodes boast extremely fast response times and reliable performance, which makes them an optimal choice for systems needing the utmost reliability and product longevity.

Normally paired with AC mains overvoltage protection, overcurrent devices such as fuses are used. For a smart energy system, fuses provide protection from internal shorting or other sustained overcurrent events. Bourns offers both slow-blow and fast-acting SMD fuses to complement a variety of voltage levels from 125-600 VAC.


*Figure 3.* | *An example of a Bourns® Model SF-3812TM-T SinglFuse™ SMD Fuse, which boasts a 600 VAC voltage rating with rated currents between 0.50 and 2.00 A*

## Metrology and Internal Power Management

This core section measures energy flow and generates stable internal power. Metrology relies on precision sensing that requires accurate current measurement. For this, a shunt resistor in series with the load line is commonly used to provide a proportional voltage drop. These low-resistance shunts are vulnerable to transients induced from the adjacent AC line, which can compromise accuracy and component integrity. A metrology IC, operating at low voltages (3.3 V or less), has minimal overvoltage tolerance. Concurrently, this section also includes the internal Power Supply Unit (PSU) that generates DC rails for the digital components. Protecting the metrology IC and sensing circuits from residual overvoltage transients is critical, as is specifying overcurrent protection for the DC power rails against internal shorts.

Residual energy and induced transients must be contained before reaching sensitive metrology and microcontroller ICs. This secondary stage focuses on voltage suppression and current limitation at low-voltage nodes, including the measurement circuitry.

For internal faults, traditional fuses are impractical due to the high cost of field replacement and should be reserved as a "line of defense". To counteract many internal faults, Polymeric Positive Temperature Coefficient (PPTC) Resettable Fuses provide an automated, virtually maintenance-free solution.

- Self-Resetting Mechanism: When current exceeds the hold current, the polymer-based PPTC heats up, rapidly transitioning to a high-resistance state to limit fault current. Once the fault is cleared and the device cools, it automatically resets to its original low-resistance state.

- Application: Bourns® Multifuse® PPTC components deliver essential protection in low-voltage power outputs, allowing the meter to recover autonomously from temporary overloads.

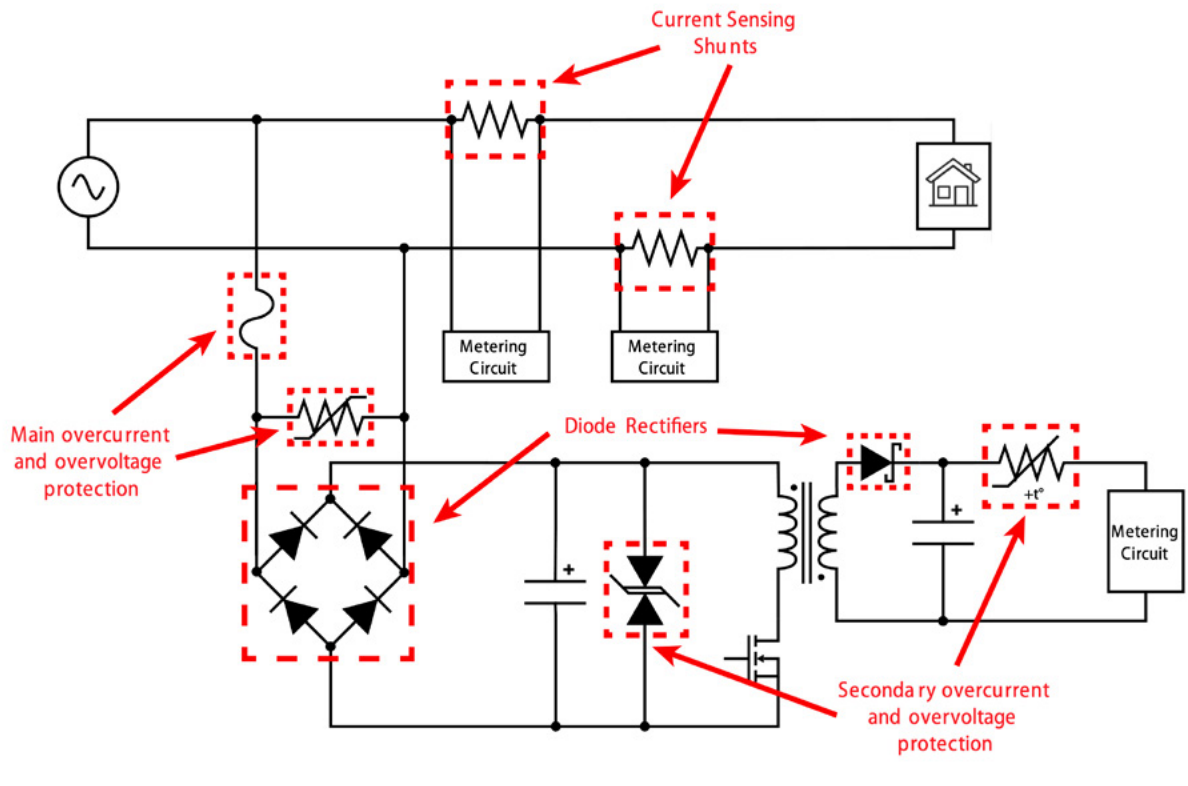


*Figure 4.* | *Simplified schematic of the input AC, metrology, and power management for a smart energy meter*

## Metrology and Internal Power Management (Continued)

For lesser overvoltage conditions or to mitigate ESD, designers will look to protect DC bus systems with either TVS diodes or Multilayer Varistors (MLVs). Both options provide exceptional performance that is needed for strict tolerance bands on DC buses. Bourns offers both technologies with multiple options in compact form factors designed to meet a wide range of application needs. In addition to protection, Bourns has an advanced portfolio of passive components that are essential solutions for accurate metrology. These include precision resistor shunts for current measurement and diode rectifiers for power delivery. The long-term accuracy of the meter depends entirely on the stability of these components.

Bourns® high-precision, low-ohmic Shunts feature the capabilities to help minimize power loss while providing an accurate voltage drop. Key specifications for smart meter shunts include:

- Low Temperature Coefficient of Resistance (TCR): Minimizing TCR ensures stable resistance across the meter's wide operating temperature range, crucial for measurement accuracy.

- High Power Dissipation and Stability: Shunt resistors must reliably handle continuous full-load currents without drifting. Bourns® Shunts are designed for high stability and low self-heating to preserve long-term accuracy.

Bourns® Schottky and Bridge Rectifier Diodes are also available to aid in power delivery. Given that the power consumption of an energy meter is often lower than 5 W, a typical power delivery architecture is a bridge rectifier that feeds a DC-DC converter such as a flyback converter. Bourns' options for both bridge rectifiers and Schottky diodes best suit these applications, giving designers small form factor solutions that feature minimal power consumption.

## Digital Processing and Communication

In this area of a smart meter design, data processing, storage (microcontroller unit and memory), and external transmission (communication modules) are handled. Memory components tend to be highly susceptible to data corruption from electrical transients. Smart energy meters introduce two main methods of external communication: wired (Ethernet/PLC) and wireless (cellular/Wi-Fi). Both methods of communication can be exposed to surge conditions. These communication protocols require low capacitance protection that divert or block energy without degrading the system's high-speed data integrity.

The Bourns® TBU® (Transient Blocking Unit) High-Speed Protectors (HSPs) are semiconductor components designed for data and communication lines exposed to fault currents.

- Instantaneous Trip Times: TBU® devices react exceptionally fast with the ability to switch to an ultra-high impedance state in microseconds when the current threshold is exceeded. This prevents a high-current fault from destroying the transceiver IC.

- Resettable Operation: The TBU® protector is resettable, allowing the meter to automatically restore communication after the fault is cleared.

TBU® devices are typically placed in series with the communication line, coordinating with a low capacitance, overvoltage protection component such as a TVS diode array. Bourns® TVS Diode Arrays paired with its TBU® devices enhance protection by blocking excess current while clamping the residual voltage, offering exceptional protection without compromising data rate integrity.

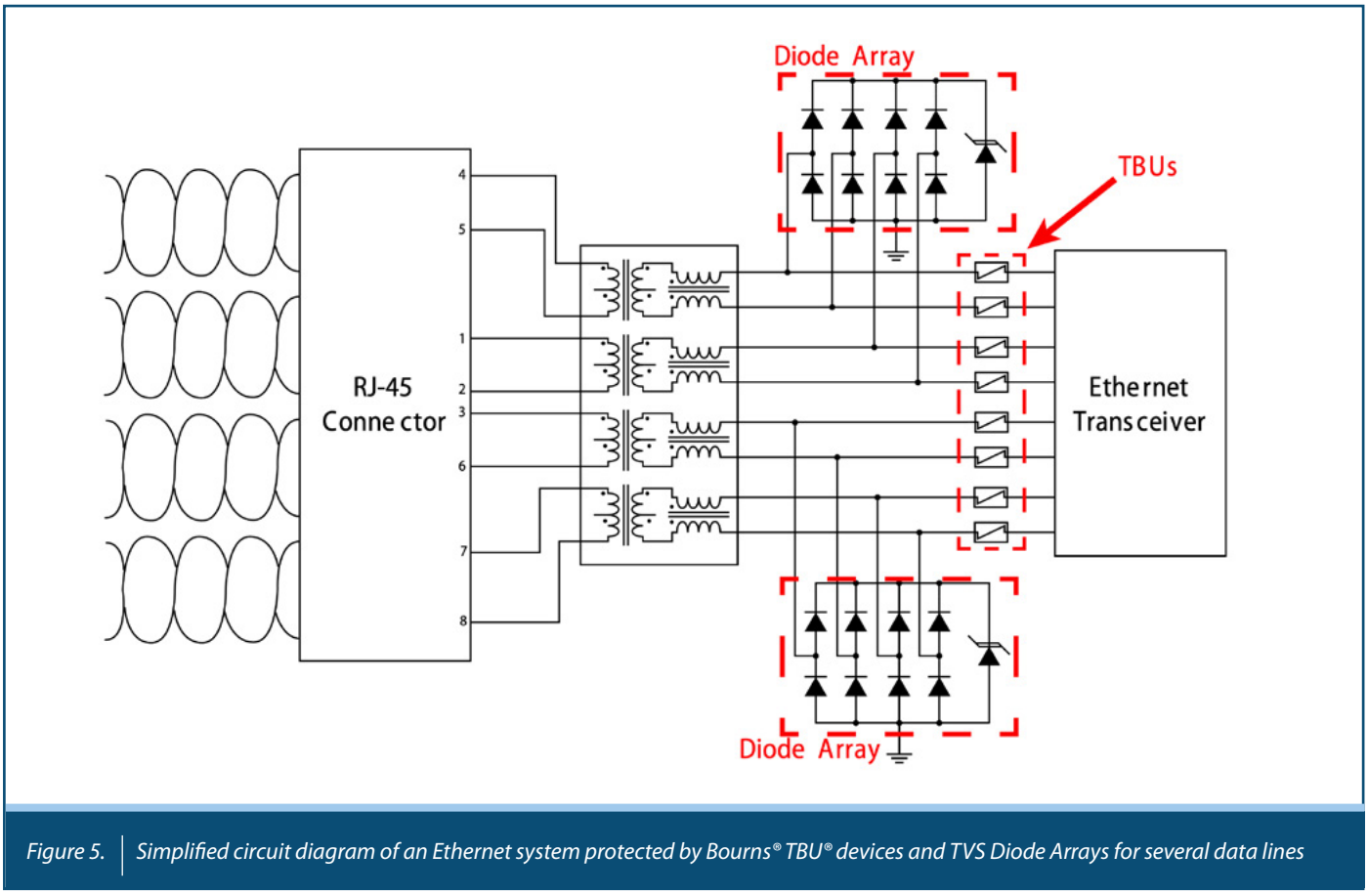


*Figure 5.* | *Simplified circuit diagram of an Ethernet system protected by Bourns® TBU® devices and TVS Diode Arrays for several data lines*

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## Bourns Component Integration Summary

The table below summarizes the multi-stage application of Bourns® products across the smart meter's critical zones. It highlights a comprehensive approach with design recommendations that help engineers maximize protection, precision, and low power operations.

*Table 2.* | *Bourns protection, sensing and power recommendations for smart energy meter designs*

| Application Areas | Key Pain Points | Bourns Product Category | Operational Benefit |
|---|---|---|---|
| Primary AC inlet | High-Energy Lightning Surges, Sustained Overvoltage | IsoMOV® Hybrid Protector, GDTs, MOVs, PTVS Diodes | Bulk energy absorption, thermal runaway mitigation, extended service life. |
| Metrology sensing | Accuracy, Thermal Drift, Transient Susceptibility | Resistor Shunts | Low TCR and high stability ensures accurate current measurement over time. |
| Secondary/DC rails | Residual Surge, ESD, Internal Overloads | MLVs, TVS Diodes, Multifuse® PPTC Resettable Fuses | Precision low-voltage clamping (TVS or MLV), self-resetting overcurrent protection (PPTC). |
| Communication I/O | Power Cross, Secondary Induction Surges | TBU® devices, TVS Diode Arrays | Microsecond current-blocking, high-speed voltage clamping, signal integrity preservation. |
| Power delivery | Forward Voltage, Form Factor, Reverse Voltage Ratings | Bridge Rectifiers, Schottky Diodes | Low forward voltage and high reverse blocking capabilities with SMD packaging. |

## Conclusion

As the electrical grid evolves toward a more intelligent, interconnected infrastructure, the reliability of every smart meter becomes the cornerstone of overall grid resilience. Each meter not only measures and reports energy usage, but also acts as a data node within the larger AMI ecosystem. To help sustain long-term reliability under harsh electrical environments, advanced circuit protection and precision components are essential design elements—not optional features.

Bourns offers a comprehensive, system-level approach to smart meter protection that addresses vulnerabilities across all operational domains. From IsoMOV® Hybrid Surge Protectors at the AC mains to Multifuse® PPTC Resettable Fuses and TBU® HSPs on communication interfaces, Bourns' component solutions deliver multi-stage protection that mitigates high-energy surges, suppresses transient voltages, and safeguard against overcurrent damage.

Complementing these protective elements, Bourns® high-stability Shunt and efficient power delivery components ensure lasting metrology accuracy and system efficiency over decades of operation.

By integrating these proven protection and passive solutions, designers can achieve significant gains in product longevity, field reliability, and maintenance cost reduction—all while maintaining compliance with global safety and performance standards. In offering a coordinated component design and protection strategy, Bourns enables smart meter manufacturers to extend service lifetimes, maintain high data accuracy, and support the resilient, self-healing smart grids of the future.