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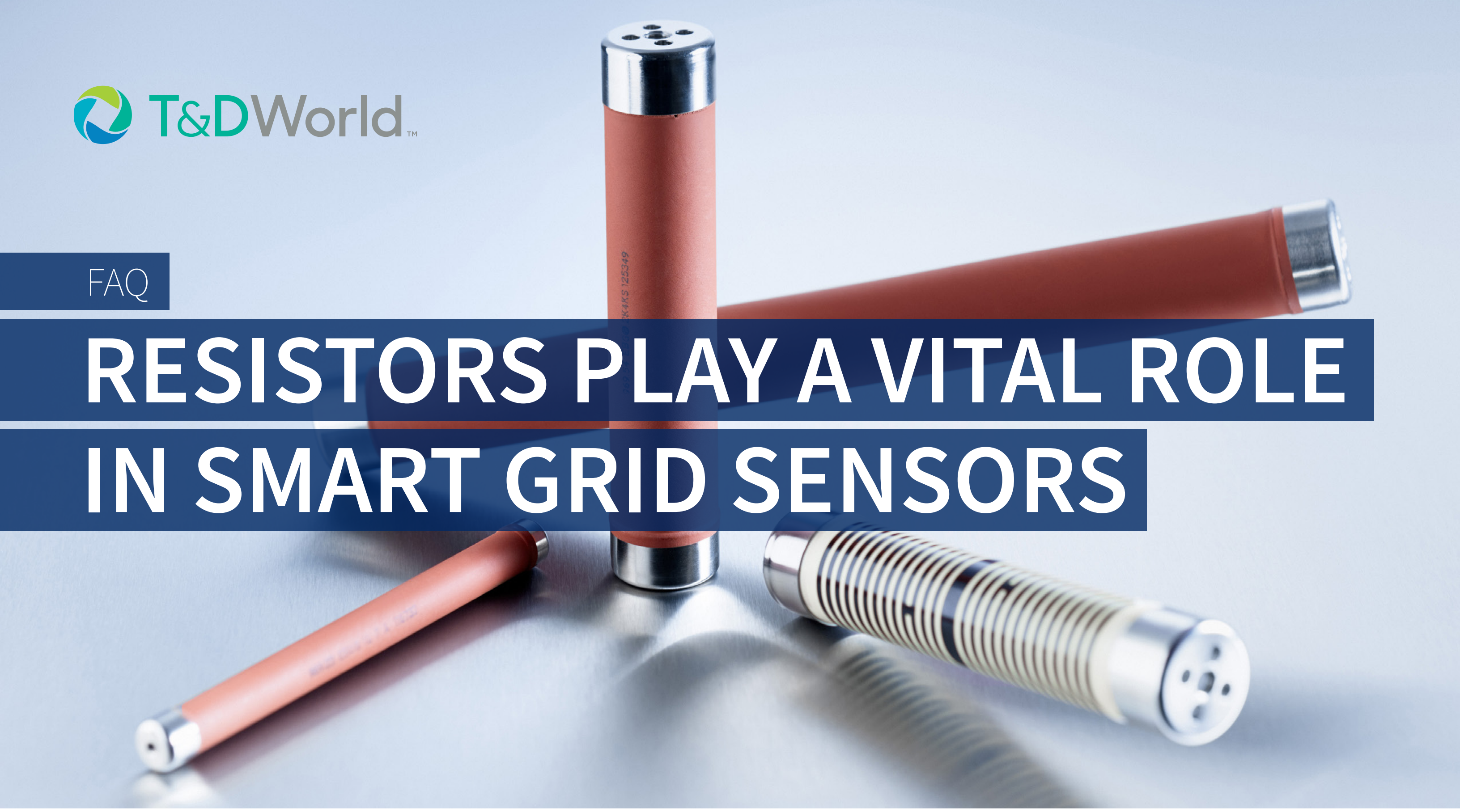
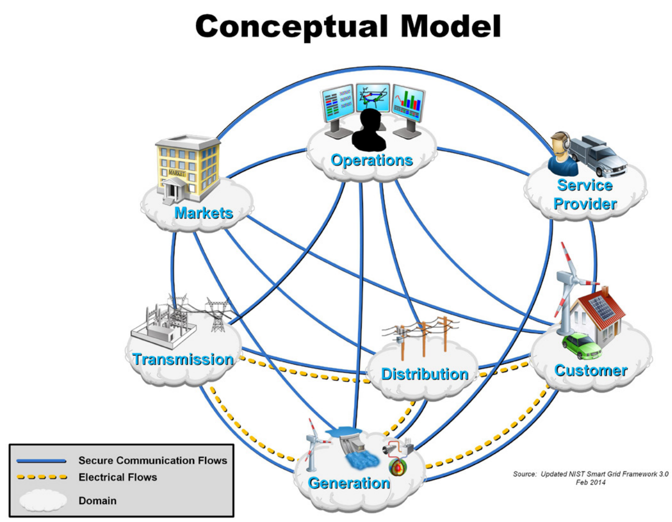


FAQ

RESISTORS PLAY A VITAL ROLE IN SMART GRID SENSORS

Often referred to as "the Internet of electricity", the Smart Grid gives utility operators the new capabilities they need to remain both competitive and sustainable in the 21st century, but they are also placing new demands on the power sensors they use to monitor voltage, current, and other vital signs at critical points throughout the distribution chain. In order for the Smart Grid to realize the greater efficiencies, increased reliability, and higher integration of renewable energy sources, the power sensors that act as the grids' "eyes and ears" must be more accurate, more responsive and more reliable than those used to monitor today's distribution networks. To meet these challenges, sensor designers must be sure the components that perform the sensing are as smart as the grids they monitor.

We've compiled this series of FAQs to help designers and technology managers understand the new requirements being placed on power sensors used in Smart Grid applications, and how those requirements affect the selection of their voltage sensing components.



Smart Grids enable intelligent 2-way interactions between energy sources, energy transmission and distribution networks, and energy users.

Source: NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.

What is the Smart Grid, and what role will sensors play in grid modernization?

The European Union Commission Task Force for Smart Grids defines a Smart Grid as " an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both"[1]

Smart Grids will rely on a distributed network of sensors to provide accurate, real-time information about critical points within their distribution network. The sensor data provides the Smart Grid control system with a detailed picture of conditions throughout its network, enabling it to respond quickly to varying load conditions and trouble spots. This allows operators to make more efficient use of existing generating capacity and reduce service interruptions for lower operating costs, higher profits, and greater customer satisfaction. Operators can dispatch precisely as much power as needed, enabling 3%-5% greater efficiency that goes directly to the operator's bottom line.

The real-time interactions made possible by Smart Grid technology also allow operators to integrate much larger amounts of time-varying renewables, such as solar and wind, into their baseline than the 5%-10% that "dumb grids" can accommodate.

How do Smart Grid sensors work and where are they used within the grid?

Smart Grid sensors measure voltage, current, power factor, and other key values at points throughout the transmission and distribution network, and relay it back to the operator's control center via a wireless network. By deploying sensors throughout transmission and distribution networks, their operators can identify load surges, load drops, power usage, and other events in time to respond before they become problems. Smart Grid sensors also provide information that enables operators to pinpoint the locations of power outages, enabling repair crews to be quickly dispatched, rather than waiting to learn about the problem from an angry customer sitting in the dark.

The most common value that sensors monitor is voltage which, depending on the location, typically ranges between 1-2 kilovolts and 230kV. In most cases, these levels are far beyond what a voltage sensor can measure safely and without risk of damage. Instead of direct measurement, a voltage divider circuit is used. It consists of two to resistive or capacitive components placed in series, in order to produce a lower, precisely scaled-down version of the line voltage that's within the range of the measurement circuit.

Voltage dividers come in two “flavors”:

Resistive Dividers: The classic divider circuit uses two resistors in series to produce an output voltage (Vout) which is a fraction of the input voltage that’s by a ratio of resistors: the bottom resistor divided by the sum of the resistors.

Capacitive Dividers: Since capacitors demonstrate a reactive impedance in the presence of the grid’s AC line frequency, it is relatively simple to calculate values for two components that will produce a Vout within the range of the sensor electronics. [3]

What are the different types of smart grid sensors?

In addition to sensing line voltage, voltage divider circuits play important roles in sensing other critical values, including current, power factor, harmonic distortion, and real vs. reactive power. These sensors are used to monitor points throughout the transmission and distribution network. For example, stand-alone sensors can be hung directly on transmission and distribution lines (conductor mount sensors) or as pole top style sensors (post sensor). In addition, equipment manufacturers a starting to incorporate Smart Sensors directly into products such as reclosers, transformers, and underground pad mount enclosures.

How do the requirements for smart grid sensors differ from the ones used in “dumb” grids?

Smart Grids are only as smart as the information they get about their network. As a result, their sensors must deliver information that is accurate, reliable, and timely over decades of service, and under a wide range of challenging conditions.

Latency: There is always a small delay when a sensor converts a voltage or other real-world variable into digital data that can be understood by the Smart Grid. This latency is due to a number of factors, including the sensor’s settling time – i.e. the time that the voltage within the sensing element takes to reach equilibrium with the point that it is monitoring.

Accuracy: Since power sensors operate under such demanding conditions, there are several types of accuracy to consider:

Temperature stability (aka TCR): The values of resistors and capacitors have a tendency to vary slightly with temperature, with the amount of drift per degree referred to as temperature coefficient (TCR). Any errors are exacerbated by the extreme outdoor conditions that Smart Grid sensors must operate in.

Voltage stability (aka VCR): Voltage variations also cause changes in the values of sensing components used in voltage dividers.

Stability over time: Prolonged exposure to extreme temperatures and high voltages can cause capacitors and resistors to degrade over the 30+ year life cycle typically expected of utility capital equipment.

Why are resistors the better choice for voltage dividers used in Smart Grid sensors?

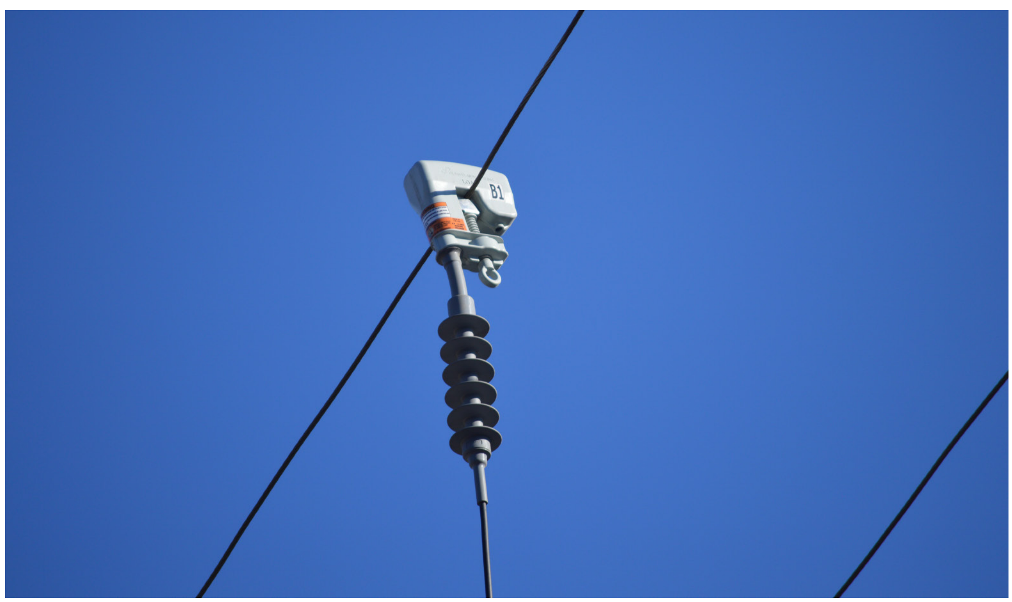
Now that we've clearly defined the requirements for the voltage dividers used in Smart Grid sensors, let's compare how well resistors and capacitors meet them:

Latency: The settling time of a voltage divider is largely determined by the time it takes to bring whatever capacitance is in the circuit into equilibrium with the line voltage. While resistors do have some small level of parasitic capacitance, it is several orders of magnitude smaller than what is present in a capacitive divider circuit. Hence, resistors have dramatically shorter settling times that results in much lower latency.

Temperature stability (TCR): Capacitors are composed of alternating layers of dielectric and conductive materials and, in some cases, an electrolytic liquid. Their capacitance tends to vary slightly with temperature as the materials that make up these complex structures expand and contact. In contrast, the metal-oxide and thick film resistors that are most frequently used in high voltage applications offer extremely low TCRs, typically in the neighborhood of 25ppm with even lower values possible.

Voltage stability (VCR): Capacitors and resistors both exhibit variations in their electrical properties as increasingly higher voltages are applied, but metal-oxide and thick film resistors vary much less than capacitive elements. Quality thick film resistors typically offer a VCR in the neighborhood of 0.03ppm/V.

Stability over time: Thanks to their simpler, more rugged construction, resistors are less subject than capacitors to physical changes, and the resulting changes in component values, that can occur during decades of exposure to outdoor conditions. Similarly, the resistive films and the rugged ceramic substrates that form the resistor bodies are more resistant to age-related breakdown than most of the dielectric materials used in capacitors, and thick film resistors stability actually gets better the more they are used.



Conclusion

In order to realize the promise of greater efficiency, higher reliability, and a more sustainable future, Smart Grids will require sensors that provide high accuracy, high reliability, and low latency.

Capacitive voltage divider elements are struggling to meet these stringent new requirements. At the same time, high-performance thick-film and metal oxide resistors, such as those offered by EBG, offer the performance and long-haul reliability that Smart Grid sensor designers need to meet today's requirements – and tomorrow's challenges.

References:

1. Expert Group 1, EU Commission Task Force for Smart Grids. (2010). "Functionalities of smart grids and smart meters, http://www.ieadsm.org/"

2. Kuphaldt, T., Starck, J., LaPlante, R. (2000-2017). "Lessons In Electric Circuits, Divider Circuits and Kirchhoff's Laws"

3. Electronics Hub (2015). "Electronics Hub Tutorials: Capacitive Voltage Divider"

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