Technical Article

Overcoming Ethernet Connectivity Challenges on the Power Grid

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Traditionally, the power grid consisted of stand-alone equipment working independently; maintenance was a manual process using paper-based inspection and reporting. As equipment like protection relays, circuit breakers and smart meters became digital, using control cables to share equipment status and fault and control data helped utilities optimize equipment usage. Eventually, utilities began deploying wired and wireless connectivity solutions.

While serial communications such as RS-232, RS-485 and Controller Area Network are still popular, in this article I will explain the challenges when migrating to Ethernet, and how TI offers solutions that can make your equipment compatible with the emerging digital grid.

Unlike the traditional grid, a digital substation digitizes all data immediately – as close to the source as possible – and sends the data over Ethernet cables to an intelligent electronic device. Ethernet connectivity offers a simple and flexible solution that can provide standardization and interoperability, resulting in a homogeneous communication platform across the substation.

Ethernet connectivity comes in two forms. Copper cables are used for lower-speed data transmission and shorter distances (<100 m) using an unshielded twisted pair cable. A fiber-optic connection offers a much higher data rate (gigabits per second) over longer distances, better immunity, reduces the risk of electrocution because it is nonconductive, and according to estimates can help reduce costs by as much as 60% compared to copper cabling. And while Ethernet connectivity for the digital grid has its benefits, it does present challenges. Here are the key challenges when implementing Ethernet onto the digital grid.

EMI/EMC

The main challenge in wired connectivity is getting reliable data in industrial environments. The chances of data corruption in such environments are higher due to electromagnetic interference (EMI), high temperature, noise and stray magnetic fields.

As shown in TI's EMI/EMC Compliant 10/100 Mbps Ethernet Brick with Fiber or Twisted Pair Interface Reference Design, the DP83822 Ethernet physical layer offers high performance in harsh industrial environments, providing an Institute of Electrical and Electronics Engineers (IEEE) 802.3u-compliant 100BASE-FX, 100BASE-TX and 10BASE-Te solution for 10-/100-Mbps copper or 100-Mbps fiber-optic interfaces. The reference design is compliant to European Standard (EN) 55011 Class-B EMI requirements and immune to International Electrotechnical Commission (IEC) 61000-4-2 Level-4 electrostatic discharge (ESD) levels, offering compliance for industrial environments and giving equipment manufacturers' confidence for quicker certification. TI's DP83822 (10/100 Mbps) and DP83867IR (10/100/1000 Mbps) Ethernet transceivers provide a high-immunity interface in harsh industrial environments while consuming low power. The functional block diagram of a fiber optic interface is shown in Figure 1.

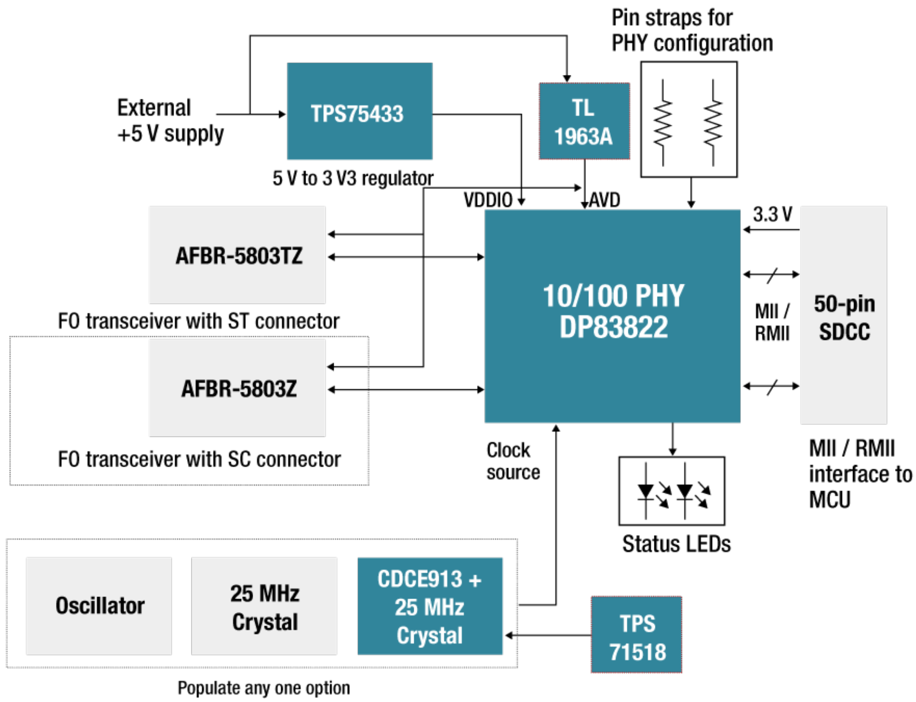

Figure 1. Ethernet Brick with Fiber Optic Interface Block Diagram

IEEE 1588 Time Stamping

Timing plays a critical role in transmitting time-critical control signals or data use in both post-failure and real-time analysis. Time stamping improves the accuracy of fault diagnosis and aids grid operators in decision-making, which helps reduce downtime.

The 10/100 Mbps Industrial Ethernet Brick with IEEE 1588 Precision Time Protocol (PTP) Transceiver reference design offers a small-form-factor, single-chip solution for both copper and fiber communication interfaces and time synchronization. The design demonstrates clock synchronization of the DP83630 based on IEEE 1588 and also enables clock generation, packet timestamping for clock synchronization, and event triggering and timestamping through general-purpose inputs/outputs.

Media Converter

Ensuring equipment interoperability between different communication interfaces (such as traditional serial) and copper- or fiber-optic-based Ethernet is another challenge. A media converter enables the use of advanced legacy products in older-generation substations with traditional communication interfaces.

The 32-Bit ARM® Cortex®-M4F MCU-Based Small Form Factor Serial-to-Ethernet Converter reference design showcases the implementation of a serial-to-Ethernet converter supporting 10/100 Base-T, which is compliant with IEEE 802.3 standards. This implementation helps overcome cable-length limitations on a serial interface by providing reliable data communication. Another piece of interoperability is compatibility between copper and fiber-optic cable connections, which can be implemented using the Ethernet Copper-to-Fiber Media Converter Reference Design for Substation and Distribution Automation as shown in Figure 2.

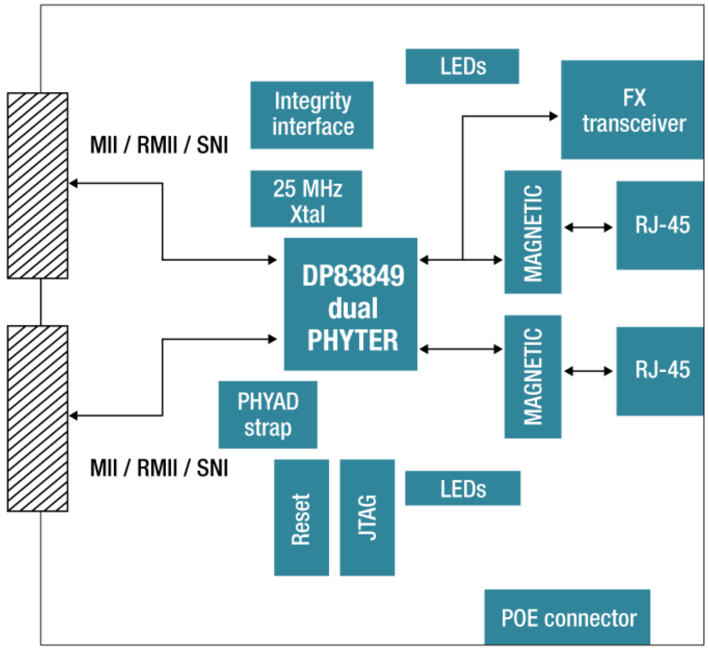

Figure 2. DP83849 Based Copper-to-fiber Optic Converter Block Diagram

HSR/PRP Redundancy

Reliability of data communication in substations – especially between the operator's control center and high-value nodes – is critical; the data needs to be communicated with low latency. For industrial Ethernet communication, the commonly followed IEC 62439 standard provides specifications for protocols such as high-availability seamless redundancy (HSR) and parallel redundancy protocol (PRP). These protocols support critical real-time systems in substations.

To facilitate high-reliability network communication for critical paths with low latency, the High-Availability Seamless Redundancy (HSR) Ethernet for Substation Automation reference design and Parallel Redundancy Protocol (PRP) Ethernet Reference Design for Substation Automation support the IEC 62439 standard running on the TI real-time operating system. The Parallel Redundancy Protocol Ethernet Reference Design for Substation Automation on Linux® enables PRP along with PTP on the Linux platform.

Conclusion

TI's integrated circuits and reference designs provide optimized and simplified resources for enabling a transition to a digital grid with advanced wired connectivity. As these designs meet compliance requirements and industry standards, they also help shorten the design and certification cycle, helping lead to a higher return on investment.

Additional Resources

- Read the short article, "Two ways to save power with low-power Ethernet."
- Read the white paper, "Enabling and integrating wired and wireless technologies for grid interoperability."
- View our reference design, "EMI/EMC Compliant Industrial Temp Dual Port Gigabit Ethernet PHY Reference Design."

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