Technical Article

How Energy Harvesting Can Extend the Life of Your Fault Indicator on the Grid

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Fault indicators are extensively used in grid infrastructure for monitoring overhead and underground transmission lines. These indicators monitor the current flowing in each phase and send commands to circuit breakers upstream to trip when they detect the passage of faulty currents.

While some fault indicators flash light-emitting diodes (LEDs) to indicate faults, others record the data and transmit it to a data collector, which then forwards information about the current to a substation for status monitoring. A fault indicator should continue to operate even when the circuit breaker trips and when there is no flow of current in the transmission line.

The key system-level challenges are to extend the life of the power supply, design fault-detection and indication blocks to consume lower power, and reduce the power-supply startup time for very light loads.

Extending the Power Supply

Backup batteries are often used to extend the life of the power supply. While a backup battery prolongs the working of the sensor element in the absence of line power, the indicating LEDs drain the battery of critical power, as they are expected to flash for a prolonged duration during fault events. Larger-capacity batteries also consume more space and are expensive.

Alternatives such as super-capacitors reduce the overall system cost. They can be sized appropriately to store enough charge for peak loads during the most demanding times. A split-core current transformer is often the primary input source to generate DC power for the circuit. The drawback with super-capacitor is that it can take a long time to charge to system bus voltage level, especially at low current levels in the transmission lines (hundreds of milliseconds, if not longer) as the time taken $T = V_{BUS} * C_{SUPERCAP}/I_{CHARGE}$.

One of the ways to overcome the slow startup issue is to use a boost converter operating at very low levels of input voltages, as shown in the Energy Harvesting and Fault Indicator Subsystem for Overhead Fault Indicators Reference Design. This reference design uses the TPS61021A boost converter, which can start boost operation at voltages as low as 0.9V on power up and can operate at voltages as low as 0.5V at the input. This enables you to power critical sections of the sensor block in the shortest duration while the super capacitor charges to the bus potential. An auto-switching power multiplexer such as TPS2113A can detect the input voltage level and can automatically switch between the current transformer input (the TPS61021A) and the primary battery.

If you prefer a secondary battery over a super-capacitor, you can use a power harvester with an integrated boost charger such as the bq25505, as shown in the energy harvesting reference design. This device can take a dual power source such as a primary battery and harvest power from a current transformer into a secondary battery. It provides a control signal for autonomous switching between the two sources and can start harvesting from as low as 0.33V on cold start up. The input can go as low as 0.12V while the device continues to harvest power.

A device such as the bq25570, from the same family of energy-harvesting devices, has an integrated buck converter for output voltage regulation. These devices have built-in Maximum Power Point Tracking (MPPT) to maximize power harvesting and offer excellent efficiency, consuming less than 1µA of quiescent current even when the sensor block is designed to operate at very low loads such as 100µA.

Reducing System Power Consumption

The other way to extend the duration of super-capacitors/batteries is by optimally designing the sensor block for power consumption. The Fault Monitoring for Overhead Fault Indicators Using Ultra Low Power Reference Design uses a dual output rail: one for critical blocks and the other for noncritical blocks.

A step-down converter such as the TPS62740 is optimal as it provides two outputs and consumes just 0.36µA of current while generating the power-supply rails for the microcontroller and other analog chips. Its integrated load switch eliminates the power consumed by certain sections of the data-acquisition blocks that are in the noncritical path by disconnecting the integrated load switch. The fault monitoring reference design demonstrates this ability when the primary source such as the current transformer has no current flowing. Disconnecting the noncritical elements extends the energy stored in the battery for a longer duration in the absence of main power.

Efficient LED drivers such as the LP55231 and LM3509 can further optimize overall power tree, thereby reducing the demand on the backup power supply as shown in the energy harvesting reference design. The LP55231's can power up to nine white LEDs, or three RGB LEDs simultaneously. An integrated charge pump allows this device to operate over a wide input voltage while maintaining high efficiency. The LM3509's integrated boost can power up to six LEDs in a series, as the output can go up to 21V.

Monitoring and protecting the energy grid is an important element of making sure that power is delivered to homes and businesses everywhere. YouTube video creator Big Clive explains how important power-line monitoring is and the benefits of fault indicators in his recent video (right around 13:50). Clive produced this video after TI challenged him to go a day without power management.

Additional Resources

- Download the user guide for the fault monitoring for overhead fault indicators reference design.
- Explore our selection of DC/DC converters.

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