The Locomotive

Providing Non-Stop Power for Critical Electrical Loads

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Introduction
In a society that is ever more dependent on things electrical, failure of supply can be much more than the inconvenience that was occasionally visited on our parents and grandparents. Loss of electric power now means interruption of some vital digital communications networks, advanced medical therapies, financial transactions such as credit cards and bank operations, vital transport such as elevator service, refrigeration of sensitive biological experiments and other essential services. The vital aspect of such functionality creates a demand for non-stop electric power.

Choosing Backup Power Systems
The phrase “non-stop” in this discussion is meant to describe those loads that cannot endure even a brief loss of power. At the upper limit of these are those that depend on microprocessors. In these digital devices even a brief interruption causes reset of digital processes and loss of all data not already recorded in nonvolatile memory — a class of memory devices that can retain data through an electric power outage. There are a number of devices that fit this category, and they can be inherently nonvolatile (no power needed) or they can be supported by internal batteries. When a power interruption resets a microprocessor and data is lost, the affected system must re-boot at such time as power supply is restored. Anyone who has waited for their desktop computer to perform that task in the morning should appreciate what could happen if a very large and complex system was involved.

There are many ways to provide auxiliary power for times when the public supply goes down. For whatever reason, we seem to think of auxiliary generators in this context. There are other devices available, including flywheel generators and battery/inverter systems. Choosing among them is the subject of this discussion.

The Transition, a Critical Time Issue
Failure of the public electric feeder is not usually an anticipated event. Whatever means have been chosen for providing alternate power will ordinarily have to function without advance warning. Since critical loads may be very intolerant of even the briefest interruptions in power flow, this is the most critical time.
Reciprocating engine driven generators are one of the most common sources of alternate power during blackout periods. These can be installed with provisions for automatic starting and automatic switching on to the load immediately upon loss of the normal supply. Unfortunately, there is an unavoidable delay imposed by the necessity to start the engine, allow it to get up to speed, and then to complete the functions necessary to allow it to assume the load. The necessary time delay is usually fairly brief, but the duration of power loss will be sufficient to cause all connected digital control and computer devices to shut down. The vital loads that involve such devices now must be restarted with all of the associated delay and annoyance that we associate with re-booting our personal computers. Remember that loss of power for only a few cycles (1/60th of 1 second = 1 cycle) is sufficient to reset most digital processor equipment.

The time delay associated with starting the emergency power plant is not the only problem in this scenario. The accumulated statistics of the Nuclear Regulatory Commission concerning the starting reliability of such generation assets serving vital safety functions in nuclear power plants is not a source of great encouragement.1, 2

**Bridging the Time Gap**

There is a need, therefore, to maintain a smooth supply of electricity to vital loads in order to effect a “bumpless” transition to alternate supply. This can be accomplished with a device called an uninterruptible power supply (UPS). Originally designed for digital computers, these devices employ a battery as a power reservoir. In a UPS, input power is reduced to a battery-compatible voltage and then rectified to direct current (DC) and directed into the battery as charging current. When input power is lost, stored energy in the battery is inverted to alternating current (AC) and continues to supply the connected loads without interruption. There are different types of UPS devices available on the market and these differ in the way that the electric energy stored in the battery is connected to its load.

In one type, the incoming AC power flow is split into two streams. One is employed to charge the battery by the means already described, while the other bypasses the battery and is sent on directly to the load. When a power outage occurs, the now dead AC input line is switched off and energy from the battery, flowing through an inverter and voltage adjustment means, continues to supply the load. The switching operations necessary to carry out this transition occur in a very brief time, but not always brief enough to avoid reset of digital circuits (see Figure 1 below).

**Figure 1:**

In the other type, a single stream of power flows through the transformer and rectifier to the DC bus and then, via the inverter and voltage adjustment means, to the load. The battery, connected to the DC bus, is maintained at charge and ready to take over the load as the DC bus voltage may require. When normal power is interrupted there is no interruption in AC power to the load. The battery replaces the DC current ordinarily received from the AC line via the rectifier and the operation of the inverter section is uninterrupted. No switching is required. As an extra benefit, because all incoming power is rectified to DC, such devices completely suppress voltage spikes in the AC line. The only issue remaining is that of capacity: how long can the battery support the load? (see Figure 2 on following page)
Combining UPS with Generator Sets

In order to best maintain the operation of vital equipment through an interruption of normal supply, a UPS system, preferably of the latter type, can be combined with a generator set. The UPS equipment provides the critical time necessary for an orderly start of the generator set. If the UPS system is of the latter type, all of the generator output is converted to DC in the rectifier/s, and the problem of synchronizing the AC waveform with the load is neatly avoided. The result is a truly uninterrupted transition from normal AC supply from the public power grid to an alternate, on-site supply. If sufficient UPS capacity is installed, even some difficulties with generator start (such as maintenance in process at the time of an outage) can be overcome without causing a power interruption.

The UPS does provide backup power supply as its name indicates, but, more important, it provides a time window during which generating capacity can be brought on line in an orderly fashion for longer term power. This should not be read to say that a battery based power supply is to be preferred to an engine generator scheme. What is meant is that the installation of a battery based system adds important advantages to any emergency power supply system, especially when the dependent electrical loads are unforgiving of even minor interruptions of supply.

Power Quality — an Unexpected Benefit

The interposition of a battery power reservoir between the AC supply and the critical load provides a benefit beyond that of an alternate power source. Because a battery is a direct current (DC) device, it is characterized by constant voltage that is presumably free of fluctuations. By the time the incoming AC energy has been supplied to the battery, it has been rectified, a word that means it has been converted from AC to DC. The essential feature of that conversion is the suppression of the sine wave that defines AC power, as well as any other voltage variations that may exist on the AC power line.

It is these latter voltage variations that we know by the names of voltage surge, harmonics, brownout and other terms. The point is that the power that now resides in the battery is devoid of these disturbances. When demand for power is made on the battery, this DC power is then inverted, another technical word meaning the conversion of constant voltage, or DC power, to AC. The result is that the conversion of AC to DC eliminates voltage disturbances, and the subsequent re-conversion of DC to AC provides a clean and constant AC wave that has been stripped of unwanted disturbances.

Planning for Equipment Failure

The design of a backup, or emergency, power supply capability should reflect how critical the loads are to be supplied. Redundancy should be in proportion to the level of risk. When truly critical electrical needs are at stake, additional reliability measures should be taken. Each element of the backup power scheme needs to be viewed as a point of failure, and the design should provide for functional duplication of each. The failure of electrical connections also needs to be anticipated.
Redundancy must be applied in such a way as to ensure that adequate power is available to the critical load(s) even when one element is not operable. If two generators are provided, each must be sized for 100 percent of the anticipated load. UPS capacity must be similarly sized. Electrical connections should be arranged in “ring” configuration to permit continued operation even if a conductor is broken. Needless to say, the design must anticipate failure of any single element in such a way that continuity of power to the critical loads is not compromised.

Footnotes:

Summary
The loss of electric power interrupts some vital digital communications networks, advanced medical therapies, financial transactions such as credit cards and bank operations, elevator service, refrigeration and other essential services. This equipment is so critical that there is a great demand for non-stop electric power. There are many ways to provide auxiliary power for times when the public supply goes down. We may think first of backup generators, but there are other devices available, including flywheel generators and battery/inverter systems. Choosing among them is the subject of this discussion.

About the Author
Robert Weir, a director with The Hartford Steam Boiler Inspection and Insurance Company, is a Professional Engineer and has an extensive background in the design and construction of power generation and industrial equipment and systems. A graduate of the U.S. Naval Academy, he holds a Master’s Degree in mechanical engineering from Worcester Polytechnic Institute and is a graduate of Suffolk University Law School. He is a member of the American Society of Mechanical Engineers (ASME), a permanent committee member of the National Fire Protection Association (NFPA 37), and is admitted to practice in Massachusetts and federal courts, including the U.S. Supreme Court. He is a registered patent attorney.