

Product Overview
The
CATERPILLAR
Uninterruptible Power System

NEW DEVELOPMENT:

The new dynamics of doing business, in conjunction with the latest stored energy technology developments, have encouraged two respected companies to join forces and create a new form of UPS that will be available for sale in early 2000. This UPS system has been optimized to supply high quality continuous power for the high availability requirements of today's world enterprises. This system has been able to supplant the need for lead-acid battery energy storage and yet provide reliabilities that match or exceed those battery-based systems used today. It eliminates the cyclic wear-out limitations of batteries and expands the application of UPS into wider temperature venues such as industrial applications.

Caterpillar has partnered with Active Power in Austin, Texas to create an engine-generator/ flywheel/ Static-UPS system that in most applications can substitute for contemporary UPS systems or offer increased levels of reliability for existing systems. This system has been optimized for reliability and for power quality but does not have any of the battery-based UPS discharge cycle limitations or temperature constraints. It can be ordered delivered and installed as one model number and will be serviced by the Caterpillar worldwide dealership network on a seven day by twenty-four hour basis.

BUSINESS CLIMATE:

There has been a significant change in the business community over the past few years. Whereas some level of computer system downtime used to be painful but tolerable, today the cost of such an event has become so high that redundancy is critical to most systems. System availability must be maintained so close to 100% that even routine maintenance is being conducted piecemeal and not on the entire system as was commonplace just a few years ago. There is no such thing as "closing shop" for preventative maintenance.

This climate change, that is being driven by the dynamics of e-commerce, competitiveness and general intolerance for unavailability of systems, is also in the process of changing the way companies view electrical power availability. Power outages were once thought of as inevitable and it was the "plan" to have UPS to ride through the short ones and allow time for an orderly shutdown of critical systems for the longer ones. This is no longer true. Now companies are installing generators that not only will keep systems operational for hours, the world-wide trend is to provide for continuous generation of electricity for as long as necessary. Because of this trend there are new energy businesses emerging that are guaranteeing 100% availability of all forms of energy delivery, from natural gas to electricity. These energy commodities are being delivered at a premium rate and are in demand today. At the same time, site-specific engine-generators are also being installed, sized to keep the entire business operational and not just the computer and phone systems that were once the only equipment protected.

Today, most businesses that cannot or will not tolerate a power disturbance or outage are installing generators with their UPS. Many are retrofitting older systems and upgrades to continuous supply of electricity for the entire operation is frequent.

ENERGY STORAGE OVERVIEW:

Contemporary Uninterruptible Power Systems (UPS) provide both power conditioning and a source of temporary power for periods when the principal electrical source has been compromised or lost. It is common practice to include a short-term source of energy in or as a part of the UPS system. This source of energy is generally assembled as a series-string of lead-acid batteries. Unfortunately, a characteristic of these lead-acid batteries is that the more you use them, the faster they wear out. A typical lead-acid industrial battery will be exhausted after 300 complete discharges. Another characteristic of the lead-acid battery is that a significant amount of maintenance is required in order to even come close to the predicted mean time between failure (MTBF) of the battery. Unfortunately, this stored-energy failure rate (1/MTBF)

can be significant because most of the currently available UPS utilize ten or more twelve-volt batteries in series, causing the string failure -rate to be multiples of the individual battery failure -rate.

It is also extremely important in the application of UPS batteries to maintain the temperature of the string at or near 77 degrees Fahrenheit in order to balance expected performance and life expectancy. For each ten degrees above 77 degrees, the user can expect the life expectancy to be cut in half. For example, in an 87-degree environment, a ten-year battery quickly becomes a five-year battery and at 97 degrees, it becomes a two and a half-year battery. For temperatures below 77 degrees the life will be extended, however the expected performance, as measured by protection time, will drop below what is needed to complete the mission successfully. Therefore, it becomes quite necessary to maintain a temperature-controlled environment – which is both difficult and expensive in industrial settings.

There is no question that the benefits of having stored energy, in an attempt to “ride through” a power outage, have been proven - especially in mission critical applications. However, the most popular solution (batteries) is also one with many problems. One major user of UPS systems analyzed all of the service actions on his UPS systems over an extended period and concluded that over 90% of these forced actions were caused by the battery string alone.

THE NEW PRODUCT:

The new Caterpillar UPS system consists of an engine-generator that has been closely matched to the operating characteristics of a true high-efficiency line-interactive UPS. An energy storage flywheel system has been integrated into the UPS and is not a supplemental add-on. This integration of UPS and flywheel provides the end-user with a value-optimized system. Additional unification between the UPS system and the engine-generator permits a total package that will support any power disturbance or outage from sub-cycle to continuous operation. No longer is there the usual 10 or 15-minute battery limit for outages. The multi-mega-joule flywheel will supply energy for all disturbances or outages from a cycle up to a minute, depending on the load profile and the system chosen. For all outages or disturbances beyond the stored energy time of the flywheel, the engine-generator will be brought on-line and will continue to supply electrical power through the on-board UPS for as long as there is fuel for the engine.

In order to compare the reliability of the Caterpillar UPS with a battery-based system, a study of engine-based failures was conducted. Generally it was found that a preponderance of the engine-generator failures was in the start function and not with the run operation. If the engine could be started, it would run successfully with an excellent MTBF. Further examination of the start problems revealed that a significant number of these failures were caused by the start battery! It is interesting to note that this is quite similar to the failure experience with battery-based UPS. The failures were caused by poor maintenance as well as actual battery failures.

Included with the new UPS system is a redundant start feature that actually supplements the standard battery start with energy from the flywheel. Since this high-energy source is always monitored for availability, the start function MTBF has been improved by orders of magnitude.

Line-Interactive UPS do not have frequency isolation as an inherent characteristic, therefore it was important that frequency accuracy and stability be ensured when power was being supplied from the engine generator. Therefore, special transient and cycling load protection was added to the UPS/Flywheel system to basically average these recurring loads over a broader time period for the engine-generator. Since the flywheel energy storage system has no usage wear-out characteristic as compared to the battery, it makes a perfect companion to the line-interactive UPS in this application.

APPLICATIONS:

Three broad market sectors were examined for applicability by the new Caterpillar UPS. These business areas represent a significant portion of the existing high power three-phase UPS power market. Specific comments about sector trends and UPS usage follows.

Industrial - The industrial sector generally refers to manufacturing and heavy transportation. This is a business segment in which continuous and undisturbed power demands are expanding as the use of

microprocessor controls, sensitive programmable controllers, variable-speed drives, robotic assembly and other critical functions are being deployed in more electronic hostile environments. Point-of-use electronics are becoming commonplace.

Although this business sector has not reached the level of sophistication in calculating system down-time costs, such as the information technology sector has, there are clear examples where process disturbances cause irreversible losses. For example, in the silicon fabrication business, a power loss during some of the critical diffusion steps can cause a batch of silicon wafers to be lost. Cost is usually measured in the millions of dollars. The same is true in the pharmaceutical industry. Some processes can not be recovered following an error caused by a power disturbance, causing whole batches and their respective revenues to be discarded. Other industries that use motor controllers or variable speed drives find that they easily trip off-line with a short voltage transient. Some are more sensitive than others and with a continuous process, one or more motors coming off-line can cause "a mess" with the raw material.

Examination of people-movers such as subways find that there can be more at stake than just money. Most underground subway stations count on continuous power for emergency system management such as fire control, lighting and floodwater pumping. Like the manufacturing floor, the environment is usually quite hostile due to dirt and temperature; which is not conducive to industrial lead-acid battery use or to current UPS designs.

The Caterpillar UPS product will be the UPS system of choice in this business sector due to its performance and to its robustness. Whereas standard UPS systems have been designed principally for use in controlled environments where the batteries can be air conditioned, the Caterpillar UPS has been designed without those limitations. The energy storage flywheel has no 77 F. degree limit, as does the lead-acid battery. Also, the flywheel has no cycle-aging properties like the battery and therefore is a much better choice for the factory floor or underground subway station, where power transients occur at a very high rate. Most new factories and many older facilities are now considering the use of engine-generators to provide continuous operations in the event of power outages. The CAT system has been designed explicitly for this type of usage.

Commercial – Demands for continuous power have accelerated in this broad segment of business. For example, in the hotel industry, electronic card-reading locks and other protection systems including lighting, smoke / fire detection and security add to the telephone and computer system loads which already require back-up power. In addition, managers are much more concerned with the "comfort" of their clientele and are now considering backing up the elevators, door opening systems and food dispensing with emergency power. This is a perfect application for the new continuous power protection system. It can provide UPS power for the entire building from the computers to the elevators, or it can be tailored to protect any subset of the commercial enterprise.

Major retail stores and chains are finding that they are now competing with e-commerce as well as with each other. Next-day delivery of almost any commodity seems to be the break-through that e-commerce has needed to begin seriously taking business from the traditional retail stores. Therefore, there is a trend for the retail stores to attempt to improve the "shopping experience" to include 24 hour operation and point-of-sale immunity to power disturbances. Add power protection to include the lighting and again, this is a clear application site for the new UPS system. A single installation can protect the retail computer as well as the store mechanics. There is no need to consider different UPS systems for different loads.

Information Technology – For conventional data applications, this would appear to be one of the most mature markets for power protection. Driven by real needs for the high levels of availability, this business segment has evolved into complex arrangements of computers, peripherals and support hardware that are hallmark with redundant concepts. Large network servers such as the Hitachi Skyline are being designed with dual processing capabilities, which also incorporate dual power supplies and dual power cords. This concept of redundancy is carried up-stream on the electrical power side to include redundant UPS, redundant sources, ring buses, dual-port static switches and redundant engine-generators – each with n+1 to even n+3 redundant engine starters. UPS systems tend to be state-of-the-art on-line parallel-redundant. Although they employ large battery strings to provide fifteen minutes of back-up time, most system

managers do not rely on the availability of the battery and will initiate an engine-generator start as soon as electrical power is suspect. With the typical start and run-up time at ten seconds or less, it is clear that the battery is being treated as a weak link, and the administrator is clearly demonstrating that no downtime can be accepted. In these applications, availability of the electrical power is measured by the number of nines following the decimal and system designer's work hard to gain "another nine" of reliability.

Although designers continue to seek out single points of failure in the system and eliminate them, there remain "load losses" in the industry, albeit they are less frequent than in the past. Unfortunately, when one load loss occurs it becomes a nightmare to "reboot" an entire data center – as recent events at the Internet site ebay.com come to mind. Even worse, it can place thousands of individuals in peril if that lost load was at an FAA air traffic control center, for example. Therefore, any new concept that can add another nine of availability is eagerly embraced.

While data networks in these organizations may approach a satisfactory level of availability for current needs, emerging applications such as Voice-over-IP and streaming-video will place new, qualitatively different demands on the network infrastructure. Mere bandwidth is a necessary but not sufficient condition for satisfactory voice communications. Users have come to expect "five nines" availability from the public switched telephone network—and will quickly become disenchanted with IT forays into voice applications at the first failed attempt to return a customer's call. To take advantage of voice over IP, IT departments must reconsider all aspects of network robustness and take availability to an even higher level.

The Caterpillar UPS is such a new concept and it clearly can add higher levels of redundancy and availability for the existing information technology installations. It can also provide a novel, simpler approach to power protection for new facilities, and new applications, that are on the drawing board today.

For existing IT facilities that have the classic UPS installation as was previously described, the administrators can have their Caterpillar engine-generator retrofitted with this new line-interactive UPS and redundant supplemental-energy engine start feature. If a new engine-generator is being contemplated for either updating or for redundancy reasons, this system should be considered for its reliability enhancing merits.

There are three key reliability-enhancing aspects that must be considered:

First, the incorporation of a flywheel energy storage system upstream of an installed UPS means that any transient power disturbance that would have previously sent the existing UPS to battery would not be exposed to that event. The battery would remain in a float state and not have a wear-out cycle occur. Since the flywheel has no cycle limit, it will easily protect the battery and provide the opportunity for the full float life to be obtained. Battery replacements would therefore be extended, lowering maintenance costs over the life of the system. And as confidence in the new Caterpillar UPS system is strengthened, the battery and all of its maintenance may actually be eliminated.

Second, parallel redundant UPS have an automatic bypass for the system. Its used because it is a reliability enhancing feature (approximately ten times) and because there is a real, albeit small, probability that the parallel redundant system can fail. If this failure occurs, then the mission critical load will be switched to the raw utility until repair can be effected – typically a four to eight hour period. By employing the line-interactive UPS within the Caterpillar UPS system, the load will still be switched away from the failed parallel-redundant UPS via the static switch, but in this case it would be switched to another UPS (with back-up power protection capability) up-stream and the critical load would have a greater degree of protection. Another nine of availability can be added.

Third, the redundant energy supply (from the flywheel) and redundant start power for the engine generator will raise the overall reliability of the engine-generator function by an order of magnitude. Even with batteries downstream this is a worthwhile addition to the overall reliability of the facility and is equal in reliability to a UPS with batteries. For the end-user who plans on using an engine-generator and finds batteries a high maintenance item and failure prone assembly, the Caterpillar UPS system should be considered as a total replacement.

SUMMARY:

The new Caterpillar UPS offering was designed to be supportive of present business trends (zero downtime tolerance) and to capitalize on state-of-the-art flywheel stored energy technology. The system is a robust engine-generator UPS combination that can supply computer-grade power from specific loads to entire enterprises. It has significantly improved the engine-start reliability and can eliminate the use of lead-acid batteries in the employment of any protection time from sub-cycle to continuous (only diesel fuel supply limited). This product can benefit any of the key business segments by providing reliability equal to existing double-conversion UPS with batteries – and yet have none of the maintenance issues associated with the lead-acid solution. It will even add a “nine” of availability to existing UPS systems that employ engine-generators or that may upgrade to include an engine-generator in the future.