



Critical Power Systems
The Lifeline of the Health Care Industry

White Paper 116

2128 W. Braker Lane, BK12

Austin, Texas 78758-4028

www.activepower.com

SUMMARY

The modern health care industry relies on clean, always-on electrical power more than ever before. Facilities ranging from mammoth hospital data centers to small medical imaging suites need power in order to ensure quality and affordable patient care.

More and more facilities are adding uninterruptible power supplies (UPS) to their electrical systems to supplement the emergency power systems specified by code and regulation. UPS systems mitigate damaging power disturbances and provide short-term backup power to bridge the time until the emergency power systems come on line.

This paper describes the key considerations a health care facility should examine when evaluating a UPS system, and evaluates both conventional battery-based systems and the Active Power CleanSource UPS and CleanSource HD UPS.

HEALTH CARE INDUSTRY BACKGROUND AND TRENDS

The modern health care industry may be the largest and most expensive endeavor of the developed world. It is a highly fragmented industry and health care systems vary from country to country, but demand for high quality health care services is on the rise around the globe. Advances in medical care and technology are driving improvements in health care organizations. Operational efficiencies associated with these technological improvements will be essential for the profitability of for-profit organizations and will aid not-for-profit organizations in their efforts to obtain grants and federal funds needed for improvements and expansion.

While there are a number of important trends that will shape the future of the healthcare industry, perhaps the most significant is the vital role “big data” and analytics will play in future patient care. Big data is being analyzed to gain valuable insights into ways to improve patient care and deliver it in a more cost effective manner. Data from a myriad of sources is being integrated to help provide a more complete view of patient problems for more effective diagnosis and treatment.

Technological advances have dominated activity in the health care industry during the last decade and have led to improved methods of diagnosing and treating illnesses and injuries. Many of the critical enabling technologies and practices that have enabled these advances (medical devices, diagnostic imaging, instrumentation, controls, software, data collection and analysis) have an absolute common requirement – electric power quality – the lifeline of the healthcare industry.

HEALTH CARE WORRIES ABOUT POWER QUALITY

Technology is increasingly impacting the ability of healthcare organizations to provide high-quality patient care. Because much of this technology is dependent upon high-quality electrical input, the industry is increasingly focusing on the role of power quality in:

- Design, construction, and maintenance of health care facilities
- Identification, selection, installation, and maintenance of medical equipment
- Upgrade and expansion of health care data centers to meet the prodigious demands for gathering and analysis of patient information

Experience has demonstrated that efforts made early to incorporate power quality solutions into these areas can minimize potentially lethal interruptions of patient care services and the significant costs associated with medical equipment downtime.

Although patient safety is the number one reason for reducing the risk of equipment malfunctions, health care administrators must also consider the bottom line. Electrical disturbances can result in repeated diagnostic tests, wasted medical supplies, and expensive service and repair calls. Minimizing equipment malfunctions and maximizing uptime is a priority.

Before the introduction of electronic medical equipment, common electrical disturbances were inconsequential to health care operations. However, modern equipment found in hospitals, clinics, nursing homes, laboratories, and surgery suites, and the IT equipment in data centers supporting these facilities, are susceptible to electrical and electromagnetic disturbances. With the digitization of the industry and accelerated use of electronic medical records, hospitals and

other health care facilities are converting into data centers with increasing reliance on digital technologies to help improve patient care, increase efficiency, and lower costs.

Electrical system failures create great risk of impacting the central mission of the health care facility, and of incurring a number of negative consequences:

- Compromised patient safety
- Patient discomfort and misdiagnosis
- Loss of health care data
- Equipment downtime and service maintenance costs
- Wasted energy
- Lost revenue because equipment is unavailable

40 percent of global health care organizations have experienced an unplanned outage in the past 12 months with loss of power being one of the major drivers at a cost of \$432,000 per incident.¹

POWER QUALITY DISTURBANCES

Power quality disturbances affecting essential electrical systems are classified in a number of schemes. The Institute of Electrical and Electronics Engineers (IEEE) recognizes nine power problems, described in Figure 1.²

Power problem		Definition	Cause
1	Power Failure	 A total loss of utility power	Lightning strikes, downed power lines, grid over-demands, accidents and natural disasters.
2	Power Sag	 Short-term low voltage	Triggered by the startup of large loads, utility switching, utility equipment failure, lightning, and power service being insufficient to meet demand.
3	Power Surge (spike)	 Short-term high voltage	Can be caused by a lightning strike and can send line voltages to levels in excess of 6,000 volts.
4	Undervoltage (brownout)	 Longer-term low voltage (minutes to days)	Can be caused by an intentional utility voltage reduction to conserve power during peak demand periods or other heavy loads that exceed supply capacity.
5	Overvoltage	 Longer-term high voltage (minutes to days)	Triggered by a rapid reduction in power loads, heavy equipment being turned off, or by utility switching.
6	Electrical Line Noise	 High frequency waveform caused by EMI interference	Can be caused by either RFI or EMI interference generated by transmitters, welding devices, SCR driven printers, lightning, etc.
7	Frequency Variation	 A change in frequency stability	Resulting from generator or small co-generation sites being loaded and unloaded.
8	Switching Transient	 Instantaneous under-voltage (notch)	Normal duration is shorter than a spike and generally falls in the range of nanoseconds.
9	Harmonic Distortion	 Distortion of the normal line waveform, generally transmitted by nonlinear loads	Switch mode power supplies, variable speed motors and drives, copiers and fax machines are examples of non-linear loads.

Figure 1. Types of Power Quality Problems

Any of the above power problems can cause malfunction or failure of medical equipment (i.e., CT, MRI, X-ray, PET, etc.) and information technology systems including network, servers, and storage equipment in data centers.

POWERING ESSENTIAL AND MISSION CRITICAL ELECTRICAL SYSTEMS

Emergency power is required by the National Electric Code (NEC) for systems whose operations are essential for safety of human life. NEC article 700.12 requires that emergency power must be available within 10 seconds of an outage. Modern generator sets are designed to meet this requirement.

Beyond code, health care facilities use uninterruptible power supplies (UPS) to ensure that electrical power is available at all times. UPS systems perform two critical roles in a health care facility. First, they mitigate any electrical disturbances, whether generated by the utility or by the medical equipment itself, such as diagnostic imaging systems that present dynamic loads to the facility electrical systems. Second, they provide continuous power to the facility by virtue of their energy storage.

Historically, the 10-second delay between a power outage and the time it took for a generator to start was acceptable. Today, prudent patient care demands no delay. Modern health care facilities utilize equipment and redundancy schemes to ensure there is no interruption in patient care, equipment availability, data storage, or data access even during that 10 second period. The UPS has become the key component to bridge the gap between utility failure and generator start.³

UPS DESIGNS

There are two main types of UPS systems sold to health care facilities. They vary both in the power quality topology and in the energy storage method used.

Double-conversion

Double-conversion UPS systems completely isolate IT loads from unconditioned utility power. As the name indicates, these systems convert utility power two times under normal operating conditions – first from AC to DC electricity and then back again from DC electricity into a conditioned AC signal. Double-conversion UPS systems always provide the load with a conditioned AC signal even during normal operation when utility power is available and no disturbances are present. Most double conversion systems use chemical batteries – known as valve-regulated lead acid batteries, or VRLAs – to provide the energy storage used to bridge to emergency power.

Parallel online

Parallel online UPS systems place the inverter and charger circuitry or transformers in parallel with the AC utility signal. This design allows a parallel online UPS to compensate for over- or under-voltages in the incoming utility power and, with the right electronics, to eliminate transients, voltage fluctuations, or other disturbances. When utility power is unavailable or reaches unacceptable limits, a parallel online UPS enters stored energy mode. The UPS disconnects the load from utility power and reroutes this load with a static switch to backup power.

Active Power’s CleanSource UPS and CleanSource HD UPS systems are examples of the parallel online design. They are driven by motion: at the core of each UPS is an integrated flywheel machine that stores kinetic energy – energy produced by motion – by constantly spinning a compact rotor in a low-friction environment. (See Figure 2.) When short-term backup power is required because utility power fluctuates or is lost, the inertia of the flywheel allows the rotor to continue spinning and the resulting kinetic energy is converted to electricity. The flywheel takes the place of battery energy storage, providing a smaller, more reliable, and more economical solution well-suited to the needs of health care applications.

300 Series Flywheel



4.4” high; 25.5” in diameter; 600 lbs rotating mass
Stores 4.3 MJ of stored energy (240 kW for 15 seconds)

HD Series Flywheel



12.5” high; 25.5” in diameter; 1700 lbs rotating mass
Stores 12.65 MJ of stored (675 kW for 15 seconds)

Figure 2. CleanSource Flywheels

UPS SELECTION CONSIDERATIONS

Selecting a UPS requires balancing a number of factors to identify the right fit for the particular health care facility. Among these considerations are:

- Energy storage method
- Power protection
- Reliability
- Footprint
- Total cost of ownership

ENERGY STORAGE METHOD

Conventional UPS systems use VRLA batteries to store energy for a number of minutes in order to provide time for emergency power to come online. While batteries are a common technology able to store large amounts of power economically, they have limitations in a health care facility installation.

First, batteries wear out with frequent use, and must be replaced every 4-6 years under normal

use in order to retain their energy storage capacity. In a health care facility where the UPS is called upon frequently, they may need to be replaced more frequently.

Second, batteries must be installed and maintained in a climate controlled environment at precisely 25 degrees Celsius. Variations above or below that temperature may significantly degrade their useful life. This generally requires the addition of cooling systems specific to the room where the batteries are located, and increases electricity costs to operate that cooling system.

Third, special care must be taken to install and maintain batteries safely. They require ventilation, fire safety, monitoring, and personnel safety systems specific to their operation, and may require extra permits or approvals from regulatory and permitting agencies due to the hazards presented by the batteries.

Compared to batteries, the CleanSource flywheel offers a number of clear advantages. The CleanSource flywheel suffers no degradation of runtime when discharged. The flywheel can be called upon to protect the load frequently for its 20-year life and still provide the same amount of stored energy as on day one. This provides significant convenience and cost savings.

The CleanSource flywheel supports a wide ambient temperature operating range from 0 to 40 degrees Celsius without any performance impact. This allows the UPS to be placed in locations where cooling is expensive or not available, providing additional convenience and flexibility to the facility. CleanSource UPS can also operate at higher ambient temperatures with less heat rejection, measurably improving cooling loading and costs.

Finally, the battery-free design reduces installation and operating costs, such as ventilation and fire safety, compared to conventional UPS solutions. This simplifies and improves the flexibility of the UPS and may ease concerns of regulatory and permitting agencies.

POWER PROTECTION

Both double conversion and parallel online UPS systems are appropriate ways of managing power quality disturbances. As shown in Figure 3 below, CleanSource UPS features a true parallel online topology enabled by the flywheel, addressing all types of power quality issues faced by a health care facility. The output of the CleanSource UPS is directly connected to a high speed IGBT (insulated-gate bipolar transistor) inverter that is producing voltage for the load. Since the inverter is switching at a rate that is over 100 times faster than 60 Hz, it can make corrections to the output voltage sine wave on a sub-cycle basis. This means that when any of the nine IEEE-defined power disturbances are detected by the CleanSource UPS input, they are actively corrected by use of transient voltage surge suppressor (TVSS), line inductance, active filtering, power converters, and load-tolerant flywheel energy storage.

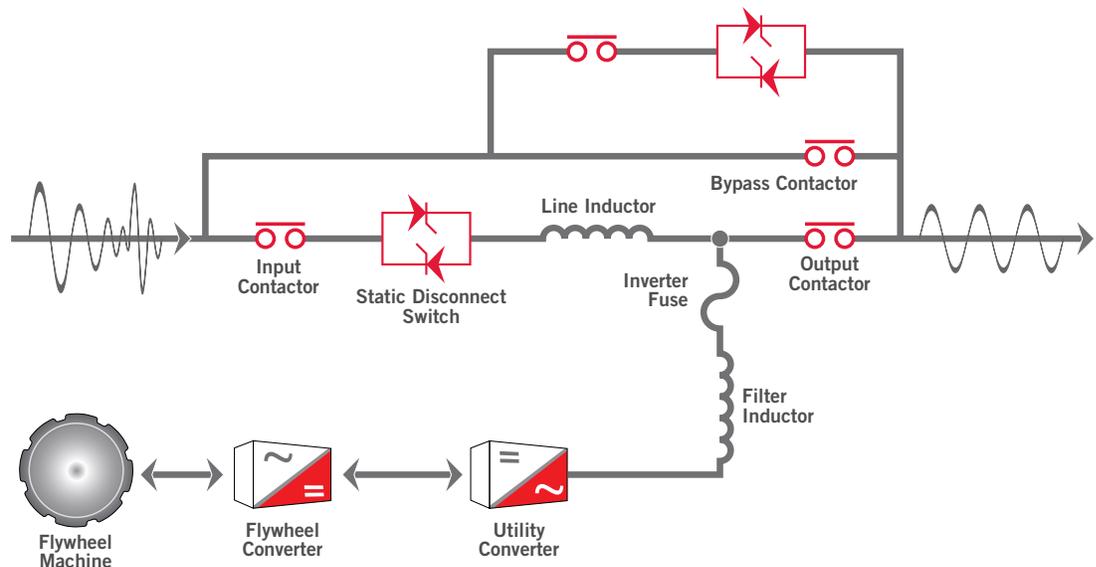


Figure 3. CleanSource Parallel Online Architecture

One issue unique to health care facilities, however, is the impact of imaging equipment such as CT scans on facility power quality. These devices use almost no power when idle, but draw a tremendous load when called into service. This presents the facility power systems with significant step loads that may cause outages or damage equipment if not managed. The traditional way of dealing with these loads is to oversize the UPS and supporting equipment. This leads to higher costs, lower energy efficiency, and wasted space for more UPS and battery energy storage.

The design of CleanSource UPS better supports these step loads and overloads than traditional UPS without oversizing. The parallel online design of CleanSource UPS has fewer components in the critical power path than a traditional UPS, which allows it to more effectively handle large power swings. CleanSource UPS supports overloads of more than 200 percent of rated load for up to 10 milliseconds, enabling it to handle these scenarios with less risk and less cost than traditional alternatives.

RELIABILITY

Given the economic and personal stakes riding on the availability of a UPS in a health care facility, the reliability of the system is a key criteria.

The weak link in most conventional UPS systems is the batteries. Battery failures are the leading cause of UPS load loss and system downtime, causing more than one-third of all outages.⁴ Batteries fail unpredictably due to aging, state-of-charge, charge and discharge events, and rest periods, resulting in diminished reliability.

The integrated flywheel energy storage at the core of CleanSource UPS makes it inherently reliable, delivering predictable, consistent backup power. The normal state of CleanSource UPS is with the flywheel spinning constantly, storing kinetic energy. When called upon during a utility outage or other power quality event, the flywheel is ready to assume the load. A study by MTechnology, Inc. shows that the Active Power CleanSource 750HD can reduce the risk of electrical system failure by 80 percent compared to conventional UPS with batteries in a short utility outage lasting less than 10 seconds.⁵

FOOTPRINT

The physical space that a UPS requires is also a key consideration. The footprint required for a UPS and other backup power systems may, in many cases, be better used by equipment more central to the mission of the facility or may cause the facility to incur extra costs to accommodate the UPS.

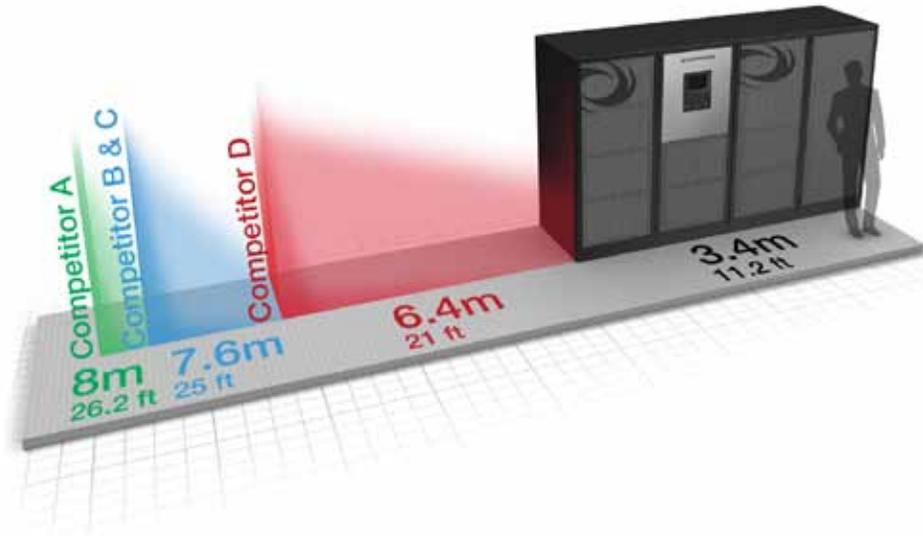


Figure 4. 750 kVA UPS Footprint Comparison. Comparison based on published specifications of 750 kVA (480V) and 625 kVA (400V) units with 4 standard battery cabinets vs. CleanSource 750HD

CleanSource UPS and CleanSource HD UPS are significantly more power dense than conventional UPS technologies with batteries. As illustrated in Figure 4 below, CleanSource HD takes up about half the floor space of leading conventional UPS. The benefits of power density for health care facilities are significant. Hospitals and other facilities can reduce the amount of space required for electrical infrastructure, freeing up room for additional patient care or staff equipment. If identified early in the project, a smaller UPS may result in a smaller land purchase or building construction, resulting in tremendous savings. A smaller footprint also makes it easier to add to a UPS to an existing facility that is looking to upgrade its power protection.

TOTAL COST OF OWNERSHIP

The most thorough measure of the economic value of a UPS system is the total cost of ownership (TCO) that assesses the purchase price, installation costs, and long run operating costs over the appropriate time period for the facility. TCO is commonly evaluated over 5 or 10 years so that the full economic impact over the life of the system can be estimated.

There are a number of factors that drive the TCO of a UPS :

Primary TCO Factors	Secondary Factors
System cost	Footprint / cost of floor space
Installation costs	Cooling requirements / cost of cooling
UPS energy efficiency	Battery monitoring
Energy cost	
Cost of replaceable items	
Maintenance requirements	

A major benefit of the integrated flywheel UPS system is its operating efficiency. Whereas most double-conversion UPS have efficiencies in the range of 92-94 percent, CleanSource UPS operates at 98 percent efficiency at full load. This difference in efficiency can quickly add up to significant cost savings. As an example, for a UPS system protecting a one megawatt load at \$0.10 per kilowatt hour, a four percentage point difference in efficiency will result in an annual savings of more than \$40,000. Further energy savings are achieved through the elimination of cooling required to maintain a fixed temperature for the battery and to eliminate the waste heat from the UPS inefficiency, adding another \$12,000 in savings per year.

The flywheel energy storage itself is a second major source of lifecycle savings. A lead-acid battery system used with a conventional UPS will typically need to be replaced twice over a 10 year period. On a 675 kW system, each replacement would typically exceed \$75,000. By contrast, the flywheel in the CleanSource UPS has a 20-year life, resulting in savings of more than \$150,000 in a 10-year period.

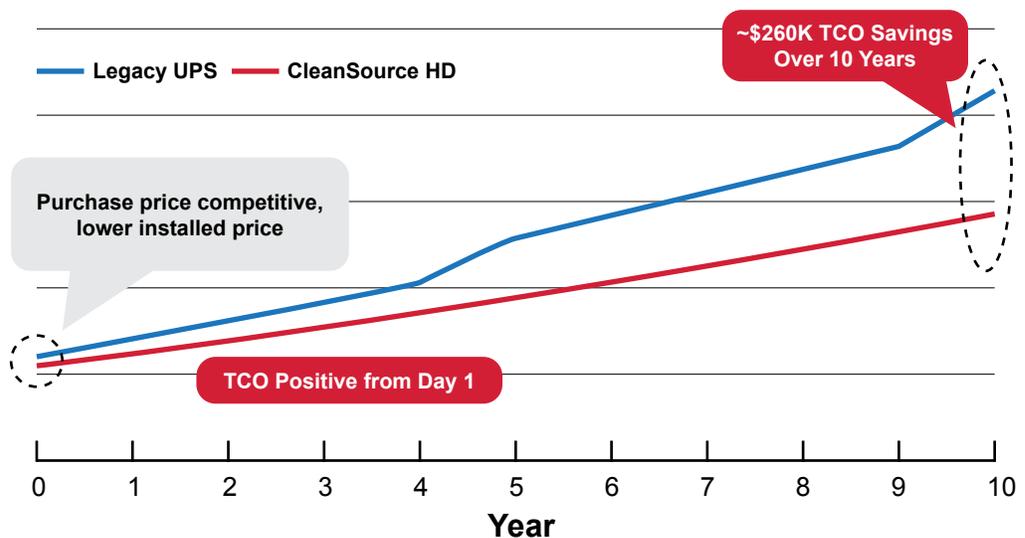


Figure 5. TCO comparison between CleanSource HD UPS and a legacy UPS. Assumptions: 1 MW load with 2N design; CleanSource 750HD: 96% efficient; legacy UPS: 93% efficient, 6 minute VRLA batteries w/ 5 year replacement cycle; \$0.10/kWh energy cost

As shown in Figure 5, CleanSource HD delivers more than 50 percent annual operating expenses savings versus an equivalent conventional UPS system, and more than \$260,000 in total savings over 10 years. Combined with a competitive first cost, the total lifecycle cost savings of CleanSource UPS and CleanSource HD UPS easily make them the ideal choice for the health care market.

CASE STUDY – PARKLAND HEALTH AND HOSPITAL

Parkland Health and Hospital is one of the largest hospital construction projects in the U.S. with a 2.5 million square foot campus that includes 862 single patient rooms. Construction was completed in August 2014 with patient care beginning in the summer of 2015.



The campus' key design goals focused on creating a sustainable community resource with a low carbon footprint and high energy efficiencies while at the same time not losing sight of the importance of reliability. The critical backup power systems support both the new data center and imaging center.

To meet its requirements, Parkland chose to deploy 10 Active Power CleanSource UPS systems totaling 29 flywheels to ensure 100 percent uptime to its most mission critical operations. The integrated flywheel UPS is an ideal fit for health care applications where power quality incidents and micro outages can be frequent. The CleanSource UPS systems provide ride through to the generator, ensuring power is available at all times. The systems will also help enable the hospital in part to earn U.S. Green Building Council LEED Silver certification due to its high energy efficiency and use of recycled materials

The driving force behind Parkland's selection of CleanSource UPS was the higher energy efficiency and superior total cost of ownership versus leading competitors. Once the hospital is fully operational, the use of CleanSource UPS is expected to save Parkland more than \$90,000 per year in electricity costs due its higher efficiency and lower cooling requirements. Further, because there are no batteries to replace, CleanSource UPS will save Parkland approximately \$800,000 every five years in avoided battery replacements.

Active Power's UPS incorporates all of Parkland's power protection requirements into a single solution that's efficient, reliable, green, and delivers low total cost of ownership.

“Active Power's UPS technology enables us to deploy a forward thinking power infrastructure design with a low carbon footprint and higher energy efficiencies versus traditional systems.”

– Lou Saksen, SVP, Facilities Planning and Development, Parkland Health and Hospital

CONCLUSION

Modern health care facilities rely on their IT and advanced medical equipment to provide quality and economical patient care. That equipment in turn relies on the availability of electrical power. In addition to the emergency power systems required by code, health care facilities are adding UPS systems to ensure their continued operation.

Active Power CleanSource UPS systems are an ideal fit for the specific demands of health care applications where electrical interruption is not an option. They are proven to provide the power quality required by both medical equipment and hospital data centers, delivering tangible performance and economic benefits ideally suited for these types of applications.

The integration of flywheel energy storage into UPS systems used in the critical power systems found in today's health care facilities addresses the central concerns of that industry. Active Power's CleanSource UPS systems have proven unequivocally to be safer, more reliable, and less costly to own and operate than comparable legacy, battery based UPS systems.

REFERENCES

¹ MeriTalk, RX: ITaaS + Trust, <http://www.meritalk.com/Rx>, 2014.

² See IEEE, 1159-2009 – IEEE Recommend Practice for Monitoring Electric Power Quality, 2009.

³ Please note: the NEC has specific requirements for the design of health facility electrical systems. Local codes may place further restrictions. Not all UPS systems are appropriate for use in specific applications such as life safety. Facility operators should consult with their UPS manufacturer and local electrical permitting/inspecting agency before installing a UPS in any health care facility.

⁴ P. Jones, Avoiding Battery Failure and Outages, DatacenterDynamics, <http://www.datacenterdynamics.com/critical-environment/avoiding-battery-failure-and-outages/85881.fullarticle>, Apr. 14, 2014.

⁵ Active Power White Paper 115, Mitigating Risk of UPS System Failure, <http://www.activepower.com/white-paper-115/>, Aug. 2014.