

Flywheel vs. Battery UPS for Medical Center IT Infrastructure

Summary

This document analyses the feasibility of Flywheel UPS systems as a replacement for the existing Battery Based UPS systems within the IT infrastructure. Although it warrants further analysis, this document does not address backing up other critical branch loads or the critical branch in its entirety. This effort will be completed as part of the Kaiser Templated Hospital project.

The flywheel UPS system is less costly in both initial capital and ongoing maintenance expense. The flywheel system uses less space and generates less heat than comparable sized battery operated system.

However, the flywheel system will only provide power for about thirty seconds after a failure of the normal power source (the battery system can provide any duration of power needed; it is outside the scope of this document to determine how much time is needed for UPS power following a failure of the normal power system).

Therefore, in any installation where Kaiser cannot tolerate a power outage for IT equipment after 30 seconds, and which has either no Emergency Power System or an Emergency Power system that cannot be relied upon to be online within 30 seconds, Kaiser should use conventional battery-backed up systems.

However, in buildings where it is not necessary that the IT systems operate for longer than 30 seconds after a failure of the primary power source, or that have Emergency Power systems judged by Kaiser to be sufficiently reliable to tolerate the 30 second limitation, Kaiser should install flywheel UPS systems instead of conventional battery backed up systems.

One incidental finding of this study was that a primary source of failures of power to IT systems is the automatic transfer switch. Kaiser could pay for the cost of a redundant switch and feeders for IT loads with the first cost savings achievable by using a flywheel as opposed to a batter-based system. That is, for the same capital cost as currently spent, Kaiser could increase the reliability of the system while accessing significant space, and life cycle maintenance, and cost savings offered by the flywheel system.

Technical Assessment – Opportunities

Within the IT infrastructure of a Kaiser Medical Center there are three distinct opportunities that warrant the consideration of a flywheel UPS system. First, to protect the

TER; second, to protect each BTR¹ per existing Kaiser Standards; and third, to provide a central UPS to protect all facility BTRs.

In the case of the typical Kaiser TER, we will assume a UPS size of 250kVA. For the BTR’s, we will assume a typical five story building, with a 60kVA UPS per BTR. For the centralized BTR protection, we will assume a total of 5 BTR’s in the facility totaling 300kVA². These values are indicative of a typical Kaiser Template Medical Center and should suffice for this comparative analysis.

Scheme	Battery Based UPS	Flywheel UPS
TER Protection	250 kVA	300 kVA ³
BTR Protection	60 kVA	130 kVA
Centralized BTR Protection ⁴	(5) 60 kVA	300 kVA

Table 1 - Analysis Schemes

Technical Assessment – Reliability

When designing a UPS system for IT applications, it is necessary to consider two main characteristics of reliability. First and foremost is the ability of the UPS system to maintain continuous power to the load until backup power can be established, referred to as “ride-through”. Second, is the ability of the UPS system to allow ample time for orderly shutdown should the backup power fail to come online. This document assumes that the backup power system is designed to provide power within 10 seconds and that the IT systems are on critical power. For systems where the IT infrastructure has no backup generator, as is the case in some MOBs, the flywheel UPS systems does not add significant value, except in its ability to condition power and provide ride-through of short term utility interruptions; therefore, flywheel UPS systems are not recommended for facilities without backup generators.

¹ It is assumed throughout this document that each BTR provides UPS protected power for a stack of TR rooms.

² The 5 BTRs include 3 BTRs in the hospital and 2 in the attached MOB.

³ Flywheel UPS systems are only available in select sizes; therefore, the next largest available product is used in this analysis.

⁴ Since that space and economics of a centralized battery based UPS system yield it impractical, as decided by KP Staff in regards to the San Leandro Medical Center, the Centralized Flywheel UPS is benchmarked to the individual Battery Based UPS systems in this analysis.

Both battery based and flywheel UPS systems are designed to supply instantaneous power to the load in the event of normal power failure. For the purposes of this document, we will ignore the normal-operation failure analysis as both systems incorporate similar bypass architectures. Also, the electronics (inverters, contactors, etc.) are largely similar between the systems, with similar probabilities of failure. The energy storage systems are the distinct differentiator and have the different characteristics and failure rates that we will discuss in this document.

The amount of energy in a flywheel, stored kinetically, can be calculated based on the angular velocity of the internal rotating mass. This value is easily measured which, along with knowledge of the load, yields distinct and predictable run-times. If the flywheel malfunctions, the loss of angular velocity is easily recognized and reported to allow timely maintenance.

The amount of energy stored in a battery bank, stored electrochemically, is calculated based on manufacturer and design values, or in some cases, on the measured value of input energy. These values are extremely volatile in practice which makes predictions of runtime inherently inaccurate. Furthermore, batteries are susceptible to undetectable deterioration and internal failures which, even with proper maintenance, can result in unpredictable system failures. Within Kaiser Permanente, such failures account for 20% of total IT power failures⁵.

The most significant difference between battery based and flywheel UPS systems is the ability to provide adequate time for an orderly shutdown should backup power fail to come online. Battery based systems allow extreme flexibility and are capable of run-times in excess of three hours with adequate battery storage while flywheel systems typically provide approximately 30 seconds (up to a maximum of 52 seconds) runtime. The need for an orderly shutdown stems from the case where the backup power does not come online. Though there are a multitude of reasons for this to happen, over 93% of the cases stem from automatic transfer switch failure⁶. In a facility where the infrastructure could supply two feeds from two different transfer switches, the overall risk of backup power failure to the IT equipment could be greatly reduced, improving the case for a Flywheel UPS system. However, the Kaiser Template hospitals typically provide a single critical transfer switch.

⁵ Kaiser Permanente Presentation, “UPS Replacement Project”, October 20, 2006 - Statistics recorded from December '04 to August '05.

⁶ “Reliability Assessment of Integrated Flywheel UPS versus Double-Conversion UPS with Batteries, White Paper 103”, MTechnology, Inc. – Commissioned by ActivePower

In order to address the significance of the need for orderly shutdown in a given facility, the IT planners must consider both the ability of their staff to perform an orderly shutdown in a given time frame and the comparative value of such a shutdown⁷. It should be noted that in the event of backup power failure in a hospital with a Flywheel UPS system, a disorderly shutdown may occur, possibly resulting in loss or corruption of data. However, in most cases, such an event would also force all other hospital equipment and computer terminals offline⁸.

It should be noted that Flywheel and Battery Based UPS systems also have differing partial load efficiencies and power conditioning strategies but there is insufficient published data to effectively capture and compare their differences.

Up-Front and Life Cycle Costs

The UPS systems themselves have almost identical installation methods except for the fact that battery based UPS require systems require additional DC wiring. For the purposes of this comparison, installation costs are considered comparable and removed from the analysis, except in the case of centralized BTR protection in which additional wire and conduits are required between BTRs.

When comparing first costs of the UPS equipment, flywheels are less expensive for a given capacity. Since the UPS topologies are largely comparable with similar costs, the significant cost differential stems from the different energy storage types. It should also be noted that the figures below depend largely on the designed run-time of the battery based system, which in this case is 30 minutes.

UPS (Type)	Equipme nt Cost (\$ / kVA)
Battery	\$669
Flywheel	\$467

Table 2 – Equipment Cost⁹

Another factor involved in first costs of new construction is the required infrastructure changes. With roughly a third of both the physical footprint and heat rejection, a flywheel

⁷ As the designed run-time of a battery based UPS system increases, it has significant affects on the capital costs, operating costs, and footprint of the system. The cost analysis in this document only considers the case of 30 minute battery backup.

⁸ Such an event would stem from high level backup power failure in the generators, paralleling gear, main feeders, or ATS. This statement does not take into account any local UPSs that may be used for computers, imaging equipment, etc.

⁹ Figures listed are the average of the cases analyzed in this document.

UPS system allows the owner to take best advantage of limited building area and can contribute to reducing over mechanical loads, as seen in the table below.

UPS (Type)	Physical Footprint (ft² / kVA)	Heat Rejection (BTU/hr/kV A)
Battery	.21	293
Flywheel	.07	93

Table 3 - Physical Characteristics⁹

When looking at the comparative life cycle costs of each UPS System, you must take into account capital costs, scheduled maintenance, major parts replacement, energy use reductions, and space savings. Scheduled maintenance for a battery based system includes but is not limited to battery cell/bank voltage readings, hydrometer testing, and cell/bank resistance readings. Scheduled maintenance for a flywheel includes but is not limited to air filter changes, diagnostics, and flywheel cleaning.

Another significant factor in the life cycle cost analysis is the major equipment replacement. For a flywheel system, this typically includes a bearing replacement every 3 years. For a battery based system, this includes the replacement of the entire battery bank every 5 years¹⁰.

UPS (Type)	Scheduled Maintenance (\$ / kVA / Year)	Major Equipment Replacement (\$ / kVA / Replacement)	Major Equipment Replacement (Interval)
Battery	94	130	5 Years
Flywheel	5	19	3 Years

Table 4 - Physical Characteristics⁹

When taking all of these variables into account over a 20 year system life with a discount rate of 10%, we arrive at the values below.

¹⁰ It should be noted that the battery replacement interval is a significant contributor to the overall reliability of a battery based UPS. The 5 years interval used here is an average of industry values.

Scheme	UPS Size		Up Front Costs ¹¹		20 Year NPV	
	Battery (kVA)	Flywheel (kVA)	Battery	Flywheel	Battery	Flywheel
TER Protection	250	300	\$214,400	\$117,453	\$559,352	\$248,745
BTR Protection	60	130	\$59,400	\$103,453	\$159,438	\$191,888
Centralized BTR (Flywheel) ⁴	(5) 60	300	\$234,000	\$137,453	\$606,074	\$287,503

Table 5 - Life Cycle Cost Analysis

Environmental Impact

The manufacturing, use, and disposal of rechargeable batteries can be a significant environmental concern. Traditional battery systems utilize valve-regulated lead-acid (VRLA) type batteries, and it is the lead in these that provide the largest environmental hazard. VRLA batteries must be in tightly controlled environments as they lose life quickly if stored in temperatures outside their normal operating range. Also, the existence of batteries requires additional ventilation systems in order to mitigate the threat of explosion and to provide a safe working environment for technicians and staff. Flywheels do not require strict temperature controls or special ventilation requirements, lowering the overall HVAC load and therefore using less energy. Lastly, when rechargeable batteries reach the end of their useful life, they must be properly recycled.

The recycling and the additional HVAC requirements incur additional costs to the owner, which were not included in the analysis here.

Conclusion and Recommendation

It is recommended that flywheel UPS systems be implemented for all TER loads and all BTR loads with the option to centralize the BTR protection when it is cost effective.

The recommendation is based on the following:

- Flywheel UPS systems are as much as seven times less likely to fail when compared to battery based UPS systems in short term (<10 second) power failures⁶. Since these outage types are the most common in hospitals, it is imperative that the UPS provide reliable power throughout.

¹¹ The cost analysis also takes into account a year zero space savings of \$900 / ft²

- Flywheel UPS systems would reduce the workload on facility maintenance personnel.
- The creation, maintenance, and disposal of lead-acid batteries has a significant negative effect on both the natural and built environment. It would be a significant step towards greening operations if Kaiser was to forgo their use.

It is also recommended that Kaiser Permanente perform an in depth analysis of the current state of orderly shutdown procedures. This analysis should include surveys of site personnel, investigation into official policies, and multiple orderly shutdown tests. If it is shown that in typical medical centers an orderly shutdown is either impractical or unlikely, then there is no tangible advantage to using battery based UPS systems.

As an option to increase the overall reliability of the emergency power system for IT equipment, Kaiser may also want to consider using the savings outlined above to install an auxiliary automatic transfer switch dedicated to the IT equipment. Since a significant proportion of upstream backup power failures are due to the failure of an automatic transfer switch, this new transfer switch (along with the existing critical transfer switch) would further reduce the probability of losing power to IT equipment.

Assumptions

1. All Flywheel UPS costs and characteristics were derived from the ActivePower line of products. Caterpillar, Liebert, and Eaton also produce a Flywheel UPS with similar characteristics.
2. All Battery Based UPS pricing and dimensions were taken provided by KPIT, "UPS_Matrix_20081215.xls"
3. Technical Specifications for UPS systems (efficiency, heat rejection, etc.) were taken from Liebert.