Managing Hospital Emergency Power Programmes

a report by

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A hospital can have a simple or complex emergency power supply system (EPSS) but ensuring that the system continues contributing to safe and effective patient care with today's challenges is rarely simple. Complexity is introduced because the EPSS powers other hospital systems such as the clinical, mechanical, vertical transportation and fire management systems. The hospital engineer must also respond to new requirements that affect the EPSS, including requirements for utility management, emergency management, patient safety, continuous quality improvement and staff education. All of these interrelationships cause complexity.

An EPSS includes generator sets, generator set auxiliary systems such as cooling, combustion air, fuel oil and starting systems, paralleling switchgear, automatic transfer switches, distribution panels, lighting and power panel boards, feeders and branch circuits. Some facilities that do not have EPSSs may have a stored-energy EPSS (SEPSS). Facilities can also have an uninterruptible power supply (UPS).

When the normal power fails, all normal loads are dead. All emergency loads experience a short loss of power unless they are backed up by an SEPSS or UPS. The hospital's clinical staff must know how to deal with this condition. The monthly load testing simulates this experience as illustrated in *Figure 1*, although the length of time without voltage during a test is likely to be less than it would be during an actual outage. A proactive EPSS management programme will use the lessons learned from the monthly load testing, along with regular normal power shutdowns, to train the clinical staff to expect and then manage this critical element of the environment of care.

Some hospitals have decided that the short period of time (10 seconds or less) that some clinical equipment, such as ventilators, would be without power during a real normal power outage is unacceptable. Those hospitals have installed UPS systems to provide uninterruptible power to their ventilators, and have identified specially marked outlets as UPS-backed outlets.

Management Programme Synopsis

Managing emergency power systems is more than just monthly generator load testing. It should also involve:

- knowing the total EPSS demand loading under the range of emergency conditions included in the hospital's hazard vulnerability analysis;
- knowing the total demand on major distribution elements of the EPSS such as transfer switches;
- reviewing unexpected occurrences and monthly test results;
- analysing trends of results and problems for continuous quality improvement;
- investigating and resolving training and/or systemic issues identified by the trend analysis;
- co-ordinating the impact of construction/renovation projects and infrastructure upgrade projects on the EPSS; and
- performing an extended-run EPSS load test at least once every 36 months.

Emergency Power Demand Load

Hospital engineers need to determine the actual EPSS peak (demand) load for due diligence and to satisfy the requirements of authorities having jurisdiction in their localities. Many hospital engineers believe that the amount of load they record during their monthly EPSS load tests is the real demand load. This assumption is flawed and can lead to some negative consequences.

The EPSS test load does not reflect the EPSS demand load because the EPSS test loading depends on the day and time of the test. Correspondingly, real EPSS loading during a utility power failure also depends upon the day and time of the power failure. Many hospitals test their EPSS at night or early in the morning before the bulk of the hospital's daily activities begin. This test time was probably chosen

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Table 1: Methods for Measuring Typical ATS Loads and Load Profiles

Fair	*Better*	*Best*
Sample with hand-held ammeter – does not result in load profile	*Record 2–3 days per ATS with portable recording instrumentation*	*Use remote power management systems*
Sample with ATS-mounted ammeter – does not result in load profile	*Use power quality meter* *Use data loggers*	*Use central data recording and storage*

to be one of low clinical activity, and that avoided clinical load will not be reflected in the EPSS test loading. Many hospitals do not test their EPSS whenever their operating theatres are in use. Also, the mechanical (see *Figure 2*), building, radiology (see *Figure 3*) and other clinical processes all vary during a typical hospital day. Finally, some equipment, such as smoke control systems and fire pumps, will not operate except during internal emergencies.

Figure 1: Impact of an EPSS Test on ATS Current

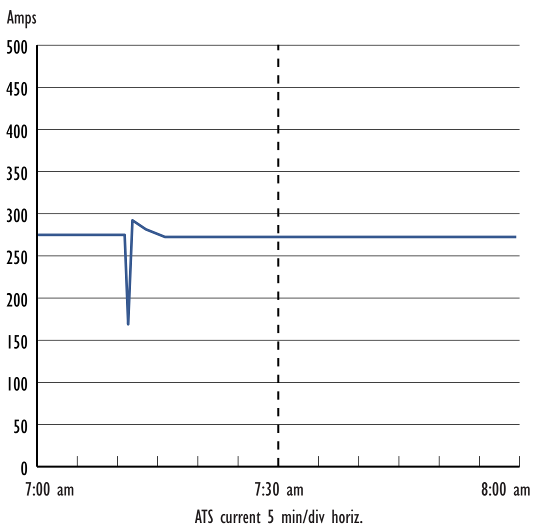
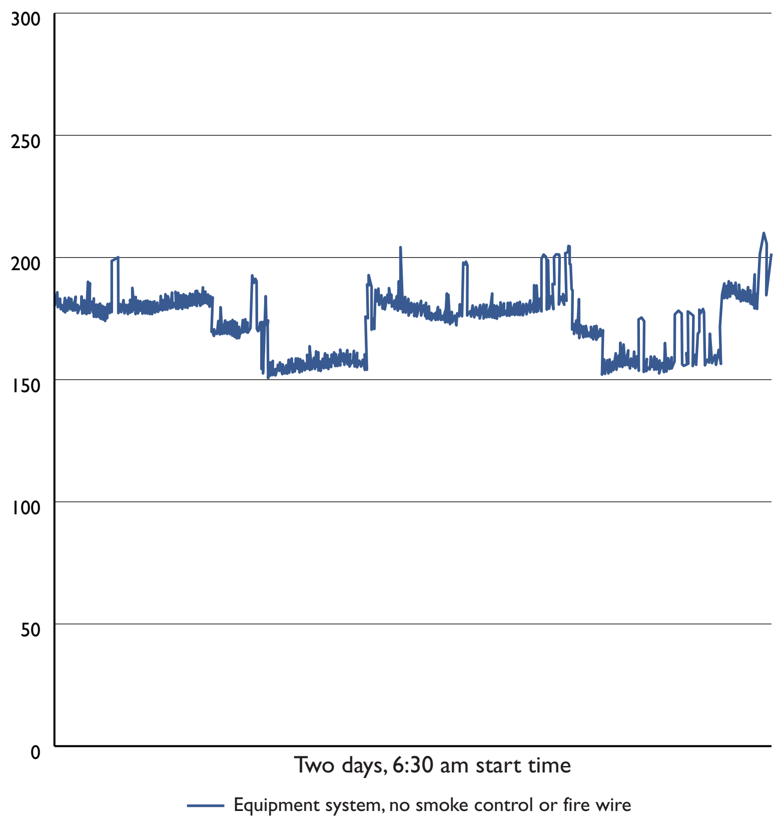


Figure 2: Sample Mechanical Equipment System ATS One-minute Load Profile



The amount of load through a piece of distribution equipment such as a transfer switch can be measured as a function of time of day. This does not include sampling in short intervals. Repeated recordings for several days with portable or permanently installed power monitors will provide the raw data from which EPSS load profiles can be generated.

During an internal emergency situation such as a working fire, the EPSS loading may include extra fire alarm system load (see *Figure 4*), may include the extra load of smoke control systems such as stairwell pressurisation fans or atrium exhaust fans and may include a fire pump. If the emergency is external, then the EPSS load may also include extra clinical activity, which some medical personnel call 'emergency department surge'.

The author's experience reviewing thousands of hospital load profiles has indicated that daily load profiles taken in the same hospital building over time tend to show similar characteristics and values. The load profiles are most likely to change due to load growth (over time), space utilisation changes and densification of occupancy or equipment. The following is a strategy for determining the peak load that provides good repeatable values:

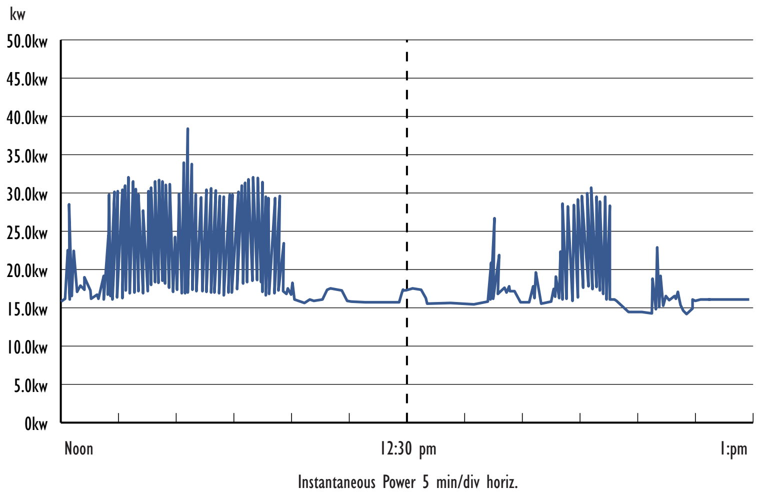
- obtain typical day load profile for each automatic transfer switch (ATS);
- add seasonal adjustments;
- adjust loading for the internal emergency condition considered (such as a fire);
- adjust loading for the external emergency condition considered; and
- adjust loading for lessons learned from planned normal power shutdowns.

Each ATS and adjustment factor is considered individually. Once all input data has been measured, calculated or analysed, *Figure 5* can be turned into the overall EPSS 'stacked area chart' (see *Figure 6*) with a simple spreadsheet command. It is important to ensure that all measurements and adjustments are in the same units. The author prefers kilovolt-amperes since it is a direct calculation from amperes, is independent of ATS voltage and does not require power factor assumptions.

Table 2

Some types of EPSS failures	*Possible result if not found and fixed before the next normal power outage*
Starting battery or cable problems	*No emergency power when needed*
Engine fuel oil contamination	*Poor operation, possible engine failure*
Faulty safety shutdown switches	*May shut off the generator set unnecessarily*
Engine fluid leaks	*Possible engine failure*
Engine mechanical failures	*Possible engine failure*
Transfer switch failures	*Failure to transfer to emergency power*
Blown control power fuses	*ATS fail to transfer, paralleling switchgear failure, generator set fail to start*
Tripped or open emergency power circuit breakers	*ATS will not transfer to a dead source*

Figure 3: Sample Radiology ATS Load Profile



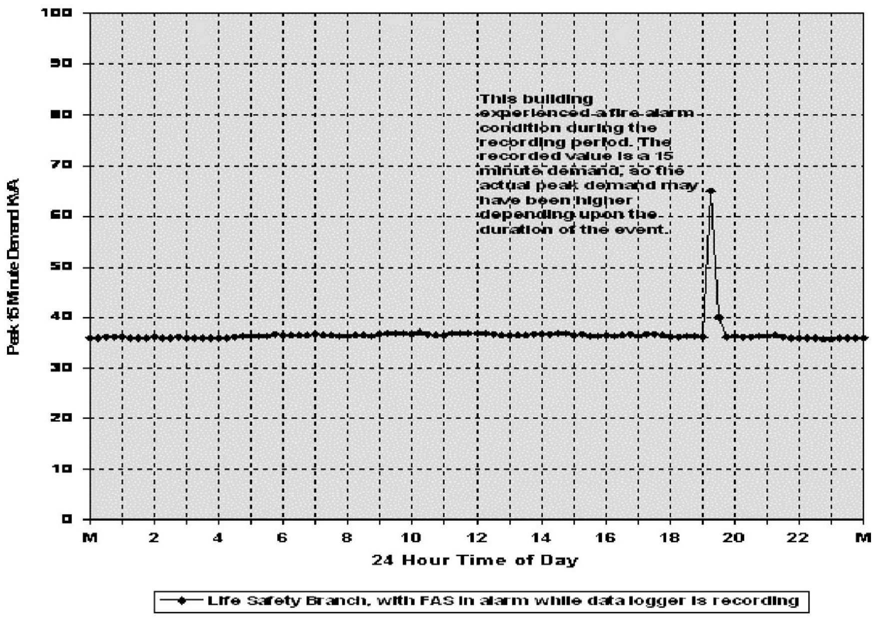
Emergency Power Testing Programme

The primary goal of a hospital's emergency power testing programme is to comply with regulatory requirements without adversely affecting the operation of the hospital or the wellbeing of the patients. Additionally, the programme needs to verify the infrastructure's ability to withstand those power transfers that will occur when utility power is lost. As these power transfers usually involve power quality issues, it is also necessary to educate clinical care-givers so that patient care is not put at risk in the event of power outages or transfers.

A comprehensive, proactive approach to emergency power testing should incorporate the following.

- Test the functionality of all equipment related to generation and distribution of emergency power.
- Train both maintenance and clinical personnel in how to deal with the loss of utility power and power system transfers.
- Test clinical equipment response to power system transfers.
- Test the mechanical and building system responses to power system transfers.
- Ascertain the causes of unexpected occurrences caused by the EPSS testing and take corrective action to preclude future failures.
- Avoid conditions that compromise patient treatment and safety.

Figure 4: Sample Hospital Emergency Power System Life Safety ATS Load Profile Using 15-minute Demands



Monthly emergency power testing may also cause EPSS failures to occur during the test because the equipment is operating. Failures that do occur during a test probably would have occurred anyway during the next normal power outage. Their impact on the hospital is lessened because plant operators are focusing on the test and normal power is still available. Experienced hospital engineers would prefer to have the next failure during the next test instead of during the next outage.

Second - order Consequences and Lessons Learned from EPSS Tests

EPSS testing can have second-order consequences, which are wide-ranging consequences beyond the primary intent of the testing. The second-order consequences of the testing may signify a potential problem with the next power outage as well. For this reason, hospital engineers should always follow up on the lessons learned from the monthly load testing, determine

Figure 5: Sample Hospital Emergency Power System ATS Load Profiles Using 15-minute Demands

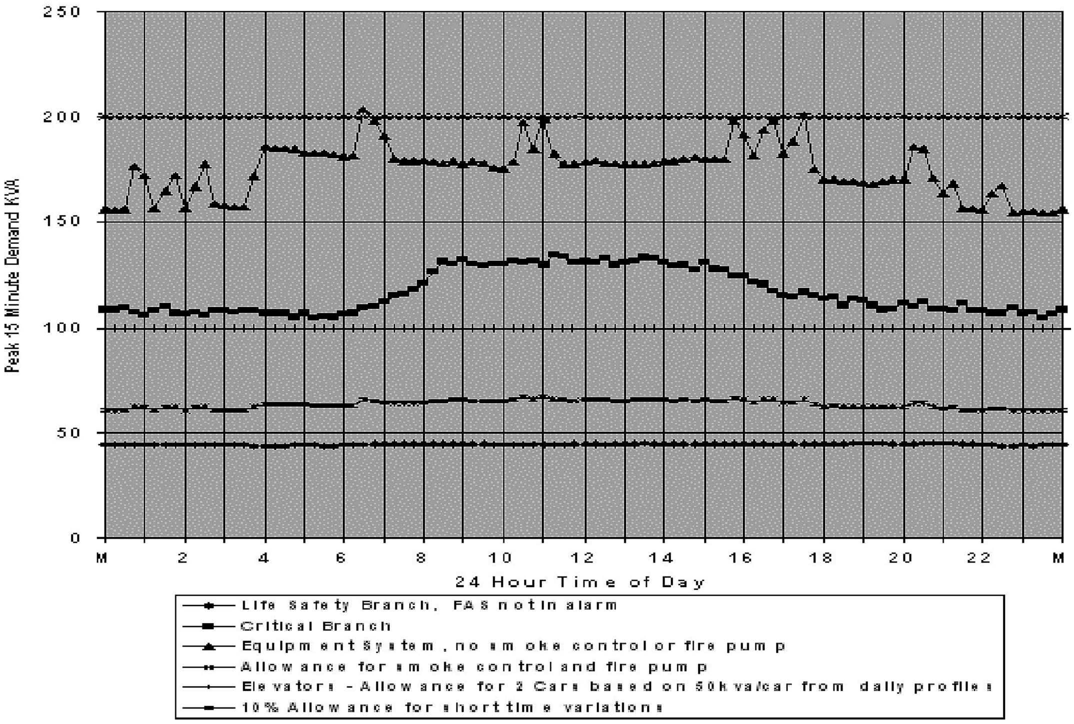


Figure 6: Sample Hospital Emergency Power Supply System Load Profile Using 15-minute Demands on 800kW/1,000kVA Generator Set

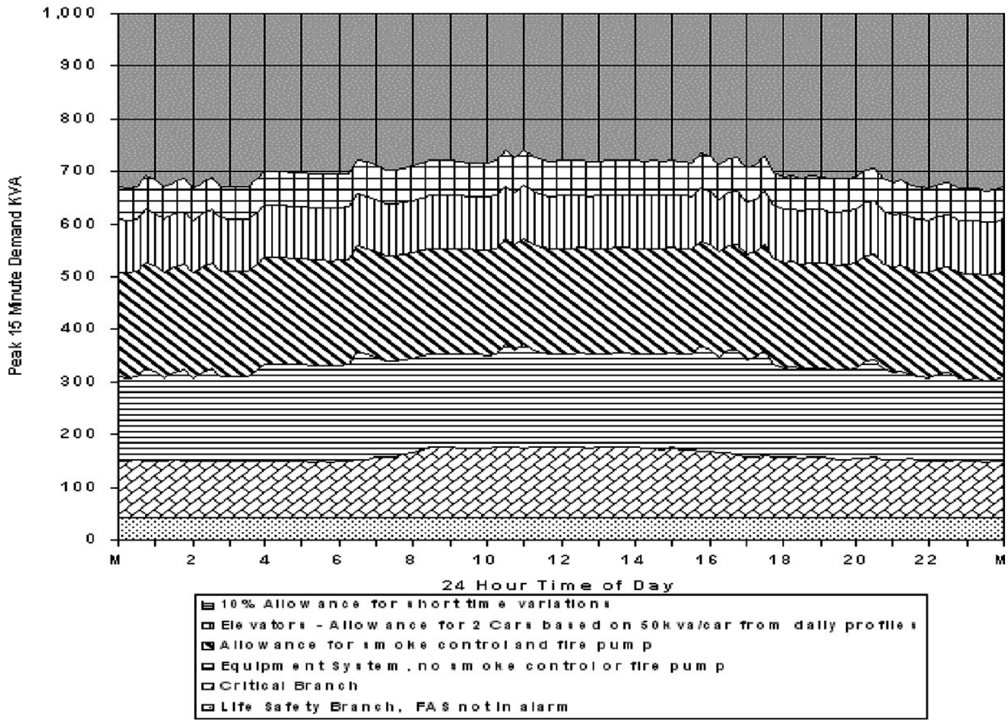


Table 3: Managing Hospital Power System Failures

Types of failures that usually have written failure procedures		Types of failures that often do not have written failure procedures	
Normal power		**Normal power**	
• Incoming utility line(s) • Main utility transformer • Main service entrance switchboard	Emergency system is still available – major impact on hospital but expectations are lower	• Large feeder or riser (busway or cable/conduit) • Large transformers and switchboards • Motor control centres, large distribution panels	Emergency system is still available – lesser impact on hospital but expectations are much higher than total outage. Could be accompanied by fire/smoke.
Emergency power		**Emergency power**	
• One generator of a multiple generator system	Remaining generators are still available	• Paralleling switchgear – most critical common mode EPSS failure	Will take out all connected generators – must rewire all ATSs.
• Single generator	Normal power is still available, may arrange for spare or rental unit		
		'Normal/emergency' power (still part of the EPSS but downstream of the transfer switch or other transfer device)	
		• Critical branch ATS or riser	Normal power is still available but clinicians must be trained so that normal power can be the back-up
		• Critical branch feeder or panel	Hard-wired equipment is very problematic
		• Life safety ATS or riser • Life safety feeder or panel	Will take out all hard-wired loads (fire alarms, emergency lights, exit signs, etc.)
		• Equipment system ATS or feeder or motor control centre	Will take down many important mechanical loads serving critical care areas
		• Uninterruptible power supply	Will take down all loads on the UPS, usually the most electrically critical.

the causes and effects of the second-order consequences and take corrective action as soon as possible. Examples of some types of second-order consequences are: unnecessary mechanical system tripping; UPSs that transfer to battery during the test; clinical equipment failures; circuit-breaker tripping; unwanted mechanical system responses; and variable-speed drive failures. Every system failure that coincides with or follows an EPSS test should be analysed for its generic relevance, considering it as a potential:

- human error;
- problem system interaction;
- test procedure inadequacy;
- equipment malfunction; or
- simple coincidence (unlikely).

Hospital engineers should proactively assess and reduce the risk of EPSS failure. The programme discussed here offers this. The following list provides a set of tools for quality improvement.

- Rotate testing personnel.
- Supervisors proactively review test results and all 'surprises'.
- Analyse test results, look for trends:
  – do not just record generator parameters.
- Review second-order consequences:
  – look for interactions between EPSS and the systems it powers.
- Use a testing event database:
  – unexpected events;
  – failures – EPSS, other systems and equipment; and
  – other unexplained occurrences.

Management of Power System Failures

Some hospitals consider power system failures as the failure of the incoming utility lines, main transformer, main switchboard, etc. This can take down the entire normal power system. In this case, the emergency power system is assumed to be available. As illustrated in *Table 3*, hospital engineers should consider different failure points, not just at the mains. The responses will be different for each type of failure and, as people sometimes find out much to their dismay, it is too late to formulate a response after the failure has occurred.

Poorly considered emergency responses can degrade patient safety if they neglect to consider all ramifications of emergency operation. Sometimes bad decisions are made by well-meaning personnel who are under a lot of pressure to act immediately. This situation can also compromise worker safety.

Hospital departments can plan and work together to deliver safe patient care, not just in the infection control and clinical arenas, but in the utility management arena as well. Basic 'what if' thinking by innovative professionals working together will improve the overall ability of the hospital to deliver safe patient care under all electrical failure eventualities.

When utility failures do occur – and they will – incident reports should be completed. When incident reports are generated, proactive utility managers will fix the immediate cause of the failure (as well as the failed equipment itself), consider the generic relevance of the failure, improve policies and procedures where warranted and make other changes to avoid similar future failures and improve overall utility reliability. Finally, all of these lessons learned should be used to improve the emergency management plan.

Planned Shutdowns

Hospital new construction and renovation projects often require carefully planned electrical shutdowns. If the critical branch panels or risers are to be shut down, then the temporary wiring and procedures that are used should be included in future emergency management documentation.

It is often necessary to power more equipment during a planned power shutdown than just code-required equipment. This is necessitated by the hospital's operating needs and if the extra equipment is not already on emergency power it must be temporarily wired for the shutdown. Many of these issues were learned for the first time when hospitals prepared themselves for Y2K.

Finally, planned shutdowns also include what emergency management policies call 'recovery' - getting back to normal. This can be a burdensome process if a lot of temporary wiring or back-feeds were used to get through the shutdown. It may be necessary to have detailed procedures for switching back to the normal operation in order to minimise the potential for accidents. Equipment that had remained de-energised during the outage should also be shut off before recovery begins to minimise the possibility of damage to sensitive electronics from power surges (voltage fluctuations) during the initial power-up.

Education

Since modern hospitals are evolving, constantly changing entities, on-going staff education is necessary. This includes highlighting and keeping current the interdependencies between each of the departments - facilities, clinical, support services, etc. The planned maintenance shutdowns and construction/renovation shutdowns provide excellent opportunities to highlight these interdependencies. ■

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