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ProCure21: dynamic approach vital

Electrical distribution strategies

Helping hand for infection control

Electrical distribution system strategies

Eugene Conroy, Eta Projects, examines the strategy adopted by the estates management of Charing Cross Hospital in implementing NHS electrical distribution system guidelines.

The electrical distribution systems in some NHS hospitals have exceeded their original design life and a risk assessment should be carried out to identify potential risk. Due to the age of some equipment, spare parts are no longer available. Therefore, should a component failure occur, a lengthy downtime could result with serious implications to patient care. In other cases, the design strategy is fundamentally flawed and the user requirements are not achieved.

Also, traditionally standby generator support was provided for essential services only. However, with the increasing reliance on technology and demand on the external network, standby generator support for critical service may not be sufficient to ensure security of supplies and therefore patient care may be compromised.

Under NHS guidelines, electrical distribution systems should be operated and maintained under the Health Technical Memorandums (HTMs).
These are as follows:

- HTM 2021 (high voltage systems)
- HTM 2020 (low voltage systems)
- HTM 2011 (emergency electrical services)

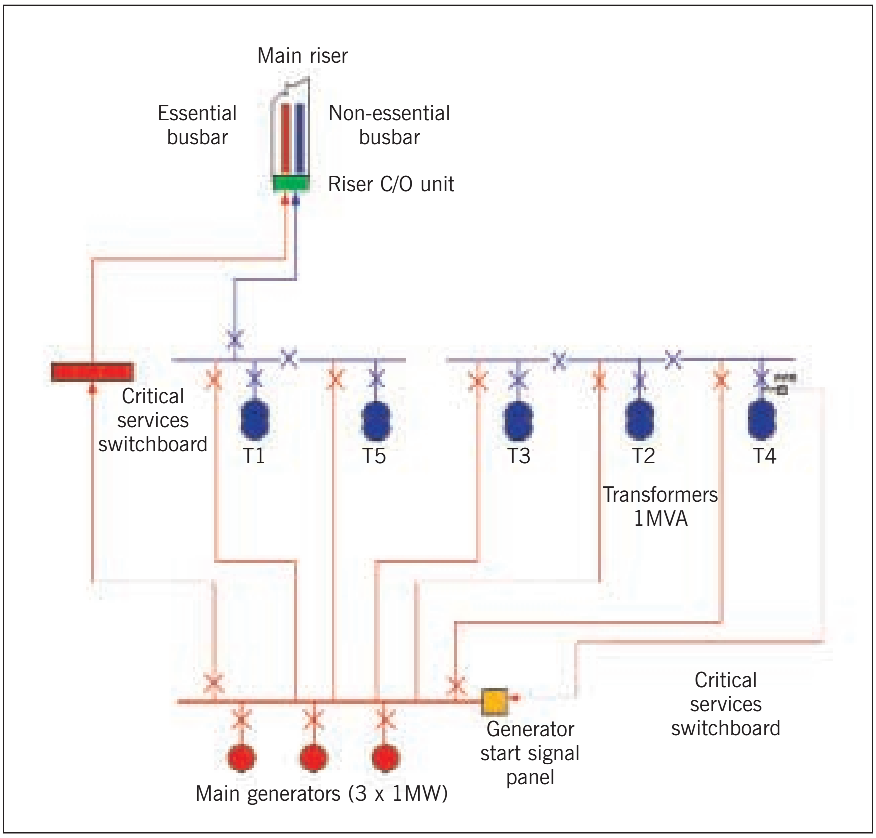


Figure 1: Typical mains/generator configuration.

These guidelines are not implemented in all hospitals. Therefore, should an incident occur, management could face prosecution under health and safety regulations due to lack of guideline implementation.

The estates management of Charing Cross Hospital have implemented these guidelines, and have a long-term strategy in place to upgrade their electrical distribution systems. This includes management and operating procedures, all of which may be of interest to design engineers who are undertaking similar hospital projects.

A chartered engineer from Eta Projects was appointed as the external "authorising engineer" as required under HTM 2021.

Eta Projects, in conjunction with the hospital estates department, carried out a detailed review of the hospital's electrical distribution system with specific priority on the high voltage systems. One point to note is that under HTM 2021, the high voltage system encompasses the HV switchgear, transformer and up to and including the transformer main "low voltage" switch. Unless design engineers recognise this last point, the correct HV/LV interfaces will not be implemented.

Hospital distribution system – Charing Cross Hospital: The system comprises five high voltage sub-stations all served from a common high voltage network. The network is configured as an open ring system. The ring is served from the supply utility main HV sub-station SS1, which is located in the hospital tower block. This sub-station is served from four independent 11 kV feeders from the external network.

The low voltage network is backed up with two independent generator systems. The main standby system is provided by three 1 MW generators configured in parallel. These generators were under-utilised and served a relatively small level of the hospital essential loads, somewhere in the region of 500 kW. Therefore, should power outages become more prevalent, the hospital made a decision to utilise the full capacity of the existing generators to provide standby support to priority loads and critical services.

Providing standby generator support to essential loads only may not be adequate in the future, due to the increasing demand on the utility networks and the increasing level of disturbances and recent failures experienced both in London and other countries. Consideration should be given to providing full generator support to hospitals to ensure patient care is not compromised.

Priority works: A detailed review was carried out as part of the authorising engineer's role and certain areas were identified that were not to current standards. A schedule of essential works was prepared and other works scheduled in order of priority.

The main priority was identified as sub-station SS4. This comprised a mixture of oil-filled equipment, some in poor condition. Also, some of the different equipment was integrated in an unconventional fashion. This equipment was completely stripped out and replaced using the Merlin Gerin "Genie Range" of switchgear.

The main switchboard in the hospital tower block was in excess of 30 years old and was identified as a major risk. The main breakers were regularly failing on their routine tests and sometimes failed to re-close. Spare parts were no longer available. Also, there was a shortfall in the control and monitoring systems, which made management of the systems cumbersome. After detailed feasibility studies, a decision was made to carry out a complete replacement of the switchboard.

The brief was to provide 100% generator support to the hospital tower block but still maintain priority for essential services.

Implication of works: The replacement programme imposed a logistical nightmare, as normal operation of the hospital had to be maintained at all times, especially the operating theatres.

Hospital electrical distribution systems are required 365 days/year. Therefore, replacing switchgear is difficult to implement and technically challenging.

The most critical load was the operating theatres and a close liaison group was established between estates and theatre to ensure continuity of supplies at all times.

It was also considered that to establish the extent of essential load, power monitoring should be undertaken on each load distribution point.

Power monitoring: Due to the extensive distribution network, it was difficult to assess the true extent of the essential loads and the spare capacity of the generator system. Therefore, a decision was made by the estates department, that power monitoring would be an integral part of future designs.

The provision for advanced power meters was incorporated into the design of the new tower block switchboard. The meters were remotely monitored from a central station in the estate office via ION Enterprise software. This is a high-level power monitoring platform which downloads all the recordings from each field meter at 30-minute intervals. It is programmed to record load trends of Amps, Volts, kW, kVA and kVAr. It also enables transient detection and alarms when any set point is exceeded i.e. "Transformer Overload" etc.

The analyser is set to trigger an alarm, should the load on any transformer exceed 90% of its rated load.

The system has proved itself on several occasions, when transient conditions on the external network caused internal interruptions on some sensitive equipment. The monitoring system enabled a rapid diagnosis of the problem and will avoid protracted fault finding in the future.

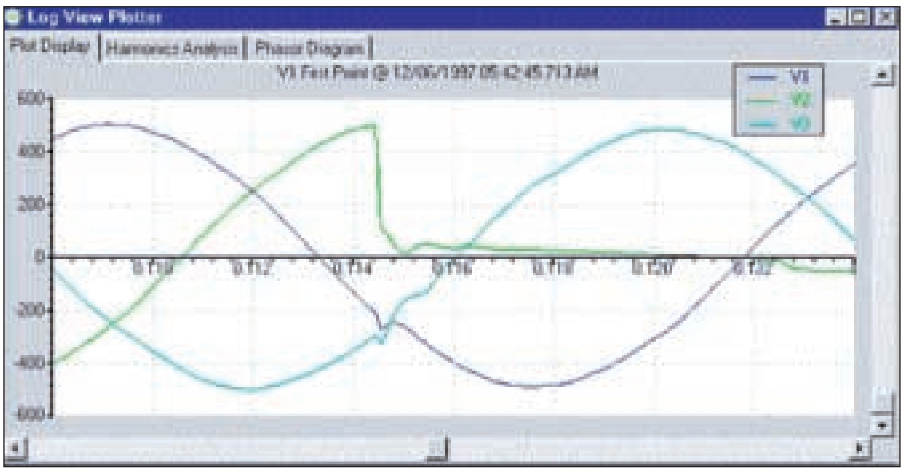


Figure 2: Waveform recording of a phase failure.

Generator control and testing: It is evident from surveys carried out on HV/LV networks that no provision is made in the design for testing standby generators. It is not acceptable to basically test the integrity of a generator by switching it on from its control panel. This does not prove the phase failure detection unit or the interface control wiring between generator and switchboard.

Therefore all switchboard designs should provide facility for testing the generator both "off-line" and "on-line". This enables the generators to be tested weekly "off-line" and monthly "on-line".

In addition, the switchboard should have clear indication of the status of the following:

- "Mains healthy"
- "Mains on-line"
- "Generator available"
- "Generator on-line"

HV/LV inter-trip controls: A HV system is defined as the HV system/breaker and up to the first main LV breaker connected to the system. It is essential to completely isolate the complete HV/LV section, should a fault occur in the zone between the HV and the LV breaker.

There appears to be some confusion amongst design engineers regarding the requirement for inter-trip controls between HV/LV systems. Should a fault occur on either the HV or the LV winding side of a transformer, it is essential that the HV breaker should trip foremost. This will isolate the primary source of energy. However, should the LV contain motive power, they will also act as generators and feed into the fault. Hence, it is important to isolate also the potential energy from the LV supply.

Therefore, the scheme should be designed to trip the HV breaker first and then give an inter-trip signal to trip the LV breaker.

This inter-trip facility should be clearly identified by incorporating inter-trip relays such as the Alstom MVAA inter-trip type relay, with each side clearly labelled, HV trip receive relay.

The arrangement, as indicated in Figure 3 will provide the necessary information and indication and identify immediately the source and location of any fault scenario.

Transformer LV winding protection: Transformer protection is required on both the primary high voltage and secondary low voltage winding side of any transformer. Overload and earth fault protection on the HV breaker protects the HV cable and HV primary windings only. Therefore, some form of independent protection is required to protect both the

LV winding and associated LV cables up to the transformer main LV switch. This is considered as part of the HV system.

The protection can either be of the Mertz Price principle (Balanced CTs on both HV and LV side) or alternatively by restricted earth fault (REF) protection. The restricted earth fault protection can either be of the 5CT principle, where direct transformer neutral earthing is carried out or the 4CT principle when the transformer earth/ neutral bond is carried out at the incoming side of the main LV switch. The latter type of earthing was utilised on the new tower block switchboard at the hospital.

When a transformer is overloaded, it is incorrect to trip the high voltage breaker as some design engineers specify. The overload condition can only be generated on the low voltage side. Therefore, to protect the transformer, it is essential to trip only the low voltage breaker via the high temperature trip.

Design risk assessment: A full design risk assessment was carried out on all elements of the design. This included design risk, installation risks and commissioning risks.

For guidance on the responsibilities and duties in the selection, use, care and maintenance of high voltage and low voltage switchgear, refer to the health and safety document, HSG 230 "Keeping Electrical Switchgear Safe."

Replacement strategy: The method to replace the old switchboard without adversely affecting the hospital was extremely challenging. It was not possible to disconnect/strip out an original section for direct replacement, as this would have involved a lengthy downtime.

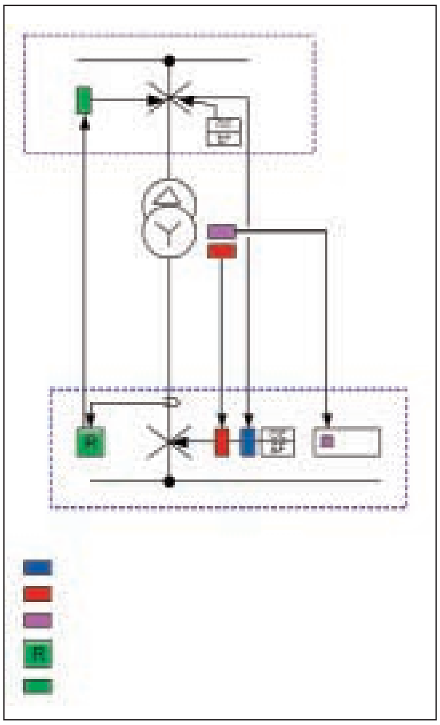
Various ways to enable the changeover were reviewed. An innovative approach was taken to create a complete new switchroom to house a three-transformer section of the new switchboard.

An adjacent storeroom was identified as most suitable as the main cable trench ran alongside it. This room was prepared complete with a computer room grade raised floor. The new switchboard was assembled, complete with new generator feeder cables. Temporary 415 Volt supplies were installed to enable an intensive testing and pre-commissioning to take place. The "mains" failure testing and correct changeovers switching was also tested on load and the tests all proved satisfactory.

New transformer cables were installed from each transformer to each section of the LV switchboard.

The services from sectioning the existing switchboard were transferred one by one to the new switchboard.

Commissioning: Adequate time is seldom programmed for commissioning work.



As a result, systems are handed over incomplete and failures occur when least expected. From extensive reviews and investigations of power problems in buildings, one of the most common problems experienced is the inadvertent operation of protective devices, because they have either been commissioned incorrectly or not at all.

Protection and discrimination: It is critical that a protection study is carried out on all new installations to ensure correct operation.

It should be noted that when circuit breakers are dispatched from the manufacturer, the protection units are generally set to minimum. Some consultants/contractors are failing to carry out proper protection commissioning and subsequent power failures occurr, when the minimum set values are exceeded.

Intensive pre-commissioning and final commissioning was carried out at each stage of the works. This included injection tests to prove the "protection systems" and "restricted earth fault" (REF) protection.

Each inter-trip function test was carried out and witnessed by all parties including London Electricity which owns the main HV sub-station. The protection settings on each individual breaker were calibrated and the settings witnessed each time by the consultant/contractor and hospital engineer.

When each and every control and monitoring function was tested and witnessed by all parties, the system was handed over for acceptance by the hospital.

Load shedding: Although, the brief was to provide 100% generator support to the tower block, load shedding was incorporated into the design. The non-essential mechanical plant is shed when operating on standby generator. However, each motor control panel was provided with a by-pass switch located in the new LV room. This enabled individual non-essential plant to be brought on-line when on generator operation, at the discretion of the hospital engineers.

Special consideration: The project would not have been a success without the commitment of the estates department electrical engineers.

The project was a serious engineering challenge, which demanded extensive knowledge of all elements of the engineering professions, from construction design management (CDM) to electrical/mechanical engineering.

Construction design and management (CDM) regulations: The construction design and management regulations give clear guidance as to the role and responsibility of each team member of a project.

It is imperative that a CDM review be carried out at the feasibility stage of any project. There is a legal obligation to comply with CDM when certain criteria of a project are present, i.e. demolition works, number of operatives on site at any time, duration of the works etc. If the project particulars dictate that CDM be implemented, then the HSE must be notified by the planning supervisor that the project is commencing.

The project was operated and controlled under the CDM regulations using GSD as the specialist company providing planning supervision. Reflexaction Services became the principal contractor.

Recommendations: Incorporate the following recommendations in all designs:

- Construction design and management regulation (CDM).
- Full indication of all breaker status.
- Generator "on-line and "off-line " testing facility.
- "Restricted earth fault" (REF) protection on transformer LV windings.
- 4-pole breakers on all main breakers.
- Dedicated inter-trip send and receive flag relays on all HV/LV systems.
- Power quality/energy monitoring on all power transformers.
- Energy monitoring on all sub-main feeders.
- Implementation of HTM 2021 (HV), HTM 2020 (LV) and HTM 2011 (emergency electrical supplies), for all systems.
- Adequate time for testing and commissioning.