Scottish Health Technical Memorandum 2011

(Part 4 of 4)

Operational management

Emergency electrical services

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The production of this document was jointly funded by the Scottish Executive Health Department and the NHSScotland Property and Environment Forum.

NHSScotland, P&EFEx, June 2001

Contents

1. Scope

General

1.1 Health care and social services premises are totally dependent upon electrical power supplies, not only to maintain a safe and comfortable environment for patients and staff, but also to give greater scope for treatment using sophisticated medical equipment at all levels of clinical and surgical care. Changes in application, design and statutory requirements have led to the introduction of a new generation of equipment and new standards of reliability.

1.2 Interruptions in electrical power supplies to equipment can seriously disrupt the delivery of health care with serious consequences for patient well-being. Health care and social services premises must therefore ensure that they can continue to provide electrical power to essential services in the event of prolonged or short disruption to supplies.

Emergency electrical services

1.3 Emergency electrical services form an integral part of the health care and social services premises supply network in meeting both safety and functional requirements. They can be in the form of batteries, uninterrupted power supply (UPS) systems, or stand-by generators.

1.4 The provision of emergency electrical services in health care and social services premises is a management responsibility at both new and existing sites. This guidance is equally applicable to premises which offer acute health care services under the Registered Establishments (Scotland) Act 1998.

2. Maintenance

Spares

2.1 Modern diesel or gas engines are capable of extensive use between overhauls. Running times between overhauls will vary considerably with type of use and nature of the fuel oil or gas used. Typical running hours between overhauls are:

Emergency generator set duties	2,000 hours, 3 years maximum;
Combined heat and power (CHP) duties	
- diesel	6,000 hours short overhaul; 12,000 hours long overhaul;
- gas	12,000 hours short overhaul 30,000 hours long overhaul;

2.2 Generators will be capable of operating for several years when confined to an emergency generating role before cylinder and crankshaft overhaul is necessary. In these circumstances, the need for spares is limited.

2.3 For emergency generator sets co-opted into a combined heat and power role, the range of available spares should be extended.

2.4 In all cases the frequency of maintenance, that is servicing and overhaul, will be influenced by the quality of fuel and lubricating oils used and the pattern of operation.

2.5 The following spares list is suggested for equipment operating in an emergency role only:

a. one complete set of cylinder gaskets, special seals and packings etc;
b. one set of renewable parts for oil fuel and air inlet filters;
c. two complete cylinder fuel oil injectors;
d. one automatic voltage regulator (AVR) replacement unit;
e. one set of rotating diodes for brushless generators;
f. one set of engine control relays.

Tools

2.6 A complete set of high quality spanners and special tools required for servicing the emergency generator set by the healthcare and social services premises' staff should be held in stock.

Instructions

2.7 Instructions for starting, stopping, operating and routine testing of the emergency generator set should be supplied by the manufacturer with each set as early as possible to assist in staff training. Planned preventive maintenance and servicing should be based on the Estates Information Management System and the appropriate maintenance instructions provided by the manufacturer. Details of all sensors, electrical protection relay settings and control fuse sizes should be recorded for future reference.

Maintenance reports

2.8 Routine servicing instructions should be scheduled and a log-book kept of all work that is carried out, including details of any parts that are renewed with a brief note of any defects or failures and rectifying action taken.

2.9 The log-book should include details of any running of the emergency generator set, for example test runs, runs caused by mains failure or scheduled mains interruptions and maintenance purposes. It should include battery and charger histories and a weekly test of specific gravity and/or cell voltages.

Test runs

2.10 It is important that regular checks are made to ensure that the engine start-up is operational.

2.11 It is advisable to turn the engine over once weekly with the fuel isolated. This routine purges the cylinders of water deposits that may have entered from leaking gasket seals from the water jacket or water deposits condensed from previous running.

2.12 A no-load run of up to 15 minutes to test the reliability of the engine start up and the electrical control system should be carried out every two weeks. Extended running at no-load is not advised, as this encourages build up of carbon and mineral salt deposits around the engine inlet ports and fuel injectors. Bearing wear also occurs disproportionately owing to the lubricating oil not being rapidly or fully heated to operating temperature at the onset of a cold start-up.

2.13 Start-ups should be made by simulating loss of normal supply, and the total time to start up the engine and re-establishing normal supply recorded.

2.14 No-load stops should be made as variable as possible to proof test and demonstrate the operation of the various protective mechanical sensors and electrical protection relays.

2.15 Loads in excess of 70% full load should be sought for periods of at least two hours on a monthly basis. Operational runs at or near full load help to remove carbon desposits accumulated during the no-load runs. The load may be obtained by the hire of a load bank, synchronising to the supply where agreements exist with the public electricity supply company, or linking the essential and non-essential loads by a coupler device.

2.16 The overspeed governor shall be operated on a monthly basis, prior to the load test. This is carried out when the generator set is operating at **no load** and the circuit breaker is open. The method to overspeed the engine will depend on whether the governor is hydraulically or electronically controlled and adapted for single or parallel running. The manufacturer's guidance should be sought.

2.17 Trip tests on load should only be attempted at loads less than 25% full load. An attendant should be ready to close the fuel rack in the event of failure of the governor trip linkage. On conclusion of load tests, engines should be allowed to run for five minutes at no-load before final shutdown to assist natural cooling of the engine and remove cylinder hot spots resulting from sudden load shut-down.

2.18 Ear muffs must be worn by attendants while engine running operations are in progress.

Engine coolants

2.19 Regular checks of the cooling radiator fluid are required to ensure there is sufficient anti-freeze and corrosion inhibitor and that no fluid leakages have occurred.

2.20 The engine jacket and secondary cooling water should be distilled, ion exchange demineralised or potable water with minimal chalk or lime solids in solution and be non-acidic (pH 8 to pH 10.5). The cooling water should be treated with an anti-freeze solution containing corrosion inhibitor having an ethylene glycol base. The anti-freeze to water mixture proportions needed will depend upon the minimum freezing temperature against which protectron is required and to ensure adequate corrosion inhibitor is present to protect all metal parts in the cooling system.

2.21 For full protection in the UK a 40% volume (35% minimum to 50% maximum) anti-freeze solution, with suitable multi-purpose additives, should be added to the jacket and radiator cooling water. The advice of the manufacturer should be followed as to the installation and period of use of anti-freeze solutions.

2.22 In no circumstances should methanol-based anti-freeze solutions be used. These have a high evaporation rate at normal engine temperatures and will lead to rapid loss of coolant.

Records

2.23 A log-book record of all test runs and specific tests carried out on the emergency generator set to demonstrate its reliability must be kept and stored in a safe place. All failures and defects noted should be recorded and a record kept of all "defect report notices" issued and maintenance correction work carried out to reinstate defective items of equipment.

Servicing of batteries

2.24 Regular servicing of battery equipment by competent personnel is essential. A large proportion of failures in emergency supplies associated with luminaires and engine starts can be attributed to battery neglect, the purchase of unsuitable batteries or incorrect interpretation of battery test results.

2.25 BS 5266 Part 1: 1988, 'Emergency Lighting' is a code of practice and contains a detailed list of routine servicing to emergency batteries. This document should be used as an essential guidance reference in conjunction with the battery and charger manufacturers' maintenance manuals.

2.26 Routine servicing should be carried out to varying degrees on the following basis:

- daily;
- monthly;
- six-monthly;
- three-yearly;
- subsequent annual tests applicable to batteries supplying self-contained luminaires.

Battery charging

2.27 The battery charger should be capable of maintaining the battery in a healthy state during long periods of non-use and of automatically recharging it to a fully charged state in the safest and shortest practicable time after use. Insufficient charge current may result in the battery becoming derated in capacity. Excess charge current can cause evaporation of electrolyte and extra internal corrosion to the plates and connecting bars. A lead-acid battery trickle charge current should maintain full charge without gassing and a constant specific gravity of 1.2 at 2.25V per cell. In general, a lead-acid battery trickle charge current of one milliampere per ampere-hour of 10-hour capacity is sufficient when new. As the battery ages, the trickle charge current may be increased up to three milliamperes per ampere-hour of 10-hour capacity.

2.28 Alkaline batteries should be continuously trickle charged and the voltage should be set at 1.45V per cell, temperature corrected and controlled. The loss of charge is minimal, and hence the trickle recharge current is very small. Boost charging at 1.6/1.7V per cell, at 6 to 12 monthly intervals, is beneficial after previous routine maintenance discharge. This operation must be continuously supervised by an attendant.

2.29 There are two nominal methods of recharging a partially or fully discharged battery, namely at constant current or at constant voltage, the latter also being known as "taper charge". The essential requirement is to ensure that all battery cells are equally charged to their maximum capacity. The current required to obtain this minimum level of charge is known as the "equalising charge current". If the charge current is not sufficient, not all the cells will be fully or equally charged. If the charge current is excess, electrolyte will be lost by evaporation and the cell plates and bars may be damaged by overheating and corrosion. Alkaline batteries are more suited to constant current charging. The general practice is that all types of batteries are charged at constant voltage to suit the required operating mode.

NOTE: Where batteries are charged at constant voltage the maximum charge current recommended by the manufacturer must not be exceeded.

In the constant current mode, the applied voltage has to rise to maintain constant current throughout the recharge process, and will necessitate higher voltage levels per cell as the battery internal resistance increases with age.

2.30 Batteries must be recharged at current/time values recommended by the manufacturer.

2.31 A range of portable battery test equipment is available from specialist manufacturers.

2.32 Recombination batteries, when subject to excessive charge current, are unable to recombine all the generated hydrogen and oxygen. A gas excess pressure occurs and can result in the lifting of the battery pressure relief valve (at typically 1 psi (7kPa)) and loss of hydrogen and oxygen gas to the atmosphere. This is ultimately a loss of irreplaceable electrolyte, which will result in a shortening of battery life. This type of battery is not as resilient as open-vented batteries during charging, owing to the smaller quantity of electrolyte present to quench internal short-circuit electrical faults if they occur.

2.33 Battery chargers are now of solid-state rectifier design. There must be adequate control for recharging currents within the manufacturer's recommended current/time range. Unregulated mains voltage fluctuations may significantly affect the state of battery charge, where the charger is provided with too close voltage/temperature control limits.

2.34 Instrumentation should be adequate and indicate mains and battery output voltage as well as charging and output currents. Battery ripple current should be limited to a maximum range of 7.5% to 10%, based upon manufacturer's recommendations. Extra costs in charger and uninterruptible power supply (UPS) equipment can be incurred if low level ripple is over-specified.

2.35 Batteries for luminaires and engine starting should be recharged immediately after use. An initial high recharge rate at constant current is acceptable for alkaline and lead-acid batteries, with a tapering transfer to a trickle charge when fully recharged.

2.36 Alkaline and lead-acid batteries must be kept topped up with approved distilled or ion exchange demineralised water at the correct levels at all times to prevent plate damage. A routine of maintenance of a good standard using the battery and charger manufacturer's instructions must be followed.

2.37 In a UPS, the total input with the battery on float charge can exceed the output load by 25% when battery recharging commences after a period of battery emergency supply operation. A large additional battery recharge load should not be imposed on the AC emergency generator set when operationally undesirable. This battery recharging load may be delayed or kept disconnected from the UPS charger by selective switching control and the energy left available for priority essential supplies until a more settled supply prevails.

2.38 Batteries in low temperature environments will require higher battery charger voltages to effect the same rate of current charge, and vice versa. Where low or high temperatures occur, voltage/temperature compensation should be used in the charger.

2.39 Manually controlled battery charging is not recommended except under specially controlled and supervised operations.

Starting batteries

2.40 Engine starting batteries should be of an approved type, regularly checked and maintained fully charged. Automotive batteries are not recommended to be used for any emergency use. The charger should be regularly checked to ensure that the trickle current recharge rate is correct. The engine battery should be well ventilated to allow hydrogen/oxygen gases to disperse. This requirement is particularly applicable to lead-acid batteries operating at high trickle charge currents. See SHTM 2011 Part 2; *Emergency electrical services*, 'Design considerations', Section 6.

3. In-house generation

Use of generators for peak load reduction or combined heat and power operation

3.1 Emergency engine-driven generators provided as a safeguard against loss of normal supply are likely to receive limited use for this purpose, and the possibility of using the equipment for peak lopping (peak load reduction) may be investigated. However, such use should be carefully considered, as the effectiveness of their primary function may be compromised. It is important to ensure that the emergency generating sets are always available for providing essential supplies in the event of the unexpected loss of normal supplies. The running hours of an engine-driven emergency generator set should be restricted to prevent a major overhaul being required before a period of three years has expired.

3.2 Peak lopping or CHP operation presupposes that the generating plant is capable of, and equipped for, running in parallel with the public electricity supply company. The engineering requirements are laid down by the Electricity Association as guidance in 'Recommendations for the Connection of Private Generating Plant to the Electricity Boards' Distribution Systems', Engineering Recommendation G59: 1985 and subsequent revisions and amendments.

3.3 An alternative to having generators in parallel with the normal mains supply is to arrange for an emergency generator to supply the essential supplies separately during peak demands to obtain more economic and efficient operation. This eliminates synchronising, system stability problems and fault current rating levels. Auto change-over switching would be necessary and should be delayed until the engine has reached an operating condition for the generator to be loaded.

3.4 The factors affecting economic viability that influence the decision whether peak lopping or CHP electrical power export uses are feasible are:

a. agreement of the public electricity supply company to issue a supplier's licence;

b. electricity tariff charges depending on the optimum point of export of electricity in relation to a nominated consumer;

c. daily load patterns and the annual load factor for private generation;

d. cost per unit generated and standing charge;

e. a variable system charge influenced by the reliability, size and number of private generating sets in relation to the public electricity supply companies' statutory requirement to maintain an available supply for consumers in the event of failure of the private generation;

f. ability and experience of staff;

g. cost of additional generator control and protection required by the public electricity supply company;

h. provision of an indemnity to the public electricity supply company in the event of damage to other consumers' equipment.

Public electricity supply company agreements

3.5 Unless technical grounds make it impracticable, a public electricity supply company must make an offer following a request from a private generator or supplier as required in the provisions of the Energy Act 1983 and Electricity Act 1989:

a. for a supply to their premises;

b. to purchase electricity generated by the private generator; or

c. permit the private generator to use the public electricity supply company system to provide a supply to any premises.

3.6 It is essential to carry out close consultation with the public electricity supply company at the earliest possible time before embarking on any detailed investigations. The primary technical considerations are:

a. parallel operation of generators for electricity export to the public supply can introduce voltage and instability hazards to the regional electricity company and health care and social services premises electrical systems;

b. if export electricity is limited by agreement then a reverse current or directional overcurrent relay needs to be fitted to the supply feeder to prevent the export of electricity above a set level by automatically opening the circuit-breaker on the supply transformer feeder;

c. additional electrical protection such as definite time directional overcurrent, rate of change of frequency relay and/or reactive export error detector, under voltage relays, will be required at the supply transformer circuit-breakers to instantaneously separate the systems. This is especially important in the event of a failure in the public electricity supply company system due to an auto reclose switching transient or blackout;

d. the rating of and export from the generators will be subject to licence and must be regulated automatically or by an operator to minimise the export or import of reactive energy between the two systems or between generators, if more than one is operated. This is particularly important if one of the generators is an induction generator;

e. the neutral earthing must comply with Electricity Supply Regulations (1988) No 1057, Part 2, for HV and LV generation. Neutral earth switching will be required to ensure that each generator can be disconnected at the star point from earth whilst running in parallel with the supply. When in parallel and separated from the regional electricity company system, only one running synchronous generator neutral shall be connected to earth;

f. larger rated switching devices and cable sizes for increased fault current ratings may be required;

g. at all times whilst the generator is connected to the public electricity supply company system, an authorised person, approved by the regional electricity company, may be required to be in attendance to regulate the active and reactive power and to maintain generator stability, and also to carry out switching functions required by the public electricity supply company, if not under their direct remote control.

3.7 In general, public electricity supply companies, since the Energy Act 1983, do not discourage small (less than 200/300kW) peak lopping schemes in parallel operation.

Electricity tariffs

3.8 Each electricity company has its own scale of charges for electricity, and most tariffs applicable to hospitals include a maximum demand charge based on twice the maximum number of units supplied during any 30 consecutive minutes within a defined period.

3.9 The tariffs most satisfactory for peak lopping schemes have a monthly maximum demand rate which varies from a maximum in winter to a minimum in seven summer months. With this tariff, generating plant need only operate up to 2,000 hours per year from 1 November to 31 March during the times of excess maximum demand in the health care and social services premises load.

3.10 For peak lopping or CHP schemes the public electricity supply companies will normally make an additional charge for holding available the necessary standby generating capacity (spinning reserve). This reserve is for use in the event of breakdown and for maintenance of all or part of the private generating plant. The charge is normally expressed in a special tariff as a system availability charge, negotiated with the consumer. Availability charges will have an important influence on the overall economics of peak lopping and CHP systems.

3.11 A pre-set maximum demand relay may be necessary to give advance warning to the operator to start the emergency generator for synchronising to the normal mains supply or to shut down when no longer required.

Daily load and annual maximum demand pattern

3.12 When investigating the possibilities of on-site generation for peak load reduction it is necessary to obtain in as much detail as possible the daily, monthly and annual profiles of the health care and social security premises' electrical demands. For existing health care and social services premises past electricity bills will provide the most useful source of information, but for projected premises outline estimates should be used. The economic possibility of peak lopping will not be worthwhile investigating unless the health care and social services premises has a peaked load curve which occurs during the winter when the total national load is greater and, hence, when a substantial part of the electricity bill comprises maximum demand charges. The most convenient method to adopt is to calculate the annual load factor. Generally peak lopping is attractive for load factors under 30%:

$$\text{Load factor} = \frac{\textit{Total energy consumed in year / period}}{\textit{Total energy that could be generated in year / period}}$$

3.13 Close attention to methods of improving the annual load factor may be more economically advantageous than peak lopping.

Cost per unit generated

3.14 The cost per unit generated will usually exceed the unit charge of the public electricity supply company and accordingly the generator should only be used for the periods necessary to achieve the most economic reduction in the maximum demand charge.

3.15 In determining the cost per unit generated it is necessary to take into account the annual plant amortisation cost as well as the additional costs of fuel, lubrication, labour and maintenance.

3.16 With peak lopping, consideration must be made that the plant was provided for emergency purposes only. It is, therefore, reasonable to assume that the additional cost is related only to such items that involve the additional plant use for peak lopping. This will include such items as bulk fuel storage facilities, synchronising and protection equipment, additional switchgear, contract maximum demand meter etc. that are wholly related to parallel running with the public electricity supply company supply. If peak lopping entails supplying the designated essential supplies during periods of maximum demand only, these essential supplies being provided entirely from the AC emergency generator, then the additional costs would relate to larger capacity fuel oil tanks and the increased maintenance and labour charges to maintain the additional supply.

3.17 For estimating purposes a typical cost per unit generated should be taken as equal to “W” pence, based on fuel oil prices of “X” pence per litre and lubricating oil prices of “Y” pence per litre and a figure of “Z” pence per unit for the reduced life of the AC emergency generator set, where
W = |X| + |Y| +.|Z|.

Size of generating set

3.18 As previously stated, electricity companies do not discourage small peak lopping schemes in parallel with their systems. It should be borne in mind that the additional cost to adapt small plant to peak lopping may not be directly proportional to the size of the plant. This is particularly so when parallel running of generating plant is being considered. Consequently, it is doubtful whether generating sets of less than 250kW rating for peak lopping would be economically advantageous.

3.19 Under the Electricity Act 1989, anyone who generates, transmits or supplies electrical energy will require a licence, unless exempted. Exemption applies to generating sets of less than 10MW rating and exporting suppliers below 500kW. Existing independent generators (as at 1989) were not required to be licensed.

3.20 Where two or more emergency generating sets are considered, it is important that they are suitable for parallel operation. The existing cables and switchgear should have sufficient fault current ratings and be protected to withstand fault currents that may occur when two or more sets operate in parallel or, more importantly, run in parallel with the public electricity supply company’s normal mains supply.

Voltage regulation

3.21 The generator terminal voltage should be automatically maintained to within ± 2.5% of the rated voltage at any load, from no load to 10% overload, between unity and 0.8 power factor (lagging). The droop in the AVR-controlled voltage should be substantially similar for all generators.

3.22 After a change in load from zero to 60% the voltage should not vary by more than ± 15% of the rated voltage and should return to within ± 3% within 0.5 seconds. On starting, the voltage overshoot should not exceed 15% and should return to within ± 3% in not more than 0.15 seconds. The manual trim controller should be able to adjust the AVR-controlled generator terminal voltage to within ± 15% of normal limits.

Excitation and control

3.23 A single AC generator running at a constant governor-controlled speed and not connected to the public electricity supply company supply will have current and power factors, at the rated voltage, determined by the impedance characteristic of the load.

3.24 When AC generators are running in **parallel**, whether connected to the regional electricity company supply or not, a continuous interaction occurs between the governors and the AVRs of AC generators, which if not regulated may eventually lead to dynamic instability in a generator operating at or near its rated output.

3.25 The excitation field current can be increased or reduced by manual adjustment of the manual trim controller, even under "auto" control in parallel with other generators and, to a greater extent, with the public electricity supply company supply, field current adjustment not only varies the voltage generated at the generator switchboard, but also causes a redistribution of inductive reactive power load between the other parallel generators. This results in changes to the load currents and power factors of each generator and the supply transformer, that is, the incoming supply. Any small changes in the field current by a generator manual trim controller should be immediately counterbalanced by small opposite adjustments in the manual trim controllers of the other parallel generators. An excessive reduction in field current can cause instability and loss of synchronism in an AC generator near or at full load. Likewise, an increase exceeding the maximum field current will cause generator rotor overheating and also reduce the stability margins in adjacent parallel generators.

3.26 In a system of balanced governor control and parallel running generators, improved stability and load sharing can be obtained by an AVR element of auto-control which responds to the summation of the reactive or quadrature vector components in each generator load current. This unified control mode, known as the "parallel mode", can be individually selected at each generator control panel.

3.27 Generators are normally provided with an "auto" and a "manual" follow up mode of excitation control. If failure to the "auto" mode occurs, the excitation trips to the "manual" mode. When a generator is operating in the "manual" mode the control of the terminal voltage is no longer responsive to a change in system voltage, nor is it able to maintain the desired terminal voltage. This can indirectly hazard the stability of a generator when connected in parallel to the normal system or other generators. Generators selected to "manual" mode of excitation control must not be left unattended.

3.28 Control of running generating plant must only be exercised by adequately trained "authorised" or "competent" persons.

Instability – pole slipping

3.29 Instability in a generator occurs when the rotor main field DC current is not of sufficient magnitude to maintain a secure magnetic field linkage between the rotor DC field and the stator AC contra-rotating field, at a specific engine input torque. This means that the input torque can sever the fixed relationship between the rotor speed and the stator magnetic field rotation. The rotor speed will increase above the pole pair related synchronous speed.

3.30 A fast relative rise in speed will result in the trip of the generator owing to operation of the field current, stator current or voltage protection devices. For small generators, a slow relative rise in speed will not cause an immediate generator loss, but will be seen on the instrumentation as a fluctuation in voltage and current in the generators and the whole neighbourhood supply system.

3.31 For practical purposes, the generator with the instrumentation readings fluctuating in the opposite direction to the others is the unstable generator. This will not be apparent with only one or two generators on load. A less than normal main field excitation current and a leading power factor are indications.

3.32 To regain stability in such marginal operating circumstances, the field current must be immediately increased, and/or the generated output reduced sufficiently to a level to remove the generator instability and prevent an imminent trip of the generator. A sudden charge in the voltage, power factor and field current in other parallel connected generators must be concurrently observed and corrected.

Governor control

3.33 The scope of a governor to regulate the supply of fuel to an engine, and hence the output from an AC generator, depends on its sensitivity in opening or closing the fuel rack. Any outside cause to change the generator speed, for example, the governor-set synchronous speed, or any speeder motor adjustment applied to the governor setting, is equivalent to a change in the electrical load demand or output required.

3.34 The governor overall control and speeder motor control function jointly to regulate the speed in single running. They automatically maintain the speed at the selected load, within a speed range of 100% to 95% and a load range of no-load to full-load respectively, that is, the governor speed characteristic:

a. in **single** running, a speeder motor auto control may be required with isochronous speed control to maintain constant speed and hence constant frequency of supply with changing load demand;

b. in **parallel** running, as described above for single running, the governor and speeder motor controls function jointly. The governor is now tied to the fluctuation of the system frequency, at a selected generator output.

3.35 A rise in system frequency will initiate the governor to close the engine fuel rack, to reduce the generator output, and similarly a fall in system frequency will further open the fuel rack, if not already fully open, and attempt to increase the generated output. This functions within the range of the governor speed characteristic, over the speed range of 100% to 105% synchronous speed, giving a load change from full load to no load respectively.

3.36 From no load to 110%, the governor should be stable and sensitive, and respond to prevent overspeed excursions reaching 110%. If a speed of 110% is reached, the governor overspeed protection closes the engine fuel rack, cutting off the fuel supply to the engine.

Power factor correction

3.37 Power factor correction (PFC) units have capacitive reactive power outputs and are installed to compensate for excessive inductive reactive power demand. These may overcompensate when in circuit with generating plant. The net result of overcompensation will be seen as a higher than normal supply voltage and a loading power factor. The PFC unit should be isolated from circuit if not reliably and automatically controlled.

3.38 A generator AVR will reduce the supply voltage, and hence the generated inductive reactive power, to reduce any PFC overcompensation. The indicated power factor will increase towards unity or to a leading power factor. This change in power factor indicates a generator is operating in a less stable operating region.

3.39 In situations where PFC overcompensation may occur, audible alarms to indicate minimum field excitation current for the generator should be provided. The additional option of automatic field excitation current “forcing” at the minimum field excitation current to maintain generator synchronism should be provided on larger generators.

References

NOTE:
Where there is a requirement to address a listed reference, care should be taken to ensure that all amendments following the date of issue are included.

Publication ID	*Title*	*Publisher*	*Date*	*Notes*
Acts and Regulations				
	Building (Scotland) Act	HMSO	1959	
	Clean Air Act	HMSO	1993	
	Control of Pollution Act	HMSO	1974	
	Electricity Act	HMSO	1989	
	Energy Act	HMSO	1983	
	Environment Protection Act	HMSO	1990	
	Registered Establishments (Scotland) Act	HMSO	1998	
	Water (Scotland) Act	HMSO	1980	
	Health and Safety at Work etc Act	HMSO	1974	
SI 3146	The Active Implantable Medical Devices Regulations	HMSO	1992	
SI 2179 & 187	The Building Standards (Scotland) Regulations (as amended)	HMSO	1990	
	The Building Standards (Scotland) Regulations: Technical Standards Guidance	HMSO	1998	
SI 1460	Chemicals (Hazard Information and Packaging for Supply) Regulations (CHIP2)	HMSO	1997	
SI 3140	Construction (Design and Management) Regulations	HMSO	1994	
SI 437	Control of Substances Hazardous to Health Regulations (COSHH)	HMSO	1999	
SI 635	Electricity at Work Regulations	HMSO	1989	
SI 1057	Electricity Supply Regulations (as amended)	HMSO	1988 (amd 1994)	
SI 2372	Electromagnetic Compatibility Regulations (as amended)	HMSO	1992	
SI 2451	Gas Safety (Installation and Use) Regulations	HMSO	1998	

Publication ID	***Title***	***Publisher***	***Date***	***Notes***
SI 917	Health & Safety (First Aid) Regulations	HMSO	1981	
SI 682	Health & Safety (Information for Employees) Regulations	HMSO	1989	
SI 2792	Health and Safety (Display Screen Equipment) Regulations	HMSO	1992	
SI 341	Health and Safety (Safety Signs and Signals) Regulations	HMSO	1996	
SI 1380	Health and Safety (Training for Employment) Regulations	HMSO	1990	
SI 2307	Lifting Operations and Lifting Equipment Regulations (LOLER)	HMSO	1998	
SI 3242	Management of Health and Safety at Work Regulations	HMSO	1999	
SI 2793	Manual Handling Operations Regulations	HMSO	1992	
SI 3017	The Medical Devices Regulations	HMSO	1994	
SI 1790	Noise at Work Regulations	HMSO	1989	
SI 3139	Personal Protective Equipment (EC Directive) Regulations (as amended)	HMSO	1992	
SI 2966	Personal Protective Equipment at Work (PPE) Regulations	HMSO	1992	
SI 128	Pressure Systems Safety Regulations (PSSR)	Stationary Office	2000	
SI 2306	Provision and Use of Work Equipment Regulations (PUWER)	HMSO	1998	
SI 3163	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)	HMSO	1995	
SI 3004	Workplace (Health, Safety and Welfare) Regulations	HMSO	1992	
British Standards				
BS 88	**Cartridge fuses for voltages up to and including 1000V AC and 1500V DC** **Part 1:** General Requirements	BSI Standards	1982	
BS 89	**Direct acting indicating electrical measuring instruments and their accessories** **Parts 1 to 9**	BSI Standards	1977	
BS 89	**Direct acting indicating electrical measuring instruments and their accessories** **Parts 1 to 9**	BSI Standards	1997	

Publication ID	***Title***	***Publisher***	***Date***	***Notes***
BS 171	**Power transformers**	BSI Standards	1970	
BS 417	**Galvanised mild steel cisterns and covers, tanks and cylinders (metric units)** **Part 2**	BSI Standards	1987	
BS 764	**Automatic change-over contactors for emergency lighting systems**	BSI Standards	1954 (1985) (1990)	
BS 799	**Oil storage tanks** **Part 5**	BSI Standards	1987	
BS 822	**Terminal markings for rotating electrical machinery** **Part 6**	BSI Standards	1964 (1988)	
BS 1361	**Cartridge fuses for AC circuits in domestic and similar premises** **Part 1**	BSI Standards	1971 (1986) AMD (1991)	
BS 1362	**General purpose fuse links for domestic and similar purposes (plugs)**	BSI Standards	1973 (1986) AMD (1991	
BS 1363	**13A fused plugs and switched and unswitched socket-outlets and boxes**	BSI Standards	AMD (1997)	
BS 1650	**Capacitors for connection to power frequency systems**	BSI Standards	1971 AMD (1991)	
BS 1710	**Identification of pipelines and services**	BSI Standards	1984	
BS 2754	**Memorandum. Construction of electrical equipment for protection against electric shock**	BSI Standards	1976	
BS 2771	**Electrical equipment of industrial machines**	BSI Standards	1986	
BS 2869	**Fuel oil for engines and burners for non-marine use**	BSI Standards	1988	
BS 3535	**Safety isolating transformers for industrial and domestic purposes**	BSI Standards	1962 (1987)	
BS 3535-1	**Safety isolating transformers for industrial and domestic purposes EN 60742** **Part 1**	BSI Standards	1996	

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BS 3938	**Current transformers**	BSI Standards	1973 (1982)	
BS 3941	**Voltage transformers**	BSI Standards	1975 (1982)	
BS 3951	**Freight containers**	BSI Standards	1969 (1977)	
BS 4196	**Sound power levels of noise sources** **Parts 0 – 8**	BSI Standards	1981 (1986)	
BS 4343	**Industrial plugs, socket-outlets and couplers for AC and DC supplies**	BSI Standards	1968	
BS 4417	**Specification for semi-conductor rectifier equipments**	BSI Standards	1969 (1981)	
BS 4752	**Circuit breakers** **Part 1**	BSI Standards	1977	
BS 4533-102.22	**Luminaires. Particular requirements. Specification for luminaires for emergency lighting. (EN 60598-2-22: 1990)**	BSI Standards	1990	
BS 4999	**Terminal markings for rotating electrical machinery** **Part 108**	BSI Standards	1987	
BS 4999-0	**General requirements for rotating electrical machines** **Part 0**	BSI Standards	1987	
BS 5000	**Rotating electrical machines of particular types or for particular applications: Index** **Parts 1 – 99**	BSI Standards		
BS 5000-3	**Generators to be driven by reciprocating internal combustion engines** **Part 3**	BSI Standards	1980 (1985) AMD 1988	
BS 5266	**Code of practice for the emergency lighting of premises** **Parts 1 – 3**	BSI Standards	1988	
BS 5304	**Code of practice for safeguarding machinery**	BSI Standards	1988	
BS 5378	**Safety signs and colours**	BSI Standards	1980	
BS 5410-3	**Code of practice for oil firing. Installations for furnaces, kilns, ovens and other industrial purposes**	BSI Standards	1976	

Publication ID	***Title***	***Publisher***	***Date***	***Notes***
BS 5424	**Contactors up to and including 1,000V AC and 1,200V DC** **Part 1**	BSI Standards	1977	
BS 5499-1	**Fire safety signs, notices and graphic symbols. Specification**	BSI Standards	1990	
BS 5514-1	**Reciprocating internal combustion engines. Performance. Standard reference conditions, declarations of power, fuel and lubricating oil consumptions and test methods. (ISO 3046-1: 1995)**	BSI Standards	1996	
BS 5514-4	**Reciprocating internal combustion engines. Performance. Speed governing. (ISO 3046-4:1997)**	BSI Standards	1997	
BS 5514	**Reciprocating internal combustion engine performance, etc** **Parts 1/6**	BSI Standards	1996	
BS 5992-1	**Electrical relays. Specification for contact performance of electrical relays.**	BSI Standards	1980	
BS 6132	**Code of practice for safe operation of alkaline cells**	BSI Standards	1983	
BS 6133	**Code of practice for safe operation of lead-acid cells**	BSI Standards	1995	
BS 6231	**PVC insulated cables for switchgear and control gear wiring**	BSI Standards	1981 1998	
BS 6260	**Open nickel-cadmium prismatic rechargeable single cells**	BSI Standards	1982 1988	
BS 6290	**Lead-acid stationary cells and batteries**	BSI Standards	1982 1988	
BS 6327	**Fire protection of reciprocating internal combustion engines**	BSI Standards	1982	
BS 6346	**PVC insulated cables for electricity supply up to and including 3300V between phases**	BSI Standards	1989 1997	
BS 6387	**Specification for performance requirements for cables required to maintain circuit integrity under fire conditions**	BSI Standard	1983	
BS 7625	**Voltage transformers**	BSI Standards	1993	
BS 7671	**Requirements for electrical installations. IEE Wiring Regulations**	HMSO	1992	Sixteenth edition

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BS 7676	**Current transformers**	BSI Standards	1993	
BS EN 60076	**Power transformers**	BSI Standards	1976	
BS EN 60146	**Specification for semi-conductor rectifier equipments**	BSI Standards	1981	
BS EN 60269	**Cartridge fuses for voltages up to and including 1000V AC and 1500V DC – General requirements** **Part 1**	BSI Standards		
BS EN 60309	**Metric units industrial plugs, socket-outlets and couplers for AC and DC supplies** **Part 2**	BSI Standards		
BS EN 60309-2	**Plugs, socket-outlets and couplers for industrial purposes. Dimensional interchangeability requirements for pin and contact-tube accessories**	BSI Standards	1992	
BS EN 60622	**Sealed nickel-cadmium prismatic rechargeable single cells**	BSI Standards	1996	
BS EN 60623	**Open nickel-cadmium prismatic rechargeable single cells**	BSI Standards	1982 1988	
BS EN 60896	**Lead-acid stationary cells and batteries** **Part 1**	BSI Standards	1982 1988	
BS EN 60947	**Circuit breakers** **Part 2**	BSI Standards		
BS EN 60947	**Contactors up to and including 1,000V AC and 1,200V DC** **Part 1**	BSI Standards	1998	
BS EN 61000	**Electromagnetic compatibility (EMC). Testing and measurement techniques (Parts 4-1 to 4-28).** **Part 4-1:** Overview of immunity tests. Basic EMC publication (IEC 61000: 1992)	BSI Standards	1995	
BS ISO 668	**Freight containers**	BSI Standards	1996	
EN 60204	**Electrical equipment of industrial machines IEC204 PT1 ZED 81** **Part 1**	BSI Standards	1993	
ISO 3046	**Reciprocating Internal combustion engine performance** **Parts 1/6**	BSI Standards		
ISO 8528	*To replace ISO 3046 after harmonisation*			

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Scottish Health Technical Guidance				
SHTM 2007	Electrical services supply and distribution	P&EFEx	2001	CD-ROM
SHTM 2011	Emergency electrical services	P&EFEx	2001	CD-ROM
SHTM 2020	Electrical safety code for low voltage systems (Escode – LV)	P&EFEx	2001	CD-ROM
SHTM 2021	Electrical safety code for high voltage systems (Escode – HV)	P&EFEx	2001	CD-ROM
SHTM 2022	Medical gas pipeline systems	P&EFEx	2001	CD-ROM
SHTM 2023	Access and accommodation for engineering services	P&EFEx	2001	CD-ROM
SHTM 2035	Mains signalling	P&EFEx	2001	CD-ROM
SHTM 2045	Acoustics	P&EFEx	2001	CD-ROM
SHPN 1	Health service building in Scotland	HMSO	1991	
SHPN 2	Hospital briefing and operational policy	HMSO	1993	
SHTN 1	Post commissioning documentation for health buildings in Scotland	HMSO	1993	
SHTN 4	General Purposes Estates and Functions Model Safety Permit-to-Work Systems	EEF	1997	
	NHS in Scotland – PROCODE	P&EFEx	2001	Version 1.1
NHS in Scotland Firecode				
SHTM 81	Fire precautions in new hospitals	P&EFEx	1999	CD-ROM
SHTM 82	Alarm and detection systems	P&EFEx	1999	CD-ROM
SHTM 83	Fire safety in healthcare premises: general fire precautions	P&EFEx	1999	CD-ROM
SHTM 84	Fire safety in NHS residential care properties	P&EFEx	1999	CD-ROM
SHTM 85	Fire precautions in existing hospitals	P&EFEx	1999	CD-ROM
SHTM 86	Fire risk assessment in hospitals	P&EFEx	1999	CD-ROM
SHTM 87	Textiles and furniture	P&EFEx	1999	CD-ROM
SFPN 3	Escape bed lifts	P&EFEx	1999	CD-ROM
SFPN 4	Hospital main kitchens	P&EFEx	1999	CD-ROM
SFPN 5	Commercial enterprises on hospital premises	P&EFEx	1999	CD-ROM
SFPN 6	Arson prevention and control in NHS healthcare premises	P&EFEx	1999	CD-ROM
SFPN 7	Fire precautions in patient hotels	P&EFEx	1999	CD-ROM
SFPN 10	Laboratories on hospital premises	P&EFEx	1999	CD-ROM

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UK Health Technical Guidance				
EH 40	HSE Occupational Exposure limits	HSE	Annual	
MES	Model Engineering Specifications	NHS Estates	1997	As required
MES C44	Diesel Engine Driven Automatic Stand-by Generator Sets	NHS Estates		
	Code of practice for reducing the exposure of employed persons to noise	HSE		
ETR No. 113	Notes of guidance for the protection of private generating sets up to 5MW for operation in parallel with the Electricity Board's Distribution Network	Electricity Assn.	1989	
Miscellaneous References				
G 59	Recommendations for the connection of private generating plant to the Electricity Board's Distribution Systems	Electricity Assn.	1985	
G 5/3	Limits for Harmonics in the UK Electricity Supply System	Electricity Assn.	1976	
	Regulations for Electrical Installations (16th edition) Institution of Electrical Engineers (IEE)			
	Lighting guide for hospitals and health care buildings Chartered Institution of Building Services Engineers			
LG 9	Lighting for communal and residential buildings Chartered Institution of Building Service Engineers		1997	
IM/17	Code of practice for gas engines. British Gas			
(ANSI/UL) 1008	Automatic Transfer Switches. American National Standards Institute/Underwriters Laboratory		1983	
IEC 947-6-l	Low voltage switch gear: Automatic Transfer Switches			
HN (76) 126	Noise control			