21 Local Emergency Generator (LEG) Requirements

21.1 Background

A Local Emergency Generator (LEG) is a fixed generator installation provided for an essential facility to ensure continued operation of the facility or equipment during a power failure. In the context of this chapter, a LEG is to be taken to incorporate the entire essential or emergency power supply system including the generator and the distribution network provided throughout the facility.

There are three main types of permanently installed emergency power systems provided at Defence establishments and facilities, namely the Central Emergency Power Station (CEPS), the LEG and the Uninterruptible Power Supply (UPS). Each emergency power system has a different application as indicated below:

a) **CEPS** - Provided at key operational establishments to support important functions and the LEGs at the establishment.

b) **LEG** - Provided to support essential loads at a facility or essential facilities. Essential loads can generally tolerate a minor power outage, but require emergency power to continue operation during a prolonged power outage.

c) **UPS** - Provided to support critical loads at a facility. Critical loads cannot tolerate any power outage or uncontrolled power down.

Based on the above, power distribution at Defence facilities is classified as shown in the table below:

<table>
<thead>
<tr>
<th>Power Distribution Classification</th>
<th>Type of Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRITICAL</td>
<td>UPS supported</td>
</tr>
<tr>
<td>ESSENTIAL</td>
<td>LEG supported</td>
</tr>
<tr>
<td>NORMAL or NON-ESSENTIAL</td>
<td>No UPS or LEG support</td>
</tr>
<tr>
<td></td>
<td>May be supported by CEPS or mobile generator</td>
</tr>
</tbody>
</table>

LEGs are used to support essential loads to prevent loss of key facilities during periods of failure of the normal supply. The LEG supplies the essential loads through the essential power distribution system, whilst the UPS supplies the critical loads through the critical power distribution system. The CEPS distribution system is through the normal high voltage reticulation and supports the normal, essential and critical power supply systems. The term 'essential' is not to be taken to apply to facilities supported by CEPS or mobile generators alone.
The requirements of this chapter are applicable to fully automated LEG systems only. Although manual LEG systems are not specifically covered, the basic requirements of this chapter could apply to manual LEGs systems as well.

LEG systems are specialised systems that can be configured in many ways and can significantly impact on the immediate environment. Therefore, due consideration shall be given to the issues of compatibility with, and impact on, other services and the building environment respectively.

The capabilities and limitations of LEGs shall be considered to ensure their suitability for supplying equipment and loads whose requirements and operational characteristics shall be adequately defined. This places an important emphasis on defining the equipment requirements and the responses under failure conditions.

Selection of LEG systems shall achieve best value for money on whole of life basis and shall also to take cognisance of the level of product support provided in Australia and locally in the region installed.

21.2 Reference Documents
Designers shall be responsible for meeting the requirements of this chapter together with those of applicable legislation and standards such as, but not limited to:

AS/NZS 3000  Wiring rules;
AS 3010   Electrical Installations - Supply by Generating Set
AS/NZS 3009  Electrical Installations - Emergency Power Supplies in Hospitals
AS 1359   Rotating Electrical Machines
AS 4594   Internal Combustion Engines
ISO 8528   Reciprocating Internal Combustion Engines Driven Alternating Current Generating Sets

21.3 Justification
This chapter does not prescribe the type of facility or area that requires the installation of emergency power. Instead, this chapter identifies those areas or functions which are normally LEG supported and establishes the basis on which project staff, sponsors and consultants shall evaluate the need and type of system required.

LEGs shall be provided to support key Defence operational facilities such as communications facilities, operational command buildings, and Air Traffic Control (ATC) facilities and in certain circumstances, Defence hospitals. LEGs may also be considered when, based on the availability of the normal supply, the costs of down time exceed the through life costs of a LEG.

The determination as to whether a LEG is required shall be by assessment, on a case by case basis, supported where appropriate by an analysis of the risks involved. The risk analysis shall be in
accordance with AS 4360 and shall consider the impact of the all possible opportunities and/or
detrimental outcomes in the Defence context inclusive, but not limited to, the following:

a) statutory requirements, standards and Defence policy requirements

b) consequences of power supply interruption in terms of:
   - loss of function
   - disruption of process
   - time to recover

c) frequency and duration of power outages

d) quality of the power supply in terms of voltage and frequency stability and ability to meet the
   equipment requirements

e) area or equipment to be supported (entire facility or part)

f) ability of any site emergency power supply (e.g. CEPS) to meet the emergency power
   requirements

g) suitability of other more cost effective means, such as mobile generators, UPS or battery
   backed systems

LEG systems shall only be considered when:

a) statutory requirement, standard or Defence policy requirement dictates the provision of a LEG
   (e.g. ATC Tower, Aircraft Navigation Aids, certain hospitals);

b) regular critical operations are undertaken at the facility that would be adversely affected by
   interruption of electricity supply (e.g. Operational Command Centres, Communication and
   Information System Centres (CISCEN) and critical communications facilities);

c) an interruption of the electricity supply would result in a severe life safety or environment
   incident for critical functions such as emergency response facilities and essential engineering
   services;

d) the frequency and duration of operations cannot be supported efficiently and cost effectively
   by mobile or hire generators. Any facility that can tolerate an outage of around 48 hours can,
   under normal circumstances, be adequately supported by mobile generator;

e) essential functions and services cannot be transferred to, or catered by, unaffected areas;

f) site emergency power supplies such as CEPS cannot meet the emergency power requirement;

and

g) the financial losses due to power interruptions, under normal supply availability conditions,
   would exceed the through life costs of a LEG (certain tactical training centres and simulator
   facilities).

Guidance on a case by case basis is available from DEEP in order to determine whether or not a
LEG should be provided.
21.4 Identify the Characteristics of the Load
The characteristics of the essential and critical load to be supplied by the LEG system shall be clearly identified. Specifically, the following equipment information shall be determined:

a) Nominal voltage and allowable voltage limits under steady state and transient state conditions. Transient limits may be different to take into account large step changes in the load and the short duration of a resulting output voltage change;

b) Full load true power rating (kW) and power factor;

c) The type of load and its characteristics, particular emphasis should be given to identifying the loads with high inrush currents or high harmonic content;

d) Indication of the inrush characteristic or harmonic content of the load and the combined affect of these. (An indication of the inrush characteristic harmonic content of a load can be obtained from measurements carried out on existing or similar loads or through consultation with relevant equipment manufacturers and suppliers);

e) Any special characteristic of the load such the power regeneration on de-energisation, restoration time on power up, restoration process and susceptibility to power outages; and

f) Required equipment connection interface.

The specifications shall clearly identify the characteristics and parameters of the installation to ensure that the LEG system is adequate for the installed conditions. Particular emphasis shall be place on defining suitable LEG system performance characteristics to ensure the anticipated step loads, inrush conditions, harmonic content of the load and the particular requirements of sensitive equipment are adequately accommodated.

21.5 Other General Design Requirements
The LEG accommodation shall be suitable for the operation of the LEG. Particular care shall be taken to ensure that the LEG heat rejection and airflow requirements are met and that the design of the ventilation system does not contaminate the air conditioning or ventilation systems of the building occupants or adjacent buildings.

The LEG system shall be fully compatible with the building power reticulation system and its connected loads to ensure harmonious and non-detrimental interfacing between the generating equipment and the building connected loads. The designer shall ensure that appropriate analysis is undertaken to determine the LEG configuration required.

LEG power shall be distributed via the building’s essential power reticulation system. Essential distribution boards are the preferred method for connecting large or unspecified equipment and for equipment rooms. The provision of under voltage releases to prevent damage to equipment susceptible to voltage transients or to uncontrolled power up should be considered and reviewed by the designer in consultation with the building’s users.
The LEG system shall have appropriate control and monitoring interfaces to enable semi-skilled operators to operate the LEG and reset minor LEG system faults.

21.6 Determination of the Required Restoration Time

The required restoration time may be that required by standards or may be a requirement of the equipment or operations supported. The restoration time is specified as the time required for the equipment to return to full operation, or as the time required for the LEG to stabilise and come online.

The designer shall ensure that the generator is up to speed and its output stabilised before transferring to the load. The designer shall ensure that, where required, the LEG restores power supply in sufficient time to enable the equipment to meet the required restoration time.

As an example, the relevant standards for aeronautical ground lighting require the return of the lighting to service within 15 seconds of a power failure. This will require the LEG to be online and fully stabilised within 8 to 10 seconds of power failure to allow enough time for lighting equipment power up to full illumination within the permissible 15 seconds.

Very short restoration times may require substantial oversizing of the engine of the generator assembly and this may impact on the required minimum load to guarantee the thermal stability of the generator engine. The designer shall ensure that, within practical limits, the adverse effects of generator engine oversizing are minimised. Where possible, as in the case of equipment supported by a UPS, the time for bringing the generator on line shall be extended to reduce or eliminate the impact of engine oversizing.

21.7 The Effect of UPS on the Generator

The controlled rectifiers of UPS systems can be a major source of harmonics which can produce distortions of the voltage and current waveforms and may have a detrimental effect on a variety of electrical equipment both upstream and downstream of the UPS system. The designer shall ensure compliance with relevant Australian Standards AS 2279 Disturbances in Mains Supply Network, AS/NZS 61000 Electromagnetic Capability (EMC) and AS 62040 Uninterruptible Power Systems (UPS) to minimise the effects of harmonics on electrical equipment.

The designer shall ensure that the LEG is suitable for operation with the intended UPS load. When the UPS rectifier load is more than about 50% of the total load connected on a generator, the following special measures shall be considered to ensure stable and reliable operation of the generator:

a) Using a three phase voltage regulator;
b) Using permanent magnet field excitation;
c) Using an electronic governor;
d) Oversizing the alternator compared to the kW rating required; and
Specifying the UPS with filtering or 12 pulse rectifiers to limit the amount of harmonic distortion, where possible.

When the UPS represents a significant load on a generator that is operating at or close to its maximum output, overloading shall be prevented by inhibiting or limiting the battery charging function of the UPS when connected to the generator supply, where possible.

21.8 Essential Load Distribution
The essential distribution system shall be capable of supplying the essential load connected to the system via the appropriate area or room essential distribution boards. Redundancy is not normally a requirement of the essential distribution system. Where redundancy is required it will be indicated in the FDB.

The transfer switch shall include an interlock to prevent simultaneous connection to both the normal and standby power supplies. The interlock shall preferably be of the mechanical type. Consideration should also be given to the requirement for the transfer switch to also switch the supply neutrals and guidance should be sought from the local Network Provider and Industry Regulator before finalising the transfer switch design arrangement.

Only essential loads shall be LEG supported and load shedding of normal or non-essential loads shall take place when the essential loads are connected to the LEG supply. The load shedding arrangement shall be kept as simple as possible so that it can be operated by the building occupants if required. Normally this load shed device would be a single contactor or motor operated circuit breaker. The proposed LEG load shedding arrangement and controls shall be detailed in the design report for agreement by DEEP.

Where the normal or non-essential load is left connected to normal mains supply at establishments provided with CEPS, the normal or non-essential loads shall be connected to the Base load shedding system. Base load shedding system requirements shall be included in the building design brief.

Transient surge protection shall be considered for LEG supply systems to prevent damage and disruption caused by lightning strikes or by switching surges/spikes.

Equipment that cannot tolerate being powered up immediately after a supply interruption shall be disconnected on power failure or protected by other suitable means such as a UPS system. The reconnection arrangement, where required, shall suit the sponsor/users requirements which can involve manual reconnection to allow controlled reconnection to the standby supply.

Redundant Supplies for Critical Facilities to Cater for Cable Failure
In critical facilities such as ATC towers, redundant submains for the essential distribution system may be specified as a specific to project requirement. This shall normally be achieved by providing, to each essential distribution board, a manual supply transfer switch which connects an alternate supply path and ensures that no supply single point of failure exists to the nominated
distribution boards. The alternate supply path shall bypass as much of the distribution system as possible for increased system reliability and the manual transfer switch shall prevent simultaneous connection to the two supplies to each essential distribution board.

21.9 Control
The generator shall be capable of operating in manual and automatic modes. Transfer between the generator operating modes shall be bumpless and shall not unnecessarily affect the operation of the generator.

The LEG supply shall not be synchronised and connected in parallel with mains supply. Appropriate switching time delays shall be incorporated to avoid any out of phase problems when changing from the normal supply to the standby supply or vice versa. Any requirement for automatic synchronisation of the LEG system shall be justified by the sponsor and agreed by DEEP before the design stage.

The control system shall be either PLC or microprocessor based and shall be site programmable without the need for any software or hardware changes. All programming tools shall be provided as part of the installation unless already available on site. All software necessary to interrogate and modify the programs shall be provided to Defence with appropriate software licences.

There shall be separate "Auto", "Off" and "Manual" selector switches provided for each of the generator, dummy load, or transfer switch controls. Each respective element shall have appropriate separate manual controls.

Control Modes

Manual Mode
Manual mode is control by an operator from the generator control panel. This mode shall be independent of any automatic control functions. A sufficient number of indicators and meters shall be available in this mode to clearly display the operational condition of the generator. All generator protection systems (trips) shall remain in operation regardless of the operating mode and manual controls shall be disabled whenever the control mode is switched to Auto.

Automatic Mode
When in automatic mode, the generator control system shall monitor mains supply and on loss of which shall start and connect the LEG automatically to the load. The speed and voltage of the generator shall be stable before any automatic transfer of load to the LEG. On restoration of mains supply the generator control system shall automatically transfer the load back to normal mains supply after an appropriate time delay (adjustable from 1 to 30 minutes). The reconnection of the load to mains supply shall be followed by the automatic shutdown of the generator through the appropriate cool down sequence period.

It shall be possible to remotely start and run the LEG when in automatic mode as required at establishments with remote control capability or requirement such as establishments with ATC
towers or CEPS. ATC only require control over the aerodrome navigation and visual aids. Remote control and monitoring requirements are detailed in paragraphs 21.10.4 and 21.10.7 below.

At establishments provided with CEPS, the LEG control system shall be provided with a “GENERATOR RUN ON” signal from the CEPS. The purpose of this signal is to ensure that all the LEGs at the establishment continue to run as required when the CEPS is supplying the Base under mains fail conditions. The LEG control system, on receiving this signal, shall ignore that mains is available and shall continue to run the LEG to supply the load. When mains supply to the Base is restored, the CEPS will no longer provide the “GENERATOR RUN ON” signal and the LEG changeover process back to normal mains supply shall be initiated. At establishments with a PCMS system, the “GENERATOR RUN ON” signal can be combined with the remote start/stop functions as detailed in the remote control and monitoring requirements below.

If the LEG fails in any mode, the load shall be transferred to normal mains supply irrespective of the “GENERATOR RUN ON” signal or source of supply, but provided the transfer switch is in automatic mode.

Automatic Control Sequence
The LEG shall be connected to the essential loads when any phase of the normal supply has been interrupted, has failed or is at a voltage that is less than 80 percent of the nominal system voltage. The changeover sequence shall only be initiated if the abnormal condition is maintained for a minimum continuous period of two seconds to prevent unnecessary start up of the generator. The time delay may be changed to meet the specific site requirements after consultation and agreement by DEEP.

On reinstatement of the normal mains supply the LEG system shall automatically restore the normal supply after the voltage has maintained nominal levels on all phases for a continuous period suitable to the Region, usually 15 minutes, adjustable between 1 and 30 minutes.

Testing the LEG
LEG test runs shall be carried out on a monthly basis and shall use either a dummy load or the essential equipment load. The control system shall be configured to allow the testing to be conducted in an easy and safe manner by both semi skilled and skilled operators. LEG testing shall generally be carried out as follows:

a) Simulated mains failure condition (once every year by skilled operators only). A power failure is initiated by isolating mains supply at the substation. Removing the fuses from the phase failure relay may not necessarily prove the performance of the system and therefore should not be used for this test. This test should not be a simulation and should involve the facility in its normal operating mode to ensure that the emergency power supply system is fully proven and that the facility and equipment operates in the correct manner.

b) Manually running the generator to supply the equipment or dummy load as selected by the operator. The generator shall continue to supply the selected load until the operator changes
the generator operating mode. When running in this mode, it shall be possible to manually test
the generator on the selected load with the transfer switch in either automatic or manual modes
as required by the operator (See also transfer switch requirements below). The LEG system
shall not be configured in any way that would require the transfer switch to be left in manual
position to enable the test to take place. The LEG shall operate in the following manner under
mains fail or LEG fail conditions:

Mains Fail
i. If normal mains failure occurs whilst the LEG is supplying the equipment load, the LEG
shall continue to run and supply the load until such time as the operator intervenes. On
restoration of mains supply, the LEG would continue to supply the equipment load.

ii. If normal mains failure occurs whilst the generator is supplying a dummy load, the LEG
shall automatically switch to the building or equipment load provided the transfer switch
is set to automatic mode. Where the transfer switch is in manual mode the operation of the
LEG cannot be changed and therefore the test shall be allowed to continue. When mains
supply returns, the LEG shall be configured to either continue to supply the equipment
load or to restore the test mode depending on the operating requirements of the facility as
determined during the design development phase.

iii. Upon mains failure and where the dummy load is in manual mode, the dummy load shall
be disconnected automatically before the LEG is transferred to the building or equipment
load. In order to prevent the generator from overloading, the dummy load shall remain
disconnected until manually reset by an operator.

iv. Where test mode is restored on reinstatement of mains supply, appropriate alarms shall be
raised to notify the operator of the mains failure condition.

LEG Fail
v. Where the LEG fails under test, the testing shall be suspended and the equipment load
shall be reconnected to mains supply. Appropriate alarms shall be raised to notify the
operator that the LEG has failed.

21.10 LEG Design Parameters
21.10.1 Generator Location
In determining the location of the generator consideration shall be given to the following:

a) Noise abatement
b) Vibration isolation
c) Ventilation
d) Exhaust dispersion
e) Weather protection
f) Cooling
g) Fuel supply
h) Excessive voltage drop
i) Environmental protection requirements  

j) Fire separation  

k) Maintenance  

l) Security; and  

m) Access

In addition to the requirements of AS 3010, generators shall be located in a separate generator room which shall be suitably fire isolated from the remainder of the building or facility. Alternatively, the generator can be located in a separate building. The generator room shall house the generator and its associated supporting equipment such as fuel tanks, starting batteries and battery charger.

The generator room shall have internal access to the low voltage switch room as well as appropriate external equipment access doors to facilitate the installation and removal of the generator (i.e. double doors to perimeter of building). The generator cooling air inlet or exhaust arrangement shall not restrict access to the generator room through any of the access doors.

The generator shall be sited as close as practicable to the load. Long LEG supply cable runs shall be avoided wherever possible to minimise interference from or damage by outside influences or events.

Where the generator is located in a tropical or subtropical region the designer shall prevent any harmful impact caused by cyclones. Generators are not normally required to run during a cyclone but are to be fully operational after the cyclone has passed. The designer shall consider the need to mount the generator, supporting auxiliaries and switchgear on platforms to prevent water contamination. In addition, the generator windings shall be provided with coalescent filters and other susceptible essential equipment shall be suitably protected to prevent water contamination due to the high moist content of the atmosphere.

Containerised LEGs shall only be considered where the expense of providing a dedicated generator room cannot be justified and where the alternative will not compromise the operation of the facility or its security. Containerised LEGs shall not be considered for important Defence operational facilities such as ATC towers or for facilities in cyclone regions. Proposals for alternative design solutions based on containerised LEG installations are required to be suitably argued by the designer and agreed by DEEP at project design stage.

An example of a suitable LEG configuration is shown in Figure 21.1.
Figure 21.1: Example LEG Arrangement
21.10.2 Generator Requirements

Rating
The generator shall be capable of simultaneously supplying the total rated load of equipment installed on site, ancillary loads such as fuel pumps, battery chargers and Uninterruptible Power Supply (UPS) charging currents whilst maintaining a 25% spare capacity. The designer shall consider the characteristics of the load when determining the generator size and output characteristics, particularly when non linear loads such as UPS systems and high inrush currents from motor starting are to be accommodated. The designer shall ensure that the manufacturer’s recommended long term minimum load for the LEG is achieved and maintained without the need for the load bank under normal operating conditions.

The generator duty rating (e.g. standby, prime or continuous) shall be selected to achieve the most cost effective arrangement on a through life basis. Normally, standby rated engines are suitable for most Defence emergency power applications. The following definitions shall apply:

a) **Prime Power Rating.** Equivalent to continuous power; the power generating set is capable of producing when operating continuously and the generator shall also have the ability of producing 10 percent in excess of the prime rating one hour in every twelve when operating continuously.

b) **Continuous Power Rating.** As defined by AS 4594.1

c) **Standby Power Rating.** Equivalent to fuel stop power as defined by AS 4594.1.

The generator shall start and supply the full rated load within the required restoration time after loss of mains supply as described in paragraph 21.9 above.

Construction
Construction shall be in accordance with the appropriate parts of AS 1359, AS 4594 and ISO 8528. The generator shall be supplied as a complete unit and the supplier shall ensure that the equipment is mechanically and torsionally compatible.

The generator shall be skid mounted and wherever possible, a day service tank shall be incorporated into the base of the skid mounting. The day service tank shall be sized for approximately 16 hours operation at full rated load or where this fuel quantity is not permitted, to the maximum permissible fuel holding capacity of the facility in accordance with relevant codes. Lower tank capacities may be permitted, subject to approval as an alternative design solution, to allow skid mounted day service tanks to be used.

All service connections (i.e. fuel, exhaust, power cabling, etc) shall allow for the easy removal or replacement of the generator as required. All connections to the generator shall ensure that they are suitably flexible to cater for movement of generator and to prevent transmission of vibration.

Voltage Regulation, Governor Performance and Short Circuit Performance
The characteristics of the generator, particularly the alternator, governor and voltage regulator, shall provide adequate and stable electricity supply to the essential services. The characteristics of
the generators and its sub-systems shall be suitable for the load and the likely load steps. Listed below are minimum generator performance requirements which may need to be made more stringent by the designer to meet specific or particular load requirements:

a) **Steady State Load Conditions.** The generator shall be capable of maintaining the voltage under steady state load conditions to within ±2.5% of the nominal voltage from no load to full load for power factors between 0.8 lagging and unity inclusive of generator speed droop.

b) **Transient Load Conditions - Load Acceptance.** The generator shall on the application of a minimum 60 percent load step, or the intended load step whichever the greater, maintain the initial voltage drop within 15 percent of the nominal voltage. The voltage shall recover to within ±3% of the nominal voltage within one second.

c) **Transient Load Conditions - Load Rejection.** The generator shall on rejection of 100 percent rated load, maintain the initial voltage rise within 20 percent of nominal voltage. The voltage shall recover to within ±3% of the nominal voltage within 1.5 seconds.

d) **Motor Starting.** The generator shall maintain the initial voltage drop within 20 percent of the nominal voltage under the most onerous motor starting conditions.

e) **Alternator Sub-transient Reactance.** The alternator sub-transient reactance shall be suitable to achieve the voltage performance specified.

f) **Governor Performance.** The performance of the generator governor shall be in accordance with AS 4594.4 and the following parameters:
   
i. Performance Class A1
   
ii. Maximum speed droop 5%
   
iii. Maximum transient speed difference 10%
   
iv. Maximum transient recovery time 8 seconds

The generator waveform shall be sinusoidal of the full range of loads and power factors. Telephone harmonic distortion shall not exceed 5 percent, total harmonic distortion shall not exceed 5 percent and the individual harmonic content shall be less than 3.5 percent.

The generator shall be constructed to withstand a sudden short circuit at the terminals without harmful deformation of the windings or other parts of the machine. Ensure that the generator has sufficient fault current to permit the correct operation of the protection equipment in the essential distribution system. Earth loop fault impedance shall take into consideration the generator voltage performance when achieving the required automatic fault disconnection times.

**Starting System**

Battery starting systems shall be used for LEG applications which shall have sufficient capacity for six normal starts or the equivalent of 60 seconds of cranking time, whichever is the greater. The starting procedure shall incorporate a crank cycle of three 10 second cranks with intermediate delays or other suitable arrangement.
The battery starting system shall be capable of recovering from a completely discharged state to 80 percent of capacity within 4 hours and to full capacity in not more than 12 hours. The batteries shall be suitable for continuous float charging and the starting duty of the generator set.

The starting batteries shall be located as close as possible to the generator to minimise starting circuit resistance. Arrange the batteries to ensure no harmful affect from the generator such as excessive vibration or heat and also to minimise exposure to dirt, oil and water. The start battery system shall allow easy servicing of the batteries.

**Ventilation**
The generator room shall be ventilated so that the safe operating temperature of the generator is not exceeded under full load conditions and that the generator combustion air is adequately supplied. The design of the ventilation system for cyclone prone areas shall minimise entry of water into the building and where necessary, the equipment rooms shall incorporate sumps and drainage to remove any water entering the rooms.

**Cooling Systems**
The generator shall be provided with suitable means to top up the cooling system. The generator shall also be provided with a suitable arrangement such as a tray, to capture any spillage or loss of coolant or oil.

**Exhaust**
The generator exhaust system shall be arranged so that the exhaust gasses, smoke or fumes will not reach dangerous concentrations or enter directly or indirectly any enclosed areas occupied by persons. Exhaust discharge shall also comply with the relevant requirements for air pollution.

The exhaust system shall be provided with a suitable means to prevent rainwater entering the piping and also a means to trap and remove condensate or water from the exhaust system. To reduce condensate, the muffler should be installed as close as practical to the prime mover so that it heats up quickly and horizontal exhaust piping should slope away from the engine to the condensate trap.

The designer shall consider the requirements to insulate the exhaust system or other suitable arrangement to suitably protect personnel, equipment and structures from the effects of heat.

**Generator Fuel System**
Appropriate underground fuel storage sized for 7 days continuous running at full rated load shall be provided, unless otherwise agreed in writing by DEEP. Underground tanks shall be double wall construction with secondary containment and interstitial space. The fuel shall be pumped from the underground bulk fuel tanks to the generator day service tank in the generator room. Prime and standby fuel transfer pumps are required. The prime pump is normally an electric pump and the standby pump can be a manual pump. Electric pumps shall have automatic and manual operating modes. In the automatic mode the electric pump shall be controlled by a float switch or similar installed in the day service tank. Overflow protection shall remain serviceable at all times.
Suitable fuel gauges shall be provided for the bulk fuel storage normally at the LEG control panel. All tanks, tank filling facilities and fuel system shall meet the requirements of AS 1940 and also Australian Institute of Petroleum (AIP) Code of Practice 4 (CP4) *The Design, Installation and Operation of Underground Petroleum Storage Systems*. Particular care needs to be taken with the tank filling point spill control which shall be meet the requirements for tank vehicle loading facilities in accordance with AS 1940.

**Controls and Instrumentation**
A separately mounted control panel containing all necessary indicators and controls shall be installed in the LV switch room associated with the facility coincident with the building main switchboard. The LEG panel indicator and control requirements shall be as detailed below.

Control batteries shall be provided, where required, to ensure the control system can function under a normal mains failure condition for a minimum period of 4 hours. The control battery system shall be separate to the start battery system and the batteries shall be suitable for continuous float charging. The control battery charging system shall ensure that the batteries can be fully recharged, from a complete discharged state, within 12 hours.

To cater for control battery system failure, the control battery system, where provided, shall be connected to the start battery system permitting the controls to operate from the starting batteries. The connection shall be made with a diode arrangement to prevent the starting system from drawing power from the control battery system. The diodes shall be sized to ensure they will not fail under short circuit conditions.

**Generator Protection**
The generator shall be provided with all protection devices necessary to ensure the safe operation of the generator and as detailed in below.

### 21.10.3 LEG Distribution System Requirements
An example of a suitable LEG configuration is shown in Figure 21.1.

Labelling and signage requirements are provided in Chapter 10 – General Technical Requirements.

**Automatic Transfer Switch**
Transfer switches shall isolate one source of supply before connecting the other. Appropriate adjustable time delays shall be incorporated to avoid any out of phase problems when transferring the load from mains supply to generator supply and vice versa. The transfer switch shall have "Auto", "Off" and "Manual" selections as well an appropriate manual control to allow an operator to select any of the transfer switch positions. Transfer switches shall be provided with suitable indication to show the status of the switch position and shall also be provided with short form operating instructions as detailed in Chapter 10 – General Technical Requirements.

It shall be possible to select the position of the transfer switch in manual mode and retain this selection in automatic mode. The exception to this would be where the generator control system is
selected to automatic mode and calls for transfer switch to change. The reason for this is to allow
testing of the LEG on the dummy load where the operator would start and run the generator in
manual mode but required the transfer switch to retain its position in automatic mode to cater for
normal power supply failure. When in automatic mode and the selected source fails, the transfer
switch shall change to an available healthy supply or to mains supply where no supply is detected
as being available. In manual mode the transfer switch shall retain the operator selected position.

21.10.4 Other Considerations

**Auxiliary Services**
The LEG and its auxiliary services shall be arranged so that they are fail safe. Failure in an
auxiliary service such as the control power supply shall not result in both the LEG supply and
normal mains supply becoming unserviceable. The control arrangement shall be configured to
provide appropriate fault warning for all battery chargers used as part of the LEG system on the
LEG control panel and in the PCMS to warn of the impending failure.

**Regenerative Loads**
Where the LEG supplies loads with inherent energy storage characteristics (e.g. radar head motors
where an EMF is produced as the motor winds down on loss of supply) particular care is required
to ensure that the necessary delay is allowed in the design (decay time) before the LEG is
connected to the load.

**Remote Control and Monitoring**
Provide remote control and monitoring of the LEG in accordance requirements provided at
paragraph 21.10.7 below and to suit the requirements of the Region.

Remote control and monitoring of the LEG shall normally be through the PCMS or equivalent
system. The LEG system design shall ensure that as a minimum, a LEG summary fault and a LEG
summary alarm are monitored by the PCMS system. Appropriate indication shall also be provided
locally at the building to meet the building occupant requirements and also at suitable remote
monitoring station as appropriate to meet the Regions requirements.

**Dummy Load**
A dummy load is required for all LEG installations. Where the generator minimum long term load
can be met by the building loads alone, permanent dummy loads may be omitted. This shall only be
considered where there is no risk of permanent harm to the generator, as an alternate design
solution. Where a permanent dummy load is not provided, a portable dummy load connection
point, similar to the mobile generator link box, shall be provided to allow connection of a portable
dummy load bank. Permanent dummy load bank requirements are detailed below.

**Mobile Generator Link Box**
All LEG installations shall be provided with a Mobile Generator Link Box (MGLB). MGLB
requirements are detailed in Chapter 22 – Mobile Generator Link Box (MGLB). The MGLB shall
allow the mobile generator to be connected in place of the LEG. The control system shall be
configured to initiate the starting and stopping of the mobile generator as required without the need
for the LEG to be in place. Dedicated LEG alarms and trips shall be de-activated by the control system when the mobile generator is connected. Suitable control connections shall be provided in the link box (e.g. no volt relays) to facilitate the required control.

21.10.5 LEG Panel Layout and Indicator Requirements

A sufficient number of indicators and meters shall be provided to clearly and accurately portray the state and condition of the whole plant to semi skilled operators. The following are general requirements:

a) It should be clear to the operator why the generator is running (e.g. cooling down mode); and
b) Shutdown or trip of the generator shall not be possible without a visual indicator operating on the generator control panel. Similarly it should be obvious to an operator why a generator will not operate or failed to operate.

The controls shall be arranged in a logical and ergonomic manner with commonality of all control switches, indicators, meters and the like. These shall be easy to operate and appropriately grouped for efficient readability. Devices shall be of the type most suitable to convey their purpose. For example:

a) meters for comparative purposes should be grouped together, i.e. generator ammeters; and
b) colour should be used to indicator status/purpose. Indicator colours shall be suitable for the condition portrayed (e.g. red fault, amber alarm, green healthy, white status indication).

Only one operator shall be used for each function (i.e. one push button switch for alarm acknowledge). A single lamp test facility shall be provided on the generator control panel to test all indicating lamps and LEDs simultaneously.

The LEG control panel shall be provided with short form operating instructions securely fixed to the panel. The short form instructions shall be an engraved two colour laminated traffolyte or similar.

All generator alarms and trips shall remain latched until manually reset by an operator.

The following indicators are required as a minimum:

- **REMOTE RUN REQUEST** Indicates a LEG request to run from PCMS (Note The PCMS system combines Start at CEPS, Start at ATC Tower and Generator Run On);
- **GENERATOR RUN ON FROM CEPS** (where not incorporated in Remote Run Request above);
- **START AT ATC TOWER** (where not incorporated in Remote Run Request above);
- **START AT CEPS** (where not incorporated in Remote Run Request above);
- **MAINS AVAILABLE**;
- **MAINS FAIL**;
- **MAINS CONNECTED**;
– **GENERATOR NOT AVAILABLE** (any condition that prevent the generator from coming online incorrect operating mode, transfer switch or circuit breaker mode or position);

– **CALL TO START**;

– **ENGINE RUNNING**;

– **GENERATOR CONNECTED**;

– **SET COOLING DOWN**;

– **EACH GENSET ALARM** (suppress consequential alarms and provide summary indication Generator Alarm for remote monitoring);

– **EACH GENSET TRIP** (provide summary indication Generator Fault for remote monitoring);

– **GENERATOR SUPPLYING DUMMY LOAD**; and

– **MOBILE GENERATOR CONNECTED**

Provide the following operators and meters on the generator control panel as a minimum:

– **MODE SELECTOR**;
  – **AUTO**
  – **OFF**
  – **MANUAL**

– **GENERATOR START** (Only effective in manual mode);

– **GENERATOR STOP** (Only effective in manual mode);

– **EMERGENCY STOP**;

– **AUDIBLE ALARM**;

– **ACKNOWLEDGE PUSHBUTTON**;

– **RESET PUSHBUTTON**;

– **LAMP TEST** (tests all lamps including LED's);

– **TRANSFER SWITCH CONTROLS**;

– **DUMMY LOAD CONTROLS AND INDICATORS**; and

– **METERING**;
  – 3Φ Amps (3 off instantaneous)
  – 3Φ Volts (selectable between phases)
  – Frequency
  – Power (kW)
  – Power Factor
  – Hours Run
– KWh (can be behind panel door and normally incorporated with the intelligent meter)
– Bulk Fuel Level
– Start Battery Volts (if not on battery charger panel)
– Control Battery Volts (if not on battery charger panel)

Engine mounted gauges shall be provided to indicate the following engine information:
– Jacket Water Temperature (In and out if radiator is remote);
– Lube Oil Pressure;
– Exhaust Gas Temperature if turbocharger fitted (each bank) for sets greater than 500kW; and
– Engine Speed

**Generator Alarms**

The following alarms shall be provided:

– **Approaching Low Fuel Level**
  Alarm when fuel level in day tank drops below the minimum fuel level (Note fuel lift pumps should operate whenever the generator is operating and shall return any excess fuel to bulk tank).

– **Approaching Low Oil Pressure**
  Set as per engine manufacturer’s recommendations. Provide override until engine up to starter cut out speed.

– **Approaching Engine High Water Temperature**
  Set as per engine manufacturer’s recommendations.

– **Start Battery Low and High Volts, Charger Fail**
  (e.g. Low 24.5 volts for 60 seconds, High 30 volts for 60 seconds)
  Annunciated as separate alarms on generator control panel if not annunciated separately on battery charger.

– **Control Battery Low and High Volts, Charger Fail**
  Annunciated as separate alarms on generator control panel if not annunciated separately on battery charger.

– **Generator Isolated**
  Initiated by transfer switch position (or other isolators) if generator is prevented from connecting.
- **Low Water Level**  
  Initiated by level switch on radiator.

- **Low Oil Level (optional)**  
  Initiated by level switch in oil level regulator, if provided.

- **Radiator Fan Fail (for remote radiators only)**  
  Initiated by contactor being open when it should be closed or local isolator being open.

- **Engine Service Due**  
  Initiated by hours run or time elapsed. Reset by appropriate means such as low oil level signal followed by normal oil level signal while set is isolated (e.g. emergency stop at set initiated).

- Other alarms as necessary to annunciate generator set is not healthy.

Alarms are shall latch until reset by the operator. The generator shall continue to operate under alarm conditions where not harmful to the generator. Provide a common alarm output for input into the PCMS.

Suppress all consequential alarms i.e. Low Oil Pressure after set trips or battery charger failed during mains failure.

Incorporate short time delays wherever possible to prevent spurious alarms due to contact bounce, noise and the like.

**Generator Set Trips**  
Provide the following trips:

- **Fail to Start**  
  Initiate if set fails to reach nominal speed and nominal voltage after complete crank cycle (e.g. 3 x 10 seconds with intermediate delays).

- **PLC or Microprocessor Failure**  
  Must be performed by a device external to PLC or microprocessor. Where PLC or microprocessor is critical to the safe operation of the generator, the PLC or microprocessor must be set up so that once CPU fails or PLC power fails a trip signal is sent to the circuit breaker (fail safe i.e. off NC contact on relay) and supply to governor (spring return) and fuel supply is de-energised.

- **Underspeed**  
  Set to manufacturers recommendations (e.g. 1250 RPM for say five seconds). Circuit to be enabled after starter cut out speed is reached.
– **Overspeed**
Set to manufacturers recommendations (e.g. 1750 RPM instantaneous). Trip shall actuate air flaps and shut off governor and fuel solenoid (Air flaps are required on all two stroke engines with hard wiring from emergency stop and over speed devices).

– **Low Level Fuel**
Initiated by extra low fuel level in day service tank.

– **Low Oil Pressure**
Set to manufacturers recommendations.

– **Low Water Level**
Initiated by level switch on radiator.

– **High Water Temperature**
Set to manufacturers recommendations.

– **Emergency Stop**
Provide on engine control panel and generator set and elsewhere as specified.

– **Over Voltage**
Set point 110% of nominal voltage for 10 second and/or 120% of nominal voltage for five seconds.

– **Under Voltage**
Set point 90% of nominal voltage for 10 seconds.

– **Overcurrent** (Alternator over current and earth fault protection)
Hard wire trip to open ACB or similar, allow cool down cycle on alternator.

– **Alternator Over Temperature Thermistor** (LV sets above 500kW)
Three phase sensing. Immediately open ACB, allow alternator cool down cycle.

– Other trips as required to prevent or limit damage to the generator set or to its associated equipment.

In the case of a trip, the circuit breaker should open and the engine shut down immediately unless noted otherwise and safe for the generator. Ensure that the LEG protection is stable during operation and starting of the LEG and that it is not possible to cause nuisance tripping.

Trips shall latch until reset by operator. Provide common outputs into the PCMS for trips.
All consequential trips shall be suppressed i.e. Low Oil Pressure after set trips or battery charger failed during mains failure.

### 21.10.6 Data Logging and Trending

All analogue information displayed on control panels or generator gauges shall be compatible with the PLC or microprocessor based monitoring system. The monitoring and trending of the generator functions and events, where required, shall be carried out by downloading to a central location on the Base. The functional design brief will identify the need and detailed requirements for remote logging and trending.

The following is provided as a guide to the future trending requirements:

- It is expected that the PLC or microprocessor system will maintain database of all monitored generator functions and events to include all sequence of events and all analogue data at 15 minute (time averaged) intervals. This data shall be downloaded to the PCMS via an intelligent meter or other suitable means. In addition, minimum voltage, maximum voltage, set maximum demand (thermal current); current, power factor, etc shall be provided for each 15 minute interval as part of the intelligent metering.
- Events log capable of registering intervals down to one second.
- Software to automatically download data from PLC or microprocessor to PCMS or portable computer.
- Output kWh and fuel consumed for calculation of generator efficiency.

### 21.10.7 LEG Remote Control and Monitoring

LEGs shall be remotely monitored through the Defence Engineering Services Network (DESN), Base PCMS or other site control and monitoring system. Remote monitoring and control is required at the CEPS, for all LEGs and at the ATC tower where associated with aircraft navigation or visual aids. Monitoring only through the PCMS shall be possible at other locations to suit the local region requirements and at some establishments remote control and monitoring is required as part of the Base energy management system or site building management system.

PCMS screen layout for the LEG status and control requirements is shown in Figure 21.2
Figure 21.2: PCMS LEG Control Screen

Indicators in the PCMS shall be arranged as follows:

Table 21.2: Colour Indicators in PCMS

<table>
<thead>
<tr>
<th>Colour</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>- Loss of communications/facility</td>
</tr>
<tr>
<td>Grey</td>
<td>- Off state</td>
</tr>
<tr>
<td>Green</td>
<td>- Selected state, healthy on</td>
</tr>
<tr>
<td>Green/Grey Flashing</td>
<td>- Processing selection (if applicable)</td>
</tr>
<tr>
<td>Amber</td>
<td>- Alarm Condition</td>
</tr>
<tr>
<td>Red</td>
<td>- Fault</td>
</tr>
</tbody>
</table>

The functions required for the PCMS system shall be as shown in Figure 21.2 and detailed below:

**PLC Status.** Status of communications LEG PCMS PLC. LEG control PLC status shall be incorporated into the Generator common fault indication. The indicator colour shall be green if OK, red if fault, white on loss of communications.

**Generator Not Available.** Condition exists that could prevent the LEG from working in its automatic mode (e.g. incorrect operating mode, transfer switch or circuit breaker mode or position,
etc). The indicator colour shall be red if not available, grey default (available), white on loss of communications.

**Generator Running.** Generator running but not necessarily connected. The indicator colour shall be green if running, grey default (not running), white on loss of communications.

**Generator Connected.** Generator on line and supplying the building/equipment load. The indicator colour shall be green if connected, grey default (not connected), white on loss of communications.

**Generator Fault.** Common or summary fault indication showing the generator in a fault/shutdown condition. The common or summary fault shall not include non-critical alarms. The indicator colour shall be red if fault, grey default (no fault), white on loss of communications. As an option, non-critical alarm conditions are permitted to be displayed by the same indicator on the PCMS screen in which case the indication shall have an additional amber indication. Should a common or summary fault and a non-critical alarm be concurrent, then the fault indication shall take precedence or the condition should occult red/amber. In this case the indicator colour shall be red if fault, amber if alarm, grey default (no fault or alarm), white on loss of communications.

**Generator Alarm.** Generator in alarm condition. (where provided and not included as part of the generator fault indication above). The indicator colour shall be amber if alarm condition exists, grey default (no alarm), white on loss of communications.

**Local Mains Available.** From phase failure relay or similar. The indicator colour shall be green if available, red if not available, white on loss of communications.

**Local Mains Connected.** Local mains on line and supplying the building/equipment load. The indicator colour shall be green if connected, grey default (not connected), white on loss of communications.

**Generator Run On.** Provided through PCMS system. The indicator colour shall be green if LEG Run On is initiated by CEPS, grey default (no run on signal), white on loss of communications.

**Start Request at ATC Tower.** Indicates a LEG request to run from the ATC. Note Start at CEPS and Start at ATC Tower can be operated concurrently. The indicator colour shall be green if started from ATC Tower, grey default (no start request), white on loss of communications.

**Start Request at CEPS.** Indicates a LEG request to run from the CEPS. The indicator colour shall be green if started from CEPS, grey default (no start request), white on loss of communications.

**PCMS LEG Start/Stop Control Selection.** Allows selection of manual start/stop control screen. The start and stop request shall be by permissive popup box to allow the operator to confirm request before the PCMS actions the request to prevent accidental starting and stopping of the
LEG. The start and stop pushbuttons shall indicate the status by displaying the button as depressed when selected.

Indicator functions required for the Australian Defence Air Traffic System (ADATS) are as follows. These outputs are required from the PCMS to the ADATS, as voltage free contacts:

- **Mains Available.** From Local Mains Available
- **Mains in Use.** From Local Mains Connected.
- **Generator in Use.** From Generator Connected.
- **Generator Fail.** From Generator Fault
- **Start Request at ATC Tower.** (may be common through PCMS system as remote run request)

Manual starting and stopping the LEG through the PCMS system shall be through a permissive pop up box to confirm the operation before passing the command through the PCMS.

Selection of the LEG stop removes the requirement for run rather than acts as a true stop function. A true stop function should not be installed, if the LEG is requested to run from any other location (i.e. ATC or power failure) the LEG shall continue to run until all requests to run are removed. This will normally be achieved through the PCMS, with the PCMS system ensuring that all valid run requests have been removed before sending the stop pulse.

Control signals from the PCMS to the LEG shall be separately pulsed on and off via two discrete outputs into the LEG controls to ensure the selected state is maintained under failure conditions. These pulse on, pulse off contacts are normally used for starting and stopping the LEG for all run requests such as the Generator Run On and the start/stop requests from the CEPS and ATC.

At establishments not currently equipped with PCMS LEG monitoring, the existing arrangement shall be maintained, however, the LEG shall be configured to meet both the existing requirements and the requirements of this Chapter. An example of the RAAF requirement is shown in Figure 21.3.
Figure 21.3: DGAW-AF 86/070/-
21.10.8 Dummy Load Requirements

A commercially available resistive dummy load rated at 100 percent of the LEG mechanical rating shall be provided which has appropriate load steps (minimum of five steps) to suit the LEG operations.

The dummy load is provided to ensure minimum load is maintained on the LEG or mobile generator (manually) and to allow testing of the LEG. It should also be used for testing the UPS if practical. The dummy load would only need to be used manually for UPS and mobile generators, however, if practical automatic control should also be implemented for the mobile generator by changing the generator rating parameter in the dummy load control or similar.

Where the building load can provide the generator minimum long term load, a permanent load bank is not essential and a portable load bank can be considered. The LEG installation should be provided with a suitable link box for the connection of the portable dummy load. Justification and agreement of this alternative design solution is required before the generator system design is completed.

The dummy load shall have automatic and manual controls. The automatic control shall monitor the load on the generator and increase or decrease the load steps as required to maintain the load on the generator at a predetermined percentage load. The latter shall be set at or above the manufacturers recommended minimum long term load, nominally between 60 and 70 percent for two stroke engines and above 35 percent for four stroke engines. It shall be possible to adjust the required generator load percentage on site without the need for any software or hardware changes.

The system shall incorporate appropriate controls for management of the load connected to the LEG and shall disconnect the load bank when it is not required. The system shall also prevent cyclic operation of the load bank and shall immediately disconnect the dummy load when the generator load (not including the dummy load) exceeds 75 percent of maximum load. There shall be appropriate measures (e.g. dead bands, load step sizes) to avoid hunting.

It shall be possible to test the generator on the dummy load alone whilst the equipment load is supplied from the mains supply. If during a test mains supply fails, the generator shall be automatically switched to the equipment load provided that the transfer switch is in automatic mode as detailed in paragraph 9.2.9 above. The dummy load shall be automatically disconnected before transfer if the dummy load is selected to manual control mode.

The dummy load controls shall be incorporated into a separate section of the LEG control panel.

The dummy load design parameters include:

- **c)** Dummy load must be fail safe. It shall not be possible for the dummy load to trip the LEG under any condition. Mechanically latched contactors are not to be used.

- **d)** Provided with appropriate protection to protect against possible faults such as equipment overheating and vent fan failure.
e) Provided with vent fan run on to cool the dummy load after use and prolong the life of components.

f) Cycle the resistive load elements, if possible, to even out usage of all load elements.

g) The dummy shall be capable of withstanding the environmental conditions of the site, particularly if it is externally mounted.

h) The generator rating and the percentage load shall easily changeable without the need for software or hardware changes.

i) Provided with the following controls and indicators:
   - Control mode selector (bumpless transfer between modes)
     - AUTO
     - OFF
     - MANUAL
   - Selector for each load step (only works in manual mode)
   - Indicator showing each load step connected or in use
   - kW meter
   - Ammeter for each phase

21.10.9 Routine Testing and Training

LEGs shall be routinely tested once a month using a dummy load or the building equipment load. LEG testing shall include a simulated mains failure at least once every 12 months. Testing shall generally be undertaken by the Defence maintenance contractor as part of the regional Comprehensive Maintenance Services contract (CMS) to ensure continuous and reliable operation of the LEG and to optimise on the life and performance of the equipment.

Routine testing of the generator at 100 percent loading shall be carried out to establish that the LEG is capable of supplying the full design load. The test shall also be used to reverse any harmful effect of the LEG operating under low load conditions. Routine tests shall be deemed to have been successfully completed when a stable engine temperature is attained, which is within the permissible range, without failure of the LEG system.

The user unit and/or building occupants shall be trained in the operation of the LEG and should participate in the monthly testing to promote and maintain the required knowledge of the LEG system. The routine tests shall ensure that the LEG is run in all operating modes to ensure that personnel are adequately trained in the operation of the LEG.

It is the responsibility of the Base Network Controller (NC) to test the LEG installation and to train the user unit and/or building occupants. The NC is the authority responsible for the safe operation of Defence electrical reticulation and generation systems. The NC, appointed and engaged as part of the CMS (reference Operation of Low and High Voltage Power Generation and Electrical Reticulation Systems), shall also be responsible for authorising users or building occupants in the operation of the LEG systems.