16 Power Systems for Aircraft Servicing and other 400Hz Applications

16.1 Background

Power systems for aircraft servicing and other 400Hz applications are specialised installations with important considerations. The aircraft servicing supplies need to be compatible with the on-board aircraft systems they serve and also ensure safety of the equipment and personnel. This policy defines the minimum engineering requirements technical requirements of fixed 400Hz power supplies for aircraft servicing in hangars, workshops and other areas.

16.2 Performance Objective

The objective of this policy is to:

a) facilitate compliance with the respective installation standards;
b) safeguard aircraft electrical systems;
c) facilitate the suitable performance of 400Hz installations
d) provide a consistent operator interface for Defence operators, and
e) ensure the economics of the design on a through life basis.

16.3 Reference Documents

**Standards/Codes**

All materials and workmanship shall be of the best standard and shall comply with the relevant legislation and Australian Standards, or if such do not exist, with the relevant IEC or International (ISO) Standards.

Irrespective of any requirements shown in these documents the installation as a whole shall comply with:

**Australian Standards**

| AS 1020 | The control of undesirable static electricity. |
| AS 1055 | Acoustics. (Series). |
| AS/NZS CISPR 14.2 | Electromagnetic compatibility - Requirements for household appliances electric tools and similar apparatus - Immunity - Product family standard |
| AS 1243 | Voltage Transformers for Measurement and Protection. |
| AS 1307 | Surge Arrestors. |
| AS 1627 | Metal Finishing – Preparation and pre-treatment of surfaces. |
| AS 1675 | Current Transformers - Measurement and Protection. |
AS 1767  Insulating Liquids. (Series).
AS/NZS 1768  Lightning Protection.
AS 1939  Degrees of Protection Provided by Enclosures for Electrical Equipment.
AS 2374  Power Transformers. (Series).
AS 2381  Electrical Equipment for Explosive Atmospheres. (Series)
AS 2467  Maintenance of Electrical Switchgear
AS 2650  High Voltage AC Switchgear and Controlgear - Common Requirements.
AS/NZS 3000  Wiring Rules.
AS 3702  Item Designation in Electrotechnology.
AS 3013  Electrical Installations – Wiring Systems for Specific Applications.
AS 4070  Recommended Practices for protection of low voltage electrical installations and equipment in MEN systems from transient voltages.
AS 61000  Electromagnetic Compatibility (series).

400Hz Standards
MIL-STD-704  Aircraft Electrical Power Characteristics
MIL-STD-1399-300  Interface Standard for Shipboard Systems
DEF (AUST) 290  Electrical Power Supply Systems Below 600 Volts
ASCC 25/19A  Connectors for 115/200 Volt 400Hz 3-Phase AC Servicing Power
DI(AF)AAP 7600.500-14M  GSE Handling Procedures General Maintenance and Safety Precautions

Other Standards
Any requirements as per the applicable IEEE, ISO and IEC Standards, including:
16.4 Technical Requirements

400Hz systems shall generally be based on 200/115V four wire systems and are required for a number of applications as follows:

a) Aircraft Hangers, Shelters and Aprons (including OLAs): To power aircraft systems without the need to run the aircraft engines

b) Workshops: To power electrical systems on electronic and weapons systems

Technical Considerations

Distribution of electrical power at 400Hz offers a number of technical challenges when compared with 50Hz. These apply largely to the impedances and losses within the distribution system, principally the cabling. Compounding the challenges associated with increased distribution losses is the quite close tolerances on both voltage drop and no-load to full-load voltage regulation required of the supply.

The nature of aircraft static earthing, and its interaction with the fixed 400Hz system is also an important consideration when determining protection system requirements.

16.4.1 Output Characteristics

The 400Hz system shall provide a sine wave output with characteristics and tolerances in accordance with the applicable standard(s) defined by the respective aircraft Systems Project Office (SPO) when measured at the following locations:

a) For aircraft power: At the 200/115v 400Hz aircraft connection,

b) For workshop power: At the 200/115v 400Hz outlet,

For certain aircraft this may require confirming the aircraft power supply meets both the current and earlier version of the standard (e.g. F111 requires compliance with MIL-STD-704A, the current standard is 704F, the design must comply with both).
Where the installation may support a number of aircraft types or loads the installation shall be
designed to comply with all standards using the most demanding criteria. Conflicts between
standards shall be dealt with as detailed in Chapter 1 – Infrastructure Electrical Engineering.
Alternative solutions must be addressed as detailed in Chapter 6 – Certification and Verification.

Frequency converters shall comply with the above characteristics for both linear and non-linear
loads as specified.

The designer must ensure that the output characteristics are maintained within prescribed limits and
for aircraft ground power, to the aircraft input receptacle. The designer must also ensure suitable
transient and surge performance of the frequency converters and the supply system.

The Tables and Classes contained in DEF(AUST)290 ELECTRICAL POWER SUPPLY
SYSTEMS BELOW 600 VOLTS shall be modified as detailed below.

DEF(AUST)290 Table IV Class D modified as follows:

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Item</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line 4</td>
<td>Transient surge component</td>
<td>Para. 4.12.1(i) - Low Limit: 16%</td>
</tr>
<tr>
<td>Line 5</td>
<td>Transient surge component</td>
<td>Para. 4.12.1(i) - Recovery Time: 1 sec</td>
</tr>
<tr>
<td>Line 6</td>
<td>Transient surge component</td>
<td>Para. 4.12.1(i) - High Limit: 16%</td>
</tr>
<tr>
<td>Line 7</td>
<td>Transient surge component</td>
<td>Para. 4.12.1(i) - Recovery Time: 1 sec</td>
</tr>
<tr>
<td>Line 17</td>
<td>Divergence</td>
<td>Para. 4.16: 5%</td>
</tr>
</tbody>
</table>

In addition all standards must include the following performance requirements:

a) Voltage spike (peak value) at the point of entry to the converter building must be at least
6000V.

b) Minimum Over Load Capacity of 200% for 250 mSec

16.4.2 System Configuration

Two types of basic configurations can be adopted in the design of fixed 400Hz system. The choice
of which system is adopted needs to be made on the basis of capital/recurrent costs on a through-
life basis, together with operational considerations.

The designer will need to confirm the most appropriate arrangement via a through-life assessment.

Distributed Systems

This configuration uses individual frequency converters for each individual location. An example is
an isolated OLA where the outlets at the OLA are supplied from a single frequency converter.
Distributed systems have advantages in terms of reduced 400Hz distribution cabling as the converter is close to the end user. However for larger installations the increased number of converters can increase both capital and ongoing maintenance costs.

**Centralised Systems**
This configuration uses a centralised converter or bank of converters to supply a number of different locations. An example is a group of OLAs where the converter/s can be located adjacent to the substation.

In order to allow the 400Hz power to be distributed across larger distances higher distribution voltages are often used in centralised systems. The typical higher voltage used in this situation is 960V. This is still LV and therefore avoids the need to apply high voltage equipment/installation standards. This arrangement does however require the installation of step-down transformers near to the point of utilisation.

The lower number of converters can offer advantages in terms of capital and ongoing maintenance and energy efficiency. However this needs to be balanced against the increased complexity of control and reduced redundancy. End of line voltage monitoring may be required as an input to the voltage regulator.

### 16.4.3 System Capacity
Aircraft and workshop loads vary greatly depending upon the type of installation and how it is operated. Aircraft loads in particular exhibit large peaks, especially when pumps and control surfaces are operated.

Note that these and other special applications may require a higher short time peak load than standard. For these special loads, the required load profile should be specified so that the appropriate characteristics can be designed into the inverter. For static systems, this may require customising the rating of reactive compensators which is more efficient than over rating the entire unit.

The following loads are offered as a guide, however the Designer shall determine the actual loads to be used in the design and confirm these in the CDR.

<table>
<thead>
<tr>
<th>Table 16.2 Aircraft Power Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
</tr>
<tr>
<td>Condition</td>
</tr>
<tr>
<td>Steady State</td>
</tr>
<tr>
<td>Peak</td>
</tr>
</tbody>
</table>

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16.4.4 Housing of Equipment
The housing of equipment, particularly the frequency converters shall consider the following factors:

a) Environmental conditions;
b) The pattern of usage of the equipment;
c) Passive defence, and
d) Post disaster functionality.

Environmental Conditions
The housing of 400Hz system components shall consider the relative sensitivity of electronic equipment and rotating machinery to environmental conditions. In areas subject to atmospheric contamination or areas subject to high relative humidity consideration should be given to housing equipment indoors.

Where equipment is located indoors suitable means shall be provided to remove heat generated from the space so that the room temperature under worst case conditions does not exceed the maximum permissible ambient temperature for the equipment.

Pattern of Usage
In certain locations fixed 400Hz systems are subject to infrequent usage. The design shall incorporate measures to ensure that environmental conditions do not result in excessive degradation of the equipment under these circumstances. The following measures shall be considered:

a) Suitable weather protection for externally mounted equipment;
b) Anti-condensation heaters; and
c) Air conditioning of indoor equipment to reduce relative humidity. Note: A cost effective solution might be to provide air conditioning when the unit is not running and provide ventilation only, at a high rate, to remove losses when the unit is running. This will of course depend upon any atmospheric pollutants.

Even when operated continuously the system might be required to operate at no load for extended periods. The system shall be constructed to withstand such usage.

Passive Defence
Auxiliary power for aircraft is an important service. The nature of much commercial equipment is such that the equipment does not survive physical attack well. For that reason additional protection will be required when Defence nominates defined passive defence requirements. These requirements will normally be identified in the FDB.

Post Disaster Functionality
Facilities that have a post disaster function require consideration to ensure a certain amount of survivability in the event of natural disaster. For example, cyclonic events and in certain circumstances the fixed 400Hz system may be required to support aircraft operations following a
cyclone. In such an instance the housing of the 400Hz installation should consider means to limit damage to the system from the cyclone including flying debris and water ingress.

16.5 System Operation

Overview (Refer to paragraph 16.14 – Standard Arrangement Drawings).
The operator is required to manually start the system. This generally occurs at the Remote Control Panel within the facility. A Control Panel is to be provided at the converter but this is largely for maintenance purposes.

The operator connects the aircraft to the 400Hz system using an umbilical lead from the wall socket to the aircraft inlet connection. The supply is energised for a period by pressing the Connect button adjacent to the wall socket.

The supply shall remain energised only if the aircraft connects, and remains connected, within the time period. Failure to do so shall automatically de-energise the supply system. Once connected, any disconnection of umbilical lead or supply shall automatically de-energise supply.

The aircraft is disconnected from the 400Hz system by pressing the Disconnect button adjacent to the wall socket and removing the umbilical lead.

The control system runs the required converters to suit the load profile of the facility. The converters remain running until the system automatically shuts down at which point it shall automatically disconnect and stop. Automatic shutdown shall be initiated if no aircraft are connected for a period of 15 minutes (adjustable from 10 min to 1 hour).

Multiple Converter Systems
Where multiple converters are provided to feed a common bus they shall be staged on and off in response to changes in electrical demand. Appropriate hysteresis shall be incorporated to optimise the utilisation of the converters and to achieve efficiency. As an example for a two converter systems this shall consist of:

a) When the running (first) converter reaches 60% load for a period exceeding 10 seconds the second converter shall start, synchronise and connect to the load.

b) When the combined load on both converters falls below 70% capacity of one converter for a period exceeding 5 minutes one converter shall disconnect and stop.

Other Facilities
The operator shall manual start and stop the system. This generally occurs at the Remote Control Panel within the facility. A Control Panel is provided at the converter but this is largely for maintenance usage.
16.6 Earthing

200/115V Systems

Prior to operations beginning on an aircraft a static earth in applied to the airframe to discharge any static electricity. Also note that from an electrical viewpoint the area immediately surrounding the fuel storage areas of aircraft are hazardous areas.

There is no earth cable in the aircraft lead and the 400Hz neutral within the aircraft is connected to the airframe. If the 400Hz system were earth referenced at the point of supply a fault within the aircraft could result in fault currents flowing in the static earthing system and possibly resulting in a spark within the hazardous area. For this reason 115V 400Hz systems are not solidly earthed. Instead protection shall be provided to detect earth faults to minimise risk to personnel and property.

960/555V Systems

960V systems are 3 wire 3 phase systems that are solidly earthed.

A separate earth cable shall be run from the converter to the step-down transformer. The earth shall not form part of the power cable where it will adversely impact of the cable asymmetry (i.e. impacting on the cable losses).

16.7 Protection

16.7.1 Fault Clearance

The fault clearance capacity of 400Hz sources can be relatively low. As a result it can be difficult to achieve mandatory fault clearance times. Considerable attention shall be given to system protection to ensure that the fault clearance requirements of AS/NZS 3000 are met.

16.7.2 Protection Equipment

All protection equipment shall be certified by the manufacturer as being suitable for use in 400Hz systems and at the applicable voltage level.

200/115V Systems

Overcurrent and fault protection shall be provided by means of circuit breaker(s).

Earth fault detection consisting of neutral displacement detection shall be provided to detect earth faults in the system. An acceptable solution is a voltage relay between neutral and earth at the source of supply. The earth fault protection shall shunt trip the circuit breaker using a 230V supply. The tripping supply shall be monitored to raise an alarm on failure.

960/555V Systems

Overcurrent and fault protection shall be provided by means of appropriately rated circuit breakers.

Where required to meet earth fault clearance times earth fault protection shall be provided. An acceptable solution is a residual current device with a definite time element that shunt trips the
circuit breaker using a 230V supply. The tripping supply shall be monitored and raise an alarm on failure.

**Transient Overvoltage**

Transient overvoltage protection shall be used to protect equipment from lightning induced transients on long cable runs or on sensitive equipment.

Where suitable equipment is commercially available the condition of the protective elements shall be monitored to raise an alarm on failure.

### 16.8 Frequency Converters

**Technologies**

Two frequency converter technologies are presently in widespread use:

a) **Static Converters** – Use solid-state inverters to generate 400Hz.

b) **Rotary Converters** – Use rotating machinery, in effect a motor and alternator to generate 400Hz.

Each type has certain advantages and disadvantages and this policy is not biased in favour of one or the other technology. Instead the technical requirements shall be specified after due consideration of such factors as the operating cycle and technical considerations such as fault clearance capacity.

For continuous operations operating costs and efficiency become more important.

**Protection**

The frequency converter shall have in-built protection against:

a) Over and under voltage disturbances on the incoming mains supply including surges caused by lightning;

b) Overcurrent and short circuit at the output terminals (for phase-to-phase and phase-to-earth faults);

c) Load switching and circuit breaker operation in the supplied distribution system;

d) Sudden changes in output load, and

e) Over-temperature.

The frequency converter shall have built-in protection for the prevention of permanent damage to itself or the connected load in the event of a fault within the frequency converter.

**Control**

Each converter shall be fitted with the following:

a) Emergency stop pushbutton

b) Control switch - Local/Remote: In the Local mode the converter shall be operated from the local panel with any control from the Remote Control Stations inhibited. In the Remote mode the controls on the local panel shall be inhibited (with the exception of the Emergency Stop),
with control of the converter only from the Remote Control Stations. Local mode disables automatic shutdown of the converter.

c) Converter Start pushbutton
d) Converter Stop pushbutton (Disconnect and Stop)
e) Converter On-line pushbutton (only if starting and connecting are a two stage process)
f) Lamp test pushbutton
g) Converter Running indicator (White)
h) Converter On-line indicator (White)
i) Converter Fault indicator (Amber)
j) Fault Reset pushbutton

**Instrumentation and Indication**

The frequency converter shall have an integral control and indicating panel, housing all instrumentation required for the efficient operation of the system. Instrumentation shall include but shall not be limited to:

a) Voltmeters or LCD to display both input and output phase to neutral voltages.
b) Ammeters or LCD to display both input and output line current.
c) Frequency meter or LCD to measure input and output frequency.
d) Hours run indicator to indicate the operating time in hours - operating time shall be taken when frequency converter is supplying load.

Indicators shall be provided for all status, fault and warning conditions such that the condition of the converter is immediately obvious to an operator who is not familiar with the equipment.

**Efficiency**

The efficiency of each converter at full load shall not be less than 85%.

**Availability**

Each frequency converter shall have a Mean Time Between Maintenance (including scheduled and unscheduled maintenance where maintenance requires a discontinuity to service) of not less than 50,000 hours when operated under the following ambient conditions:

a) Temperature of 50°C
b) Relative humidity up to 99%.

Reliability calculations shall be performed in accordance with MIL-HDBK-217D to demonstrate compliance. These calculations shall be the basis for these calculations and the source of failure rate data.

The Mean Time To Repair shall be 2 hours with a Maximum Time To Repair of 12 hours.
Standby Power Supply
The converters shall be suitable for operation from the standby generators, where these are provided.

16.9 Remote Control Panels
Provide a Remote Control Panel at a convenient location within each facility. For larger facilities supplied from a single converter multiple Remote Control Panels might be required.

The control station shall provide the following functions and status indications:

a) Converter Start pushbutton
b) Converter Stop pushbutton (not for aircraft supplies)
c) Lamp Test pushbutton
d) Mute pushbutton
e) Converter Online indicator (White): Indicates that a converter is running and connected
f) Converter Fault indicator (Amber)
g) Converter Fault audible indicator

Instrumentation to display analogue information such as volts amps etc is not required at the Remote Control Station.
16.10 Transformers

The transformer shall have the following basic construction:

- **Table 16.3: Transformer Characteristics**

<table>
<thead>
<tr>
<th>Type:</th>
<th>Dry type - Fully enclosed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling:</td>
<td>Air, Natural Convection</td>
</tr>
<tr>
<td>Overloading:</td>
<td>10% for 1 hr</td>
</tr>
<tr>
<td>Rated voltages:</td>
<td></td>
</tr>
<tr>
<td>- Primary voltage windings:</td>
<td>960/560V</td>
</tr>
<tr>
<td>- Secondary voltage windings:</td>
<td>200/115 V</td>
</tr>
<tr>
<td>Insulation grade:</td>
<td>B to AS 2768</td>
</tr>
<tr>
<td>Insulation level:</td>
<td>5 kV peak</td>
</tr>
<tr>
<td>Neutral terminal impulse withstand:</td>
<td>3 kV peak</td>
</tr>
<tr>
<td>Losses:</td>
<td></td>
</tr>
<tr>
<td>- No load:</td>
<td>To suit the system</td>
</tr>
<tr>
<td>- Load:</td>
<td>To suit the system</td>
</tr>
<tr>
<td>Parallel operation:</td>
<td>None</td>
</tr>
</tbody>
</table>

16.11 400Hz Outlets

16.11.1 Aircraft Outlet Location

The outlets should generally be wall mounted at approximately 1.2 m above floor level wherever possible.

Where wall mounting is not practical the outlets can be either fixed to the end of a cable reel suspended from the roof structure or in-ground mounted. The use of in-ground outlets shall generally be avoided.

**Provide prominent warning label adjacent to outlets to state the voltage and frequency.**

16.11.2 Outlet Type

The type of outlets will depend upon the installation method as follows:

a) Wall Mounted Outlets:

400 Hz outlets shall consist of 200A 9 pin de-contactor type modified so that one of the 200A pins is converted into a multiple control pin allowing for interlocking arrangement and for provision of 28VDC “feedback” from the aircraft. The interlock should be such that power outlet cannot be energised without a plug being inserted into the outlet and an attempt of pulling out the plug will disconnect power supply to the outlet before the active and neutral pins of the plug and the socket are decoupled.

Adequate capacity 9-pin outlets (200A for “active” and “neutral” pins, and control pins capable of accepting a minimum of 2.5mm2 control cables), with provisions for interlocking
circuit and 28VDC control form the aircraft will be considered if submitted in accordance with specified procedures for alternatives.

b) Cable Reel Outlets:
A separate outlet is not required. The aircraft plug shall be directly affixed to the end of the trailing cable.

c) In-ground Outlets:
The Designer shall investigate alternatives and advise the selected solution.

All pins at the outlet and the plug shall be labelled. It is acceptable to have power supply earthing conductor connected directly to the body of the socket outlet. The earthing conductor does not need to be extended to the aircraft.

16.11.3 Aircraft Connected Indication
When 400Hz supply is connected to an aircraft it returns a 28VDC signal. This signal is used to determine if an aircraft is connected to the supply.

16.11.4 Aircraft Outlet Control
A stainless steel control box housing the following shall be located adjacent to the outlet:

a) Connect pushbutton
b) Disconnect pushbutton
c) Connected indicator
d) Power contactor
e) Associated control equipment.

The power contactor shall control the energisation of the outlet as follows:

a) The contactor shall be disabled if a plug is not inserted into the outlet.
b) When the Connect pushbutton is pressed the contactor shall close and remain closed for an adjustable period (1 – 60 seconds, default 20 seconds). During this time the Connected indicator shall flash.
c) If an aircraft does not connect during this time period the outlet shall de-energise.
d) If the aircraft connects while the outlet is energized the contactor shall latch closed and the Connected indicator shall stop flashing and illuminate.
e) If the umbilical is removed from either the outlet or the aircraft the outlet shall de-energise.
f) The outlet shall de-energise if the Disconnect pushbutton is pressed.

16.11.5 Aircraft Connection Configuration
Aircraft connectors shall comply with ASCC 25/19A and are to be configured to meet the aircraft requirements.
Generally the configuration of the socket on the aircraft is as follows:

- **Table 16.4: Socket Configuration on Aircraft**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A Phase, 400Hz.</td>
</tr>
<tr>
<td>B</td>
<td>B Phase, 400Hz.</td>
</tr>
<tr>
<td>C</td>
<td>C Phase, 400Hz.</td>
</tr>
<tr>
<td>N</td>
<td>Neutral, 400Hz. Connected to airframe</td>
</tr>
<tr>
<td>F</td>
<td>28VDC Aircraft Connected signal from aircraft. This signal goes ‘HI’ if the external supply has been connected to the aircraft connector</td>
</tr>
<tr>
<td>E</td>
<td>28VDC Enable External Power signal to the aircraft. If this signal goes ‘HI’ the aircraft will connect the external supply to the aircraft systems, provided other checks, e.g. phase rotation, are also satisfactory.</td>
</tr>
</tbody>
</table>

For the aircraft to connect the external supply the aircraft plug must therefore have an internal bridge between pins E and F.

The sequence of operations for connection is as follows:

a) The umbilical lead is attached to the aircraft, connecting the neutral to the airframe.
b) 400Hz supply is made available. The aircraft returns a 28VDC signal on Pin F.
c) 28VDC is returned to the aircraft on Pin E.
d) If checks within the aircraft on the quality of the 400Hz supply are satisfactory the 400Hz supply is connected to the aircraft systems.

**16.11.6 Workshop Outlets**

Workshop outlets shall comply with the requirements of DI(AF)AAP 7600.500-14M.

Workshop outlets shall be energised whenever the converter is running and connected.

**16.12 Cabling**

The performance of cabling systems at 400Hz differs from that at 50Hz and in particular:

a) The influence of cable reactance increases with frequency. This increases voltage drop.
b) Resistance increases marginally as a result of skin effect.
c) Reactance of the individual phase conductors is a function of the physical arrangement of the conductors. Asymmetrical phase conductor arrangements can result in different reactance’s for each of the three phases. For longer cabling runs this can have an effect on voltage balance.

**200/115V Systems**

For short runs, where the conductor reactance is a small component of the overall system impedance, standard 4 core cables can be utilised.

For longer runs specialist low-reactance 400Hz cables should be used to maintain phase voltage balance.
The earth should be run as a separate cable as its inclusion with the phase conductors will result in further asymmetry.

**960/555V Systems**

1000V rated three core cables are generally acceptable for most situations.

The earth should be run as a separate cable as its inclusion with the phase conductors will result in a degree of asymmetry.

**Umbilical**

Special configuration (Copper 7-core for power, 2 core per phase and one neutral, and 2-cores for control) low reactance cables (LRC) minimum 200A per phase capacity shall be provided for 400Hz umbilical’s.

Suitable cable storage facilities shall also be provided.

**Shielding**

Shielding should be considered where there is a potential for induction into adjacent systems.

**Termite Protection**

Termite protection (comprising a Nylon jacket and sacrificial over sheath) shall be provided to all underground cabling in regions subject to high termite activity. For those special types of cables that are not available with termite protection, double insulated cables may be used without Nylon termite protection provided they are enclosed in uPVC conduit.

**Cable Enclosures**

Cable enclosures and supports should preferably be non-ferrous.

Care shall be exercised when penetrating ferrous enclosures or building elements to minimise the effects of eddy currents.

**16.13 Defence Engineering Services Network (DESN) Monitoring Requirements**

Provide voltage free contacts to allow monitoring of the status of the system as follows:

a) Run, On-line, Fault status of each converter  
b) The status of surge diverters  

Where required by the FDB, the DESN will be required to monitor the frequency converter operation and provide exception reports when the frequency converters are being run excessively or not automatically shutting down.

**Load Shedding**

Where centralised 400Hz systems are supplied directly from substations separate load shedding and metering is generally required. Distributed 400Hz systems are usually supplied from the associated facility switchboard and are therefore load shed as part of the facility.
16.14 Standard Arrangement Drawings
- Figure 16.1: Typical 400Hz Outlet Schematic
Figure 16.2: Typical 400Hz Distributed System Configuration
Figure 16.3: Typical 400Hz Centralised System Configuration