



RP 12-5

ELECTRICAL SYSTEMS AND INSTALLATIONS - POWER SUPPLIES FOR CONTROL SYSTEMS

March 1998

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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group. Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Forward' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

BP Group RP 12 Series define BP general requirements for electrical systems, equipment, materials and installations.

BP Group RP 12-5 defines BP general requirements for electrical power supplies and distribution for control systems. Such control systems may include instrumentation, data collection, fire and gas detection systems, telecommunication equipment, computers and associated equipment and may be onshore or offshore, within established infrastructures or in remote locations.

Those power supplies which form an integral part of a control package do not come within the scope of this document, unless specifically required in other documentation.

Application

Text in *italics* is Commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Principal Changes from Previous Edition

This document is an update of BP CP 17 Part 5 (June 1986). The document now reflects current practice and has been reformatted into the Recommended Practice (RP) style.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP Group Recommended Practices, to assist in the process of their continuous improvement.

For feedback and further information, please contact Engineering Practices Group, BP International or the Custodian. See Quarterly status List for contacts.



1. SCOPE

- 1.1 BP Group RP 12 series define BP general requirements for electrical systems, equipment, materials and installations.
- 1.2 BP Group RP 12-5 defines BP general requirements for electrical power supplies and distribution for control systems. Such control systems may include instrumentation, data collection, fire and gas detection systems, telecommunication equipment, computers and associated equipment and may be onshore or offshore, within established infrastructures or in remote locations.
- 1.3 Those power supplies which form an integral part of a control package do not come within the scope of this document, unless specifically required in other documentation.

2. GENERAL

2.1 Use of This Recommended Practice

This Recommended Practice shall be used in conjunction with BP Group [RP 12-1](#).

2.2 Quality Assurance

Verification of a vendor's quality system is normally part of the pre-qualification procedure, and is therefore not specified in the core test of this practice.

Further suggestions may be found in the BP Group RPSE's Introductory volume.

3. CLASSIFICATION OF CONTROL SYSTEMS AND THEIR POWER SUPPLIES

3.1 General

- 3.1.1 Control systems and their power supplies shall be selected Class A, Class B, or Class C to reflect the following factors:
 - (a) The required availability of each part of the overall system.
 - (b) The importance of the connected load in terms of overall plant operation.
 - (c) The quality and reliability of the primary power source.



Class A systems typically are those for which the highest degree of security is required. Historically these have required two batteries and two rectifiers which would indicate that any one from the four elements could provide power. However this historical consideration also allowed blocking diodes between the rectifier/battery infeed and the output bus in order that a battery/rectifier line fault would not constitute a bus fault. Therefore the historical options often came to any one of two power supplies.

Class B systems are those which would warrant one battery and an alternative mains derived supply. In d.c. terms this was one battery and a rectifier.

Class C systems were those which could operate from mains power.

The approach used in this recommended practice is to continue the historical approach but to provide a more logical and rigorous method of selection for the power supply system security.

3.1.2 The control system loads shall be tabulated and their classification defined. The definition of the classes are given in 3.2 to 3.4.

3.1.3 Emergency and shutdown systems shall be classified Class A.

ESD systems are those that require the highest order of power supply security. The nature of these systems is that on power loss the ESD system operates and the plant is shut down.

3.2 Class A Systems

Class A systems are defined as those which by malfunction or failure can cause any of the following:-

(a) A shutdown of the whole or major part of a plant or process.

Some equipment requires a single power source and then sub-divides this for multiple purposes. Where any of these purposes are classified as Class A, then the entire system should be classified Class A, except where 4.9 is applied.

(b) A failure to shut down, under emergency conditions, the whole or major part of a plant or process.

A notable exception to this rule is the electrical power system circuit breaker arrangements which are often shunt coil tripped. The reasoning for this is that the electrical system is set up for discrimination and failure to trip of one faulty unit would mean that an upstream unit would subsequently trip.



- (c) A loss of monitoring facilities on any equipment which may itself cause a shutdown of the whole or major part of a plant or process.

Flame failure devices or monitoring equipment on certain items of machinery which are critical to the whole or major part of a plant should be considered as Class A systems.

- (d) A loss of alarm annunciation for fire and gas detection as defined in BP Group [RP 24-1](#) and BP Group [RP 24-2](#).
- (e) A loss of alarm annunciation for any other system specified by BP such as burner logic alarms etc.

Alarm annunciation facilities in addition to those for fire and gas detection, which may be considered as Class A systems, can include:-

- (i) Shutdown annunciators
- (ii) Major machinery alarms, etc.

3.3

Class B Systems

Class B systems are defined as those which by malfunction or failure can cause any of the following:

- (a) A degradation of normal control or monitoring of the plant or process where alternative methods of control, such as local plant control panels, handwheels etc are available.

This requirement is typified by systems such as:-

A computer control supervisory system where instrumentation back-up exists in the event of failure of the computer system. Control room operation where a panel local to the plant exists.

The form of back-up control envisaged will usually lead to a demand for a temporary increase in operational staff which the operational organisation has to meet and this should be considered in system design. Whilst it may be theoretically possible to operate a plant from handwheels, this is unlikely to be considered a 'normal' method of control due to manning constraints. (Process considerations may also make handwheel operation

- (b) An acceptable temporary loss of control of the whole or part of a plant or process.

Typical of this is for 50% of central control room screens to be supplied from one class B UPS system. Where the UPS output fails, the remaining 50% of screens is from a second class B UPS.



- (c) A loss of alarm annunciation facilities not covered by 3.2.

3.4 Class C Systems

Class C systems are defined as those which by malfunction or failure cannot seriously impair the continued safe operation of a plant or process, or the ability of the operator to monitor and control critical features of a plant or process.

A typical example here is for the illumination local to an instrument which needs to be lit in order to make the instrument easier to read. Other examples could be chart recorders and logging instruments which provide trends for later analysis but which do not influence the immediate plant operation.

4. BASIC DESIGN REQUIREMENTS

- 4.1 D.C. power supplies should comply with BP Group [GS 112-11](#) and a.c. power supplies should comply with BP Group [GS 112-10](#).

Group Standards are provided for guidance. These offer a ready way for the power supply systems to be ordered and for alternative quotations to be sought but new technological trends in power supplies for these purposes should not be discounted. Further, rotating UPS arrangements could be usefully considered, particularly for the larger or intermittent load types of demand or where diesel engine back up is also part of the UPS system provisions.

- 4.2 Equipment and system supply capacities shall take account of the effects of transients, start-up loads and switching surges. Systems and equipment should generally be capable of supplying a minimum of 110% of an estimated maximum load which includes allowances for harmonic and transient loads.

Where static inverters are employed the transient effects may require that the inverter is rated larger than the normal load capacity intended may indicate. This would be in order that the inverter would operate within its design parameters when the largest block of loads is switched on or transferred to the UPS.

- 4.3 On systems where it is known that a future expansion will occur, the estimated maximum demand shall reflect the anticipated future requirements.

Clearly the future requirement needs to be considered in the light of the transient performance too. This is not merely a kVA capacity count. The amount of spare capacity for future expansion needs to be specified (or at least approved) by the project.



- 4.4 The security and configuration of the supply and distribution equipment shall be consistent with the requirements of the overall control and standby supply philosophy.

There is no reliability based design criteria for power supplies to control/instrument systems existing at the time this document is written. The general considerations around the need for security of supply in fact is contained within this document. Although sensible that the control system power supply security should not be overdesigned bearing in mind the importance of the sub process it must be realised that the importance of power to the overall output can change with time and it may not be advisable to underdesign the installation without a clear and feasible way of upgrading the security in the future.

- 4.5 Supply and distribution systems shall be designed specifically to avoid the generation and/or transmission of induced electrical interference which could affect the safe and correct operation of any control equipment.

Electrical equipment incorporating contactors with solid state circuitry may be adversely affected by UHF radio communication devices operating in close proximity (less than approximately 100 mm). Field trials are therefore recommended in these circumstances to check that maloperation will not occur. Not also the needs of [RP 30-8](#) which relates to the EMC issues and emerging specifications and European Directives.

- 4.6 Voltage levels of supplies to all equipment shall be selected according to a sensible appraisal of systems which may be already existing on a plant and on appropriate National Standards. Supplies to control systems should not exceed nominal voltages of 120V r.m.s. a.c. or 120V d.c.

Maximum nominal voltages of 120V rms a.c. or 120V d.c., have been selected to provide standardisation and appropriate personnel safety margins. The latter is particularly relevant where there is limited space or access to equipment such as control panels. Nevertheless, it is appreciated that some proprietary equipment or cable limitations may require higher voltages to be used. These should be avoided whenever possible and only adopted when there are no alternatives. The use of higher voltages must be subject to specific project approval.

- 4.7 Wherever possible, power supply equipment shall be located in a nonhazardous area.

If this proves impossible then the electrical equipment installed in hazardous areas shall be selected according to the appropriate National or Internationally accepted standards. Further information on this issue is contained in [RP12-2](#)

- 4.8 Where the location of the installation is classified as non hazardous but such classification is dependent on the integrity of other equipment, e.g. a continuously purged module forming part of an offshore platform, the



power supply system shall incorporate automatic de-energisation equipment. Purging equipment shall satisfy the requirements of the appropriate national or international code such as IEC 79-14.

Installations such as Ex(p) as implied above should be certified in accordance with the requirements of national or international standards. RP 12-2 provides further guidance on policy associated with the use of electrical equipment in hazardous areas. Where offshore installations are involved there are often designs and procedures which may be project specific. (E.g. the need for gas detection shutdown in the event of ventilation failure.) The project specific issues shall be taken into account when designing and installing this equipment.

4.9 For Supervisory Control and Data Acquisition (SCADA) or Distributed Control Systems, power shall be supplied by either of the methods A or B detailed in 4.9.1 and 4.9.2.

It is generally considered preferable to supply these systems with d.c. power. However, some manufacturers are unable to provide equipment to this specification and in these cases a.c. power has been found to be acceptable provided the need for high reliability has been addressed.

The two methods suggested below apply to different manufacturers. Method A is appropriate to Honeywell whilst Method B applies to Foxborough. For other manufacturers, a combination of these two methods may be appropriate. The overriding concept is that no single failure in the power source shall prohibit the control system from operating the plant.

4.9.1 Method A

Central controllers shall be arranged into not less than two groups. Each group shall be capable of maintaining the control system operation. Where possible, each group shall have an individual and dedicated Class A d.c. power source. Where d.c. is not technically acceptable to the manufacturer of the control equipment, power shall be provided via invertors to a minimum Class B integrity.

Clearly an overall Class A may be assigned to a control system employing duplicate computers (i.e. main and standby) each supplied by a separate Class B power supply.

Peripheral controllers shall have individual and dedicated Class B d.c. supplies. These will normally be designed to form an integrated element of the manufacturer's system. Where d.c. is not technically possible, a.c. may be permitted subject to approval of the reliability of the system.

Approval should be by the contractor or designer of the power supply system as meeting the overall reliability needs of the project.



Common mode failure shall be limited for one single incident to either one of the central control groups or a single peripheral controller.



4.9.2 Method B

Two separate 100% power sources shall be provided which should be d.c. Class A or a dual redundant a.c. inverter arrangement.

A dual redundant inverter system with mains by pass has been considered to offer an acceptable level of reliability where a.c. power supplies have been used.

Each control equipment shall have dual redundancy and provision for connection to each of the power sources. Upon failure of one of the sources, the controller shall be capable of continued operation from the alternate. Power circuits should be arranged such that loads are balanced between the two sources under normal conditions.

It is considered preferable that the inverters operate in parallel redundant mode rather than in hot standby mode. This is not a hard and fast rule but conceptually it is better that the inverters are thermally "warmed" up and ready to suddenly take over half the load rather than being ready to take over the full load.

4.9.3 Whichever system is adopted, maximum use shall be made of the manufacturer's proprietary cabinet systems provided that they meet the criteria in 4.9.1 or 4.9.2.

Specifying something unusual to an equipment manufacturer is not considered to offer good practice because the manufacturers price will escalate rapidly for special designs. Further, subsequent spares and servicing would constitute special arrangement which makes the annual cost escalate too.

4.9.4 For some applications, particularly central control equipment requiring an a.c. power source, it may be more economical to provide individual invertors without mains bypass. Providing satisfactory redundancy is obtained from the integrated control systems, this is permitted.

Owing to the problems that have been experienced with mains by-pass devices, these have been considered a source of unreliability. Some installations have removed the automatic feature of the mains by pass in favour of a manually operated by pass or even no by pass at all. These systems usually require two dual redundant inverter installations (with no by pass) with half the load being shared between the systems. It is necessary for the plant to continue operating with one system shut down for maintenance. Note that a similar reliability level could be obtained by two Class B UPS systems each sharing half the load.

4.10 The calculated mean time between failures and the on-line availability of the power supply equipment shall be assessed and shall be declared to the operator.

A mean time between failures of greater than 6 years should be sought for Class B; Class A should have at least 15 years.



All common mode failure conditions should be avoided where feasible. For example the d.c. parts of dual fed battery inverters should not be interconnected. Similarly the failure modes for any static switch should be examined to determine whether any reliance is placed on one of the infeeds for continuance of supply, which in consequence could thus disconnect all the output in event of its failure (a common mode failure).

4.11

All power supplies shall satisfy the requirements of the connected system and equipment at all times and for all parameters, e.g. voltage, frequency, rate of change of frequency, RF content, maximum interruption time, power factor and harmonic content.

Control system power supply tolerances should be specified by and agreed with the manufacturers of the equipment to be fed by the power supply. These tolerances should include the items given in the following table and in the absence of any specified data, the criteria indicated are recommended.

ITEM	D.C	A.C.
Voltage	+10%, -20%	+1%, -1%
Frequency	N/A	Synchronised Mode 48Hz 52Hz Freewheel Mode +0.5Hz, -0.5Hz
Rate of Change of Frequency	N/A	0.2Hz/s
R.F. Content	See BS EN 55014	See BS EN 55014
Interruption Time	N/A	10 ms
Harmonic Voltage Content Current	5% Ripple	5% r.m.s. total See notes
Voltage Recovery After 100% Load Step	N/A	Assuming Power Factor 0.7 lag. to 50% Normal : 1 cycle to 70% Normal : 2 cycles to 100% Normal : 4 cycles

The recommendations for d.c. supplies should apply to both Class A and Class B supply systems.

Particular attention should be paid to harmonic generation in a.c. supplies and both the supply equipment and the load equipment should be examined in this regard. The harmonic content of the output voltage waveform of an inverter can be maintained within the stated tolerance when supplying a linear load of the relevant rating and power factor. However, excessive harmonic generation in the system can occur when certain types of 'switched' instrument power pack loads are connected. This can necessitate redesign of the inverter output filter equipment and/or a reduction in inverter rating particularly for small (less than 10 KVA) single phase inverters in order to maintain the voltage harmonic distortion within tolerance.



Tests on systems supplying a range of typical loads have demonstrated that the level of harmonic generation in the inverter output current can be up to 40% of the fundamental for the 3rd harmonic, 30% of the fundamental for the 5th harmonic and 7% of the fundamental for any one of higher order odd harmonics. Where non linear loads are anticipated, these figures may be used as guidance when definitive data for an individual project is not available. The supply equipment manufacturer should confirm that the specified equipment can withstand distortion of the output current of this magnitude on a continuous basis without any deleterious effect or any reduction in the equipment rating.

For Class B a.c. supplies using the primary a.c. source as the standby circuit, raw mains frequency variations of between 48 Hz and 52 Hz may occur on a nominal 50 Hz system. The normal circuit from the inverter will be designed to remain synchronised with the standby circuit within these limits unless specified otherwise and thus equipment fed by the power supply may experience these frequency variations. In the event that load equipment requires its supply frequency to be maintained within more constrained limits, such as 49.5 Hz to 50.5 Hz for example, then this should be specified by the manufacturer of the equipment to be fed by the power supply. The power supply equipment should be specified so that the inverter operates in the 'freewheel' mode when the standby circuit experiences frequency values outside the specified limits.

4.12

The supply system design shall prevent damage to, or malfunction of, connected apparatus from transients. It shall withstand any effects, such as output current waveform distortion, resulting from the non-linear loading characteristics of the connected system.

There may occur from time to time, voltage transients on the power supply system which powers the Control System power supply equipment. The equipment should not allow these transients to be passed onto the output voltage waveform. It is possible that when a UPS is operating in mains by pass mode (perhaps during maintenance of the UPS system) there could be transients that would be passed directly to the output. A project specific view needs to be taken for this situation. Should the power supply system be so prone to transient disturbances that would cause problems to the Control systems which receive a supply from the power system, then some mitigation for the mains by-pass needs to be considered. Alternatively an arrangement not reliant on mains by-pass for maintenance could be contemplated.



5. PARTICULAR REQUIREMENTS: CLASS A POWER SUPPLIES

- 5.1 Class A power supplies shall automatically maintain a continuously uninterrupted electricity supply within required control system tolerances upon failure or deterioration of the primary source, or any other item of the power conversion equipment, for a period of 30 min or as otherwise specified. They shall be separate and independent from other supplies except the primary a.c. source.

Class A control system power supplies are required to be of the highest integrity and in consequence they should preferably be d.c. A similar a.c. configuration requires the parallel operation of two or more invertors into a common distribution busbar. Due to the technical complexity of multi inverter operation these arrangements cannot be considered to have the same integrity as d.c. However, there are occasions when a.c. power of the highest possible integrity is required and in these cases a dual inverter arrangement is recommended.

Guidance given on 6.1 regarding the standby time and associated battery capacity may also be applied to Class A supplies.

- 5.2 Duplicate fully rated rectifier-battery systems shall be used. The a.c. supplies to the rectifiers shall be supplied from different switchboards or different busbars of the same switchboard. Where standby or emergency generation is available, one of the a.c. supplies to the rectifiers shall be supplied from the generator busbar.

It has been found that unsynchronised power supplies to UPS dual systems can cause the inverter controls to "hunt". Prevention of this should be considered at the design stage.

- 5.3 Class A power systems shall be designed such that upon the occurrence of a fault in any one incoming power circuit, the faulty circuit shall be isolated without supply disruption and the alternative supply shall then maintain the load within the defined tolerance.

Clearly for d.c. power supply systems this requirement will necessitate the installation of blocking diodes at the paralleling point. However the voltage drop through the diodes can cause problems in meeting the tolerances necessary for output voltages. Where this has been the case the use of blocking diodes has sometimes been dispensed with in the interests of economy. Reduction in reliability has been found acceptably small.

- 5.4 Each rectifier shall be capable of supplying the complete load within the specified control system tolerances.

This often requires that the charger is a high quality device with inherent ripple reduction.



6. PARTICULAR REQUIREMENTS: CLASS B POWER SUPPLIES

- 6.1 Class B power supplies may be d.c. or a.c. and, after primary supply loss, shall automatically maintain continuity of electricity supply within the specified control system tolerances for a period of 30 min, or as otherwise specified. Normal and standby circuits shall be provided. The changeover on failure of the normal circuit shall not affect process operations. The changeover time, where applicable, shall be suitable for the required performance of the driven equipment and shall be not greater than 10 msec.

On offshore installations, control system power supplies for life support systems including telecommunications and fire and gas alarms should always have individual consideration and a minimum standby time of one hour. Where necessary, there should be consultation with the appropriate certifying or insurance authority.

- 6.2 For those systems requiring d.c. power, the normal circuit shall be via a rectifier-battery system and the standby circuit via a rectifier.

This ensures that the battery is charged. When the normal system fails the standby rectifier may take over the load and the battery charging albeit with the battery charge regime slightly reduced from that enjoyed by the main charger.

- 6.3 For those systems requiring a.c. power, the normal circuit shall be via a rectifier-battery-inverter. The standby circuit shall be connected to the primary a.c. source. The a.c. supplies to the normal and standby circuits shall be supplied from different switchboards or different busbars of the same switchboard. Where emergency generation is available, one of the circuits shall be supplied from the generator busbar.

Where an emergency generator is not available, the supplies must be obtained either from:-

- (a) Both sides of a parallel fed main distribution board.*
- (b) Two independent switchboards which are not necessarily operated in parallel.*

- 6.4 Class B a.c. power supplies should not produce any transients due to changeover which could cause mal-operation of the connected equipment.

The choice for change over of output supplies are either via a synchronised arrangement for “bumpless” transfer or via a break-before-make system. Modern UPS systems should maintain synchronism with the by-pass supplies except where the voltage and frequency is varying to an unusual degree.



7. PARTICULAR REQUIREMENTS: CLASS C POWER SUPPLIES

- 7.1 Class C power supplies should normally be a.c. and fed from a primary source without standby.

8. BATTERY SELECTION

- 8.1 The type of battery chosen shall take into account the following:-

- (a) Existing installations, if any.
- (b) Capital costs and replacement costs.
- (c) Required life.
- (d) Size and weight.
- (e) Reliability.
- (f) Robustness.
- (g) Charging method.
- (h) Temperature effects.

Life expectation, capex, size and weight all affect the economics in a direct manner. Charging method and temperature effects can affect the rating of the battery and also its reliability to perform. Robustness and reliability reflect on the necessary annual expense that must be made to maintain the system in an operational form. The battery economics should consider alternatives covering the full life of the installation. The lowest capital cost solution need not be the optimum choice if reliability is made low or annual maintenance and early replacements are necessary.

- 8.2 The re-charge time of batteries shall be less than 12 hours. Special charge arrangements may be employed to achieve this according to the classification of the system. Class A systems shall not be boost charged.

To achieve a recharge time of the battery to the required capacity within 12 hours, one of the following techniques will have to be adopted:-

- (a) *Sizing of the cell and charger capacity based on a single normal charging voltage. It should be assumed that the cell electrolyte top up periods will be 52 weeks and the charging voltage selected to enable recharging capacity to be achieved within 12 hours.*
- (b) *Sizing of the cell and charger capacity based on a dual normal charging voltage. This should be arranged with automatic selection of the higher voltage to achieve recharging within 12 hours and reversion to the lower voltage after that period.*

In establishing the lower normal charge voltage, it should be assumed that the cell electrolyte top up period will be 52 weeks. The higher voltage level should not exceed the maximum voltage tolerances of the control system and equipment.



(c) On-line fast charging using counter e.m.f. diodes to ensure that the maximum voltage tolerances of the control system and equipment are not exceeded.

(d) Off-line fast charging.

As Class A power supplies require the highest possible security of battery back-up system, it is recommended that method (a) be adopted since it will have the lowest probability of component failure.

For Class B power supplies consideration may be given to either a recharge period longer than 12 hours coupled with use of method (a), or the use of methods (b) or (c). Of the latter methods, (b) will give the greatest security of battery back-up system since failure of the charging

8.3 Where possible, provision should be made for determining the charge state of all batteries without affecting plant operation.

The following items in respect of battery condition should be determined:-

- (a) Charge.
- (b) Cell voltage.
- (c) Electrolyte level.
- (d) Cleanliness and soundness.

With nickel cadmium cells, the determination of some items will not always be possible.

The electrolyte level may not be readily checked with batteries made with certain case materials.

With sealed Lead Acid Batteries the only sure way of assessing the battery capacity may be the undertake a discharge test on an annual basis.

8.4 Specific measures shall be taken to minimise gassing and loss of electrolyte at all charging rates, particularly at float charge levels.

The use of catalytic gas recombination caps is encouraged. Excess electrolyte systems could be considered for breathing Nickel Cadmium systems to also extend battery maintenance periods.

8.5 Where installations are subject to vibration or movement, battery cell cases should be steel or moulded rubber.

Pasted plate battery designs are unsuitable for conditions of high vibration owing to the higher probability of material loss from the plates. NiCad batteries offer the best performance for harsh vibration conditions.



- 8.6 Valve Regulated Lead Acid (VRLA) batteries should be installed with allowances made for temperature equalisation and maintenance checking to be made. Harmonic and ripple effects that the batteries will experience should feature specifically in the design of the charger and filtration units associated with the system.

There is experience of early failure of some cells. It has been found that there needs to be space allowed around the battery cells as installed to allow air circulation and temperatures to stabilise. It should be noted also that although low maintenance there remains a need for the regular checking of these batteries and hence allowance should be made for the cell terminals to be accessed safely and adequately. There needs to be clear advice given by manufacturers as to necessary condition monitoring and discharge testing in order that the life and reliability of the installation are maximised.

9. DISTRIBUTION SYSTEM AND CIRCUIT PROTECTION

- 9.1 Separate feeders shall be provided where control system equipment is duplicated.

Separate cables increase the reliability of the Control System. It is noted that a common busbar may be the source of both cables, however the overall system reliability may be considered to be satisfactory.

- 9.2 Where the operator interface is made up of a number of similar operating stations, distribution shall ensure that an individual sub-circuit failure does not cause outage of more than 25% of the operator stations, or one station in the case of less than four.

It is recognised that there may be common equipment where a single fault could mean loss of all of the operator interface screens (e.g. a power supply system busbar.) The susceptibility of the common component to a fault condition shall be assessed as part of the overall supply system security.

- 9.3 Spare circuits and sub-circuits shall be provided as appropriate throughout the distribution system to permit utilisation of any spare capacity.

The amount of spare should be assessed on a project specific basis but as a general rule a 25% spare provision would be usual for new installations.

- 9.4 Power supply equipment shall be located as close as practicable to the building or facility in which the primary control equipment is located.

The reasoning for this is that reliability is increased where cabling distances are small. Further the cost of the distribution is kept to a minimum by having short cable routes.



- 9.5 As far as is practicable, power distribution and sub-distribution boards should be mounted adjacent to the relevant equipment.

Where the power distribution is adjacent to the supplied equipment, the cable distances are kept to a minimum and reliability and costs are generally minimised.

- 9.6 Where control room equipment which is independent of a control system is powered from the same supply, a separate sub-circuit and distribution board shall be provided.

Keeping the supplies separate makes faults on equipment which is unrelated to the control system affect only that equipment.

- 9.7 Each circuit, sub-circuit and piece of peripheral equipment of a control system power supply shall be individually protected. Where unearthed systems are provided, all poles shall be fitted with protective devices. Duplication of protective devices when they are provided in individual items of equipment should be avoided if possible.

The current which flows into a short circuit fault will depend upon the impedance of both the source supply (e.g. internal battery resistance for d.c. systems) and the impedance of the fault itself. The voltage will also distribute itself in direct proportion to these impedances.

For a short circuit without fault impedance, all of the voltage drop occurs in the supply system and the fault current is at a maximum level. If the short circuit occurs on a distribution system, the voltage will collapse throughout the complete system downstream of the fault and for a large part of the system upstream of the fault. In order to minimise the effect of this voltage to each instrument, faults of this nature must be isolated as rapidly as possible. Past experience indicates that providing the fault is isolated at a distribution board within 10 msec, only the faulty circuit will be affected and the remaining circuits connected to the distribution board will function normally.

The most satisfactory way of achieving this rapid clearance of faults is the use of cartridge type fuses for circuit protection. If the fault current is sufficiently high, the fuse will rupture or 'blow' instantly (under 5 msec). This phenomenon of instant operation is known as 'cut off' operation and this criterion may at times limit the maximum size of fuse that can be utilised on the distribution system.

Fuse rating is particularly critical on inverter fed systems since these devices cannot generate large currents under fault conditions.

Some manufacturers may offer cost attractive schemes whereby a mains bypass circuit is used to rupture fuses under fault conditions with the supply reverting to the inverter when the fault is thus isolated. The systems with this feature are inherently less reliable than having the inverter capable of fault clearance, owing to the necessity to revert to inverter feed after the fault has been cleared. Such arrangements should not be considered for these power supplies which are often the most critical link in a control system.



In particular, 9.7 specifies that the supply system shall produce sufficient fault current, with its output voltage being maintained at 75% (i.e. 25% internal voltage drop within the supply equipment) to cause 'cut off' operation of the protective fuses. If the voltage is maintained above 75%, most relays and equipment will function normally for a short period and 'cut off' operation of the protective device is not required.

The use of moulded case and miniature circuit breakers is not recommended but may under some circumstances be acceptable. The operating time of these devices is comparatively long (greater than 10 msec), and voltage sensitive loads on a distribution system may therefore be affected before these devices operate.

In addition existing national and international standards for moulded case and miniature circuit breakers do not provide adequate specification of their protective characteristics to ensure effective series discrimination between successive devices within a circuit, particularly between circuit breakers and fuses.

- 9.8 Where a shutdown system comprises a number of individual devices and a supply failure to part of the system could lead to a hazardous condition, then the complete system only, rather than the individual items, should be protected.

The arrangement of feeding individual components with different power supplies means that withdrawing any one of the fuses could shut down the plant. If the numerous components all have the same power supply, although all of the devices lose power for a fault on any part of the cable system giving the looped supplies, the effect on the plant is no worse than if only one of the devices were to lose the power. Therefore reliability is increased by having numerous items on a single power supply in this instance.

- 9.9 Protective devices in control system power distribution circuits shall be time and current graded to maintain discrimination. Clearance of faults which result in greater than 25% regulation of voltage shall be achieved within 10 msec.

It has been found historically that supply losses for up to 10mS can be generally withstood without plant shutdown. However this requirement is job specific and could be reviewed for the specific project.

For UPS systems a mains by-pass is often stated as the power to achieve a fuse rupture within 10mS. Refer to comments under 9.7 above for related information on this topic.

- 9.10 Cartridge type fuses should be used throughout control system power supplies. Protective circuit breakers e.g. miniature circuit breakers and moulded case circuit breakers, may be used in the final sub-circuits provided it is demonstrated that the incorporated protective devices will discriminate satisfactorily with all other protective devices in the system and satisfy the requirements of 9.9.



Historically only cartridge fuses could be relied upon to yield rapid and reliable fault clearances. However as MCB technology develops these devices may be able to offer reliable and repeatable service.

- 9.11 The sub-circuit loads from Class A, Class B and Class C power supplies shall be segregated and protected separately.

- 9.12 Power supply system outputs shall be so connected as to ensure that looping of the earth and neutral connections cannot occur between computer and associated control systems and other equipment. Where necessary, isolating transformers shall be used.

It is often necessary to ensure that earthing arrangements which may be standardised for some items of equipment provided with a power supply from this system do not allow the possibility of "earth loops". Such loops in the earth conductor has been found to cause interference to some control systems. Neutral connections may similarly affect control systems if there is a possibility of "loop currents."

- 9.13 For large instrumentation and control installations, e.g. computer suites and associated peripheral equipment, dedicated power outlets shall be provided for computer test equipment within the computer suite. The supply to these outlets shall be from a protected sub-circuit of the appropriate computer system supply.

Providing such dedicated supplies for test equipment avoids the need to have temporary cables spanning floorways and removes the concerns over power supply interference during the testing.

- 9.14 Isolation of each item of peripheral equipment or sub-system on control system power circuits shall be provided by a switching device or disconnecting plug as appropriate, with due regard to the particular voltage and current level concerned, located within the equipment or sub-system.

The electrical isolation of all pieces of equipment should be by double pole switching in order that inadvertent "neutral loops" and sparking of the neutral will not occur when testing or doing other work during the isolation.

- 9.15 All switches and protective devices shall comply with the appropriate national standard and shall be clearly labelled regarding service and rating.

A colour code is an acceptable arrangement for indicating the rating of devices provided it is clearly marked as part of the equipment.



10. EARTHING

- 10.1 Earthing systems and equipment should generally be arranged so that the installation conforms with BP Group [RP 12-16](#).

Power supplies for control and instrumentation devices should generally provide the means by which the protective earth is connected.

- 10.2 Single phase a.c. control system power supplies shall be earthed on one pole which shall be permanently and solidly connected to the general power system earth.

Some control systems are thought to require a reference earth or protective earth which is connected to a separate earth pin not interconnected with the main earth. This practice is not considered to offer a safe arrangement and should be avoided.

- 10.3 Unless the control system requires one pole to be earthed, d.c. power supplies should be unearthed and provided with an integrated earth fault detection scheme which shall maintain earth potential at the midpoint of the supply voltage when there is no earth fault on the system. The earth fault detection scheme shall be:-

- (a) Set to a value such that it will not be operated by the normal system leakage.
- (b) In the event of a single solid earth, the magnitude of the fault current shall be such that circuit protection devices (fuses) do not operate.
- (c) In the event of a single solid earth, the magnitude of the fault current shall be such that 'normally held on' circuits are not permanently energised by the earth fault current.

The earth fault detection system needs to be effective because if two earth faults occur on the same pole localising the problem can prove difficult. Further if a second earth fault occurs on the other pole but on a separate circuit, then both circuits will be lost and the plant outage problem exacerbated. Despite these potential problems an unearthed d.c. power supply system is considered to offer higher reliability.

- 10.4 Special earthing arrangements may be required for telecommunication power supplies where radio frequency currents may be present.

Radio transmitters and their associated transmission lines generate standing waves and the standing wave voltage peaks/troughs can be close together (metres apart - depends on the wavelength). For radio frequency transmission lines it is therefore



normal practice to earth the outer of the coaxial cable or waveguide as frequent as possible along its entire length to avoid high potential voltage differences to earth. In some cases where radio frequencies may be induced into power supply cables and they are close to (say) high power transmitters then the same practice should apply. i.e. earthed more frequently along the entire length of the cable. This is really only applicable to power supply cables for HF (3-30MHz i.e. 10-100m) transmissions where the transmit RF power is high and the induced voltage could also be high (i.e. greater than 50v). Usually the practice is to keep power cables away from RF transmitters and cables so that this problem does not exist.

11. MONITORING AND ALARM SYSTEMS

- 11.1 Alarm systems should generally comply with BP Group [RP 30-5](#).
- 11.2 Alarms shall be provided to indicate at a manned control point, malfunction of any major unit of any normal and standby power supply and distribution system.
- 11.3 Power supply equipment shall incorporate sufficient alarm and diagnostics on a local-to-equipment panel to enable rapid identification of a fault or to confirm a healthy condition. The extent of diagnostic detail and its presentation should be appropriate to the project which the equipment supports. Any local-to-equipment alarm diagnostics shall always be capable of common remote alarm initiation.

The purchase standard for this type of equipment, [GS 112-10](#) or [GS 112-11](#) contains indications of the alarm needs. Clearly the more complex the equipment the greater is the expectation that an alarm indication, perhaps detailed local to the equipment but grouped for remote alert purposes, will be specific as to the nature of the problem and of the need for a solution to the problem.

- 11.4 Remote signalling of alarm conditions should be classified into the following categories:-

- (a) Emergency Trip.
- (b) Urgent Alarm.
- (c) Information.

There should always be provided a grouped remote alarm facility rather than providing numerous remote repeat alarms because there is little that can be achieved from a control room in remedying the condition of the alarm. However should this situation change, perhaps due to the amount of status and control information that can be given to a remote point, the need for remote indication could be revised to allow for the more detailed presentation of the overall system status as part of the alarm screen.



DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSEs Introductory volume.

Abbreviations

BS	British Standard
ESD	Emergency Shutdown
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardization
UPS	Uninterruptable Power Supply
RF	Radio Frequency



LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Reference standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

International Standards

[IEC 79-14](#) Electrical Apparatus for Explosive Gas Atmospheres-Electrical Installations in Hazardous Areas (other than mines)

British Standards

[BS EN 55014](#) Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purposes, electric tools and similar electric apparatus

BP Group Documents

BP RP 12-1	Electrical Systems and Installations - General
BP RP 12-2	Electrical Equipment in Flammable Atmospheres and Combustible Dusts
BP RP 12-16	Earthing and Bonding
BP RP 24-1	Fire Protection - Onshore
BP RP 24-2	Fire Protection Offshore
BP RP 30-5	Instrumentation and control - Selection and use of equipment for instrument protection systems
BP RP 30-8	Instrumentation and control - Electromagnetic Compatibility for Instrument and Control Systems
GS 112-10	Secure Static A.C. Power Supplies for Control Systems
GS 112-11	D.C. Power Supplies

