

DEP SPECIFICATION

APPLICATION OF PROTECTIVE FUNCTIONS FOR ELECTRICAL SYSTEMS

DEP 33.64.10.17-Gen.

September 2011

DESIGN AND ENGINEERING PRACTICE



© 2011 Shell Group of companies

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the recommended standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs, they shall be solely responsible for such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal.

The right to obtain and to use DEPs is restricted, and is typically granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE	4
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	4
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES	7
1.6	COMMENTS ON THIS DEP	8
2.	DESIGN AND ENGINEERING PRINCIPLES	9
2.1	STANDARDS, CODES AND REGULATIONS	9
2.2	OPERATIONAL SAFETY, RELIABILITY AND MAINTENANCE	9
3.	GENERAL PROTECTION AND SAFEGUARDING REQUIREMENTS	11
3.1	BACKGROUND	11
3.2	PROTECTION PHILOSOPHY	11
4.	ELECTRICAL SYSTEM STUDIES	12
4.1	PROTECTION COORDINATION STUDY	12
4.2	SYSTEM SETTING MANAGEMENT	13
4.3	STUDY TIMING	13
5.	INSTALLATION AND DESIGN REQUIREMENTS	14
5.1	GENERAL REQUIREMENTS	14
5.2	EMISSION REQUIREMENTS FOR PROTECTION RELAYS	14
5.3	IMMUNITY REQUIREMENTS FOR PROTECTION RELAYS	14
5.4	PERFORMANCE CRITERIA	15
5.5	POWER SUPPLY FOR PROTECTION RELAYS	15
5.6	TRIPPING SCHEMES	16
5.7	NUMERICAL RELAYS	16
5.8	APPLICATION OF NUMERICAL RELAYS	17
6.	CURRENT AND VOLTAGE TRANSFORMERS	18
6.1	CURRENT TRANSFORMERS	18
6.2	VOLTAGE TRANSFORMERS	19
7.	EQUIPMENT PROTECTION SCHEMES	20
7.1	PROTECTION OF HV CABLES	20
7.2	PROTECTION OF OVERHEAD LINES	21
7.3	PROTECTION OF HV/LV TRANSFORMERS	24
7.5	PROTECTION OF INDUCTION MOTORS	32
7.6	PROTECTION OF OTHER INDUCTION MOTORS	35
7.7	PROTECTION OF SYNCHRONOUS MOTORS	36
7.8	PROTECTION OF GENERATORS	37
7.9	BUSBAR PROTECTION	40
7.10	HARMONIC FILTERS AND CAPACITOR BANKS	41
8.	SYSTEM PROTECTION	43
8.1	FREQUENCY DISTURBANCES	43
8.2	ISLANDING	43
9.	BASIS OF PROTECTION SETTINGS	45
9.1	GENERAL	45
9.2	OVERCURRENT AND EARTH FAULT RELAYS (ANSI 50, 51, 50N, 51N, 67, 67N)	45
9.3	MOTOR THERMAL OVERLOAD RELAYS (ANSI 49)	47
9.4	DIFFERENTIAL RELAYS FOR TRANSFORMERS (ANSI 87)	47
9.5	HIGH IMPEDANCE RESTRICTED EARTH FAULT RELAYS (ANSI 64)	47
9.6	REVERSE POWER (ANSI 32) AND NEGATIVE SEQUENCE (ANSI 46) RELAYS	48
9.7	VOLTAGE (ANSI 27 AND 59) AND FREQUENCY (ANSI 80) RELAYS	48
10.	REFERENCES	49

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design, engineering and installation of electrical protection for electrical facilities within a petrochemical or oil and gas operating environment.

This is a revision of the DEP of the same number dated September 2010; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil refineries, chemical plants, gas plants, exploration and production facilities and supply/distribution installations. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Inverse definite minimum time relay	Dependent-time relay with an operating time that is inversely proportional to the input quantity and with a fixed minimum time at a fixed multiple of the input.
Protection system	Complete arrangement of protection equipment, including current transformers, voltage transformers, communication links wiring, trip circuit, etc. to achieve a certain protection function.
Relay characteristic	Electrical input quantity that characterises the relay performance in terms of current versus time, i.e. SI or EI curve.

Term	Definition
Relay operating time	The time interval from the occurrence of a specified input condition into a relay until its operation.
Relay operation	The condition attained by a relay when it performs its designated function.
Relay pickup	The condition attained by a relay when its input quantity exceeds the setting.
Relay reset	The condition attained by a relay when it returns to its initial condition.
Relay setting	The threshold value of the input at which the relay shall operate.

1.3.3 Abbreviations

AVR	Automatic Voltage Regulator
BDEP	Basic Design Engineering Package (project phase)
BOD	Basis of Design (project phase)
CB	Circuit Breaker
CBCT	Core Balance Current Transformer
CT	Current Transformer
EF	Earth Fault
EI	Extremely Inverse Curve
HV	High Voltage
IDMT	Inverse Definite Minimum Time
LV	Low Voltage
MTBF	Mean Time Between Failure
NER	Neutral Earthing Resistor
OC	Overcurrent
OLTC	On Load Tap Changer
PLC	Power Line Carrier
PPE	Personal Protective Equipment
RMU	Ring Main Unit
RTD	Resistance Temperature Detector
SI	Standard Inverse Curve
TB	Terminal Box
UCP	Unit Control Panel
VSD	Variable Speed Drive
VT	Voltage Transformer

1.3.4 ANSI Codes

The ANSI codes used in this DEP are as follows:

26OT	Transformer oil temperature element
26WT	Transformer winding temperature element
21	Distance protection
25	Synchro-check
27	Undervoltage protection
32	Reverse power protection
40	Field failure protection
46	Phase unbalance protection
49	Thermal overload protection
49S/51LR*	Stall protection during starting and running protection
50	Instantaneous overcurrent protection
50N*	Instantaneous earth fault protection
51	Inverse Definite Minimum Time (IDMT) overcurrent protection
51N*	IDMT earth fault protection
51S*	Time dependent sensitive earth fault protection
51G*	Standby earth fault protection
51V	Voltage restrained overcurrent protection
58	Diode failure protection
59	Overvoltage protection
63	Buchholz relay
64	Restricted earth fault protection
67	Directional overcurrent protection
67N*	Directional earth fault protection
74	Trip circuit supervision
79	Delayed three-phase auto-reclose
81	Underfrequency and overfrequency protection
86	Lockout relay
87	Differential protection
94B*	Buchholz alarm and trip protection
94OT*	Transformer oil temperature alarm and trip protection
94WT*	Transformer winding temperature alarm and trip protection

* NOTE: The additional letters are not part of the ANSI code.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (10).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated September 2010. This version has been updated to reflect comments from users and relay Vendors. The following are the main, non-editorial changes.

Old section	New section	Change
5.5	5.5	Added: No looping of power supplies allowed.
5.14.2	5.14.2	Added: RJ45 connection IEC60870 5-103.
5.14.5	5.14.5	Added: Ethernet based time synchronization shall be used as an alternative to IRIG-B with the Principal's approval.
6.2.2	6.2.2	Added: For protection the earthed VT shall be used.
6.2.3	6.2.3	Removed: In an effectively earthed system, the maximum phase–earth voltage on a healthy phase during an earth fault is limited to 1.4 times the normal phase–earth voltage.
Table 7.3.1	Table 7.3.1	Added: Use of CB for RMU and additional Standard Drawing S 67072.
7.3.6	7.3.6	Clarified: Use of drop out fuses on HV transformers
Table 5	Table 5	Distance to define long /short changed to 500 m. ANSI 51 replaced by ANSI 50. Optional text removed.
7.4.2	7.4.2	Biased functionality added as option.
7.4.4	7.4.4	Separate devices preferred for REF and differential. Low impedance systems allowed as option.
7.4.5	7.4.5	Added: Preference for core balanced CT. Removed: Selecting an NER rating equal to the Full Load current of the transformer will inherently match CT ratings. However, care needs to be taken to ensure the resulting earth fault levels are not excessive, especially under parallel operating conditions. Removed: Setting calculations of the restricted earth fault protection scheme shall be approved by the Principal before the relay and CTs are ordered.
Table 6	Table 6	Trip function added to secondary standby earth fault operation.
Table 7	Table 7	ANSI 51 replaced by ANSI 50.
7.5.3 I	7.5.3 I	Low impedance type devices allowed with principal approval.
7.5.4	7.5.4	Short circuit protection added.
7.5.5	7.5.5	Added for clarity: Thermal conditions to be considered.
7.5.8	7.5.8	Use of negative phase sequence data added for clarity.
Table 8	Table 8	ANSI 51 replaced by ANSI 50.
7.6.3	7.6.3	Removed: The thermal overload relay shall be coordinated with the overcurrent relay used to protect the VSD.
Table 10	Table 10	Added: Optional instantaneous overcurrent protection for synchronised generators (50) Added: Pole slip protection.

Old section	New section	Change
7.8.8	7.8.8	Added: Pole slip protection.
Table 11	Table 11	Updated to include missing trip functions for main CB and field switch.
7.10	7.10	Reworded and differential protection function added.
8.3.5	8.3.5	Islanding criteria clarified.
9.5	9.5	Reworded and simplified to remove references to specific setting ranges.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

2. DESIGN AND ENGINEERING PRINCIPLES

2.1 STANDARDS, CODES AND REGULATIONS

This DEP is based on the publications of the International Electrotechnical Commission (IEC) and the European Committee for Electrotechnical Standardisation (CENELEC). Where relevant, the specific publications are referenced in this DEP.

The design and engineering of the protection system for an electrical installation shall satisfy all statutory requirements of the national and/or local authorities of the country in which the electrical installation will be located.

The protection system for an electrical installation shall be suitable for the site conditions as specified by the Principal. Where necessary, special attention shall be paid to the selection and installation of electrical equipment suitable for seismic conditions.

Furthermore, the contents of this DEP and of standards and publications referred to herein shall be adhered to, except where amended by specific requirements given by the Principal relating to a particular installation, and as far as is permitted under the statutory requirements mentioned above.

Electrical equipment and materials shall comply with the relevant DEP and/or MESC (Group Materials and Equipment Standards and Code) specifications, which in turn shall be considered as supplementary to IEC equipment standards.

CENELEC or national standards of the country in which the installation will be located may be used in lieu of IEC standards for the design and engineering of the electrical installation, provided they are not less stringent in their total requirement. Equipment to be installed in the European Union Member States shall have the appropriate 'CE' marking.

In the event of contradiction between the requirements of DEP specifications and IEC, CENELEC or national standards, the former shall prevail, provided the statutory obligations in the country of installation are satisfied.

Standard Drawings in series S 64, S 67, S 68 and S 69 shall apply, except where this DEP specifies otherwise.

2.2 OPERATIONAL SAFETY, RELIABILITY AND MAINTENANCE

The design of the protection system for an electrical installation shall be based on the provision of a safe and reliable supply of electricity at all times. Safe conditions shall be the basis for the protection system design under all operating conditions, including those associated with start-up and shutdown of plant and equipment, and throughout the intervening shutdown periods. DEP 80.64.10.10-Gen. shall apply with respect to electrical safety rules.

The design of electrical protection systems and equipment shall ensure that all operating and maintenance activities can be performed safely and conveniently and shall permit periods of continuous operation of at least 6 years. For non-spared equipment in vital or essential duty, the period of continuous operation shall be determined by the major shutdown intervals of the associated plant, which may exceed four years. To fulfil the above requirements, the provision of alternative supply sources and supply routes, spare/stand-by capacity, load shedding and automatic restarting schemes, etc. may be required. The simultaneous failure of two pieces of protection equipment shall not be catered for. The protection devices shall have a design life of 25 years, assuming normal routine maintenance activities are carried out and an MTBF of 90,000 hours.

Because of the self-monitoring features and self-diagnostics of numerical relays, it may be possible to extend the maintenance interval for numerical protection beyond the routine periodic interval. Some standards recommend a four-year interval. However, due consideration shall also be given to any national regulations for such a maintenance interval.

However, regular checks shall be performed based on the relay's load or fault data to confirm its continued satisfactory performance. Immediate action shall be taken if there are any internal relay failure alarms.

At a period advised by the relay Manufacturer, but no more than 12 years, the power supply and output cards of numeric relays shall be assessed for replacement.

3. GENERAL PROTECTION AND SAFEGUARDING REQUIREMENTS

3.1 BACKGROUND

Electrical plant, machines and distribution systems shall be protected against damage which may occur during abnormal conditions due to:

- (a) operation outside the design rating due to overloading or incorrect functioning of the system.
- (b) fault conditions due usually to breakdown of some part of the system.

Besides equipment and system protection, personal protection shall be factored into the design of the electrical installation.

3.2 PROTECTION PHILOSOPHY

This DEP provides the details of the minimum requirements of protection necessary to provide a robust and safe system.

The prime objectives of electrical protection systems are to reliably:

- identify system faults and automatically initiate action to isolate the affected equipment or section of electrical network whilst minimising disruption to the healthy part of the system;
- prevent, or minimise, equipment damage and reduce the arc flash energy by quick identification of fault conditions and rapid disconnection of faulty equipment or section of electrical installation;
- maintain the plant availability – i.e. by successfully isolating the faulty section with minimal disruption and returning the system to normal, while at the same time avoiding nuisance trips.

To meet the above objectives, the main requirements of a protection system are:

- a) Redundancy - i.e. if a single protection device or circuit fails there shall be an independent secondary method for fault identification and isolation. A single relay shall not be used as both main and back-up protection, e.g. differential and overcurrent. However, it is permitted to use a single relay for two separate main protection functions, e.g. differential and restricted earth fault protections, which may also share current transformers.

NOTE: The possibility of dormant, un-revealed faults in protection systems shall be minimised by design, e.g. use of trip circuit supervision, self-checking relays etc.
- b) Positive operation for the full range of anticipated system fault levels.
- c) Fault clearance near generator sources should be cleared within the critical clearing times to ensure system stability.
- d) Stable operation for short time overloads (within the safe limit of equipment) and normal system transients, such as motor starting currents, transformer magnetising inrush currents, switching surges etc.
- e) Protection of electrical equipment.

4. ELECTRICAL SYSTEM STUDIES

4.1 PROTECTION COORDINATION STUDY

The purpose of conducting a protection coordination study is to ensure that there is proper coordination of the overcurrent and earth fault relays. At the same time, the relays shall be able to isolate the fault as fast as possible to protect equipment and personnel.

For all switchboards which have been tested for control of internal arcs, the withstand durations identified in test documents shall not be exceeded. If this restriction is complied with then there is no requirement to carry out arc flash energy calculations for normal operation of the switchboard.

Where the switchboards have not been tested for control of an internal arc, or protection trip time is more than Internal Arc Containment Time then an assessment is required of the potential arc flash energy that could be released. To do this a short circuit study shall initially be undertaken. Thereafter a coordination study shall be performed. The results of these studies shall then be used to determine arc flash boundary distances, incident energy and the resultant minimum PPE requirement. The calculations use the equations given in IEEE 1584. In general faster tripping times based on the co-ordination study will result in lower arc flash energy levels. A common aim is to reduce arc flash energy levels to $\leq 13 \text{ cal/cm}^2$ where ever practicable. Choice of 13 cal/cm^2 is based upon this representing a level of PPE which will not significantly impede a person executing normal operational tasks on the switchgear.

The prerequisite for a coordination study is the short-circuit calculation. The short-circuit study provides the minimum and maximum fault levels for the setting of the protective devices.

Other studies required to complete the coordination study are motor starting and transient stability studies, which will define the settings for undervoltage/overvoltage and frequency-based relays.

A protection drawing in the form of a single-line diagram shall be prepared for the complete electrical power system to indicate the types and locations of all protective devices and associated current and voltage transducers.

An electrical protection report shall be prepared to demonstrate the adequacy of all protective systems in fulfilling the above requirements. The report shall be initiated in the FEED phase of the design and be continued through to the final design phase and thereafter maintained by the plant electrical engineer (4.2).

The protection report shall include at least:

- a) a description of the system and of the system operating modes on which the settings have been based;
- b) relevant short-circuit current calculations for the specified minimum and maximum supply or generation conditions;
- c) single-line diagrams for each part of the system;
- d) tabulated settings of the individual devices e.g. setting range, steps, CT ratio, type of relay curve;
- e) coordinated characteristics of the protective devices, fuses, dynamic and thermal withstand curves. The protection coordination curve shall clearly show the points related to fault current at various bus locations to clearly understand the relay operation time for the faults at these locations;
- f) transformer inrush and motor starting currents;
- g) generator fault decrement curves, etc. plotted in graphical form.

The minimum and maximum supply or generation supply capacity conditions shall be representative of those conditions that can arise during normal operation of process units, production facilities and their utilities.

The protection of distribution systems during special conditions, such as those occurring at the time of starting up generating plants, shall be ensured by appropriate adjustments of protection settings or selection of protection groups.

Where relevant, the dynamic performance of the system shall be analysed to verify the adequacy of the protection provided in ensuring successful system recovery to stable operation following the incidence of system faults. In particular, a system incorporating its own generation as a means of power supply shall be studied to establish the extent to which re-energisation of essential service loads may be accomplished. See (8.3.7).

The protection of the interconnection with the public utility shall be subject to the Principal's requirements and shall be co-ordinated and agreed with the public utility.

The fault criteria and system operating modes on which system studies are based shall be subject to agreement with the Principal.

The format of the protection report shall be such that data is captured and maintained in a logical and efficient manner. As a minimum the format shall include data on circuit identification, protective device application, current and voltage transformer rating, key device setting parameters, logics and interlocks and a unique reference to coordination graphs with identification of relevant fault currents for ease of identification. This format shall include an electronic database wherever possible; Manufacturer-specific setting capture software may be used if its details and narratives are included as described above. The protection report shall also detail the philosophy applied in selecting the relay settings and highlight any areas where necessary compromises are made.

The nomination of the party performing the relevant system studies and the type of power system analysis programs used shall be subject to the Principal's approval.

4.2 SYSTEM SETTING MANAGEMENT

In order to maintain the integrity of the electrical protection system a documented database and system narrative shall be developed that shall include sufficient controls to enable the long-term storage and safe keeping of protection system data. This system shall also include facilities and procedures for authorised access and change control.

4.3 STUDY TIMING

The timing and content of electrical studies is related to the phase of the project. In the early phases, such as the SELECT phase, neither a formal system study nor a coordination study need be carried out. However, in the DEFINE phase, system studies and protection schematics shall be produced based upon the S 67 Standard Drawings. If the electrical network is complex or contains novel equipment, specific protection schematics shall be produced to describe any unusual features.

In the EXECUTE phase, specific protection schematics, wiring diagrams, coordination diagrams, setting reports and associated narratives as described in (4.1) above shall be produced, based upon the S 67 Standard Drawings already provided in the previous phase and aligned with Manufacturer-specific data and engineering requirements to satisfy the project specification and standards.

5. INSTALLATION AND DESIGN REQUIREMENTS

5.1 GENERAL REQUIREMENTS

Protection relays shall be mounted in the switchgear cubicle or associated relay panel/UCP. All protective relays shall be visible from the front of the panel without having to open the panel door. Relays shall be flush or rack mounted in dust- and moisture-proof cases to IP5X in accordance with IEC 60529. Relays with LED or LCD displays shall be mounted at such a height that the LED labels and LCD displays can be easily read. The setting / operating parameters and status of the relay should be easily readable and the display should be back-lit.

The relays with programmable logic capabilities shall be provided with PC based Graphical User Interface. All software and hardware for communication and interfacing with ENMC, SCADA and computers shall be provided on the relay for local access during commissioning and maintenance.

All solid-state equipment shall be designed to withstand impulse and high frequency test requirements in accordance with IEC 60255-22-1.

The trip contact from protective relays shall be directly wired to the trip coils. Another contact shall be used for energising an associated lockout relay when provided in accordance with the standard protection scheme.

5.2 EMISSION REQUIREMENTS FOR PROTECTION RELAYS

Electronic protection relays shall comply with generic emission requirements for the industrial environment in accordance with IEC 61000-6-4.

5.3 IMMUNITY REQUIREMENTS FOR PROTECTION RELAYS

Electronic protection relays installed in a separate control room shall comply with the immunity requirements of IEC/TS 61000-6-5, area G (equipment installed in power stations and MV substations).

Electronic protection relays installed in a HV switchgear room, back-to-back with switchgear cubicles, shall comply with the immunity requirements of IEC/TS 61000-6-5, area H (equipment installed in HV substations), regardless of the level of the high voltage.

In addition to the above, electronic protection relays in areas G and H, as defined in IEC/TS 61000-6-5, shall comply with the oscillatory wave immunity requirements of IEC 62271-1 and IEC 61000-4-12, with test frequencies of 10 MHz and 50 MHz and test levels as specified in Table 1. Reference shall also be made to DEP 33.64.10.33-Gen. Protection relays shall be suitable for and able to perform their correct functions in a network subject to harmonic distortion level limits indicated in IEC/TR 61000-3-6:2008, Table 1.

Table 1 Additional immunity requirements for protection relays in areas G and H , as defined in IEC/TS 61000-6-5

Basic standard	Immunity aspect	Port	Test level (Normal EMC severity class)		Performance criterion ^b
IEC 61000-4-12	Oscillatory wave immunity f = 10 MHz and 50 MHz (in addition to f = 1 MHz)	Power lines	CM	2.5 kV	1
			DM	1.0 kV / 2.5 kV ^a	
		Control lines (measurement)	CM	2.5 kV	1
			DM	1.0 kV / 2.5 kV ^a	
		Communication (unshielded)	CM	2.5 kV	1
			DM	1.0 kV	
		Shielded lines	2.5 kV		1

^a For all secondary circuits installed inside HV cubicles, such as VT, CT, pressure transmitters, temperature transmitters, position indicators etc.

^b Assessment criteria according to IEC 61000-4-1:
1 = normal performance within the specification limits. In the generic immunity standards, normal undisturbed performance is referred to as "A".

5.4 PERFORMANCE CRITERIA

The protection relay shall withstand each of the immunity tests specified in (5.3) without damage or malfunction. Where the primary protection and measurement functions of protection relays are concerned, no degradation or temporary loss of function is allowed (performance criterion 1 or A of IEC/TS 61000-6-5). Performance criteria for various functions of secondary equipment shall be in accordance with IEC/TS 61000-6-5.

5.5 POWER SUPPLY FOR PROTECTION RELAYS

The power supply from the DC (preferred 110V) distribution board shall be routed independently to protection relays and trip coils through the associated relay and control panel. As the integrity of the power supply to protective relays is of paramount importance to plant safety, the design of any protective scheme shall ensure that the risk of damage to the power supply cabling or of power system failure shall be minimised.

The auxiliary power supply wiring inside the relay and control panel shall be done by looping in all the equipment supply terminals in parallel, thus forming positive and negative supply buses with as many connection points as required by the number of circuits. These supply buses shall end at the terminals of the DC supply supervision relay. This arrangement ensures 100 % coverage of auxiliary supply wiring for supervision. No looping of the power supply shall be made from one relay to another.

Where in use, the two breaker trip coils shall be wired to two supplies drawn from two different DC buses. The associated main and back-up protection equipment shall also be supplied from two independent DC buses. Each DC supply bus shall be independently supervised by a supply supervision relay. The same principle shall be followed for DC supply distribution of switchgear that utilises only one trip coil. Outgoing power circuits with only one protective device installed shall be supplied from a DC supply bus derived from two independent sources connected together by blocking diodes.

External wiring systems for numerical relays that exit the substation building shall be designed so that electromagnetic interference does not adversely affect the operation of the protection devices. This shall be achieved by utilising a secure auxiliary DC supply via interposing relays to provide digital inputs to these sensitive devices ensuring that the independent DC bus voltage does not exit the substation. In addition the operating time of the protective device shall take account of the additional time required for the operation of these interposing relays (20 ms).

5.6 TRIPPING SCHEMES

5.6.1 Tripping and lockout relays

A circuit breaker shall be tripped directly or also through a tripping relay. The operating time of the tripping relay shall be less than 10 ms. Tripping relays shall have the facility to be programmed to self-reset and shall be suitable for continuous energisation.

A tripping relay that has extensive external wiring associated with its operating coil circuits shall be of the high burden type.

The tripping contacts shall have sufficient making capacity to handle the maximum current that can occur in the circuits controlled by these relays. They shall also be capable of breaking such currents unless other contacts elsewhere in the circuits are used to break the trip current.

Lockout relays shall be used to block the closing of a breaker under faulty conditions. To prevent resetting of this relay on failure of auxiliary supply, the latching mechanism of the lockout relay shall be mechanical. The reset mechanism of the lockout relay shall be electrically operated to facilitate both local and remote resetting. Lockout relays shall be equipped with a pair of normally closed contacts arranged to break their own coil circuit when in the latched position, thus avoiding battery drain.

A combined relay performing both trip and lockout functions may be used provided it meets the requirements of both applications.

5.6.2 Inter-tripping

Power circuits, typically HV transformer or plain feeder circuits to HV systems that have no inherent inter-tripping capability, shall be equipped with a send and receive inter-trip relay. This system shall indicate the activation of the inter-trip feature at both ends of the circuit.

5.6.3 Trip circuit supervision

This feature shall be incorporated in the design of all high voltage circuit protection schemes; the operation of any trip circuit supervision relay shall activate an alarm. This feature shall be provided as a separate relay if a single digital or multi-functional relay is fitted. Trip circuit supervision will be arranged to monitor the tripping coil in both the open and closed conditions.

5.6.4 Breaker fail protection

This feature shall be incorporated in the protection schemes of the outgoing circuits of main intake switchboards, main generation switchboards and other primary distribution switchboards where an upstream bus coupler circuit breaker can operate to reduce the consequences of the outage.

5.7 NUMERICAL RELAYS

5.7.1 Main features

Multifunction numerical protection relays incorporating features such as self-checking, programmable scheme logic, communications, measured value display and disturbance and event recording facilities shall be applied unless otherwise agreed by the Principal.

The self-check feature for multifunction relays shall include the following minimum continuous self-monitoring features:

- a) auxiliary supply supervision;
- b) checksum on all protection algorithms;
- c) memory checks;
- d) checks on input and output modules including A/D converters and filters;
- e) watchdog supervision on program execution.