



IEEE Standard Specifications for Maintenance and Test of Distributed Control Systems in Thermal Power Stations: General Requirements and Definitions

IEEE Standards Association

Developed by the
Corporate Advisory Group

IEEE Std 1865™-2019

STANDARDS

IEEE Standard Specifications for Maintenance and Test of Distributed Control Systems in Thermal Power Stations: General Requirements and Definitions

Developed by the

Corporate Advisory Group
of the
IEEE Standards Association

Approved 7 November 2019

IEEE SA Standards Board

Abstract: The technical and managerial requirements for operational maintenance, repair, and tests of distributed control systems (DCSs) in power stations are specified. This standard is applicable to the operational maintenance, repair, and tests of DCSs in conventional thermal power stations after commencement of commercial operation.

Keywords: DCS, distributed control system, fault handling, I&C, IEEE 1865™, instrument and control, maintenance, operation service, repair, scheduled maintenance, technical management, test, thermal power plant

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2019 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 20 December 2019. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-6288-4 STD23967
Print: ISBN 978-1-5044-6289-1 STDPD23967

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important notices and disclaimers concerning IEEE Standards documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important notices and disclaimers concerning IEEE standards documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

Notice and disclaimer of liability concerning the use of IEEE Standards documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Xplore at <http://ieeexplore.ieee.org/> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this IEEE standard was completed, the Specifications for Maintenance and Testing of Distributed Control Systems in Power Plants Working Group had the following membership:

ABB (China) Ltd.	Guangdong Datang International	Yangcheng International Power
China Datang Corporation, Ltd.,	North China Electric Power	Generation Co., Ltd.
Guangdong branch	University	Zhejiang Datang Wushashan Power
China Energy Engineering Group,	Rundian Energy Science and	Generation Co., Ltd.
Co., Ltd.	Technology Co., Ltd.	Zhejiang Energy Technology
Chaozhou Power Generation Co.,	State Grid Zhejiang Electric Power	Research Institute Co, Ltd.
Ltd.	Research Institute	
Emerson Automation Solutions		

The Working Group gratefully acknowledges the contributions of the following participants. Without their assistance and dedication, this standard would not have been completed.

Yiying Tong, *Chair*
Changsheng Sun, *Vice Chair*
Li Zhou, *Secretary*

Chengwei Dai	Yucheng Liu	Wei Xue
Bo Feng	Zhihao Luo	Feng Yin
Weimin Guo	Tianlin Meng	Jinbin Zhang
Guolian Hou	Yongcheng Qiao	Weijian Zheng
Shuyun Hu	Lihui Su	Li Zhou
Guosheng Li	Ming Xia	Beiheng Zhu

The following members of the entity balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

ABB (China), Ltd.	China Southern Power Grid Co.,	North China Electric Power
Beijing GreenValley Technology	Ltd.	University
Co., Ltd.	ChongQing University	Schneider Electric
Beijing Sifang Automation Co.,	Emerson Electric Co.	Southwest Jiaotong University
Ltd.	Harbin Institute of Technology,	State Grid Corporation of China
BII Group Holdings, Ltd.	China	(SGCC)
Chaincomp Technologies Co., Ltd.	Hongguang Electric Group Co.,	Tianjin University
China Datang Corporation, Ltd.	Ltd.	Xilinx, Inc.
China Energy Engineering Group	Huawei Technologies Co., Ltd.	Zhejiang Provincial Energy Group
Co., Ltd.	Huazhong University of Science	Company, Ltd.
	and Technology	

When the IEEE SA Standards Board approved this standard on 7 November 2019, it had the following membership:

Gary Hoffman, *Chair*
Ted Burse, *Vice Chair*
Jean-Philippe Faure, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi	Christel Hunter	John D. Kulick
Stephen D. Dukes	Thomas Koshy	David J. Law
J. Travis Griffith	Joseph L. Koepfinger*	Joseph Levy
Guido Hiertz	Thomas Koshy	Howard Li

Xiaohui Liu
Kevin Lu
Daleep Mohla
Andrew Myles

Annette D. Reilly
Dorothy Stanley
Sha Wei
Phil Wennblom

Philip Winston
Howard Wolfman
Feng Wu
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 1865™-2019, IEEE Standard Specifications for Maintenance and Test of Distributed Control Systems in Thermal Power Stations: General Requirements and Definitions.

Distributed control systems (DCSs) are in wide use today for monitoring and control of power generating units and their auxiliary systems. However, there are several factors—for example, quality of DCSs, the technical and managerial problems or potential risks involving design and configuration, factory acceptance test, installation and commissioning, operation, maintenance, and test process of DCSs—that may directly or indirectly affect the safe, reliable, and economical operation of power generating units.

The safe, reliable, and economical operation of the DCS are based on proper design and configuration, quality of installation and commissioning, and supported by effective maintenance and technical management. To assure long-term safe, stable, and reliable operation of DCS, it is necessary to exercise effective management and control throughout design and configuration, maintenance, test and routine service, and to exercise comprehensive management of safety related external equipment, and their storage and operating environment and conditions.

Therefore, standards were developed based on the summarization of experiences and expertise and lessons learned from the operational maintenance, repair, test, troubleshooting, and technical management to serve as an international technical and management standard. The related standards are:

IEEE Std 1865: General requirements and definitions

This standard specifies the basic requirements for operational maintenance, repair, and test of DCSs in power stations, and defines the applicable terms. It mainly covers:

- Overview, including maintenance and life cycle of DCS
- Basic requirements, including maintenance principle, planning, procedure and documentation, maintenance personnel, special tools and devices, and records
- Repair and test of control system, including general provisions for repair, requirements for basic repair, and overall repair of DCS, test purpose, determination of test items and cycle, classification of tests, basic requirements for tests, and relevant requirements for test acceptance
- Operation, maintenance, management, and assessment of control system, including basic requirements for operational maintenance, requirements for routine and periodic maintenance and shutdown of control system, basic requirements for control system management, requirements for setting management, performance management, safety management, fault and defect management, risk control, materials plan development management, spare parts management, technical data management, outsourcing management, assessment method, and handling of assessed problems

IEEE Std 1865.1™: Maintenance and testing

This standard specifies the basic principle of repair and testing, test performance indicators, and technical requirements for repair acceptance of DCSs. It mainly covers:

- Basic repair items and technical requirements
- Basic test items and technical requirements
- Technical requirements for functional repair and testing of monitoring systems

- Technical requirements for repair
- Testing of common systems and circuits, and repair and test acceptance

IEEE Std 1865.1 deals with the basic repair items and quality requirements that are intended to provide the basis for restoring and confirming the quality of control system and equipment, minimizing the omissions in repair and maintenance, and improving the reliability of the instrument and control (I&C) system.

IEEE Std 1865.1 also covers the technical criteria, test items, methods of the system, as well as the quality acceptance criteria and the post-repair acceptance items and criteria.

IEEE Std 1865.2™: Operation service and management

This standard specifies the basic principle of operation service, test performance indicators, and technical requirements of operation, maintenance, and test of DCSs. It mainly covers:

- Environment of DCS
- Operation and test of DCS
- Maintenance of DCS technical management of DCS
- Technical requirements and technical assessment of DCS
- The basic items, methods, and technical requirements of scheduled maintenance

The clauses about scheduled maintenance describe the basic items, methods, and technical requirements of periodic maintenance. The clauses about emergency handling and management of faults describe the development procedure and structure of emergency plans, general requirements, and basic principles to be followed for emergency handling of faults, and handling procedures in case of faults. Clauses about management requirements cover the technical requirements for repair and operation management, software/hardware and upgrade management, storage and management of spare parts, and software/hardware reliability management of control systems.

Contents

1. Overview	11
1.1 Scope	11
1.2 Purpose	11
1.3 Word usage	12
2. Normative references	12
3. Definitions, acronyms, and abbreviations	12
3.1 Definitions	12
3.2 Abbreviations and acronyms	16
4. General	17
4.1 Maintenance	17
4.2 Life cycle of DCS	18
5. Basic requirements	21
5.1 Maintenance principle	21
5.2 Planning, procedure, and documentation	22
5.3 Maintenance personnel	26
5.4 Special tools (apparatus)	28
5.5 Records	29
6. Repair and test of DCS	30
6.1 Repair	30
6.2 Test	36
6.3 Acceptance	41
7. Operational maintenance, management, and assessment of DCS	41
7.1 Operational maintenance	41
7.2 Management of DCS	45
7.3 Assessment	48
Annex A (informative) Distributed control system (DCS) in power station	52
Annex B (informative) Reliability-centered maintenance (RCM) analysis	54
Annex C (informative) Classification of control system and equipment by importance	56
Annex D (informative) Classification of equipment defects and faults	58
Annex E (informative) Test, inspection, acceptance, and repair records of control system and equipment	61
Annex F (informative) Special tools (apparatuses)	72
Annex G (informative) Standard and special maintenance items for distributed control system (DCS)	74
Annex H (informative) Maintenance document package	77
Annex I (informative) Bibliography	80

IEEE Standard Specifications for Maintenance and Test of Distributed Control Systems in Thermal Power Stations: General Requirements and Definitions

1. Overview

1.1 Scope

This standard specifies the technical and managerial requirements for operational maintenance, repair, and tests of distributed control systems (DCSs) in power stations.

This standard is applicable to the operational maintenance, repair, and tests of DCSs in conventional thermal power stations after commencement of commercial operation.

IEEE Std 1865™ specifies the general requirements applicable to all standards in the IEEE 1865 series. IEEE Std 1865.1™ and IEEE Std 1865.2™ concentrate on more specific topics.

IEEE Std 1865.1 provides detailed requirements for the repair and test of DCSs, including items, methods, and procedures.

IEEE Std 1865.2 provides detailed requirements for the operational maintenance and management of DCSs, including items, methods, and procedures.

1.2 Purpose

This standard is intended to help maintain good conditions and reliable operation of DCS by providing technical and managerial requirements for the repair, test, and operational maintenance, based on proven engineering philosophy, methods, procedures, and field experiences with DCS of different brands. It aims to:

- a) Specify requirements for inspection and maintenance of DCS hardware/software; checking and testing system performance, basic application functions, and monitoring and control functions; and their respective acceptance
- b) Specify requirements for day-to-day management, periodic maintenance, and the procedures to deal with DCS hardware/software failure

- c) Provide a guide for developing manuals for repair, test, operational maintenance, acceptance, and technical management of power stations

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).^{1,2}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 60812, Failure modes and effects analysis (FMEA and FMECA).³

IEC 62381, Automation systems in the process industry—Factory acceptance test (FAT), site acceptance test (SAT), and site integration test (SIT).

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁴

annual maintenance: The yearly maintenance of a unit. The maintenance class may be determined according to the maintenance scope and downtime.

computerized maintenance management system (CMMS): A type of management system that performs functions in support of management and tracking of maintenance activities.

condition-based maintenance: A maintenance schedule arranged according to the health condition of equipment, by which any equipment abnormality is identified and any equipment fault is predicted based on the equipment condition information available from advanced condition monitoring and diagnostic techniques. It is performed before the occurrence of faults. *Syn:* **predictive maintenance**. *See:* **maintenance types**.

¹The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

²The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

³IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

⁴*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>.

conventional thermal power station: A thermal power station in which the thermal energy is obtained by combustion of coal or hydrocarbons.

corrective maintenance: Maintenance and repair activities performed after the equipment or system fails so as to restore the faulty equipment or system to the state in which the equipment or system is able to perform its specified function, including diagnosis, recovery, and replacement. This maintenance type can save considerable labor, materials, and financial resources. Currently, majorities of distributed control system (DCS) units other than nuclear generating units adopt corrective maintenance types within their life cycle. (In some countries where periodic maintenance is adopted, it is specified in their electric power industry standards that Class C equipment in electric power production systems should adopt a corrective maintenance strategy). The scheduled overall maintenance, the repair or replacement of damaged and worn internal parts of the equipment or system during preventative maintenance process are classified as corrective maintenance. *Syn:* **passive maintenance.** *See:* **maintenance types.**

data acquisition system (DAS): A monitoring system that detects the operating parameters and status of the process system and equipment, processes, records, and displays detection results and gives alarms, calculates and analyzes the operation status of units, and gives instructions by a computer system accordingly.

defect: A phenomenon failing to meet the specified quality requirements—but having no detrimental effect on normal operation of the equipment for the moment—which however may give rise to unsafe events.

digital electro-hydraulic (DEH) control system: A turbine control system composed of sensitive elements and digital circuits based on electrical principle, amplifying elements, and hydraulic servomechanism based on hydraulic pressure principles.

electronic equipment room: A room in which control stations and other electronic equipment cabinets of monitoring and control systems (including distributed control systems [DCSs]) of power stations are centrally installed.

engineer room: A room in which the engineer stations of the distributed control system (DCS) in power stations are installed for use by the DCS engineers.

factory acceptance test: Activities which demonstrate that the vendor system and additionally supplied systems are in accordance with the specifications.

fault: State of a system or component characterized by the inability to perform an intended function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources. *See:* **functional fault, multiple fault, potential fault.**

NOTE 1—A failure of a system or component is in fault state, and it is an event that results in a fault of that system or component.⁵

NOTE 2—The difference between defect, failure, and fault is that *defect* is a phenomenon, *failure* is an event, as distinguished from *fault*, which is a state.

fault classification: A process by which equipment faults are classified and recorded according to what degree the operational safety of units is affected by the faults.

functional fault: An event or state in which a component or system cannot perform an intended function. Functional faults may be classified into *evident fault* and *latent fault*. *Evident functional faults* refer to those in which at least one characteristic or parameter of the component or system experiences observable deviation

⁵Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

beyond the acceptable range under the current state. *Latent functional faults* refer to those that cannot be directly identified under the current state unless the component or system is brought to another state (such as inspection and testing after equipment shutdown). *See: fault.*

furnace safeguard supervisory system (FSSS): A supervision and control system that serves for programmed automatic control over the igniter, burner, oil gun or gas gun, or lance of boiler (including atmospheric fluidized-bed boiler) to prevent furnace explosions/implosions in boiler (including atmospheric fluidized-bed boiler) as a consequence of loss of flame, overpressure, or other reasons. The system consists of fuel safety system and burner control system.

health, safety, and environment (HSE): Responsibility for protecting the health and safety of workers and the surrounding community and maintaining high environmental stewardship.

H point (hold point): A quality check point that shall be checked and certified by a quality control person on site. *See: quality control points.*

main auxiliary equipment: Auxiliary machineries of electric power generation, e.g., forced draft fan, induced draft fan, coal pulverizer, primary air fan, and feedwater pump.

main equipment: Boiler, steam turbine, gas turbine, generator, main transformer, unit controls, and their ancillary equipment.

maintainability: The ability of a system or component under given conditions of use to be retained in, or restored to, a state in which it can perform a required function when the maintenance is performed under given conditions and using stated procedures and resources. *Syn: performance.*

maintenance class: The maintenance of units is classified into Maintenance Class A, B, C, and D based on maintenance scope and downtime. *See: Maintenance Class A; Maintenance Class B; Maintenance Class C; Maintenance Class D.*

Maintenance Class A: A complete overall inspection and repair of all equipment of a power generating unit to maintain, recover, or improve the equipment performance. *See: maintenance class.*

Maintenance Class B: Overall inspection and repair of some equipment of a power generating unit. Maintenance Class B may involve some Maintenance Class A items or periodic rolling maintenance items based on the assessment of equipment conditions. *See: maintenance class.*

Maintenance Class C: Inspection, assessment, and repair of selected components of a unit according to their wear and aging patterns. Maintenance Class C may involve replacement of a few parts, defect elimination, adjustment, and preventive test of equipment, and some Maintenance Class A items or periodic rolling maintenance items. *See: maintenance class.*

Maintenance Class D: Defect elimination for the auxiliaries while a unit is operating normally. Maintenance Class D may involve some Maintenance Class C items based on the assessment of equipment conditions. *See: maintenance class.*

maintenance supportability: Capability of a maintenance organization to provide the resources required for maintaining a system or component under the prescribed conditions in accordance with prescribed maintenance strategies.

maintenance types: An activity conducted on a system or component to eliminate the potential fault or faults arising during its operation process so as to restore, maintain, or improve the performance of the system or component. *See: condition-based maintenance; corrective maintenance; periodic maintenance; proactive maintenance; reliability-centered maintenance.*

master fuel trip (MFT): A control measure to quickly cut off all fuel supply (including fuel to the furnace, igniter, and air duct burner) to the boiler (including atmospheric fluidized-bed boiler) by means of human intervention or by automatic activation of protection.

modulation control system (MCS): A generic term for control systems used for continuous automatic control of process parameters of boiler, turbine, and auxiliary system by means of feed-forward and feedback, including automatic compensation and computation of process parameters, automatic control, bumpless switchover of control modes, as well as deviation alarm.

multiple fault: A fault event consisting of two or more cascaded independent faults, which may lead to a consequence that cannot be brought about by any single fault thereof. *See:* **fault**.

on-off control system (OCS): A generic term for control systems used for startup and shutdown or switching on/off of the main and auxiliary equipment in the process of production by means of binary control. *Syn:* **sequence control system (SCS)**.

periodic maintenance: A maintenance mode in which appropriate maintenance grade, interval, and items and required spare parts and materials are periodically predetermined. These determinations are primarily based on time interval, supplemented by equipment condition, according to the statistical rule of equipment fault and aging. This includes maintenance or replacement of the equipment which has deteriorated but not yet failed, or periodic repair or replacement of equipment which has not been damaged but suffers potential fault risk as judged by statistical rule. *Syn:* **preventative maintenance; scheduled maintenance**. *See:* **maintenance types**.

potential fault: Latent defects which do exist but have not yet been noticed, and possibly lead to abnormal operation of control system or trip of unit. *See:* **fault**.

proactive maintenance: A maintenance mode in which the equipment is renovated according to the state-of-the-art technical level and development trend in case the equipment defect cannot be eliminated through repair or the equipment suffers frequent faults, or due to the launching of new equipment version or difficulties in procurement of components of the original equipment. The above renovation is achieved during the process of maintenance, aiming at eliminating the equipment defects radically and improving the technical performance and availability of the equipment. *Syn:* **upgrade and modification maintenance for control systems**. *See:* **maintenance types**.

process control unit (PCU): An independent unit at the process control level of the distributed control system (DCS), used for direct digital control of the industrial production process and composed of controller, communication module, analog and digital interfaces and modules, field bus interface, etc.

quality control points: Quality check points for key processes which are set according to the importance and difficulty of a certain process. These control points have to be checked and certified before proceeding to next step. *See:* **H point (hold point); W point (witness point)**.

reliability-centered maintenance (RCM): A maintenance mode in which initial preventive maintenance requirements are established or the existing preventive maintenance requirements for equipment are optimized based on the consequences of equipment failure. The failure consequences are determined by analyzing the possible failure modes of each component in an operating system and determining how that failure would affect the system and overall mission. *See:* **maintenance types**.

sequence control system (SCS): A control system which is intended to control the main equipment or a process system of the unit or the main auxiliaries according to a given pattern (in the sequence of input signal condition, operation, or time). *Syn:* **on-off control system (OCS)**.

site acceptance test: Activities intended to demonstrate that the installation of the various vendor systems is in accordance with the applicable specifications and installation instructions.

site integration test: Activities intended to demonstrate that the merging of the various systems to one overall system is completed and that all components work together as specified.

spot checking of equipment: A management method for regular checking of equipment by a specific person (who is determined according to the region, equipment, and personnel quality) with senses and tools at a specific position (which is determined through scientific analysis on deterioration-prone parts of the equipment, and the items and contents for spot checking at this position shall be specified) in accordance with predetermined technical standards.

special maintenance items: Special maintenance items are items other than standard maintenance items for periodic maintenance of the distributed control system (DCS). *See:* **standard maintenance items**.

standard maintenance items: Standard maintenance items are intended for periodic maintenance of the distributed control system (DCS) for the purpose of eliminating potential fault, and ensuring that the performance and function indicators of the DCS meet or are close to the manufacturer's requirements.

W point (witness point): A quality check point that shall be checked and confirmed by a quality control person on site. *See:* **quality control points**.

whole-process management of maintenance: Each item, document, and person are put under control through assessment, development of maintenance plans, procurement of materials and spare parts, preparation of technical documents, maintenance activities, static/dynamic acceptance, and post-maintenance summary to achieve the expected maintenance effectiveness and quality requirements.

3.2 Abbreviations and acronyms

AI	analog input
AO	analog output
CCS	coordinated control system
CFB	circulating fluidized bed
CMMS	computerized maintenance management system
DAS	data acquisition system
DCS	distributed control system
DEH	digital electro-hydraulic control system
DI	digital input
DO	digital output
DVD	digital versatile disc
ESD	electrostatic discharge
ETS	emergency trip system
FAT	factory acceptance test
FMEA	failure mode and effects analysis
FSSS	furnace safeguard supervisory system

H	hold
HRSG	heat recovery steam generator
HSE	health, safety, and environment
I&C	instrumentation and control
I/O	input/output
MCS	modulation control system
MFT	master fuel trip
MTTR	mean time to repair
OCS	on-off control system
O&M	operation and maintenance
PCU	process control unit
PI	pulse input
PLC	programmable logic controller
RCM	reliability-centered maintenance
RTD	resistance temperature detector
SAT	site acceptance test
SCS	sequence control system
SIT	site integration test
SOE	sequence of event
SOP	standard operating procedure
TC	thermocouple
UPS	uninterrupted power supply
VDU	video display unit
TBM	time-based maintenance
W	witness

4. General

4.1 Maintenance

DCS is a commonly used control system in power stations (see [Annex A](#) for the DCS architecture and functions). The safe, economic, reliable, and efficient operation of power generating units depends on the reliability of DCS during their life cycle. The reliability of DCS depends not only on the integration of DCS hardware, software, operating console/panel, and environment as a whole, but also on the quality of DCS logic design, installation, commissioning, maintenance, operation management, as well as professional skills. Any problem arising from these aspects would potentially lead to partial function failure or DCS fault. Evidence shows that the reliability of DCS is determined by the hardware/software quality and correctness of control logic and supported by regular and effective maintenance, as well as good management practice. Therefore, it is necessary to take DCS and the relevant personnel and environment as a whole to carry out whole-process management of reliability, repair, test, operation, and service of DCS during the life cycles. Also necessary is the supervision of the operating environment related to the safety of DCS to confirm that the measures taken in case of different faults of DCS are practicable. All these measures are essential for the safe operation of DCS.

Maintainability of DCS refers to the availability of necessary maintenance to be conducted in a simple, economic, safe, and accurate manner, and can be measured either in terms of a probability or in the level of resources required to maintain DCS. Hence, maintainability of DCS has a direct influence on DCS's ability to deliver required function and performance. The maintenance of DCS refers to the activities which are conducted to maintain or recover the ability of DCS.

Maintenance activities of DCS involve repair, service, and replacement, and also inspection, test, and calibration, etc., intended to maintain or recover the required performance of DCS. In general, maintenance activities are classified into passive maintenance, preventative maintenance, predictive maintenance, and reliability-centered maintenance:

- a) Passive maintenance has the advantages of low maintenance investment and few maintenance personnel during normal operation time. But passive maintenance has disadvantages, such as increased overall cost due to unscheduled equipment shutdown, uncontrollable labor cost as a result of emergency maintenance, inefficient utilization of maintenance resources, and potential damage of other associated equipment and systems caused by fault or failure of DCS equipment.
- b) Preventative maintenance has many advantages, such as cost-effectiveness, flexibility in maintenance period, extended service life, energy saving, reduced equipment fault/failure, and generally lower overall cost than passive maintenance. But it cannot completely prevent catastrophic failure/fault, and has disadvantages, such as intensive labor and potential equipment damage caused by unnecessary maintenance.
- c) Predictive maintenance has the advantages of extended service life of equipment, improved equipment availability, potential risks being identified promptly, corrective maintenance being performed before faults occur, shortened equipment downtime, reduced spare parts quantity and labor cost, energy savings, improved operational safety of equipment and system, etc. But it has drawbacks including increased investment in diagnostic equipment and training of maintenance personnel.
- d) Reliability-centered maintenance is one of the most effective maintenance types. It can reduce total cost significantly through avoiding unnecessary maintenance or equipment shutdown, minimize the frequency of equipment maintenance, reduce the probability of unexpected failure of equipment, improve equipment reliability, and focus maintenance activities on critical components. Its disadvantages include higher start-up cost and more personnel training. See [Annex B](#) for an analysis method of reliability-centered maintenance.

The maintenance types of DCS in a specific power station should be selected by the user according to the reliability requirements and taking into full consideration the availability of maintenance equipment, maintenance personnel skills, investment, technical management proficiency, etc. DCS is so important to the safe operation of power stations that usually a combination of several maintenance types may be used to improve reliability and optimal performance of DCS in a cost-effective manner.

A computerized maintenance management system (CMMS) automates most of the logistical functions performed by maintenance staff and management and has many advantages over manual maintenance tracking systems. Hence it is preferred whenever possible.

4.2 Life cycle of DCS

The life cycle of DCS, illustrated in [Figure 1](#), refers to the entire process from concept and definition phase to disposal phase, including concept and definition phase, design and development phase, type selection and engineering design phase, manufacturing and configuration phase, installation and commissioning phase, operation and maintenance phase, and disposal phase. Although the maintenance and test activities of DCS described herein are defined for the operation and maintenance phase of DCS that has been put into commercial operation, the results of preceding phases may strongly impact the reliability and maintenance cost throughout the life cycle of DCS once in commercial operation. In addition, these results may consequently influence the

safety and economical efficiency of units. Maintenance demands may also significantly affect the amount of DCS life cycle cost, therefore these activities shall be fully taken into consideration at each phase of the DCS life cycle to achieve whole-process and all-around management and control of DCS design, installation, commissioning, maintenance, and repair. Such consideration is critical to ultimately achieve the required reliability and maintainability targets or required profit margins. For example, if maintainability requirements are not fulfilled, the availability and cost effectiveness of DCS may be severely influenced.

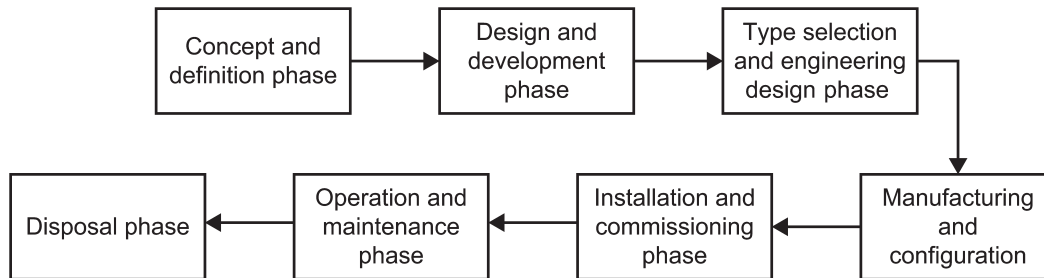


Figure 1—Activity model of the life cycle of DCS

To achieve high maintainability of DCS, the following maintainability-related requirements shall be met at each phase of life cycle of DCS:

- a) **Concept and definition phase:** A phase in the life cycle of DCS during which the product requirements for DCS are defined and developed into a specification. Maintainability should be taken into account early in this initial phase of life cycle of DCS, and a clear maintenance policy should be defined. Special attention shall be given to availability requirements, environment conditions under which the product is operated/maintained, amount of preventive maintenance, the life required from the product, and the method of disposal, and safety requirements.
- b) **Design and development phase:** A phase in the life cycle of DCS during which the hardware and software of DCS and relevant documents (such as detailed production specification, software coding specification, user manuals, and maintenance manuals) are developed. At this phase, maintainability studies, in conjunction with reliability studies, are undertaken to translate operational requirements into detailed qualitative and quantitative maintainability requirements and design criteria. In the analysis, special consideration shall be given to skill levels of maintenance personnel, recommended maintenance site, workload and type of maintenance, accessibility, modularity, functional interchangeability of product, mean time to repair (MTTR), and maintenance cost. Maintenance support may also need to be considered during this phase to assure that DCS can be fully supported when it is brought into operation.
- c) **Type selection and engineering design phase:** A phase in the life cycle of DCS during which the user selects the type of DCS and the engineering design of DCS is performed. When selecting DCS type, the following shall be investigated and evaluated: the reliability of DCS controllers, communication network, input/output (I/O) signals and software function configuration, integrity of functional configuration of human-machine interfaces including operator stations and engineer stations, adaptability to operating environment, real-time performance, system accuracy, fail-safe, system usability, maintainability, functional interchangeability, expandability, maintenance cost, ease of repair, and MTTR. The above factors as well as the unit control functions are analyzed comprehensively and systematically and the analysis results are translated into detailed qualitative and quantitative reliability indicators and engineering design criteria. At this phase, emphasis shall be placed on collecting the information on design rationality, logic validity, operational reliability and existing defects. Safety assessment results at the occurrence of fault of the selected DCS type used in similar units. Accordingly, management and control measures shall be developed to avoid

such similar defects in engineering design. Where practical, the effectiveness of these management and control measures shall be verified. On the premise of fulfilling the same functions, selection and configuration of DCS shall follow the criteria of structural reliability, simplicity, practicability, and less maintenance effort.

- d) **Manufacturing and configuration phase:** A phase in the life cycle of DCS during which the DCS hardware is manufactured and assembled and the DCS software is configured. Ideally, verification of functional parameters should have been undertaken during the development of the DCS and test on prototype or on standard product developed earlier. However, these results may not represent the standard achieved in full production models. While the results of some maintainability verification carried out during this period may be useful, the full verification of whether the maintainability targets have been achieved has to await the production of representative equipment. Upon completion of DCS manufacturing and configuration, the DCS supplier shall establish simulation environment to perform all internal tests prior to the factory acceptance test (FAT) of DCS. Before the DCS is ready for shipment and delivery, a FAT scheme for DCS should be prepared in accordance with IEC 62381, and the DCS shall be subject to FAT. Before getting down to FAT, the DCS supplier should complete all internal tests and provide test reports for review. Any problems identified during acceptance test should be eliminated before the DCS leaves the factory. Alternative corrective plans should be in place during installation if any problems persist.
- e) **Installation and commission phase:** A phase in the life cycle of DCS during which DCS is installed and commissioned. After completion of installation and commissioning of DCS, site acceptance test (SAT), site integration test (SIT), verification test and dynamic test of monitoring/control functions, and system availability assessment test are the first opportunity to test the maintainability performance of DCS products. At this moment, accessibility and ability of handling, installation, commissioning, and test of various components are key factors. The requirements for these tests are outlined as follows:
 - 1) **SAT:** After DCS is transported to the user's project site and installed and commissioned, a SAT scheme should be prepared in accordance with IEC 62381, and the DCS supplier shall perform SAT in cooperation with the user to verify whether or not the DCS functions normally after transportation, installation, and commissioning. Records shall be made during SAT, and SAT reports shall be prepared promptly after completion of SAT for review.
 - 2) **SIT:** To ensure the integrated system consisting of two or more independent systems can deliver the function prescribed in the project control scheme, after each individual system successfully passes the SAT, a SIT scheme shall be prepared in accordance with IEC 62381, and the entire integrated system shall be subject to SIT as required. Records shall be made during SIT, and SIT reports shall be prepared promptly after completion of SIT for review.
 - 3) **Verification test of DCS monitoring and control functions:** After completion of SIT test and before the startup of units, a scheme for verification test of DCS monitoring and control functions shall be prepared, and DCS shall be subject to the verification test as required. Records shall be made during the verification test, and test reports shall be prepared promptly after completion of verification test for review.
 - 4) **Dynamic test of DCS monitoring and control functions:** After units are put into trial operation, dynamic test of DCS monitoring and control functions shall be performed. A dynamic test scheme shall be prepared before the test. Records shall be made during the dynamic test, and test reports shall be prepared promptly after completion of dynamic test for review.
 - 5) **DCS availability assessment test:** After units are put into normal operation, DCS availability assessment test shall be performed, and tests reports shall be provided for review. A scheme for DCS availability assessment test shall be prepared before the test.
- d) **Operation and maintenance phase:** A phase in the life cycle of DCS during which the DCS is put into operation and is maintained and serviced. IEEE Std 1865.1 and IEEE Std 1865.2 specify the specific technical and management requirements for this phase, including:

- 1) Periodic maintenance of DCS, including cleaning and inspection of equipment and components, replacement of vulnerable parts, tightening of all wiring and connectors, SIT, verification test, and dynamic test of monitoring and control functions after maintenance, and acceptance after maintenance and test.
 - 2) DCS operation monitoring and control, including display and spot check of accuracy of measured parameters, check of operation quality of modulating control system, operating condition of on-off control system, and current and historical trend recording curves, online test of relevant equipment, defect elimination, emergency handling of faults and drills thereof, etc.
 - 3) Routine maintenance of DCS, including patrol inspection of working conditions of hardware and software, analysis and handling of abnormalities and faults, periodic test, component replacement, etc.
- e) Disposal phase: A phase in the life cycle of DCS following operation and maintenance phase, during which the product may be removed from its application place, and dismantled, destroyed, or where necessary, stored in protected environment. The decision to dispose of a product may be governed partially based on such factors as the product's ability to continue function satisfactorily, its level of maintainability, reliability, and operating costs. And in turn, these factors are dependent on the continued supply of spare parts, and supportability and availability of replacement equipment.

When the DCS is upgraded and modified in part or in whole, the above requirements for corresponding phase of life cycle of DCS should also be met.

5. Basic requirements

5.1 Maintenance principle

5.1.1 General

Maintenance of DCS shall conform to “safety first” policy and meet the requirements of health, safety, and environment (HSE). A process quality control plan for maintenance and test of DCS shall be established for power stations to examine carefully that all jobs affecting the quality of maintenance and testing of distributed control system and equipment are performed by qualified personnel with qualified tools under the specified controlled conditions in accordance with the specified technical standards, procedures, detailed rules, or other applicable documents. A process quality control plan should also assure that the corresponding maintenance and test work of DCS and equipment is completed in such a manner that the processes involved that have a bearing on quality are under control.

5.1.2 Determination of maintenance types and cycle

The maintenance types and cycle of DCS and equipment shall be determined reasonably in accordance with the legislations and standards in the country concerned, with reference to maintenance documents provided by DCS manufacturer, maintenance time of the main equipment and main auxiliary equipment, maintenance experience of DCS used by similar units, and results of condition assessment of DCS and equipment thereof, and fully taking into consideration the configuration of maintenance equipment, capability of maintenance personnel, investment, and technical and management level. Budget management and cost control shall be applied. To achieve safe and reliable operation of power stations, passive maintenance shall not be adopted for overall maintenance of the DCS.

5.1.3 Quality and defect control principle

As early as the preparations for maintenance, various plans and specific measures shall be established, and procedural documents shall be completed. Process management shall be implemented. Maintenance, acceptance, and post-maintenance evaluation activities shall be well conducted. Standardized operation and whole-process quality supervision shall be practiced. Control points (H or W points) shall be set

according to work flow and quality requirements. Maintenance and test acceptance items that influence the safety performance and important functions of control system shall be accepted by setting H points. Other maintenance and test acceptance items may be accepted by setting W points.

The timeliness and correctness of DCS maintenance are the guarantee for reliability of DCS hardware and software. The working conditions of internal and external equipment (including software functions) of DCS shall be fully managed. Equipment faults, defects, and safety-related problems arising during operation shall be identified, handled, and eliminated promptly. For those that cannot be eliminated, measures shall be taken to reduce propagation of such faults and defects. For remaining defects that affect the safe and economical operation of power generating units, remedy plans shall be developed, and these defects shall be corrected within the specified time.

5.1.4 Technical management principle

The effectiveness of technical management of DCS (such as management of DCS hardware, software, and operating environment, management of repair, operation and maintenance, management of fault and defect handling, technical procedures and archives, statistics of performance index, storage of spare parts, and management of personnel qualification, etc.) has an immediate influence on the safe and economical operation of power generating units. The repair, test, operation, and maintenance activities shall be combined with technical management effectively, and appropriate technical procedures and rules shall be developed and improved to provide basis for carrying out repair, operation, maintenance, and management by professional personnel.

The CMMS shall be used to establish and maintain technical archives and data and to achieve computerized management of whole process—from selection, application, repair, maintenance, test to disposal of the equipment—so as to timely control the quality of equipment over its entire service life. Through data statistics analysis and traceability analysis of calibration data, it is possible to renovate the equipment to continuously improve the equipment availability and accuracy as well as maintenance process quality.

Greater attention shall be paid to the management of maintenance interfaces. For power stations with the repair and maintenance being outsourced, all organizations involved in the repair and maintenance of DCS and its equipment shall designate liaison staff for their repair and maintenance projects, and the technical and management responsibilities and obligations of organizations and departments concerned shall be explicitly stipulated in written form, and the maintenance interfaces shall be always under control.

Equipment condition monitoring and diagnosis system should be established. Condition-based maintenance shall be performed for key equipment that affects the operational reliability and safety of units greatly in accordance with condition monitoring and diagnosis data. The proportion of condition-based maintenance should be increased gradually on the basis of periodic maintenance, aiming at ultimately establishing an optimized repair and maintenance mode that combines periodic maintenance, condition-based maintenance, proactive maintenance, and corrective maintenance.

5.2 Planning, procedure, and documentation

5.2.1 General

Work plans, technical specifications, safety-controlled measures, field change and (provisional) modification procedures, and other relevant documents shall be developed and implemented for operation, maintenance, repair, and test activities to achieve whole-process management of their reliability and quality.

5.2.2 Development of procedures (or planning

To improve the performance, safety, and efficiency of operation, maintenance, repair, and test, a DCS operation and maintenance procedure and a DCS repair and test procedure shall be developed respectively:

- a) DCS operation and maintenance procedure: mainly covering routine maintenance and management, periodic maintenance, and fault handling. Its technical management contents shall include maintenance items, fault and defect management, safety and emergency measures, responsibility, work procedures, quality indicators, and supervision requirements.
- b) DCS repair and test procedure: mainly covering maintenance and test items, maintenance class, important technical measures, scheduled maintenance time and downtime, post-repair test plan, and in-service periodic test plan. Its technical management contents shall include repair schedule, labor hours and expenses, repair and test items, organization and management (including responsibility requirements), repair and test preparation (including repair materials, spare parts, and test tools), repair and test procedure, scheduling, safety and emergency measures, quality control and supervision, acceptance, and evaluation requirements.

The associated performance and application function of repaired control system shall be checked, tested and adjusted, and the corresponding working hours shall be included in the repair and maintenance plan for units.

The details of procedures shall be determined according to the user manuals and maintenance manuals provided by DCS manufacturer, DCS actual configuration, DCS operating conditions (including environmental severity, service time, and work cycle), and as-built documents, and with reference to regulatory requirements, plant management rules, maintenance supportability, and characteristics of controlled objects. During implementation, the procedures may be modified as appropriate.

- a) Effective DCS maintenance necessitates close coordination of operation, maintenance, engineering, training, and management. In addition to the requirements for staff responsibility and technical management for maintenance, the procedures shall also contain staff responsibility and basic requirements in terms of operation, engineering, training, and management.

5.2.3 Safety measures

Potential fault risks and their possible influence on the system should be identified with reference to [Annex D](#) and the actual configuration of DCS. Emergency response plans should be developed based on the specific conditions of units to address faults of control system under various conditions. Drills for emergency response to faults of control system and review of emergency plans should be performed regularly. When necessary, emergency plans should be revised.

Effective HSE measures should be taken for the maintenance process to make sure that working environment and labor conditions are improved, working personnel and equipment are safe and reliable, workplace is clean and neat, and various wastes are properly disposed.

The equipment maintenance should be carried out in conformity with safety rules, and safety management should be strengthened with all safety responsibilities clarified and all safety precautions in place, so as to maintain the safety of personnel and equipment. The permit-to-work system and safety protocols for outsourced work should be strictly implemented. Safety engineers should enhance safety inspection, and convene safety analysis meeting regularly.

5.2.4 Establishment of normative documents library

Normative document library issued by superior management department (including discipline-related national and industrial regulations, rules, and accident prevention measures) and normative work document library that are developed by disciplines (including various management rules, procedures for repair, operation and maintenance, work instructions for repair or test, and work document package for maintenance or test) shall be established and maintained.

Normative documents shall be updated promptly, and studied, understood, and implemented by operation and maintenance personnel. When necessary, implementation rules shall be tailored for the user according to normative documents. Work documents shall be planned by the person in charge of the discipline concerned, prepared by technical supervisors of the discipline, and effected and implemented after they are reviewed and approved by authorized personnel, aiming at guiding operation and maintenance personnel to properly perform DCS repair, operation, and maintenance and arrange work sequence as well as achieving good process control. Specifically, the work document package for maintenance or test should specify the type, measuring range, and required accuracy of test equipment used for each task. Maintenance or test work documents shall be in sufficient detail that is commensurate with the importance and complexity of works.

5.2.5 Technical specifications

Technical and management specifications for DCS repair, operation, and maintenance shall be developed according to national and industrial technical standards in the country concerned in combination with technical and management requirements for the control system and equipment furnished by DCS manufacturer as well as experiences and lessons learned from the repair, operation, and maintenance of DCS in other power stations. These specifications shall stipulate the items, methods, procedures, criteria of repair, operation, maintenance, as well as technical management requirements, and shall be verified to be normative and correct through practices of repair, operation, and maintenance so that the operation and maintenance personnel can perform relevant works according to the specifications.

To improve the operational reliability of DCS, rules for patrol inspection, routine operation, maintenance, scheduled maintenance, and test of DCS shall be established based on the importance classification, online operation quality, and actual operability of DCS equipment. Patrol inspection items, routine operation, maintenance items, periodic maintenance items, and test items shall be determined and relevant normative record cards shall be developed.

The test cycle of basic performance and application functions of DCS shall be specified. Standard operation cards for test of basic performance and application functions of DCS shall be developed. The test of basic performance and application functions of DCS shall be performed according to these operation cards. For units that have been repaired or shut down for more than one month, their relevant main performance shall be tested before restoring operation. During normal operation, the load rate of various control stations, operator stations, and data communication buses shall be tested online regularly, and the test data shall be filed.

To maintain the operational reliability of protection and interlock systems, the cycle and schemes of periodic inspection and test for protection and interlock systems shall be established. To reduce bad behaviors in repair, test, operation, and maintenance activities that may lead to potential fault and malfunction of protection system of units, special test operation cards shall be developed for testing protection and interlock systems, and appropriate management rules for test, settings management, change and switching on/off of protection and interlock systems shall be established.

To ensure that the control performance of a modulating control system meets the operation requirements, the cycle and schemes of inspection and test on control quality of the modulating control system shall be established. The professionals of control and instrumentation discipline shall inspect and test the control system for control performance periodically in accordance with appropriate inspection and test schemes. If any nonconforming control performance is identified during operation, the control system in question shall be inspected, adjusted, and tested. The inspection and adjustment records and test reports shall be filed to make it traceable.

To reduce inconsistent contents and editions, delayed backup and non-unified management of software as a result of poor software management practices, the DCS software management shall be under proper control in respect of software backup and storage, non-temporary and temporary software configuration modification, and DCS hardware and software upgrade.