



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

STANDARDS

IEEE Standards Association

Developed by the
Corporate Advisory Group

IEEE Std 1865.1™-2019

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

Developed by the

Corporate Advisory Group
of the
IEEE Standards Association

Approved 7 November 2019

IEEE SA Standards Board

Abstract: The basic principles, items, methods, performance indicators, and acceptance requirements for the maintenance and testing of distributed control systems (DCSs) of thermal power plants are specified. This standard is mainly applicable to the maintenance and testing of DCSs of conventional thermal power plants in commercial operation.

Keywords: DCS, distributed control system, fault handling, I&C, IEEE 1865.1™, 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 23 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 978-1-5044-6321-8 STD23986
Print: ISBN 978-1-5044-6322-5 STDPD23986

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 U.S. 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 ten years. When a document is more than ten 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.
China Datang Corporation Ltd.,
Guangdong Branch
China Energy Engineering
Group
Emerson Automation
Solutions

Guangdong Datang
International Chaozhou Power
Generation Co. Ltd.
State Grid Zhejiang Electric
Power Research Institute

Yangcheng International
Power Generation Co., Ltd.
Zhejiang Datang Wushashan
Power Generation Co., Ltd.
Zhejiang Energy Technology
Research Institute Co, Ltd.

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

Sun Changsheng, *Chair*

Tong Yiyi, *Vice Chair*

Li Zhou, *Secretary*

Bo Feng
Zhu Beiheng
Feng Bo
Zhao Changzhi
Dai Chengwei
Yin Feng
Hou Guolian

Zhang Jinbin
Zhou Li
Guo Lingyun
Liu Linhu
Meng Tianlin
Xue Wei

Zheng Weijian
Guo Weimin
Luo Xingyu
Su Ye
Liu Yucheng
Tian Yucong
Luo Zhihao

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

ABB Ltd.
Beijing GreenValley Technology
Co., Ltd.
Beijing Sifang Automation Co.,
Ltd.
BII Group Holdings, Ltd.
Chaincomp Technologies Co.,
Ltd.
China Datang Corporation
China Energy Engineering
Group Co., Ltd.

China Southern Power Grid Co.,
Ltd.
Chongqing University
Harbin Institute of Technology,
China
Hongguang Electric Group Co.,
Ltd.
Huawei Technologies Co., Ltd.
Huazhong University of Science
and Technology

North China Electric Power
University
Schneider Electric
Southwest Jiaotong University
State Grid Corporation of China
(SGCC)
Tianjin University
Zhejiang Provincial Energy
Group Company, Ltd.

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
Stephen D. Dukes
J. Travis Griffith
Guido Hiertz
Christel Hunter
Thomas Koshy
Joseph L. Koepfinger*
Thomas Koshy

John D. Kulick
David J. Law
Joseph Levy
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 1865.1™-2019, IEEE Standard Specifications for Maintenance and Test of Distributed Control Systems in Thermal Power Stations: Maintenance and Testing.

Distributed control systems (DCSs) are widely used today for monitoring and control of power-generating units and their auxiliary systems. However, there are several factors—for example, the quality of DCSs, technical and managerial problems, potential risks involving design and configuration, factory acceptance test, installation and commissioning, and the 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 is 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, this standard is 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.

This standard specifies the basic principle of repair and test, 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 test of monitoring system
- Technical requirements for repair and test of common systems and circuits
- Repair and test acceptance

This standard deals with the basic repair items and quality requirements which 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 instrument and control (I&C) systems.

Also, it covers the technical criteria, test items, methods of the system, as well as the quality-acceptance criteria and post-repair acceptance items and criteria.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
1.3 Word usage	2
2. Normative references	2
3. Definitions, acronyms, and abbreviations	2
4. Maintenance of DCS	4
4.1 General	4
4.2 Shutdown of DCS	5
4.3 Maintenance and repair of DCS	7
4.4 DCS power up and check	16
5. Test of DCS	26
5.1 General	26
5.2 Basic check and test	28
5.3 Basic performance test of DCS	31
5.4 Test of data acquisition function	45
5.5 Test of modulation control function	47
5.6 Test of protection, interlock, and on-off control function	62
5.7 Functional test of turbine digital electro-hydraulic system (DEH)	78
5.8 Functional test of gas turbine control system (TCS)	82
6. Acceptance of DCS	90
6.1 Acceptance of DCS after check and repair	90
6.2 Acceptance of DCS after test	90
Annex A (informative) Table of maintenance items for distributed control systems (DCSs)	93

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

1. Overview

1.1 Scope

This standard specifies the basic principles, contents, methods, performance indicators, and acceptance requirements for scheduled maintenance and testing of distributed control systems.

This standard applies to the maintenance and testing of distributed control systems (DCSs) of conventional thermal power plant in commercial operation. Reference may be made to this standard for factory acceptance tests, installation, commissioning, and site acceptance tests of DCSs of other types of power plants or DCS before commercial operation.

1.2 Purpose

This standard, based on the engineering principles, methods, practices, procedures, and field experience which have been demonstrated in many power plants, specifies the details, methods, and technical requirements of maintenance and tests after the technical modification or temporary or scheduled maintenance of a DCS of a thermal power plant. The standard aims to standardize maintenance and inspection, performance test, functional test, and acceptance of DCS, to provide guidance and basis for instrument and control (I&C) personnel of power plants to confirm DCS maintenance and test quality, and to eliminate defects impairing the operational reliability of units after maintenance and test.

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.

IEEE Std 1046™-1991, IEEE Application Guide for Distributed Digital Control and Monitoring for Power Plants.

IEEE Std 1050™-1996, IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations.

3. Definitions, acronyms, and abbreviations

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.³

automatic generation control (AGC): A control mode of a coordinated control system (CCS), in which the generating unit is controlled as a whole according to the unit load demands sent from the grid to meet the constantly changing grid demands.

automatic turbine control (ATC): An automatic control system that directs the turbine control system and other relevant control systems to jointly act to fulfill the startup, grid connection, loading, shutdown, safe and cost-effective operation of turbine based on the operating parameters and thermal stress of the turbine.

coordinated control system (CCS): A unit-level control system that controls the boiler-turbine generating unit as a whole and is mainly aimed to meet the load requirements of units and maintain the main steam pressure and other key parameters within the allowable range on the condition of meeting requirements for unit efficiency and energy saving and emission reduction. It mainly consists of unit load demand (ULD), boiler master and turbine master, BTU correction, primary frequency correction, run back, etc.

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

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

³ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>.

electrical control system (ECS): A control system serving for operation, interlock, display, and alarming of switchgears and synchronization devices of the auxiliary power system and grid-connection system. The control scope of the electrical control system covers the electrical system of each unit and common electrical system.

emergency trip system (ETS): An automatic control system that takes appropriate measures to deal with the abnormal situation occurring during operation of turbine, and shuts down the turbine when the abnormal situation evolves to potentially endanger equipment and personnel.

fast cut back (FCB): A control measure to keep the boiler working when load rejection occurs on a turbine or generator. According to the operating requirements of a turbine following FCB, there are two operating modes: 1) the unit operating independently with auxiliary power, 2) steam turbine being stopped while the boiler is not stopped.

gas turbine control system (TCS): The system that fulfills automatic control of various operating conditions of gas turbine, i.e., automatically maintains the speed, load, temperature, and other parameters of gas turbine within the specified range.

overspeed protection control (OPC): An overspeed control function, which can be realized by acceleration restriction or on-off control. In the former case, when the turbine starts to accelerate, an override command will be given, and the governing valve (GV) and intercept valve (IV) be closed. When the acceleration falls to zero, the normal speed control loop will function to maintain the turbine at normal speed. In the latter case, when the speed of the turbine rises to 103% of the rating, the GV and IV will be closed automatically, and when the speed restores back to normal, these valves will be opened again. This process will repeat until the normal speed control loop can maintain the turbine at the normal speed. These two control methods may be used in combination.

overspeed protection trip (OPT): A function of the turbine protection system, which will close the main steam valve (MSV), governing valve (GV), reheat stop valve (RSV), and intercept valve (IV) quickly to automatically trip the turbine when the speed of turbine surges to a certain value.

primary frequency correction (PFC): A function of coordinated control system (CCS), which responses to grid frequency correction requirements by means of ratio control, refers to the automatic control process in which the control system of generator unit in a grid automatically increases or decreases the active power of the unit to stabilize grid frequency when grid frequency deviates excessively from rated frequency.

protective grounding: The connection of metallic enclosures and circuit reference points of relevant equipment of the control system to earth, in order to 1) form a low-impedance discharge path for faulty current and high-frequency noise, 2) maintain the said enclosures at the same potential as the earth, 3) avoid such hazards as lightning strikes, current leakage, and electrostatic discharge (ESD), and 4) protect operators from electrical hazards, thereby ensuring human and equipment safety.

run back (RB): The control functions for main auxiliary machine failures, which rapidly reduce the unit load when part of the main auxiliary machines (such as feedwater pumps, forced draft [FD] fans, induced draft [ID] fans, etc.) fail and withdraw from work, and the unit cannot carry the current load.

system grounding: The connection of the grounding point of a distributed control system (DCS) (a zero voltage reference of circuit) with the grounding device (or electrical ground) via conductors of an effective sectional area to help ensure that DCS can withstand the overcurrent and discharge of overcurrent to earth when signals transmitted to the DCS, power supply, or DCS itself become abnormal.

4. Maintenance of DCS

4.1 General

4.1.1 Maintenance mode and items

To verify the operational reliability of DCS, periodical maintenance is required. Normally, the maintenance of DCS is performed with the unit overhaul, that is, the maintenance of DCS is carried out when units are shut down:

- a) If scheduled classified maintenance is performed for the unit, the maintenance class of DCS should be Class A, B, C, or D, which shall be consistent with the maintenance class of the unit.
- b) If scheduled annual maintenance is performed for the unit, the annual maintenance of DCS shall be performed simultaneously with unit maintenance that is in line with the annual maintenance plan of the current year.
- c) If condition-based maintenance is performed for the unit, maintenance of DCS shall be performed simultaneously with unit maintenance that is in line with the maintenance plan made based on the health status of the equipment.

The DCS maintenance items should be predetermined according to the maintenance mode of the unit as well as the defects found during operation and issues identified in checks before shutdown of the unit.

In the case of scheduled classified maintenance, see Annex A for maintenance items of different classes:

- Class A maintenance: Comprehensive cleaning, disassembly check and maintenance of DCS to maintain the tidiness of equipment and to recover, maintain, or improve the performance and reliability of DCS.
- Class B maintenance: Cleaning of DCS, disassembly check and repair of the control system equipment or components where problems occurred. During Class B maintenance, some Class A maintenance items or scheduled rolling repair items may be performed according to the evaluation results of DCS conditions.
- Class C maintenance: Check, evaluation, repair, and cleaning of DCS according to the regular pattern of fault occurrence, wear and tear and aging of equipment. During Class C maintenance, minor replacement of components, elimination of defects, adjustment and preventive test of equipment may be performed, and some Class A maintenance items or scheduled routine maintenance items may be performed as well.
- Class D maintenance: Defect elimination of the auxiliary system and devices of key equipment when DCS of a unit is in satisfactory operation. During Class D maintenance, some Class C maintenance items may also be performed according to the evaluation results of equipment conditions.

In the case of scheduled annual maintenance, comprehensive cleaning of DCS with relevant check and maintenance shall be performed in accordance the operating conditions of DCS.

In the case of condition-based maintenance, maintenance items shall be determined based on the condition check results, and the maintenance decisions shall be made in view of the condition evaluation and risk assessment of the equipment.

4.1.2 Maintenance management

In case where maintenance of DCS equipment is conducted along with unit maintenance, all standard maintenance items, non-standard maintenance items, safety measures, and the maintenance plan shall be prepared prior to the unit maintenance according to the technical requirements for DCS (see Annex A for units employing scheduled classified maintenance) and operating status of the unit or requirements of IEEE Std 1046™-1991. Operation instructions, test plans, and acceptance criteria for different maintenance items should also be developed. After gaining experience in condition-based maintenance, standard and non-standard maintenance items of Classes A, B, and C maintenance for DCS may be adjusted appropriately.

Full consideration should be given to the unit maintenance work as well as the post-maintenance testing and adjustment time in the maintenance plan.

Prior to the commencement of maintenance, it is necessary to check the availability of spare parts, tools, and materials required to verify that they meet the maintenance demands.

It is necessary to check that all technical documents, records, data, and drawings concerning the operation, faults, defects, changes, calibration, and tests of DCS are consistent with the actual condition. Check that the DCS equipment repair records and equipment fault, damage, and replacement records have been established before the commencement of maintenance work. Work permits and operation permits shall be well managed during the maintenance, and the maintenance shall be implemented as planned along with strict safety measures and proper supervision.

Change of logics, signals, parameters, wiring, etc., shall strictly follow the relevant rules and shall be recorded as per the specified work procedure during the maintenance. Upon completion of the maintenance, both maintenance record and equipment replacement record shall be sorted out and timely reviewed, the software and forced signals shall also be restored, and backup of the application software shall be made according to the relevant requirements.

4.2 Shutdown of DCS

4.2.1 Work before shutdown of DCS

4.2.1.1 Check of operating status

Thoroughly inspect the operating status of DCS. Make a record of abnormal information and phenomenon in a dedicated record sheet and add them to the list of maintenance items:

- a) Check the parameters, equipment status, network status, and alarm signals displayed on the screen of the operator station, and record important abnormal information (such as redundancy loss or unexpected switchover of controller, loss of important signals or abnormality of key parameters, data overflow, frequent bus switching) in detail.
- b) Check the operating status of all modules and components inside the cabinet and the cooling fans of the cabinet and equipment.
- c) Check the status of forced signals (or disabled scan service) to the channels and damage of the module channels.
- d) Check and measure the voltage of uninterruptible power supply (UPS), voltages of various power supplies, and temperatures at the main connections of power supply modules and power supply circuits inside the cabinet.

- e) Check and measure the ambient temperature, humidity, and dust content in the control room, engineer room, and electronic equipment room as well as the ambient temperature of fieldbus and local cabinets for remote input/output (I/O).
- f) Check the operating status of peripheral devices, components, and printers. Review all print records and hard copies.
- g) Check the operation logs and alarm logs of the DCS.

Check and summarize the abnormal information recorded in the DCS self-diagnostic system.

Check the DCS routine maintenance records for all the eliminated defects and remaining defects, and make a list of defects to be eliminated during the unit shutdown.

4.2.1.2 Software and data backup

A full backup of software and data of DCS shall be made before and after the maintenance of DCS (refer to Class A and Class B maintenance in the case of scheduled maintenance). Attention shall be paid to the following points when making backups:

- a) Backup of the data shall be made completely at the same time.
- b) No person shall be allowed to log into the backup computer during the backup process.
- c) Backup shall be carried out on the master computer, or on both the master and slave computers.
- d) Backup of the database shall be carried out when no one is using the database, and configuration files shall be consistent with the controller parameters.
- e) Backup of redundant computer systems shall be carried out after the redundant switchover has completed and the systems are restored to normal operation.

Each backup file should be labeled with the number, name, time of backup, etc. Data quality check should be carried out for the backup to help ensure it is error-free; the contents, file size, and date of the backup should all be correct.

4.2.1.3 Tests before shutdown of DCS

In order to find the hidden risks in DCS and improve the quality of unit maintenance, relevant tests can be conducted selectively according to the DCS operation records and the current conditions before its shutdown.

4.2.1.4 Check and equipment isolation

Before stopping the DCS, confirm that all the related running processes have been stopped (or proper isolation measures have been made), and that the following requirements are met; otherwise it is forbidden to shut down the entire DCS:

- a) Confirm that all check, processing, and information storage work has been completed.
- b) All running equipment involved has been taken out of service or have been isolated properly.
- c) Confirm that all subsystems involved in the power outage have been out of service and the system is allowed to be powered off.
- d) If maintenance of common equipment is to be performed, such common equipment has been isolated safely.

- e) Confirm that no one is still working on the DCS, all formalities required for shutdown are completed, and the maintenance environment, safety measures, and preparation work have met the requirements for maintenance.

4.2.2 Procedure for shutdown of DCS

To reduce unpredictable events due to direct loss of power supply of the DCS, the DCS shall be shut down according to the following procedure:

- a) Disconnect the in-cabinet power supply of the process control unit (PCU) and confirm that the power supply is disconnected in the self-diagnostic display on the operator workstation.
- b) Disconnect the power supply of the PCU in the power distribution cabinet.
- c) Perform a normal shutdown of each server (if any) according to the requirements of database and operating system, and then disconnect the power supply of each server.
- d) Disconnect the power supply of each network switch.
- e) Shut down the operating system of each operator station according to the operating system requirements, and then disconnect the main power supply of each operator station.
- f) Disconnect the power supply of each display, printer, and other peripheral equipment.
- g) Turn off the main power switch of the DCS and place the warning signs.

4.3 Maintenance and repair of DCS

4.3.1 General requirements

Prior to the maintenance and repair of DCS, confirm again that its power switch is turned off and warning signs are in place.

Check that the air-conditioning systems in the electronic equipment room, engineer room, and control room have sufficient cooling capacity with an excellent performance of regulating the temperature and humidity, and that the ambient temperature, humidity, and cleanliness meet the manufacturers' requirements with good record made.

Check that the power supply fuses are in good condition and their capacity and type meet the requirements of equipment usage. Record any damaged fuses and replace them with new ones of matching ratings.

The computer devices shall be visually intact without missing components, rusting, deformation, or obvious damage, and shall be placed in order. Connecting cables shall be routed and tied neatly and connected reliably, and all labels shall be in place and legible.

For devices that are required to be resistant to static charge, anti-static measures shall be taken during repair. The compressed air (nitrogen or inert gas are preferable) used to blow modules shall be free of water and oil contamination, and its pressure shall be maintained around 0.05 MPa. The power of the vacuum cleaner shall be sufficient to quickly collect the flying dust. A specialized cleaning agent shall be used to clean the devices.

When cleaning the cabinet, remove all modules and mark their positions clearly, and then clean the modules, cabinet, as well as racks, slots, and dust filter inside the cabinet. Check the cabinet's dust filter and make a timely replacement if damage occurs. The internal and external components/parts of the cabinet shall be installed securely, and the grounding bus, bolts for fixing terminal blocks, wiring terminals, and screws shall be tightened and not become loose.

Fasten all the joints (or the screws that fix the joints in place), connectors, and wiring terminals. After the maintenance, pull all the joints, connectors, and wiring terminals gently to verify that they do not become loose.

The inspection and maintenance should comply with the respective requirements of the country or the industry in the country (unless otherwise specified by the manufacturer).

4.3.2 Maintenance and repair of DCS equipment

4.3.2.1 Hardware of human-machine interface (HMI) stations, servers, and switches

Perform the following maintenance after confirming that the power supply for the equipment to be maintained is reliably disconnected:

- a) Confirm that the equipment is disconnected from the power supply. Open the casing of the cabinet (or switch if necessary), eliminate defects, and replace damaged components. Check that circuit boards inside the cabinet are free of obvious damage, burn marks, or abnormality of parts. Check that connecting wires and cables are not broken. Check that elements, components, and boards are securely installed, and that connectors and ports are correctly connected and screws are tightened and the clamps are locked.
- b) Clean the parts inside and outside the casing (including cooling fans) and the filters. After cleaning, the inside and outside of the casing shall be clean, ash-free, and stain-free. The cooling fans shall rotate freely without jamming; the filters shall be undamaged, dust-free, and have good ventilation.
- c) After cleaning is completed, confirm that the internal components are normal, and the voltage level of power supply is correctly set, and then reinstall the casing.

4.3.2.2 Hardware of PCUs

Confirm that the equipment and control subsystems to be maintained at the process control station have been removed out of service and are reliably disconnected from the power supply. Place the warning signs to the corresponding power switches in the power supply cabinet, and then perform the repair as follows:

- a) Mark the number and position of modules, components and slots, and jumper settings inside the cabinet to be cleaned, then remove the modules and components/parts and place them in safe positions.
- b) Clean the cabinet and modules, components (including cooling fans), and filters; inspect and handle any abnormal issues found.
- c) Check that the cabinet, modules, and components/parts are clean and in good condition. Verify that the components of modules are securely installed and the connectors are correctly connected. Check modules with fuses and confirm that the fuses are in good condition and have a correct capacity. Check and verify that the cooling fans can rotate freely without jamming, labels attached to modules are correct and legible, and filters are dust-free, undamaged, and have good ventilation.
- d) Check and confirm that the setting of the PCU modules is correct. For modules equipped with a backup battery, the battery shall be checked and replaced as per the manufacturer's instructions and requirements; when the new battery is installed, verify that any parameters of the software and settings are not lost.
- e) After checking modules and cleaning the cabinet, racks, and slots, reinstall the modules into the corresponding slots in order according to the cabinet and slot serial numbers marked on the modules.

- f) After the modules are reinstalled, check that all cables connecting the modules are connected in the right positions without looseness, and if any screws and/or clamps are used, verify that the screws are tightened and the clamps are in place.

4.3.2.3 Network and interface devices

Remove the system out of service, turn off the power switch of devices, and then perform the check and repair as follows:

- a) Clean, check, and repair the external and internal parts of the network equipment (communication modules, switches, concentrators, couplers, repeaters, and optical transceivers), verify that the equipment is clean, the internal parts are without abnormality, the connectors are firmly connected, and the contacts are good; reinstall the casing/housing after fastening the wiring.
- b) Check that all interfaces (optical cable, RJ45, BNC, etc.) are free of breakage and deformation, and replace them with new ones if necessary; check that the ports, terminal connection, and termination resistors are connected correctly and reliably/firmly; measure the insulation resistance of the devices and cooling fans as well as the impedance of bus terminal matcher, which shall meet the nominal value requirements.
- c) Check that cables and optical cables are undamaged and free from breakage. In the case of replacement following a fault, they shall be tied neatly and properly with the bending radius complying with relevant requirements. The metallic protection tubes of site communication cables shall be reliably grounded. Communication cables and optical cables that are to be maintained shall be marked properly at the connections before disassembly, and optical connectors shall be wrapped immediately after they are disassembled to avoid contamination. Restore the connection upon completion of the repair.
- d) Check the interface with the external data management system, and use physical isolation devices that have passed information security certification.

4.3.2.4 Satellite timing system

Cut off the power supply for the master clock system and then perform the following basic checks:

- a) Clean the master clock or standard clock of the satellite timing system. Its appearance should look clean after cleaning.
- b) Check that the antennae of the satellite timing system are installed vertically, and there shall be no obstructions around the antenna. The antenna plugs shall be plugged reliably and the feeders shall not be broken or fractured.
- c) Check that the communication interfaces of master clock and the standard clock of satellite timing system are connected correctly and the communication cables are in good condition without damage.

4.3.3 Peripheral devices

4.3.3.1 Display devices

Turn off the power switch of the display, disconnect the display from the power supply, and perform the maintenance as follows:

- a) Open the cover of the display and clean the inside and outside of the display. Check the internal components and eliminate abnormality if any. Check that all plugs are reliably connected and

clamps are securely locked. No connecting wire shall be broken or loose. Tighten the screws for the screwed parts and then reinstall the display cover.

- b) Clean the screen with dedicated cleaning agent. After cleaning, the screen appearance should look clean without dust or stain.
- c) Check that the external connecting cables for the display signals are free of defects such as damage or breakage. Measure of equipment insulation which shall comply with relevant requirements.

4.3.3.2 Printers and copiers

Turn off the power switch of the printer and disconnect the printer from the power supply, and then perform the repair as follows:

- a) Remove paper scraps from inside the printer, clean the paper feeder and paper feed roller, and eliminate abnormality of parts, if any. After the repair/maintenance, the printer should be clean without dust or contamination, all parts shall be returned to normal, and all wires or cables shall be connected correctly without looseness or breakage. Fasten all parts.
- b) Measure and record the insulation resistance, which shall be consistent with the nominal value.
- c) Add lubricant to the mechanical rotating parts of the printer that require oil lubrication. The amount of lubricant shall not be excessive.
- d) Restore the printer. Check that the various printer switches, jumpers, and parameters are set correctly. In the case of a dot matrix printer, it is also necessary to re-adjust the platen gap adjustment lever to match with the paper thickness.

4.3.3.3 Mouse or trackball

Turn off power switch of the computer and disconnect the mouse (or trackball) from the host computer, and then perform the maintenance as follows:

- a) Loosen the screw to remove the cover of the mouse (or trackball), carefully clean the ball, scroll wheel, and photoelectric reflector. After cleaning, the mouse (or trackball) should look clean without dust or contamination.
- b) All components on the circuit board shall be free of abnormalities, the wiring shall not have broken wire or signs of breakage, and the connections shall be correct without looseness. Tighten all the mounting screws.
- c) Reinstall the cover of mouse (or trackball) and tighten the cover fixing screws.

4.3.3.4 Keyboards

Before powering off the DCS, press each key while ensuring a safe condition. Record keys that fail to respond or respond with a delay or error. Turn off the power switch of the computer, disconnect the keyboard from the computer, and perform maintenance as follows:

- a) Clean the surface of the keyboard and loosen the screws used for fixing the keyboard. Clean the dust deposited in spaces between keys.
- b) Check the interior of the keyboard and eliminate abnormalities if any. Pay special attention to keys with records of defects.
- c) After the maintenance, the components on the internal circuit board shall return to normal, all wires or cables shall be free of looseness or breakage, the contact point of keyboard and the interface with computer shall be in good condition and free of dust or contamination.

4.3.4 Power supply system

4.3.4.1 Uninterruptible power supply (UPS)

Shut down the unit and remove the system out of service, turn off the power supplies involved, turn off the power switch of the UPS and disconnect the UPS from its power supply, and then perform the check and repair as follows:

- a) Remove dust from inside and outside the UPS to keep it clean.
- b) Check and eliminate abnormalities of UPS components, and fasten all internal wiring and plug-ins.
- c) Check that the output-side power distribution switches, fuses, and sockets are in good condition.
- d) Measure the insulation resistance of the cables (when the power supply output is equipped with an isolating transformer, the insulation resistance between the primary and secondary windings of the power isolation transformer and the primary terminal to ground shall also be measured) which shall meet the nominal value requirement.
- e) When the UPS is equipped with battery, check that the battery is leak-free.

4.3.4.2 Cabinet power supply equipment

Deactivate the relevant systems, mark and record each power plug or connection, cut off the connections between the cabinet and the power supply, and perform the following maintenance:

- a) Clean relevant equipment (modules, fans, and parts) of the power supply to keep them clean and keep fans rotating freely.
- b) Check the interior of power supply modules. The capacitors shall be free from deformation or leakage, and the components on the circuit board shall be free of abnormalities. Damaged fuses shall be recorded and then replaced with new fuses of the same capacity after the cause for the damage is identified.
- c) Check that the power supply circuit and terminals are in good condition without damage, and the sheath of conductors or cables are intact without overheating and burning marks. The common lines shall be connected in a reliable loop, without disconnection or looseness. Fasten all wires to verify reliable connection.
- d) Measure the insulation resistance between the power supply system and ground, which shall be greater than 20 M Ω .
- e) Check the main protection interlock output relay. The trip solenoid valve of each channel in the “dual channel” design shall be powered by separate power supplies.
- f) Restore the power supply equipment, confirm that all power plugs or connecting wires are reliably connected according to the recorded marks, and confirm their ratings are set correctly.
- g) Check that the two 220 V ac main power supplies that back up each other are independent and are of the same phase (generally Phase A).
- h) Check that the power supply labels are consistent with the actual power supply.

4.3.5 Grounding system

4.3.5.1 Maintenance of protective grounding

The protective grounding shall be secure and reliable, and can be connected to the electrical protective grounding grid. Its grounding resistance shall meet the design requirements.

Exposed metallic components of live equipment that may come into contact with the human body shall have faultless protective grounding.

4.3.5.2 Maintenance of system grounding of DCS

The system grounding of DCS refers to the connection of the grounding system from the cabinet to the electrical grounding grid. The following works shall be done during maintenance:

- a) Check that the connections of the whole grounding system between the various groundings of the cabinet and the electrical grounding grid are reliable and conform to the requirements of IEEE Std 1050™-1996 or design requirements of the control system. When an independent grounding grid is used, it should be arranged as far as possible from the lightning grounding grid. When the control system shares the same grounding grid with the electrical system of the power station, the ground wire of DCS should be connected to the electrical grounding grid using low-voltage insulated power cables and allow only one connection point.
- b) Check the cabinets that are not allowed to be directly connected to the steel bars of the buildings, and disconnect the cabinets from ground wires. Check that the insulation resistance between the cabinets and the ground is greater than 2 MΩ. Reconnect the cabinets to the ground wires, and check that the connections between cabinet enclosure ground, power supply ground, shield ground, and the general grounding plate conform to the design (or the manufacturer's) requirements and are reliable.
- c) For DCS with single-point grounding requirements, check that all ground wires in the cabinet are connected reliably, and instruments are directly connected to the common ground wire in the cabinet via insulated copper wires (with a core area no less than 4 mm²) rather than intermediate objects fixed by screws (such as the wiring trough in the cabinet). Unless otherwise specified by the manufacturer, the grounding of various characteristics in the entire DCS shall be led to the grounding plate in the grounding cabinet via insulated cables or wires to verify *one-point grounding*.
- d) When a group of cabinets in the DCS are connected to the master ground bar of the DCS via one common ground wire/cable, the cabinet grounding for the cabinets in the same group should be star-connected.

The grounding requirements and the test items and methods of shielded cables vary with the types of DCS and they should be maintained as per the manufacturer's instructions or the corresponding requirements.

- Check the interconnection between ground wires of terminals and the common wire in the cabinet, which shall form a closed loop and be tightly connected.
- The grounding location of the shielding layer shall conform to the design specifications: when the signal source is floating, the shielding layer shall be grounded beside the panel or computer; when the signal source is grounded, the shielding layer shall be grounded near the signal source; when the amplifier is floating, one end of the shielding layer shall be connected with the shield cover and the other end connected to the ground wire of the signal source (when the signal source is grounded) or to the site ground (when the signal source is floating).

- Unless otherwise specified by the manufacturer, verify that the shielding layer of the same signal circuit or the same line is only permitted to have one single-ended grounding point and the electrical continuity of the shielding layer along the entire signal circuit. During the repair, disconnect the shielding wires of cables in the cabinet from ground in order. Measure the insulation resistances between the shielding wires and ground, which shall be consistent with the nominal value. Restore the connection and measure the resistance again at the starting end on site, which shall be less than $4\ \Omega$. Check that the connection of shielding layers of cables inside the junction box is made via wiring terminals.
- The metallic protective tubes of communication cables shall be well grounded.

4.3.6 Maintenance of cabinets

4.3.6.1 Introduction

Cabinets stated herein include power cabinet, control cabinets, panels, consoles and boxes, and intermediate terminal cabinet, which are hereinafter collectively referred to as the *cabinet*.

4.3.6.2 Cabinet cleaning and inspection

Before cleaning and maintenance of the cabinet, verify all equipment inside the cabinet are taken out of service and all power supplies are cut off.

Blow and clean the interior and exterior of cabinet to remove dust and dirt. Check the protections in the cabinet and eliminate defects. After the maintenance, the following requirements shall be met:

- a) The cabinet should be clean and free of dust or stain. Module slots on racks shall be clean and dust-free.
- b) The filters shall be free of dust, damage, or blockage. The feet should be free of rusting, and paint coat inside and outside the cabinet is in good condition.
- c) The sealing strips for cabinet door and the sealing gaskets for the cabinet bottom shall be intact, and the door handles, locks, latches, and other accessories shall be complete.
- d) The openings for cables and cable conduits in the cabinet shall be hermetically blocked. The bushings for cables and incoming/outgoing wires shall be neatly arranged with joints fastened.
- e) The cabinet shall be provided with reliable waterproofing measures, and wires shall be led in from the bottom or may be led in from the side instead if there is good protection.

4.3.6.3 Equipment and components in the cabinet

Check the components and accessories in the cabinet, and eliminate defects and replace damaged parts. After maintenance, the following requirements shall be met:

- a) Components in the cabinet shall be undamaged, free from deformation, and intact, reliably installed on the metallic/supporting frame. The screws shall be secured and locks buckled.
- b) The rack slots for installation of modules shall be undamaged, the slots and plug-ins free of deformation and damages (pins shall not be bent or fractured). The modules shall not be fractured, mechanically damaged, loose, or have missing elements, and the printed circuit board shall be free of burn marks.
- c) The plugging of modules and plug-ins shall be smooth. After the connection is restored, the plug-ins shall be connected securely and all fasteners shall not become loose.

- d) Check relays in accordance with relevant procedures. The relays shall be free of overheating or burning. Calibrate relays to make sure they conform to nominal value requirements.
- e) Check that all power switches in the cabinet operate without getting stuck. Measure their opening and closing resistance, which shall meet the nominal value requirements. The fault alarm contact shall act reliably, and the capacity of upper-level and lower-level fuses shall match with each other and meet the relevant requirements.
- f) Check that sockets and lighting fixtures function well, and that lighting switches operate reliably.
- g) Check that the backup operation devices are correctly connected. Operate the dual manual buttons for boiler master fuel trip (MFT), turbine trip, and generator trip. Measure the contact resistance at each contact point, which shall be less than 1 Ω when closed and greater than 1 M Ω when opened.
- h) Cooling fans in the cabinet shall rotate without jamming and be securely connected, and shall be regularly replaced as required or when necessary.
- i) Measure the insulation of equipment and components, which shall meet the nominal value requirements.

4.3.6.4 Wiring in the cabinet

Check, repair, and fasten cables and wires of control panels, consoles, and cabinets. Replace cables and wires which have an unsatisfactory insulation or are damaged. Perform maintenance as follows:

- a) Check that cables/optical cables are undamaged and not broken. During repair, make marks before disconnecting fieldbus cables/optical cables, and the connectors of the cables shall be wrapped immediately after disconnection. When replacing defective cables/optical cables, verify that the cables bear no stress (tension and/or squeezing), and that the bending radius of cables and the distance to other cables meet relevant specifications or the manufacturer's requirements.
- b) Check that all connectors or terminals of fieldbuses are connected reliably, the shield drain wires are fixed and banded firmly and provided with insulation bushings, and the termination resistor is reliably connected.
- c) Measure and record the insulation resistance of cables of cabinet power supply and wirings for important protection, interlock, and control loops, which shall meet the nominal value requirements.
- d) Check the grounding of cable shields of supervisory system requiring single-point grounding as per 4.3.5.2.
- e) Arrange cables and wires to keep them neat, and tie them securely. Standby cables shall be properly protected to reduce the introduction of interference signals due to antenna effect.
- f) Check that screws used for fixing the wiring terminal are complete and without discharge or burning marks, conductors are connected reliably and neatly (in the case of crimping or wrap connection, verify that the wires are in good contact with terminals; while in the case of connecting stranded flexible cores to terminals, add lugs or plate tin at the connections). Gently pull the wires and verify that they shall not become loose. Preferably one wire is connected to each terminal and at most two wires are allowed to connect to each terminal.
- g) Connectors shall be connected properly, and any unexpected exposed wires shall be restored after the causes are identified. Exposed wires that are confirmed to be useless shall be tied and put in the wiring duct. There shall be no exposed wire when the maintenance is accepted.
- h) During repair, if there is any change or modification to the wiring circuit, the relevant management procedure shall be followed, and the wiring of the relevant control loop shall be checked and tested against the correct drawings to verify compliance of the actual wiring with drawings.

4.3.6.5 Cabinet and device labels

The labels of instrumentations of panels and consoles and the name and number of cabinets shall be correct, complete, and legible; important cabinets shall be provided with conspicuous labels.

The equipment, rack slots, and power switches installed inside cabinets shall all be provided with clear labels.

The marks of cables and connectors in cabinets shall be complete, legible, and correct.

A legible equipment layout drawing and terminal wiring diagram shall be attached to the inner surface of the cabinet door and regularly updated.

4.3.7 Check of preventions

4.3.7.1 Explosion preventions

The DCS equipment, components, and laying of cables and pipes in areas exposed to explosion and fire hazards shall comply with the current national or industrial explosion-proof and fireproof standards and specifications, and necessary measures shall be taken during repair.

4.3.7.2 Preventions against fire and over-temperature

The openings where cables and measuring piping go through the cable mezzanine, tunnels, floors, walls, cabinets, and panels and the gaps between panels (including gaps between the through-wall bushings and cables) in the control room, electronics room, computer room, etc., shall be blocked with satisfactory non-combustible or flame-resistant materials, and the fireproof measures shall meet the relevant specifications.

Reliable thermal insulation measures shall be taken for cables in the vicinity of high-temperature pipes, valves, and other heat sources.

4.3.7.3 Preventions against freezing and water

In cold regions, anti-freezing measures provided for field cabinets shall be in good condition after repair, tests show that the startup and stop control is normal, and heating performance can meet the demands for freezing prevention.

Outdoor panels and devices shall be sealed and provided with reliable waterproof measures.

Control panels and cabinets in the control room and electronics room shall have preventions in place against leakage of heating and ventilation pipes.

4.3.7.4 Preventions against corrosion and moisture

When DCS devices, components, and cables are arranged in a place prone to contamination, dust deposit, and corrosion, reliable measures to reduce dust and corrosion shall be provided in place.

Anti-moisture measures for control equipment shall function effectively and conform to relevant specifications and the manufacturer's requirements.

4.3.7.5 Preventions against interference

Anti-interference measures for equipment, measuring probes, and elements that may operate unexpectedly due to electromagnetic interference shall be in good condition and function reliably.

Measures to reduce unintentional operation of operating or emergency buttons that may affect the safe operation of units shall be in good condition and function reliably.

4.3.7.6 Environment check

Check that measures for preventing entry of small animals to electronics room, engineer room, and control room are reliable and effective.

Check that security measures taken for the electronics room, engineer room, and cable bays are effective, and registration of visitors is complete.

Check that the temperature and humidity automatic regulation devices in electronics room, engineer room, and control room shall work reliably. The environmental indicators displayed on the thermometer and hygroscope shall conform to Table 1 or the manufacturer's requirements.

Table 1—Environmental indicators for DCS

Items	Temperature (°C)	Change rate of temperature (°C/s)	Humidity (%)	Vibration (mm)	Dust content (mg/m ³)
Required value	15 to 28	≤ 5	45 to 70	< 0.5	≤ 0.3

The identifying number and names of cabinets at various control stations and intermediate terminal cabinets shall be conspicuous. Control panels and cabinets involved in important protection shall be distinguished with different colors of name labels.

4.4 DCS power up and check

4.4.1 Check before power up

4.4.1.1 Basic check

Check that the temperature, humidity, and cleanliness of the places where computer equipment is located comply with the operational requirements of the equipment.

Verify that repair is completed, hardware devices of DCS are restored and installed correctly and securely, the circuit is connected safely and reliably, the waterproof, fireproof, and dustproof measures for control cabinet are in good condition, and the capacity of fuses in each power circuit complies with relevant requirements.

The names and identifying numbers of each PCU cabinet and intermediate terminal cabinet shall be conspicuous. The terminal block wiring diagram should be placed in the cabinet, the accessories shall be

intact, and lighting should be normal. The power lines, ground wires, and common wires of measuring circuits shall be connected in loops correctly, firmly, and neatly.

The incoming and outgoing cables of intermediate terminal cabinets and PCU cabinets shall be arranged neatly, connected correctly, firmly, and neatly. Their marks, labels, and wiring numbers shall be complete and legible.

4.4.1.2 Check of PCU

Perform checks as follows in order and the PCU shall comply with the following requirements:

- a) All power supply modules, master controllers, functional modules, and other equipment inside the cabinet shall be restored and correctly and securely installed.
- b) All signal lines, power lines, ground wires, and cables that led to the PCU cabinet shall be connected correctly, securely, and neatly.
- c) Data communication lines of each PCU and redundant communication lines between PCUs shall be connected correctly, securely, and neatly.
- d) The cables used for connecting various functional modules to the corresponding terminal blocks inside the intermediate terminal cabinet shall be connected correctly and securely.

4.4.1.3 Check of HMI stations and servers

Perform check as follows for the operator station, engineer station, and server station in the following order:

- a) Check that the power supplies of computers, displays, and printers at the operator station, engineer station, and server station are well connected.
- b) Check that the keyboard, mouse or trackball, and signal lines of display and printer shall be intact and correctly connected to the computer.
- c) Check that the data communication lines at the operator station, engineer station, and server station are connected correctly and securely.

4.4.1.4 Check of power supply circuit

Check that all DCS-related circuits are in a safe status and that no one is working on the power supply circuit of a subsystem. All formalities required for energization and operation of DCS-related subsystems shall be complete. Remove warning signs placed for the power switches in the power cabinet.

Measure the resistance between the output lines of power supply and between the output lines and the ground in order and make sure the resistance is consistent with nominal values.

Check that the redundant power supply has a correct voltage class and the measured voltage is consistent with nominal value. Before energization of the DCS for the first time, check that the voltage of the two redundant power supplies is within the allowable range. When the power supply is floating, check that electrostatic voltage between neutral lines, and that between live lines of the two power supplies, is at or below 70 V; otherwise, the network switches and controllers will be susceptible to damage during a switchover of power supply.

4.4.2 Power up and putting into service

4.4.2.1 Introduction

Power up the modules in the control cabinet in order according to the procedure specified by the manufacturer. In this process, measure and record the output voltage of each channel of the power supply modules and the power supply voltage of the energized equipment or system to verify that these voltages are consistent with nominal values and that the module indicators function correctly.

Only after it is confirmed that the power supply voltage of the energized equipment or system is normal, and module indicators function correctly, can the equipment or system of the lower level be energized.

4.4.2.2 Cabinet power up

For systems complete with self-contained UPS, after it is confirmed that the devices are ready for energization, restore the connection between the power supply and the UPS, close the power switch, and perform check as follows:

- a) When the UPS is started, all indicators shall work normally, and no fault alarms or other abnormalities are displayed in the self-check process.
- b) Check that the switch between inverter power supply and bypass power supply of the UPS is normal.
- c) Check that all parameters of the UPS are consistent with nominal values specified by the manufacturer.
- d) In the case of UPS equipped with battery, conduct charge and discharge tests according to the manufacturer's requirements. Replace the battery if it fails to pass the tests.

After it is confirmed that the cabinet is ready for energization, restore the connection between power supply and cabinet, close the power switch, and perform check as follows:

- Power supply devices shall be free of abnormal noise and smell, fans rotate normally, no fault alarm be given, and various indicators work normally.
- Measure the voltage of each circuit inside the cabinet and record it (for new units, records shall be set up). For power circuits whose voltage is not consistent with the nominal value, measures shall be taken to solve the problem. Compare the measured voltage with that recorded during the last repair, and if the voltage changes significantly, investigate the cause and take appropriate measures to solve it.
- For the provided redundant power supplies, switch off any one of them and check that the controller circuit shall work normally.
- For a power supply of a cabinet which will result in severe unit faults after power loss, verify through tests that its redundant power supply system and automatic switch-in device can be switched in within the specified time, and in the case of loss of any main power supply, the associated control panel will give correct audible and visual alarm signals.

4.4.2.3 HMI stations and servers power up

Power up devices at the operator station, engineer station, and server station as follows (confirm whether the procedure is correct for first energization):

- a) Close the main power switch to turn on the power supplies of the engineer station and server station to start up. Check that the equipment is free of abnormal noise and smell when working and cooling fans rotate normally. After information pops up on the display, enter the operating system, check that all status indicators and interfaces display normally and that no error information is displayed during the self-check process, and then start the application program (or the system starts automatically).
- b) Turn on the main power switch of each operator station. After an operator station is started, check that the equipment is free of abnormal noise and smell when working and fans rotate normally. After information pops up on the display, enter the operating system, check that all status indicators and interfaces display normally, and that no error information is displayed during the self-check process. The system automatically enters the application program.
- c) Check that the cooling fan of the large-screen display rotates freely without jamming.

4.4.2.4 PCU power up

The energization of the PCU shall follow the procedure below:

- a) Turn on the main power switch of the PCU.
- b) Turn on the power switch of the PCU system, and then turn on the on-site power switch of the PCU.
- c) Start up the PCU, and it shall operate automatically, and various status indicators at the station shall indicate normal operating status (which may be observed through self-diagnostic program) and cooling fans shall operate normally.
- d) Check that the configuration of modules (including terminal board) and peripheral devices comply with corresponding requirements and meet the unit operational requirements.
- e) For PCUs equipped with display, keyboard, and mouse interfaces, connect display and operating devices to carry out check if necessary.

4.4.2.5 Printer power up

Confirm that the printer is connected with the power supply, turn on the power switch, and perform check as follows:

- a) After the power supply is turned on, the printer shall start the self-check program and print a report when the program is completed. Check that the printed reports are correct, legible, and without deformation of characters.
- b) Deal with abnormalities (for instance, replace the print head or ribbon if discontinuous dots are found for a dot matrix printer). Replace the ink cartridge with a new one of the same model if an ink-jet printer has such defects as line loss or ink drop, or a laser printer has such defects as black lines or weak adhesion of ink.
- c) In the case of a hardcopy unit, energize it to carry out an overall test. Make a copy of one page of a colorful picture to check if the picture and color are proper and the characters are legible.

4.4.2.6 Network and interface power up

Start all computers in order following the procedure stated above until the entire DCS is started, and check the communication of the entire system:

- a) Network devices shall not emit abnormal noise and smell and fans rotate in the correct direction, and no error is displayed in the self-check process.
- b) Check the status of indicators of network devices or start the system diagnosis program to verify that the communication bus system and associated modules or components work normally and in redundant state.
- c) Check all control subsystems by system diagnosis tools/functions or other methods provided by the manufacturer to confirm that all displayed information of communication is consistent with actual conditions.
- d) Check that configurations of system interface comply with corresponding requirements and unit operational requirements. Data communication with the external system shall be realized by means of outward unidirectional transmission, and other control systems communicating with DCS shall comply with relevant information safety requirements.
- e) If necessary, special check tools and dedicated software may be used for further check.

4.4.2.7 Satellite timing system power up

Turn on the power switch of the master clock system and check the following functions:

- a) The satellite timing system shall automatically start initialization and self-check, during which no error is indicated.
- b) After initialization and self-check, the lock indicator of the satellite timing system shall light up and its internal timekeeping clock shall work normally in case this system is out of synchronization.
- c) Start master clock and check that synchronism check function of master clock (check against standard time) is normal.
- d) Start clock calibration function of all stations to calibrate their time indication such that the time displayed at these stations is synchronized with the master clock or the standard clock device of the satellite timing system.

4.4.3 System check

4.4.3.1 Keyboard check

The human-machine interface (HMI) is reliably connected to keyboard (standard keyboard or special keyboard). When pressing any key, it shall respond normally. Perform check as follows:

- a) Check that the switchover between special keyboard and standard keyboard is normal.
- b) Check that all letters and numbers on the special keyboard can be entered normally.
- c) Check that keys preset for displays can correctly call out the corresponding picture.
- d) Check that each functional key can fulfill its functions.
- e) Check that the mouse (or trackball) is flexible without jamming and can respond correctly.

4.4.3.2 Operating system check

During energization and startup of the control system, perform check as follows on the operating system:

- a) No abnormality or error information is indicated during the energization and automatic startup of operating system. If an error is indicated and automatically eliminated, shut down the operating system normally and restart it, then check that defects are completely repaired. Otherwise, backup and recovery or reinstallation shall be considered.
- b) After the operating system is started, all application files should be closed. Start the disk detection and repair program to detect and repair errors in disks.
- c) Enter the “Setting” interface and adjust the brightness, contrast, color temperature, focusing, and location of the display. All these functions shall work normally. Make further adjustments to make the whole picture clearer, the brightness, color, and resolution evenly distributed, and free of flicker or jitter.
- d) Enter the area setting interface and check that the time zone is the country where the device is located, and help ensure that the format of date and time complies with the requirements of this country.
- e) Search and delete temporary files in the system and empty the recycle bin. For computer stations that are incapable of automatic cleaning, manually remove useless data and files.
- f) Check that the settings of account password, audit entrusting relationship, domains, and groups are correct and comply with system requirements. Check that sharing settings of all devices and/or files and folders comply with system requirements.
- g) Check that the storage media works normally. Start the defragmenter to clean and optimize the storage spaces to meet the requirements for storage of unit operation parameters.

4.4.3.3 Check of network address settings of DCS

Check the media access control (MAC) address setting. The checking methods are different for different operating systems. This standard provides checking methods for Windows systems (refer to the user manual provided by the manufacturer for inspection methods of other operating systems): input “cmd” at the operating window of computer (including operator station, engineer station, and server). Then input “ipconfig/all”, identify and record the MAC address. Confirm that the MAC address is set correctly (refer to relevant documents for inspection of MAC address of switches and various ports).

Check the IP address setting: if DCS is configured with Ethernet, select the IP address setting. If DCS is configured with a private network, select the private IP address setting according to instructions of the supplier and make record.

4.4.3.4 Check of settings of switch-related parameters

Log in to the interface of the switch (or super terminal or create interface) on the host computer and check the settings of the switch, especially the settings of IP address and relevant parameters.

4.4.3.5 Check of application software

Confirm there is no abnormality in the startup of application software, and perform checks on the application software and its integrity as follows:

- a) Check and confirm that software system is complete based on startup of the system.

- b) According to software list provided by the manufacturer, check that the application software for the operator station, engineer station, server, controller, I/O modules, and communication network management is of the correct version and complete and consistent with the last version provided by the manufacturer.
- c) Start the self-monitor, error-checking, and self-diagnosis software of the DCS. Check that the results are consistent with actual conditions and comply with the manufacturer's requirements.
- d) Start other application software at all operator stations, engineer stations, and server stations and confirm that there are no error alarms.
- e) Scan and check the integrity of the software system by using the utility programs and tools provided.
- f) Reading of backup information is normal. If the DCS logical configuration is modified, backup of the software shall be made again after the modification.

4.4.3.6 Check of authority settings

Perform check as follows according to relevant specifications and requirements:

- a) Check and confirm that user authority settings of the operator stations, engineer stations, and server stations comply with relevant management and safety requirements.
- b) Check and confirm that user authority settings of network interface stations, or gateways if applicable, comply with relevant management and safety requirements.
- c) Check port service settings of network interface stations or gateways if applicable and close unused port services. Enter the manage tool interface, check that the setting of keys and user authorities comply with management requirements and can help avoid loss of passwords.
- d) Check that sharing or access authorities for all devices and/or files and folders are set correctly.
- e) In the case that the DCS networks of two units are coupled by a DCS common system network, check that the authority to operate the common system operator station is blocked and only the DCS operator of one unit has the operation authority.

4.4.3.7 Check of database

Perform check as follows according to relevant specifications and requirements:

- a) The settings of database access authority shall be correct and comply with relevant management and data safety requirements.
- b) Review the databases and confirm that relevant information in databases and tables are correct.
- c) Delete useless historical data.
- d) Back up and clear database log records if they are full.

4.4.3.8 Check of communication functions

Energize the system and check that indicators of communication interface modules work correctly. Start the communication drive software, no error information shall be indicated, and then perform check as follows:

- a) Use network software tool or special communication test software tool to verify that physical communication connection is correct and effective.
- b) Use application software or simulation method to check that test data are sent and received normally, and its real-timeliness satisfies design requirements.