

TECHNICAL REPORT



Unified power flow controller (UPFC) installations – System tests

Sample Document

get full document from standards.iteh.ai



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

TECHNICAL REPORT



Unified power flow controller (UPFC) installations – System tests

Sample Document

get full document from standards.iteh.ai

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.240.99

ISBN 978-2-8322-9828-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	8
4 Objectives of system tests.....	9
4.1 Purpose.....	9
4.2 Basic principles.....	9
4.3 Items of system tests	10
5 Preconditions of system tests	15
5.1 Basic conditions.....	15
5.2 Preconditions of system tests for the UPFC installation.....	15
5.3 Preconditions of system tests for the AC grid.....	15
6 Converter unit tests	16
6.1 Trip test.....	16
6.1.1 Purpose of test.....	16
6.1.2 Test preconditions	16
6.1.3 Test procedure	16
6.1.4 Evaluation of test results	17
6.2 Energizing test of the shunt transformer.....	17
6.2.1 Purpose of test.....	17
6.2.2 Test preconditions	17
6.2.3 Test procedure	17
6.2.4 Evaluation of test result	17
6.3 Energizing test of the series transformer.....	17
6.3.1 Purpose of test.....	17
6.3.2 Test preconditions	18
6.3.3 Test procedure	18
6.3.4 Evaluation of test results	19
6.4 Energizing test of the shunt converter.....	19
6.4.1 Purpose of test.....	19
6.4.2 Test preconditions	20
6.4.3 Test procedure	20
6.4.4 Evaluation of test results	20
6.5 Energizing test of the series converter.....	20
6.5.1 Purpose of test.....	20
6.5.2 Test preconditions	20
6.5.3 Test procedure	21
6.5.4 Evaluation of test results	21
6.6 Output phase sequence verification test of the shunt converter.....	21
6.6.1 Purpose of test.....	21
6.6.2 Test preconditions	21
6.6.3 Test procedure	22
6.6.4 Evaluation of test results	23
6.7 Output phase sequence verification test of the series converter.....	23
6.7.1 Purpose of test.....	23

6.7.2	Test preconditions	23
6.7.3	Test procedure	23
6.7.4	Evaluation of test results	24
7	System function and performance tests	24
7.1	Initial operation tests.....	24
7.1.1	Purpose of test	24
7.1.2	Test preconditions	25
7.1.3	Test procedure	25
7.1.4	Evaluation of test results	26
7.2	Steady-state performance tests.....	26
7.2.1	Purpose of test	26
7.2.2	Test preconditions	27
7.2.3	Test procedure	27
7.2.4	Evaluation of test results	28
7.3	Dynamic performance tests.....	28
7.3.1	Purpose of test	28
7.3.2	Test preconditions	28
7.3.3	Test procedure	29
7.3.4	Evaluation of test results	30
7.4	Fault switching tests of control system	30
7.4.1	Purpose of test	30
7.4.2	Test preconditions	30
7.4.3	Test procedure	30
7.4.4	Evaluation of test results	31
7.5	Transfer tests of auxiliary system	31
7.5.1	Purpose of test	31
7.5.2	Test preconditions	32
7.5.3	Test procedure	32
7.5.4	Evaluation of test results	32
7.6	Grid control function tests (optional)	32
7.6.1	Purpose of test	32
7.6.2	Test preconditions	33
7.6.3	Test procedure	33
7.6.4	Evaluation of test results	34
7.7	Other operation mode tests	34
7.7.1	General	34
7.7.2	STATCOM mode tests	34
7.7.3	SSSC mode tests	35
7.8	Heavy load and overload tests	36
7.8.1	Purpose of test	36
7.8.2	Test preconditions	36
7.8.3	Test procedure	37
7.8.4	Special measurements during the test	37
7.9	Artificial short circuit test on AC grid (optional).....	37
7.9.1	Purpose of test	37
7.9.2	Test preconditions	37
7.9.3	Test procedure	38
7.9.4	Evaluation of test results	38
8	Trial operation	38

8.1	Purpose of test	38
8.2	Test preconditions	38
8.3	Test procedure.....	39
8.4	Evaluation of test results.....	39
Annex A (informative) Artificial short circuit test example of a UPFC installation		40
A.1	Purpose of test	40
A.2	Test preconditions	40
A.2.1	Components and placement of artificial single-phase-to-earth fault generating device	40
A.2.2	Instalment of artificial single-phase-to-earth fault generating device	41
A.3	Test procedure.....	42
A.3.1	Testing fire of the artificial transmitting device	42
A.3.2	Official testing procedure	42
Bibliography.....		43
Figure 1 – Structure diagram of the UPFC installation.....		10
Figure 2 – Energizing test of the shunt transformer		12
Figure 3 – Energizing test of the series transformer		12
Figure 4 – Energizing test of the shunt converter		13
Figure 5 – Energizing test of the series converter		13
Figure 6 – Output phase sequence verification test of the shunt converter		13
Figure 7 – Output phase sequence verification test of the series converter		13
Figure 8 – System function and performance tests of UPFC.....		14
Figure 9 – Other operation mode tests – STATCOM mode		14
Figure 10 – Other operation mode tests – SSSC mode		14
Figure 11 – Trial operation.....		14
Figure 12 – Test procedure diagram of series transformer energizing test		19
Figure 13 – Test procedure diagram of output phase sequence verification test of the shunt converter.....		22
Figure 14 – Test procedure diagram of output phase sequence verification test of the series converter		24
Figure A.1 – The artificial single-phase-to-earth fault generating device.....		41
Table 1 – Test stage, item and configuration of system tests		11

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**UNIFIED POWER FLOW CONTROLLER (UPFC) INSTALLATIONS –
SYSTEM TESTS****FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 63500 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
22F/781/DTR	22F/795/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

Sample Document

get full document from standards.iteh.ai

INTRODUCTION

IEC TR 63262:2019 introduces the importance of the system tests of unified power flow controller (UPFC) installations and gives the test items of the system tests. However, the details of the system tests of UPFC installations, including test methods and test procedures, are not given. For the commercial use of UPFC installations, this document provides the details of the system tests of UPFC installations for reference. The system tests are to verify the quality of UPFC after on-site installation and integration, the coordination between a UPFC installation and the grid, the fault ride-through performance of the UPFC installation and so on, which make the commercial operation of the UPFC installation more efficient and safer.

This document summarizes the system test experience of the existing UPFC projects, and the content has been verified by several years of stable operation of the UPFC projects.

Sample Document

get full document from standards.iteh.ai

UNIFIED POWER FLOW CONTROLLER (UPFC) INSTALLATIONS – SYSTEM TESTS

1 Scope

This document provides the general information, items, conditions, and evaluation of test results for on-site system tests of unified power flow controller (UPFC) installations based on modular multi-level converter (MMC) technology. For special functions or performances that are claimed by specific projects, some extra test items not included in this document can be added according to the technical specification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TR 63262:2019, *Performance of unified power flow controller (UPFC) in electric power systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TR 63262 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

unified power flow controller UPFC

equipment which has two (or more) voltage sourced converters (VSCs) sharing common DC bus connected to the transmission system in parallel and in series, and can control the line impedance, voltage amplitude and phase angle at the same time

[SOURCE: IEC TR 63262:2019, 3.1.1]

3.2

system test

test verifying functions and performances of UPFC installations as a whole as well as the interaction with adjacent AC systems

[SOURCE: IEC 61975:2010 and IEC 61975:2010/AMD1:2016, 3.1.2, modified – The words "HVDC system" have been changed to "UPFC installations".]

3.3

converter unit test

test verifying functions and performances of converter units, including the shunt unit and series unit

3.4

subsystem test

test verifying functions and performances of subsystems, such as converter system, water cooling system, relay protection system

3.5

thyristor bypass switch

TBS

power electronic switch with anti-parallel connected thyristors between the converter and the series transformer valve-side winding

[SOURCE: IEC TR 63262:2019, 3.1.6]

3.6

mechanical bypass switch

MBS

mechanical switch between the grid-side winding terminals of the series transformer

4 Objectives of system tests

4.1 Purpose

The system tests complete the commissioning of a UPFC installation. For the user, the completion of the system tests marks the beginning of the commercial operation of the UPFC installation. For the supplier, the system tests verify the suitability of the installed UPFC equipment and the functional completeness of the UPFC system. Moreover, adjustments and optimizations of the UPFC installation are made according to the results of system tests.

The system tests are to demonstrate that the requirements and stipulations in the contract are met.

The system tests consist of five major aspects:

- a) UPFC installation equipment;
- b) UPFC installation control and protection equipment and their settings;
- c) environmental considerations;
- d) interaction between the parallel unit and series unit;
- e) system performance when the UPFC installation jointly operated with connected AC systems.

4.2 Basic principles

The basic principles for the system tests of the UPFC installation are as follows.

- a) For the safety of the UPFC installation, the system tests are conducted until the completion of equipment factory tests, equipment on-site tests and on-site subsystem tests;
- b) All designed functions and performances are tested to confirm that all technical requirements are satisfied;
- c) The system test plan is agreed between the supplier and the user.

4.3 Items of system tests

A typical structure of the UPFC installation is illustrated in Figure 1, consisting of the main circuit (shunt unit and series unit) and a control and protection system. The main circuit consists of two VSCs connected back-to-back by the DC bus, and the AC terminals are connected to the AC grid via two transformers: the shunt converter is connected to the transmission line in parallel via shunt transformer, and the series converter is connected to the transmission line serially via series transformer. The shunt converter and shunt transformer are the main components of the shunt unit. The series converter, TBS, MBS and series transformer are the main components of the series unit. The TBS is connected between the series converter and the series transformer.

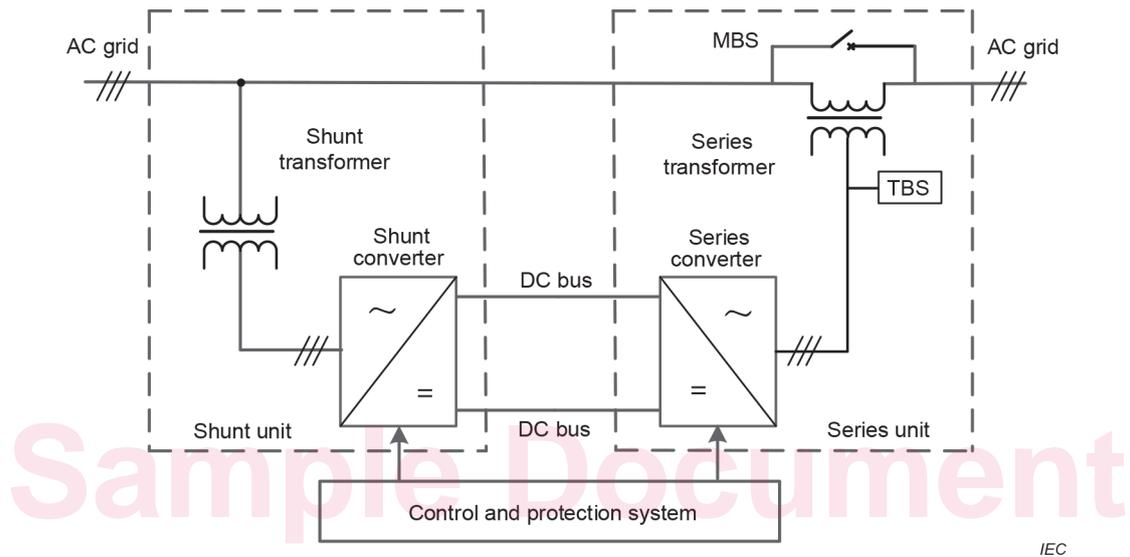


Figure 1 – Structure diagram of the UPFC installation

The typical control structure of the UPFC installation generally includes a system control, a converter control, and a valve control. The converter control and valve control are equipped independently for the series converter and shunt converter.

a) System control

Coordinates the control objects and targets of different converters, and mainly achieves the coordination control among substations and among different converters.

The system control functions include the following:

- power coordination control of power grid;
- power control of transmission interface;
- emergency power control and emergency voltage control of power grid;
- power oscillation damping control, etc.