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IEEE Guide for the Functional Specification of Medium Voltage (1 kV—35 kV) Electronic Shunt Devices for Dynamic Voltage Compensation

IEEE Power Engineering Society

Sponsored by the
Substations Committee

IEEE

3 Park Avenue, New York, NY 10016-5997, USA

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Substations Committee
of the
IEEE Power Engineering Society

Approved 7 February 2005

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Abstract: This document provides general guidelines for the preparation of a functional specification for solid-state electronic shunt devices used mainly for compensation of voltage fluctuation. The guide covers devices rated to medium voltage (1 kV–35 kV). This device contains in general: an inverter, rectifier or DC converter, energy storage device, and coupling transformer. The device typically is connected in parallel with the network using a coupling transformer.
Keywords: coupling transformer, energy storage, inverter, parallel compensation, power electronics, power quality, sensitive loads, voltage control

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Introduction

This introduction is not part of IEEE Std 1623-2004, IEEE Guide for the Functional Specification of Medium Voltage (1 kV−35 kV) Electronic Shunt Devices for Dynamic Voltage Compensation.

Several utilities are experimenting with electronic devices to reduce voltage fluctuations. Industrial customers with sensitive loads are installing different electronic devices to mitigate voltage fluctuations. A significant number of these devices are installed every year. Most of these devices are bought using specifications provided by various manufacturers. Technical literature describes the operation of specific devices and provides results of computer simulations to prove the effectiveness of the devices. However, no document defines the technical data that has to be collected and used for the specification of a new device.

The working group collected specifications from different manufacturers and utilities. These documents have been combined together to define a comprehensive method for the specification of future devices. This guide is not a tutorial. The application of its content to prepare a specification requires technical knowledge and understanding. Each user should modify the material to meet with user specific conditions. This guide does not include all topics necessary for every application and does not address the commercial aspect of the specifications.

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Participants

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George G. Karady, *Chair*

Neil Woodley, *Vice Chair*

Stephan Arnold
Hubert Bilodeau
Jacques Brochu
Tom Cease
Jeff Fleeman
Brian Gemmell
Chris Horwill
William O. Kramer
Thomas W. LaRose
Stig Nilsson
Duane Torgerson
Terry Treasure
John Schwarzenberger
Ronald Sharp
Teruo Yoshino

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

William Ackerman
Hubert Bilodeau
Michael Bio
Thomas Blair
William Brumsickle
Tommy Cooper
Luis Coronado
R. Daubert
Matthew Davis
Frank Denbrock
Dr. Guru Dutt Dhingra
Paul Drum
Amir El-Sheikh
Ahmed Elneweihi
Gary Engmann
Edward Horgan Jr.
George Karady
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Thomas LaRose
Stephen R. Lambert
Wayne Litzenberger
Fortin Marcel
Frank Mayle
Mark McGranaghan
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Georges Montillet
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IEEE Guide for the Functional Specification of Medium Voltage (1 kV–35 kV) Electronic Shunt Devices for Dynamic Voltage Compensation

1. Overview

1.1 Scope

This document provides general guidelines for the preparation of a functional specification for solid-state electronic shunt devices used mainly for compensation of voltage fluctuation. The guide covers devices rated to medium voltage (1 kV–35 kV). This device contains in general: an inverter, rectifier or dc converter, energy storage device, and coupling transformer. The device typically is connected in parallel with the network using a coupling transformer.

Normally this device is not designed for flicker compensation. If flicker compensation is needed, the specification has to be modified, and the manufacturer has to design the device for flicker compensation.

In order to interface these devices with the network, additional equipment should be provided, including current and potential transformers, bypass and isolation breakers, disconnect switches and three-phase low-voltage service for auxiliary power.

1.2 Purpose

This guide includes technical clauses describing the user's requirements, including operation methods and environmental conditions. It specifies basic requirements of solid-state electronic shunt devices used for compensation of voltage fluctuations by injection of reactive power.

1.3 Application

This guide should be considered as a general-purpose source and does not include all details needed for specific applications. Likewise, because the electronic device is typically designed to address a specific application, not every part of this guide may be applicable. The user of this guide should evaluate how and to what extent each clause applies to the development of a specific device specification.

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The required environmental and electrical system information at the location of the device appears in Clause 7 and Clause 8 of this guide.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C2, National Electrical Safety Code® (NESC®).[1]

ANSI Std C37.06, American National Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.[2]

IEEE Std 80™, IEEE Guide for Safety in AC Substation Grounding.[3],[4]

IEEE Std 139™, IEEE Recommended Practice for the Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises.

IEEE Std 141™, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Red Book).

IEEE Std 493™ IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book).

IEEE Std 519™, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

IEEE Std 693™, IEEE Recommended Practice for Seismic Design of Substations.

IEEE Std 1031™, IEEE Guide for the Functional Specification of Transmission Static VAR Compensators.

IEEE Std 1100™, IEEE Recommended Practice for Powering and Grounding Electronic Equipment (IEEE Emerald Book).

IEEE Std 1159™, IEEE Recommended Practice for Monitoring Electric Power Quality.

IEEE Std 1250™, IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances.

IEEE Std C37.30™, IEEE Standard Requirements for High-Voltage Switches.

IEEE Std C37.90.1™, IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.

IEEE Std C37.100™, IEEE Standard Definitions for Power Switchgear.

IEEE Std C57.12.00™, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

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IEEE Std C57.12.90™, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers.

IEEE Std C57.16™, IEEE Standard Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors.

IEEE Std C57.21™, IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated Over 500 kVA.

IEEE Std C62.11™, IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV).

NFPA 70, National Electrical Code® (NEC®).[5]

SEMI F47-0200 Specification for Semiconductor Processing Equipment Voltage Sag Immunity.[6]

3. Definitions

For the purposes of this guide, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards* [B1][7], should be referenced for terms not defined in this clause.

3.1 voltage sag: A short duration decrease of the rms voltage value, at the power frequency. Typical values are between 0.1 and 0.9 pu, at the power frequency, for 0.5–120 cycles in duration. (IEEE Std 1250)

NOTE—The International Electrotechnical Commission (IEC) terminology is voltage dip.[8]

3.2 voltage swell: A short duration increase of the rms voltage value, at the power frequency, typical values are between 0.5–120 cycles in duration. (IEEE Std 1250)

3.3 voltage flicker: A slow, low frequency modulation of the sinusoidal voltage of the load or supply.

3.4 two-quadrant control: An inverter control algorithm, which makes the inverter capable of accepting or delivering power between the dc bus and the line. (NASA-Kennedy Space Center, Technique OPS-7, AC - Variable Frequency Drive Systems). A shunt device using this control absorbs or generates reactive power.

3.5 four-quadrant control: An inverter control algorithm, which allows real and reactive power (watts and vars) to be independently delivered to or extracted from a load. A shunt device, using this control generates or absorbs both real and reactive power.

4. System description

The solid-state electronic shunt device is a power electronic primary power delivery (distribution) system element that is connected in parallel with a primary power delivery circuit typically via a coupling transformer. The device will supply reactive power to, as well as absorb reactive power from, the power delivery system, either to regulate voltage to a set point value or inject reactive power as specified by the

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[6] SEMI documents can be obtained from Semiconductor Equipment and Materials International, 3081 Zanker Road, San Jose, CA 95134 USA (http://wps2a.semi.org/wps/portal).
[7] The numbers in brackets correspond to those of the bibliography in Annex A.
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user. The most frequent function of the device is to dynamically regulate the load voltage of a sensitive load by rapid reactive power exchange.

Optionally, the device may be equipped with a four-quadrant control and energy storage subsystem to allow voltage control by both real and reactive power exchange with the system.

Figure 1 shows an example for the circuit diagram of a solid-state electronic shunt device used for compensating voltage fluctuations by reactive power injection or absorption. In case of a voltage disturbance on the utility feeder, the device injects an appropriate amount of reactive power to maintain the feeder voltage.

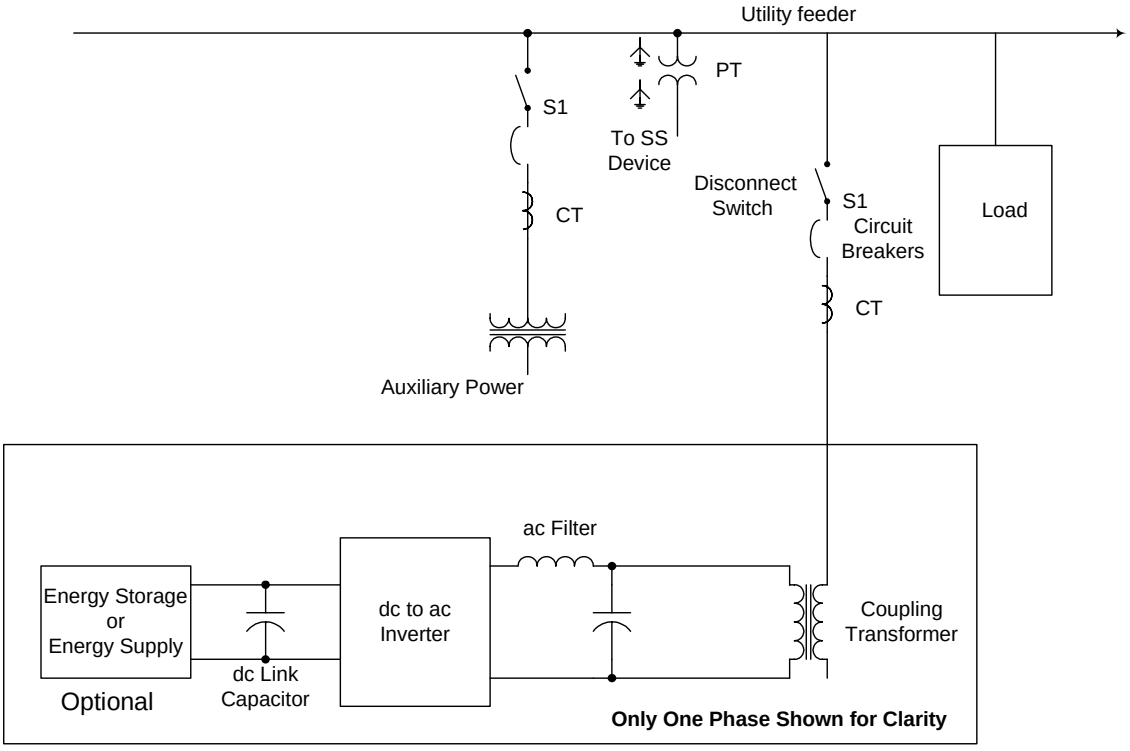


Figure 1—Example circuit diagram of a three-phase solid-state shunt electronic voltage compensation device

In Figure 1 a converter (dc to ac inverter) generates ac voltage and injects or absorbs reactive or active power through a coupling transformer whose secondary is connected in parallel with the feeder. A dc link provides the input voltage and stored energy to the inverter. The inverter uses the energy stored in a capacitor or other kinds of energy storage devices, such as batteries, a superconducting magnetic energy storage (SMES) device or a flywheel, through a suitable converter, or from an ac source (supply feeder) through a rectifier.

The device may or may not require dedicated energy storage, depending on the anticipated magnitude of sag or swell. The device controls can minimize the need for energy storage during unbalanced fluctuation by charging the dc bus from the high (unaffected or swelled) voltage phase(s). Sufficient stored energy must be provided to allow the device to compensate fluctuation of maximum expected duration.

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In order to interface the device with the power delivery network, additional equipment should be provided, including current and potential transformers, surge arresters, isolation breakers, disconnect switches and three-phase low-voltage service for auxiliary power. Surge arresters may not be required for all conditions.

Figure 1 is a representative example for the dynamic compensation device. However, other system configurations are available. Clause 4 may not be included in the specification issued by the purchaser.

5. Project description

This specification defines the project scope to furnish, install, test, commission, warrant, train user personnel, and place into commercial operation an electronic device for compensation of voltage fluctuations at _____(*general location*)_____.

The purpose of the device is to correct the voltage of __ (*feeder name*)_____, connected to __(*location*)_____ point.

The device should dynamically maintain voltage at acceptable levels to the above feeder during momentarily voltage fluctuations (both balanced and unbalanced) that occur on the feeder, assuming that the voltage deviation is within the device ratings. As an additional feature, the device may be used for steady-state voltage regulation of a load and phase balancing of line voltages.

The nominal injection current is _____A at nominal voltage and frequency.

The nominal feeder current is _____ A at nominal voltage and frequency.

The maximum injection current is _____ A at nominal voltage and frequency.

The system short circuit level is _____ MVA at nominal voltage and frequency.

The system impedance times the injection current determines the voltage that compensates the dip or swell. The nominal kVA rating of the device converter and associated power electronics is specified as the maximum voltage times the injected current.

The power delivery system voltage is _____ kV, and the acceptable load voltage variation is ±_____% of nominal voltage.

For systems with energy storage device and capability to inject real power the nominal energy rating of the device should be at least _____Joules.

NOTE—The nominal energy rating or usable stored energy is defined as nominal feeder voltage times the maximum desired injection current during balanced sag times the maximum duration of the sag.

The maximum sag/swell to be compensated is for:

Three-phase disturbance _____ V Line-to-line disturbance _____V

Single-phase disturbance _____ V

The maximum duration of the sag/swell is for:

Three-phase disturbance _____ s Line-to-line disturbance _____ s

Single-phase disturbance _____s

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NOTE—Typically the voltage sag or swell is caused when:

a) A single-line-to-ground fault on the system causes a temporary voltage rise on the un-faulted phases and a voltage sag on the faulted phase

b) A line-to-line fault occurs

c) A large load is switched off

d) A large shunt capacitor bank is switched on or off

e) A transmission line feeding the bus is switched off

However, the duration of the last two events tends to be longer.

The maximum acceptable sag magnitude versus sag duration ratio is _____.

The response time of the device shall be less than _____sec.

NOTE—Several existing power quality standards, like the IEEE Std 493 (Gold Book), ITIC (Information Technology Industrial Council, Curve 2000) or SEMI F47 criteria, address maximum acceptable sag magnitude versus sag duration ratio, but the user is cautioned that such standards may not fit the specific application. Therefore the user is urged to evaluate the specific requirement before specifying the device.

NOTE—Many drive systems restrict voltage change to 10%. This will be relative to the pre-disturbance voltage and not 10% of nominal.

The regional and local site location is shown in Figure _____. The proposed one line diagram of the facility after installation of the device is shown on drawing _____. The area of the device facility is shown on drawing _____.

The manufacturer should agree to provide device dimensions, weight, center of gravity, and auxiliary power requirements____ days after the signature of the contract.

The point of electric interconnections of the supplier-furnished electronic device and the user-furnished facilities are shown in the following drawings:

Drawing No:	Description
_____	Main single line diagram
_____	Auxiliary power single line diagram
_____	Grounding plan and details
_____	Control and protection
_____	Location layout, general arrangement, elevation drawings, road access
_____	Site sub-surface and geo-technical data in case of outdoor installation
_____	Foundation and civil drawings including grading and drainage
_____	Others (conduits, cable summary etc.)
_____	Communications interface (telecom, SCADA, Ethernet, etc.)
_____	External control interface

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6. Scope of supply and schedule

6.1 Scope of supply and warranty

The equipment, materials, and services to be furnished by the supplier include, but are not limited to the following:

a) dc to ac converter

b) Coupling transformer or reactor as appropriate

c) ac filter as appropriate

d) Isolation circuit breaker(s) and disconnect switch

e) MOV surge arresters if necessary

f) Current and voltage transformers (optional)

g) Energy storage device, including charging unit or transformer and rectifier to supply the dc link (optional)

h) Control, protection, alarm and monitoring system for the device

i) On-line monitoring and annunciation system via common IT systems (modem, Internet)

j) Special maintenance equipment and tools

k) Training program for operation and maintenance personnel

l) Spare parts

m) Testing and commissioning service

n) Documentation including instruction manuals, software description and licenses, etc.

6.2 Equipment, material, and services furnished by the user or its agent

The following equipment, materials, and services to be furnished by others include, but are not limited to, the following:

a) Site suitable for the device available _____ days after contract start.

b) Existing facilities and equipment.

c) Station service during construction (auxiliary power) for the device at _____ V, _____ A available _____ days after contract start (if needed).

d) Station service (permanent auxiliary power) for the device at _____ V, _____ A available _____ days after contract start.

e) The foundations and buildings for the device will be available _____days after the contract start.

f) Interconnections and all ancillary service will be available _____days after the contract start.

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6.3 Schedule

a) Project completion is _____ calendar days after contract start.

b) The supplier project schedule is due _____ days after contract start and should include, but not be limited to, the dates for commencement and completion of the work of several controlling features of the project, dates for user furnished services, dates on which supplier-furnished drawings will be provided and the required approval dates, and the dates and length of time of any required power outages.

c) Review meetings should be held between the user and supplier to review and discuss progress of the supply of the device. The first review should be held within _____ days after contract start.

7. User furnished site and environmental data

The device should be designed to meet all ratings and performance requirements specified herein while operating in the following site and environmental conditions. Usual design values are given in parenthesis.

a) Site elevation above sea level _____

b) Maximum ambient air temperature (50^{o}C at rated load) _____

c) Minimum ambient air temperature (-40^{o}C may use supplementary heating) _____

d) Maximum relative humidity _____

e) Solar radiation
(Peak, Daily maximum watt-hours/m^2, Annual total watt-hours/ m^2 yearly) _____

f) Seismic zone and withstand data _____

g) Isokeraunic level _____

h) Contamination (dust, chemicals, etc.) _____

i) Wind velocity (maximum sustained and maximum gusts, if applicable) _____

j) Ice loading (maximum, if applicable) _____

k) Availability of cooling media (water flow rate, pressure, cleanliness level, maximum ambient water temperature, etc.) _____

8. Power system characteristics

The ac power system characteristics at the point of connection prior to device installation are listed below. Usual design values are given in parenthesis.

a) Nominal ac system frequency (50 or 60 Hz) _____

b) Frequency variation (0.5 Hz from nominal, 1 Hz from nominal for 1 min maximum, 1.5 Hz maximum, 4.0 Hz for 0.35 s maximum from nominal for 30 s maximum, 2.5 Hz for 10 s) _____

c) Maximum rate of change of frequency (10 Hz/s) _____

d) Maximum continuous ac system voltage, line-to-line (V or %) _____

e) Minimum continuous ac system voltage, line-to-line (V or %) _____

f) Maximum load current _____

g) Maximum short-term ac system voltage, line-to-line
(110% of the ITIC high voltage) _____

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h) Voltage Total Harmonic Distortion (THD) _____

i) Voltage Single Harmonic Distortion _____

j) Current THD _____

k) Current Single Harmonic Distortion _____

l) Minimum short term ac system voltage, line-to-line _____

m) Continuous negative sequence voltage component (4%) _____

n) Continuous zero sequence voltage component _____

o) Basic Impulse Insulation Level (BIL), if applicable. _____

p) Switching Impulse Insulation level (SIL) _____

q) Three-phase fault current _____

r) Maximum single phase fault current _____

s) Harmonic impedance sectors _____

t) Background harmonic voltage or current spectrum _____

9. Shunt compensation device characteristics

9.1 Rating

The device should inject positive sequence current, as required, into the feeder.

The functional application of the device is to dynamically maintain line-to-line or line-neutral voltage as measured prior to an event (fault) and in accordance with IEEE Std 141[9], IEEE Std 519 or ITIC levels, to three-phase or single-phase loads during large voltage fluctuations (i.e., balanced or unbalanced sags or swells) that occur on the feeder. The voltage must be self-adjustable to the pre-event voltage between the specified upper and lower voltage limits.

NOTE—For the short duration of a voltage sag, harmonics may be of a lesser issue than speed of response.

The response of the device should be such that the device should inject full current from a state of zero injected current within time periods that maintain load voltage. The load voltage should be maintained within the ITIC Curve 2000, IEEE Std 141 limits, or otherwise specified voltage profile.

The device should be capable of attaining 90% of nominal rated output prior to the event (sag or swell) with detection in _____ cycles or less. A typical response time is more than ¼ cycles.

Energy storage elements, if used, should be in sizes compatible with customer voltage restoration requirements. Energy storage elements should have a _____ kVA short term rating and _____J capacity. The system should be designed to recharge the energy storage either through the main converter or through a dedicated charging unit.

The device can be built with smaller modules connected in parallel or series. The manufacturer should specify the module size, the number of modules, the module configuration and the number of modules that can fail without having to shut down the system.

[9] Information on references can be found in Clause 2.

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If the system contains several modules connected in parallel, equal current sharing among the modules should be achieved by suitable circuits, which are incorporated in the converter modules. The current sharing should be better than 95% among the in-service modules.

If the system contains several modules connected in series, equal voltage sharing among the modules should be achieved by suitable circuits, which are incorporated in the converter modules. The voltage sharing should be better than 95% among the in-service modules.

9.2 Losses

a) The supplier should specify the total system losses in idle mode, including transformer losses, in kW and in percentage of the device rating. In addition, the losses should include all auxiliary loads including cooling fans and pumps, battery chargers, UPS systems, controls and other auxiliary loads and losses.

b) Losses evaluation should be performed using _____ $/kW and _____ $/kWh values.

c) The supplier should present alternative methods to reduce losses.

9.3 Harmonic performance

a) Total voltage and current harmonic distortion should be calculated under worst-case system conditions in accordance with the procedure outlined in IEEE Std 519. These calculations should be done based on the kVA capacity and harmonic impedance of the supplying source.

b) The harmonic distortion should be verified through tests. The test results should be made available to the customer. The manufacturer should propose a standardized or industry-accepted test method to verify harmonic performance.

c) The device should be configured to avoid resonance with common power system components, including shunt capacitors.

9.4 Audible noise

Noise generated by the device in idle and full load operation should not exceed _____ dBA and _____ dBA respectively. The noise is measured at 3 m from the nearest surface of the device enclosure. The suppliers should establish existing audible noise level prior to installation of the device. A report should record the audible noise levels prior to and after the installation of the device. The selection of the noise level should comply with IEEE C57.12.90.

9.5 Electromagnetic interference (telephone and radio)

a) Radiated and conducted EMI generated within the device should be suppressed to prevent excessive interference with nearby electronic equipment. The I·T product should be less than _____, where I·T is defined as the square root of the sum of the squares of the weighted harmonic current; the corresponding weights are the TIF (Telephone Influence Factor) weighting factors established in 1960 (IEEE Std 519).

b) The V·T product should be less than _____, where V·T is defined as the square root of the sum of the squares of the weighted harmonic voltage; the corresponding weights are the TIF (Telephone Influence Factor) weighting factors established in 1960 (IEEE Std 519).

c) The device should not be susceptible to misoperation due to EMI generated by a handheld general mobile radio service transmitter from a distance of 61 cm (2.4 in.) in front of the device with the doors closed. Specific frequencies for testing must be supplied by the user.

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d) Higher frequency electromagnetic emissions should be limited to avoid interference with any properly licensed radio, TV, microwave or other equipment in service. The radio frequency emission produced by the device should be less than _____ mV over a range of 0.15 MHz–1 MHz, when measured 500 m from the building. The measurement should be made in accordance with IEEE Std 139, using a quasi-peak detector reading.

9.6 Cooling and ventilation

a) The cooling system should be able to maintain full capacity at maximum ambient temperature and maximum device losses.

b) The cooling system should be able to operate at the lowest ambient temperature and minimum device losses, and the supplier should describe how this is done.

c) Replacement of selected critical cooling equipment if defective should be possible while the cooling system still operates. However the user has to determine whether this redundancy is required.

d) The supplier should describe the necessary maintenance actions and their frequency.

9.6.1 Air cooling (if applicable)

a) Cooling for semiconductors should be by natural convection or forced air.

b) An air-cooling system should provide full heat rejection with redundancy in blowers, filtering, monitoring, and heat exchangers (if required).

c) The supplier should describe the air filtering system and details of monitoring of the status of blowers, filters, and other components.

d) If filters are used, all air inlets should have exchangeable filters. Filters should be provided with pressure differential alarms.

9.6.2 Liquid cooling (if applicable)

a) A closed loop re-circulating system should provide full heat rejection capacity with redundancy for pumps, heat exchangers and fans, appropriate to the device availability requirements.

b) The cooling system should be able to maintain full capacity at maximum ambient temperature and maximum device power output.

c) The cooling system should be able to operate at the lowest ambient temperature and zero output and the supplier should describe how this is done.

d) If high resistivity is required, purifying loop to maintain liquid resistivity should be provided. The supplier should state the design value of liquid resistivity and describe methods of detecting and responding to abnormal conditions.

e) If high resistivity is required, the quantity of de-ionizing material should be sufficient to operate correctly for a period 1½ times longer than the specified maintenance interval operation without replacement. De-ionizing materials should be replaceable without cooling system shut down. Instructions for frequency of inspection and change should be given.

f) The supplier should describe the necessary maintenance actions and their frequency.

g) Maintenance of closed loop systems and make up for loss of liquid should not be required more than once a year.

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9.6.3 Cooling system protection

The cooling system should monitor its own operation and the condition of the cooling medium. In a redundant cooling system the component failure should activate alarms first. If the cooling system has no remaining redundancy, the component failure should shut down the system. The warning and shutdown alarms should be modified according the cooling system configuration.

a) For air-cooled systems, the protection system should include as a minimum the following warning alarms:
    1) Blower transfer, if applicable
    2) High exhaust air temperature or high heat sink temperature
    3) High differential pressure across the filter, if applicable
    4) Low air flow, if applicable

b) For air-cooled systems, the protection system should include as a minimum the following shutdown alarms:
    1) Excessive exhaust air temperature or high heat sink temperature
    2) Loss of air flow

c) For liquid-cooled systems, the protection system should include as a minimum the following warning alarms:
    1) Depleted de-mineralized (de-ionizing) cell, if high resistivity is required
    2) Low water resistivity, if high resistivity is required
    3) Low coolant level
    4) Primary pump stopped
    5) Primary fan stopped
    6) High coolant temperature
    7) Failure of pump cycling scheme
    8) Leak detected

d) For liquid-cooled systems, the protection system should include as a minimum the following shutdown alarms:
    1) Extra high temperature
    2) Extra low coolant level
    3) Both pumps stopped or blocked flow

9.7 Enclosures

a) The device system shall be housed in enclosures appropriate to the application.

b) For outdoor pad-mounted installations, all device system components should be enclosed in an electrically grounded weatherproof enclosure with provisions for securely anchoring the enclosure to the foundation.

c) For outdoor overhead installation, all device system components shall be housed in electrically grounded rain-tight enclosures (NEMA 3R) designed for ease of installation and maintenance access from standard utility overhead line service equipment.

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d) For indoor installation, all device system components shall be housed in electrically grounded metal enclosures designed to ensure that the opening of a door exposes no live parts. A dust proof enclosure (NEMA 12) is recommended for indoor installation.

e) Energy storage in excess of 500 kJ usable capacitive energy storage, or rectifier, if appropriate, should be located in a suitable separate enclosure with mechanical and electrical interlocks provided to maintain a proper and safe operating sequence.

f) If transportable device modules are mounted on a trailer, the trailer dimension should not exceed in most cases 2.6 m (8.5 ft) in width, 14.6 m (48 ft) in length, and 4.5m (14.5 ft) in height. Otherwise, special oversize load permits may be required for transporting the unit.

g) Supplier should furnish shipping weights and dimensions of each individual separately shipped module.

h) Supplier should furnish detailed foundation requirements (drawings) showing all tie down points, pier foundation location and load bearing requirements, and ground pads.

10. Reliability, availability and maintenance

a) Design availability of an individual module should exceed 98% for forced outages and should exceed 99.5% for scheduled outages, after the commissioning period.

b) Design availability factor for forced outages of devices consisting of multiple modules (including provisions for de-rating) should exceed 95% after the commissioning period.

c) Scheduled maintenance that requires that the unit be taken out of service should not exceed 8 h per year, on average, for a 20-year minimum design lifetime.

d) Replacement of any power electronics assembly should be capable of being accomplished in 2 h or less, with parts available on site.

e) The device should be able to withstand the loss of one cooling fan or pump with no degradation in nominal output capability.

f) The device should be capable of operation in high isokeraunic areas (80 or more thunderstorm days per year). The device should be capable of restoring voltage for multiple (not less than five) sequential maximum duration, maximum depth sags at 5 s intervals if required by the user.

11. Control and diagnostics

a) The device control should achieve the functional objectives outlined in Clause 9. The accuracy of the voltage should be within 2% of the reference voltage. The response of the control to a disturbance should be faster than 2 ms.

b) Control interface should provide access to the adjustment of control parameters both locally and remotely, via a modem or by an Internet/LAN connection. The control interface should allow the setting of the following parameters both locally or remotely:

   1) Start and stop of operation

   2) Change of reference voltage

   3) Alarm acceptance and, if appropriate, reset

c) The automatic functions include pre-start verification of the control and protective functions, synchronization of the control to the bus voltage, and closing of the isolation switches. None of these operations should produce a transient in the load voltage, which exceeds 3% for 2 cycles or more.

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d) The device should be able to be shut down from a remote command or from an internal diagnostic or protective command. The automatic functions include shutdown of the converter, discharge of the dc bus and energy storage, and release of protective interlocking for the equipment. None of these operations should produce a transient in the load voltage, which exceeds 3% for 2 cycles or more.

e) The device should be able to accommodate momentary outages of source power. When the condition has passed, the device should automatically restart and resume normal operation. This operation will not have critical time constraints, and outages lasting several minutes will be acceptable.

f) Sufficient diagnostics should be made available so that the source of a failure of a major electronic component or sub-assembly can be accurately and quickly identified by maintenance personnel. The diagnostic data available from the modem or other communication device should include, but not be limited to, the following:

1) Three line voltages (magnitude and phase)
2) Three line currents (magnitude and phase)
3) Three converter voltage magnitudes and phase, if applicable
4) Three converter current magnitudes and phase, if applicable
5) Ambient temperature
6) dc bus voltage
7) Converter valve status for all valves
8) Semiconductor element status
9) Cooling system status
10) Breaker status
11) UPS/battery status, if required
12) Energy storage status (level stored. if applicable)
13) On-board Power Quality Monitor for voltages and currents

As an option, a Remote Terminal Unit (RTU) for connection to a Supervisory Control and Data Acquisition (SCADA) System should be made available at additional cost to the customer.

12. Protection

a) The control of the device should monitor its operation and the operation of various components. Two levels of protection should provide warning and shutdown where appropriate. A warning indicates a developing problem that exists but the equipment or its proper operation is not in immediate danger. A shutdown indicates fault that prevents operation or that may cause damage if left uncorrected.

b) The device protection should be properly coordinated to prevent incorrect operation. Fail-safe principles should be applied. The protection system should be equipped with voltage and current transformers, which are either part of the device package or supplied by the user. Redundant protective functions should be demonstrated and recorded.

c) The device should withstand an external phase-phase or phase-ground fault cleared by backup protection without the failure of a major sub-assembly.

d) The device should withstand internal fault on the ac side of the converter bridges cleared by backup protection from the distribution system without failure of the converter components and without damage to the dc bus or energy storage system.

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e) The protection should remove the device from the service with appropriate diagnostic message in case of:

   1) High impedance faults

   2) Short circuit as specified previously

f) The device should detect over-voltage and over-current conditions within the converter circuits, the dc bus circuit, and the energy storage circuits. It should initiate a shutdown rapidly enough to prevent consequential failure of components. It shall provide diagnostic information that shows the reason for each shutdown.

13. Insulation and grounding

a) The device system should be equipped with switches (circuit breakers or disconnect switches as appropriate) to permit isolation from the primary system voltage. The transformer insulation level (BIL) should be in accordance with appropriate ANSI/IEEE standards. The insulation level of the converter side of the transformer should be coordinated with that of the converter. Surge protective equipment should be used as required.

b) The switches and links should be adequately sized to carry the maximum steady state and transient fault currents.

c) Grounding switches or equipment and grounding points should be provided for maintenance and repair.

d) The device enclosure shall be grounded to the facility ground grid in at least two points.

14. Safety and signs

a) Equipment should be furnished with permanent conspicuous signs stating “Danger - High Voltage - Keep Out” in accordance with National Electrical Code® (NEC®) (NFPA 70), and customers should be apprised of the need to provide clear working space during maintenance in accordance with Table 110-34(a) of the NFPA 70.

b) Suitable interlocks should be placed in service to insure that the equipment cannot be energized with personnel inside a converter or energy storage module.

15. Lead time

a) Delivery to the installation site should be within _____ months. Typical delivery time is 9 mos after the contract award.

b) The installation time is _____ months, and the commissioning requires _____ months.

16. Installation and spare parts

a) The user provided wiring installation and handling should be in accordance with manufacturer's recommendations.

b) The user should provide adequate storage space for the equipment supplied by the device manufacturer. Prior to installation and during construction at the job site, the device should be protected against damage at all times. The device should be stored in a clean, dry environment with temperature and humidity within the range as specified by the device manufacturer. Space heaters should be energized during storage, as recommended by the manufacturer.

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c) The manufacturer should provide the necessary spare parts for the first year of operation. The manufacturer should prepare a spare part list that assures trouble free operation.

d) Manufacturer should provide a maintenance recommendation, which includes the description of the maintenance procedures and schedules.

e) Any special tools required for routine maintenance should be provided.

17. Equipment testing and system commissioning

The device should be fully tested at the manufacturing location. The supplier must provide a test program ____ weeks prior to the start of the tests. The tests should include:

a) Type test performed on selected components. The manufacturer should maintain a certified copy of the test reports.

b) Production tests performed on the components/assemblies manufactured for this installation. The manufacturer should maintain a certified copy of the test reports. The owner may send a representative to witness the tests.

c) The manufacturer and the owner should perform joint checkout and start-up test of the solid-state electronic device equipment under the technical direction of the manufacturer's service engineer.

d) The manufacturer and the owner should perform joint functional test to prove the overall integrated system performance and design.

e) The manufacturers should provide training to the owners operation and maintenance personnel.

A copy of all tests and checks performed in the field, complete with meter readings and recordings, where applicable, should be submitted to the owner for its record.

18. Quality assurance

The manufacturer should demonstrate that an established quality assurance program will be used during the manufacturing of the device. This program has to be agreeable for both parties.

19. Contractual generalities

a) The manufacturer should provide to the owner a start-up service for the device provided. This service should include:

   1) Inspection, final adjustments, operational checks of the provided device

   2) Functional checks of spare parts

   3) Final report for record purposes

b) The manufacturer should include _____ parts and labor warranty from date of completion of commissioning for the device provided.

c) System will not be accepted by owner until satisfactory completion of the commissioning of the unit.

d) The manufacturer should provide a training course for the owner's personnel. It should be completed within one week after the completed installation. Representatives of the manufacturer should present the course at the job site or other location selected by the owner.

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Annex A

(informative)

Bibliography

[B1] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.[10]

[B2] ITIC Curve 2000.[11]

[B3] NEMA Standards Publication 250, Enclosures for Electrical Equipment.[12]

[B4] NEMA ICS 1, Industrial Control Systems—General Requirements.

[10] The IEEE standards or products referred to in this annex are trademarks of the Institute of Electrical and Electronics Engineers, Inc.
[11] ITIC documents can be obtained from the Information Technology Industrial Council, 1250 Eye Str. NW. Suite 200, Washington DC 2005, Tel: 202-737-8888, http://www.itic.org.
[12] NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (http:// global.ihs.com/).

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