

IEEE Guide for the Functional Specification of Transmission Static Var Compensators

IEEE Power & Energy Society

Sponsored by the
Substations Committee



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of the

IEEE Power & Energy Society

Approved 14 May 2011

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Abstract: An approach to preparing a specification for a transmission static var compensator is documented by this guide. The intention of this document is to serve as a base specification with an informative annex provided to allow users to modify or develop specific clauses to meet a particular application.

Keywords: filters, harmonics, IEEE 1031, static var compensators, static var system, thyristor-controlled reactor (TCR), thyristor valves, thyristor-switched capacitor (TSC), thyristor-switched reactor (TSR)

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Introduction

This introduction is not part of IEEE Std 1031-2011, IEEE Guide for the Functional Specification of Transmission Static Var Compensators.

This document is a revision of IEEE Std 1031™-2000. The guide has been renamed and provides an example and general information that may be considered when developing a technical specification for a transmission static var compensator (SVC).

This guide is not a tutorial, and application of its contents in preparing a technical specification shall be done with sufficient technical knowledge and understanding. This guide may not include all topics necessary for every SVC application and does not address any commercial conditions applicable to specific projects.

This guide was prepared by a task force of Working Group I4, FACTS Controllers in Substations, of the High Voltage Power Electronic Stations Subcommittee for the IEEE PES Substations Committee.

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1. Overview

1.1 Scope

This ~~document provides general guidelines toward~~guide assists users in specifying the ~~preparation of a~~ functional requirements for transmission static Var compensators (SVCs) using conventional thyristor technology. Many sections will be useful for compensator systems using gate turn-off thyristor technology [static synchronous compensator (STATCOM)] or other semiconductor devices, or SVCs associated with high-voltage direct current (HVDC) converter stations, or industrial and distribution applications. Although this guide may not directly serve for SVCs primarily associated with industrial drives nor with the correction of load disturbances or phase unbalance, many sections will be useful also for these applications.

General terms and conditions forming the commercial part of a specification for a particular project are outside the scope of this document.

1.2 Purpose

~~Starting at Clause 4,~~ This document presents technical sections that may be used as the basis of a functional SVC specification. The wording deliberately uses “should” rather than “shall” because this document is a guide, not a specification. The user of this guide might wish to make this adjustment when converting sections into a specification. ~~Annex B of this document contains supplemental information intended to further develop specific clauses. Further information is referenced by the same subdivision numbering used in the main text.~~

[The guide describes the following:](#)

- ↓ [Newer developments in SVC component equipment and particularly control systems](#)
- ↓ [Updated information on latest practices for SVC applications](#)
- ↓ [Clarification on topics which led to misunderstanding in the previous version](#)
- ↓ [An informative annex to allow users to modify or develop specific clauses to meet a particular application](#)

1.3 Application

The guide should be considered as a general purpose resource and does not include all details needed for a specific application. Likewise, because transmission SVCs are 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 an SVC specification.

Clause 3 gives definitions such as a static var compensator (SVC), a static var system (SVS), and associated other reactive elements. This guide applies to the SVC.

1.4 Word usage

[In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability.](#)

2. [Normative](#) references

~~This guide should be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.~~

[The following referenced documents and URLs 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.](#)

~~Accredited Standards Committee C2-1997, National Electrical Safety Code^{1, 1, 2}, NESC^{1, 1, 2}~~

ANSI C63.16, American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment.¹

BS EN 61803, Determination of [Power Losses](#) in High-Voltage direct current (HVDC) Converter Stations [with Line-Commutated Converters](#).²

IEC 61954-2011, Power Electronics for Electrical Transmission and Distribution Systems—Testing of Thyristor Valves for Static VAR Compensators.³

IEC/TR 60815-05, Guide for the Selection of Insulators in Respect of Polluted Conditions.

¹ ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

² EN publications are available from the European Committee for Standardization (CEN), 36, rue de Stassart, B-1050 Brussels, Belgium (<http://www.cenorm.be>).

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IEEE Std 18™, IEEE Standard for Shunt Power Capacitors.^{4,5}

IEEE Std 80™, IEEE Guide for Safety in AC Substation Grounding.

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 519-1992™, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.

IEEE Std 693™, IEEE Recommended Practice for Seismic Design of Substations. IEEE Std 1303™, IEEE Guide for Static Var Compensator Field Tests.

[IEEE Std C37.90™, IEEE Standard for Relays and Relay Systems Associated With Electric Power Apparatus.](#)

[National Electrical Safety Code® \(NESC®\) \(Accredited Standards Committee C-2\).](#)⁶

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of ~~Electrical and Electronics~~ Terms & Definitions* should be ~~referenced~~[consulted](#) for terms not defined in this clause.⁷

commercial operation: The acceptance, by the user, of the static var compensator (SVC) from the supplier.

contract start: The date a contract to supply a static var compensator (SVC) becomes effective, and the user has given notice to proceed.

control range: The total inductive plus capacitive range of reactive current or megavar variation of the static var compensator (SVC), at the point of connection.

lagging operation: Inductive ~~megavars~~[operation or reactive power](#) absorption of the static var compensator (SVC), similar to a shunt reactor.

leading operation: Capacitive operation or reactive power generation of the static var compensator (SVC), similar to a shunt capacitor.

mechanically switched capacitor (MSC)[/mechanically switched capacitive damping network \(MSCDN\)](#): A shunt-connected circuit containing a mechanical power-switching device in series with a capacitor bank and sometimes also a ~~damping-current limiting~~ reactor (MSC). [In typical MSCDN branches, the reactor/auxiliary capacitor is paralleled by a resistor.](#)

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⁷ The IEEE Standards Dictionary: Glossary of Terms & Definitions is available at <http://shop.ieee.org/>.

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mechanically switched reactor (MSR): A shunt-connected circuit containing a mechanical power switching device in series with a reactor.

point of common coupling (PCC⁸): The [connection point between the SVC and the power system at which performance requirements are defined](#), ~~busbar from which other loads sensitive to voltage may be connected as well as the static var compensator (SVC) and any disturbing load it is required to compensate.~~

point of connection (POC⁹): For an SVC with a dedicated transformer, the high-voltage (HV) bus to which the whole is connected. For an SVC connected to an existing transformer or direct connected ~~at low voltage~~, the busbar to which [the SVC](#) is connected.

reference voltage (Vref¹⁰): The point on the voltage/current (V/I) characteristic where the static var compensator (SVC) is at zero output (i.e., where no ~~vars are reactive power is~~ absorbed from, or supplied to, the transmission system ~~at the point of connection~~[where the voltage is controlled](#)).

response time: The duration from a step change in control signal input until the voltage changes by 90% of its final change, before any overshoot.

settling time: The duration from a step change in control signal input until the SVC output settles to within $\pm 5\%$ of the required control output.

slope: The ratio of the voltage change to the current change over [a defined controlled range of the SVC normally](#) the full (inductive plus capacitive) ~~linearly-controlled range of the static var compensator (SVC)~~ at nominal voltage, expressed as a percentage.

static synchronous compensator (STATCOM)~~(static compensator)~~: A static synchronous generator operated as a shunt-connected SVC, whose capacitive or inductive output current can be controlled independently of the ac system voltage.

static var compensator (SVC): A shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current to maintain or control specific parameters of the electrical power system (typically bus voltage).

static var system (SVS): A combination of different static var devices and mechanically switched var ~~compensators~~ devices whose outputs are coordinated.

thyristor-controlled reactor (TCR): A shunt-connected ~~thyristor-controlled inductor-reactor in series with a thyristor valve~~. The effective reactance of the inductor is varied in a continuous manner by partial conduction of the thyristor valve.

thyristor-switched capacitor (TSC): A shunt-connected ~~thyristor-switched capacitor whose effective reactance is varied in a stepwise manner by full or zero conduction operation of the thyristor valve-capacitor (or capacitor arranged as a filter) in series with a thyristor valve which is used to switch the capacitor ON or OFF. A current limiting reactor or a damping network is connected in series with the capacitor and the thyristor valve.~~

thyristor-switched reactor (TSR): A shunt-connected reactor in series with a thyristor valve that is used to switch the reactor ON or OFF. ~~thyristor-switched inductor whose effective reactance is varied in a stepwise manner by full or zero conduction operation of the thyristor valve.~~

voltage/current (V/I) characteristic: The relationship between the ~~steady-state~~ current of the SVC and the voltage at its point of connection.

⁸ Refer to Figure 1.

⁹ Refer to Figure 1.

¹⁰ Refer to Figure 1.

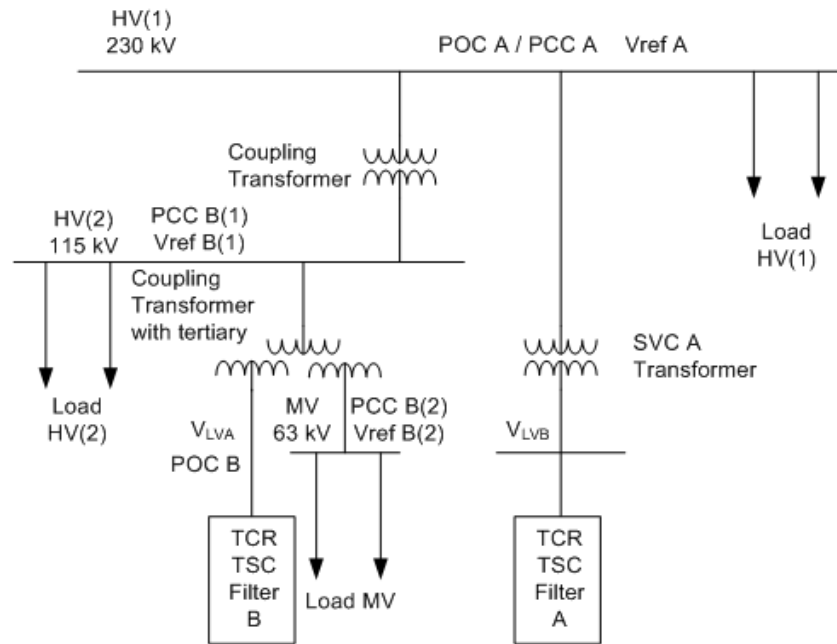


Figure 1—Explanatory figure to POC, PCC, and Vref

3.2 Acronyms and abbreviations

~~BIL~~	~~basic impulse level~~
ac	alternating current
CT	current transformer
~~EMI~~	~~electromagnetic interference~~
~~ETT~~	~~electrically triggered thyristors~~
~~FACTS~~	~~flexible AC transmission systems~~
~~GTO~~	~~gate turn-off~~
<u>dc</u>	<u>direct current</u>
<u>GIC</u>	<u>geomatically induced current</u>
HV	high voltage
HVDC	high-voltage direct current
~~LTT~~	~~light triggered thyristors~~
LV	low voltage
MSC	mechanically switched capacitor
<u>MSCDN</u>	<u>mechanically switched capacitive damping network</u>
MSR	mechanically switched reactor
PCC	point of common coupling
~~PT~~	~~potential transformer~~
<u>PLC</u>	<u>power line carrier</u>
<u>POC</u>	<u>point of connection</u>
<u>QP</u>	<u>quasi-peak</u>

RI radio interference
 rms root mean square
 STATCOM static [synchronous](#) compensator
 SVC static var compensator
 SVS static var system
 SWC surge withstand capability
[TCR](#) [thyristor-controlled reactor](#)
[THD](#) [total harmonic distortion](#)
 TIF telephone influence factor
~~TNA transient network analyzers~~
 TSC thyristor-switched capacitor
 TSR thyristor-switched reactor
 TVI television interference
 V/I voltage/current
[VSC](#) [voltage sourced converter](#)
[VT](#) [voltage transformer](#)

4. SVC project description

This specification is for the design, manufacture of equipment, construction, installation, test, commission, warranty, training, and placement into commercial operation of an SVC at __substation connected to the __busbar.

The purpose of the SVC is to regulate the voltage of the __kV busbar. The nominal ratings of the SVC are __Mvar leading at 1.0 pu voltage to __Mvar lagging at 1.0 pu voltage.

A regional and local site location map is shown in Figure xy_. [A simplified system, one-line diagram showing the sources, interconnected transmission lines, and other system components is attached in](#) Figure xy_. A proposed one-line diagram of the __substation after installation of the SVC is shown in Figure xy_. The area for the SVC facility is shown in Figure xy_. The points of electrical interconnection of the supplier-furnished SVC and the user-furnished facilities are shown on the following figures:

Figures xy____

__ [\(site location\)](#)
 __ [\(system one line diagram / substation electrical environment\)](#)
 __ (power circuit)
 __ (grounding)
 __ (station service)
 __ (control and protection)

and, for turnkey projects

__ (fencing)
 __ (site subsurface and geotechnical data)
 __ (other)

The design and layout of the SVC facility should provide for future expansion requirements as shown in Figure xy__.

The “figures xy” mentioned previously are figures that may be attached to the specification as additional information but are not necessary information for the design of the basic SVC components

See Annex B for additional discussion of the SVC specification.

5.Scope of supply and schedule

5.1 Scope of supply

The equipment, materials, and services to be furnished by the supplier may include, but are not limited to, the list shown in Table 1.

Table 1—Example for equipment , materials , and services to be furnished by the supplier

~~b) –High voltage (HV) ac equipment, transformer, switchgear, circuit breaker, disconnects, potential transformers (PTs), current transformers (CTs), surge arresters grounding transformers~~

~~e) –Reactors, capacitors, and harmonic filters~~

~~For turnkey supply, following are added:~~

<u>No.</u>	<u>Item</u>	<u>Check if requested</u>	<u>Turnkey projects</u>	<u>Remarks</u>
1	SVC thyristor valve and valve cooling equipment			
~~2~~	~~Step down or coupling transformer~~			
~~3~~	~~HV switchgear: circuit breaker, disconnects, grounding switches~~			
~~4~~	~~Low voltage (LV) switchgear (circuit breaker, disconnects, grounding switches) and cables if used for connection to LV bus~~			
~~5~~	~~Measuring equipment Voltage transformers (VTs) Current transformers (CTs)~~			
~~6~~	~~Surge arresters~~			
~~7~~	~~Grounding transformers~~			
~~8~~	~~Reactors~~			
~~9~~	~~Capacitors~~			
~~10~~	~~Harmonic filters~~			
11	SVC station services			
12	SVC yard control, protection, and alarm and monitoring systems			
13	Special maintenance equipment and tools			

14	Training program for operation and maintenance personnel			
15	Spare parts			
16	Testing and commissioning services			
17	Documentation including instruction manuals			
18	Civil works for the SVC, including the switchyard, fencing, drainage, and access and parking		X	
19	SVC building, including air conditioning and grounding		X	
20	SVC foundations and structures to mount busbars, including grounding and ground mat connections		X	
21	Fire detection and protection systems (building and components)			
22	Physical security systems			
23	Others			

5.2 Equipment, materials, and services furnished by the user

The nonelectrical data to be supplied by the user is given in Clause 6; the electrical data is in Clause 7 through Clause 9.

The user should furnish the following equipment, materials, and services:

- Site for the SVC available _calendar days after contract start
- Source of water for construction
- Source of temporary station service power for construction at __kV, available _calendar days after contract start
- sources of permanent station service power for the SVC at ___ kV, available _calendar days after contract start
- Existing facilities and equipment

5.3 Schedule

Project completion is _calendar days after contract start. The supplier's project schedule is due _calendar days after contract start and should include such details as dates for commencement and completion of work on several controlling features of the project, dates for user-furnished services, dates on which supplier-furnished drawings will be provided and approval given, and dates and length of time of any required power outages.

Design review meetings should be held between the user and supplier to review and discuss progress of the design and supply of the SVC. The first design review should be held within _calendar days after contract start. Subsequent design reviews should be held ~~every _calendar days~~ [according to the agreed project schedule](#).

6. Site and environmental data

The SVC should be designed to meet all rating and performance requirements specified in this document while operating in the site and environmental conditions listed in Table 2.

Table 2—Example for site and environmental data

No.	Type of information	Value	Units
1	Site elevation above sea level		m
2	Maximum ambient dry-bulb temperature		°C
3	Maximum ambient wet-bulb temperature		°C
4	Minimum ambient air temperature		°C
5	Maximum daily average ambient air temperature		°C
6	Minimum daily average ambient air temperature		°C
7	Ice loading conditions (thickness)		mm
8	Maximum ground snow depth		m
9	Maximum frost depth		m
10	Maximum steady wind velocity		m/s
11	Wind gust factor or maximum wind gust		m/s
12	Seismic zone and withstand data as per IEEE Std 693™		
13	Isokeraunic level		days/year
14	Dust concentration (or pollution level per IEC 60815-05)		mg/cm ²
15	Salt concentration		mg/cm ²
16	Solar radiation level		W/cm ²
17	Ground Earth resistivity		Ohm-m
18	Humidity		%

7. Power system characteristics

The alternating current (ac) power system characteristics apply at the point of connection ~~prior to SVC installation~~. Normal SVC operation is required within the parameter values and durations given in Table 3.

Table 3—Example of necessary power system characteristics

No.	Type of information	Value	Units
1	Nominal ac system voltage, line to line		kV
2	Maximum continuous ac system voltage, line to line		kV
3	Minimum continuous ac system voltage, line to line		kV
4	Maximum short-term ac system voltage, line to line		kV
5	Maximum duration of item 4)		s
6	Minimum short-term ac system voltage, line to line		kV
7	Maximum duration of item 6)		s
8	Continuous negative-sequence voltage component(used for performance calculation)		%
9	Continuous negative-sequence voltage component (used for rating calculation)		%
10	Continuous zero-sequence voltage component		%
11	Nominal ac system frequency		Hz
12	Maximum continuous ac system frequency		Hz
13	Minimum continuous ac system frequency		Hz
14	Maximum short-term ac system frequency		Hz
15	Maximum duration of item 14)		s
16	Maximum rate of change of frequency (df/dt)		Hz/s
17	Minimum short-term ac system frequency		Hz
18	Maximum duration of item 17)		s
19	Basic insulation level		kV peak
20	Switching impulse level		kV peak
21	Power frequency withstand voltage		kV
22	Maximum three-phase fault current —For performance requirements —For rating of SVC (see item 8.1.k)		kA kA for ___ s
23	Existing three-phase fault current		kA
24	Minimum three-phase fault current —For performance requirements —For safe operation of SVC		kA kA kA
25	Maximum single-phase fault current		kA
26	Existing single-phase fault current		kA
27	Minimum single-phase fault current		kA
28	Harmonic impedance sectors for each harmonic number or system impedance data as R-X values with frequency steps not larger than 1 Hz (for performance and/or SVC component rating)	(A figure or table shall be attached)	_____
29	Background harmonic voltage (or current) spectrum (for SVC components rating)	(A figure or table shall be attached)	_____

f) Lightning impulse protective level (BIL) _____ kV-peak

8. Main SVC characteristics

The output of an SVC can be adjusted continuously (smoothly) or in discrete steps depending on the thyristor branches connected to the SVC LV side. If the proposed SVC configuration is made up by only switchable branches (TSC and TSR), the switching of the largest branch should not result in voltage step larger than ___% at the point where the voltage/current (V/I) characteristic is defined.

8.1 SVC rating

These clauses define the ratings of the compensator equipment. More detailed information on the following items are added to Annex B:

- a) The SVC should regulate the ___kV bus voltage to a reference voltage of ___kV (1.0 per unit), continuously adjustable between ___per unit and ___per unit.
- b) The nominal capacitive reactive power output of the SVC should be ___MVar at 1.0 pu ac bus voltage and nominal system frequency, and 20 °C ambient temperature. Refer to the voltage/current (V/I) characteristic on Figure 3 at point A.
- c) The nominal inductive reactive power output of the SVC should be ___MVar at 1.0 pu ac bus voltage (and nominal system frequency, and 20 °C ambient temperature. Refer to the voltage/current (V/I) characteristic on Figure 3 at point B.
- d) The nominal slope of the characteristic should be adjustable in steps of not greater than ___% between ___% and ___%, on a basis of ___ (A+B (optional G+B)) MVA (see Figure 2 and Figure 3).
- e) The SVC should continue to generate reactive power during a temporary undervoltage down to the value given in line 6 of Table 3 for the duration given in line 7 of Table 3 (point C optional C' on Figure 2 and Figure 3); the SVC may be tripped (or blocked) if the undervoltage persists for more than ___s.
- f) The SVC should continue to absorb reactive power during a temporary overvoltage in a controlled manner up to the value given in line 4 of Table 3 for the duration given in line 5 of Table 3 (point D on Figure 2 and Figure 3); the SVC may be tripped if the overvoltage persists for more than ___s.
- g) (Optional) The temporary capacitive reactive power output of the SVC should be ___Mvar at ___per unit ac bus voltage for ___s (Figure 3, point G), after 1 h operation at or below the level specified under item b).
- h) (Optional) Continued controllable conduction of the SVC to absorb reactive power should be possible up to ___per unit ac bus voltage for ___s, following 1 h operation at or below the level specified under item c).
- i) The SVC should be capable of repeating temporary operation as defined in any one of items e), f), or g) every ___min.
- j) The compensator transformer and all bus equipment such as filter branches, TSC branches, thyristor-switched reactor (TSR branches, thyristor-controlled reactor (TCR) branches,

capacitor bank branches, and reactor bank branches (whether at HV or LV) should be rated to withstand the specified continuous and shortterm operation, and to withstand or be protected against voltage and current stresses that exceed these conditions.

- k) All equipment in the SVC system should be capable of sustaining, without damage, any fault limited by the maximum design short-circuit level of the system and the SVC transformer impedance. ~~Taken with its normally connected, if a coupling transformer, all SVC equipment should sustain, without damage, any internal fault no matter what fault level is available on the HV system(s) used.~~

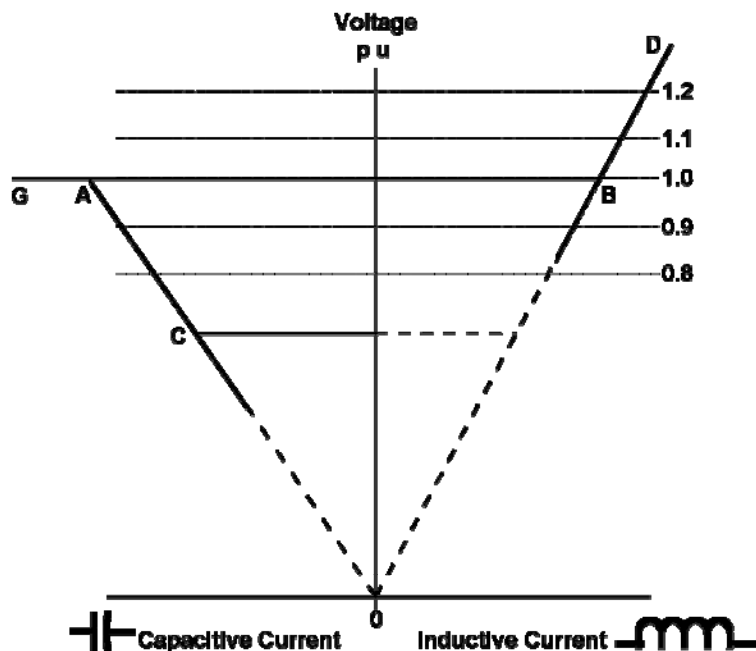


Figure 2—V/I characteristic of the SVC to define ~~ratings at nominal voltage~~ operating points

A is defined by item b) giving the ~~nominal~~ capacitive ~~susceptance, OA.~~ B design point for continuous operation.

B is defined by item c) giving the ~~nominal~~ inductive ~~susceptance, OB.~~ design point for continuous operation.

C, C' is defined by Clause 7 (lines 6 and 7 of Table 3).

Below point C, C' the SVC should normally block TSC branches, if included, and await a recovery of voltage before resuming normal action.

D is defined by Clause 7 (lines 4 and 5 of Table 3). It is an extension of line OB.

E is an extension of line OA at maximum reference voltage (K) and minimum slope.

F is an extension of line OB at maximum reference voltage (K) and maximum slope.

G is defined by item g) giving the capacitive design point for short time operation.

~~H and J give minimum voltage settings for continuous operation at maximum and minimum slope, respectively. K is a most severe operating condition, chosen to define filter component ratings.~~

H is an extension of line OA at minimum reference voltage (M) and maximum slope.
J is an extension of line OB at minimum reference voltage (M) and minimum slope.
K is the maximum reference voltage.
L is the nominal reference voltage.
M is the minimum reference voltage.

Figure 3—Details of SVC operating points

8.2 Control objectives

8.2.1 SVC functions, with priority

The desired function(s) and the priority in which the SVC should respond to them are as follows:

- a) Control of three-phase average or positive sequence of the fundamental voltage in steady state and ~~post-fault~~dynamic operation, with slope in the range of __% to __%.
- b) Control ~~of phase~~ voltage based on either
 - 1) Individual phase voltage or
 - 2) Positive ~~and negative~~ sequence voltage
- c) Control of voltage with superimposed reactive power control. The reactive power returns SVC output slowly to a preset steady-state value, so that its megavar capacity to support voltage is held in reserve.
- d) Voltage control with superimposed damping control based on active power, speed, or frequency measurements to damp oscillations or to enhance the power transfer capability.
- ~~e) —The SVC should not trip during the dead time of ____ms during automatic reclosing operations.~~

8.2.2 Response

The change of measured system voltage to small disturbance (typically <3%) should reach 90% of the desired total change within __ms of the initiating ~~control signal a~~ % step change of voltage reference. The maximum overshoot should not exceed ____% of the ~~ordered change final value~~, and the settling time should not exceed __ms, after which the voltage should be within ±5% of the final value (see Figure 4). This response ~~is required~~characteristic within these limits shall be achieved when the system three-phase fault MVA is between the minimum and the maximum value defined in Clause 7. The response of the system voltage using the actual controller should be validated on a real-time simulator. A Thevenin network equivalent is sufficient for this purpose.

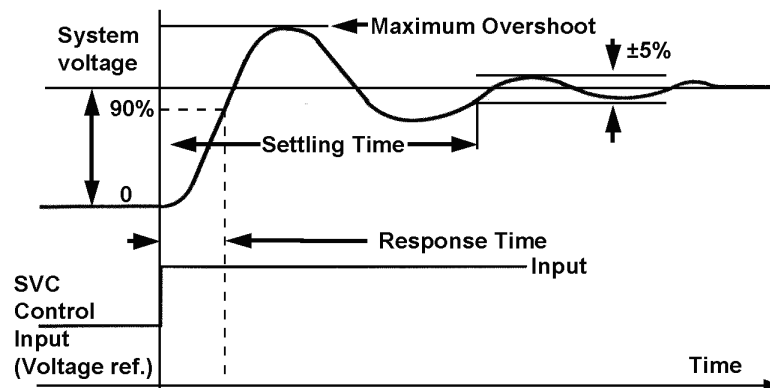


Figure 4—Definition of response and settling time

8.3 Harmonic performance

The SVC system should be designed to minimize [the effects of](#) resonance among its shunt capacitor banks, filter branches, and the ac system as well as to limit the harmonic distortion imposed on the connected transmission system.

[The maximum permissible voltage distortion in transmission systems \(often termed “planning level”\) is given in various national standards. The contribution of harmonic distortion from the SVC should not exceed a specific amount that has to be stated by the SVC purchaser so as not to result in excessive voltage distortion in cases where high harmonic distortion already exist due to other harmonic sources.](#)

[The SVC purchaser will also need to indicate whether the full planning level limit \(taking into account the distortion already existing\) is available for the distortion due to the SVC or only a part of that planning level is available based on the size of the SVC as a proportion of the total MVA capability of the substation \(refer to Appendix E of IEC 61000-6-3:2011 \[B20\]¹¹\).](#)

[Consideration should also be given as to whether the specified limits are “incremental,” i.e., due only to the effects of SVC generated harmonics, or “aggregate,” i.e., due to the effects of the SVC generated harmonics plus the effects that the SVC has on preexisting distortion \(due to magnification or attenuation\). The latter is preferred because the principal concern in respect of power quality is the total change that the SVC causes. This is particularly relevant in TSC applications where often only an incremental specification is provided; a low loss designed TSC while not generating harmonic distortion itself can, however, lead to a significant increase in preexisting distortion due to resonance between it and the supply system.](#)

[The SVC purchaser should also specify whether the performance limits are such as to satisfy planning levels at the PCC itself only, or to satisfy planning limits at “remote” busbars also \(to a certain degree this depends on the performance standard chosen\).](#)

8.3.1 Filter performance

The ~~maximum voltage~~ distortion levels as specified should be met for the following:

- The continuous range of system and environmental conditions stated in Clause 6 and Clause 7
- Variation in ~~tolerance of~~ total filter capacitance, ~~including permissible fuse failures~~ due to manufacturing tolerance, ambient temperature, aging, and changes in capacitance up to alarm level
- Variation in tolerance for SVC parameters, such as transformer winding unbalances, valve firing variations, and unequal reactor and capacitor reactance between phases

These performance requirements may be exceeded for system conditions outside the continuous normal envelope specified in Clause 7.

Calculation should take into account all possible combinations and should not be applied equally on each filter branch.

A more detailed description is available in B.5.3.

Typically, one or more filter branches are used to limit the distortion levels in the system.

8.3.2 Filter component rating

The harmonic filter components (and other SVC components) should be rated to carry continuously the harmonic currents caused by the background harmonic distortion of the system and the harmonic currents produced by the SVC itself. Unless otherwise specified, harmonic currents from the system and the SVC ~~should be added quadratically (root sum of squares); the same order should be added arithmetically. All filter harmonic currents of different order should be added quadratically (root sum of squares).~~

¹¹ The numbers in brackets correspond to those in the bibliography in Annex A.

The rated voltage of capacitors should be derived from the largest arithmetic sum of the power-frequency and individual harmonic voltages obtained from stress calculations in continuous operating conditions.

NOTE—Maximum fundamental voltage and maximum harmonic contributions may not exist at the same time for SVC configurations including TSCs or MSCs.¹²

For the filter capacitor voltage rating, the loss of capacitor unit or elements should be considered up to the trip level.

The rated voltage of so-called “low-voltage” capacitors (e.g., in double- or triple-tuned filters) should be chosen such as to also withstand imposed transient stresses from energization or other switching events.

Filter rating should take into account additional constraints generated by geomagnetically induced current (GIC) when it applies.

[A more detailed description is also available in B.5.3.](#)

8.4 Telephone and radio interference

8.4.1 Telephone interference

[For additional details, refer to subclause 6.9 of IEEE Std 519™-1992.¹³](#) Limits for telephone interference should be given, where applicable, as follows:

- ↓ The $I \times T$ product should be less than ___, where $I \times T$ is defined as the square root of the sum of the squares of harmonic current (I_n) and the corresponding weighting factor from the “C-message” weighting factors established in IEEE Std 519-1992.
- ↓ The $kV \times T$ product, otherwise known as telephone influence factor (TIF), should be less than ___, where $kV \times T$ is defined as the square root of the sum of the squares of harmonic voltage (V_n) and the corresponding weighting factor from the “C-message” weighting factors established in IEEE Std 519-1992

[TIFs are required in cases when telephone lines are running close by. Where a current-based criterion is required, the specification of system harmonic impedance, in particular minimum resistance, needs careful definition.](#)

[Typical values for TIF are in the range of 20 to 50 and 10 000 A to 30 000 A for the \$I \times T\$ value. More information is provided in B.5.4.1. The user should specify the impedance and the equivalent circuit or model that has to be used for the calculation.](#)

8.4.2 Radio interference

~~. In addition, the radio frequency emissions produced by the SVC should not exceed ___ $\mu\text{V}/\text{m}$ over the range of 150 kHz to 1 MHz, when measured 500 m from the SVC station perimeter, except where overhead lines leave the station. The measurements should be made in accordance with IEEE Std 139-1988, based on quasi-peak detector readings.~~

8.4.2 Broadband interference

[The electromagnetic interference generated by substations and transmission lines is propagated by radiation and conduction. The purpose of these general requirements are \(1\) to limit the electromagnetic noises likely to disturb the power line carrier and \(2\) to protect the band used in the aid to navigation \(200 kHz to 415 kHz\), the domestic broadcasting band, and other communication systems located in the frequency range of 5 kHz and 30 MHz, under all conditions of short-time durations or continuous operation. There could be also a need to protect control and protection equipment. The SVC design and layout should take necessary precautionary measures to avoid misoperation, damage, or danger to any equipment or system due to broadband interference and effects. The potential for higher frequency emissions should be limited to avoid interference with any properly licensed or authorized radio, television, microwave, or other equipment in service. Typical guidelines are given in B.5.4. However, the user has to refer to local standards to determine the specific limits acceptable for his or her respective country.](#)

¹² Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

¹³ Information on references can be found in Clause 2.

More detailed information is described in IEEE Std 139™ and is available in B.5.4.2.

8.5 Audible noise

- | | | |
|----|--|------------|
| a) | Station fence | _____dB(A) |
| b) | Within compressor areas | _____dB(A) |
| c) | At a distance of ____m outside of compressor area enclosure(s) | _____dB(A) |
| d) | At a distance of ____m outside of mechanical equipment areas | _____dB(A) |
| e) | Maintenance workshop | _____dB(A) |
| f) | Control rooms | _____dB(A) |
| g) | Relay rooms | _____dB(A) |
| h) | Other accessible rooms | _____dB(A) |

The supplier should design and construct the SVC to limit the audible noise interior and exterior to the facilities. Local noise ordinances and safety codes can be used to establish maximum allowable audible noise levels for interior and exterior areas. Audible noise limits outside the SVC building *typically* apply at the substation fence line. Inside the building, they apply at a specified distance (*typically* 3 m) from the emitting source ~~and include the following:~~ An example for measurement locations is given in B.5.5.

~~The supplier should also be responsible for establishing existing audible noise levels prior to construction of the facilities and for preparation of a report. The final report should record audible noise levels prior to and after construction.~~

The SVC specification should establish whether a supplier, customer, or third-party acoustic consultant will be responsible for the measurement of audible noise levels. In addition to measurement locations (as discussed previously), the time of day, SVC output levels, instrumentation, and reporting format may be identified.

Existing audible noise levels should be established at the identified locations prior to the construction of the facilities and can be included as part of the specification to bid if available. It is recommended that both preconstruction and postenergization audible noise measurements be performed by the same party using identical instrumentation.

For installations where audible noise output of the SVC is strictly enforced and in cases where ambient noise levels vary, such as in windy environments, the accuracy and repeatability of the acoustic measurements may be critical in establishing compliance with specified values. Class 1/type 1 sound level meters as specified by IEC 61672-1:2003 [B21] and ANSI S1.4-1983 [B4], respectively, are recommended in these applications.