IEC/TR 60919-1

Edition 3.0 2013-04

TECHNICAL REPORT

AMENDMENT 1

Performance of high-voltage direct current (HVDC) systems with line-commutated converters –
Part 1: Steady-state conditions

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Performance of high-voltage direct current (HVDC) systems with line-commutated converters –
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FOREWORD

This amendment has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment.

The text of this amendment is based on the following documents:

DTR	Report on voting
22F/277/DTR	22F/286A/RVC

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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

CONTENTS

Replace, the titles of Clause 19 and its subclauses as follows:

Add the title of Annex A as follows:

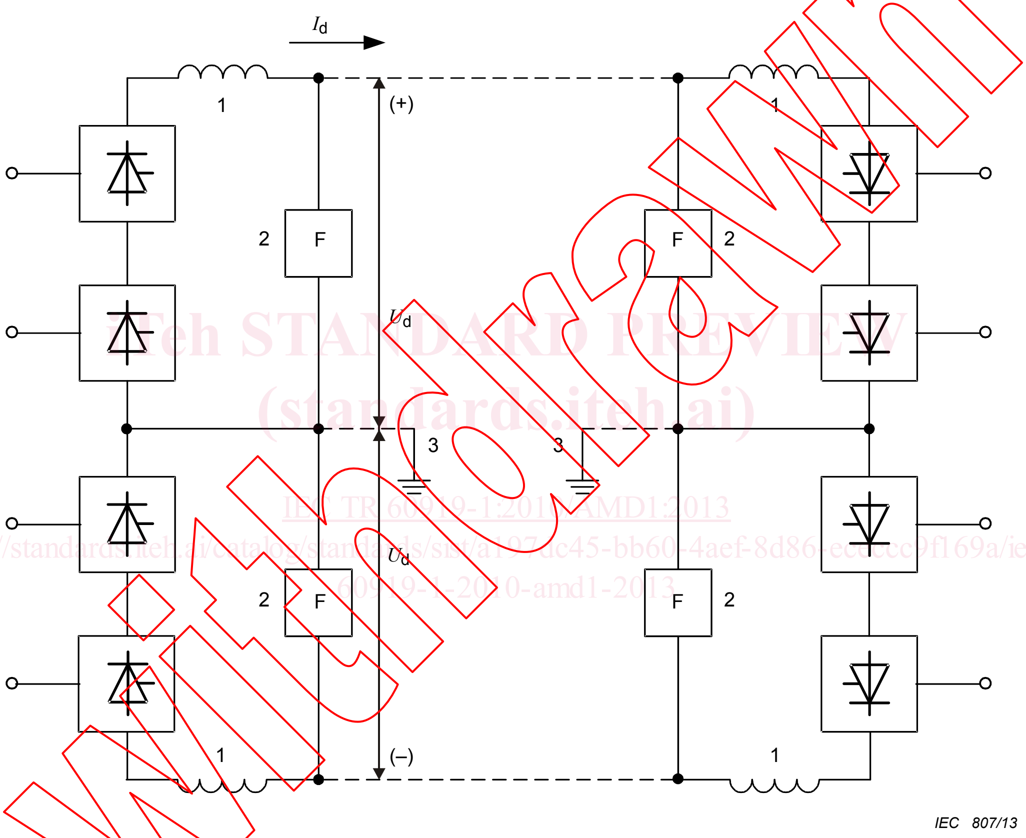
Replace, in the list of figures, the title for Figure 23 as follows:

Figure 23 – RY COM noise meter results averaged – Typical plot of converter noise levels on the d.c. line corrected and normalized to 3 kHz bandwidth – 0 dBm = 1 mW corresponding to 0,775 V at a pole-to-pole surge impedance of 600 Ω

Add, in the list of figures, the title for Figure 25 as follows:
Figure 25 – Recommended measurement procedure with definition of measuring point

Figure 7 – Bipolar system

Replace Figure 7 by the following new figure:



Key

1 DC reactor

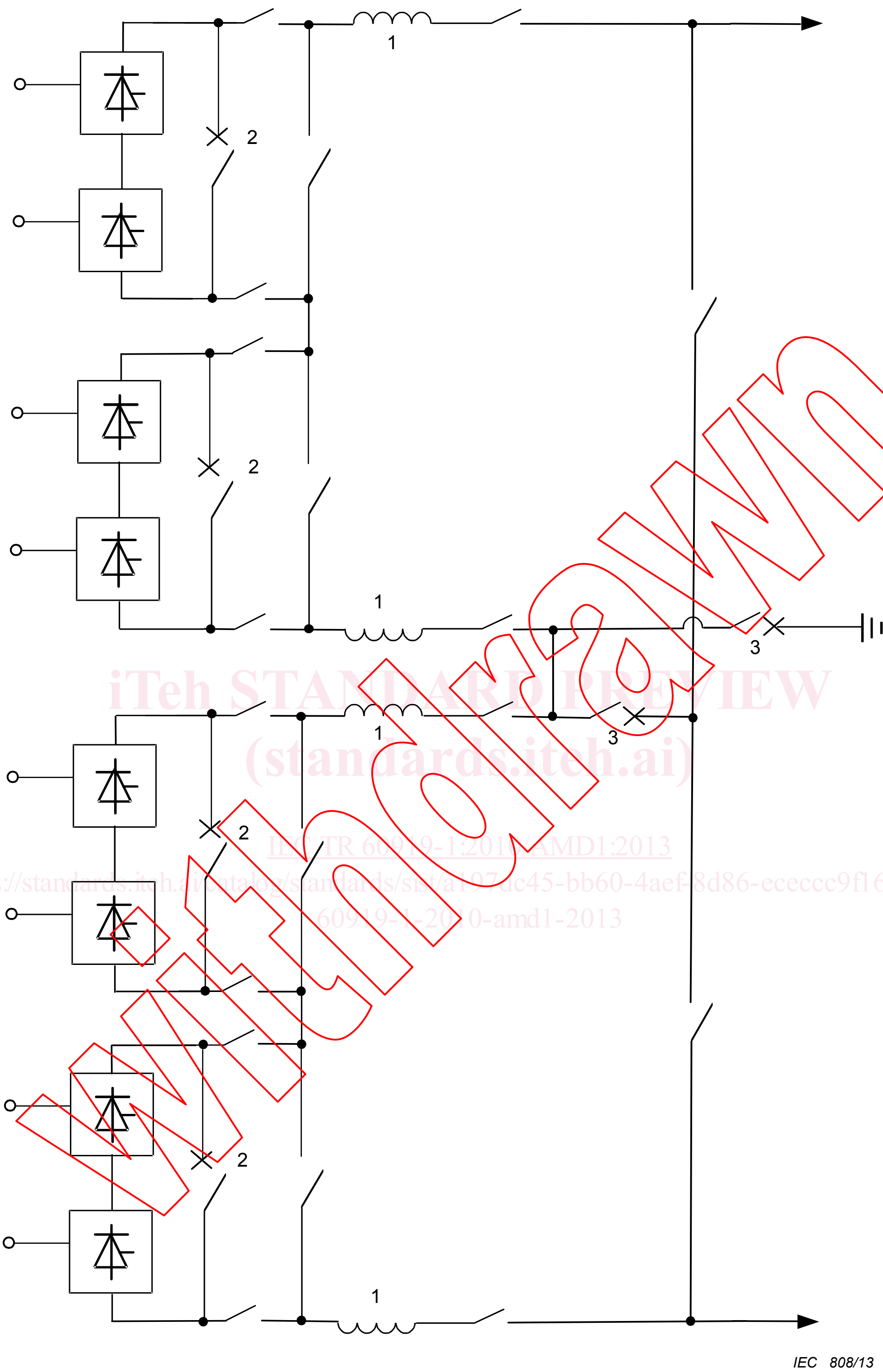
2 DC filter

3 Earth electrodes

Figure 7 – Bipolar system

Figure 10 – Bipolar system with two 12-pulse units in series per pole

Replace Figure 10 by the following new figure:



Key

1 DC reactor

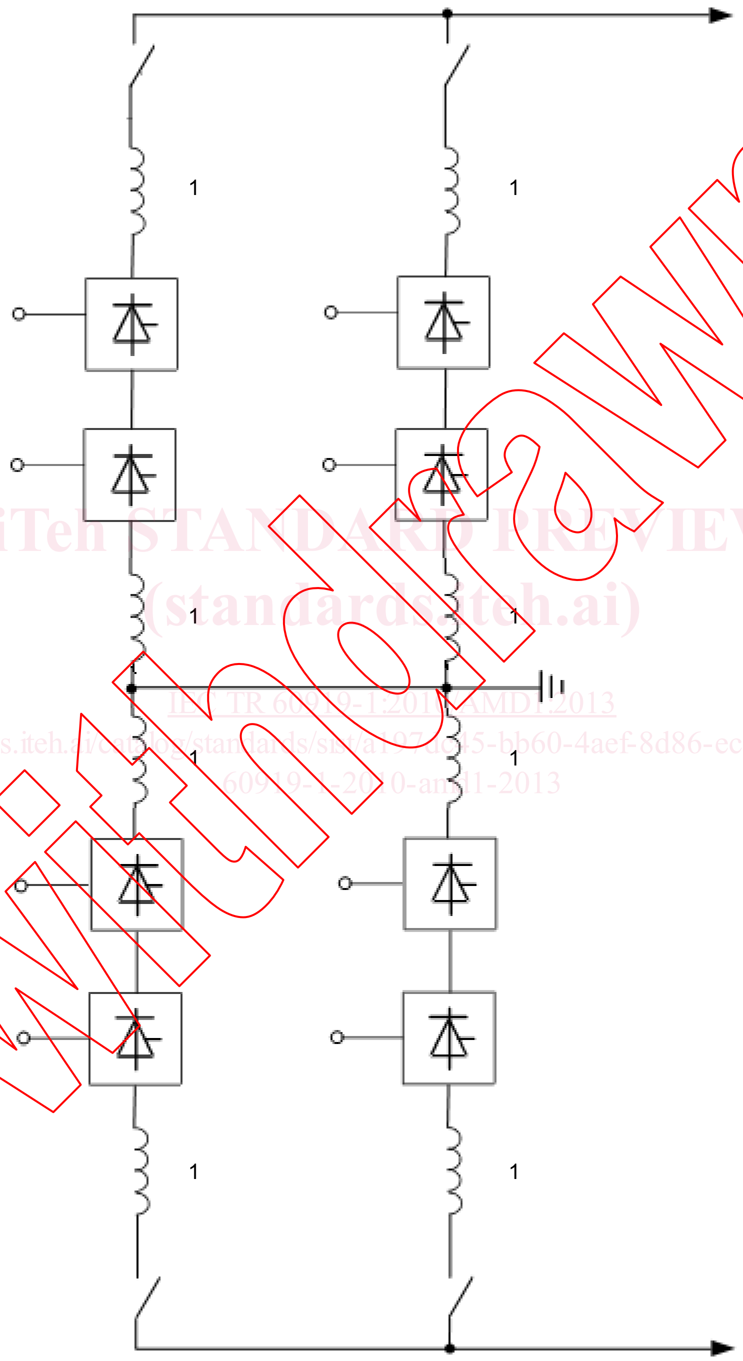
2 By-pass switch

3 DC switch

Figure 10 – Bipolar system with two 12-pulse units in series per pole

Figure 11 – Bipolar system with two 12-pulse units in parallel per pole

Replace Figure 11 by the following new figure:



IEC 809/13

Key

1 DC reactor

Figure 11 – Bipolar system with two 12-pulse units in parallel per pole

10.2.2 Electrical parameters

Replace, in item 1) the words “100 Hz” *by* “two times of the fundamental frequency”.

Replace, in item 3) the words “100 kHz” *by* “two times of the fundamental frequency”.

11.1 General

Add, in the second paragraph after the second sentence ending “.... during the acceptance period of an HVDC system.” *the following new sentence:*

Please refer to Annex A for more information on factors affecting reliability and availability of converter stations.

13.6 Optical fibre telecommunication

Add the following new sentence at the end of the third paragraph:

Use of OPGW (optical ground wire) as one of shielding wire is another typical arrangement used in many overhead lines schemes.

18.1 General

Replace the third paragraph by the following new paragraph:

Field experience shows that thyristor valves generate about 10 dB to 15 dB less conducted noise interference than mercury arc valves.

18.2 Performance specification

Replace the fifth paragraph by the following new paragraph:

Where dBm is defined as a means of interference measurement in which 0 dB is specified to 1,0 mW, which corresponds to 0,775 V pole-to-pole interference voltage assuming a line to-line surge impedance of 600 Ω. In a 50 Ω cable on the low voltage side, 0 dBm and 1 mW corresponds to 0,224 V.

Add the following new sentence at the end of the sixth paragraph after "...should be evaluated"*:*

It should be considered that the cost for a broad band PLC filter is significantly higher than the cost for a narrow band PLC filter. Especially, filters for the lower frequencies 20 kHz to 50 kHz cost significantly more than PLC filters for higher frequencies.

Figure 23 – RY COM noise meter results averaged – Typical plot of converter noise levels on the d.c. line corrected and normalized to 3 kHz bandwidth – 0 dBm = 0,775 V

Replace the existing title of Figure 23 by the following new title:

Figure 23 – RY COM noise meter results averaged – Typical plot of converter noise levels on the d.c. line corrected and normalized to 3 kHz bandwidth – 0 dBm = 1 mW corresponding to 0,775 V at a pole-to-pole surge impedance of 600 Ω

19 Radio interference

Replace the title and text of Clause 19 by the following:

19 Radio frequency interference

19.1 General

Historically Radio Frequency Interference (RFI) from high voltage electric power installations has been related to interference with AM broadcast distribution due to high voltage a.c. line corona. Consequently, this aspect is covered well in the literature and in relevant standards, i.e. the CISPR 18 series. RFI from substations has been of minor practical concern. Therefore very little has been documented regarding RFI from HV and MV substations. However, CIGRÉ Technical Brochure No. 391, provides a thorough analysis of the aspect related to RFI from substations, including HVDC substations. The analysis is based on both theory and measurement results.

One important aspect that is treated in the Technical Brochure (TB) is the attenuation of the RFI versus distance, including how the attenuation depends on the frequency.

RFI relates to a quite wide frequency range. According to CISPR 11 frequencies between 9 kHz and 400 GHz may be used for wireless communication and are therefore covered by the International Telecommunication Union (ITU) current international table of frequency allocations. Consequently, electromagnetic interference in this frequency range is defined as Radio Frequency Interference (RFI). However, the frequencies below 150 kHz are nowadays sparsely used and the standards for frequencies above 1 GHz are under development.

19.2 RFI from HVDC systems

19.2.1 RFI sources

RFI energy at the HVDC substation is produced by the turn-on and turn-off sequences in the valves, from corona on the high voltage switchgear and lines, and from sparking and gap discharge activities within the switchyard.

The RFI noise from the valve operation is predominantly produced by the fast voltage collapse during the turn-on sequence. These transients excite localized resonance circuits formed by stray capacitance and inductive elements in the bus structures, bushings, reactors, converter transformers, etc.

RFI generated by the a.c. corona in the high voltage a.c. switchyard of the HVDC substation varies significantly with the weather conditions and is highest at bad weather. RFI generated by d.c. corona is highest near the positive conductor and decreases with the radial distance from the conductor. DC corona does not vary very much with the weather conditions and is somewhat higher at fair weather.

Recent measurements have indicated that there may be a significant high frequency RFI from the a.c. part of a substation, especially at dry weather conditions if the substation is old. This high frequency RFI noise is considered to be generated by gap discharge and/or sparking activities. For more information reference is made to CIGRÉ TB No. 391.

19.2.2 RFI propagation

RFI generated in the HVDC substations may propagate as:

a) a guided wave transmission propagating along the HVDC transmission line;

b) a guided wave transmission propagating along the a.c. transmission lines;

c) direct wave radiation from the HVDC substation.

The attenuation of the RFI versus distance varies with the frequency as follows.

a) The attenuation for the line-to-earth mode of RFI propagating along the lines is in the order of $3f^{0,8}$ dB/km with f in MHz. The attenuation varies with line design parameters and the soil resistivity.

b) The attenuation for the line-to-line mode of RFI propagating along the lines is in the order of $0,3f^{0,8}$ dB/km with f in MHz. The attenuation varies with line design parameters and the soil resistivity.

c) The physics for attenuation of the direct wave RFI with distance is quite complex. As an approximation, at a distance from a substation shorter than $\lambda/2\pi$ or longer at a certain distance d(SA) the attenuation of the field strength decreases as $1/r^2$ (where λ is the wavelength of the EM radiation and r is the distance to the installation). For intermediate distances, the attenuation is proportional to 1/r. The distance d(SA) depends on the frequency, the height of the antennas and the soil properties. For more information reference is made to CIGRÉ TB No 391. For a realistic example in the TB, the distance d(SA) is in the order of 25 m at 50 MHz and increases linearly with the frequency for higher frequencies. For lower frequencies than 50 MHz, the distance d(SA) varies as 1/f.

The implication of the above is that for RFI propagating along the lines, the high frequency RFI vanishes after a few kilometres, especially the line-to-earth component that is dominating. However, low frequency RFI will propagate quite a long distance, especially the line-to-line component.

Within a few hundred meters from the substation, the direct wave RFI can have a quite broad frequency range. However, when normal design is applied, the RFI has diminished to the background RFI level after 0,5 km to 1 km.

19.2.3 RFI characteristics

The general characteristic of the RFI noise from an HVDC substation is repeated transients regardless that the noise is produced by the commutation process, corona, sparking or gap discharge. Due to the different sources the frequency characteristics of the broad band RFI from a converter station can be quite complex and very irregular. To some extent this is valid for any high voltage substation.

RFI noise generated by the commutation process of the HVDC converter has the following characteristics.

a) Interference energy is directly proportional to the magnitude of the voltage jumps produced during the turn-on sequences of the valves and also depends on circuit parameters. The voltage jumps at turn-off has less impact as the rise time at turn-on is much shorter than the rise time at turn-off.

b) As the RFI due to the converter commutation process depends on the circuit resonances, the frequency spectrum is quite irregular.

c) Due to the defined rise time for the voltage jumps at turn-on, the RFI due to the commutation process decays for frequencies above 1 MHz and is negligible for frequencies above 10 MHz.

d) The noise that comes out from the valve hall is predominantly the noise conducted through the wall or transformer bushings if the valve hall is designed with good RF shielding.

e) The noise level is essentially independent of the operating current.

f) The number of converters has minor impact on the noise level.

The dominant mode for all RFI generated in a substation is the line-to-earth mode.

19.3 RFI performance specification

19.3.1 RFI risk assessment

The process for the specification should start with an RFI risk assessment regarding any local conditions requiring specific precautions regarding RFI. It should be noted that the risk for interference is related to nearby radio receivers, not to nearby radio transmitter. A nearby airport may imply an extra risk for RFI with the airplanes approaching the airport for landing.

Of special concern is interference related to the non-directional beacons (N DB) as their operating frequency is coincident with the frequency range for the converter RFI emission.

Also local communication centres with dual communication such as fire brigade stations should be considered in the risk assessment.

The important factors are: Frequencies used, the bandwidth, the signal level, the noise to signal requirement and the distance to and the location of the antenna of the radio receivers.

19.3.2 Specification RFI limit and its verification

The specified RFI requirement should include all sources related to the relevant delivery. The specification shall define all steady state operation modes and conditions and weather conditions during which the criteria shall be met.

Basically a single basic criterion shall be specified to be applied to all steady state operation modes, at any load up to and including the full load rated value, and within the design range of firing angle and all weather conditions is recommended. The performance criterion should cover the normal a.c. and d.c. operating voltage ranges. For practical reasons, then overall verification of the RFI performance by measurements shall be performed under fair weather conditions while the RFI emission due to a.c. corona under bad weather conditions shall be verified by calculation.

The requirement shall be specified as a graph of the maximum E-field in dB[μV/m] versus frequency for the entire frequency band 0,9 kHz to 1 GHz. There should be one graph for the substation limit and one graph for line limits. Suitable limits for the normal cases are given in CIGRÉ TB No. 391, with justifications.

The recommended procedure for verification by measurements is shown in Figure 25. The recommendations are detailed in CIGRÉ TB No. 391.