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**IEEE Recommended Practice for  
Measurement of Electrical Noise and  
Harmonic Filter Performance of  
High-Voltage Direct-Current Systems**

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# **IEEE Recommended Practice for Measurement of Electrical Noise and Harmonic Filter Performance of High-Voltage Direct-Current Systems**

Sponsor

**Transmission Systems Committee of the  
IEEE Communications Society**

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## Foreword

(This Foreword is not part of IEEE Std 368-1977, IEEE Recommended Practice for Measurement of Electrical Noise and Harmonic Filter Performance of High-Voltage Direct-Current Systems.)

There has long been a need to provide standard methods of measuring electrical noise and harmonic filter performance of high-voltage direct-current (HVdc) systems. In recognition of this fact the Inductive Coordination and Electrical Protection (ICEP) subcommittee of the Transmission Systems Committee (formerly Wire Communications Committee) established a Working Group to research this problem. The personnel of the High-Voltage AC/DC Working Group which developed this guide are as follows:

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# IEEE Recommended Practice for Measurement of Electrical Noise and Harmonic Filter Performance of High-Voltage Direct-Current Systems

## 1. Scope

1.1 This guide contains information and recommendations pertaining to measurement of induced electrical noise generated by high-voltage direct-current (HVdc) power transmission systems and measurement of the performance of filtering equipment designed to mitigate that noise.

## 2. Purpose

2.1 The primary purpose of this guide is to establish uniform methods of measuring the performance of harmonic filters and to establish uniform methods of testing for the presence of noise on and in proximity to HVdc transmission systems and their associated ac systems. This guide is applicable for induced noise effects to wire communication systems; that is, telephone, data transmission, and railroad signaling systems. The frequencies of concern include the voice band 120 to 5000 Hz and the carrier band 5 to 100 kHz and above. This guide does not address itself to radio-frequency interference (RFI) effects (300 kHz and above) from HVdc converter stations and HVdc transmission lines.

## 3. Definitions

### 3.1 HVdc Transmission Facility.

3.1.1 An HVdc transmission facility consists of converters located at terminal stations connected by a transmission line, bus, or cable systems, which operate at elevated potentials

and currents, and transmit electrical energy between ac systems. The converters, when functioning as a rectifier, change alternating current to direct (unidirectional) current, the transmission line transfers the power between terminal stations where the converters, functioning as an inverter, change the direct current back into alternating current. HVdc transmission facilities can also serve as asynchronous ties between ac systems.

### 3.2 HVdc Converter Station Noise.

3.2.1 The processes of rectification and inversion create undesirable harmonic voltages and currents on both the ac and dc portions of the power system. Audio-frequency harmonics are low-order multiples of the fundamental ac frequencies which exist at the HVdc converter station line terminals. The audio-frequency range of major concern is up to approximately 5 kHz. The voltage and current wave distortion which result from the ac-dc conversion process produce frequencies in the carrier range of approximately 5 to 100 kHz and above. Currents at these frequencies appear on the ac or dc, or both, systems at excessive levels if they are unfiltered or inadequately reduced by other means at the converter terminals. Harmonic and carrier frequency currents can propagate for up to 160 km (99.4 mi) or more on transmission lines. The actual distance of propagation varies and is dependent on the frequency, wavelength, and attenuation by the power system impedance.

3.2.2 The order of characteristic voltage harmonics found on a dc transmission line is given by  $KP$ , and the order of characteristic current harmonics found on the ac lines at the HVdc line terminals is given by  $KP \pm 1$ , where  $K$ , the rectifier phase number, is the total number of rectifier conduction pulses per cycle based on the ac system frequency, and  $P = 1, 2, 3, \dots$ , any positive integer. Table 1 gives

**Table 1**  
**Orders of Characteristic Harmonics**

| <i>Pulse No</i> | <i>DC Side</i>   | <i>AC Side</i>                  |
|-----------------|------------------|---------------------------------|
| <i>K</i>        | <i>KP</i>        | <i>KP ± 1</i>                   |
| 6               | 0, 6, 12, 18, 24 | 1, 5, 7, 11, 13, 17, 19, 23, 25 |
| 12              | 0, 12, 24        | 1, 11, 13, 23, 25               |

orders of characteristic harmonics for 6- and 12-pulse converters. (Also see Ref [1].)

**3.2.3** The predominant audio-frequency range harmonics and carrier range frequencies, if unfiltered or improperly filtered, will tend to create undesirable longitudinal voltages in communications circuits located in proximity to the HVdc line or associated ac lines, by means of electromagnetic or electrostatic, or both (also dc ionic drift) coupling. Filters for these noise sources are usually installed at the converter station, but because of design limitations, may not be completely effective.

**3.2.4** These longitudinally induced harmonics can, if sufficient in amplitude, be manifested as audible noise in communications systems because they act on inherent communication circuit unbalances (the conversion of common-mode potentials to differential-mode potentials). Data transmission and pulse-type signals can also be adversely affected depending on the situation.

### **3.3 HVdc Converter Station Filter System.**

**3.3.1** The harmonic filter system is designed to suppress, at their source, one or more predominant harmonic frequency currents and voltages which appear on the ac and dc transmission lines because of the ac-dc and dc-ac conversion processes.

**3.3.2** Harmonic filter system components consist of resistors and reactors (capacitive and inductive) of fixed or variable (controlled) values which make up discrete tuned filters (band-pass-to-ground) designed to limit the magnitude of a specific harmonic current and voltage, or high-pass (broad-band-to-ground) filters which can be effective over a wide frequency range.

**3.3.3** Carrier frequency noise can be caused by high-frequency current oscillations occurring during solid-state or mercury arc valve commutation. One method of noise suppression is

by placing series inductors in the ac supply to the conversion equipment. In addition, precautions should be taken to minimize coupling through the interwinding capacitance of the converter transformers and also through the dc neutral circuit. Methods of reducing power system influence levels in this range (5 kHz and above) need to be carefully analyzed at the design stage to provide adequate filtering in order that interference to carrier frequency communications systems can be avoided.

**3.3.4** A high-pass (broad-band-to-ground) filter is used to suppress harmonics over a wide frequency range. It consists of a parallel *RL* network in series with a capacitor and is not sharply tuned. It can be designed to be effective above any of the harmonics from about the 11th to the 20th harmonic, and can also serve to suppress carrier frequency noise.

**3.3.5** A discrete frequency (band-pass-to-ground) filter can be tuned to one or more specific lower order harmonics up to the 17th or 19th harmonic (that is, odd multiples of a fundamental on the ac bus, and even multiples on the dc side).

**3.3.6** On the dc side, series smoothing reactors and surge capacitors should be considered, in addition to band-pass and high-pass filters, as means of suppressing harmonics.

### **3.4 Telephone Influence Factor.**

**3.4.1** The telephone influence factor (TIF) is a dimensionless quantity which includes C-message weighting and is used to express the effect of the deviation of a voltage or current wave shape from a pure sinusoidal wave on a voice-frequency communication network caused by electromagnetic or electrostatic induction, or both. The frequencies and amplitudes of harmonics present on the power circuit, among other factors, determine a power circuit's inductive influence on a voice communications circuit. TIF expressed in terms of