

# VLF AC Withstand Testing of Cables

## Testing Methodology

When VLF Withstand testing cable, the proper test voltage and time duration are critical for the success of the test. A defect that is big enough to be excited by the applied voltage will grow to failure during the test. Lesser defects are not affected. They remain dormant and are not aggravated by the test voltage. The information and data that follows is taken directly from the IEEE 400.2-2013 Standard.

## IEEE Std. 400.2-2013

IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

**Table 3 - VLF withstand test voltages for sinusoidal and cosine-rectangular waveforms (see note 1)**

WAVEFORM	Cable system rating (phase to phase) [kV]	Installation (phase to ground)		Acceptance (phase to ground)		Maintenance <sup>2</sup> (phase to ground) (see Note 2)	
		[kV RMS]	[kV PEAK]	[kV RMS]	[kV PEAK]	[kV RMS]	[kV PEAK]
Sinusoidal	5	9	13	10	14	7	10
	8	11	16	13	18	10	14
	15	19	27	21	30	16	22
	20	24 (Note 3)	34 (Note 3)	26	37	20	28
	25	29 (Note 3)	41 (Note 3)	32	45	24 (Note 3)	34 (Note 3)
	28	32	45	36 (Note 3)	51 (Note 3)	27	38
	30	34	48	38	54	29 (Note 3)	41
	35	39	55	44	62	33	47
	46	51	72	57	81	43	61
	69	75	106	84	119	63	89

VLF ac voltage testing methods utilize ac signals at frequencies in the range of 0.01 Hz to 1 Hz. The most commonly used, commercially available VLF ac voltage test frequency is 0.1 Hz. VLF ac test voltages with cosine- rectangular and the sinusoidal wave shapes are most commonly used. While other wave shapes are available for testing of cable systems, recommended test voltage levels have not been established.

**NOTE 1** If the operating voltage is a voltage class lower than the rated voltage of the cable, it is recommended that the maintenance test voltages should be those corresponding to the operating voltage class.

**NOTE 2** The maintenance voltage is about 75% of the acceptance test voltage magnitude.

**NOTE 3** Some existing test sets have a maximum voltage that is up to 5% below the values listed in the table. These test sets are acceptable to be used. However, there is a risk that the cable may be “undertested” due to a combination of lower test voltage and allowed uncertainty of the measuring circuit.

## 5.1 General VLF ac Withstand Voltage Testing

### 5.1.1 VLF ac withstand voltage test parameters

The purpose of a withstand test is to verify the integrity of the cable under test. If the cable under test has a defect big enough to be excited by the voltage applied, an electrical tree will initiate and grow through the insulation.

## 5.1 General VLF ac Withstand Voltage Testing (cont.)

Inception of an electrical tree and channel growth time are functions of several factors including test voltage, source frequency and amplitude, and the geometry of the defect. For an electrical tree from the tip of a needle in PE insulation in laboratory conditions to completely penetrate the insulation during the test duration, VLF ac voltage test levels and testing time durations have been established for the two most commonly used test voltage sources, the cosine-rectangular and the sinusoidal wave shapes. However, the time to failure will vary according to the type of insulation such as PE, paper, and rubber. Thus the electrical tree growth rate is not the same for all materials and defects.

The voltage levels (installation and acceptance) are based on the most used, worldwide practices of from  $2U_0$  to  $3U_0$ , where  $U_0$  is the rated rms phase to ground voltage, for cables rated between 5 kV and 69 kV. The maintenance test level is about 75% of the acceptance test level.

One can reduce the test voltage by another 20% if the voltage is applied for longer times (Bach [B2]; Baur, Mohaupt, and Schlick, [B6]; Krefter [B27]). Evidence (Hernandez-Mejía, et al. [B21]) indicates that increasing the voltage above  $3U_0$  to compensate for reduced test cycles (time) does not replicate performance either on test or in service as compared to the lower voltage, longer time tests.

Table 3 lists voltage levels for VLF withstand testing of shielded power cable systems using cosine-rectangular and sinusoidal waveforms (Bach [B2]; Eager, et al. [B9]; Krefter [B27]; Moh [B28]). For a sinusoidal waveform the rms is 0.707 of the peak value, assuming the harmonic distortion is less than 5%. The rms and peak values of the cosine-rectangular waveform are assumed to be equal.

It should be noted that terminations may need to be added to avoid flashover for installation tests on cables rated above 35 kV.

### Regarding the test times:

- The recommended minimum testing time for a simple withstand test on aged cable circuits is 30 min at 0.1 Hz (Goodwin, Oetjen, and Peschel [B13]). If a circuit is considered as important, e.g., feeder circuits, then consideration should be given to extending the testing time to 60 min at 0.1 Hz (Hampton, et al. [B19]).
- The recommended minimum testing time for an installation and/or acceptance withstand test on new cable circuits is 60 min at 0.1 Hz.
- A test time within the range 15–30 min may be considered if the monitored characteristic remains stable for at least 15 min and no failure occurs. It should be noted that the recommended test time for a withstand test is 30 min.