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TECHNICAL REPORT

UHV AC transmission systems – Part 303: Guideline for the measurement of UHV AC transmission line power frequency parameters

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UHV AC TRANSMISSION SYSTEMS –

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FOREWORD

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IEC TR 63042-303 has been prepared by IEC technical committee 122: UHV AC transmission systems. It is a Technical Report.

The text of this Technical Report is based on the following documents:

DTR	Report on voting
122/105/DTR	122/112/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 63042 series, published under the general title *UHV AC transmission systems*, can be found on the IEC website.

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

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- withdrawn,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

INTRODUCTION

AC transmission line power frequency parameters are important basic data used for various power system's calculations and applications, including engineering design verification, commissioning, and operation.

Due to the complication of the geological conditions along the corridor of long distance UHV AC transmission lines, it is difficult to obtain accurate transmission line power frequency parameters through theoretical analysis and calculation. To obtain the accurate power frequency parameters, a field measurement is necessary.

This document provides the guidance for measurement of UHV AC transmission lines power frequency parameters which include sequence parameters and phase parameters, etc. The measurement conditions, measurement methods, data process methods, safety requirements, etc. are described.

UHV AC TRANSMISSION SYSTEMS –

Part 303: Guideline for the measurement of UHV AC transmission line power frequency parameters

1 Scope

This part of IEC 63042 specifies measurement methods of UHV AC transmission line power frequency parameters. These measured parameters mainly include sequence parameters, mutual parameters between double-circuit lines, phase parameters and some other related parameters.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC Guide 115:2007, *Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
offset frequency method
method that can measure the parameter of transmission line by applying a test power source with a frequency offset from the power frequency

3.2
source terminal
terminal of a transmission line, at which a power source is applied for the parameter measurement

3.3
ending terminal
terminal opposite to the source terminal of a transmission line

3.4
one-terminal measurement method
measurement method, at which only source terminal is measured

3.5
two-terminal synchronous measurement method
measurement method at which both source terminal and ending terminal are measured synchronously

3.6
phase parameter
type of power frequency parameters, which characterize electric and magnetic coupling characteristic for single phase or between two phases, including self-impedance, mutual impedance, self-capacitance and coupling capacitance

3.7
induced voltage
voltage caused by the electromagnetic or electrostatic effect of adjacent energized lines or equipment

3.8
induced current
electric current resulting from the displacement of charge carriers due to an induced voltage

[SOURCE: IEC 60050-121:2008, 121-11-29]

4 General

4.1 Background

Due to the complication of the geological conditions along the corridor of long distance UHV AC transmission lines, where soil resistivity and transmission tower size vary, it is difficult to obtain accurate transmission line power frequency parameters through theoretical analysis and calculation. To obtain the accurate power frequency parameters, field measurement is necessary. However, the accuracy of field measurement is influenced by measurement methods due to the distributed characteristic and electromagnetic coupling of UHV AC lines. Therefore, appropriate measurement methods are important to obtain accurate power frequency parameters. In this document, different measurement methods are applied to acquire accurate parameters.

4.2 Measurement items

The recommended parameters which need to be measured are as follows:

- positive-sequence impedance,
- positive-sequence capacitance,
- zero-sequence impedance,
- zero-sequence capacitance,
- mutual impedance and coupling capacitance between double-circuit lines,
- self-impedance of one phase,
- self-capacitance of one phase,
- mutual impedance between two phases,
- coupling capacitance between two phases,
- induced voltage and induced current,
- phase verification and insulation resistance,
- DC resistance.

4.3 Main circuit configuration

Disconnectors at the two terminals of the transmission line should be open during measurement.

Parallel with the transmission line, connected equipment should be disconnected, such as shunt reactors and capacitive transformer.

Series reactors and capacitors used in the transmission line shall be bypassed.

If the transmission line to be measured is composed of overhead lines, cables or gas-insulated lines (GIL), it is recommended to measure the parameters of the overhead lines, cables or GIL, separately.

To eliminate the resistance of the connecting lines for test, two connecting lines, i.e. voltage and current connecting lines, can be applied. If only one connecting line is applied, the obtained line resistance should be reduced by the connecting line resistance. The measurement system should be reliably connected to the substation earthing system.

4.4 Measurement condition

Close attention should be paid to the weather condition along the line during the measurement. The measurement should be stopped if the weather is not suitable for measurement.

Ambient temperature of measuring instrument: −10 °C to +40 °C, relative humidity: ≤ 85 %.

Before starting the measurements, check that all temporary grounding connections have been removed. No work may be done on the lines during the measurements. Make sure that this rule is followed. All local and international safety regulations shall be known and strictly observed. Safety precautions are given in Annex C.

5 Requirement of measuring instrument

5.1 Current transformer

Uncertainty of current transformer (CT) should be equal to or better than 0,5 %. It is obtained based on the method of IEC Guide 115.

5.2 Voltage transformer

Uncertainty of voltage transformer (VT) should be equal to or better than 0,5 %. It is obtained based on the method of IEC Guide 115.

5.3 Measuring instrument of DC resistance

The instrument to measure the DC resistance of a transmission line can be a special instrument or the combination of a DC power source, a DC voltmeter and a DC ammeter.

If the DC resistance measurement meter is used, its uncertainty should be equal to or better than 0,5 %.

If the combination of a DC resistance, a DC power source, a DC voltmeter and a DC ammeter is used, the uncertainty of the DC voltmeter and ammeter should be equal to or better than 0,5 %.

5.4 Offset frequency power source

The offset frequency power source should be capable of supplying sinusoidal signals at a single frequency that can be adjustable. Normally, the power source should generate a sinusoidal signal at $f - \Delta f$ or $f + \Delta f$, where Δf is usually less than 10 Hz, such as 2,5 Hz, 5 Hz or 7,5 Hz.

NOTE ± 5 Hz are two typical values of frequency offset; the frequency of test power source can thus be 45 Hz or 55 Hz for a 50 Hz system.

The total harmonic distortion for the voltage output of offset frequency power source should be within 3 %. It is recommended by IEC 61000-2-4:2002.

5.5 Special measuring instrument of transmission line power frequency parameter

The instrument should meet the requirement as follows:

- The measuring instruments at the source and ending terminals should have the function of synchronous phasor measurement and be capable of sampling single-phase and three-phase voltage and current phasors which include amplitude and phase angle of voltage and current.
- For each measurement, all the measured voltage and current phasors take a GPS PPS as a reference; phase angle of voltage or current is the difference between the measured voltage or current phasor and the reference. The magnitude of voltage or current is amplitude.
- The synchronization error of sampling between the source terminal and ending terminal should be less than 100 ns.
- The measuring instrument should be capable of eliminating signal aliasing and leakage.
- The measuring instrument should be capable of completing data analysis and calculation according to the prescribed method.

6 Conversion of offset frequency measurement results

If there are no induced voltage and induced current on the measured line at power frequency, a power frequency test power source can be directly used.

If there are induced voltage and induced current on the measured line at power frequency, an offset frequency test power source should be used to eliminate the power frequency interference. The offset frequency measurement method is usually used to measure UHV transmission line power frequency parameters. However, the parameters measured by using offset frequency method need to be converted to the parameters at power frequency.

Generally, the two frequencies $f - \Delta f$ and $f + \Delta f$ will be selected for the measurement.

The procedure of offset frequency measurement is as follows:

- Firstly, replace the frequency of power source f by $f - \Delta f$, measure and calculate parameters of the transmission lines at frequency $f - \Delta f$ according to the procedures and equations.
- Secondly, replace the frequency of power source f by $f + \Delta f$, measure and calculate parameters at frequency $f + \Delta f$ according to the procedures and equations.
- Finally, calculate the impedance parameters at power frequency f by

$$z_f = r_f + jx_f = \left(r_{f-\Delta f} + r_{f+\Delta f}\right)/2 + j2\pi f\left(\frac{x_{f-\Delta f}}{2\pi\left(f-\Delta f\right)} + \frac{x_{f+\Delta f}}{2\pi\left(f+\Delta f\right)}\right)/2 \quad (1)$$