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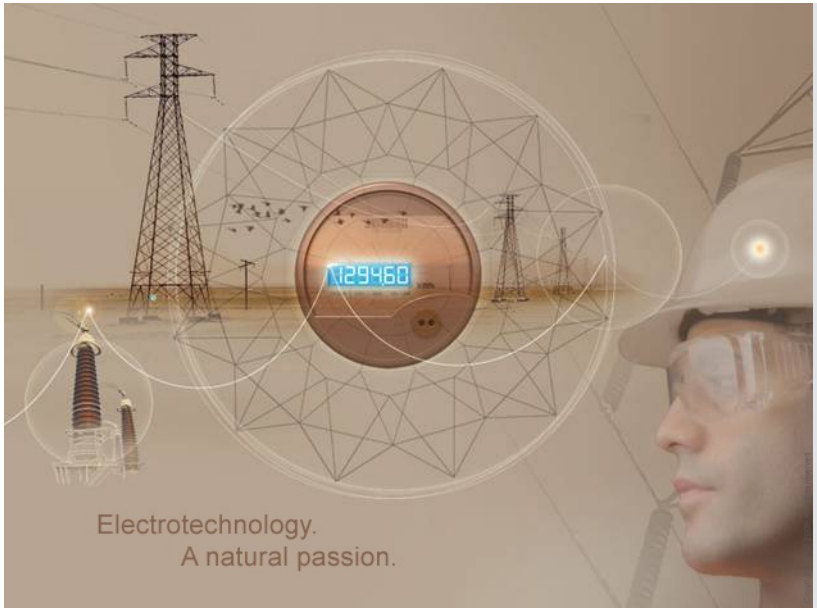
Recent Activities of insulation coordination for UHV AC transmission systems in CIGRE C4 and IEC TC 28



2016 CIGRE-IEC Colloquium
Montreal, May 10, 2016

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Contents

1. Introduction

- Economical and highly reliable transmission line and substations equipment with environmental consideration are essential in the UHV system.
- Insulation coordination is a key technology of UHV transmission line and substation design.
- Transmission line and substation should be technically and economically designed to be compact by suppressing overvoltage in UHV transmission system.
- This paper presents the recent activities of insulation coordination for UHV AC transmission systems in CIGRE C4 and IEC TC 28.

2. UHV AC standardization in collaboration with CIGRE

IEC TCs/SCs have successfully developed UHV related standards based on the investigation by CIGRE WGs since 2007.

IEC TCs / SCs

- TC 8 (Standard voltages)
- TC 14 (Power Transformers)
- SC 17A (High-voltage switchgear and controlgear)
- TC 28 (Insulation co-ordination)
- TC 37 (Surge arresters)
- TC 42 (High-voltage and high-current test techniques)

CIGRE / WGs

- CIGRE WG A3.22/28 TB 362 & 456 (Requirements for substation equipment)
- CIGRE WG B3.22/29 TB 400 & 562 (Requirements for substation)
- CIGRE AG A2.5 (UHV Transformer AC&DC)
- CIGRE WG C4.306 TB 542 Insulation Coordination for UHV AC Systems)
- CIGRE D1.36 Special Requirements for Dielectric Testing for UHV Equipment

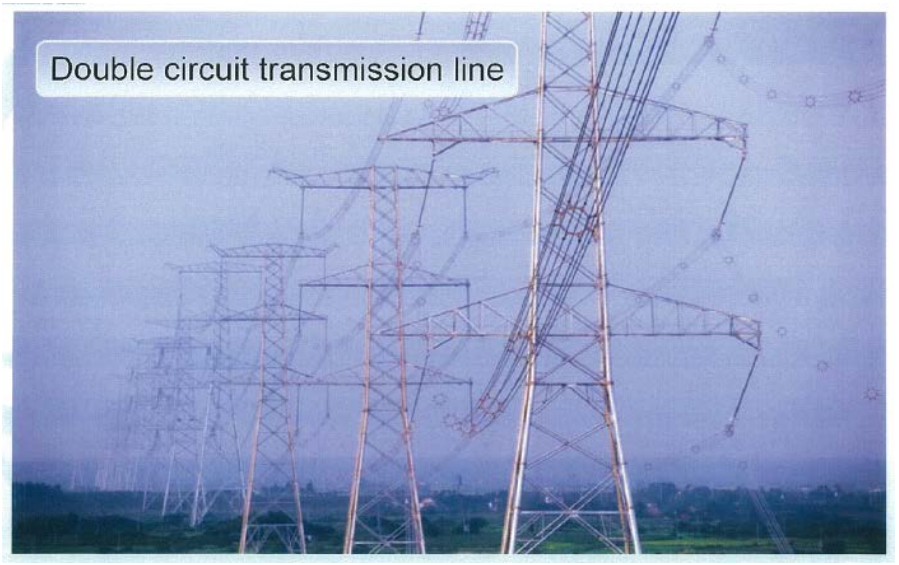
3. UHV Project in China, Japan and India

(a) UHV substation in China project (1100kV)

(b) UHV test station in Japan project (1100kV)

3. UHV Project in China, Japan and India

(c) UHV test station in India project (1200kV)



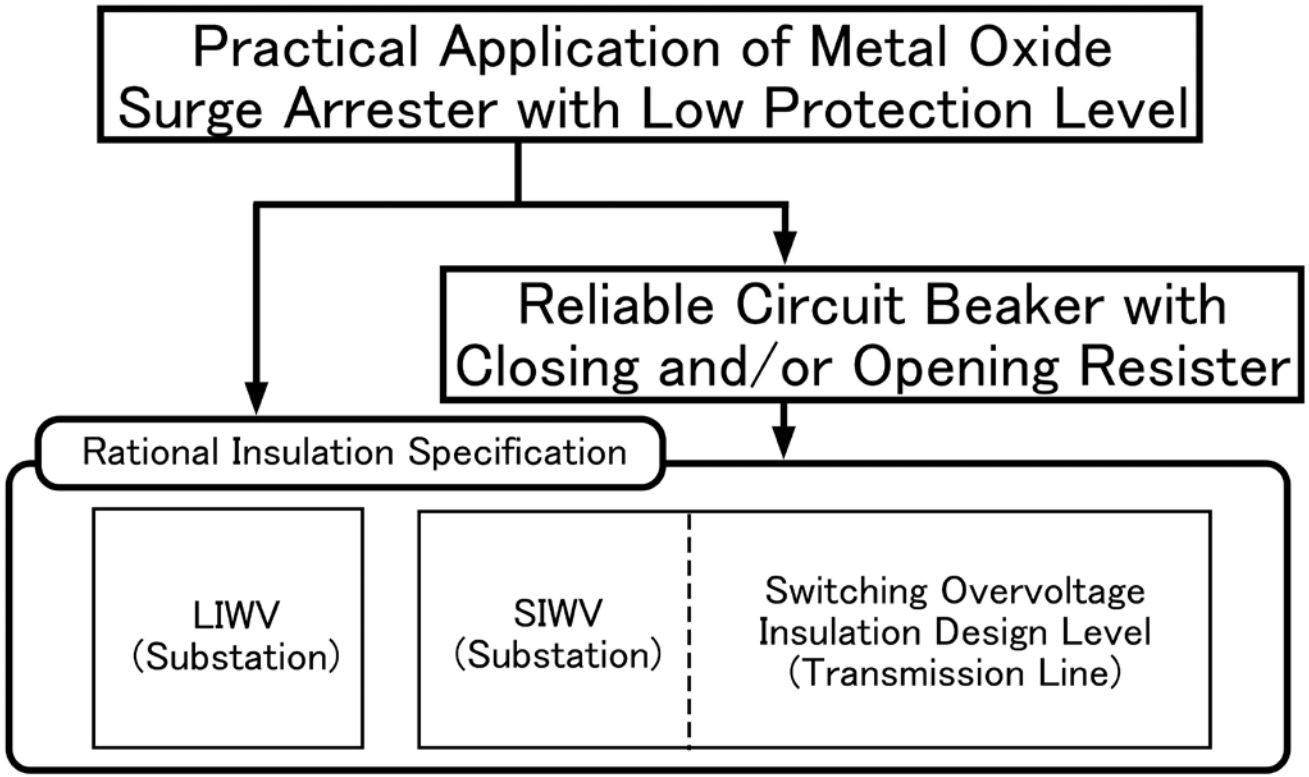
(d) UHV Transmission line in China project (1100kV)

4. CIGRE C4 Activity on UHV insulation coordination

- In CIGRE, WG C4.306 has reviewed and discussed insulation coordination practice in the UHV AC range taking into account the state-of-the-art technology and actual practices of Chinese, Indian and Japanese UHV projects.
- Technical Brochure No. 542 was published in June, 2013. It covers recent practices of insulation coordination based on the surge arrester with low protection level, overvoltage estimation to peculiar to UHV such as VFFO (Very Fast Front Overvoltage), conversion method for standard waveform, safety factor and air clearance in UHV range.

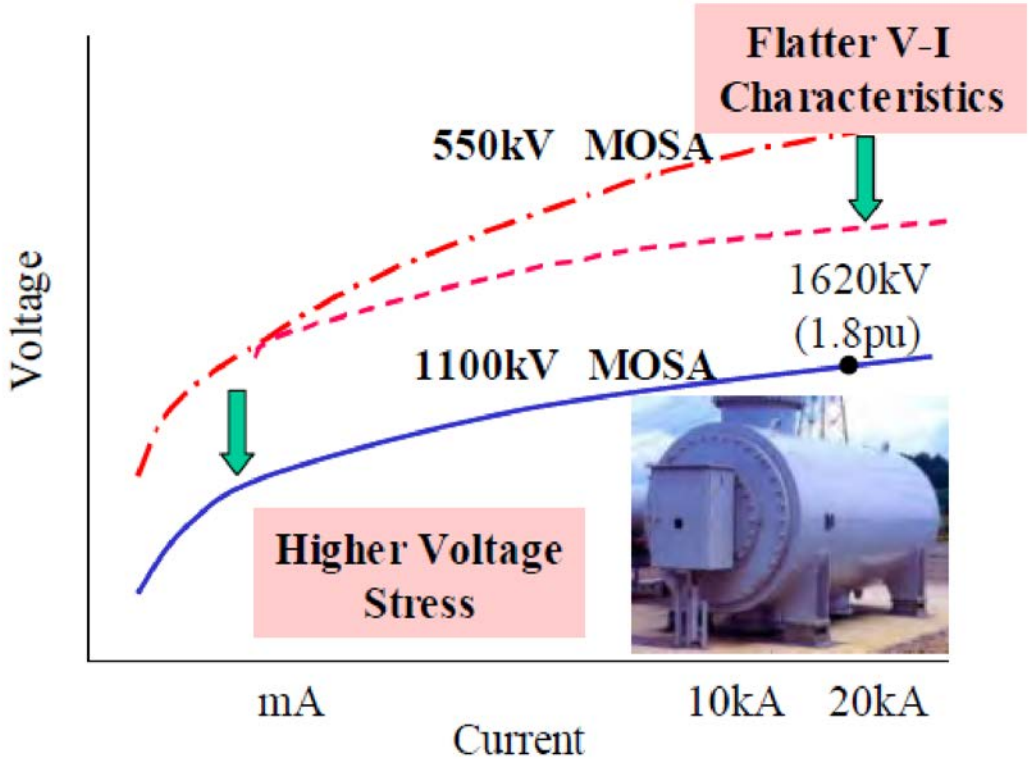
4. Recent Practice on Insulation Coordination for UHV System

In UHV projects of China, Japan and India, suppressing overvoltage by surge arrester with low protection level is a common countermeasure, and additional countermeasure, such as suppressing switching overvoltage using circuit breaker with closing and/or opening with pre-insertion resistors, is adopted for each project.



4. Surge arrester with low protection level

The surge arresters with low protection level (V20kA=1620kV for 1100kV) have been applied to suppress overvoltages in the UHV substation and transmission lines. Its reliability has been confirmed throughout its massive application in 550 kV systems



4. Switching overvoltage mitigation with resister fitted circuit breakers

The flashover voltage of air insulated gaps for switching overvoltage has a tendency to saturate. Switching overvoltage should be suppressed by the application of resistor closing and/or resistor opening with surge arrester with the low protection level.

Table 1. Suppression methods and Insulation design

	China	Japan	India
Highest voltage for equipment	1100 kV	1100 kV	1200 kV
Suppression of switching overvoltage	MOSA Closing R (600 Ω)	MOSA Closing & opening R (700 Ω)	MOSA Closing R (600 Ω)
Switching overvoltage design level	1.7 p.u.	1.6/1.7 p.u.	1.7 p.u.

4. Insulation levels of UHV AC substation

Table 2. Insulation level for UHV AC substation

	Insulation Level	China (Jindongnan)	Japan (Shin-Haruna)	India (Bina)
Highest voltage for equipment		1100 kV	1100 kV	1200 kV
Transformer	LIWV	2250 kV	1950 kV	2250 kV
	SIWV	1800 kV	1425 kV	1800 kV
GIS	LIWV	2400 kV	2250 kV	2400 kV
	SIWV	1800 kV	1550 kV	1800 kV
Surge arrester	V_{20kA}	1620 kV	1620 kV	1700 kV

5. IEC TC 28 Activity on UHV insulation coordination (60071-1)

- In IEC TC 28, regarding IEC 60071-1 (Insulation co-ordination - Part 1: Definitions, principles and rules), rated insulation levels for UHV system are standardized in Amendment 1 Ed.8.1 (March 2011).
- The standard specifies rational insulation levels with the assumptions that metal-oxide surge arresters with low protection level are installed at adequate locations, and utilities can choose the reasonable insulation level to meet their own specifications.

5. Standard Insulation levels for UHV
(IEC 60071-1 Ed. 8, 2011-03)

Highest voltage for equipment U_m kV (r.m.s. value)	Standard rated switching impulse withstand voltage			Standard rated lightning impulse withstand voltage [b] kV (peak value)
	Longitudinal insulation [a] kV (peak value)	Phase-to-earth kV (peak value)	Phase-to-phase (ratio to the phase-to-earth peak value)	
1 100	–	1 425 [d]	–	1 950
				2 100
	1 425	1 550	1,70	2 100
				2 250
	1 550	1 675	1,65	2 250
				2 400
	1 675	1 800	1,6	2 400
				2 550
1 200	1 550	1 675	1,70	2 100
				2 250
	1 675	1 800	1,65	2 250
				2 400
	1 800	1 950	1,60	2 550
				2 700

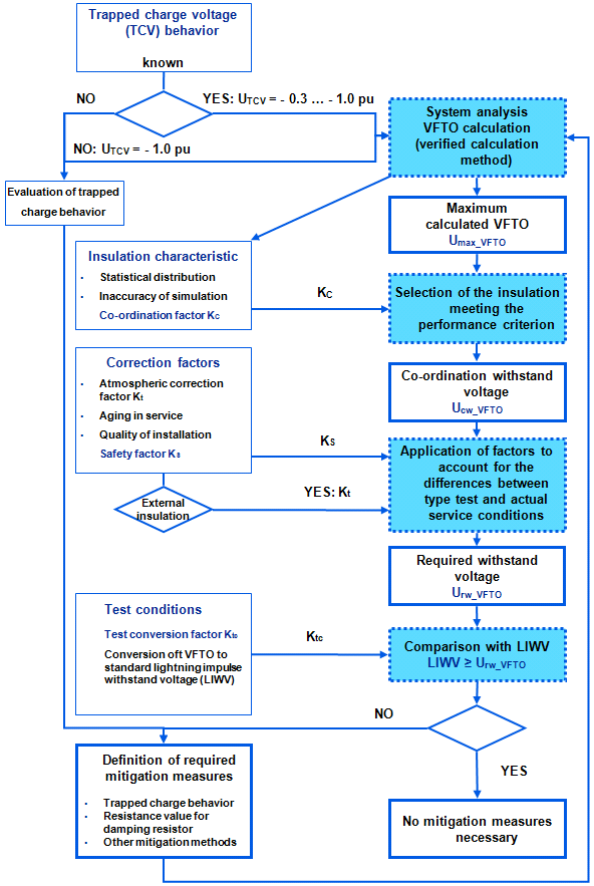
[d] This value is only applicable to the phase-to-earth insulation of single phase equipment not expose to air.

5. IEC TC 28 activity on UHV insulation coordination (60071-2)

- Regarding IEC 60071-2 (Insulation co-ordination - Part 2: Application guide), IEC TC 28/MT 9 started to revise 60071-2 based on the recommendation result of CIGRE WGC4.306 in November 2014.
- The revised items will be suppression method of overvoltage, overvoltage estimation to peculiar to UHV such as VFFO and recent practice of insulation coordination in UHV area.
- CD has been circulated in February. The revision will be expected to be published in 2018.

5. Evaluation of VFFO

- A three step procedure is recommended for VFFO evaluation.
- Damping resistor is also recommended in case of the fast acting disconnector.



Three step procedure

Step 1 Calculation of VFTO (peak value and rise time)

Step 2 Comparison of calculated VFTO values with LIWV level for the different equipment by using:
- Co-ordination factor K_c
- Safety factor K_s
- Test conversion factor K_{tc}

Step 3 Definition of measures according to the insulation co-ordination

6. Conclusion

- This paper presents the recent activities of insulation coordination for UHV AC transmission systems in the collaboration of CIGRE C4 and IEC TC 28.
- CIGRE WG C4. 306 has reviewed and discussed insulation coordination practice in UHV AC and published the technical brochure No. 542.
- IEC TC 28 has revised 60071-1 and has also started the revision of 60071-2 on the recommendations by CIGRE TB. CD has been circulated in February, 2016.
- Authors hope that these CIGRE and IEC cooperative activities will contribute the development of UHV AC system all over the world.

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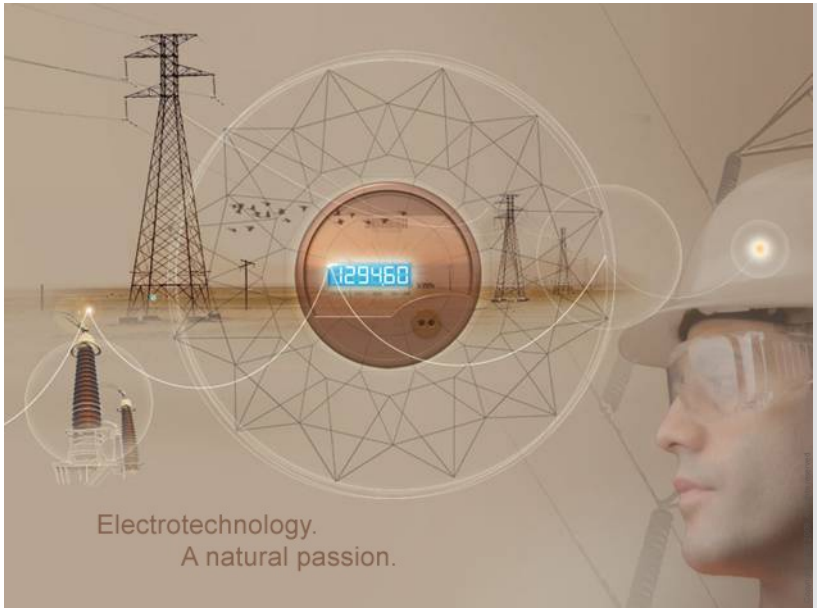
Thank you for your attention!



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