

IEEE WG Revision C37.011 Application Guide for TRV for High-Voltage Circuit Breakers

Agenda of WG meeting in Orlando/Lake Buena Vista, May 18th 2011

- ▶ Introduction of Members & Guests**
- ▶ IEEE SA Bylaws on Patents**
- ▶ Minutes of meeting in Las Vegas**
- ▶ Reminder: ballot of draft D7**
- ▶ Resolution of comment 76 (TRV interpolation)**
- ▶ Resolution of non critical comments (input by e mail)**
- ▶ Resolution of remaining comments**
- ▶ Next steps**

**Denis Dufournet
Chair WG C37.011**

Ballot of draft D7

- ▶ (First) Ballot Open Date:02-Jul-2010
- ▶ Ballot Close Date:08-Aug-2010
- ▶ **112 eligible people** in the ballot group (72 in 2004, previous revision)
- ▶ **98 votes received = 87% returned, > 75%: requirement is met**
 - ◆ **89** affirmative votes **92% affirmative, requirement is met**
 - ◆ **7** negative votes with comments
 - ◆ 0 negative votes without comments
 - ◆ 2 abstention votes

▶ **General overview on negative votes**

- ◆ 4 mainly based on minor technical / editorial comments
- ◆ 1 with technical comments that can be easily accepted
- ◆ 2 with comments that need a WG discussion

▶ **Main issue**

- ◆ Interpolation of TRV withstand capabilities between T30 and T60

▶ **Comments**

- ◆ 181 comments

Discussion of Comments on D7

Comment # 76

▶ Subclause 4.2

▶ Comment

- ◆ This subclause talks about Circuit breaker capability. it is assumed to be the required TRV as defined by the system. This is understood and technically sound for the interpolation between T10 and T30 as well as for the interpolation between T60 and T100. However the transition from 2 parameter (T30) to 4 parameter (T60) is not understood. It is understood that the first freq. is defined by a transformer, inductance close to the breaker while the second freq. is given by the traveling wave. In this case the peak voltage of the first frequency (u_1) should be always in the same order of magnitude, while the time to U_c may change

▶ Proposed change

- ◆ Develop a more technical sound method to interpolate between T30 and T60.

Comment # 76

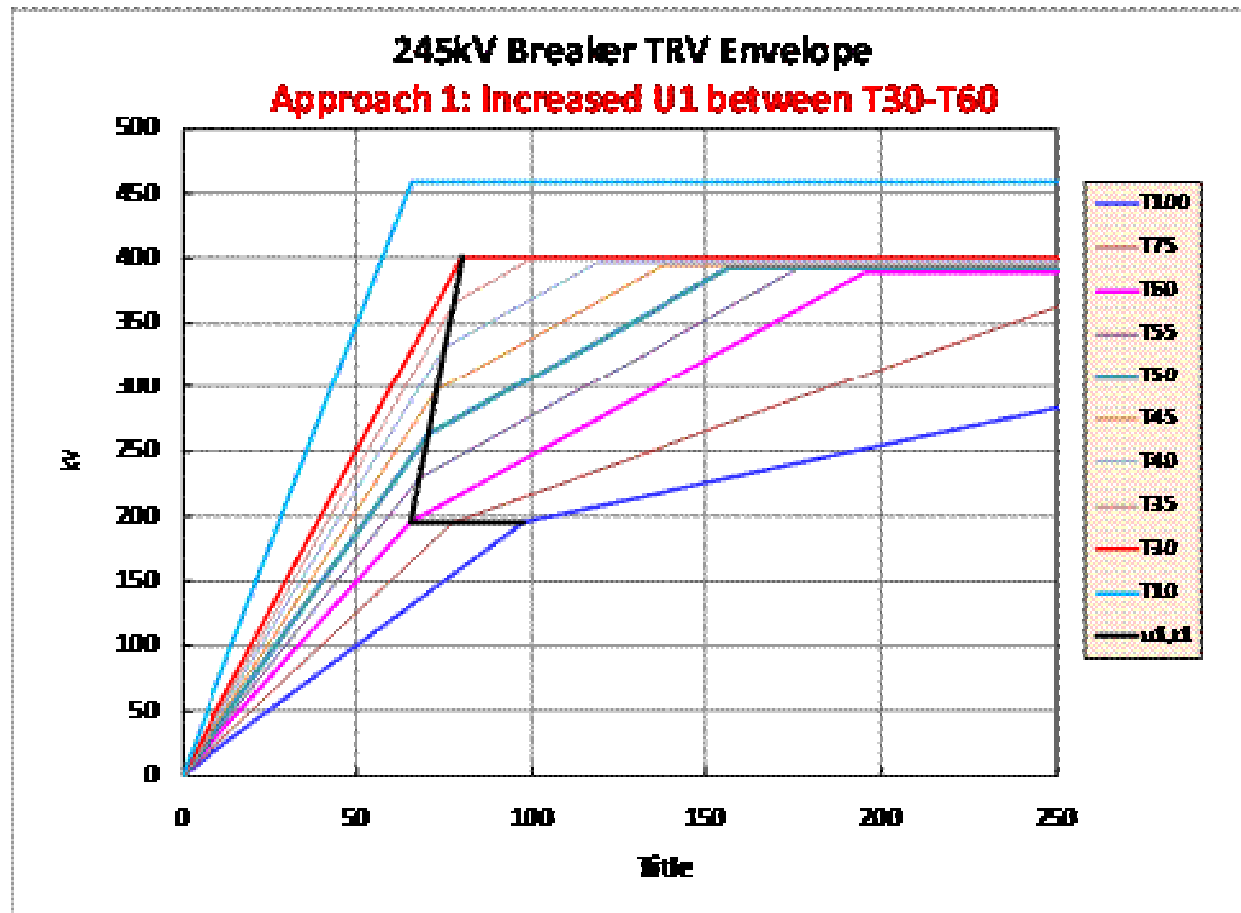
► Resolution

- ◆ **Two methods to interpolate TRVs between T30 and T60, selected during the meeting in Las Vegas (see next slide)**
 - **Approach 1 as defined in the present draft (u1 is interpolated between u1 of T60 and uc of T30)**
 - **Approach 2 as discussed in Las Vegas, with u1 constant between T30 and T60**
- ◆ **Discussion done by WG in November-December 2010 and April-May 2011**

Discussion of Comments on D7

Resolution of Comment # 76

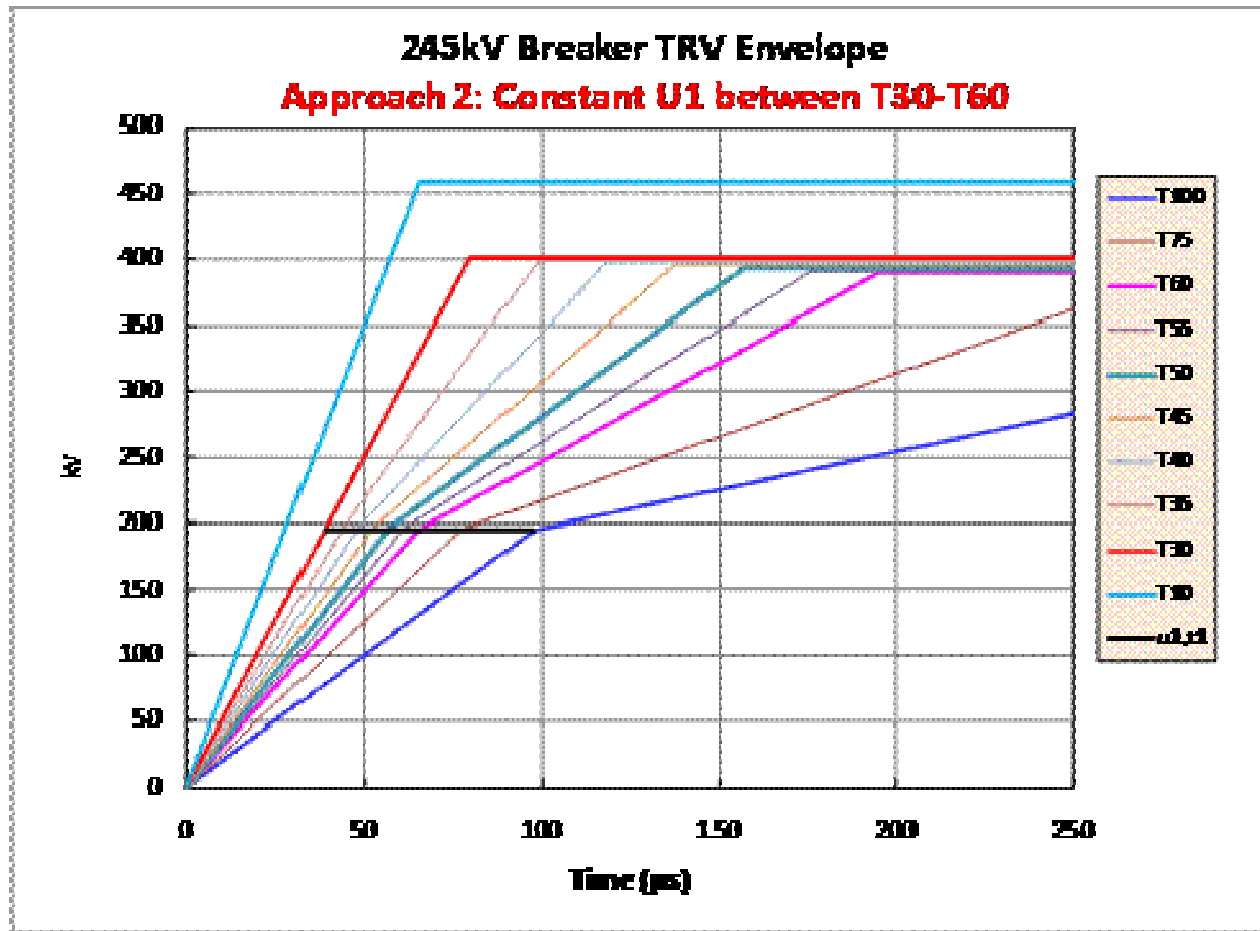
► Approach 1



Discussion of Comments on D7

Resolution of Comment # 76

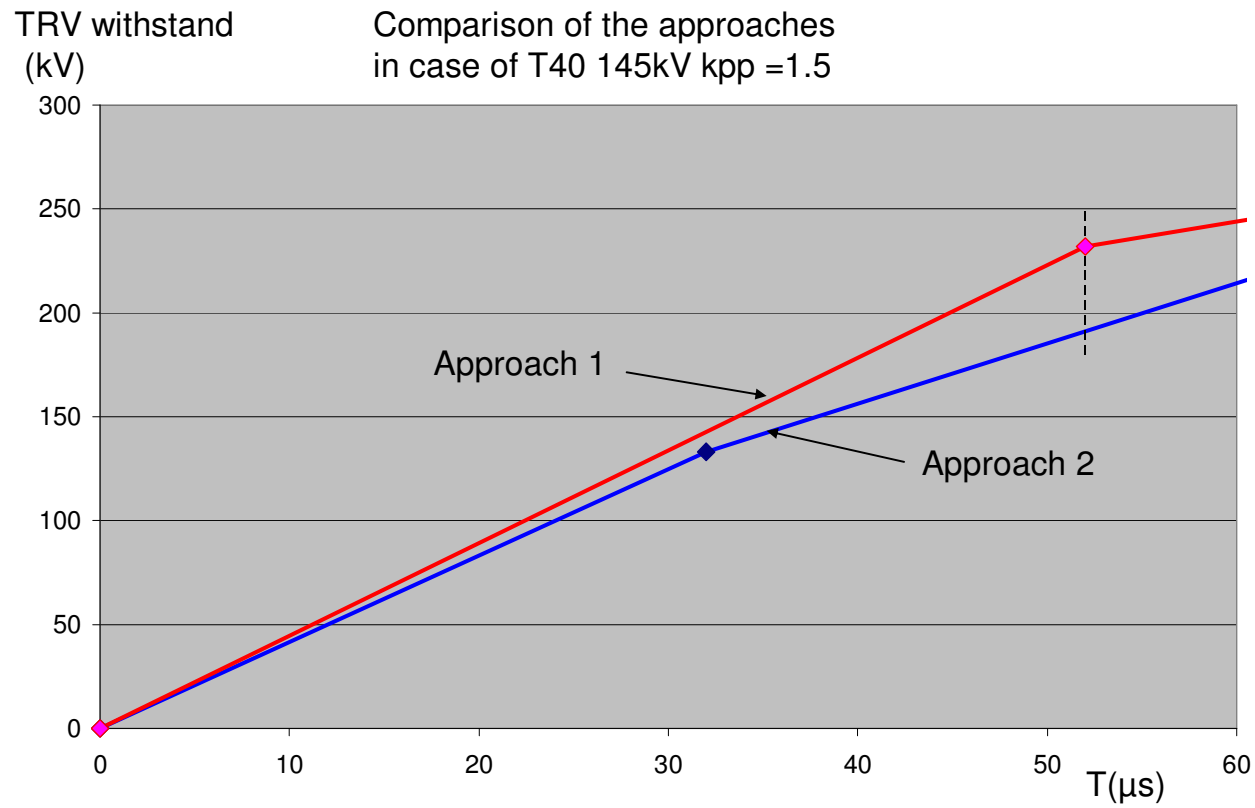
► Approach 2



Discussion of Comments on D7

Resolution of Comment # 76

- ▶ What is the issue?
- ▶ It is the TRV withstand by a circuit breaker that can be expected after current zero until a time up to (approximately) t_3 for T30.



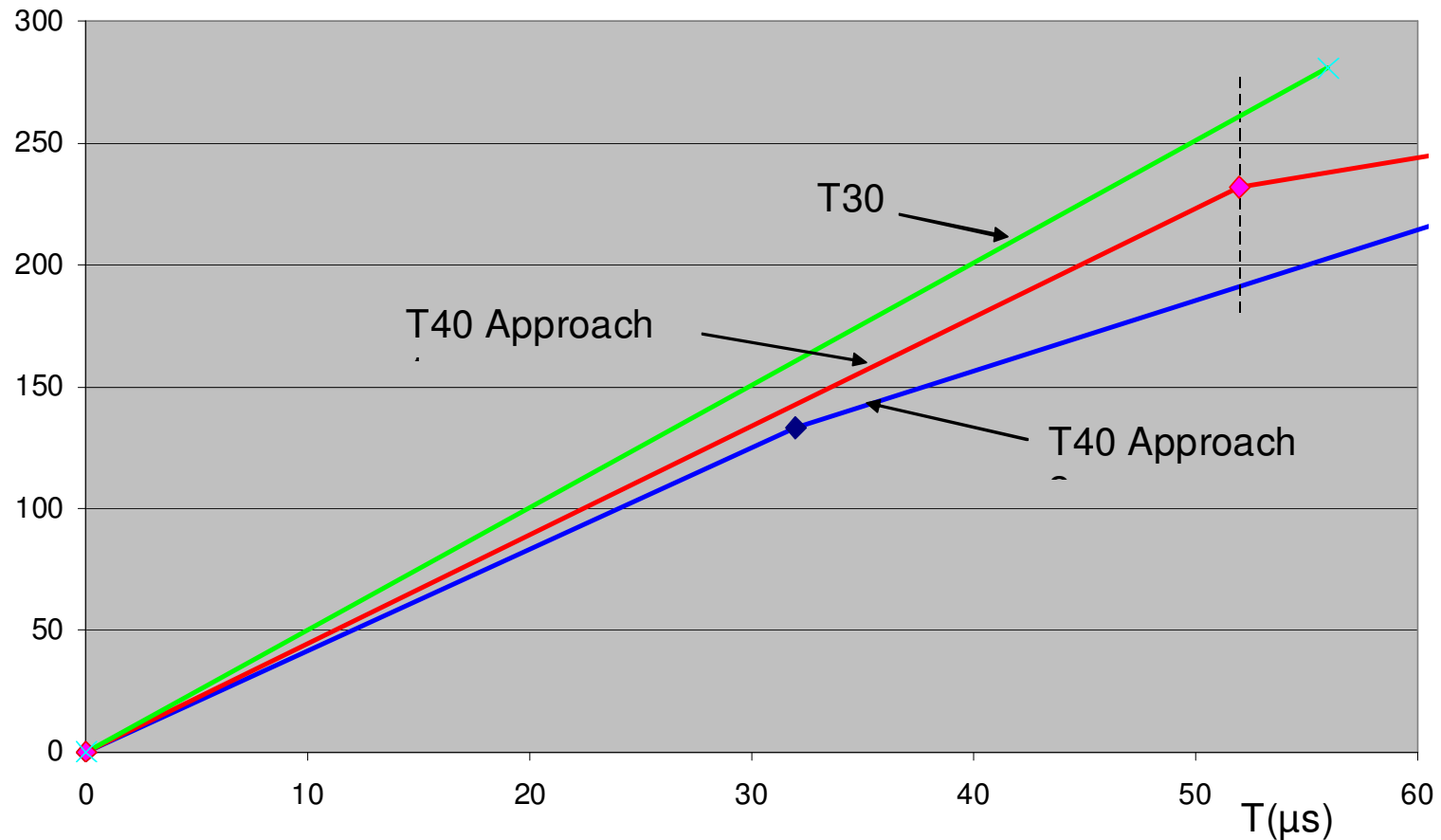
Discussion of Comments on D7

Resolution of Comment # 76

- ▶ Comparison of the TRV for T30 and the two approaches for T40

TRV withstand
(kV)

Comparison of the approaches
in case of T40 145kV kpp = 1.5



Comment # 76

▶ Resolution by WG vote

- ◆ **17 in favour to keep the approach 1 of Draft 7**
- ◆ 1 in favour to adopt approach 2 with a constant u_1 between T30 and T60
- ◆ 1 abstention

Approach 1 will be kept in the next draft.

Discussion of Comments on D7

Comment # 142

▶ **Subclause Table 2 page 32**

▶ **Comment**

- ◆ On page 31 it explains that the first-pole-to-clear factors considered in Table 2 are 1.5 for 120 and 161 kV and 1.3 for 230, 315 and 735 kV. This should be in a note for Table 2 so the user can quickly see this detail without have to look in the text for it.

▶ **Proposed change**

- ◆ Add a NOTE to Table 2: "The first-pole-to-clear factors considered are 1.5 for 120 kV and 161 kV, and 1.3 for 230 kV, 315 kV and 735 kV."

▶ **Resolution status**

- ◆ Accepted

▶ **Resolution detail**

- ◆ a note will be added to give the values of the first-pole-to-clear and to explain the meaning of d and Z. Rated voltages will be used.

Comment # 144

▶ Subclause 4.2.4.7

▶ Comment

- ◆ In line 16 the term "short-line fault" is spelled out and in line 18 the abbreviation SLF is used. Not sure when SLF is defined for the first time, but the term should be handled consistently.

▶ Proposed change

- ◆ Consistently use "short-line fault" or SLF within the text.

▶ Resolution status

- ◆ Accepted

▶ Resolution detail

- ◆ "short-line fault" will be used here.
- ◆ The use of SLF will be checked in the document.

Discussion of Comments on D7

Comment # 153

▶ Subclause Annex A.2 Table A.2

▶ Comment

- ◆ Add typical surge impedance for 170kV overhead lines in Table A.2.

▶ Proposed change

- ◆ Here are surge impedance values for 3 different 161kV line configurations.

161-kV Horizontal config on steel towers:

$$X_{\text{series}} = 0.7366 \text{ ohms/mile}$$

$$Y_{\text{shunt}} = 5.800/10^6 = \text{mhos/mile}$$

$$Z_c = \sqrt{0.7366/[5.800/10^6]} = 356.37 \text{ ohms}$$

161 kV H-frame steel-pole line:

$$X_{\text{series}} = 0.7390 \text{ ohms/mile}$$

$$Y_{\text{shunt}} = 5.849/10^6 = \text{mhos/mile}$$

$$Z_c = \sqrt{0.7390/[5.849/10^6]} = 355.45 \text{ ohms}$$

161 kV Double circuit steel-pole line with both sides strung:

$$X_{\text{series}} = 0.7417 \text{ ohms/mile}$$

$$Y_{\text{shunt}} = 5.779/10^6 = \text{mhos/mile}$$

$$Z_c = \sqrt{0.7417/[5.779/10^6]} = 358.25 \text{ ohms}$$

Comment # 153 (Cont'd)

▶ Resolution status

- ◆ Accepted in principle

▶ Resolution detail

- ◆ In the second column 145kV will be replaced by 145/170 kV

Discussion of Comments on D7

Comment # 154

▶ **Subclause Annex B** page 70

▶ **Comment**

- ◆ Add capacitance values for other voltage CVTs.

▶ **Proposed change**

- ◆ Capacitances of commercially available 170kV CVTs range from 4000 to 16000 pF. I'll provide info to the WG Chair for available CVTs.

▶ **Resolution status**

- ◆ Accepted

▶ **Resolution detail**

- ◆ Values for 170kV will be added and values will be updated.

Comment # 157

▶ **Subclause Figure 2 page 5**

▶ **Comment**

- ◆ add "at T100" after "cable-system TRV"

▶ **Proposed change**

- ◆ change to "Figure 2-Comparison of line-system TRV and cable-system TRV at T100"

▶ **Resolution status**

- ◆ Not accepted

▶ **Resolution detail**

- ◆ It will be indicated that time is in μ s and TRV is in kV

Discussion of Comments on D7

Comment # 158

▶ **Subclause 4.2.1** **page 13**

▶ **Comment**

- ◆ In the top figure, change "2.106" to "2.107" to be consistent with the multiplier Ku1 at T30 for 100 kV and above breakers in Table 1.

▶ **Proposed change**

- ◆ In the top figure, change "2.106" to "2.107" to be consistent with the multiplier Ku1 at T30 for 100 kV and above breakers in Table 1

▶ **Resolution status**

- ◆ Accepted in principle.

▶ **Resolution detail**

- ◆ The numbers will be given with 3 significant digits.

Comment # 166

▶ **Subclause** **Figures 22a and 22b** **page 33**

▶ **Comment**

- ◆ In Figure 22a, change one of the solid red curves and one of the solid blue curves to dash lines for easier identifications.

▶ **Proposed change**

- ◆ In Figure 22a, change one of the solid red curves and one of the solid blue curves to dash lines for easier identifications

▶ **Resolution status**

- ◆ Accepted

▶ **Resolution detail**

- ◆ The figure will be modified as proposed.

Comment # 167

▶ **Subclause 4.2.4.10** **page 34**

▶ **Comment**

- ◆ change "special customized tests or other means may be required" to "special customized tests or other means should be required". This is consistent with CIGRE WG A3.19 report that "Utilities for whom this position is unacceptable should request special type tests for the particular conditions" and is consistent with our company's emphasis on safety.

▶ **Proposed change**

- ◆ change "special customized tests or other means may be required" to "special customized tests or other means should be required". This is consistent with CIGRE WG A3.19 report that "Utilities for whom this position is unacceptable should request special type tests for the particular conditions" and is consistent with our company's emphasis on safety.

Comment # 167 (Cont'd)

▶ Resolution status

- ◆ Not accepted

▶ Resolution detail

- ◆ The text will be changed to "special customized tests or other means can be specified"

Comment # 173

▶ **Subclause 1.1** page 10

▶ **Comment**

- ◆ calculation should be plural

▶ **Proposed change**

- ◆ change "calculation" to "calculations"

▶ **Resolution status**

- ◆ Not accepted

▶ **Resolution detail**

- ◆ The scope cannot be changed (without changing the PAR). The wording is taken from the existing standard.

Comment # 86

▶ Subclause 3.3.1

▶ Comment

- ◆ C37.04 Subclause 5.9 states "At the rated maximum voltage, each circuit breaker shall be capable of interrupting three phase grounded and ungrounded terminal faults at the rated short circuit current in any circuit in which the TRV does not exceed the rated TRV envelope." The document needs a statement related to terminal faults in a three phase common gas-insulated switchgear enclosure.

▶ Proposed change

- ◆ In the case of a three phase common gas-insulated switchgear enclosure, an arc between phase and ground will, within a few milliseconds, evolve into a three phase fault between conductors, owing to the ionization of the gap between the conductors, and at the same time the phase to ground arc will extinguish. Consequently, an enclosure burn-through is not likely. Since within the range of 20-50ms the fault has evolved into a three phase ungrounded fault, and since the breaker contacts typically begin to part at or after 50ms, then the three phase ungrounded fault should be considered in TRV analysis for three phase common gas-insulated switchgear enclosures.

Comment # 86

▶ Subclause 3.3.1

▶ Resolution

- ◆ Accepted in principle

▶ Resolution detail

- ◆ The following text will be added:

For GIS with all three phases in one enclosure a grounded fault can evolve into a three-phase ungrounded fault prior to interruption. The user should choose the appropriate first pole to clear factor i.e. $k_{pp}=1.5$ for three-phase ungrounded faults.

Comment # 102

▶ **Subclause 4.2.4.1** **page 21**

▶ **Comment**

- ◆ I have not seen any documentation that relates the 450ohm surge impedance with conductor clashing. Many tests have been done to cause conductor clashing without success. It is very rare and therefore the 450ohm surge impedance has no relevance to clashing.

▶ **Proposed change**

- ◆ Remove all instances where the 450ohm surge impedance is related to conductor clashing.

▶ **Resolution status**

- ◆ Not accepted

Comment # 102

► Resolution detail

- ◆ Early editions of international standards (ANSI/IEEE and IEC) for HV circuit breakers have values of (line) surge impedance that were lower than 400 ohms in case of bundle conductors, due to their geometry. Studies made at the end of the 1960's-beginning of the 1970's showed that if conductors clash during a short-circuit then the surge impedance rise to a value approaching 450 ohm as the bundle can then be approximated by a single conductor. This studies lead to the generalization of the 450 ohm value in the full voltage range, in both IEC and ANSI/IEEE standards (previously IEC had 375 Ω for 2 conductors/phase and 330 Ω for 3 or 4 conductors per phase, ANSI/IEEE had similar values for bundled conductors: 360 ohm for 362kV and above).
- ◆ Information on conductor clashing can be found in particular in "Surge impedance of overhead lines with bundle conductors during short-line fault". Electra N°17 , published in April 1971. The conclusion of the paper is as follows: "When the conductors are clashed together, these surge impedances will take a value of approximately 450 ohm whatever the number of conductor in bundle may be".

Comment # 102

▶ Resolution detail (Cont'd)

- ◆ Link between the generalization of 450ohm and bundle contraction can also be found in CIGRE Technical Brochure 305 (page 37).
- ◆ This matter has been recently reviewed by CIGRE WG A3-22 for the specification of the surge impedance of lines in 1100 kV networks. Due to their large geometry and weight it has been concluded that conductor clashing cannot occur in this case, so that the surge impedance had to be reduced to 330 ohm.
- ◆ In case of multi-conductors per phase, conductor clashing is the assumption behind the 450 ohm value, the guide presents the existing situation, if later on standards are revised with a different assumption (leading to a lower value of the surge impedance) then this guide will be aligned.

Comment # 103

▶ **Subclause 4.2.4.1** **page 17**

▶ **Comment**

- ◆ An assumption is implied that the majority of cases has short lines with X0 being 2 to 3 times larger than X1. This is not necessarily true and should be removed.

▶ **Proposed change**

- ◆ Remove this assumption.

▶ **Resolution status**

- ◆ Not accepted

▶ **Resolution detail**

- ◆ The text is correct, this is generally true. It should be reminded that effectively grounded systems have by definition a ratio X0/X1 equal or lower than 3.

Comment # 104

▶ **Subclause 4.2.4.4** **page 28**

▶ **Comment**

- ◆ Remove reference to bundle clashing, it is not a proven phenomenon that affects these calculations.

▶ **Proposed change**

- ◆ Remove the reference to bundle clashing.

▶ **Resolution status**

- ◆ Not accepted

▶ **Resolution detail**

- ◆ See resolution to comment 102.

Comment # 105

▶ **Subclause 4.2.4.5** **page 30**

▶ **Comment**

- ◆ 450ohm surge impedance is not over-specified and is bundle clashing is not common and should not be referenced to the 450ohm surge impedance.

▶ **Proposed change**

- ◆ Remove this whole paragraph as it does not provide any useful information.

▶ **Resolution status**

- ◆ Not accepted

▶ **Resolution detail**

- ◆ See resolution to comment 102.

Comment # 106

▶ **Subclause 4.2.4.7** **page 32**

▶ **Comment**

- ◆ The CIGRE study referenced is highly controversial and its conclusion are not widely accepted by users who would be using this guide. This document is not written to show that testing is sufficient for all cases and therefore all references to that effect should be removed. In reading this document it appears to be pointing to tests that cover certain fault cases. This guide is to help evaluate the system and not testing.

▶ **Proposed change**

- ◆ Remove the reference and conclusions of the highly controversial CIGRE study.

▶ **Resolution status**

- ◆ Not accepted

Comment # 106

► Resolution detail

- ◆ Concerning the reference to CIGRE: see resolution to comment #109
- ◆ This subclause explains the influence of the short-circuit power of the source on the TRV for a given current. There is nothing controversial about this as explained in the answer to comment #107.
- ◆ When the short-circuit power of the source is reduced, a given fault current, e.g. 90% or 75% of rated short-circuit current, is obtained with a shorter length of line, as a consequence the TRV peak is lower (RRRV is the same but the time to peak related to the travel time of the wave is shorter). When the short-circuit power of the source is reduced, for the same length of faulted line the fault current is lower and as a consequence the TRV peak is lower (RRRV is lower as it is proportional to current, and the time to peak is unchanged). This subclause could be developed further to explain this. What is explained here is pure physics and cannot be contested.

Comment # 107

► Resolution detail

- ◆ Figures are better than a thousand words, they illustrate in a clear way that for a given fault current, the amplitude of the first peak of TRV is greatly influenced by the short-circuit power of the source. This is relevant in a Guide on TRVs in which the influence of different parameters on TRVs is explained. There is nothing controversial about this (as well as other parts of the CIGRE study), it could be proven also by a simplified calculation that the Chair will be happy to provide, if necessary.
- ◆ These figures have nothing to do with testing and would be of no interest in C37.09.

Comment # 108

▶ **Subclause 4.2.4.10** **page 34**

▶ **Comment**

- ◆ This clause appears to be the conclusion of the comparison added to the document. This is not the place to repeat a highly controversial conclusion. This guide should show how to calculate/determine the system TRV and compare it to the TRV testing. Anything beyond that uses assumptions and rationals that are controversial and not proven by tests.

▶ **Proposed change**

- ◆ Remove the clause.

▶ **Resolution status**

- ◆ Not accepted

Comment # 108

► Resolution detail

- ◆ After the explanations given in the previous subclauses, the aim of this one is to draw the attention of the reader to a few important aspects that need to be taken into consideration, in particular when writing specifications, to avoid unrealistic demands. Experience shows that there is some misunderstanding concerning the TRVs during three-phase terminal faults ($k_{pp} = 1.5$ is not applicable to the last pole to clear), such misunderstanding must be avoided also in the case of three-phase line faults.
- ◆ The reader of the guide must understand that a peak factor (d) higher than 2 is only possible when there is coupling between phases, and therefore cannot be requested for the last-pole-clear and the relevant arcing times (no coupling possible when the other lines are opened).
- ◆ This has nothing to do with testing, but is about the understanding of three-phase line fault TRVs. The wording can be improved but this must be covered here.

Discussion of Comments on D7

Comment # 109

▶ **Subclause reference B19** **page 81**

▶ **Comment**

- ◆ This is highly controversial and does not belong in the document.

▶ **Proposed change**

- ◆ Remove this reference.

▶ **Resolution status**

- ◆ Not accepted

Comment # 109

► Resolution detail

- ◆ The reference to CIGRE Technical Brochure 408 will be kept as it represents the most comprehensive and recent study on line fault phenomena and their implications for 3-phase short and long line fault clearing. It is useful to the reader who wants to have a deep understanding of these phenomena.
- ◆ CIGRE is a world renowned organization that thoroughly checks the content of its publications. The document was submitted to the members of the CIGRE study committee A3 and approved before publication.
- ◆ In TB 408 CIGRE gives technical information and refrains from making recommendation on standardization work. The view expressed in the comment is personal and not accepted.
- ◆ The reference is also needed as text and Figures are taken from [B18] (formerly B19).

Discussion of Comments on D7

▶ **Next steps/Actions**

- ◆ The file of comments made during the ballot of Draft 7 will be updated with the resolutions decided during the meetings in Las Vegas and Lake Buena Vista. It will be sent to WG members (Denis).
- ◆ Prepare a new draft that takes into account the resolutions on comments (Denis)
- ◆ The revised draft will be sent to WG members to check that the changes reflect the resolutions (All).
- ◆ Helmut will send a proposal to revise the TLF section (Helmut).
- ◆ Roy will provide a text to comment on range on CVT capacitance values in Table B.4 (Roy).
- ◆ The new draft for recirculation will be D9
- ◆ Recirculate D9 preferably between mid-August and mid-September in order to have votes and comments available for the next WG meeting in October 2011 (Denis).
- ◆ The comments made during recirculation will be sent before the next WG meeting in October (Denis).

IEEE WG C37.011
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▶ **Thanks for your participation !**