Minutes of Meeting
Working Group C37.010 – Application Guide for AC High-Voltage Circuit Breakers > 1000 VAC Rated on a Symmetrical Basis

Location: Westin Beach (Fort Lauderdale, FL)
Date: Tuesday April 2, 2024 (4:15PM - 6:00PM PST)
Quorum: Membership Count: **40** Members Present: **31**

Agenda
Andy Keels w/ kEElectric Engineering, LLC called the meeting to order and presented the agenda.

Introduction of Members and Guests
Introductions and attendance gathered in -person
68 Total in Attendance (31 Members, 37Guests) – Quorum Achieved

Review of Attendance Logging via IEEE Attendance Tool
See meeting slides for details

Review of IEEE Patent and Copyright Policies
No Essential Patent Claims noted

Review of Schedule and Future Meetings

Quorum Check: 31 Members – Quorum Achieved

Review of Reference Documents loaded into IMeetCental
Motion: Approve October 9, 2023 In-Person Meeting Minutes: Carl Schuetz
2nd to the Motion: David Mitchell
Vote: Approved without objection/abstention

Motion: Approve January 17, 2024 Virtual Meeting Minutes: Carl Schuetz
2nd to the Motion: David Mitchell
Vote: Approved without objection/abstention

Review of References to existing Standards
All standards are in "Reference Documents" section of IMeet Central

Table 6 & Table 7 Presentation/Discussion
- See minutes slides
- Comments related to recommendation to add a cautionary note to Table 6:
    - What additional design components may need to be considered when exceeding temperature limits. For example, glue joints may fail suddenly vs. components that will fail due to aging.
    - Should the aging behavior of epoxy and composite materials (not part of the current path) be considered.

- Comments related to the significance of overload capability/duration general guidance within the current guide that the utility uses to calculate overload condition.
    - Additional cautionary comments and notes being considered for inclusion in the document should either be removed or clarified. They reduce effectiveness of existing equations within the guide.
- Comment noted existing thermal time constants are based on oil circuit breakers. This is addressed in Section 4.5.4.2 of the existing document.
- Actions:
    - Task force consisting of Dan Schiffbauer, Carl Schuetz and Dan Benedict will review cautionary notes in more detail and provide recommendation to the working group at a future meeting.
    - Chair will delete the second sentence of proposed additional cautionary note and add to the draft document. Next review of the draft document during virtual meeting in August 2024 will follow-up on this topic.

<u>Sub-Group presentation of Update on User-Specified 105% of Rated Maximum Voltage.</u>
- See slides in Meeting Minutes
- General Comment:
    - Most utilities do not exceed 100% of the rated maximum voltage because that would be a NERC violation.
- Comments to Clause 4.2 Revision Recommendation:
    - In addition to short circuit functions, it is recommended to add the following: capacitive, inductive, load switching, and other applicable switching duties.
    - Reference should be made to the maximum operating voltage in C37.04 vs C84.1.
    - Add a reference back to C37.06 bibliography for referring back to circuit breakers qualified prior to 2018.
- Member presented a proposed paragraph that suggests the use of TRV multiplying factors to cover circuit breaker operation over the maximum rated value
    - Actions:
        - Victor Hermisillo to post the proposal in IMeetCentral for the working group to review.

<u>Sub-Group presentation of Update on Inverter Based Resources and the Impact on Fault Currents</u>
- See slides in Meeting Minutes
- General Comments/Questions:
    - What is the fault output capability of the IBR based on the algorithms internal to the equipment.
    - Utility representative commented that their company has lots of data that could be used to support the sub-groups evaluation (fault current and voltage oscillographs).

<u>Presentation of Topic related to HV CB Generator Synchronization Scope Proposal</u>
- See Slides in Meeting Minutes
- The following members formed a sub-group to evaluate this proposal:
    - Jan Weisker, Dave Mitchell, Andy Chovanic, Victor Hermisillo
- Action:
    - Chair to add proposal discussion to next meeting agenda

Schedule
Next Virtual Meeting: August 23, 2023 @ 11:00AM EST
Next in-person meeting: October 13th – 17th, 2024 at the Oklahoma City, OK

Meeting adjourned by the chair at 6:00PM (EST) on 4/2/2024
Reported by:
Jeremy Hensberger, Lucas Collette & Andy Keels

	Name	Affiliation	Member
1	Aristizabal, Mauricio	Hitachi Energy USA	
2	BECKEL, ANDREW	Xcel Energy	
3	Becker, George	POWER Engineers, Inc.	X
4	Beecher, Zachary	Southern States LLC	
5	Benedict, Dan	PPL Corporation	X
6	Benge, Jonathan	Oklahoma Gas and Electric	
7	Bolar, Sanket	Oncor Electric	
8	Bornuat, Albane	General Electric Company (GE); GRID SOLUTIONS	
9	Brogdon, Jeffrey	Georgia Transmission Corporation	
10	Bryant, Craig	Duke Energy	X
11	Bufi, Arben	Meiden America Switchgear	X
12	byreddy, sudarshan reddy	Burns & McDonnell	
13	Chovanec, Andrew	Power Grid Components	X
14	Collette, Lucas	Duquesne Light Co.	X
15	Crawford, Michael	Mitsubishi Electric Power Products, Inc. (MEPPI)	X
16	Cunningham, Jason	Southern States LLC	
17	Cuppett, Matthew	Hitachi Energy	
18	Eastman, Maxwell	Black and Veatch	
19	Flores, Sergio	Schneider Electric USA Inc.	
20	Hanna, Robert	JST Power Equipment Inc	X
21	Hensberger, Jeremy	Mitsubishi Electric Power Products Inc	X
22	Hermosillo, Victor	GE Grid Solutions	X
23	Irwin, Todd	GE Grid Solutions	X
24	Jaggernauth, Sudesh	Florida Power & Light	
25	Jarnigan, Christopher	southern company/ southern nuclear	X
26	Keels, Thomas	kEElectric Engineering, PLLC	X
27	Krause, Dwight	Black and Veatch	
28	Kurinko, Carl	Hitachi Energy	X
29	Lee, Yongwoo	Korea Electrotechnology Research Institute(KERI)	
30	Livshitz, Albert	Schneider Electric	X
31	Lopez, Leo	WIKA	
32	Ma, Chunming	Burns & McDonnell	
33	Marshall, Vincent	southern company/ southern nuclear	X
34	MARZEC, PETER	S and C Electric Co	
35	May, Steven	Southern Company Services	X
36	McGlown, Kevin	JST Power Equipment	
37	Meekins, Gary	Southern States LLC	
38	Mitchell, David	Southern States LLC	X
39	Natale, Anthony	HICO America	
40	Ordein, Fernando	Dominion Energy	X
41	Orosz, Miklos	CBT&S Consulting LLC	
42	Pecile, Conrad	Myers Power Products, Inc,	
43	Pedreros Ratmiroff, Javier	GE Grid Solutions	
44	Peterson, Mark	Xcel Energy	
45	Polchinski, Craig	Mitsubishi Electric Corporation	X
46	Pounders, Isaac	Meiden America Switchgear	

47	Rebovich, Justin	GE Vernova; General Electric Company (GE)	
48	Rexroad, Aaron	Meiden America Switchgear inc.	X
49	Ricciuti, Anthony	Eaton Corporation	X
50	Roberts, Brian	Southern States LLC	
51	Sax, Benjamin	Nashville Electric Service	
52	Schiffbauer, Daniel	Toshiba International Corporation	X
53	Schuetz, Carl	American Transmission Co., LLC	X
54	Scott, Jeffrey	Ameren	X
55	Sharma, Devki	Entergy Corporation	X
56	Shirode, Aniket	ABB Ltd.	
57	Skidmore, Michael	American Electric Power (AEP)	
58	Tarleton, John	Southern States LLC	
59	Terry, Timothy	meiden	
60	Toups, Vernon	Siemens Energy Inc	X
61	Usner, Joseph	AEP	
62	Webb, John	ABB Ltd.	
63	Weeks, Casey	Siemens Energy, Inc.	X
64	Weisker, Jan	Siemens Energy	X
65	Woodyard, Terry	Siemens Industry, Inc.	
66	York, Richard	Mitsubishi Electric Corporation	
67	Young, Marcus	Mitsubishi Electric Power Products, Inc.	X
68	Zaharko, Samuel	Mitsubishi Electric Corporation	X
		Members Present	**31**
		Guests Present	**37**

C37.010 Working Group

Application Guide for AC High-Voltage Circuit Breakers >1000Vac
Rated on a Symmetrical Basis

Tuesday, April 2nd, 2024

16:15 – 18:00 EDT

Chair: T. Andy Keels w/ kEElectric Engineering, PLLC

Secretary: Jeremy Hensberger w/ MEPPI

Vice-Chair: Lucas Collette w/ Duquesne Light Co.

Starting Document: IEEE Std C37.010-2016 (Revision of C37.010-1999)

Agenda

1. Chairman’s call to order
2. Introduction of attendees:

   Please announce your *Name*, *Affiliation*, *Location*
3. Attendance Logging Instructions
4. Workgroup Required Reading
5. Anticipated Schedule (*Best laid plans*)
6. iMeet Central Workspace
7. Minutes Approval
8. Discussion of Table 6 and Table 7 (Dan Benedict w/ PPL Energy)
9. Report from Sub-group on “User-Specified 110% Voltage Duty” (Carl Schuetz w/ ATC)
10. Proposed revison on TRV multiplying factors (Victor Hermosillo w/ GE HVCB)
11. Call for additional revisions to Section 4 or Section 5, or Annex A or B
12. Next meetings

Logging Your ATTENDANCE To This Meeting

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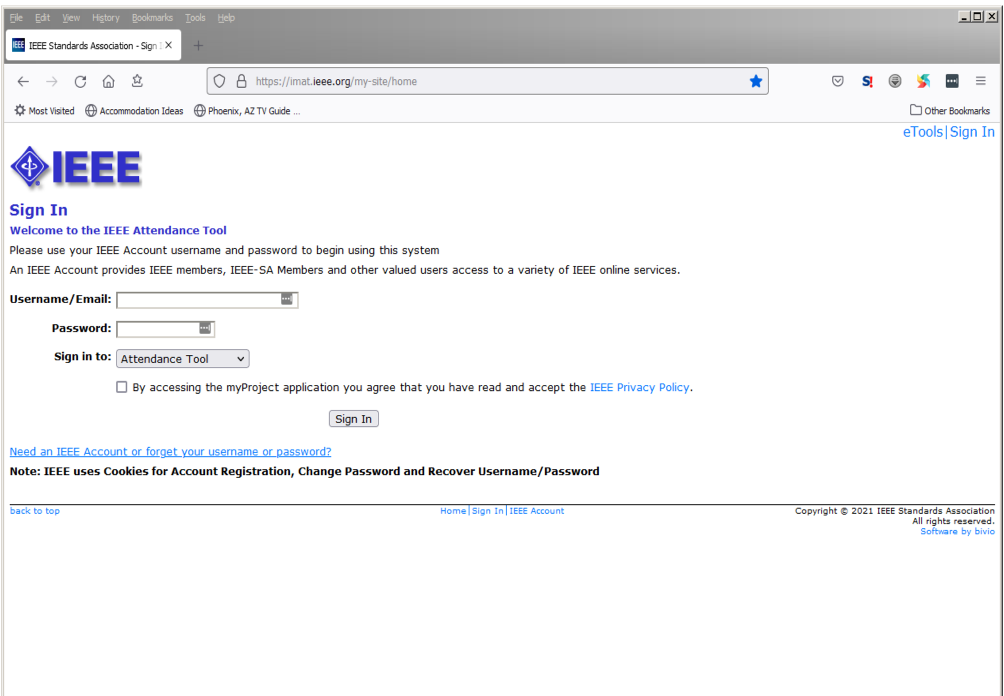
1. Go To: IEEE SA eTools, Then click on **IEEE Attendance Tool**
2. **Google:** IEEE Attendance Tool
3. Go directly to: https://imat.ieee.org/my-site/home



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Home - Thomas Keels, SA PIN: 88780

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Active Meetings

Please select the meeting you are currently attending

IEEE PES Switchgear Spring 2024 Meeting	Ft. Lauderdale	02-Apr-2024
IEEE P802.3dj COM Implementation and Execution Ad Hoc meeting		02-Apr-2024
802 April/May/June Telecons		01-Apr-2024
IEEE 802.3 test meeting		29-Mar-2024
IEEE 802.18 teleconference call (24/03/24 to 09/05/24)		21-Mar-2024
802.11 Telecons (March 19-May 10)		19-Mar-2024
802.1 Telecons (Mar-May)		18-Mar-2024

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Then select the Working Group

If it is a ‘virtual meeting’ the WG Chair should have the link listed here

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IEEE PES Switchgear Spring 2024 Meeting (edit)

Ft. Lauderdale, FL

IEEE PES Switchgear Spring 2024 Committee Meetings

Westin Beach Resort

Ft. Lauderdale, FL

Select Working Group

PE/SWG/HVCB-WG_C37.010 Attendance

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PE/SWG/HVCB-WG_C37.010 Attendance Log

Attendee: Thomas Keels, SA-Pin: 88780
Affiliations: PE/SWG/HVCB-WG_C37.010 kEElectric Engineering, PLLC

Manage Attendee

TUE 2-Apr-2024 | **WED** 3-Apr-2024

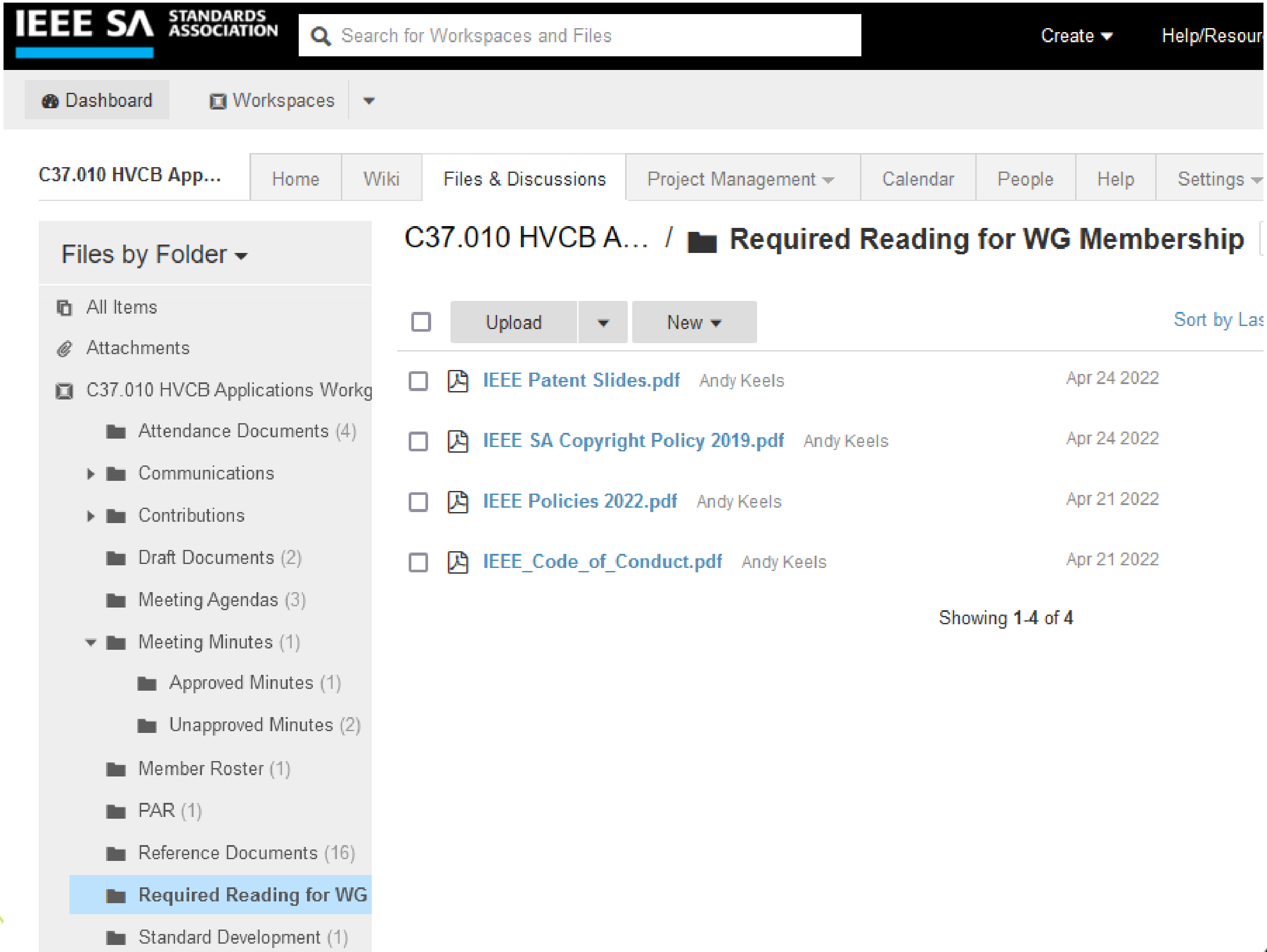
Schedule	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
C37.010 HVCB Applications WG Meeting																	

Please record your attendance for an active breakout (denoted by yellow bar) by clicking on the yellow bar. Once your attendance has been recorded, the yellow bar changes to a green bar.

Submittal: As the person submitting this form, I certify that:

1. *I am submitting this attendance record for myself and not someone else. DO NOT SUBMIT FOR OTHERS!*
2. *At the time of the submittal, I am currently in the Event above.*

Workgroup Required Reading



Meeting Schedule

~~04/11/2022~~ ~~1st working group meeting~~

~~10/17/2022~~ ~~2nd working group meeting Burlington, VT~~

~~02/03/2023~~ ~~3rd working group meeting VIRTUAL Google Meeting~~

~~04/26/2023~~ ~~4th working group meeting Virtual WebEx~~

~~07/19/2023~~ ~~5th working group meeting VIRTUAL WebEx~~

~~10/10/2023~~ ~~6th working group meeting San Diego, CA~~

04/02/2024 7th working group meeting Ft. Lauderdale, FL

08/23/2024 8th working group meeting VIRTUAL WebEx

10/14/2024 9th working group meeting Oklahoma City, OK

01/02/2025 10th working group meeting VIRTUAL WebEx

04/07/2025 11thworking group meeting Orlando, FL

C37.010 Working Group

- Review of WG Membership Master List
- Quorum Check
- Review of iMeet Central Workspace
- Approval of Minutes of last meeting

Current Member List For Quorum Check

1 Aaron Rexroad
2 Albert Livishitz
3 Andrew Chovanec
4 Anthony Ricciuti
5 Arben Bufi
6 Carl Kurinko
7 Carl Schuetz
8 Casey Weeks
9 Chris Jarnigan
10 Craig Bryant
11 Craig Polchinski
12 Dan Benedict
13 Dan Shiffbauer
14 *David Caverly**
15 David Mitchell
16 Devki Sharma
17 Don Steigerwalt
18 Mikos Orosz
19 George Becker
20 Jake Walgenbach
21 Jan Weisker
22 Jeff Scott
23 Jeff Ward
24 Jennifer Hunter
25 Jeremy Hensberger
26 Lucas Colette
27 Marcus Young
28 Matt Westerdale
29 Michael Christian
30 Michael Crawford
31 Miklos Palazzo
32 R. Kirk Smith
33 Robert Hanna
34 Samuel Zaharko
35 Steven May
36 Thomas 'Andy' Keels
37 Todd Irwin
38 Vernon Toups
39 Victor Hermosillo
40 Vincent Marshall
41 Wei Zhang

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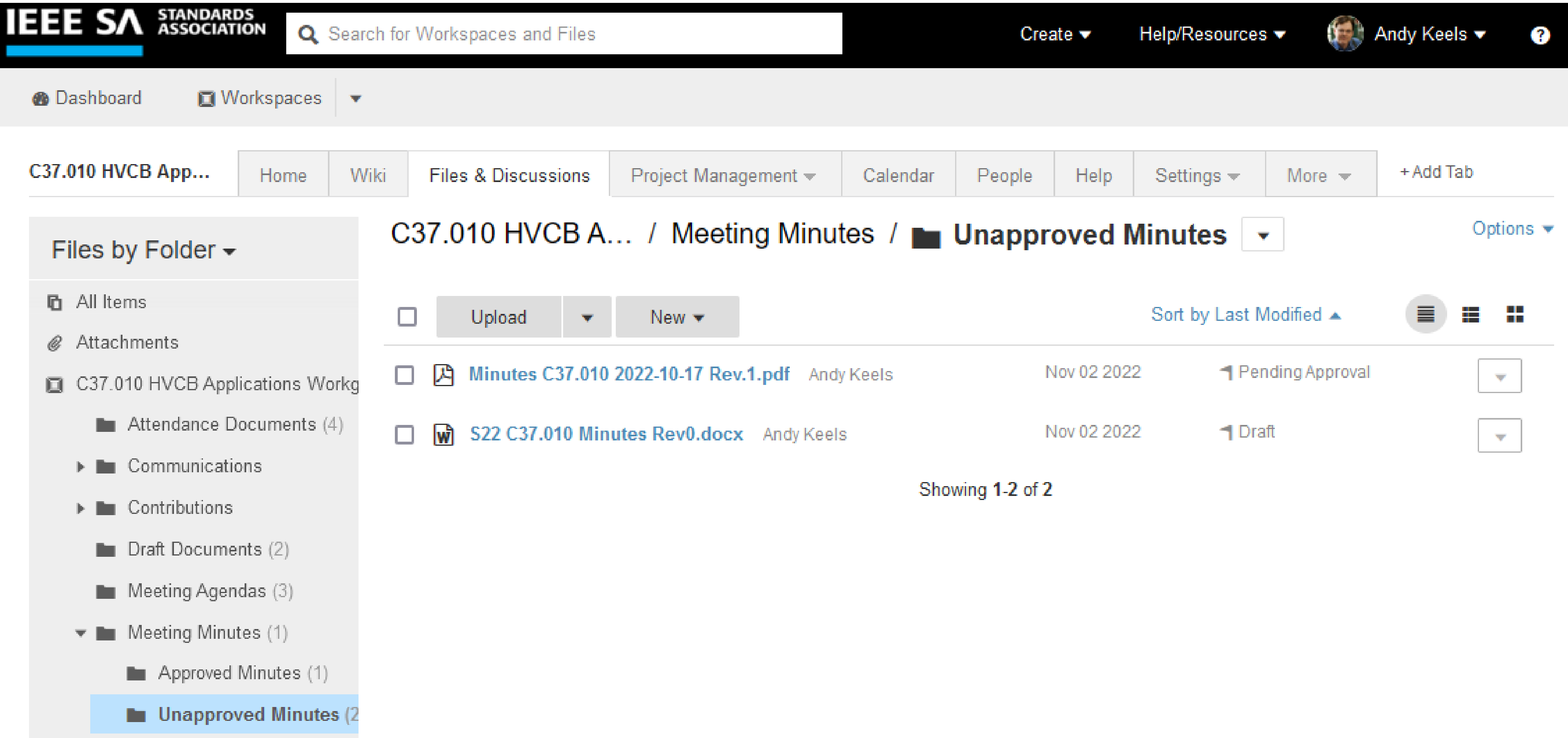

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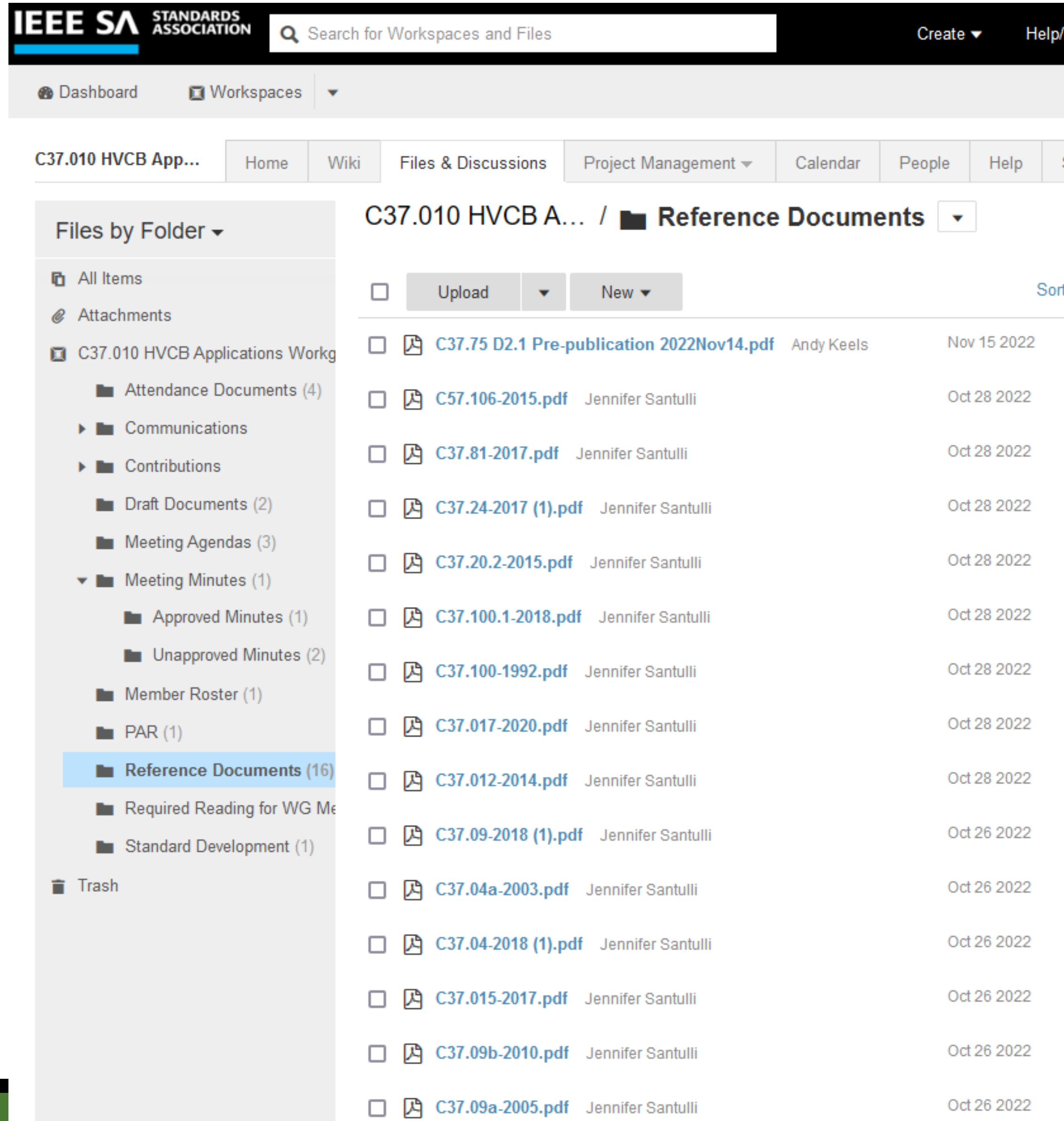
C37.010 Working Group

Reference Standards for IEEE PES C37.010 Working Group

Got It	Std Number	Year	Title
	C37.010	-2016 & 1999	Application Guide for AC High-Voltage Circuit Breakers > 1000 Vac Rated on a Symmetrical Current Basis
	C37.04	-2018	Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
	C37.04a	-2003	Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis: Amendment 1 Capacitance Current Switching
	C37.06	-2009 & 2018	Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis–Preferred Ratings and Related Required Capabilities for Voltages Above 1000 V
	C37.09	-2018	Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
	C37.09a	-2005	Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis- Amendment 1: Capacitance Current Switching
	C37.09b	-2010	Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis -- Amendment 2
	C37.011	-2019	Guide for the Application of Transient Recovery Voltage for AC High-Voltage Circuit Breakers with Rated Maximum Voltage above 1000 V
	C37.012	-2014	Guide for the Application of Capacitance Current Switching for AC High-Voltage Circuit Breakers Above 1000 V
	C37.017	-2020	Standard for Bushings for High-Voltage [over 1000 V (ac)] Circuit Breakers and Gas-Insulated Switchgear
	C37.015	-2017	Guide for the Application of Shunt Reactor Switching
	C37.20.2	-2015	Standard for Metal-Clad Switchgear
	C37.24	-2017	Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear
	C37.81	-2017	Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies
	C37.100	-1992 ??	Standard Definitions for Power Switchgear
	C37.100.1	-2018 ?	Standard for Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V
	C57.106	-2015	Guide for Acceptance and Maintenance of Insulating Mineral Oil in Electrical Equipment
	ANSI C37.7	-1960 ??	INTERRUPTING RATING FACTORS FOR RECLOSING SERVICE FOR AC HIGH-VOLTAGE CIRCUIT BREAKERS RATED ON A TOTAL CURRENT BASIS
	IEC 62271-100	-2021	High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers

C37.010 Working Group



Discussion of Table 6 & Table 7

C37.010 working group meeting

April 2, 2024

Dan Benedict

Andy Chovanec

Dan Schiffbauer

Goal of sub-workgroup

Clarify Table 6 and Table 7 related to emergency load current-carrying capability

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Discussion of Table 6 and Table 7

Proposed Changes

- Added Section 3 – definitions, acronyms, and abbreviations; updated subclause references throughout
- Updated values within Tables 3-11 to correct minor errors and round consistently
- Added θ_{max} of 95 ℃ column to relevant tables
- Caution statement if exceeding rated temperature limits of circuit breaker:

Extreme care must be exercised by the equipment operator when exceeding the total temperature limits for the circuit breaker. There could be auxiliary components not identified in IEEE Std. C37.04 or IEEE Std. C57.13 that suddenly fail at temperatures greater than the standard total temperature limits. The manufacturer should be consulted prior to the total temperature limits being exceeded to determine if any components would not tolerate a higher temperature.

Discussion of Table 6 and Table 7

Proposed Changes (cont'd)

- Separated continuous current equation based on ambient temperature

$$I_a = I_r \left[\frac{\theta_{\max} - \theta_a}{\Delta\theta_r} \right]^{\frac{1}{1.8}} \Rightarrow I_a = \begin{cases} I_r \left[\frac{\theta'_{max} - \theta_a}{\Delta\theta'_r} \right]^{\frac{1}{1.8}} & \text{for } \theta_a \leq 40\ ^\circ\text{C} \\ I_r \left[\frac{\theta''_{max} - \theta_a}{\Delta\theta''_r} \right]^{\frac{1}{1.8}} & \text{for } \theta_a > 40\ ^\circ\text{C} \end{cases}$$

- Clarified 4 h and 8 h emergency load current-carrying capabilities

$$I_e = \begin{cases} I_r \left[\frac{\theta'_{max} + 15\ ^\circ\text{C} - \theta_a}{\Delta\theta'_r} \right]^{\frac{1}{1.8}} = I_r \left[\frac{\theta'_{max} - 25\ ^\circ\text{C}}{\Delta\theta'_r} \right]^{\frac{1}{1.8}} & \text{for a 4-h emergency period} \\ I_r \left[\frac{\theta'_{max} + 10\ ^\circ\text{C} - \theta_a}{\Delta\theta'_r} \right]^{\frac{1}{1.8}} = I_r \left[\frac{\theta'_{max} - 30\ ^\circ\text{C}}{\Delta\theta'_r} \right]^{\frac{1}{1.8}} & \text{for an 8-h emergency period} \end{cases}$$

Discussion of Table 6 and Table 7

Proposed Changes (cont'd)

- Updates to Tables 6 and 7 → creation of new Tables

Table 6: I_{ea}/I_r 4-h emergency
- Table 6: I_{ea}/I_r 4-h emergency ($\leq$ 40 °C)
- Table 7: I_{ea}/I_r 4-h emergency (50 °C)
- Table 8: I_{ea}/I_r 4-h emergency (60 °C)

Table 7: I_{ea}/I_r 8-h emergency
- Table 9: I_{ea}/I_r 8-h emergency ($\leq$ 40 °C)
- Table 10: I_{ea}/I_r 8-h emergency (50 °C)
- Table 11: I_{ea}/I_r 8-h emergency (60 °C)

Discussion of Table 6 and Table 7

Proposed Changes (cont'd)

- Update to Table 4

Table 4—Typical thermal time constants

Circuit breaker category	Typical thermal time constant τ (h)
Circuit breakers in ~~metal~~ metal-clad switchgear	~~0.5~~IEEE Std. C37.20.2
Circuit breaker in ~~gas insulated switchgear (GIS)~~MEGIS	0.5
Circuit breakers not in metal-~~enclosed~~clad switchgear and not in ~~GIS~~MEGIS	0.5

- Added Annex C for derivations and example calculations

Sub-Group Update
HVCB Operation at 105% of Rated Maximum Voltage

C37.010 meeting
Ft. Lauderdale-April 2023

Arben Bufi
Andrew Chovanec
Luke Collette
Craig Polchinski
Carl Schuetz
Markus Young

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Goal of the Sub-Group

To provide more detailed guidance in the application guide for users when the power system is operated up to 5% above nameplate voltage value

(10% above system nominal voltage as defined in C84.1)

- No proposition is made to change the rating structure or its values

Update on clause 4.2 revision

4.2 Maximum voltage for application

The operating voltage should not exceed the rated maximum voltage of the circuit breaker. The rated maximum voltage is the voltage on which all the corresponding type tests have been based. The type tests values include some margins in order to accommodate aging as well as statistical behavior.

- Two online meetings were held to discuss the revisions and draft recommended content
- The recommended content is thought to provide greater clarity for the understanding of what aspects rated maximum voltage (RMV) have on circuit breaker performance
- Guidance is also provided to have the user perform some means of determining what the recovery voltages are (for varying conditions) and discuss these (and other voltage capability aspects) with the manufacturer

ANSI C84.1 - Table 1: Standard nominal voltages and voltage

VOLTAGE CLASS	Nominal System Voltage (Note a)			Nominal Utilization Voltage (Note h)	Voltage Range A (Note b)			Voltage Range B (Note b)		
					Maximum	Minimum		Maximum	Minimum	
	2-wire	3-wire	4-wire	2-wire 3-wire 4-wire	Utilization and Service Voltage (Note c)	Service Voltage	Utilization Voltage	Utilization and Service Voltage	Service Voltage	Utilization Voltage
	Single-Phase Systems									
Low Voltage (Note 1)	120			115	126	114	110	127	110	106
		120/240		115/230	126/252	114/228	110/220	127/254	110/220	106/212
	Three-Phase Systems									
			208Y/120 (Note d)	200	218Y/126	197Y/114	191Y/110	220Y/127	191Y/110 (Note 2)	184Y/106 (Note 2)
			240/120	230/115	252/126	228/114	220/110	254/127	220/110	212/106
		240		230	252	228	220	254	220	212
			480Y/277	460Y/266	504Y/291	456Y/263	440Y/254	508Y/293	440Y/254	424Y/245
		480		460	504	456	440	508	440	424
		600 (Note e)		575	630 (Note e)	570	550	635 (Note e)	550	530
Medium Voltage		2400			2520	2340	2160	2540	2280	2080
			4160Y/2400		4370/2520	4050Y/2340	3740Y/2160	4400Y/2540	3950Y/2280	3600Y/2080
		4160			4370	4050	3740	4400	3950	3600
		4800			5040	4680	4320	5080	4560	4160
		6900			7240	6730	6210	7260	6560	5940
			8320Y/4800		8730Y/5040	8110Y/4680		8800Y/5080	7900Y/4560	
			12000Y/6930		12600Y/7270	11700Y/6760		12700Y/7330	11400Y/6580	(Note f)
			12470Y/7200		13090Y/7560	12160Y/7020	(Note f)	13200Y/7620	11850Y/6840	
			13200Y/7620		13860Y/8000	12870Y/7430		13970Y/8070	12504Y/7240	
			13800Y/7970		14490Y/8370	13460Y/7770		14520Y/8380	13110Y/7570	
		13800			14490	13460	12420	14520	13110	11880
			20780Y/12000		21820Y/12600	20260Y/11700		22000Y/12700	19740Y/11400	
			22860Y/13200		24000Y/13860	22290Y/12870		24200Y/13970	21720Y/12540	(Note f)
		23000			24150	22430	(Note f)	24340	21850	
			24940Y/14400		26190Y/15120	24320Y/14040		26400Y/15240	23690Y/13680	
			34500Y/19920		36230Y/20920	33640Y/19420		36510Y/21080	32780Y/18930	
		34500			36230	33640		36510	32780	
					Maximum Voltage (Note g)					
		46000			48300					
		69000			72000					
High Voltage		115000			121000					
		138000			145000					
		161000			169000					
		230000			242000					
Extra-High Voltage		345000			362000					
		400000			420000					
		500000			550000					
		765000			800000					
Ultra-High Voltage		1100000			1200000					

NOTE 1—Minimum utilization voltages for 120-600 volt circuits not supplying lighting loads are as follows:

Nominal System Voltage	Range A	Range B
120	108	104
120/240	108/216	104/208
* 208Y/120	187Y/108	180Y/104
240/120	216/108	208/104
240	216	208
480Y/277	432Y/249	416Y/240
480	432	416
600	540	520

* - (Note 2)

NOTE 2—Many 220-volt motors were applied on the assumption that the utilization voltage would be less than 187 volts. Caution should be exercised in applying the Range B minimum voltages of table 1 and note (1) to existing 208-volt systems supplying such motors.

IEEE Standards References on RMV Ratings

IEEE C37.04-2018

5.2 Rated maximum voltage (*V*) or (U_r)

The rated maximum voltage of a circuit breaker is the highest rms phase-to-phase voltage for which the circuit breaker is designed, and is the upper limit for operation. Rated maximum voltage has the same meaning as maximum system voltage rating referred to in ANSI C84.1 [B3].

IEEE C37.010-2016

4.2 Maximum voltage for application

The operating voltage should not exceed the rated maximum voltage of the circuit breaker. The rated maximum voltage is the voltage on which all the corresponding type tests have been based. The type tests values include some margins in order to accommodate aging as well as statistical behavior.

ANSI C84.1-2006

(g) For these systems, Range A and Range B limits are not shown because, where they are used as service voltages, the operating voltage level on the user's system is normally adjusted by means of voltage regulators or load tap-changers to suit their requirements.

IEEE Standards References on RMV Ratings

IEEE C37.09-2018

4.2 Maximum voltage tests

There is no specific test to demonstrate this rating. However, the ability of the circuit breaker to operate successfully at rated maximum voltage is demonstrated by performing short-circuit current interruption and other current switching rating tests in accordance with Table 1, and specified values of circuit transient recovery voltage (TRV), as given in IEEE C37.04.

IEEE Standards References on RMV Ratings

IEEE C37.09-2018

Table 1—Single-phase or three-phase test duties for short-circuit current tests

Test duty	Operating duty	Test voltage (kV)	Making I [kA (pk)]	Short-circuit current (kA)	% asymmetry @ contact part
T10	O–t_r–CO–t_r'–CO	E		0.1 I	<20
T30	O–t_r–CO–t_r'–CO	E		0.3 I	<20
T60	O–t_r–CO–t_r'–CO	E		0.6 I	<20
T100s	O–t_r–CO–t_r'–CO or T100s(a) and T100s(b)	E	$F \times I$	I	<20
T100s(a)	C–t_r'–C	E	$F \times I$		
T100s(b)	O–t_r–O–t_r'–O	E		I	<20
T100a	Three Os	E		see 4.8.4.4	>20
Single-phase fault tests					
T100s 1ph	O				<20
T100a 1ph	O	$\frac{U_r}{\sqrt{3}}$		see 4.8.4.5	>20
Single-phase, short-line fault tests					
L75	Three Os	$\frac{U_r}{\sqrt{3}}$		0.7 I to 0.8 I	<20
L90	Three Os	$\frac{U_r}{\sqrt{3}}$		0.9 I to 0.95 I	<20
Short-time current test					
STC	Closed position		$F \times I$	I for T seconds	

Testing voltage '*E*'

$$E = \frac{k_{pp}}{\sqrt{3}} \times U_r$$

Ur is Rated maximum voltage

k_{pp} is First-pole-to-clear factor:

1.3 for grounded neutral systems

1.5 for isolated neutral systems.

Rated TRV 'u_c'

u_c = 1.49 x Ur, for k_{pp} = 1.3

u_c = 1.72 x Ur, for k_{pp} = 1.5

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Clause 4.2 Revision Recommendation

The operating voltage should not exceed the rated maximum voltage of the circuit breaker. The rated maximum voltage is the voltage on which all the corresponding type tests have been based, including the short circuit interrupting capability tests. Some values used in the short circuit interrupting type tests include margins in order to accommodate aging and statistical behavior.

Informative NOTE:

If system voltage operation above values ascribed in ANSI C84.1 voltage Range A are experienced, the system TRV and switching recovery voltages must remain within the circuit breaker capability as demonstrated in the type test reports. These system recovery voltage values should be confirmed on a case-by-case basis performed by system study, calculation, or some other means. For such cases, it is recommended that the user consults the manufacturer to verify the dielectric withstand and recovery voltages capabilities of selected circuit breaker.

Impact of inverters on fault current calculation methods

- Luke Collette
- Craig Polchinski
- Carl Schuetz
- Marcus Young

Learnings to date

- The IEEE Power Systems Relay Committee (PSRC) has authored a technical report that describes how available fault current calculation software programs determine phasor domain fault current from an Inverter Based resource (IBR)
  - PES-TR78 “ Modification of Commercial Fault Calculation Programs for Wind Turbine Generators”

  - The IBR fault current consists of transient and controlled response periods
    - Since the software solutions are prepared in the phasor domain a different approach is needed to determine peak currents in the first cycle (see Fig. 4-8 in PES-TR78)
    - Presently this different approach is to perform simulations in a time domain transient analysis program

  - The dynamic period fault currents are determined by the control algorithm and its settings

Learnings to date (cont'd.)

- A liaison representative from PSRC was provided to help guide the sub-group request for information regarding transient currents from an IBR
- An online meeting was held to determine:
  - A) if the PSRC has intentions to investigate transient IBR currents
  - B) determine any additional fault current calculation learnings since the TR
  - C) if the fault current calculation software companies have plans to model transient currents
- The answer to these inquiries are:

  A) the PSRC presently has no intention of determining transient currents

  B) the transient period current for an IBR is best based on transient time domain simulations

  - The accuracy of those simulations within the transient period is not known since the simulation performer does not typically have the manufacturers component data and algorithm

  C) the software companies have not expressed an interest in determining transient currents

  - EPRI has a project to do so

Learnings to date (cont'd.)

- PES TR-78 provide examples of relay oscillography that recorded the phase current for different faults
  - The oscillography shows asymmetric current present for 2 – 3 cycles, supplied by Type III Wind Turbine Generators (Figs. 4-8, 4-15, 4-17)
  - Only Type III WTG fault currents were provided
- A research paper within IEEE Xplore titled "Study On The Fault Current Transient Features of the PV Inverter" provides transient simulation currents for three-phase faults
  - Transient currents are present for ~ ½ cycle however, they do not exhibit a high degree of asymmetry
  - The transient period duration and current magnitude are significantly reduced when an enhanced control algorithm is used in the converter controller

Initial conclusions and recommendation for further work

- The fault current calculation software companies can model IBR fault currents in the phasor domain but not in the time domain
- Peak transient currents may be dependent on what type of IBR generation is present
  - Type III WTG / Type IV WTG, PV-VSC converter, BES-VSC converter
- Time domain simulation methods may not adequately capture the transient period fault currents since the actual component values and control algorithms are not known

RECOMMENDATION

Develop a user Request for Oscillography data of IBR fault currents and send to users

Proposed paragraph that suggests the use of TRV multiplying factors to cover circuit breaker operation over the maximum rated voltage

It is possible to apply a circuit breaker tested for ungrounded conditions at its maximum rated voltage in applications operating over this voltage with a reduction of TRV factors and limiting its use to solidly grounded networks. For terminal fault short-circuit current breaking, it is necessary that the circuit tested be tested with a combination of peak TRV with first pole to clear factor (k_{pp}) of 1.5 and demonstration of an arcing window width for k_{pp} of 1.3. For out-of-phase breaking, if testing was performed with 2.5 factor, it can cover applications at higher operating voltage with a reduced 2.0 factor. In the case of capacitive load current switching, a circuit breaker tested to 1.4 voltage factor (k_v) can be applied at higher operating voltage with a reduced k_v of 1.2 that still covers lines, cables and grounded shunt capacitor banks.

Contributed by: Victor Hermossillo, GE Vernova HVCB, 3/28/2024

Open Call for Additional Suggestions for Revisions

Contents

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Next On-Line Meeting will be via IEEE WebEx

Friday, August 23 2024
13:00pm EDT (10am PDT)

Our Next in-person meeting is scheduled to be at:

Omni Hotel, Oklahoma City, OK

October 13 - 17, 2024

Would someone like to make a motion to adjourn?