C37.012a Capacitor Switching Application Guide April 26, 2017

Minutes of meeting

- Brian Roberts volunteered to be Secretary.
- Introduction from Roy – going over agenda
- 19 Signed as members, 20 guests
- A task force was initiated to develop a new capacitive inrush current rating structure with 14 members.
- Roy gave his presentation on impact of Capacitive discharge current on an SF6 circuit breaker.
- Roy presented C37.012a list of items needing amendment (below)
- Questions/discussion
- Meeting adjourned

C37.012a list of items needing amendment

Global:

References to C37.06 need to be changed to C37.04

Specific clauses

1) 2.0 fix the normative references and add IEEE 1036
2) Last paragraph of 3.0 listing available classes (C0 needs to be added)
3) 4.2.2 After the last paragraph on page 6 an additional paragraph should be added:
   Perhaps more common than an escalating overvoltage is a succession of restrikes with overvoltage between 2.2 and 3.0 on successive power frequency half cycles. Such events have been responsible for capacitor unit failures and / or system surge arrester failures. Restrike events with as many of 17 successive restrikes have been recorded, and even longer ones witnessed.

4) 4.3.3 first and 2nd paragraphs on page 16
   Replace with:
   Typical amplitudes of the inrush current for back to back energization of capacitor banks are several 10s of kiloamperes with frequencies of 2kHz (for medium voltage) ranging up to 15kHz for EHV. Some values are given in C37.04. Internally fused capacitors can normally withstand currents up to 100 times normal charging current. fuseless and externally fused capacitors (commonly used in North America) can withstand an order of magnitude higher values. See IEEE 1036 for guidance.

   Oil circuit breakers will require the inrush di/dt to be limited. Other circuit breaker types will not require limitation of inrush current magnitude nor frequency. If the Charge stored in the capacitor is extremely large (i.e. greater than several Coulombs) it may be desirable to limit the inrush to prolong life of the circuit breaker beyond 1000 operations. Preinsertion resistors/inductors, and controlled switching are the most effective means of limiting contact damage from inrush and would be expected to prolong life by about a factor of 10. Adding inductance only helps if the inductors are very large. When adding inductors the contact wear is only reduced proportionally to the fourth root of the (final inductance/initial inductance).

5) 5.3.2.2
Page 22 two paragraphs above eq(34) Delete the second sentence "for application purposes…."

The paragraph immediately above eg (34) and be eliminated. at least any reference to rated inrush frequency must be removed.

6) 6.1.1 2nd paragraph on pg 25
I believe the Ferranti effect numbers need to be increased
The rise for 300km should be 24% and for 200kM 4%
7) 9.6 on page 36 need to add C0 and remove the note about it
8) 9.7 on page 37 C0 use needs to be addressed.
9) 9.10.3 page 40 the clause needs to be expanded to discuss the possibility of missing current zeros immediately after energization when the line is compensated beyond 50%. A warning needs to be provided not to open the line within the first few seconds of energization so that the breaker will not be subject to missing zeros.
10) 9.11.2.3 This will need a substantial rewrite.
The 3rd paragraph is no longer true. It only applies to oil circuit breakers.
The 4th paragraph is also not true. Back to back switching has little impact on power quality. It is predominantly a local phenomenon.

The examples given are fine to demonstrate how to use the equations but they have no bearing on the circuit breaker application.

If we wish to educate people on the coulomb transfer method we will need different examples.

The concepts of a rated inrush current and frequency are not really valid for determining the impact of the capacitive inrush on a circuit breaker. So should these even be ratings?

C37.100.2 , C37.04, and C39.09 will need rating structure amendments after they are approved. I recognize this is too "radical" a change to incorporate into the present revisions, and demonstration work is still ongoing.

11) 9.12.1 the top paragraph on page 48 can be deleted. There is no upper limit to inrush frequency.
12) 9.14.2 the 2nd last paragraph on pg 51 should be amended, di/dt is not an issue for non oil circuit breakers. We can leave it and say ONLY a concern for oil circuit breakers.
I also believe the present legislated limit to the peak current rating of the breaker can also be exceeded without harming the breaker.

13) 9.18.3.2 2nd paragraph the numbers are 2400 operations of 100kA@ 25kHz

14) Annex: Add TR16 to the bibliography. And possibly a paper (s) yet to come.

$$\text{Erosion} = k\pi\sqrt{2} \times P/V \sum_{j=1}^{t/(\pi\sqrt{(LC)})} \sqrt{(D)^j}$$

V is RMS phase to ground voltage

C is the equivalent capacitance
t is the prearc duration
L is the inductance in the discharge circuit
D is the full cycle damping factor
P is the transferred energy

$$\text{Erosion} = k\pi VC \sum_{j=1}^{t/(\pi\sqrt{(LC)})} \sqrt{(D)^j}$$

V is RMS phase to ground voltage

C is the equivalent capacitance
t is the prearc duration
L is the inductance in the discharge circuit
D is the full cycle damping factor

These are good when there are several loops of discharge during the prearc time. It sums the contribution from each loop to get the total charge transferred.

When the natural frequency is so low that there are 2 or fewer loops of current during “t” then it gets in accurate.

If there is less than one loop things get dicey.

If there is ½ of a loop it is ok table below is an example

Loop fraction	Charge fraction
1.0	1.0
0.75	.91
0.5	0.5
0.25	.087

Name	Affiliation	role	TF on inrush rating structure
Roy Alexander	RWA Engineering LLC	Chair	yes
Brian Roberts	Southern States	Secretary	yes
Denis Dufournet	GE Grid solutions	member	
Xi Zhu	Ge Grid solutions	member	yes
Jan Weisker	Siemens	member	yes
Helmut Heirmeir	ABB	member	yes
Neil McCord	Soutern States	member	
Anne Bosma	ABB	member	
Luke Colletti	MEPPI	member	yes
Vernon Toups	Siemens	member	
Carl schuetz	ATC	member	yes
Neil Hutchins	Southern Company	member	
Jim Van deLight	shaw	member	yes
Alan Morse	schnieder	member	
Nigel McQuin	McQuin Consulting	member	
Sushil Shinde	ABB	member	yes
Jeff Brogdon	?	member	yes
Arben Bufi	HVB	member	
Hua Liu	SCE	member	yes
Tom Pellerito	DTE	Guest	
Dragan Tabakovic	?	Guest	
Curtiss Frazier	Ameren	Guest	
Roy Ayers	Nespower	Guest	
Bruce Fennell	Nespower	Guest	
Chuck Corley	Eaton	Guest	
Alex Hoover	Siemens	Guest	
John Houston	?	Guest	
Rich York	MEPPI	Guest	yes
Vincent Marshal	Southern Company	Guest	
Michael Christian	ABB	Guest	
Pat Dilillo	Con Ed	Guest	
Jason Cunningham	HVB	Guest	
John Hall	TVA	Guest	
Jon Schumann	ATC	Guest	
Will Zhang	Hitachi	Guest	
Amir Khosravi	BC hydro	Guest	
Bob Behl	ABB	Guest	
Mike Skidmore	AEP	Guest	
Stephen Cary	GE Grid solutions	Guest	yes