General Rating Structure of High Voltage Circuit Breakers: IEEE C37.04-1999
and
Considerations for selection of Circuit Breakers for Capacitive Current Switching and TRV

Summary Prepared by
Himanshu Bahirat
Michigan Technological University
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General Rating Structure of High Voltage Circuit Breakers :IEEE C37.04-1999

Recloser Type	PVDR	PVDR
Rated Maximum Voltage	15.5kV	27.0kV
Nominal Voltage	15.5kV	27.0kV
Frequency	60Hz	60Hz
Low Frequency Withstand		
60Hz dry for 1 minute	50kV	60kV
60Hz wet for 10 seconds	45kV	50kV
Fullwave Withstand - B.I.L.	110kV	125kV
Continuous Current Rating @ 60Hz	200A thru 1120A	200A thru 1120A
Standard Duty Cycle	O + 0 sec + CO + 5 sec + CO	O + 0 sec + CO + 5 sec + CO
Interrupting Time	5 cycles (3 cycles optional)	5 cycles
Closing Time	4.5 cycles	4.5 cycles
Rated Short Circuit (RMS)	2kA thru 16kA	2kA thru 16kA
Close and Latch Rating		
RMS Asymmetrical	3kA thru 26kA	25.6kA
Peak 5kA thru	43kA	42.5kA
3 Second Short Time Currect Rating (RMS)	2kA thru 16kA	16.0 kA
Reclosing Time	5 or 3 seconds	5 or 3 seconds
Permissible Tripping Delay	2 seconds	2 seconds
Capacitance Current Switching		
General Purpose Duty		
Line Charging Current	2A	2A
Isolated Cable Charging Current	250A	250A
Isolated Capacitor Bank Rating	250A	250A
Transient Recovery Voltage Peak	29kV	50.5kV
Time to Crest of Transient Recovery Voltage	36 microseconds	52 microseconds
Number of Operations		
Load Current Switching	2500 Before Servicing	2500 Before Servicing
Full Fault Unit Operations	18 Before Servicing	18 Before Servicing
Control Voltage	DC: 48V, 125V, 250V AC: 120V, 240V (60Hz)	DC: 48V, 125V, 250V AC: 120V, 240V (60Hz)

GE Technical Data of Power/Vac Three Phase Vacuum Recloser

Considerations for selection of Circuit Breakers for Capacitive Current Switching

Ratings for capacitance current switching

1) Rated overhead line charging current;
2) Rated isolated cable and isolated shunt capacitor bank switching current;
3) Rated back-to-back cable and isolated shunt capacitor bank switching current;
4) Rated transient inrush current peak;
5) Rated transient inrush current frequency;

Considerations for selection of Circuit Breakers for Capacitive Current Switching

Capacitive currents can be encountered in following situations :-

- Switching of no-load overhead lines
- Switching of no-load cables
- Switching of capacitor banks
- Switching of filter banks

Selection of rating of circuit breakers to switch capacitive current following considerations are required:-

- Application
- Power frequency of the network
- Grounding situations of the network
- Presence of single or two phase ground faults

Overhead line charging current and Interruption

No-Load Overhead Lines :-
- Uncompensated
- Compensated

Uncompensated lines :- Especially long lines are represented as capacitance.
High charging current and Recovery voltages on interruption of charging currents

Compensated Lines :- Have lesser charging currents hence lesser recovery voltages.

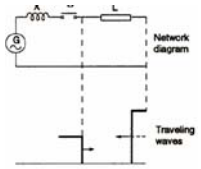


Figure —Energization of no-load lines: basic phenomena

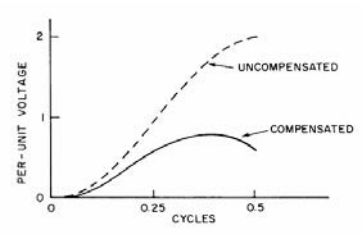


Figure —Half cycle of recovery voltage

Cable Energization and de-energization

Energization of cables :-
- Isolated Cable
- Back-to-Back Cable

The inrush currents in cables is non-oscillatory.
Initial Rate of Rise should not over the breaker rating.

$$f_{eq} = f_s\left[\frac{u_m - u_t}{\omega(L_1 + L_2)I_{ir}}\right]$$

$$i(t) = \frac{u_m - u_t}{Z_1 + Z_2}\left[1 - \exp(-\frac{Z_1 + Z_2}{L}t)\right]$$

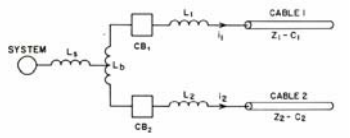
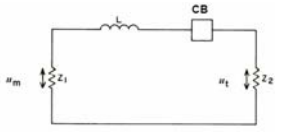


Figure —Typical circuit for back-to-back switching



Figure—Equivalent circuit for back-to-back cable switching

Shunt capacitor bank energization and de-energization

Energization of shunt capacitor banks :-
- Isolated capacitor banks
- Back-to-Back capacitor banks

The inrush currents are oscillatory and have high frequencies

Initial Rate of Rise should not over the breaker rating.

Recovery voltages can be high ,especially if there are restrikes.

$$i_i = \hat{u}\sqrt{\frac{C_1}{L_s}}\sin\omega_i t$$

and

$$f_i = \frac{1}{2\pi\sqrt{(L_s + L_1)C_1}}$$

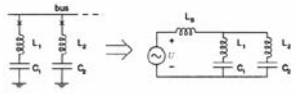


Figure —Parallel capacitor banks

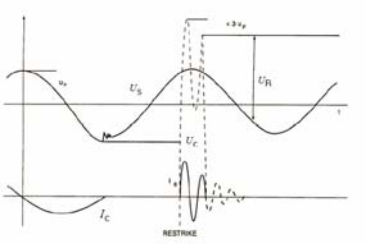


Figure —Voltage and current wave shapes in the case of a restrike

Table 3A – Preferred capacitance current switching ratings for outdoor circuit breakers rated 123 kV and above, including circuit breakers applied in gas insulated substations

				General-Purpose Circuit Breaker (1) (2)		Definite-Purpose Circuit Breaker (2)(4)				
						Isolated		Back-to-Back		
Line No.	Rated Maximum Voltage kV, rms	Rated Continuous Current Amperes, rms	Rated Short-Circuit Current kA, rms	Rated Overhead Line Current Amperes, rms	Rated Isolated Current Amperes, rms	Rated Capacitor Bank Current Amperes, rms	Rated Overhead Line Current Amperes, rms	Rated Capacitor Bank Current Amperes, rms	Rated Inrush Current (3)(5) kA, peak	Rated Inrush Current (3)(5) Frequency Hz
	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10
1	123	1200, 2000	31.5	50	50	315	160	315	16	4250
2	123	1600, 2000, 3000	40	50	50	315	160	315	16	4250
3	123	2000, 3000	63	50	50	315	160	315	16	4250
4	145	1200, 2000	31.5	80	80	315	160	315	16	4250
5	145	1600, 2000, 3000	40	80	80	315	160	315	16	4250
6	145	2000, 3000	63	80	80	315	160	315	16	4250
7	145	2000, 3000	80	80	80	315	160	315	16	4250
8	170	1600, 2000	31.5	100	100	400	160	400	20	4250
9	170	2000, 3000	40	100	100	400	160	400	20	4250
10	170	2000, 3000	50	100	100	400	160	400	20	4250
11	170	2000, 3000	63	100	100	400	160	400	20	4250
12	245	1600, 2000, 3000	31.5	160	160	400	200	400	20	4250
13	245	2000, 3000	40	160	160	400	200	400	20	4250
14	245	2000, 3000	50	160	160	400	200	400	20	4250
15	245	2000, 3000	63	160	160	400	200	400	20	4250
16	362	2000, 3000	40	250	250	500	315	500	25	4250
17	362	2000, 3000	63	250	250	500	315	500	25	4250
18	550	2000, 3000	40	400	400	500	500	500	25	4250
19	550	3000, 4000	63	400	400	500	500	500	25	4250
20	800	2000, 3000	40	900	500	500	900	--	--	--
21	800	3000, 4000	63	900	500	500	900	--	--	--

Transient Recovery Voltage

Voltage which appears across the circuit breaker contacts after interruption of fault or interruption of circuit .

It consists of the high frequency voltage superimposed on system frequency voltage

Generally the resultant voltage wave turns out to be 1-cosine wave and also has the exponential component.

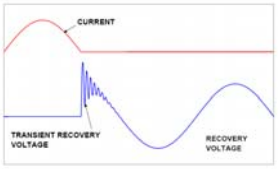


Figure 1 Current, TRV and Recovery Voltage

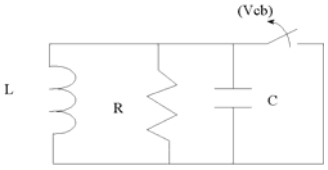


Figure – Equivalent RLC circuit

Transient Recovery Voltage

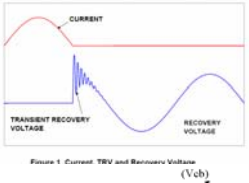
IEEE C37-011 Application guide for Transient Recovery voltage of AC High Voltage circuit breakers:-Specifies the TRV envelope to be used for selection of circuit breakers.

Based on System Voltage

System Conditions decide

The circuit breaker specific TRV envelope is to be calculated and system TRV is to be compared to this envelope.

The system TRV should be below the circuit breaker TRV envelope to make the application.



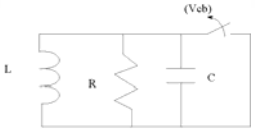


Figure – Equivalent RLC circuit

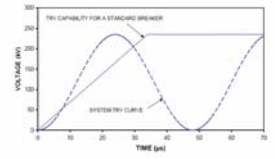


Figure 12 - Comparison of TRV capability for 145 kV circuit breaker (at 10% of its rated interrupting current capability) and system TRV

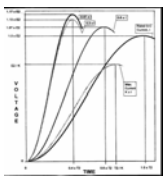
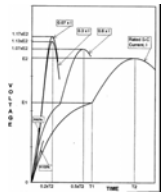


Figure —TRV envelopes 100 kV and below



Figure—TRV Envelopes above 100 kV