Multipulse Burst Surge Testing

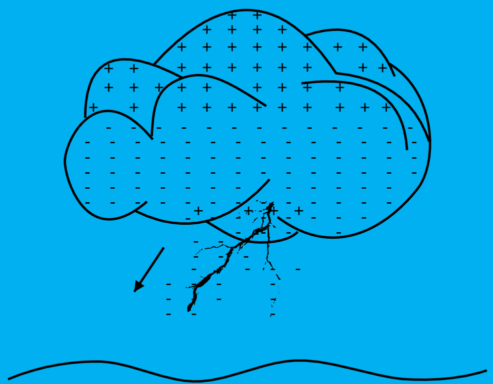
PEG CONFERENCE

Presented by:
Mick Maytum
ICT Surge Protection Consultant
ictsp-essays.info

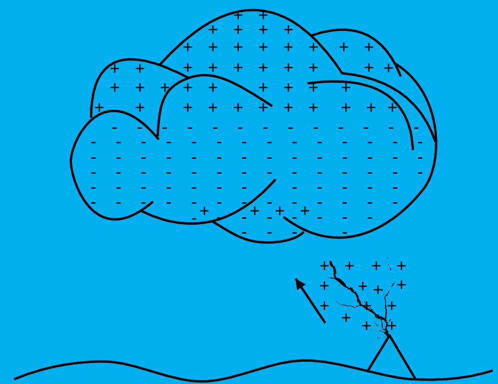
Contents

- Lightning parameters
- Multi-stroke lightning flash generators and tests
- Analysis of MOV burst capability
- Comments

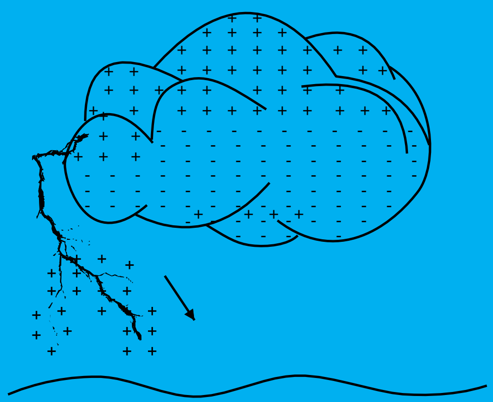
Four lightning types



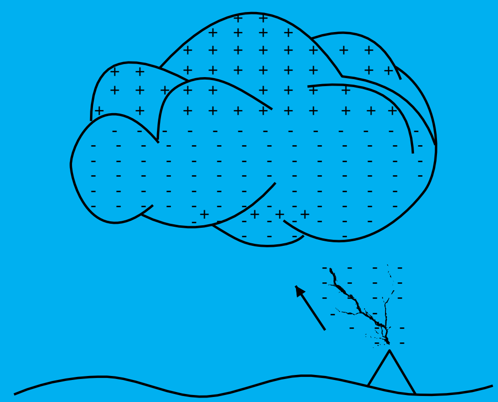
Negative Lightning — Downward - leader



Negative Lightning — Upward + leader



Positive Lightning — Downward + leader



Positive Lightning — Upward - leader

Lighting typical parameters

First stroke: 30 kA, 5.5/75, 5.2 C
Subsequent strokes: 12 kA, 1.1/32, 1.4 C,
60 ms interval, 5x
Continuing current 200 A, 15 ms, 0.3 C, 6x

Negative Lightning — Downward - leader

Initial continuing current: 100 A, 250 ms, 30 C
Followed by negative lightning flash

Negative Lightning — Upward + leader

First stroke: 35 kA, 22/230, 16 C
Flash: 65 ms, 80 C
Continuing current: 1 kA, 65 ms, 64 C

Positive Lightning — Downward + leader

First stroke: 4 kA, ?/?, ? C
Flash: 55 ms, 65 C

Positive Lightning — Upward - leader

CIGRÉ Technical Bulletin 549 Lightning Parameters for Engineering Applications, 2014 PEG

Background

http://ten350.com/index-18-test.html

For over 30 years projects have been reported on emulations of multi-stroke lightning flashes.

Many implementations consisted of multiple charged networks connected time sequentially to a common output by some form of selection switch.

2011 Beijing SPD 8/20 burst testing

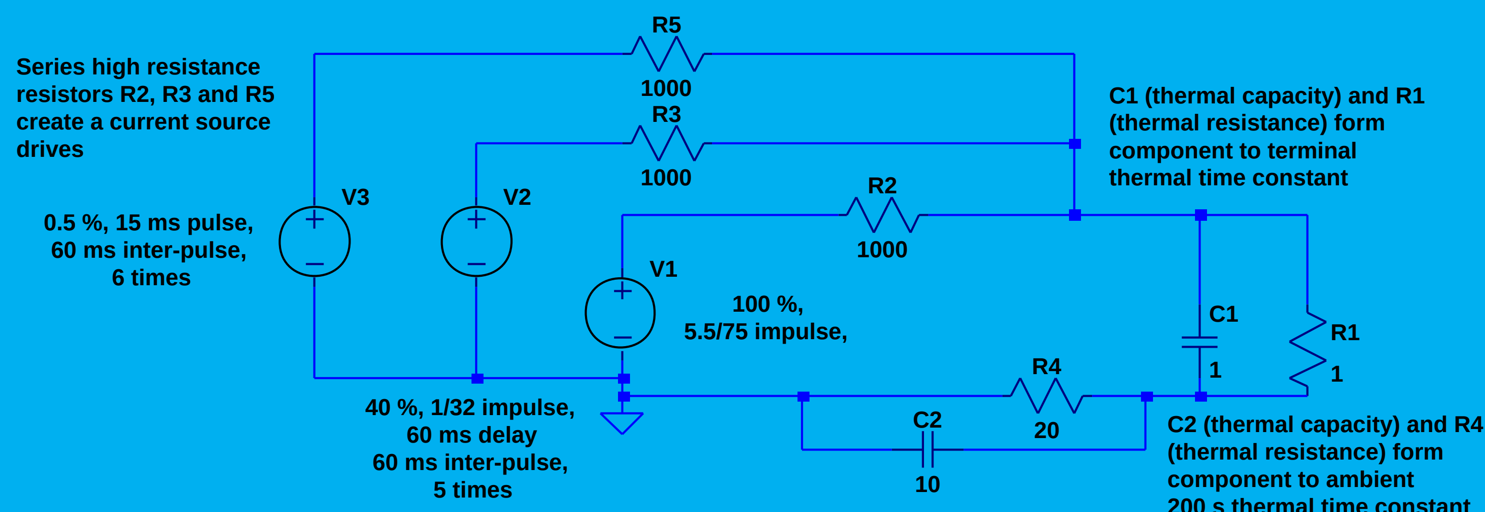
- Reported at http://ten350.com/index-17-challenge.html
- 11 manufacturers (A to K) submitted one SPD each (spark gap or MOV technologies) for a test sequence of 11 tests.
- Each part of the test sequence consisted of a 100 % amplitude 8/20 impulse followed by 1 or 3 or 5 or 8 50 % amplitude 8/20 impulses ending with a repeat of the first 100 % 8/20 impulse.
- First impulse amplitudes of 30 kA, 60 kA and 100 kA where used.
- The inter-impulse interval was 60 ms for tests 1 through 10 and 30 ms for test 11.

2011 Beijing SPD testing results

Test #	Burst amplitudes kA	Total Q C	SPD Manufacturer Test Fails	Cumulative Failures
1	30+1x15+30	1.305		
2	30+3x15+30	1.827		
3	30+5x15+30	2.349	A	1
4	30+8x15+30	3.132	B, C	3
5	60+1x30+60	2.61	D	4
6	60+3x30+60	3.654	E, F, G	7
7	60+5x30+60	4.698	H, I, J	10
8	60+8x30+60	6.264		
9	100+1x50+100	4.35		
10	100+3x50+100	6.09		
11	100+5x50+100	7.83	K damaged	

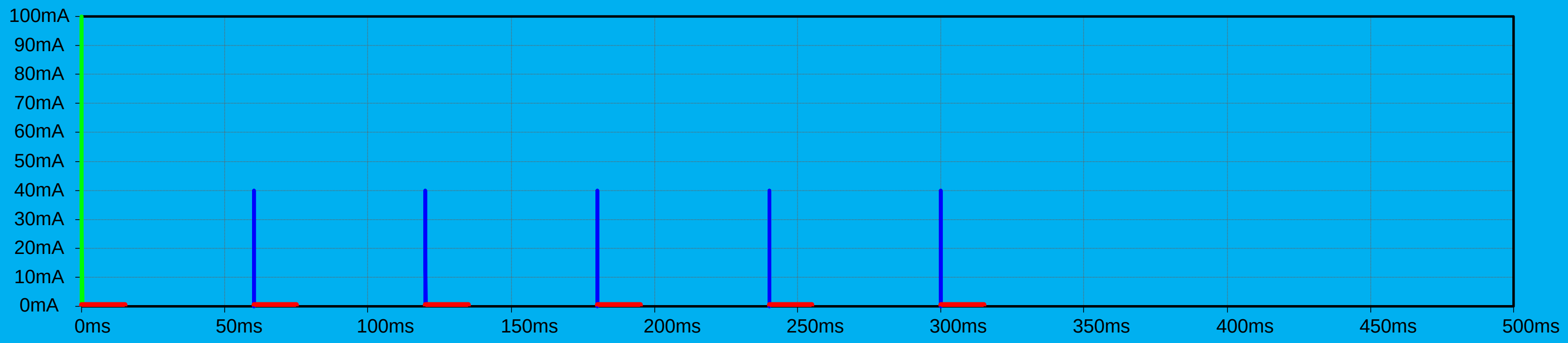
Simplified thermal modeling

Thermal circuits can be modelled like electrical circuits with the current being the thermal energy (W), voltage being temperature (°C), resistance being thermal resistance (K/W) and capacitance being thermal capacity (J/K). The model has three thermal energy sources; V1 the first impulse, V2 the subsequent 5 impulses and V3 the continuing current following each impulse. C1 and R1 form the component thermal circuit and C2 and R4 form the thermal circuit from component to ambient.



Thermal modeling impulses

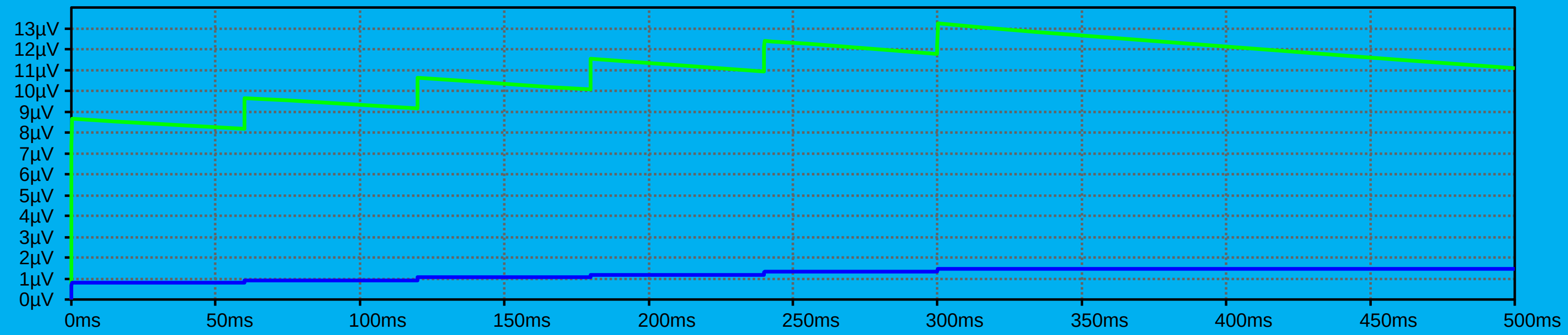
Green is first 100 % 5.5/75 impulse. Blue is the subsequent 5 40 % 1/32 impulses. Red is the 0.5 % 15 ms continuing current pulses following each impulse. Inter-impulse time is 60 ms.



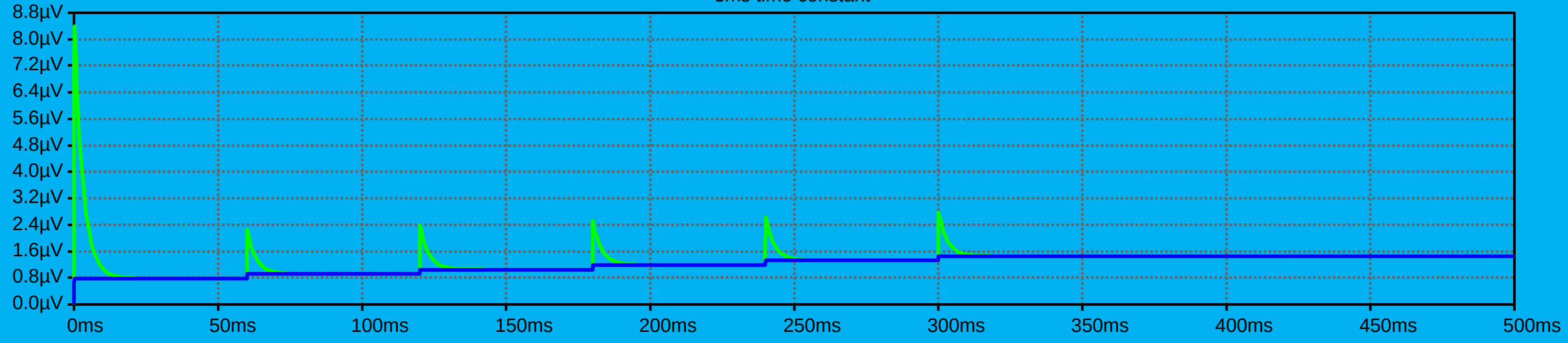
Thermal modeling temperatures - 1

These graphs show first and subsequent impulses only for component time constants of 1 s (MOV) and 3 ms (silicon). Green is the component internal temperature. Blue is the component terminal temperature.

1 s time constant

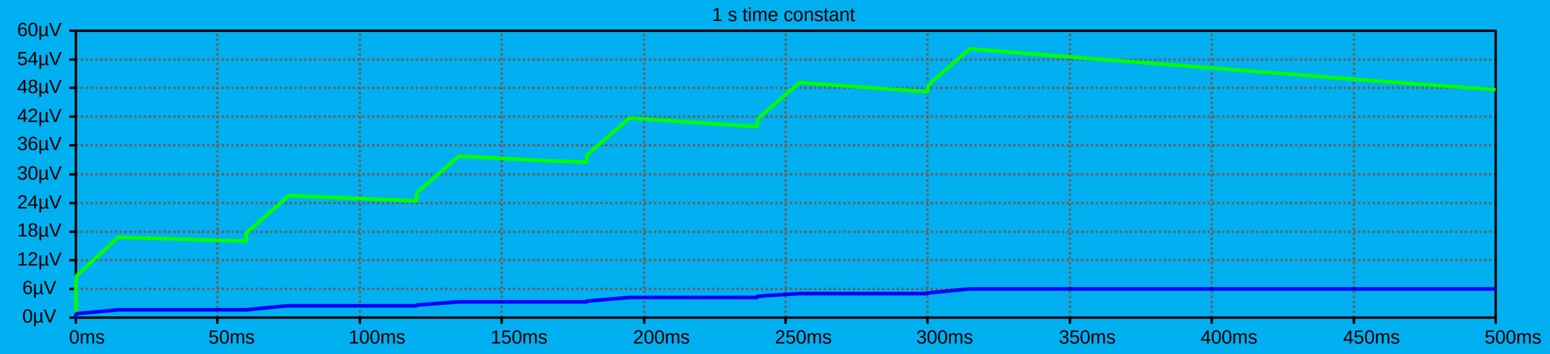


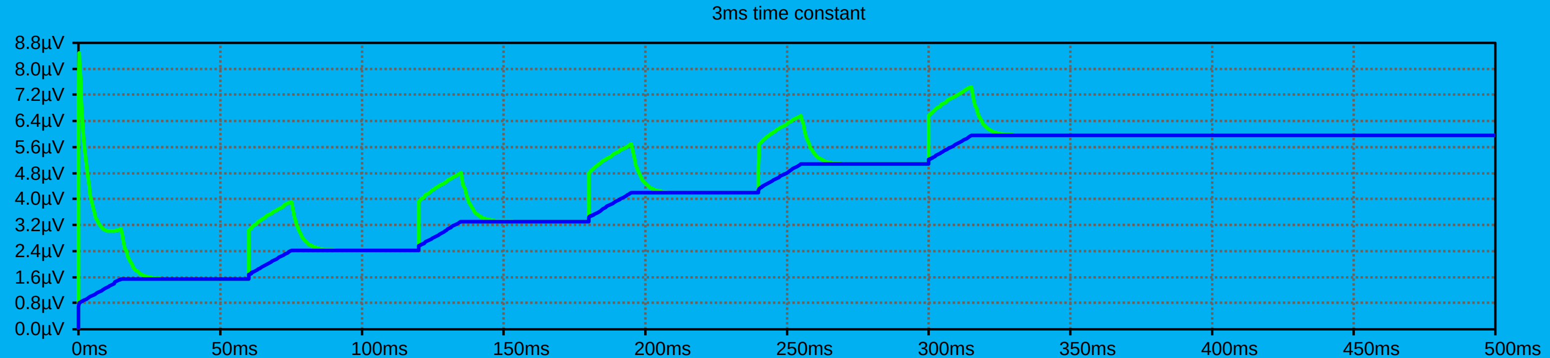
3ms time constant



Thermal modeling temperatures - 2

These graphs show first and subsequent impulses together with continuing current pulses for component time constants of 1 s (MOV) and 3 ms (silicon). Green is the component internal temperature and blue is component terminal temperature.



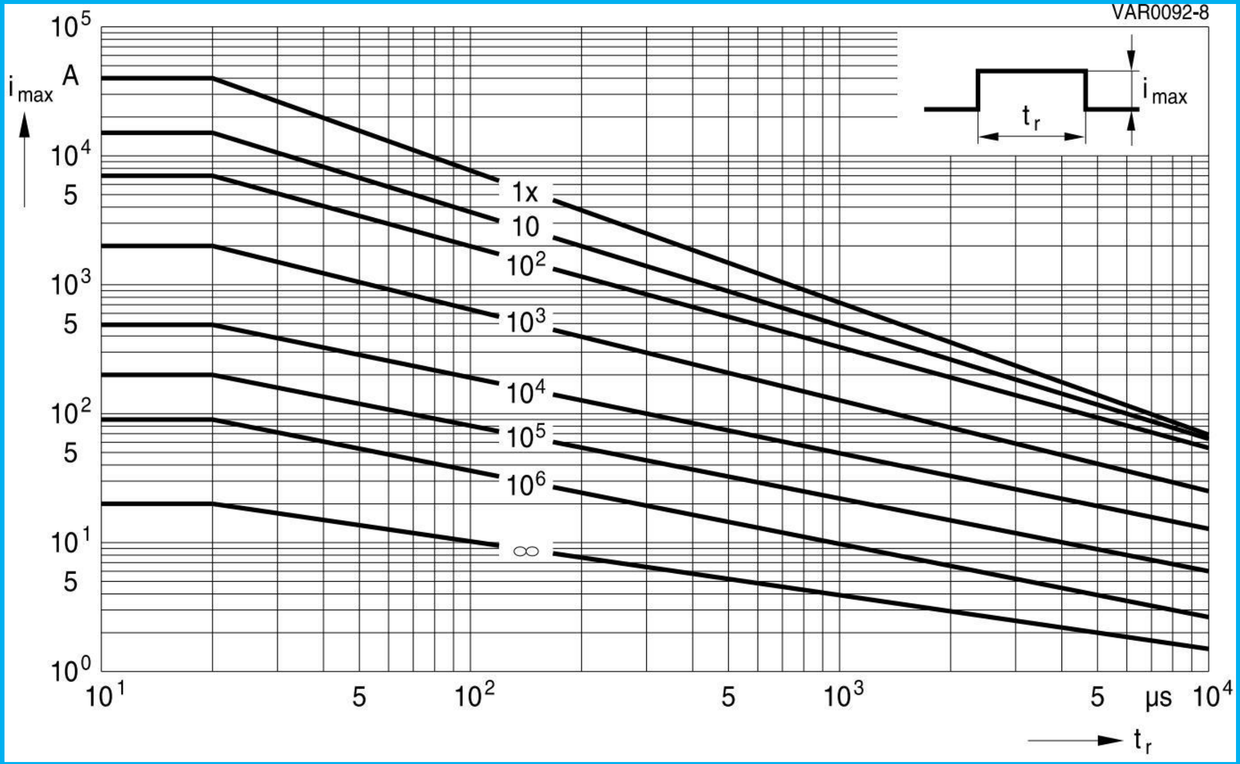


Thermal modeling takeaways

- Components with long thermal time constants (MOVs) will step up in temperature during the impulse burst.
- Components with short thermal time constants (silicon) will recover to ambient (terminal) temperature during the inter-impulse period.
- Low amplitude, but long ms duration, continuing current pulses may cause more temperature rise than the impulses particularly for long thermal time constant components.

MOV Design Example - 1

MOV parameters 40 kA @ 8/20, $V_{(BR)}$ 1 mA 510 V ±10 %, V_{CMAX} = 840 V @300, 640 J @ 2 ms and P_D 1.4 W.

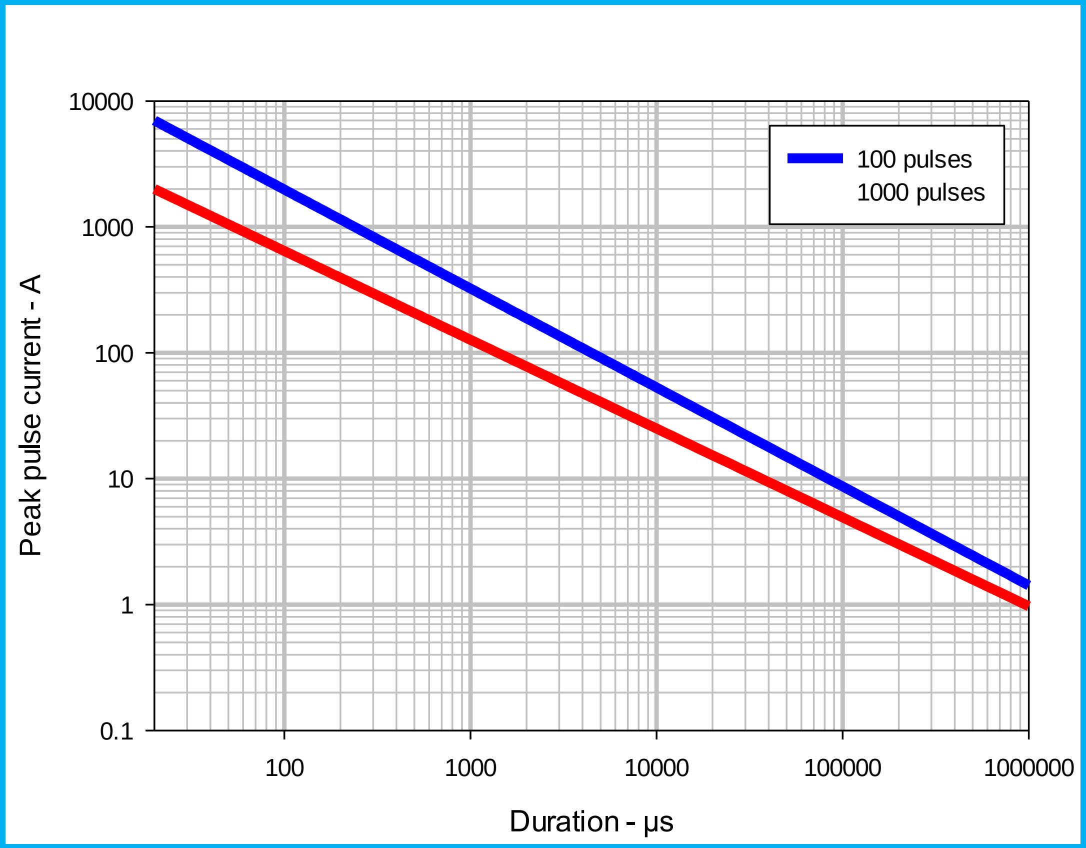


i_{MAX} = EXP(a-b*LN(t_r))
for tr >20 µs

pulses	a	b
1	13.66	1.021
10	12.24	0.876
100	11.21	0.786
1000	9.71	0.705
10000	8.01	0.600
100000	6.99	0.564
1000000	6.21	0.570
infinity	4.25	0.417

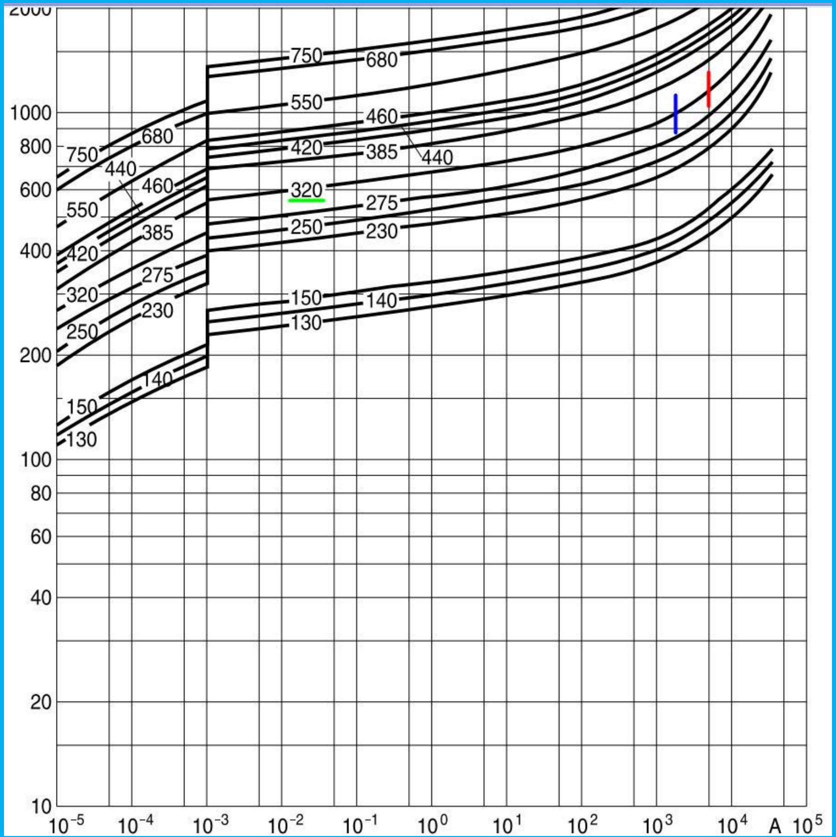
MOV Design Example - 2

Extended duration peak pulse current vs duration curves for 100 and 1000 pulses.



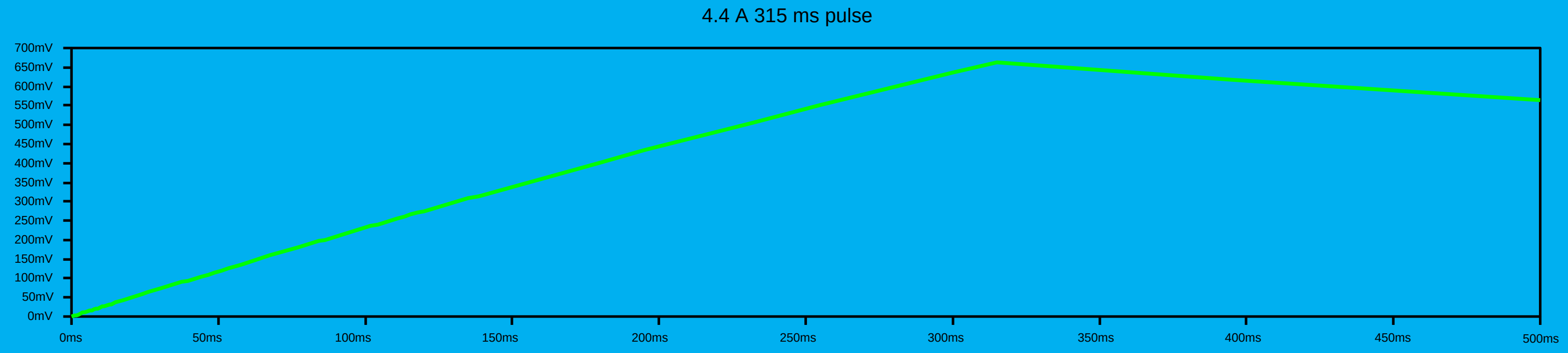
MOV Design Example - 3

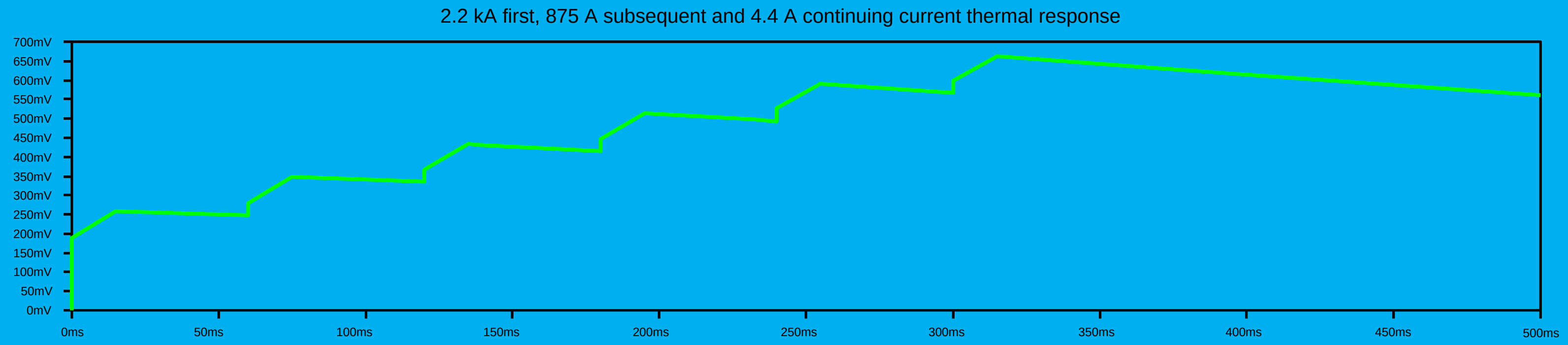
Voltage vs current characteristic



MOV Design Example - 4

A 2.2 A 315 ms impulse (1000 pulse rating) creates a thermal circuit voltage peak of 0.663 V. To create a similar burst rise requires values of 2.2 kA 5.5/75, 875 A 1/32 (5x) and 4.4 A 15 ms pulse (6x).





MOV Design Example - 5

Summary

- This work indicates that the chosen 40kA 8/20 single impulse MOV has a durability of 1000, 315 ms bursts of 2.2 kA 5.5/75 + 875 A 1/32 (5x) + 4.4 A 15 ms continuing current pulses (6x).
- Continuing current can be responsible for most of the burst temperature rise.
- On powered a.c. lines the continuing current can be absorbed by the a.c. supply.
- MOV manufacturers could help by supplying derating curves extended to 1 s and thermal parameters.
- Typical burst values should be worked with as extreme burst values will get nowhere near 40 kA and will be counteracted by lower than typical bursts.

Comments

- Further development of burst testing should comprehend continuing current
- We should be interested in burst durability not the maximum single burst withstand.
- **MOVs** could be verified by derating curves, V-I curves, thermal models and "real" (~~8/20~~) burst models.
- On powered a.c. lines the continuing current can be absorbed by the a.c. supply.
- **Silicon PN junction voltage limiters** should be verified to the maximum amplitude surge as they fail instantly when their surge rating is exceeded. In many cases only the first single pulse is relevant.
- **GDT ?**