

Surge current rating (or I_{max}): everything about it



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Surge current rating (or I_{max}): everything about it

- The discussion is about one of the most famous characteristics claimed by the US SPD manufacturers and requested by the SPD's users through specifications. Surprisingly, that characteristic is not defined anywhere in the official literature. There are several discussions on how to clarify the definition of the I_{max} at various standardization organization levels but no agreement yet has been reached. This means that manufacturers and users are totally free to interpret what the I_{max} could be... There isn't a right or wrong definition of the I_{max} , and this paper is an attempt to sum up all the various interpretations that can be found in the field depending on who is addressing them or justifying them.
- This paper will also attempt to provide various key points on the definition for the selection of SPDs based on this characteristic and its impact when the SPD is in use.
- During the discussion, the surge risk will be addressed and the expected life duration of an SPD.



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Specification in the US...

3 – PRODUCTS

...

3.2 AC POWER :

...

3.2.2 PERFORMANCE

...

3.2.2.2 SPD Maximum Discharge Current per phase ($I_{max} - 8/20\mu s$) shall be:

- a. **450 kA** or above for Service Entrance or transfer Switch.
- b. **200 kA** or above for Distribution Panelboard and MCC
- c. **100 kA** or above for Branch Panel

...

Specification in the US...

B. Service Entrance/Transfer Switch SPDs:

...

5. Minimum Surge Current Rating: **200kA** per phase.

...

Specification in the US...

...

2.11 SURGE PROTECTIVE DEVICE(S)

A. Electrical Requirements

2. ...

3. The device shall have a minimum surge current rating of **125kA** per mode / **250kA** per phase with a minimum of 20,000 category C3 impulses (10kA, 20kV) per mode.

4. ...



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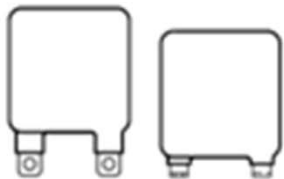
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***What Is this Surge Current Rating
or I_{max} ??***

***What does it mean for SPD
selection???***

MOV Manufacturers data...



Strap varistors

HighE, standard, LS40 series

Maximum ratings ($T_A = 85^\circ\text{C}$)

Ordering code	Type	V_{RMS}	V_{DC}	i_{max} (8/20 μs)	V_{max} (2 ms)	P_{max}
	SIOV-	V	V	A	V	W
Bent strap terminals						
B70 40L 141K 100	LS40 141K 20QP	130	170	40000	310	1.4
B70 40L 141K 100	LS40 141K 20P	140	180	40000	340	1.4
B70 40L 141K 100	LS40 141K 20P	150	200	40000	360	1.4
B70 40L 141K 100	LS40 141K 20P	230	300	40000	460	1.4
B70 40L 141K 100	LS40 141K 20P	250	320	40000	490	1.4
F 22 0L027 100	LS40 270K 20P	275	350	40000	550	1.4
L 2240L0321 100	LS40 320K 20P	320	420	40000	640	1.4

MOV Manufacturers data...

Electrical Characteristics (@ $T_A = 25\text{ }^{\circ}\text{C}$ Unless Otherwise Noted)

Bourns Part No.	Max. Continuous Voltage (V)		Voltage @ 1 mA DC (V)			Voltage @ Class Current (8/20 μs)		Max. Peak Current (8/20 μs)	Max. Energy (J)	Max. Cap. (pF)
	r.m.s.	d.c.	Min.	Nom.	Max.	Class Current (A)	Max. Clamping Voltage (V)	One Time	8/20 μs	1 kHz
MOV-20D180K	11	14	16	18	20	20	36	2000	11.0	28500
MOV-20D220K	14	18	20	22	24	20	43	2000	14.0	18500
MOV-20D270K	17	22	24	27	30	20	53	2000	18.0	13000
MOV-20D330K	20	26	30	33	36	20	65	2000	23.0	11500
MOV-20D390K	25	31	35	39	43	20	77	2000	26.0	8500

MOV Manufacturers data...

METAL OXIDE VARISTORS

34 Ultra High Energy (UHE) Series Electrical Characteristics

34.5mm - 1"

Part Number	Maximum Continuous Rated Voltage		Rated Single Pulse Transient		Varistor Voltage @1mA DC		Maximum Clamping Voltage @Test Current 8/20µs		Typical Capacitance @1KHZ 25°C
			Energy	Peak					
	AC RMS Volts	DC Volts	10/1000µs (joules)	8/20µs KA	Min Volts	Max Volts	Volts	Amps	pF
EV 150K-H	60	85	200	45	90	110	165	300	15000
EV 175K-H	75	100	250	45	108	132	200	300	12200
EV 195K-H	95	125	300	50	135	165	250	300	10000
EV 220K-H	120	150	400	50	162	198	300	300	8250
EV 240K-H	130	170	450	50	185	225	340	300	6750
EV 260K-H	140	180	500	50	198	242	360	300	6400
EV 280K-H	150	200	550	50	222	270	395	300	5650

MOV Manufacturers data...

Device Ratings & Specifications

Part Number	Maximum Rating (75°C)					Specifications (25 °C)				
	Continuous		Transient			Varistor Voltage at 1mA Test Current		Maximum Clamping Voltage 8/20µs		Typical Capacitance f = 1MHz
	AC Volts	DC Volts	Energy 2ms	Peak Surge Current 8/20µs	Nominal Discharge Current	Varistor Voltage at 1mA Test Current		Maximum Clamping Voltage 8/20µs		Typical Capacitance f = 1MHz
	$V_{M(AQ)}$	$V_{M(DC)}$	W_{TM}	I_{TM}	I_n	$V_{N(DC)}$	$V_{N(DC)}$	V_c	I_{PK}	C
	(V)	(V)	(J)	1 x Pulse (A)	(A)	(V)	(V)	(V)	(A)	(pF)
MOV3451	115	150	280	40000	20000	162	198	305	200	11500
MOV3451N	130	175	310	40000	20000	184.5	225.5	345	200	10000
MOV3451M	150	200	360	40000	20000	216	264	405	200	8000
MOV3451S	180	240	400	40000	20000	256	312	488	200	6800



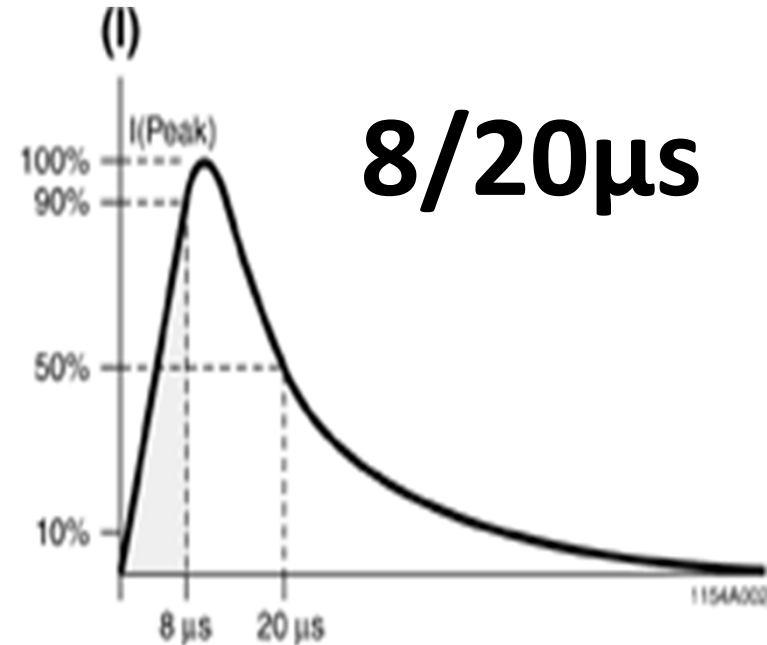
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Wave Shape???

*From
Specifications
and MOV
manufactures:*





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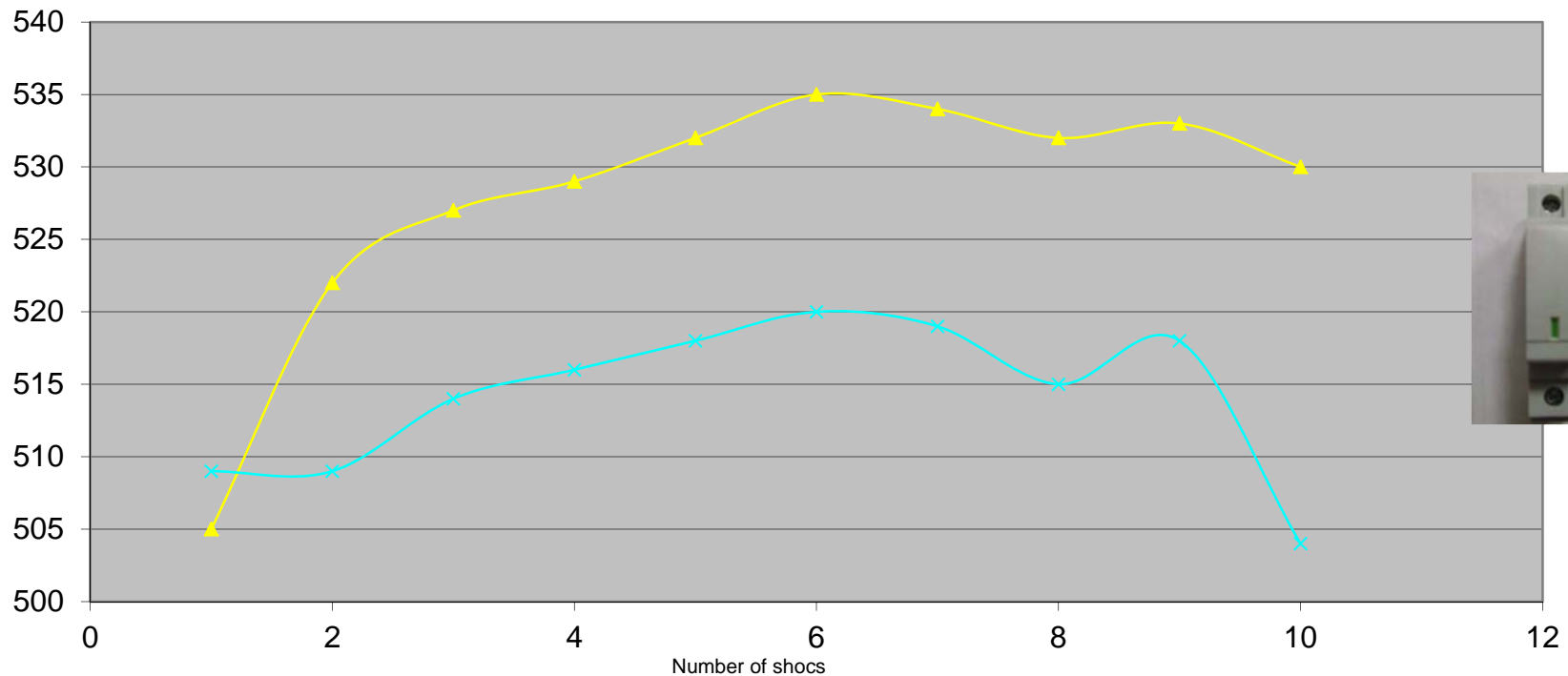
What pass criteria?

***Depending on MOV
manufacturers...***

What pass criteria? For SPD manufacturer???

Evolution of the voltage to get 1mA of current flowing through an MOV rated 40kA I_{max} (20kA I_n) versus the number of shocks set to I_{max} (40kA 8/20)

Voltage to get 1mA
(V)



—▲— Echantillon # 2 U1mA en > 0 (en Volt)

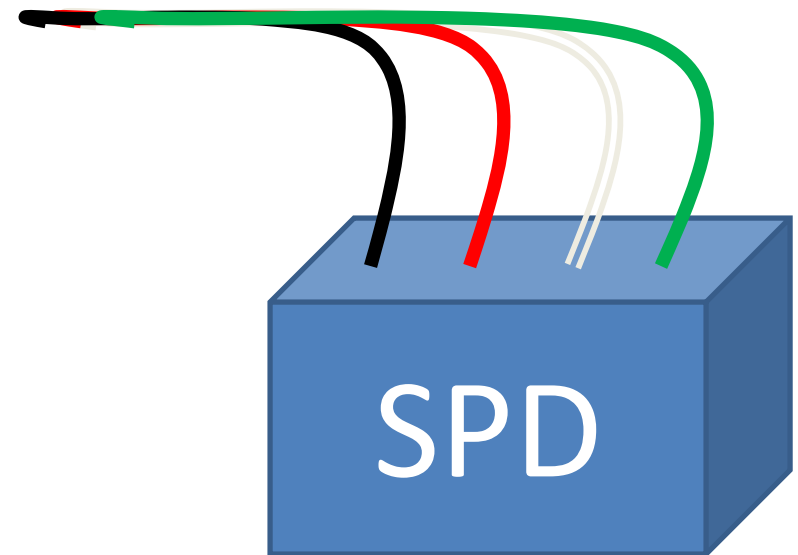
—×— Echantillon # 2 U1mA en < 0 (en Volt)

SPD: Per mode, Per Phase, I_{total} ...

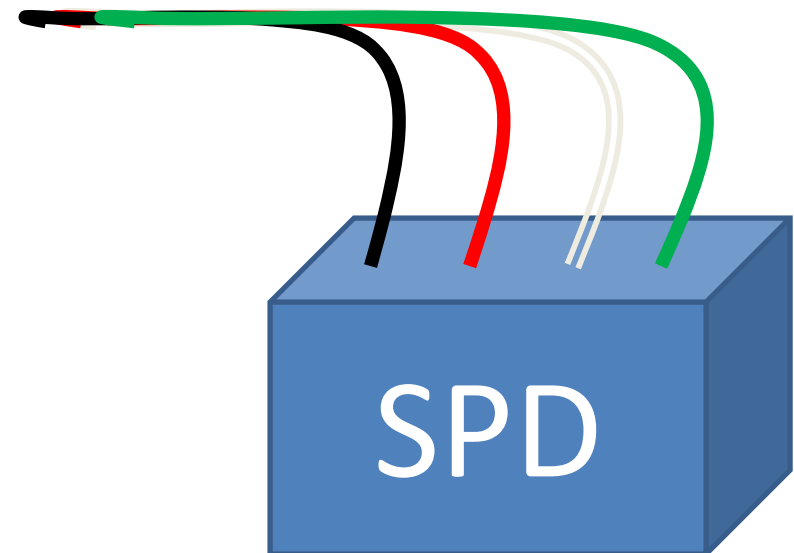
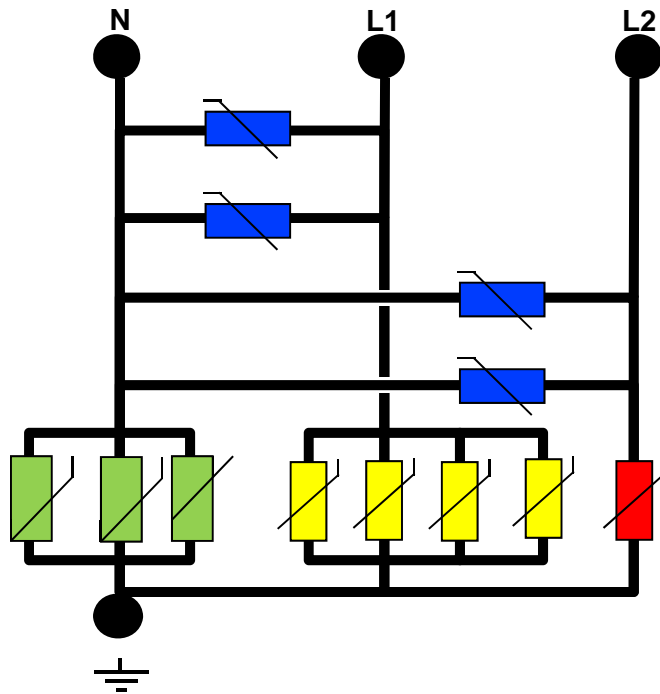
***What can happen in
this box???***

***How the surge current
will split?***

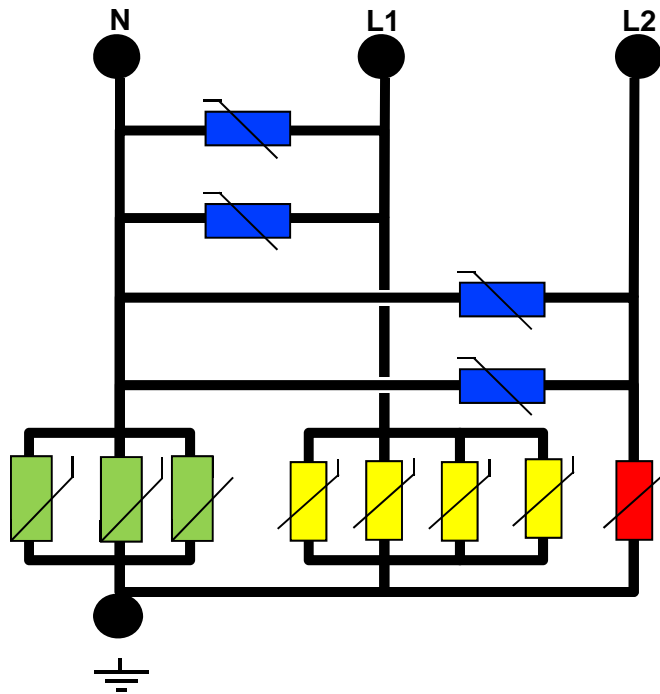
***Is the power system
impacting this surge
current sharing?***



SPD: Per mode, Per Phase, I_{total} ...



SPD: Per mode, Per Phase, I_{total}...



Per Mode:

L1-N = 40kA

L2-N = 40kA

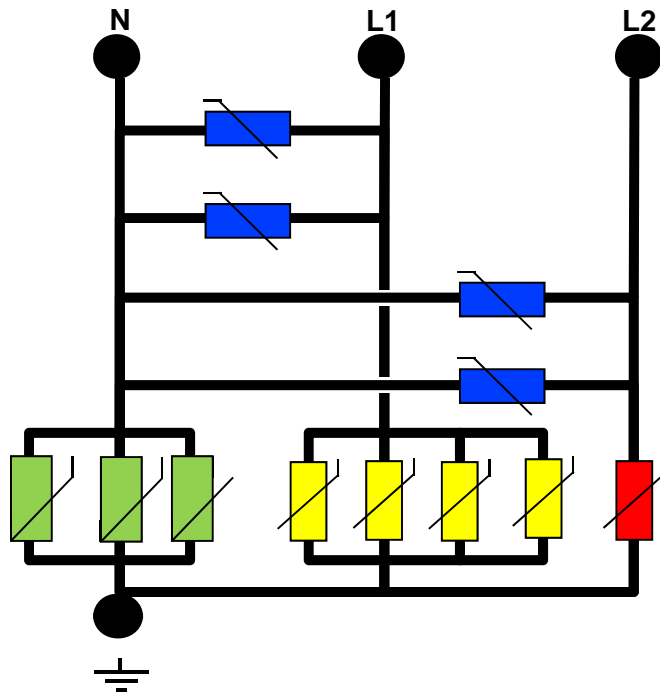
L1-G = 80kA

L2-G = 20kA

N-G = 60kA

Let's assume that 1 MOV is 20kA

SPD: Per mode, Per Phase, I_{total}...



Per Phase:

L1:

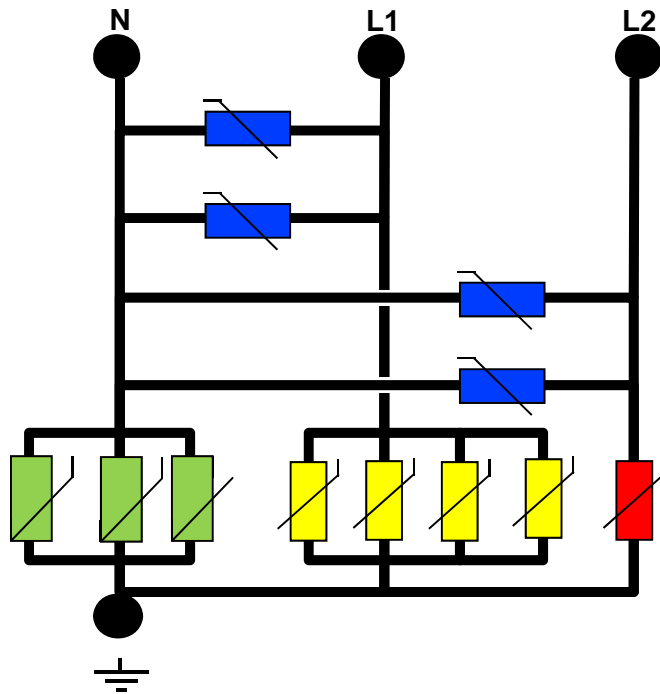
$$(L1-G) + (L1-N) = 120kA$$

L2

$$(L2-G) + (L1-N) = 60kA$$

Let's assume that 1 MOV is 20kA

SPD: Per mode, Per Phase, I_{total}...



Total:

$$(L1-G) + (L2-G) + (N-G) = 160kA$$

Let's assume that 1 MOV is 20kA



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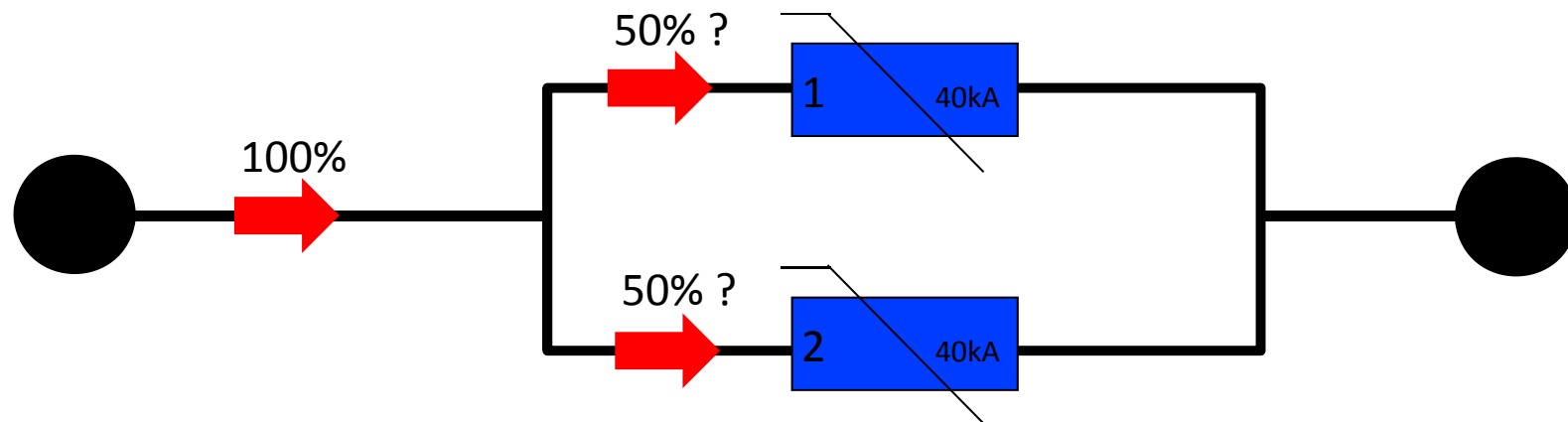
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Current Sharing...

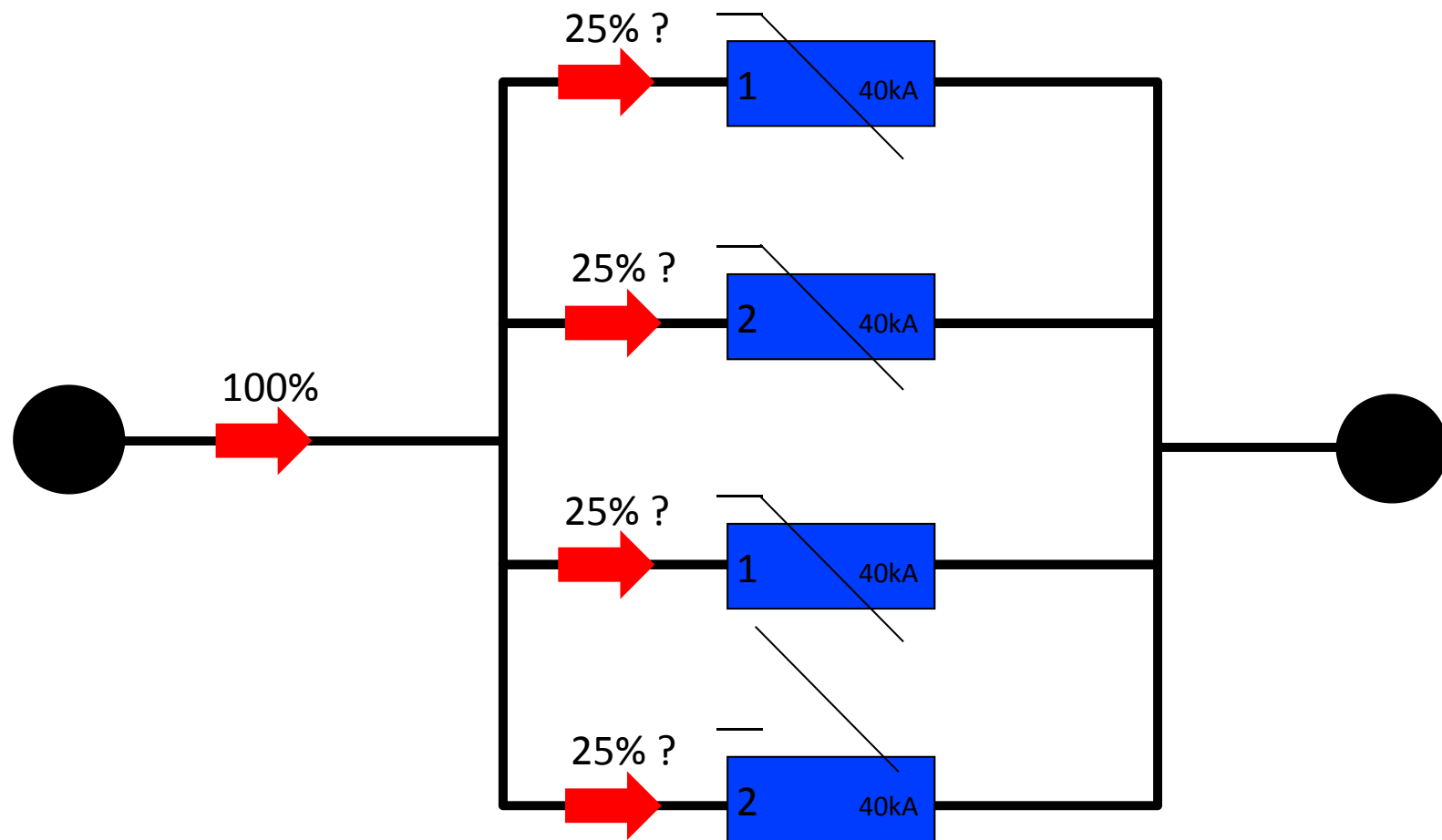
- When several MOVs in parallel are subject to surge current, the exact quantity of energy that each single MOV will have to withstand is not equal to the other MOVs resulting in the chance that one MOV is exposed to higher energy that it can handle.
- It is possible to apply a de-rating coefficient to consider this point.

Current Sharing... Real life for I_{max} ...

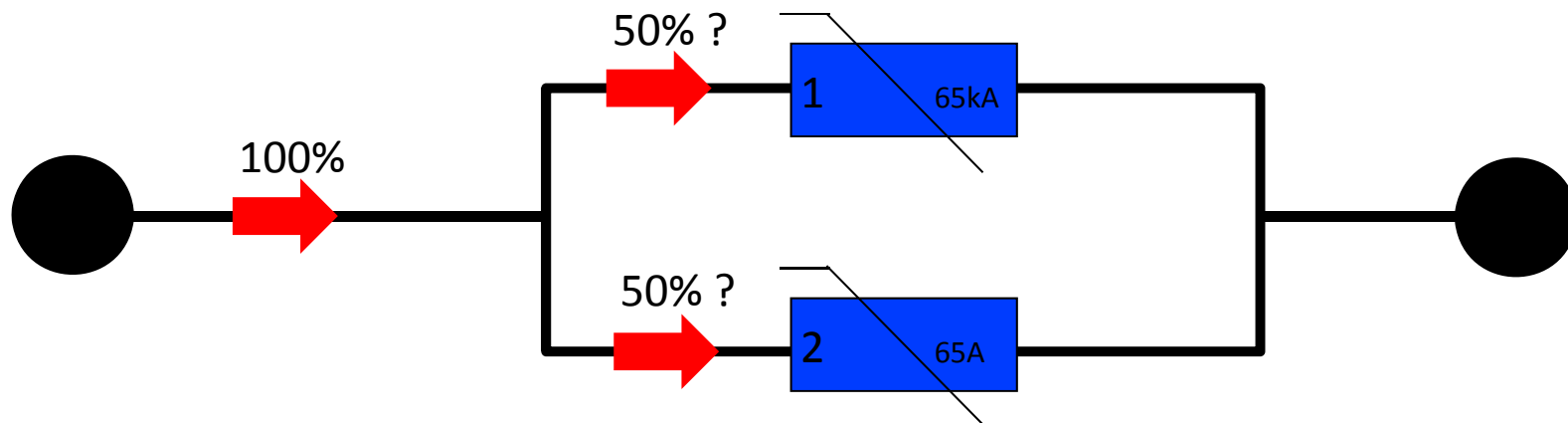


- **Worst case:** $I_{max} = 0.8 \times (I_{max_1} + I_{max_2}) \rightarrow I_{max} = 65kA$
- **Medium case:** $I_{max} = 0.9 \times (I_{max_1} + I_{max_2}) \rightarrow I_{max} = 72kA$
- **Dreamed case:** $I_{max} = 1 \times (I_{max_1} + I_{max_2}) \rightarrow I_{max} = 80kA$

Current Sharing... Real life for I_{max} ...



Current Sharing... Real life for I_{max} ...



- **Worst case:** $I_{max} = 0.8 \times (65 + 65) \rightarrow I_{max} = 104kA$

Instead of: $4 \times 40 = 160kA!!!!$

TEST?

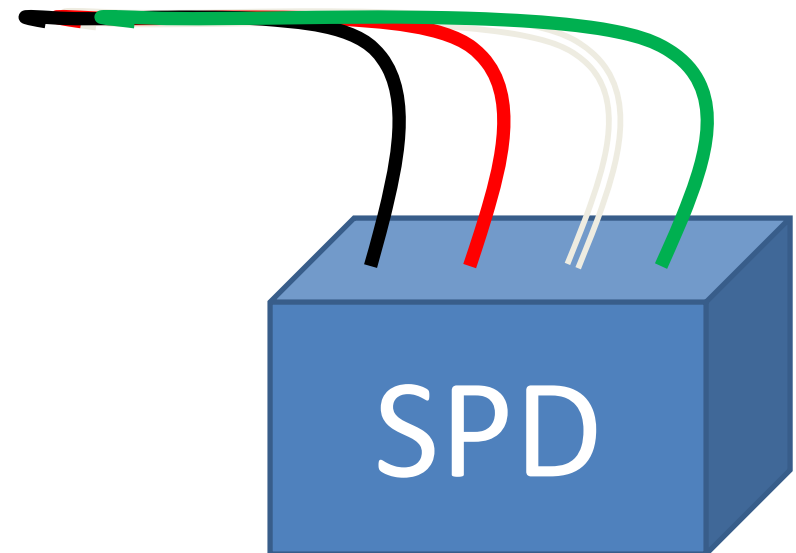
IEC propose one but it is optional:

2 shocks at I_n (+&-) + 1 single shock at I_{max} .

- These 3 shocks are with cooling time in between each shocks.
- Power is supplied to the SPD during shocks (90° and 270°).

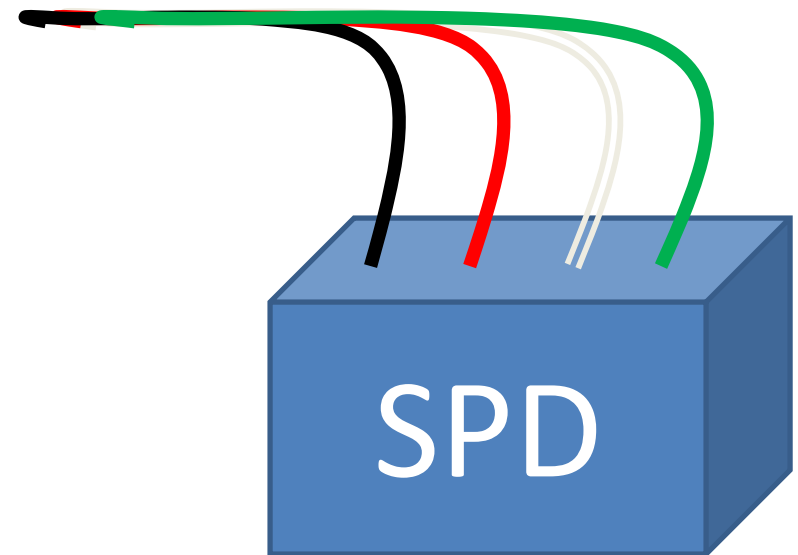
Pass Criteria:

No explosion (only!!!)



TEST?

***No test is today
available in the
US do test this
I_{max} or Surge
rating for an SPD.***



Risk in real installation??

First approach is to reject these values for the very good reason that an installed SPD will never be subjected to these (as a recall, usual stress evaluated by various US guides or standards is less than 20kA).

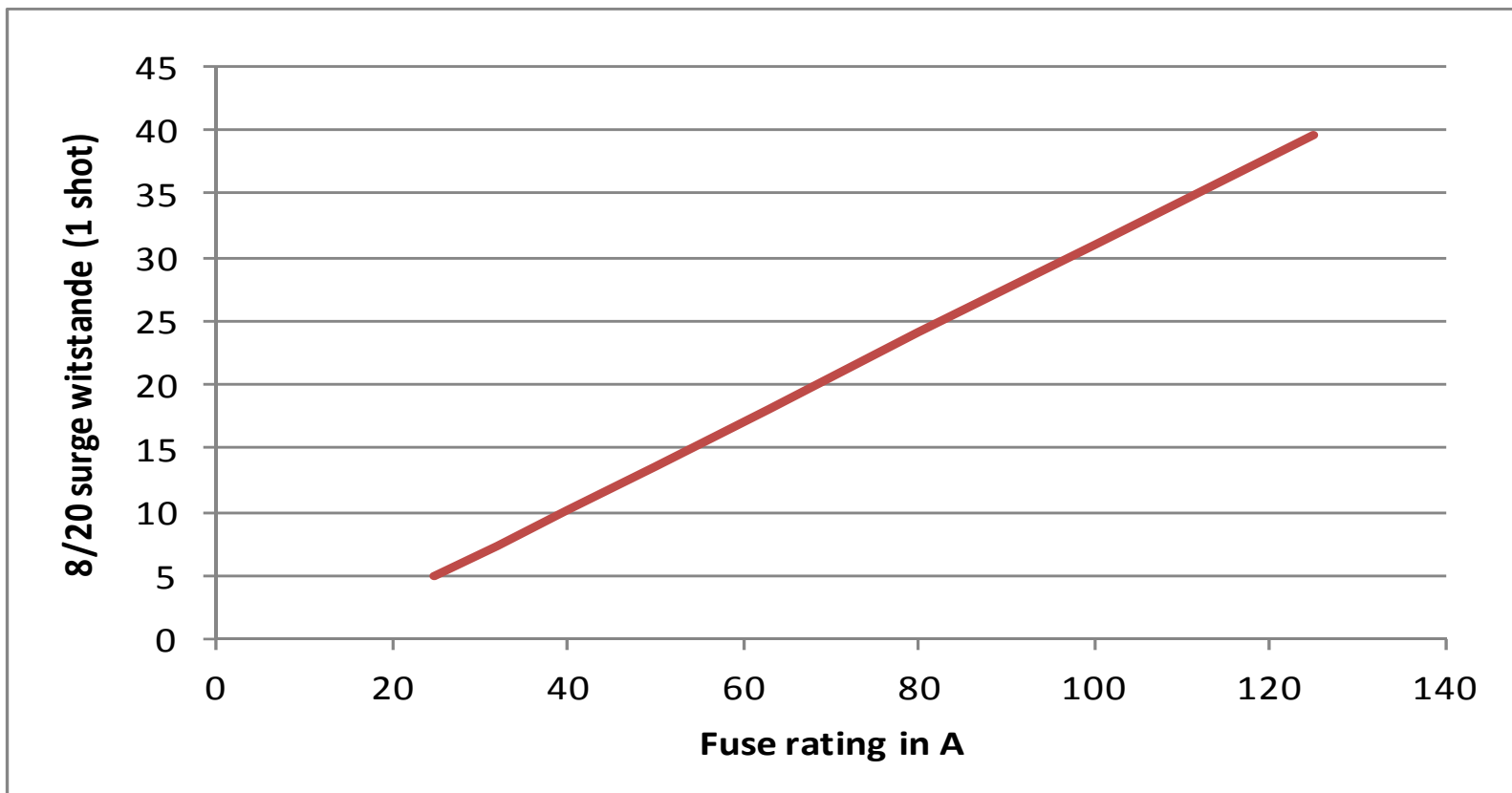


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Risk in real installation??





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400kA 8/20 μ s test lab???

Risk in real installation??

IEC has a different approach when the maximum threat is to be considered... But not to be discussed here...

Even if recent input from IEEE groups introduced new parameters such as:

- Different wave form (See RHU IEEE guide)
- Number or surge repetitions



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What could be the benefit of Surge current rating (or I_{max}) as it is presented today in the US?

- Marketing horse power race???
 - ➔ For sure!!!!
- Expressing the maximum stress that the SPD can withstand???
 - ➔ More than doubtful!!!
- Expressing the maximum stress that the installation is going see one day???
 - ➔ No way!!!

The device shall have a minimum surge current rating of **125kA** per mode / **250kA** per phase
.....



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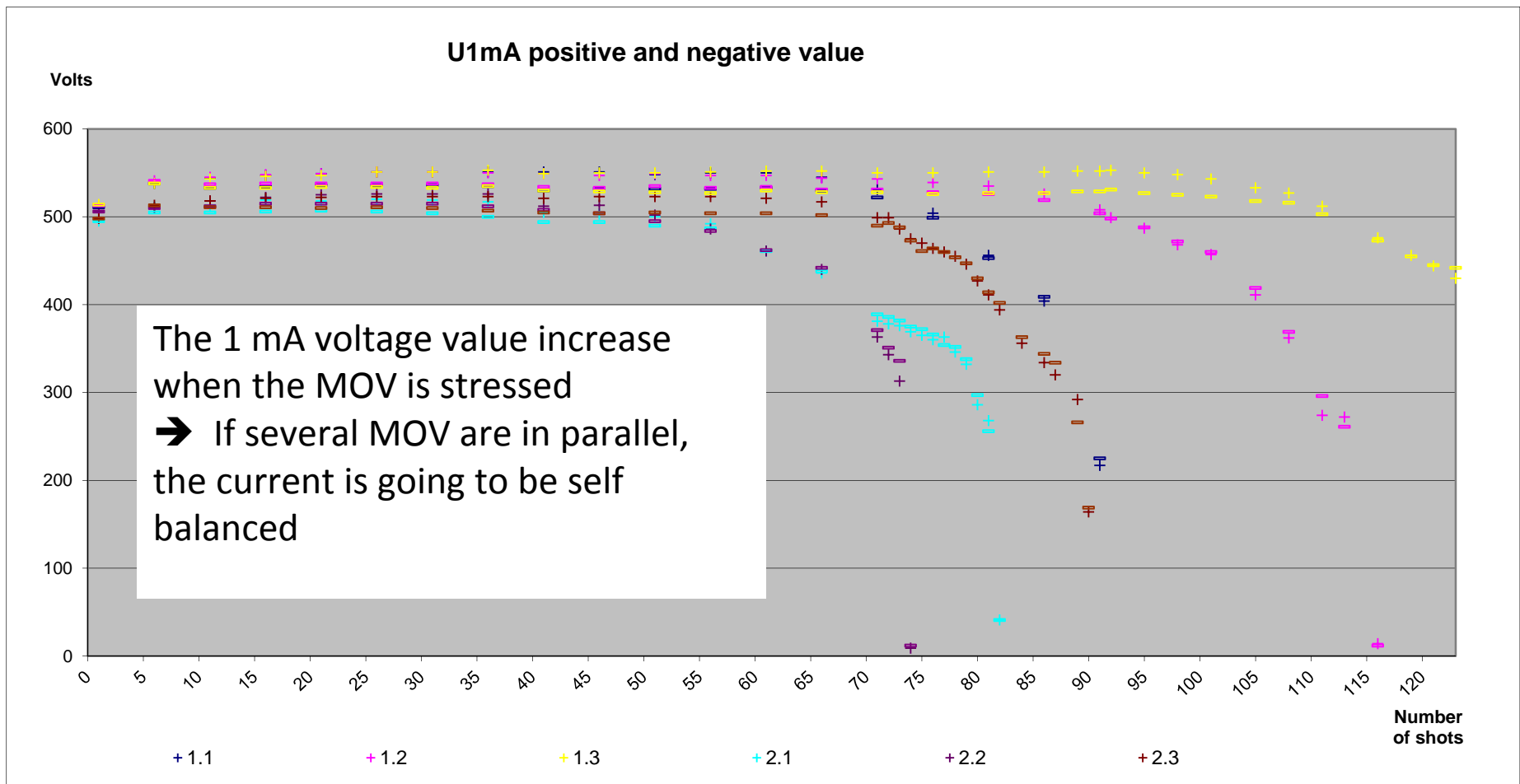
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What could be the benefit of Surge current rating (or I_{max}) as it is presented today in the US?

Usually, high declared values can only be achieved by using multi MOVs in parallel...

Current Sharing... Real life for n or lower surge current...



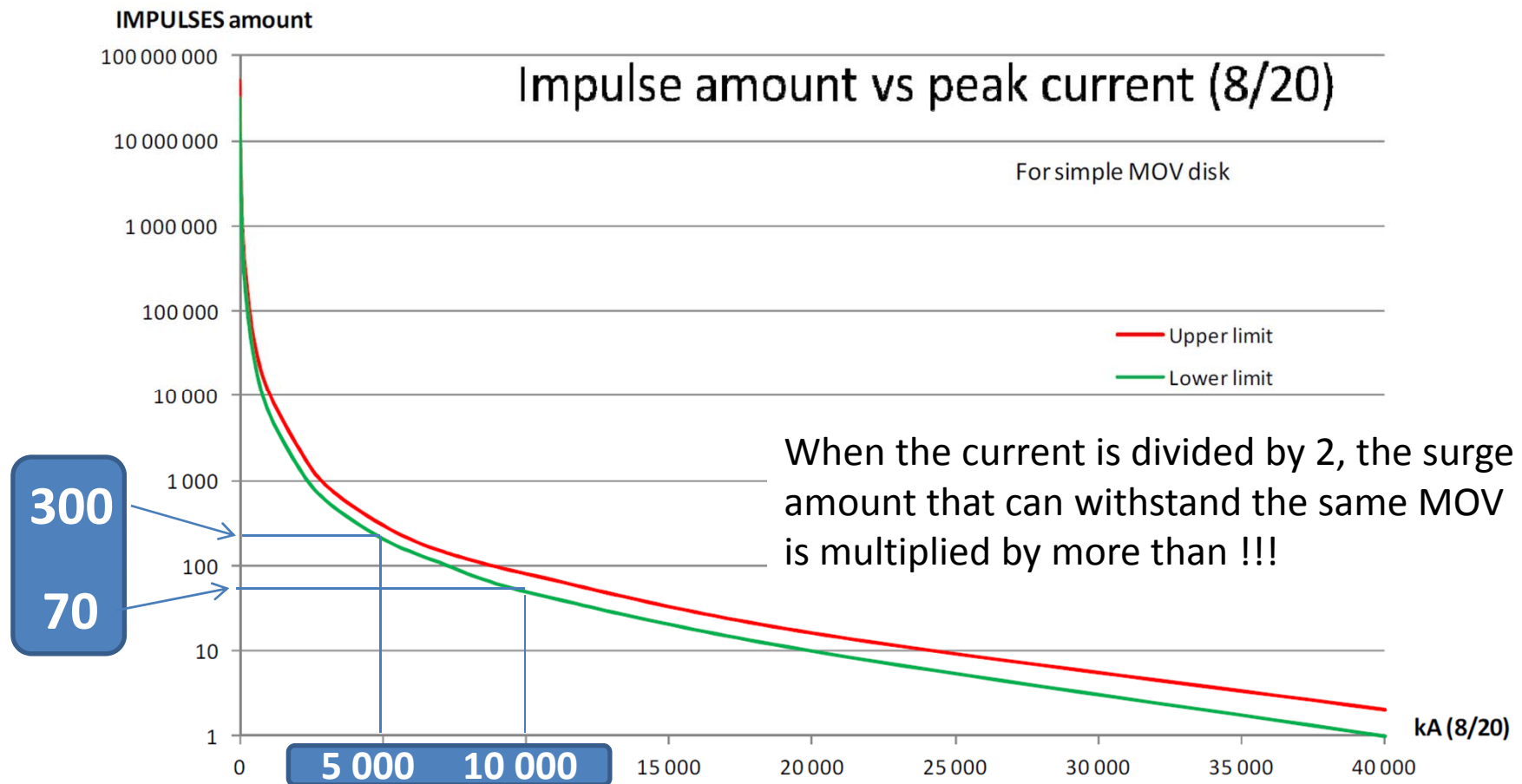


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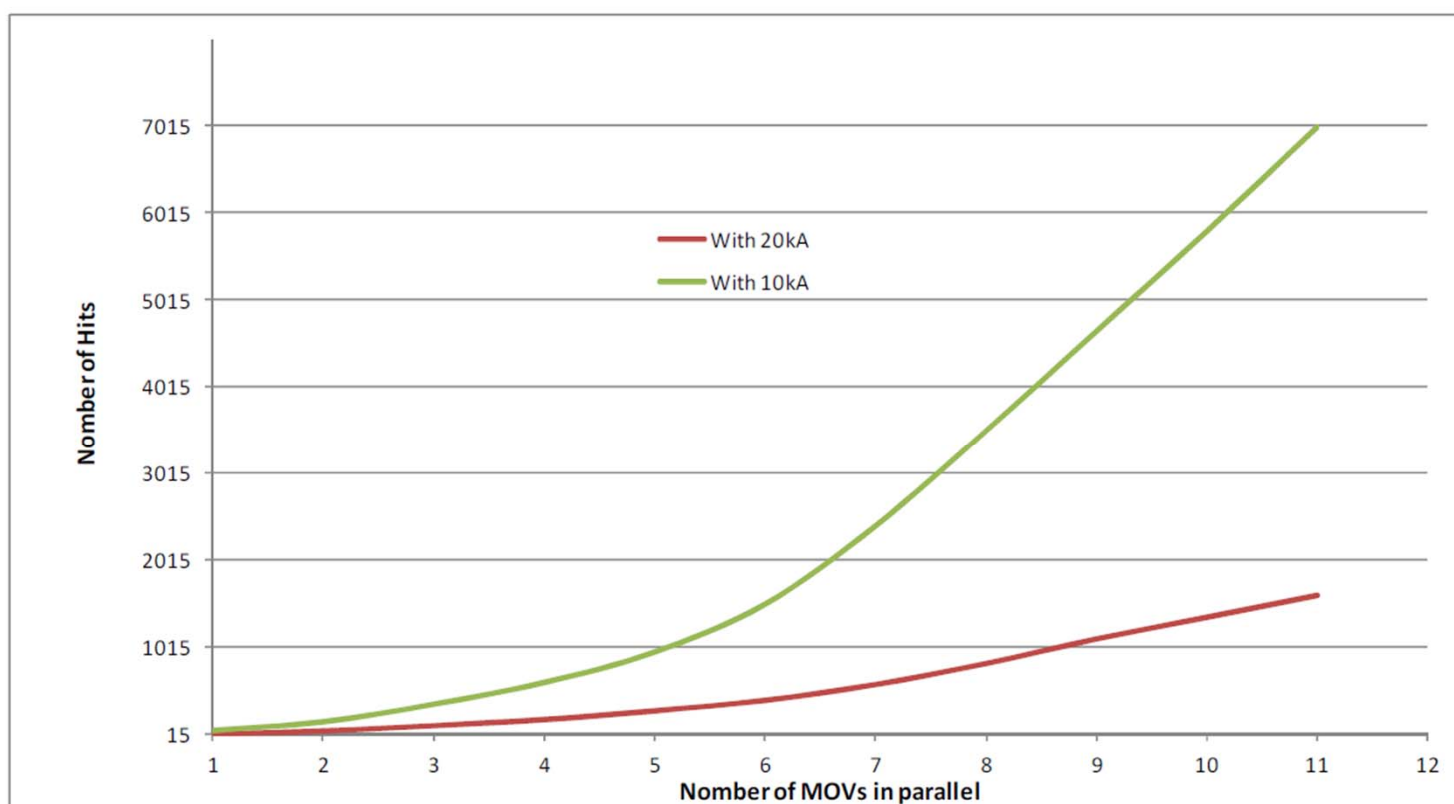
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Current Sharing... Real life for I_n or lower surge current...

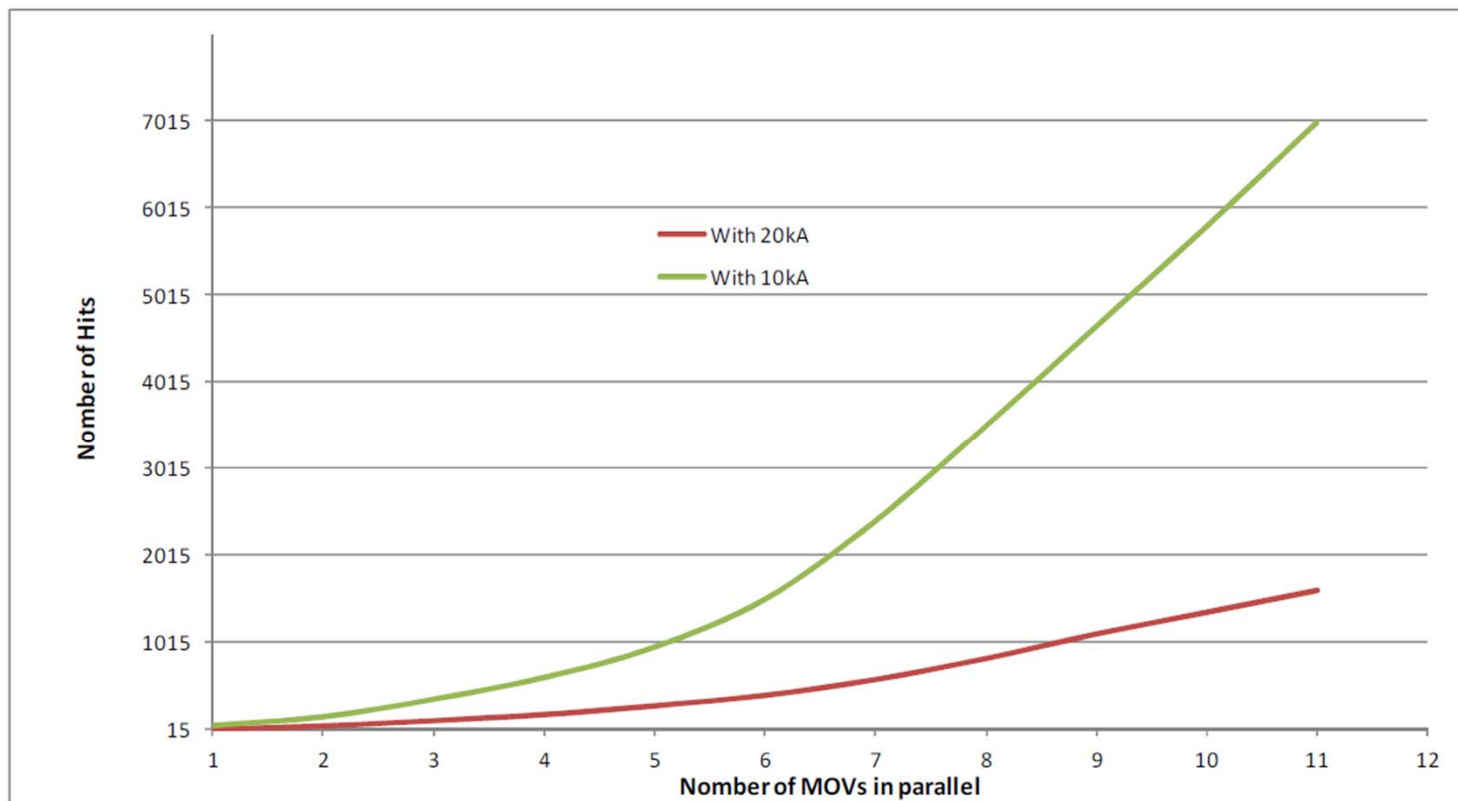


Current Sharing... Real life for I_n or lower surge current...



$I_n=20\text{kA}$ and I_{max} for each individual MOVs is 40kA

Imax or surge rating



$I_n=20\text{kA}$ and I_{max} for each individual MOVs is 40kA

Surge current rating (or I_{max}): Conclusion

- If tested (standard's request) it will drastically decrease the numbers that are used in US since decades... But Why not? This will imply to declare various pass criteria (e.g. Withstand, Disconnected,
- If declared high values for Surge current rating (or I_{max}) are the reflect of multi MOV, then it can be used for SPD selection in regards either to life duration or co