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Missing link and pulsed power values

Shocking Electricity - 3

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Overview

Network powering of equipment is now common-place such as PoE (Power over Ethernet and SPoE (single-pair power over Ethernet). This presentation first looks at safe DC powering values and then investigates pulse powering. Power source equipment and network powered device testing will often not comprehend the network link cable capability as this is a usurer or installer issue.

Safe pulsed powering in terms of voltage amplitude and duration have yet to be standardised. The possible values resulting from four different approaches (IEC 61140, IEC 62368-1, IEC 60479 and various papers) are discussed and evaluated.

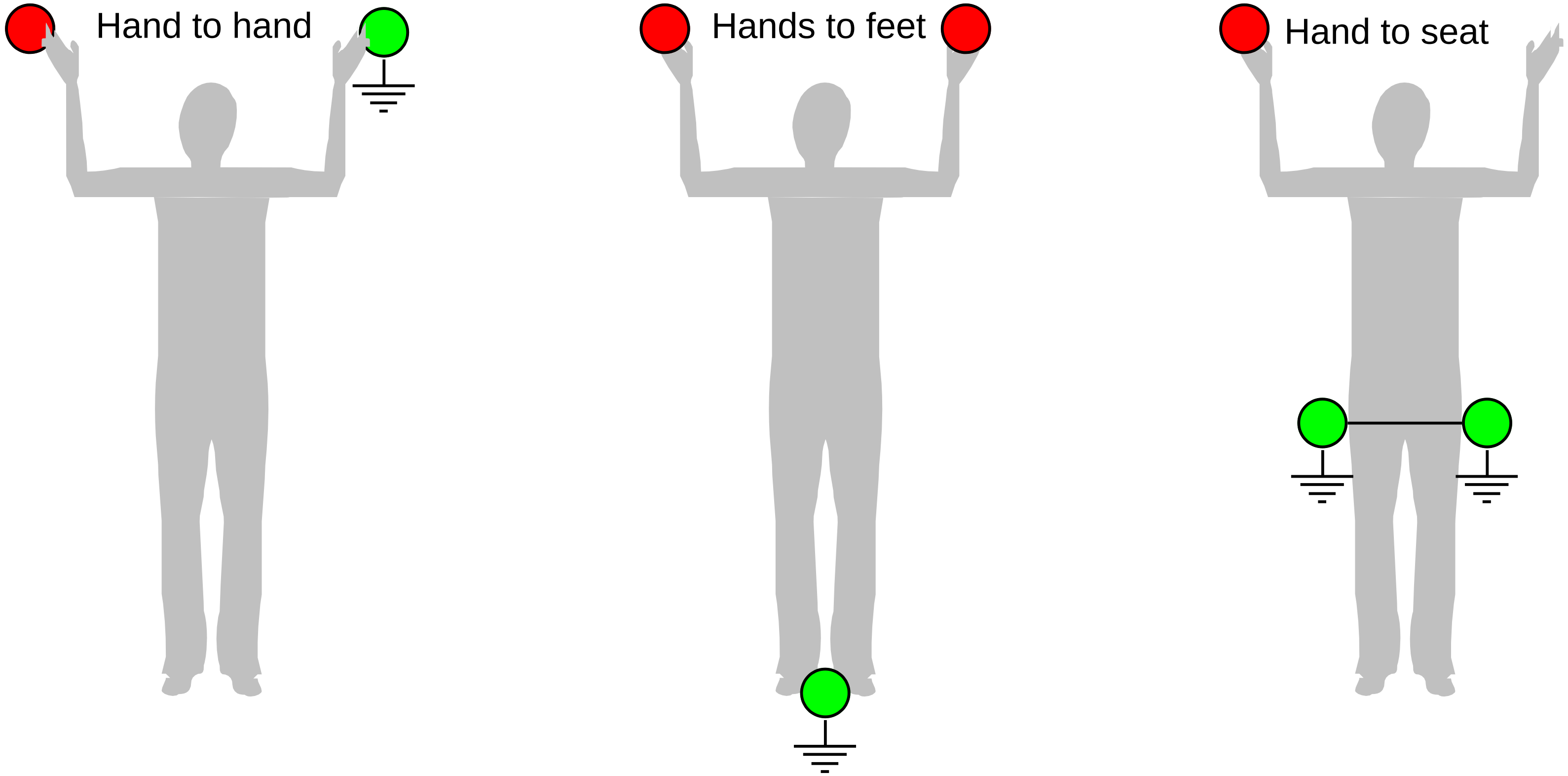
Electric shock factors –IEC 60749 shock reaction voltage thresholds

startle reaction
minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing

strong muscular reaction
minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let-go from an electrode (a.c.), but not including startle reaction

ventricular fibrillation
minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause ventricular fibrillation

Electric shock factors – Three basic IEC 60749 body current paths

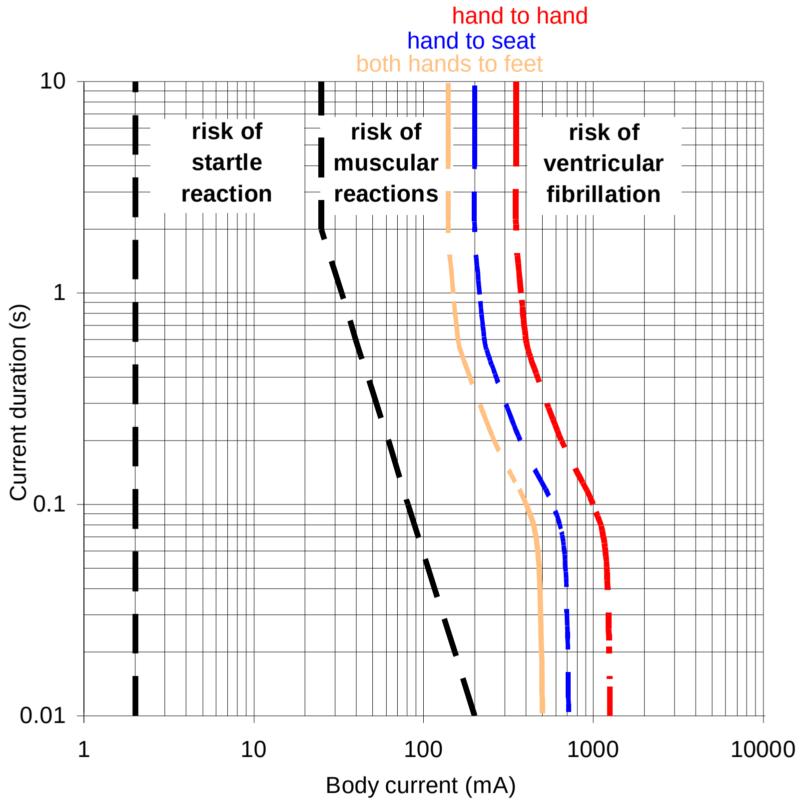


Electric shock factors – Three basic IEC 60749 skin conditions and contact areas

- Skin conditions: Dry, water wet and salt water wet

- Contact areas: 1 cm^2, 12.5 cm^2 and 82.5 cm^2 areas (IEC 61140 uses 3.5 cm^2)

IEC 60479 DC reaction currents



IEC 60479 DC reaction voltages

Reaction	Current path	Current threshold mA	DC touch voltage thresholds for long duration V								
			Saltwater-wet			Water-wet			Dry		
			1 cm² contact	12.5 cm² contact	82.5 cm² contact	1 cm² contact	12.5 cm² contact	82.5 cm² contact	1 cm² contact	12.5 cm² contact	82.5 cm² contact
Startle	Hand-to-hand	2	12	4	2	56	12	3	78	23	7
	Both-hands-to- feet	2	6	2	1	35	7	2	59	15	4
	Hand-to-seat	2	6	2	1	28	6	1	39	12	3
Strong muscular	Hand-to-hand	25	112	44	24	156	81	29	156	89	43
	Both-hands-to- feet	25	63	23	13	133	51	16	133	67	26
	Hand-to-seat	25	56	22	12	78	41	15	78	45	21
Ventricular fibrillation	Hand-to-hand	350	467	351	263	470	353	264	470	264	264
	Both-hands-to-feet	140	220	121	68	223	143	75	223	143	87
	Hand-to-seat	200	201	126	83	203	127	85	203	127	85

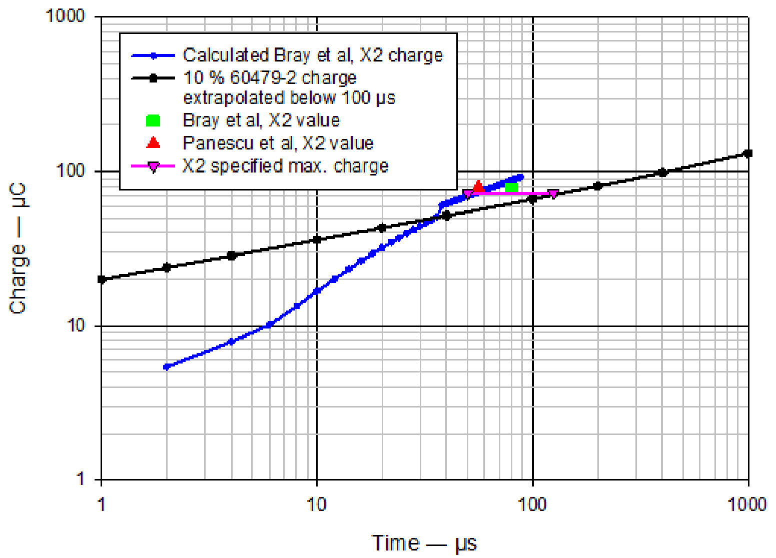
What about durations below 10 ms?

Electric fence pulses was one of the first safety evaluations.

These evaluations led to the adoption of maximum pulse charge values of 2.5 mC to 4 mC in various countries. See Reference 1.

However, bizarrely the subsequent IEC 60335 standard changed the charge-based limit to an inappropriate energy limit . One writer observed “Energy heats. Charge stimulates”

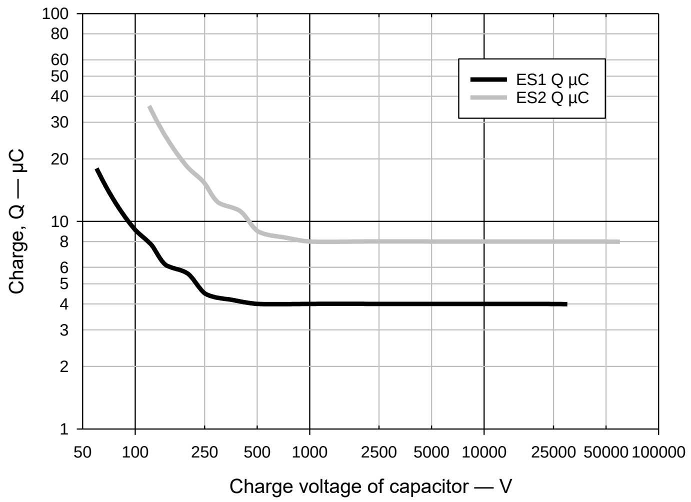
Taser™ pulses have also been evaluated in terms of charge. See Reference 2

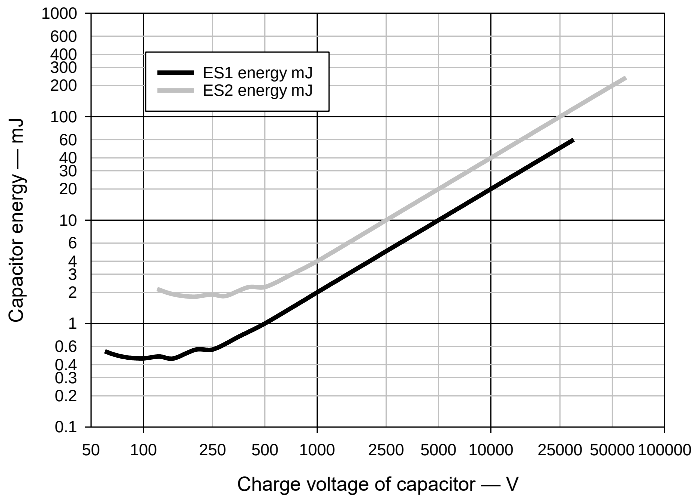


IEC 62368-1 capacitive discharge

IEC 62368-1 lists a series of ES1 and ES2 charged capacitor values having minimum charge values of 4 µC and 8 µC.

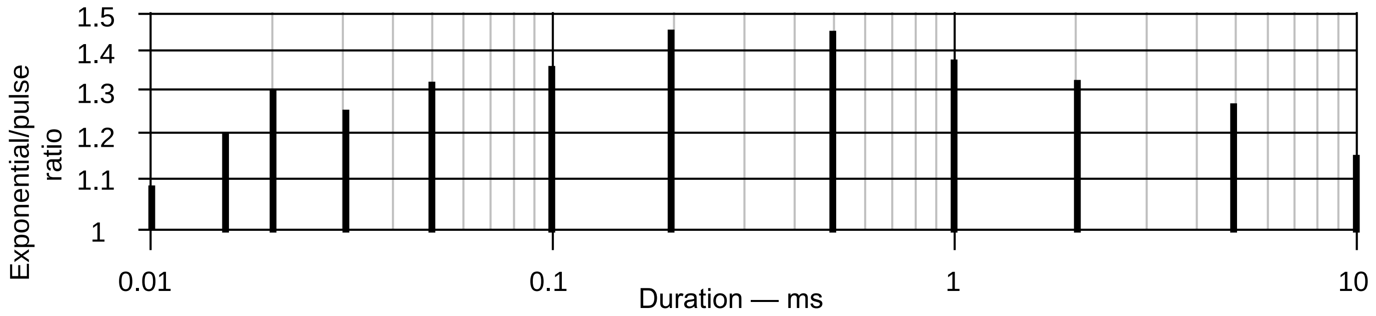
The corresponding capacitor energy values are shown below





Exponential or rectangular pulse current?

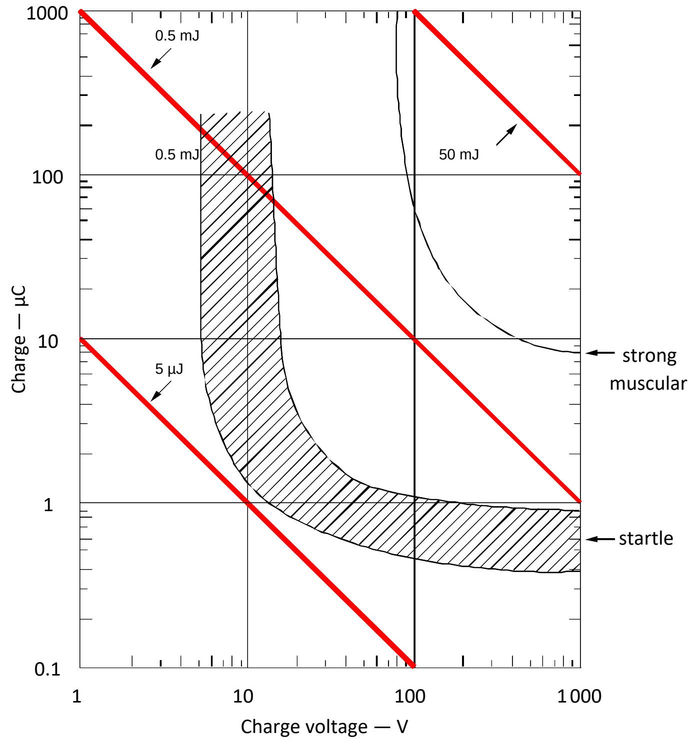
Wessale, Reference 3, comparied the peak waveform currents for the same reaction for durations of 0.01 ms to 50 ms. Generally the pulse current was 75 % of the exponential peak current (1/1.3). The duration used was the discharge time constant, which is only 63 % of total charge. For the same delivered charge this means the pulse amplitude would be about 50 % of the exponential peak current.



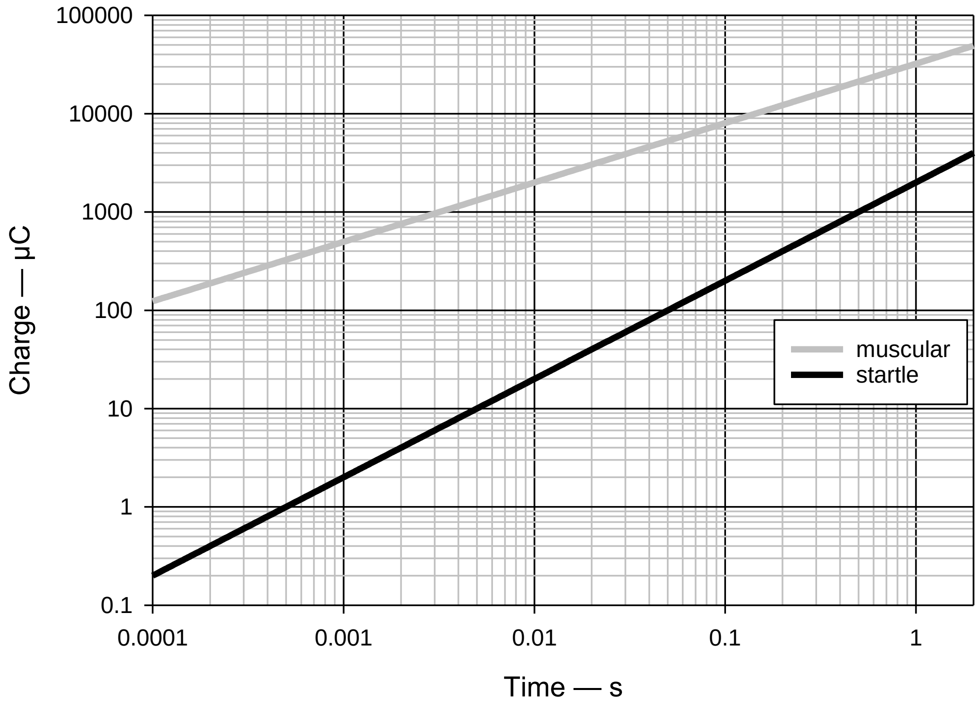
IEC 61140: Protection against electric shock

Uses energy – 5 µJ for startle and 0.5 mJ for strong muscular based on Figure 19 of IEC TS 60479-2:2007 (discharge of a capacitor (dry hands, large contact area)). (In IEC 60479-2:2019 shown as Figure 22.) Neither the 5 µJ nor the 0.5 mJ lines intersect the startle or strong muscular reaction curves in Figure 19. Careful study shows the intercepts are at 15 µJ and 2.5 mJ.

Overall the parameters presented in Figure 19/22 do not correlate with other standards.

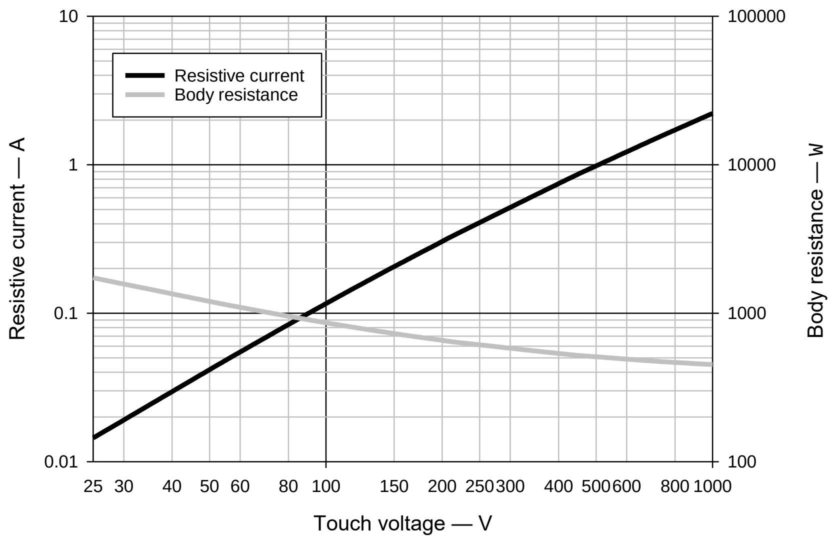


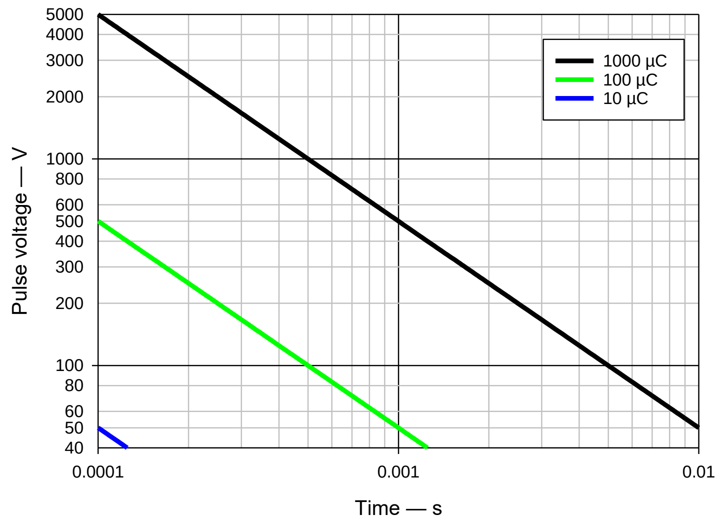
Current × time (charge) from IEC 60479 reaction current graph



IEC 60479 hands to feet body resistance

The body current and resistance versus voltage is shown below (LHS).
The peak pulse voltage against time is shown for a 500 Ω for various µC values (RHS).





Overview — 1

For electrical shocks below 10 ms safety standards are in disarray. To narrow down to applicable standards one needs to:

- Classify the event type – capacitive discharge or pulse
- Current path – hand to hand, hands to feet, hands to seat
- Contact conditions – small, medium or large areas
- Skin conditions – dry, wet or saltwater wet
- Evaluation parameter – charge or energy

Overview — 2

Having selected a set of standards one needs to select the most appropriate standard to test to.

- Determine event duration – 63 % or 3 × discharge time constant or pulse duration or disconnect time
- Evaluation load – often 500 Ω but could be a touch current circuit
- Clearly define in the test report what standard and the test circuit was used.

Electric shocks below 10 ms are an area where harmonised standardisation needs to occur.

References

1. Kroll, Panescu, Hirtler, Koch and Andrews, Dosimetry for Ventricular Fibrillation Risk with Short Electrical Pulses: History and Future, Annual International Conference of the IEEE Engineering in Medicine and Biology Society.
2. Mick Maytum, Shocking Electricity — 2, ATIS Protection Engineers Group conference, 2018.
3. Wessale, J.L., Geddes, L.A., Ayers, G.M. et al. Comparison of rectangular and exponential current pulses for evoking sensation. Ann Biomed Eng 20, 237–244 (1992).
4. IEC 60479, Effects of current on human beings and livestock: IEC 60479-1:2018, IEC 60479-2:2019, IEC TR 60479-4:2020 and IEC TR 60479-5:2007
5. IEC 61140:2016, Protection against electric shock - Common aspects for installation and equipment
6. IEC 62368-1:2018, Audio/video, information and communication technology equipment - Part 1: Safety requirements
7. Kroll, Perkins, Pratt, Stuart, Bury and Panescu, Safety of a High-Efficiency Electrical Fence Energizer, 2020 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC).
8. Nute, Technically speaking, Body resistance — A review, Product Safety Newsletter 1993 V06 N01