

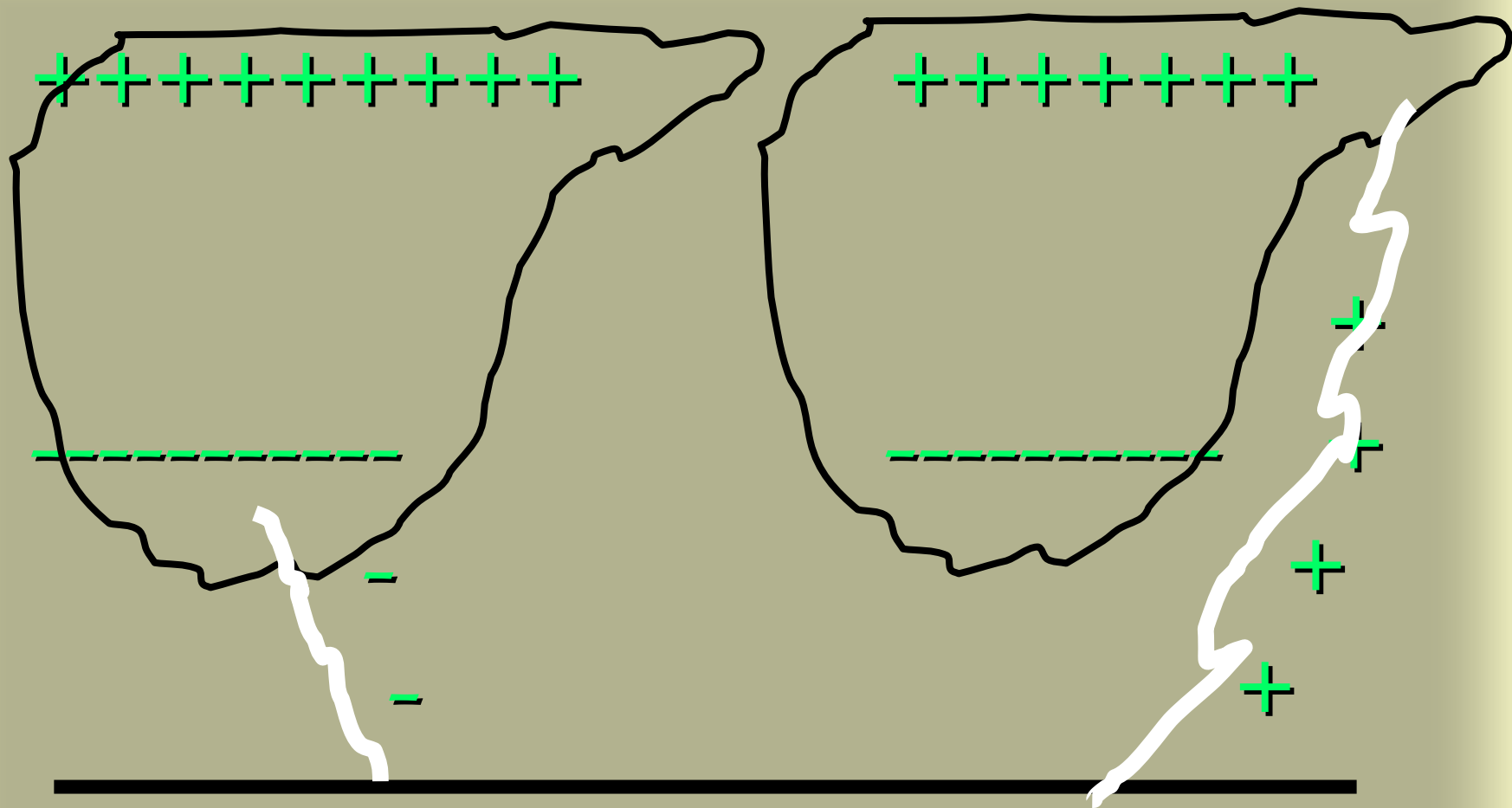
Lightning & insulation coordination

**S. R. LAMBERT
SHAWNEE POWER Consulting, llc**

*LIGHTNING
FLASH
CHARACTERISTICS*

FLASH STATISTICS

- 55% OF FLASHES HAVE MORE THAN ONE STROKE
- 90% OF FLASHES HAVE LESS THAN NINE STROKES
- MEAN NUMBER OF STROKES/FLASH - THREE
- 80-90% OF STROKES ARE NEGATIVE



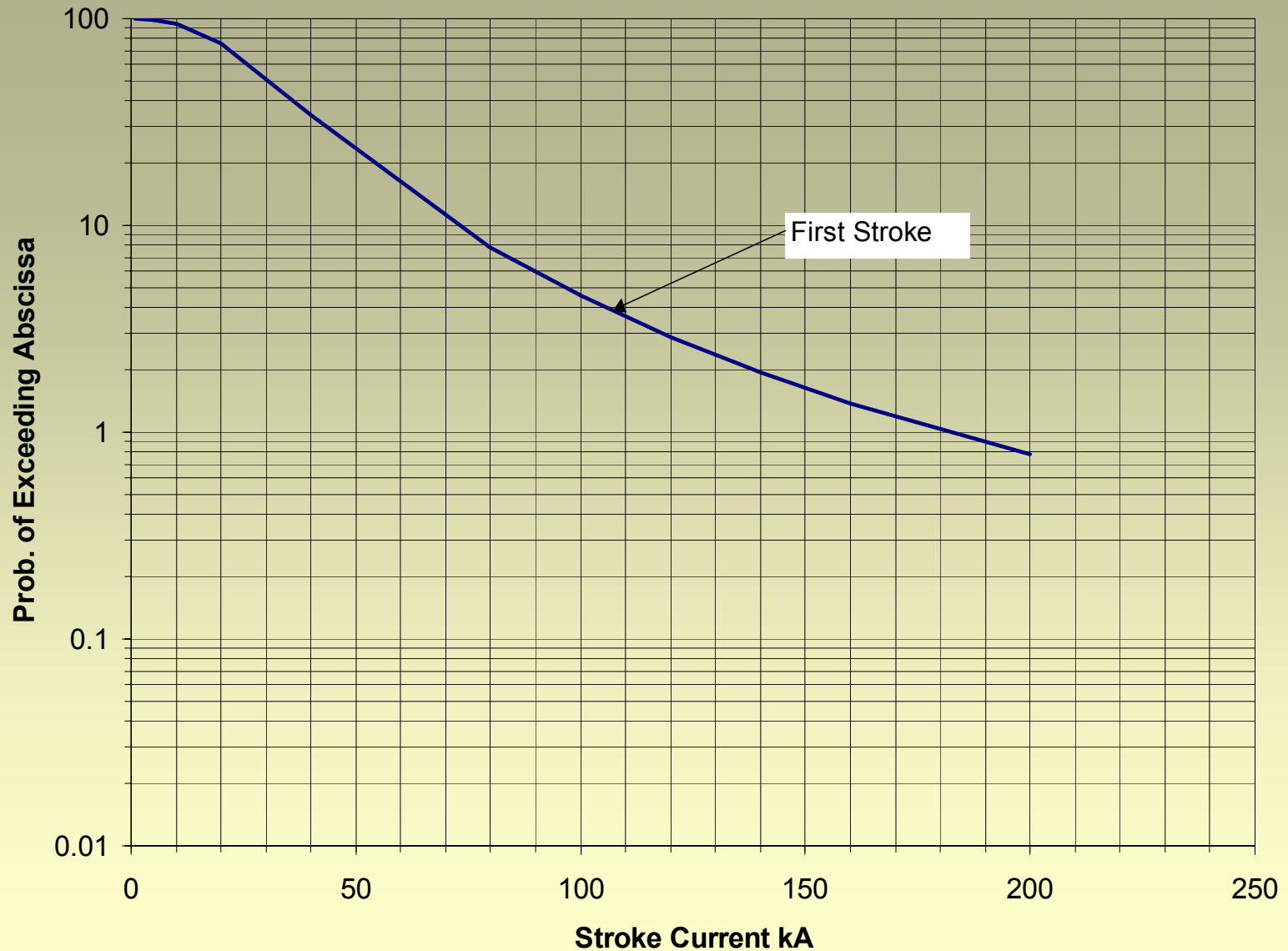
Neg Flash

Pos Flash

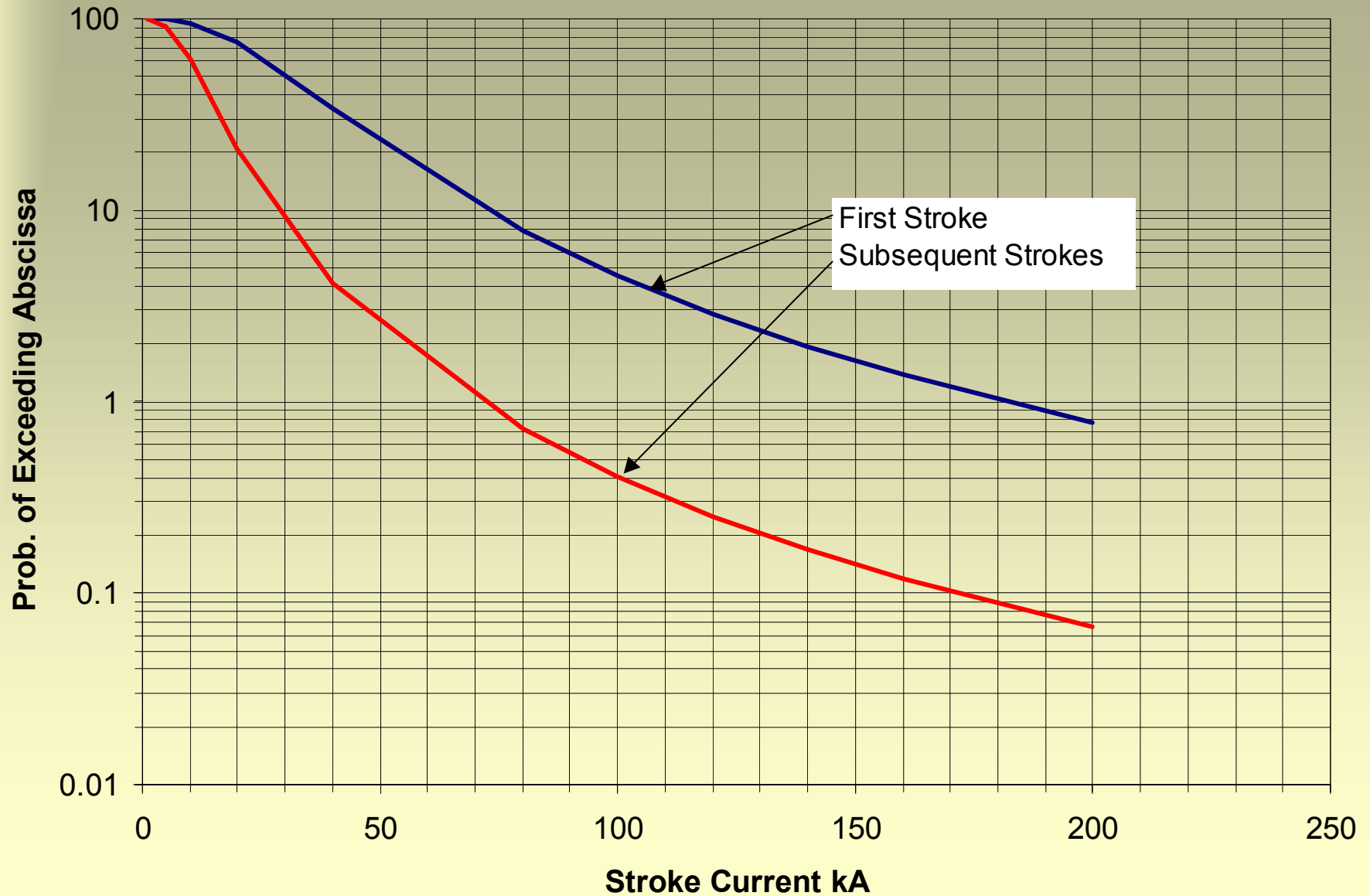
LIGHTNING

- CHARACTERIZED BY
 - ◆ CURRENT MAGNITUDE
 - ◆ STROKE RISE TIME
 - ◆ KERAUNIC LEVEL OR FLASHES/km²

STROKE MAGNITUDES



STROKE MAGNITUDES



STROKE MAGNITUDES

$$P_I = \frac{1}{1 + \left(\frac{1}{31}\right)^{2.6}}$$

FIRST STROKE

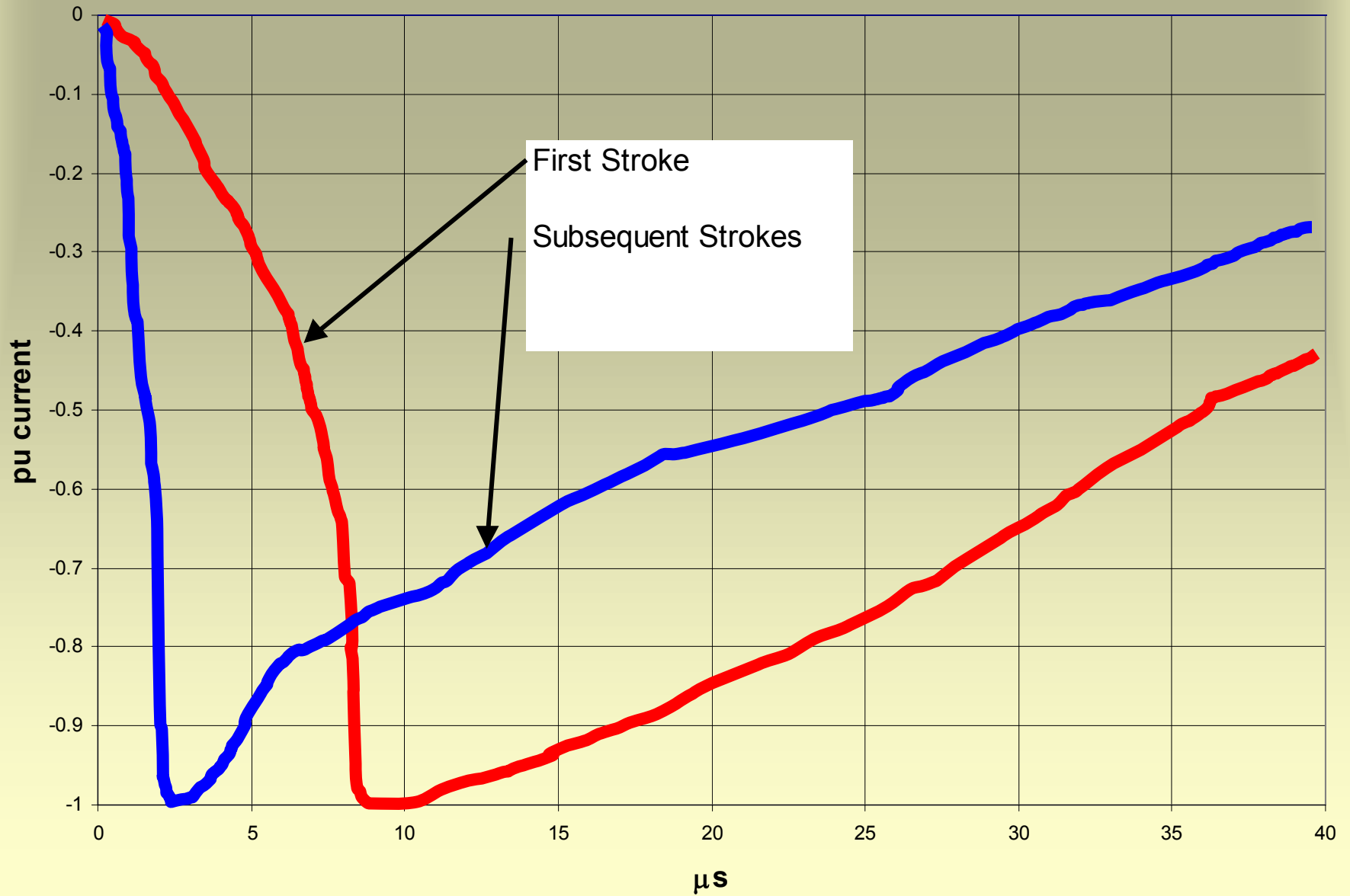
$$P_I = \frac{1}{1 + \left(\frac{1}{12}\right)^{2.6}}$$

SUBSEQUENT
STROKES

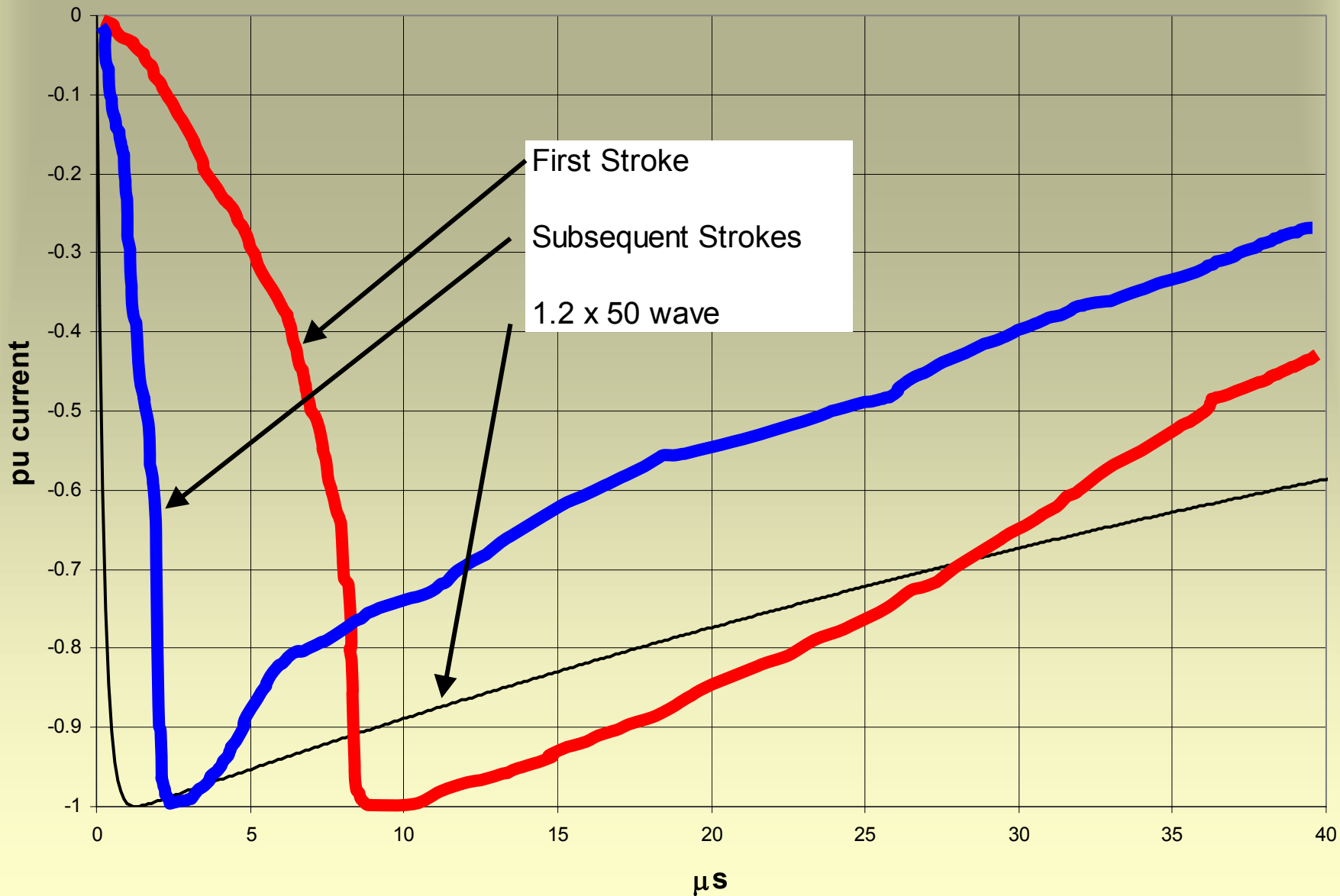
TYPICAL FIRST STROKE



SUBSEQUENT STROKES



1.2 x 50 IMPULSE SHAPE



GROUND FLASH DENSITY

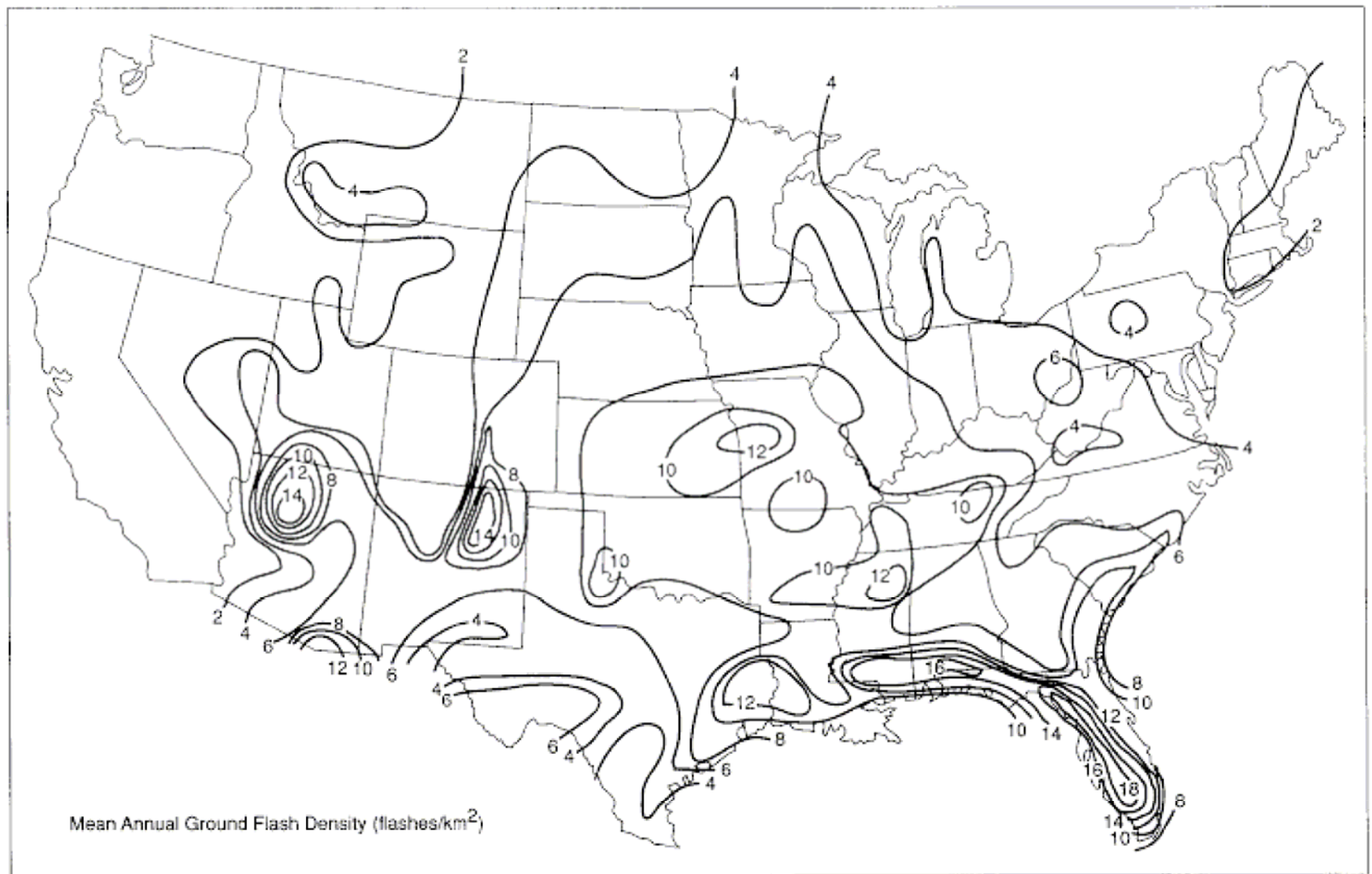
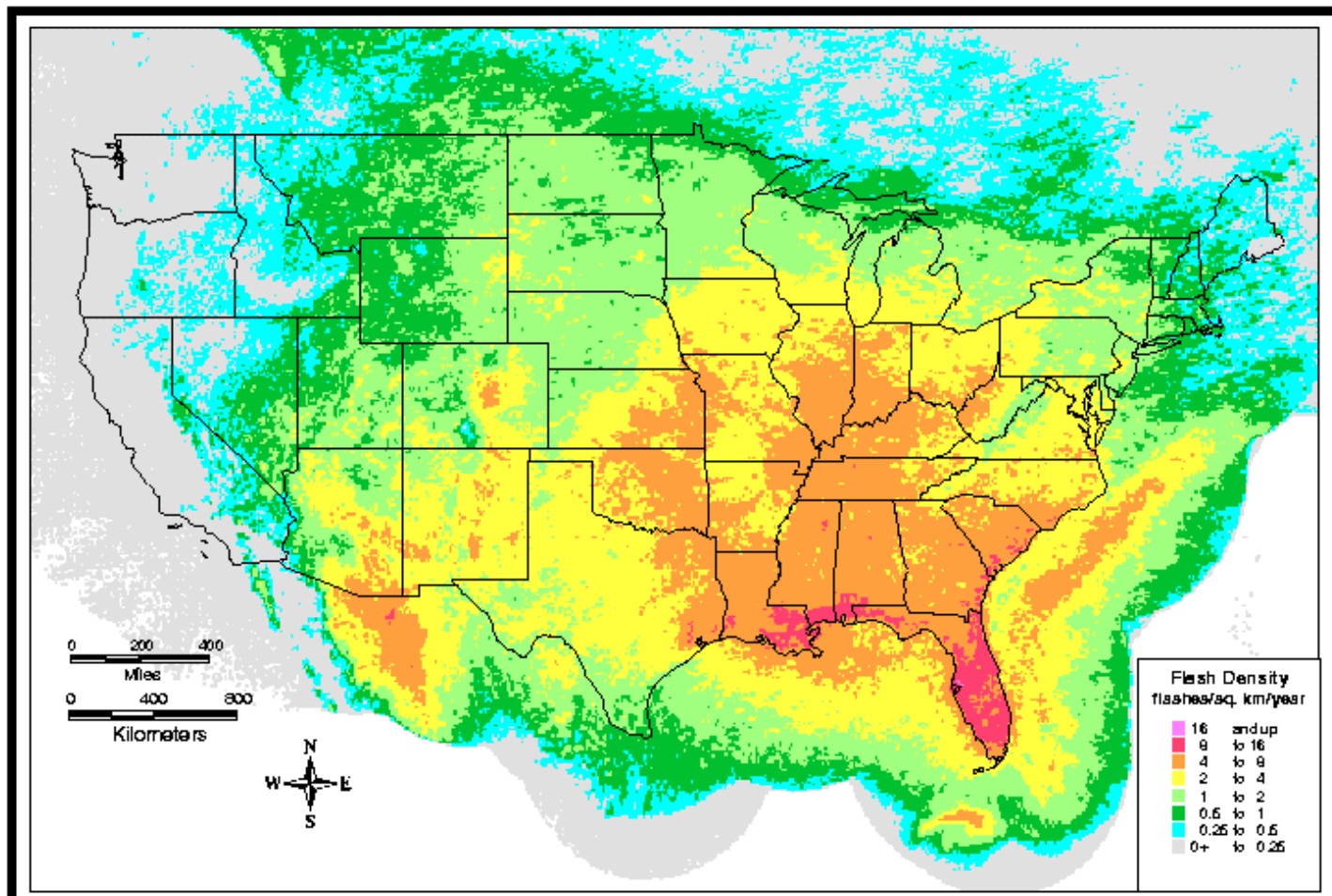


Figure 2. Contour Map of Mean Annual Lightning Strike Density.

GROUND FLASH DENSITY



Global Atmospherics, Inc.
Fault Analysis and Lightning Location System

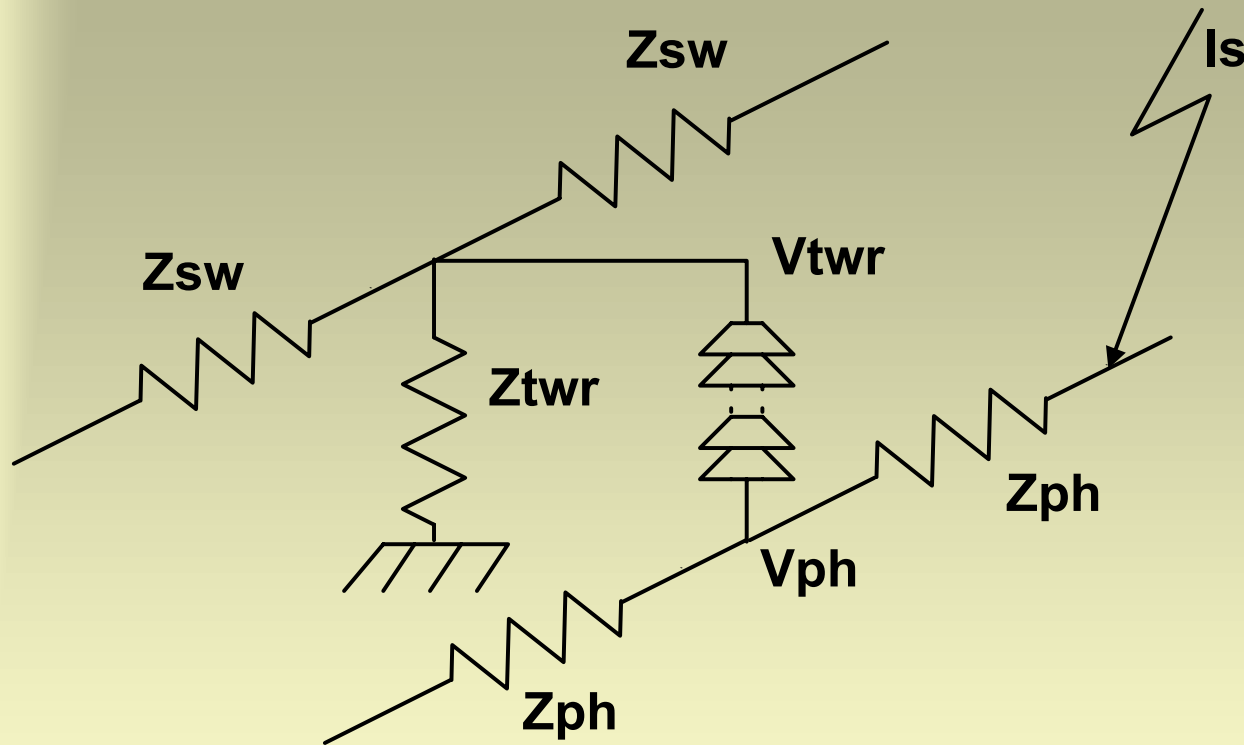
1996-2000 Flash Density Map
10 kilometer grid

Jan 1, 1996 00:00:00 GMT
To
Dec 31, 2000 23:59:59 GMT

HOW DOES LIGHTNING GET INTO THE SYSTEM?

- Shielding Failures
- Back Flashovers
- Induced Surges

SHIELDING FAILURE



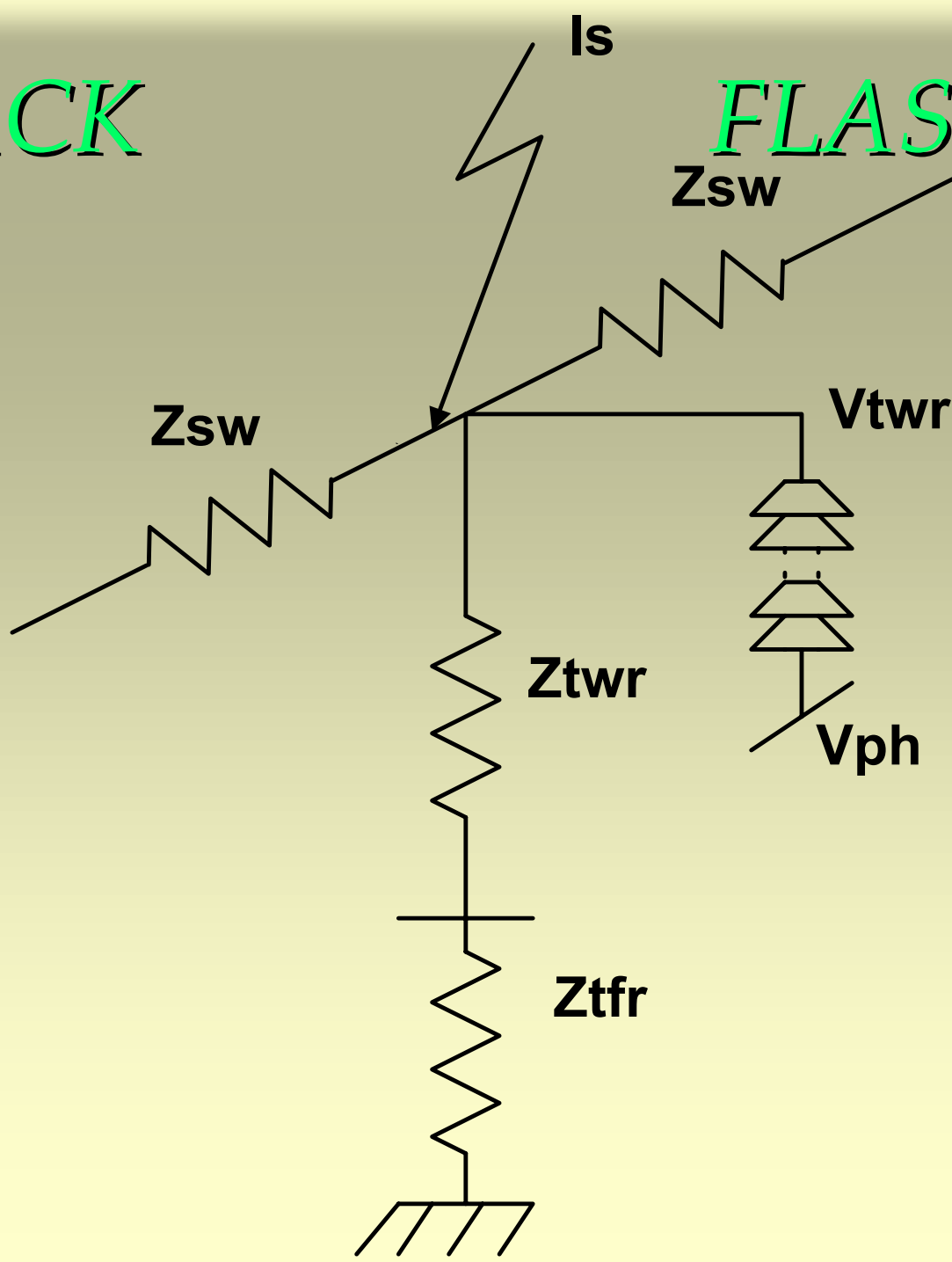
- $Z_{ph} 400 \Omega$

- $I_s = 5 \text{ kA}$

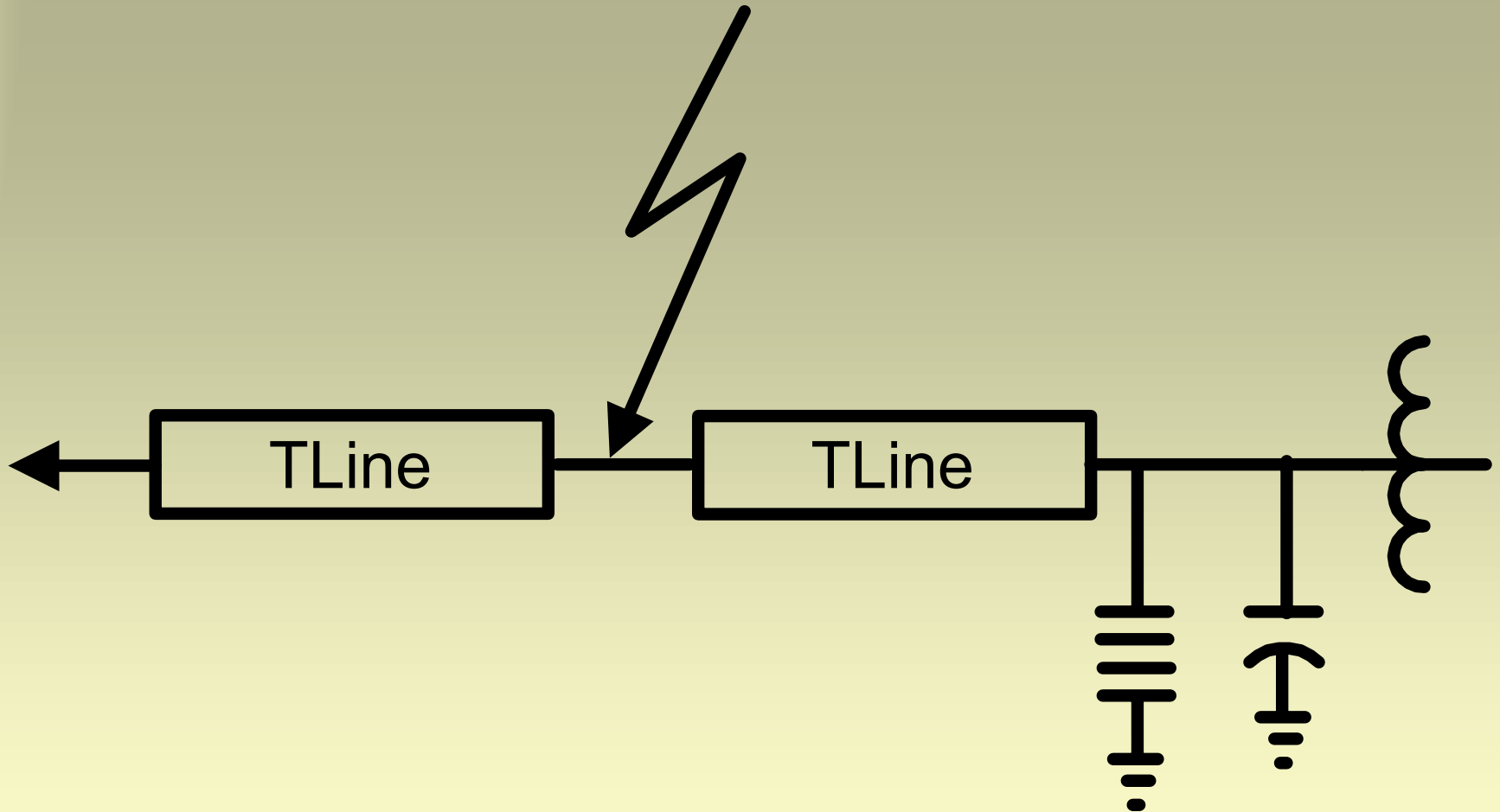
- $V_{ph} =$
 $5 \text{ kA} / 2 \times$
 $400 =$
 1 MV

BACK

FLASHOVER

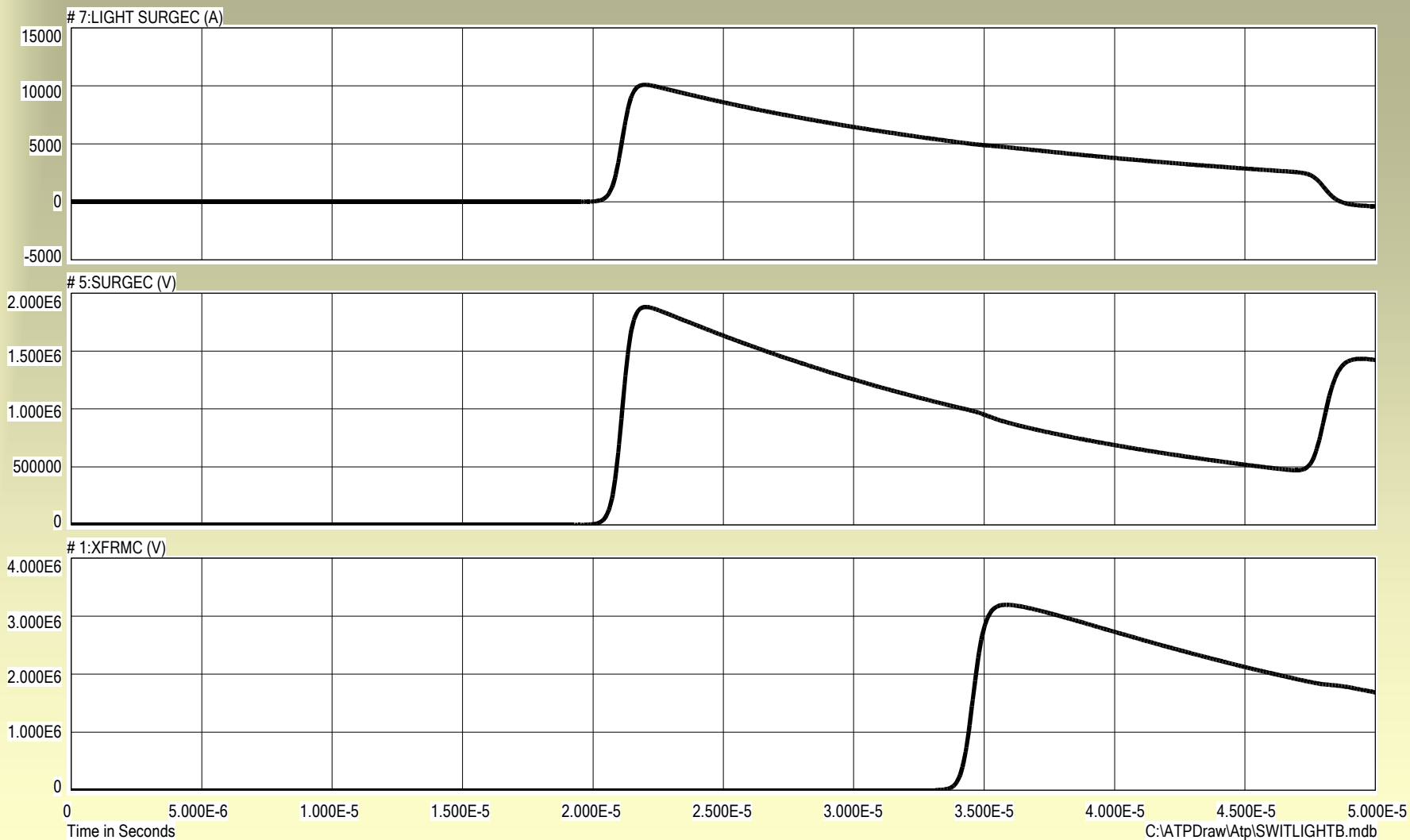


EXAMPLE

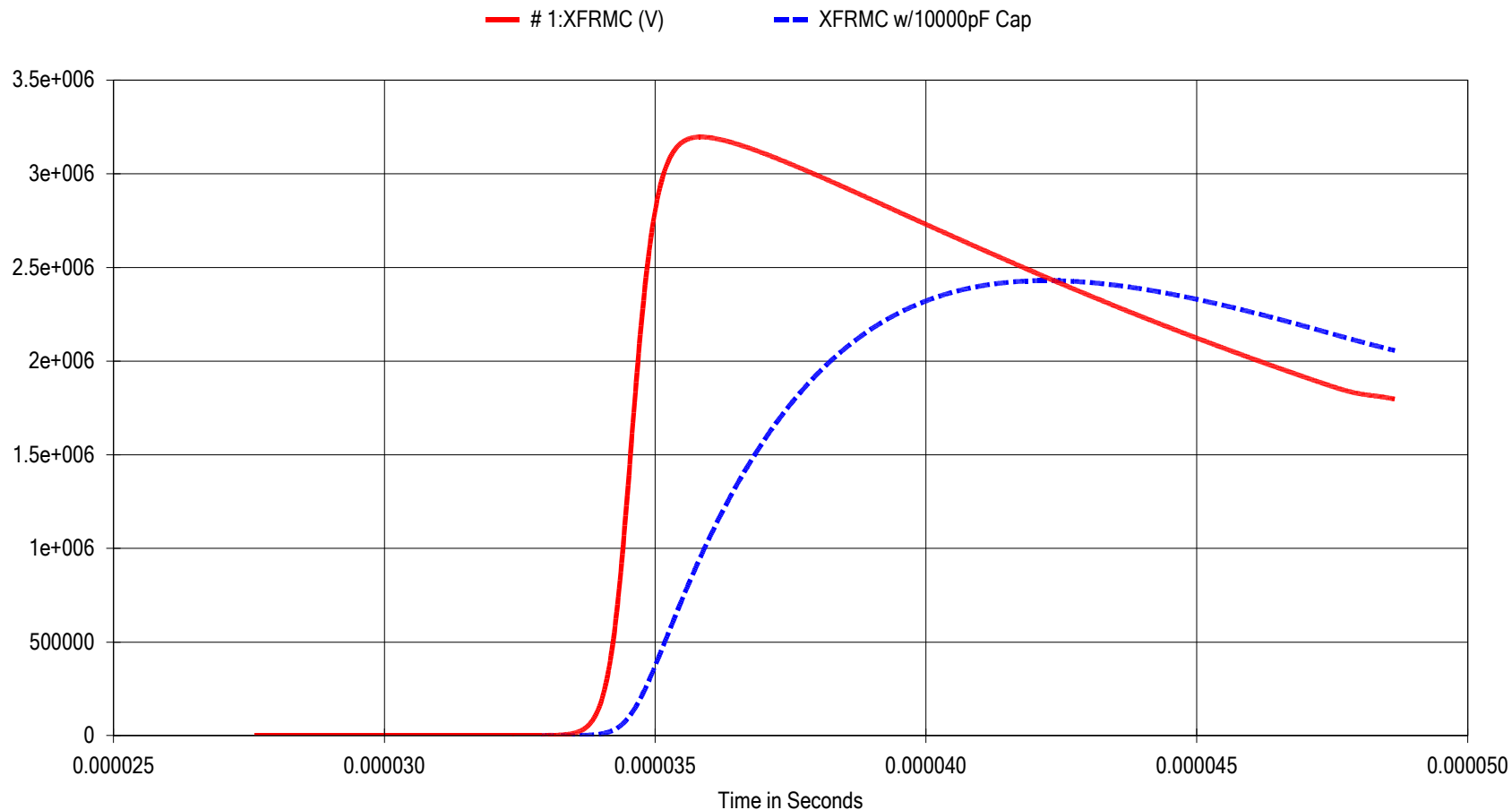


SWITLIGHTB

10 kA SURGE

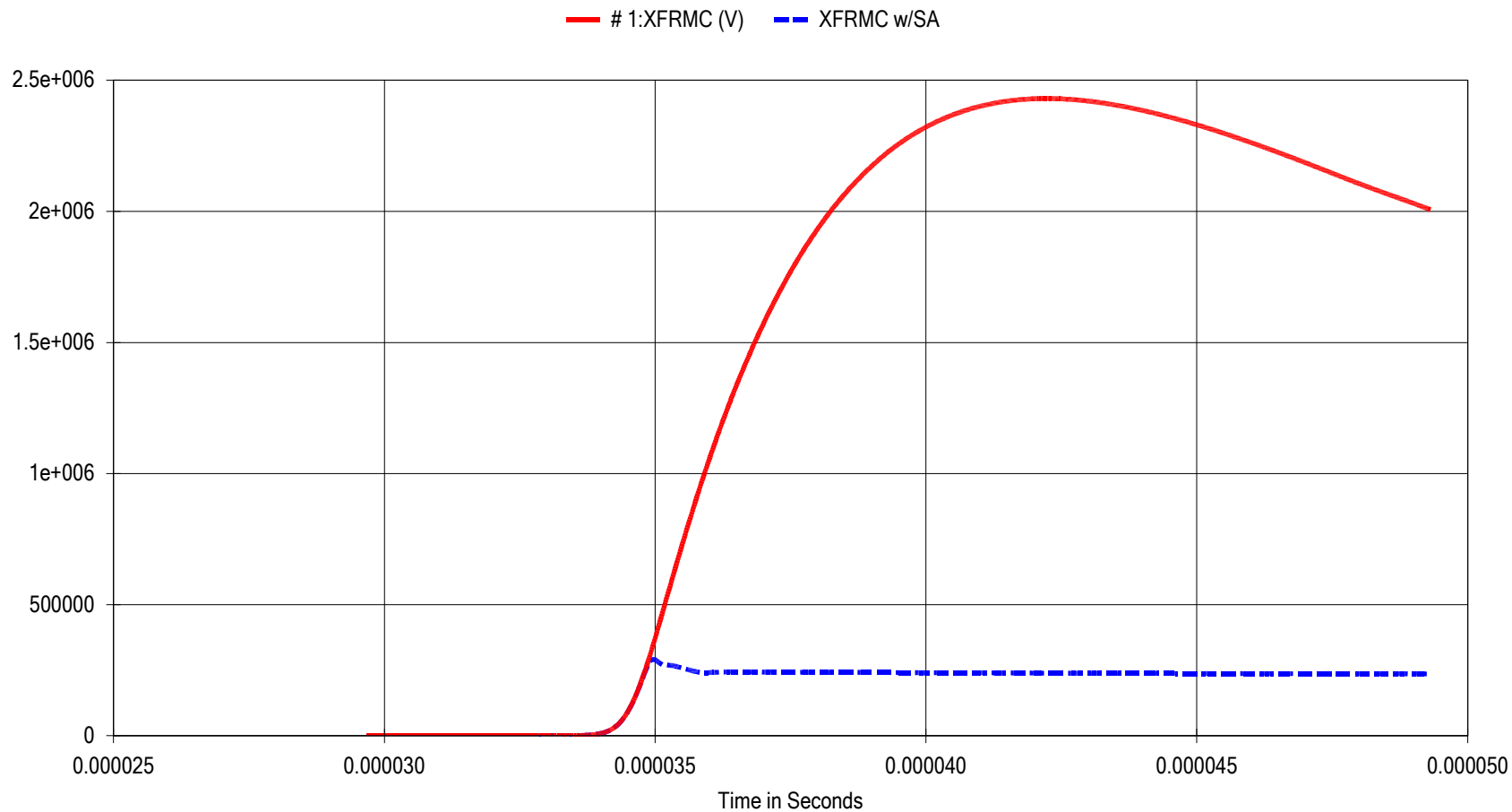


XFRM W/O CAPACITOR



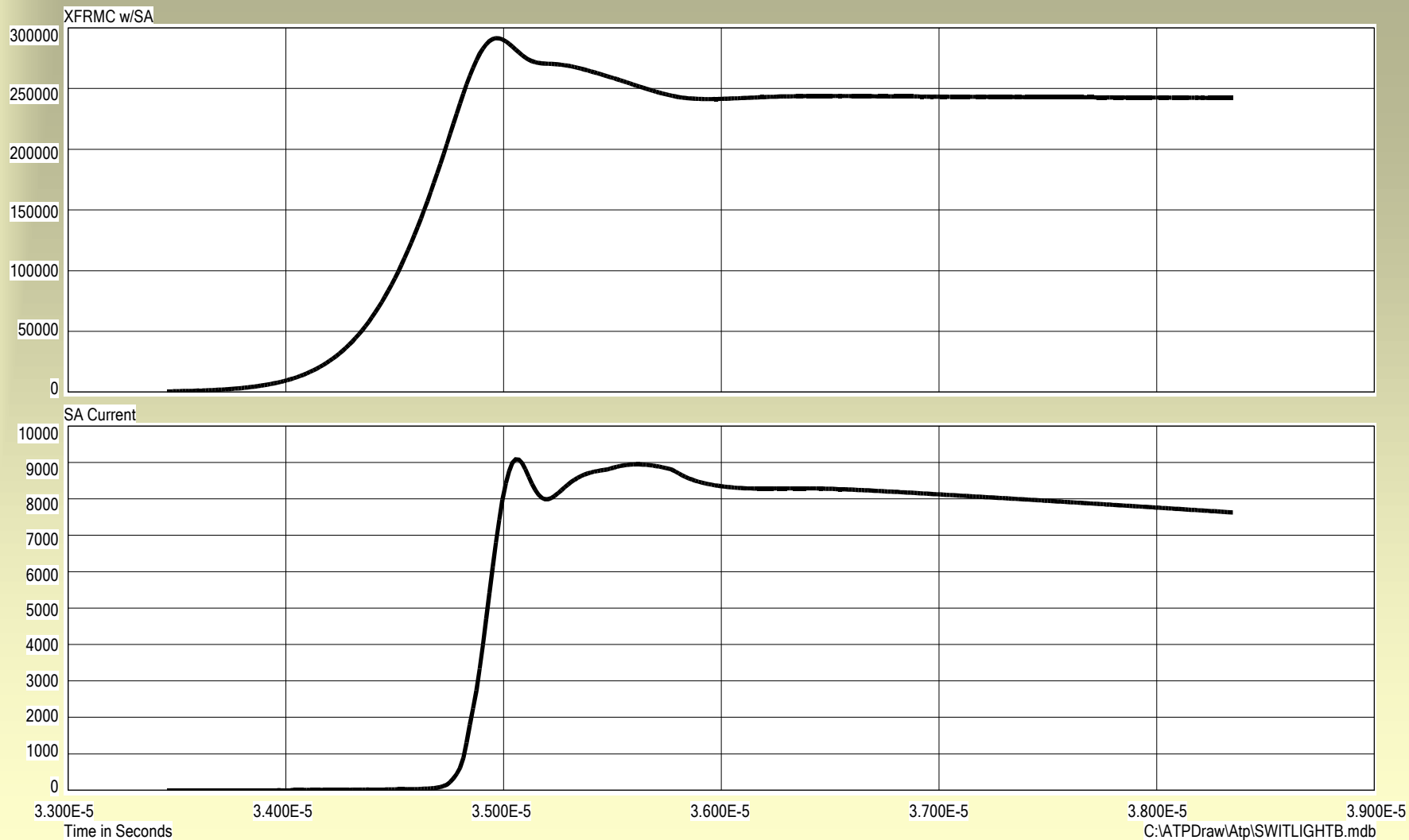
SURGE ARRESTER APPLICATION

WITH CAP AND SA



SWTLIGHTB

XFRM VOLTAGE-SA AMPS



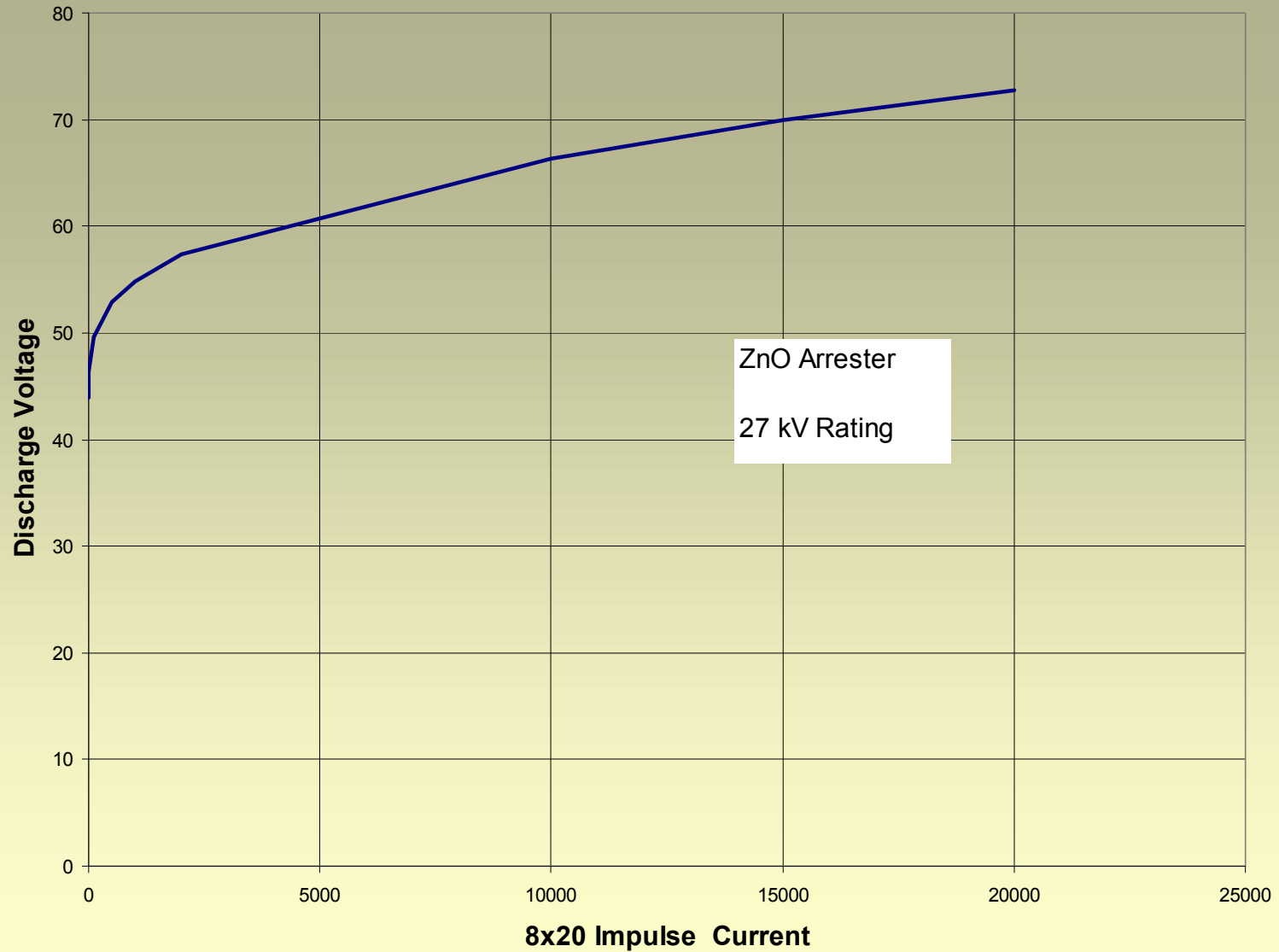


SURGE ARRESTER

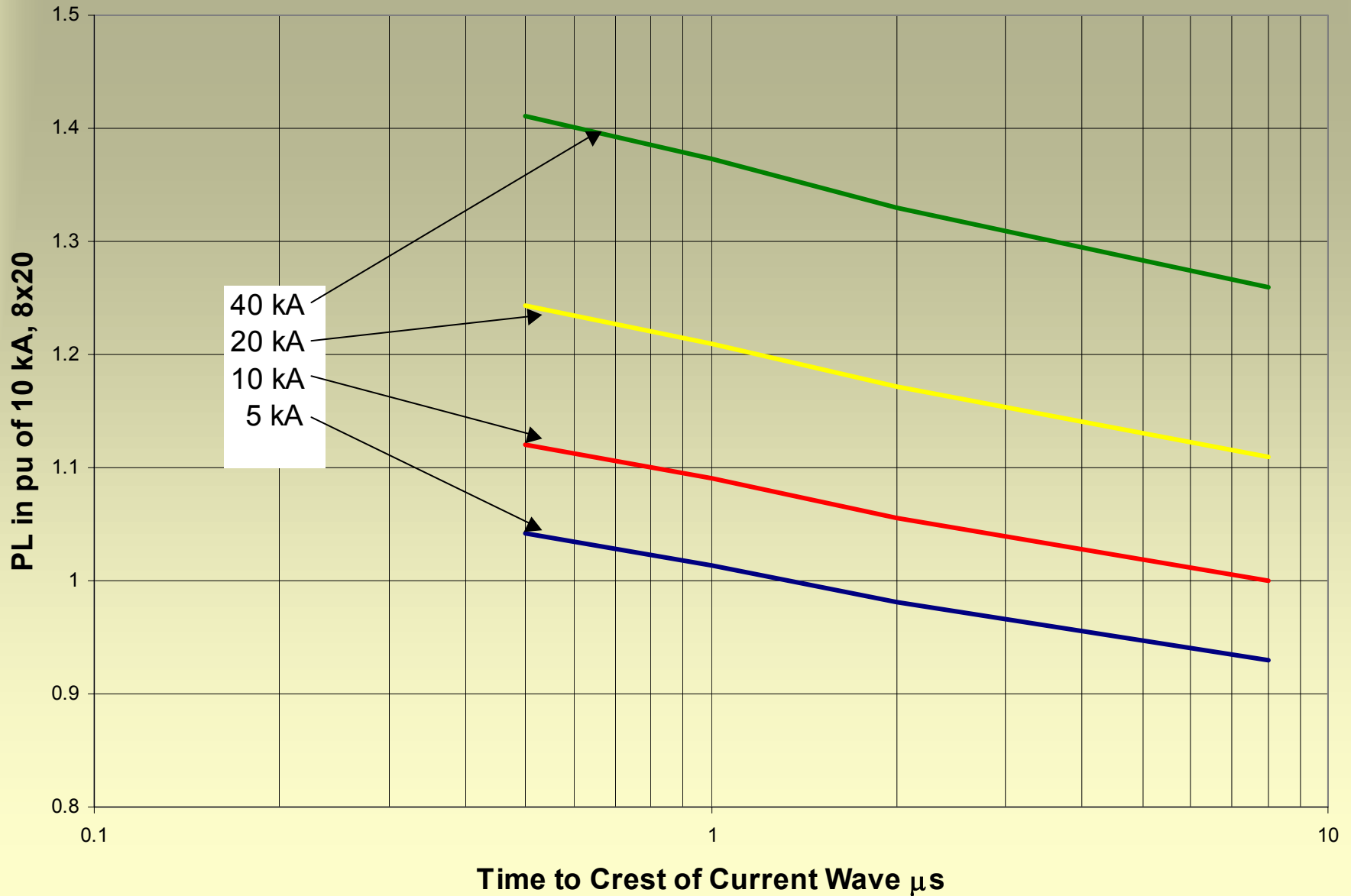
APPLICATION - ZnO TYPE

- FOR THE ARRESTER TO SURVIVE:
 - ◆ MCOV - maximum continuous operating voltage
 - ◆ TOV - temporary overvoltage capability
 - ◆ ENERGY - Absorption Capability
- PROTECTIVE LEVEL - function of surge magnitude and rise time

PROTECTIVE LEVEL



PL as $f(\text{rise time, current})$



WHERE DID BIL'S COME FROM

- LOW FREQUENCY TEST
- BIL - (from transformers)

2.2 X LOW FREQUENCY TEST + 40 kV

- 38 kV - $70 \times 2.2 + 40 = 194 \text{ kV} :: 200 \text{ kV BIL}$

TEST LEVELS

ANSI C37.06-2000

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Table 4 – Preferred dielectric withstand ratings and external insulation (1)

Line No.	Rated Maximum Voltage kV, rms	Rating Table No.	Dielectric Withstand Test Voltages						Minimum Creepage(5) Distance of External Insulation to Ground mm
			Power Frequency		Impulse Test 1.2 x 50 μsec wave		Switching Impulse		
			1 Minute Dry kV, rms	10 Second Wet kV, rms	Full Wave (2)(6) Withstand kV, Peak	2 μsec Chopped Wave Withstand kV, Peak Minimum Time to Sparkover	Withstand Voltage Terminal to Ground With Breaker Closed kV, Peak	Withstand Voltage Terminal to Terminal on One Phase with Circuit Breaker Open kV, Peak	
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	
1	4.76	1	19	(3)	60	(3)	(3)	(3)	(3)
2	8.25	1	36	(3)	95	(3)	(3)	(3)	(3)
3	15.0	1	36	(3)	95	(3)	(3)	(3)	(3)
4	15.5	2	50	45	110	142	(3)	(3)	250
5	25.8	2	60	50	150	194	(3)	(3)	420
6	25.8 (4)	2	60	50	125	(3)	(3)	(3)	420
7	27.0	1	60	(3)	125	(3)	(3)	(3)	(3)
8	38.0	1	80	(3)	150	(3)	(3)	(3)	(3)
9	38.0	2	80	75	200	258	(3)	(3)	610
10	38.0 (4)	2	80	75	150	(3)	(3)	(3)	610
11	48.3	2	105	95	250	322	(3)	(3)	780
12	72.5	2	160	140	350	452	(3)	(3)	1170
13	123	3	260	230	550	710	(3)	(3)	1990
14	145	3	310	275	650	838	(3)	(3)	2340
15	170	3	365	315	750	968	(3)	(3)	2750
16	245	3	425	350	900	1160	(3)	(3)	3960
17	362	3	555	(3)	1300	1680	825	900	5850
18	550	3	860	(3)	1800	2320	1175	1300	8890
19	800	3	960	(3)	2050	2640	1425	1500	12900

NOTES

- (1) For circuit breakers applied in gas insulated substations, see Table 5.
- (2) 1.2 x 50 μ seconds positive and negative wave as defined in ANSI/IEEE Std. 4. All impulse values are phase-to-phase and phase-to-ground and across the open contacts.
- (3) Not required.
- (4) These circuit breakers are intended for application on grounded wye distribution circuits equipped with surge arresters.
- (5) Minimum creepage corresponds to Light Pollution level. Refer to ANSI/IEEE C37.010 for special cases of pollution level, or to the manufacturer.
- (6) For outdoor circuit breakers rated 123 kV and above and that have isolating gaps in series with the interrupting gaps, or have additional gaps in the resistor or capacitor circuits, the impulse test for interrupters and resistors shall be 75% of the value shown in column 5.

SA PROTECTIVE MARGINS

- AFTER SELECTING ARRESTER FOR MCOV AND TOV
- CALCULATE MARGIN - BIL DIVIDED BY PROTECTIVE LEVEL - at 10 kA, 8x20 μ s
- 27 kV - 10 kA PL is 66.3 kV
 - ◆ 150 kV BIL/ 66.3 kV PL = 2.26 or 126% MARGIN
 - ◆ SEPARATION DISTANCE, ALTITUDE, LEAD LENGTH, CURRENT MAGNITUDE, RISE TIME
 - ◆ I THINK A MARGIN OF 40% IS THE MINIMUM ACCEPTABLE FOR NSR

ARRESTER SEPARATION DIST.



ARRESTER SEPARATION DIST.

