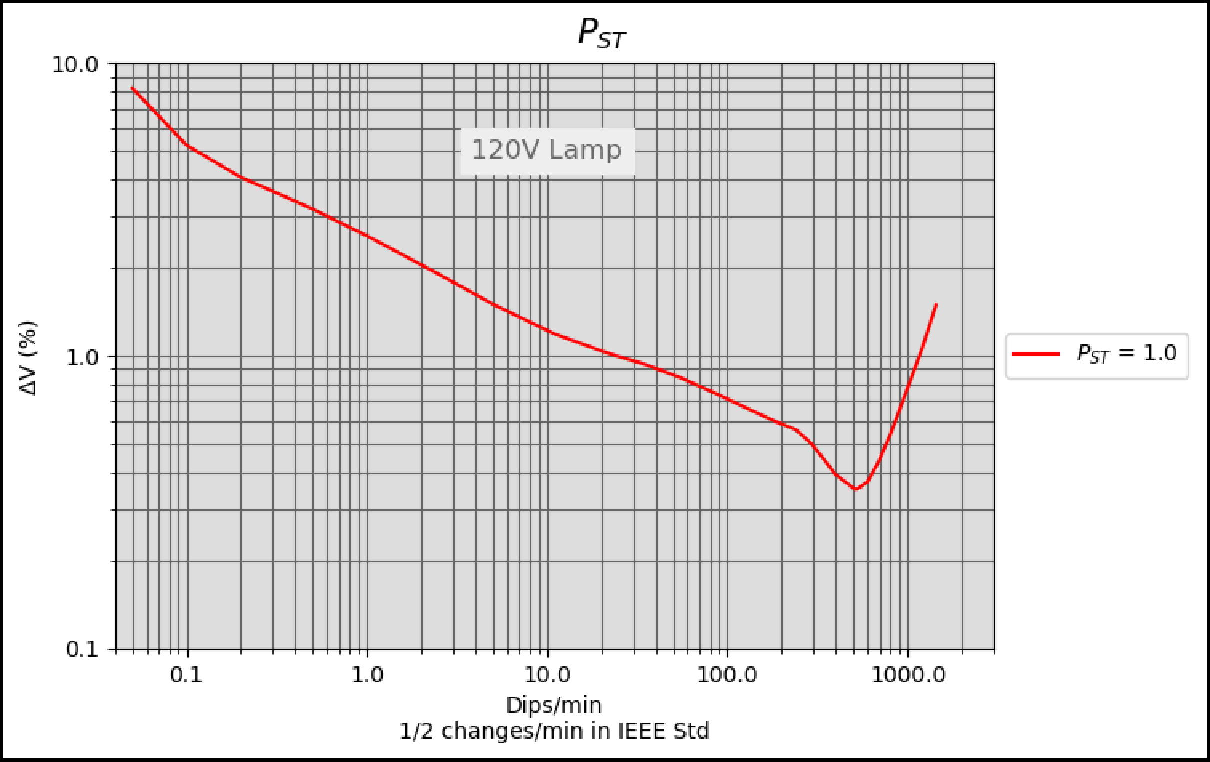
P_{st} and P_{lt} calculator assumptions

the P_{st} - P_{lt} worst case calculator assumes rectangular voltage change waveforms

(same as IEEE 1453 and IEC 61000 published curves)

Dips per min	Changes per min	230V Pst = 1 ΔV/V (%)	120V Pst = 1 ΔV/V (%)
0.05	0.10	7.4000	8.2020
0.10	0.20	4.5800	5.2320
0.20	0.40	3.5400	4.0620
0.30	0.60	3.2000	3.6450
0.50	1.0	2.7240	3.1660
1.0	2.0	2.2110	2.5680
1.5	3.0	1.9500	2.2500
2.5	5.0	1.6400	1.8990
3.5	7.0	1.4590	1.6950
5.0	10.0	1.2900	1.4990
11.0	22.0	1.0200	1.1860
19.5	39.0	0.9060	1.0440
24.0	48.0	0.8700	1.0000
34.0	68.0	0.8100	0.9390
55.0	110.0	0.7250	0.8410
88.0	176.0	0.6400	0.7390
136.5	273.0	0.5600	0.6500
187.5	375.0	0.5000	0.5940
240.0	480.0	0.4800	0.5590
292.5	585.0	0.4200	0.5010
341.0	682.0	0.3700	0.4450
398.0	796.0	0.3200	0.3930
510.0	1020.0	0.2800	0.3500
527.5	1055.0	0.2800	0.3510
600.0	1200.0	0.2900	0.3710
695.0	1390.0	0.3400	0.4380
810.0	1620.0	0.4020	0.5470
1200.0	2400.0	0.7700	1.0510
1437.5	2875.0	1.0400	1.4900

test points for
rectangular voltage fluctuations
IEEE 1453 and IEC 61000

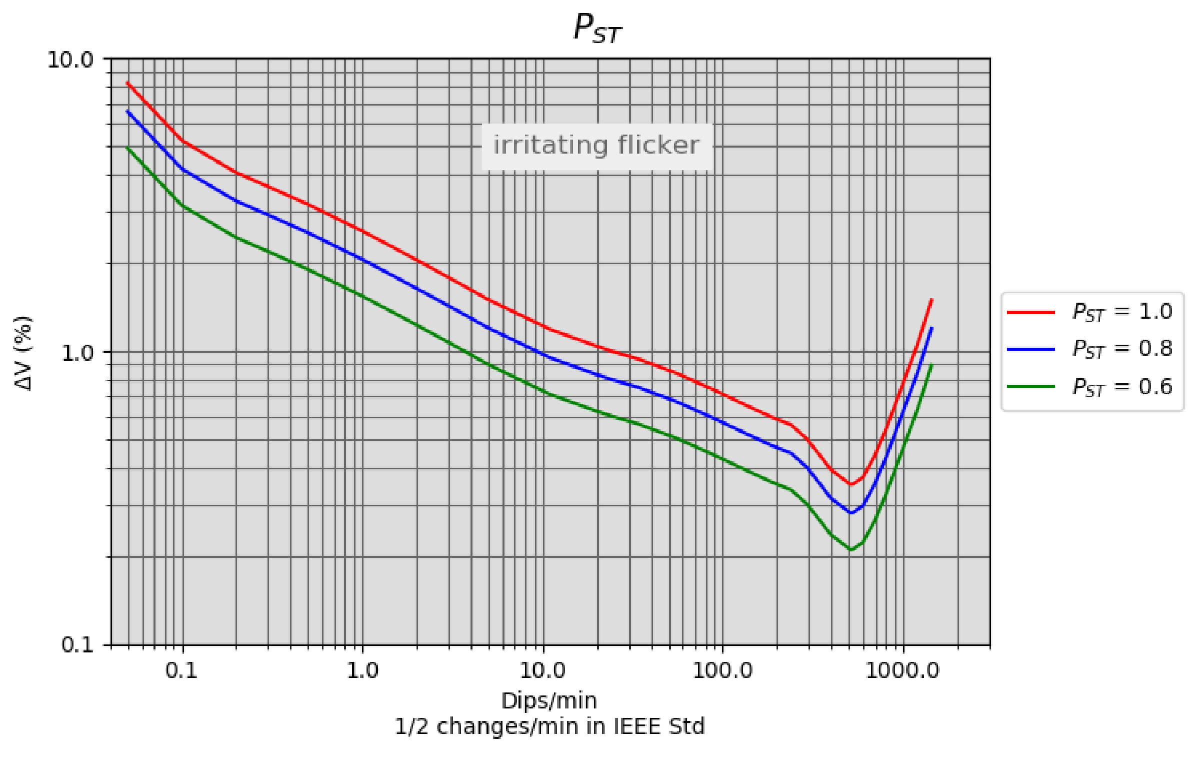


120V lighting equipment was chosen to reflect North America.
Voltage Dips/minute was used as the fluctuation frequency.
(Dips/min seems more intuitive for user input)

with these assumptions, the P_{st} = 1.0 curve was plotted

P_{st} and P_{lt} calculator assumptions (cont.)

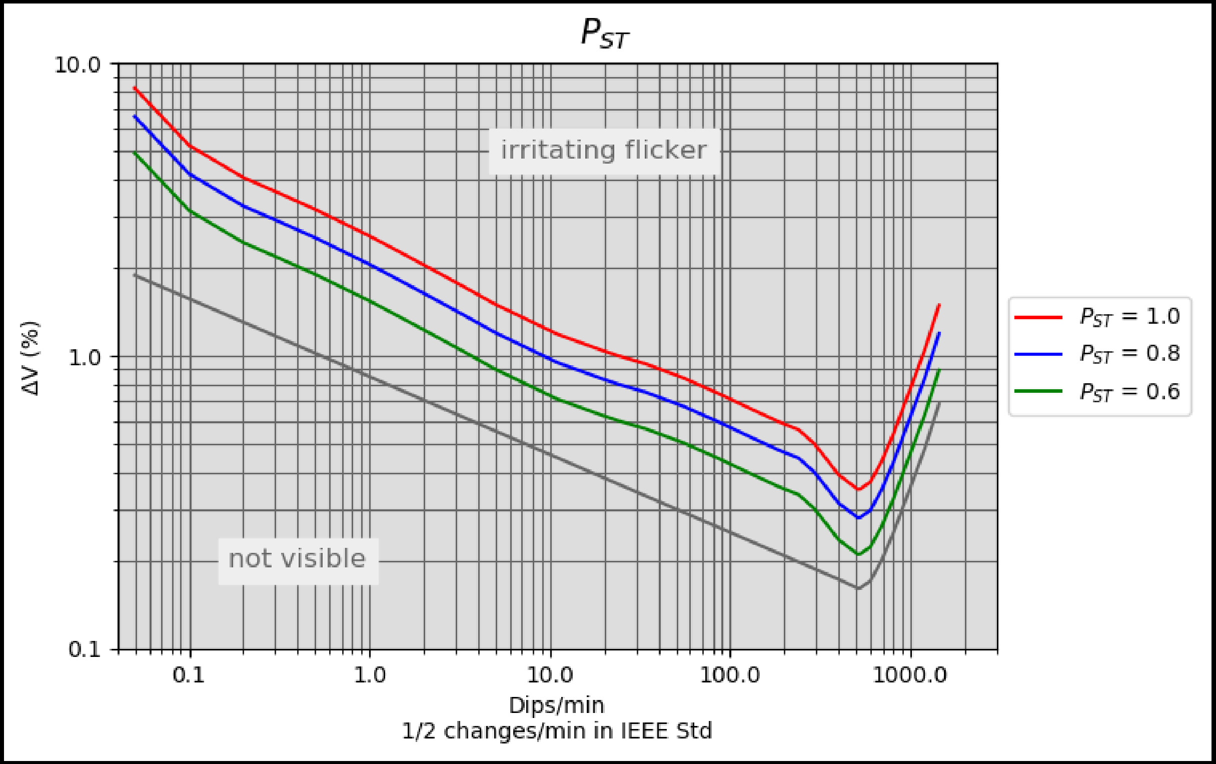
Dips per min	120V Pst = 1 ΔV/V (%)	120V Pst = 0.8 ΔV/V (%)	120V Pst = 0.6 ΔV/V (%)
0.05	8.2020	6.5616	4.9212
0.10	5.2320	4.1856	3.1392
0.20	4.0620	3.2496	2.4372
0.30	3.6450	2.9160	2.1870
0.50	3.1660	2.5328	1.8996
1.0	2.5680	2.0544	1.5408
1.5	2.2500	1.8000	1.3500
2.5	1.8990	1.5192	1.1394
3.5	1.6950	1.3560	1.0170
5.0	1.4990	1.1992	0.8994
11.0	1.1860	0.9488	0.7116
19.5	1.0440	0.8352	0.6264
24.0	1.0000	0.8000	0.6000
34.0	0.9390	0.7512	0.5634
55.0	0.8410	0.6728	0.5046
88.0	0.7390	0.5912	0.4434
136.5	0.6500	0.5200	0.3900
187.5	0.5940	0.4752	0.3564
240.0	0.5590	0.4472	0.3354
292.5	0.5010	0.4008	0.3006
341.0	0.4450	0.3560	0.2670
398.0	0.3930	0.3144	0.2358
510.0	0.3500	0.2800	0.2100
527.5	0.3510	0.2808	0.2106
600.0	0.3710	0.2968	0.2226
695.0	0.4380	0.3504	0.2628
810.0	0.5470	0.4376	0.3282
1200.0	1.0510	0.8408	0.6306
1437.5	1.4900	1.1920	0.8940



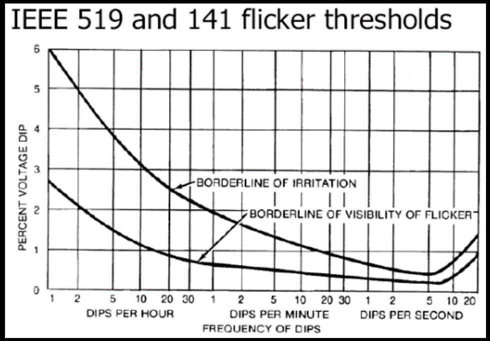
since P_{st} values change linearly with respect to voltage change …
P_{st} = 0.8 and P_{st} = 0.6 curves were plotted.
since P_{st} values >= 1.0 are considered "irritating" flicker …
a label was added in that region for reference.

P_{st} and P_{lt} calculator assumptions (cont.)

Dips per min	Border Line ΔV/V (%)
0.05	1.8847
0.10	1.5673
0.20	1.3033
0.30	1.1700
0.50	1.0213
1.0	0.8493
1.5	0.7624
2.5	0.6655
3.5	0.6085
5.0	0.5534
11.0	0.4487
19.5	0.3853
24.0	0.3646
34.0	0.3323
55.0	0.2924
88.0	0.2580
136.5	0.2296
187.5	0.2110
240.0	0.1975
292.5	0.1874
341.0	0.1799
398.0	0.1727
510.0	0.1608
527.5	0.1612
600.0	0.1704
695.0	0.2012
810.0	0.2512
1200.0	0.4827
1437.5	0.6844



a border-line of flicker visibility curve was estimated and plotted from legacy IEEE 519 and 141 standards.
a label in that region was added for reference.



P_{st} and P_{lt} calculator assumptions (cont.)

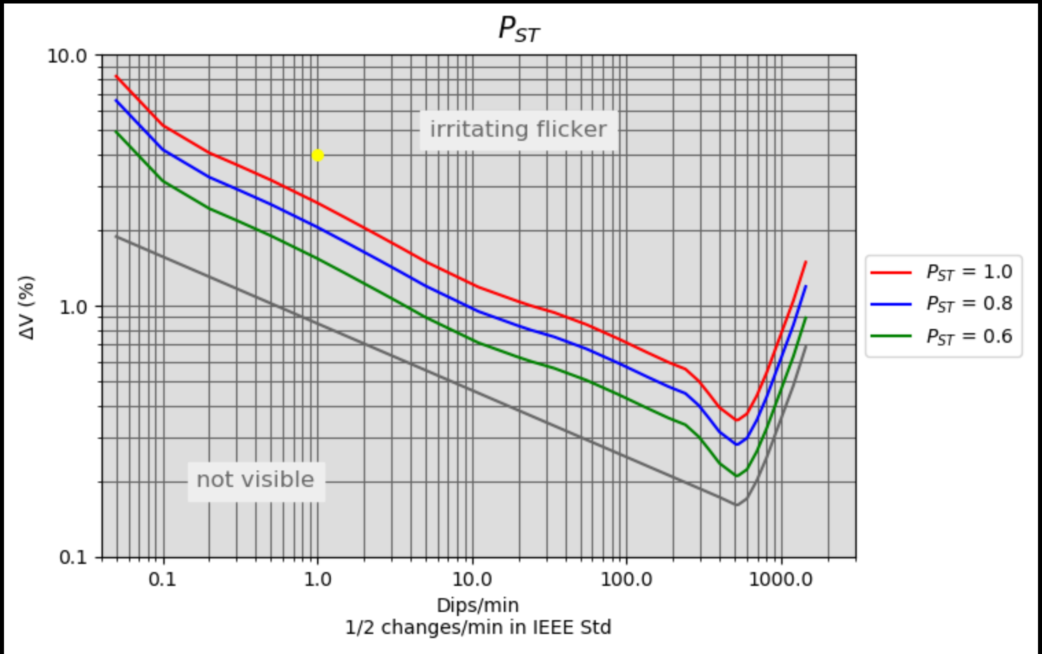
the user is prompted for input

ΔV (%)	Num Dips	Every	Time Unit	Dips/min	$P_{ST} = P_{LT}$
4.0	10	10	Minutes	1.0	1.5576
how much voltage change ?	how many times does it occur ?	how often does it repeat this pattern ?		Dips/min is calculated	worst case P_{st} is calculated

$$P_{st} = \frac{\Delta V}{\Delta V_{P_{st}=1}}$$

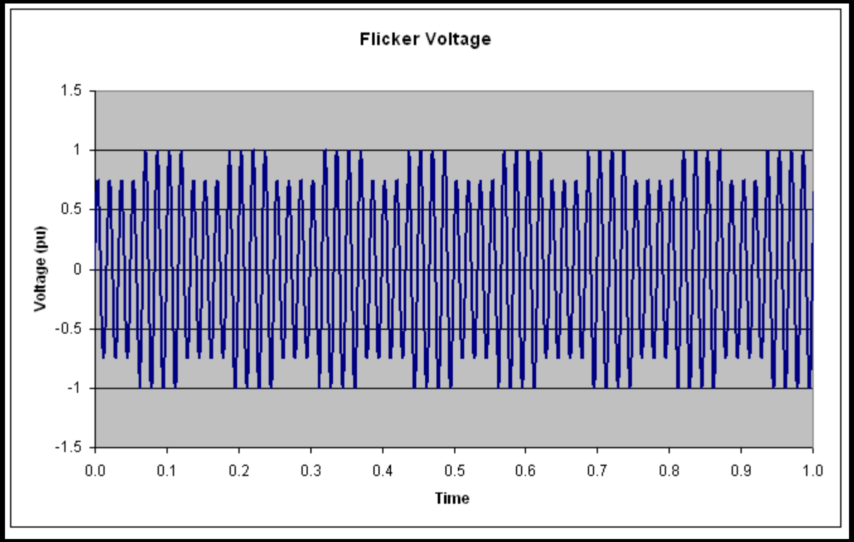
since voltage change waveform is rectangular

$$P_{lt} = P_{st}$$

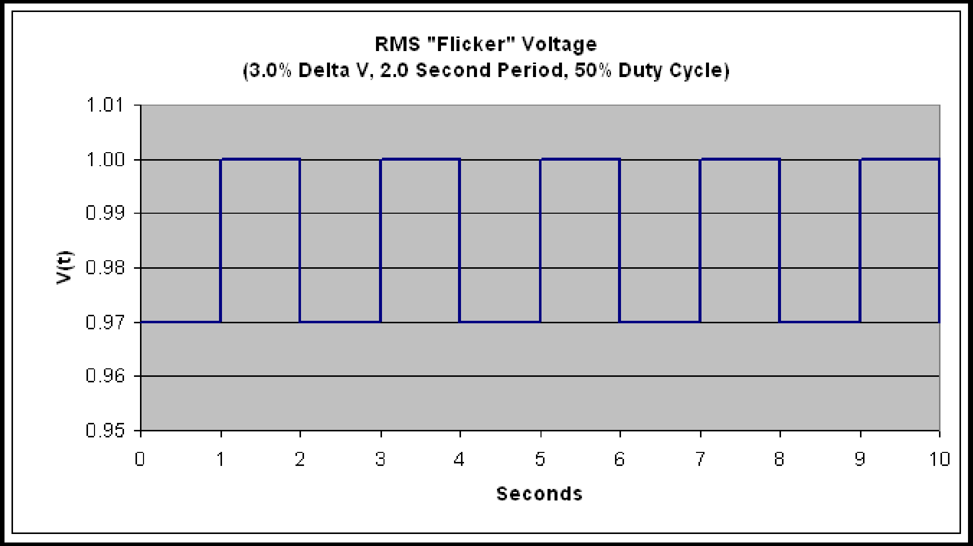


user operating point is plotted with a yellow dot

P_{st} and P_{lt} calculator assumptions (cont.)



example 60Hz waveform
$\Delta V = 2.5\%$
8 dips per second
480 dips per minute



example RMS waveform
$\Delta V = 3.0\%$
1 dip every 2 seconds
0.5 dips per second
30 dips per minute

P_{st} and P_{lt} calculator assumptions (cont.)

P_{st} can also be estimated with an analytical approach presented in IEC 61000-3-3
this method is based on calculating a "flicker time" (t_f) for each voltage change

let :
$d = \Delta V\%$
cpm = *voltage changes per minute*
dpm = *voltage dips per minute*
$cpm = 2 \cdot dpm$
$\#min$ = *test period in minutes*
T_P = *test period in seconds*

Dips per min	230V Pst = 1 ΔV/V (%)	120V Pst = 1 ΔV/V (%)	IEC 61000 Pst = 1 ΔV/V (%)
0.05	7.4000	8.2020	8.7756
0.10	4.5800	5.2320	7.0665
0.20	3.5400	4.0620	5.6903
0.30	3.2000	3.6450	5.0131
0.50	2.7240	3.1660	4.2734
1.0	2.2110	2.5680	3.4412
1.5	1.9500	2.2500	3.0316
2.5	1.6400	1.8990	2.5843
3.5	1.4590	1.6950	2.3264
5.0	1.2900	1.4990	2.0810
11.0	1.0200	1.1860	1.6266
19.5	0.9060	1.0440	1.3601
24.0	0.8700	1.0000	1.2746
34.0	0.8100	0.9390	1.1432
55.0	0.7250	0.8410	0.9837
88.0	0.6400	0.7390	0.8493
136.5	0.5600	0.6500	0.7404
187.5	0.5000	0.5940	0.6705
240.0	0.4800	0.5590	0.6207
292.5	0.4200	0.5010	0.5835
341.0	0.3700	0.4450	0.5562
398.0	0.3200	0.3930	0.5300
510.0	0.2800	0.3500	0.4904
527.5	0.2800	0.3510	0.4853
600.0	0.2900	0.3710	0.4662
695.0	0.3400	0.4380	NA
810.0	0.4020	0.5470	NA
1200.0	0.7700	1.0510	NA
1437.5	1.0400	1.4900	NA

slightly higher ΔV allowed for $P_{st} = 1$ (rows 0.05 to 600.0)

$$t_f = 2.3[d \cdot F]^{3.2}$$

if voltage changes are rectangular …
- *the shape factor $F = 1$*
- *all voltage changes are equal*

$$t_f = 2.3d^{3.2}$$

$$P_{st} \approx \left[\frac{\sum t_f}{T_p}\right]^{\frac{1}{3.2}}$$

$$P_{st} \approx \left[\frac{cpm \cdot \#min \cdot t_f}{\#min \cdot 60}\right]^{\frac{1}{3.2}}$$

$$P_{st} \approx \left[\frac{cpm \cdot t_f}{60}\right]^{\frac{1}{3.2}}$$

$$P_{st} \approx d\left[\frac{2.3 \cdot cpm}{60}\right]^{\frac{1}{3.2}}$$

$$P_{st} \approx d\left[\frac{1.15 \cdot dpm}{60}\right]^{\frac{1}{3.2}}$$

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Questions or Comments …

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