PDHonline Course E426 (3 PDH)

Voltage Drop Calculations

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Table 2

Derivation of Value K for Copper Using NEC Table 8			
Wire Size (Stranded)	NEC Table 8 Circular Mils (C.M.)	NEC Table 8 DC Ohms per 1,000 ft	DC Ohms*C.M./ft
12	6,530	1.98	12.929
10	10,380	1.24	12.871
8	16,510	0.778	12.845
6	26,240	0.491	12.884
4	41,740	0.308	12.856
2	66,360	0.194	12.874
1	83,690	0.154	12.888
1/0	105,600	0.122	12.883
2/0	133,100	0.0967	12.871
250	250,000	0.0515	12.875
350	350,000	0.0367	12.845
500	500,000	0.0258	12.900
			12.877 Average Value

Comparison to NEC Table 9 in Steel Conduit					
Wire Size (Stranded)	NEC Table 8 Circular Mils (C.M.)	NEC Table 9 AC Ohms per 1,000 ft	AC Ohms*C.M./ft	NEC Table 9 Effective Z at 0.85 PF per 1,000 ft	Effective Z at 0.85 PF Ohms*C.M./ft
12	6,530	2.0	13.060	1.7	11.101
10	10,380	1.2	12.456	1.1	11.418
8	16,510	0.78	12.878	0.70	11.557
6	26,240	0.49	12.858	0.45	11.808
4	41,740	0.31	12.939	0.30	12.522
2	66,360	0.20	13.272	0.20	13.272
1	83,690	0.16	13.390	0.16	13.390
1/0	105,600	0.12	12.672	0.13	13.728
2/0	133,100	0.10	13.310	0.11	14.641
250	250,000	0.054	13.500	0.073	18.250
350	350,000	0.039	13.650	0.060	21.000
500	500,000	0.029	14.500	0.050	25.000

Table 3

Effective Z at 0.85 PF for Selected Wire Sizes in Steel Conduit						
Wire Size	X_L (Reactance)	Alternating-Current Resistance	Power Factor PF [cos(θ)]	Rcos(θ)	Xsin(θ)	Effective Z = Rcos(θ) + Xsin(θ)
12	0.068	2.0	0.85	1.700	0.036	1.7
10	0.063	1.2	0.85	1.020	0.033	1.1
4	0.060	0.31	0.85	0.264	0.032	0.30
2	0.057	0.20	0.85	0.170	0.030	0.20
1/0	0.055	0.12	0.85	0.102	0.029	0.13
250	0.052	0.054	0.85	0.046	0.027	0.073
500	0.048	0.029	0.85	0.025	0.025	0.050

Table 4

Effective Z at Selected PF for Selected Wire Sizes in Steel Conduit						
Wire Size	X_L (Reactance)	Alternating-Current Resistance	Power Factor PF [cos(θ)]	Rcos(θ)	Xsin(θ)	Effective Z = Rcos(θ) + Xsin(θ)
12	0.068	2.000	0.80	1.600	0.041	1.641
12	0.068	2.000	0.85	1.700	0.036	1.736
12	0.068	2.000	0.90	1.800	0.030	1.830
12	0.068	2.000	1.00	2.000	0.000	2.000
10	0.063	1.200	0.80	0.960	0.038	0.998
10	0.063	1.200	0.85	1.020	0.033	1.053
10	0.063	1.200	0.90	1.080	0.027	1.107
10	0.063	1.200	1.00	1.200	0.000	1.200
4	0.060	0.310	0.80	0.248	0.036	0.284
4	0.060	0.310	0.85	0.264	0.032	0.295
4	0.060	0.310	0.90	0.279	0.026	0.305
4	0.060	0.310	1.00	0.310	0.000	0.310
2	0.057	0.200	0.80	0.160	0.034	0.194
2	0.057	0.200	0.85	0.170	0.030	0.200
2	0.057	0.200	0.90	0.180	0.025	0.205
2	0.057	0.200	1.00	0.200	0.000	0.200
1/0	0.055	0.120	0.80	0.096	0.033	0.129
1/0	0.055	0.120	0.85	0.102	0.029	0.131
1/0	0.055	0.120	0.90	0.108	0.024	0.132
1/0	0.055	0.120	1.00	0.120	0.000	0.120
250	0.052	0.054	0.80	0.043	0.031	0.074
250	0.052	0.054	0.85	0.046	0.027	0.073
250	0.052	0.054	0.90	0.049	0.023	0.071
250	0.052	0.054	1.00	0.054	0.000	0.054
500	0.048	0.029	0.80	0.023	0.029	0.052
500	0.048	0.029	0.85	0.025	0.025	0.050
500	0.048	0.029	0.90	0.026	0.021	0.047
500	0.048	0.029	1.00	0.029	0.000	0.029

Table 5

Vdrop Error for 10 Hp at 480V/3Φ, 0.85 PF

Wire Size	Table 8 Cir. Mils	Table 8 DC Ohms	Table 9 X_L (React) Ohms/k-ft	Table 9 AC Ohms/k-ft	Power Factor PF [cos(θ)]	Rcos(θ) per k-ft	Xsin(θ) per k-ft	NEC Effective Z at 0.85 PF	Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft	Full-Load Current	One-Way Wire Length (ft)
12	6,530	1.98	0.068	2.000	0.85	1.700	0.036	1.700	1.736	14.0	200.0

Equation 11: Error = $\{Vs - \sqrt{[Vs^2 - (IX\cos\Phi - IR\sin\Phi)^2]}\}$ Result: 0.0140 V Error line-to-neutral

Equation 15: Error = $\sqrt{3}*\{Vs - \sqrt{[Vs^2 - (IX\cos\Phi - IR\sin\Phi)^2]}\}$ Result: 0.0243 V Error line-to-line

Vdrop Error for 15 KW at 480V/3Φ, 1.0 PF

Wire Size	Table 8 Cir. Mils	Table 8 DC Ohms	Table 9 X_L (React) Ohms/k-ft	Table 9 AC Ohms/k-ft	Power Factor PF [cos(θ)]	Rcos(θ) per k-ft	Xsin(θ) per k-ft	NEC Effective Z at 0.85 PF	Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft	Full-Load Current	One-Way Wire Length (ft)
10	10,380	1.24	0.063	1.200	1.00	1.200	0.000	1.100	1.200	18.0	200.0

Equation 11: Error = $\{Vs - \sqrt{[Vs^2 - (IX\cos\Phi - IR\sin\Phi)^2]}\}$ Result: 0.0001 V Error line-to-neutral

Equation 15: Error = $\sqrt{3}*\{Vs - \sqrt{[Vs^2 - (IX\cos\Phi - IR\sin\Phi)^2]}\}$ Result: 0.0002 V Error line-to-line

Vdrop Error for 250 Hp at 480V/3Φ, 0.9 PF

Wire Size	Table 8 Cir. Mils	Table 8 DC Ohms	Table 9 X_L (React) Ohms/k-ft	Table 9 AC Ohms/k-ft	Power Factor PF [cos(θ)]	Rcos(θ) per k-ft	Xsin(θ) per k-ft	NEC Effective Z at 0.85 PF	Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft	Full-Load Current	One-Way Wire Length (ft)
500	500,000	.0258	0.048	0.029	0.90	0.026	0.021	0.050	0.047	302.0	200.0

Equation 11: Error = $\{Vs - \sqrt{[Vs^2 - (IX\cos\Phi - IR\sin\Phi)^2]}\}$ Result: 0.006 V Error line-to-neutral

Equation 15: Error = $\sqrt{3}*\{Vs - \sqrt{[Vs^2 - (IX\cos\Phi - IR\sin\Phi)^2]}\}$ Result: 0.011 V Error line-to-line

Table 7

Comparing the Results of Different Line-to-Line Vdrop Formulas for 10 Hp at 480V/3Φ, 0.85 PF											
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
12	6,530	1.98	0.068	2.000	0.85	1.700	0.036	1.700	1.736	14.0	200.0
Equation 4:	Vdrop = $\sqrt{3} * I * K * R * L / A$			See Note below.		K = 12.9		Result:	9.581 V Approx.		1.995%
Equation 3:	Vdrop = $\sqrt{3} * I * R * L$					Using DC Ohms Only		Result:	9.602 V Approx.		2%
Equation 3:	Vdrop = $\sqrt{3} * I * R * L$					Using AC Ohms Only		Result:	9.699 V Approx.		2.02%
Equation 3:	Vdrop = $\sqrt{3} * I * R * L$					Using Effective Z at 0.85 PF		Result:	8.245 V Approx.		1.717%
Equation 9:	Vdrop = $\sqrt{3} * (IR\cos\theta + Ix\sin\theta) * L$					Calculated Effective Z		Result:	8.418 V Estimated		1.753%
Equation 16:	Vdrop = $\sqrt{3} * \{Vs + IRL\cos\theta + IXL\sin\theta - \sqrt{[Vs^2 - (IXL\cos\Phi - IRL\sin\Phi)^2]}\}$					Vs = 277V line-to-neutral		Result:	8.443 V Actual		1.758%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 8

Comparing the Results of Different Line-to-Line Vdrop Formulas for 15 KW at 480V/3Φ, 1.0 PF											
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
10	10,380	1.24	0.063	1.200	1.00	1.200	0.000	1.100	1.200	18.0	200.0
Equation 4:	Vdrop = √3 * I * K * R * L / A			See Note below.		K = 12.9		Result:	7.749 V Approx.		1.614%
Equation 3:	Vdrop = √3 * I * R * L					Using DC Ohms Only		Result:	7.732 V Approx.		1.61%
Equation 3:	Vdrop = √3 * I * R * L					Using AC Ohms Only		Result:	7.482 V Approx.		1.558%
Equation 3:	Vdrop = √3 * I * R * L					Using Effective Z at 0.85 PF		Result:	6.859 V Approx.		1.428%
Equation 9:	Vdrop = √3 * (IRcosθ + Ixsinθ) * L					Calculated Effective Z		Result:	7.482 V Estimated		1.558%
Equation 16:	Vdrop = √3 * {Vs + IRLcosθ + IXLsinθ - √[Vs^2 - (IXLcosΦ-IRLsinΦ)^2]}					Vs = 277V line-to-neutral		Result:	7.4826 V Actual		1.558%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 9

Comparing the Results of Different Line-to-Line Vdrop Formulas for 250 Hp at 480V/3Φ, 0.9 PF											
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
500	500,000	.0258	0.048	0.029	0.90	0.026	0.021	0.050	0.047	302.0	200.0
Equation 4:	Vdrop = $\sqrt{3} * I * K * R * L / A$			See Note below.		K = 12.9		Result:	2.699 V Approx.		0.562%
Equation 3:	Vdrop = $\sqrt{3} * I * R * L$					Using DC Ohms Only		Result:	2.699 V Approx.		0.562%
Equation 3:	Vdrop = $\sqrt{3} * I * R * L$					Using AC Ohms Only		Result:	3.034 V Approx.		0.632%
Equation 3:	Vdrop = $\sqrt{3} * I * R * L$					Using Effective Z at 0.85 PF		Result:	5.231 V Approx.		1.089%
Equation 9:	Vdrop = $\sqrt{3} * (IR\cos\theta + Ix\sin\theta) * L$					Calculated Effective Z		Result:	4.919 V Estimated		1.024%
Equation 16:	Vdrop = $\sqrt{3} * \{Vs + IRL\cos\theta + IXL\sin\theta - \sqrt{[Vs^2 - (IXL\cos\Phi - IRL\sin\Phi)^2]}\}$					Vs = 277V line-to-neutral		Result:	4.930 V Actual		1.027%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 10

Line-to-Line Vdrop for 10 A, 0.9 PF with 100' of 10 AWG Conductors — **120 V/1Φ**

Wire Size	Table 8 Cir. Mils	Table 8 DC Ohms	Table 9 X_L (React) Ohms/k-ft	Table 9 AC Ohms/k-ft	Power Factor PF [cos(θ)]	Rcos(θ) per k-ft	Xsin(θ) per k-ft	NEC Effective Z at 0.85 PF	Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft	Full-Load Current	One-Way Wire Length (ft)
10	10,380	1.24	0.063	1.200	0.90	1.080	0.027	1.100	1.107	10.0	100.0

Equation 4:	Vdrop = 2 * I * K * R * L / A	K = 12.9	Result:	2.486 V Approx.	2.071%
Equation 3:	Vdrop = 2 * I * R * L	Using DC Ohms Only	Result:	2.480 V Approx.	2.066%
Equation 3:	Vdrop = 2 * I * R * L	Using AC Ohms Only	Result:	2.400 V Approx.	2%
Equation 3:	Vdrop = 2 * I * R * L	Using Effective Z at 0.85 PF	Result:	2.200 V Approx.	1.833%
Equation 9:	Vdrop = 2 * (IRcosθ + Ixsinθ) * L	Calculated Effective Z	Result:	2.215 V Estimated	1.845%
Equation 16:	Vdrop = 2 * $\{Vs + IRL\cos\theta + IXL\sin\theta - \sqrt{[Vs^2 - (IXL\cos\Phi - IRL\sin\Phi)^2]}\}$	Vs = 277V line-to-neutral	Result:	2.216 V Actual	1.846%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 11

Line-to-Line Vdrop for 10 A, 0.9 PF at One-Way Cable Length in Feet = Applied Voltage									120 V/1Φ		
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
12	6,530	1.98	0.068	2.000	0.90	1.800	0.030	1.700	1.830	10.0	120.0
Equation 4:	Vdrop = 2 * I * K * R * L / A					K = 12.9		Result:	4.741 V Approx.		3.95%
Equation 3:	Vdrop = 2 * I * R * L					Using DC Ohms Only		Result:	4.752 V Approx.		3.96%
Equation 3:	Vdrop = 2 * I * R * L					Using AC Ohms Only		Result:	4.800 V Approx.		4%
Equation 3:	Vdrop = 2 * I * R * L					Using Effective Z at 0.85 PF		Result:	4.080 V Approx.		3.4%
Equation 9:	Vdrop = 2 * (IRcosθ + Ixsinθ) * L					Calculated Effective Z		Result:	4.391 V Estimated		3.659%
Equation 16:	Vdrop = 2 * $\{Vs + IRL\cos\theta + IXL\sin\theta - \sqrt{[Vs^2 - (IXL\cos\Phi - IRL\sin\Phi)^2]}\}$					Vs = 120V line-to-neutral		Result:	4.399 V Actual		3.665%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 12

Line-to-Line Vdrop for 10 A, 0.9 PF at One-Way Cable Length in Feet = Applied Voltage									208 V/3Φ		
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
12	6,530	1.98	0.068	2.000	0.90	1.800	0.030	1.700	1.830	10.0	208.0
Equation 4:	Vdrop = √3 * I * K * R * L / A					K = 12.9		Result:	7.117 V Approx.		3.421%
Equation 3:	Vdrop = √3 * I * R * L					Using DC Ohms Only		Result:	7.133 V Approx.		3.429%
Equation 3:	Vdrop = √3 * I * R * L					Using AC Ohms Only		Result:	7.205 V Approx.		3.464%
Equation 3:	Vdrop = √3 * I * R * L					Using Effective Z at 0.85 PF		Result:	6.125 V Approx.		2.944%
Equation 9:	Vdrop = √3 * (IRcosθ + Ixsinθ) * L					Calculated Effective Z		Result:	6.592 V Approx.		3.169%
Equation 16:	Vdrop = √3 * {Vs + IRLcosθ + IXLsinθ - √[Vs^2 - (IXLcosΦ-IRLsinΦ)^2]}					Vs = 120V line-to-neutral		Result:	6.612 V (Actual)		3.178%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 13

Line-to-Line Vdrop for 10 A, 0.9 PF at One-Way Cable Length in Feet = Applied Voltage									277 V/1Φ		
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
12	6,530	1.98	0.068	2.000	0.90	1.800	0.030	1.700	1.830	10.0	277.0
Equation 4:	Vdrop = 2 * I * K * R * L / A					K = 12.9		Result:	10.944 V Approx.		3.95%
Equation 3:	Vdrop = 2 * I * R * L					Using DC Ohms Only		Result:	10.969 V Approx.		3.96%
Equation 3:	Vdrop = 2 * I * R * L					Using AC Ohms Only		Result:	11.080 V Approx.		4%
Equation 3:	Vdrop = 2 * I * R * L					Using Effective Z at 0.85 PF		Result:	9.418 V Approx.		3.4%
Equation 9:	Vdrop = 2 * (IRcosθ + Ixsinθ) * L					Calculated Effective Z		Result:	10.136 V Estimated		3.659%
Equation 16:	Vdrop = 2 * $\{Vs + IRL\cos\theta + IXL\sin\theta - \sqrt{[Vs^2 - (IXL\cos\Phi - IRL\sin\Phi)^2]}\}$					Vs = 277V line-to-neutral		Result:	10.154 V Actual		3.665%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.

Table 14

Line-to-Line Vdrop for 10 A, 0.9 PF at One-Way Cable Length in Feet = Applied Voltage									480 V/3Φ		
Wire Size	**Table 8 Cir. Mils**	**Table 8 DC Ohms**	**Table 9 X_L (React) Ohms/k-ft**	**Table 9 AC Ohms/k-ft**	**Power Factor PF [cos(θ)]**	**Rcos(θ) per k-ft**	**Xsin(θ) per k-ft**	**NEC Effective Z at 0.85 PF**	**Effective Z = Rcos(θ) + Xsin(θ) Ohms/k-ft**	**Full-Load Current**	**One-Way Wire Length (ft)**
12	6,530	1.98	0.068	2.000	0.90	1.800	0.030	1.700	1.830	10.0	480.0
Equation 4:	Vdrop = √3 * I * K * R * L / A					K = 12.9		Result:	16.424 V Approx.		3.421%
Equation 3:	Vdrop = √3 * I * R * L					Using DC Ohms Only		Result:	16.461 V Approx.		3.429%
Equation 3:	Vdrop = √3 * I * R * L					Using AC Ohms Only		Result:	16.628 V Approx.		3.464%
Equation 3:	Vdrop = √3 * I * R * L					Using Effective Z at 0.85 PF		Result:	14.134 V Approx.		2.944%
Equation 9:	Vdrop = √3 * (IRcosθ + Ixsinθ) * L					Calculated Effective Z		Result:	15.211 V Approx.		3.169%
Equation 16:	Vdrop = √3 * {Vs + IRLcosθ + IXLsinθ - √[Vs^2 - (IXLcosΦ-IRLsinΦ)^2]}					Vs = 277V line-to-neutral		Result:	15.259 V (Actual)		3.178%

Note: Equation 4 above is the only equation in which the one-way wire length is not divided by 1,000, since the units of K are (Ohms*C.M.) / ft.