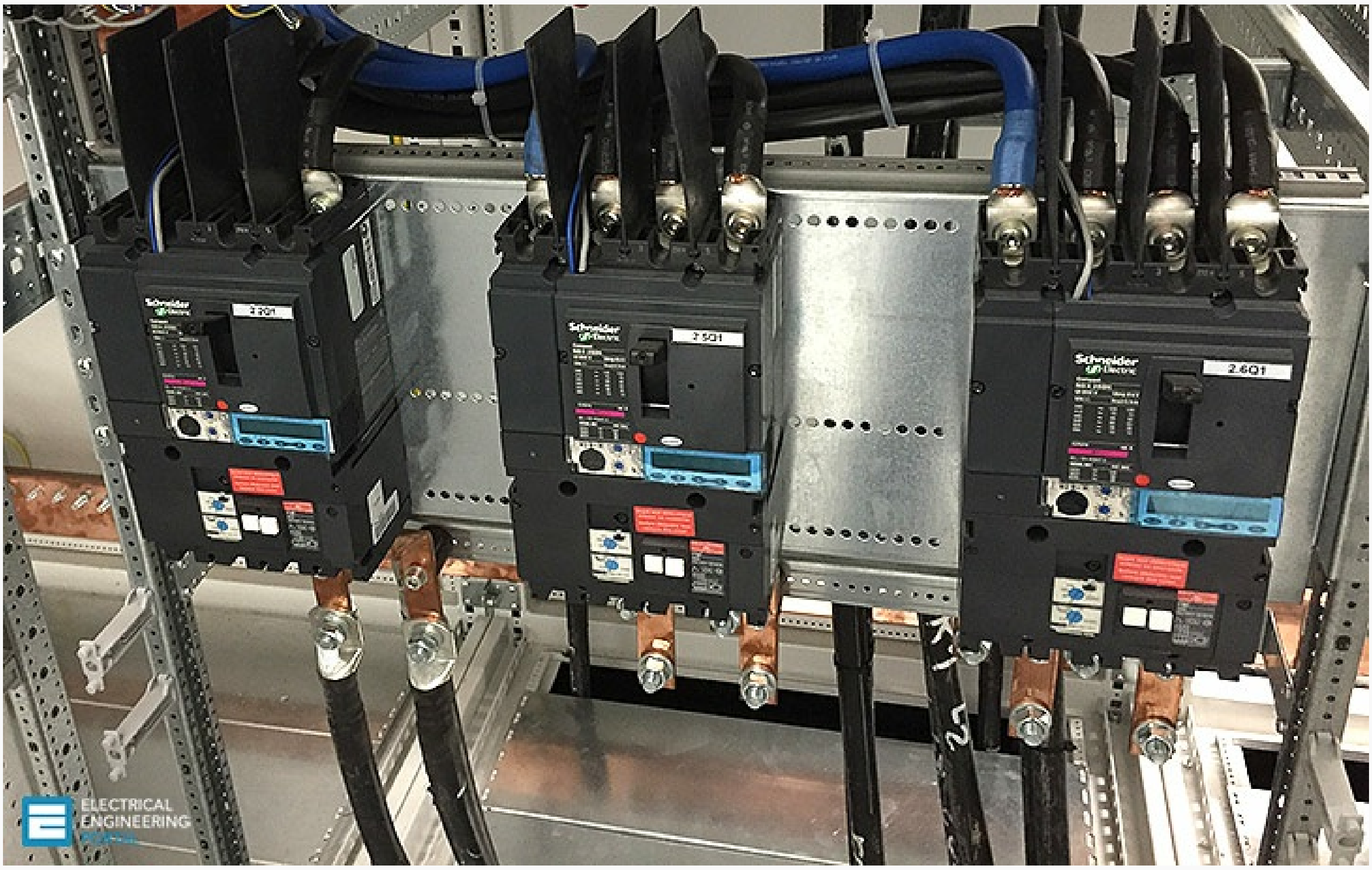
Voltage Drop Calculations For Engineers – Beginners



Voltage Drop Calculations For Engineers - Beginners (on photo: Low voltage circuit breakers type NSX 250H, 600V)

Voltage drop formulas //

Voltage drop calculations using the **DC-resistance formula** are not always accurate for AC circuits, especially for those with a less-than-unity power factor or for those that use conductors larger than 2 AWG.

Table 1 allows engineers to perform simple ac voltage drop calculations. Table 1 was compiled using the Neher–McGrath ac-resistance calculation method, and the values presented are both reliable and conservative. This table contains completed calculations of **effective impedance (Z)** for the average ac circuit with an **85 percent power factor** (*see Calculation Example 1*).

If calculations with a different power factor are necessary, Table 1 also contains the appropriate values of inductive reactance and AC resistance (*see Example 2*).

The basic assumptions and the limitations of Table 1 are as follows:

1. Capacitive reactance is ignored.
2. There are three conductors in a raceway.
3. The calculated voltage drop values are approximate.
4. For circuits with other parameters, the Neher–McGrath ac-resistance calculation method is used.

Calculation Example #1

A feeder has a **100 A continuous load**. The system source is **240 volts**, **3 phase**, and the supplying circuit breaker is **125 A**. The feeder is in a trade size 1¼ aluminum conduit with **three 1 AWG THHN copper conductors** operating at their maximum temperature rating of **75°C**. The **circuit length is 150 ft**, and the **power factor is 85 percent**.

Using Table 1 below, **determine the approximate voltage drop of this circuit**.

See the solution //

STEP-1 // Find the approximate line-to-neutral voltage drop.

Using the Table 1 column "**Effective Zat 0.85 PF for Uncoated Copper Wires**", select aluminum conduit and size 1 AWG copper wire. Use the given value of **0.16 ohm per 1000 ft** in the following formula:

$$\begin{aligned}\text{Voltage drop}_{\text{(line-to-neutral)}} &= \begin{matrix}\text{table}\\\text{value}\end{matrix} \times \frac{\begin{matrix}\text{circuit}\\\text{length}\end{matrix}}{1000\ \text{ft}} \times \begin{matrix}\text{circuit}\\\text{load}\end{matrix}\\ &= 0.16\ \text{ohm} \times \frac{150\ \text{ft}}{1000\ \text{ft}} \times 100\ \text{A}\\ &= 2.40\ \text{V}\end{aligned}$$

STEP-2 // Find the line-to-line voltage drop:

$$\begin{aligned}\text{Voltage drop}_{\text{(line-to-line)}} &= \text{voltage drop}_{\text{(line-to-neutral)}} \times \sqrt{3}\\ &= 2.40\ \text{V} \times 1.732\\ &= 4.157\ \text{V}\end{aligned}$$

STEP-3 // Find the voltage present at the load end of the circuit:

$$240\ \text{V} - 4.157\ \text{V} = 235.84\ \text{V}$$

Calculation Example #2

A **270 A continuous load** is present on a feeder. The circuit consists of a single **4-in. PVC conduit** with **three 600-kcmil XHHW/USE aluminum conductors** fed from a **480 V**, 3-phase, 3-wire source. The conductors are operating at their maximum rated temperature of **75°C**.

If the **power factor is 0.7** and the circuit length is **250 ft**, is the voltage drop excessive?

See the solution //

STEP-1 // Using the Table 1 column "*X_L (Reactance) for All Wires*", select PVC conduit and the row for size **600 kcmil** A value of **0.039 ohm per 1000 ft** is given as this **X_L**. Next, using the column "*Alternating-Current Resistance for Aluminum Wires*", select PVC conduit and the row for size 600 kcmil. A value of **0.036 ohm per 1000 ft** is given as this **R**.

STEP-2 // Find the angle representing a **power factor of 0.7**.

Using a calculator with trigonometric functions or a trigonometric function table, find the arccosine ($\cos^{-1}$) θ of 0.7, **which is 45.57 degrees**. For this example, call this angle.

STEP-3 // Find the **impedance (Z)** corrected to **0.7 power factor (Z_c)**:

$$
\begin{aligned}
Z_c &= (R \times \cos\theta) + (X_L \times \sin\theta) \\
&= (0.036 \times 0.7) + (0.039 \times 0.7141) \\
&= 0.0252 + 0.0279 \\
&= 0.0531 \text{ ohm to neutral}
\end{aligned}
$$

STEP-4 // As in Calculation Example 1, find the **approximate line-to-neutral voltage drop**:

$$
\begin{aligned}
\text{Voltage drop}_{(\text{line-to-neutral})} &= Z_c \times \frac{\text{circuit length}}{1000 \text{ ft}} \times \text{circuit load} \\
&= 0.0531 \times \frac{250 \text{ ft}}{1000 \text{ ft}} \times 270 \text{ A} \\
&= 3.584 \text{ V}
\end{aligned}
$$

STEP-5 // Find the approximate line-to-line voltage drop:

$$
\begin{aligned}
\text{Voltage drop}_{(\text{line-to-line})} &= \text{voltage drop}_{(\text{line-to-neutral})} \times \sqrt{3} \\
&= 3.584 \text{ V} \times 1.732 \\
&= 6.208 \text{ V}
\end{aligned}
$$

STEP-6 // Find the approximate voltage drop expressed **as a percentage of the circuit voltage**:

$$
\begin{aligned}
\text{Percentage voltage drop}_{(\text{line-to-line})} &= \frac{6.208 \text{ V}}{480 \text{ V}} \times 100 \\
&= 1.29\% \text{ VD}
\end{aligned}
$$

STEP-7 // Find the voltage present at the load end of the circuit:

$$480 \text{ V} - 6.208 \text{ V} = 473.8 \text{ V}$$

Conclusion // According to 210.19(A)(1), Informational Note No. 4, **this voltage drop does not appear to be excessive**.

TABLE 1 //

Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-Phase, 60 Hz, 75°C (167°F)

Three Single Conductors in Conduit //

Size (AWG or kcmil)	Ohms to Neutral per Kilometer / Ohms to Neutral per 1000 Feet														Size (AWG or kcmil)
	X_L (Reactance) for All Wires		Alternating-Current Resistance for Uncoated Copper Wires			Alternating-Current Resistance for Aluminum Wires			Effective *Z* at 0.85 *PF* for Uncoated Copper Wires			Effective *Z* at 0.85 *PF* for Aluminum Wires			
	PVC, Aluminum Conduits	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	PVC Conduit	Aluminum Conduit	Steel Conduit	
14	0.190 0.058	0.240 0.073	10.2 3.1	10.2 3.1	10.2 3.1	— —	— —	— —	8.9 2.7	8.9 2.7	8.9 2.7	— —	— —	— —	14
12	0.177 0.054	0.223 0.068	6.6 2.0	6.6 2.0	6.6 2.0	10.5 3.2	10.5 3.2	10.5 3.2	5.6 1.7	5.6 1.7	5.6 1.7	9.2 2.8	9.2 2.8	9.2 2.8	12
10	0.164 0.050	0.207 0.063	3.9 1.2	3.9 1.2	3.9 1.2	6.6 2.0	6.6 2.0	6.6 2.0	3.6 1.1	3.6 1.1	3.6 1.1	5.9 1.8	5.9 1.8	5.9 1.8	10
8	0.171 0.052	0.213 0.065	2.56 0.78	2.56 0.78	2.56 0.78	4.3 1.3	4.3 1.3	4.3 1.3	2.26 0.69	2.26 0.69	2.30 0.70	3.6 1.1	3.6 1.1	3.6 1.1	8
6	0.167 0.051	0.210 0.064	1.61 0.49	1.61 0.49	1.61 0.49	2.66 0.81	2.66 0.81	2.66 0.81	1.44 0.44	1.48 0.45	1.48 0.45	2.33 0.71	2.36 0.72	2.36 0.72	6
4	0.157 0.048	0.197 0.060	1.02 0.31	1.02 0.31	1.02 0.31	1.67 0.51	1.67 0.51	1.67 0.51	0.95 0.29	0.95 0.29	0.98 0.30	1.51 0.46	1.51 0.46	1.51 0.46	4
3	0.154 0.047	0.194 0.059	0.82 0.25	0.82 0.25	0.82 0.25	1.31 0.40	1.35 0.41	1.31 0.40	0.75 0.23	0.79 0.24	0.79 0.24	1.21 0.37	1.21 0.37	1.21 0.37	3
2	0.148 0.045	0.187 0.057	0.62 0.19	0.66 0.20	0.66 0.20	1.05 0.32	1.05 0.32	1.05 0.32	0.62 0.19	0.62 0.19	0.66 0.20	0.98 0.30	0.98 0.30	0.98 0.30	2
1	0.151 0.046	0.187 0.057	0.49 0.15	0.52 0.16	0.52 0.16	0.82 0.25	0.85 0.26	0.82 0.25	0.52 0.16	0.52 0.16	0.52 0.16	0.79 0.24	0.79 0.24	0.82 0.25	1
1/0	0.144 0.044	0.180 0.055	0.39 0.12	0.43 0.13	0.39 0.12	0.66 0.20	0.69 0.21	0.66 0.20	0.43 0.13	0.43 0.13	0.43 0.13	0.62 0.19	0.66 0.20	0.66 0.20	1/0
2/0	0.141 0.043	0.177 0.054	0.33 0.10	0.33 0.10	0.33 0.10	0.52 0.16	0.52 0.16	0.52 0.16	0.36 0.11	0.36 0.11	0.36 0.11	0.52 0.16	0.52 0.16	0.52 0.16	2/0
3/0	0.138 0.042	0.171 0.052	0.253 0.077	0.269 0.082	0.259 0.079	0.43 0.13	0.43 0.13	0.43 0.13	0.289 0.088	0.302 0.092	0.308 0.094	0.43 0.13	0.43 0.13	0.46 0.14	3/0
4/0	0.135 0.041	0.167 0.051	0.203 0.062	0.220 0.067	0.207 0.063	0.33 0.10	0.36 0.11	0.33 0.10	0.243 0.074	0.256 0.078	0.262 0.080	0.36 0.11	0.36 0.11	0.36 0.11	4/0
250	0.135 0.041	0.171 0.052	0.171 0.052	0.187 0.057	0.177 0.054	0.279 0.085	0.295 0.090	0.282 0.086	0.217 0.066	0.230 0.070	0.240 0.073	0.308 0.094	0.322 0.098	0.33 0.10	250
300	0.135 0.041	0.167 0.051	0.144 0.044	0.161 0.049	0.148 0.045	0.233 0.071	0.249 0.076	0.236 0.072	0.194 0.059	0.207 0.063	0.213 0.065	0.269 0.082	0.282 0.086	0.289 0.088	300
350	0.131 0.040	0.164 0.050	0.125 0.038	0.141 0.043	0.128 0.039	0.200 0.061	0.217 0.066	0.207 0.063	0.174 0.053	0.190 0.058	0.197 0.060	0.240 0.073	0.253 0.077	0.262 0.080	350
400	0.131 0.040	0.161 0.049	0.108 0.033	0.125 0.038	0.115 0.035	0.177 0.054	0.194 0.059	0.180 0.055	0.161 0.049	0.174 0.053	0.184 0.056	0.217 0.066	0.233 0.071	0.240 0.073	400
500	0.128 0.039	0.157 0.048	0.089 0.027	0.105 0.032	0.095 0.029	0.141 0.043	0.157 0.048	0.148 0.045	0.141 0.043	0.157 0.048	0.164 0.050	0.187 0.057	0.200 0.061	0.210 0.064	500
600	0.128 0.039	0.157 0.048	0.075 0.023	0.092 0.028	0.082 0.025	0.118 0.036	0.135 0.041	0.125 0.038	0.131 0.040	0.144 0.044	0.154 0.047	0.167 0.051	0.180 0.055	0.190 0.058	600
750	0.125 0.038	0.157 0.048	0.062 0.019	0.079 0.024	0.069 0.021	0.095 0.029	0.112 0.034	0.102 0.031	0.118 0.036	0.131 0.040	0.141 0.043	0.148 0.045	0.161 0.049	0.171 0.052	750
1000	0.121 0.037	0.151 0.046	0.049 0.015	0.062 0.019	0.059 0.018	0.075 0.023	0.089 0.027	0.082 0.025	0.105 0.032	0.118 0.036	0.131 0.040	0.128 0.039	0.138 0.042	0.151 0.046	1000

TABLE 1 – Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-Phase, 60 Hz, 75°C (167°F) – Three Single Conductors in Conduit

Reference // *National Electrical Code Handbook – Mark W. Earley, P.E., Jeffrey S. Sargent, Christopher D. Coache and Richard J. Roux (National Fire Protection Association, Quincy, Massachusetts)*