**US Army Corps
of Engineers
Afghanistan Engineer District**

AED Design Requirements:

Voltage Drop Calculation Process

Various Locations,
Afghanistan

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AED DESIGN REQUIREMENTS
Voltage Drop Calculation

The voltage drop of any insulated cable is dependent upon the length of the cable, the current on the cable and the impedance (ohm) per unit length of the cable.

Voltage drop on the cable shall be limited to the following:

- The voltage drop of the secondary service of 3%.
- The voltage drop of a feeder or branch circuit of 2%.

The combined voltage drop of feeder and branch circuit shall not exceed 5%.

There are two methods of determining the voltage drop of a cable. The difference depends upon whether the cable supplied meets American (U.S) standards or European standards.

If the cable meets European standards, the formula is as follows:

European Formula (mV/A/m)

VD = R x I x L / 1000

VD: The voltage drop (V).
R: The resistance value from voltage drop per ampere per meter table (mV/A/m) supplied by the cable manufacturer.
I : The load current (A)
L: The length of conductor (m)

The value R is determined from a table provided by the cable manufacturer. See Table 1 below as an example of a table that is provided by a manufacturer.

Below is an example calculation for determining voltage drop.

Determine the voltage drop of a 380V, 3 phase circuit with a current of 100A and a length of 150 m and a conductor size of 35 mm. This is a secondary service feed.

The voltage drop of secondary service is limited to 3% (380 x 3% = 11.4 Volts).

Volt drop = Resistance x Current x Length / 1000. Resistance is found on Table 1 below.

VD = 1.1 x 100 x 150 / 1000
= 16.5 V

The maximum voltage drop allowed is 11.4 V. To determine the size of cable that will be required to meet the voltage drop requirement, determine the value of R that will meet the requirement.

11.4 = R x 100 x 150 / 1000
R = 11.4 x 1000/100 x 150
= 0.76 mV/A/m

Referencing the table provided by the cable manufacturer (Table 1), the cable that has a resistance of .76mV/A/m or less is a 70 mm cable with a resistance of 0.55 mV/A/m.

Calculating the voltage drop for the 70mm cable results in:

VD = R x I x L / 1000
= 0.55 x 100 x 150 / 1000
= 8.25 V

The percentage voltage drop is:

Percentage Voltage Drop = 8.25 x 100 / 380 = 2.17 %

Therefore, in order to transmit a 3 phase current of 100A per phase over a length of 150 m, with a total voltage drop equal to or less than the maximum 11.4 volts, a 70 mm cable is needed.

This same procedure would be repeated for a feeder or branch circuit and the results added. The total voltage drop should not exceed 5%.

TABLE 1

VOLTAGE DROP PER AMPERE PER METER (mV). Conductor operating temperature: 70ºC

Conductor Cross Sectional Area	Two Core Cable D.C.	Two Core Cable SIngle Phase A.C.			Three or Four Core Cable Three phase A.C.		
mm	mV		mV			mV	
1.5	29		29			25	
2.5	18		18			15	
4	11		11			905	
6	7.3		7.3			604	
10	4.4		4.4			308	
16	2.8		2.8			204	
		R	**X**	**Z**	**R**	**X**	**Z**
25	1.75	1.75	0.170	1.75	1.50	0.145	1.50
35	1.25	1.25	0.165	1.25	**1.10**	0.145	1.10
50	0.93	0.93	0.165	0.94	0.80	0.140	0.81
70	0.63	0.63	0.160	0.65	**0.55**	0.140	0.57
95	0.46	0.47	0.155	0.50	0.41	0.135	0.43
120	0.36	0.38	0.155	0.41	0.33	0.135	0.35
150	0.29	0.30	0.155	0.34	0.26	0.130	0.29
185	0.23	0.28	0.150	0.29	0.21	0.130	0.25

240	0.180	0.190	0.150	0.24	0.165	0.130	0.21
300	0.145	0.155	0.145	0.21	0.136	0.130	0.185
400	0.105	0.115	0.145	0.185	0.100	0.125	0.160

If the cable meets European standards, the formula is as follows:

U.S Formula (NEC)

For three phase: **VD = 1.732 x L x R x I / 1000**
For single phase: **VD = 2 x L x R x I / 1000**

VD: The voltage drop (V)
L : The length of conductor (m)
R: The resistance value from Chapter 9, Table 8 (ohm/km).
I : The load current (A)

The value R is determined from the National Electrical Code (NEC), Chapter 9, Table 8 column Direct Current Resistance at 75 degrees C/ Copper/ Uncoated. See Table 2 below for the NEC table.

Below is an example calculation for determining voltage drop.

Determine the voltage drop of a 380V, 3 phase circuit with a current of 100A and a length of 150 m and a conductor size of 35 mm. This is a secondary service feed.

VD = 1.732 x Length x Resistance x Current / 1000. Resistance is found in Table 2 below:
= 1.732 x 100 x 0.802 x 100 /1000
= 13.89 V

The maximum voltage drop allowed is 11.4 V. To determine the size of cable that will be required to meet the voltage drop requirement, determine the value of R that will meet the requirement.

11.4 = 1.732 x 150 x R x 100 / 1000
R = 11.4 x 1000/1.732 x 150 x 100
= 0.438 ohm/km

Referencing the NEC table (Table 2) indicates that the cable size with a voltage drop of 0.438 ohm/km or less is 1/0 AWG (70 mm)cable with a resistance of 0.399 ohm/km.

Calculating the voltage drop for the 1/0 AWG (70mm) cable results in:

VD = 1.732 x L x R x I / 1000
= 1.732 x 150 x 0.399 x 100 / 1000

= 10.36 V

The percentage voltage drop is:

Percentage Voltage Drop = 10.36 x 100 / 380 = 2.73 %

Therefore, in order to transmit a 3 phase current of 100A per phase over a length of 150 m, with a total voltage drop equal to or less than the maximum 11.4 volts, a 1/0 AWG (70 mm2) cable is needed.

This same procedure would be repeated for a feeder or branch circuit and the results added. The total voltage drop should not exceed 5%.

TABLE 2

Chapter 9 • Tables

Table 8 Conductor Properties

Size (AWG or kcmil)	Area		Conductors							Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall				Copper				Aluminum	
				Diameter		Diameter		Area		Uncoated		Coated			
	mm²	Circular mils	Quantity	mm	in.	mm	in.	mm²	in.²	ohm/km	ohm/kFT	ohm/km	ohm/kFT	ohm/km	ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100

Computer programs can be used to calculate the voltage drop, however the Contractor shall provide a sample hand calculation for a single feeder, branch circuit or secondary service to identify the formula that is being used to calculate voltage drop.