13. FORMULAS AND CONSTANTS

CONTENTS

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13. FORMULAS AND CONSTANTS

13.1 Electrical Properties of Circuits

Table 13.1–Electrical properties of circuits

Desired Data	Alternating Current			Direct Current
	Single Phase	Two Phase Four Wire*	Three Phase	
Kilowatts (kw)	$\frac{I \times V \times \cos\theta}{1{,}000}$	$\frac{2 \times I \times V \times \cos\theta}{1{,}000}$	$\frac{1.73 \times I \times V \times \cos\theta}{1{,}000}$	$\frac{I \times V}{1{,}000}$
Kilovolt-amperes (kva)	$\frac{I \times V}{1{,}000}$	$\frac{2 \times I \times V}{1{,}000}$	$\frac{1.73 \times I \times V}{1{,}000}$	$\frac{I \times V}{1{,}000}$
Horse-power Output	$\frac{I \times V \times \cos\theta \times \text{Eff.}}{746}$	$\frac{2 \times I \times V \times \cos\theta \times \text{Eff.}}{746}$	$\frac{1.73 \times I \times V \times \cos\theta \times \text{Eff.}}{746}$	$\frac{I = V \times \text{Eff.}}{746}$
Amperes When Horse-power is Known (I)	$\frac{hp \times 746}{V \times \cos\theta \times \text{Eff.}}$	$\frac{hp \times 746}{2 \times V \times \cos\theta \times \text{Eff.}}$	$\frac{hp \times 746}{1.73 \times V \times \cos\theta \times \text{Eff.}}$	$\frac{hp \times 746}{V \times \text{Eff.}}$
Amperes When Kilowatts are Known (I)	$\frac{kw \times 1{,}000}{V \times \cos\theta}$	$\frac{kw \times 1{,}000}{2 \times V \times \cos\theta}$	$\frac{kw \times 1{,}000}{1.73 \times V \times \cos\theta}$	$\frac{kw \times 1{,}000}{V}$
Amperes When Kilovolt-amperes are Known (I)	$\frac{kva \times 1{,}000}{V}$	$\frac{kva \times 1{,}000}{2 \times V}$	$\frac{kva \times 1{,}000}{1.73 \times V}$	$\frac{kva \times 1{,}000}{V}$

* In two-phase three-wire circuits, the current in the common conductor is 1.41 times that in either phase conductor.

NOTATION

$\cos\theta$ = Power factor of load (pf)
V = Volts between conductors
Eff. = Efficiency of motor

13.2 Resistance and Weight of Conductors

The resistance and weight of any uncoated copper wire at 20°C (68°F) having a conductivity of 100% IACS may be calculated from the following formulas:

$$\text{Ohms per 1,000 feet} = \frac{0.0081455}{\text{Cross-sectional area in sq. in.}} \text{ or } \frac{10371.176}{\text{Cross-sectional area in circ. mils}}$$

Pounds per 1,000 feet = Area in sq. in. × 3,854.09 or Area in circ. mils × 0.0030269

13.3 Resistance, Inductance, and Capacitance in AC Circuits

Table 13.2–Resistance, inductance, and capacitance in AC circuits

If Circuit Contains:	Reactance is:	Impedance is:	"V" for a Current "I" is:	Power Factor is:
Resistance (R)	0	R	IR	1
Inductance (L)	$2\pi fL$	$2\pi fL$	$I2\pi fL$	0
Capacitance (C)	$\frac{1}{2\pi fC}$	$\frac{1}{2\pi fC}$	$I\frac{1}{2\pi fC}$	0
Resistance & Inductance in Series (R & L)	$2\pi fL$	$\sqrt{R^2+(2\pi fL)^2}$	$I\sqrt{R^2+(2\pi fL)^2}$	$\frac{R}{\sqrt{R^2+(2\pi fL)^2}}$
Resistance & Capacitance in Series (R & C)	$\frac{1}{2\pi fC}$	$\sqrt{R^2+\left(\frac{1}{2\pi fC}\right)^2}$	$I\sqrt{R^2+\left(\frac{1}{2\pi fC}\right)^2}$	$\frac{R}{\sqrt{R^2+\left(\frac{1}{2\pi fC}\right)^2}}$
Resistance, Inductance & Capacitance in Series (R & L & C)	$2\pi fL - \frac{1}{2\pi fC}$	$\left(2\pi fL - \frac{1}{2\pi fC}\right)^2$	$I\sqrt{R^2+\left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$	$\frac{R}{\sqrt{R^2+\left(2\pi fL - \frac{1}{2\pi fC}\right)^2}}$

V = Voltage in volts
f = Frequency in cycles per second
C = Capacitance in farads
I = Current in amperes
R = Resistance in ohms
π = 3.1416
L = Inductance in henries

13.4 Series and Parallel Connections

Table 13.3 – Series and parallel connections

	Resistance (R)	Inductance (L)	Capacitance (C)
Series	$R = R_1 + R_2 + R_3 + \dots$	$L = L_1 + L_2 + L_3 + \dots$	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$
Parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \dots$	$C = C_1 + C_2 + C_3 + \dots$

13.5 Engineering Notation

Table 13.4 – Engineering notation

		Multiplying Factor	
Prefix	**Symbol**	**Scientific**	**Conventional**
tera	T	10^{12}	1,000,000,000,000
giga	G	10^{9}	1,000,000,000
mega	M	10^{6}	1,000,000
kilo	k	10^{3}	1,000
hecto	h	10^{2}	100
deca	da	10^{1}	10
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	µ	10^{-6}	0.000001
nano	n	10^{-9}	0.000000001
pico	p	10^{-12}	0.000000000001
femto	f	10^{-15}	0.000000000000001
atto	a	10^{-18}	0.000000000000000001

Table 13.5 – Engineering notation

e	= 2.7183		
π	= 3.1416		
$\sqrt{2}$	= 1.4142		
$\sqrt{3}$	= 1.7321	sinh x	$= (e^x - e^{-x})/2$
$\pi/4$	= 0.7854	cosh x	$= (e^x + e^{-x})/2$
1/C	= one conductor		
3/C	= three conductor		
$>$	greater than		
$\leq$	less than or equal to		
$<$	less than		
$\geq$	greater than or equal to		

13.6 Diameter of Multiconductor Cables

To calculate the overall diameter of a group of round conductors of uniform diameters twisted together, multipy the diameter of an individual conductor by the applicable factor below:

Table 13.6 – Diameter of multiconductor cables

Number of Conductors	Factor
1	1.000
2	2.000
3	2.155
4	2.414
5	2.700
6	3.000
7	3.000
8	3.310
9	3.610

13.7 Determination of Largest Possible Conductor in Cable Interstices

The following factors permit the calculation of the maximum size conductor that will fit into the **interstices** (open spaces) of various conductor configurations, while keeping within a circumscribing circle. Multiply the diameter of one main conductor by the factor from the chart below to obtain the largest diameter that will fit into the interstices.

Table 13.7–Determination of largest possible conductor in cable interstices

Number of Main Conductors	Factor
2	0.667
3	0.483
4	0.414
5	0.377
6	0.354

13.8 Conductor Diameter from Wire Diameter

To calculate the nominal diameter of any concentric-lay-stranded conductor made from round wires of uniform diameters, multiply the diameter of an individual wire by the applicable factor below:

Table 13.8–Concentric stranded conductor diameter from wire diameter

Number of Wires in Conductor	Factor to Calculate Conductor Diameter
3	2.155
7	3.000
12	4.155
19	5.000
37	7.000
61	9.000
91	11.00
127	13.00
169	15.00
217	17.00
271	19.00

For a greater number of wires use the formula:

$$\text{Conductor Diameter} = \text{Wire Diameter} \times \sqrt{1.273 \times \text{No. of Wires}}$$

13.9 Coaxial Capacitance

$$C = \frac{7.354\ \epsilon_0}{\text{Log}_{10}\ (1 + 2t/D)}$$

Where

C is Capacitance in picofarads per foot
ϵ_0 is the Dielectric constant (SIC)
t is Insulation thickness in mils
D is Diameter over the conductor (diameter under the insulation) in mils