2026 EDITION · POWER SYSTEMS

Electrical Engineering

Formula Cheat Sheet

Quick reference for power factor correction, transformers, transmission lines, fault analysis, and motor calculations

Power Equations | PF Correction | Transformers | Fault Analysis | Motors | Transmission

1 Basic Power Equations

Single-Phase Power

$$P = V \times I \times \cos(\varphi)$$

Real power consumed by a single-phase load

P = Real power (W) · **V** = RMS voltage (V)
I = RMS current (A) · **cos(φ)** = Power factor

Tip: cos(φ) = 1 for purely resistive loads

Three-Phase Power

$$P = \sqrt{3} \times V_L \times I_L \times \cos(\varphi)$$

Real power in a balanced three-phase system

V_L = Line-to-line voltage · I_L = Line current

Delta: $I_L = \sqrt{3} \times I_{ph}$ · **Wye:** $V_L = \sqrt{3} \times V_{ph}$

Apparent Power

$$S = V \times I \mid S = \sqrt{3} \times V_L \times I_L$$

Total power delivered to circuit (VA or kVA). Left: 1φ, Right: 3φ

Reactive Power

$$Q = V \times I \times \sin(\varphi) \mid Q = \sqrt{S^2 - P^2}$$

Power absorbed by inductive/capacitive elements (VAR)

Power Triangle

$$S^2 = P^2 + Q^2$$

Relationship: Apparent (VA), Real (W), Reactive (VAR)

Power Factor

$$PF = \cos(\varphi) = P / S$$

Ratio of real to apparent power (0 to 1)

Lagging = Inductive (motors) · **Leading** = Capacitive

2 Power Factor Correction

Required Reactive Compensation

$$Q_C = P \times (\tan \varphi_1 - \tan \varphi_2)$$

Capacitive kVAR needed to improve PF from $\cos(\varphi_1)$ to $\cos(\varphi_2)$

Q_C = Required capacitor kVAR · **P** = Real power (kW)

φ_1 = Original PF angle · **φ_2** = Target PF angle

This is the key formula for PF correction capacitor sizing in the field!

Capacitor — Single Phase

$$C = Q_C / (2\pi f V^2)$$

Capacitance needed for single-phase PF correction

C = Farads · **f** = Hz · **V** = RMS voltage

Capacitor — Three Phase (Delta)

$$C = Q_C / (2\pi f V_L^2)$$

Per-phase capacitance for delta-connected cap banks

Note: Delta needs ⅓ the capacitance of wye for same kVAR

PF Correction Current Savings

$$I_{saved} = P \times (1/PF_{old} - 1/PF_{new}) / (\sqrt{3} \times V_L)$$

Current reduction from power factor improvement — lower current = smaller cables, reduced losses

kVAR Multiplier Table — Quick Capacitor Sizing

Multiply your kW load by this factor to find required kVAR

Original PF	→ 0.90	→ 0.95	→ 0.98	→ 1.00
0.50	1.248	1.403	1.529	1.732
0.60	0.849	1.005	1.131	1.333
0.65	0.685	0.840	0.966	1.169
0.70	0.536	0.691	0.817	1.020
0.75	0.398	0.553	0.679	0.882
0.80	0.266	0.421	0.547	0.750
0.85	0.135	0.291	0.417	0.620
0.90	—	0.155	0.281	0.484

★ Worked Example: PF Correction

A factory has a 200 kW load at PF = 0.70. Utility requires PF ≥ 0.95.

Step 1: From table, multiplier for 0.70 → 0.95 = **0.691**

Step 2: Q_c = 200 × 0.691 = **138.2 kVAR**

Step 3: Select nearest standard cap bank: **150 kVAR**

`Answer: Install a 150 kVAR capacitor bank`

3 Transformer Calculations

Turns Ratio

$$a = N_1/N_2 = V_1/V_2 = I_2/I_1$$

Fundamental transformer voltage-current relationship

N = Turns · **V** = Voltage · **I** = Current
Subscript 1 = Primary · 2 = Secondary

kVA Rating

$$S = \sqrt{3} \times V_L \times I_L / 1000$$

Three-phase transformer apparent power (kVA)

Sizing: kVA = Total_kW / PF × 1.25 safety factor

Efficiency

$$\eta = P_{out} / (P_{out} + P_{cu} + P_{core})$$

Efficiency including copper and core losses

P_{cu} = Copper losses ($\propto I^2$) — load dependent
P_{core} = Core losses — constant

Voltage Regulation

$$VR\% = (V_{NL} - V_{FL}) / V_{FL} \times 100$$

% change from no-load to full-load voltage

Good: VR < 5% · **Excellent:** VR < 2%

4 Transmission Lines

Voltage Drop — 1φ

$$V_{drop} = 2\ I\ L\ (R \cos\varphi + X \sin\varphi)$$

Voltage drop across a single-phase line

L = Length · **R** = Ω/unit · **X** = Ω/unit

Voltage Drop — 3φ

$$V_{drop} = \sqrt{3}\ I\ L\ (R \cos\varphi + X \sin\varphi)$$

Voltage drop across a three-phase line

NEC: Branch circuit < 3% · Total < 5%

Line Losses

$$P_{loss} = 3 \times I^2 \times R \times L$$

Total power dissipated in 3-phase conductors

Key: Doubling voltage → ¼ the losses for same power

Cable Derating

$$I_{rated} = I_{base} \times CF_T \times CF_G \times CF_B$$

Actual ampacity after correction factors

CF: Temperature · Grouping · Burial depth (NEC 310.16)

5 Short Circuit & Fault Analysis

Symmetrical Fault Current

$$I_{fault} = V_{base} / (\sqrt{3} \times Z_{total})$$

Max short circuit current (3φ bolted fault)

Fault MVA

$$MVA_{fault} = S_{base} / Z_{pu(total)}$$

Short circuit capacity at a system point

Per-Unit System

$$Z_{pu} = Z_{actual} / Z_{base}$$

Normalized impedance for multi-voltage analysis

$Z_{base} = V^2_{base} / S_{base}$ · S_{base} typically 100 MVA

Advantage: Per-unit values stay constant through transformers!

6 Motor Calculations

Synchronous Speed

$$n_s = 120 f / P$$

Rotating magnetic field speed (RPM)

f = Hz · **P** = Number of poles

Motor Horsepower

$$HP = (V \times I \times \eta \times PF) / 746$$

Mechanical output power (746 W = 1 HP)

Slip

$$s = (n_s - n_r) / n_s$$

Difference between sync and actual rotor speed

Typical: 2–5% at full load · Zero slip = no torque

FLA Quick Estimate

$$FLA \approx HP \times 1.25 \ (480V\ 3\varphi)$$

Rule-of-thumb motor full load amps

240V 3φ: FLA ≈ HP × 2.5 · Always verify NEC 430.250

Common Motor Speeds at 60 Hz

Poles	Sync Speed	Typical Full-Load	Common Use
2	3,600 RPM	3,450 – 3,550	Pumps, compressors
4	1,800 RPM	1,725 – 1,770	General purpose, HVAC
6	1,200 RPM	1,140 – 1,175	Conveyors, crushers
8	900 RPM	850 – 880	Low-speed drives