



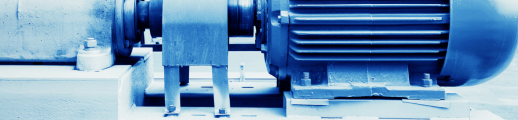
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CIEP TRAINING PROGRAM

FOR INDUSTRIAL ENERGY SPECIALISTS

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ENERGY SPECIALIST CURRICULUM





ELECTRIC MOTORS AND DRIVES - 3

CIEP TRAINING PROGRAM

FOR INDUSTRIAL ENERGY SPECIALISTS

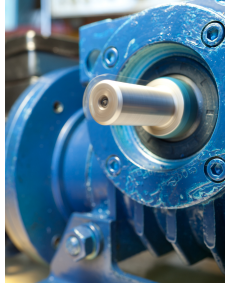
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LEARNING OBJECTIVES





Savings Considerations: Lifecycle vs. First Cost for Installing Energy Efficient Motors/VSDs

Motor Terminology and Performance Factors

Load Factors and Ability to Estimate Motor Loads

Variable Volume Options and Frequency Drives (VFD)

ELECTRIC MOTOR MANAGEMENT



- ✓ Why bother?
- ✓ Electric motor basics
- ✓ Electricity and electric motors
- ✓ Energy efficient electric motors
- ✓ Electric motor inventories and rewind policies
- ✓ Motor drives
 - VFDs
 - Eddy current clutches
 - Permanent magnetic drives
 - Hydraulic drives, etc.
- ✓ Electricity basics review



ELECTRIC MOTOR MANAGEMENT WHY BOTHER?



- ✓ A heavily used motor can cost 10 times its first cost to run for one year!
- ✓ US motor use statistics
 - Electric motors use over ½ all U.S. electricity
 - Motor driven systems use over 70% electric energy for many plants
 - Motor driven systems cost about \$90 billion to operate per year



ELECTRIC MOTOR MANAGEMENT WHY SO DIFFICULT?



- ✓ Load on most driven systems is unknown at least on retrofits
- ✓ Very difficult to determine load accurately through measurements
- ✓ Electric motor management is FULL of surprises
- ✓ Yet, savings can be large (small percentage of a big number is a big number)
- ✓ Important note: Often oversized wiring (above code) is cost effective in heavily used systems as it reduces I²R losses. (CDA and Southwire Corp.)



ELECTRIC MOTOR MANAGEMENT TYPES OF MOTORS



✓ AC Synchronous motors

- ✓ One to two percent or so (but large motors)
- ✓ Large KW and slow speed applications typical
- ✓ Similar in construction to induction motors, but more expensive
- ✓ More efficient, can be run at leading PF (Cos phi)
- ✓ Can generate or absorb reactive power



ELECTRIC MOTOR MANAGEMENT + TYPES OF MOTORS



✓ DC Motors

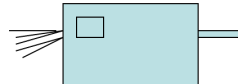
- ✓ Good for precise speed control and strong torque properties
- ✓ Not efficient, (historically) high maintenance, and higher down time (commutator and brushes need inspection and maintenance)
- ✓ Newer brushless motors much better
- ✓ Less than 5% of the motors today are DC (US)
- ✓ Replacing with a VFD driven AC motor may be cost effective especially if down time is reduced



ELECTRIC MOTOR MANAGEMENT + TYPES OF MOTORS



- ✓ KW ____ (shaft power design- output)
- ✓ NLRPM (synchronous speed)
- ✓ FLRPM (running RPM at design load)
- ✓ LRA (starting amps – 1 sec?)
- ✓ FLA (amps at design load and voltage)
- ✓ Volts (design voltage)
- ✓ Max. capacitor
- ✓ Efficiency (test vs. guaranteed)
- ✓ Service factor





MOTOR NAMEPLATE DATA +



TERMINOLOGY (US, NEMA)

NEMA (National Electrical Manufacturers Association) standards used in US

Standard Efficiency Motors: Any Pre EPACT 1992 motor (US Energy Policy Act of 1992)

Energy Efficient Motors: Motors meeting EPACT 1992 requirements

Premium Efficiency Motors: Motors exceeding EPACT 1992 requirements (extra efficient, ultra high efficient, but these terms are not used by NEMA)

GENERIC TERMINOLOGY



Standard efficiency motor

High efficiency motor

Premium efficiency motor
Or Ultra high efficiency motor

ELECTRIC MOTOR BASICS MOTOR SPEEDS

Alternating current, thus speed will vary with pole pairs (inside motor, pole pairs between stator and rotor)

One pole pair (2 poles) - one RPM per cycle (50 cps or Hertz); two pole pairs - ½ rpm per cycle, etc.

Thus

$$\text{SPEED} = \frac{50 \text{ cycles}}{\text{sec}} \times \frac{60 \text{ sec}}{\text{min}} \div \text{number of pole pairs}$$

SPEED = 3000, 1500, 1000, 750, 600, 500, etc.
(no other choices) for 50 Hz power to motor



ELECTRIC MOTOR BASICS SLIP

Design (Full Load) Slip = (NLRPM - FLRPM)

True (Actual) Slip = (NLRPM - RPM measured)

% Load = (True Slip)/(Design Slip)

Perfect indicator but very difficult to measure accurately (+/- 1% typical)

Many don't use this - why?

- ✓ Difficult to measure accurately
- ✓ Large motors are more efficient than small motors (more later)



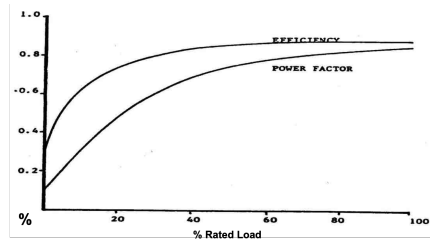
ELECTRIC MOTOR BASICS SLIP EXAMPLE

- ✓ FLRPM = 1460 (off name plate)
- ✓ Design KW = 50 (off name plate)
- ✓ Measured RPM = 1476
- ✓ NLRPM = ? (obviously 1500)
- ✓ Design slip = 1500 - 1460 = 40
- ✓ True slip = 1500 - 1476 = 24 % load = 24/40 = 0.6 or 60%
- ✓ True load = 50 KW x (0.6) = 30 KW
- ✓ See plot next slide, motors run very well at 60% load
- ✓ This motor will run very cool, is not causing a problem, why bother!!

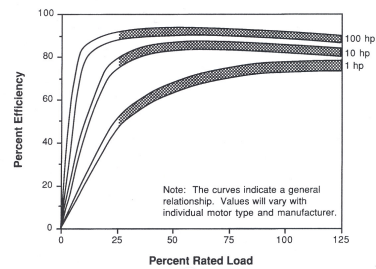
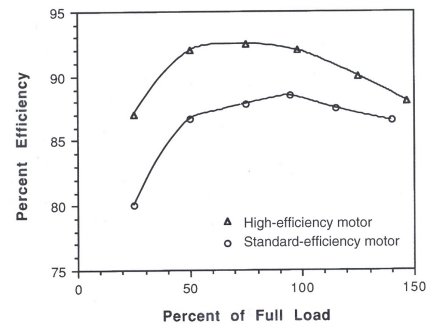


MOTOR PERFORMANCE & EFFICIENCY DATA

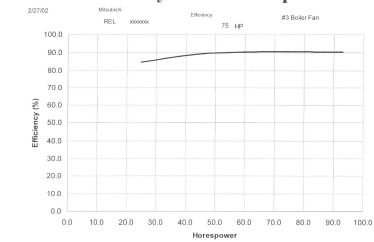
Efficiency and PF vs. Load:



Typical Efficiency vs. Load Curves for 1,800 rpm, Three-Phase, 60 Hz, Design B Squirrel-Cage Induction Motors



Motor Efficiency Versus Output Power

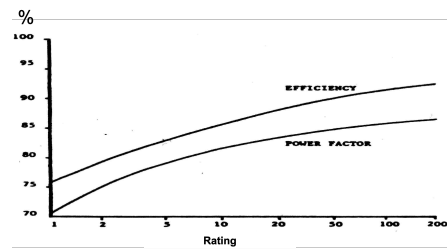


RELIANCE
ELECTRIC

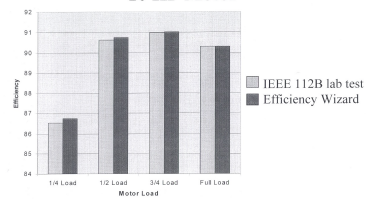
In-field electric motor efficiency measurement

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Efficiency Calculation Accuracy 10 HP Motor



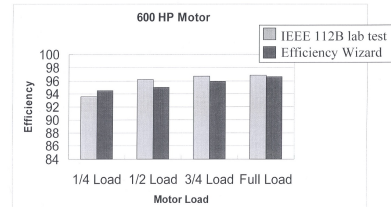
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In-field electric motor efficiency measurement

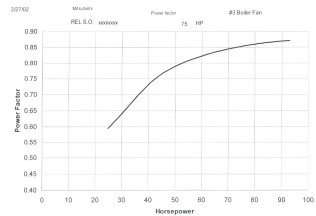
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Efficiency Calculation Accuracy



Power Factor vs Output Power



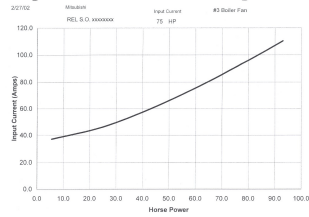
Proposed European Union-CEMEP Energy Efficiency Classification Scheme for Two- and Four-Pole Induction Motors

Minimum Nominal Efficiency
(as determined by Method IEC 34.2)
(%)

Motor Size (kW)	Class 2		Class 1	
	2-pole	4-pole	2-pole	4-pole
1.1	76.2	76.2	82.2	83.8
1.5	78.5	78.5	84.1	85.0
2.2	81.0	81.0	85.8	86.4
3.0	82.6	82.6	86.7	87.4
4.0	84.2	84.2	87.6	88.3
5.5	85.7	85.7	88.5	89.2
7.5	87.0	87.0	89.5	90.1
11.0	88.4	88.4	90.6	91.0
15.0	89.4	89.4	91.3	91.8
18.5	90.0	90.0	91.8	92.2
22.0	90.5	90.5	92.2	92.6
30.0	91.4	91.4	92.9	93.2
37.0	92.0	92.0	93.3	93.6
45.0	92.5	92.5	93.7	93.9
55.0	93.0	93.0	94.0	94.2
75.0	93.6	93.6	94.6	94.7

Source: European Union-CEMEP 1999

Input Current Versus Output Power

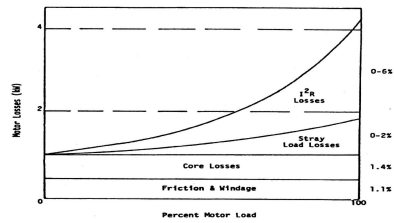


RELIANCE
ELECTRIC

In-field electric motor efficiency measurement

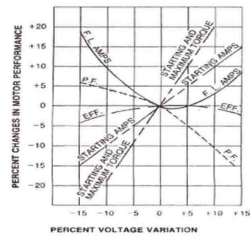
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ELECTRIC MOTOR MANAGEMENT-LOSSES IN MOTORS



☒ **Note:** This graph explains the efficiency drop off with load reduction Source: "Electrical Motors and Energy Conservation", Ronald Cota, Specifying Engineer, July, 1978.

EFFECT OF VOLTAGE VARIATION

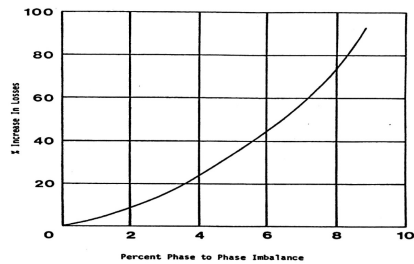


VOLTAGE AND FREQUENCY VARIATION

CHARACTERISTIC	VOLTAGE	FREQUENCY
Starting Torque	110% 10% Up 21% Down 10%	95% 1% Up 1% Down 10%
Maximum Torque	10% 10% Up 21% Down 10%	11% 1% Up 1% Down 10%
Percent Slip	10% 10% Up 20% Down 30%	10% 1% Up 1% Down 10%
Efficiency	Down 0-3% Full Load 0-2% % Load 0-2%	Up 0-3% Down 0-2% Slightly Down
Power Factor	Up 0-5% Full Load 1% % Load 1%	Down 0-5% Up 1% Slightly Down
Full Load	Down 5-15% % Load 5-15% % Load 5-15%	Up 5-15% Down 5-15% Slightly Down
Full Load Current	Up 10-20% Down 10% Slightly Up	Down 10-20% Up 10% Slightly Down
Starting Current	Up 10% Down 10% Slightly Up	Down 5% Up 5% Slightly Down
Full Load Temperature Rise	Up 10% Down 10% Slightly Up	Down 5% Up 5% Slightly Down
Maximum Overload Capacity	Up 21% Down 10% Slightly Up	Down 10% Up 10% Slightly Down
Magnetic Noise	Up 21% Down 10% Slightly Up	Down 10% Up 10% Slightly Down

Source: <http://www.lorencook.com/pdf/locookbook.pdf> <http://www.reliance.com/mvmt/pvpmvnm.htm>

VOLTAGE IMBALANCE IMPACT



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- ☒ Leave existing motors alone until they fail except:
 - Exceptionally oversized motors (25% loading or so)
 - Sizes that are needed elsewhere (requires inventory)
- ☒ When they fail, maybe buy new energy efficient motors (EPACT or Premium) instead of paying for rewind (much more on this later)
- ☒ If financial incentives are available, much more may be done
- ☒ Premium efficient motors need economic help in much of the country (PUC, Utility, motor mfgs.)

MOTOR BASICS-MOTOR REWINDS

- ✓ Most rewind motors over ____ KW
- ✓ Typical rewinds cost 60+% of a new motor
- ✓ New motor could be an energy efficient motor
- ✓ Motor efficiency often suffers during rewind. Average drop about 1% according to one study & sometimes significantly more.
- ✓ If efficiency drops, losses increases, motor runs hotter and won't last as long
- ✓ Rewinds can be done well. Use DoE rewind specifications, inspect shop, and periodically requests tests. However, 1% still seems valid
- ✓ Why does efficiency drop?
 - ⇒ Oven temperature of burnout and cure is critical
 - ⇒ Reassembly can cause more acute problems



PROPOSED MOTOR REWIND POLICY

- ✓ If motor is energy efficient, go ahead and rewind, except _____.
- ✓ If failed ODP motor is not energy efficient, scrap for copper and buy a new energy efficient motor.
- ✓ If failed TEFC motor is not energy efficient, scrap for copper and buy a new energy efficient motor unless motor is larger than ____ KW. Then, rewind.
- ✓ If rewind, use a good shop, use DoE specifications and periodically inspect
- ✓ See reference, Horse Power, a DoE publication.



ELECTRIC MOTOR MANAGEMENT ENERGY EFFICIENT MOTORS (INDUCTION)

- ✓ Energy efficient
 - ⇒ More copper – less resistance losses I^2R or HEAT because of larger wire
 - ⇒ Lower loss core material
 - ⇒ Better fans and bearings more carefully lubricated
 - ⇒ Better engineering design Longer and heavier



ELECTRIC MOTOR MANAGEMENT ENERGY EFFICIENT MOTORS

☒ Energy efficient motor characteristics

- ➔ More efficient, and often higher power factor
- ➔ Save energy and reduce demand
- ➔ Reduce load on cables, transformers, etc. (note double whammy with higher efficiency and higher PF (Cos phi))
- ➔ Speed is slightly higher (can be critical)
- ➔ Significantly larger inrush (LRA)



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☒ Watch carefully energy efficient motor retrofits on centrifugal applications

☒ Faster speed

- ➔ More volume (work)
- ➔ More power requirement (cube)

☒ Re-sheave to lower speed?

- ➔ Same (or less) volume
- ➔ Reduced power requirement
- ➔ Watch retrofit applications in other areas also e.g. screw compressors

☒ Watch LRA and circuit breakers



Table 2-8

Nominal Full-Load Efficiencies for the Most Efficient Three-Phase, 1,800 rpm, NEMA Design B, General Purpose Induction Motors Available: 1999

Manufacturer	Open Drip-Proof															
	1	2	3	5	7.5	10	25	50	75	100	200					
Baldor	85.5	86.5	89.5	89.5	91.0	91.0	94.1	94.5	95.0	95.4	95.8					
Dayton	85.5	86.5	89.2	89.5	91.7	91.7	94.1	94.5	94.5	94.5	94.5					
GE	NA	NA	86.5	88.5	91.0	91.0	93.6	94.5	94.5	95.4	95.8					
Lincoln	85.5	86.5	89.5	89.5	91.0	91.0	94.1	94.5	95.0	95.4	95.8					
MagnaTek	NA	NA	86.5	89.5	91.7	91.7	93.6	94.5	94.5	94.5	94.5					
Marathon	84.0	85.5	89.5	89.5	91.0	91.0	91.7	93.0	94.5	95.0	95.8					
Reliance	87.4	88.8	89.3	89.3	89.5	91.3	93.0	93.0	95.0	95.4	95.8					
Siemens	85.5	85.5	87.5	88.5	90.2	90.2	93.0	93.0	94.5	94.5	94.5					
Teco/Westinghouse	84.0	86.5	87.5	88.5	91.0	91.0	93.6	94.5	95.0	94.5	95.0					
Toshiba	84.0	86.5	89.5	89.5	91.7	91.7	94.1	94.5	95.0	95.4	95.8					
U.S. Motors	85.5	86.5	90.2	89.5	91.7	91.7	93.6	95.0	95.4	95.4	96.2					
WEG	82.5	84.0	86.5	87.5	88.5	89.5	91.7	93.0	94.1	94.1	95.0					
Average Premium	86.2	87.3	89.7	89.5	89.8	91.7	94.0	94.5	95.0	95.4	95.0					



Totally Enclosed Fan-Cooled											
Manufacturer	Horsepower										
	1	2	3	5	7.5	10	25	50	75	100	200
Baldor	85.5	86.5	89.5	90.2	89.5	89.5	93.6	94.1	95.4	95.4	96.2
Dayton	86.5	84.0	87.5	90.2	90.1	91.0	93.6	94.5	94.1	94.5	95.0
GE	NA	NA	89.5	89.5	91.0	91.7	93.6	94.1	94.5	95.0	95.8
Lincoln	85.5	85.5	89.5	89.5	90.1	91.0	94.1	95.0	95.0	95.8	96.5
Marathon	82.5	85.5	87.5	90.2	91.7	91.7	93.6	94.1	94.5	95.8	95.4
MagnaTek	84.5	86.5	88.5	89.5	91.0	91.0	93.0	94.1	95.4	95.4	95.8
Reliance	NA	88.8	90.3	88.5	90.2	90.2	93.6	94.5	95.0	95.4	96.2
Siemens	84.0	86.5	89.5	89.5	89.5	89.5	93.0	93.6	94.1	94.5	95.8
Teco/Westinghouse	86.5	86.5	89.5	89.5	91.7	91.7	93.6	94.5	95.4	95.4	96.2
Toshiba	85.5	86.5	89.5	89.5	91.0	91.0	93.6	94.1	95.4	95.4	96.2
U.S. Motors	86.5	86.5	89.5	90.2	91.7	91.7	93.6	94.1	95.4	95.4	96.2
WEG	85.5	86.5	89.5	89.5	91.7	92.4	93.0	94.5	94.5	95.0	96.2
Average Premium	85.9	86.9	89.5	89.7	91.7	91.7	93.7	94.5	95.4	95.5	96.2

Table 2-9
Minimum Full-Load Efficiencies for NEMA Energy-Efficient and CEE Premium-Efficiency Open and Enclosed Motors

Horsepower	1,000 rpm				1,800 rpm				3,600 rpm			
	EPAct Energy Efficient (%)	CEE Premium-Efficiency (%)	EPAct Energy Efficient (%)	CEE Premium-Efficiency (%)	EPAct Energy Efficient (%)	CEE Premium-Efficiency (%)	EPAct Energy Efficient (%)	CEE Premium-Efficiency (%)	EPAct Energy Efficient (%)	CEE Premium-Efficiency (%)	EPAct Energy Efficient (%)	CEE Premium-Efficiency (%)
1	80	82.5	82.5	85.5	N/A	80	80	82.5	80	82.5	80	82.5
1.5	84	86.5	84	86.5	84	86.5	84	86.5	84	86.5	84	86.5
2	85.5	87.5	84	86.5	84	86.5	84	86.5	84	86.5	84	86.5
3	86.5	89.5	86.5	89.5	86.5	89.5	86.5	89.5	86.5	89.5	86.5	89.5
5	87.5	89.5	87.5	89.5	87.5	89.5	87.5	89.5	87.5	89.5	87.5	89.5
7.5	88.5	91.7	88.5	91.7	88.5	91.7	88.5	91.7	88.5	91.7	88.5	91.7
10	90.2	92.4	91	93	89.5	91.7	88.5	90.2	91	93	89.5	91.7
15	90.2	92.4	91	93	89.5	91.7	88.5	90.2	91	93	89.5	91.7
20	91	92.4	91	93	90.2	92.4	91	93	91	93	90.2	92.4
25	91.7	93	91.7	93.6	91.7	93.6	91.7	93.6	91.7	93.6	91.7	93.6
30	92.4	93.6	92.4	94.1	91	93	91	93	91	93	91	93
40	93	94.1	93	94.5	92.4	93.6	92.4	93.6	92.4	93.6	92.4	93.6
50	93	94.1	93	94.5	92.4	93.6	92.4	93.6	92.4	93.6	92.4	93.6
60	93.6	95	93.6	95	93	94.1	93	94.1	93	94.1	93	94.1
75	93.6	95	94.1	95	93	94.1	93	94.1	93	94.1	93	94.1
100	94.1	95	94.1	95.4	93	94.5	93	94.5	93	94.5	93	94.5
125	94.1	95.4	94.5	95.4	93.6	95	93.6	95	94.5	95.4	94.5	95.4
150	94.5	95.8	95	95.8	93.6	95.4	93.6	95.4	94.5	95.4	94.5	95.4
200	94.5	95.4	95	95.8	94.5	95.4	94.5	95.4	94.5	95.4	94.5	95.4

Note: Reported levels are nominal efficiencies, representing the median efficiency of a population of motors of a given design as determined by IEEE Method 12-8.

Sources: CEE 1996; NEMA 1999, MG 1, Section 12-10

ENERGY EFFICIENT MOTORS CALCULATING SAVINGS



- ✓ Power and energy savings depends of efficiency of standard vs. energy efficient motor

$$\text{Power savings} = \text{kW}_e = \left[\frac{\text{KWNP} \times \text{LF}}{\text{EFF}} \right]_{\text{Stan}} - \left[\frac{\text{KWNP} \times \text{LF}}{\text{EFF}} \right]_{\text{EE}}$$

Energy savings = Power savings x Time = kW_e X
Operating hours



EXAMPLE CALCULATING SAVINGS FROM USING A HIGH EFFICIENCY MOTOR



- ✓ Facility has a 55 kW pump motor operating at an annual load factor of 70%
- ✓ Existing motor is 87% efficient, and operates 4000 hours each year
- ✓ Electric cost is \$0.10 per kWh New 55 kW motor will be 94% efficient
- ✓ New high efficiency motor premium is about \$1200



$$S = \text{KWNP} \times \text{LF} \times C \times N \times \left[\frac{100\%}{\text{Ea}} - \frac{100\%}{\text{Eb}} \right]$$

- ✓ S = Annual savings in dollars on energy use
- ✓ kWNP = kW Name Plate Rating
- ✓ C = Energy Cost, dollars per kWh
- ✓ N = Annual hours per year running time
- ✓ Ea = Efficiency of standard motor
- ✓ Eb = Efficiency of higher efficient motor
- ✓ LF = Load factor of motor



CALCULATION OF ENERGY SAVINGS

$$S = \text{kWNP} \times \text{LF} \times C \times N \times \left[\frac{100\%}{E_a} - \frac{100\%}{E_b} \right]$$

$$S = 55 \times 0.7 \times \$0.10 \times 4000 \times \left[\frac{100\%}{87\%} - \frac{100\%}{94\%} \right]$$

$$S = 55 \times 0.7 \times \$0.10 \times 4000 \times \left[\frac{100\%}{87\%} - \frac{100\%}{94\%} \right]$$

✓ Savings is \$1318.24

✓ Cost is about \$1200

✓ SPP = \$1200/\$1318.24 per year
= 0.9 years

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✓ Energy efficient motors (used 2000 hours or more per year) are almost always cost effective for new purchases

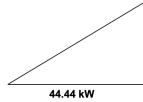
✓ Energy efficient motors as an alternative to rewinds is almost always cost effective (2000+ hrs) for all except large TEFCs (see earlier discussion)

✓ Premium efficiency motors are difficult to justify economically without DSM (design-side management program) help unless hours are very high and energy is expensive (bull frog is already close to the pond)

ELECTRIC MOTOR PRINCIPLES REVIEW

✓ A three phase 50 kW motor with a load factor of 0.8 has an efficiency of 90%, what is the kW electrical power input?

$$\text{kWin} = \frac{50 \text{ kW} \times 0.80}{0.90} = 44.44 \text{ kW}$$



ELECTRIC MOTOR PRINCIPLES REVIEW

2. For the motor in 1, if the PF = cos phi = 0.7 and voltage is 380 V, what is the kVA and what is the amp draw?

$$\text{PF} = 0.7 = \text{kW}/\text{kVA}$$

$$0.7 = 44.44/\text{kVA} \quad \text{or} \quad \text{kVA} = 44.44/0.7 = 63.49 \text{ kVA}$$

$$\text{Also } \text{kVA} = \sqrt{3} \times (\text{kV}) \times I = (\sqrt{3})(0.380) I = 63.49 \text{ kVA}$$

$$I = 63.49 / (\sqrt{3} \times 0.380) = 96.47 \text{ amps}$$

ELECTRIC MOTOR PRINCIPLES REVIEW

3. Next, we want to correct the PF (cos phi) to 0.90. What size capacitor is needed and what is the impact on the amperage?

$\Delta \text{kVAR} = 44.44 (\tan \cos^{-1} 0.7 - \tan \cos^{-1} 0.9) = 23.82 \text{ kVAR}$ You will find the value for () above in PF table (see Section K) (.536)

$$\text{New kVA} = 44.44/0.9 = 49.38 \quad \text{kVA} = 49.38 = (\text{kV})I/\sqrt{3}$$

$$I = 49.38/(\sqrt{3} \times 0.380) = 75.03 \text{ amps}$$

Thus, PF correction dropped amperage (upstream of the capacitor) from 96.47 to 75.03 amps or 22%

$$\text{Also, new } \text{kVA} = \sqrt{3} \text{ kV } I = 49.38 \text{ kVA}$$

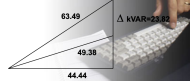


Table 11.7 Power-Factor Improvement*

Original Power Factor (%)	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Desired Power Factor (%)																				
50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.442	1.481	1.529	1
51	0.937	0.962	0.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1
52	0.893	0.919	0.945	0.971	0.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1
53	0.850	0.876	0.902	0.928	0.954	0.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.270	1.308	1.349	1.397	1
54	0.809	0.835	0.861	0.887	0.913	0.939	0.966	0.992	1.019	1.047	1.075	1.103	1.134	1.166	1.199	1.232	1.269	1.308	1.356	1
55	0.769	0.795	0.821	0.847	0.873	0.899	0.926	0.952	0.979	1.007	1.035	1.063	1.093	1.124	1.156	1.190	1.228	1.268	1.316	1
56	0.730	0.756	0.782	0.808	0.834	0.860	0.887	0.913	0.940	0.968	0.996	1.024	1.053	1.085	1.117	1.151	1.189	1.229	1.277	1
57	0.692	0.718	0.744	0.770	0.796	0.822	0.849	0.875	0.902	0.929	0.956	0.984	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1
58	0.655	0.681	0.707	0.733	0.759	0.785	0.812	0.838	0.865	0.891	0.918	0.945	0.974	1.005	1.042	1.076	1.114	1.154	1.202	1
59	0.618	0.644	0.670	0.696	0.722	0.748	0.775	0.801	0.828	0.856	0.884	0.912	0.939	0.973	1.005	1.039	1.077	1.117	1.165	1
60	0.584	0.610	0.636	0.662	0.688	0.714	0.741	0.767	0.794	0.822	0.850	0.878	0.905	0.939	0.971	1.003	1.043	1.083	1.131	1
61	0.549	0.575	0.601	0.627	0.653	0.679	0.706	0.732	0.759	0.787	0.815	0.843	0.870	0.904	0.936	0.970	1.008	1.046	1.096	1
62	0.515	0.541	0.567	0.593	0.619	0.645	0.672	0.698	0.725	0.752	0.780	0.809	0.836	0.870	0.902	0.936	0.974	1.014	1.052	1
63	0.483	0.509	0.535	0.561	0.587	0.613	0.640	0.666	0.693	0.720	0.747	0.775	0.804	0.838	0.871	0.904	0.942	0.982	1.020	1
64	0.450	0.476	0.502	0.528	0.554	0.580	0.607	0.633	0.660	0.687	0.714	0.741	0.771	0.805	0.837	0.871	0.909	0.949	0.997	1
65	0.419	0.445	0.471	0.497	0.523	0.549	0.576	0.602	0.629	0.657	0.685	0.713	0.740	0.774	0.806	0.840	0.878	0.919	0.966	1
66	0.388	0.414	0.440	0.466	0.492	0.518	0.545	0.571	0.598	0.626	0.654	0.682	0.709	0.743	0.775	0.809	0.847	0.887	0.935	0
67	0.358	0.384	0.410	0.436	0.462	0.488	0.515	0.541	0.568	0.596	0.624	0.652	0.679	0.713	0.745	0.779	0.817	0.857	0.905	0
68	0.329	0.355	0.381	0.407	0.433	0.459	0.486	0.512	0.539	0.567	0.595	0.623	0.650	0.684	0.716	0.750	0.788	0.828	0.876	0
69	0.299	0.325	0.351	0.377	0.403	0.429	0.456	0.482	0.509	0.537	0.565	0.603	0.631	0.665	0.696	0.730	0.768	0.798	0.848	0
70	0.270	0.296	0.322	0.348	0.374	0.400	0.427	0.453	0.480	0.506	0.536	0.564	0.591	0.625	0.657	0.691	0.729	0.769	0.811	0

71	0.242	0.268	0.294	0.320	0.346	0.372	0.399	0.425	0.452	0.480	0.508	0.536	0.563	0.597	0.629	0.660	0.701	0.741	0.783	0
72	0.213	0.239	0.265	0.291	0.317	0.343	0.370	0.396	0.423	0.451	0.479	0.507	0.534	0.568	0.600	0.634	0.672	0.712	0.754	0
73	0.186	0.212	0.238	0.264	0.290	0.316	0.343	0.369	0.396	0.424	0.452	0.480	0.507	0.541	0.573	0.607	0.645	0.685	0.727	0
74	0.159	0.185	0.211	0.237	0.263	0.289	0.316	0.342	0.369	0.397	0.425	0.453	0.480	0.514	0.546	0.580	0.618	0.658	0.700	0
75	0.132	0.158	0.184	0.210	0.236	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0
76	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.288	0.315	0.343	0.371	0.399	0.426	0.460	0.492	0.526	0.564	0.604	0.645	0
77	0.079	0.105	0.131	0.157	0.183	0.209	0.236	0.263	0.290	0.317	0.345	0.373	0.400	0.426	0.446	0.500	0.526	0.578	0.598	0.600
78	0.053	0.079	0.104	0.131	0.157	0.183	0.210	0.236	0.263	0.291	0.319	0.347	0.374	0.408	0.440	0.474	0.512	0.552	0.594	0.600
79	0.026	0.052	0.078	0.104	0.130	0.156	0.183	0.209	0.236	0.264	0.292	0.320	0.347	0.381	0.413	0.447	0.485	0.525	0.567	0.600
80	0.000	0.026	0.052	0.078	0.104	0.130	0.157	0.183	0.210	0.238	0.266	0.294	0.321	0.355	0.387	0.421	0.459	0.499	0.541	0.600
81	0.000	0.026	0.052	0.079	0.104	0.131	0.157	0.184	0.212	0.240	0.268	0.295	0.329	0.361	0.395	0.433	0.473	0.515	0.559	0.600
82	0.000	0.026	0.052	0.079	0.105	0.131	0.158	0.186	0.214	0.242	0.269	0.295	0.325	0.355	0.389	0.427	0.467	0.489	0.531	0.600
83	0.000	0.026	0.052	0.079	0.105	0.132	0.160	0.188	0.216	0.243	0.272	0.300	0.343	0.381	0.421	0.461	0.481	0.523	0.565	0.600
84	0.000	0.026	0.053	0.079	0.106	0.134	0.162	0.190	0.217	0.251	0.283	0.317	0.355	0.395	0.437	0.477	0.517	0.559	0.600	0.600
85	0.000	0.027	0.053	0.080	0.108	0.136	0.164	0.191	0.225	0.257	0.291	0.329	0.369	0.417	0.457	0.497	0.539	0.581	0.600	0.600
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ELECTRIC MOTOR PHASING SINGLE PHASING

Single phasing is the loss of one phase in a 3 phase system

Worst case scenario of voltage imbalance

Causes

- In plant
- Pole hits
- Tree limbs
- Animals
- Lightning In other words, this does happen

MOTOR PRACTICE PROBLEM

✓ A recent advertisement said a premium efficiency 50 KW motor is available at 94.5%. It would replace a motor that presently runs at 90.7%. Given the parameters below, calculate the cost of operating both motors and the savings for conversion:

- ➡ Motor runs 8760 hours/year
- ➡ Demand cost is \$10 per kW month
- ➡ Energy cost is \$0.06/kWh
- ➡ Motor runs at 80% load all the time



MOTOR PRACTICE PROBLEM

✓ Cost to operate existing motor

- ➡ Demand
- ➡ Energy
- ➡ Total

✓ Savings



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MARKETPLACE**