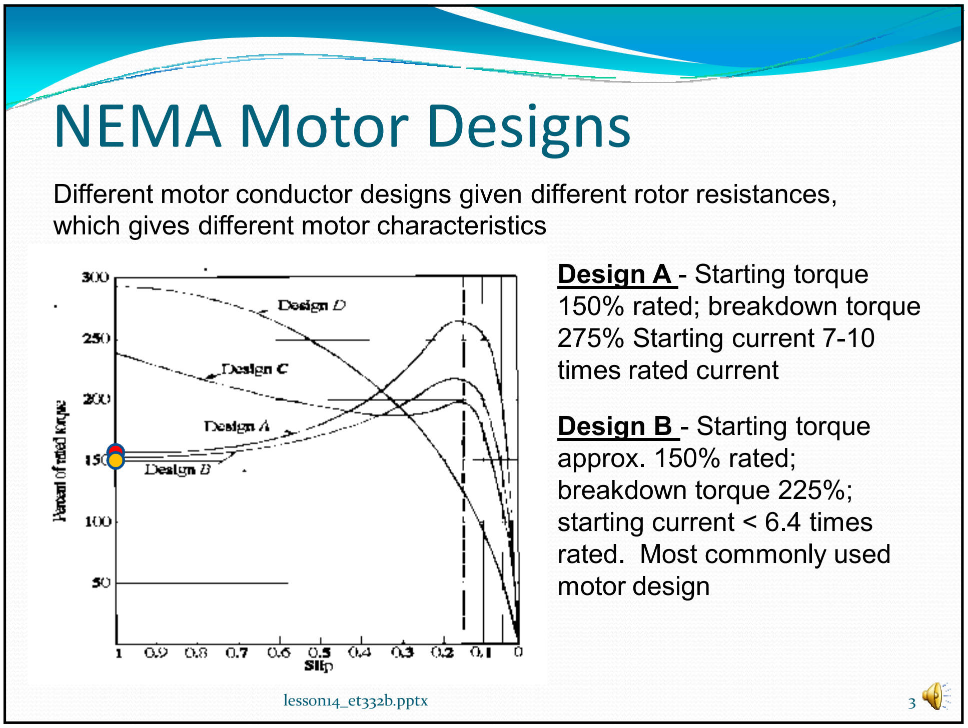
Lesson 14: NEMA Designs and Induction Motor Nameplate Data

ET 332b
Ac Motors, Generators and Power Systems

Learning Objectives

After this presentation you will be able to:

- List the characteristics of NEMA Design motors.
- Identify and interpret motor nameplate data.
- Use kVA codes to compute motor starting currents.
- Explain the effects of reduced motor voltage and frequency on machine performance.
- Compute the changes in motor speed and torque when voltage and frequency change.

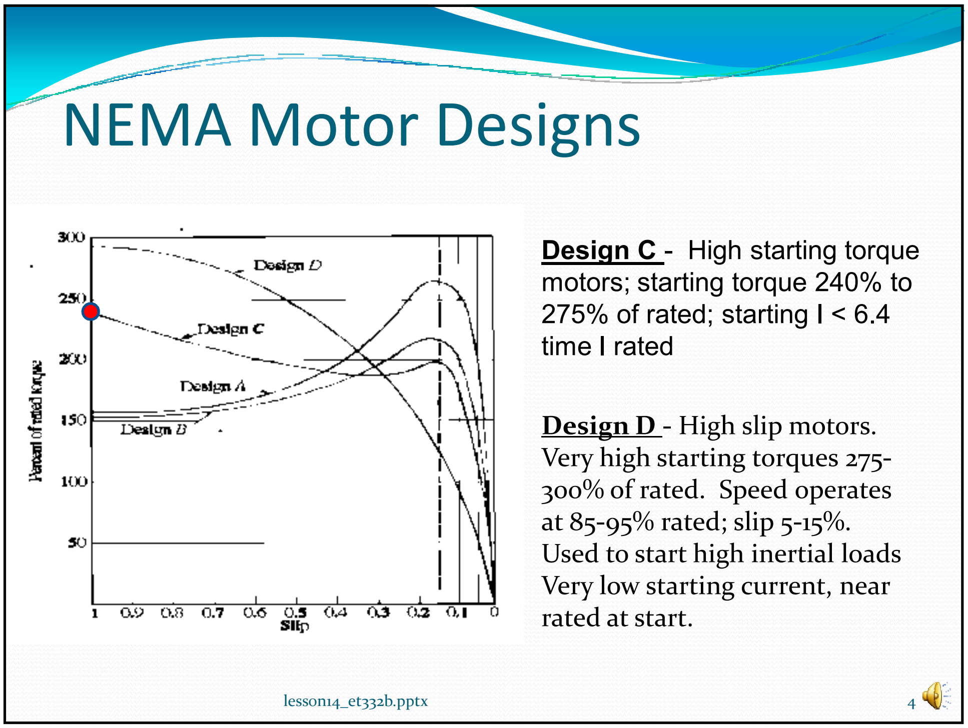


NEMA Motor Designs

Different motor conductor designs given different rotor resistances, which gives different motor characteristics

Design A - Starting torque 150% rated; breakdown torque 275% Starting current 7-10 times rated current

Design B - Starting torque approx. 150% rated; breakdown torque 225%; starting current < 6.4 times rated. Most commonly used motor design



NEMA Motor Designs

Design C - High starting torque motors; starting torque 240% to 275% of rated; starting I < 6.4 time I rated

Design D - High slip motors. Very high starting torques 275-300% of rated. Speed operates at 85-95% rated; slip 5-15%. Used to start high inertial loads Very low starting current, near rated at start.

Motor Nameplate Data

Nominal Efficiency - minimum efficiency that is guaranteed for design class. Given for one value of output - rated

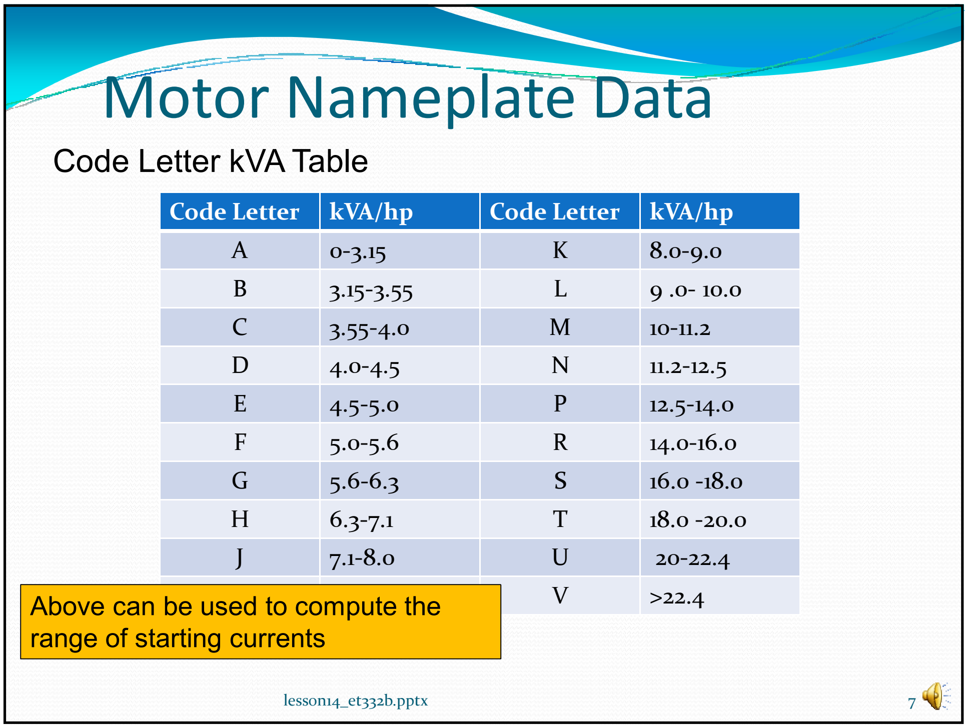
Design Letter - indicates NEMA design type A, B, C, D

Service Factor - (S.F.) number that indicates the maximum permissible loading

Motor Nameplate Data

Insulation Class - specifies maximum allowable temperature rise for motor windings

Code Letter - means of determining the expected locked-rotor inrush current at rated voltage and rated frequency

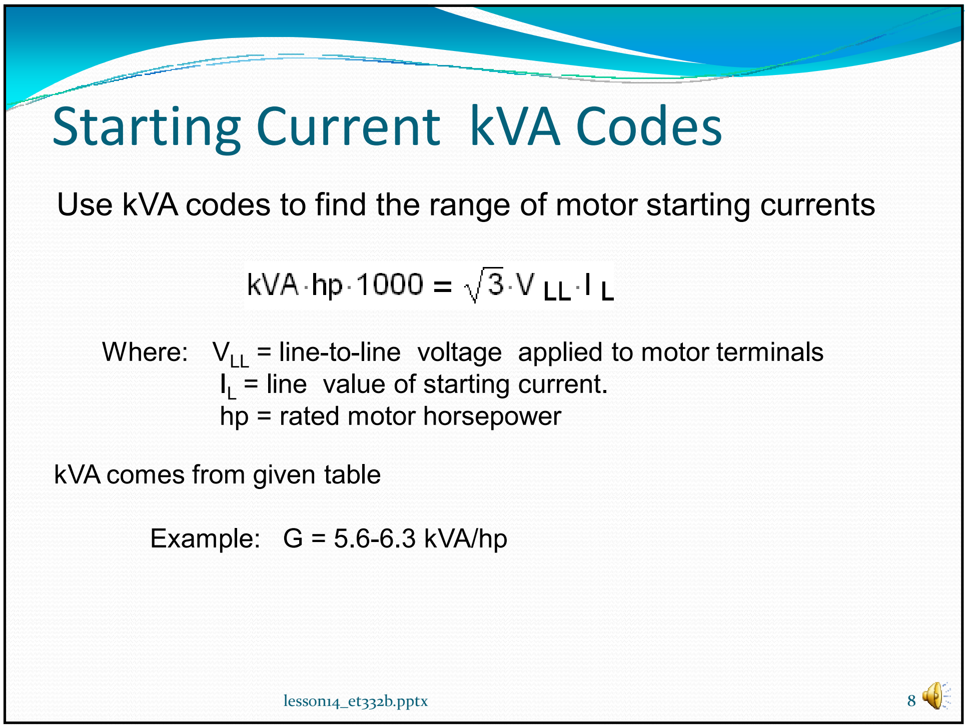


Motor Nameplate Data

Code Letter kVA Table

Code Letter	kVA/hp	Code Letter	kVA/hp
A	0-3.15	K	8.0-9.0
B	3.15-3.55	L	9 .0- 10.0
C	3.55-4.0	M	10-11.2
D	4.0-4.5	N	11.2-12.5
E	4.5-5.0	P	12.5-14.0
F	5.0-5.6	R	14.0-16.0
G	5.6-6.3	S	16.0 -18.0
H	6.3-7.1	T	18.0 -20.0
J	7.1-8.0	U	20-22.4
		V	>22.4

Above can be used to compute the range of starting currents



Starting Current kVA Codes

Use kVA codes to find the range of motor starting currents

$$kVA \cdot hp \cdot 1000 = \sqrt{3} \cdot V_{LL} \cdot I_L$$

Where: V_{LL} = line-to-line voltage applied to motor terminals
I_L = line value of starting current.
hp = rated motor horsepower

kVA comes from given table

Example: G = 5.6-6.3 kVA/hp

Starting Current kVA Codes

Example 14-1: A NEMA design motor is rated at 150 hp at 460, 60 Hz. It has a rated current of 163 A and a nominal efficiency of 96.2%. The locked rotor code is G. Find the range of starting current that can be expected from this machine.

Range for code G 5.6-6.3 kVA/hp

Low value of kVA $5.6 \cdot \left(\frac{\text{kVA}}{\text{hp}}\right) \cdot 150 \cdot \text{hp} = 840\,\text{kVA}$

High value of kVA $6.3 \cdot \left(\frac{\text{kVA}}{\text{hp}}\right) \cdot 150 \cdot \text{hp} = 945\,\text{kVA}$ $V_L := 460 \cdot V$

Low value of starting current

$$I_{lr} := \frac{840 \cdot \text{kVA} \cdot 1000}{\sqrt{3} \cdot 460 \cdot V} \qquad I_{lr} = 1054.3\text{A}$$

High value of starting current

$$I_{lr} := \frac{945 \cdot \text{kVA} \cdot 1000}{\sqrt{3} \cdot 460 \cdot V} \qquad I_{lr} = 1186.1\text{A}$$

Range $1054.3 \leq I_{lr} \leq 1186.1$

Effects of Reduced Terminal Voltage and Frequency

Machines can operate +- 10% of rated terminal voltage without significant change in characteristics.

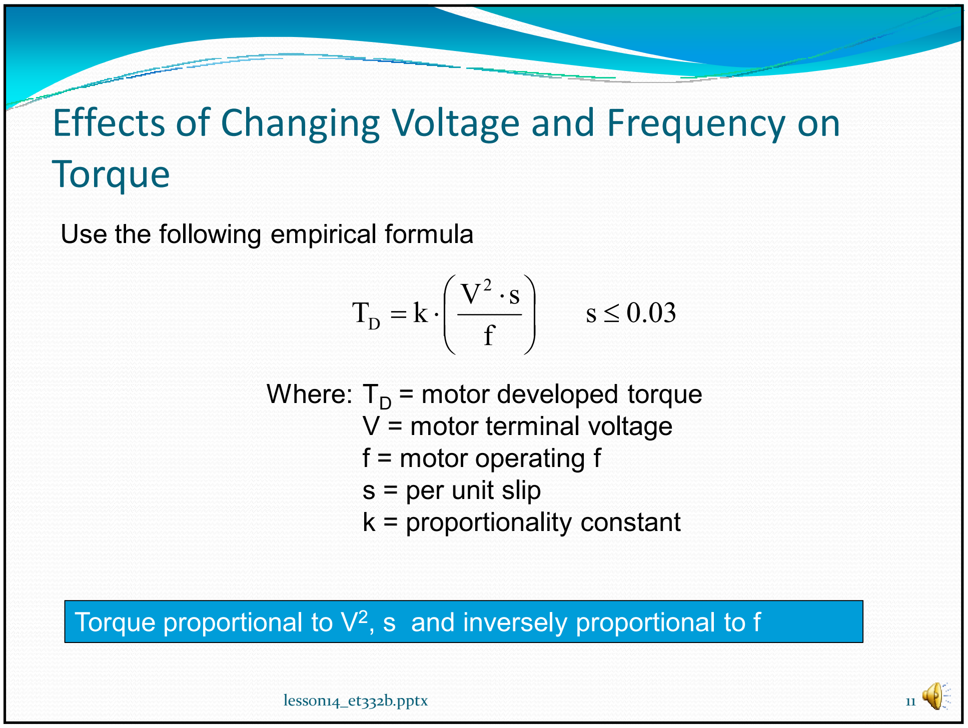
Motor rated voltage 460 V, Supply voltage 480 V

$$\%V = \left(\frac{V_{supply}}{V_{rated}}\right) \cdot 100\%$$

$$\%V = \left(\frac{480\ \text{V}}{460\ \text{V}}\right) \cdot 100\%$$

$$\%V = 104\%$$

Generally must change both voltage and frequency to maintain torque-speed characteristic (constant flux) (Can't vary terminal voltage for speed control)



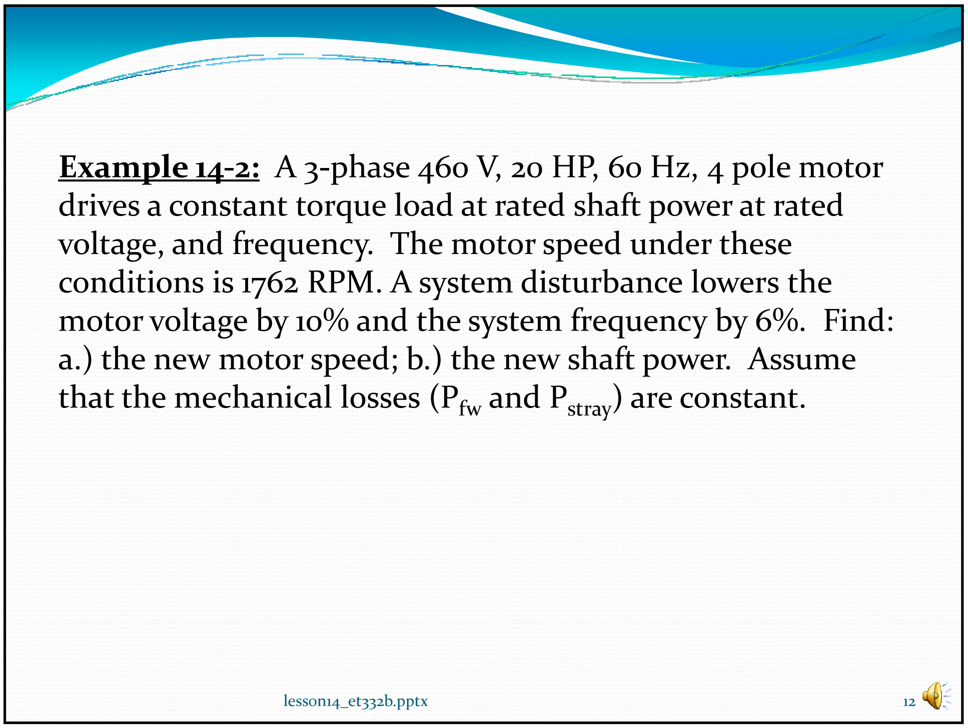
Effects of Changing Voltage and Frequency on Torque

Use the following empirical formula

$$T_D = k \cdot \left(\frac{V^2 \cdot s}{f} \right) \qquad s \leq 0.03$$

Where: T_D = motor developed torque
V = motor terminal voltage
f = motor operating f
s = per unit slip
k = proportionality constant

Torque proportional to V^2, s and inversely proportional to f



Example 14-2: A 3-phase 460 V, 20 HP, 60 Hz, 4 pole motor drives a constant torque load at rated shaft power at rated voltage, and frequency. The motor speed under these conditions is 1762 RPM. A system disturbance lowers the motor voltage by 10% and the system frequency by 6%. Find: a.) the new motor speed; b.) the new shaft power. Assume that the mechanical losses (P_{fw} and P_{stray}) are constant.

Example 14-2 Solution (1)

Define equations

$$T_{D1} = k\left[\frac{V_1^2 s_1}{f_1}\right] \qquad T_{D2} = k\left[\frac{V_2^2 s_2}{f_2}\right]$$

FOR CONSTANT TORQUE LOAD

$$T_{D1} = T_{D2}$$

OTHER KNOW VALUES

$f_1 = 60\ \text{HZ}$ $V_1 = 460\ \text{V}$ $n_{r1} = 1762\ \text{RPM}$ $P = 4$

For 10% voltage reduction

$$V_2 = (1-0.1)\cdot 460\text{V} = 414\ \text{V}$$

6% frequency Reduction $f_2 = (1-0.06)(60\text{Hz}) = 56.4\text{Hz}$

Find s_1. This requires synchronous speed

$$n_{s1} = \frac{120 f_1}{P}$$

$$n_{s1} = \frac{120(60\text{Hz})}{4} = 1800\ \text{RPM}$$

Example 14-2 Solution (2)

Compute slip for 1st case

$$s_1 = \frac{n_{s1} - n_{r1}}{n_{s1}} = \frac{(1800-1762)\ \text{RPM}}{1800\ \text{RPM}}$$

$$s_1 = 0.0211$$

Constant torque load so equate torques

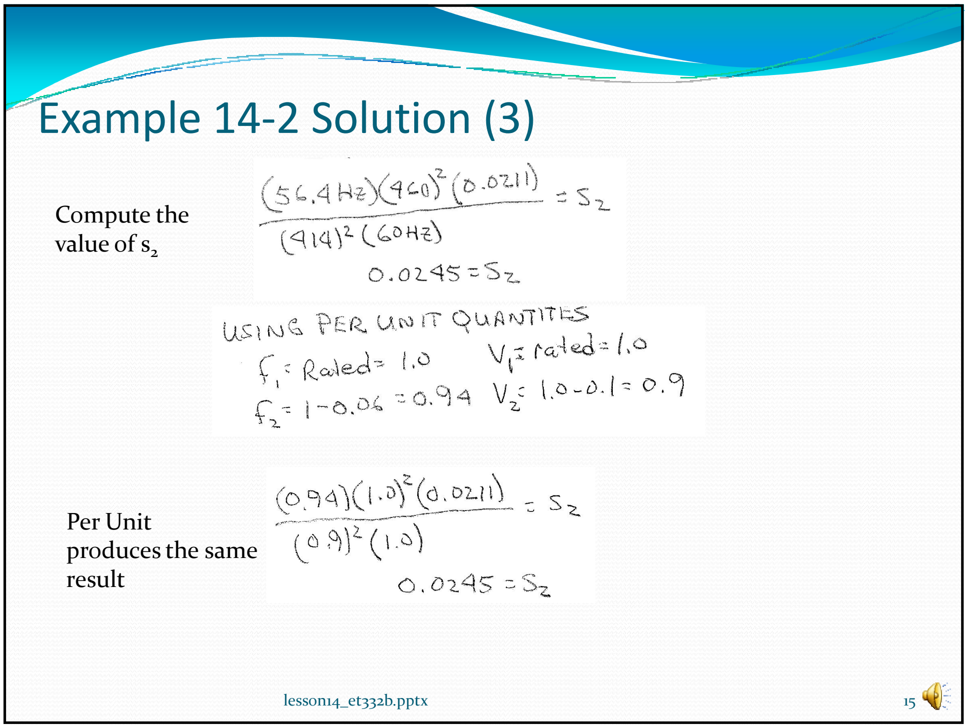
WITH $T_{D1} = T_{D2}$

$$k\left[\frac{V_1^2 s_1}{f_1}\right] = k\left[\frac{V_2^2 s_2}{f_2}\right]$$

Solve for s_2

$$\frac{V_1^2 s_1}{f_1} = \frac{V_2^2 s_2}{f_2}$$

$$\frac{f_2 V_1^2 s_1}{V_2^2 f_1} = s_2$$



Example 14-2 Solution (3)

Compute the value of s_2

$$\frac{(56.4\,\text{Hz})(460)^2(0.0211)}{(414)^2(60\,\text{Hz})} = S_2$$

$$0.0245 = S_2$$

USING PER UNIT QUANTITES

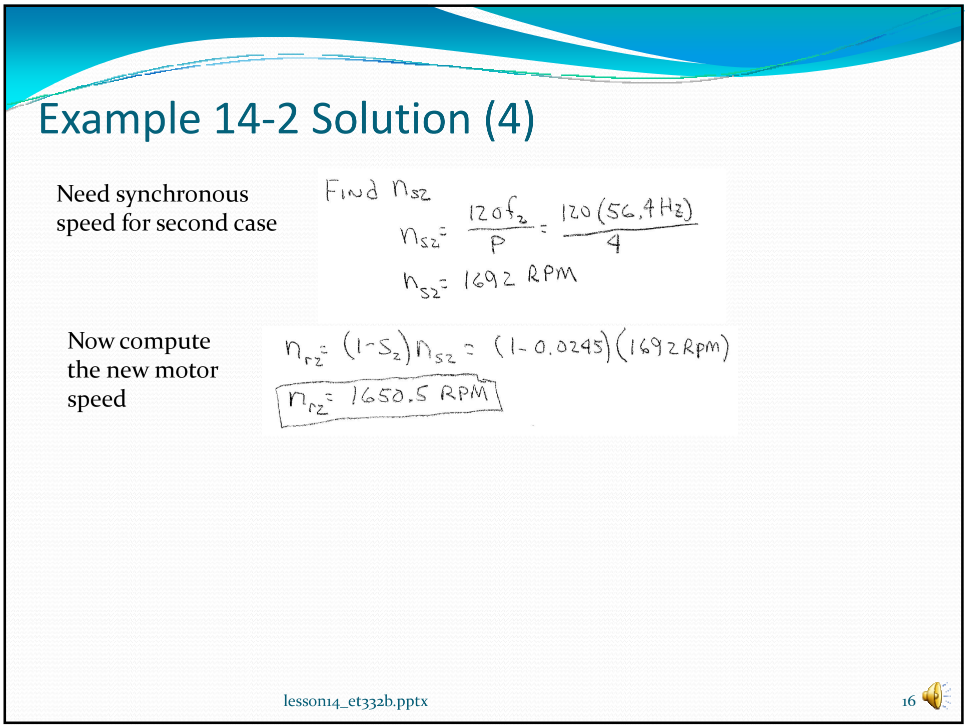
$f_1 = \text{Rated} = 1.0 \qquad V_1 = \text{rated} = 1.0$

$f_2 = 1 - 0.06 = 0.94 \qquad V_2 = 1.0 - 0.1 = 0.9$

Per Unit produces the same result

$$\frac{(0.94)(1.0)^2(0.0211)}{(0.9)^2(1.0)} = S_2$$

$$0.0245 = S_2$$



Example 14-2 Solution (4)

Need synchronous speed for second case

Find n_{s2}

$$n_{s2} = \frac{120 f_2}{P} = \frac{120(56.4\,\text{Hz})}{4}$$

$$n_{s2} = 1692\ \text{RPM}$$

Now compute the new motor speed

$$n_{r2} = (1 - S_2)\, n_{s2} = (1 - 0.0245)(1692\ \text{Rpm})$$

$$\boxed{n_{r2} = 1650.5\ \text{RPM}}$$

Example 14-2 Solution (5)

Solve part b. P_1=rated horsepower=20 hp

T_{s1} = shaft torque state 1
T_{s2}= shaft torque state 2

For constant torque load $T_{s1}=T_{s2}$

FOR T (lb-ft)

$$\frac{P_1}{P_2} = \frac{\frac{T_{s1} n_{r1}}{5252}}{\frac{T_{s2} n_{r2}}{5252}} \quad \text{SINCE} \quad T_{s1} = T_{s2}$$

$$\frac{P_1}{P_2} = \frac{n_{r1}}{n_{r2}} \Rightarrow P_1 = \frac{n_{r1}}{n_{r2}} P_2$$

$$P_2 = \left[\frac{n_{r2}}{n_{r1}}\right] P_1$$

$$P_2 = \left[\frac{1650.5\ \text{RPM}}{1762\ \text{RPM}}\right] 20\ \text{hp}$$

$$\boxed{P_2 = 18.73\ \text{hp}}$$

End Lesson 14: NEMA Designs and Induction Motor Nameplate Data

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