ECE 385 – Fall 2024

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HW #6

Due Date: Uploaded to D2L by 10 PM Friday November 15, 2024

Problem 1

A 3φ, 280 V, 60 Hz, 20 hp, four-pole induction motor has the following equivalent circuit parameters.

$R_s = 0.12\Omega$
$R_r = 0.1\Omega$
$X_s = X_r = 0.25\Omega$
$X_m = 10.0\ \Omega$

The rotational loss is 400 W. For 5% slip, determine

(a) The motor speed in rpm and radians per sec.
(b) The motor current.
(c) The stator cu-loss.
(d) The air gap power.
(e) The rotor cu-loss.
(f) The shaft power.
(g) The developed torque and the shaft torque.
(h) The efficiency.

Use the IEEE-recommended equivalent circuit.

In your answer, please identify and briefly explain knowns and unknowns of this problem, the formulas you will use to solve the problem, and your solution approach.

Problem 2

You have been asked to design the electric service to a new water pumping station in a rural area of Southern Illinois.

- The water pump is an intermittent load that requires a 50 hp motor, and can operate effectively between 1700 – 1800 rpm.
- The pumping station is located at the end of a 2-mile long three phase overhead 12,470 / 7,200 V wye connected distribution line with sufficient capacity to serve the new pumping station, but maintaining voltage is a concern for the utility.
- The water district that will operate the pumping station has a limited budget, so initial construction and operating costs are a concern.
- The water district is socially conscience and is also concerned about its environmental impact and prefers to use U.S. made products.

a) Assuming you have the options below for the distribution transformer and pump motor, which transformer and motor option would you choose for your design and why? Explain your answer in terms of the system electric needs, efficiency, cost, and environmental and global impact.

b) Assuming interconnection wiring has negligible losses, what is the overall efficiency of your design when the pump is running at full load (I.E. – P_{out} / P_{in})?

Motor Options:

Motor 1:

- Made in China
- Cost = $3,400

PERFORMANCE DATA

HP	RPM	Frame	Voltage	Frequency (Hz)	Full Load S.F.	Insulation Class	NEMA Design	Slip (%)	NEMA Code	Enclosure Type	IP Rating	Max. Ambient
50	1778	326TS	230/460	60	1.15	F	B	1.2	G	ODP	23	40 °C

Amps (460V)		Efficiency (%)			Power Factor			Torque (ft-lb)			DE Bearing	ODE Bearing	Connection	Weight (lbs.)
FLA	LRA	100%	75%	50%	100%	75%	50%	FLT	LRT %	BDT %				
59	362	94.5	94.5	94.0	0.83	0.80	0.70	148.4	170	260	6312	6312	12 Lead 2Δ/Δ	569

**Usable at 208 Volts*

Motor 2:

- Made in Japan
- Cost = $4,200

PERFORMANCE DATA

HP	RPM	Frame	Voltage	Frequency (Hz)	Full Load S.F.	Insulation Class	NEMA Design	Slip (%)	NEMA Code	Enclosure Type	IP Rating	Max. Ambient
50	1780	326T	230/460	60	1.15	F	C	1.1	G	TEFC	55	40 °C

Amps (460V)		Efficiency (%)			Power Factor			Torque (ft-lb)			DE Bearing	ODE Bearing	Connection	Weight (lbs.)
FLA	LRA	100%	75%	50%	100%	75%	50%	FLT	LRT %	BDT %				
58.3	362	94.5	94.5	94.6	0.83	0.79	0.70	148.4	200	255	6312	6312	12 Lead 2Δ/Δ	580

**Usable at 208 Volts*

Motor 3:

- Made in USA
- Cost = $5,500

Performance Data

Frame	: 404/5T
Output	: 50 HP
Frequency	: 60 Hz
Poles	: 6
Full load speed	: 1120 rpm
Slip	: 6.67 %
Voltage	: 208-230/460 V
Rated current	: 134-118/59.2 A
Locked rotor current	: 722/361 A
Locked rotor current (Il/In)	: 6.1
No-load current	: 33.0/16.5 A
Full load torque	: 231 lb.ft
Locked rotor torque	: 300 %
Breakdown torque	: 0 %
Design	: D
Insulation class	: F
Temperature rise	: 80 K
Locked rotor time	: 25 s (hot)
Service factor	: 1.15
Duty cycle	: S1
Ambient temperature	: -20°C - +40°C
Altitude	: 1000 m
Degree of Protection	: IP55
Approximate weight	: 1036 lb
Moment of inertia	: 36.025 sq.ft.lb
Noise level	: 68 dB(A)

	D.E.	N.D.E.
Bearings	NU-316 C3	6314 C3
Regreasing interval	12000 h	17000 h
Grease amount	34 g	27 g

Load	Power factor	Efficiency (%)
100%	0.89	88.1
75%	0.87	87.5
50%	0.80	86.5

Transformer Options

Transformer #1

- Pad-Mount – 25 kVA, 60 Hz
- 12,470 V to 480 V
- Efficiency = 97.90%
- Cost = $7,500
- Made in USA

Transformer #2

- Pole-Mount – 50 kVA, 60 Hz
- 12,470 V to 480 V
- Efficiency = 98.89%
- Cost = $9,000
- Made in Germany

Transformer #3

- Pad-Mount – 75 kVA, 60 Hz
- 12,470 V to 480 V
- Efficiency = 98.70%
- Cost = $22,000
- Made in China

Problem 3

In a factory, the following are the loads:

Induction motors: 1000 hp
0.7 average power factor
0.85 average efficiency
Lighting and heating load: 100 kW

A 3φ synchronous motor is installed to provide 300 hp to a new process. The synchronous motor operates at 92% efficiency.

a. Determine the kVA rating of the synchronous motor if the overall factory power factor is to be raised to 0.95.
b. Determine the power factor of the synchronous motor

In your answer, please identify and briefly explain knowns and unknowns of this problem, the formulas you will use to solve the problem, and your solution approach.