EEET – 241 FINAL EXAM 2519

Read the Exam carefully – it should look similar to things you have done before (but not exact). Don't try to do the work on these sheets – make your own sheets and just label the first page with "EEET-241 Final Exam" and your name.

Make sure, for **all** parts of **all** problems, show your work.
For all questions below, be sure to show your work <u>clearly</u>.
Do not just write the answer.
Partial credit, cannot be awarded, without you showing your work.

Assume all Voltages, for all problems, are 60 Hz Alternating Current.

Make sure all of your values have units (ohms, volts, amps, VA, W, VAR, etc.)

#1 (20 Points)

A utility provides a three phase voltage source of 4160V at 60 Hz. It is shown in phasor notation as $4160<0^{o}$.

Plot the following:

Plot A: Show the plot of the open circuit voltage versus time on a graph. Be sure to clearly indicate the peak and RMS values and the period of the waveforms. Be sure to show all three phases on the same graph. Show two waveform periods of time on the graph.

Plot B: Show the voltages (all three phases) in phasor notation.

The utility source has a short circuit ("withstand") current of 1000A (1 KAIC) with a pf = 0.0 (READ THIS CAREFULY!). Find the impedance of the source. Include the angle for the impedance. Determine the angle for the short circuit current.

Connect the utility to a variable frequency drive (VFD) that controls the speed of a motor with PWM. The three phase voltage provides 20A of (line) current to the motor at full speed. This equates to 20A of current from the utility into the VFD. If the utility has a problem and loses one of the three phases (continues to run on only two phases), what is the current into the VFD? Prove this.

#2 (30 points)

You are given a single phase transformer rated as follows:

2400-240VAC, 100 KVA, Z = 10%, 60 Hz, 135 degree temperature rise

(for this problem, assume the impedance is all reactive)

Hint: We are assuming that the magnetizing core impedance is negligible (i.e. extremely high or $Z_m \sim \infty$).

Part A:

Clearly show the circuit and label all voltages and currents.

Find the turns ratio.

Find the base KVA of the transformer alone (without any load).

Find the base impedance of the primary of the transformer (without any load).

Find the actual transformer impedance (Z_{fp}) as seen looking into the primary (high voltage) side (without any load).

Find the secondary (open circuit) voltage (without any load).

Hint: The open circuit voltage is when there is no load ($Z_l = \infty$).

Part B:

Connect the secondary to a 1 ohm (reactive) load.

Clearly show the circuit and label all voltages and currents.

Find the total impedance Z_p (with the load) looking into primary of the transformer.

Part C:

Connect a 2400VAC utility source to the primary (high voltage) side of the transformer (with the load attached). Assume this is an infinite bus so $Z_{utility}$ = 0 ohms.

Clearly show the circuit and label all voltages and currents.

Find the primary current I_p.

Find the secondary current I_s.

Find the current through the load (I_l).

Find the voltage across the load (V_l).

Part D:

Calculate the real power (P), the reactive power (Q) and the total apparent power (S) delivered by the utility.

Calculate the real power (P) the reactive power (Q) and the total apparent power (S) dissipated in the load.

Find the voltage regulation for this circuit, given the load indicated.

#3 (30 points)

This is a three phase design problem where a utility is connected to a transformer, which will, in turn, power a motor.

UTILTY INFORMATION:

The utility is a 240V three phase source. Draw the circuit of the three-phase 240V utility. It should be on the left side of your page. You should model it as a DELTA source. Ignore any utility impedance (i.e. this is an infinite bus so assume $Z_{utility}$ = 0 ohms). Draw this first before you go to the next item.

TRANSFORMER INFORMATION:

Connect the utility to the primary of a three-phase transformer. You will only have three "lines" (wires) from the utility to the transformer primary. The transformer nameplate rates the transformer as 1000KVA, 240-208/120V, 60 Hz. Ignore the transformer impedances (assume an ideal transformer –> $Z_{transformer}$ = 0%). Be sure you know the wiring configuration of the transformer based on the nameplate rating.

Add this to your circuit diagram before you go to the next item.

MOTOR (LOAD) INFORMATION:

Connect a motor to the secondary of the transformer. The nameplate of the inductive motor indicates:

HP = 10 HP

PH (Phases) = 3

Voltage = 200V (Remember this is the <u>rated</u> voltage of the motor)

Assume the motor is wired as DELTA internally

FLA = 30A (Hint: Remember this is line current at Full Load.)

LRA = 180A (Hint: Remember this is line current at Locked Rotor conditions.)

Rotational speed = 1070 RPM (This is at Full Load)

Efficiency = 80% (This is at Full Load)

P.F. (of motor) = 70.71%

Service Factor = 1.05%

Enclosure = TEFC

Add the motor to the circuit above before you go on.

Clearly label (on the circuit) each voltage. Hint: There is no calculation needed, you have all of the numbers needed – just label them on the drawing.

The voltage ($V_{utility\ line-line}$) across each line-to-line of the utility.

The voltage ($V_{primary\ line-line}$) across each line-to-line of the primary of the transformer.

The voltage ($V_{primary\ phase}$) across each phase (coil) of the primary of the transformer.

The voltage ($V_{secondary\ phase}$) across each phase (coil) of the secondary of the transformer.

The voltage across each line-to-line from the secondary of the transformer to the motor ($V_{secondary\ line-line}$).

The voltage (V_{motor}) applied to the motor. This is the line voltage applied to the motor.

WHAT YOU NEED TO DETERMINE:

How many poles does this motor have?

What is the Synchronous Speed of this motor?

What is the Slip of this motor?

What is the mechanical output (in BHP) of this motor at full speed?

What is the Total impedance (Z_{motor}) of this motor at <u>Full Load</u> (express this as a magnitude and angle)?

What is the Resistive impedance (R_{motor}) of this motor at <u>Full Load</u> (express in ohms)?

What is the Reactive impedance (X_{motor}) of this motor at <u>Full Load</u> (express in ohms)?

What is the X/R ratio of the motor?

What is the Full Load Apparent power drawn by this motor (express in kva)?
(Remember KVA = V * FLA * √3)
Hint: Remember the electrical power of a motor is NOT dependent on the HP, it is based on voltage and current.

What is the Full Load Active power drawn by this motor (express in kw)?

What is the Full Load Reactive Power drawn by this motor (express in kvar)?

What is the Locked Rotor Apparent power drawn by this motor (express in kva)? (Remember KVA = V * FLA * √3)

From the numbers above:

Determine the current for each line from the secondary of the transformer ($I_{secondary\ line}$).

Determine the current ($I_{secondary\ phase}$) in each phase of the secondary of the transformer.

Determine the current ($I_{primary\ phase}$) in each phase of the primary of the transformer.

Determine the current for each line to the primary of the transformer ($I_{primary\ line\text{-}line}$).

Determine the current in each utility line feeding the primary of the transformer ($I_{utility\ line}$).

The power delivered by each phase of the transformer secondary.
The <u>total</u> power out of the secondary of the transformer.

The power delivered to each phase of the transformer primary.
The <u>total</u> power into the primary of the transformer.

The total power delivered by the utility.

Hint: The total power delivered to the motor should be the same as the total power delivered by the utility – check your answer. Make sure you show this check.

#4 (10 points)

We want to use a single phase autotransformer to generate 208V single phase from a 240V single phase source to power a 1000 ohm (resistive) load at 208V. The autotransformer is a common core, common coil configuration.

Draw the circuit CLEARLY showing the primary and secondary of the transformer (and load). Ignore all transformer impedances (assume and ideal transformer).

Determine the turns ratio (sometime called the tap position).

Be sure to show the two sections of the coil and show how the ratio is calculated.

Be sure to clearly label and determine all the currents in each part of the common coil:

- -the load current.
- -the secondary current.
- -the primary current.
- -the current in each section of the transformer (be sure to correlate with the currents as labeled above).

If the total coil has 1792 coils total, how many coils are connected to the primary and how many coils are connected to the secondary? Show coil numbers on your circuit diagram.

#5 (10 Points)

For a Single Phase Capacitor <u>Start</u> Motor running at 240V (remember single phase) 60Hz at a speed of 1700 rpm, running a water pump.

Calculate the following:

What is the synchronous speed of the motor?

What is the slip of the motor?

How many poles does this motor have?

Draw a circuit that shows this motor and how it works. Make sure you show both (all) the windings.

Explain how this motor works.

Explain how the motor starts.

After installing this motor, we find that the rotational direction of the motor is backwards. How do we change this so the pump will always run in the correct rotational direction? Be very clear and exact.