THE UNIVERSITY of ADELAIDE

Quiz 1, 2021

Electric Power Systems (ELEC ENG 3110)
Power Systems PG (ELEC ENG 7074)

Instructions:

Allotted Time
Quiz start: 15:10
Quiz end: 16:30
Duration: 80 minutes (60 min writing, 20 min download and upload).

A total of 80 minutes is allotted for you to download the quiz questions, write your quiz solutions and upload your solutions. The quiz questions are intended to be answered in 60 minutes thus allowing 20 minutes for you to download the questions and to scan and upload the solutions.

Late penalty: Solutions that are uploaded up to 30 minutes after the due time will be accepted but will receive a 50% penalty. Solutions that are uploaded more than 30 minutes after the due time will not be marked and will be assigned zero marks.

Write your solutions on your own paper (or virtual paper using a tablet app)
- Start the answer of each main question on a new sheet of paper.
- Clearly preface the answer of each question with the main-question number and sub-question number and rule a line under your answer to each sub-question.
- Clearly and neatly write your answers and show all working. These aspects will be taken into account in marking your paper.

Submission of solutions to myUni.
- If you have a scanner, scan your solutions into a PDF file and upload the file to MyUni.
- If you do not have a scanner, you may photograph your solutions and submit the photographs (in one file) to myUni. Please use a low resolution mode so files are not too large. If you can generate a PDF file, that is preferred.
- If you use a virtual paper app then generate a PDF file of your solutions and upload the PDF file to myUni. (DO NOT upload the solution in the native format of the virtual paper app.)

Academic Integrity.
Normal University rules regarding academic honesty apply. If similarity between submissions is detected then academic integrity hearings will be instituted.

1) Sinusoids and Phasors [12 marks]

The phase to neutral voltage of one phase of a balanced three-phase source is to be expressed in the following form

$$v(t) = V_p \cos(\omega t + \alpha) \tag{1}$$

and the line current of the corresponding phase is to be expressed in the following form

$$i(t) = I_p \cos(\omega t + \alpha + \theta) \tag{2}$$

1a) Sinusoidal waveforms [6 marks]

Figure 1 below shows the phase to neutral voltage of the source and the corresponding line current supplied by the source to the system.

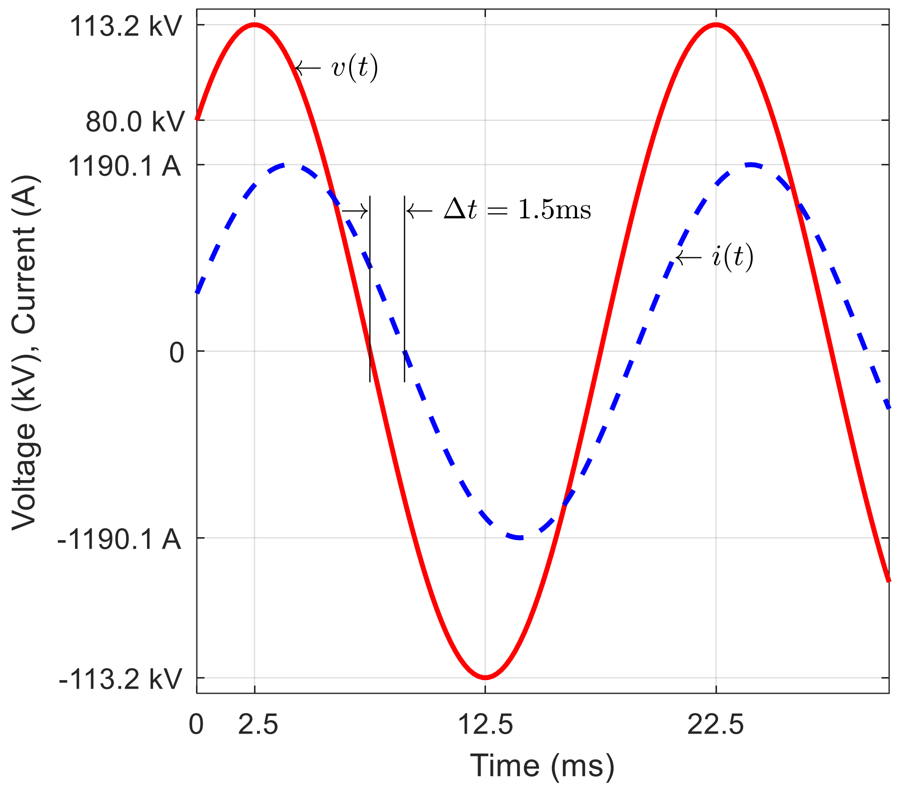

Figure 1: Voltage and current waveform

i) Determine the frequency of the voltage waveform, ω (in rad/s)? [1 marks]

ii) Referring to equation (1) and the voltage waveform determine the values of V_p and α ? [3 marks]

iii) Referring to equation (2) and the current waveform determine the values of I_p and θ ? [2 marks]

1b) Phasors and Complex Power [6 marks]

Referring to equation (1) $V_p = 235.8\ \text{kV}$, $\alpha = -30°$ and the total real and reactive power supplied by all three phases of the balanced source is $P = 200\ \text{MW}$ and $Q = -65\ \text{MVAr}$.

i) Express the voltage as an RMS cosine-referenced phasor. [1 mark]

ii) Calculate the line current phasor in magnitude / phase form. [3 marks]

iii) Determine the values of I_p and θ in (2). [2 marks]

2) a.c. Circuit Analysis [13 marks]

Consider the a.c. network in Figure 2 which represents one phase of a balanced 50 Hz three-phase system under steady-state a.c. conditions.

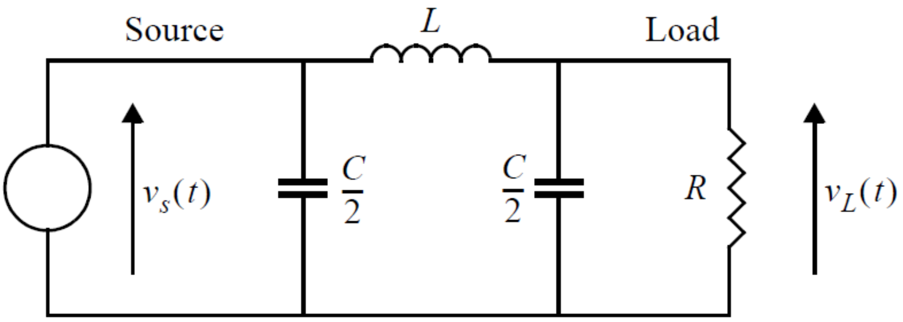

Figure 2: a.c. circuit for question 2

The peak value of the source voltage is 408 kV, which occurs at time t = 0 s. The line inductance is $L = 0.172\ \text{H}$, the line capacitance is $C = 2.76\ \text{uF}$ and the load resistance is $R = 250\ \Omega$.

i) What is the source voltage RMS cosine-referenced phasor, $\hat{V}_S$? [1 mark]

ii) Calculate the load voltage RMS cosine referenced phasor, $\hat{V}_L$, in magnitude / phase form. [7 marks]

iii) Calculate the real and reactive power supplied by a single phase of the source (in MW and MVAr) [5 marks]

3) Power Transmission and Phasor Diagrams [8 marks]

Figure 3 represents the transmission line between two parts of a power system. The transmission line reactance , X , is assumed to be known.

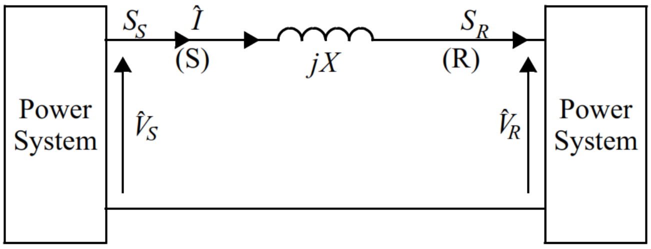

Figure 3: Circuit for question 3

3a) Power Transmission [4 marks]

i) Suppose the receiving end voltage phasor, $\hat{V}_R$, and complex power, $S_R = P_R + jQ_R$ is known. Derive an equation for the sending-end voltage phasor, $\hat{V}_S$.
(You must clearly show the steps in your derivation.) [2 marks]

ii) If $\hat{V}_R = 1.05\angle 0°$ per-unit, $S_R = 1.2 + j0.2$ per-unit and $X = 0.3$ per-unit calculate $\hat{V}_S$ (in magnitude / phase form) using the equation that you derived in (i). Is the calculated source voltage within prescribed limits? [2 marks]

3b) Phasor diagram [4 marks]

Suppose the sending and receiving end voltages are respectively $\hat{V}_S = Ve^{j\delta}$ and $\hat{V}_R = V\angle 0°$ as shown in the phasor diagram in Figure 4. Show on the phasor diagram the derivation of the transmission line current phasor $\hat{I}$ using a geometric approach. *You must clearly show and explain the steps in your derivation*.
[Hint: As shown in Figure 5 the bisector OC of the chord AB of a circle is perpendicular to the chord.]

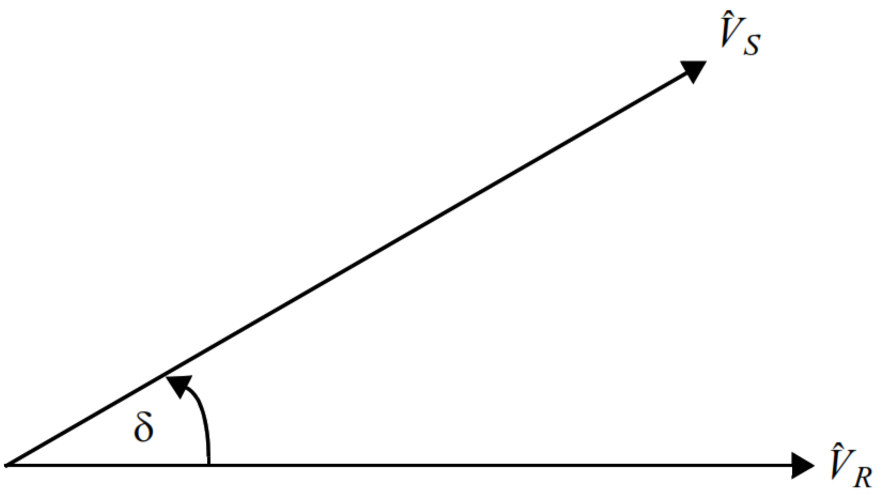

Figure 4: Phasor diagram for problem 3b)

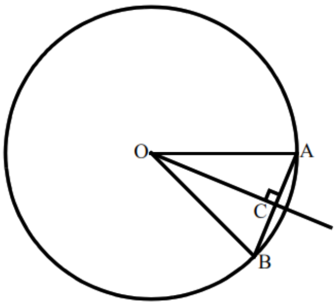

Figure 5: Hint for problem 3b)

4) Power and Frequency Control [7 marks]

4a) System Inertia [3 marks]

In a large 50 Hz power system the demand and supply is balanced before a power-station is abruptly disconnected due to a fault. Recordings show that (i) the rate-of-change-of-frequency (RoCoF) immediately following the disconnection of the power-station is approximately -0.5 Hz/s; and (ii) the power output from the station immediately before its disconnection was 2,500 MW. On the basis of these measurements estimate the total online synchronous inertia following the disconnection of the power-station.

4b) Security constrained dispatch [4 marks]

The following table shows the bids in $/MWh that generator owners are prepared to sell the output from their power stations during the next 5-minute dispatch cycle. The system operator estimates that the total system demand will be 1,500 MW during the next dispatch cycle. Some bids are marked as unacceptable because output from these power stations would violate security constraints.

Generator Owner	**Capacity Offered (MW)**	**Bid Price ($/MWh)**	**Secure Bid (Y/N)**
A	500	20	No
B	600	-100	Yes
C	200	200	Yes
D	600	100	Yes
E	400	120	Yes

i) List those generators which will be permitted to generate in the next 5-minute dispatch cycle. [2 marks]

ii) What price ($/MWh) will all dispatched generators receive in the next 5-minute dispatch interval? [1 mark]

iii) Calculate the total cost of the <u>energy</u> generated in the next 5-minute dispatch interval. [1 mark]

END OF QUESTIONS