Department of Electrical and Computer Engineering

CANDIDACY EXAM: **Power Systems**

Time: 3 hours (9:00 AM – 12:00 noon)

Name:____________________________________

Student number:_____________

Student’s signature:____________________________________

General Instructions:

1. This is a closed-book exam. One single-sided formula sheet is allowed.
2. There are a total of seven problems, Q1-Q7, in this exam. **You are to choose only five problems for marking.** On the list below circle the problems you want marked and only those will be marked. **If none are circled the first five will be marked.**
3. No large memory programmable calculators are permitted.
4. Cell phones and other wireless devices must be turned off.
5. You will be provided with scrap paper.
6. Make sure that your name, student number, and signature are written on this page.

Q1: ____________/20

Q2: ____________/20

Q3: ____________/20

Q4: ____________/20

Q5: ____________/20

Q6: ____________/20

Q7: ____________/20

TOTAL: ____________/ 100

Q1 [20 marks]

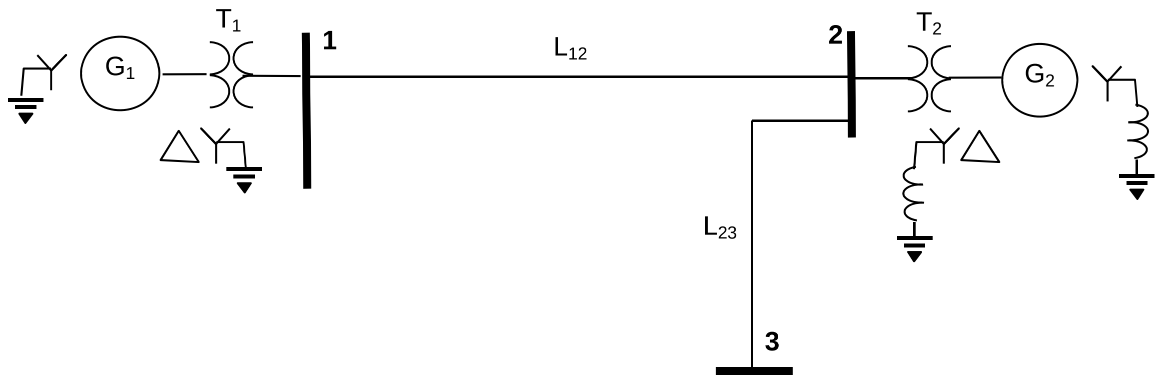


Fig. 1

The reactance data for the power system shown in Fig. 1 is given in the following table. All data are in pu on a common base.

Item	X^1	X^2	X^0
G_1	0.15	0.15	0.05
G_2	0.1	0.1	0.05
T_1	0.25	0.25	0.25
T_2	0.2	0.2	0.2
L_{12}	0.3	0.3	0.75
L_{23}	0.29	0.29	0.74
Grounding reactance of transformer T_2 = 0.05			
Grounding reactance of generator G_2 = 0.1			

a) A bolted (Z_f = 0) line to ground (LG) fault occurs at bus-3. Compute the fault current. [8 marks]

b) Calculate the Phase-A voltage at bus-1 after the fault. [6 marks]

c) What would happen to the magnitude of fault current, if the grounding reactance of transformer T_2 is zero? A qualitative answer is sufficient. [3 mark]

d) What would be the effect on fault current, if the grounding reactance of generator G_2 is zero? A qualitative answer is sufficient. [3 mark]

Q2 [20 marks]

a) Compare the Newton-Raphson and the decoupled NR load flow solution methods highlighting the advantages and disadvantages of each method. Give at least one example where de-coupled load flow solution is useful. [4 marks]

A simple 3 bus power system is shown in Fig. 2. All admittances are given in pu on a common base. Voltage at bus -1 is controlled at 1.0 pu and that of bus-2 is controlled at 1.05 pu. In order to perform de-coupled NR load flow, consider bus-1 as the slack bus and start with initial estimates of V2 = 1.05∠0o and V3 = 1.0∠0o.

b) Determine the bus admittance matrix. [3 mark]

c) Determine the vectors of unknowns and the corresponding bus susceptance matrices B' and B" required for performing the fast decoupled NR load flow solution. [4 marks]

d) Calculate the mismatch vectors [ΔP/|V|] and [ΔQ/|V|] for the first iteration. [5 marks]

e) Compute the new value of |V3|. [4 marks]

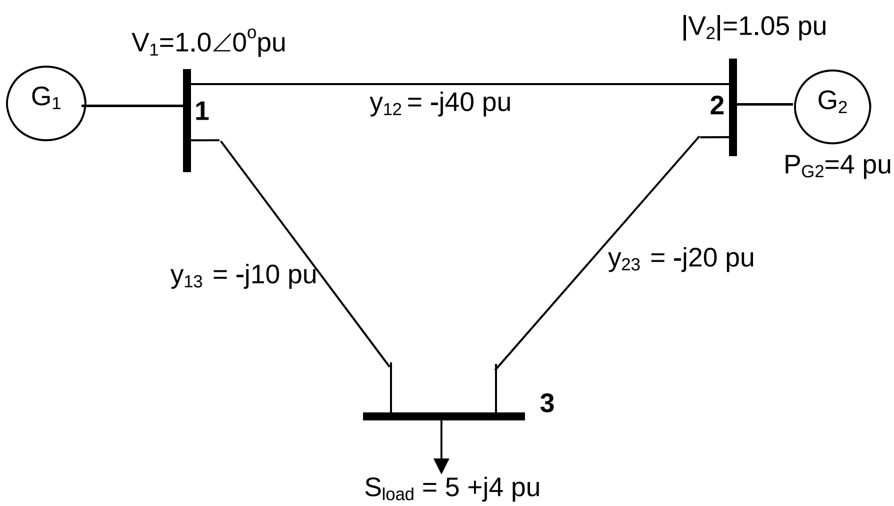


Fig. 2

Q3 [20 marks]

A 275 kV, three-phase transmission line shown in Fig 3 has the following line parameters:

$$A = 0.93\angle 1.5^o \qquad B = 115\angle 77^o\ \Omega$$

The source G2 supplies 100 MW of real power at unity power factor while maintaining the receiving end voltage at 275 kV.

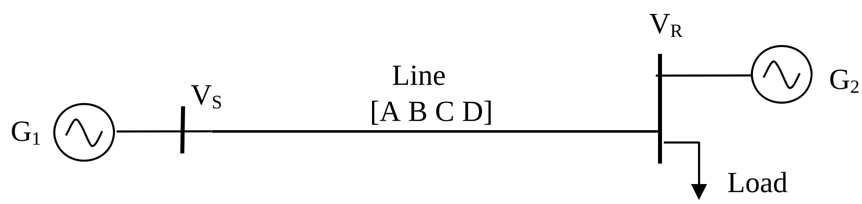


Fig 3

a) Determine the sending-end voltage required if the load being delivered at the receiving end is 200 MW at 0.85 lagging pf. [8 marks]

b) The load of at the receiving end is changed to 300 MVA at 0.8 lagging pf while the sending end voltage being held at 290 kV. Determine the additional reactive power that has to be supplied by G2 in order to maintain the receiving end voltage at 275 kV. [8 marks]

c) Calculate the transmission efficiency of the line under the condition in (b). [4 marks]

Q4 [20 marks]

a) Explain what is the "surge impedance loading" of a transmission line. What is its relevance to line compensation? Sketch the voltage profile along a lossless transmission line under surge impedance loading. [4 marks]

b) A 50 MVA, 24 kV, 60 Hz, generator has the reactances: X_d = 1.0 pu, X_d' = 0.3 pu, and X_d'' = 0.15 pu. The generator is operating at no load and rated voltage when a three-phase short circuit occurs at the terminals. Considering the fault current just after the short circuit, find

   i) Initial symmetrical rms current [2 marks]

   ii) Maximum possible dc component [2 marks]

   iii) Maximum possible asymmetrical rms current [2 marks]

   You may use the following equation:

$$i(t) = E_m\left[\frac{1}{X_d} + \left(\frac{1}{X_d'} - \frac{1}{X_d}\right)e^{-\frac{t}{T_d'}} + \left(\frac{1}{X''_d} - \frac{1}{X'_d}\right)e^{-\frac{t}{T_d''}}\right]\cos(\omega t + \lambda) - \frac{E_m}{X_d''}\cos(\lambda)e^{-\frac{t}{T_a}}$$

c) Explain why the make duty (closing duty) of a circuit breaker is different from its break duty (opening duty). Which duty is larger? [3 marks]

d) In the power system shown in Fig. 4, two 30 kV generators are connected to a 400 kV transmission line through a 30/400 kV transformer. Impedances of the generators and the transformer are given in pu based on their own ratings. Find the fault level (short circuit MVA) at bus-3. [7 marks]

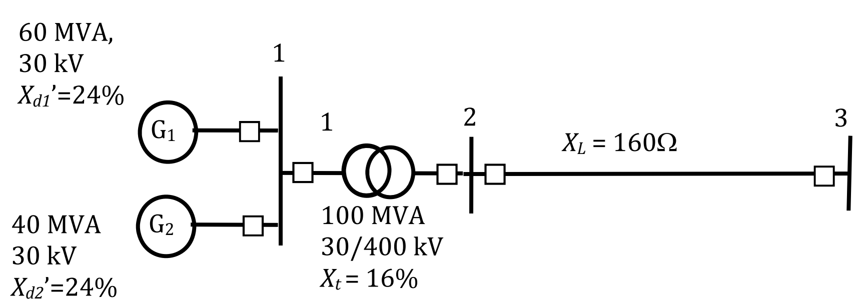
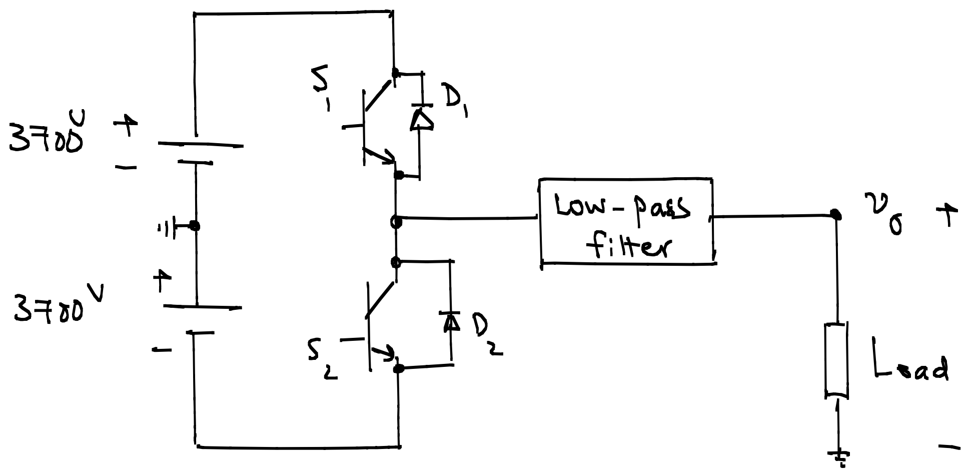
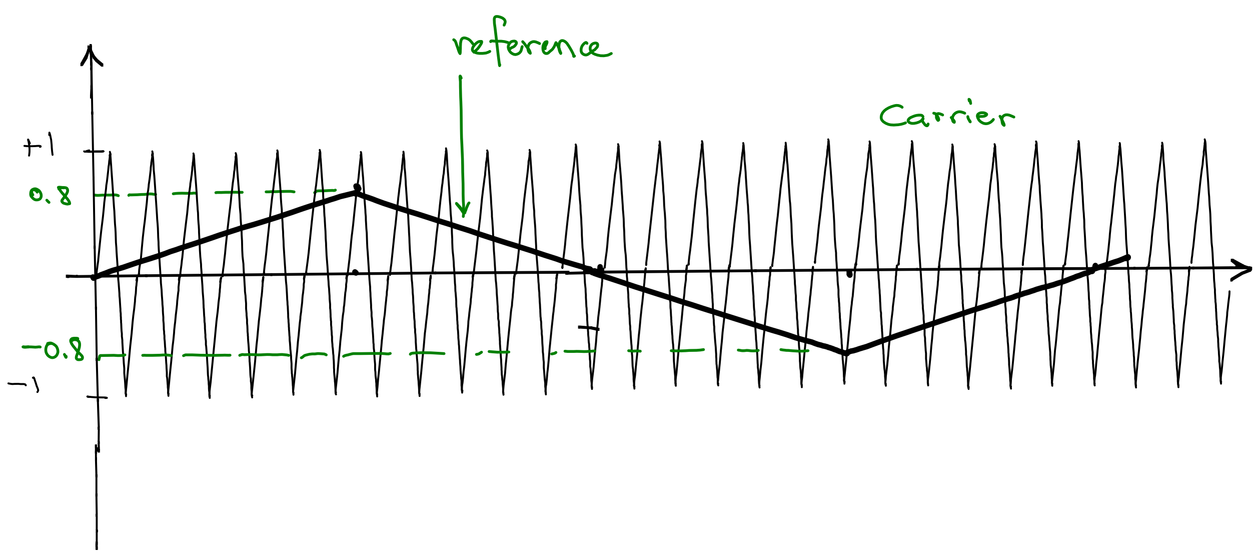


Fig. 4

Q5 [20 marks]

Consider the following dc-ac converter. The frequency of the carrier waveform is set to 6 kHz. The reference waveform has a frequency of 60 Hz. The cut-off frequency of the filter is set to 1 kHz. Draw and fully label the waveform of the load's terminal voltage (v_0).





Q6 [20 marks]

A three-phase induction machine operates under constant terminal V/f. While the machine is accelerating to its reference speed, the speed controller remains in saturation and hence the machine operates with a constant slip speed. Show that under operation with a constant slip speed the torque produced by the machine is proportional to the ratio $(E/f)^2$, where E is the internal emf of the machine across its magnetization branch.

Q7 [20 marks]

A salient pole synchronous generator with saturated synchronous reactances X_d = 1.72 pu and X_q = 1.47 pu is connected to an infinite bus through an external impedance of X = 0.09 pu on the generator base. The generator is operating at rated voltage and rated MVA at 0.95 power factor lagging as measured at the generator terminals.

a) Draw a phasor diagram, indicating the infinite bus voltage, the armature current, the generator terminal voltage, the excitation voltage and rotor angle (measured with respect to the infinite bus);

b) Calculate the pu terminal, infinite bus and generated voltages and the rotor angle in degrees as measured with respect to the infinite bus.