Tampere University
Electrical Engineering

EE.EES.300 Fundamentals of Electrical and Power Engineering 4.11.2024

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Programmable calculator allowed 5 questions/ á 6 pts

Q1: A symmetrical three-phase load is fed through a three-phase feeder. The three-phase voltage source (Phases A, B, C) at the sending end (beginning of feeder) of the feeder is also symmetrical. The phase voltage (phase-to-earth voltage) of Phase A is U_A. The voltage $U_A = 325.3 * \cos(314.16t + 55°)$ V. The symmetrical feeder is 1.5 km long, having parameters R = 1.3 Ω/km and X = 0.2 Ω/km. The load in the receiving end of the feeder is a constant impedance load having impedance $\underline{Z}_L = (10 + j4)$ Ω/phase. (2 pts/sub-question)

a) Draw the single-line diagram of the network and calculate the phase currents for phases A, B and C. Draw the phasor diagram of the current and voltage of Phase A.
b) Calculate the three-phase real power, reactive power, apparent power and power factor of the source.
c) Calculate the three-phase real power, reactive power, apparent power and power factor of the load.

Q2: Three-phase transformer has the following rating plate values: $S_n = 200$ kVA, $U_p / U_s = 20500 / 410$ V, $z_k = 4$ % (relative short-circuit impedance), $P_k = 2295$ W (nominal load losses). (2pts/sub-question)

a) Determine a transformer equivalent circuit (including impedance values) suitable for load flow studies at the primary potential (20500 V).
b) A constant impedance load having nominal power of 50 kVA and power factor 0.9 lagging is connected to the transformer secondary. Determine the load impedance at the primary side of the transformer.
c) Calculate the load current in amperes at the secondary.

Q3: A three-phase power system consisting of one generator, two transformers, a transmission line and loads is presented in Figure 1. The parameters of the system are the following:

Generator 1 (G1): 50 MVA, 11 kV, X1 = 0.15, X2 = 0.1, X0 = 0.03 pu
Transformer 1 (T1): 50 MVA, 11/110 kV, X1 = X2 = X0 = 9 %
Transformer 2 (T2): 25 MVA, 110/20 kV, X1 = X2 = X0 = 10 %
Transmission line 1: Z1 = Z2 = j30 Ω, Z0 = 2.3*Z1
Load 1 (L1): $P_{nom} = 10$ MW, 20 kV
Load 2 (L2): $Q_{nom} = 5$ MVAr, 20 kV

a) The loads are modelled using a constant impedance load model such that they consume their nominal powers at the nominal voltage. The given power is three-phase power and the voltage 20 kV is the nominal line-to-line voltage. Calculate the impedance values for the loads. [1 pts]
b) Draw the positive and zero sequence impedance networks of the circuit. Use per unit values and 50 MVA base power. [3 pts]
c) Calculate the load current (pu) flowing through the transmission line according to the positive sequence network. The internal emf (field voltage) of the synchronous generator G1 can be assumed to be 1.05∠0° pu. [2 pts]

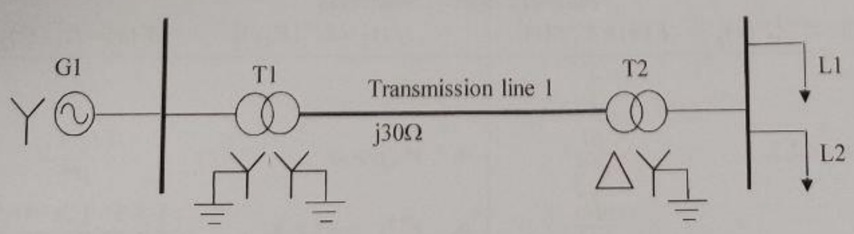

Figure 1. The power system of Question 3.

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Q4: Figure 2 presents an electric circuit and all the relevant parameter values. Voltages of the voltage sources connected to Nodes 1 and 2 are 1.1 p.u. and 1.05 p.u. correspondingly. Notice loads in nodes 3 and 4. (2 pts/sub-question)

a) Determine the nodal admittance matrix of the electric circuit.
b) Calculate the voltages at Nodes 3 and 4.
c) Determine the real (P) and reactive (Q) powers injected by the voltage source at Node 1.

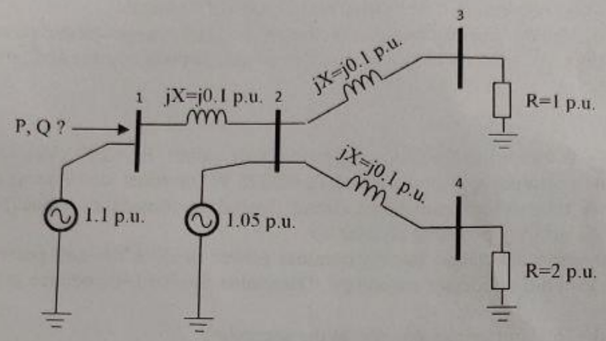

Figure 2. The electric circuit of Question 4.

Q5:

a) Determine the transfer function of the closed-loop system of Fig. 3 when C(s)=K and G(s)=1/(1+sT).
b) What are the targets of selecting and adjusting C(s) so that Y(s) = Y_{ref} (s)?
c) Determine the expression for the time-domain to a unit step input when C(s) = K and G(s) = 1/(1+sT).
(2.5 pts/a, 1 pts/b, 2.5 pts/c)

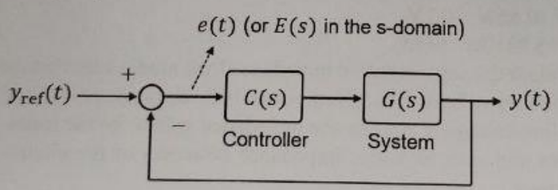

Figure 3. Closed-loop system of Question 5.

Table of Laplace Transforms

	$f(t)=\mathfrak{L}^{-1}\{F(s)\}$	$F(s)=\mathfrak{L}\{f(t)\}$		$f(t)=\mathfrak{L}^{-1}\{F(s)\}$	$F(s)=\mathfrak{L}\{f(t)\}$
1.	1	$\frac{1}{s}$	2.	e^{at}	$\frac{1}{s-a}$
3.	$t^n,\ n=1,2,3,\ldots$	$\frac{n!}{s^{n+1}}$	4.	$t^p, p>-1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5.	$\sqrt{t}$	$\frac{\sqrt{\pi}}{2s^{\frac{3}{2}}}$	6.	$t^{n-\frac{1}{2}},\ n=1,2,3,\ldots$	$\frac{1\cdot3\cdot5\cdots(2n-1)\sqrt{\pi}}{2^n s^{n+\frac{1}{2}}}$
7.	$\sin(at)$	$\frac{a}{s^2+a^2}$	8.	$\cos(at)$	$\frac{s}{s^2+a^2}$