Tampere University
Electrical Engineering

EE.EES.300 Fundamentals of Electrical and Power Engineering 16.10.2023

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Programmable calculator allowed 5 questions/ á 6 pts

Q1:

a) Find Thevenin equivalent for the circuit shown in Figure 1. The rms voltage of the sinusoidal voltage source $V_g = 230\ \angle 0°$ V and frequency 50 Hz. R1 = 27 Ω, R2 = 8 Ω, L1 = 150 mH, L2 = 60 mH and C = 67 μF. [3 pts]

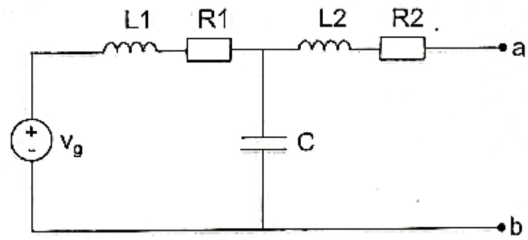

Figure 1. Electric circuit of Question 1 a).

b) Below are presented unbalanced three-phase voltages for Phases a, b and c. Find the symmetrical components for the voltage of Phase a. Draw the phasor diagram which includes the original voltage phasor V_a and its symmetrical components. [3 pts]

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1.1\angle 9° \\ 0.8\angle 130° \\ 1.2\angle -70° \end{bmatrix} p.u.$$

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: The electric circuit in Figure 2 comprises three nodes in addition to the reference node 0 (ground), two voltage sources, reactive branches and one transformer connected as shown in the Figure 2. All the relevant parameter values are given in Figure 2. (2pts/sub-question)

a) Determine the nodal admittance matrix of the electric circuit.

b) Calculate the voltage at node 2.

c) Determine the powers injected by two voltage sources at nodes 1 (S_1) and 3 (S_3) and the power flowing between nodes 1 and 2 (S_{12}).

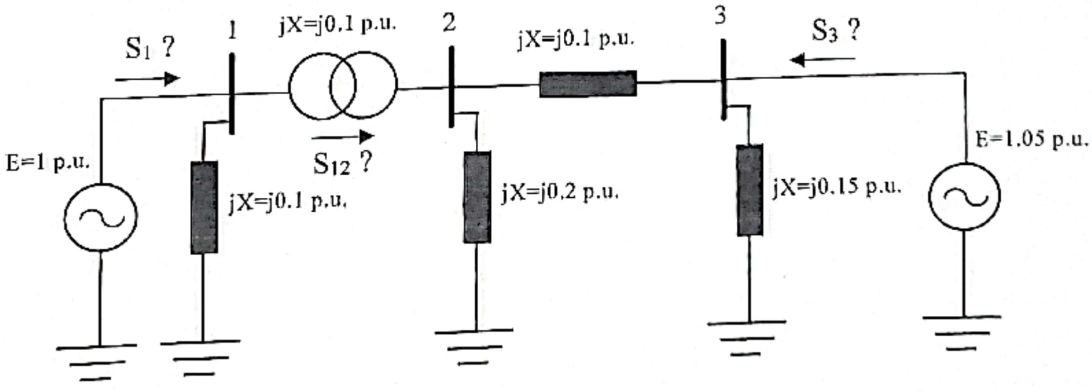

Figure 2. The electric circuit of Question 3.

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Q4: A three-phase power system consisting of one generator, two transformers, a transmission line and loads is presented in Figure 3. 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]

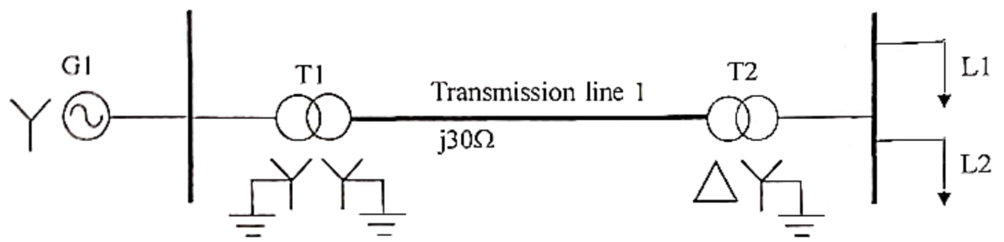

Figure 3. The power system of Question 4.

Q5: Figure 4 presents a first order RC circuit. A step change of 10 V is applied to the input voltage u_{in}. Initial conditions are zero, i.e. u_{in} and u_0 are zero.

a) Determine transfer functions for determining u_0 and i_{in}. [3 pts]
b) Apply the inverse Laplace transform and determine the responses for u_0 and i_{in} in a time domain. Utilize the table of Laplace Transforms below. The mathematical expression as a function of time are acceptable, the graphs are not required. [3 pts]

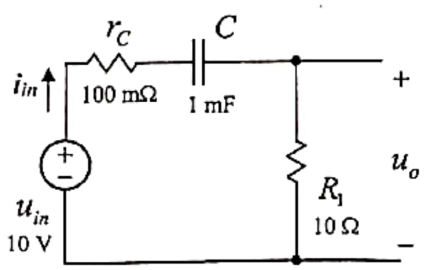

Figure 4. RC circuit of Question 5.

Table of Laplace Transforms

	$f(t)=\mathcal{L}^{-1}\{F(s)\}$	$F(s)=\mathcal{L}\{f(t)\}$		$f(t)=\mathcal{L}^{-1}\{F(s)\}$	$F(s)=\mathcal{L}\{f(t)\}$
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.	$t^p, p>-1$	$\frac{\Gamma(p+1)}{s^{p+1}}$