Tampere University of Technology
Electrical Engineering

Flexible Transmission Systems DEE-24126 17.10. 2018

Attempt ALL questions

The numbers in square brackets indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

An electronic calculator may be used provided that it does not have a facility for either textual storage or display, or for graphical display.
If a calculator is used, intermediate steps in the calculation should be indicated.

Question 1:

A) State which are the characteristic harmonics of a six-pulse thyristor-controlled reactor (TCR) and a twelve-pulse TCR. [2p]

B) A TCR connected to bus l through an interfacing transformer, draws reactive power, as shown schematically in Figure 1. The nominal reactance of the TCR's linear inductor and the transformer are j0.05 p.u. and j0.10 p.u., respectively. The nodal voltage magnitude is to be kept at 1 p.u while drawing 0.6 p.u. of reactive power; determine the thyristor's firing angle α_{TCR} that would be required to achieve this. Carry out two Newton-Raphson iterations. Choose $\alpha_{TCR}=120°$ as the initial starting condition. [4p]

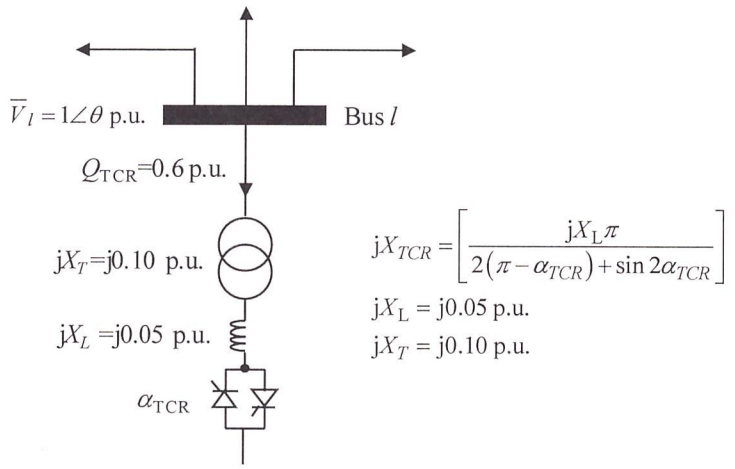

Figure 1.

Question 2:

A) Explain the working principles of the bipolar, sinusoidal PWM control operating in the *linear* region and in connection with a single-phase, full-bridge, two-level inverter. In particular, refer to the amplitude modulation index and to the frequency modulation index, in your discussion. Use any equations and figures that you may find useful to enhance your explanation. [4p]

B) State the role that a Voltage Source Converter plays in a STATCOM application aimed at reactive power and nodal voltage control. [2p]

Question 3:

The schematic diagram of a conventional HVDC link is shown in Figure 3. It uses two 6-pulse thyristor converters rated at 50 MW and 80 kV, to link a wind farm on an island to a load supply point in the mainland. The island electrical subsystem is referred as System 1 and the mainland subsystem is referred as System 2. The line-line voltage at the high-voltage side of System 1's converter transformer is 192 kV and the frequency is 50 Hz. Its source inductance is 5 mH. The line-to-line voltage at the high-voltage side of System 2's converter transformer is 270 kV and the frequency is 50 Hz. Its source inductance is 7 mH. The cable has a DC resistance of 3.75 Ω. If the HVDC link is carrying constant current of 400 A and delivering 30 MW into the inverter station, find the firing advance angle of the inverter and the firing angle of the rectifier. [6p]

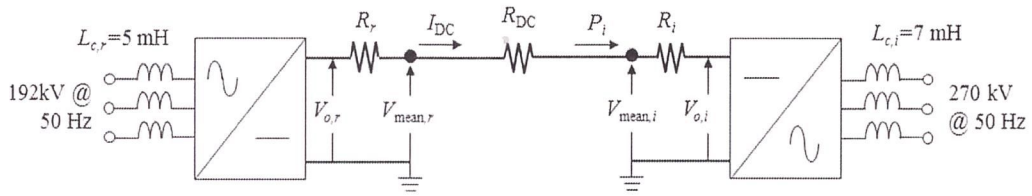

Figure 3.

Question 4:

A) Describe using your own words what an Optimal Power Flow (OPF) solution is. State what are the main advantages of using a full OPF solution to determine the optimal operation of a power grid compared to using the equal incremental costs method. [2p]

B) Determine the Economic Dispatch solution of the two-generator system shown in Figure 4. Carry out one iteration of the equal incremental costs method. [4p]

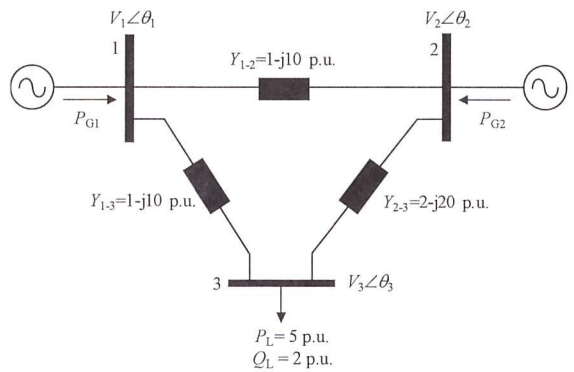

Figure 4

The generators cost functions and the power loss function are:

$$C_1 = 0.1 + 2P_{G1} + 0.4\,P_{G1}^2$$

$$C_2 = 0.2 + 3P_{G2} + 0.6\,P_{G2}^2$$

$$P_{loss} = \frac{1}{400}P_{G1}^2 + \frac{2}{400}P_{G2}^2 - \frac{10}{400}P_{G1}P_{G2}$$

Question 5: Describe in detail the main physical and operational characteristics of a STATCOM, emphasizing those characteristics that can be accommodated within the Power Flow application using the Newton-Raphson algorithm. Use as many diagrams and equations, which you may deemed necessary to carry out a comprehensive description. [6p]