☑ ENE411-G, general information

Course code: ENE411
Course name: Power Systems Dynamics

Date: May 29th 2019
Duration: 4 hours

Resources allowed: Approved type of scientific calculator, physical and mathematical tables. No textbooks, handwritten notes. No mobiles / tablets.

Notes: Attempt all questions. There are four questions with sub sections. Easch question is 25 marks and total marks are 100.

Make suitable assumptions, if necessary.

The professors sometimes ask for exam answers to be used for teaching purposes, but in order for this to take place, the university needs your consent.
Do you grant the University of Agder permision such permission?
Select one alternative

- ○ Yes
- ○ No

Attaching sketches to this question?
Use the following code:

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Replace with question text.

Fill in your answer here

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Attaching sketches to this question?

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Replace with question text.

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Attaching sketches to this question?

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Replace with question text.

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Attaching sketches to this question?
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Replace with question text.

Fill in your answer here

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Attaching sketches to this question?
Use the following code:

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Question 1
Attached

ENE411 - May 2019

Question 1

(a) A cylindrical rotor synchronous generator has synchronous impedance 0+j0.8 per unit per phase, and it is synchronized with infinite bus at rated voltage. The field current (i.e. excitation) is adjusted to have the voltage (i.e. E_f) at 1.3 p.u. and the generator is delivering active power output 0.5 p.u. Plot the phasor diagram and it may also be useful for explaining the following tasks.

(a-i) Under the above operating condition, determine the load angle, armature current (in p.u.) and the operating power factor of the generator.

(a-ii) The generator must deliver the same active power and armature current (as in a-i), but the requirement of reactive power is changed. Therefore, the generator excitation or field current is adjusted to operate at another value of excitation, which results the same active power output and armature current (as in a-i). Under these conditions, find the excitation voltage (i.e. E_f) in p.u., load angle and the power factor.

(a-iii) The excitation in (a-i) and the obtained in (a-ii), which is more likely to be used in practical situations and why?

(Marks 10)

(b) A salient pole synchronous generator, used in hydro power plant, is operating at a power angle δ at lagging power factor. This generator is connected to the power system network at voltage V_t, and its excitation voltage is E_f. Due to saliency, this generator has d-axis synchronous reactance X_d and q-axis synchronous reactance X_q. The armature resistance may be negligible.

(b-i) Draw a phasor diagram for this salient pole synchronous generator.

(b-ii) Show that this generator is delivering active power (per phase):

$$P = \frac{E_f V_t}{X_d} sin\delta - \frac{V_t^2}{2}\left(\frac{1}{X_d} - \frac{1}{X_q}\right) sin2\delta$$

(b-iii) The reactances X_d and X_q. are 1.00 and 0.60 per unit respectively. Compute the generated voltage (i.e. E_f), when the generator delivers its rated kVA at 0.80 lagging power factor at rated terminal voltage.

(Marks 15)

Question 2

Attached

ENE411 - May 2019

Question 2

(a) A 6 MVA, star 3- phase connected, 50 Hz, 8 pole cylindrical rotor synchronous generator has synchronous reactance of 0.5 pu. It is operating in parallel with infinite bus at rated line voltage of 11 kV. Calculate the synchronizing power and the corresponding torque coefficients per degree mechanical shift of rotor angle angle at (i) no-load and (ii) at full load, 0.8 power factor lagging.

The synchronizing power coefficient (*P*sy) is defined as the rate at which synchronous power (P) varies with load angle (δ). It is useful for analyzing the stiffness of coupling or stability factor of the generator. Torque * speed = Power

$Real\ Power\ P = \frac{E_f V_t}{X_s} sin\delta$ and $Reactive\ Power\ Q = \frac{E_f V_t}{X_s} cos\delta - \frac{V_t^2}{X_s}$

Mechanical angle (in rad) = (P/2) * Electrical angle (in radian)

(marks 18)

(b) A salient pole synchronous generator with synchronous reactance X_d = 0.71 pu and X_q = 0.58 pu connected to an infinite bus with 1 pu voltage through external reactance Xe = 0.08 pu. It is supplying only reactive power to the bus (i.e. I_q = 0). Find the maximum and minimum pu field excitation (i.e. E_f) if the armature current is not to exceed rated value.

(marks 7)

Question 3
Attached

ENE411 - May 2019

Question 3

(a) (a-i)

For an isolated power system, draw active power - frequency control block diagram using 'first order transfer functions' of speed governing system, turbine model and generator-load model.

(5 marks)

(a-ii)

A turbo-generator (comprising speed-governor, turbine, generator and load) is operating in an isolated power system area. In such power system area, the frequency is assumed to be the same throughout steady state and dynamic conditions. It leads to the natural suggestion that the speed changer (governing system) settings be adjusted automatically by monitoring the frequency changes. For this purpose, a signal from frequency (Δf) is fed through an integrator (it has proportional constant K_i) to the speed changer, resulting in the block diagram configuration shown in Fig.3.

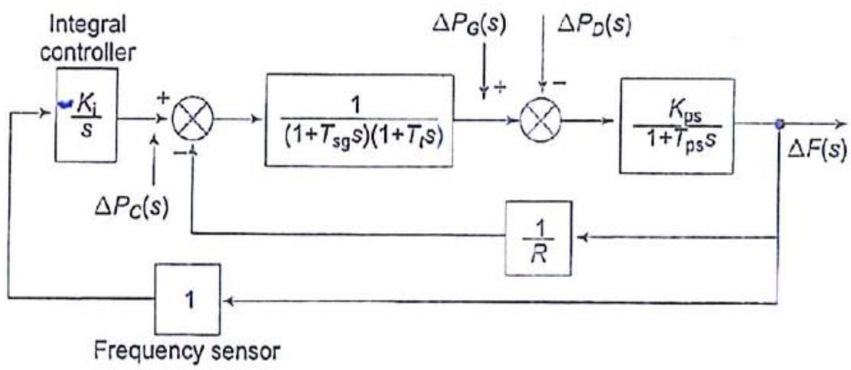


Fig 3. Proportional plus integral load frequency control of an isolated power system area

In such isolated power system, assume the load demand is changing as step function $\Delta P_D(s) = \Delta P_D/s$. Change in speed governor setting ($\Delta P_C(s)$) is adjusted automatically by monitoring the frequency changes through proportional integral controller. For such operation, describe (with mathematical equations) the steady state change in the system frequency.

(10 marks)

(b) In a distributed network, two small capacity generators (G1 and G2) are operating in parallel for supplying total load of 2.8 MW at 0.8 pf lagging. The droop slope (characteristics) of both generators are 1 Hz/MW and one generator (G1) has no load frequency 51.8 Hz and another (G2) has 51 Hz.

(b-i) At what frequency is the system operating and what is the load sharing among two generators?

(b-ii) If the load is now increased by 1 MW, what will be the frequency and the load sharing?

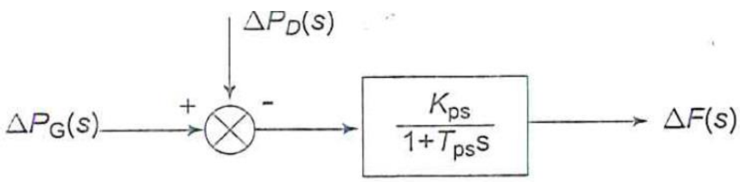
(b-iii) In part (b-ii) which should be the set point of G2 for the system frequency to be 50 Hz?

(10 marks)

Question 4
Attached

Question 4

(a) A 2000 MVA power plant has 4 synchronous generators (500 MVA each) units operating in parallel. This power plant is operating at rated frequency (f_o) of 50 Hz. The equivalent inertia constant (i.e. *H*) of the power plant is 5 MW-sec/MVA. The rate of change of load with respect to frequency is considered constant (i.e. B = 0.75 pu). The equivalent power plant – load block diagram representation is given in following figure.



$$T_{ps} = \frac{2H}{Bf^o} = \text{power system time constant}$$

$$K_{ps} = \frac{1}{B} = \text{power system gain}$$

When there is sudden drop in load by 20 MW, then find the frequency deviation. Consider there is no speed-governing-turbine action (i.e. $\Delta P_G(s) = 0$).

(9 marks)

(b) A 100 MVA, 50 Hz, synchronous generator operates at no load at 3000 rpm. A load of 25 MW is suddenly applied to the generator and the steam valves to the turbine commence to open after 0.6 sec due to the time-lag in the governor system. Assume inertia constant H of 4.5 kW-sec per kVA of generator capacity. Calculate the frequency to which the generated voltage drops before the steam flow commences to increase to meet the new load.

Note: *stored kinetic energy* $\propto$ *(frequency)*^{2}

The H parameter is defined as kinetic energy stored in the rotating part per rated apparent power of the generator unit.

(9 marks)

(c) Explain automatic voltage control of a synchronous generator with the help of a schematic diagram.

(7 marks)