E4.48
C3.2

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2008

MSc and EEE PART IV: MEng and ACGI

POWER SYSTEM CONTROL, MEASUREMENT AND PROTECTION

Monday, 19 May 2:30 pm

Time allowed: 3:00 hours

Corrected Copy

There are SIX questions on this paper.

Answer FOUR questions.

All questions carry equal marks.

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible	First Marker(s) :	B.C. Pal
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The Questions

1.

a) Why is the current so important a consideration in lightning protection design?

[2]

b) How is the switching transient in power transmission networks characterised?

[3]

c) How does the phenomenon of sub synchronous resonance (SSR) develop and manifest in the system?

[3]

d) In a salient pole synchronous generator, the voltage current relations along the **d** and **q** axis are as follows:

$E_{fd} - V_q + I_d X_d = 0$

$V_d + I_q X_q = 0$

where the symbols carry there usual meanings.

Taking the terminal voltage $\bar{V}_t$ as the reference vector, the q-axis is defined to lead $\bar{V}_t$ by an angle δ.

The terminal voltage and current vector of the machine are related by:

$$\bar{V}_q + j\bar{V}_d = \bar{V}_t e^{-j\delta}; \; \bar{I}_q + j\bar{I}_d = \bar{I}_t e^{-j\delta}$$

i) Making use of the above information, derive the power angle relationship of the machine.

[6]

ii) For the following values of the variables in p.u. obtain the real and reactive power output of the machine in p.u.

$X_d = 2.0$, $X_q = 1.8$, $V_t = 1.05$, $E_{fd} = 3.0$ and $\delta = 20$ degrees

[3]

iii) Suddenly the machine loses excitation. Justify through load angle computation whether the stability will be maintained if the mechanical input was to remain unchanged.

[3]

2.

a) Briefly describe the functions of the following components in excitation systems:

i) voltage regulator

[3]

ii) power system stabiliser

[3]

iii) limiter and protective circuits

[3]

iv) field forcing

[3]

b) Other than synchronous generator, mention various other options of voltage control and describe two of them in reasonable detail.

[8]

3.

a) Briefly describe the nature and importance of the primary frequency control in power systems.

[3]

b) Including the effect of the governor droop characteristic, establish the following relationship:

$$\Delta\omega_{ss} = -\frac{\Delta P_L}{D + \frac{1}{R}}$$

where, D is the load damping co-efficient, ΔP_L is change in demand, R is the droop and $\Delta\omega_{ss}$ is the steady state angular frequency deviation in p.u.

[8]

c) A small 50 Hz system consists of 5 identical 600 MVA units feeding a total load of 1550 MW. The H constant of each unit is 6.0 sec on their own base MVA. Each unit has 5% governor droop mechanism fitted. The load varies by 2% for 1% change in frequency. For a sudden increase of 50 MW of load find the steady state frequency deviation in Hz. Obtain the frequency deviation

i) without droop

[4]

ii) with droop.

[4]

iii) comment on the effectiveness of droop control in view of the results obtained above.

[1]

4.

a) Briefly describe the necessity of area wise load frequency control

[2]

b) Establish the steady state power frequency characteristics of a two-area system. Assume that each area has the following characteristic parameters:

Area 1: inertia constant: M_1, droop: R_1 and damping co-efficient: D_1

Area2: inertia constant: M_2, droop: R_2 and damping co-efficient: D_2

[6]

c) Consider two interconnected areas as follows: Area 1: Gen 19,000 MW, Load 20,000 MW: Area 2: Gen 41000 MW, Load: 40,000 MW. The load in each area varies by 1% with 1% change in frequency (D = 1.0). The speed regulation, R, is 5% for all the units. Area 1 is importing 1000 MW from Area 2.

Area 1 is operating with a spinning reserve of 1000 MW spread uniformly over a generation of 4000 MW capacity, and Area 2 is operating with a spinning reserve of 1000 MW spread uniformly over a generation of 10,000 MW. The nominal frequency is 50 Hz.

Determine the steady state frequency, generation and load of each area, and the tie line power for each of the following contingencies, when the generation carrying spinning reserve in each area is on supplementary control with frequency bias factor settings of 250 MW/0.1 Hz for Area 1 and 500 MW/0.1 Hz for Area 2.

i) Loss of 1000 MW load in Area 1 without supplementary control

[6]

ii) Loss of 2000 MW generation in area 1 which is not part of spinning reserve with supplementary control.

[6]

5.

a) Describe purpose of the protection systems

[4]

b) Discuss the various components and functionalities of numerical relays

[5]

c) Distinguish between the dependability and security of a relay.

[4]

d) The performance of an over current relay was monitored for a period of one year. It was found that the relay operated 14 times, out of which 12 were correct trips. If the relay failed to issue trip decisions on 3 occasions, compute the dependability, security and reliability of the relay as a percentage of ideal performance

[7]

6.

a) Why should the secondary of a current transformer never be left open?

[3]

b) List two primary types of current transformer and briefly describe the functional requirement and design specifications of any one of them.

[6]

c) What is the function of a tuning inductor in a capacitive coupled voltage transformer (CCVT)?

[3]

d) A 1200/5, C400 CT is connected on the 1000/5 tap. The secondary winding resistance is 0.51 Ω. Obtain the maximum allowable burden in the CT at 20 times the rated symmetrical secondary current with rated accuracy

[8]