EE4-48
EE9-CS6-2
EE9-FPN1-03

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2018

MSc and EEE PART IV: MEng and ACGI

POWER SYSTEM DYNAMICS, STABILITY AND CONTROL

Wednesday, 16 May 10:00 am

Corrected copy

Time allowed: 3:00 hours

There are FOUR questions on this paper.

Answer ALL 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
Second Marker(s) : A. Junyent-Ferre

The Questions

1.

a)

i) How is the switching surge in power networks characterised? [2]

ii) How does the switching surge influence circuit breaker design and operation? [2]

b)

i) What is oscillatory instability in the context of power system operation? [5]

ii) Why such instability is of diminishing concern in the context of renewable generation? [3]

iii) A system is transiently stable but it can be oscillatory unstable- justify this statement [2]

iv) How is such instability in the system prevented? [3]

c)

i) What is the primary purpose of having a speed governing system? [2]

ii) Why is it relatively difficult to design speed governing system for hydro turbine for operating a large synchronous generator? [3]

iii) What is transient gain reduction in the context of speed govern control design? [3]

[25 marks]

2.

a)

i) How does amortisseur winding help in system stabilisation? [3]

iii) How is an amortisseur winding modelled in power system stability study? [3]

iii) A round rotor synchronous generator has synchronous reactance of 2.2 pu on its own base. When sudden short circuit happens at rated terminal voltage – the initial current is 4-5 times the rated current which lasts for about 4-6 seconds followed by a gradual fall. Why is the generator initial output current so high? [4]

iv) Why does not synchronous generator permit identical overload capability both in the lagging as well as leading power factor range? [4]

v) What is the purpose of d-q transformation in synchronous machine modelling and analysis? [3]

vi) Despite having a d-q transformation, why is it necessary to have machine to network reference frame transformation ? [3]

vii) Express the relationship between machine to network frame assuming the angle difference between the two reference frames is δ-0. [5]

[25 marks]

3.

a)

Fig Q3.1 shows a simple power system model with one synchronous generator connected to a power network through generator transformer and a section of power transmission line to deliver real and reactive power to the system. The values of various parameters shown in the diagram are as follows.

E = 3.0 pu, V_t = 1.0 p.u, X_s= 2.0 p.u, X_t=0.1 p.u, X_l= 0.2 p.u , δ = 30 degree

i) Compute the real and reactive power at the network end [5]

b)

Because of a transient disturbance in the system, the network voltage dropped slightly and temporarily initiating the electromechanical dynamics of the generator connected to the system. Assuming a classical swing equation model (speed ω_r and load angle δ as only dynamic variables) with an inertia constant H (sec) and damping constant D (in pu)

i) Write down the swing equations [4]

ii) For the following values of the operational variables and constants, obtain the linearized dynamics in state space form treating mechanical power as input and generator real power as output.

E = 3.0, V_t = 1.0, X_s= 2.0, X_t=0.1, X_l=0.2, all in pu δ = 30 degree, H = 5.0 sec, D = 10.0 p.u, operating frequency is 50 Hz or 314 rad/sec. [8]

iii) Comment on the small signal stability of the system with the help of obtained eigen-values of the system state matrix [8]

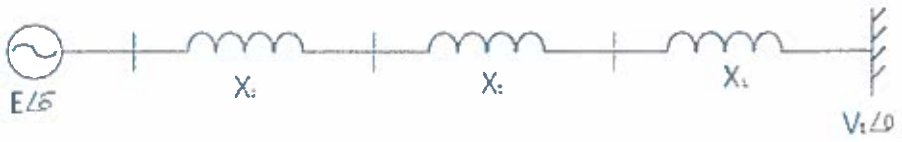

Fig Q3.1 A Simple Power System

[25 marks]

4.

a)

i) What is the performance co-efficient (C_p) of a wind turbine? [2]

ii) Show that the theoretical maximum value of C_p is 16/27 or 59.3 %. [7]

iii) What is the function of the gear box in a wind turbine generator (WTG)? [2]

iv) Why does the Type-4 (full converter machine) machine have large number of poles in the rotor? [3]

v) How does the insertion of an external resistance in the rotor circuit help capture more energy from the variable wind? [3]

vi) How is it possible to operate a Type-3 (DFIG) machine at lower than synchronous speed (positive slip) in generator mode? [3]

vii) Describe the process of obtaining the initial values of voltages, currents, angles, speed to start a dynamic simulation when prevailing wind speed is less than the rated one? [5]

[25 marks]