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

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2017

MSc and EEE PART IV: MEng and ACGI

POWER SYSTEM DYNAMICS, STABILITY AND CONTROL

Thursday, 18 May 10:00 am

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.

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The Questions

1.

a)

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

ii) Why is the consideration of lightning surge so important in power system design and operation? [2]

b)

i) What is sub synchronous resonance (SSR) in the context of power system stability? [5]

ii) What types of turbine in power plants exhibit SSR? [2]

iii) What is the range of frequencies of SSR? [2]

iv) How is the problem of SSR solved? [3]

c) i) What is the primary purpose of having a high gain fast acting excitation system? [4]

ii) Why is a power system stabiliser (PSS) necessary for operating a large synchronous generator? [3]

iii) What is the range of frequencies at which a PSS should be designed to provide stabilisation? [2]

[25 marks]

2.

a)

i) The rotor of a synchronous generator is of solid construction whereas the stator is made up of laminated steel. Provide technical reasons to justify such constructional practice. [4]

ii) Why is it easier to control a steam turbine than a hydro turbine? [5]

iii) Why is the stator winding in a synchronous generator star connected? [3]

iii) Modern synchronous generators are designed to have a large steady state synchronous reactance (between 1.0 to 2.0 pu). However, when a direct terminal short circuit occurs, the initial currents are several times the load current. Explain the reason. [5]

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

v) Two synchronous generators of identical capacities are delivering similar amount of load to a grid network. One of them is non-salient pole (round rotor) and other one is salient pole (non-round rotor). Excitation is suddenly lost in both cases while the turbine inputs continue. Which one will go out of synchronism faster? Justify your answer with reason. [4]

[25 marks]

3.

a)

i) Generally synchronous machines are analysed in d-q reference frame (Park reference frame). Why another transformation is necessary when connected to a multi-machine large power system network? [3]

iii) Derive the relationship between the quantities in two reference frames when the angle difference between the two reference frames is δ-θ. [5]

iv) A synchronous generator supports a terminal voltage of 23.5 kV line to line at the generator terminal bus. This bus is part of a large network which has a reference bus at another location. The power flow solution produces an angle (θ) of 10 degree for this bus voltage. The generator load angle (δ) is 30 degree. Compute the direct and quadrature axis components of this terminal voltage. [5]

b)

i) As of December 2016, roughly how much is the installed capacity of wind power worldwide? [2]

ii) List top three countries in terms of installed capacities of wind power. [2]

iii) Why are Type 3 and Type 4 wind turbine generators preferred over Type 1 and Type 2? [2]

iv) What is parking mode in the context of wind turbine operation? [3]

v) In a large wind farm the wind velocity is 1m/s more than the cut in velocity. There are 10 rows of turbine. It was observed that some turbines in the subsequent rows were not producing power. Explain clearly what could be the reason(s). [3]

[25 marks]

4.

a)

i) What is the function of a gearbox in a wind turbine generator? [2]

ii) The gear box is not necessary for some types of wind turbine generators. Explain the reason behind such an option. [2]

iii) How does one represent the gear box in the simulation programme for stability studies? [2]

b)

i) What is meant by stall control? [4]

ii) How is passive stall control implemented? [3]

iii) Why is generator torque/power control preferred over pitch control when wind blows at less than its rated speed? [3]

c)

i) What is the tip speed ratio (TSR)? [2]

ii) Why is it important to have an optimal TSR? [3]

e)

How is it possible to operate a Type-3 (DFIG) machine at lower than synchronous speed (positive slip) in generator mode? [4]

[25 marks]