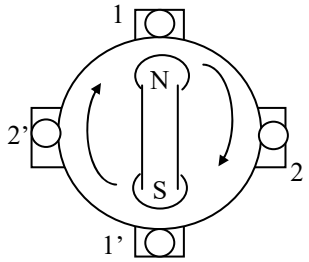
Chapter 3 Synchronous Machines

Objective Practice Questions

3.1 Principle and Construction

01. Four conductors in a stationary armature (alternator) are shown as 1, 1^{1}, 2^{1}, and 2. For given direction of rotation of rotor the direction of induced emf (at the instant shown) in the conductors respectively



Conductor

	1	1'	2	2'
(a)	⊗	⊙	O	O
(b)	O	O	⊗	⊙
(c)	⊗	⊙	⊗	⊙
(d)	⊙	⊗	⊙	⊗

02. Two mechanically coupled alternators deliver power at 50 Hz and 60 Hz respectively. The highest speed of the alternators is
(a) 3600 rpm (b) 3000 rpm
(c) 600 rpm (d) 500 rpm

03. The breadth factor for 3rd harmonic emf of a 3-phase, 4-pole, synchronous machine having 36 stator slots is **(IES-16)**
(a) 0.47 (b) 0.53
(c) 0.67 (d) 0.73

3.2 Armature Winding

04. A 3-phase, 20-pole, synchronous generator has 180 stator slots with single layer full pitch coils. There are 6 conductors per slot and all coils per phase are connected in series. The rotor is driven at 300 rpm and the flux per pole (sinusoidally distributed) is 25m Wb. The induced voltage per phase is nearest to
(a) 500 V (b) 960 V
(c) 1500 V (d) 2000 V

05. The armature of a single phase alternator is completely wound with T single turn coils distributed uniformly. The induced voltage in each turn is 2 Volts (rms). The emf of the whole winding is **(GATE-98)**
(a) 2 T volt (b) 1.11 T volt
(c) 1.414 T volt (d) 1.273 T volt

06. A 3 - ϕ, 4 – pole alternator has 48 stator slots carrying the 3 - ϕ distributed winding. Each coil of winding is chorded by one slot pitch. The winding factor is given.
(a) $\frac{1}{16}\cos 7.5^{0}$ (b) $\frac{1}{8}\cot 7.5^{0}$
(c) $\frac{1}{16}\sin 7.5^{0}$ (d) $\cos 7.5^{0}$

07. The armature of a star connected alternator is uniformly wound with T coils, each coil having N full pitched turns. The generated emf per conductor is 2V (rms). The per phase emf is
(a) $\frac{3}{\pi}$ NT volts (b) $\frac{4}{\pi}$ NT volts
(c) $\frac{6}{\pi}$ NT volts (d) $\frac{2}{\pi}$ NT volts

Common Data for Questions 08 to 13

A 4 pole, 50 Hz, synchronous generator has 48 slots in which a double layer winding is house. Each coil has 10 turns and is short pitched by an angle to 36 degrees electrical. The fundamental flux per pole is 0.025 Wb

08. The line to line induced emf, for a three phase star connection is approximately
(a) 808 (b) 888
(c) 1400 (d) 1538

09. The line to line induced emf, for two phase connection is
(a) 1143 (b) 1332
(c) 1617 (d) 1791

10. The fifth harmonic component of phase emf, for a three phase star connection is
(a) 0 (b) 269
(c) 281 (d) 808

11. The induced EMF for single phase connection is____

12. If the turns are connected among two parallel paths, for three phase connection, the phase EMF is_____, line EMF is_____

13. If the turns are connected among two parallel paths, for two phase connection, phase EMF is_____, Line EMF is_____

3.3 Armature Reaction & Voltage Regulation & Two Reaction Theory

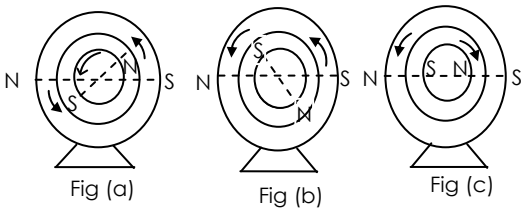
14. A synchronous machine has its field winding on the stator and poly phase armature winding on the rotor. When running under steady state – conditions, its armature field is
(1) Stationary with respect to stator
(2) Rotating at synchronous speed Ns with respect to stator.
(3) Rotating in same direction as that of rotor
(4) Rotating in a direction opposite rotor rotation
From these, correct answer is
(a) 2, 4 (b) 1, 4
(c) 3, 4 (d) 1, 3

15. A synchronous machine has its field winding on the rotor and poly phase armature winding on the stator. When running under study conditions, its armature field and air gap field is
1. Stationary with respect to stator
2. Rotating at synchronous speed Ns with respect to stator.
3. Rotating at double the Ns with respect to rotor.
4. Stationary with respect to rotor
5. Rotating at Ns in the direction of rotor rotation

From these, correct answer is
(a) 2, 5 (b) 1, 4, 5
(c) 2, 3, 4 (d) 2, 4, 5

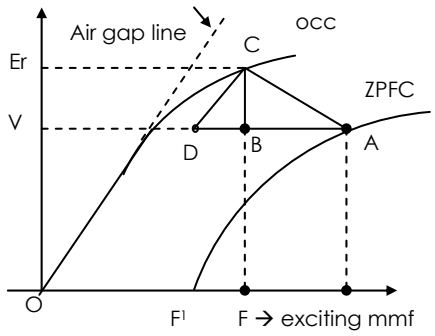
16. Consider the following statements regarding the operation of 3 – phase synchronous machines depicted in fig. a, b & c.
    1. Machine of fig (a) is operating as a synchronous motor at some load
    2. Machine of fig (a) is operating as an alternator some load
    3. Machine of fig. (b) is operating as an synchronous motor at some load
    4. Machine of fig. (b) is operating as an alternator at some load
    5. Machine of fig. (c) is operating as a synchronous motor at no load
    6. Machine of fig. (c) is operating as an alternator at no load

    From these, the correct statements are
    (a) 2, 3, 5, 6 (b) 1, 4, 5
    (c) 1, 4, 6 (d) 2, 3, 6



17. The flux per pole in a synchronous motor with the field circuit ON and the stator disconnected from the supply if found to be 25 mwb. When the stator is connected to the rated supply with the field excitation unchanged, the flux per pole in the machine is found to be 20 mWb while the motor is running on no-load. Assuming no – load losses to be zero, the no – load current drawn by the motor from the supply
    (a) Lags the supply voltage
    (b) Leads the supply voltage
    (c) in phase with the supply voltage
    (d) is zero

18. The ZPF characteristics, along with open circuit characteristics (OCC) as shown in the given fig. one used to determine the leakage reactance drop $I_a X_l$ at the rated current I_a from the potier triangle ABC. In the triangle BC represent the $I_a X_l$ (= V_x) drop because



    (a) V_x is induced by mmf AB
    (b) V_x is induced by the mmf BD
    (c) V_x is induced by mmf OF
    (d) V_x and the air gap voltage Er and 180° out of phase at ZPF load.for

19. Match the List I. with List II regarding the regulation & regulation Methods of alternator

List I	List II
A. EMF	1. 13%
B. MMF	2. 18%
C. ZPF	3. 32%
D. ASA	4. 20%
E. synch saturated reactance Method	5. 25%

	A	B	C	D	E
(a)	3	1	2	4	5
(b)	1	2	3	4	5
(c)	2	3	4	5	1
(d)	3	1	4	2	5

Common Data For Question 20 & 21

A salient pole synchronous generator with negligible resistance has the per unit parameters $X_d = 0.8$, $X_q = 0.5$, If the generator is supplying rated kVA at rated voltage and at 0.8 P.F lagging,

20. The load angle is
    (a) 17.1° (b) 29.74°
    (c) 32° (d) 23.4°

21. The Excitation emf in P.U is
    (a) 1.72 (b) 1.603
    (c) 0.8 (d) 1.0

22 The direct axis and quadrate axis reactances of a salient pole alternator are 1.2 p.u and 1.0 p.u respectively. The armature resistance is negligible. If this alternator is delivering rated KVA at upf and at rated voltage then its power angle is
    (a) 30^0 (b) 45^0
    (c) 60^0 (d) 90^0

23. A 3.5 MVA, slow speed, 3-phase star connected synchronous generator rated at 6.6 kV has 32-poles. The voltmeter and ammeter readings measured by the slip test are (phase values):
    $I_{a\,min} = 10$ A : $I_{a\,max} = 15$ A
    $V_{min} = 90$ V : $V_{max} = 96$ V
    Armature resistance is negligible. When the machine is supplying a load of 2.5 MW at 0.8 lag, the load angle is
    (a) 15.3° (b) 30.6°
    (c) 23.5° (d) 45.2°

Common data for Q. 24 to 27

A 3 - ϕ, 415V, 10KVA, γ - connected alternator has per phase impedance of (0.4 + j5) Ω.

24. The power factor at which voltage regulation is zero
    (a) 0.8 lead (b) 0.974 lag
    (c) 0.974 lead (d) 0.1456 lead

25. The power factor at which voltage regulation is maximum
    (a) 0.8 lag (b) 0.08 lag
    (c) 0.1456 lag (d) ZPF lag

26. The maximum possible voltage regulation at rated condition is___

27. The voltage regulation at 0.8 power factor leading at half rated condition is___

28. A 3 – phase $200\sqrt{3}V$, 3 kVA, star – connected synchronous machines has a synchronous per phase of 30 Ω and negligible resistance. Its maximum voltage regulation when supplying lagging loads is _____%

29. A 25 kVA, 400 V, Δ-connected, 3-phase, cylindrical rotor synchronous generator requires a field current of 5 A to maintain the rated armature current under short-circuit condition. For the same field current, the open-circuit voltage is 360 V. Neglecting the armature resistance and magnetic saturation, its voltage regulation (in % with respect to terminal voltage), when the generator delivers the rated load at 0.8 pf leading at rated terminal voltage is _____ .

(GATE-17-S2)

3.4 Parallel Operation of Alternators

30. Two alternators (M_1 and M_2) have been properly synchronized and connected in parallel to a common bus bar. If there is no load on the bus bar and the field excitation of the second alternator (M_2) in increased gradually by a small amount, from its normal excitation for which the induced emf's E_1 and E_2 of the two machines are equal, the armature reaction due to the circulating armature current would be
    (a) Magnetizing for M_1, but demagnetizing for M_2.
    (b) Demagnetizing for M_1, but magnetizing for M_2
    (c) Magnetizing for both M_1 and M_2
    (d) Demagnetizing for both M_1 and M_2

31. Two alternators (M_1 and M_2) of same rating, excited equally are connected in parallel, and supplying for a pure resistive load. If the excitation of M_1 is increased, then
    (a) M_1 is operating at LAG pf and M_2 is operating at LEAD pf
    (b) M_1 is operating at LEAD pf and M_2 is operating at LAG pf
    (c) Both M_1 and M_2 operating at UPF
    (d) Both are operating at LAG pf.

32. Two alternators running in parallel and supplying a fixed load operate with same excitation voltage and the same armature currents. If the steam input to alternator 1 is increased, then
    A. Alternator 1 shares increased armature current I_a with improved power factor
    B. Alternator 1 shares increased I_a with worsened power factor
    C. Alternator 2 shares decreased I_a with improved power factor
    D. Alternator 2 shares decreased I_a with worsened power factor

    From these, the correct answer is
    (a) A, C (b) A, D
    (c) B, C (d) B, D

33. Two alternators running in parallel have the same excitation voltage and armature current and same power factor. If excitation of alternator1 is increased, then for the same terminal voltage.
    A. Alternator 1 operate at a poor power factor with increased I_a
    B. Alternator 1 operate at a better power factor with increased I_a
    C. Alternator 2 operate at a poor power factor with decreased I_a
    D. Alternator 2 operate at a better power factor with decreased I_a

    From these, the correct answer
    (a) A, C (b) A, D
    (c) B, C (d) B, D

34. When two alternator are operating in parallel and at perfect synchronization, their synchronizing power is
    (a) negative
    (b) positive
    (c) maximum positive
    (d) zero

35. If the field of one of the alternators running in parallel, is adjusted it will
    (a) reduce its speed
    (b) change its load
    (c) change its power factor
    (d) change its frequency

36. For the alternators operating in parallel, if the load shared by one of them is to be increased, its field excitation is
(a) to be kept constant torque should be increased
(b) to be kept constant but input torque should be decreased
(c) to be weakened keeping input torque same.
(d) to be strengthened keeping input torque same.

37. When an alternator running in parallel with other alternators, is to be taken off the bus, which of the following procedure is to be performed first?
(a) to increase alternator excitation
(b) to reduce the power fed to the prime mover
(c) to reduce alternator excitati
(d) non of the above is true.

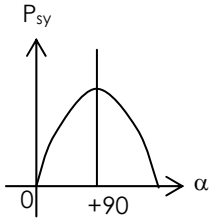
38. For parallel operation of the two alternators, it is preferred that both should have
(a) low resistance as compared to synchronous reactance
(b) more of resistance as compared to synchronous reactance
(c) same reactance
(d) same resistance

39. An alternator of frequency 50.2 Hz is to be synchronized with an infinite bus of frequency 50 Hz by means of three-dark-lamp method. The lamp-flicker per minute will be
(a) 6 (b) 25
(c) 30.6 (d) 12.

40. An alternator of 300 kW is driven by a prime-mover of speed regulation 4% and another alternator of 400 kW by a prime mover (P.M) of speed regulation 5%. Governor settings of PM is are such that their no-load speed is the same. The total load the two alternators in parallel can take, without overloading any one of the two, is
(a) 600 kW (b) 620 kW
(c) 650 kW (d) 720 kW

41. Two alternators A and B, running in parallel, supply power to a resistive load. For the same terminal voltage and steam inputs, if excitation of alternator A is increased, then
(a) A will supply lagging kVAR
(b) B will supply leading kVAR
(c) As load is resistive, A cannot supply lagging kVAR,
(d) As load is resistive, B cannot supply leading kVAR.

42. The variation of synchronizing power for variation of power angle for a salient pole machine will be

(a)


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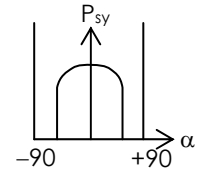
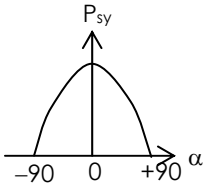
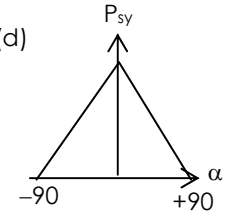


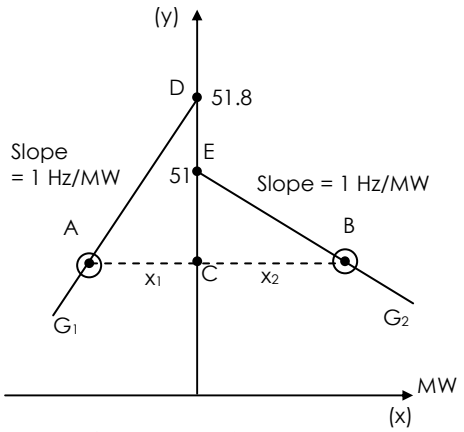
(c)


(d)


43. Which one of the following is not a necessary condition to be satisfied for synchronizing an incoming alternator to an already operating alternator?
    (a) same voltage magnitude
    (b) same frequency
    (c) same prime mover speed
    (d) same phase sequence

44. Two 3 phase, star connected alternators are to be paralleled to a set of common bus bars. The armature has a per phase synchronous reactance of 1.7 ohm and negligible armature resistance. The line voltage of the first machine is adjusted to 3300V and that of the second machine is adjusted to 3200V.The machine voltages are in phase at the instant they are paralleled. Under this condition, the synchronizing current per phase will be
    (a) 16.98A (b) 29.41A
    (c) 33.96A (d) 58.82A

45. Figure shows speed (frequency) load characteristics of two generators supplying in parallel to a load of 2.8 MW at 0.8 pf lagging.



    (a) At what frequency is the system operating and what is the load supplied by each generator.
    (b) If the load is now increased by 1MW. What will be the frequency and load sharing.
    (c) In part b which should be the set point of G_2 for the system frequency to be 50 Hz. What should be the load sharing now.

46. Two generators rated at 200 MW and 400 MW are operating in parallel. Their governor droop characteristic are respectively 4% and 5% from no-load to full-load. At no-load, the system frequency is 50 Hz. When supplying a load of 600 MW,
    (i) The system frequency will be
    (a) 50 Hz (b) 49 Hz
    (c) 51.3 Hz (d) 47.7 Hz

    (ii) The load shared by machine 1 is ----- and machine 2 is ------

    (iii) The maximum load the set can supply with out over loading any machine is -------

47. The following data is pertaining to two alternators working in parallel and supplying a total load of 80mw.
    Machine – I: 40MVA with 5% speed regulation
    Machine– II: 60MVA with 5% speed regulation
    The load sharing between machine I & II will be
    (a) 20MW, 60MW (b) 40MW, 40MW
    (c) 32MW, 48MW (d) 50MW, 30MW

48. Two parallel connected, three-phase, 50 Hz, 11 kV, star-connected synchronous machines A and B, are operating as synchronous condensers. They together supply 50 MVAR to a 11 kV grid. Current supplied by both the machines are equal. Synchronous reactances of machine A and machine B are 1 Ω and 3 Ω, respectively. Assuming the magnetic circuit to be linear, the ratio of excitation current of machine A to that of machine B is _____. (Give the answer up to two decimal places). **(GATE-17-S1)**

3.5. Parallel Operation of the Alternator with Infinite Bus bar

Common Data for Questions 49 to 52

A 3-phase, turbo alternator, with a synchronous reactance of 10Ω per phase and negligible armature resistance is connected to 11kv constant voltage constant frequency bus bars and supplies 100A at unity p.f to the system. If the turbine power is kept constant and the excitation of the alternator is increased by 25%.

49. The new load angle will be
    (a) 8.94° (b) 7.14°
    (c) 58.4° (d) 4.12°

50. The new current
    (a) 190.6A (b) 100A
    (c) 125A (d) 330.2A

51. The new power factor is _____

52. A 6600 V, 1200 kVA alternator has a reactance of 25% and is delivering full load at 0.8 p.f lag. It is connected to constant frequency busbar, if the steam supply is gradually increases the current at which p.f is unity
    (a) 645A (b) 105 A
    (c) 70.25 A (d) 252 A

Common data for questions 53 & 54

A 1000 kVA, 6.6 kV, 3-phase star connected cylindrical pole synchronous generator has a synchronous reactance of 20Ω. Neglect the armature resistance and consider operation at full load and 0.8 pf leading

53. The induced emf (line- to-line) is _____

54. The power (or torque) angle is _____

Common data for questions 55 to 61

An alternator with synchronous reactance of 0.8 p.u is connected to an infinite bus at rated voltage with it's excitation e.m.f is adjusted to 1.3 p.u. The alternator delivers an output of 0.5 p.u.(Neglect all losses)

55. The load angle δ is.....
    (a) 31° (b) 17.92°
    (c) 9.6° (d) 21°

56. The armature current is
    (a) 0.581p.u (b) 0.375 p.u
    (c) 1 p.u (d) 0.8 p.u

57. The power factor is _____.

58. The reactive power is _____ pu.

59. The current at maximum power output is_____ pu.

60. The p.f at maximum power output is _____.

61. The reactive power at max power output is_____ pu.

62. A non-salient pole synchronous generator having synchronous reactance of 0.8 pu is supplying 1 pu power to a unity power factor load at a terminal voltage of 1.1 pu. Neglecting the armature resistance, the angle of the voltage behind the synchronous reactance with respect to the angle of the terminal voltage in degrees is _____.

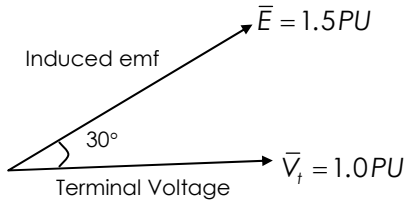
(GATE-14-S3)

63. A synchronous generator is connected to an infinite bus with excitation voltage E_f = 1.3 pu. The generator has a synchronous reactance of 1.1 pu and is delivering real power (P) of 0.6 pu to the bus. Assume the infinite bus voltage to be 1.0 pu. Neglect stator resistance. The reactive power (Q) in pu supplied by the generator to the bus under this condition is _____. **(GATE-14-S2)**

3.6 Synchronous Motors

64. A 480V, 60Hz, four-pole synchronous motor is drawing 50A of current at full load and unity power factor. Assume that the motor is lossless. The output torque of the motor equals to
(a) 220.7N-m (b) 160.5 N-m
(c) 23.11 N-m (d) 282.1 N-m

65. The phasor diagram of a synchronous machine connected to an infinite bus is shown in above figure. The machine is acting as a



(a) generator and operating at a lagging power factor
(b) generator and operating at a leading power factor
(c) motor and operating at a leading power factor
(d) motor and operating at a lagging power factor

66. A 8-pole, 50Hz, 3-phase synchronous motor and an 6-pole, 50Hz, 3-phase slip ring induction motor are mechanically coupled and operate on the same 3-phase, 50 Hz supply system. If they are left open-circuited, then the frequency of the voltage produced across any two slip rings would be
(a) 12.5 Hz (b) 25.0 Hz
(c) 37.5 Hz (d) 50.0 Hz

67. An industrial system has a load of 100 kVA at 0.6 pf lagging. A synchronous motor is added to the system to improve the overall power factor. If the synchronous motor is operating at 10kW and 0.5 pf leading, then the overall power factor of the system is
(a) 0.58 (lagging) (b) 0.74 (lagging)
(c) 0.99 (leading) (d) 0.39 (leading)

68. A 3 – phase, 200 V per phase, 50 HZ supply is applied to a balanced star-connected 3-phase load of (4 + j3) Ω/ph. A synchronous motor connected in parallel to the load makes the power factor of the over all load 1. The motor has negligible resistance and 10 Ω /phase of synchronous reactance. Current drawn by the motor must be_____ A.

Common Data for Questions 69 to 71

A 3 - ϕ star – connected 400v synchronous motor takes a power input of 5KW at rated voltage its synchronous reactance is 10 Ω/phase resistance is negligible. If it's excitation voltage adjusted equal to the rated voltage of 400V

69. The load angle is
(a) 9.1^0 (b) 18.2^0
(c) 30^0 (d) 25^0

70. Power factor is
(a) 0.9874 lead (b) 0.654 lead
(c) 0.9874 lag (d) 0.654 lag

71. The armature current is
(a) 10 A (b) 12.65 A
(c) 23.1 A (d) 7.3 A

Common Data for Questions 72 to 75

A 2000V, 3-ϕ, star connected synchronous motor has an effective resistance and synchronous reactance of 0.2Ω and 2.2Ω respectively. The input is 800 kW at normal voltage and the induced line voltage is 2,500V.

72. The line current is
(a) 254 A (b) 440 A
(c) 231 A (d) 400 A

73. The power factor is
(a) 0.908 lag (b) 0.968 lead
(c) 0.7 lag (d) 0.7 lead

74. The mechanical power developed is _____

75. The torque developed is _____

Common data for questions 76 & 77

A 230V, 4-pole, 50Hz star connected synchronous motors has an impedance of 0.6 + j3Ω per phase. Its field current is so adjusted that motor draws 10A at UPF from rated voltage sources. With the field current unchanged, the load on the motor is increased till its draws 40A from the supply.

76. The operating power factors
(a) UPF (b) 0.954 lag
(c) 0.954 lead (d) 0.603 lag

77. The torque developed is
(a) 65.3 N-m (b) 26.50 N-m
(c) 78.45 N-m (d) 45.3 N-m

Common Data for Questions 78 & 79

A 6.6 kV star connected 3- phase synchronous motor works at constant voltage and constant Excitation. Its synchronous reactance is 12Ω/ phase when the input power is 1000 kW, the P.F is 0.8 leading. If the input is increased to 1500 kW.

78. The load angle will be
(a) 13.4° (b) 19.5°
(c) 17.2° (d) 7.13°

79. The operating power factor
(a) 0.92 lead (b) 0.92 lag
(c) 0.8 lead (d) 0.8 lag

80. A 3-phase, 400 V, 100 kVA, star-connected synchronous machine is used as a motor. The stray loss of the machine, assumed to be constant, is 4000W. The synchronous impedance per phase of the machine is $0.13 + j1.3\Omega$. What is the efficiency when the excitation is so adjusted as to take a line current equal to its rated value keeping the power delivered constant at 75 kW.
(a) 84.5 (b) 94.5
(c) 74.5 (d) 86

KEY				
01. (a)	02. (c)	03. (c)	04. (b)	05. (d)
06. (b)	07. (b)	08. (a)	09. (c)	10. (a)
11. 1616V		12. 404V, 700V		
13. 571 V, 808.5 V		14. (b)	15. (d)	16. (a)
17. (b)	18. (b)	19. (a)	20. (a)	21. (b)
22. (b)	23. (a)	24. (c)	25. (b)	26. 29%
27. –6.95%		28. 75	29. –14.8	
30. (a)	31. (a)	32. (b)	33. (b)	34. (d)
35. (c)	36. (a)	37. (b)	38. (a)	39. (d)
40. (b)	41. (a)	42. (b)	43. (c)	44. (a)
45. (a) 50 Hz, 1.8 MW, 1 MW, (b) 49.5 Hz, 2.3 MW, 1.5 MW, (c) 52 Hz, 1.8 MW, 2 MW				
46. (i) (d), (ii) 230.7 MW & 369.3MW, (iii) 520 MW				
47. (c)	48. 0.74		49.(b)	50. (a)
51. 0.56 lag		52. (d)	53. 5360 V	
54.28.6°	55. (b)	56. (a)	57. 0.86 lag	
58. 0.296 pu		59. 2.05 pu		
60. 0.791 lead		61. –1.25 pu		62. 32.96°
63. 0.1088		64. (a)	65. (a)	66. (a)
67. (b)	68. 24	69. (b)	70. (c)	71. (d)
72. (a)	73. (b)	74. 760.9 kW		
75. 4.84 N-m		76. (b)	77. (c)	78. (b)
79. (a)	80. (d)			