TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2082 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV/ II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE 76501)*

- ✓ *Candidates are required to give their answers in their own words as far as practicable.*
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What do you mean by un-compensated symmetrical transmission line? Explain how shunt capacitor compensation and series capacitor compensation on the un-compensated symmetrical transmission line helps to improve the transient stability. [8]

   b) A 100 km long, 132 kV (line to line), 50 Hz transmission line has parameters as follow: [8]

   Resistance of the line : Negligible
   Inductance of the line : 1.85 mH /km

   The above line is used to transmit the power with sending end and receiving end voltage constant at 132 kV with a phase angle of 30^0 between them. Calculate:

   (i) The total power transmitted over the line and mid point voltage.

   (ii) A series compensator is to be used to achieve the power transmitted increased by 25%, calculate the amount of capacitance to be connected in series.

2. a) Explain the operating principle of Thyristor Control Reactor (TCR) and derive the expression for effective reactance as a function of firing angle. [8]

   b) In a fixed capacitor thyristor controlled reactor scheme, the value of fixed capacitor of 100μF and inductor is 100mH. Calculate the net effective reactance of the scheme at a firing angle of 45° and state whether the net reactance is capacitive or inductive. [8]

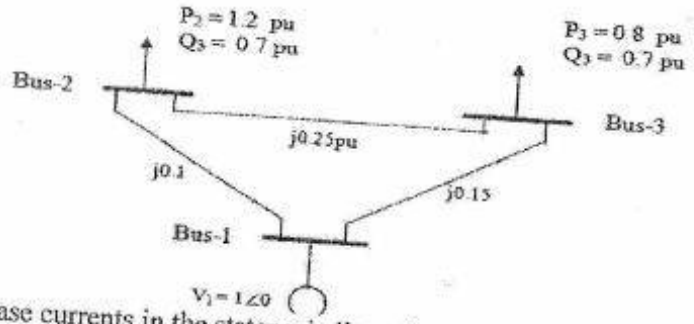
3. a) Explain the operating principle of SSSC with necessary diagram. Derive the expression of the additional active power flow in the line due to SSSC. [8]

   b) A symmetrical transmission line has sending and voltage (V_S) and receiving end voltage (V_R) equal to 132 kV. The phase angle between V_S and V_R is 25^0. The line reactance is 20 Ω per phase. SSSC is connected in the line with series injected voltage of 0.2 pu which lags the line current by 95^0. Calculate the active power flow through the line without and with SSSC. [8]

4. a) Explain the operating principle of STATCOM with help of corresponding figures and phasor diagram. [8]

   b) The inverter branch of the SATCOM has R_0= 0.06 ohm and X_0= 0.12 ohm. The system load is 25 kW per phase at 230 V and pf is0.8 lag. Calculate the magnitude and phase of the inverter output voltage required for the unity power factor operation. Also calculate the source current without and with STATCOM. [8]

5. a) For the network shown below, perform one iteration of Load flow analysis with Fast Decoupled Load Flow method to calculate the magnitude and phase of voltage at bus -2 and bus-3. [10]



b) The three phase currents in the stator winding of a synchronous machine are given by: i_a =100 cos(ωt-ϕ), i_b =100 cos(ωt- 120^0 -ϕ) and i_c = 100cos(ωt- 240^0 -ϕ). Taking the help of Park's transformation: Calculate the equivalent I_d and I_q components of i_a, i_b, i_c. [6]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2082 Shrawan

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE 76501)*

- ✓ *Candidates are required to give their answers in their own words as far as practicable.*
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Draw phasor diagram and derive the expression for midpoint voltage, current flow, active power, and reactive power flow through the symmetrical transmission line. [8]

   b) 200 km long, 132 kV, 50 Hz, symmetrical transmission line has an inductance of 1 mH/km per phase. The phase angle between sending end voltage and receiving end voltage is 30°. Neglecting the resistance and shunt capacitance of the line, calculate: [8]
   (i) Active and reactive power through the line
   (ii) Value of series capacitor required to increase the active power flow by 10%.

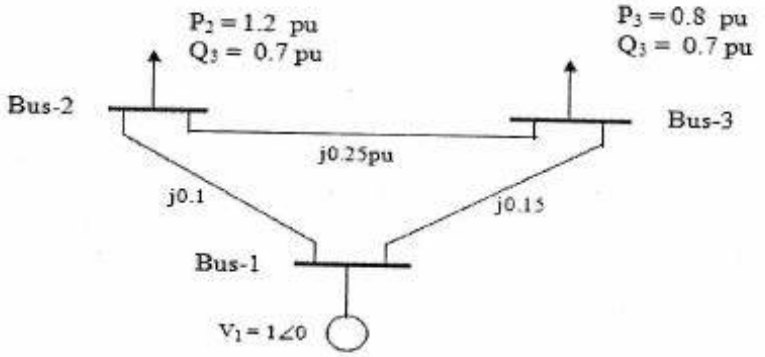
2. a) What is voltage stability? Explain effects of series and shunt compensation on voltage stability with the help of P- V curve. [8]

   b) A Fixed Capacitor Thyristor Controlled Reactor (FCTCR) scheme has a fixed capacitor of 100 μF and an inductor of 50 mH. If the scheme is operated at an firing angle $\delta = \pi/6$, Calculate the net effective reactance of the scheme and state whether the net reactance is capacitive or inductive. [8]

3. a) What is abc to dq0 transformation? Why d-q model is preferable for analysis of synchronous machine with silent pole rotor? [8]

   b) Explain the operation of SSSC with necessary diagrams and phasor diagram. Perform a mathematical analysis to calculate the additional active power flow in the line due to SSSC. [8]

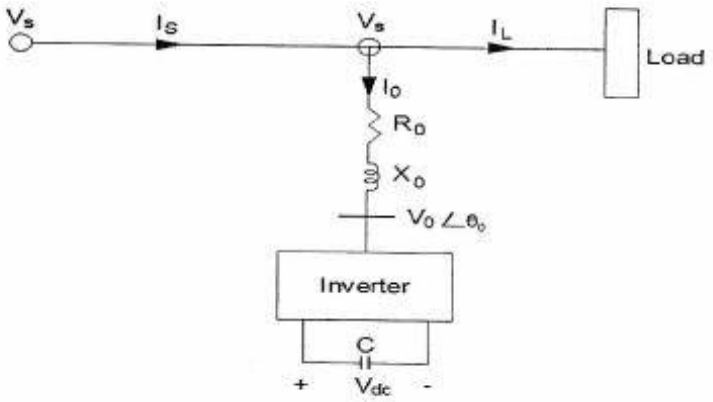
4. a) For the 3-bus network shown below, perform one iteration of load flow analysis with Fast Decoupled Load Flow method to calculate the magnitude and phase of voltage at bus -2 and bus-3. [10]



   b) The three phase currents in the stator winding of a synchronous machine are given by: $i_a = 250\ \text{Cos}(\omega t - \phi)$, $i_b = 250\ \text{Cos}(\omega t - 120^0 - \phi)$ and $i_c = 250\ \text{Cos}(\omega t - 240^0 - \phi)$
   Calculate the equivalent Id and Iq for $\phi = 30^0$. [6]

5. a) A symmetrical transmission line has sending and voltage (V_S) and receiving end voltage (V_R) equal to 132 kV. The phase angle between V_S and V_R is 25^0. The line reactance is 25 ohms per phase. SSSC is connected in the line with series injected voltage of 0.2 pu which lags the line current by 80^0. Calculate the active power flow through the line without and with SSSC. [8]

b) The following figure shows the per phase equivalent circuit diagram STATCOM used as a shunt compensator. [8]



The system load is 25 kW per phase at 230 V with 0.8 $p.f$ lagging. The inverter branch of STATCOM has coupling inductor of 0.05 Ω resistance and 0.12 Ω reactance per phase. The inverter output voltage is 240V< -3^0 with system main voltage as a reference phasor. Calculate the

(i) Reactive power generated by the STATCOM
(ii) Active power loss in STATCOM branch
(iii) Source current is without and with STATCOM

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2079 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

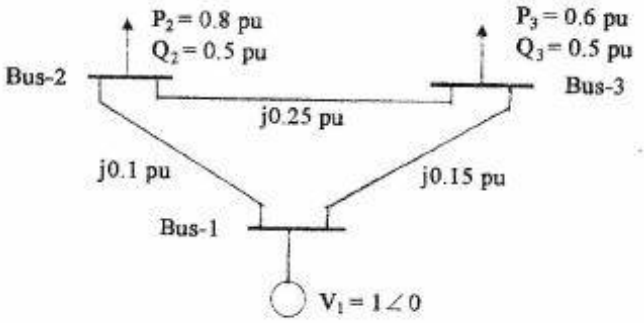
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ ***All** questions carry equal marks.*
- ✓ *Assume suitable data if necessary.*

1. a) A 100 Km long, 50 Hz symmetrical transmission line has parameters as follows: Inductance of the line: 1.5mH/Km per phase. The phase angle between sending end and receiving end voltage is 30: [5+5]
   (i) Neglecting the resistance and shunt capacitance of the line, calculate the active and reactive power flow through the line.
   (ii) Calculate the value of series capacitor to be connected in each phase of the line to increase the active power in the line by 25%.

   b) What is dq transformation? What is it necessary to analyze salient pole synchronous machine? [6]

2. Explain the operating principle of the Fixed Capacitor Thyristor Controlled Reactor with circuit diagram and associated waveforms. If a fixed capacitor of 300 micro farad and an inductor of 30mH is used in the scheme, calculate the net effective reactance of the scheme at a firing angle $\delta = 20°$ and state whether the net reactance is capacitive or inductive. [16]

3. For the 3-bus network shown below, perform two iteration of Load flow analysis with Fast Decoupled Load Flow method. [16]



4. Explain the basic principle of operation of Unified Power Flow Controller (UPFC) with basic circuit diagram and phasor diagram and describe how it can perform all three actions of voltage regulation. Series compensation and phase angle control. Perform a mathematical analysis to show that the extra active power and reactive power through the transmission line due to UPFC are: [16]

$$P_{extra} = \frac{VV_{pq}}{X}\sin(\delta+\rho) \text{ and } Q_{extra} = \frac{VV_{pq}}{X}\cos(\delta+\rho)$$

5. Explain the basic operation of STATCOM with the help of necessary circuit and phasor diagram. The inverter of the STATCOM has $R_0 = 0.06$ ohm and $X_0 = 0.12$ ohm. The system load is $P_L = 25$ kW per phase at 230 V with pf = 0.8 lag. Calculate the magnitude and phase of the inverter output voltage ($V_0 < \theta_0$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Take load voltage as reference phasor. [16]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2079 Jestha

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System analysis (*Elective II*)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Explain the basic concept of shunt compensation and series compensation in symmetrical transmission line. Explain how these compensations effect the transient stability of the system. [8]

   b) What is voltage stability of an inter-connected power system? In which aspect is different from transient stability? Explain how shunt and series compensations help to improve the transient stability. [8]

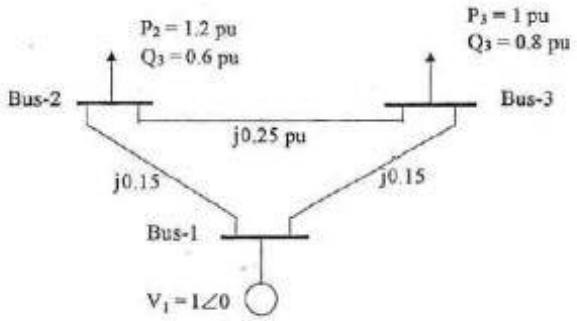
2. a) Explain the operating principle of GTO Controlled Series Capacitor scheme and derive the expression for effective series capacitive reactance as the function of Turn Off Angle. [8]

   b) A FCTCR scheme has fixed capacitor of 80 μF and an inductor of 50 mH. Calculate the net effective reactance of the scheme at a firing angle of 15° and state whether the net reactance is capacitive or inductive. [8]

3. a) Explain the operating principle of Static Synchronous Series Compensator (SSSC) with basic circuit diagram and phasor diagram. Perform a mathematical analysis to get an expression for additional power flow in the line due to SSSSC. [8]

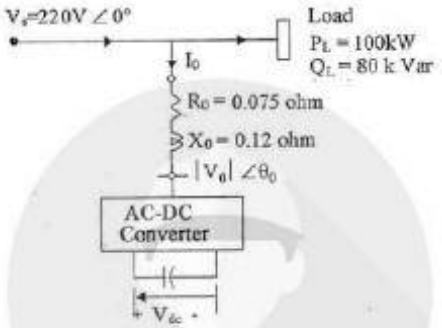
   b) Briefly explain the why dq0 model is necessary to analyze a salient pole Synchronous machine more accurately. [8]

4. For the 3-bus network shown in figure below, perform Load flow analysis with Gauss-Siedal method. Perform up to two iterations to calculate voltage magnitude and phase at bus -2 and bus-3. [16]



5. a) Explain the basic operating principle of STATCOM with necessary circuit diagram and phasor diagram for unity power factor operation. [8]

b) The Figure shows the per phase basic circuit diagram of STATCOM used as reactive power compensator. [8]



Calculate:

i) Magnitude and phase of Inverter output voltage for unity power factor operation.
ii) Active power loss in STATCOM branch.
iii) Reactive power supplied from the source in the absence of STATCOM.

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2079 Shrawan

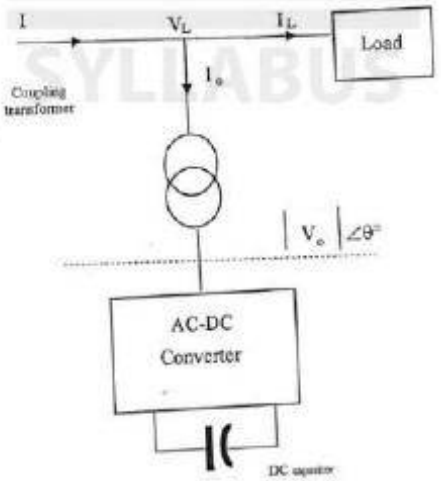
TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2079 Shrawan

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis (*Elective II*)(*EE76501*)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ *Assume suitable data if necessary.*

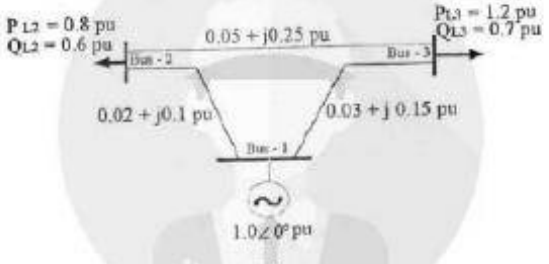
1. Draw phasor diagram and derive the equations for mid-point voltage, current flow, active power flow and reactive power flow through transmission line. [8]
2. A 220 km long, 132 kV, 50 Hz, symmetrical transmission line has an inductance of 1 mH/km per phase. The phase angle between sending end voltage and receiving end voltage is 30°. Neglecting the resistance and shunt capacitance of the line, calculate:
   a) Active and reactive power through the line
   b) Value of series capacitive compensation required to increase the active power flow by 12%. [8]
3. Explain how shunt compensation can improve the transient stability of power system. [8]
4. How can we generate varying lagging and leading VARs using conventional thyristors and GTO in shunt compensation technique? [8]
5. A symmetrical transmission line has a reactance of 1.15pu. The magnitude of sending end voltage and receiving end voltage are 1pu each. The power transmitted through the line is 0.55pu. A SSSC is introduced in line with series injected voltages $V_q = 0.2\ pu \angle -90°$ with respect to line current. Calculate the active power flow through the line. [8]
6. The following figure a basic circuit diagram STATCOM used as reactive power compensator.



The inverter branch of the STATCOM has Ro = 0.05 and Xo = 0.1 ohm. The system load is PL = 22 kW per phase at 230 V with pf = 0.85 lag. Calculate the magnitude and phase of the inverter output voltage ($V_o\angle\theta°$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Take load voltage as reference phasor. [8+8]

7. Explain the operation of Static Synchronous Series Compensator (SSSC) with basic circuit diagram and phasor doagram. Derive the expression for additional active power flow through the line with SSSC. What are the advantages of SSSC with comparison to conventional series capacitor compensation? [8]

8. For the three-bus network shown below, perform the load flow analysis with fast decoupled method for loss less line and calculate voltage magnitude and phase at BUs-2 and Bus-3. [16]



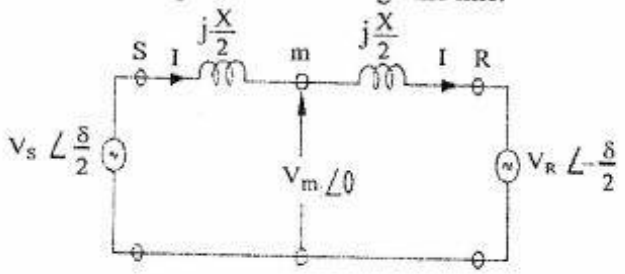
TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2078 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. The figure show the circuit diagram of an symmetrical uncompensated transmission line. In such a line, lowest voltage point will be mid-point. Derive the expression for Mid-point voltage, active power and reactive power flow through the line. [8+8]

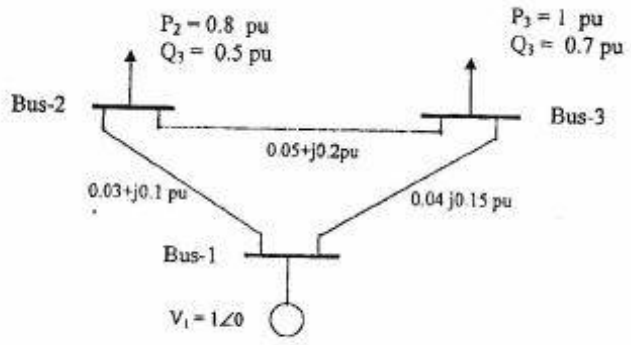


If a shunt reactive power compensator is connected at the mid-point 'm' so as to make magnitude of mid-point voltage equal to magnitude of sending end voltage and receiving end voltage, then where will be lowest voltage point? Derive the expression for magnitude of voltage at new lowest voltage point.

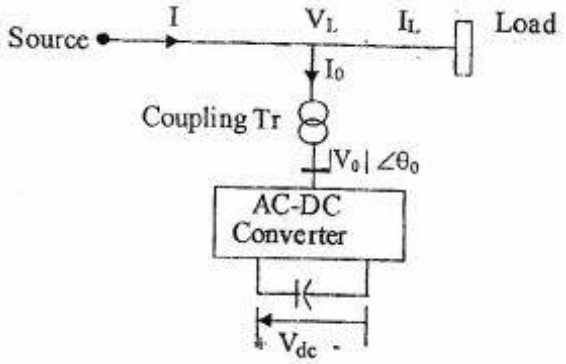
2. Explain the operating principle of the Fixed Capacitor Thyristor Controlled Reactor (FCTCR) with necessary circuit diagram and waveforms. If the Capacitor used in the scheme has a value of 100 μF and the inductor of the scheme has an inductance of 100 mH. Calculate the effective reactance of the scheme at a firing angle $\alpha = \frac{3\pi}{4}$ (i.e. $\delta = \frac{\pi}{4}$) and state whether effective reactance is capacitive or inductive. [8+8]

3. Explain the operation of Unified Power Flow Controller (UPFC) with basic circuit diagram and phasor diagram and describe how it can perform all the three actions of voltage regulation, series compensation and phase angle control. Perform a mathematical analysis to derive the expression for additional active and reactive power flow in the line due to UPFC. [16]

4. For the 3-bus network shown below, perform one iteration Load flow analysis with Gausidel method to calculate voltage magnitude and phase at bus -2 and bus – 3. Also calculate total line losses. [16]



5. a) The following figure shows a basic circuit diagram STATCOM used as reactive power compensator. Explain its operation in brief with the help of phasor diagram.



The inverter branch of the STATCOM has $R_0 = 0.06$ ohm and $X_0 = 0.12$ ohm. The system load is $P_L = 25$ kW per phase at 230 V with pf = 0.8 lag. Calculate the magnitude and phase of the inverter output voltage ($V_0 \angle\theta_0$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Calculate the source current 'I' in the absence of STATCOM and with STATCOM. [10]

b) Three phase currents in the stator winding of a synchronous machine are given by:

$i_a = I_m \cos(\omega t - \phi)$
$i_b = I_m \cos(\omega t - 120° - \phi)$
$i_c = I_m \cos(\omega t - 240° - \phi)$

Taking the help of Park's transformation, prove that the equivalent currents in D and Q coils are constant DC currents. [6]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2077 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) A 120 km long, 132 kV (line to Line), 50 Hz transmission line has parameters as follow:

Resistance of the line:	Negligible
Inductance of the line:	1.2 mH / km
Capacitance of the line:	Negligible

   The line is used to transmit the power with sending end and receiving end voltage constant at 132 kV with a phase angle of 45° between them.

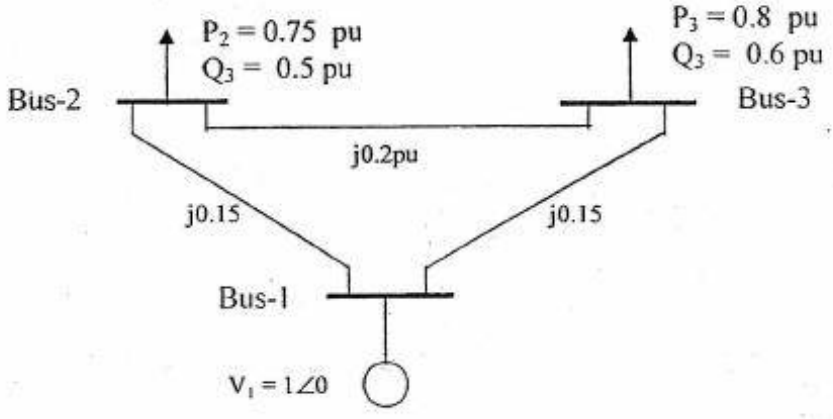
   (i) Calculate active and reactive power flow through the line. [5]
   (ii) Calculate the value of series capacitor per phase to be connected in the line so that the active power flow increase by 20%. Also calculate the reactive power flow through the line with this series capacitor. [5]

   b) Explain how the phase angle compensator can be used to increase or decrease the active power flow through a transmission line. [6]

2. Explain the operating principle of the FCTCR scheme with necessary diagram and waveforms. If the capacitor used in scheme has a value of 100 μF and the inductor of the scheme has an inductance of 100 mH. Calculate the effective series reactance of the scheme for firing angle $\delta = 45°$ and state whether effective reactance is capacitive or inductive. [16]

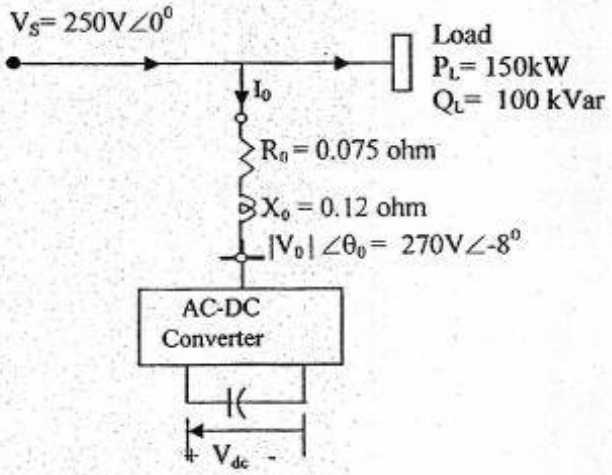
3. Explain the operation of Unified Power Flow Controller (UPFC) with basic circuit diagram and phasor diagram and describe how it can perform all three actions of voltage regulation, series compensation and phase angel control. Perform a mathematical analysis to derive the expression for the extra active power and reactive power through the transmission line due to UPC. [16]

4. For the 3-bus network shown in figure below, perform Load flow analysis with Fast Decoupled Load Flow method. Perform up to two iterations to calculate voltage magnitude and phase at bus-2 and bus-3. [16]



5. a) Explain the basic operating principle of STATCOM with basic circuit diagram and phasor diagram. [8]

b) The figure below shows a basic circuit diagram of STATCOM used as reactive power compensator. [8]



Calculate:

(i) Magnitude and Phase of Inverter branch current I_0
(ii) Reactive power generated by STATCOM
(iii) Active power loss in STATCOM branch
(iv) Reactive power supplied from the source

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NATIONAL COLLEGE OF ENGINEERING

QUESTION BANK

Advanced Power System Analysis

(Elective II)(EE76501)

BEL IV/II

15 A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2075 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

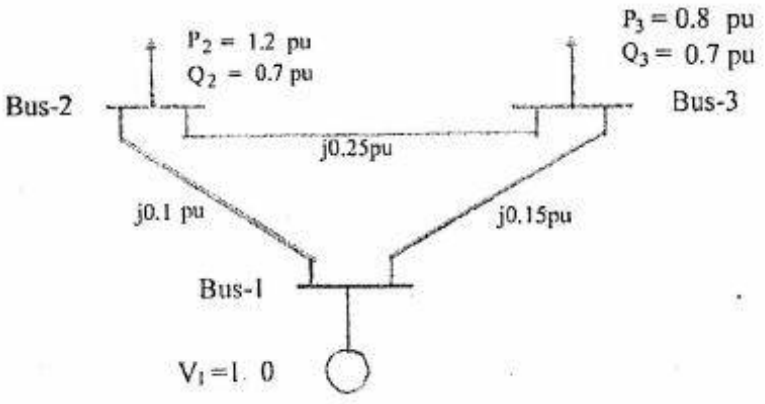
1. a) Describe the basic concept of shunt and series compensation of a transmission line. Explain how these compensations improve the transient stability of the system. [8]

   b) A 250 km long, 132 kV (Line to Line), 50 Hz transmission line has line inductance of 1.2 mH per km. The above line is transmitting the power with sending end and receiving end voltage constant at 132 kV with a phase angle of 30° between them. Calculate the value of series capacitor to be added in the line so that the active power flow through the line increases by 20%. [8]

2. Explain the operation of the Fixed Capacitor Thyristor Controlled Reactor (FCTCR) scheme with necessary diagram and waveforms. Elaborate its advantage and disadvantage with compare to discrete Thyrirstor Switched Capacitor scheme. [8]

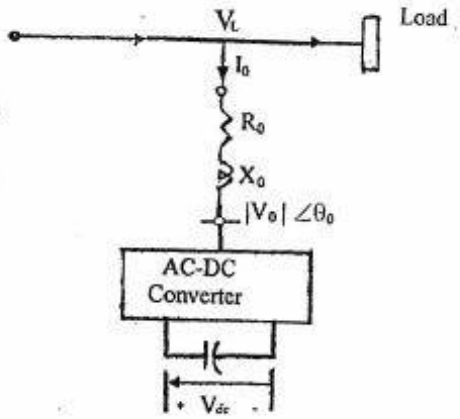
   If the Capacitor used in the scheme has a value of 120μF and the inductor of the scheme has an inductance of 125mH. Calculate the Effective series reactance of the scheme at a firing angle $\alpha = \frac{3\pi}{4}$ (i.e. $\delta = \frac{\pi}{4}$) and state whether Effective reactance is capacitive or inductive. [8]

3. For the 3-bus network shown below, perform one iteration of Load flow analysis with Fast Decoupled Load Flow method. [16]



4. a) Explain the operation Static Synchronous Compensator (STATCOM) with basic circuit diagram and phasor diagram. [8]

b) The following figure shows a basic arrangement of STATCOM used as reactive power compensator.



The inverter branch of the STATCOM has $R_0 = 0.06$ ohm and $X_0 = 0.12$ ohm
The system load is $P_L = 24$ kW per phase at 230 V with pf = 0.85 lag
Calculate the magnitude and phase of the inverter output voltage ($V_0\angle\theta_0$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Take load voltage as reference phasor. [8]

5. Why d-q equivalent circuit is necessary to analyze the salient pole synchronous machine? The current drawn by a three phase load is given by the following equations:

$i_a = 10\ \text{Cos}(\omega t - \phi)$
$i_b = 10\ \text{Cos}(\omega t - 120° - \phi)$
$i_c = 10\ \text{Cos}(\omega t - 240° - \phi)$

Calculate the magnitude of d-q component of the three phase current. [8+8]

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25A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2074 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. What do mean by un-compensated symmetrical transmission line? Prove that the mid-point voltage, active power and reactive power through such line are given by: [8+8]

$$V_m = V\,Cos\frac{\delta}{2},\quad P = \frac{V^2}{X}Sin\delta \quad \text{and} \quad Q = \frac{V^2}{X}(1-Cos\delta)$$

Where, V = magnitude of receiving end voltage per phase

δ = Phase angle between sending end voltage and receiving end voltage

X = Reactance of the line per phase

If shunt, series and phase angle compensators are installed on above un-compensated symmetrical transmission line. Explain their effects on transient stability.

2. a) Explain the operation of GTO controlled series capacitor scheme. If the Capacitor used in the GTO controlled Series Capacitor scheme has a value of 100 μF and the inductor of the scheme has an inductance of 100 mH. Calculate the effective series reactance of the scheme for turnoff angle $\gamma = 45°+\pi/2$ and state whether effective reactance is capacitive or inductive. [10]

   b) The three phase stator current of synchronous generator are: [6]

$$i_a = 50\cos(\omega t-\theta),\ i_b = 50\cos(\omega t-120°-\theta)$$

and $i_c = 50\cos(\omega t-240°-\theta)$. Calculate d – q components.

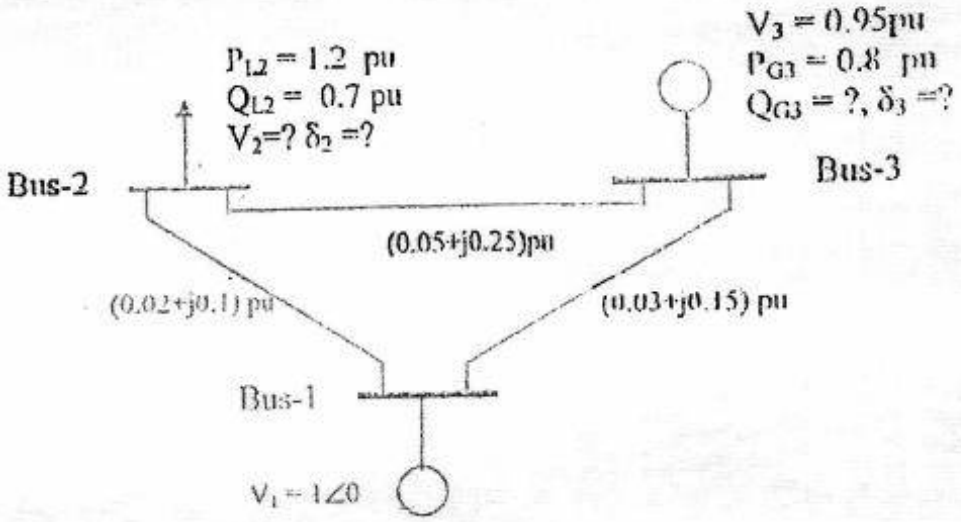
3. a) Explain the operation of Static Synchronous Series Compensator (SSSC) with basic circuit diagram and phasor diagram. Derive the expression for additional active power flow through the line with SSSC. What are the advantages of SSSC with compare to conventional series capacitor compensation? [10]

   b) Why d-q model is preferable to analysis synchromous machine with salient polerotor? Explain briefly. [6]

4. a) Explain the operation of STATCOM with help of corresponding figures and phasor diagram. [8]

   b) The inverter branch of the STATCOM has $R_0 = 0.06$ ohm and $X_0 = 0.12$ ohm. The system load is $P_L = 25$ kW per phase at 230 V and pf = 0.8 log. Calculate the magnitude and phase of the inverter output voltage required for the unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. [8]

5. For the given 3-bus system shown below, perform one iteration of Load Flow analysis with Fast Decoupled Load Flow method. [16]



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25 A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2073 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) A 200 km long, 132KV, 50Hz, symmetrical transmission line has an inductance of 1 mH/km per phase. The phase angle between sending end voltage and receiving end voltage is 30°. Neglecting the resistance and shunt capacitance of the line, calculate:

   (i) Active and reactive power flow through the line
   (ii) Value of series capacitive compensation required to increase the active power flow by 15% [4+4]

   b) Why d-q equivalent circuit is necessary to analyze the salient pole synchronous machine? The current drawn by a three phase load is given by the following equations:

   $i_a = 50\cos(wt-\theta)$
   $i_b = 50\cos(wt-120°-\theta)$
   $i_c = 50\cos(wt-240°-\theta)$
   Calculate the magnitude of d-q component of the three phase current. [3+5]

2. a) What is transient stability? Explain effects of shunt and series compensation on transient stability. [6]

   b) Explain the operating principle of Thyristor Controlled Reactor (TCR) with a pure inductive reactor with necessary waveforms. For a system of 33KV, if an inductor of 2H per phase is used in TCR scheme, calculate effective reactance and reactive power consumed by TCR branch for delay angle $\delta = 45°$. [10]

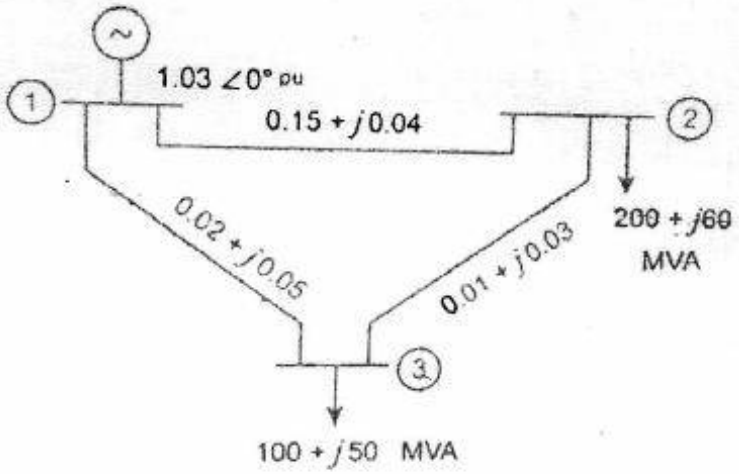
3. Explain the operation of Unified Power Flow Controller, (UPFC) with basic circuit diagram and phasor diagram and describe how it can perform all the three actions of voltage regulation, series compensation and phase angle control. Perform a mathematical analysis to show that the extra active power and reactive power through the transmission line due to UPFC are:

$$P_{extra} = \frac{v.vpq.\sin(\delta+\rho)}{x} \text{ and } Q_{extra} = \frac{v.vpq.\cos(\delta+\rho)}{x}$$ [16]

4. a) Explain the operating principle of STATCOM with neat circuit diagram and phasor diagram. [8]

   b) A 400V, 50Hz 3-phase voltage source is supplying a complex power of (25+j20) KVAR per phase. A STATCOM is connected in parallel with load for reactive power compensation. The STATCom branch has coupling inductor having reactance of 2 ohm and resistance of 0.5 ohm per phase. Calculate magnitude and phase of inverter output voltage for unity power factor operation. [8]

5. Calculate the voltages and phase angles of bus2 and bus 3 after one iteration by using fast decoupled load flow for the system as shown in figure below. The line parameters are given in per unit. [16]



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25 A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2073 Magh

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What do you mean by symmetrical transmission line? Derive the formula for active power flow and reactive power flow in such line. [4]

   b) A 200 miles long, 400 KV (Line to Line), 50 Hz transmission line has parameters as follow:

   Resistance of the line : Negligible
   Inductance of the line : 1.2 mH/mile
   Capacitance of the line : Negligible

   The above line is used to transmit the power with sending end and receiving end voltage constant at 400 KV with a phase angle of 30° between them. Calculate

   (i) The total power transmitted over the line and mid-point voltage 1061.53, 386.83
   (ii) A mid point shunt voltage compensator is used to regulate the midpoint voltage equal to $|V_S| = |V_R|$. Calculate the power transmitted through the line and Var required to be supplied by the compensator. 1099.019, 139.75
   (iii) A series compensator is used to transmit the power transmitted by above line with shunt compensator. What is the value of capacitance to be connected in series? What is Var handled by series capacitor? 1.24×10^{-3} F, 20.77 MVAR [12]

2. Describe the basic concept of shunt compensation, series compensation and phase angle control of a transmission line. Explain how these compensations improves the transient stability of the power system. [16]

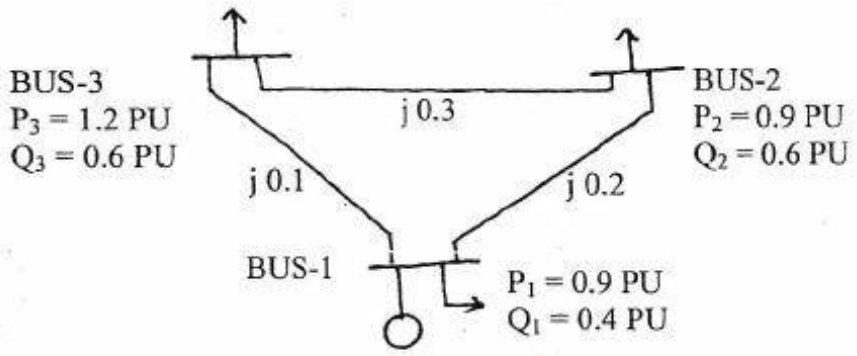
3. a) Explain the operation of United Power Flow controller (UPFC) in detail and hence derive the expression for active power and reactive power for UPFC. [8]

   b) If the capacitor used in Thyristor controlled series capacitor (TCSC) scheme has a value of 200 μF and inductor has value of 50 mH, calculate effective series reactance of the scheme at $\alpha = \frac{2\pi}{3}$. [8]

4. a) Explain the operation of static synchronous series compensator (SSSC) with neat circuit diagram and phasor diagram. [8]

   b) In a fixed capacitor thyristor controlled reactor scheme, the value of fixed capacitor of 100μF and an inductor is 100 mH. Calculate the net effective reactance of the scheme at a firing angle of $\delta = 45°$ and state whether the net reactance is capacitive or inductive. [8]

5. a) For the three bus network shown below, perform Load flow analysis with Gauss-seidal method with two iterations at each bus to calculate voltage magnitude and phase at bus-2 and bus-3. [10]



b) Why d-q modeling is necessary to analyze the salient pole synchronous machine? Explain. [6]

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25A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2072 Ashwin

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advance Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

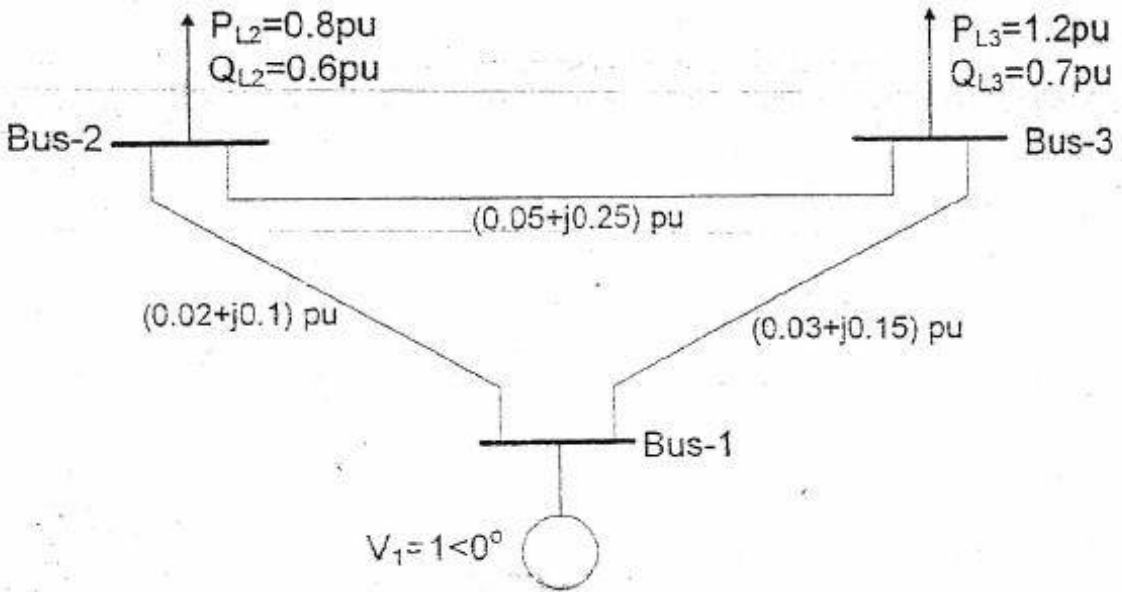
1. A 150 miles long, 220 kV (Line to Line), 50 Hz transmission line has parameters as follows:

   Resistance of the line : Negligible
   Inductance of the line : 1.82 mH /mile
   Capacitance of the line : 0.01 μF / mile (line to neutral)
   The line is used to transmit a power of 450MW with sending end and receiving end voltage constant at 220 kV. Calculate the phase angle between sending end voltage and receiving end voltage neglecting the shunt capacitance. 52.88

   i) A mid point SVC is used to regulate the mid point voltage equal to $|V_S| = |V_R|$. Calculate the Power transmitted through the line and Var required to be supplied by the SVC. 502.55, 105.708

   ii) A series compensator is to be used to achieve the power transmitted equal to that of in part in part (i). Calculate the amount of capacitance to be connected in series. What is the Var handled by the series capacitor? 3.55×10^{-4}, 58.384 [16]

2. For a three bus network shown below, perform the load flow analysis to compute the bus voltages after 2nd iteration using Gauss-Siedal method. [16]

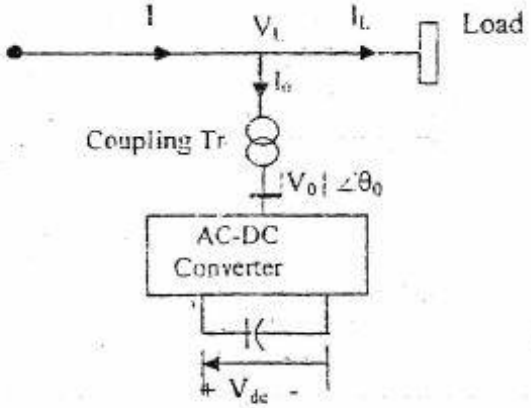


3. a) Explain the operation of SSSC with basic circuit diagram and phasor diagram. Perform a mathematical analysis to derive the equations for Active and Reactive power flow in a transmission line with SSSC. [10]

b) Explain why d-q modeling is necessary to analyze a synchronous machine with salient pole rotor? [6]

4. Explain the operating principle of Thyristor Controlled Series Reactor (TCSC) scheme with necessary circuit diagram and waveform. If the capacitor used in the scheme has a value of 100μF and the inductor of the scheme has an inductance of 100mH, calculate the effective series reactance of the scheme at a firing angle $\delta = 45°$ and state whether the effective reactance is capacitive or inductive. [8+8]

5. The Following figure shows a basic circuit diagram STATCOM used as reactive power compensator. Explain its operation in brief with the help of phasor diagram.



The inverter branch of the STATCOM has $R_0 = 0.06$ ohm and $X_0 = 0.12$ ohm
The system load is $P_L = 24$ kW per phase at 220 V with pf = 0.8 lag
Calculate the magnitude and phase of the inverter output voltage ($V_0\angle\theta_0$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Take load voltage as reference phasor. [16]

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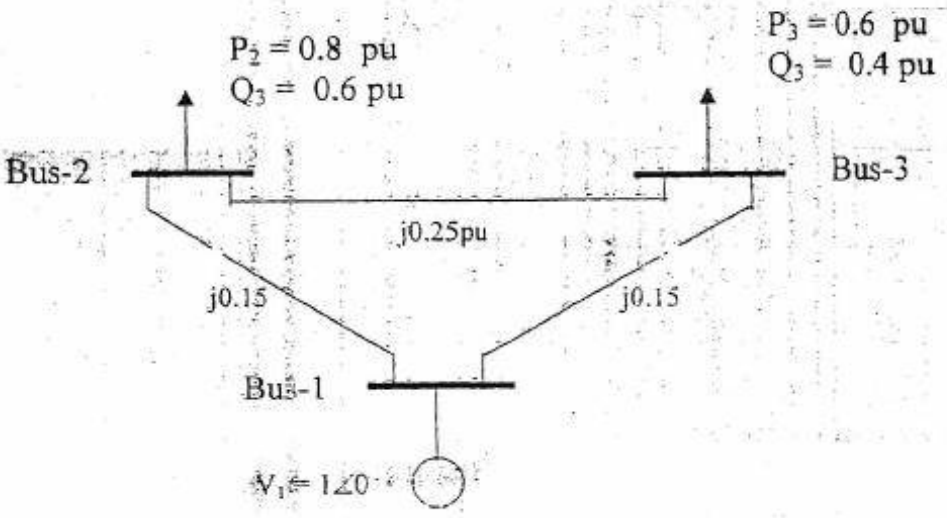
25A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2072 Magh

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advance Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) A 350 km long un-symmetrical, 3-phase, 50 Hz transmission line has line inductance of 1 mH/km and negligible resistance. If the receiving end voltage is to be maintained at 220 kV and for the active power flow of 225 MW and power angle of 30°, Calculate: [8]
   i) Sending end voltage magnitude 224.89 ?
   ii) The degree of series compensation required to increase the active power flow through the line by 20%. 16.66 %
   b) What is the complexity in analyzing a three-phase salient pole synchronous machine in abc system? How dq0 modeling simplifies the complexity? Explain briefly. [8]
2. Explain the operating principle of the GTO Controlled Series Capacitor with necessary diagram and waveforms. If the Capacitor used in the scheme has a value of 100μF and the inductor of the scheme has an inductance of 100 mH. Calculate the Effective series reactance of the scheme for turnoff angle $\Upsilon = \frac{\pi}{2} + 30°$ and state whether Effective reactance is capacitive or inductive. [16]
3. a) Explain the operating principle of STATCOM with circuit diagram and phasor diagram. [8]
   b) A symmetrical transmission line has a reactance of 1.2 pu. The magnitude of sending end voltage and receiving end voltage are 1 pu each. The power transmitted through the line is 0.5 pu. A SSSC is introduced in the line with series injected voltages Vq = 0.2 pu <-90° with respect to line current. Calculate the active power flow through the line. [8]
4. For the 3-bus network shown in figure below, perform Load flow analysis wih Fast Decoupled Load Flow method. Perform up to two iterations to calculate voltage magnitude and phase at bus -2 and bus-3. [16]



TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Bhadra

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76502)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What is symmetrical transmission line? Draw phasor diagram and derive the equations for mid-point voltage, current flow, active power flow, and reactive power flow through symmetrical line. [8]

   b) A 120 km long symmetrical transmission line has following parameters: [3+5]

   $V_s = 410$ kV $< 30°$, $V_r = 400$ kV $< 0°$, inductance of line is 3 mH/km/Phase. Calculate:

   i) Active and reactive power flow through line
   ii) degree of series capacitive compensation required to increase the active power flow by 10%

2. a) Describe the basic principle of shunt compensation. Explain how shunt compensation can improve voltage profile and transient stability. [8]

   b) Derive the equivalent d-q circuit model of salient pole 3-phase synchronous machine. [8]

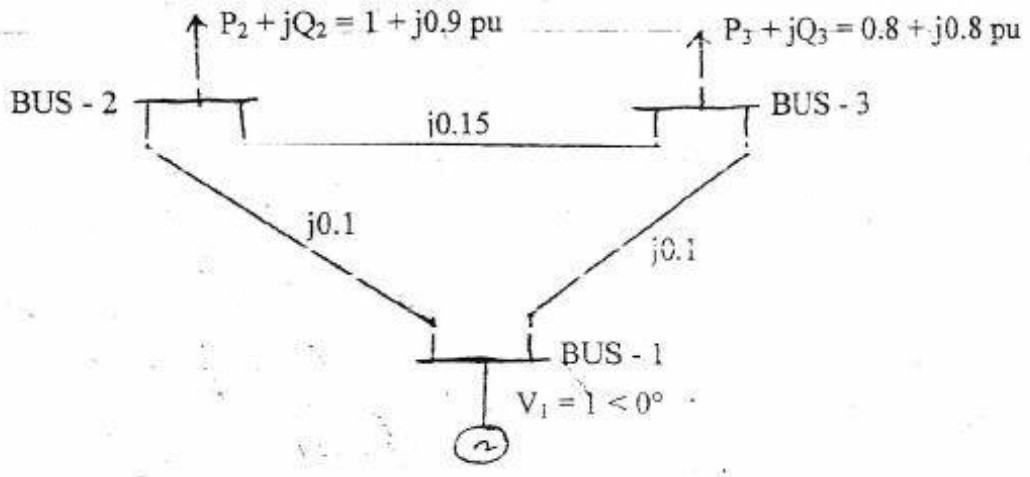
3. a) What are the advantages of Fixed Capacitor Thyristor Controlled Reactor (FCTCR) over Thyristor.Switched Capacitor (TSC)? Explain the operating principle of FCTCR scheme. [8]

   b) A fixed capacitor of 150 μF is used in GTO controlled series capacitor. Calculate the net effective capacitance of the scheme at $\gamma = 120°$. [8]

4. a) How all three types of compensation can be achieved by using unified power flow controller? Show that additional active power flow due to UPFC is $(V.V_{PQ} * \sin(\delta+\rho))/x$. [8]

   b) The inverter branch of STATCOM has $R_0 = 0.05\ \Omega$ and $X_0 = 0.10\ \Omega$. The system load is $P_L = 20$ KW at 0.70 pf lagging per phase at 2340 V. Calculate the magnitude and phase of inverter output voltage required for unity pf operation. [8]

5. For the three bus network shown below, perform the load flow analysis with fast decoupled method to calculate the magnitude and phase of voltage at bus-2 and bus-3. [16]



25A TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Magh

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis *(Elective II) (EE76501)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

QN1 (a) A 100 km long, 132 kV , 50 Hz, Symmetrical transmission line has parameters as follow:
Inductance of the line : 1.5 mH /km per phase
The phase angle between sending end voltage and receiving end voltage is 30^0.

i) Neglecting the resistance and shunt capacitance of the line, calculate the active and reactive power flow through the line. 184.96 , 49.56 [5+5]

ii) Calculate the value of series capacitor to be connected in each phase of the line to increase the active power in the line by 25%. 3.381X10⁻⁴F

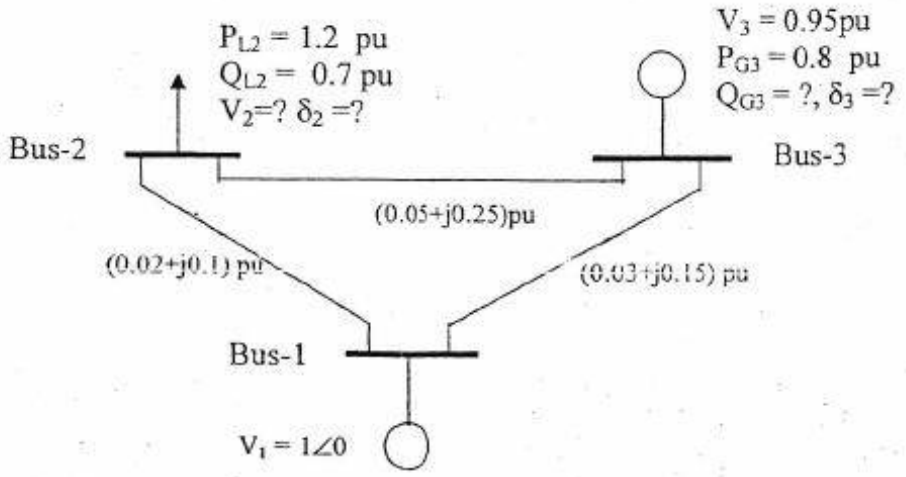
b) What is abc to d-q-o transformation? Why it is necessary to analyze a salient pole synchronous machine? Explain briefly. [6]

QN2 Explain the operating principle of the Fixed capacitor Thyristor Controlled Reactor with circuit diagram and Associated waveforms. If a fixed capacitor of 200 μF and an inductor of 20mH is used in the scheme, Calculate the net effective reactance of the scheme at a firing angle of $\delta = 20^0$ and state whether the net reactance is capacitive or inductive. [16]

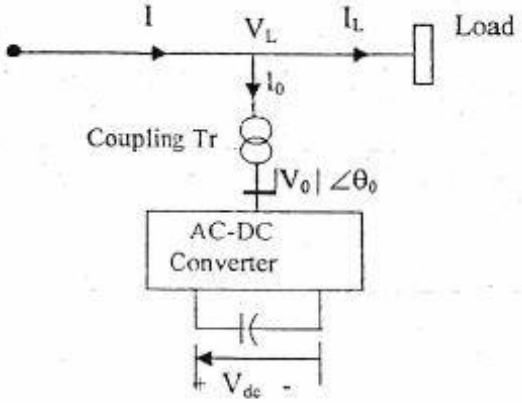
QN3 Explain the operation of Unified Power Flow Controller (UPFC) with basic circuit diagram and phasor diagram and describe how it can perform all the three actions of voltage regulation, series compensation and phase angle control. Perform a mathematical analysis to show that the extra active power and reactive power through the transmission line due to UPFC are :

$$P_{extra} = \frac{V.Vpq}{X}\sin(\delta+\rho) \quad \text{and} \quad Q_{extra} = \frac{V.Vpq}{X}\cos(\delta+\rho) \qquad [16]$$

QN4 For the 3-bus network shown below, perform two iterations of Load flow analysis with Fast Decoupled Load Flow method. [16]



QN5 (a) The following figure shows a basic circuit diagram STATCOM. used as reactive power compensator. Explain its operation with the help of phasor diagram.



(b) The inverter branch of the STATCOM has R_0 = 0.06 ohm and X_0 = 0.12 ohm
The system load is P_L = 25 kW per phase at 230 V with pf = 0.7 lag
The inverter output voltage $V_0\angle\theta_0 = 250V\angle -12^0$ per phase
Calculate: [8+8]

i) Reactive power generated by STATCOM
ii) Line current 'I' without and with STATCOM

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25C TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2070 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advanced Power System Analysis ***(Elective II) (EE76502)***

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

QN1 (a) A 300 km long, 132 kV , 50 Hz. Symmetrical transmission line has parameters as follow: [10]

Resistance of the line : 0.001 ohm/km per phase
Inductance of the line : 1.2 mH /km per phase
Capacitance of the line : 0.01 μF / mile (line to neutral)
The phase angle between sending end voltage and receiving end voltage is 30°.

i) Neglecting the resistance and capacitance of the line, calculate the active and reactive power flow through the line.

ii) A mid point SVC is used to regulate the mid point voltage equal to $|V_S| = |V_R|$. Calculate the Power transmitted through the line and Var required to be supplied by the SVC.

iii) Considering the resistance of the line, calculate the total power loss in the line.

iv) Assuming the shunt capacitance is lumped at mid-point of the line, calculate the sending end current when the receiving end is open without load.

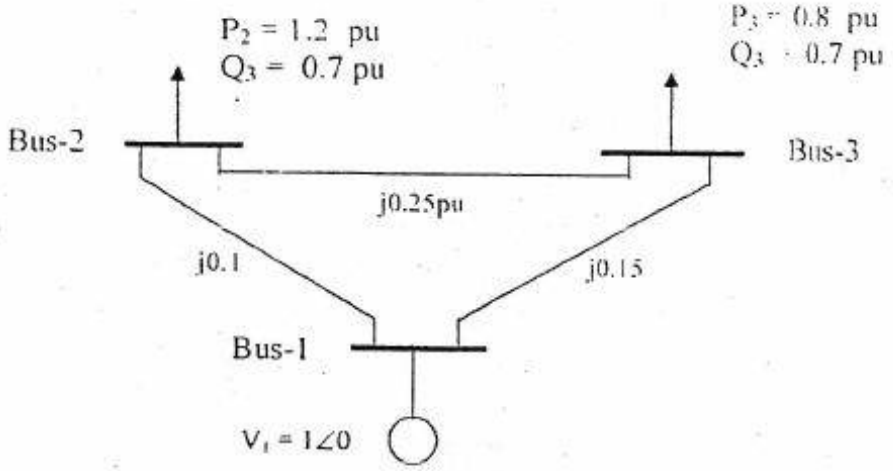
b) Why d-q-o modeling is necessary to analyze salient pole synchronous machine? Explain briefly. [6]

QN2 Explain the operating principle of the Thyristor Controlled Series Capacitor with necessary diagram and waveforms. If the Capacitor used in the scheme has a value of 120μF and the inductor of the scheme has an inductance of 120mH. Calculate the Effective series reactance of the scheme at a firing angle $\delta = \pi/4$ and state whether effective reactance is capacitive or inductive. [8+8]

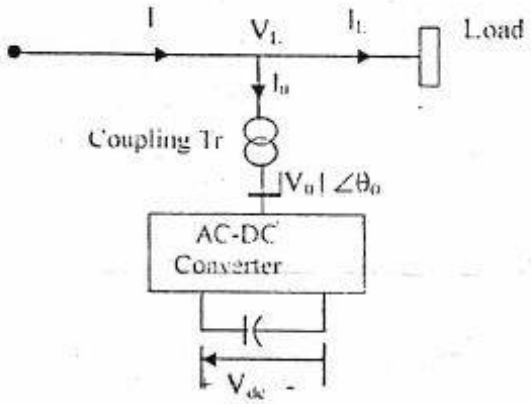
QN3 Explain the operation of Unified Power Flow Controller (UPFC) with basic circuit diagram and phasor diagram and describe how it can perform all the three actions of voltage regulation, series compensation and phase angle control. Perform a mathematical analysis to show that the extra active power and reactive power through the transmission line due to UPFC are :

$$P_{extra} = \frac{V.Vpq}{X} \sin(\delta + \rho) \quad \text{and} \quad Q_{extra} = \frac{V.Vpq}{X} \cos(\delta + \rho)$$ [16]

QN4 For the 3-bus network shown below, perform Load flow analysis with Fast Decoupled Load Flow method. Perform up to two iterations to calculate voltage magnitude and phase at bus -2 and bus-3. [16]



QN5 The following figure shows a basic circuit diagram STATCOM used as reactive power compensator. Explain its operation with the help of phasor diagram.



The inverter branch of the STATCOM has R_a = 0.06 ohm and X_a = 0.12 ohm
The system load is P_L = 25 kW per phase at 230 V with pf = 0.8 lag
Calculate the magnitude and phase of the inverter output voltage ($V_a \angle \theta_a$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Take load voltage as reference phasor. [8+8]

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25B TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2070 Magh

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advance Power System Analysis *(EE76502) (Elective II)*

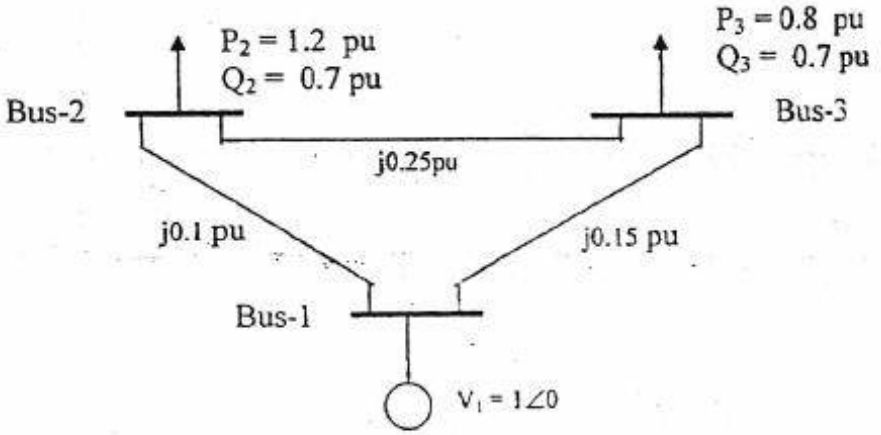
- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt any **Four** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. *a)* Describe the basic concept of shunt and series compensation of a transmission line. Explain how these compensations improve the transient stability of the system. [10]

   b) A 250 km long, 132 kV (Line to Line) , 50 Hz transmission line has line inductance of 1.2 mH per km. The above line is transmitting the power with sending end and receiving end voltage constant at 132 kV with a phase angle of 25^0 between them. Calculate the value of series capacitor to be added in the line so that the active power flow through the line increases by 20%. 9.098×10^{-4} F [10]

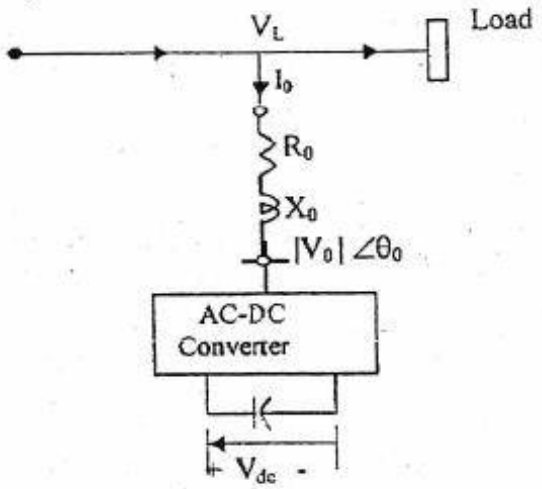
2. Explain the operating principle of the Fixed Capacitor Thyristor Controlled Reactor (FCTCR) with necessary diagram and waveforms. If the Capacitor used in the scheme has a value of 100μF and the inductor of the scheme has an inductance of 100mH. Calculate the Effective series reactance of the scheme at a firing angle $\delta = \frac{\pi}{4}$ and state whether Effective reactance is capacitive or inductive. [20]

3. For the 3-bus network shown below; perform one iteration of Load flow analysis with Fast Decoupled Load Flow method. [20]



4. a) Explain the operation Static Synchronous Compensator (STATCOM) with basic circuit diagram and phasor diagram. [10]

b) The following fig shows a basic arrangement of STATCOM used as reactive power compensator.



The inverter branch of the STATCOM has $R_0 = 0.05$ ohm and $X_0 = 0.12$ ohm
The system load is $P_L = 24$ kW per phase at 230 V with pf = 0.85 lag
Calculate the magnitude and phase of the inverter output voltage ($V_0\angle\theta_0$) required for unity power factor operation. Also calculate the magnitude and phase of the current through the inverter branch. Take load voltage as reference phasor. [10]

5. Why d-q equivalent circuit is necessary to analyze the salient pole synchronous machine? The current drawn by a three phase load is given by the following equations:

$i_a = 100\ \text{Cos}(\omega t - \phi)$
$i_b = 100\ \text{Cos}(\omega t - 120^0 - \phi)$
$i_c = 100\ \text{Cos}(\omega t - 240^0 - \phi)$

Calculate the magnitude of d-q component of the three phase current. [10 +10]

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26E TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2069 Bhadra

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - Advance Power System Analysis (EG785EE) (Elective II)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt any **Five** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. Prove that the mid-point voltage, active power and reactive power through a symmetrical transmission line are given by :

$$V_m = V \cos\frac{\delta}{2}, \qquad P = \frac{V^2}{X}\sin\delta \quad \text{and} \quad Q = \frac{V^2}{X}(1-\cos\delta)$$

Where,
V = magnitude of receiving end voltage per phase
δ = Phase angle between sending end voltage and receiving end voltage
X = Reactance of the line per phase

In the above transmission line, the receiving end voltage is equal to 132kV and the receiving end voltage lags the sending end voltage by 30^0 and the line reactance is 100 ohms per phase.
i) Calculate the line current .
ii) If a midpoint compensator is connected which draw a 90^0 leading current of 100 amp per phase and receiving end current remains same as before, calculate the new sending end current and mid point voltage. [10 + 6]

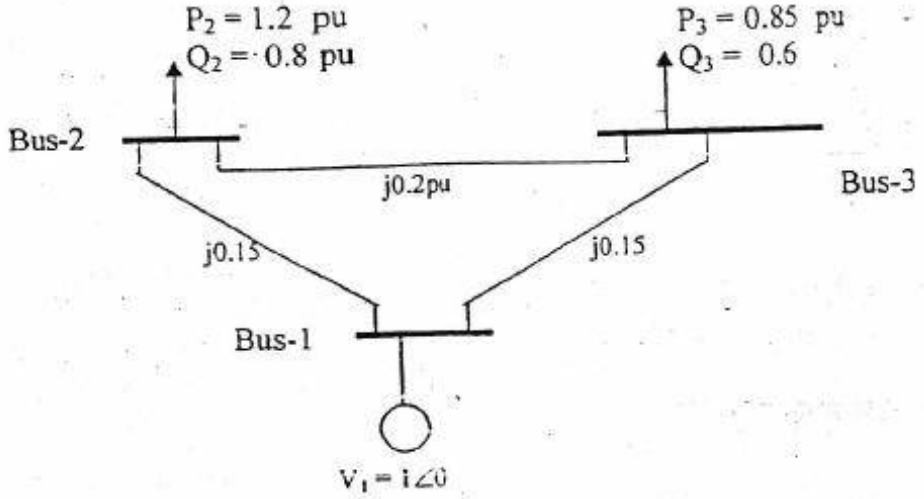
2 a) Explain the operating principle of Thyristor Control Reactor (TCR) and derive the expression for effective reactance as a function of firing angle. [8]

b) A 200 miles long, 50 Hz transmission line has parameters has following parameters:
$|Vs| = 224\text{kV}\angle 30^0$, $|V_R| = 220\text{kV}\angle 0^0$, Inductance of the line : 360mH per phase.
iii) Calculate the active power flow through the line.
iv) Calculate the degree of series capacitive compensation required to increase the active power flow through the line by 20%. [8]

3 (a) Explain the operating principle of GTO Controlled series capacitor with circuit diagram and Associated waveforms. [8]

(b) If a fixed capacitor of 200 μF is used in the scheme, Calculate the net effective capacitance of the scheme at a of $\gamma = 120^0$. [8]

4. For the 3-bus network shown below, perform one iteration Load flow analysis with Fast Decoupled method to calculate the magnitude and phase of voltage at bus -2 and bus-3. [16]



5- (a) What is the complexity in analyzing a three phase salient pole synchronous machine in abc system? How dq0 modeling simplifies the complexity? Explain in detail. [10]

(b) The three phase stator currents of a synchronous machine are given by:

$i_a = 200\ \mathrm{Cos}(\omega t - \phi)$

$i_b = 200\ \mathrm{Cos}(\omega t - 120^0 - \phi)$

$i_c = 200\ \mathrm{Cos}(\omega t - 240^0 - \phi)$

Calculate the magnitude of d-q component of the three-phase current. [6]

6 a) Explain the operating principle of STATCOM with circuit diagram and phasor diagram. [8]

b) A low voltage STATCOM scheme has following parameters: [8]

The system load is $P_L = 25$ kW per phase at 230 V with pf = 0.8 lag

The coupling inductor between system main and STATCOM has resistance of 0.05 ohms per phase and reactance of 0.12 ohms per phase.

The inverter output voltage $|V_0| \angle\theta_0 = 250\text{V} \angle -10^0$ with system main voltage as reference phasor.

i) Calculate reactive power exchange between system main and STATCOM

ii) Active power loss in STATCOM branch.

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