FLEXIBLE AC TRANSMISSION SYSTEMS

QUESTION BANK

(2 MARK Q &A, 16 MARK Q)

UNIT I INTRODUCTION

1. What is meant by FACTS?

FACTS devices are made by advanced power electronic control equipments. The Flexible ac transmission systems (FACTS) give solutions to the problems and limitations which were introduced in the power system with the introduction of power electronics based control for reactive power.

2. What is real power?

The real power flows from source to load. Unit: Watts (W)

3. What are the sources of real power?

All dc and ac generators

4. What is the need for reactive power?

The reactive power is essential for the operation of electromagnetic energy devices; it provides required coupling fields for energy devices.

5. What is reactive power?

The reactive power flows from load to source. The average value for reactive power is zero. It does not result in any active power consumption. Unit: Volt Ampere Reactive (VAR).

6. What are the sources of reactive power?

i) Capacitor
ii) Synchronous generator (it can generate both real and reactive power)

7. Main objectives of FACTS?

i) The power transfer capability of transmission system is to be increased.
ii) The power flow is to be kept over designated routes.

8. Who implemented the FACTS concept? For what?

The concept of FACTS was first defined in 1988 by N.G.Hingorani. It controls the interrelated parameters which are involved in power system operation such as series and shunt impedance, current, voltage and phase angle. Also it damps the oscillations at various frequencies below the rated frequency.

9. What are the types of FACTS devices?

SVC - Static Var Compensator

TCSC - Thyristor Controlled Series Capacitor

UPFC - Unified Power Flow Controller

IPFC - Interline Power Flow Controller

SSSC - Static Synchronous Series Compensator

SSC - Static Synchronous Compensator (STATCOM)

10. What are the types of FACTS controllers?

i) Series controller

ii) Shunt controller

iii) Combined series-series controllers

iv) Combined series-shunt controllers

11. Where the first STATCOM was implemented?

Tennesee Valley Authority (TVA) installed the first static synchronous compensator (STATCOM) in 1955 to strengthen transmission line ties between its Sullivan substation and the rest of its network. It reduces the need of additional transformer bank and avoiding more labours.

12. Where the first UPFC was implemented?

In 1998 installation of the first unified power flow controller (UPFC) was completed at the Inez Substations owned by American Electrical Power (AEP). It represents the first controller capable of providing complete control of all the three basic transmission system parameters that is voltage, line impedance, phase angle.

13. Write down the advantages of FACTS.

i) It controls line impedance angle and voltage which helps in controlling the power flow in transmission lines.

ii) The power flow in the transmission lines can be made optimum.

iii) It helps in damping out the oscillations and avoids damage of various equipments.

iv) It limits the impacts of faults and equipment failures.

14. Define reactive power control.

To make transmission networks operate within desired voltage limits, methods of making up or taking away reactive power is called reactive power control.

15. What is the reactive power value 'Q' for electromagnetic devices?

Electromagnetic devices store energy in their magnetic fields. These devices draw lagging current, there by resulting in positive values of Q; therefore they are frequently referred to as the absorbers of reactive power.

16. What is the reactive power value 'Q' for electrostatic devices?

Electrostatic devices store energy in their electric fields. These devices draw leading current and result in a negative value of 'Q'; thus they are seen to be suppliers of reactive power.

17. What is reactive power compensation? Compensators?

Reactive power control for a transmission line is often called reactive power compensation. External devices or sub systems that control reactive power on transmission line are known as compensators.

18. What is shunt compensation?

The Shunt compensators are connected parallel to the transmission lines with the help of Circuit breakers. Shunt reactors compensate for the line capacitance, and they control over voltages at no loads and light load conditions. The shunt compensators need careful system design because of high charging in-rush currents.

19. What is series compensation?

The Series compensators are connected series with the transmission lines. Series compensators are used to partially offset the effects of the series inductances of transmission lines. It provides automatic adjustment of reactive power compensation.

20. What are the design factors considered for the series compensators?

i)The voltage magnitudes across the capacitor bank

ii) The fault currents at the terminals of a capacitor bank

iii) The fault currents at the terminals of a capacitor bank

iv) The placement of shunt reactors in relation to the series capacitors

21. What are the methods used for compensating the uncompensated transmission lines?

i) Load compensation- One capacitor is connected parallel across the load

ii) System compensation - In addition with the parallel capacitor the power utility devices are also connected.

22. Compare the conventional series controller with the advanced series controller (IPFC).

Conventional series controller	Advanced series controller (IPFC)
1. Load balancing of transmission lines is very Poor.	1. It has better load balancing.
2. It has very low X/R ratio.	2. It has high X/R ratio.
3. Transmission line losses are very high.	3. Transmission line losses are low.
4. It controls both real and reactive power with low operating efficiency.	4. It controls both real and reactive power with high operating efficiency.

16 MARKS:

1. Describe briefly the load and system compensation schemes.

2. Explain the operation of UPFC with diagram.

3. Explain the reactive power compensation at the sending, mid-point and receiving ends of the transmission lines.

4. Explain the principle, working and characteristics of static VAR compensator with a neat circuit diagram.

5. Explain the working and characteristics of Thyristor switched series capacitor with a neat diagram.

6. Discuss briefly about the variation of the TCSC reactance with firing angle 'alpha'.

7. Explain the V-I capability characteristics of single module TCSC.

8. Explain with neat circuit diagram about fixed capacitor-Thyristor controlled reactor.

UNIT II STATIC VAR COMPENSATOR (SVC) AND APPLICATIONS

1. Short notes on voltage control by SVC?

The transmission line voltage is maintained by connecting static var compensator (SVC) in the receiving end side. The comparator will measure the actual and reference values of transmission line voltage; depends on the comparator output the reactive power is injected into the transmission line, and the transmission line voltage will be controlled.

2. Write down the equation for SVC bus voltage.

$$V_S = V_{SVC} + I_{SVC} X_S$$

3. Give the advantages of the slope in the SVC dynamic characteristics.

i) The reactive power rating is reduced

ii) SVC is prevented from reaching its reactive power limit too frequently

iii) It provides effective parallel operation of two parallel connected SVC's

4. What is SVC slope in the dynamic characteristics?

To improve the power system operating performance 2.5% voltage de-regulation will be provided in SVC operation. So this voltage de-regulation results in 5% slope in the SVC dynamic characteristics.

5. How the SVC prevents the reactive power rating, reaching its limit too frequently?

Due to slope in the SVC dynamic characteristics the no load to change in load variation limit will be increased, so the SVC is prevented from reaching its reactive power limit too frequently. Thus the total reactive power needed is reduced to certain limit.

6. Explain the load sharing of two parallel connected SVC's.

Without slope in the SVC dynamic characteristics there is a discontinuous gap between capacitive and inductive region. This gap will be reduced by operating two parallel connected SVC's with slope (2.5% voltage de-regulation) in the SVC dynamic characteristics.

7. What are the conditions involved for influence of the SVC on system voltage?

i) Coupling transformer ignored

ii) With coupling transformer

iii) System gain

8. What is ESCR?

Effective short circuit ratio (ESCR) = $1 / X_S$

$= 1 / (-\Delta svc / \Delta Isvc)$

$= B_S$(equivalent system susceptance)

9. What is system gain?

System gain $K_N = Vs / ESCR$

$= Vs / B_S$

10. What is per unit system gain?

Per unit System gain $K_N = \Delta Vsvc / Bsvc$

$$= Qsvc / Sc \text{ p.u}$$

11. What is short circuit power?

Short circuit power S_c = (base voltage) × (short circuit current)

$$= (V_b) \times (B_S . V_S)$$

12. What is SMIB system?

A single synchronous generator connected with more number of transmission lines in electric power system is called single machine infinite bus (SMIB) system.

13. What are the different cases involved in power angle curves of a SMIB system?

i) Uncompensated case

ii) Ideal midpoint SVC unlimited rating (Qsvc > 4 Pmax)

iii) Fixed capacitor connected at its midpoint

iv) Midpoint SVC with limited rating (Qsvc = 2Pmax)

14. What is the objective of SVC enhancement in transient stability?

An SVC significantly enhances the ability to maintain synchronism of a power system that is controlled and co-ordinated system, even when the system is subjected to large sudden disturbances. So the SVC enhancement in transient stability provides steady power transfer in transmission lines.

15. What is synchronizing power co-efficient?

Synchronizing power co-efficient $Ks = \Delta_{PE} / \Delta \delta$

Where Δ_{PE} - change in generator power output

$\Delta \delta$ - change in generator rotor angle

16. What is SVC susceptance?

Susceptance $B_S = (\alpha_c / x_c) - (\alpha_i / x_i)$

Where x_i - total inductive reactance of the SVC

x_c - total capacitive reactance of the SVC

α_i - the conducting fraction of TCR

α_c - the conducting fraction of TSC

17. Write down the equation for synchronizing torque co-efficient.

Synchronizing torque co-efficient Ks

$$Ks = \Delta_{PE} / \Delta\square$$

$$= ((V_1\ V_2\ COS\ \square) / X_T) + ((V_1\ V_2\ SIN\ \square) / (V_m\ X_T))\ 2 \times (X_2 / 4X_T)$$

18. Write short notes on prevention of voltage instability.

By connecting SVC at receiving end bus the transmission line voltage will be maintained even when the power factor value varies (p.f.-lag, lead, unity) with load. Thus the SVC prevents the voltage instability in a power system.

16 MARKS:

1. Explain the design of SVC voltage regulator. Also discuss the influence of SVC on system voltage.

2. Discuss in detail the effect of SVC for the enhancement of transient stability.

3. Using a general schematic diagram, explain the three basic modes of SVC control in detail.

4. Explain the application of SVC for prevention of voltage instability.

5. How do you enhance the damping in power system using SVC?

6. Explain the design of SVC voltage regulator and discuss the voltage control capability of SVC. What are the advantages of slope in dynamic characteristics of SVC?

7. Discuss in detail about the role of SVC in improving the stability limit and enhancing the power system damping

8. Describe the construction and operating characteristics of synchronous condensers.

9. Derive and explain the series and shunt compensation of symmetrical transmission lines.

UNIT III THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) AND APPLICATIONS

1. What is meant by TCSC?

TCSC is a thyristor controlled series capacitor. It has one parallel connected thyristor controlled inductor and a series capacitor connected with the transmission line. It provides continuous variable capacitive reactance and variable inductive reactance to control the transmission line parameters.

2. Write down the expression for equivalent impedance of a TCSC.

Equivalent impedance of a TCSC, $Z_{eq} = -j\left(\frac{1}{\omega c - 1/\omega L}\right)$

3. What is the condition for variable capacitive reactance in a TCSC?

If $(\omega c - (1/\omega L)) < 0$ - the TCSC provides variable capacitive reactance mode.

4. What is the condition for variable inductive reactance in a TCSC?

If $(\omega c - (1/\omega L)) > 0$ - the TCSC provides variable inductive reactance mode.

5. What are the different modes of operation of TCSC?

i) Bypassed- thyristor mode

ii) Blocked - thyristor mode

iii) Partially conducting thyristor or Vernier mode

6. Give short notes on Bypassed- thyristor mode.

In this mode the TCSC module behaves like a parallel capacitor - inductor combination. The susceptance (increase in power flow) value of inductor is higher than the capacitor. This mode is employed for control purposes and initiating certain protective functions.

7. Give short notes on Blocked - thyristor mode.

In this mode, also known as the waiting mode, here the firing pulses of thyristor switches are blocked. The TCSC behaves like a fixed series capacitor and the net TCSC reactance is capacitive. In this mode the dc-offset voltages of the capacitors are monitored and quickly discharged using a dc-offset control without causing any harm to the transmission system transformers.

8. Give short notes on capacitive Vernier mode.

In this mode the TCSC provides continuously controllable capacitive reactance. It is achieved by varying the thyristor pair firing angle in an appropriate range. A variant of this mode is the capacitive vernier mode, in which the thyristor are fired when the capacitor voltage and current have opposite polarity. This condition causes a thyristor controlled reactor (TCR) current that has a direction opposite that of the capacitor current thereby resulting in a loop-current flow in the TCSC controller. This loop current increases the voltage across the fixed capacitor (FC), effectively enhancing the equivalent capacitive reactance and the series compensation level.

9. Give short notes on inductive Vernier mode.

In this mode the TCSC provides continuously controllable inductive reactance. Here the TCSC can be operated by having a high level of thyristor conduction. In this mode the direction of the circulating current is reversed and the controller presents a net inductive impedance.

10. What are the conclusions made from the TCSC modes of operation?

i) Thyristor switched series capacitor (TSSC), which permits a discrete control of the capacitive reactance.

ii) Thyristor controlled series capacitor (TCSC), which offers a continuous control of capacitive or inductive reactance. Practically TSSC is more commonly used.

11. What are the modeling techniques involved in TCSC?

i)Variable reactance model (1. Transient stability model 2. Long term stability model)

ii)An advanced transient stability studies model

12. What is the need for modeling of a TCSC?

A TCSC involves continous - time dynamics, relating to voltages and currents in the capacitor and reactor, and nonlinear discrete switching behavior of thyristors. So it is very important to derive a model for a TCSC controller to maintain the stability of a power system.

13. Give short notes on variable reactance model.

It is a quasi-static approximation model. This model provides multimode TCSC configuration that is the discontinuity gap between inductive and capacitive regions are reduced by providing continous reactance range. This model is generally used for inter-area mode analysis, and it provides high accuracy when the reactance boost factor is less than 1.5.

14. What is reactance boost factor of a TCSC model?

Reactance boost factor = X_{TCSC} / X_C

15. Write short notes on Transient stability model.

In the variable reactance model for stability studies, a reference value of TCSC reactance X_{ref}, is generated from the power scheduling controller based on the power flow specification in the transmission lines. Then X_{ref} is converted into X_{total} with the help of modulation controller, delay circuit, lag circuit, X_{aux} signal and X_{fixed} signals. Finally the required X_{total} control value will be converted into per unit value and it pass through the control unit.

16. Write down the TCSC base reactance value.

TCSC base reactance Z_{base} = (KV_{TCSC}) 2 / MVA_{sys}

Where KV_{TCSC} - rms line - line voltage of the TCSC in KV

MVA_{sys} - 3phase MVA base of the power system

17. What is long term stability model?

The capability curves of the TCSC depend on the duration for which the voltage and current operating conditions persist (keep on continued) of the TCSC. For long term dynamic simulation, an over load management function needs to be incorporated in the control system. It determines the appropriate TCSC overload range, for which it modifies the X_{max} limit and X_{min} limit. It then applies the same modifications to the controller. This model is used widely in commercial stability programs because of its simplicity, and it is also used for system planning studies as well as for initial investigations of the effects of the TCSC in damping power oscillations.

18. What is the use of advanced transient stability studies model?

This model is used to solve the TCSC time varying dynamics with the help of differential equations. It calculates the capacitor voltage, capacitor current, inductor voltage and inductor current for every half cycle of zero - crossing.

19. Write down the expression for proportional controller gain and integral controller gain.

Proportional controller gain K_p =-10 exp (- ((65 - σ_{req}) / 2)2)

Integral controller gain K_i = -23-24 exp ((σ_{req} -65) / 2)

20. What is the need for improvement in the TCSC system stability limit?

In a power system due to critical faults, the large volume of power tends to flow in parallel paths of a transmission lines; it would create severe overload condition. The conventional fixed-series compensation on the parallel paths of a transmission line provides the solution for the above problem but it increases the total system losses. Therefore, it is advantageous to install a TCSC in key transmission paths, which provides series compensation according to their system requirements with lower system losses. So the improvement in the TCSC system stability limit was very important in power system.

21. What are functions of damping controller?

i) It stabilizes both the post disturbance oscillations and growing oscillations during normal operation.

ii) It must reduces the interaction of high frequency phenomena in power system, such as network resonances.

iii) It eliminates the local instabilities within the controller band width.

iv) It should be robust; it provides desired damping over a wide range of system operating conditions.

v) It should be reliable.

22. Write short notes on bang-bang control.

Bang-bang control is a discrete control form in which the thyristors of inductor bank are either fully switched on or fully switched off. Thus the TCSC alternates between a fixed inductor and a fixed capacitor respectively, and it is advantageous that such control is used not only for minimizing first order swing oscillations but for damping any subsequent swing oscillations as well.

23. What are the two auxiliary signals for TCSC modulation?

i) Local signals

ii) Remote signals

24. What are the local auxiliary signals for TCSC modulation?

i) The line current

ii) The real power flow

iii) The bus voltage

iv) The local bus frequency

25. What are the remote auxiliary signals for TCSC modulation?

i) The rotor-angle/speed deviation of a remote generator

ii) The rotor-angle/speed (frequency) difference across the system

iii) The real power flow on adjacent transmission lines

16 MARKS:

1. Explain the principle of operation of TCSC. Also discuss the different modes of TCSC.
2. Explain the effect of TCSC for the enhancement of system damping.
3. Explain the need for variable and fixed series compensation schemes.
4. Describe the variable reactance model of TCSC.
5. Explain the different modes of operation of TCSC.
6. Describe the modeling of TCSC for load flow study.
7. Explain the working, characteristics and operating modes of variable reactance model of thyristor controlled series capacitor.
8. Explain in detail the applications of thyristor controlled series capacitor.
9. How TCSC is used for the improvement of the stability of a system.

UNIT IV EMERGING FACTS CONTROLLERS

1. What is meant by emerging facts controllers?

The emerging facts controllers exchange the reactive power to the transmission lines with the help of phase shifting techniques. If needed the real power is also supplied in addition to the reactive power in to the transmission line with the help of emerging FACTS devices such as STATCOM and UPFC. Here the need of large size capacitor bank and inductor bank are reduced, so the operating performance will be improved.

2. What is meant by STATCOM?

The static synchronous compensator (STATCOM or SSC) is a shunt connected reactive power compensation device that is capable of generating and/or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from a dc energy source or energy storage device at its input terminals.

3. What are the functions of STATCOM in the improvement of power system performance area?

i) It provides dynamic voltage control in transmission and distribution system

ii) It provides damping against the oscillation in power system.

iii) It provides better transient stability

iv) It has voltage flicker control (it withstands sudden changes)

v) It controls both real and reactive power

4. What are the common advantages of STATCOM?

i) It required small space because it replaces the passive inductor and capacitor bank by compact electronic converters.

ii) It has modular factory build electronic equipments, so site work and commissioning time will be reduced.

iii) It uses encapsulated electronic converters, thereby minimizing its environmental impact.

5. Give details about first installed STATCOM device at Sullivan Sub-station.

Tennessee Valley Authority (TVA) installed the first ± 100 MVA STATCOM in 1995 at its Sullivan substation.

6. What are the applications of first installed STATCOM device at Sullivan Sub-station?

The application of this STATCOM is expected to reduce the TVA's need for load tap changing transformers, there by achieving savings by minimizing the potential for transformer failure. This STATCOM solves the problems against off-peak dilemma of over voltages in the Sullivan substation area while avoiding the more labor and apace intensive installation of an additional transformer bank.

7. What are the advantages of first installed STATCOM device at Sullivan Sub-station?

i) It increases the capacity of transmission line voltage by providing instantaneous control.

ii) It provides greater flexibility in bulk power transactions.

iii) It also increases the system reliability by damping grids of major oscillations in this grid.

8. Write short notes on principle of operation of STATCOM.

A STATCOM is a controlled reactive power source. It provides the desired reactive power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage source converter.

9. Give the explanation about reactive power exchange between converter and the ac system.

If the ac system voltage is lesser than the sending end voltage then the converter inject the reactive power to the transmission line. If the ac system voltage is higher than the sending end voltage then the converter absorb the reactive power from the transmission line.

10. What is the importance of V-I characteristics of STATCOM?

The V-I characteristics of STATCOM shows that it can supply both the capacitive and inductive compensation and is able to independently control its output current over the rated maximum capacitive or inductive range irrespective of the amount of ac system voltage. That is, the STATCOM can provide full capacitive reactive power at any ac system voltage even as low as 0.15 p.u.

11. How will you determine the maximum attainable transient over current region?

The maximum attainable transient over current in the capacitive region is determined by the maximum current turn-off capacity of the converter switches.

12. Why the converters (STATCOM) absorb the small amount of real power from the ac system?

The converter absorbs the small amount of real power from the ac system to meet its internal losses and keep the capacitor (energy storage device) voltage at the desired level.

13. Write short on UPFC.

The unified power flow controller (UPFC) is the most versatile FACTS controller developed so far, with all encompassing of voltage regulation, series compensation and phase shifting. It can independently and very rapidly control both real and reactive power flows in a transmission line.

14. What are the functions of series converter in the UPFC?

In a UPFC series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated or absorbed by the series converter, the real power generation or absorption is made feasible by the dc energy storage device.

15. What are the functions of shunt converter in the UPFC?

In a UPFC shunt converter mainly used to supply the real power demand of series converter, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus. In addition, the shunt converter functions like a STATCOM and independently regulate the terminal voltage of the interconnected bus by generating or absorbing a requisite amount of reactive power.

16. What are the operating variable constraints of UPFC?

i) The series injected voltage magnitude

ii) The line current through series converter

iii) The shunt converter current

iv) The maximum line side voltage of the UPFC

V) The minimum line side voltage of the UPFC

vi) The real power transfer between the series converter and the shunt converter

17. What was the result of case study of an UPFC at 100 miles length transmission line power system?

In that case study of a 100 miles long two area model transmission line the 3Φ to ground fault has been applied four times then disconnected. The result indicates that with UPFC the power transfer is 357 MW, without UPFC the power transfer is 176 MW. Thus the power transfer will be increased with the help of an UPFC.

18. What was the effect of damping by using UPFC in case study power system transmission lines?

In that case study of a 100 miles long two area model transmission line the 3Φ to ground fault has been applied four times then disconnected. The result indicates that with UPFC the power transfer is 357 MW, without UPFC the power transfer is 176 MW. Thus the power transfer will be increased with the help of an UPFC. Also the oscillations in the transmission line will be damped by UPFC. That is with UPFC the oscillation range will be -14 MW to -15 MW per second but without UPFC the oscillation range will be -9 MW to -21 MW per second.

16 MARKS:

1. With a neat sketch, explain the implementation of UPFC.

2. Explain the working of STATCOM with a neat sketch. In what way it differs from SVC?

3. Explain the operation of STATCOM with its V-I characteristics.

4. Explain the performance of VSC based STATCOM.

5. Describe the modeling of UPFC for power flow and transient stability studies.

6. Explain the basic principle and control capability of unified power flow controller.

7. Explain the power transfer capability of UPFC and compare its capabilities with other FACTS controllers.

8. Describe the construction of UPFC with a block diagram and its characteristics with phasor diagrams.

9. Explain the power flow control and oscillation damping in the two area system using UPFC.

UNIT V CO-ORDINATION OF FACTS CONTROLLERS

1. What is meant by controller interactions?

If two or more FACTS devices are connected in same transmission line then the operating variables between them must have better co-ordinated, that is called controller interaction. If FACTS devices are not co-ordinated, it creates unwanted oscillation in the transmission lines.

2. What are the types of controller interactions?

i) Multiple FACTS controller of a similar kind

ii) Multiple FACTS controller of a dissimilar kind

iii) Multiple FACTS controllers and HVDV converter controllers

3. What are the frequencies ranges of controller interactions?

i) 0 Hz for steady state interactions

ii) 0 - 3/5 Hz for electromechanical oscillations

iii) 2 - 15 Hz for small signal or control oscillation

iv) 10 - 50/60 Hz for sub synchronous resonance (SSR) interaction

v) > 15 Hz for electromagnetic transients, high - frequency resonance or harmonic resonance interactions, and network resonance interactions

4. What is meant by steady state interaction?

Steady-state interactions between different controllers (FACTS-FACTS or FACTS-HVDC) occur between their system related controls. They are steady state in nature and do not involve any controller dynamics. These interactions are related to issues such as the stability limits of steady state- state voltage and steady-state power, included are evaluations of the adequacy of reactive-power support at buses, system strength and so on. Eg) Steady state voltage control between FACTS-HVDC for ac voltage regulation.

5. What is the analysis method used to determine the steady state interaction?

To determine this interaction Load-Flow and Stability programs are used.

6. What is meant by electromechanical oscillation interaction?

Electromechanical oscillation interaction between FACTS controllers involve synchronous generators, compensator machines and associated power system stabilizer control. The oscillations include local mode oscillations typically in the range of 0.8 - 2 Hz, and inter-area mode oscillations, typically in the range of 0.2 - 0.8 Hz. The local mode is contributed by synchronous generators in a plant or several generators located in close vicinity, the inter-area mode results from the power exchange between tightly coupled generators in two areas linked by weak transmission lines.

7. What is the analysis methods used to determine the electromechanical oscillation interaction?

To determine this interaction eigen value analysis programs are used.

8. What is meant by control or small signal oscillation interactions?

Controller interactions between individual FACTS controllers and the network or between FACTS controllers and HVDC links may lead to the onset of oscillations in the range of 2 - 15 Hz. These oscillations are largely dependent on the network strength and the choice of FACTS controller parameters, and they are known to result from the interaction between voltage controllers of multiple SVC's, the series resonance between series capacitors and shunt reactors in the frequency range of 4 - 15 Hz and so forth. The emergence of these oscillations significantly influences the tuning of controller gain.

9. What are the analysis methods used to determine the control or small signal oscillation interaction?

These high frequency oscillation interactions are determined by frequency scanning programs, electromagnetic transient programs (EMTP's), Physical simulators and eigen value analysis programs.

10. What is meant by sub synchronous resonance interactions?

Sub synchronous oscillations may be caused by the interaction between the generator torsional system and the series compensated transmission lines, the HVDC converters, the generator excitation control or even the SVC's. Theses oscillations usually in the frequency range of 10 - 50/60 Hz, can potentially damage generator shafts.

11. What are the analysis methods used to determine the sub synchronous resonance interactions?

These SSR oscillation interactions are determined by frequency scanning programs, electromagnetic transient programs (EMTP's), Physical simulators and eigen value analysis programs.

12. What is meant by high frequency interaction?

High-frequency oscillations in excess of 15 Hz are caused by large nonlinear disturbances, such as the switching of capacitors, reactors, or transformers for which reason they are classified as electromagnetic transients. FACTS controllers need to be co-ordinated to minimize such interactions.

13. What causes the geomagnetically induced currents (GIC's) during controller interactions?

Transformer saturation causes the geomagnetically induced currents (GIC's) during controller interactions.

<u>16 MARKS:</u>

1. Using linear control techniques, explain the co-ordination of multiple controllers.
2. Explain the controller interactions between multiple SVCs (SVC-SVC) in a large power system.
3. Explain the FACTS controller interactions with similar, dissimilar HVDC controller links.
4. Describe the genetic algorithm based control co-ordination of FACTS controllers.
5. Explain the co-ordination of multiple controllers using genetic algorithm.