Final Assignment

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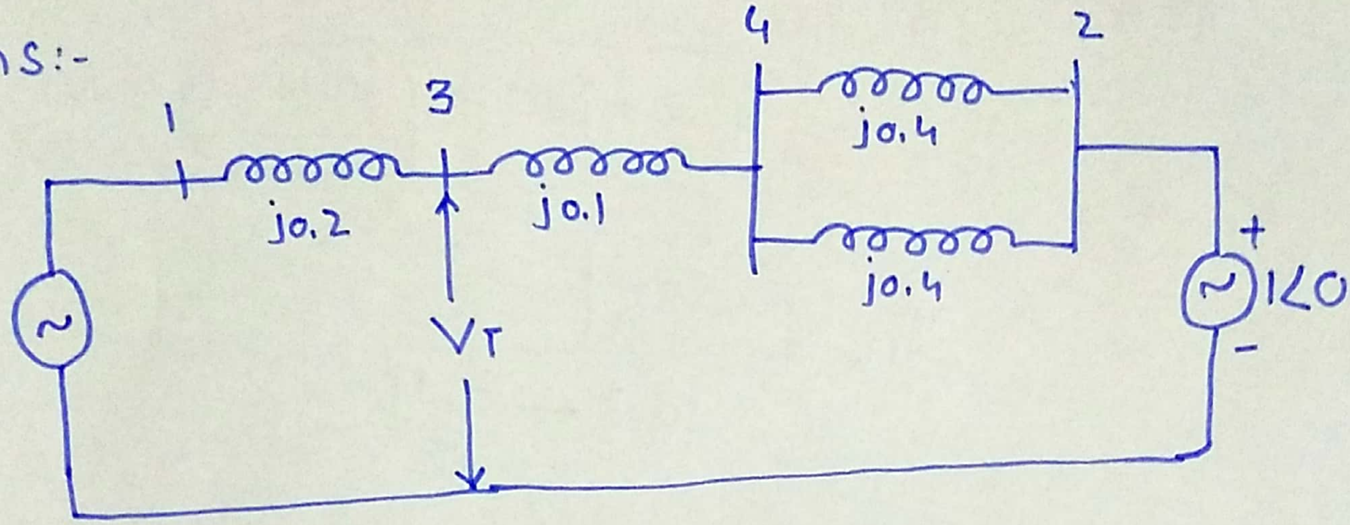
Q1

Ans:-



Given

$V = 1.0\angle 0°$ P.U

$X_d = 0.2$ P.U

Transformer = X_T = 0.1 P.U

Transmission Line = $X_{T/L}$ = 0.4 P.U

Terminal Voltage = 1.1 P.U

Power = P = 0.9 P.U

Inertia Constant = H = 6 MJ/MVA

Required:-

Equation of Motion of the machine = ?

Solution:-

Here $\bar{y}_{12} = \dfrac{1}{j0.2 + j0.1 + \left(\dfrac{j0.4 \times j0.4}{j0.4 + j0.4}\right)}$

$$\bar{y}_{12} = \frac{1}{j0.3 - \frac{0.16}{j0.8}}$$

$$\bar{y}_{12} = \frac{1}{0.3 + j0.2}$$

$$\boxed{\bar{y}_{12} = -j2}$$

$\therefore$ $\boxed{\bar{y}_{10} = 0}$

$\therefore$ $\bar{Y}_{11} = \bar{y}_{12} + \bar{y}_{10}$

$\bar{Y}_{11} = -j2 + 0 \Rightarrow \boxed{\bar{Y}_{11} = -j2}$

$\theta_{11} = -\pi/2 \Rightarrow \boxed{Y_{11} \angle \theta_{11}}$

and $\bar{Y}_{12} = -\bar{y}_{12}$

$\bar{Y}_{12} = -(-j2) \Rightarrow \boxed{\bar{Y}_{12} = j2}$

$\theta_{12} = \pi/2 \Rightarrow Y_{12} \angle \theta_{12}$

$\therefore (Y_{11} = 2$ and $Y_{12} = 2)$

$P_c = 0$ and $\gamma = 0$

$P_e = P_1 = P_c + E V Y_{12} \sin(\delta - \gamma)$

$\quad " \quad " = 0 + E \times 1 \times 2 \sin(\delta - 0)$

$\boxed{\quad " \quad " = 2E \sin \delta}$

and

$P_{eo} = 2E \sin \delta_o = 0.9$

$E \sin \delta_o = \frac{0.9}{2}$

$\boxed{E \sin \delta_o = 0.45}$

Now to find the initial Conditions

$P_{eo} = \frac{V V_t}{X} \sin \theta_{to}$

$0.9 = \frac{1.1 \times 1}{0.1 + (j0.4 || j0.4)} \sin \theta_{to}$

$$\sin\theta_{to} = \frac{0.9}{3.5}$$

$$\sin\theta_{to} = 0.25 \Rightarrow \boxed{\theta_{to} = 14.21^\circ}$$

Now

$$\text{Current} = \bar{I} = \frac{\bar{V}t - \bar{V}}{\bar{Z}}$$

$$'' \quad = I = \frac{1.1\angle 14.21 - 1\angle 0}{j0.3}$$

$$'' \quad = I = \frac{1.066 + j0.27 - 1}{j0.3}$$

$$'' \quad = I = \frac{0.277\angle 76.26}{0.3\angle 90^\circ}$$

$$'' \quad = \boxed{I = 0.923\angle -13.74^\circ}$$

Now

Internal Machine Angle

$$E\angle\delta = Vt + \bar{I} \cdot \bar{X}d$$

$$E\angle\delta = 1.1\angle 14.21 + (0.923\angle -13.74)(0.2\angle 90^\circ)$$

$$E\angle\delta = 1.07 + j0.27 + 0.184\angle 76.24$$

$E\angle\delta = 1.07 + j0.27 + 0.04 + 0.18j$

$E\angle\delta = 1.11 + j0.45$

$E\angle\delta = 1.20\angle 22.07^\circ$

E = Constant During Transients

$\delta_0 = 22.07 \Rightarrow 0.385$ rad

So

$P_e = E V Y_{12} \sin\delta$

$P_e = 1.20 \times 1 \times 2 \sin\delta$

$P_e = 2.4 \sin\delta$

Swing Equation:-

$$\frac{2H}{W_r}\frac{\partial^2\delta}{\partial t^2} = P_m - P_e$$

$$\frac{\partial^2 \delta}{\partial t^2} = \left(0.9 - 2.4 \, Sin \, \delta\right) \frac{377}{2 \times 6}$$

$$\boxed{\frac{d^2 \delta}{d t^2} = \left(0.9 - 2.4 \, Sin \, \delta\right) \frac{377}{12} \; rad/sec^2}$$

Non Linear Equation solved with Numerical method

Q2

Ans:-

$$\bar{y}_{12} = -j\left(\frac{3.33 \times 5}{18.33}\right)$$

$$\boxed{\bar{y}_{12} = -j0.909}$$

(Product of admittance between 1 and 2 Node and Divide by the sum of admittance)

$$\boxed{\bar{Y}_{12} = -\bar{y}_{12} = j0.909}$$

$$P_e = E V Y_{12} \sin\delta$$

$$P_e = 1.20 \times 1 \times 0.909 \sin\delta$$

$$\boxed{P_e = 1.09 \sin\delta}$$

Equation of Motion:-

$$\frac{\partial^2 \delta}{\partial t^2} = \frac{377}{12}\left(0.9 - 1.09 \sin \delta\right)$$

At the start of transient

$$\sin \delta_0 = \sin(22.07) = 0.375$$

$$\frac{\partial^2 \delta}{\partial t^2} = \frac{377}{12}\left(0.9 - 1.09 \times 0.375\right)$$

$$\frac{\partial^2 \delta}{\partial t^2} = 15.43 \text{ rad/sec}^2$$

Fault cleared by the open Line

$$X_{eq} = 0.2 \text{ p.u} + 0.1 \text{ p.u} + 0.4 \text{ p.u}$$

$$X_{eq} = 0.7 \text{ p.u}$$

$$\bar{Y}_{12} = j1.502 \text{ p.u}$$

Equation of Motion:-

$$\frac{d^2\delta}{dt^2} = \frac{377}{2\times 6}\left(0.9 - 1.732 \sin\delta\right)$$

$$\boxed{\frac{d^2\delta}{dt^2} = 31.4\left(0.9 - 1.732 \sin\delta\right)}$$

Question # 3

a) Evaluate the synchronizing power and natural frequency of oscillations. Do they affect power system stability?

Answer:

Synchronizing power coefficients

- Consider a machine connected to an infinite bus, i.e. the voltage V is always held at 1 pu
- The initial power delivered by the machine be Poat δo
- Assume a change of δΔ which corresponds a change of PΔ

$$P_0 + P_\Delta = P_M \sin(\delta_0 + \delta_\Delta) = P_M(\sin\delta_0 \cos\delta_\Delta + \cos\delta_0 \sin\delta_\Delta)$$

If δ_Δ is small then, approximately, $\cos\delta_\Delta \cong 1$ and $\sin\delta_\Delta \cong \delta_\Delta$, or

$$P_0 + P_\Delta \cong P_M \sin\delta_0 + (P_M \cos\delta_0)\delta_\Delta$$

and since $P_0 = P_M \sin\delta_0$,

$$P_\Delta = (P_M \cos\delta_0)\delta_\Delta$$

Synchronizing power ⟶ $P_s \triangleq P_M \cos\delta_0 = \left.\frac{\partial P}{\partial \delta}\right]_{\delta=\delta_0}$

Power-angle curve of a synchronous machine

- In the above analysis the appropriate values of x and E should be used to obtain PM.
- In dynamic studies xd' and the voltage E' are used, while in steady-state stability analysis a saturated steady-state reactance xdis used.
- If the control equipment of the machine is slow or inoperative, it is important that the machine be operating such that $0 < \delta < \pi/2$ for the operating point to be stable in the static or steady-state sense.

Natural Frequencies of Oscillation of a Synchronous Machine

- After disturbances, the synchronous machine has several modes of oscillation with respect to the rest of the system, causing fluctuations in bus voltages, system frequencies, and tie-line power flows.
- These oscillations should be small in magnitude and should be damped for stable power system operation
- If a unit step function is applied to the generator connected to an infinite bus, then

$$\omega = \omega_0 + \epsilon u(t).$$

Swing equation → $$M\ddot{\delta}/S_{B3} + P_e = P_m.$$

let $\delta = \delta_0 + \delta_\Delta$ such that $\ddot{\delta} = \ddot{\delta}_\Delta$

$P_e = P_{e0} + P_{e\Delta}$; P_m is constant

Then $M\ddot{\delta}_\Delta/S_{B3} + P_{e\Delta} = P_m - P_{e0} = 0$

for small δ_Δ we write $P_{e\Delta} = P_s\delta_\Delta$

Swing equation → $$M\ddot{\delta}_\Delta/S_{B3} + P_s\delta_\Delta = 0$$

Natural frequency of Oscillation

$$\delta_\Delta(t) = \epsilon\sqrt{\frac{M}{P_s S_{B3}}}\sin\sqrt{P_s S_{B3}/M}\, t \text{ elect rad}$$

$$M/S_{B3} = 2H/\omega_m \text{ or } P_s S_{B3}/M = P_s\omega_m/2H$$

For example, a system having $P_s/S_{B3} = 2$ pu, $H = 8$,

$$\omega_{osc} = \sqrt{(2 \times 377)/(2 \times 8)} = 6.85 \text{ rad/s}$$

$$f_{osc} = 6.85/2\pi = 1.09 \text{ Hz}$$

System of two finite machines can be reduced to a single equivalent finite machine against an infinite bus

Equivalent inertia: $J1 \bullet J2/(J1+J2)$

Angle: $\delta 1\Delta - \delta 2\Delta$

- Thus each machine oscillates with respect to other machines, each coherent group of machines oscillates with respect to other groups of machines, and so on.
- The frequencies of oscillations depend on the synchronizing power coefficients and on the inertia constants.

Effect of synchronizing power:

When a synchronous machine is operating in parallel with other machines or connected to a supply system their frequencies at steady state is the same. Now if a small disturbance in the form of change in input or output or any minor disturbance to the machine occurs, this disturbing torque is countered by the generation of restoring torque. This restoring torque is called the synchronizing torque which in terms of power is known as 'synchronizing power'.

When you mark the operating point of this generator on the power angle curve, say at any power angle d, then the slope at this angle on the curve is the synchronizing power.

Neglecting machine and line resistances, at any power angle d:

P = (EV/Xd) sin d ←— Power developed by the machine

(dP/dd) = (EV/Xd) cos d ←— synchronizing Power developed by the machine

where E=induced emf of generator, V= bus bar voltage, Xd= synchronous reactance of the generator.

Note that the synchronizing power at d = 90 deg is zero whereas the power developed is maximum.

Effect of natural frequency of oscillations:

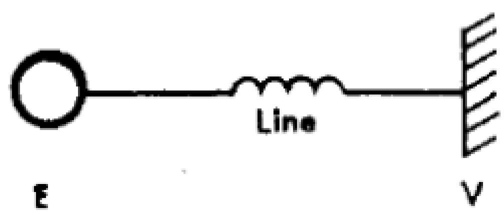
After disturbances, the synchronous machine has several modes of oscillation with respect to the rest of the system, causing fluctuations in bus voltages, system frequencies, and tie-line power flows. These oscillations should be small in magnitude and should be damped for stable power system operation.

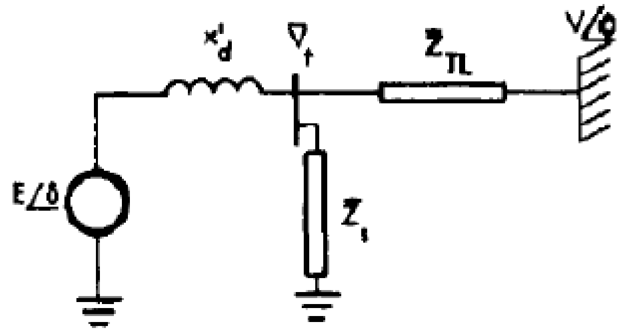
b) Why it is assumed in the classical model of one machine system that mechanical power input remains constant during the transient period?

Answer:

Classical Model of one Machine system against an Infinite system

- An infinite bus (source of invariable frequency and voltage) is the major bus of a power system of very large capacity compared to the rating of the machine under consideration.
- Consider a power system consisting of one machine connected to an infinite bus through a transmission line





Swing equation provides the equation of motion of the rotor of the finite machine and it require development of expressions for the mechanical and the electrical powers

- Period of interest is the first swing of the rotor angle **δ** (usually on the order of one second or less).
- At the start of the transient, the rotor angle increases and if it increases indefinitely, the machine loses synchronism and stability is lost. If it reaches a maximum and then starts to decrease, the resulting motion will be oscillatory and with constant amplitude. Thus according to this model and the assumptions used, stability is decided in the first swing.

Classical Model of one Machine system against an Infinite system

Assumptions:

–The mechanical power input remains constant during the period of the transient.

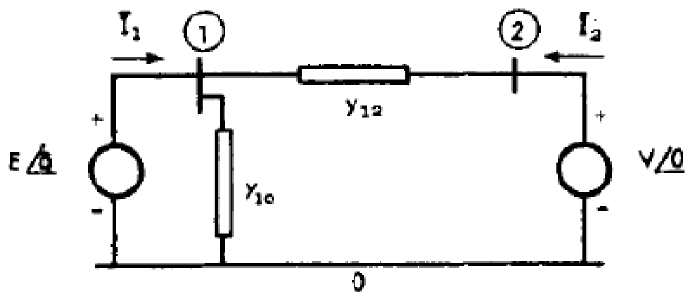
–Damping or asynchronous power is negligible

–Synchronous machine can be electrically represented by a constant voltage source with a transient reactance

–Rotors mechanical angle coincides with the electrical phase angle of the voltage

–Local load at the terminal voltage of machine can be represented as constant impedance (admittance)

Terminal voltage VT is eliminated with Y-Δ transformation.



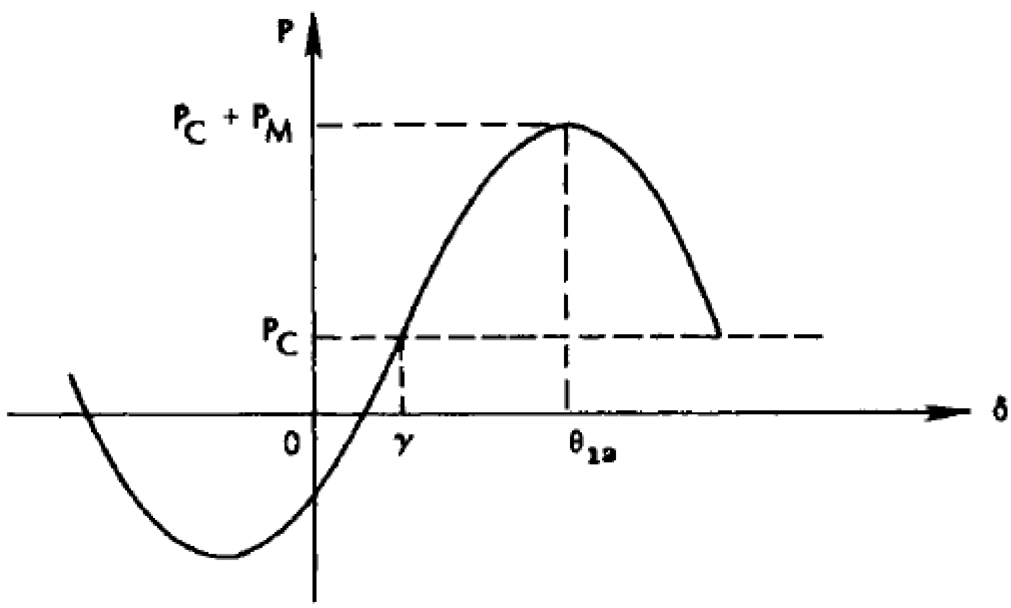
$$\begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \end{bmatrix} = \begin{bmatrix} \bar{Y}_{11} & \bar{Y}_{12} \\ \bar{Y}_{21} & \bar{Y}_{22} \end{bmatrix} \begin{bmatrix} \bar{E} \\ \bar{V} \end{bmatrix}$$

Power at node **1** is given by P1= ***Real (EI*)*** = (E^2) Y11 cosθ11+ EVY12cos(θ12-δ)

- Definig, G11≈ Y11cosθ11and γ = θ12–π/2, then P1= (E^2) G11 + EVY_{12} sin(δ-γ) = PC+ PMsin(δ-γ)

Question:4

The power-angle curve of a synchronous machine connected to an infinite bus is provided in Figure 3, where the sine curve displaced from the origin vertically by an amount Pc and horizontally by the angle γ. Illustrate in few words, what Pc and γ represents?



Answer:

Power-angle curve of a synchronous machine connected to an infinite bus is a sine curve displaced from the origin vertically by an amount ***Pc,*** which represents the power dissipation in the equivalent network, and horizontally by the angle ɤ, which is determined by the real component of the transfer admittance **Y12.**

In the special case where the shunt load at the machine terminal is open and where the transmission network is reactive, we can easily prove that Pc = 0 and ϒ= 0.

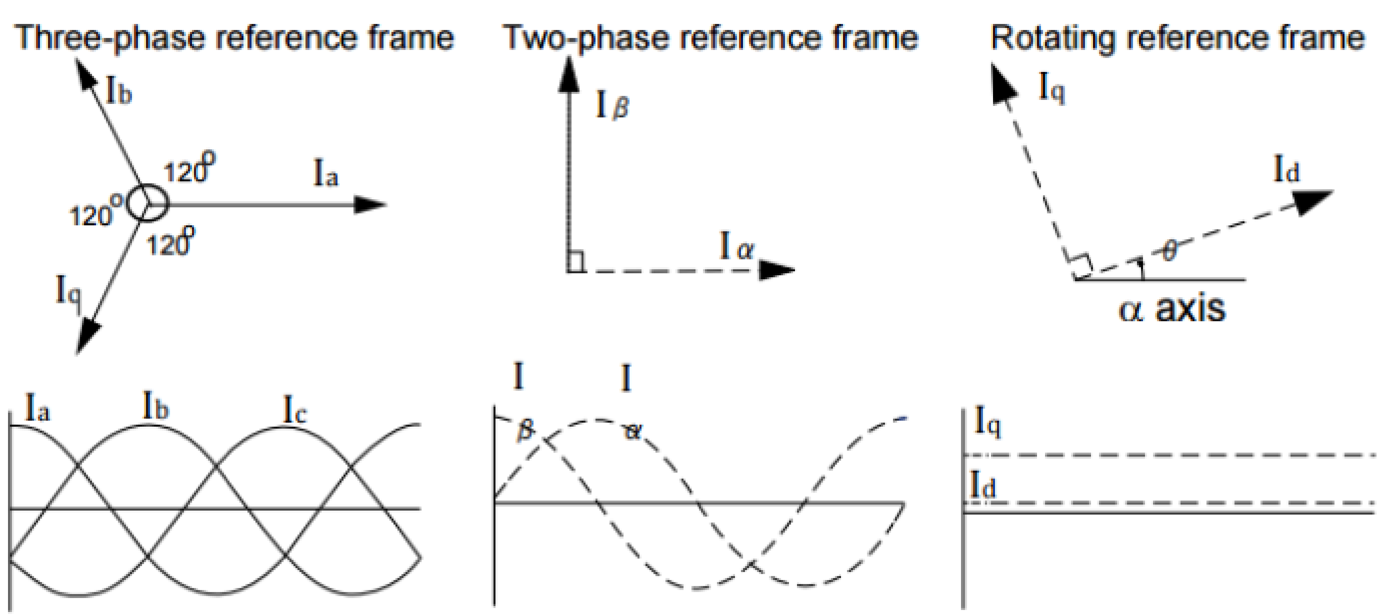
Question # 5

a) Illustrate why three phase quantities (abc) are transformed two phase quantities dq0?

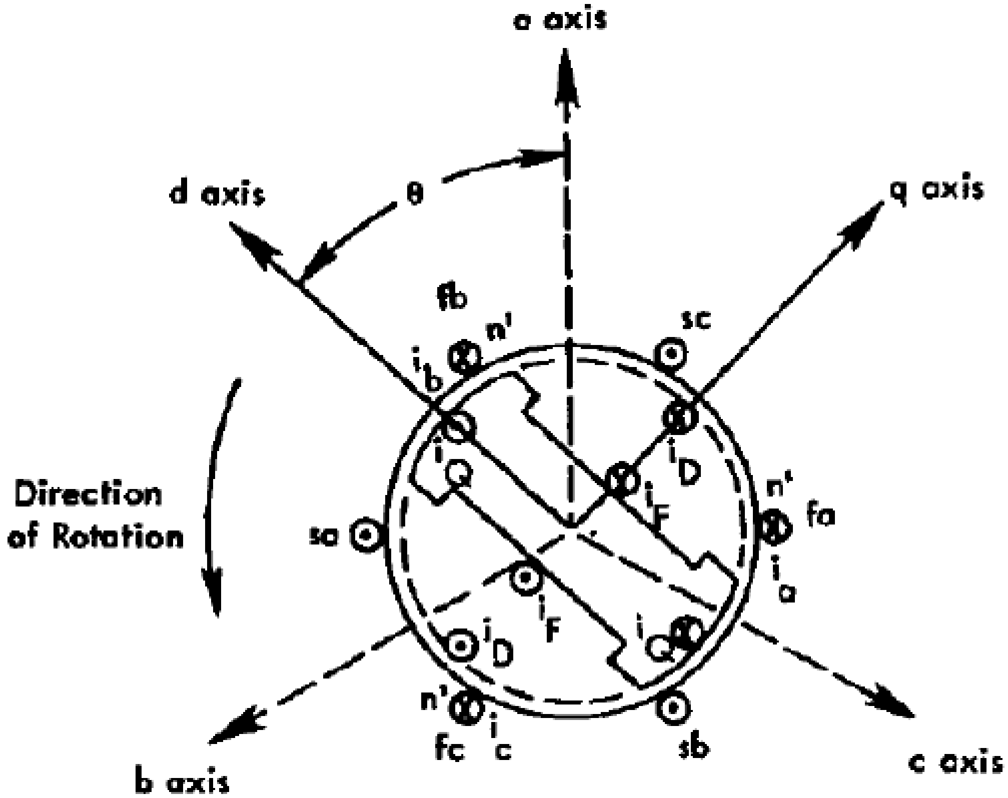
Answer:

Park's or dq0 transformation

- New set of stator variables such as currents, voltages, or flux linkages are obtained from the projection of the actual variables on three axes; one along the direct axis of the rotor field winding, called the direct axis; a second along the neutral axis of the field winding, called the quadrature axis; and the third on a stationary axis.
- The transformation converts vectors in balanced two-phase orthogonal stationary system into orthogonal rotating reference frame.
- Three-phase reference frame, in which Ia, Ib, and Ic are co-planar three phase quantitiesatof120degreestoeachother.
- Orthogonal stationary reference frame, in which Iα (along α axis) and Iβ (along β axis) are perpendicular to each other, but in the same plane as the three-phase reference frame.
- Orthogonal rotating reference frame, in which Id is at an angle θ (rotation angle) to the α axis and Iq is perpendicular to Id along the q axis.



Pictorial representation of a synchronous machine



Define the *d* axis of the rotor at some instant of time to be at angle Θ radians with respect to a fixed reference position and project the stator phase currents ia, iband ic, (currents leaving the generator terminals) along the d and *q axes of the rotor*

$$
\begin{aligned}
i_d &= k_d \left[i_a \cos\theta + i_b \cos\left(\theta - \frac{2\pi}{3}\right) + i_c \cos\left(\theta + \frac{2\pi}{3}\right) \right] \\
i_q &= -k_q \left[i_a \sin\theta + i_b \sin\left(\theta - \frac{2\pi}{3}\right) + i_c \sin\left(\theta + \frac{2\pi}{3}\right) \right]
\end{aligned}
$$

The constants *kd* and *kq* are arbitrary and in most synchronous machine literature their value is selected to be 2/3, then the peak values of *id*and *iq*become equal to the peak values of the stator currents.

In order to be able to transform the stator currents over to the rotor side and then back again, an equation system with three equations and three unknowns is needed.

- A third component must therefore be defined.
- Since id and iq together produce a field identical to that produced by the original set of stator currents, the third component must not produce field in the air gap.
- Therefore, the zero sequence current i0is used as the third component in the transformation.

i0=1/3 (ia+ ib+ ic)

- The transformation from the abc phase variables over to the $dq0$ variables can be written in the following matrix form:

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ -\sin\theta & -\sin(\theta - 2\pi/3) & -\sin(\theta + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

- The inverse transformation becomes:

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 1 \\ \cos(\theta - 2\pi/3) & -\sin(\theta - 2\pi/3) & 1 \\ \cos(\theta + 2\pi/3) & -\sin(\theta + 2\pi/3) & 1 \end{bmatrix}\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix}$$

b) Relate the concept of power system stability with power system security and power system reliability.

Answer:

Relationship between the Concepts of Reliability, Security and Stability of a Power System

(a) Power System Stability:

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.

The definition applies to an interconnected power system as a whole. Often, however, the stability of a particular generator or group of generators is also of interest. A remote generator may lose stability (synchronism) without cascading instability of the main system. Similarly, stability of particular loads or load areas may be of interest; motors may lose stability (run down and stall) without cascading instability of the main system.

The power system is a highly nonlinear system that operates in a constantly changing environment; loads, generator outputs and key operating parameters change continually. When subjected to a disturbance, the stability of the system depends on the initial operating condition as well as the nature of the disturbance.

Stability of an electric power system is thus a property of the system motion around an equilibrium set, i.e., the initial operating condition. In an equilibrium set, the various opposing forces that exist in the system are equal instantaneously (as in the case of equilibrium points) or over a cycle (as in the case of slow cyclical variations due to continuous small fluctuations in loads or aperiodic attractors).

Power systems are subjected to a wide range of disturbances, small and large. Small disturbances in the form of load changes occur continually; the system must be able to adjust to the changing conditions and operate satisfactorily. It must also be able to survive numerous disturbances of a severe nature, such as a short circuit on a transmission line or loss of a large generator. A large disturbance may lead to structural changes due to the isolation of the faulted elements.

At an equilibrium set, a power system may be stable for a given (large) physical disturbance, and unstable for another. It is impractical and uneconomical to design power systems to be stable for every possible disturbance. The design contingencies are selected on the basis they have a reasonably high probability of occurrence. Hence, large-disturbance stability always refers to a specified disturbance scenario. A stable equilibrium set thus has a finite region of attraction; the larger the region, the more robust the system with respect to large disturbances. The region of attraction changes with the operating condition of the power system.

The response of the power system to a disturbance may involve much of the equipment. For instance, a fault on a critical element followed by its isolation by protective relays will cause variations in power flows, network bus voltages, and machine rotor speeds; the voltage variations will actuate both generator and transmission network voltage regulators; the generator speed variations will actuate prime mover governors; and the voltage and frequency variations will affect the system loads to varying degrees depending on their individual characteristics. Further, devices used to protect individual equipment may respond to variations in system variables and cause tripping of the equipment, thereby weakening the system and possibly leading to system instability.

If following a disturbance, the power system is stable, it will reach a new equilibrium state with the system integrity preserved i.e., with practically all generators and loads connected through a single contiguous transmission system. Some generators and loads may be disconnected by the isolation of faulted elements or intentional tripping to preserve the continuity of operation of bulk of the system. Interconnected systems, for certain severe disturbances, may also be intentionally split into two or more “islands” to preserve as much of the generation and load as possible. The actions of automatic controls and possibly human operators will eventually restore the system to normal state. On the other hand, if the system is unstable, it will result in a run- away or run-down situation; for example, a progressive increase in angular separation of generator rotors, or a progressive decrease in bus voltages. An unstable system condition could lead to cascading outages and a shutdown of a major portion of the power system.

Power systems are continually experiencing fluctuations of small magnitudes. However, for assessing stability when subjected to a specified disturbance, it is usually valid to assume that the system is initially in a true steady-state operating condition.

Power system stability refers to the continuance of intact operation following a disturbance and it depends on the operating condition and the nature of the physical disturbance. a system may be stable following a contingency, yet insecure due to post-fault system conditions resulting in equipment overloads or voltage violations. Stability is a time-varying attribute which can be judged by studying the performance of the power system under a particular set of conditions.

(b) Power System Security:

The degree of risk in the ability to survive imminent disturbances (contingencies) without interruption of customer service is known as power system security and it depends on the system operating condition as well as the contingent probability of disturbances. To be secure the system must be stable but must also be secure against other contingencies that would not be classified as stability problems, e.g. damage to equipment such as an explosive failure of a cable, fall of transmission towers due to ice loading or sabotage. System security may be further distinguished from stability in terms of the resulting consequences.
–For example, two systems may both be stable with equal stability margins, but one may be relatively more secure because the consequences of instability are less severe
Security is a time-varying attribute which can be judged by studying the performance of the power system under a particular set of conditions.

An overriding factor in the operation of a power system is the desire to maintain system security. System security involves practices designed to keep the system operating when components fail. For example, a generating unit may have to be taken off-line because of auxiliary equipment failure. By maintaining proper amounts of spinning reserve, the remaining units on the system can make up the deficit without too low a frequency drop or need to shed any load. Similarly, a transmission line may be damaged by a storm and taken out by automatic relaying. If, in committing and dispatching generation, proper regard for transmission flows is maintained, the remaining transmission lines can take the increased loading and still remain within limit.

Because the specific times at which initiating events that cause components to fail are unpredictable, the system must be operated at all times in such a way that the system will not be left in a dangerous condition should any credible initiating event occur. Since power system equipment is designed to be operated within certain limits, most pieces of equipment are protected by automatic devices that can cause equipment to be switched out of the system if these limits are violated. If any event occurs on a system that leaves it operating with limits violated, the event may be followed by a series of further actions that switch other equipment out of service. If this process of cascading failures continues, the entire system or large parts of it may completely collapse. This is usually referred to as a system blackout.

An example of the type of event sequence that can cause a blackout might start with a single line being opened due to an insulation failure; the remaining transmission circuits in the system will take up the flow that was flowing on the now-opened line. If one of the remaining lines is now too heavily loaded, it may open due to relay action, thereby causing even more load on the remaining lines. This type of process is often termed a cascading outage. Most power systems are operated such that any single initial failure event will not leave other components heavily overloaded, specifically to avoid cascading failures.

Most large power systems install equipment to allow operations personnel to monitor and operate the system in a reliable manner. We will lump these under the commonly used title system security. Systems security can be broken down into three major functions that are carried out in an operations control center:

1. System monitoring. 2. Contingency analysis. 3. Security-constrained optimal power flow.

System monitoring provides the operators of the power system with pertinent up-to-date information on the conditions on the power system. Generally speaking, it is the most important function of the three. From the time that utilities went beyond systems of one unit supplying a group of loads, effective operation of the system required that critical quantities be measured and the values of the measurements be transmitted to a central location. Such systems of measurement and data transmission, called telemetry systems, have evolved to schemes that can monitor voltages, currents, power flows, and the status of circuit breakers, and switches in every substation in a power system transmission network. In addition, other critical information such as frequency, generator unit outputs and transformer tap positions can also be telemetered. With so much information telemetered simultaneously, no human operator could hope to check all of it in a reasonable time frame. For this reason, digital computers are usually installed in operations control centers to gather the telemetered data, process them, and place them in a data base from which operators can display information on large display monitors. More importantly, the computer can check incoming information against prestored limits and alarm the operators in the event of an overload or out-of-limit voltage.

State estimation is often used in such systems to combine telemetered system data with system models to produce the best estimate (in a statistical sense) of the current power system conditions or “state.”. Such systems are usually combined with supervisory control systems that allow operators to control circuit breakers and disconnect switches and transformer taps remotely. Together, these systems are often referred to as SCADA systems, standing for supervisory control -- and data acquisition system. The SCADA system allows a few operators to monitor the generation and high-voltage transmission systems and to take action to correct overlords or out-of-limit voltages.

The second major security function is contingency analysis. The results of this type of analysis allow systems to be operated defensively. Many of the problems that occur on a power system can cause serious trouble within such a quick time period that the operator could not take action fast enough. This is often the case with cascading failures. Because of this aspect of systems operation, modern operations computers are equipped with contingency analysis programs that model possible systems troubles before they arise. These programs are based on a model of the power system and are used to study outage events and alarm the operators to any potential overlords or out-of-limit voltages. For example, the simplest form of contingency analysis can be put together with a standard power-flow program together with procedures to set up the power-flow data for each outage to be studied by the power-flow program. Several variations of this type of contingency analysis scheme involves fast solution methods, automatic contingency event selection, and automatic initializing of the contingency power flows using actual system data and state estimation procedures.

The third major security function is security-constrained optimal power flow. In this function, a contingency analysis is combined with an optimal power flow which seeks to make changes to the optimal dispatch of generation, as well as other adjustments, so that when a security analysis is run, no contingencies result in violations. To show how this can be done, we shall divide the power system into four operating states.

- **Optimal dispatch** this is the state that the power system is in prior to any contingency. It is optimal with respect to economic operation, but it may not be secure.
- **Post contingency**: is the state of the power system after a contingency has occurred. We shall assume here that this condition has a security violation (line or transformer beyond its flow limit, or a bus voltage outside the limit).
- **Secure dispatch:** is the state of the system with no contingency outages, but with corrections to the operating parameters to account for security violations.
- **Secure post-contingency**: is the state of the system when the contingency is applied to the base-operating condition-with corrections.

(c) Power System Reliability:

Power system reliability shows the probability of satisfactory operation over the long run and it denotes the ability to supply adequate electric service on a nearly continuous basis, with few interruptions over an extended time period Reliability is the overall objective in power system design and operation. To be reliable the power system must be secure most of the time. Reliability, on the other hand, is a function of the time-average performance of the power system. It can only be judged by consideration of the system's behavior over an appreciable period of time. For reliable service, a power system must remain intact and be capable of withstanding a wide variety of disturbances It is usually impractical to achieve stable operation for all possible disturbances or contingencies. The general practice is to design and operate the power system so that the more probable contingencies can be sustained without loss of system integrity.

- "Normal Design Contingencies"

Loss of any single element, either spontaneously or proceeded by a fault This is referred to as the "N-1 criterion" because it examines the behavior of an N-component grid following the loss of any one major components. Events that exceed the severity of normal design contingencies can in fact occur:

- "Extreme Contingencies"

Measures should be taken to minimize their occurrence and impact

The basic function of an electric power system is to satisfy the system load requirements as economically as possible and with a reasonable assurance of continuity and quality. In order to achieve the required degree of reliability, power system managers, designers, planners and operators have utilized a wide range of criteria in their respective areas of activity. Initially all of these criteria were deterministically based and many of these criteria and associated techniques are still in use today. The basic weakness of deterministic criteria is that they do not respond to nor do they reflect the probabilistic or stochastic nature of system behavior, of customer demands, or of component failures. These factors can be incorporated in a probabilistic approach to electric power system reliability assessment and a wide range of techniques and criteria are available.

Electrical power systems are very complex and highly integrated. Failure in any part of the system can cause interruptions of supply to end users. Power system reliability is increasingly a concern to the power industry and society at large. At present, power system operations are to be handled in a heterogeneous environment. Generally, reliability analysis is being carried out during planning stage of power system operations. In order to maintain the operational state of the power systems at the required levels and subsequently to meet the load demand satisfactorily, the power system operations such as state estimation, reliability analysis etc., are to be carried out at frequent intervals. Perhaps, the above operations have to be invoked dynamically whenever the power system resumes its operation back after had experienced sudden failure or outage. Reliability analysis has to be carried out at regular intervals during operating period of power systems in order to monitor the customer requirement satisfaction at desired levels. The reliability evaluation system should be dynamically adaptable to the current operating conditions of the power systems.

The primary function of a power system is to supply its customers with electrical energy as economically as possible with acceptable reliability and quality. Power system reliability is defined as the ability of the system to satisfy the customer demand. Demands for electric power with high reliability and quality have increased tremendously in the past few decades due to the digital revolution. It is expected that the requirements for high quality, reliable power supply will continue to increase in the immediate future. Customers such as commercial, industrial and residential users expect a highly reliable supply with relatively low rates. The electric power industry throughout the world is undergoing considerable changes in information systems, and Web enabled service oriented architectural models are emerging to support the integration of different power system applications. The evolving changes in power system planning and operation needs require a distributed control center that is decentralized, integrated, flexible, and open.

Proper application of equipment also can also help to increase overall reliability. For example, not overloading equipment and applying proper protection against surges. Equipment failures cause a number of interruptions if they appear on underground circuits. Keeping track of those failures (either by year of installation or installation type) and failures of accessory and then replacing equipment with reliability indexes can help to improve reliability. Monitoring and keeping information of circuit loadings can help to distinguish circuits that may fail from thermal stress.

Poor equipment can be identified before it gets into service by conducting quality acceptance tests. These tests are particularly important for underground cables. These tests can include evaluation of slices of cables to discover voids and drosses in samples. Bad cable batches can be discovered by a high-pot test. Workmanship plays an important role in quality of underground cable splices therefore keeping track of this information can also prevent future problems. For example, if a cable splice breaks down after 6 months and if it is known who made the splice, future problems can be eradicated or prevented whether it was due to workmanship or improper manufacturing quality

Electrical utilities use different inspection programs and methods to improve overall system reliability. For example, in visual inspections the maintenance teams often find gross problems such as seriously degraded poles, damaged or broken conductor strands, and broken insulators. Particular electrical utilities conduct frequent and planned visual inspections but more commonly, maintenance teams inspect circuits during other activities. In some situation same teams conduct targeted, visual inspection based on circuit performance. The most efficient visual inspections are those focused on finding fault sources which may be subtle. Maintenance teams need to be educated to discover them. load shedding, system robustness against the fault occurrence are the examples. Reliability has to do more with the load end of the business and keeping all of the customers connected. The unreliability (and exposure to interruptions) of the system is mostly at the distribution end where trees, lightning, equipment failures, etc. can interrupt service to some of the customers.