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DIPLOMA WALLAH

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Practice the sample paper covered both important questions and exam patterns

Subject: Advanced Electrical Power System (EEE301) **Full Marks: 70** **Time: 3 Hours**

Instructions:

- Question No. 1 is compulsory. (7 MCQs, 2 Marks each)
- Answer any FOUR questions from the remaining (Q.2 to Q.7).
- Q.2 to Q.6 carry 14 marks each (Divided into A and B, 7 Marks each).
- Q.7 consists of Short Notes (Answer any FOUR, 3.5 Marks each).

Q.1 Choose the correct option (Compulsory - 7 x 2 = 14 Marks)

i) The primary advantage of using the Per-Unit (PU) system in power system analysis is that:

a. It eliminates the need for phase-angle calculations
b. The PU impedance of a transformer is the same on both primary and secondary sides
c. It increases the actual voltage of the system
d. It converts reactive power into active power

ii) In a load flow study, the Jacobian matrix is uniquely associated with which solution method?

a. Gauss-Seidel Method
b. Newton-Raphson Method
c. Fast Decoupled Method
d. Cramer's Rule

iii) A Swing Curve in power system stability analysis is a plot of:

a. Voltage vs. Time
b. Power Angle (δ) vs. Time
c. Active Power vs. Reactive Power
d. Frequency vs. Time

iv) Which sequence component is strictly present ONLY when there is an unsymmetrical fault involving the ground (like Line-to-Ground fault)?

a. Positive Sequence
b. Negative Sequence
c. Zero Sequence
d. Infinite Sequence

v) At a Generator Bus (PV Bus), the variables that are specified (known) beforehand are:

a. Active Power (P) and Reactive Power (Q)
b. Active Power (P) and Voltage Magnitude (|V|)
c. Voltage Magnitude (|V|) and Phase Angle (δ)
d. Reactive Power (Q) and Phase Angle (δ)

vi) Which technology enables two-way communication and real-time data monitoring in a Smart Grid?

a. Buchholz Relay
b. Advanced Metering Infrastructure (AMI)
c. Peterson Coil
d. Surge Arresters

vii) Transient stability of a power system can be significantly improved by:

a. Increasing the fault clearing time
b. Using fast-acting circuit breakers
c. Decreasing the system voltage
d. Removing all transmission lines

Answer any FOUR questions from Q.2 to Q.7

Q.2 A) What is the Per-Unit (PU) system? Write the formula to convert PU impedance from an old base to a new base. Why is it highly preferred in power system fault calculations? *(7 Marks)*

Q.2 B) Explain the step-by-step procedure of the Gauss-Seidel method for solving the power flow (load flow) problem. *(7 Marks)*

Q.3 A) Define Symmetrical Components. Explain the method of Sequence Components and how Sequence Networks (Positive, Negative, Zero) are formed for fault analysis. *(7 Marks)*

Q.3 B) Derive the Swing Equation of a synchronous generator. Explain the terms: Inertia Constant (H) and Power Angle (δ). *(7 Marks)*

Q.4 A) Explain the concept of Transient Stability in a power system. What are the key factors affecting transient stability, and how can it be improved? *(7 Marks)*

Q.4 B) Discuss the differences between an Autonomous Micro-grid and a Non-Autonomous (Grid-connected) Micro-grid. Mention their specific applications. *(7 Marks)*

Q.5 A) Differentiate between Symmetric and Asymmetric faults in an electrical system. Give examples of each. Which fault is the most severe and which is the most common? *(7 Marks)*

Q.5 B) What is the significance of Load Flow studies? Classify the buses used in power system load flow analysis and specify the known and unknown parameters for each. *(7 Marks)*

Q.6 A) Derive the expression for Maximum Power Flow under steady-state conditions for a transmission line connecting two active sources. *(7 Marks)*

Q.6 B) Discuss the concept and architecture of a Smart Grid. How does it overcome the limitations of a conventional power grid? *(7 Marks)*

Q.7 Write short notes on any FOUR of the following (4 x 3.5 = 14 Marks)

A. Jacobian Matrix in Newton-Raphson Method
B. Dynamic State Stability
C. Adverse effects of power system instability
D. Sequence Networks for a Single Line-to-Ground Fault
E. Phasor Measurement Units (PMUs) in Smart Grids

SOLUTIONS FOR SAMPLE PAPER 2

MCQ Answer Key

i) b, **ii)** b, **iii)** b, **iv)** c, **v)** b, **vi)** b, **vii)** b

Model Answers for Long Questions

Q.2 A) Per-Unit (PU) System:

The PU system normalizes electrical quantities by expressing them as a decimal fraction of a pre-defined "base" quantity.
PU Value = (Actual Value) / (Base Value).
Change of Base Formula:
$Z_{pu(new)} = Z_{pu(old)} \times [(kV_{base(old)} / kV_{base(new)})^2] \times [(MVA_{base(new)} / MVA_{base(old)})]$
Why it is preferred in Fault Calculation:
1. It eliminates the ideal transformer from the equivalent circuit, as the PU impedance of a transformer is the same whether referred to the primary or secondary side.
2. It drastically simplifies calculations in networks with multiple voltage levels.
3. Values of PU impedances for similar equipment (like transformers or generators of different ratings) fall within a narrow, predictable range, making data checking easier.

Q.2 B) Gauss-Seidel (GS) Method for Load Flow:

The Gauss-Seidel method is an iterative numerical technique used to solve the non-linear algebraic equations of load flow.
Procedure:
1. Formulate the Bus Admittance Matrix (Y_{bus}).
2. Assign initial guess values for unknown voltages. For PQ buses, assume $V = 1.0 \angle 0°$ pu. For PV buses, assume $\delta = 0°$.
3. Set the iteration counter k = 1.
4. For each PQ bus, update the voltage using the GS voltage equation, substituting the most recently calculated voltage values of other buses immediately.
5. For each PV bus, calculate the reactive power (Q). If Q violates its limits, fix Q at the limit and treat the bus as a PQ bus. If within limits, update the phase angle δ.
6. Calculate the maximum change in voltage magnitude from the previous iteration. If the change is less than a specified tolerance (ε), the solution has converged. If not, advance k = k + 1 and repeat from step 4.

Q.3 A) Symmetrical Components & Sequence Networks:

Definition: Fortescue's theorem allows an unbalanced 3-phase system to be resolved into three balanced sets of phasors: Positive Sequence (abc sequence), Negative Sequence (acb sequence), and Zero Sequence (in-phase).

Sequence Networks: For asymmetric fault analysis, the power system is modeled as three separate, decoupled networks:
1. *Positive Sequence Network:* Contains the internal voltage sources of generators and normal system impedances.
2. *Negative Sequence Network:* Similar to the positive network but contains no voltage sources, as generators only produce positive sequence voltages.
3. *Zero Sequence Network:* Contains zero sequence impedances. Current only flows if there is a path to ground (e.g., star-grounded connections).

Q.3 B) Swing Equation:

The Swing Equation dictates the dynamic behavior of a synchronous machine rotor during disturbances. Let J be the moment of inertia, θ_m be the mechanical angle, T_m be the mechanical torque, and T_e be the electrical torque.
$J (d^2\theta_m / dt^2) = T_m - T_e$
Multiplying by angular velocity ω_m:
$\omega_m J (d^2\theta_m / dt^2) = P_m - P_e$
Replacing θ_m with the electrical power angle δ and defining M as the angular momentum:
$\mathbf{M (d^2\delta / dt^2) = P_m - P_e}$
Inertia Constant (H): It is the stored kinetic energy in MJ at synchronous speed divided by the machine rating in MVA. It relates to M.
Power Angle (δ): The electrical angle by which the rotor magnetic field leads the synchronously rotating stator field. It dictates active power transfer.

Q.4 A) Transient Stability:

Concept: Transient stability is the ability of the power system to remain in synchronism after a severe and sudden disturbance, such as a large fault, loss of a generator, or line tripping.
Factors Affecting: Machine inertia (H), fault clearing time, system reactance, and pre-fault power loading.
Methods to Improve:
1. *Fast Fault Clearing:* Using high-speed circuit breakers to isolate the fault before the power angle δ swings beyond the critical clearing angle.
2. *Reduction of System Reactance:* Using parallel transmission lines or series capacitors.
3. *High-Speed Excitation Systems:* To quickly boost terminal voltage during a fault.
4. *Fast Valving:* Rapidly reducing mechanical power input (P_m) to the turbine during the fault.

Q.4 B) Autonomous vs Non-Autonomous Micro-grids:

Non-Autonomous (Grid-Connected): The micro-grid operates in parallel with the main utility grid. The main grid dictates the voltage and frequency. The micro-grid's Distributed Generators (DGs) operate in current-control mode (PQ mode) to supply specific active and reactive power. Used in industrial parks or campuses to reduce grid dependency and peak load charges.
Autonomous (Islanded): The micro-grid is disconnected from the main grid (due to a grid failure or geographical remoteness). Here, the micro-grid must establish its own voltage and frequency. The DGs must operate in voltage-control mode (V/f mode) and share the load changes using droop control. Used in remote villages, military bases, or during blackouts for critical loads.

Q.5 A) Symmetric vs Asymmetric Faults:

Symmetric Faults: Faults involving all three phases equally. The system remains balanced even during the fault.
Examples: 3-Phase Short Circuit (LLL) or 3-Phase-to-Ground (LLLG).
Severity: Most severe (highest fault current) but rarest (around 5% of all faults).
Asymmetric Faults: Faults involving one or two phases, leading to unbalanced currents and voltages.
Examples: Single Line-to-Ground (LG), Line-to-Line (LL), and Double Line-to-Ground (LLG).
Commonality: LG fault is the most common (70-80% of all faults) but generally less severe than 3-phase faults.

Q.5 B) Load Flow Significance and Bus Classification:

Significance: Determines steady-state voltage magnitudes and angles at all buses, and active/reactive power flows in lines. Essential for planning, economic dispatch, and ensuring voltage stays within limits.
Classification of Buses:
1. **Load Bus (PQ Bus):** Known: Active Power (P) and Reactive Power (Q). Unknown: Voltage magnitude ($|V|$) and phase angle (δ).
2. **Generator Bus (PV Bus):** Known: Active Power (P) and Voltage magnitude ($|V|$). Unknown: Reactive Power (Q) and phase angle (δ).
3. **Slack/Swing Bus:** Known: Voltage magnitude ($|V|$) and phase angle ($\delta = 0°$). Unknown: P and Q. It balances the real and reactive power in the system.

Q.6 A) Maximum Power Flow Derivation:

For a short transmission line with negligible resistance, having Sending end voltage $V_S = |V_S|\angle\delta$ and Receiving end voltage $V_R = |V_R|\angle 0°$, connected by a reactance X.

The complex power at the receiving end is:

$S_R = V_R \times I^*$

Where $I = (V_S - V_R) / jX$.

Solving for the real part (Active Power, P):

$P = (|V_S| \times |V_R| / X) \times \sin(\delta)$

Under steady-state, maximum power flows when $\sin(\delta) = 1$ (i.e., $\delta = 90°$).

$\mathbf{P_{max} = (|V_S| \times |V_R|) / X}$

Q.6 B) Smart Grid Concept:

Concept & Architecture: A Smart Grid modernizes the traditional electrical grid by integrating two-way digital communication, sensors, and computer-based remote control. It integrates Advanced Metering Infrastructure (AMI), SCADA, Phasor Measurement Units (PMUs), and Distributed Energy Resources (DERs) like solar and wind.

Overcoming Limitations: Conventional grids are one-way (generation to consumer), prone to cascading blackouts, and blind to real-time consumer demand. Smart Grids enable self-healing (automatic fault isolation), demand response (shifting load during peak hours), seamless integration of renewable energy, and real-time pricing.

Short Answer Solutions (Q.7)

A) Jacobian Matrix in Newton-Raphson Method: In the NR load flow method, the Jacobian matrix contains the partial derivatives of real and reactive power with respect to voltage magnitudes and phase angles. It linearly relates the small changes in specified powers to small changes in bus voltages, steering the iteration quickly towards the solution.

B) Dynamic State Stability: It is the ability of the power system to maintain stability under continuous, small disturbances (like load fluctuations). It heavily depends on the action of automatic controls like Automatic Voltage Regulators (AVR) and speed governors to dampen out low-frequency oscillations.

C) Adverse effects of power system instability: Loss of synchronism causes pole-slipping in generators, violent power swings, severe mechanical stress on turbine-generator shafts, large voltage dips, tripping of transmission lines, and can lead to cascading failures causing wide-area blackouts.

D) Sequence Networks for a Single Line-to-Ground Fault: In an LG fault on phase A, the fault current flows to the ground. Using symmetrical components, this fault condition forces the Positive, Negative, and Zero sequence currents to be equal. Therefore, the equivalent circuit is formed by connecting the Positive, Negative, and Zero sequence networks in **Series**.

E) Phasor Measurement Units (PMUs): Devices used in Smart Grids to measure electrical waves (voltage and current phasors) on an electricity grid in real-time. They use GPS to perfectly synchronize the measurements across widely separated locations, providing a dynamic, wide-area view of grid stability.
