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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) In load flow studies, a PQ bus is also known as a:

a. Slack bus
b. Generator bus
c. Load bus
d. Reference bus

ii) The swing equation of a synchronous machine describes the relative motion of the:

a. Stator magnetic field
b. Rotor with respect to the synchronously rotating stator field
c. Load angle with respect to terminal voltage
d. None of the above

iii) The per-unit (PU) impedance of a transformer is:

a. Larger on the primary side
b. Larger on the secondary side
c. The same whether calculated from the primary or secondary side
d. Always zero

iv) A micro-grid that operates completely independently of the main utility grid is called an:

a. Autonomous micro-grid
b. Non-autonomous micro-grid
c. Smart grid
d. Interconnected grid

v) Which of the following is considered an asymmetric fault?

a. Three-phase short circuit
b. Three-phase to ground fault
c. Single line-to-ground fault
d. All of the above

vi) The active power flow in a transmission line is predominantly governed by the:

a. Voltage magnitude difference between the two ends
b. Power angle (delta) difference between the two ends
c. Line resistance only
d. Reactive power generated

vii) In the Gauss-Seidel method for load flow solutions, the number of iterations required generally:

a. Increases directly with the number of buses
b. Decreases with the number of buses
c. Is completely independent of the number of buses
d. Is always exactly three

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

Q.2 A) What is the significance of load flow studies in a power system? Classify and explain the different types of buses used in power flow analysis. *(7 Marks)*

Q.2 B) Explain the concept of the Per-Unit (PU) system. Derive the expression for changing the base impedance from an old base to a new base. *(7 Marks)*

Q.3 A) Derive the Swing Equation of a synchronous machine and clearly state the significance of the power angle (δ). *(7 Marks)*

Q.3 B) Define symmetrical components. Explain how the method of sequence components is used to analyze asymmetric faults in a power system. *(7 Marks)*

Q.4 A) What is a Smart Grid? Discuss the basic architecture and the key technologies involved in a modern smart grid system. *(7 Marks)*

Q.4 B) Differentiate between Steady-State Stability and Transient Stability. Explain the various methods used to improve the transient stability of a power system. *(7 Marks)*

Q.5 A) Define a Micro-grid. Differentiate between autonomous and non-autonomous micro-grids, and briefly explain the operation of micro-grids with multiple Distributed Generators (DGs). *(7 Marks)*

Q.5 B) Compare the Gauss-Seidel method and the Newton-Raphson method for load flow solutions. Which method is generally preferred for large systems and why? *(7 Marks)*

Q.6 A) Discuss the nature of faults in an electrical system. Differentiate between symmetric and asymmetric faults with suitable examples. *(7 Marks)*

Q.6 B) Derive the expression for maximum active power flow under steady-state conditions in a transmission line. *(7 Marks)*

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

A. Complex Power and Power Triangle
B. Adverse effects of instability
C. Sequence Networks
D. Dynamic State Stability
E. Newton-Raphson Method features

SOLUTIONS FOR SAMPLE PAPER 1

MCQ Answer Key

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

Model Answers for Long Questions

Q.2 A) Load Flow Studies & Classification of Buses:

Significance: Load flow (or power flow) studies are essential for planning, economic scheduling, and control of an existing power system as well as planning its future expansion. They determine the voltage magnitude and phase angle at each bus, and the active/reactive power flow in each transmission line under steady-state operation[cite: 8, 10, 24].

Classification of Buses:

1. **Load Bus (PQ Bus):** Here, Active Power (P) and Reactive Power (Q) are specified. The unknowns are Voltage magnitude (|V|) and phase angle (δ). Most buses in a system are PQ buses.
2. **Generator Bus (PV Bus):** Here, Active Power (P) and Voltage magnitude (|V|) are specified. The unknowns are Reactive Power (Q) and phase angle (δ).
3. **Slack/Swing/Reference Bus:** Here, Voltage magnitude (|V|) and phase angle (δ) are specified (usually |V| = 1.0 pu and δ = 0°). It supplies the transmission losses of the entire system. P and Q are the unknowns.

Q.2 B) Per-Unit (PU) System & Changing the Base:

Concept: The Per-Unit system normalizes power system variables (Voltage, Current, Power, Impedance) by expressing them as a ratio of their actual value to an arbitrarily chosen base value.

Per-Unit Value = (Actual Value) / (Base Value).

It simplifies calculations in complex power systems with multiple voltage levels connected by transformers, as the PU impedance of a transformer is the same regardless of the side from which it is viewed.

Changing the Base Formula:

Often, equipment impedance is given on its own rating, but system analysis requires a common base.

$Z_{pu(new)} = Z_{pu(old)} \times [\ (kV_{base(old)} / kV_{base(new)})^2\ ] \times [\ (MVA_{base(new)} / MVA_{base(old)})\ ]$

Q.3 A) Swing Equation & Power Angle Significance:

Swing Equation: It describes the relative dynamics of the synchronous machine rotor with respect to a synchronously rotating reference frame under transient disturbances.
If M is the angular momentum (or inertia constant), P_m is the mechanical power input, and P_e is the electrical power output:
$M (d^2\delta / dt^2) = P_m - P_e$
Significance of Power Angle (δ): The power angle is the electrical angle between the rotor magnetic axis and the stator rotating magnetic field. It directly determines the amount of active power transferred. If δ exceeds a critical limit (usually around 90°), the generator loses synchronism with the grid.

Q.3 B) Symmetrical Components & Sequence Networks:

Symmetrical Components: Fortescue's theorem states that any unbalanced 3-phase system of phasors can be resolved into three balanced systems of phasors known as symmetrical components:
1. **Positive Sequence:** Three phasors equal in magnitude, displaced by 120°, with the same phase sequence as the original system.
2. **Negative Sequence:** Three phasors equal in magnitude, displaced by 120°, with the reverse phase sequence.
3. **Zero Sequence:** Three phasors equal in magnitude with zero phase displacement.
Usage: For analyzing asymmetric faults (like Single Line-to-Ground), the complex unbalanced system is broken down into three decoupled sequence networks (Positive, Negative, Zero). These independent networks are solved separately and superimposed to find the actual fault currents and voltages, vastly simplifying the math[cite: 15, 24].

Q.4 A) Smart Grid Architecture & Technologies:

Smart Grid: An advanced, modernized electrical grid that utilizes two-way digital communication and automated control to improve the efficiency, reliability, economics, and sustainability of power generation and distribution.
Architecture & Technologies:
- Advanced Metering Infrastructure (AMI): Smart meters providing real-time data.
- SCADA & Phasor Measurement Units (PMUs): For wide-area monitoring and control.
- Distributed Energy Resources (DERs): Integration of solar, wind, and energy storage systems.
- Information & Communication Technology (ICT): IoT, secure wireless networks, and cloud computing to manage grid data.

Q.4 B) Stability Types & Improving Transient Stability:

Steady-State Stability: The ability of a power system to remain synchronized after small, slow disturbances (like gradual load changes).
Transient Stability: The ability of a power system to maintain synchronism after a severe and sudden disturbance (like a major short circuit fault or loss of a large generator).
Methods to Improve Transient Stability:
1. Fast-acting fault clearing using high-speed circuit breakers.
2. Using bundle conductors to reduce series reactance.
3. Series capacitor compensation in transmission lines.
4. Fast-valving of turbines to quickly reduce mechanical input power (P_m).
5. High-speed excitation systems.

Q.5 A) Micro-grids & Autonomous vs Non-Autonomous:

Micro-grid: A localized group of electricity sources (Distributed Generators like solar, wind, diesel) and loads that normally operates connected to and synchronous with the traditional wide area synchronous grid (macrogrid), but can also disconnect to function autonomously as physical or economic conditions dictate.
Non-Autonomous (Grid-Connected): Operates in parallel with the main utility grid. It imports or exports power based on local generation and demand.
Autonomous (Islanded): Operates completely isolated from the main grid (e.g., during a blackout or in remote areas). The local DGs must manage voltage and frequency control entirely on their own.
Multiple DGs: In micro-grids with multiple DGs, hierarchical control (droop control) is used to share active and reactive power load proportionally among the generators without relying on communication links.

Q.5 B) Gauss-Seidel vs Newton-Raphson Method:

Gauss-Seidel (GS): An iterative numerical method. It requires less memory and the computation time per iteration is small. However, the rate of convergence is slow, and the number of iterations increases directly with the size of the power system.
Newton-Raphson (NR): Uses Taylor series expansion and the Jacobian matrix. Computation time per iteration is higher, and it requires more memory. However, it has a quadratic convergence characteristic, making it extremely fast. The number of iterations is almost independent of the system size (usually converges in 3-5 iterations).
Preference: For large power systems, the Newton-Raphson method is overwhelmingly preferred due to its highly reliable and fast convergence.

Q.6 A) Nature of Faults & Symmetric vs Asymmetric:

Nature of Faults: A fault is any abnormal condition that causes a disruption in the normal flow of current, usually leading to excessively high currents and low voltages[cite: 15, 24].
Symmetric Faults: Involve all three phases simultaneously. The system remains balanced. Example: 3-phase short circuit (LLL) or 3-phase-to-ground fault (LLLG). They are rare (approx. 5%) but the most severe.
Asymmetric Faults: Involve only one or two phases, causing unbalanced currents and voltages. Example: Single Line-to-Ground (LG), Line-to-Line (LL), and Double Line-to-Ground (LLG). LG is the most common fault (approx. 70-80% of all faults).

Q.6 B) Maximum Power Flow Derivation:

For a lossless short transmission line with sending end voltage $|V_S|$, receiving end voltage $|V_R|$, and line reactance X:
The active power flow (P) equation is:
$P = (|V_S| \times |V_R| / X) \times \sin(\delta)$
Where δ is the power angle between V_S and V_R.
Under steady-state conditions, for a given line reactance and fixed terminal voltages, the power flow P will be maximum when sin(δ) reaches its maximum value.
Maximum value of sin(δ) = 1 (which occurs at δ = 90°).
Therefore, Maximum Steady-State Power (P_{max}) = $(|V_S| \times |V_R| / X)$.

Short Answer Solutions (Q.7)

A) Complex Power and Power Triangle: Complex Power (S) is the vector sum of Active Power (P) and Reactive Power (Q). S = P + jQ. The power triangle geometrically represents this relationship in a right-angled triangle, where the base is P, the perpendicular is Q, and the hypotenuse is Apparent Power |S|.

B) Adverse effects of instability: If a power system loses stability, it leads to pole slipping of generators, violent fluctuations in voltage and current, severe mechanical stress on turbine shafts, and ultimately tripping of protective relays resulting in large-scale blackouts.

C) Sequence Networks: Used in asymmetric fault analysis. An unbalanced system is broken down into three independent, balanced networks: Positive sequence (represents normal operation direction), Negative sequence (reverse rotation), and Zero sequence (in-phase, associated with ground paths).

D) Dynamic State Stability: A subset of steady-state stability. It relates to the system's ability to maintain stability under small, continuous disturbances, often relying on the automatic control devices (like Automatic Voltage Regulators - AVR and speed governors) to dampen the oscillations over time.

E) Newton-Raphson Method features: Highly robust load flow technique that solves non-linear power flow equations using the Jacobian matrix. Its main features are quadratic convergence, requirement of a good initial guess (usually flat start), and its execution time being almost independent of the network size.