K. K. Wagh Institute of Engineering Education and Research, Nashik
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End-Sem Examination-I, Winter 2025

Academic Year: 2025-2026 **Semester: I**

Name of Program: Electrical Engineering **Pattern: 2024**

Name of Course: Computer Added Power System Analysis Course **Code: 2406501**

Max Marks: 60 **Duration: 2:30 Hr.**

Set B
Paper Solution

Q1. Comparison of GS, NR and FDLF method

Aspects	GS method	NR method	FDLF method
(1) Convergence	Slow	Fast	Faster than NR
(2) Computational effort	Low	High	Very high
(3) Accuracy	Low	High	Moderate
(4) Complexity	Simple	Complex	Simple
(5) Memory Requirement	Low	High	Low

Q.2. Soln: Given $V_{a0} = 10\angle 180°V$, $V_{a1} = 50\angle 0°V$, $V_{a2} = 20\angle 90°V$.

$= -10+j0$ $\quad = 50+j0$ $\quad = 0+j20\,V$

$a = 1\angle 120$

$a^2 = 1\angle 240$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}$$

$$V_a = V_{a0} + V_{a1} + V_{a2}$$

$$= (-10+j0) + (50+j0) + (0+j20) = 40+j20$$

$$\boxed{V_a = 44.72\angle 20° V}$$

1

$V_b = V_{a0} + a^2 V_{a1} + a V_{a2}$

$= (10 + j0) + (-25 + j43.30) + (-17.32 - j10) = -52.32 - j53.70$

$= 74.69 \angle -134° V$

$V_c = V_{a0} + a V_{a1} + a^2 V_{a2}.$

$= (-25 - j43.30) + (-25 + j43.30) + 17.32 - j10$

$= -17.68 + j33.3$

$\boxed{V_c = 37.70 \angle 118° V}$ Ans

Q 3.(a) The state estimation problem for a 3-bus system using the weighted least square (WLS) method:-

State vector: $x = [\theta_2, \theta_3, V_1, V_2, V_3]^T$.

Measurement (z) to the state variable (x):

$z = h(x) + e$,

The WLS objective func.

$J(x) = \sum_{i=1}^{m} w_i [z_i - h_i(x)]^2$; $w_i = \frac{1}{\sigma_i^2}$

In matrix form m = no. of measurements

$J(x) = [z - h(x)]^T W [z - h(x)]$.

$W = diag.(w_1, w_2 ... w_m)$.

The state estimate $\hat{x}$ is obtained by minimizing $J(x)$

$\frac{\partial J(x)}{\partial x} = 0$

& $x(k+1) = x(k) + \Delta x$

where $\Delta x = [H^T W H]^{-1} H^T W [z - h(x^k)]$

Q3(C)
(a) Mathematical formulation of WLS method in state estimation

Assume,
State vector $x = [\theta_2, \theta_3 \ldots \theta_n, V_1, V_2, \ldots V_n]^T$.
The measurement z
$$z = h(x) + e,$$
The WLS method minimizes the weighted sum of squared residuals
$$J(x) = \sum_{i=1}^{m} w_i [z_i - h_i(x)]^2.$$
In matrix form
$$J(x) = [z - h(x)]^T W [z - h(x)], \quad W = R^{-1}$$
Linearization of measurement model
$$h(x) = h[x^{(k)}] + H\Delta x$$
H is Jacobian matrix of h(x) w.r.t x,
$$H_{ij} = \frac{\partial h_i(x)}{\partial x_j} \quad ; \quad \Delta x = x - x^{(k)}$$
Residual vector $r^{(k)} = z - h[x^{(k)}]$
$$\Delta x = [H^T W H]^{-1} H^T W r$$
Updated state vector
$$x^{(k+1)} = x^{(k)} + \Delta x$$

Q.3 (b) Significance of Jacobian matrix in state estimation
In state estimation for PS, the Jacobian matrix play a crucial role in linking the system's state variable (e.g. voltage magnitude and phase angles) to the measurements (e.g. power flow and voltage magnitudes). The Jacobian matrix contains

Changes in state variable affect the measurement making it an essential component for solving the state estimation problem.

Q3. (a). False Data Injection Attacks in state estimation.

A false data injection attack is a type of cybersecurity threats where an attacker deliberately manipulate or injects incorrect data into the measurement system of a power grid or any other infrastructure with the intent of causing misleading information to be used in state estimation.

Impact of false data injection on state estimation

1. Degradation of state estimation accuracy
2. Incorrect system behavior prediction
3. Impact on grid operations and control
   - Inadequate control action
   - Grid instability
4. Compromising system security
   - Undetected faults.
   - Vulnerability to further attacks
5. Impact on security and reliability of the power system

Q. 4. (a) Given,

$$C_1 = 2000 + 2.5P_1 + 0.01P_1^2$$

$$C_2 = 400 + 2P_2 + 0.02P_2^2$$

$P_1 = 325\,MW$, $P_2 = 175\,MW$, $\frac{dP_L}{dP_2} = 0.2$

With economic dispatch

$$PF_1 \cdot \frac{dC_1}{dP_1} = PF_2 \frac{dC_2}{dP_2} \quad \text{---}(1)$$

$\frac{dC_1}{dP_1} = 2.5 + 0.02 P_1$, $\frac{dC_2}{dP_2} = 2 + 0.04 P_2$

$PF_2 = \frac{1}{1 - \frac{dP_L}{dP_2}} = \frac{1}{1 - 0.2} = 1.25$ Ans

$P_1 = 325$ mw, $P_2 = 125$ mw

from (1)

$PF_1 \times (2.5 + 0.02 \times 325) = 1.25 (2 + 0.04 \times 125)$

$\boxed{PF_1 = 1.25}$ Ans

Q4. (a)

Given

$F_1 = 60 + 30P_1 + 0.2P_1^2$ Rs/hr

$F_2 = 80 + 20P_2 + 0.15P_2^2$ Rs/hr

$d = 120$ Rs/mwhr

$\frac{dF_1}{dP_1} = (0.4P_1 + 30)$ Rs/mwhr — (1)

$\frac{dF_2}{dP_2} = (0.30P_2 + 20)$ Rs/mwhr — (2)

$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2} \Rightarrow 0.4P_1 + 30 = 0.30P_2 + 20 = 120$ — (3)

from (3)

$0.4P_1 + 30 = 120$

$P_1 = \frac{90}{0.4} = 225$ Rs/hr

$0.30P_2 + 20 = 120$

$P_2 = \frac{100}{0.30} = 333.33$ Rs/hr

$P_D = P_1 + P_2 = 225 + 333.33 = 558.33$ Rs/hrs (5)

Q4. (b). Difference betn Economic load dispatch (ELD) and Unit Commitment (UC)

Aspect parameter	ELD	UC
(1) Objective	Minimize total gen. cost for a given load demand	Determine which generator should on or off and their o/p to minimize cost.
(2) Scope	Dispatched power among Online Units (no decision on which units are online)	Decides which unit to commit (on)/off and how much power each unit generate
(3) Input	Known total load demand for a specific period.	Load forecast for multiple time periods.
(4) Output	Optimal power gen. level for each online unit	Optimal scheduling of unit commitment (on/off decisions) and their generation levels
(5) Constraints	Gen. capacity, limits, power balance	→ Minim up/down times.
(6) Time horizon	Shorter term	Longer term
(7) Complexity	Less Complex	More Complex
(8) Example	Dispatching power from a set of running units to meet a specific load.	Scheduling the operation of units over a time period to meet varying load demand.

Q. 4(d) Lagrange multiplier method for solving Optimal power flow (OPF) problems.

The Lagrange multiplier method is a powerful mathematical technique used for solving optimization problem with constraints.

OPF problem, These constraint include:-

1. Power balance
2. Generator limit
3. Voltage limit
4. Line flow limit

(a). Loss Coefficient using Sensitivity approach in Optimal power flow (OPF)

In power system, the losses are an important factor that must be accounted for during optimization, as they affect the over system efficiency and cost of generation. The loss coefficient is a key parameter in case of the losses, which represent the sensitivity of the system losses to changes in the gen. levels.

The losses in power system.

$$L = \sum_i \sum_j b_{ij} P_i P_j$$

Sensitivity approach to Loss Coefficient.

- Loss sensitivity matrix

$$L = \sum_i \sum_j b_{ij} P_i P_j$$

- Sensitivity coefficient

$$\frac{\partial L}{\partial P_i} = \sum_j b_{ij} P_j$$

Q.5 (b) Generation Shift Sensitivity Distribution (GSSD) in power system — GSSD is a method used in power system analysis to understand the impact of changes in power generation at one bus on the power flows across the transmission network.

GSSD expressed mathematically

$$\Delta P_{ij} = \sum_k S_{ij,k} \Delta P_k.$$

GSSD is based on the sensitivity of power flows in the network to changes in generation levels. It is derived from the system's power flow eqn and associated Jacobian matrix in the load flow solution process.

Q.5 (b) Loss coefficients in power system analysis

Loss coefficients also known as B-coefficients or loss Sensitivity coefficients, are numerical factors used to estimate the tran losses in power system as a function of power generation at various buses. They provide a relationship betn the active power injection at generator buses and total system losses.

Mathematically

$$L = \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} \cdot P_i P_j + \sum_{i=1}^{n} B_{i0} P_i + B_{00} \quad \text{(1)}$$

Significance of loss-coefficient

1. Calculation of tr. losses
2. Economic load dispatch
3. Optimal power flow
4. System planning
5. Generation dispatch and load sharing.
6. Voltage and stability analysis

Q5 (d) Derivation of tr. loss in terms of Generation and Demand

The tr. loss formula relates the total power losses in a system to the power injection at different buses. Tr. losses occur due to the resistive elements in tr. lines and depend on the power flow and network topology.

1. Power balance eqn

$$P_G = P_D + P_L \quad \text{(1)}$$

2. Loss formular

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} P_i P_j + \sum_{i=1}^{n} B_{i0} P_i + B_{00} \quad \text{(2)}$$

3. $P_i = P_{Gi} - P_{Di}$