Q1
(a) Describe at least two different factors other than the direct cost factor, that need to be considered in selecting power plants for construction out of a list of candidate plants. [30]

(b) Explain the concept of present value used in evaluating financial feasibility of long life engineering projects. An income of $x$ per year is generated annually for a period of $N$ consecutive years. If the present value of the total income generated is represented by $p$ under a discount rate of $r$ show that

$$p = \frac{(1 + r)^N - 1}{r(1 + r)^N}$$

[30]

(c) Calculate the specific cost of generation (Rs/kWh) of a proposed hydroelectric power plant, based on the following data neglecting inflation and possible price escalations. Clearly state the assumptions you make.

<table>
<thead>
<tr>
<th>Rated Power output</th>
<th>: 75 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment with interest during construction</td>
<td>: 160,000 Rs/kW</td>
</tr>
<tr>
<td>Economic life</td>
<td>: 50 years</td>
</tr>
<tr>
<td>Operation &amp; Maintenance cost</td>
<td>: 13 million Rs/year</td>
</tr>
<tr>
<td>Expected average generation</td>
<td>: 270 GWh/year</td>
</tr>
<tr>
<td>Discount rate</td>
<td>: 10%</td>
</tr>
<tr>
<td>Scrap value at the end of economic life</td>
<td>: negligible</td>
</tr>
</tbody>
</table>

[40]

Q2
a) Develop a simple transfer function for a power system modeled by a generator load system. [20]

b) Draw block diagram representations of a single area power system with governor action. [20]

c) A power system operating at 50 Hz has the inertia constant $H = 5.0$ s and the governor droop characteristic $R = 2.0$ Hz/pu active power. The load characteristic $D = \frac{\partial P}{\partial f}$ is equal to $10^2$ pu active power/Hz. Calculate the time constant of the system in responding to a small change of the load neglecting the time constant of the governor and the turbine/generator combination. [60]
Q3

a) Explain what is meant by cost of unserved energy in relation with electrical power systems. [20]

b) The demand curve of a power system for an average working day is approximated in the table below:

<table>
<thead>
<tr>
<th>Time period (hrs of the day)</th>
<th>load (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 5.00</td>
<td>100</td>
</tr>
<tr>
<td>5.00 - 6.00</td>
<td>200</td>
</tr>
<tr>
<td>6.00 - 9.00</td>
<td>150</td>
</tr>
<tr>
<td>9.00 - 12.00</td>
<td>400</td>
</tr>
<tr>
<td>12.00 - 18.00</td>
<td>200</td>
</tr>
<tr>
<td>18.00 - 24.00</td>
<td>100</td>
</tr>
</tbody>
</table>

Draw the load duration curve \( P^0(x) \) for the system. [10]

c) Four generators are available to meet the above demand and the generator characteristics are given in the following table:

<table>
<thead>
<tr>
<th>Generator</th>
<th>Capacity (MW)</th>
<th>Forced Outage Rate (FOR)</th>
<th>Cost (units/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>200</td>
<td>0.05</td>
<td>1.0</td>
</tr>
<tr>
<td>G2</td>
<td>150</td>
<td>0.08</td>
<td>1.5</td>
</tr>
<tr>
<td>G3</td>
<td>100</td>
<td>0.10</td>
<td>2.5</td>
</tr>
<tr>
<td>G4</td>
<td>50</td>
<td>0.12</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Calculate the remaining load duration curve \( P^1(x) \) after dispatching the most economical Generator. [30]

d) Calculate LOLP and the cost of generation for this system. [40]

Q4

(a) Using usual notation obtain an expression for the shape of the curve taken by a transmission line conductor in x-y coordinates. [30]

(b) What approximations can be made if the sag is less than 10% of the span? [20]

(c) Also obtain approximated expressions for the maximum sag and span. [20]

(d) Explain how sag templates are used in positioning towers along the route at the design stage of a new transmission line. [30]
Q5

(a) Why is it desirable to operate grid connected, partially loaded generators at the same incremental cost? [10]

(b) A thermal power station operates three units with following cost functions. For unit i, \( F_i \) denotes the cost of operation in Currency Units (CU) when serving a load \( P_i \).

\[
\begin{align*}
F_1 &= 173.0 + 8.7P_1 + 0.0023P_1^2 \quad 50 \leq P_1 \leq 250\text{MW} \\
F_2 &= 180.0 + 9.0P_2 + 0.0026P_2^2 \quad 50 \leq P_2 \leq 150\text{MW} \\
F_3 &= 165.0 + 9.2P_3 + 0.0020P_3^2 \quad 50 \leq P_3 \leq 150\text{MW}
\end{align*}
\]

Prepare a merit order list considering per MWh cost of each unit at its maximum possible load. [20]

(c) Determine the loading of each of the units to meet a total load of 350 MW using merit order loading. Also calculate the total cost. [30]

(d) If the dispatch is done using the incremental cost method what would be the individual loading of the units? What is the total cost under this method? [30]

(e) Explain why merit order dispatch does not always give the optimum solution. [10]

Q6

(a) Describe a method available for the solution of the transient stability of a synchronous generator connected to an infinite bus. [30]

(b) Data of a synchronous generator connected to an infinite bus is shown in figure Q6. When the system is working at steady state at an angle of 30° determine the frequency of oscillations of the rotor for a small disturbance. [40]

(c) Explain the concept of under-frequency load shedding and how it helps to avoid possible total blackouts in a contingency situation. [30]

[Figure Q6]

\[E=1.2 \text{ pu}\]
\[H=5 \text{ sec}\]
\[f=50 \text{ Hz}\]

\[\text{Infinite bus}\]
\[V=1.0 \text{ pu}\]

\[x=1.0 \text{ pu}\]
Q7

(a) Develop an expression for the complex voltage difference between two bus-bars in a power system in terms of P and Q flow, along the line connecting the two bus-bars, and R and X values of the line. [20]

(b) Use the above expression to determine the complex voltages of nodes 2 and 3 of the three node power system shown in figure Q7. All relevant data are indicated in the figure in pu. [30]

(c) In general power flows are unknown and the generation injected and loads connected to bus bars are known. Describe the Gauss-Seidel method of solution to solve this problem assuming line resistances are negligible. [20]

(d) Propose a faster method for the solution of this problem deriving necessary mathematical expressions. [30]

\[ S_{12} = 0.018 - j0.5 \]
\[ S_{13} = 0.605 + j0.047 \]
\[ Z_{12} = Z_{23} = Z_{13} = 0.02 + j0.08 \]

Figure Q7