1. (32 pts) A transmission line having $R=0.005$ pu and $X=0.05$ pu (charging capacitance is negligible) is operating so that the voltage magnitudes and angles at its terminals are given by the data below:

<table>
<thead>
<tr>
<th>Voltage Magnitude for p-bus (pu)</th>
<th>Voltage Angle for p-bus (deg)</th>
<th>Voltage Magnitude for q-bus (pu)</th>
<th>Voltage Angle for q-bus (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.15</td>
<td>10</td>
<td>0.95</td>
<td>0</td>
</tr>
</tbody>
</table>

All per unit values are given on a 100 MVA base. A relation that may be helpful to you is this:

$$P_{pq} = V_p^2 G - V_p V_q G \cos(\varphi_p - \varphi_q) + V_p V_q B \sin(\varphi_p - \varphi_q)$$

Compute:

(a) (22 pts) the real power flowing into and out of the line, in MW;

**Solution:**

$$P_{pq} = V_p^2 G - V_p V_q G \cos(\varphi_p - \varphi_q) + V_p V_q B \sin(\varphi_p - \varphi_q)$$

$$= 1.15^2 (1.98) - (1.15)(0.95)(1.98)\cos(10^\circ) + (1.15)(0.95)(19.80)\sin(10^\circ) = 4.2445$$

So real power into line = $100(4.245) = 424.5$ MW

$$P'_{pq} = -P_{qp} = -\left[ V_q^2 G - V_q V_p G \cos(\varphi_q - \varphi_p) + V_q V_p B \sin(\varphi_q - \varphi_p) \right]$$

$$= -[0.95^2 (1.98) - (0.95)(1.15)(1.98)\cos(-10^\circ) + (1.15)(0.95)(19.80)\sin(-10^\circ)] = 4.0996$$

So real power out of the line = $100(4.0996) = 409.96$ MW

(b) (10 pts) the real power absorbed by the transmission line impedance.

**Solution:**

$$P_{loss} = P_{pq} - P'_{pq} = 424.5 - 409.96 = 14.49$$ MW

2. (36 pts) Short answers on transmission lines:

(a) If a transmission line is bundled so that it requires a total of 12 conductors, how many conductors per phase are being used?
Solution: 4

(b) Which is larger for a transmission circuit: capacitance between the phases or capacitance between phases and ground?

Solution: Capacitance between the phases.

(c) What is the range for the ratio $X_L/R$ for a typical conductor?

Solution: About 10. I would accept any number or range between 2 and 20.

(d) If a transmission line has impedance of $Z = R + jX = 2 + j5$, is it true that $G = \text{Re} \{ Y \} = 1/R = 0.5$?

Solution: No, it is not true.

$$G = \text{Re} \{ Y \} = \text{Re} \{ 1/Z \} = \text{Re} \{ 1/(2+j5) \} = \text{Re} \{ 0.69-j0.1724 \} = 0.69$$

3. (32 pts) True/false on the power flow problem.

____a. In the power flow problem, the engineer inputs the flows on all of the circuits, and MW and MVAR generation and load values are computed for all buses in the network.

____b. A generator capability curve, which specifies a boundary for operating a synchronous generator in terms of MW and MVAR output, is approximated within a power flow program as a rectangular region specified by $Q_{\text{max}}$, $Q_{\text{min}}$, and $P_{\text{max}}$ for each generator.

____c. A bus “$k$” with load but no generator would satisfy: $P_{\text{inj},k} \leq 0$.

____d. All buses with loads only are type “PV.”

Solutions:

a. F
b. T
c. T
d. F