EE 341 - Quiz #5

Name (please print): Solution The last four digits of your SSN: 

1. The following figure shows a power system consisting of a three-phase generator supplying a load through a transmission line with a pair of transformers at either end. If the load side voltage is to be kept at 480-V, compute the active and reactive power supplied by the generator.

![Power System Diagram]

480/13,800 V  13,800/480 V
1000 kVA  500 kVA
R=0.01 pu  R=0.02 pu
X=0.04 pu  X=0.085 pu
0.8 PF lagging

Solution:
This problem can be solved using per-unit system.

<table>
<thead>
<tr>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{base1} = 1000$ kVA</td>
<td>$S_{base2} = 1000$ kVA</td>
<td>$S_{base3} = 1000$ kVA</td>
</tr>
<tr>
<td>$V_{L,base1} = 480$ V</td>
<td>$V_{L,base2} = 13,800$ V</td>
<td>$V_{L,base3} = 480$ V</td>
</tr>
</tbody>
</table>

$Z_{base2} = \frac{V_{L,base2}^2}{S_{base2}} = \frac{(13800V)^2}{1000kVA} = 190.44 \Omega$

$Z_{L,pu} = \frac{Z_L}{Z_{base2}} = \frac{1.5 + j10}{190.44} = 0.00788 + j0.0525 pu$

$Z_{T1,pu} = 0.01 + j0.04 pu$

Impedance of T2 needs to be transformed to new bases:

$Z_{T2,pu} = (0.02 + j0.085) \frac{(13800V)^2(1000kVA)}{(13800V)^2(500kVA)} = 0.04 + j0.17 pu$

Load in per-unit:

$S_{load,pu} = \frac{500kVA}{1000kVA} \angle \cos^{-1}(0.8) = 0.5 \angle 36.87^\circ pu$
Voltage at load side:
\[ V_{load,pu} = \frac{480V}{480V} \angle 0 = 1\angle 0^\circ \text{ pu} \]

The per-unit equivalent circuit is as follows:

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Load current:
\[ I_{load,pu} = \left( \frac{S_{load,pu}}{V_{load,pu}} \right)^* = \left( \frac{0.5 \angle 36.87^\circ}{1\angle 0^\circ} \right)^* = 0.4 \angle -36.87^\circ \text{ pu} \]

Generator voltage:
\[ V_{G,pu} = V_{load,pu} + I_{load,pu} (Z_{T1,pu} + Z_{L,pu} + Z_{T2,pu}) \\
= 1\angle 0^\circ + 0.5 \angle -36.87^\circ [(0.01 + j0.04) + (0.00788 + j0.0525) + (0.04 + j0.17)] \\
= 1.102 + j0.0876 = 1.1054\angle 4.55^\circ \text{ pu} \]

Generator power in per-unit:
\[ S_{G,pu} = V_{G,pu}I_{load,pu}^* = 1.1054\angle 4.55^\circ \times (0.5\angle -36.87)^* \\
= 0.4145 + j0.3656 \text{ pu} \]

Actual generator power:
\[ S_G = S_{G,pu}S_{base1} = (0.4145 + j0.3656) \times 1000 = 414.5 + j365.6 \text{ kVA} \]

So, active power \( P = 424.5 \text{ kW} \), reactive power \( Q = 365.6 \text{ kvar} \).