POWER SYSTEM ANALYSIS - I FINAL EXAM

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#1) 400 MVA is drawn at 345 kV_{LL} and 0.8 lagging power factor from the receiving end of a 400 km transmission line whose ABCD parameters are given as follows;

$A = D = 0.8180\angle 1.3^{\circ}\ pu,\quad B = 172.2\angle 84.2^{\circ}\ \Omega,\quad C = 0.001933\angle 90.4^{\circ}\ S$

a) Calculate the rms value of line to line voltage at the sending end of the line. Determine also three phase active and reactive power pumped from the sending end of the line.

b) Determine efficiency and regulation of the line.

#2) Two buses abc and $a'b'c'$ are connected by two parallel lines L_1 and L_2 with positive sequence $X_{L1} = 0.3\,pu$ and $X_{L2} = 0.35\,pu$ values. A regulating transformer, which advances the phase 3° toward bus abc, is paced in series with L_1 at bus $a'b'c'$. Those parallel lines supply a balanced load with load current of $1.0\angle -35^{\circ}\ pu$. Determine,

a) 2x2 positive sequence bus admittance matrix of the system,

b) active and reactive power supplied to the load bus from each parallel line when no regulating transformer exists,

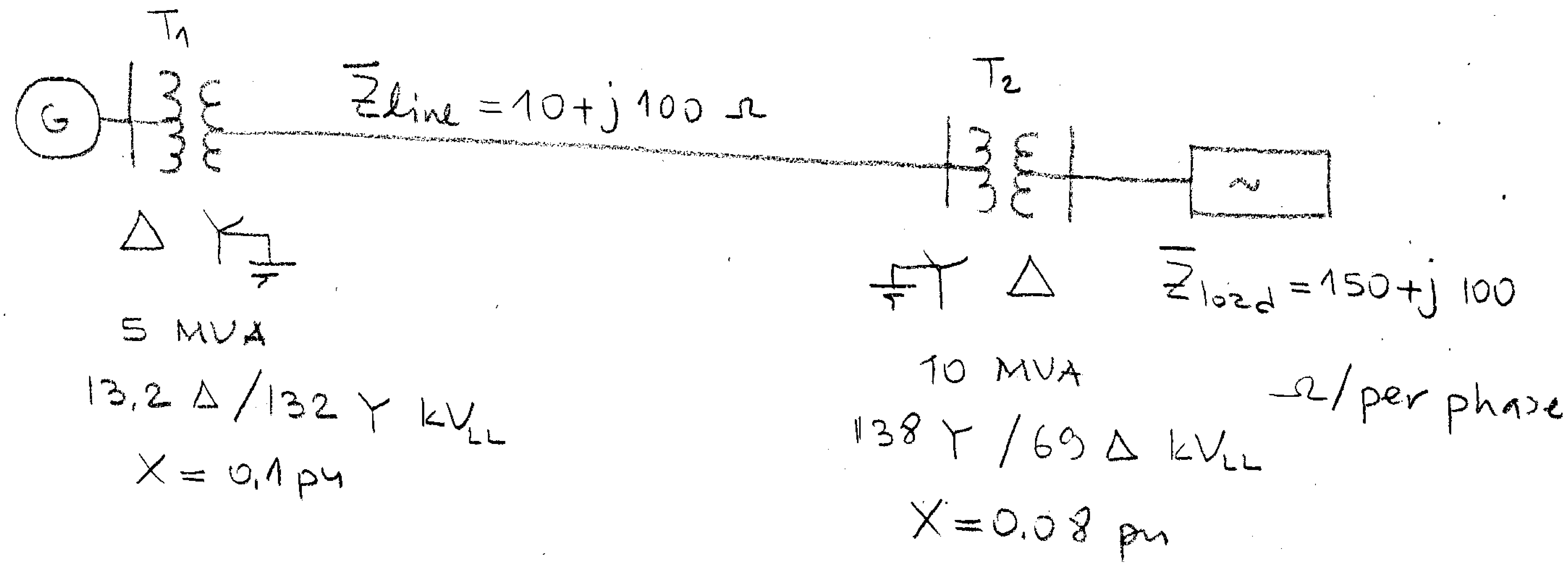
c) active and reactive power supplied to the load bus from each parallel line when there is phase angle regulating transformer at bus $a'b'c'$ exists.

Assume that the voltage at bus abc is so adjusted that the voltage at bus $a'b'c'$ remains at $1.0\angle 0^{\circ}\ pu$. Assume also that the phase regulating transformer is ideal one.

#3) Terminal voltage of the generator that is shown in the figure is $13.2\ kV_{LL}$. Take 138 kV_{LL} as voltage base in the line region and 10 $MVA_{3\Phi}$ as common $S_{base,3\Phi}$.

a) Determine the pu equivalent circuit of the system.

b) Determine the actual generator current.



POWER SYSTEM ANALYSIS-I FINAL EXAM SOLUTION MANUAL (Summer School - 2009)

Dr. Salih FADIL

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#1)
a)

$\bar{V}_{S_{LN}} = \bar{A}\,\bar{V}_{R_{LN}} + \bar{B}\,\bar{I}_R$, $\bar{V}_{R_{LN}} = \frac{345}{\sqrt{3}}\angle 0^\circ$ kV

$$\bar{I}_R = \frac{400\ 10^6}{\sqrt{3}\ 345\ 10^3}\angle -\cos^{-1}0.8 = 669,39\angle -36.8^\circ \text{ A.}$$

$$\bar{V}_{S_{LN}} = 0,818\angle 1,3^\circ \times \frac{345}{\sqrt{3}}\angle 0^\circ + 172,2\angle 84,2^\circ \times 0,6694\angle -36.8 \text{ kV}$$

$$\bar{V}_{S_{LN}} = 162.934\angle 1,3^\circ + 115,27\angle 47,4^\circ = 162.892 + j3.696 + 78.02 + j84.85$$

$$\bar{V}_{S_{LN}} = 240.912 + j88.546 = 256,67\angle 20,18^\circ \text{ kV}$$

$$\boxed{|\bar{V}_{S_{LL}}| = 256,67 \times \sqrt{3} = 444,56 \text{ kV}}$$ 16

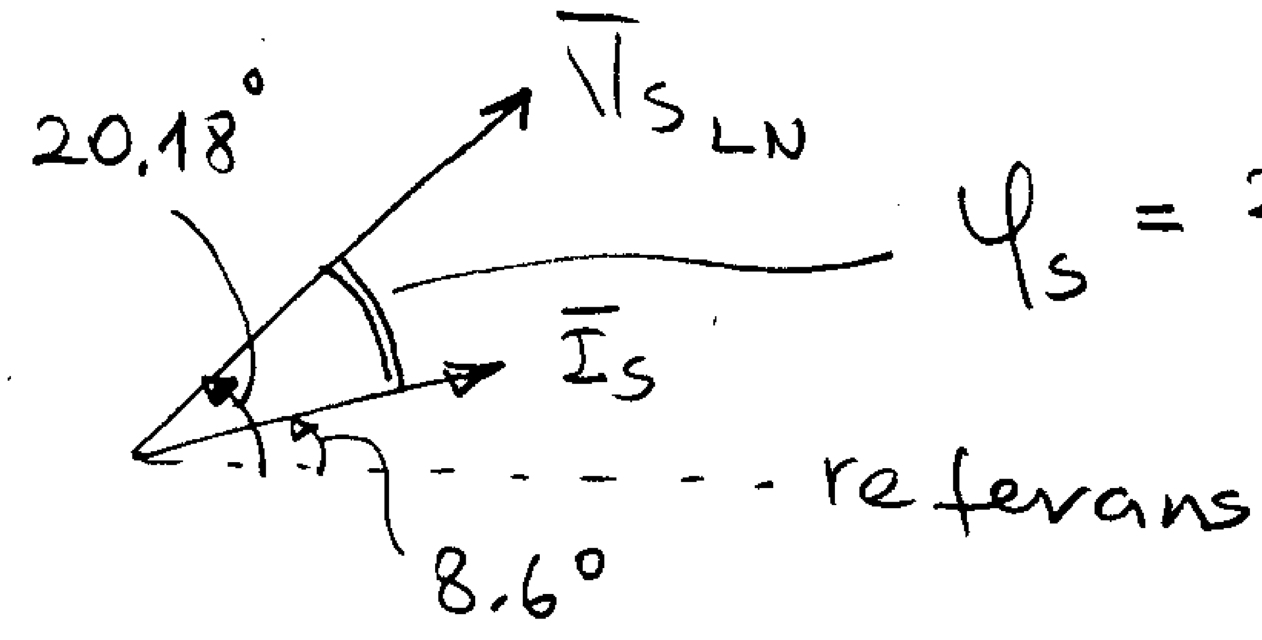
$$\bar{I}_S = \bar{C}\,\bar{V}_{R_{LN}} + \bar{D}\,\bar{I}_R$$

$$\bar{I}_S = 0,001933\angle 90.4^\circ \times \frac{345}{\sqrt{3}}\angle 0^\circ + 0,818\angle 1,3^\circ \times 0,6694\angle -36.8^\circ \text{ kA}$$

$$\bar{I}_S = 0,385\angle 90,4^\circ + 0,5475\angle -35.5^\circ \text{ kA}$$

$$\bar{I}_S = -2,687\ 10^{-3} + j0,3849 + 0,4457 - j0,3179 \text{ kA}$$

$$I_S = 0,4430 + j0.067 = 0,448\angle 8,6^\circ \text{ kA}$$



$$\varphi_S = 20.18 - 8,6^\circ = 11,58^\circ \text{ lagging}$$

$$\boxed{\begin{aligned} P_{S,3\phi} &= 3\times 256.67\times 0.448\cos(11.58) = 337.942 \text{ MW} \\ Q_{S,3\phi} &= 3\times 256.67\times 0.448\sin(11.58) = 69.246 \text{ MVAr} \end{aligned}}$$

b) $P_{R,3\phi} = 400\cos(36.8) = 320$ MW

$$\eta = \frac{337.942}{320}\times 100 = 94.69\ \%$$

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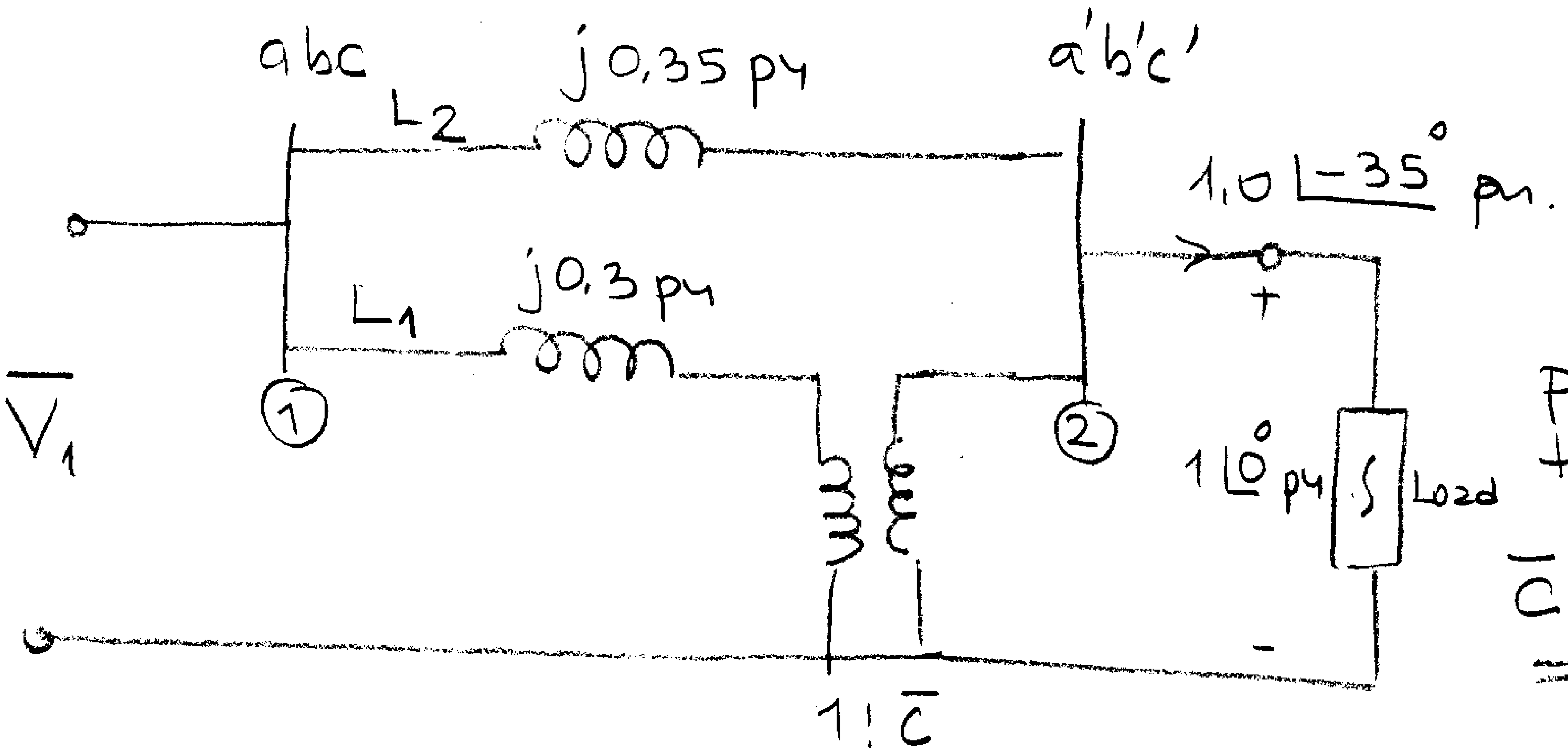
$$\%VR = \frac{\left|\frac{V_S}{A}\right| - |V_{RFL}|}{|V_{RFL}|}\times 100$$

$$\%VR = \frac{\frac{444.56}{0.818} - 345}{345}\times 100 = 57.52\ \% \quad \text{(too much)}$$

#2)

a)



phase increase toward bus abc

$\overline{C} = 1\angle 3^\circ$

$$\overline{Y}_{11_{L2}} = \overline{Y}_{22_{L2}} = \frac{1}{j0.35} = -j2.8571 \qquad \overline{Y}_{12_{L2}} = \overline{Y}_{21_{L2}} = -\frac{1}{j0{,}35} = +j2.8571 \text{ pu}$$

$$\overline{Y}_{11_{L1}} = \frac{1}{j0{,}3} = -j3{,}3\bar{3}\ , \quad \overline{Y}_{12_{L1}} = -1\angle 3^\circ\ \frac{1}{j0{,}3} = 3{,}3\bar{3}\angle 93^\circ \text{ pu}$$
$$= -0{,}1745 + j3{,}3287 \text{ pu}$$

$$\overline{Y}_{21_{L1}} = (-1\angle{-3^\circ})\frac{1}{j0{,}3} = 3.3\bar{3}\angle 87^\circ \text{ pu}$$
$$= 0{,}1745 + j3.3287 \text{ pu}$$

$$\overline{Y}_{22_{L1}} = |1\angle 3^\circ|^2(-j3.3\bar{3}) = -j3{,}3\bar{3} \text{ pu.}$$

$$[Y] = \begin{bmatrix} (-j2{,}8571 - j3{,}3\bar{3}) \, , & \underbrace{(+j2{,}8571 - 0{,}1745 + j3{,}3287)}_{-0{,}1745 + j6{,}1858} \\ (j2{,}8571 + 0{,}1745 + j3{,}3287) \, , & -j2{,}8571 - j3{,}3\bar{3} \end{bmatrix}$$

$$= \begin{bmatrix} -j6{,}1904 & 6{,}1882 \angle 91{,}61^\circ \\ 6{,}1882 \angle 88{,}3^\circ & -j6{,}1904 \end{bmatrix} \text{ pu}$$

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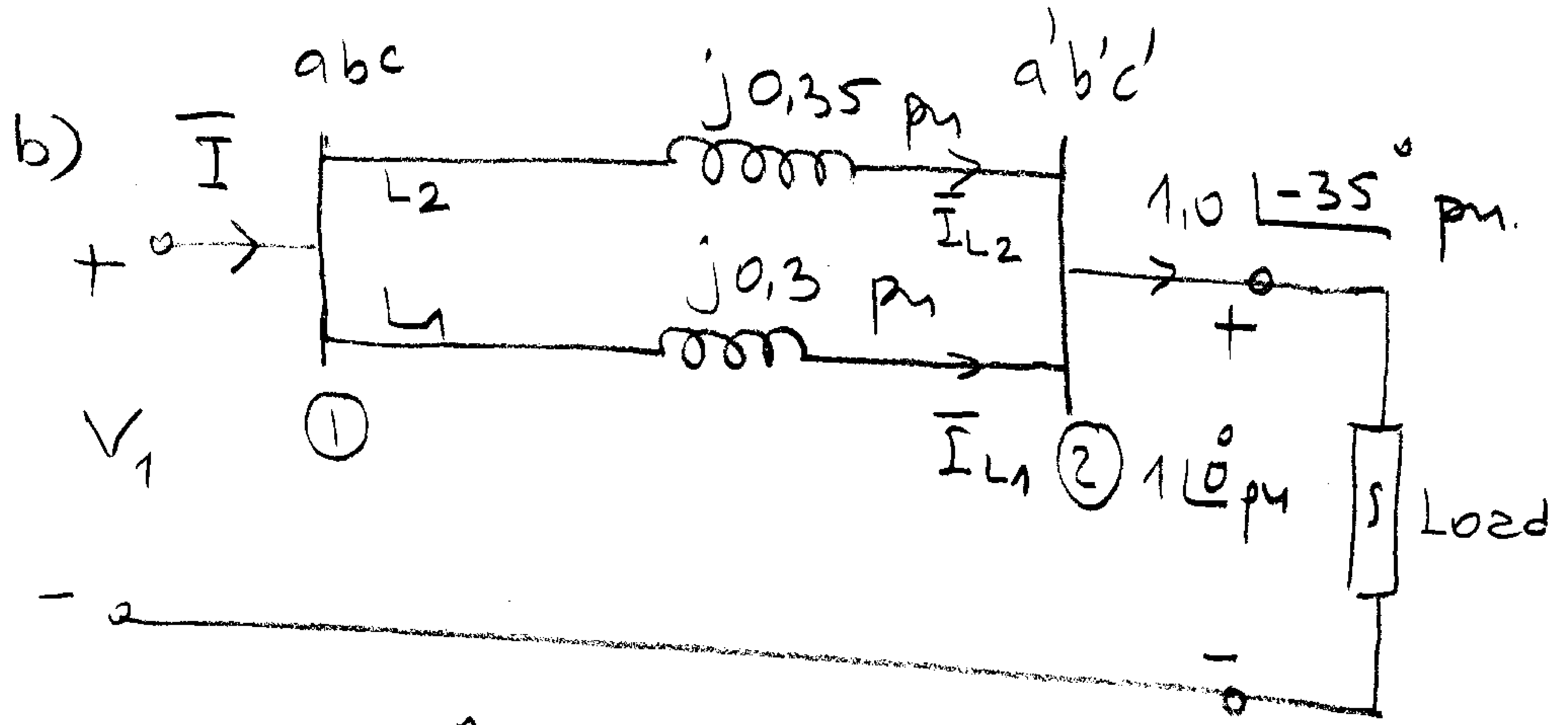
b)



$$\bar{I}_{L2} = 1{,}0 \angle -35^\circ \; \frac{0{,}3}{0{,}65} = 0{,}46154 \angle -35^\circ = 0{,}3780 - j0{,}2647 \text{ pu}$$

$$\bar{I}_{L1} = 1{,}0 \angle -35^\circ \; \frac{0{,}35}{0{,}65} = 0{,}53846 \angle -35^\circ = 0{,}4410 - j0{,}3088 \text{ pu}$$

$$\bar{S}_{L2} = 1 \angle 0^\circ \times 0{,}46154 \angle +35^\circ = \underbrace{0{,}3780}_{P_{L2}} + j\underbrace{0{,}2647}_{Q_{L2}} \text{ pu}$$

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$$\bar{S}_{L1} = 1 \angle 0^\circ \; 0{,}53846 \angle +35^\circ = \underbrace{0{,}4410}_{P_{L1}} + j\underbrace{0{,}3088}_{Q_{L1}} \text{ pu.}$$

c)

$$\begin{bmatrix} 6{,}1904 \angle -90^\circ & 6{,}1882 \angle 91{,}61^\circ \\ 6{,}1882 \angle 88{,}3^\circ & 6{,}1904 \angle -90^\circ \end{bmatrix} \begin{bmatrix} \bar{V}_1 \\ 1 \angle 0^\circ \end{bmatrix} = \begin{bmatrix} \bar{I} \\ -1{,}0 \angle -35^\circ \end{bmatrix}$$

$$6.1882 \angle 88.3^\circ \, \overline{V}_1 + 6.1904 \angle -90^\circ = -1.0 \angle -35^\circ$$

$$\overline{V}_1 = \frac{1.0 \angle 145^\circ + 6.1904 \angle 90^\circ}{6.1882 \angle 88.3^\circ} = \frac{-0.81915 + \overbrace{j0.5736 + j6.1904}^{j6.764}}{6.1882 \angle 88.3^\circ}$$

$$\overline{V}_1 = \frac{6.8134 \angle 96.8^\circ}{6.1882 \angle 88.3^\circ} = 1.1010 \angle 8.5^\circ \text{ pu}$$

$$\overline{I}_{L2} = \frac{1.1010 \angle 8.5^\circ - 1.0}{j0.35} = \frac{1.0889 + j0.1627 - 1.0}{j0.35}$$

$$\overline{I}_{L2} = \frac{0.0889 + j0.1627}{j0.35} = \frac{0.1854 \angle 61.34^\circ}{0.35 \angle 90^\circ} = 0.5297 \angle -28.6^\circ$$
$$= 0.4650 - j0.2535$$

$$\overline{I}_{L1} = 1 \angle -35^\circ - (0.4650 - j0.2535)$$
$$= 0.81915 - j0.5736 - 0.4650 + j0.2535 = 0.35415 - j0.3201 \text{ p-}$$

decrease

$$\overline{S}_{L1} = 1 \angle 0^\circ \, \overline{I}_{L1}^* = \underbrace{0.35415}_{P_{L1}} + j\underbrace{0.3201}_{Q_{L1}} \qquad 0.4410 + j0.3088$$

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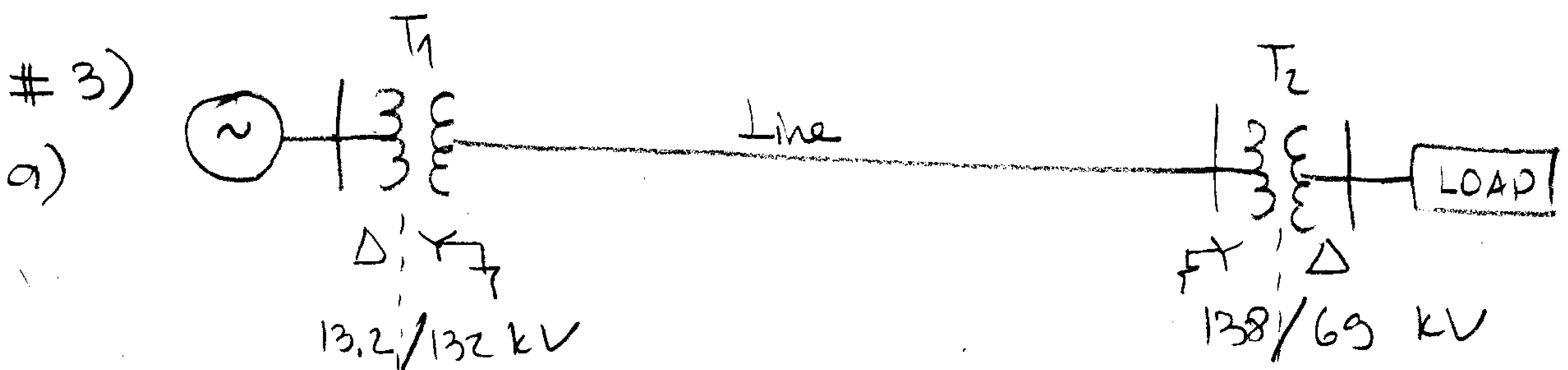
$$\overline{S}_{L2} = 1 \angle 0^\circ \, \overline{I}_{L2}^* = 0.4650 + j0.2535 \qquad 0.3780 + j0.2647$$

increase

no phase regulating transformer exists.

3)
a)



$V_{base_{LL}} = 13.8$ kV $\qquad V_{base_{LL}} = 138$ kV. $\qquad V_{base_{LL}} = 69$ kV

$$\bar{V}_G = \frac{13,2\angle 0^\circ}{13,8} = 0,9565\angle 0^\circ$$

$$X_{T_1} = 0,1\left(\frac{13,2}{13,8}\right)^2\left(\frac{10}{5}\right) = 0,183 \text{ pu.}$$

$$\bar{Z}_{line} = \frac{10+j100}{\frac{(138)^2}{10}} = \frac{100}{(138)^2} + j\frac{1000}{(138)^2} = 5,2501\ 10^{-3} + j0,0525 \text{ pu}$$

$$X_{T_2} = 0,08$$

$$\bar{Z}_{load} = \frac{150+j100}{\frac{(69)^2}{10}} = \frac{1500}{(69)^2} + j\frac{1000}{(69)^2} = 0,315 + j0,210$$

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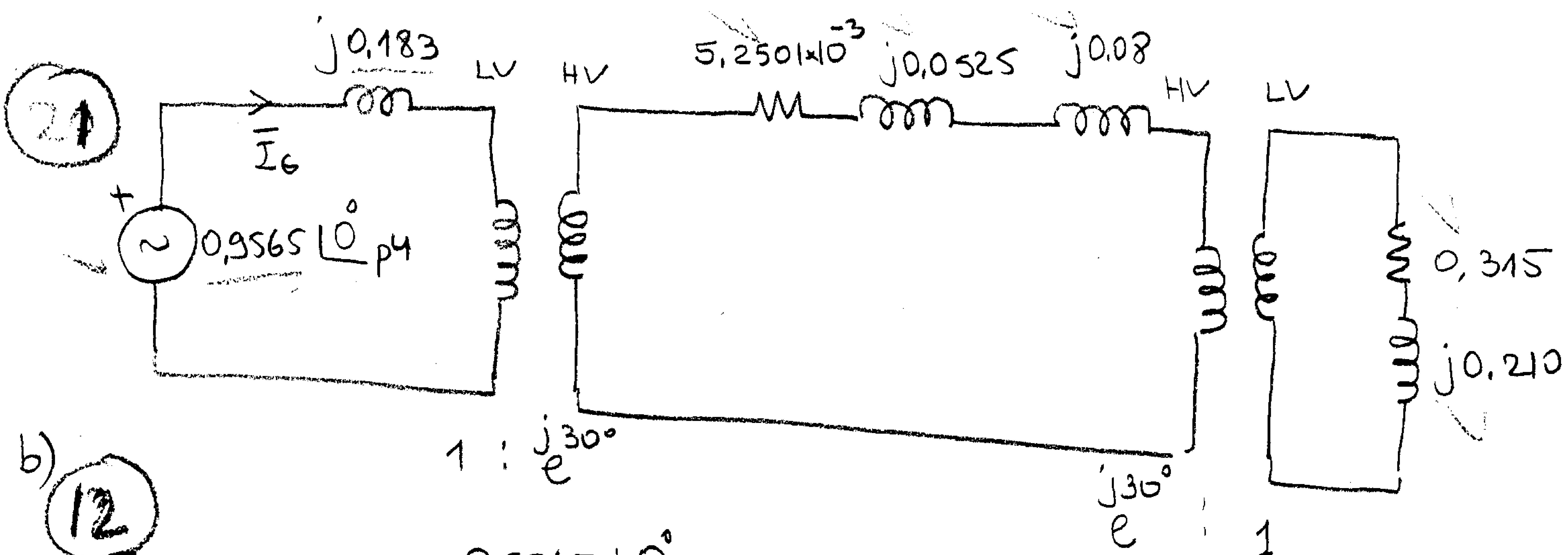

b) 12

$$I_G = \frac{0,9565\angle 0^\circ}{\underbrace{(5.25\ 10^{-3}+0,315)}_{0,32025} + j\underbrace{(0,183+0,0525+0,210)}_{0,5255}} = \frac{0,9565\angle 0^\circ}{0.6154\angle 58.64^\circ}$$

$$\bar{I}_G = 1,554\angle -58,64^\circ \text{ pu.}$$

$$\bar{I}_G = 1,554\ \frac{10\ 10^6}{\sqrt{3}\ 13,8\ 10^3}\angle -58,64^\circ = 650.14\angle -58.64^\circ \text{ A}$$