Power Systems Analysis, L2 2018

Lennart Söder

Professor in Electric Power Systems

Per-unit (PU)-system 3

1. Chose a suitable base power for the system. It should be in the same range as the rated power of the installed system equipment's.

2. Chose a base voltage at one section of the system. The system is divided into different sections by the transformer.

3. Calculate the base voltages in all sections of the system by using the transformer ratios.

4. Calculate all per-unit values of all system components that are connected.

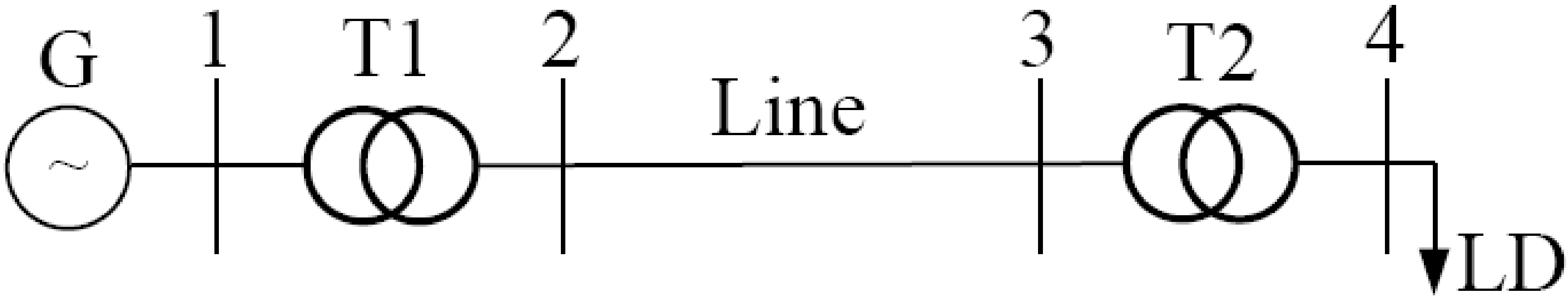
5. Draw a single-line diagram of the system.

6. Perform the requested analysis.

7. Transform the result back to nominal values

Example 5.2

A power system is given in the figure where a load is fed by a generator via a transmission line and two transformers. Calculate the load voltage as well as the active power of the load.



Example 6.2

Generator G: 13.8 kV phase-to-phase voltage.

Transformer T1: 10 MVA, 13.8/69 kV, j1.524 Ω (13.8. kV-side)

Line L: 10 km, j0.8 Ω/phase, km

Transformer T2: 5 MVA, 66/13.2 kV, x = 8%

Load LD: 4 MW, cosφ = 0.8, 13.2 kV, impedance characteristic.

Home Exam S1-S3 (Sept-18)

For this home exam you need a unique number, called B-number. To get your B-number send an email to eg2100@ee.kth.se, and write “B-number" in the subject of the email, and your name, your personal number and your email address in the body of your message.

Based on your B-number you will receive an excel file in which the system data for all assignments is given. All your assignments will be performed based on your individual system.

In each report,

- all introduced variables, matrices and equations must clearly be defined,
- the equations and numerical answers must be given in a similar way as those given in the examples of the compendium.
- the variables must be properly denoted, and their units must also be given,
- the impedance and complex power must be given in rectangular form, voltage and current must be given in polar form, angle must be given in degrees,
- the single-line diagrams of the systems must be drawn digitally and neatly. Also, the components of the single-line diagram should be mentioned and named properly.

Matlab example of rectangular and polar coordinates

```
>> voltage=1+i
voltage =
   1.0000 + 1.0000i
>> abs(voltage)
ans =
    1.4142
>> angle(voltage)*180/pi
ans =
    45
>>
```

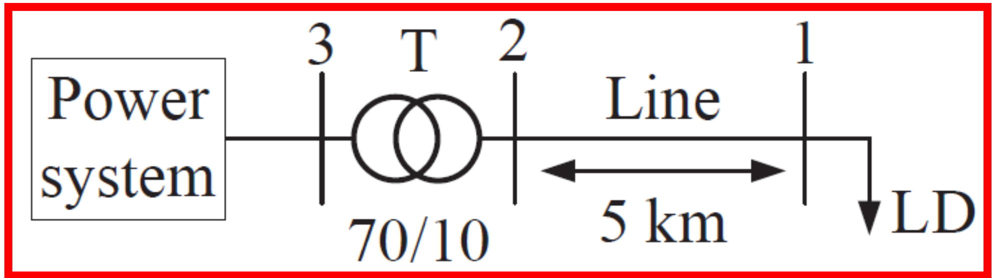
Please note that your MATLAB-code must be appended in your report (as an appendix).

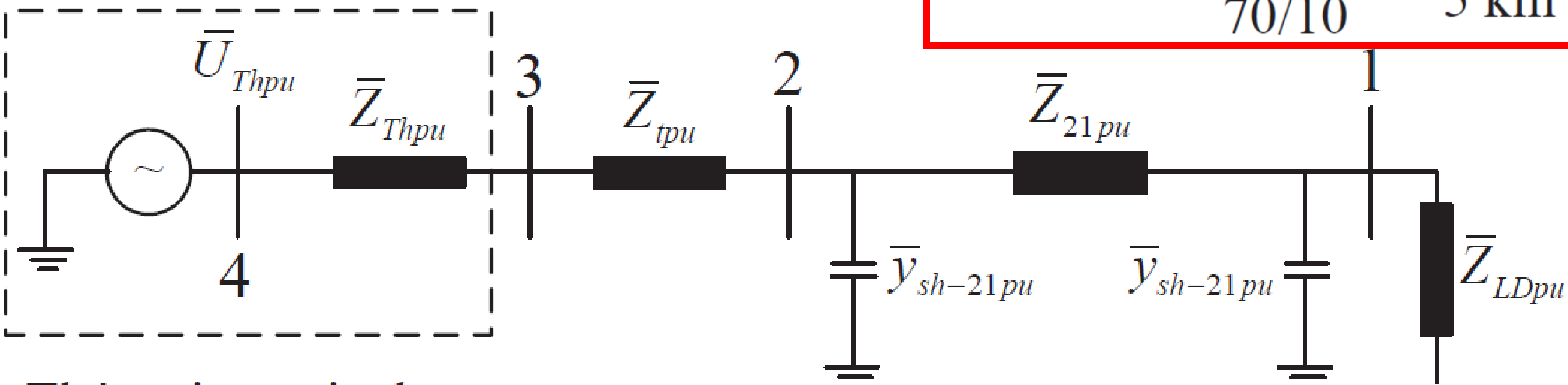
For the assignments S1 to S3, the results from one assignment will be used in the next one. Therefore, you may create one MATLAB-file for S1, one for S2 and one for S3. The two latter files use the results from the previous one. It is therefore important to have relevant names of all variables you use in your MATLAB-files for S1 to S3.

Home Exam S1 (Sept-18)

This assignment is dealing with the electrical network of a factory **<u>fed from</u>** a 40 kV meshed grid. The system data can be found in the Excel file.

Example 6.2





Thévenin equivalent of the power system

Transformer

Line

Industry

Home Exam S1 (Sept-18), Part 1

a. Based on the given data, draw the single-line diagram of the electrical network of the factory. **(5%)**

b. As seen from node **a**, make the two-port model and give the values of the elements of the two-port matrix in pu. **(10%)**

c. Give the value of the impedance of the entire system in pu. **(10%)**

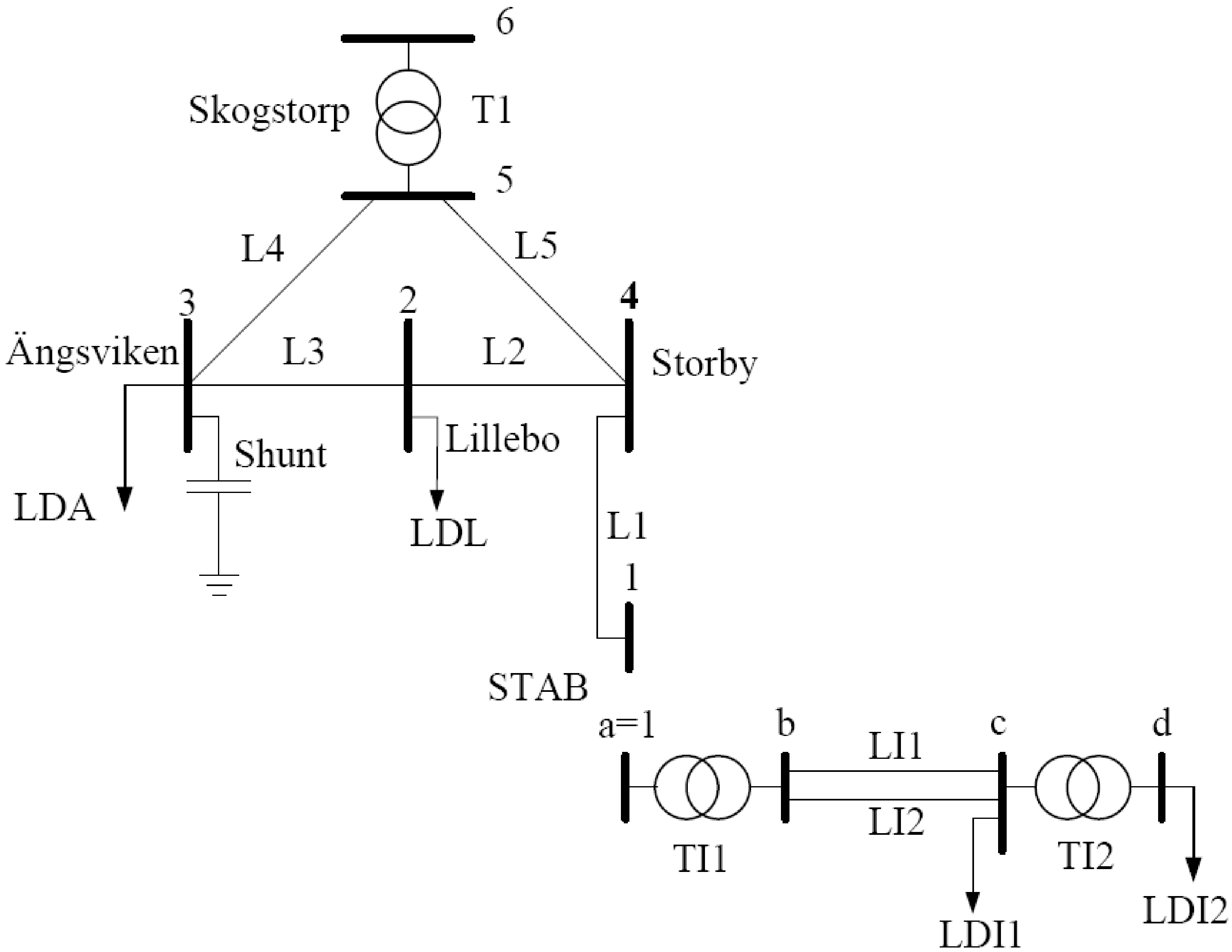
d. Assume that the transformer “TI1” is fed with nominal voltage. Find the voltage at node **e** in kV. **(20%)**

e. Find the consumed active power of the load at node **e** in MW, and also its power factor. **(20%)**

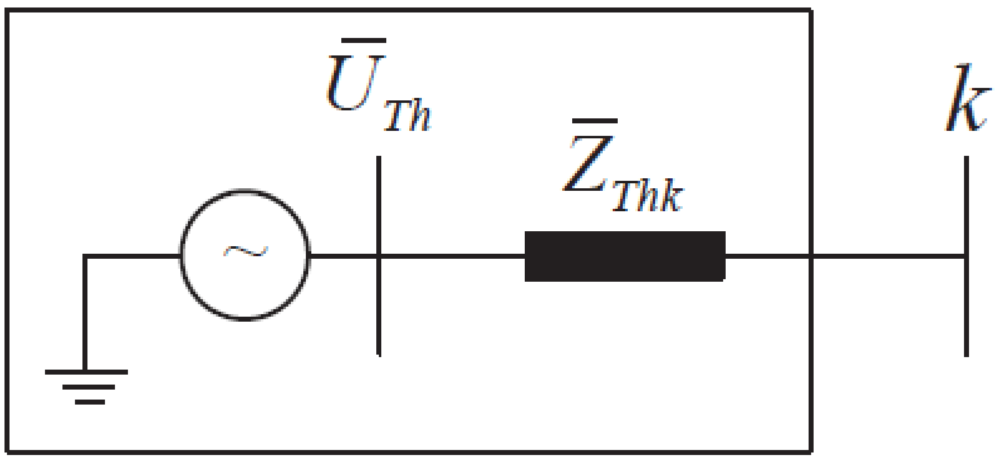
f. Find the total losses in the factory in kW. **(20%)**

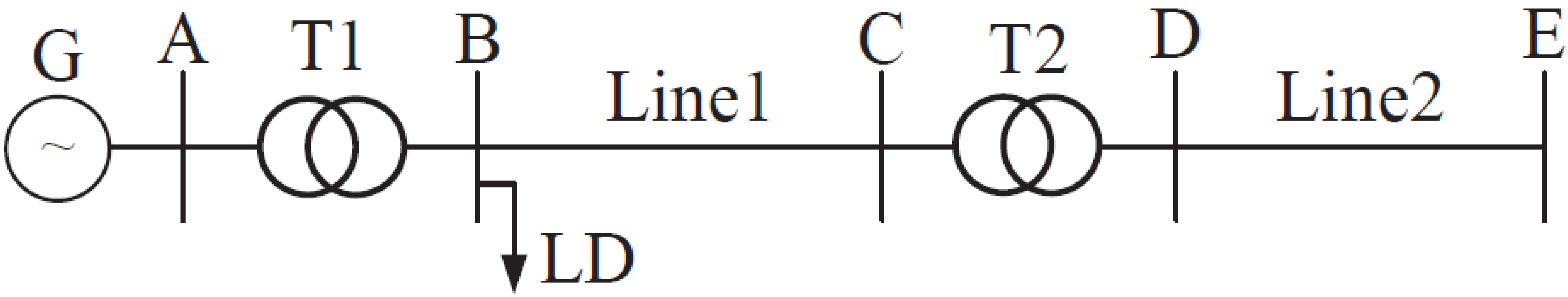
g. Plot the normalized active power consumption at node **e** (based on the obtained active power in task d) when the voltage at node **a** varies from 0.8 to 1.2 pu. **(15%)**

Home Exam S1-S3



Connection to a network





Example 6.1

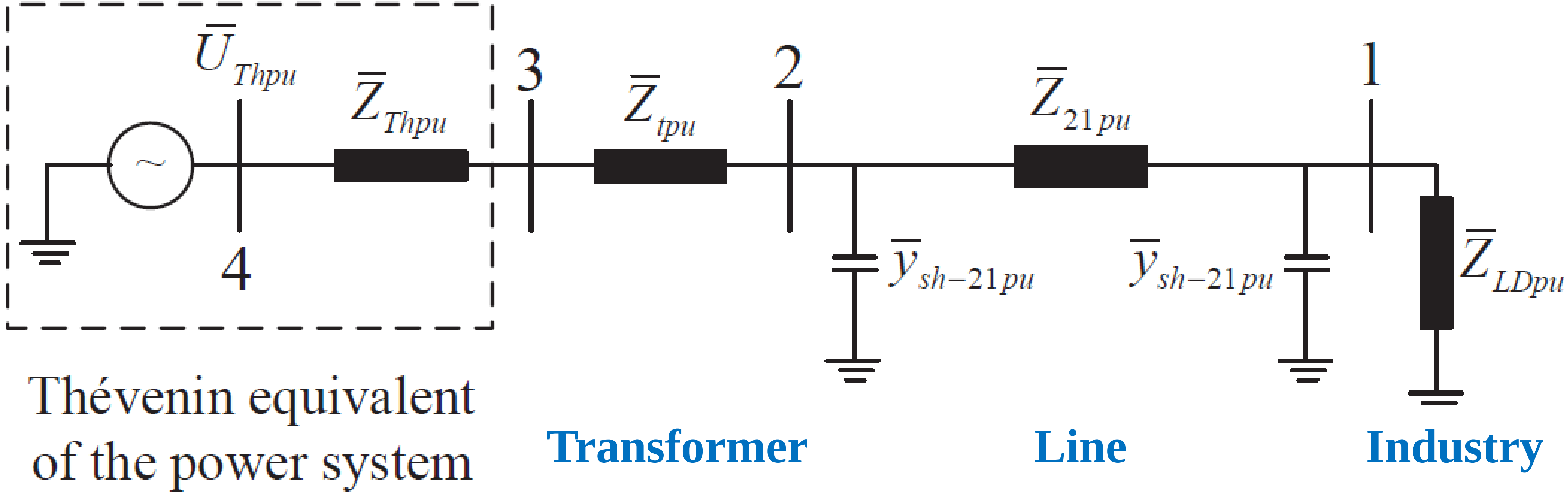
At a bus with a short circuit capacity of 500 MVA and $\cos\varphi_k = 0$, inductive, an impedance load of 4 MW, $\cos\varphi_{LD} = 0.8$ at nominal voltage, is connected.

Calculate the change in bus voltage when the load is connected.

Example 6.2

A small industry is fed by a transformer (5 MVA, 70/10 kV, x = 4%) which is located at a distance of 5 km. The electric power demand of the industry is 400 kW at cosφ=0.8, lagging, at a voltage of 10 kV. The industry can be modeled as an impedance load. The 10 kV line has an series impedance of 0.9+j0.3 Ω/phase, km and a shunt admittance of $j3 \cdot 10^{-6}$ S/phase, km. Assume that the line is modeled by the II-equivalent. Calculate the voltage level at the industry as well as the power fed by the transformer into the line. When the industry is not connected, a short circuit current of 0.3 kA side of the transformer when a three-phase short circuit is applied at nominal voltage.

Example 6.2



$\overline{U}_{Thpu}$
$\overline{Z}_{Thpu}$
3
$\overline{Z}_{tpu}$
2
$\overline{Z}_{21\,pu}$
1
4
$\overline{y}_{sh-21\,pu}$
$\overline{y}_{sh-21\,pu}$
$\overline{Z}_{LDpu}$
Thévenin equivalent
of the power system
Transformer
Line
Industry

```
clear

deg=180/pi;
rad=1/deg;

%--- Example 6.2
% Choose the base values
Sb=0.5; Ub10=10; Ib10=Sb/Ub10/sqrt(3);Zb10=Ub10^2/Sb;
Ub70=70; Ib70=Sb/Ub70/sqrt(3);

%Calculate the per-unit values of the Thevenin equivalent of the system
UTh=70*exp(j*0*rad);
Isc=0.3*exp(j*-90*rad);
UThpu =UTh/Ub70;
Iscpu =Isc/Ib70;
ZThpu =UThpu/Iscpu;

% Calculate the per-unit values of the transformer
Zt=j*4/100;Snt=5;
Ztpu=Zt*Sb/Snt;

%Calculate the per-unit values of the line
Z21pu=5*(0.9+j*0.3)/Zb10;
ysh21pu=5*(j*3*1E-6)*Zb10/2;

%Calculate the per-unit values of the industry impedance
cosphi=0.8;sinphi=sqrt(1-cosphi^2);
Un=Ub10;PLD=0.4;absSLD=PLD/cosphi;
SLD=absSLD*(cosphi+j*sinphi);
ZLDpu=Un^2/conj(SLD)/Zb10
```

```
% The twoport of the system
AL=1+ysh21pu*Z21pu;
BL=Z21pu;
CL=ysh21pu*(2+ysh21pu*Z21pu);
DL=AL;

F_L=[AL BL ; CL DL];
F_Th_tr=[1 ZThpu+Ztpu ; 0 1];
F_tot=F_Th_tr*F_L;

%The impedance of the entire system
Ztotpu=(F_tot(1,1)*ZLDpu+F_tot(1,2))/(F_tot(2,1)*ZLDpu+F_tot(2,2))
I4pu = UThpu/Ztotpu;

%The power fed by the transformer into the line
U2pu_I2pu=inv(F_Th_tr)*[UThpu;I4pu];
S2=U2pu_I2pu(1,1)*conj(U2pu_I2pu(2,1))*Sb

%The voltage at the industry
U1pu_I1pu=inv(F_tot)*[UThpu;I4pu];
U1=abs(U1pu_I1pu(1,1))*Ub10,
```