Exercises of course ELEC0029

Power flow computation and sensitivity analysis in a simple system

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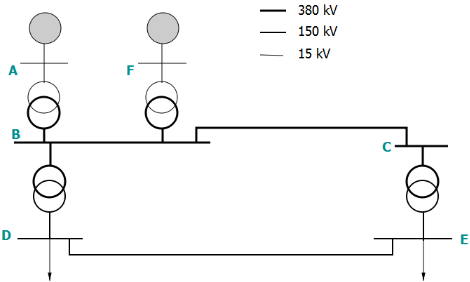
System data



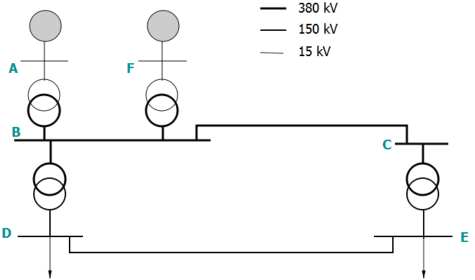
Lines data

U_N (kV)	X (Ω/km)	X/R	$\omega C/2$ (μS/km)	S_N (MVA)	km
380	0.3	10	1.5	1350	50
150	0.4	5	1.2	300	50

Transformers data

orig	extr	R (pu)	X (pu)	B (pu)	S_N (MVA)	n ("extr" side)
A	B	0	0.14	0	500	1.08
F	B	0	0.14	0	250	1.08
D	B	0	0.14	0	300	1.00
E	C	0	0.14	0	600	1.00

Operating point data



- generators:
  - voltage at bus A: 15 kV
  - voltage at bus F: 15 kV
  - production of F: 150 MW
- loads:
  - at bus E: 400 MW / 120 Mvar
  - at bus D: 100 MW / 30 Mvar

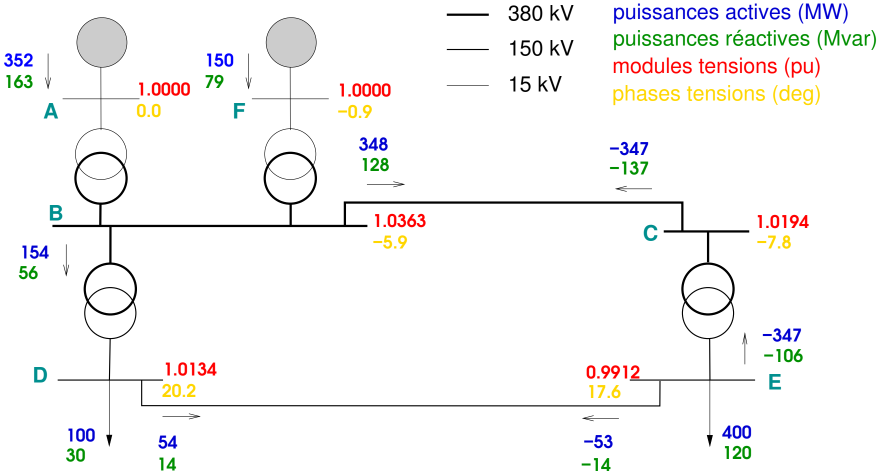
- Specify the data at all buses and run a power flow computation to determine the electrical state of the system. In this computation assume that transformers D-B and E-C are of Yd11 type, and take into account the phase angle of their transformer ratios.

  The data are available in the file 6bus.dat, while the results can be displayed on the one-line diagram by using the file 6bus.svg

- Detail the active and reactive power balances of the system.

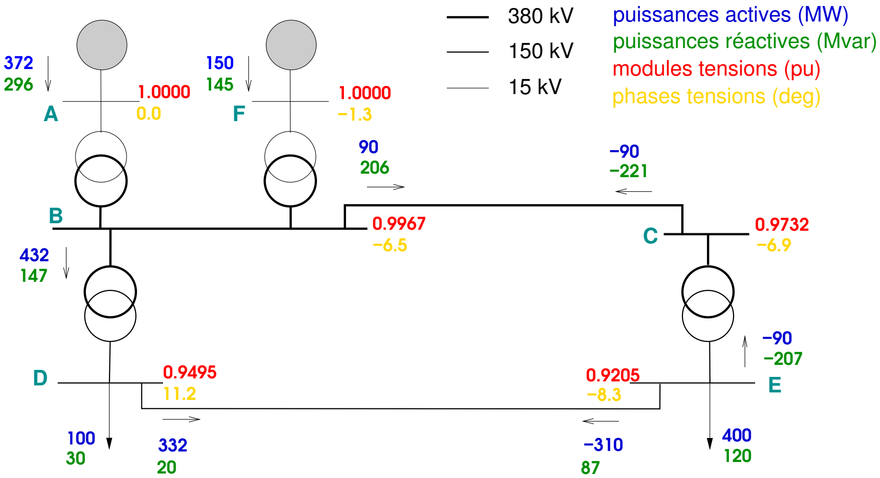
- Check that line D-E and transformer C-E operate below their thermal ratings.

Transformers D-B et E-C of type Yd11; complex ratios



- Simulate the misuse of a transformer E-C of type Yy0, while transformer D-B is of type Yd11. Show that the resulting electrical state is unacceptable.

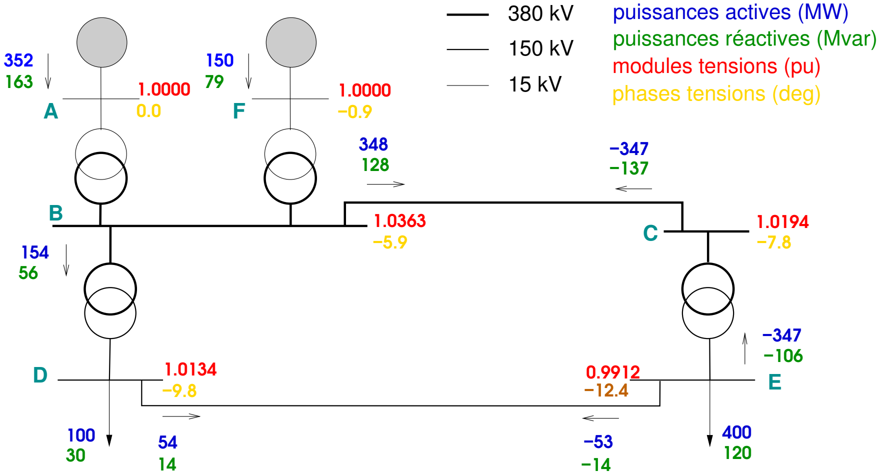
Transformer D-B of type Yd11 and E-C of type Yy0



- Getting back to the correct configuration of the transformers, perform a new power flow computation in which the phase angles of the transformer ratios are set to zero. Comment on the results obtained.

  Unless otherwise specified, the phase angles are neglected in the sequel.

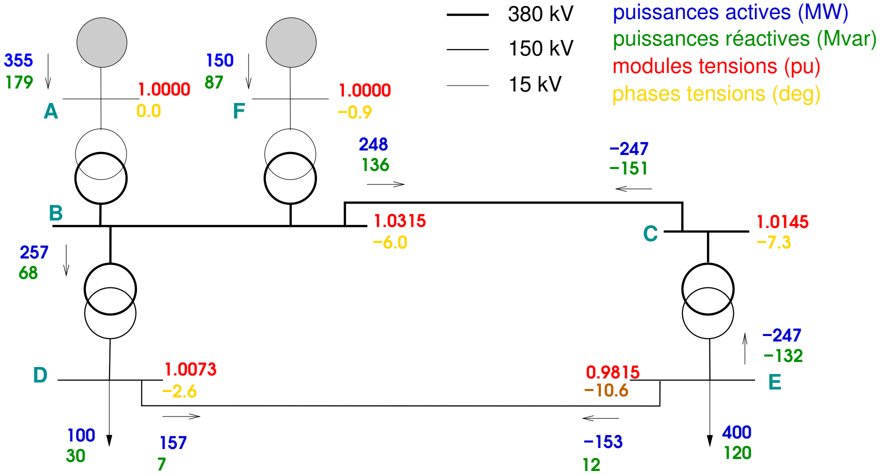
Phase angles of transformer ratios neglected



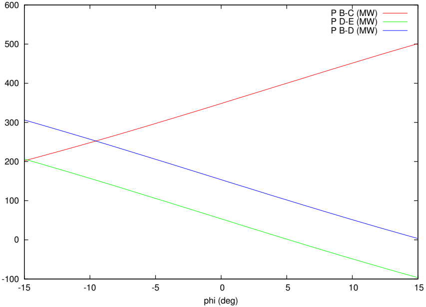
- Assuming that transformer D-B is equipped with a phase shifting device allowing to vary progressively the phase angle of its transformer ratio, study the impact of this phase angle on branch power flows and bus voltage magnitudes.

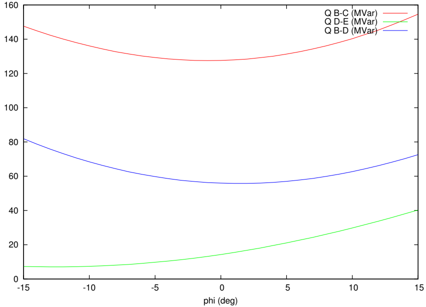
Varying the phase angle of the ratio of transformer D-B

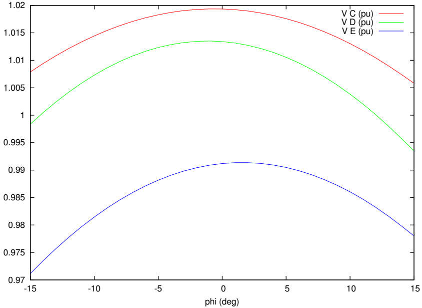
$1\angle 0^\circ$ for E-C and $1\angle\phi^\circ$ for D-B. Example for $\phi = -10^\circ$.



Variation of ϕ





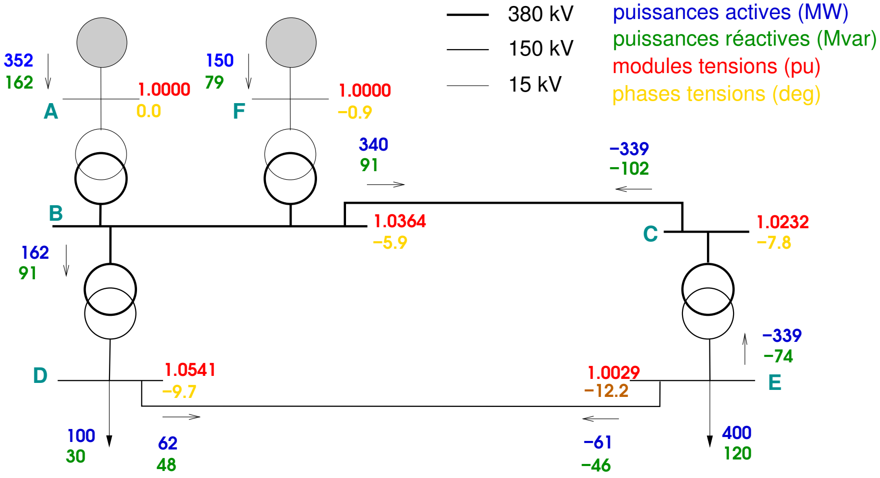


- Assuming that transformer D-B is equipped with a tap changer allowing to vary progressively (the magnitude of) its transformer ratio, study the impact of this ratio on branch power flows and bus voltage magnitudes.

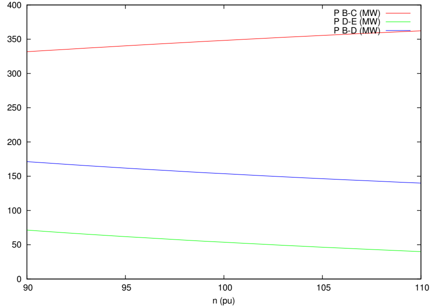
- Same question for an identical variation of the ratios of both transformers D-B an E-C.

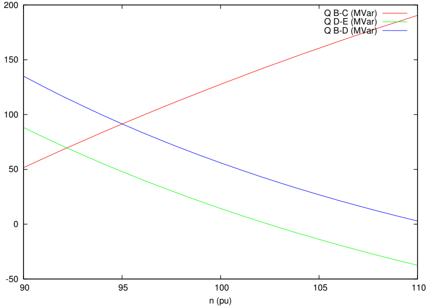
Varying the (magnitude) of the ratio of transformer D-B

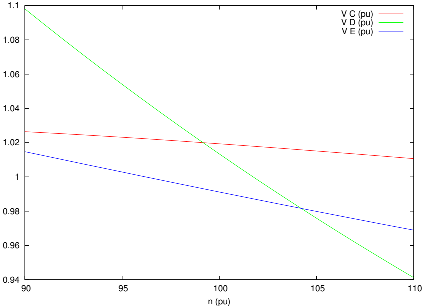
$1\angle 0°$ for E-C and $n\angle 0°$ for D-B. Example for $n = 0.95$.



Variation of n

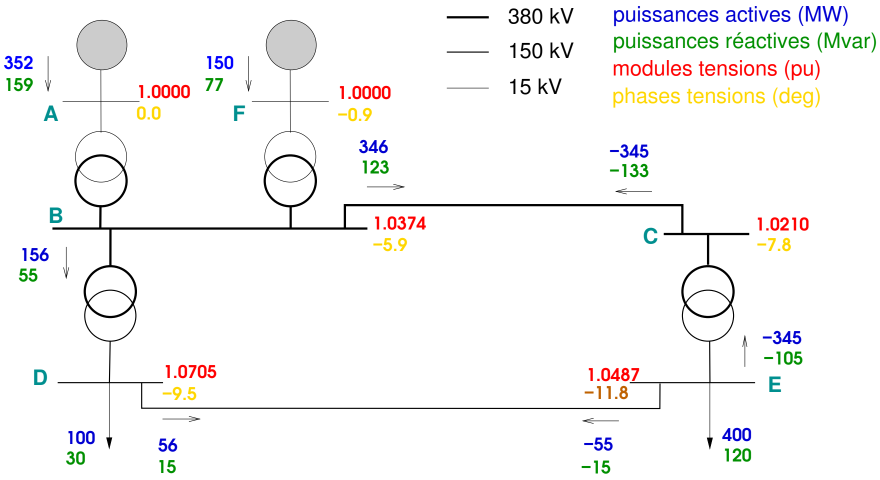




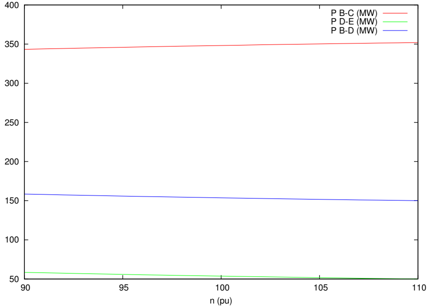


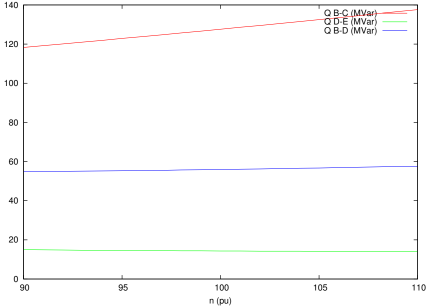
Same variation of the ratios of transformers D-B et E-C

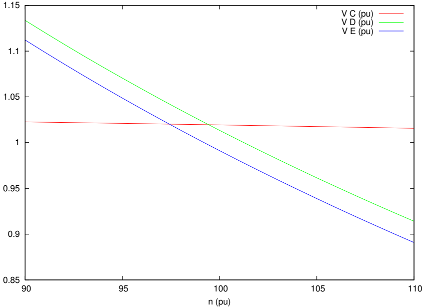
$n\angle 0°$ for both transformers. Example for $n = 0.95$.



Same variation of *n* in both transformers







- Let ARTERE (the power flow computation software) adjust automatically the ratios of both transformers D-B and E-C so as to bring the voltages at buses D and E in the dead-band [1.02 1.04] pu

Automatic adjustment of the ratios of both transformers to bring the voltages at buses D and E in [1.02 1.04] pu

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  iter    max mismatches :  MW        Mvar     phi(MVA)

    1                    395.2       407.1        605.1
    2                     27.4        62.4         78.0
    3                      1.0         1.2          2.0
    4                      0.1         0.1          0.1
 in-phase trfo taps :   2 down      0 up
    4                      4.4        58.8         90.6
    5                      0.2         0.8          1.0
    6                      0.0         0.1          0.1
 in-phase trfo taps :   1 down      0 up
    6                      4.5        61.1         83.7
    7                      0.1         0.7          0.7
    8                      0.0         0.0          0.0
 in-phase trfo taps :   1 down      0 up
    8                      4.5        63.5         86.9
    9                      0.1         0.7          0.7
   10                      0.0         0.0          0.0

 transfo               ctld bus   volt   set-pt   tol     ratio   tap  max

 E-C                   E         1.0275 1.0300 0.0100  0.963   14   25
 D-B                   D         1.0350 1.0300 0.0100  0.988   16   25
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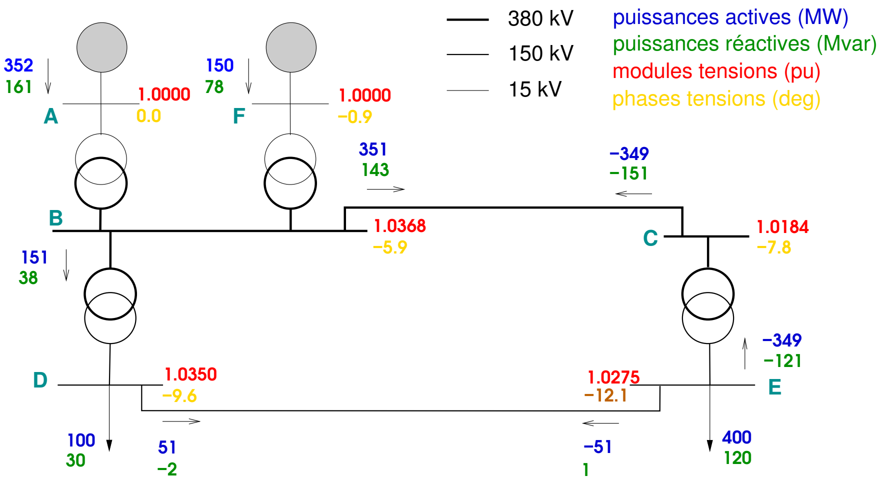
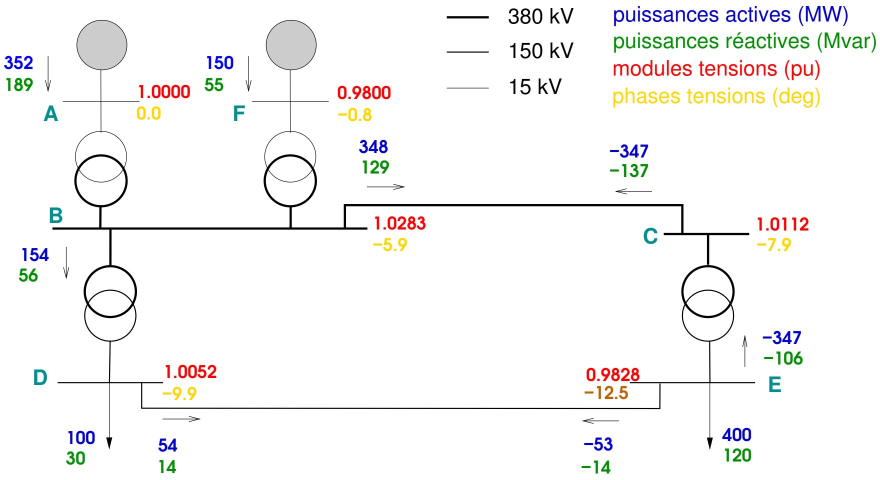
Situation after the transformers have been adjusted



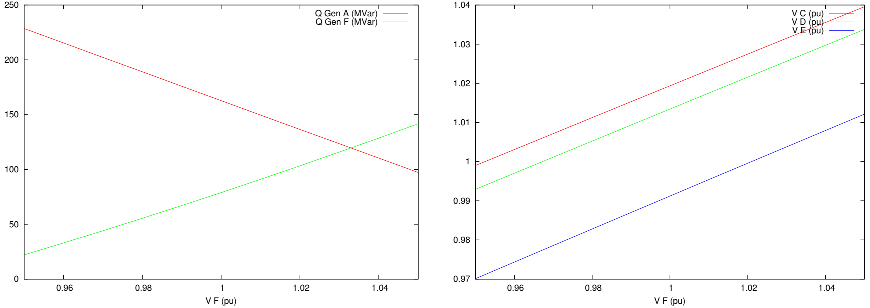
- Study the effect of varying the voltage of generator F on the reactive power productions of both generators, on the branch power flows and on the bus voltage magnitudes.
- Same question for an identical variation of the voltages of both generators A and F.

Varying the voltage of generator F

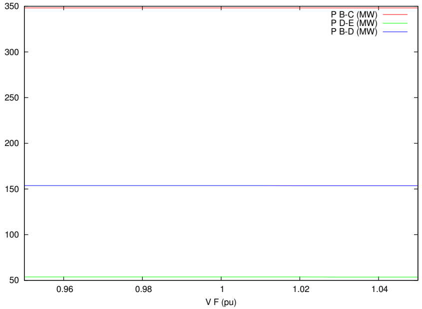
Example: $V_F = 0.98$ pu

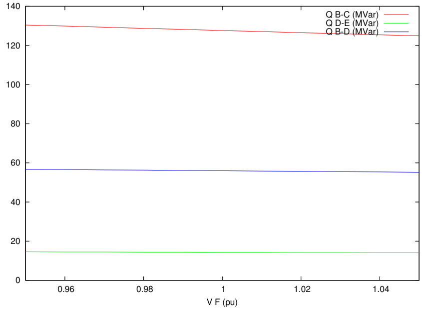


Variation of V_F



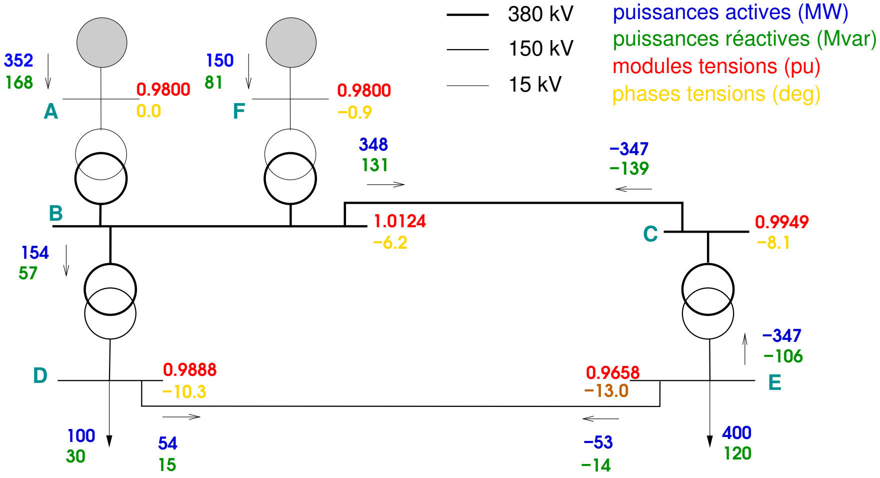
Variation of V_F



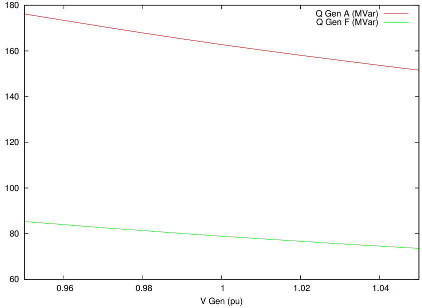


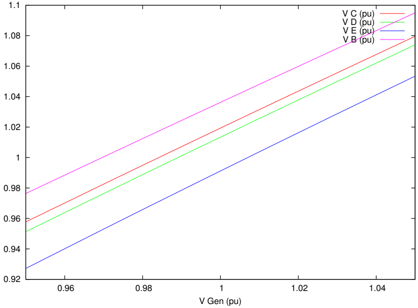
Same variation of voltages of generators A and F

Example: $V_F = V_A = 0.98$ pu



Variation of $V_F = V_A$





Variation of $V_F = V_A$