Exercise 1

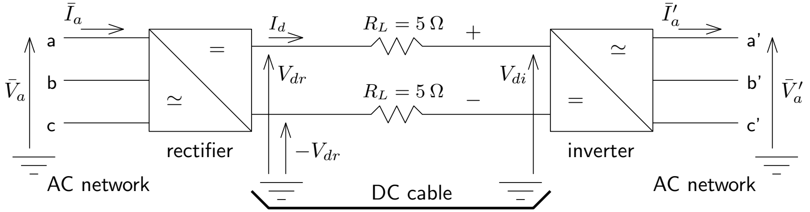
Here is a snapshot of the RMS voltages, RMS currents, three-phase active, reactive and apparent powers measured in several MV/LV sub-stations of the Sart Tilman campus :

B28 : Montefiore	15437V	15436V	15428V	19.8A	20.39A	19.48A	0kW	0kW	0kW	507kW	152kVAr	529kVA	16530158kWh	0kWh	3158035kVAr	2kVAr	03/10/2017 11:37:00
B30 : Cyclotron	235V	236V	236V	118.68A	114.17A	100.69A	25kW	24kW	20kW	3.38kW	35.58kVAr	77.55kVA	2035001kWh	0kWh	905384kVAr	0kVAr	03/10/2017 11:37:00
B31 : Droit	15454V	15447V	15442V	12A	11A	11A	0kW	0kW	0kW	281kW	116kVAr	304kVA	1910050kWh	0kWh	322539kVAr	248389kVAr	03/10/2017 11:37:00
B34 : GIGA	15317V	15324V	15295V	4A	4A	4A	36kW	39kW	38kW	113kW	20kVAr	115kVA	3279821kWh	0kWh	628493kVAr	10kVAr	03/10/2017 11:37:00
B36 : Pharmacie	15424V	15414V	15367V	40.7A	37.85A	39.05A	0kW	0kW	0kW	978kW	360kVAr	1042kVA	30098454kWh	81kWh	12633902kVAr	29kVAr	03/10/2017 11:37:00
B41 : FMV06	15394V	15381V	15335V	17A	15A	17A	0kW	0kW	0kW	356kW	233kVAr	426kVA	5829855kWh	0kWh	4002455kVAr	0kVAr	03/10/2017 11:37:00
B42 : FMV08	15281V	15289V	15243V	9A	10A	10A	70kW	76kW	75kW	220kW	122kVAr	252kVA	5400510kWh	0kWh	2531453kVAr	0kVAr	03/10/2017 11:37:00
B52 : Genie Civil	15381V	15434V	15459V	18.98A	18.71A	18.83A	0kW	0kW	0kW	446kW	233kVAr	503kVA	10807323kWh	0kWh	5263374kVAr	0kVAr	03/10/2017 11:37:00

- neglecting the (small) imbalance of voltages and currents, check the values of the RMS currents in the B28 sub-station;
- compare the power factors measured in the B28 and B52 sub-stations, respectively.

Exercise 2

Consider the High Voltage Direct Current (HVDC) link shown in the figure below.



- AC voltage at rectifier end : 400 kV   AC voltage at inverter end : 380 kV
- voltage V_{dr} at rectifier end of DC cable : 270 kV (between + pole and ground)
- active power entering the rectifier : 1000 MW
- reactive power consumed by the rectifier : 650 Mvar
- reactive power consumed by the inverter : 600 Mvar [1]
- rectifier and inverter assumed lossless.

Determine the AC current in each phase of the rectifier and of the inverter.

Draw the phasor diagrams of $(\bar{V}_a, \bar{I}_a)$ and $(\bar{V}'_a, \bar{I}'_a)$, respectively.

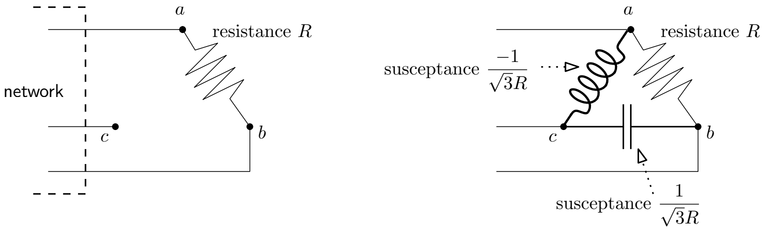
[1] HVDC link with “Line Commutated Converters” : consumes reactive power at both ends

Exercise 3

A single-phase resistive load is connected between phases *a* and *b* of a three-phase network, as shown in the left figure below. It is thus creating an imbalance.

Consider the same load "compensated" as shown in the right figure below.

- Show that, if the network voltages are balanced, so are the line currents[2].
- What is the per-phase equivalent of the compensated load ?
- What is the three-phase reactive power consumed by the compensated load ?



Using the above result, determine how to compensate a double-phase load made up of two identical resistors, one between phases a and b, and one between phases b and c. *Hint: use superposition.*

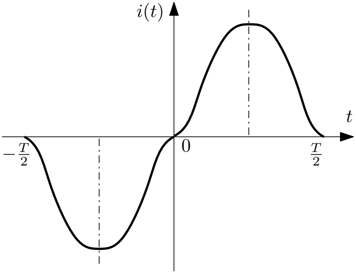
[2] In other words, the load together with its compensator appear balanced if the supply voltages are balanced.

Exercise 4

This exercise is to show the advantage of connecting in delta the loads that produce some current harmonics. The latter are undesirable because they create additional losses, vibrations in rotating machines, etc.

Consider a delta-connected three-phase load, with each branch carrying a current $i(t)$:

- periodic, with period T
- odd: $i(-t) = -i(t)$
- exhibiting inside each half period, a symmetry characterized by : $i(\frac{T}{2} - t) = i(t)$



Show that the currents in the line that feeds this load do not include even harmonics, nor any harmonic with frequency smaller than $5f$ where $f = \frac{1}{T}$ is the frequency of the fundamental component.