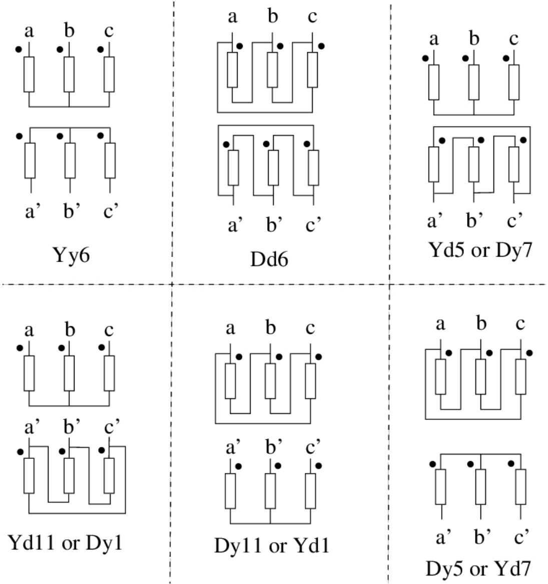
Exercise 1

Confirm the designation of the transformers indicated below the schemes. The black dots indicate primary and secondary voltages which are in phase.



Exercise 2

A transformer used to connect a 15-kV distribution network to a 70-kV sub-transmission network has the following characteristics:

- nominal apparent power: 35 MVA
- nominal primary voltage: 15.3 kV
- nominal secondary voltage: 72.6 kV

Two tests were performed and the following measurements collected:

- open-circuit test:
  - primary: under nominal voltage (15.3 kV)
  - secondary: opened, measured voltage: 72.6 kV
  - current in primary winding: 40. A.
- short-circuit test:
  - primary: reduced voltage of 1.563 kV
  - secondary: short-circuited, nominal current
  - power entering primary winding: 196 kW.

Determine the equivalent circuit of the transformer with the parameters:

- in Ω and S
- in pu on the base of the nominal voltages and power (35 MVA, 15.3 kV, 72.6 kV)
- in pu on the base (35 MVA, 15 kV, 70 kV).

Exercise 3

A three-winding transformer has the following characteristics:

- primary: nominal voltage: 222.0 kV nominal power: 90 MVA
- secondary: nominal voltage: 73.5 kV nominal power: 90 MVA
- tertiary: nominal voltage: 16.5 kV nominal power: 30 MVA.

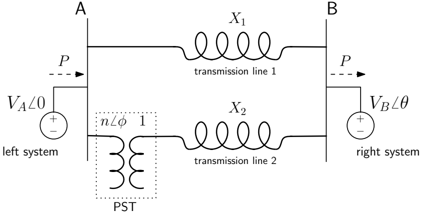
From the measured values given in the table below, determine the parameters of the equivalent circuit, in per unit on the base voltages of 220, 70 and 15 kV. The magnetizing reactance is considered infinite and the copper losses are neglected.

configuration	primary	secondary	tertiary
A	under 28.419 kV voltage	short-circuited, nominal current	opened
B	under 29.527 kV voltage	opened	short-circuited, nominal current
C	opened	under 5.172 kV voltage	short-circuited, nominal current

Exercise 4

In the system below, both transmission lines have the same thermal rating but different reactances: $X_1 = 0.05, X_2 = 0.10$ pu. An active power P of 10 pu is transferred from the left to the right system.

One of the lines is equipped with a Phase Shifting Transformer (PST) with a complex ratio whose magnitude n and phase angle ϕ can be adjusted independently.



- Determine the current in each line without the PST (i.e. $n = 1$ and $\phi = 0$);
- determine the value of ϕ (with $n = 1$) so that the active power flows are the same in both lines;
- determine the values of n and ϕ so that the active and reactive power flows are the same in both lines.

For simplicity the terminal voltages V_A and V_B are assumed constant and equal to 1 pu. The PST is assumed ideal (or its short-circuit reactance is included in X_2).