Departament d'Enginyeria Elèctrica

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Master's degree in Energy Engineering

Power Quality and Renewable Integration in Networks (QSIRX)

Chapter 3: Non-periodic disturbances. Asymmetries and unbalances.

Juan José Mesas García (juan.jose.mesas@upc.edu)

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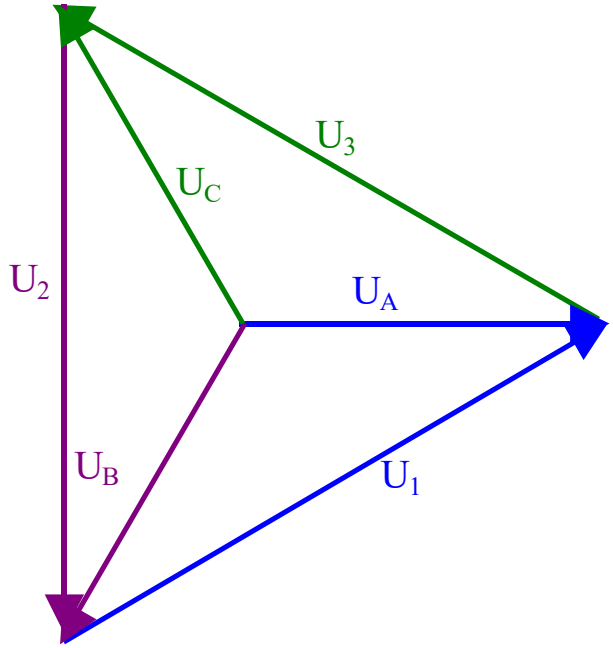
Asymmetries and unbalances

Content

1. Definitions
2. Origin and causes
3. Analytical study
4. Characterization
5. Effects
6. Solutions

Asymmetries and unbalances

- Definitions
  - *Asymmetries*: The phase-to-phase voltages are not equal. They are not an equilateral triangle
  - *Unbalances*: The neutral (origin of the phase-to-neutral voltages) is not in the mass center of the phase-to-phase voltage triangle



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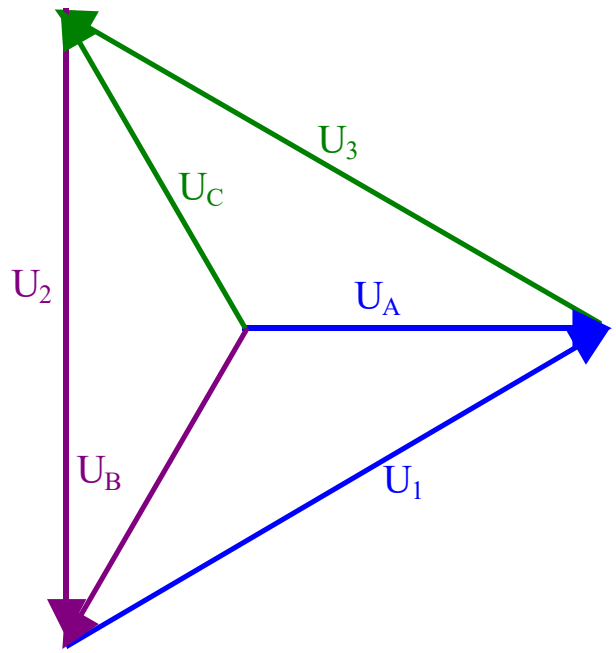

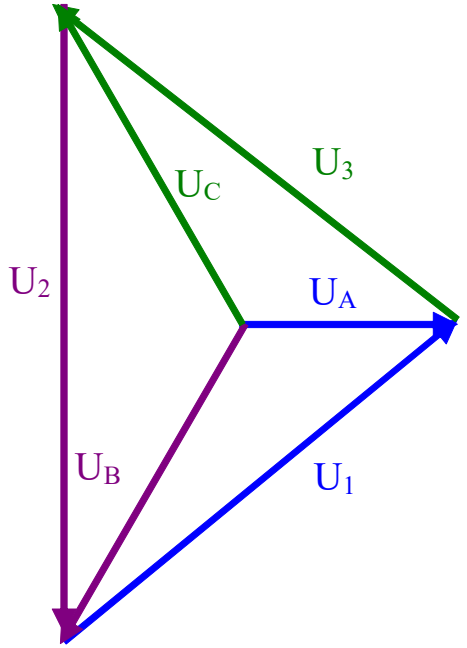

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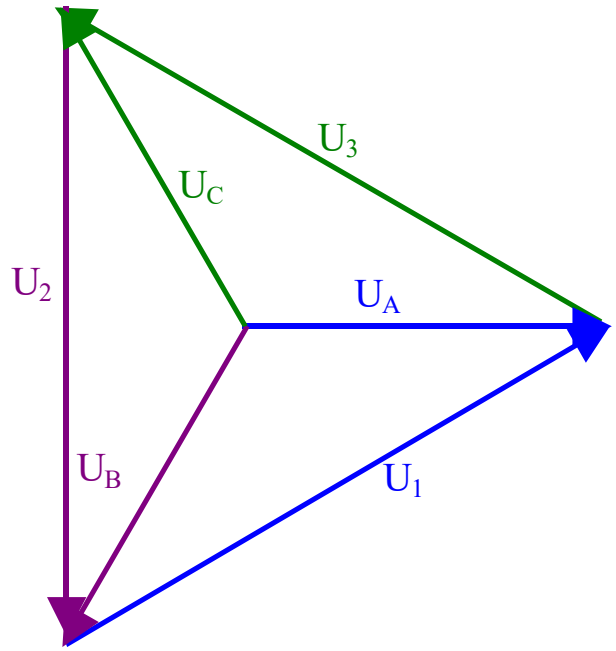
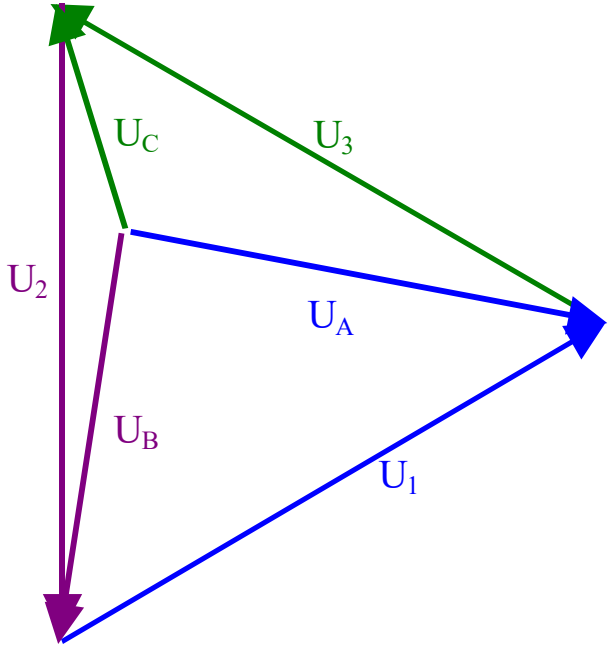
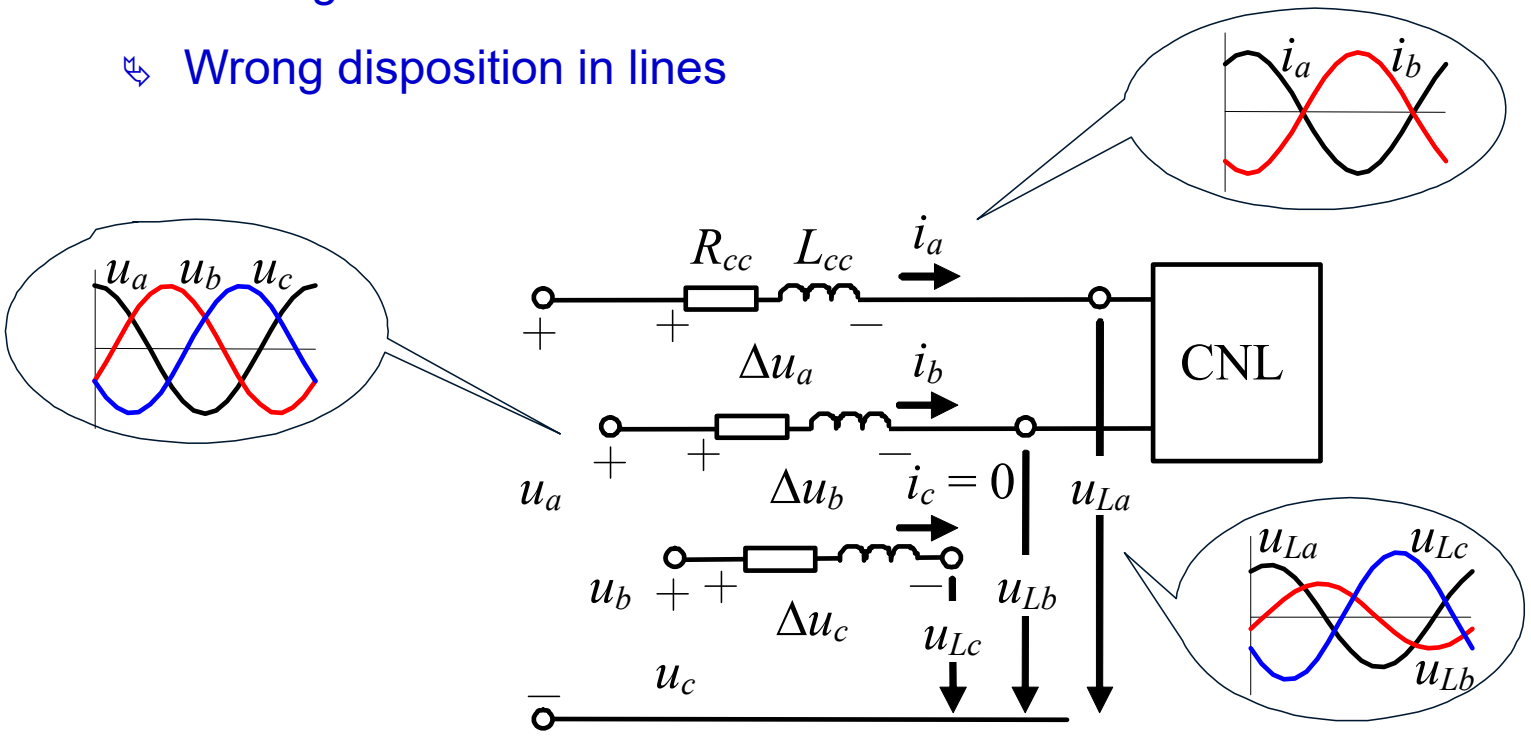




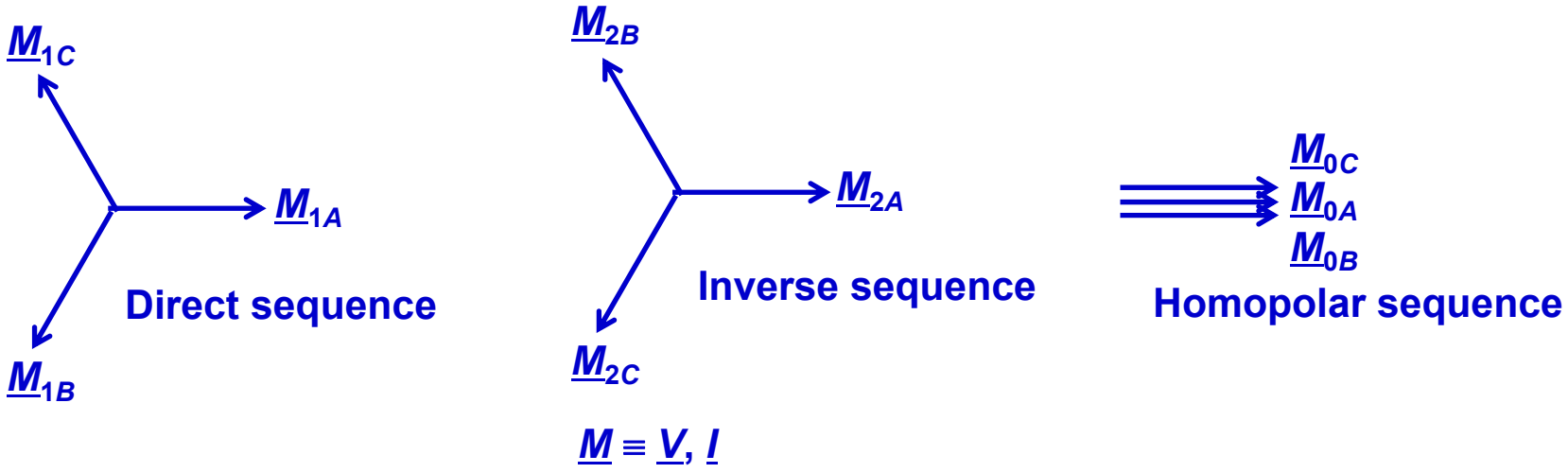
Asymmetries and unbalances

- Origin and causes
  - Large power single-phase loads
  - Single-phase and unbalanced short-circuits
  - Damage in transformers
  - Wrong disposition in lines



Asymmetries and unbalances

- Analytical study
  - Fortescue transformation: An unbalanced three-phase system can be decomposed in three independent systems with three phasors of the same magnitude.
    - Direct (or positive) sequence system
    - Inverse (or negative) sequence system
    - Homopolar (or zero) sequence system



$\underline{M} \equiv \underline{V}, \underline{I}$

Asymmetries and unbalances

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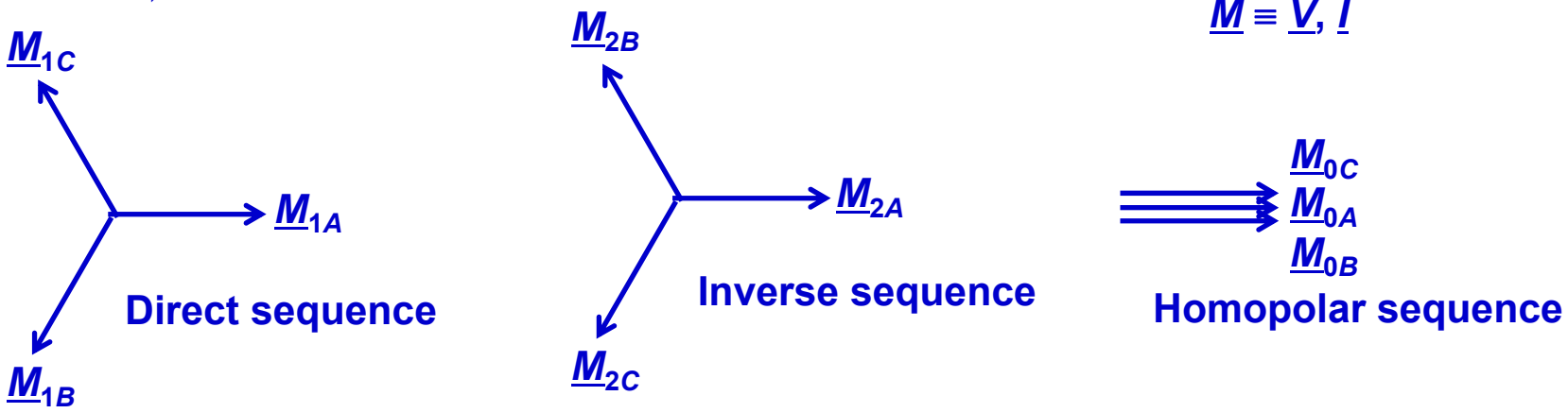

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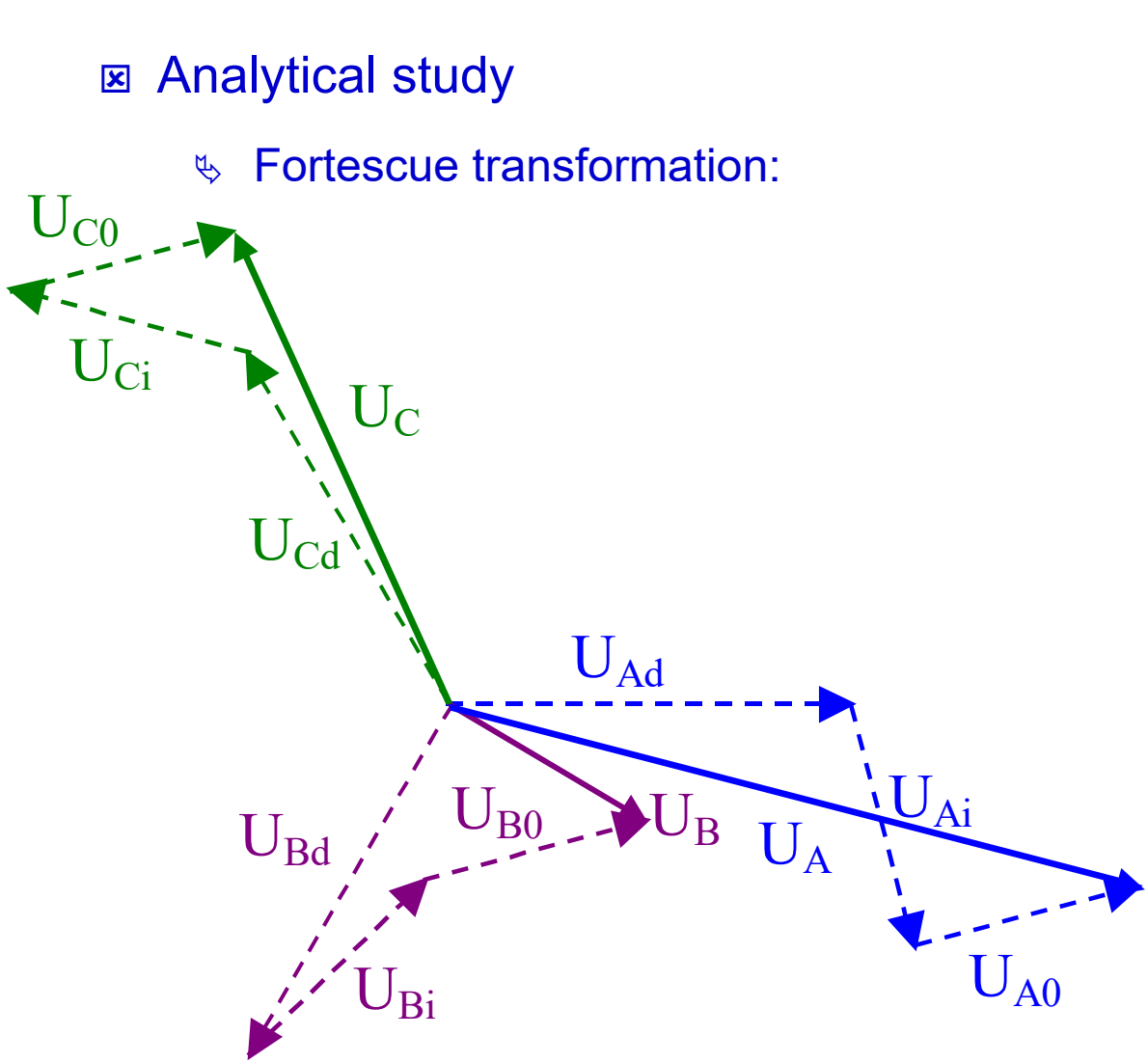
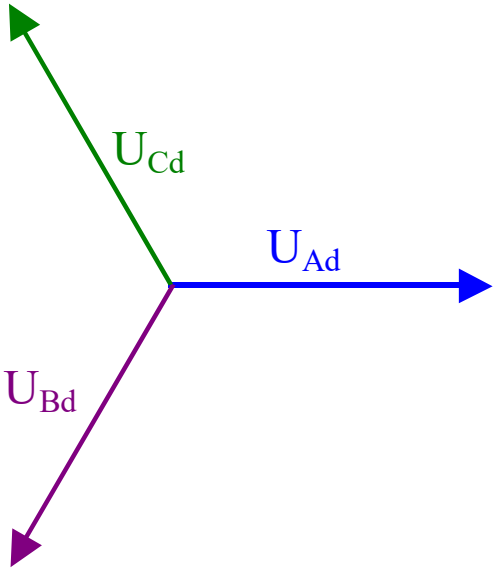
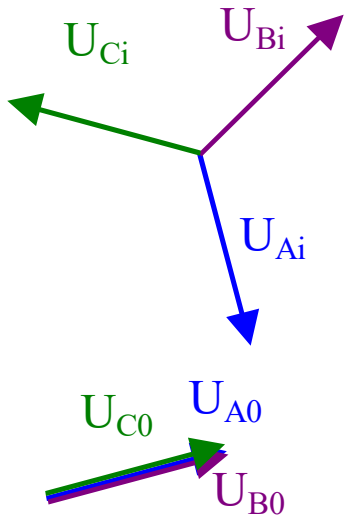






Asymmetries and unbalances

- Characterization
  - Asymmetry factor (UNE 50160):

$$K_A = \frac{U_i}{U_d} < 2\%$$

  - Unbalance factor:

$$K_U = \frac{U_0}{U_d} < 2\%$$

  - Practical ratio for characterizing asymmetries and unbalances

$$K(\%) = \frac{P_m}{P_{CC}} 100$$

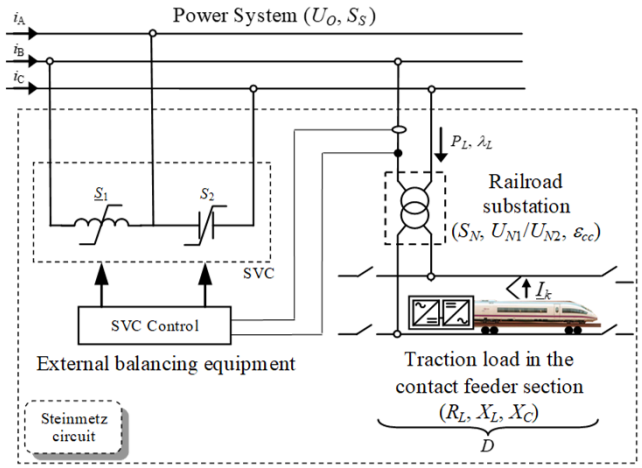
- P_m single-phase load active power consumption
- P_{cc} short-circuit power of the three-phase system

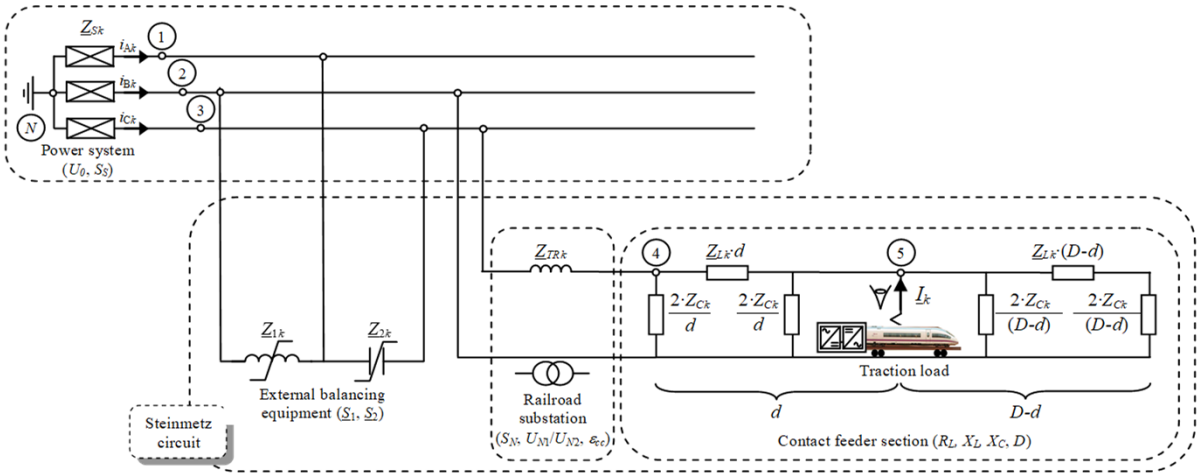
Asymmetries and unbalances

- Effects
  - Torque oscillations and motor heating
    - Alternators $K_A < 0.05$ (5 %)
    - Motors $K_A < 0.03 – 0.04$ (3 – 4 %)
  - Malfunctioning of three-phase converters and electronic equipment
  - Power limitation in transformers

Asymmetries and unbalances

- Solutions
  - Connection to strong grids with small short-circuit ratios
  - Connection through special transformers
  - External balancing equipment (Steinmetz system)
  - Transposition of lines





Asymmetries and unbalances

Hw: Program 4

- function Prog4
- %
- f=50;
- w=2*pi*f;
- %
- % Tensiones sinusoidales asimetricas y desequilibradas.
- %
- Ua=230*exp(1j*0);
- Ub=0.8*230*exp(1j*(-110*pi/180));
- Uc=0.9*230*exp(1j*(100*pi/180));

$$\begin{bmatrix} \underline{U}_0 \\ \underline{U}_1 \\ \underline{U}_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \underline{a} & \underline{a}^2 \\ 1 & \underline{a}^2 & \underline{a} \end{bmatrix}\begin{bmatrix} \underline{U}_a \\ \underline{U}_b \\ \underline{U}_c \end{bmatrix} \qquad (\underline{a} = e^{j\frac{2\pi}{3}}) \quad \Rightarrow \quad K_A = \frac{U_2}{U_1} \quad , \quad K_U = \frac{U_0}{U_1}$$