Politechnika Wrocławska

# Wroclaw university of Science and technology

## Topic:
## Q14_Simulation and analysis of power system transients

6/28/2023

# OUTLINE

- Digital models of linear elements of an electric network
- Line model with distributed parameters
- Single-phase saturable transformer model
- Numerical stability of digital models-numerical oscillations, suppression /elimination of numerical oscillations

# Digital models of linear elements of an electric network

The network model is derived from differential equations that relate currents and voltages in network nodes according to Kirchoffs law.

The simulation models are usually based upon equivalent network diagrams derived under simplified assumptions (which sometimes can be significant) that are applied to the network elements representation. In this respect models can be divided into two basic groups:

# Digital models of linear elements of an electric network

- Lumped parameter models:

3D properties of elements are neglected, sophisticated electromagnetic relations that include space geometry of the network are not taken into account.

- Distributed parameter model

Some geometrical parameters are used in the model describing equations (usually the line length)

# Digital models of linear elements of an electric network

In classic theory relations between currents and voltages on the network elements are continuous functions of time. In digital simulations the numerical approach must be applied. Two ways are applied for this purpose:

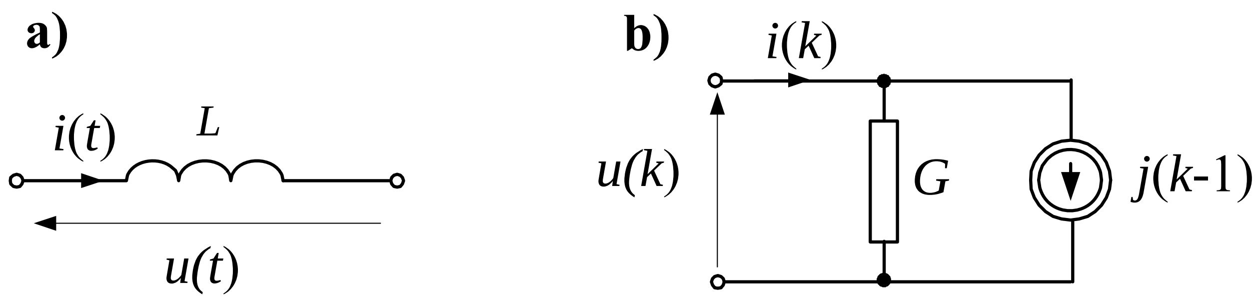
- Transformation of continuous differential relations into discrete (difference) ones,
- State variable representation in continuous domain and its solution by use of numerical methods.

# Digital models of linear elements of an electric network

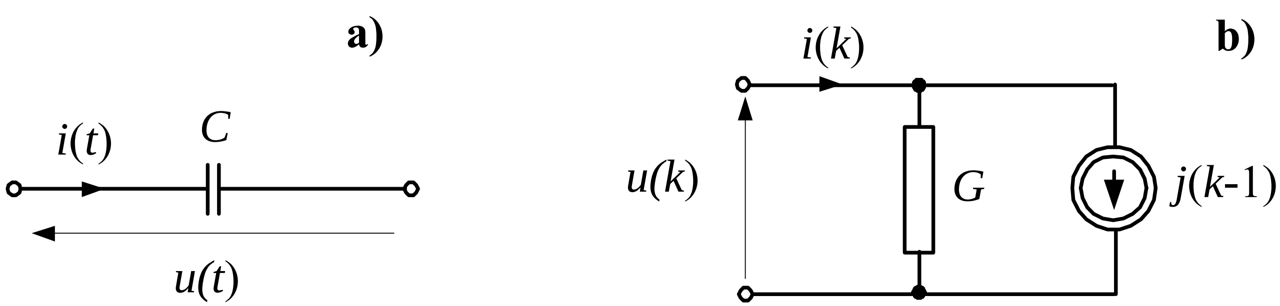
Consequences of transformation from continuous to discrete domain:

- Problem of accuracy. Discrete representations are always certain (better or worse) approximation of continuous reality,
- Frequency characteristics become periodic according to Shannon’s theorem
- Problem of numerical stability. Numerical instability may appear even though the continuous representation of the network is absolutely stable.

# Digital models of linear elements of an electric network

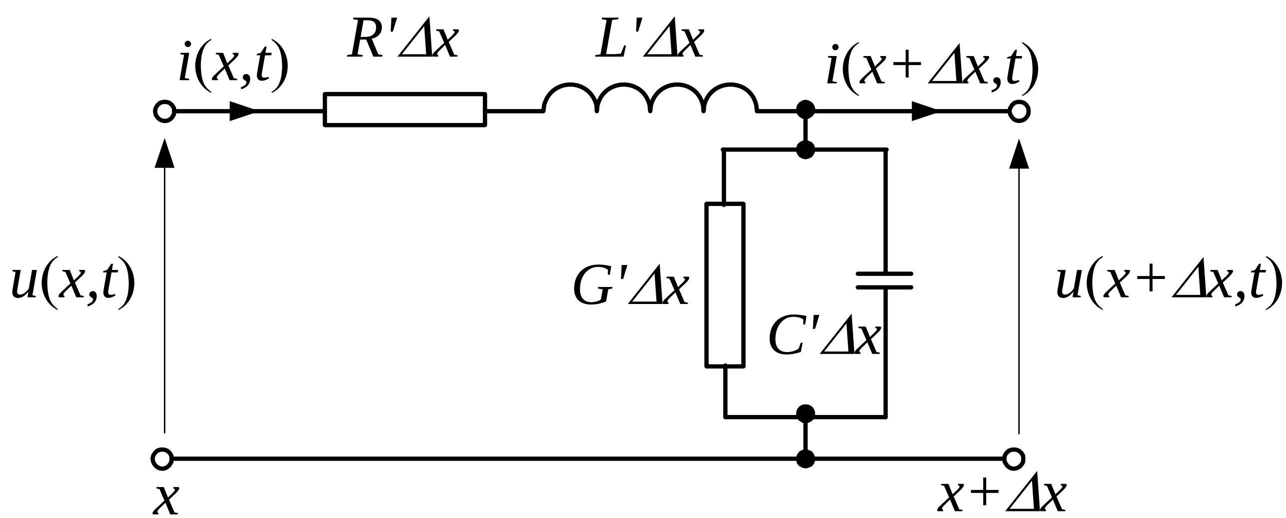



Discrete model of inductance; a) symbol; b) companion discrete model

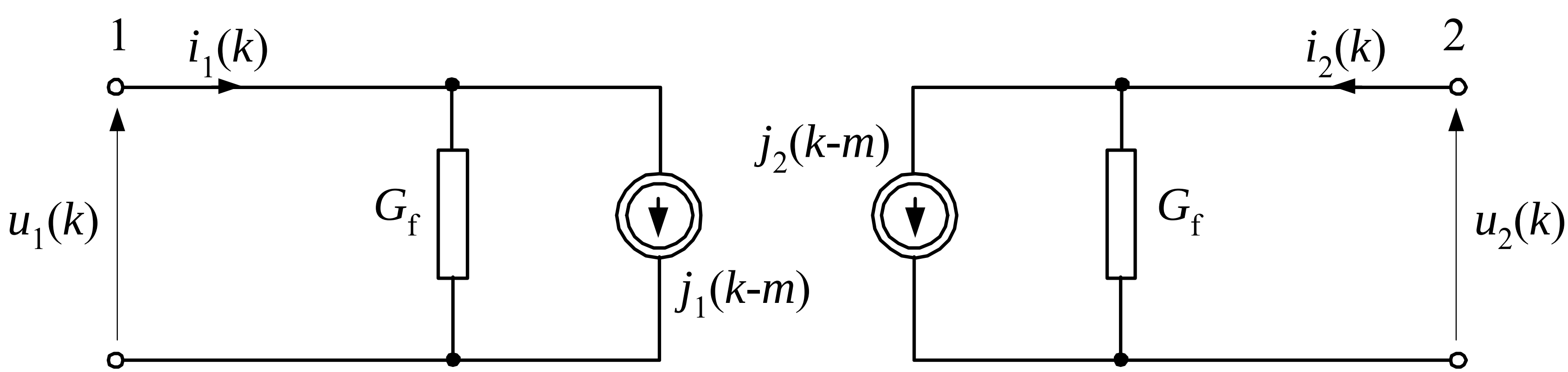



Discrete model of capacitance; a) symbol; b) companion discrete model

# Line model with distributed parameters




## Lossless line model



# Single-phase saturable transformer model

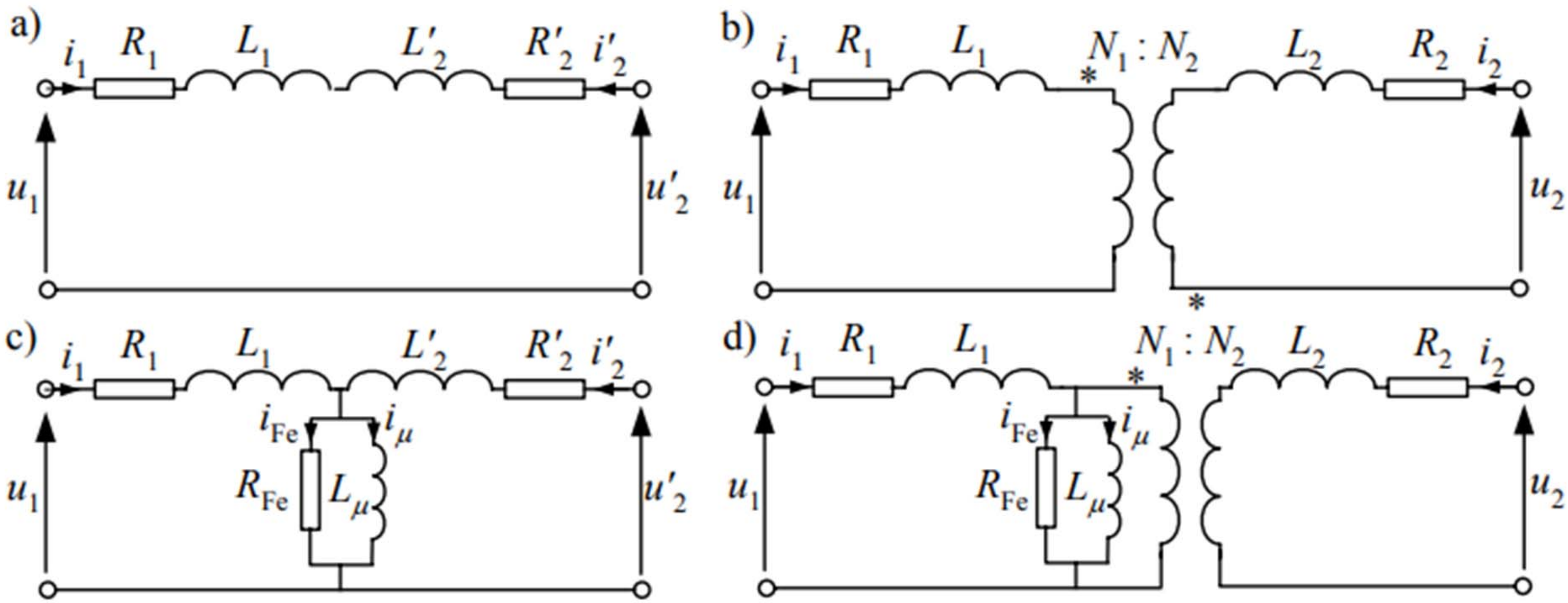



Fig. 5.2. The equivalent circuits of the single phase two-winding transformer:
a) calculated for the common voltage, b) with ideal transformer
and c), d) with magnetizing branch

# Numerical stability of digital models- numerical oscillations

Numerical models used for simulation of transient processes in power networks can be deemed as satisfactory if the simulation results are adequate to processes observed in real networks. There are two basic sources of errors that can make the simulation results inadequate, namely,

- omission of the elements which are essential for the network operation
- application of numerical methods that are inadequate for calculation of analyzed effects.

# Numerical stability of digital models- numerical oscillations

The problems concerned may appear in some specific situations only. For example, the ideal switch that is represented by two limit values of conductance (0 and $\infty$) can be used as a circuit breaker if the values of the current to be broken are relatively low.

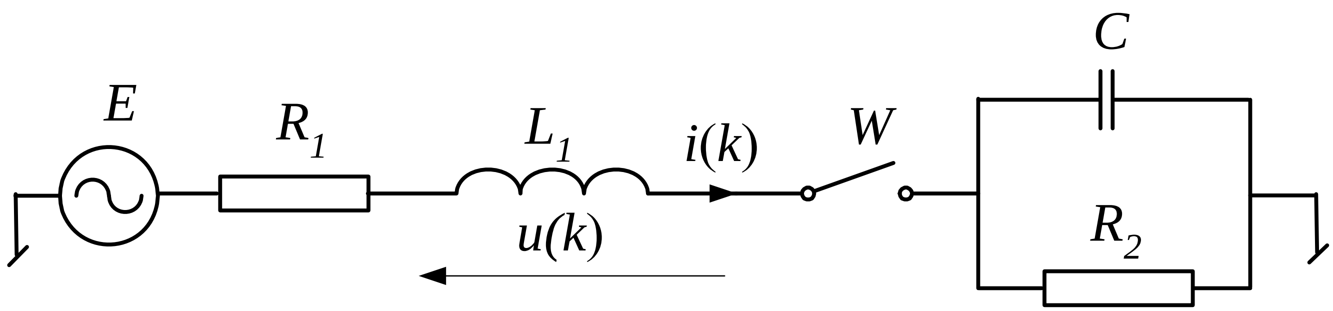
Similar problems may occur due to application of inadequate numerical methods resulting in numerical instability.

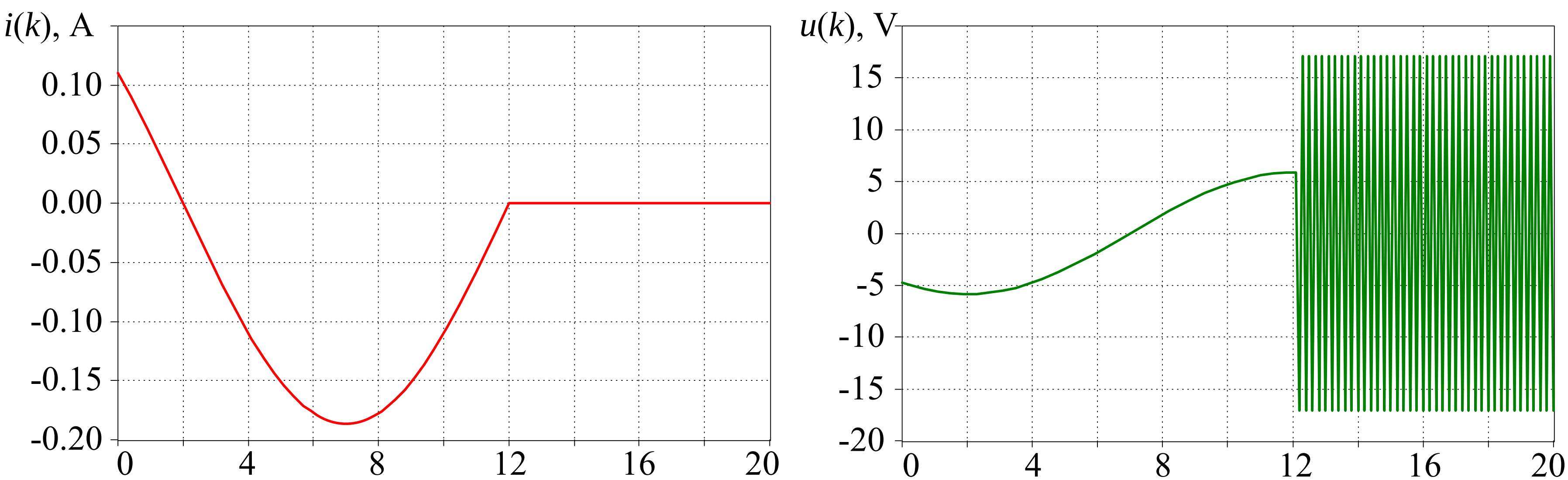
Numerical instability appears when the errors caused by numerical round up of calculation results sum up in each calculation step.

Practically, the both considered types of errors are related very closely as the further analysis shows .

# Numerical stability of digital models-numerical oscillations

## Numerical oscillations in transient state simulations




a) the current in the switch

b) the voltage across the inductance $L_1$

# Suppression /elimination of numerical oscillations

The most obvious way of oscillation suppression is the use of nonlinear model that matches reality. However, sometimes this approach may be very  difficult or even impossible. In such cases the use of linear resistance can bring the satisfactory results.

- Suppression of oscillations by use of a damping resistance
- Suppression of numerical oscillations by change of integration method (Euler's method , Trapezoidal methos)

**THANK YOU !**