Simulation Peculiarities of High-Frequency Zero-Current Switching Quasi-Resonant Boost Converter

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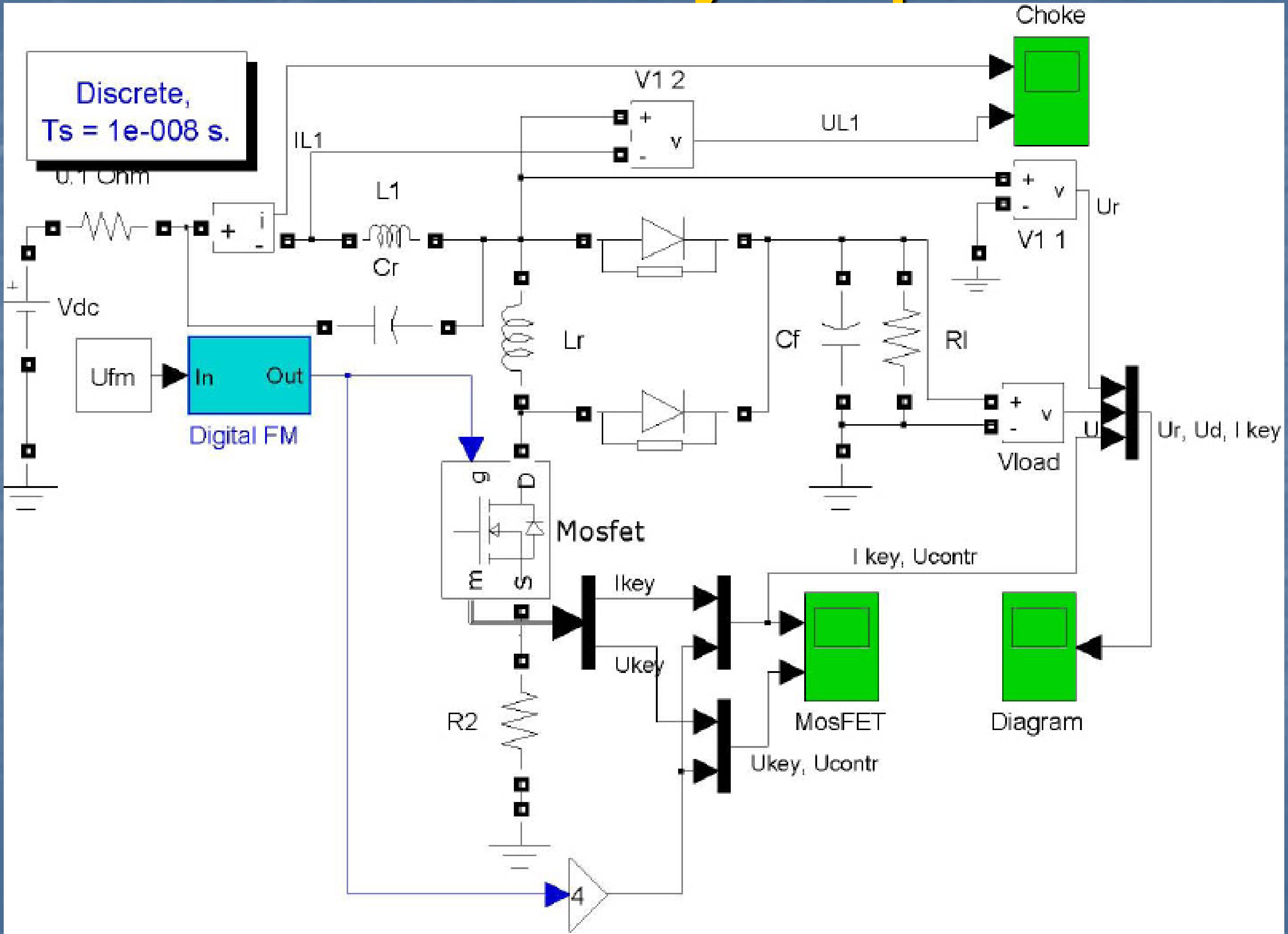
Introduction

- **High-frequency quasi-resonant converters** – high energy efficiency based on low power losses in power switch due to:
  - zero-current switching (ZCS) or
  - zero-voltage switching (ZVS)
- **Zero-current switching quasi-resonant boost converters (ZCS-QRBC):** the main advantage is primarily associated to a significantly **higher switching frequency** compared with conventional boost converters
- **Results into:**
  - improvement in the weight and size parameters of the entire system
  - the dynamics of the converter can be increased
  - improves the accuracy of output voltage stabilization
  - can be used in high-performance industrial controllers

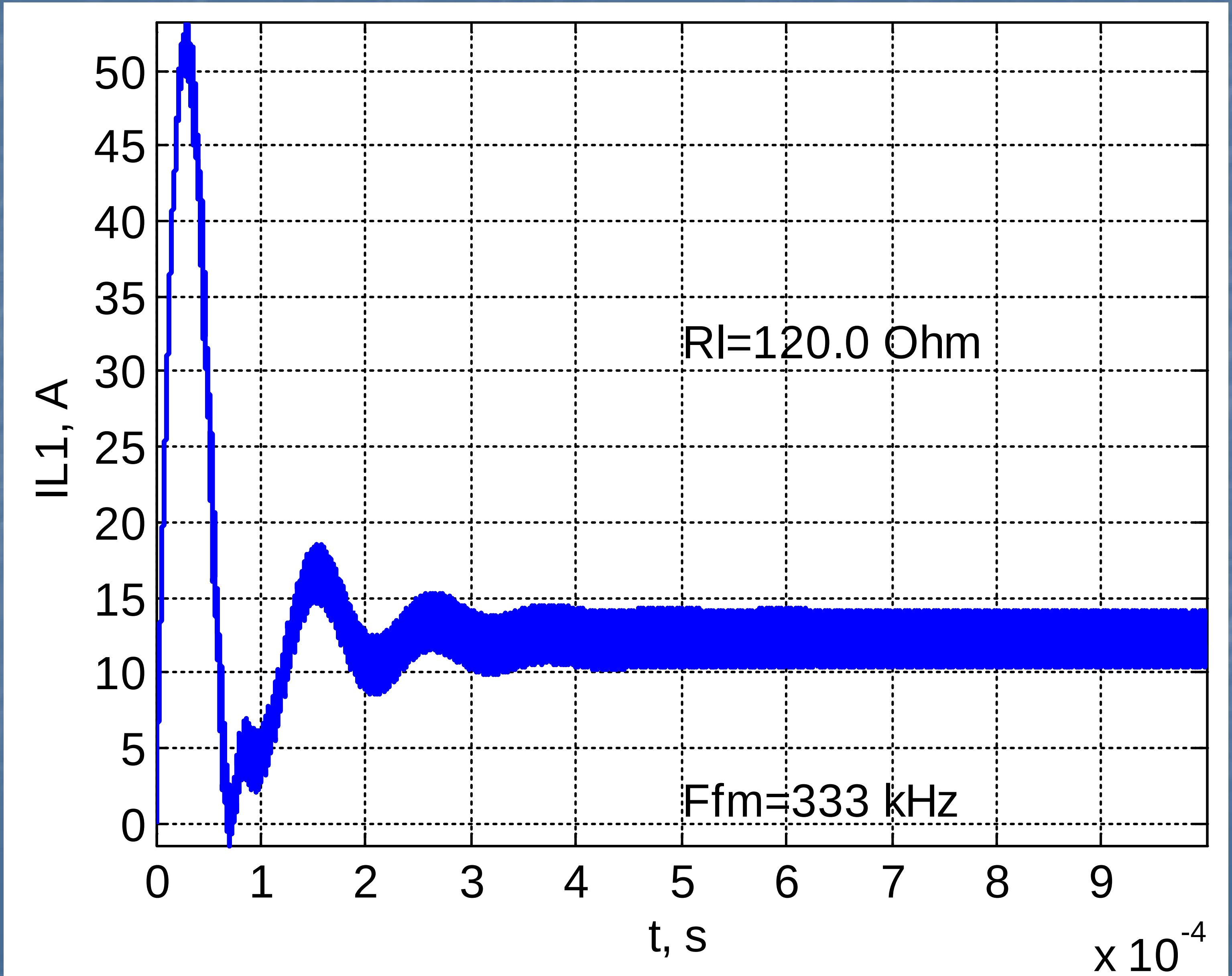
Problems

- **Provide the precise switching at a zero current**
  - limits the operating range of the converter both in frequency and output voltage
  - leads to the need of keep track the switch current
  - etc.
- **Parasitic parameters of the circuit and the experimental board on high frequencies:**
  - could significantly degrade the quality of the energy conversion
  - also endanger the overall operation of the physical model.
- **There is a need for a computer simulation of ZCS-QRBC**
  - significantly reducing the time and costs for experimental prototyping and industrial design
- **The parameters of modern computers**, despite significant progress, **have some limitations**
  - performance, memory and cost

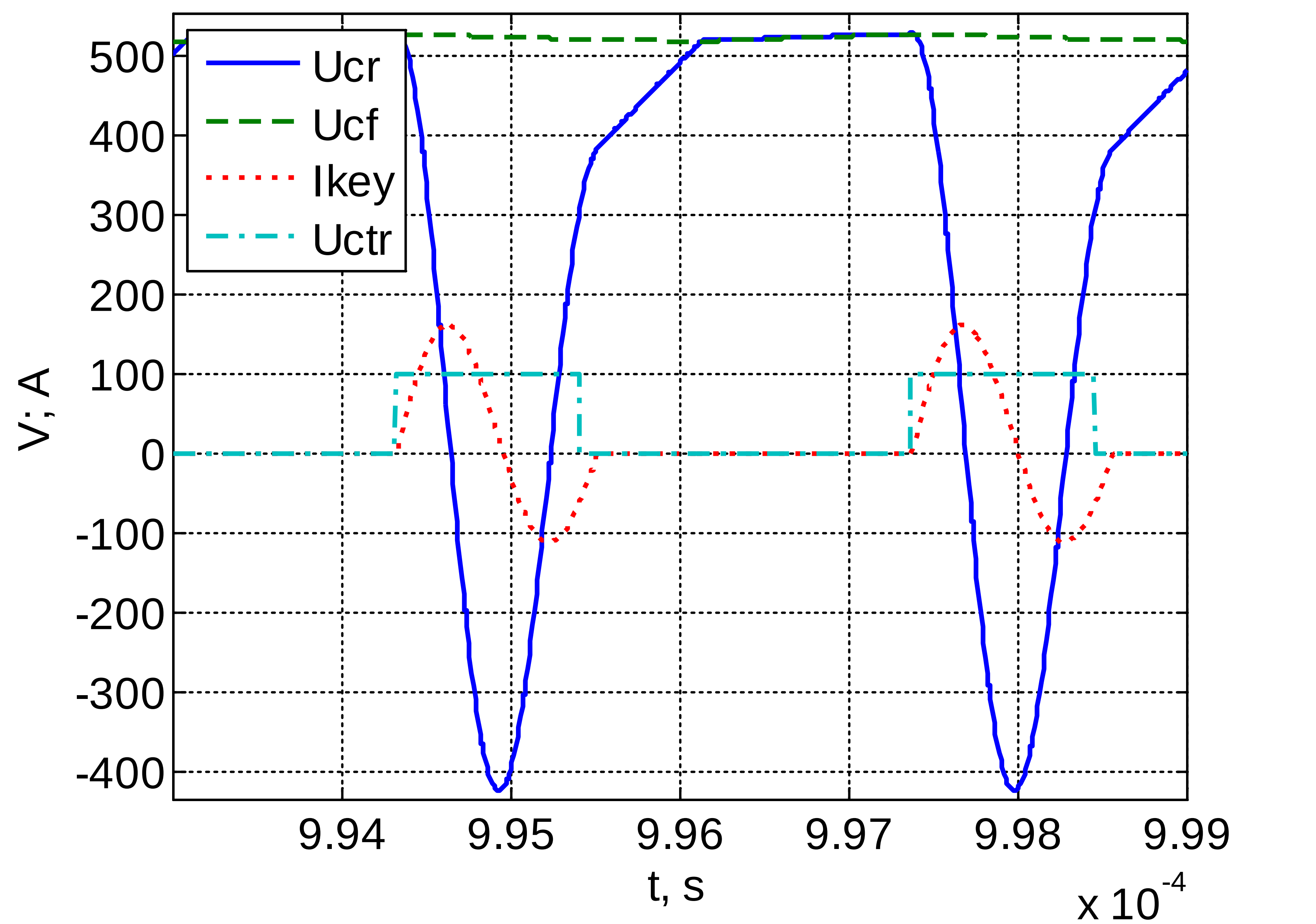
ZCS-QRBC Model Based on Power Electronics Library Components



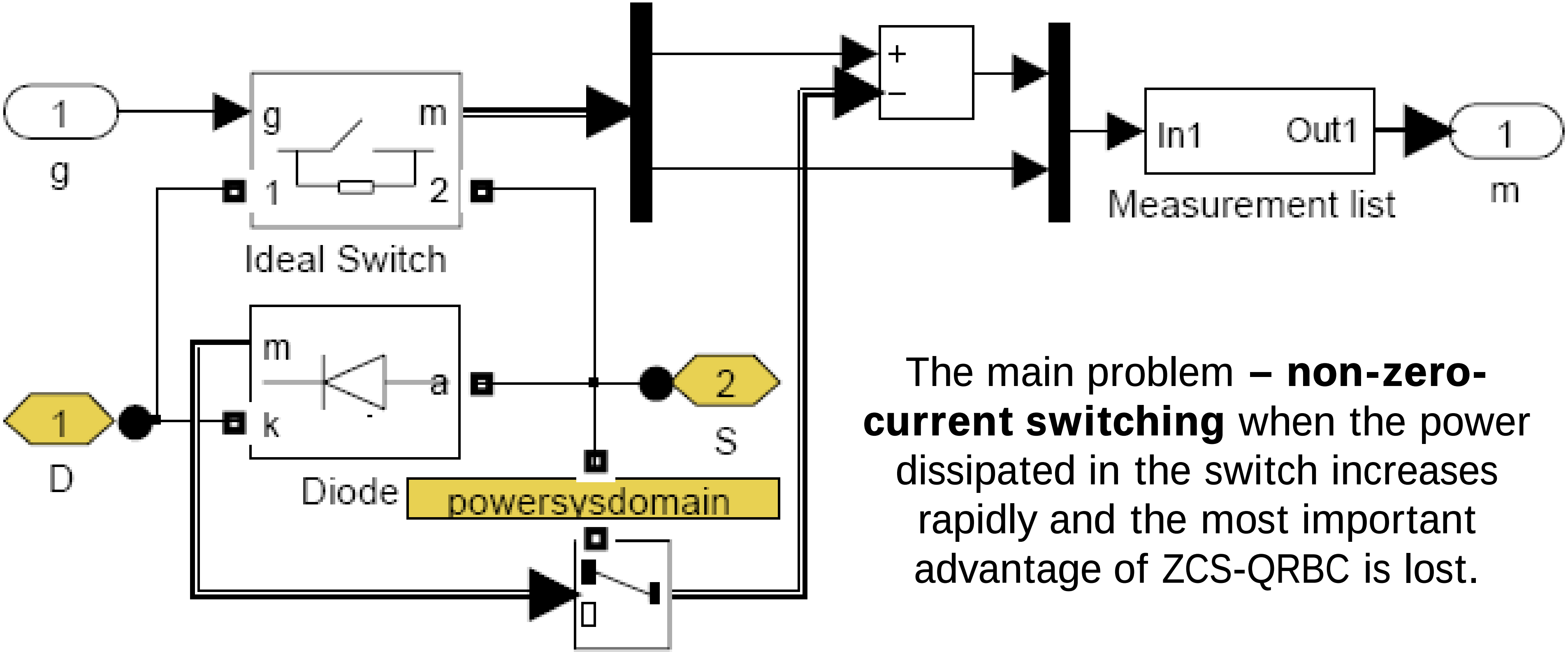
A current transient process in the storage inductor



Steady-state in a zero-current switching quasi-resonant boost converter



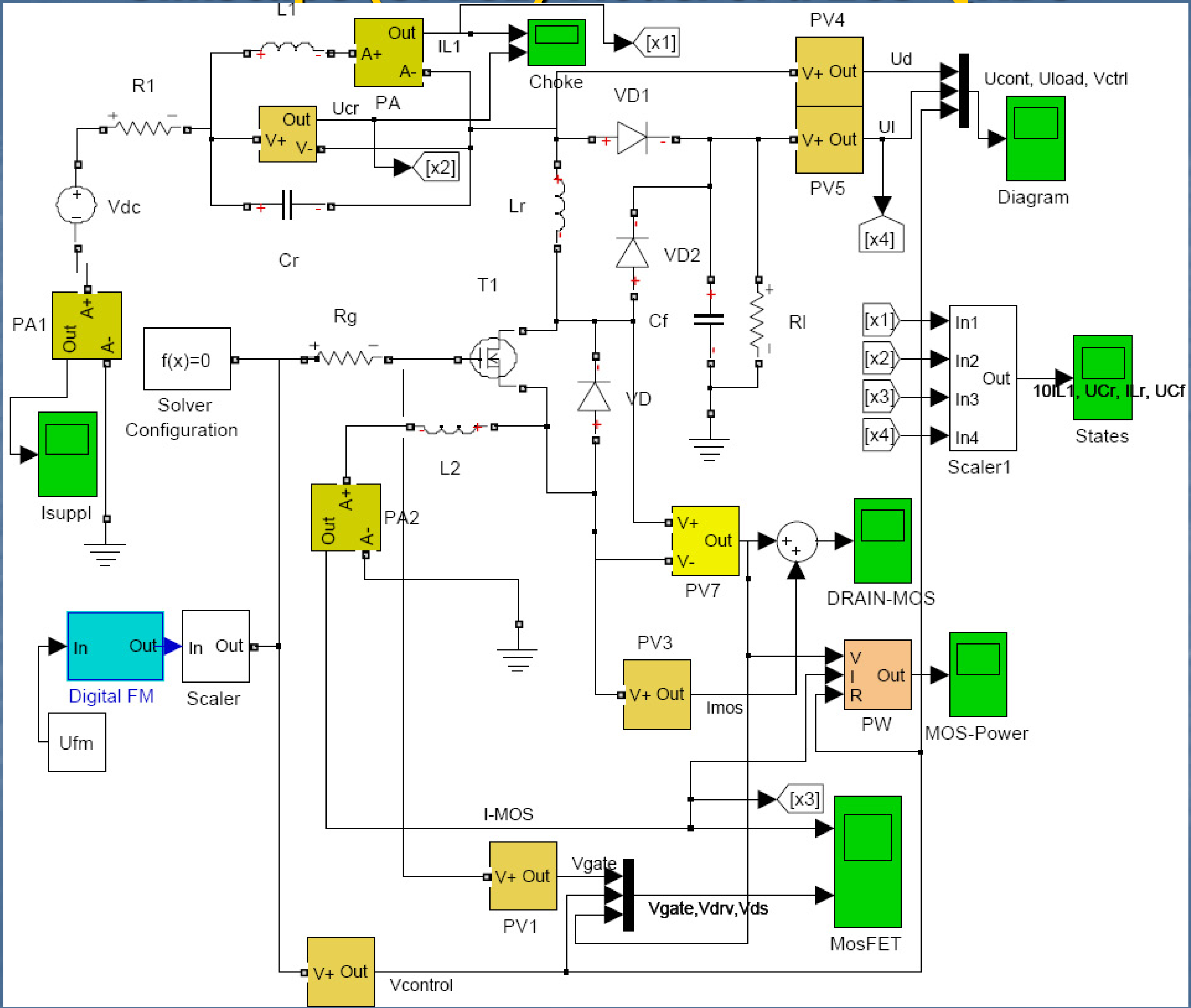
MOSFET model from PowerGUI library



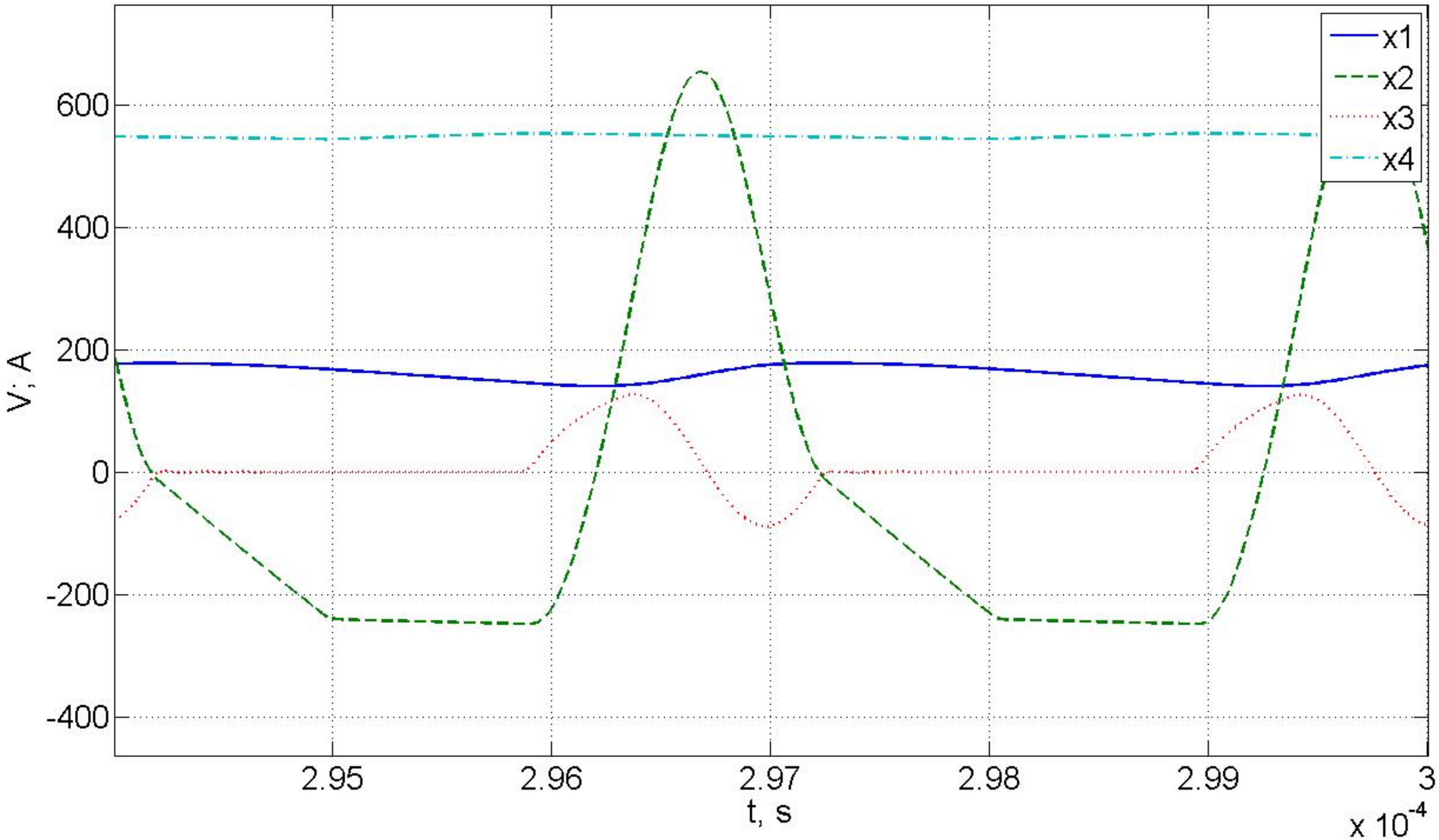
The main problem – **non-zero-current switching** when the power dissipated in the switch increases rapidly and the most important advantage of ZCS-QRBC is lost.

- The power switch is ideal with the logical level control, which does not require any special driver – does not true!
- Most important parameter of MOSFET used in ZCS-QRBC is the resistance of the channel in the open state – is absent!
- Are absent another important elements of the real scheme (the series resistor in the gate circuit, the current sensor...)

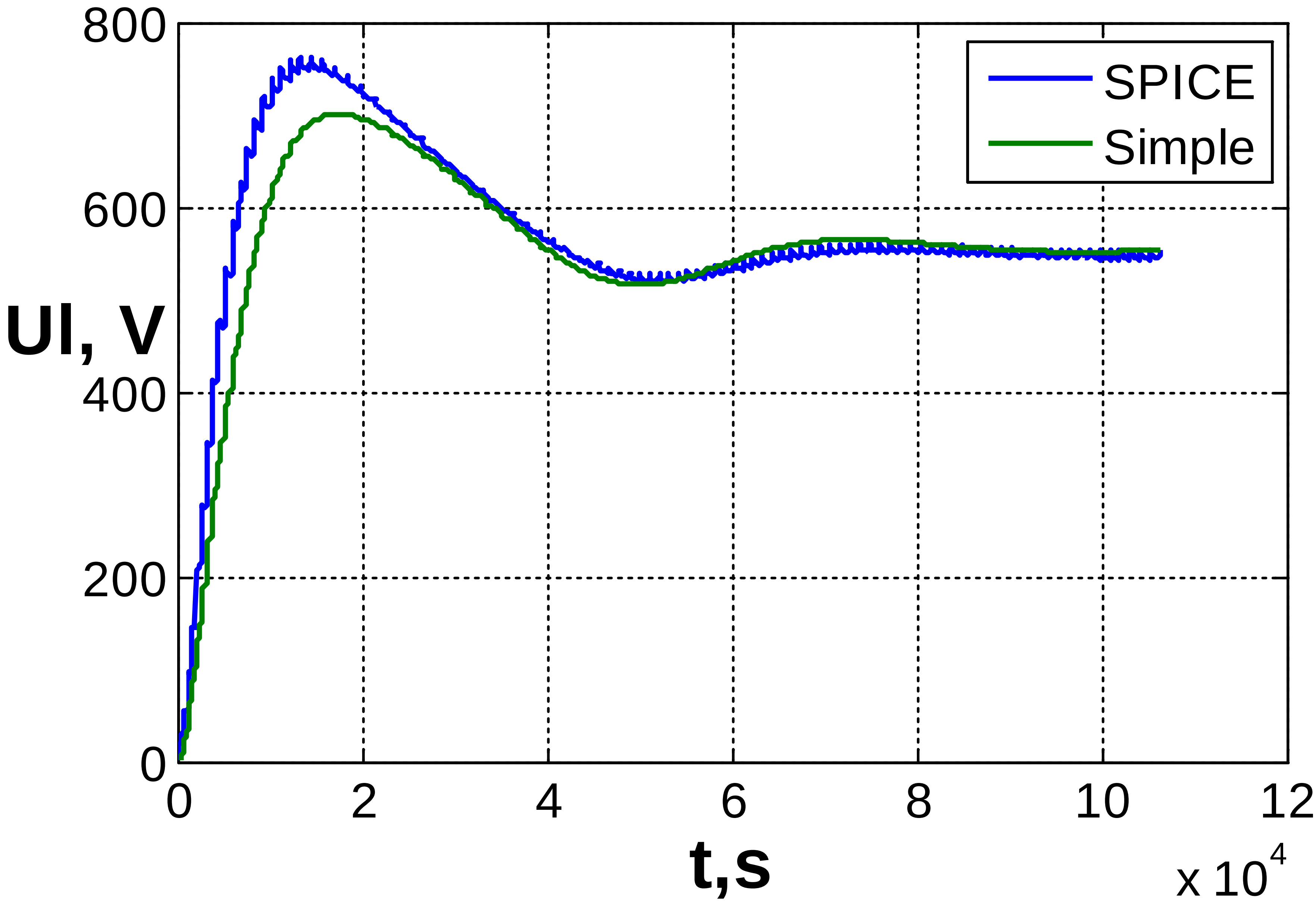
Simscape (SPICE) Model of a ZCS-QRBC



State variables in a zero-current switching quasi-resonant boost converter



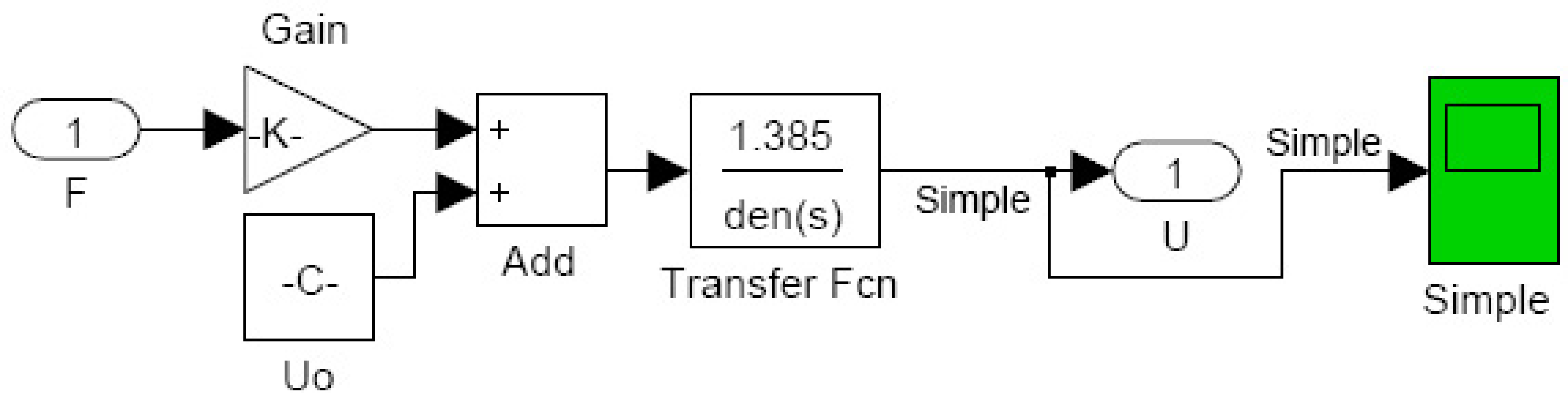
Transient response in a ZCS-QRBC



Simplified Model of a ZCS-QRBC

- Transfer function of the approximating oscillating unit:

$$K_{QRBC}(s) = \frac{K_o}{D_2 s^2 + D_1 s + 1} \quad (1)$$



$$K_{QRBC} = \frac{U_{L\max} - U_{L\min}}{F_{\max} - F_{\min}} \quad (2)$$

$$U_{QRBC} = U_{L\max} - K_{QRBC} F_{\max} = U_{L\min} - K_{QRBC} F_{\min} \quad (3)$$

K_{QRBC} = 0.015 V/kHz; U_{QRBC} = 10.4375 V.

Conclusions

1. Three simulation approaches for high-frequency ZCS-QRBC were proposed, and appropriate models were analyzed in Matlab Simulink, which are deemed the most suitable for the various stages of studying the systems in order to effectively achieve the experimental prototyping.
2. The use of Power Electronics library components from the SimPowerSystems Toolbox – the most effective for a quick introduction to the basics of QRBC operation and for educational purposes.
3. The SPICE-model of ZCS-QRBC, which is based on the physical principles of elements' operation, is preferable to use for a quick obtaining of practical results, elaboration of ZCS-QRBC topology, selection of components and building the background for experimental investigations.
4. In the following stages of the system design, the limited use of the simplified model is possible in order to comply with the requirements of existing computational resources. It allows estimating the influence of a control method on the system dynamics, control accuracy or stabilization of specific parameters.

Thank you