STABILITY ANALYSIS AND OPTIMAL CONTROL DESIGN FOR AC-DC POWER SYSTEM WITH CONSTANT POWER LOAD

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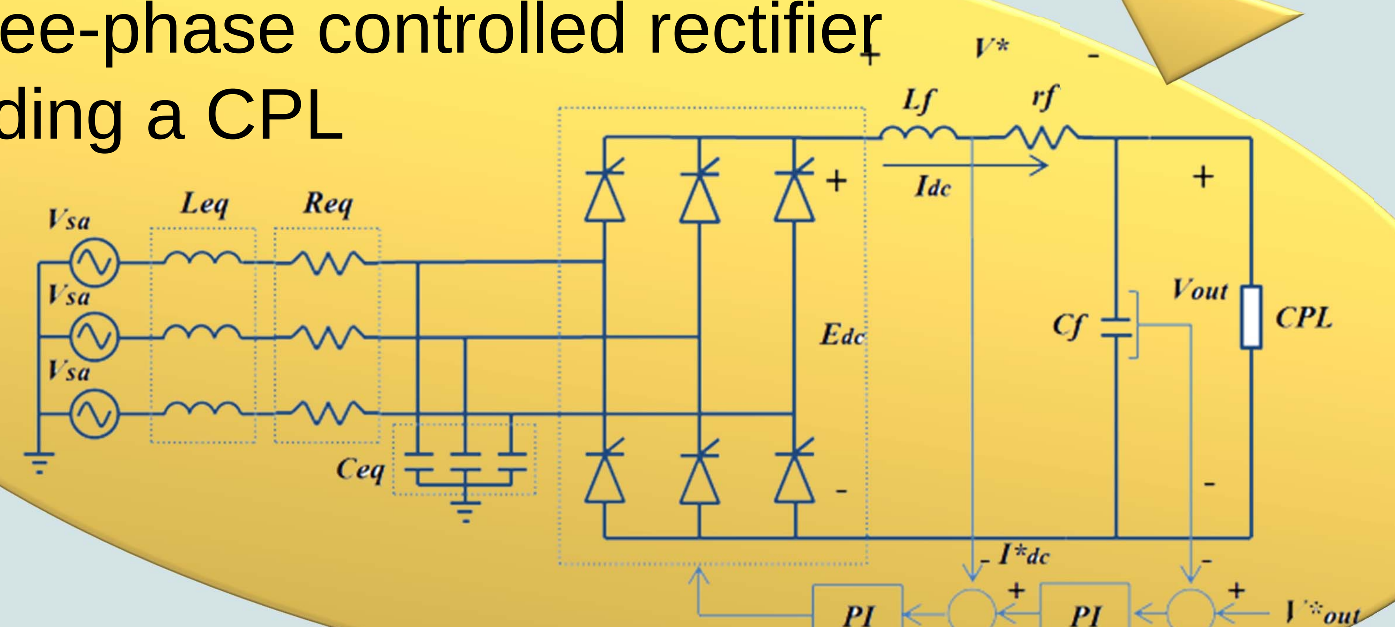
- Goal of the study
  - Derive the DQ model
  - Derive the control scheme
  - Determine the stability limits
  - Improve the system using Linear Quadratic Regulator method
- System
  - Three-phase Controlled Rectifier
  - Double PI controller which maintains regulates constant current and voltage through the inductance L_f and resistance r_f

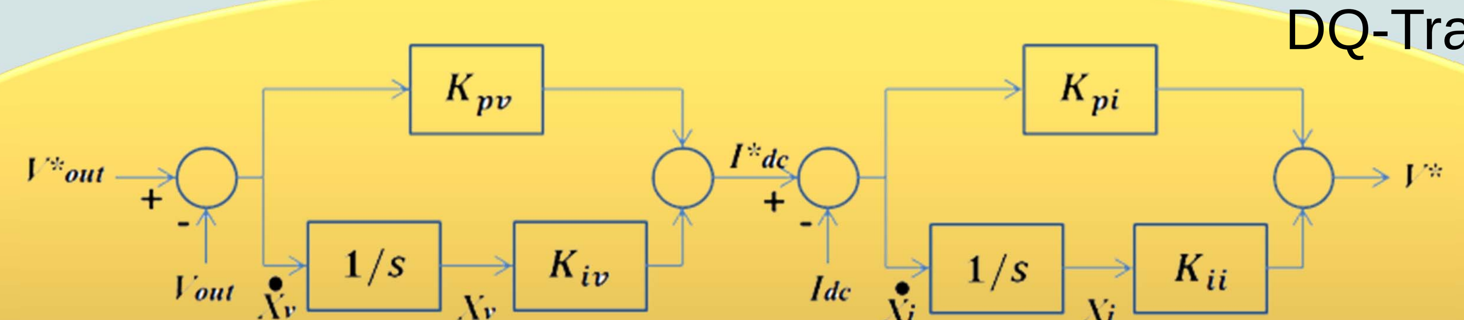
Three-phase controlled rectifier feeding a CPL



The model is composed of:

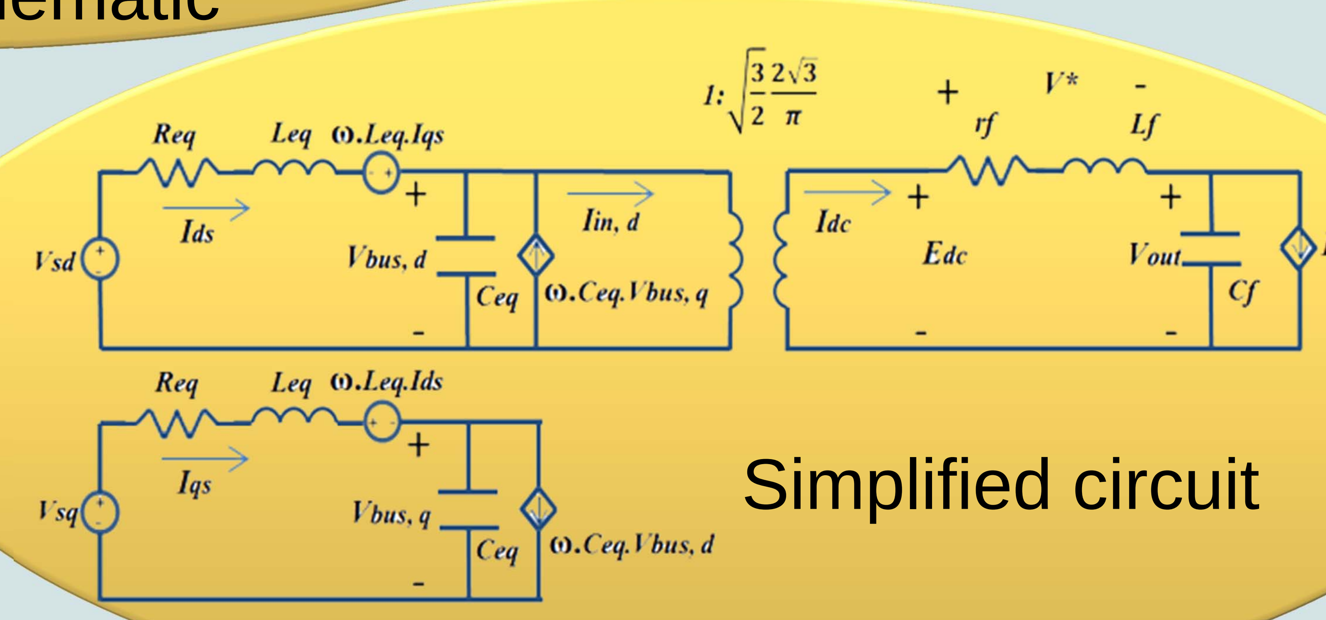
- A balanced three-phrase voltage source: *Vsa, Vsb* and *Vsc*
- A transmission line: *Req, Leq and Ceq*
- A 6-pulse controlled rectifier
- Filters: *rf* , *Lf* and *Cf*
- A constant power load

DQ-Transformation



Controllers schematic

- Voltage control loop
- Current control loop



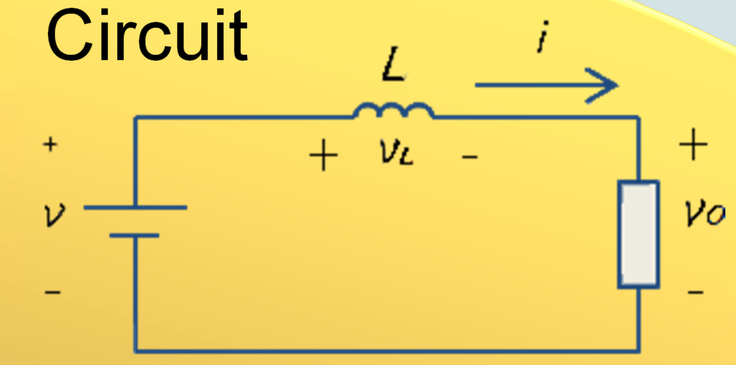
Simplified circuit

The original double PI control strategy offers a narrow stability margin.

The linear quadratic regulator allows us to overcome these limitations.

Description of the negative impedance instability

Circuit

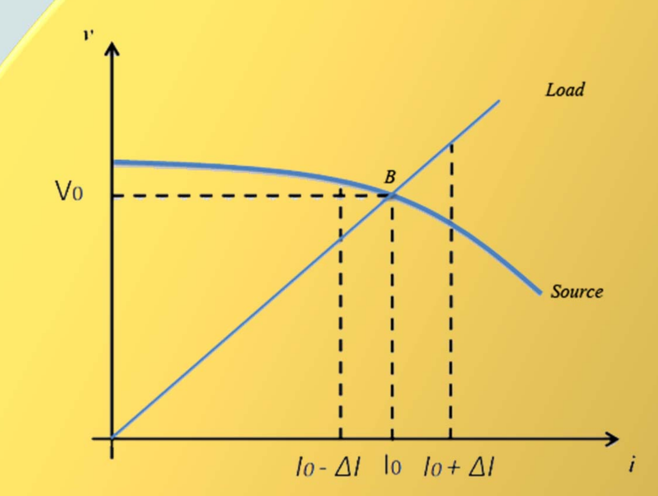


This circuit consists of:

- A DC voltage source
- An inductance L
- A load

Constant power loads exhibit a negative impedance characteristic which represents an important issue. It often leads to system instability in the case of a disturbance and impacts power quality.

Resistive load



Assume an increase in the current:

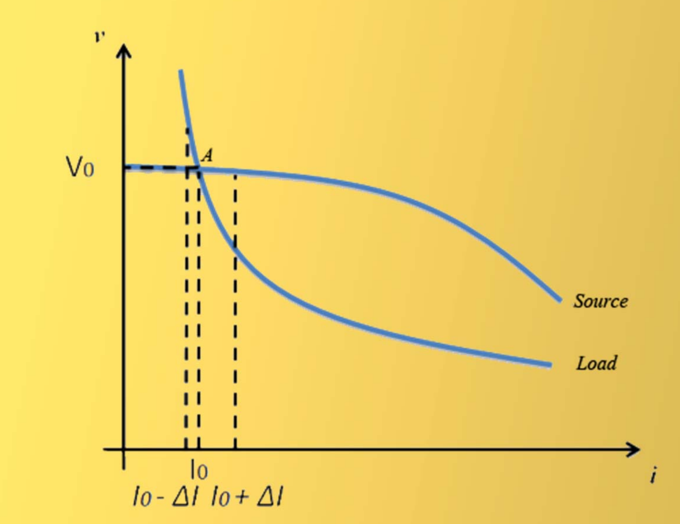
$\Rightarrow v_{load} > v_{source}$

$\Rightarrow v_L < 0$

$\Rightarrow i$ decreases and returns to original point

$\Rightarrow$ Stability

Constant power load



Assume an increase in the current:

$\Rightarrow v_{load} < v_{source}$

$\Rightarrow i$ increases more

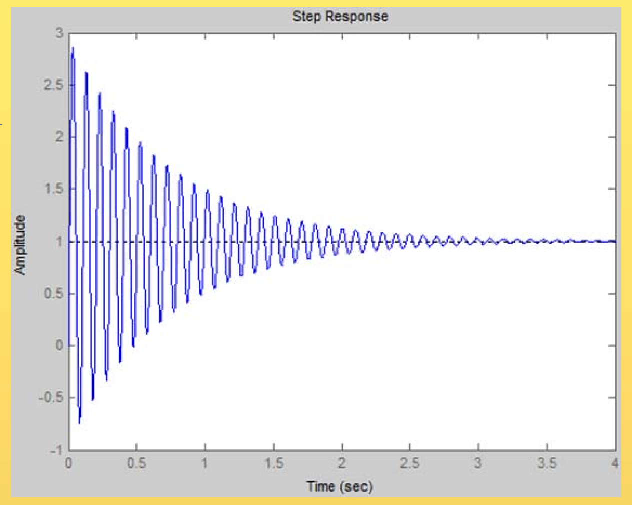
$\Rightarrow$ Moves away from original point

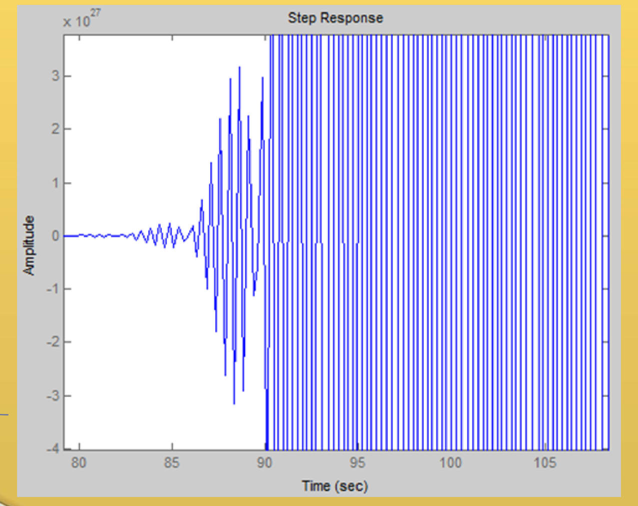
$\Rightarrow$ Instability

Simulations and results

Original control

Power: 25 kW





Power: 26 kW

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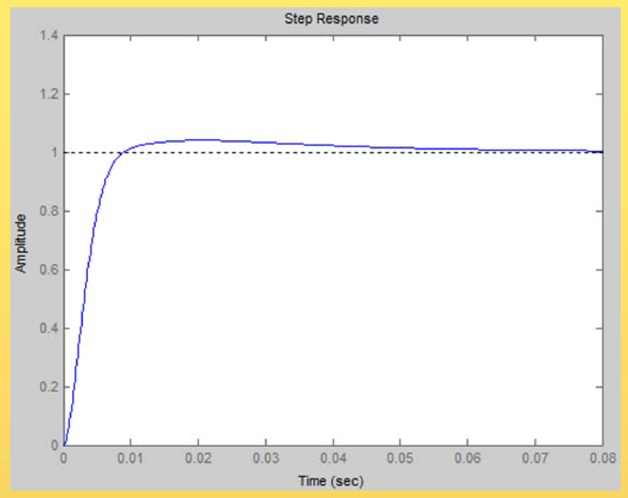

After applying LQR

- Stability limits of the original system: *25 kW*
- Linear Quadratic Regulator has tremendously enhanced the stability limits.