

# Active Resistance Emulation in Three-Phase Rectifier with Suboptimal Current Injection

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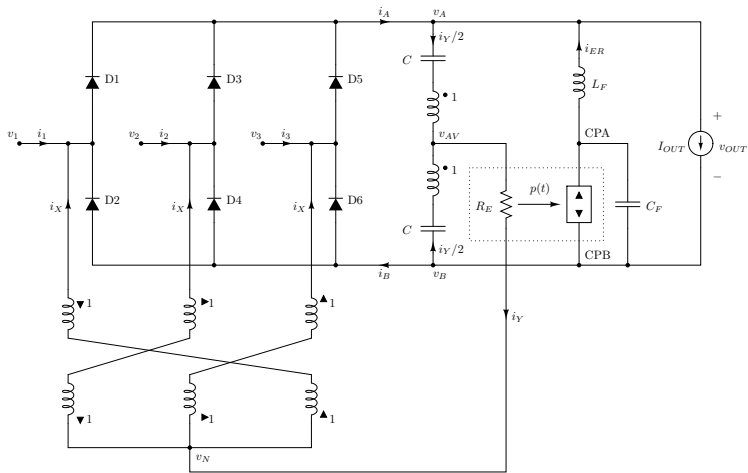
# Introduction

- ▶ three-phase current injection based rectifier
- ▶ suboptimal current injection
- ▶ resistance emulator to improve efficiency
- ▶ to use the dc-side filter or not?

Predrag Pejović, Predrag Božović, Doron Shmilovitz, “Low Harmonic, Three-Phase Rectifier that Applies Current Injection and a Passive Resistance Emulator,” IEEE Power Electronics Letters, vol. 3, no. 3, pp. 96–100, September 2005

- ▶ optimization of  $R_E$  to achieve minimal THD
- ▶ the optimum somewhere close to the CCM-DCM boundary
- ▶ models needed to optimize  $R_E$
- ▶ optimization
- ▶ experiments

# Introduction, the rectifier



# Introduction, now makes sense

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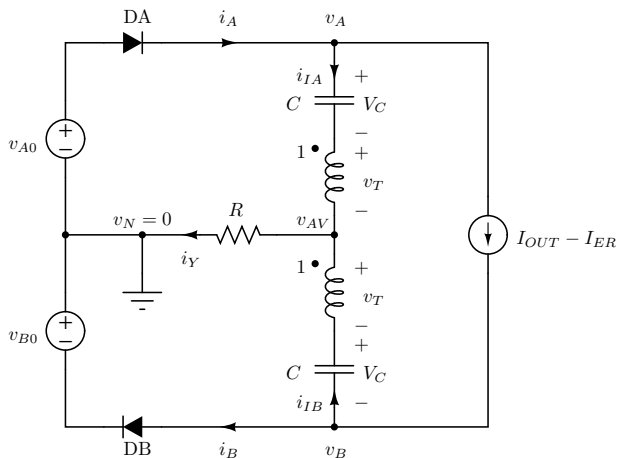
# Models

- ▶ goal: determine  $i_k$ ,  $k \in \{1, 2, 3\}$
- ▶ simplify the circuit as much as reasonably possible
- ▶ include the DCM!!!
- ▶ equivalent circuit methods

Predrag Božović, Predrag Pejović, “Current Injection Based Low Harmonic Three Phase Diode Bridge Rectifier Operating in Discontinuous Conduction Mode,” IEE Proceedings Electric Power Applications, vol. 152, no. 2, pp. 199-208

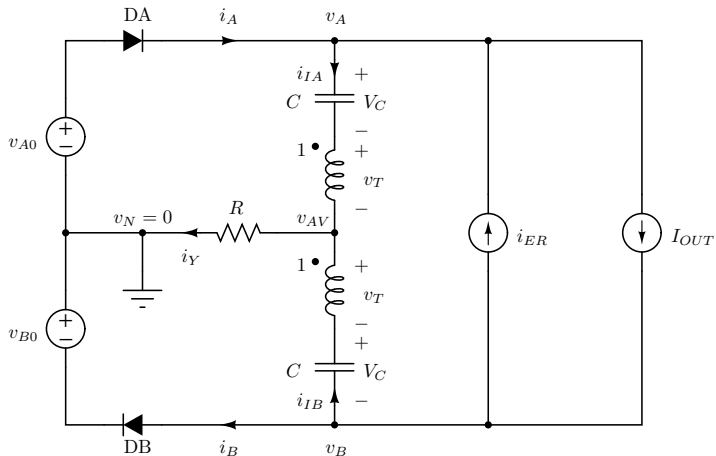
- ▶ let's define:
  1.  $v_{A0} = \max(v_1, v_2, v_3)$
  2.  $v_{B0} = \min(v_1, v_2, v_3)$
- ▶ diodes DA and DB to model the DCM
- ▶ out of four possible diode state combinations, three are of interest

## Model of the rectifier with the filter



$$I_{ER} = \overline{v_{AV} i_Y} / \overline{(v_A - v_B)}, \text{ averaging present}$$

## Model of the rectifier without the filter



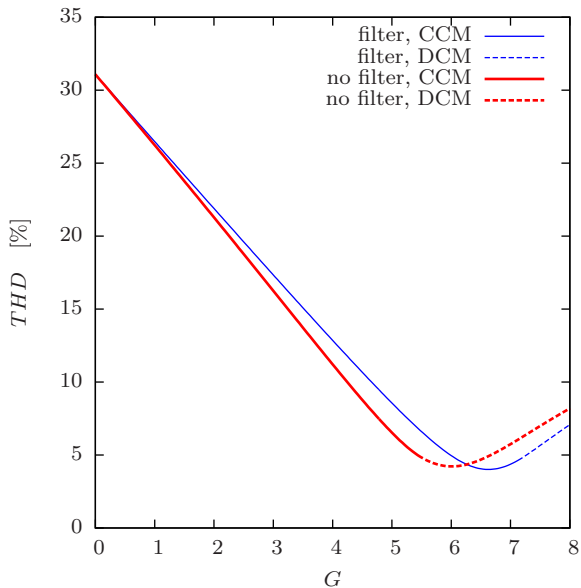
$$i_{ER} = v_{AV} i_Y / (v_A - v_B) , \text{ no averaging}$$

## Solving the models

- ▶ determine  $i_A$  and  $i_B$  from the equivalent circuits
- ▶ determine  $i_1$ ,  $i_2$ , and  $i_3$  from  $i_A$  and  $i_B$
- ▶ convenient to normalize,  $v$ 's over  $V_m$ ,  $i$ 's over  $I_{OUT}$
- ▶ the rest is mathematics ...
- ▶ iterate over  $R_E$  to optimize
- ▶ normalization, not exactly  $R_E$ , but  $G \triangleq V_m / (I_{OUT} R_E)$



# Optimization



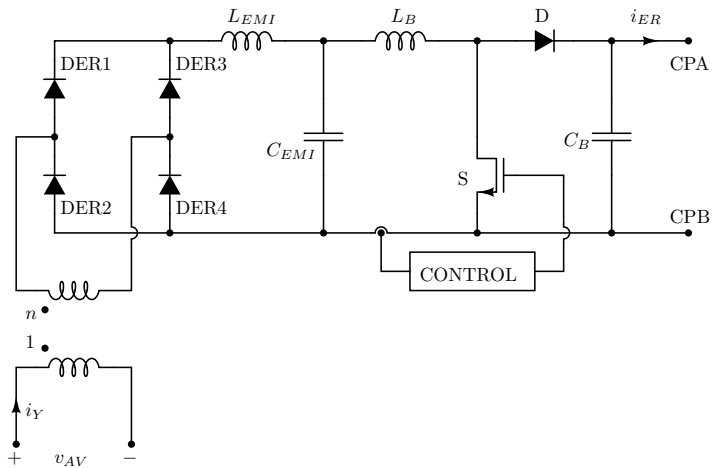
# Optimization results

- ▶ with filter:
  1.  $G_{OPT} = V_m / (I_{OUT} R_{E\ OPT}) = 6.62$
  2. optimum in CCM
  3.  $THD_{min} = 4.01\%$
  4. on  $R_E$  there is 8.66% of  $P_{IN}$
- ▶ without filter:
  1.  $G_{OPT} = V_m / (I_{OUT} R_{E\ OPT}) = 6.50$
  2. optimum in DCM
  3.  $THD_{min} = 4.22\%$
  4. on  $R_E$  there is 8.40% of  $P_{IN}$
- ▶ there is no need to use the filter!

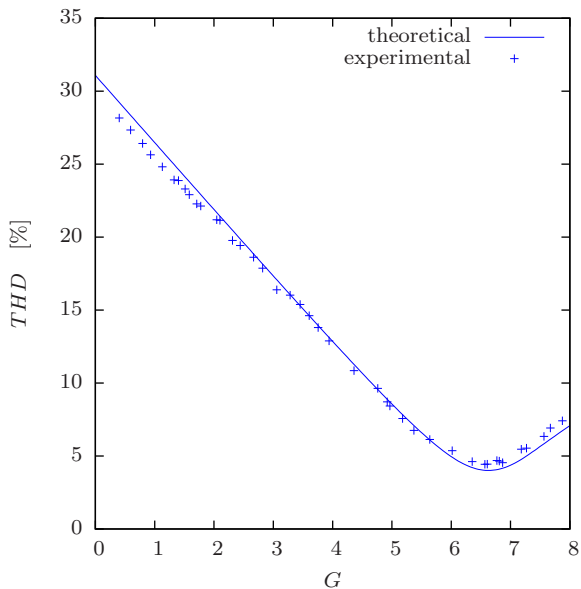
# Experiments

- ▶ goal: to verify models and the analysis
- ▶ up to 2 kW experimental setup
- ▶ input voltages 100 V rms
- ▶ output voltage about 230 V
- ▶ output current 5 A

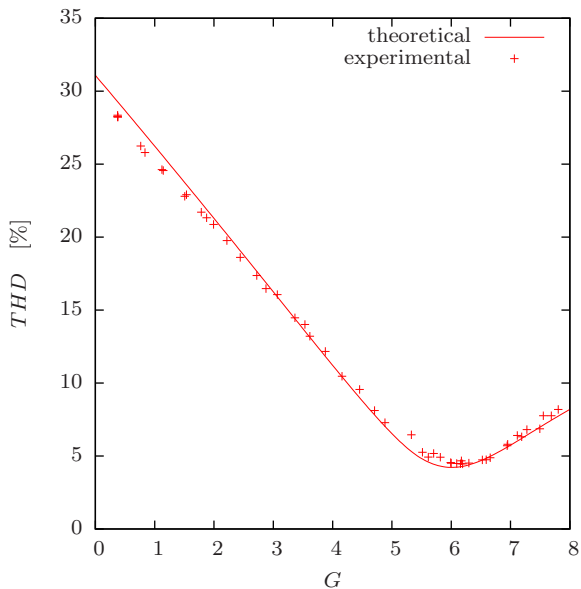
# Resistance emulator



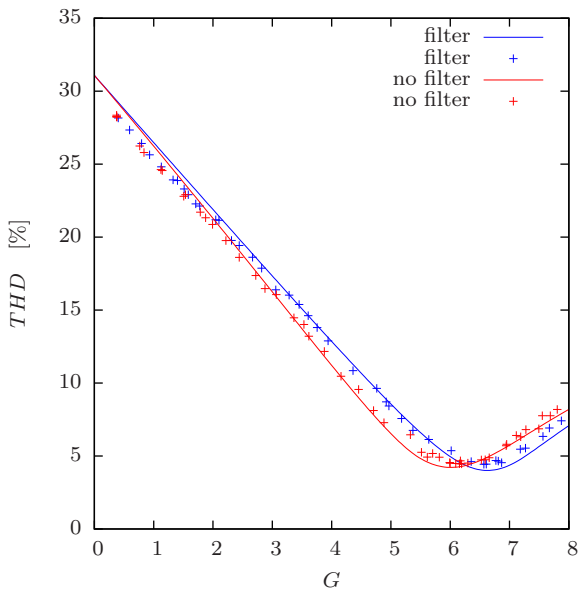
# Experimental results, with the filter



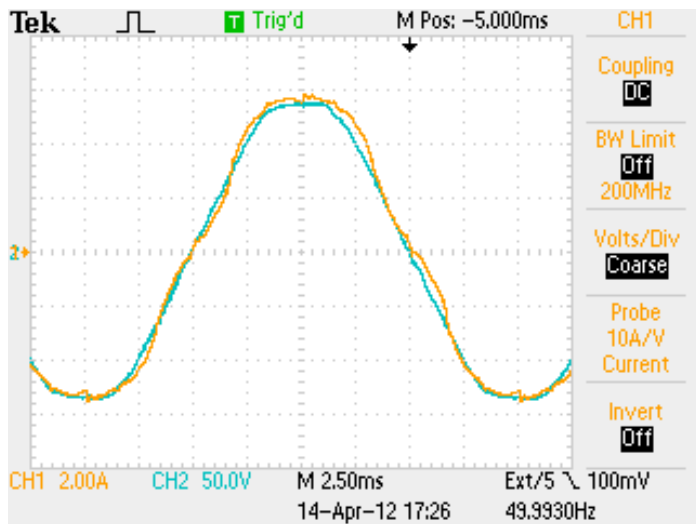
# Experimental results, without the filter



# Experimental results, joined

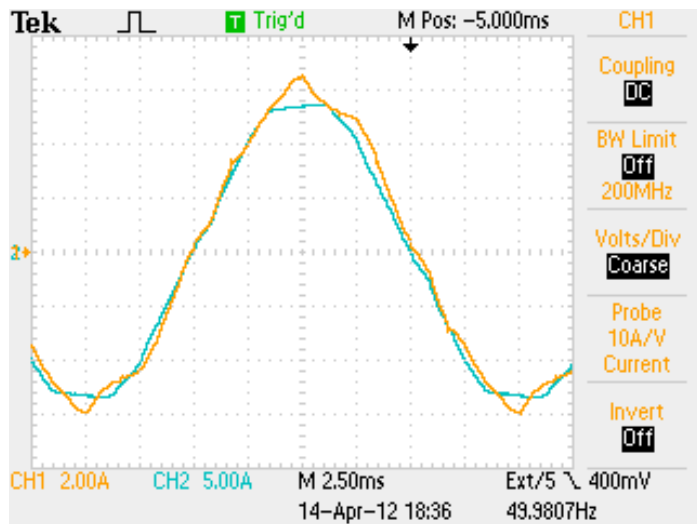


# Experiment, no filter, $i_1$ and $v_1$

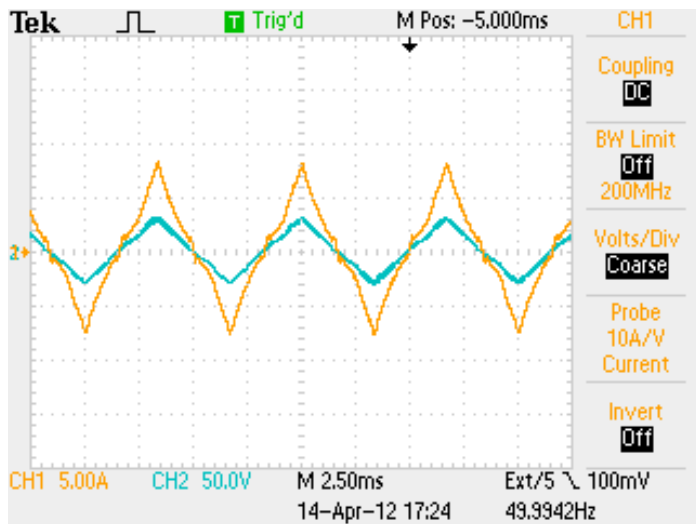




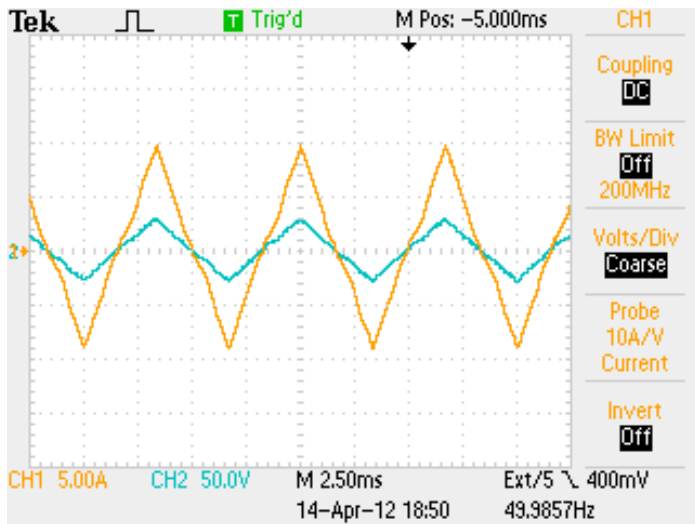
Experiment, with filter,  $i_1$  and  $v_1$



# Experiment, no filter, $i_Y$ and $v_{AV}$

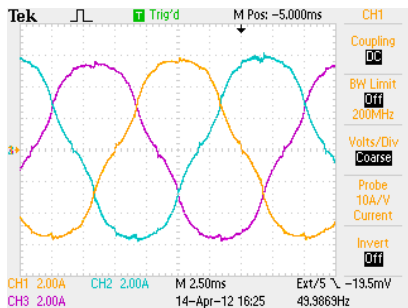


# Experiment, with filter, $i_Y$ and $v_{AV}$

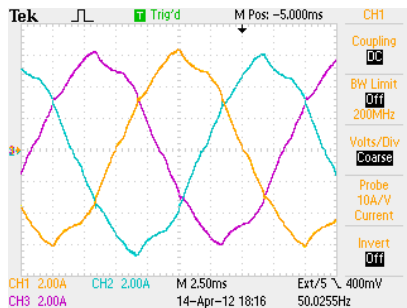


# Experiment, phase currents shapes

no filter



with filter



# Conclusions

- ▶ three-phase rectifier with suboptimal current injection
- ▶ resistance emulator, output filter needed or not?
- ▶ models developed, DCM included
- ▶ optimization over  $R_E$  to minimize  $THD$  performed
- ▶ optimization results:
  1. with filter  $THD_{min} = 4.01\%$ , in CCM, 8.66% of  $P_{IN}$
  2. without filter  $THD_{min} = 4.22\%$ , in DCM, 8.40% of  $P_{IN}$
- ▶ **filter not needed!!!**
- ▶ experimental verification
- ▶ excellent agreement with the model