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

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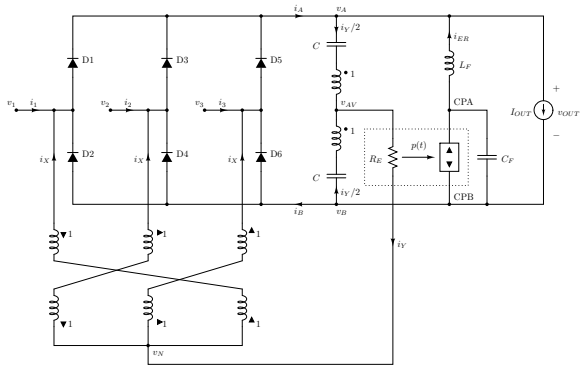
Introduction

- 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

- three-phase current injection based rectifier
- suboptimal current injection
- resistance emulator to improve efficiency
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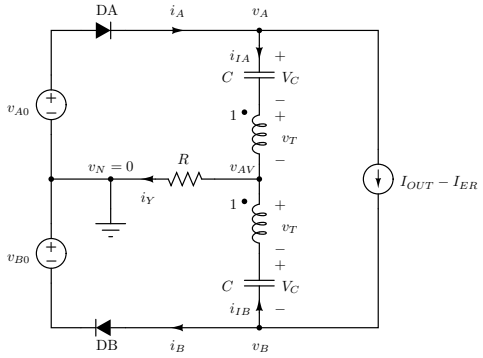
Models

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

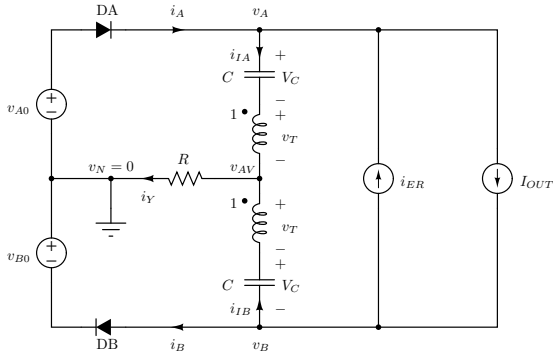
  Predrag Božović, Predrag Pejović, "Current Injection Based Low Harmonic Three Phase Diode Bridge Rectifier Operating in Discontinuous Conduction Mode," IEE Proceedings Electric Power Applications, vol. 152, no. 2, pp. 199-208
- let's define:
  1. $v_{A0} = \max(v_1, v_2, v_3)$
  2. $v_{B0} = \min(v_1, v_2, v_3)$
- 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



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

Model of the rectifier without the filter

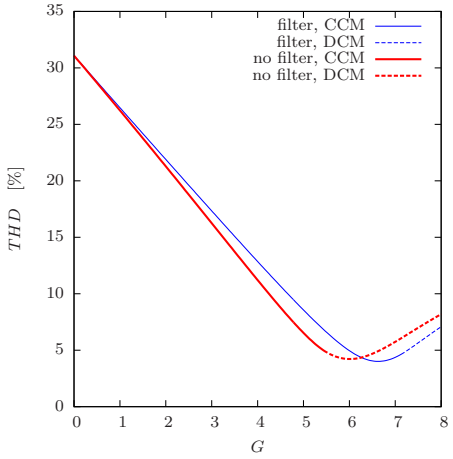


$i_{ER} = v_{AV}\, i_Y \;/\; (v_A - v_B)$, no averaging

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



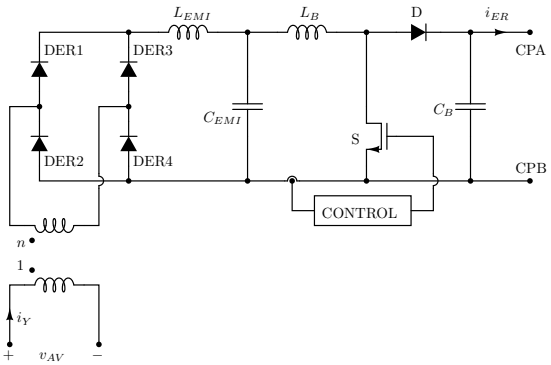
Optimization results

- 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!

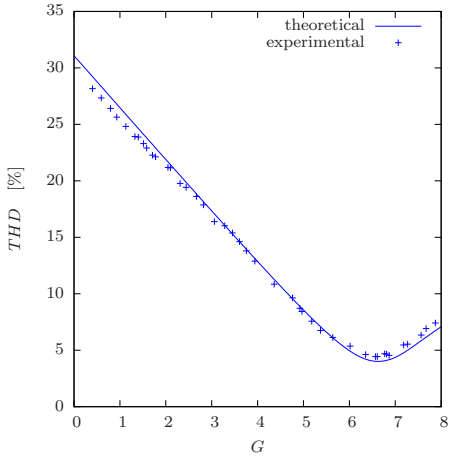
Experiments

- 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

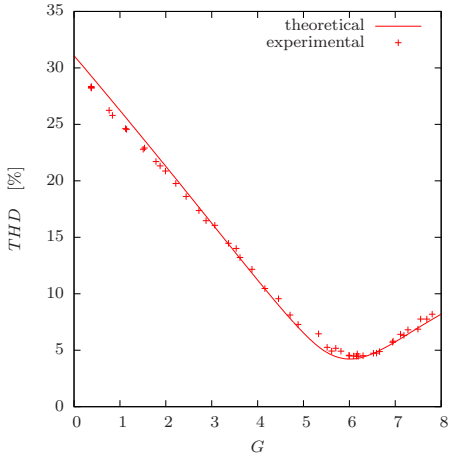
Resistance emulator



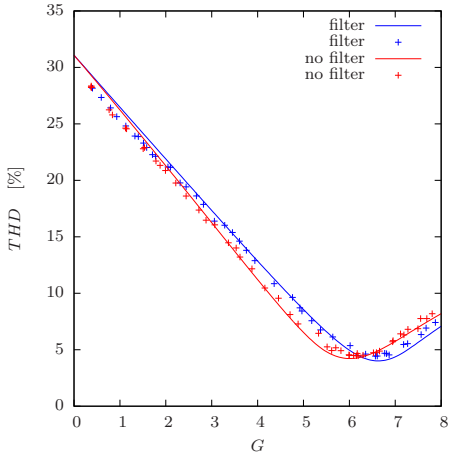
Experimental results, with the filter



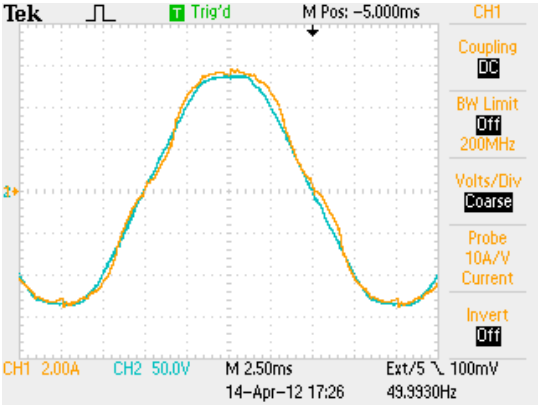
Experimental results, without the filter



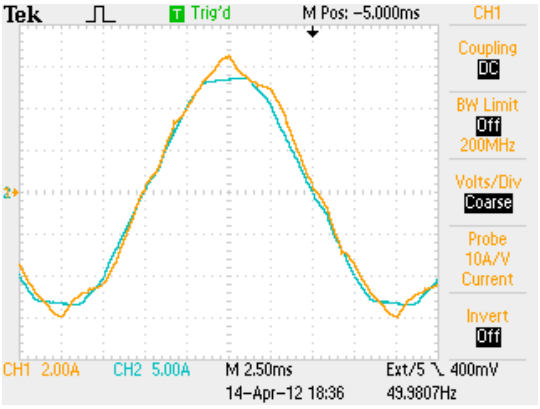
Experimental results, joined



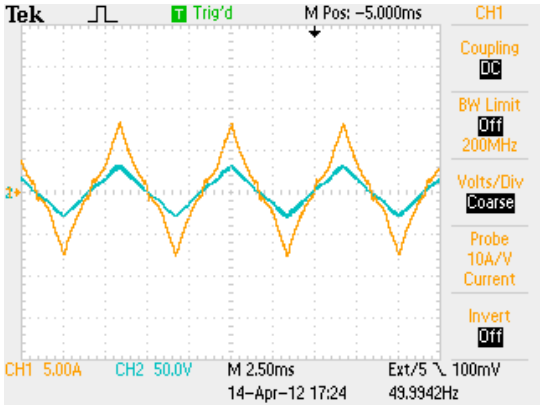
Experiment, no filter, i_1 and v_1



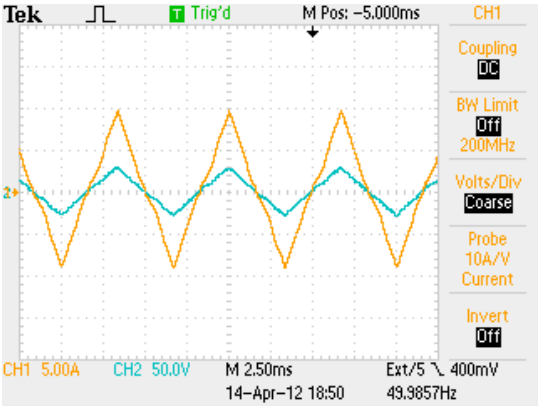
Experiment, with filter, i_1 and v_1



Experiment, no filter, i_Y and v_{AV}

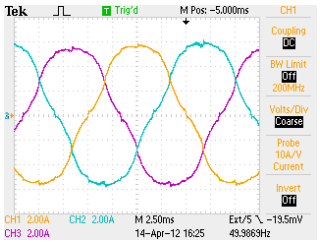


Experiment, with filter, i_Y and v_{AV}

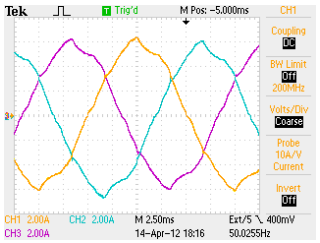


Experiment, phase currents shapes

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