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Bidirectional Optimal Trajectory Control for Series-Resonant Converters

Remco Bonten, AME / TU/e

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1931 Congrescentrum Den Bosch
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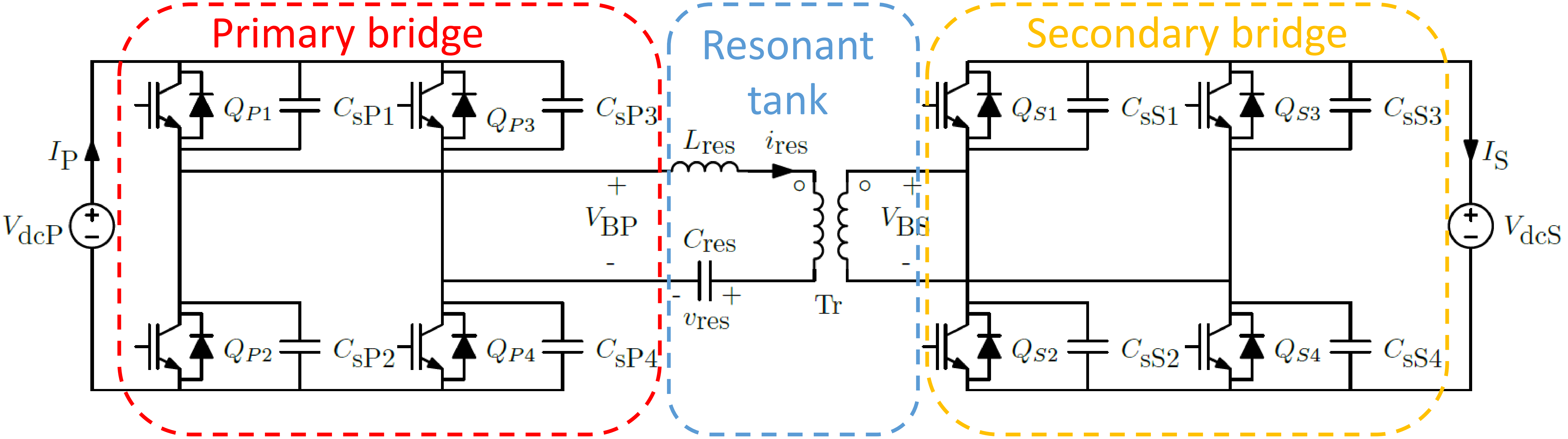
Content

- Topology
- Assumptions & definitions
- Bidirectional Optimal Trajectory Control
- Implementation
- Results
- Conclusion
- Questions

Topology

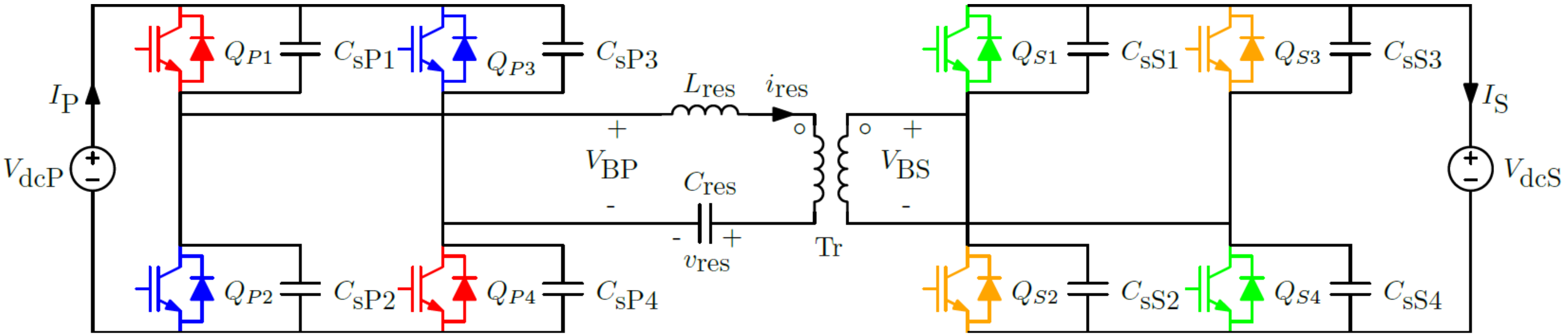


$$C_{sP1} = C_{sP2} = C_{sP3} = C_{sP4} = \frac{C_{sP}}{2}$$

$$C_{sS1} = C_{sS2} = C_{sS3} = C_{sS4} = \frac{C_{sS}}{2}$$

Assumptions & definitions

- Ideal circuit elements
- Constant in- and output voltages during a resonant half-cycle
- Positive power transfer is from the primary to the secondary side
- Bipolar switching



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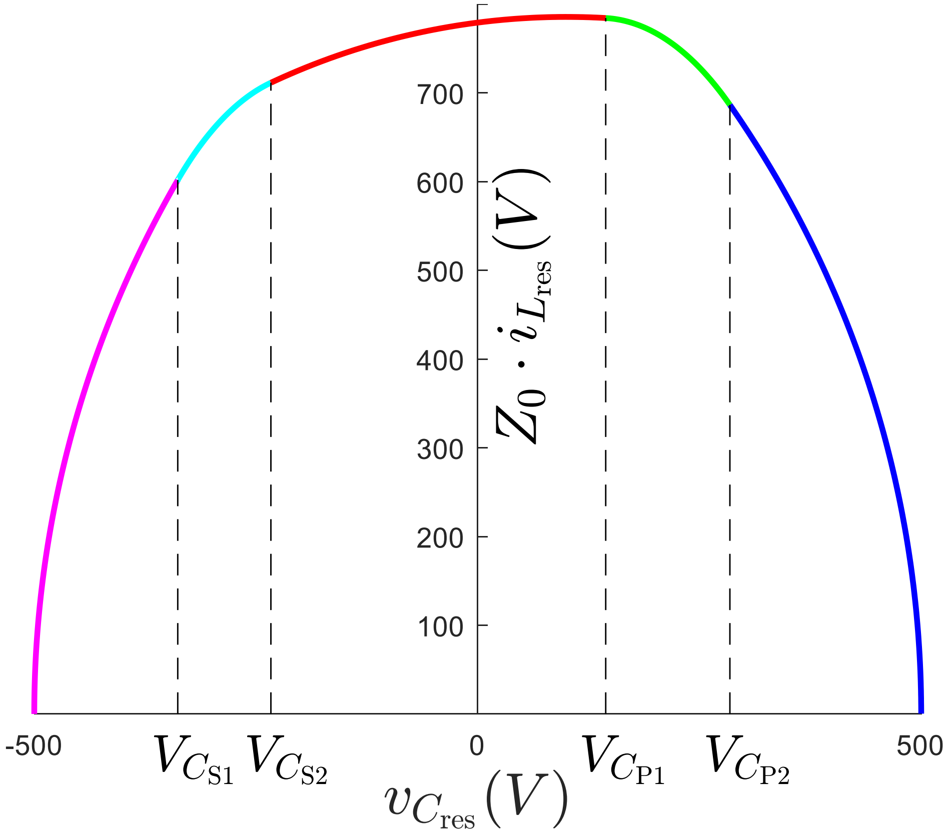
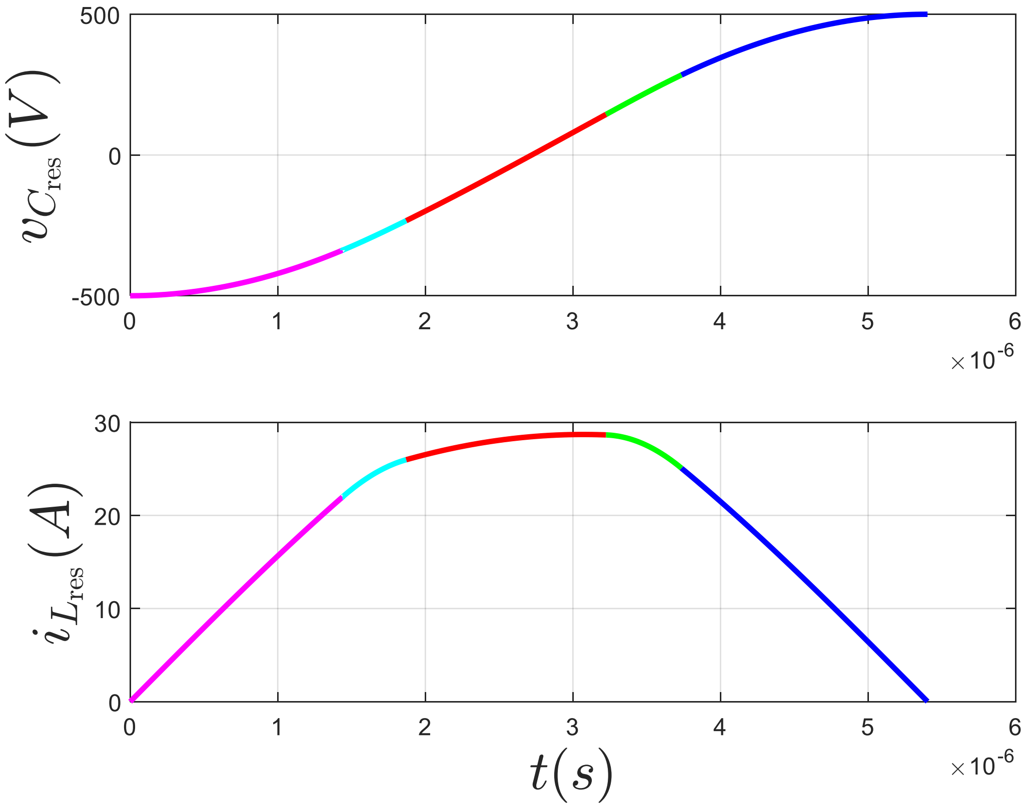
Bidirectional Optimal Trajectory Control

- Charge based
- Varying frequency
- Calculate switching moment with respect to voltage across resonant capacitor

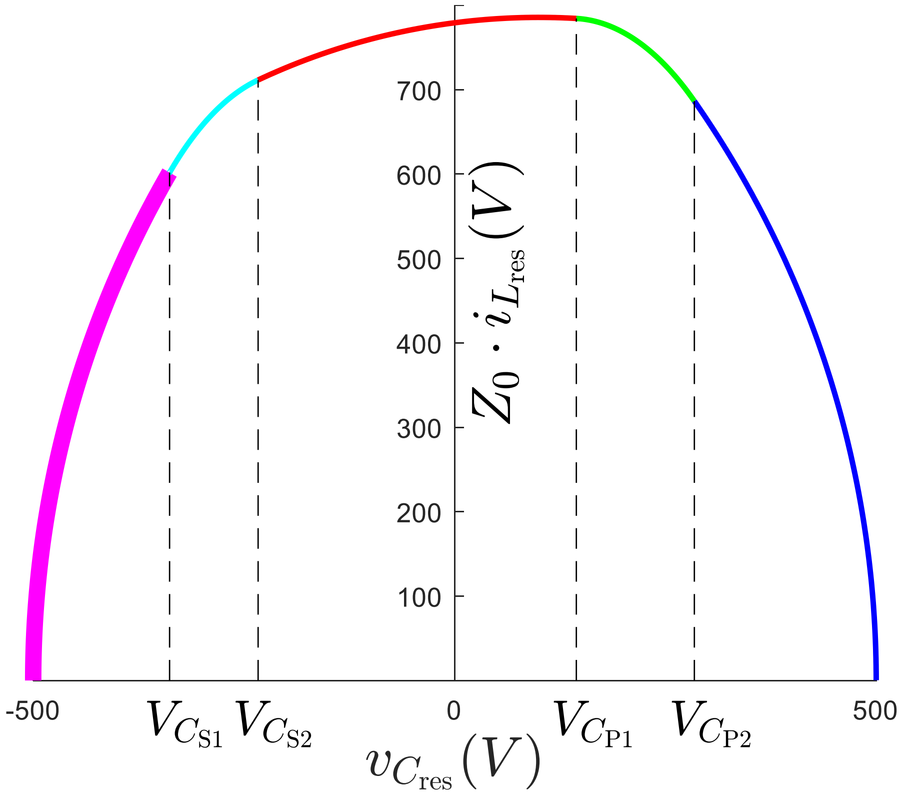
Bidirectional Optimal Trajectory control



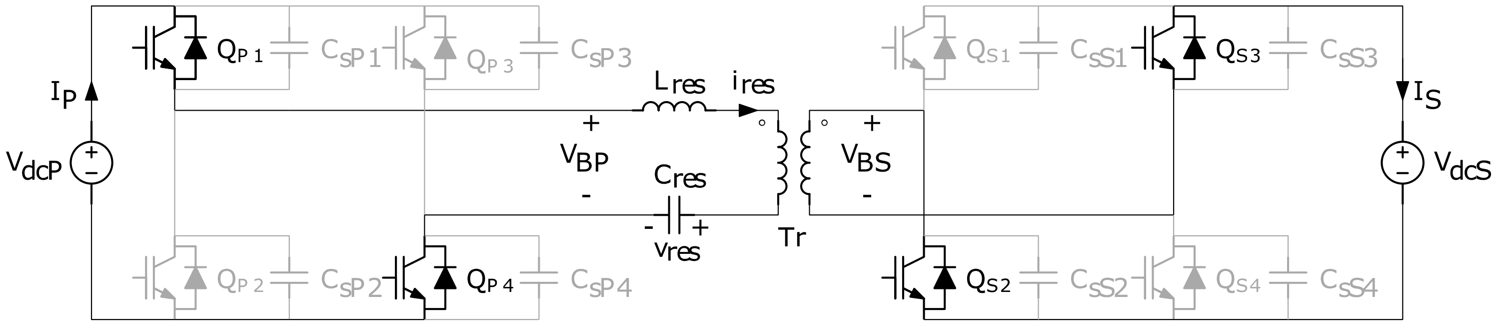


** Only positive half-cycle is shown, negative half-cycle will be shown at results

Bidirectional Optimal Trajectory Control



$$V_{C_{\rm init}} \leq V_{C_{res}}(V) \leq V_{C_{\rm S1}}$$



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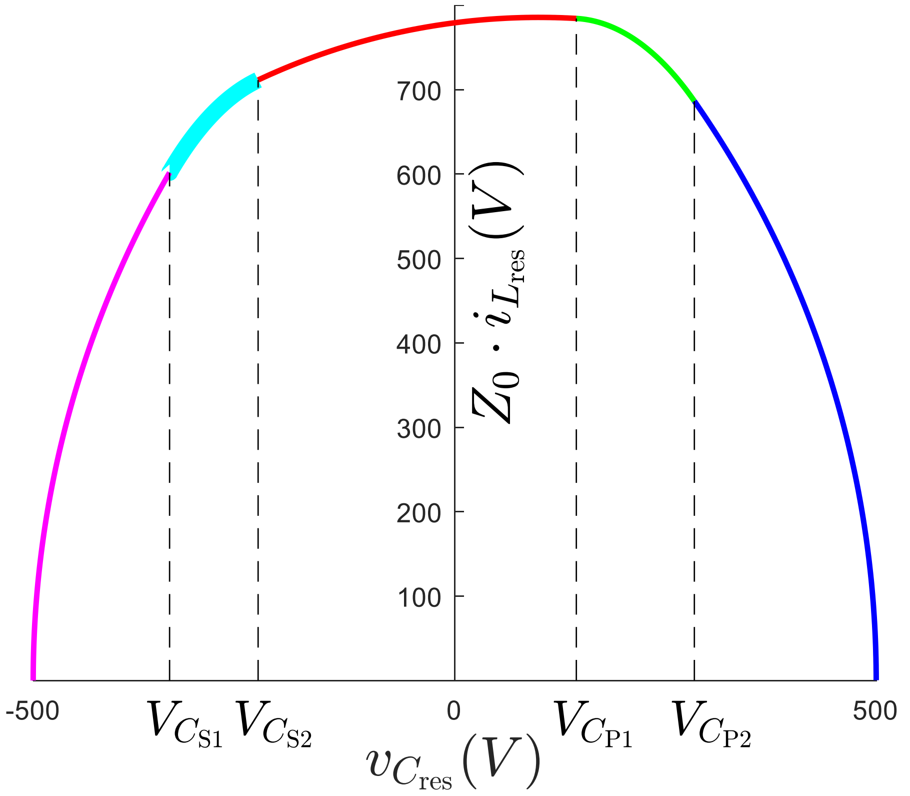
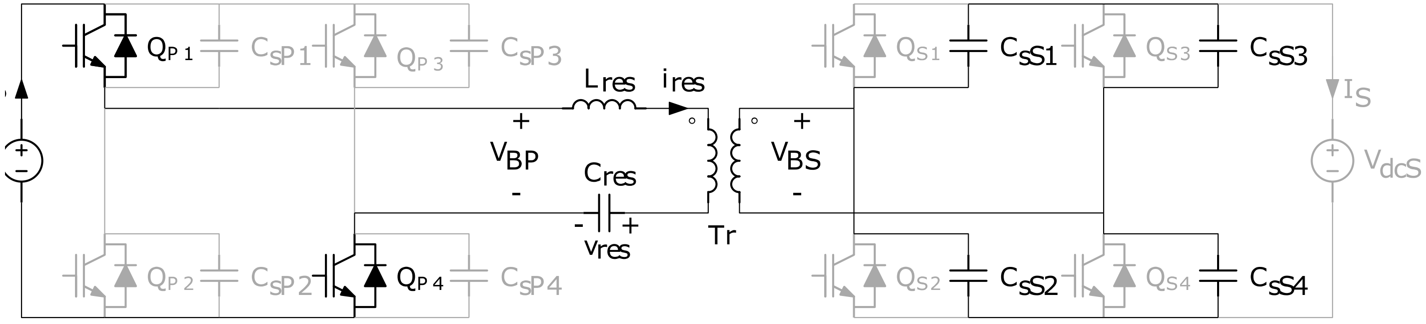
Bidirectional Optimal Trajectory Control



$$V_{C_{S1}} \leq V_{C_{res}}(V) \leq V_{C_{S2}}$$



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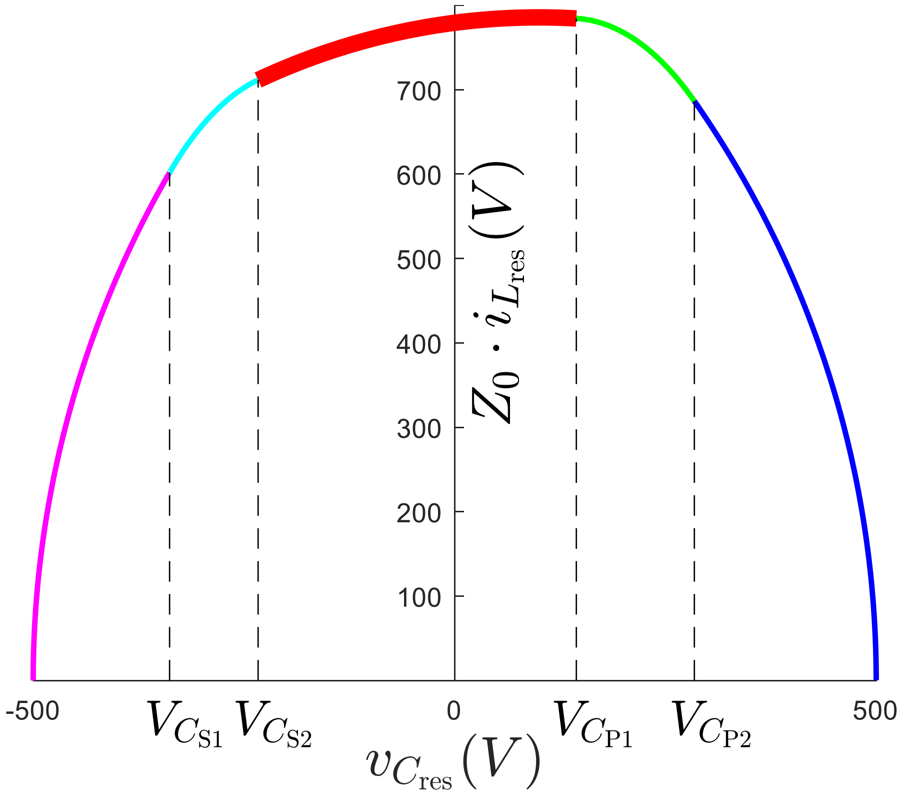
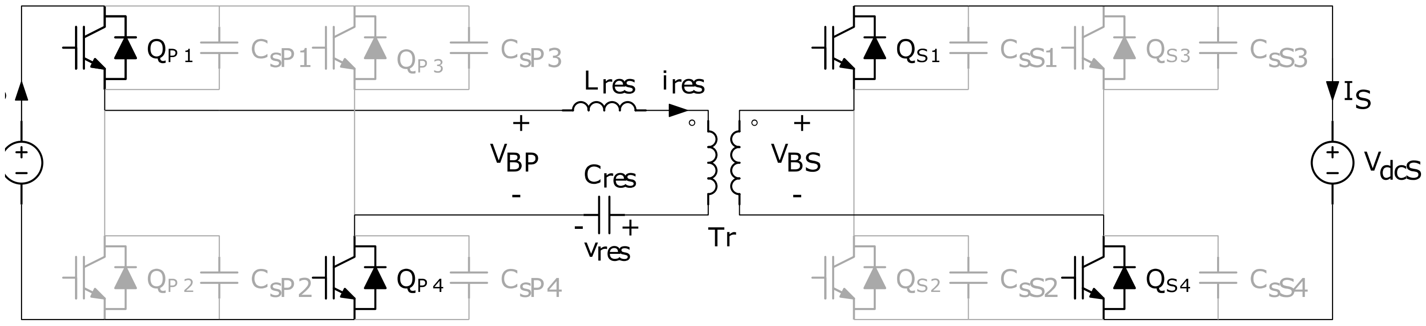
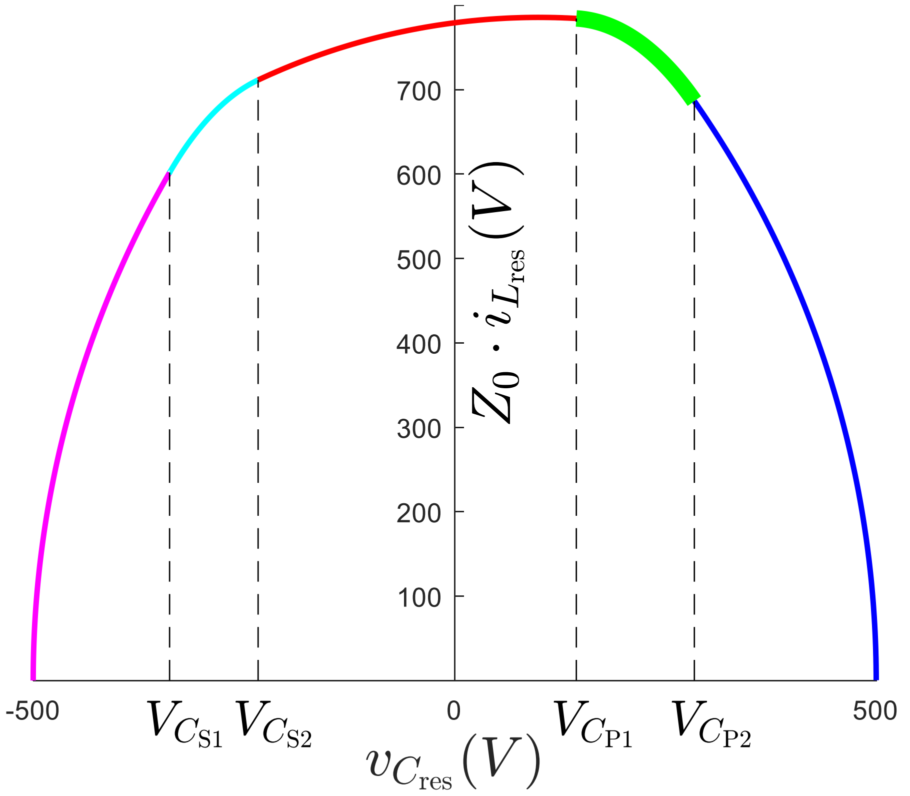
Bidirectional Optimal Trajectory Control



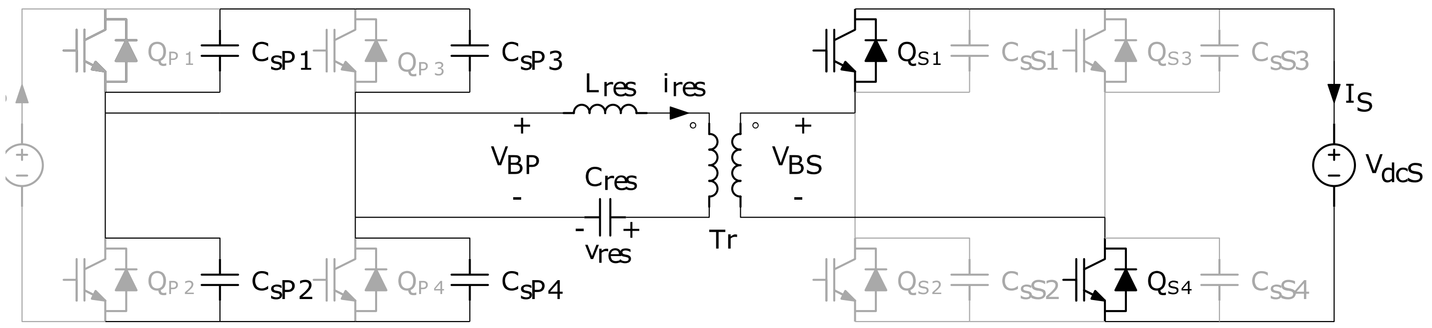
$$V_{C_{S2}} \leq V_{C_{res}}(V) \leq V_{C_{P1}}$$



Bidirectional Optimal Trajectory Control



$$V_{C_{P1}} \leq V_{C_{res}}(V) \leq V_{C_{P2}}$$



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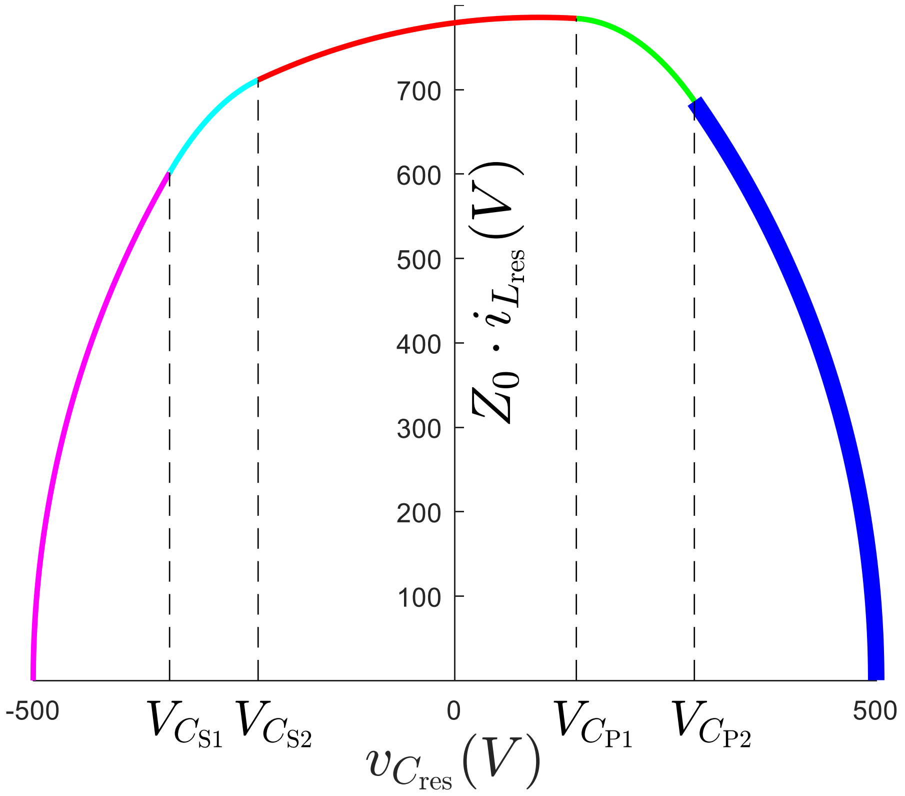
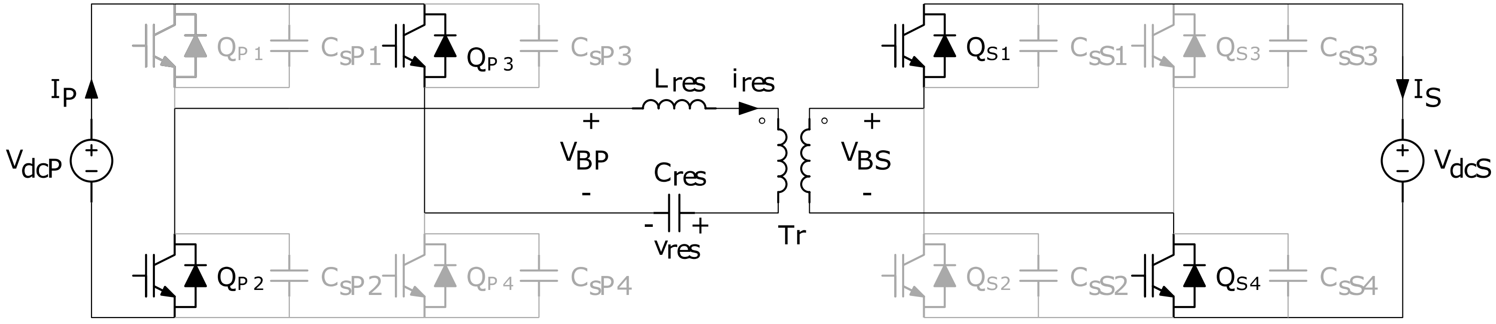
Bidirectional Optimal Trajectory Control



$$V_{C_{P2}} \leq V_{C_{res}}(V) \leq V_{C_{end}}$$



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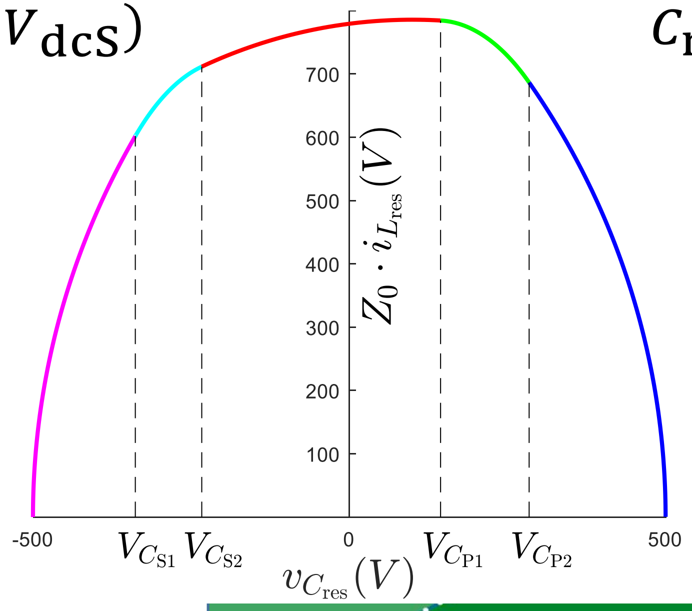
Bidirectional Optimal Trajectory Control

- $V_{C_{P1}} = \frac{(2V_{dcP}+2V_{dcS}+V_{C_{end}}-V_{C_{init}})(V_{C_{init}}+V_{C_{end}})}{4(V_{dcP}+V_{dcS})} + \frac{V_{dcS}Q_{P2S}}{C_{res}(V_{dcP}+V_{dcS})} - \frac{V_{dcP}}{2}\frac{C_{sP}}{C_{res}}$
- $V_{C_{S1}} = \frac{(2V_{dcP}+2V_{dcS}+V_{C_{end}}-V_{C_{init}})(V_{C_{init}}+V_{C_{end}})}{4(V_{dcP}+V_{dcS})} - \frac{V_{dcP}Q_{P2S}}{C_{res}(V_{dcP}+V_{dcS})} - \frac{V_{dcS}}{2}\frac{C_{sS}}{C_{res}}$



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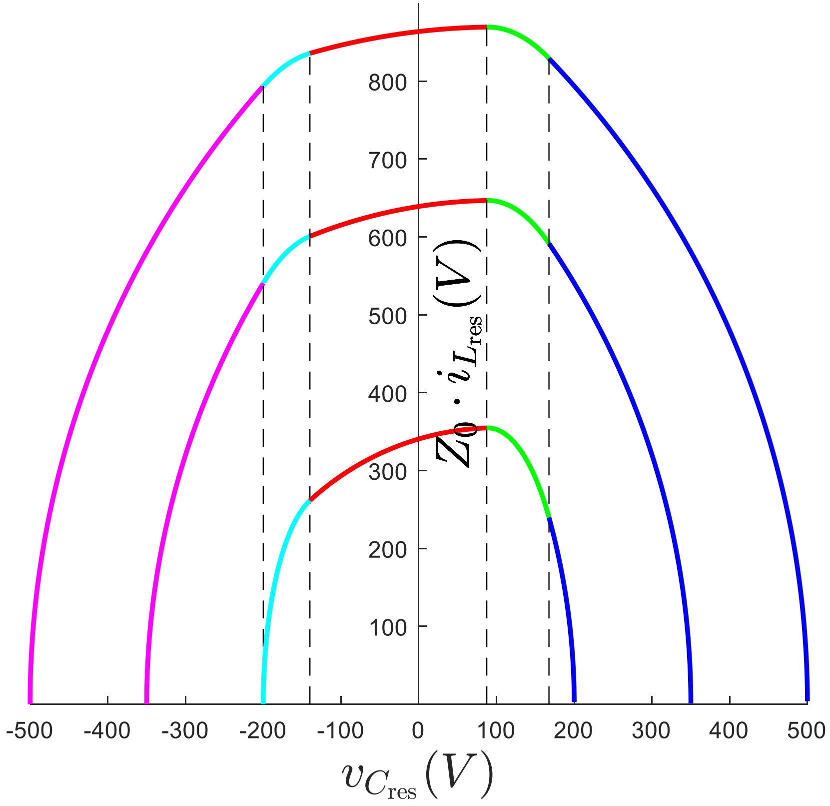
Bidirectional Optimal Trajectory Control

- Reduction of solution space
  - Minimize reactive power by minimizing the voltage swing across the resonant capacitor.

- $V_{C_{P1}}$ and $V_{C_{S1}}$ can then be calculated.



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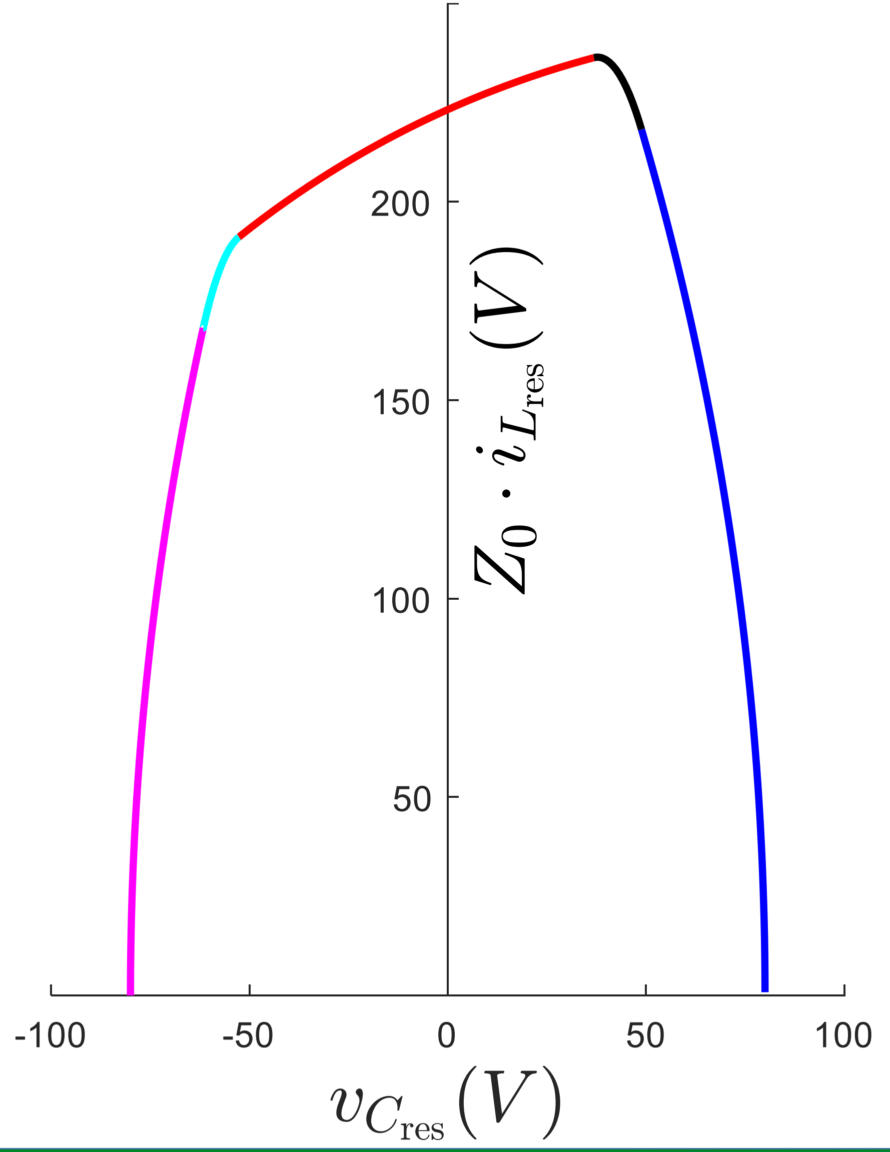
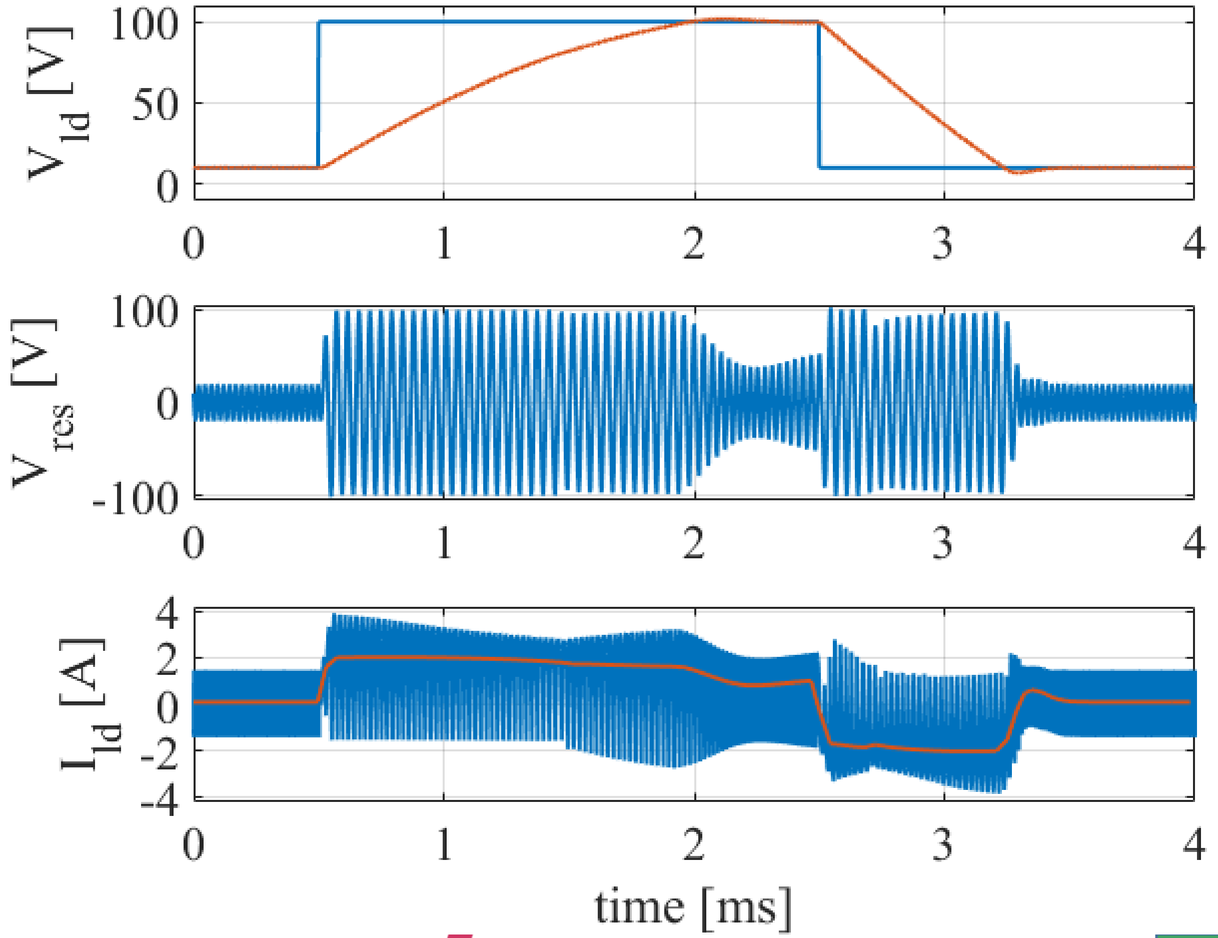
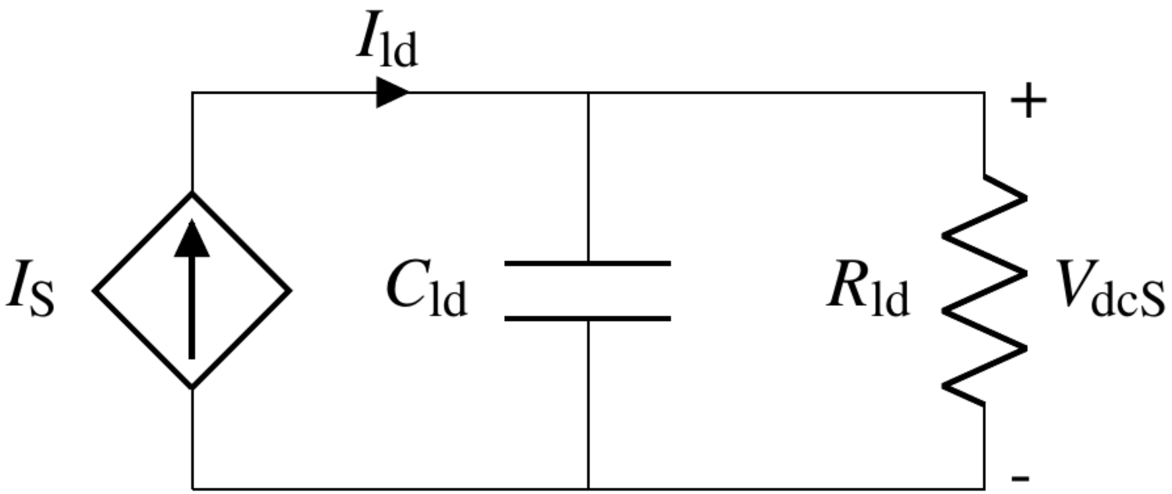
Implementation

- $V_{C_{\text{end}}}$ is a function of Q_{P2S}
  - $Q_{P2S} \downarrow$ leads to $f_{\text{sw}} \uparrow$
  - Lower boundary on $V_{C_{\text{end}}} \rightarrow V_{C_{\min}}$
  - Reactive power to maintain $V_{C_{\min}}$



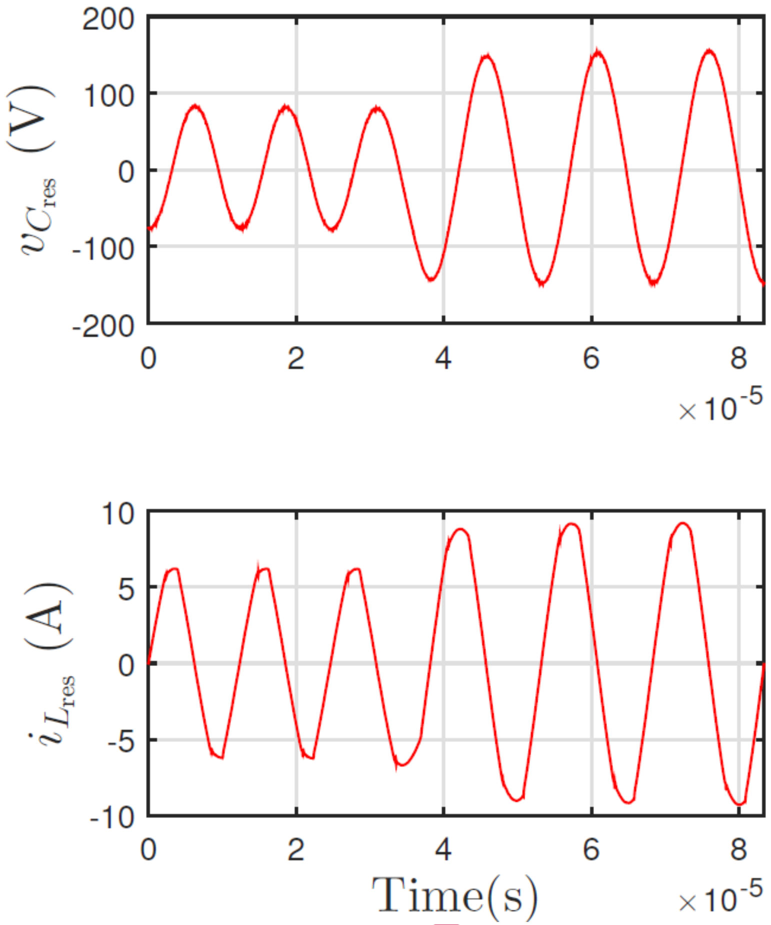
Results - Simulation

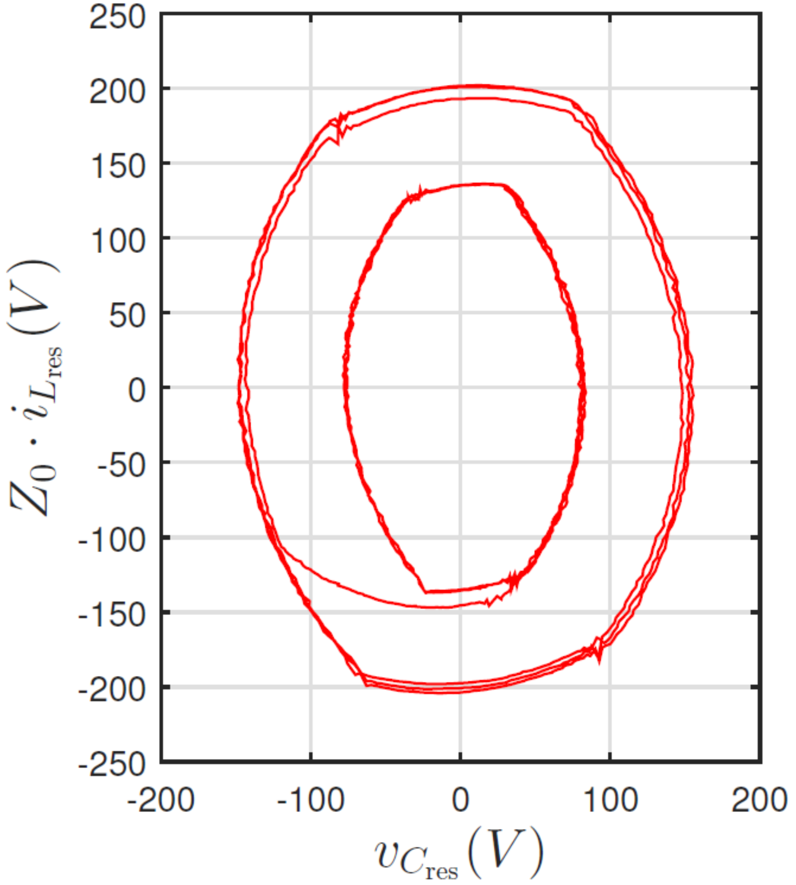




Parameter	Value
V_{dcP}	75 V
V_{dcS}	V_{ld}
C_{res}	250 nF
C_{ld}	10 uF
R_{ld}	100 Ω

Results – Test



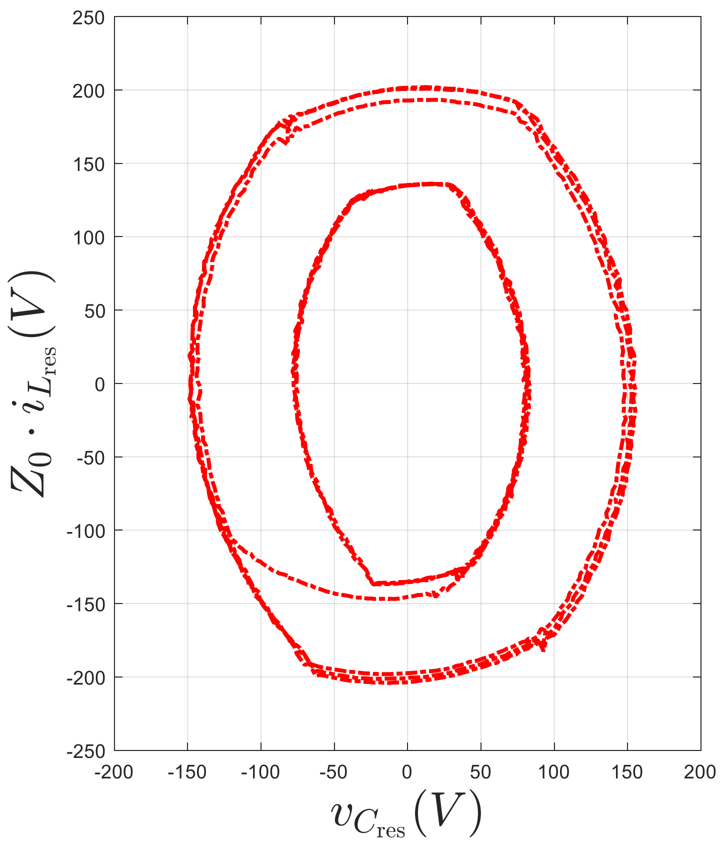


Parameter	Value
V_{dcP}	150 V
V_{dcS}	12 V
C_{res}	300nF
L_{res}	75 uH
Q_{t1}	24 uC
Q_{t2}	72 uC

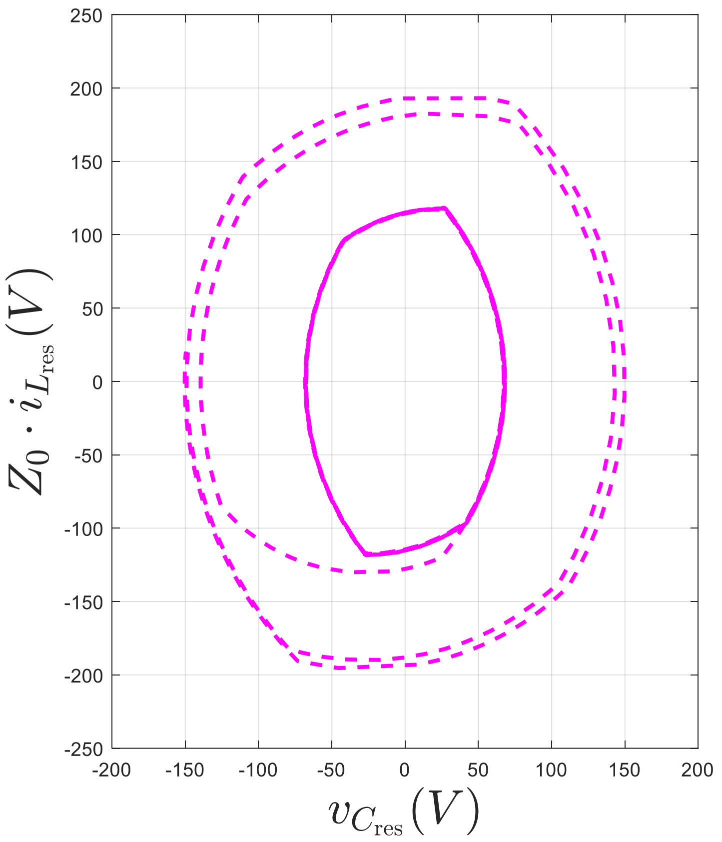
Results – Test

Simulation

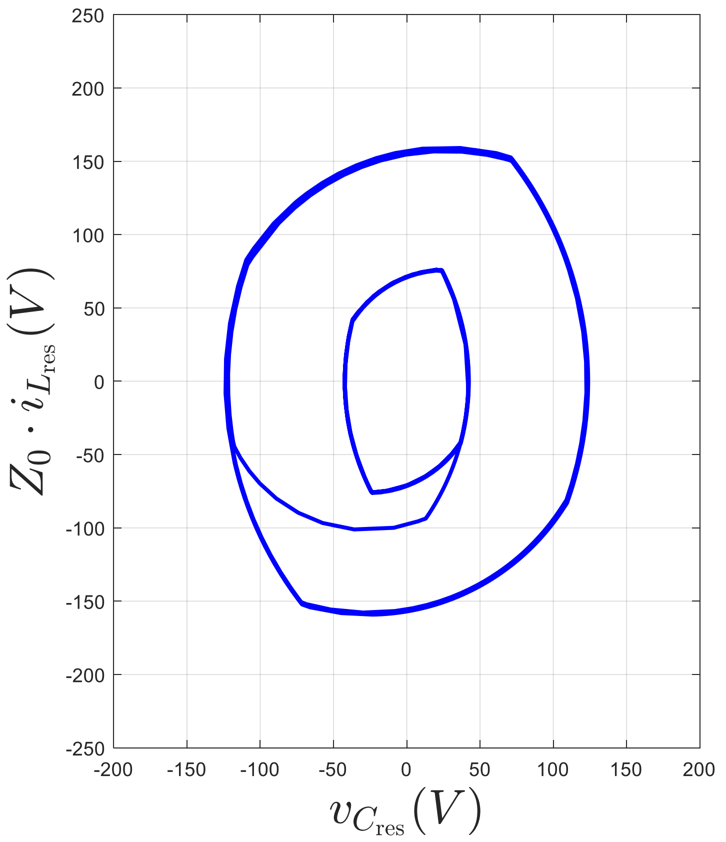
Test



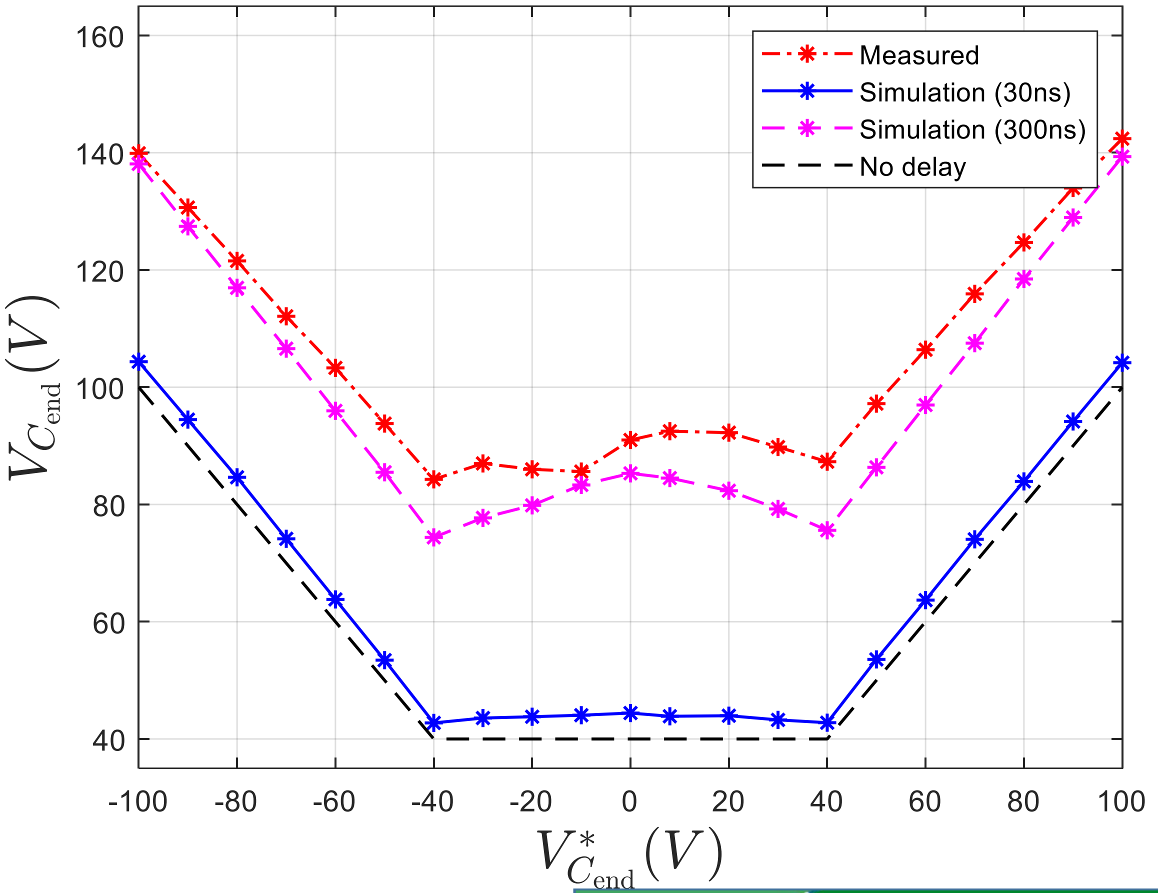
Realistic



Goal



Results – Test



Conclusion

- Bidirectional optimal trajectory control
  - Charge based control
  - Dead-beat control
  - Calculate switching events every resonant half-cycle
- Verified both by simulation and testing

That’s it!

Thank you for your attention!

Are there any questions?