Norway
grants

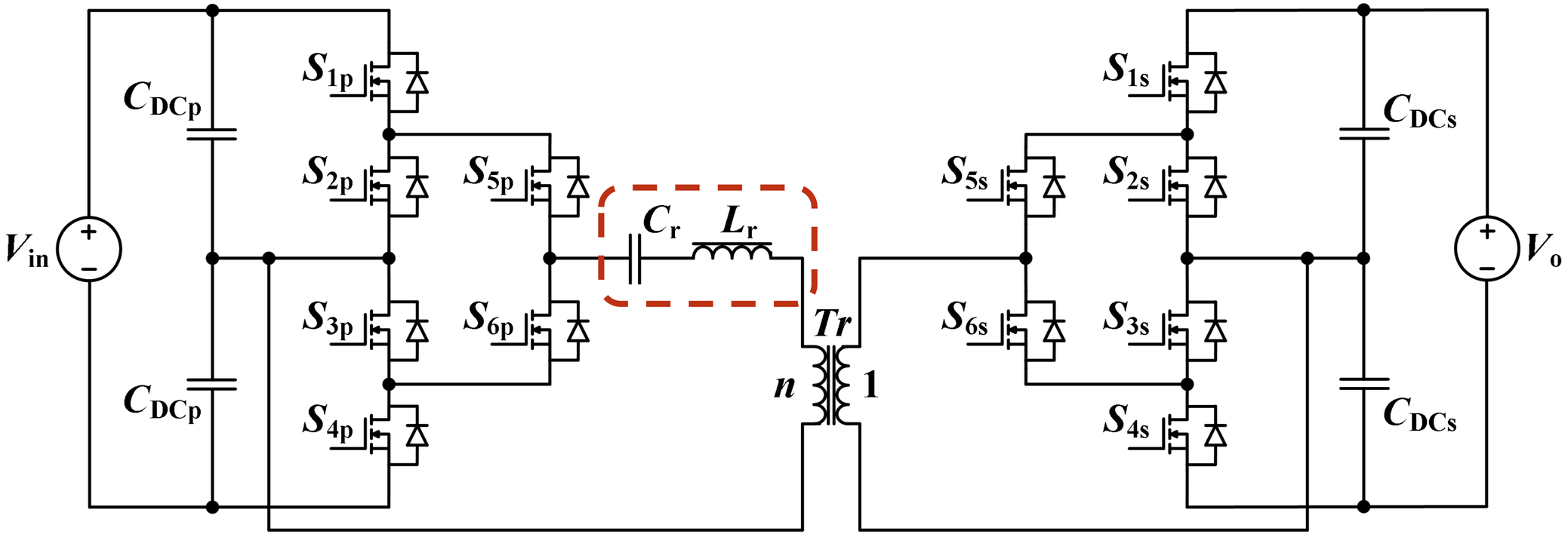
Series-resonant dual active bridge (SRDAB) with ANPC submodules

Selection of resonant tank components in 10 kW SRDAB converter

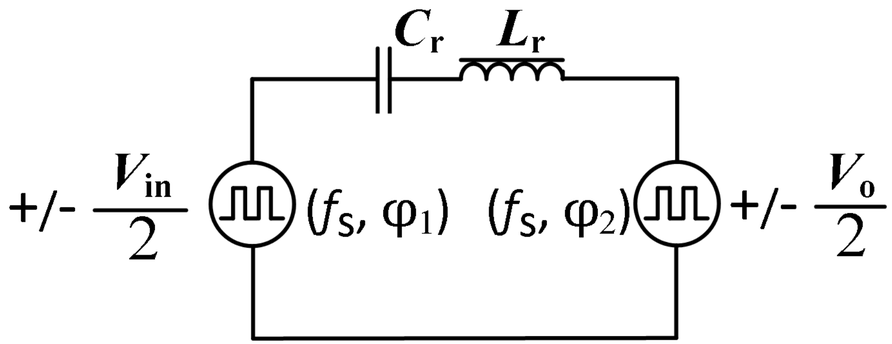
Przemysław Trochimiuk Warsaw University of Technology

28.09.2022

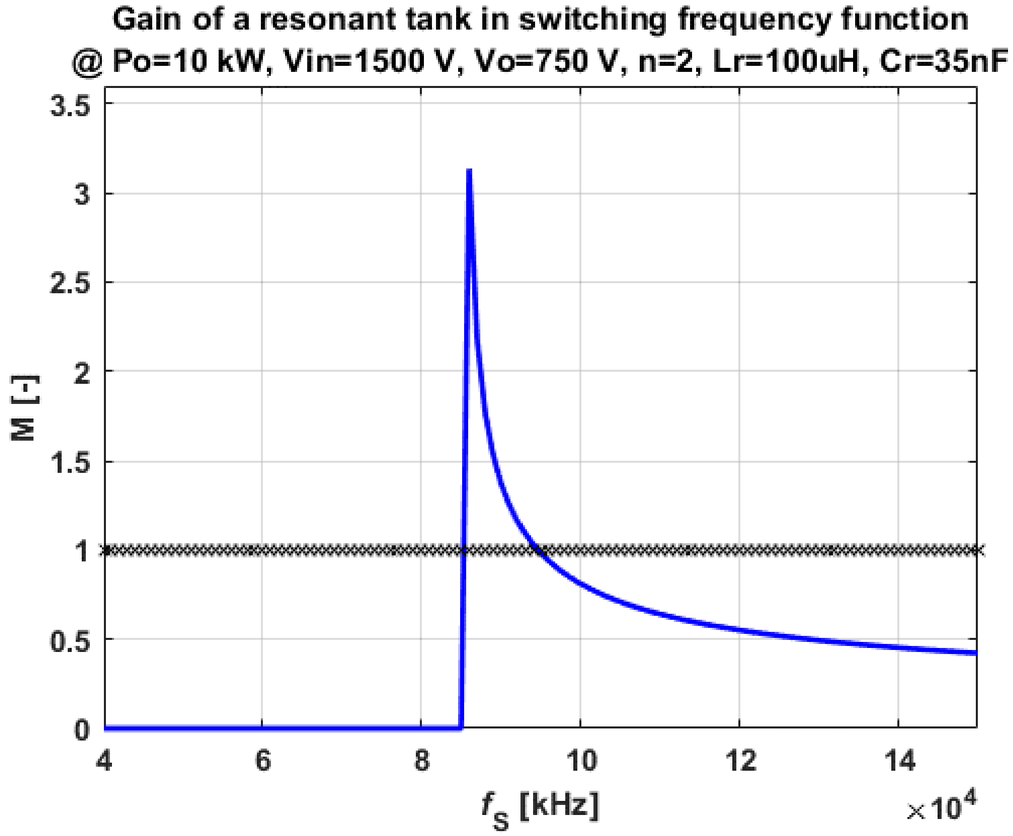
SRDAB with ANPC submodules – overall schematic



SRDAB with ANPC submodules – simplified schematic and gain of a resonant tank in f_s function



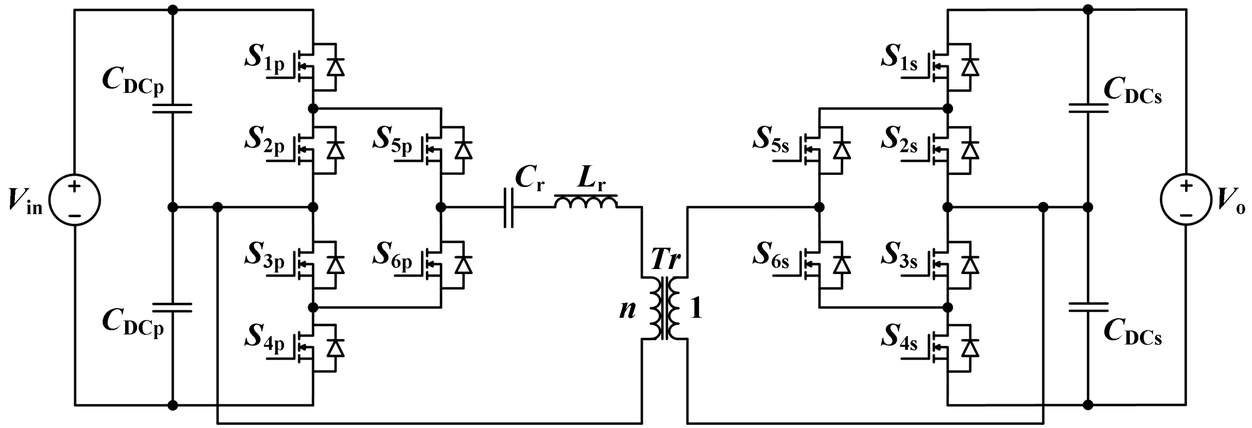
$$\varphi_2 - \varphi_1 = \Phi$$



Basic equations

$$M = \frac{8 \sin \phi}{\pi^2 Q (F - 1/F)}$$

$$M = \frac{n V_o}{V_{in}}$$



$$P_{o,pu} = \frac{1}{2\pi} \int_0^{2\pi} P_{pu}(t) d(\omega_s t) = \frac{8M}{\pi^2 Q (F - 1/F)} \sin \phi = M^2$$

X. Li and A. K. S. Bhat, "Analysis and Design of High-Frequency Isolated Dual-Bridge Series Resonant DC/DC Converter," in *IEEE Transactions on Power Electronics*, vol. 25, no. 4, pp. 850-862, April 2010, doi: 10.1109/TPEL.2009.2034662.

Input parameters:

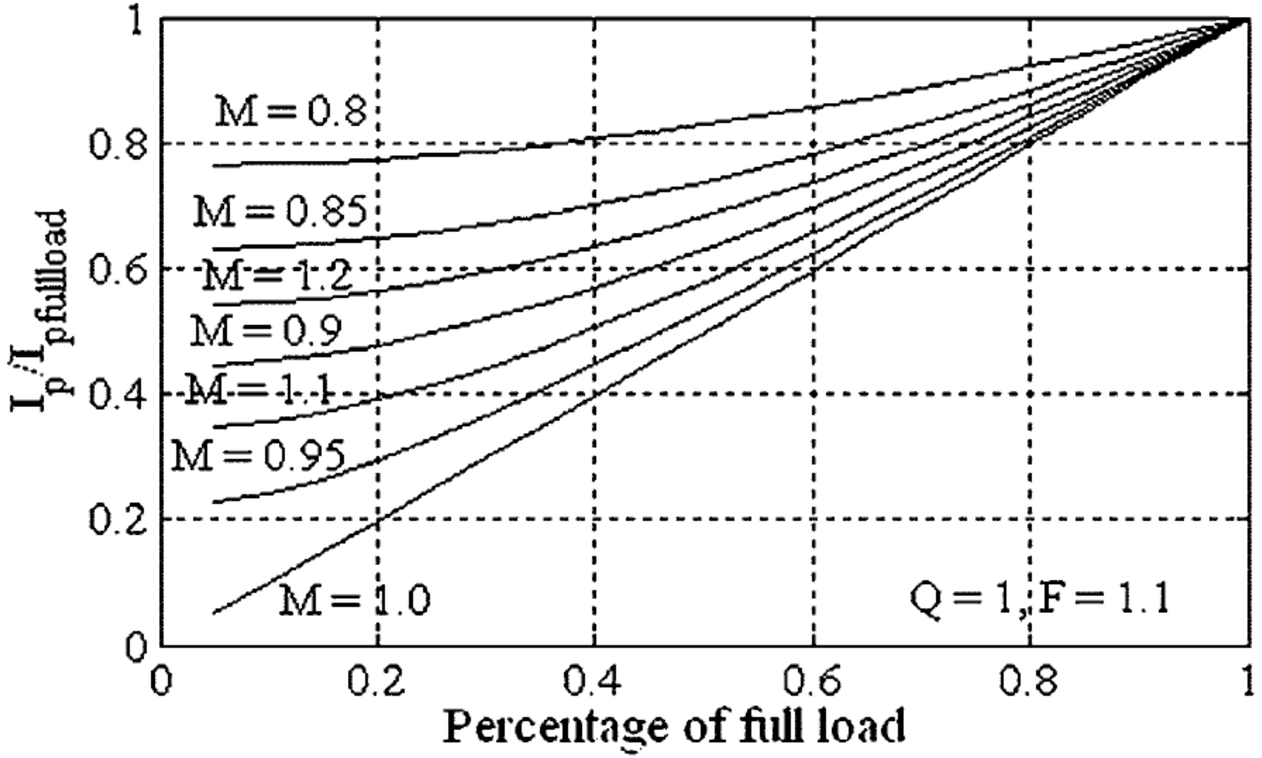
$$V_{in}\,,\ V_o,\ \ P_o,\ \ f_s$$

Parameters to be selected:

$$M = \frac{nV_o}{V_{in}}$$

Parameters to be calculated:

$$n$$



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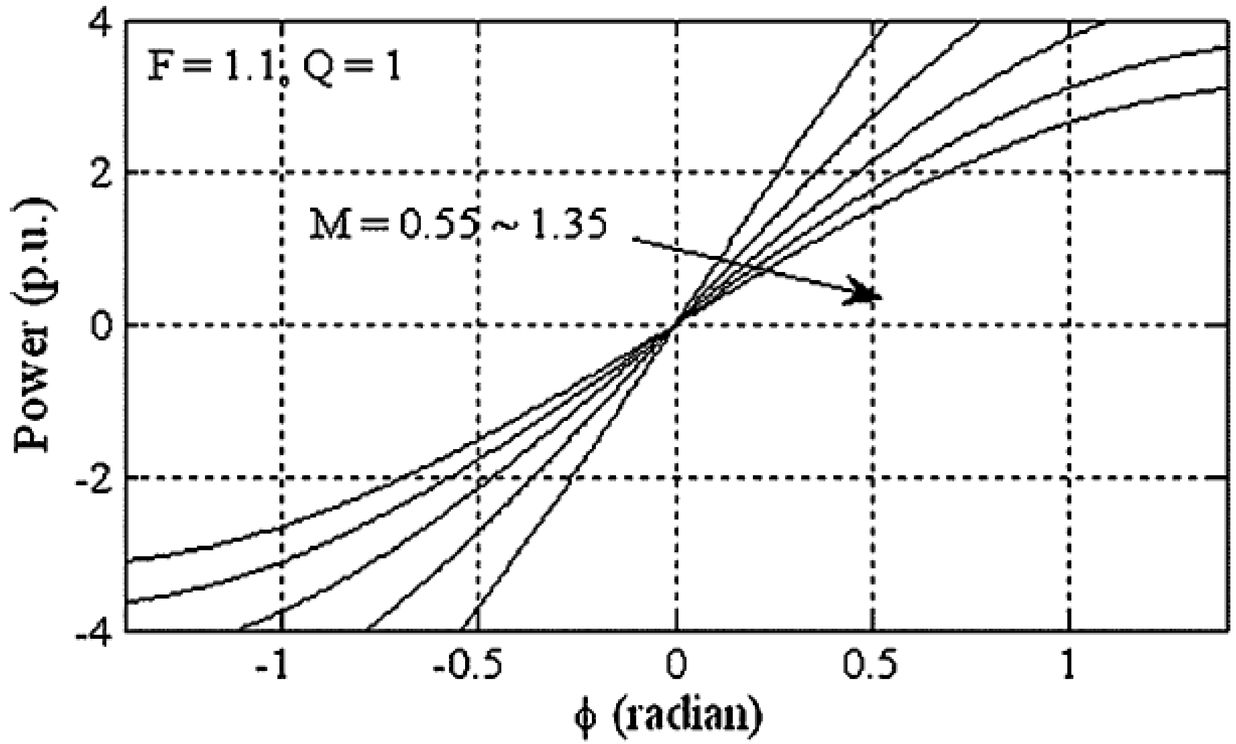

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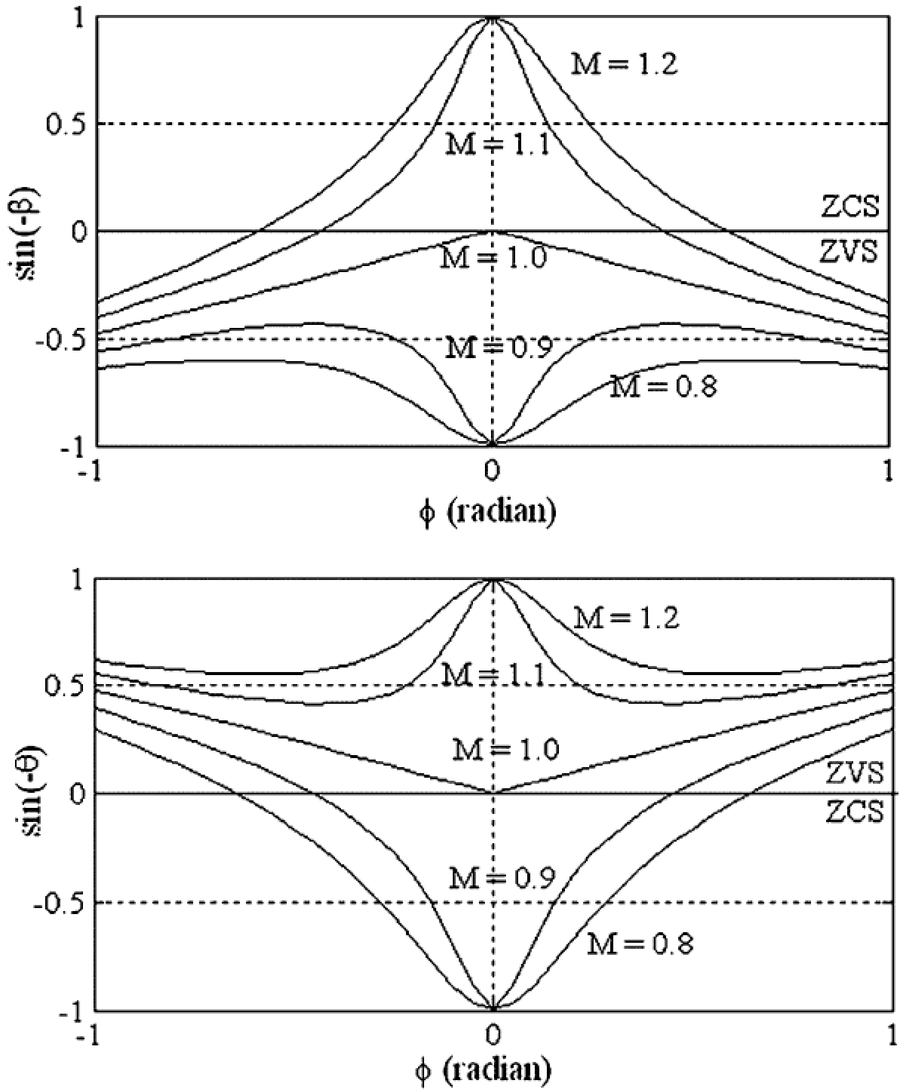

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Known parameters:

$$V_{in}\,,\;\; V_o,\;\; P_o,\;\; f_s,$$

$$M,\;\; n$$

Parameters to be calculated:

$$V_B = V_{in}\,, \quad Z_B = n^2 \frac{V_{out}^2}{P_o}\,,$$

$$I_B = \frac{V_B}{Z_B}$$

X. Li and A. K. S. Bhat, "Analysis and Design of High-Frequency Isolated Dual-Bridge Series Resonant DC/DC Converter," in *IEEE Transactions on Power Electronics*, vol. 25, no. 4, pp. 850-862, April 2010, doi: 10.1109/TPEL.2009.2034662.

Known parameters:

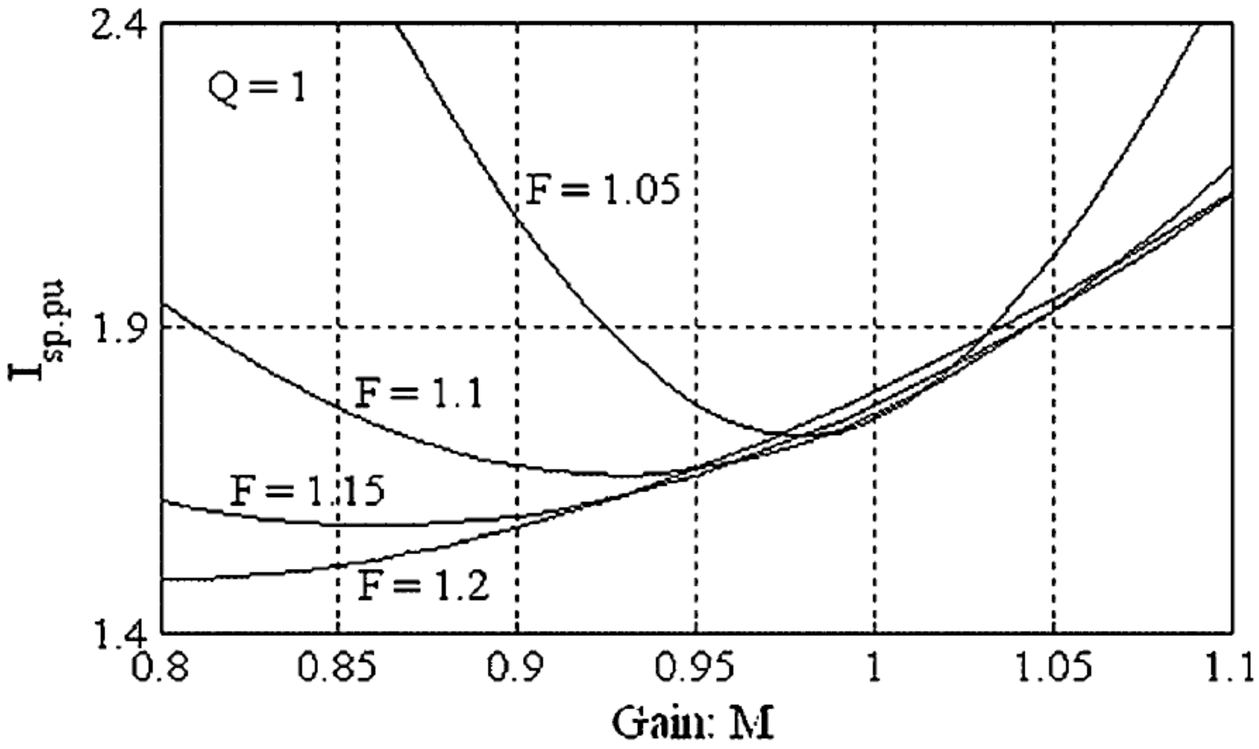
$$V_{in},\ V_o,\ P_o,\ f_s,$$
$$M,\ n,\ V_B,\ I_B,\ Z_B$$

Parameters to be selected:

$$F = \frac{\omega_s}{\omega_r} = \frac{f_s}{f_r}$$

Parameters to be calculated:

$$f_r$$



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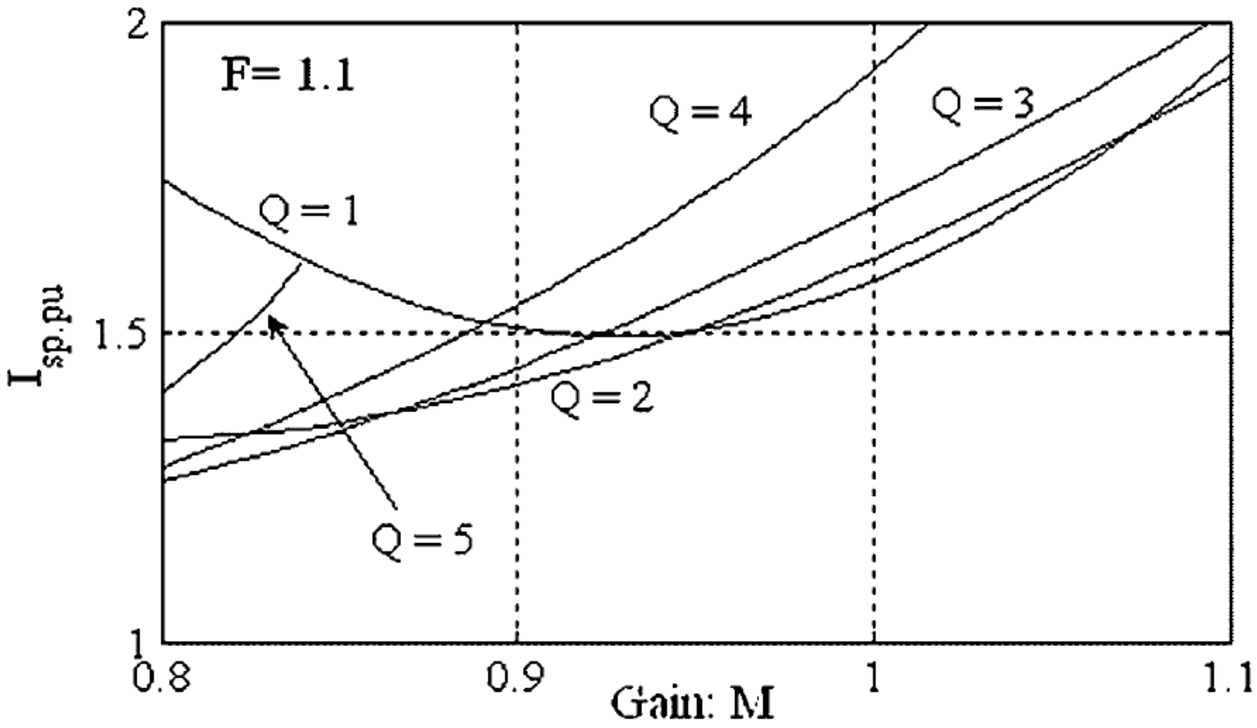
Known parameters:

$$V_{in},\ V_o,\ P_o,\ f_s,$$
$$M,\ n,\ V_B,\ I_B,\ Z_B,$$
$$F,\ f_r$$

Parameters to be selected:

$$Q = \frac{2\pi f_r L_r}{Z_B}$$



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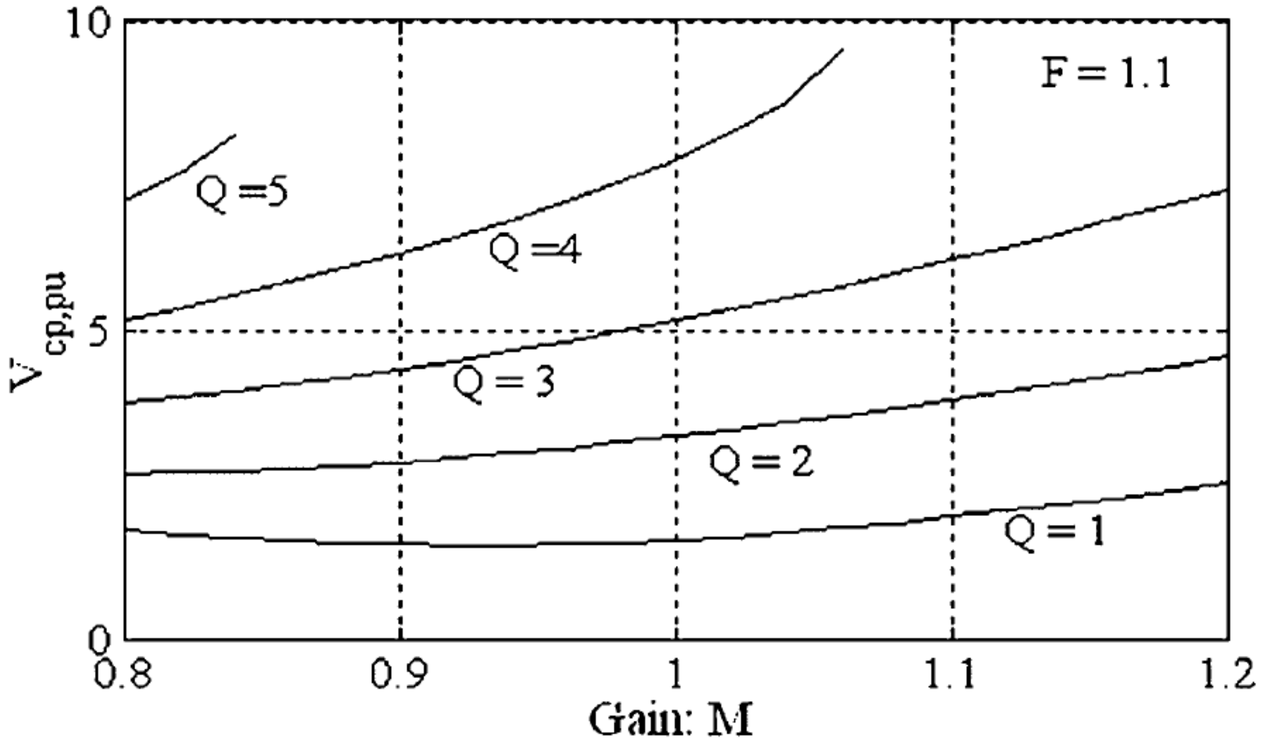

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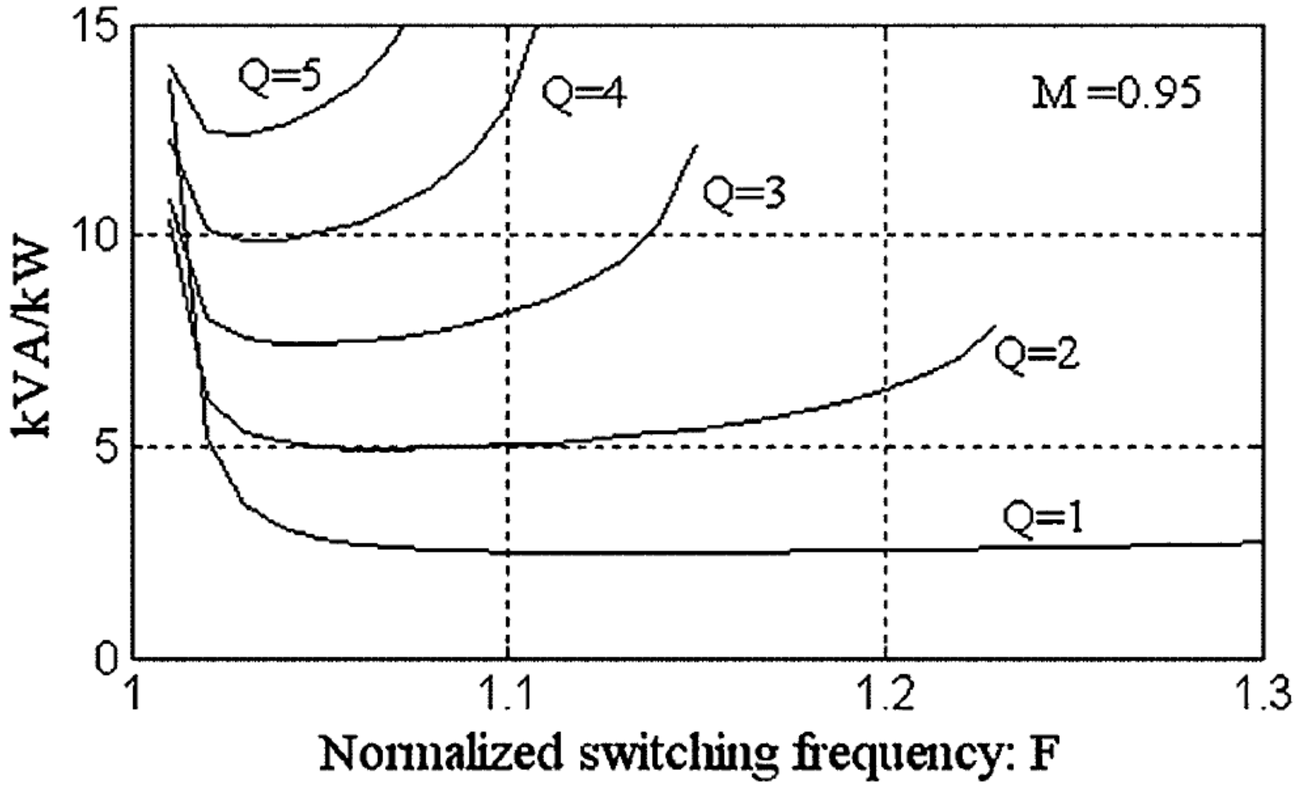

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$$F,\ f_r$$

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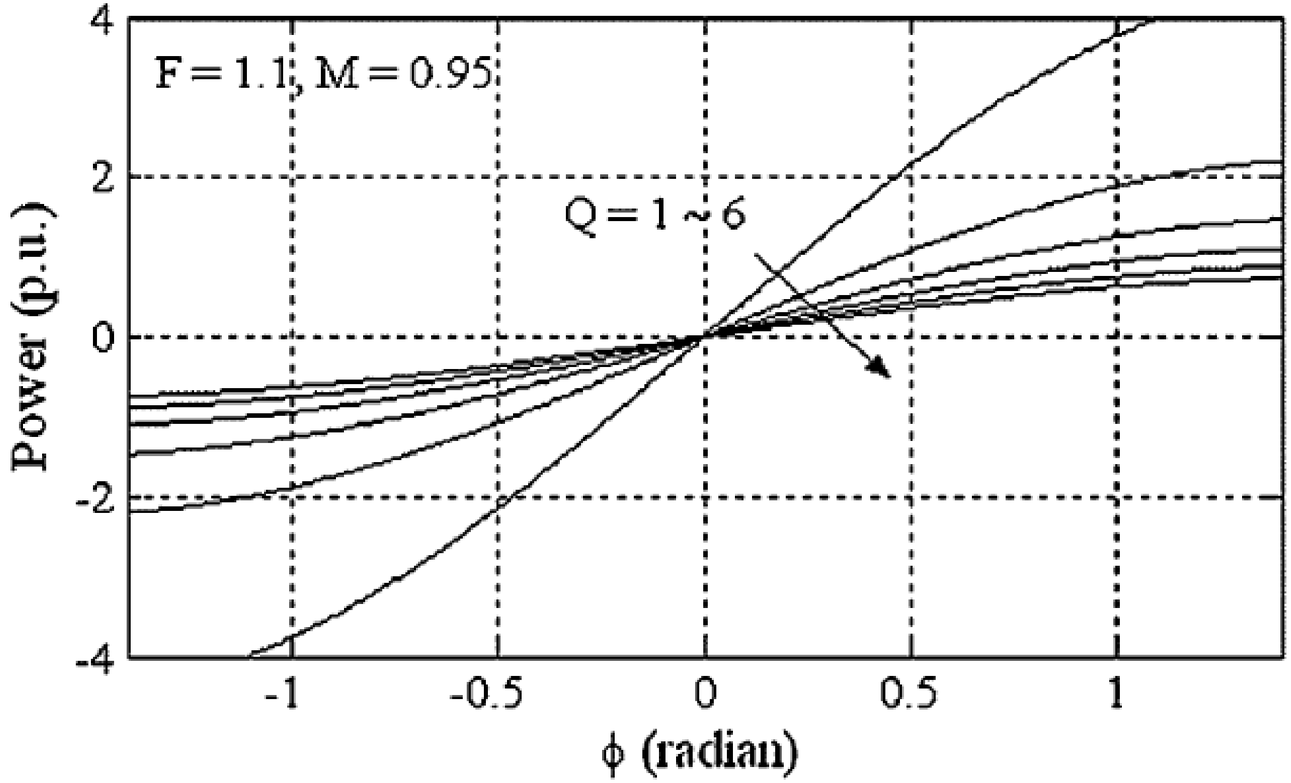

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Known parameters:

$$V_{in}\,,\ V_o,\ \ P_o,\ \ f_s,$$
$$M,\ \ n,\ \ V_B,\ \ \ I_B,\ \ Z_B,$$
$$F,\ \ f_r,\ \ Q$$

Parameters to be calculated:

$$L_r = \frac{QZ_B}{2\pi f_r}\,, \quad C_r = \frac{1}{4\pi^2 f_r^2 L_r}$$

X. Li and A. K. S. Bhat, "Analysis and Design of High-Frequency Isolated Dual-Bridge Series Resonant DC/DC Converter," in *IEEE Transactions on Power Electronics*, vol. 25, no. 4, pp. 850-862, April 2010, doi: 10.1109/TPEL.2009.2034662.

Conclusion

General dependency of voltage gain M

- *=<1 guarantees ZVS turn-on on the primary side switches*
- *=>1 guarantees ZVS turn-on on the secondary side switches*
- *the farther from 1 the greater the peak resonant current*
- *the lower value enables a narrower range of Φ to control power in the full range*

X. Li and A. K. S. Bhat, "Analysis and Design of High-Frequency Isolated Dual-Bridge Series Resonant DC/DC Converter," in *IEEE Transactions on Power Electronics*, vol. 25, no. 4, pp. 850-862, April 2010, doi: 10.1109/TPEL.2009.2034662.

Conclusion

General dependency of freqency factor F

- *the higher value the smaller the increase in peak resonant current as a function of* M
- *the higher value requires larger passive elements*

X. Li and A. K. S. Bhat, "Analysis and Design of High-Frequency Isolated Dual-Bridge Series Resonant DC/DC Converter," in *IEEE Transactions on Power Electronics*, vol. 25, no. 4, pp. 850-862, April 2010, doi: 10.1109/TPEL.2009.2034662.

Conclusion

General dependency of factor Q

- *the higher value the smaller the increase in peak resonant current as a function of* M
- *the lower value the lower the peak voltage on the resonant capacitor* C_r
- *the lower value the lower reactive power in the resonant tank*
- *the lower value enables a narrower range of Φ to control power in the full range*

X. Li and A. K. S. Bhat, "Analysis and Design of High-Frequency Isolated Dual-Bridge Series Resonant DC/DC Converter," in *IEEE Transactions on Power Electronics*, vol. 25, no. 4, pp. 850-862, April 2010, doi: 10.1109/TPEL.2009.2034662.

Conclusion

Recommendations – good starting point:

M *-> around **1** – dependent on the soft switching range*

F *-> around **1.1** – to achieve small resonant tank components with assumed switching frequency* f_s

Q *-> around **1** – to get a compromise between low voltage and power in resonant tank and resonable increase in current with* M

Based on selected values calculate: L_r *and* C_r

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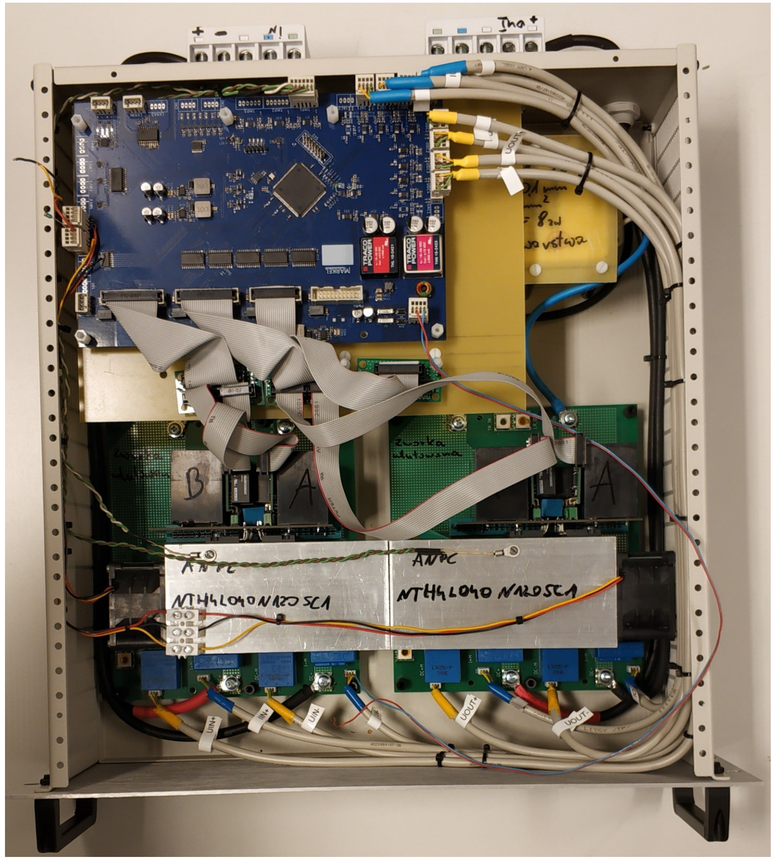
What should still be presented?

Minimum Current Trajectory (MCT) algorithm

Unfortunately, not today but on the next occasion…

Plans for the nearest future



Norway grants

Thank you!

1st Workshop on Advanced Charging Systems

Gdynia 2022

moresic-project

https://www.ee.pw.edu.pl/moresic-project/

Warsaw University of Technology

NTNU Norwegian University of Science and Technology

MARKEL energoelektronika to nasza pasja

AREX GRUPA WB