Design of the LC + Trap Filter for a Current Source Rectifier

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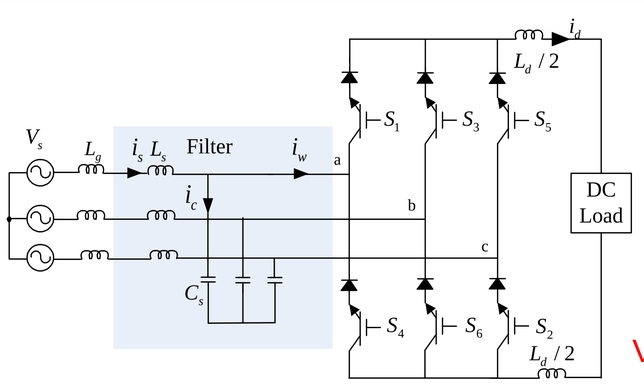
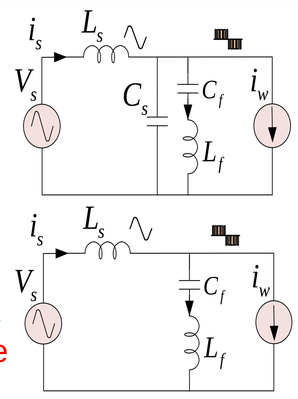
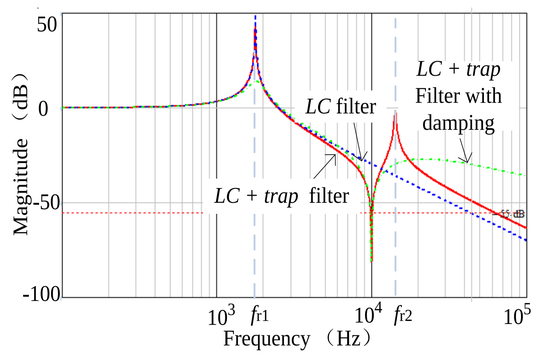
***Abstract* – This paper proposes an *LC* + trap filter for current source converters to improve the switching harmonic attenuation with reduced size and cost. The filter resonance characteristics of current source rectifier are analyzed. A filter design procedure is proposed based on the input power factor, filter capacitor voltage and the line current THD for space vector modulation. It is shown that the input filter resonance may be excited by the Pulse Width Modulation (PWM) and thus a simple passive damping is designed for resonance damping. The analysis and design of the input *LC* + trap filter have been verified by simulations in MATLAB/Simulink.**

Trap Filter for Current Source Rectifier

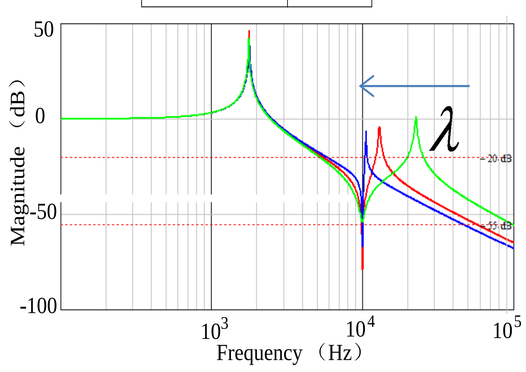




Voltage spike



$$C_s = \lambda C_f$$



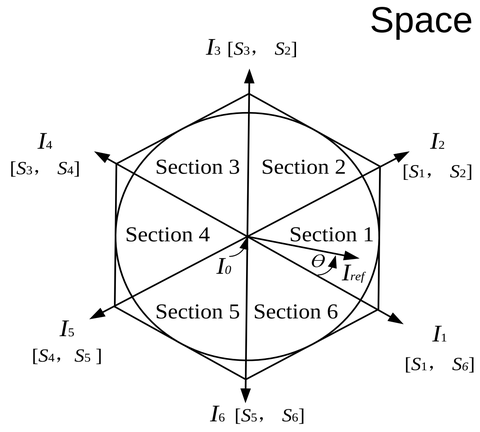
$$\omega_{sw} = \frac{1}{\sqrt{L_f C_f}}$$

$$\omega_{r1} = \frac{1}{\sqrt{\left(L_s + L_f + L_g\right)\left(C_s + C_f\right)}}$$

$$\omega_{r2} = \sqrt{\frac{C_s + C_f}{L_f C_f C_s}} = \omega_{sw}\sqrt{1 + \frac{1}{\lambda}}$$

Space Vector Modulation and Control

Space vector diagram



$$T_1 = m\sin(\frac{\pi}{3} - \theta)T_s$$

$$T_2 = m\sin\theta T_s$$

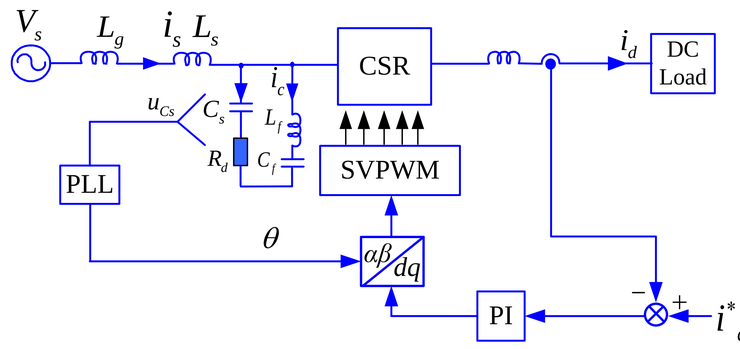
$$T_0 = 1 - T_1 - T_2$$

$$V_{h,k} = \frac{mI_{h,k}}{C_s 2\pi f_i \sqrt{2}}$$

$$I_{ref} = i_a + i_b e^{j\frac{2\pi}{3}} + i_c e^{j-\frac{2\pi}{3}}$$

$$\Delta i_w = \sqrt{m\left(\frac{2}{\pi} - \frac{m}{2}\right)}I_{dc}$$

Control block of CSR with passive damping



LC + Trap Filter Design

❖ **Design the total capacitance** $\left(C_f + C_s\right) \le 0.1C_b$

❖ **Design of capacitor *Cs* and *Cf***

$$\Delta v = \frac{\Delta i_w}{(\omega C_s + \frac{\omega C_f}{1 - L_f C_f \omega^2} - \frac{1}{\omega L_s})} = \frac{\Delta i_w}{\left[\omega C_f (\lambda + \frac{1}{1 - L_f C_f \omega^2}) - \frac{1}{\omega L_s}\right]}$$

Define the value of λ

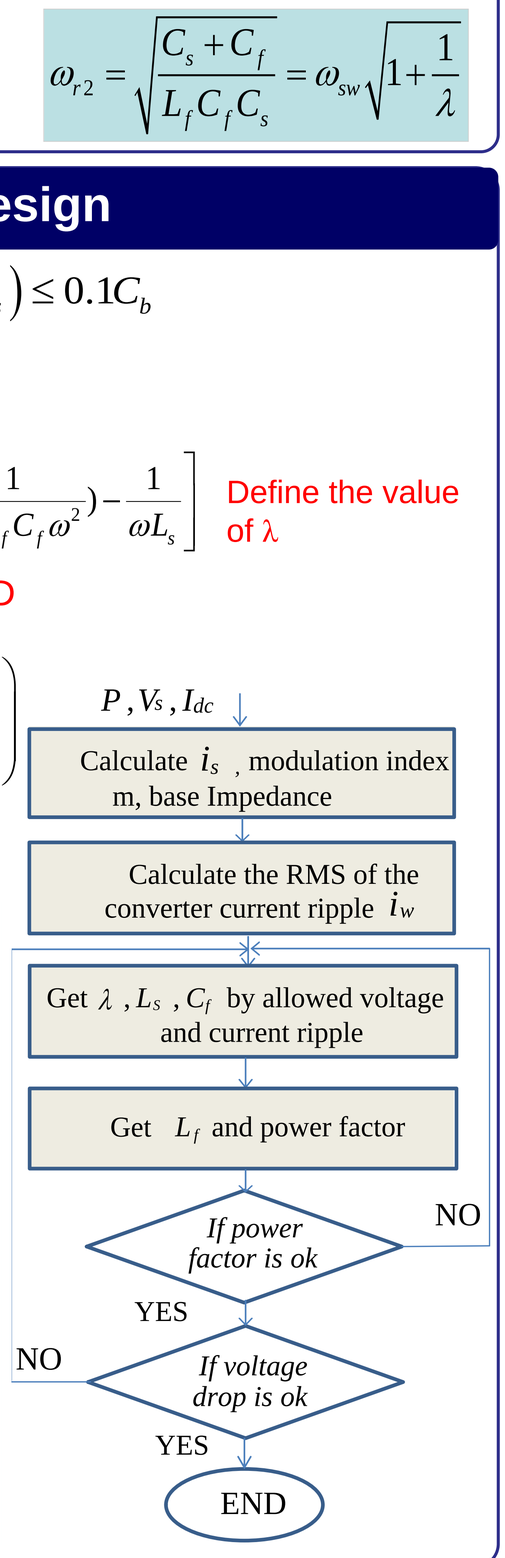
❖ **Design of inductor *Ls*** Grid current THD

$$\Delta i_s = \frac{\Delta i_w}{\left(\frac{1 - L_f C_f \omega^2}{1 - L_f C_f \omega^2 - L_s C_f \omega^2 - L_s C_s \left(1 - L_f C_f \omega^2\right)}\right)}$$

❖ **Design of resonant inductor L_f**

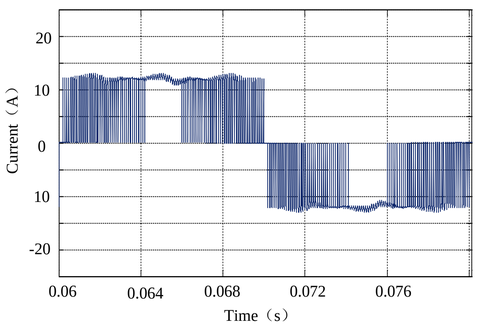
Parameters of the designed filter

Description	LC filter	LC + trap filter
Rated power	6 kVA	6 kVA
Grid line voltage	380 V	380 V
Grid frequency	50 Hz	50 Hz
Input filter inductance *Ls*	0.025 p.u.	0.025 p.u.
Switching frequency *fsw*	10000 Hz	10000 Hz
Trap circuit capacitor *Cf*	---	0.03 p.u.
Trap circuit inductor *Lf*	---	0.0008p.u.
Input filter capacitance *Cs*	0.06 p.u.	0.03 p.u.
DC link inductance *Ld*	0.06 p.u.	0.06 p.u.
DC load *Rd*	1 p.u.	1 p.u.

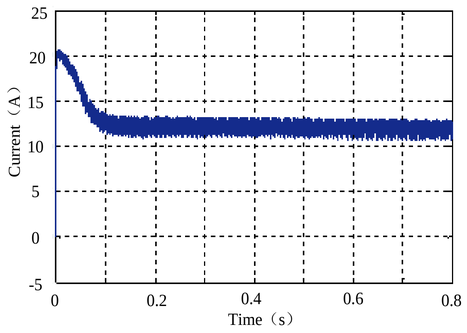


Simulation Verifications

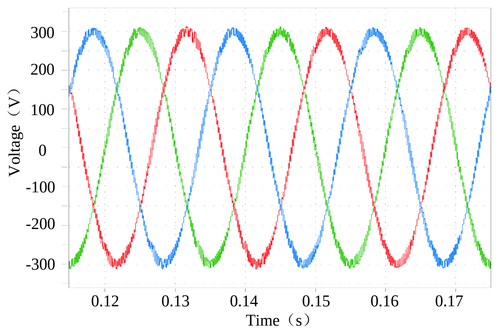
Rectifier-side current i_w



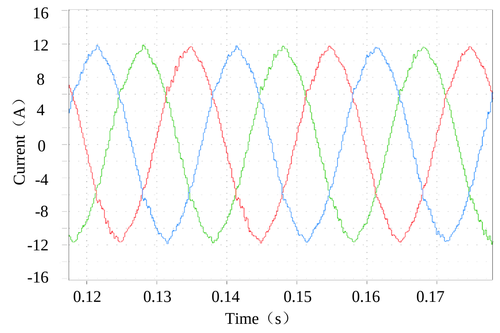
DC-link current i_{dc}



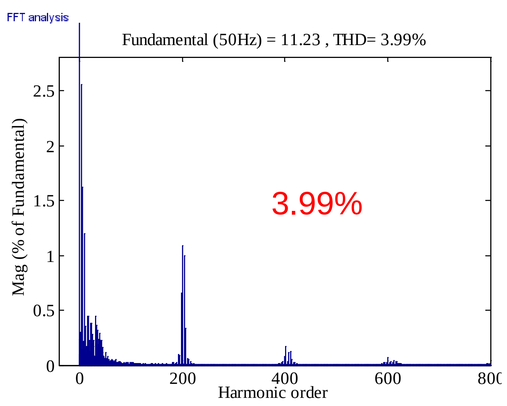
Phase voltage of the capacitor *Cs*



Grid current i_g



Grid current spectrum of *LC* filter



Grid current spectrum of *LC* + trap filter