1093 – Improved Passive Damped LCL Filter to Enhance Stability in Grid-Connected Voltage-Source Converters

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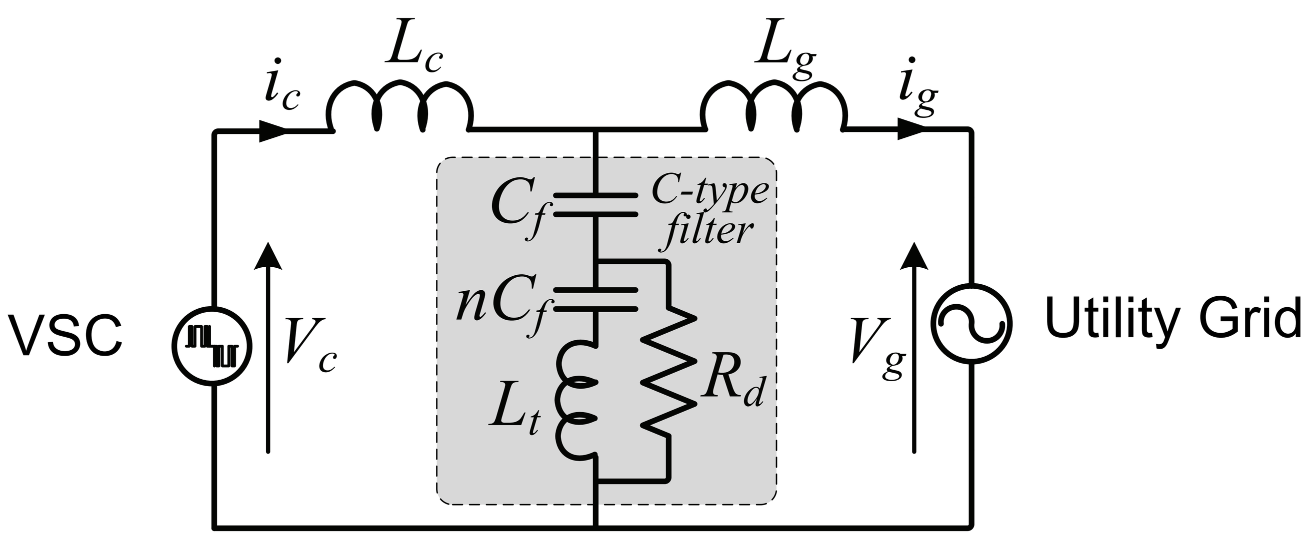
Problem

- **Bulky nature** of the **passive components** in VSC
- **Damping** the system resonances may requires additional passive components

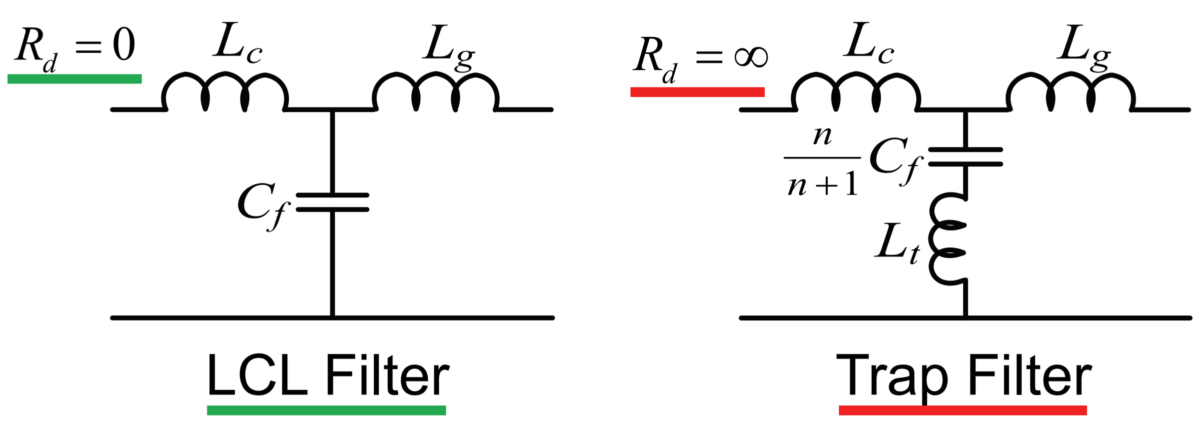
Solution

- ***C-type*** filter adopted to cancel VSC switching harmonics
- Provides benefits of the well known ***LCL*** or ***Trap*** filters

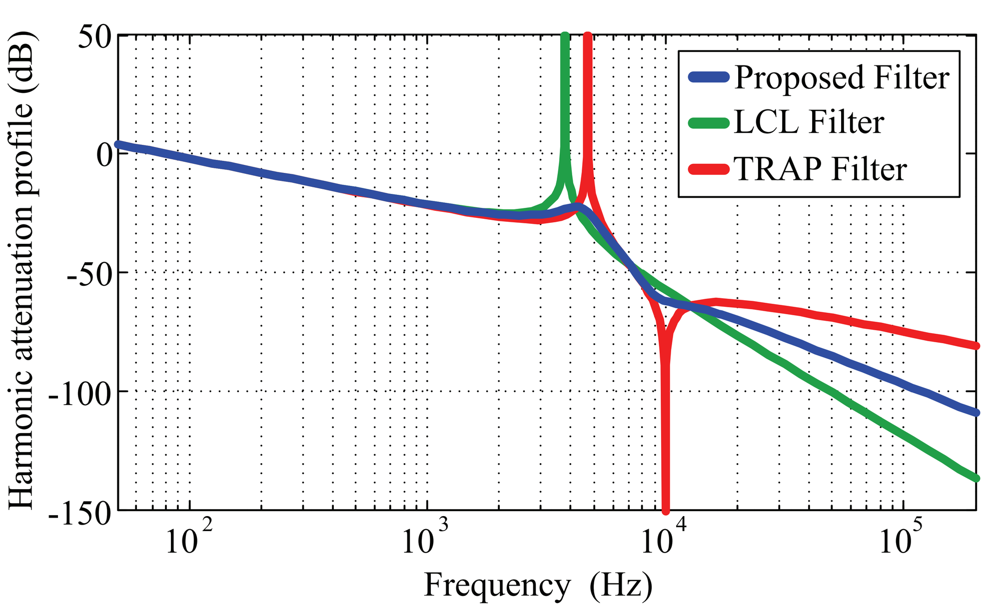


Design Method

$$Y_{gc} = \frac{i_g}{V_c}\bigg|_{V_g=0} = \frac{1}{s\left(L_c+L_g\right)}\,\frac{\frac{s^3}{\omega_0\omega_t^2 Q}+\frac{s^2}{\omega_t^2}+(n+1)\frac{s}{\omega_0 Q}+1}{\frac{s^4}{\omega_0^2\omega_t^2}+\left(\frac{n}{\omega_0^3}+\frac{1}{\omega_0\omega_t^2}\right)\frac{s^3}{Q}+\left(\frac{1}{\omega_0^2}+\frac{1}{\omega_t^2}\right)s^2+(n+1)\frac{s}{\omega_0 Q}+1}$$



Magnitude Of The Filter Attenuation Admittance



Design guidelines:

$$\omega_t = \frac{\omega_{sw}}{\sqrt{(n+1)}}$$

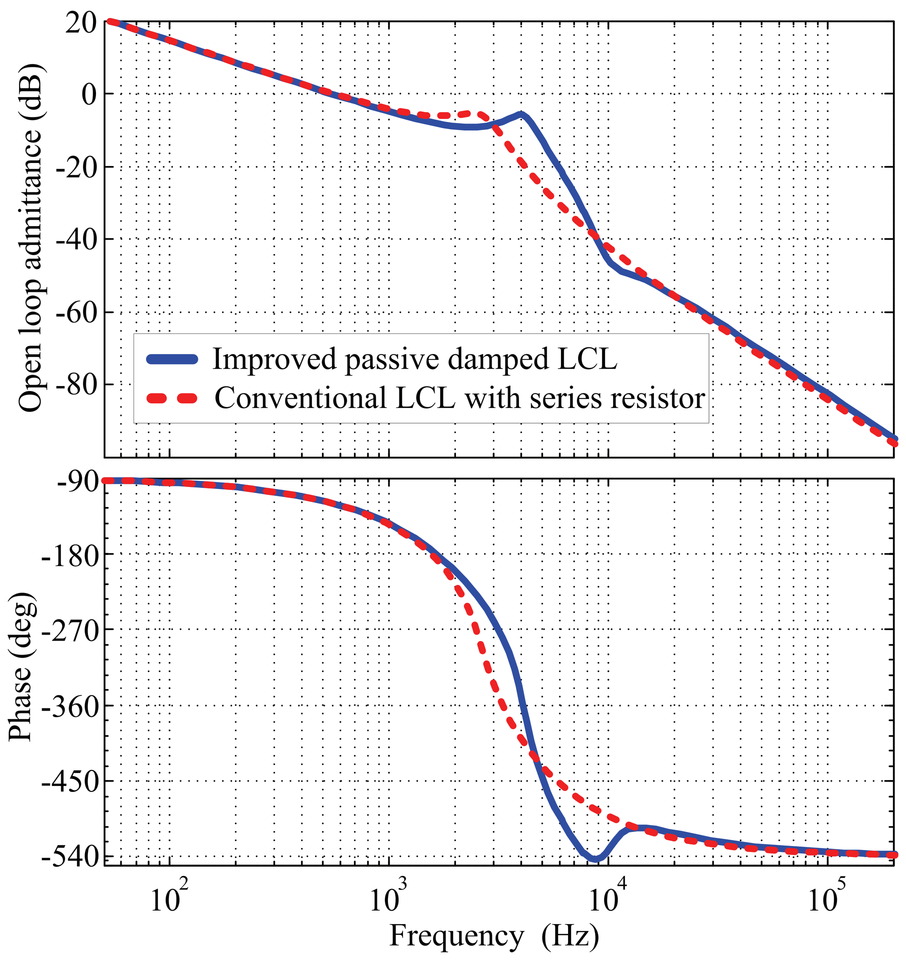
- in conventional C-type filter the tuned frequency is 50 Hz

$$\omega_{sw} = \sqrt{\frac{(n+1)}{nL_t C_f}}$$

$$Q = \frac{R_0}{R_d}$$

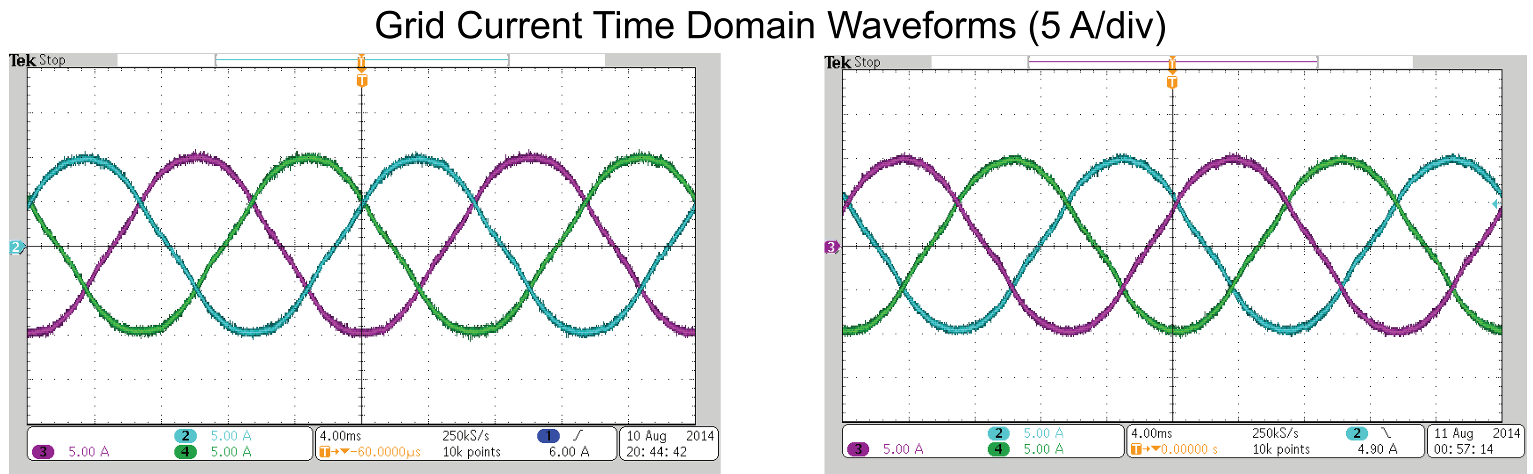
Results

Proposed Filters Open Loop Magnitude and PM

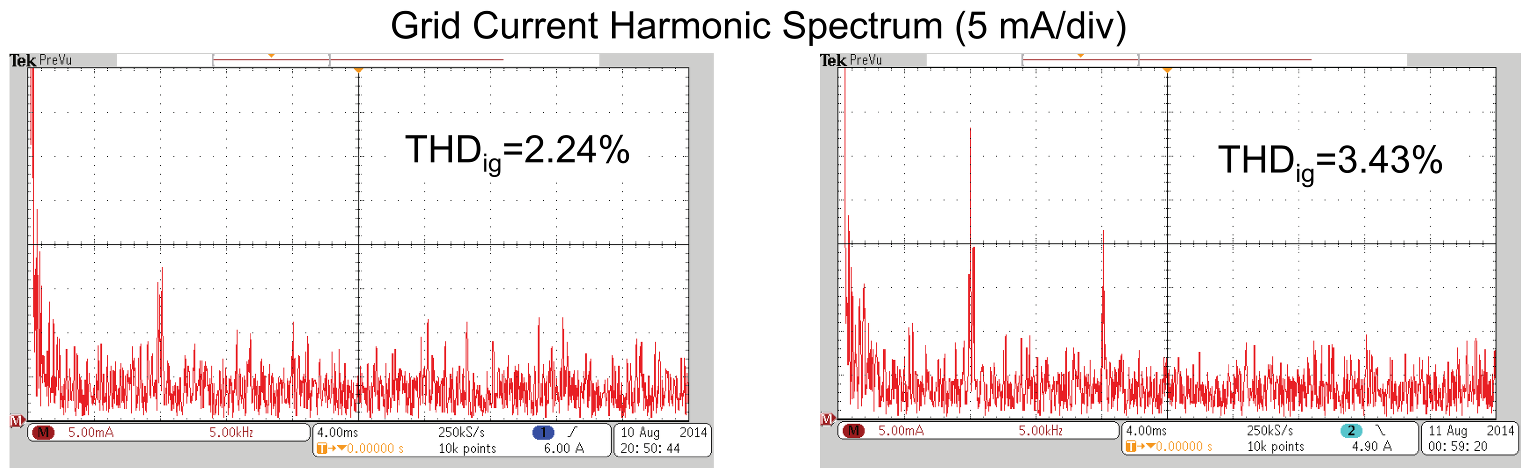


- if $\omega_t = 2\pi 50$ rad/s
  n is very large
  → low resonance damping
- high resonance damping
  $n \leq 1$
  → $\omega_t \approx \omega_{sw}$

Grid Current Time Domain Waveforms (5 A/div)



Grid Current Harmonic Spectrum (5 mA/div)



Conventional LCL Filter | **Improved** LCL Filter

Conclusions

- C-type filter adopted for VSC is more **efficient** than conventional passive damping methods
- It provides overall **lower ratings** of the passive components
- Because of more passive components it is more difficult to design and implement

Main differences between proposed filters

Filter topology	Grid side inductor		Damping Resistor		Tuned Inductor		Tuned Capacitor		Resonance Frequency	Damping Losses		Filter Efficiency
	Ap	mH	Wp	Ω	Ap	mH	Vp	μF	kHz	Sim. (%)	Exp. (%)	Exp. (%)
LCL	21	1.5	85	5.6	-	-	-	-	1/4 f_{sw}	0.2	0.12	98.89
Improved LCL	21	0.5	18	3.3	2.3	0.084	9	4.7	2/5 f_{sw}	0.06	0.04	99.06