

# State Current Controller with Oscillatory Terms for Three-level Grid-connected PWM rectifiers under Distorted Grid Voltage Conditions

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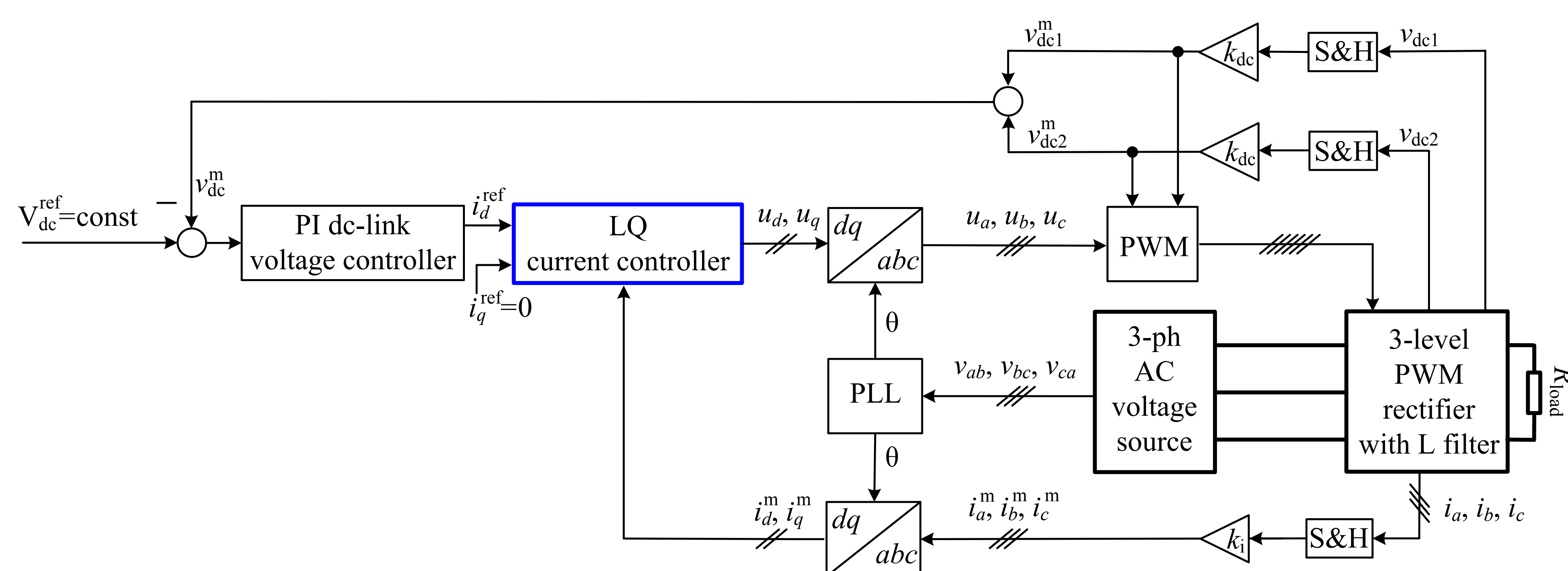
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## Objectives

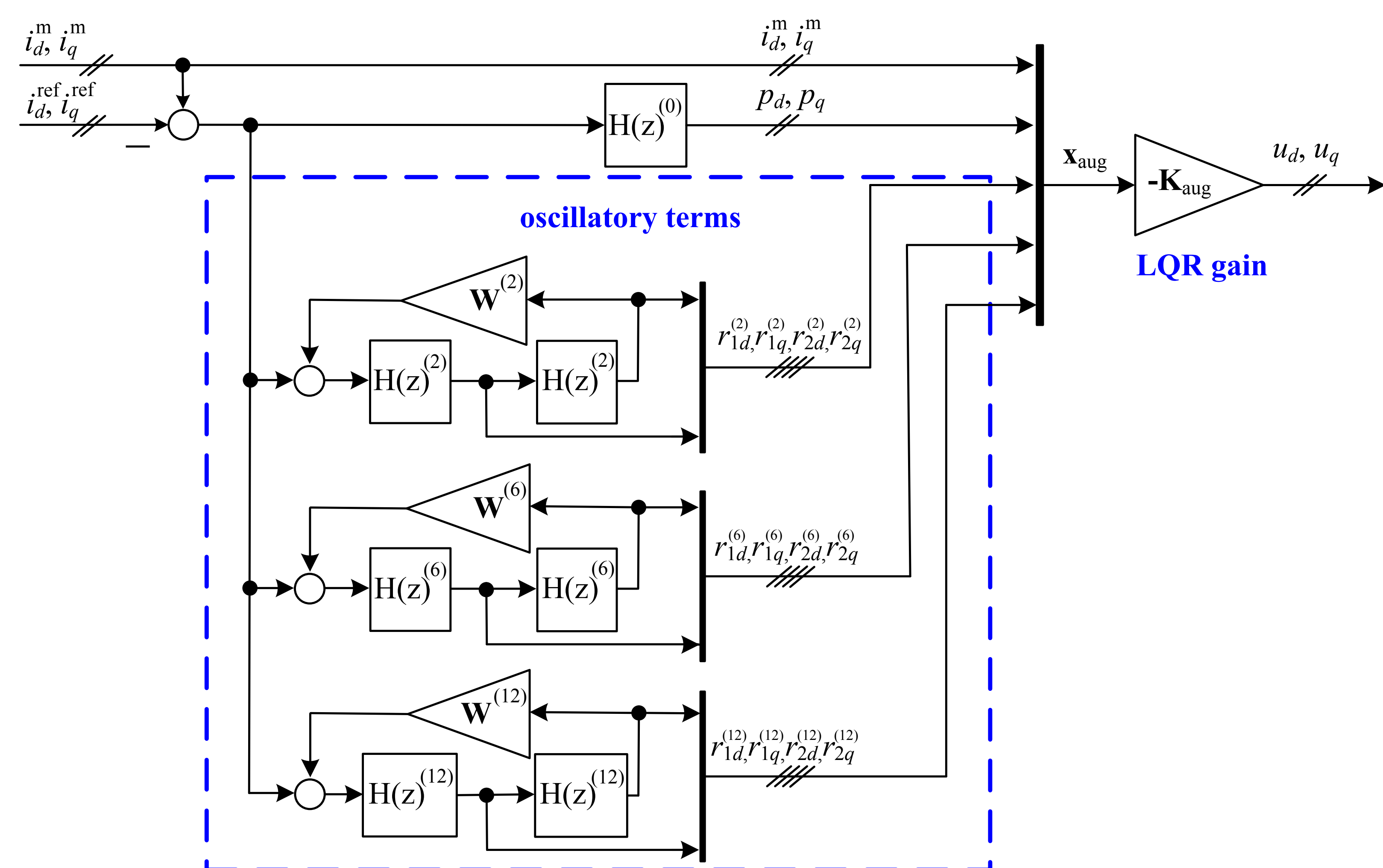
Development of a control method based on a linear-quadratic (LQ) current controller which enables a three-phase grid-connected converter to:

- draw balanced input currents from a balanced/unbalanced voltage source,
- shape near sinusoidal inputs currents in the presence of a distorted voltage source.

## PWM rectifier control strategy

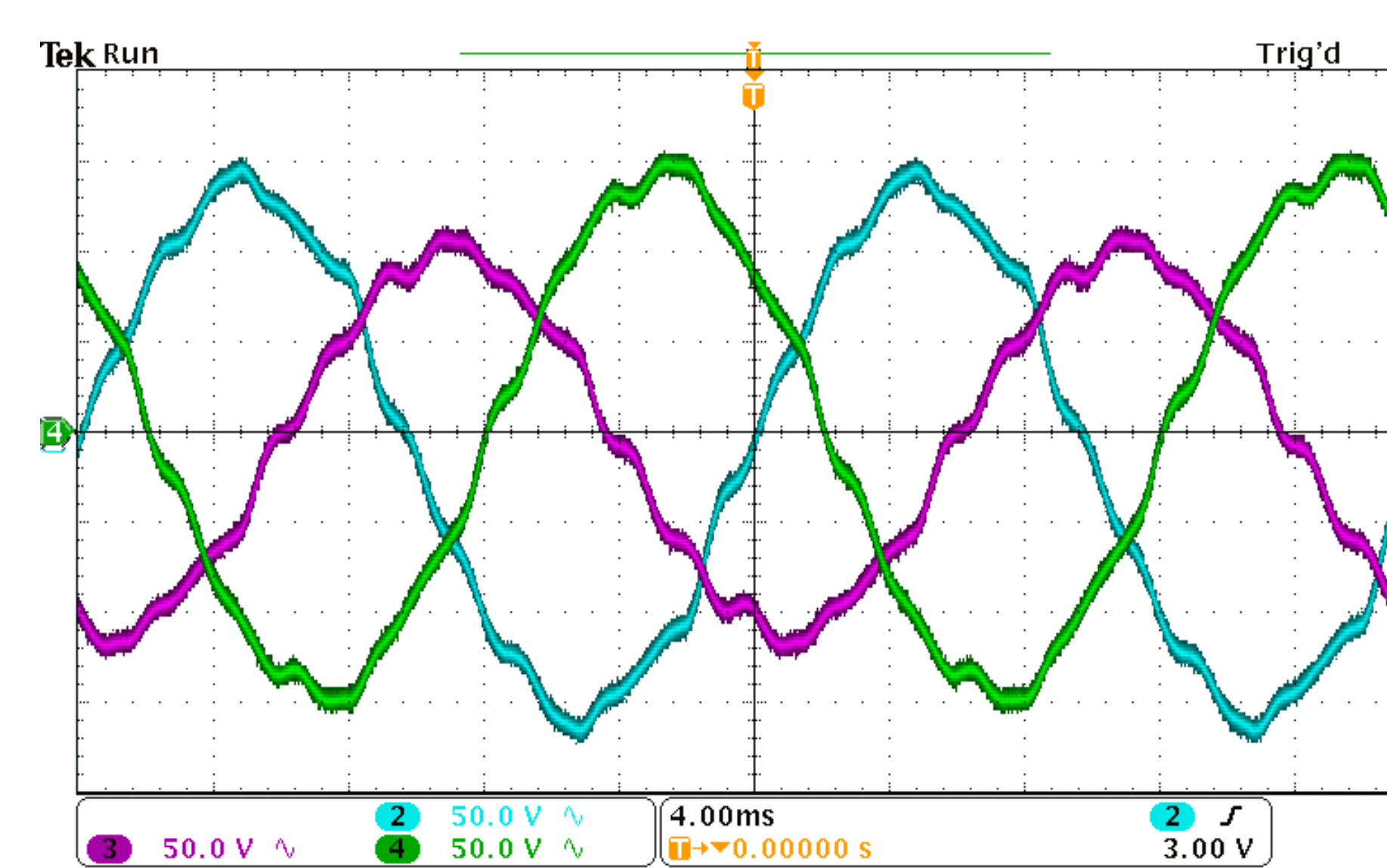


## LQ current controller with integral and oscillatory terms



- Selective harmonic compensation:  $\mathbf{W}^{(h)} = -\text{diag}([(h\omega)^2, (h\omega)^2])$ , where  $h = \{2, 6, 12\}$  – harmonic order
- Tustin approximation with frequency prewarping:  $H(z)^{(h)} = \frac{h\omega_s}{\tan(\frac{h\omega_s T_s}{2})} \frac{z-1}{z+1}$ ,  $H(z)^{(0)} = \frac{2}{T_s} \frac{z-1}{z+1}$

## Experimental results



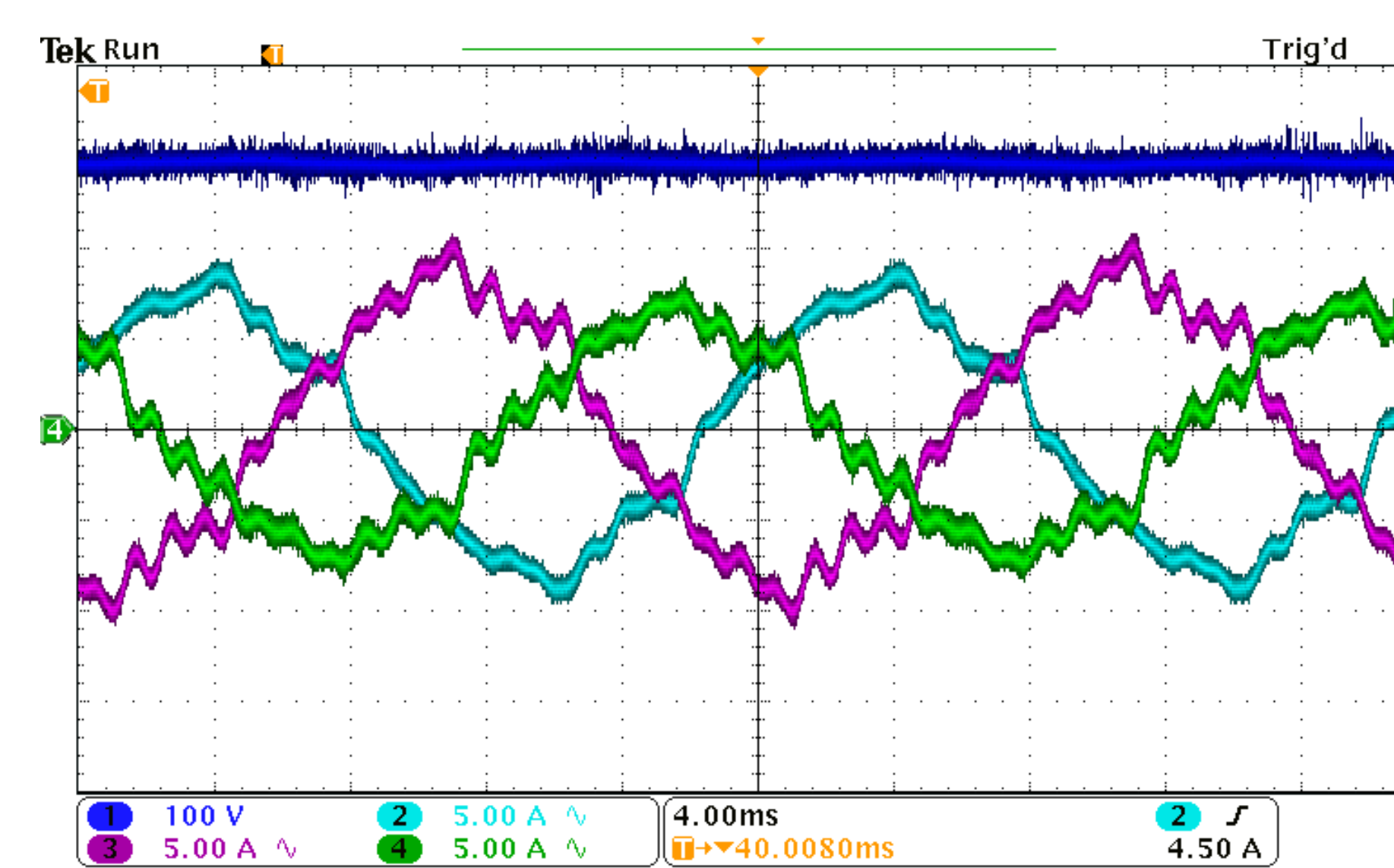
Distorted and unbalanced phase voltages

$v_a$  (ch. 2),  $v_b$  (ch. 3),  $v_c$  (ch. 4).

$\text{RMS}_v^a = 104 \text{ V}$ ,  $\text{RMS}_v^b = 75 \text{ V}$ ,  $\text{RMS}_v^c = 102 \text{ V}$

$\text{THD}_v^a = 6.1\%$ ,  $\text{THD}_v^b = 7.2\%$ ,  $\text{THD}_v^c = 5.3\%$

### Case A:

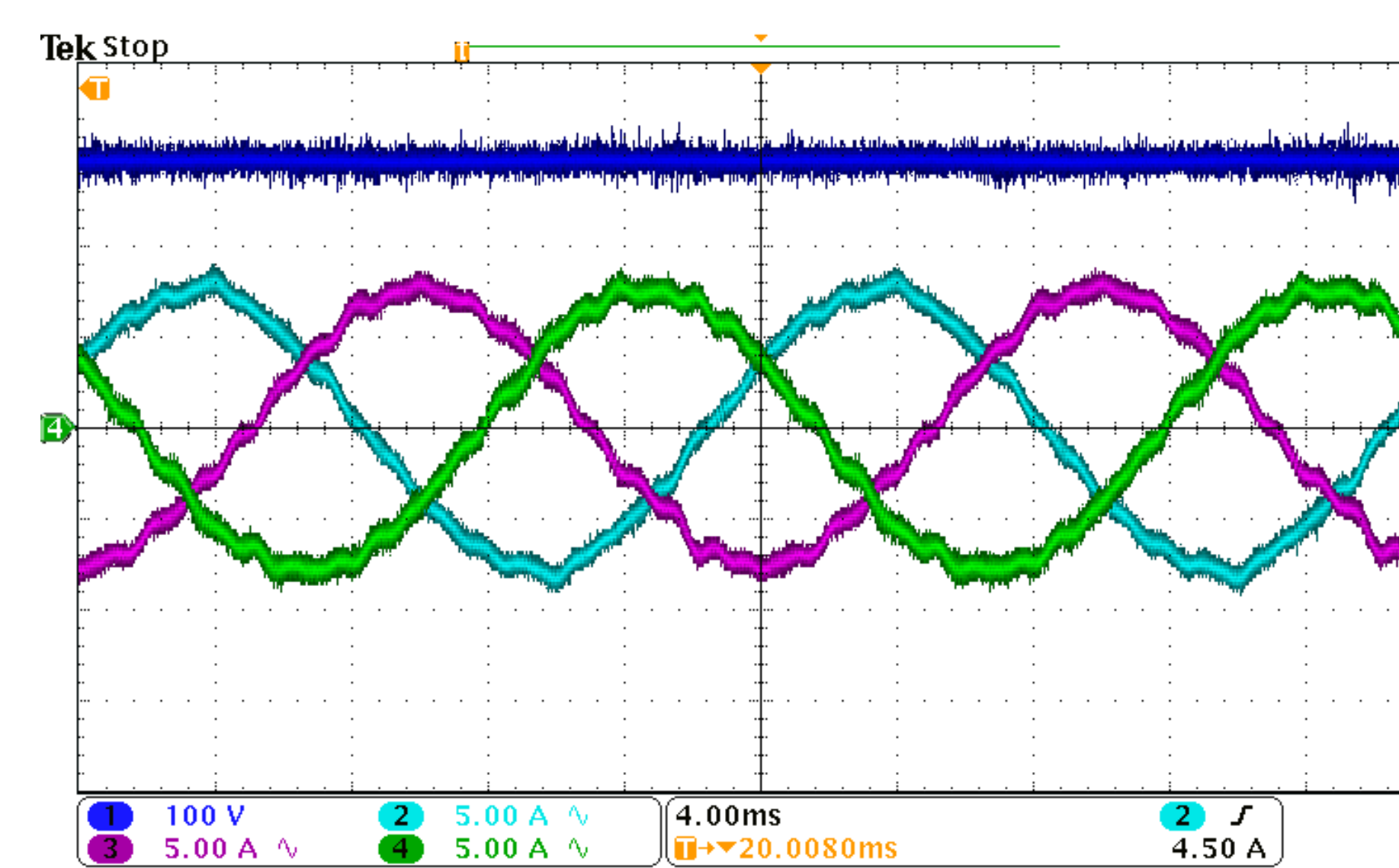


DC-link voltage  $v_{dc}$  (ch. 1) and grid currents  $i_a$  (ch. 2),  $i_b$  (ch. 3),  $i_c$  (ch. 4) – **the LQ current controller without oscillatory terms.**

$\text{RMS}_i^a = 5.5 \text{ A}$ ,  $\text{RMS}_i^b = 6.0 \text{ A}$ ,  $\text{RMS}_i^c = 4.7 \text{ A}$

$\text{THD}_i^a = 11.2\%$ ,  $\text{THD}_i^b = 13.2\%$ ,  $\text{THD}_i^c = 14.8\%$

### Case B:



DC-link voltage  $v_{dc}$  (ch. 1) and grid currents  $i_a$  (ch. 2),  $i_b$  (ch. 3),  $i_c$  (ch. 4) – **the LQ current controller with oscillatory terms.**

$\text{RMS}_i^a = 5.4 \text{ A}$ ,  $\text{RMS}_i^b = 5.3 \text{ A}$ ,  $\text{RMS}_i^c = 5.5 \text{ A}$

$\text{THD}_i^a = 5.5\%$ ,  $\text{THD}_i^b = 6.1\%$ ,  $\text{THD}_i^c = 6.3\%$

Symbol	Value	Description
$V_{dc}$	300 V	Nominal DC-link voltage
$V$	185 V	Nominal grid voltage RMS value
$\omega$	$100\pi \frac{1}{s}$	Nominal pulsation of the grid voltage
$L$	2.0 mH	Inductances of the input filter
$R_{load}$	66 $\Omega$	Resistances of the load
$F_s$	10 kHz	Switching/sampling frequency

## Summary

An LQ current controller in the synchronous reference frame has been designed for PWM rectifier operated under distorted grid voltage conditions. Two current control strategies are verified in the experiment:

- In the **case A**, the presented state regulator without the oscillatory terms is applied, wherein the obtained currents are polluted by higher order harmonics.
- In the **case B**, six oscillatory terms are incorporated to ensure balanced currents and reduce the components of the pulsations  $5\omega, 7\omega, 11\omega$  and  $13\omega$  (the most influential low-order voltage harmonics) in the current represented in the natural coordinates. The converter current THDs have decreased twofold. The currents are balanced as it is apparent from RMS of the 1st harmonic.

## Numerical model

The exemplary numerical model is available at MATLAB Central as “LQ current controller with oscillatory terms”.

## Contact Information

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## Invitation

