Real-Time Laboratory Implementation Results of an Active Filter

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The 9th International Conference on Environment and Electrical Engineering (EEEIC)

Prague, Czech Republic, May 16 – 19, 2010

Summary:

- ✓ Introduction
- ✓ Instantaneous active and reactive powers theory
- ✓ Equipments used for the laboratory tests
- ✓ Real-time results of the power hardware in the loop (PHIL)
- ✓ Conclusion

Introduction:

- Proliferation of power electronics converters and electronic equipments has dramatically increased electric pollution in electrical distribution power systems.
  - ✓Active filters (capable of injecting distorted currents in order to cancel harmonics coming from non-linear loads)
- Consequently, many theories have been developed to control active filters.
  - ✓Instantaneous power (*p-q theory*), an overview of the instantaneous compensation theory will be presented.
- To illustrate the effectiveness of such compensation an HIL system is realized in laboratory.
  - ✓PHIL system with a real-time Opal-RT simulator.
- The analysis of the real-time results to proven the instantaneous compensation of the controller.

Instantaneous active and reactive powers:

$$v = \begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} \quad , i = \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$p_{3\varphi} = \vec{v} \cdot \vec{i} = v_{an} i_a + v_{bn} i_b + v_{cn} i_c$$

$$= v_\alpha i_\alpha + v_\beta i_\beta + v_0 i_0 = p + p_0$$

$$i_{\alpha\beta 0} = \begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \underbrace{\sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix}}_{C} \times \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$\vec{q} \triangleq \vec{v} \times \vec{i} \qquad q = v_\beta i_\alpha - v_\alpha i_\beta$$

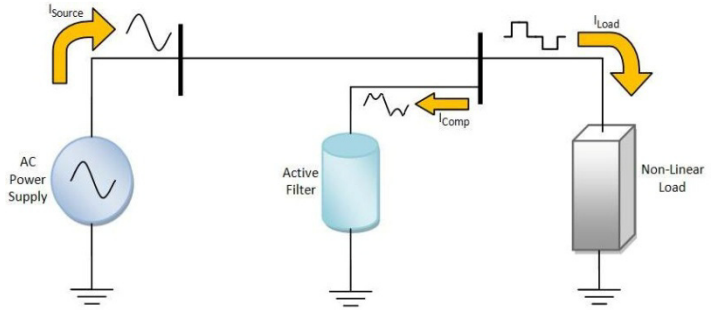
Instantaneous powers are divided into an average value and an oscillating portion:

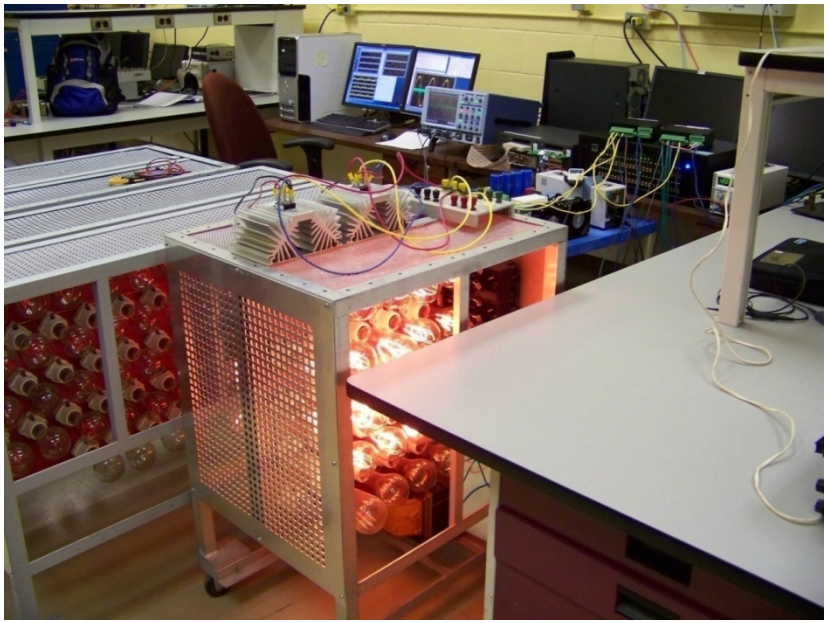
$$p = \bar{p} + \tilde{p} \qquad p_0 = \bar{p}_0 + \tilde{p}_0$$

$$q = \bar{q} + \tilde{q}$$

Where "·" is the internal product of vectors and "×" denotes the exterior product of vectors

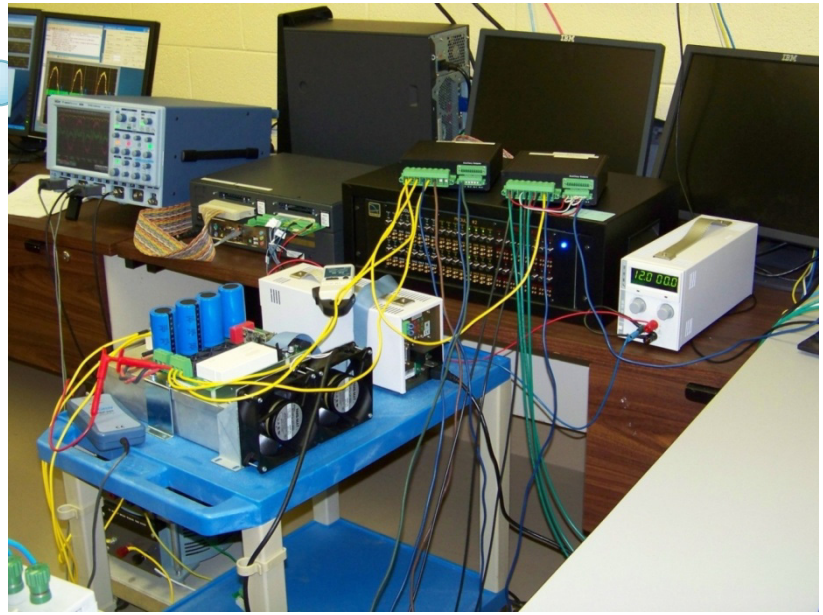
Equipments:





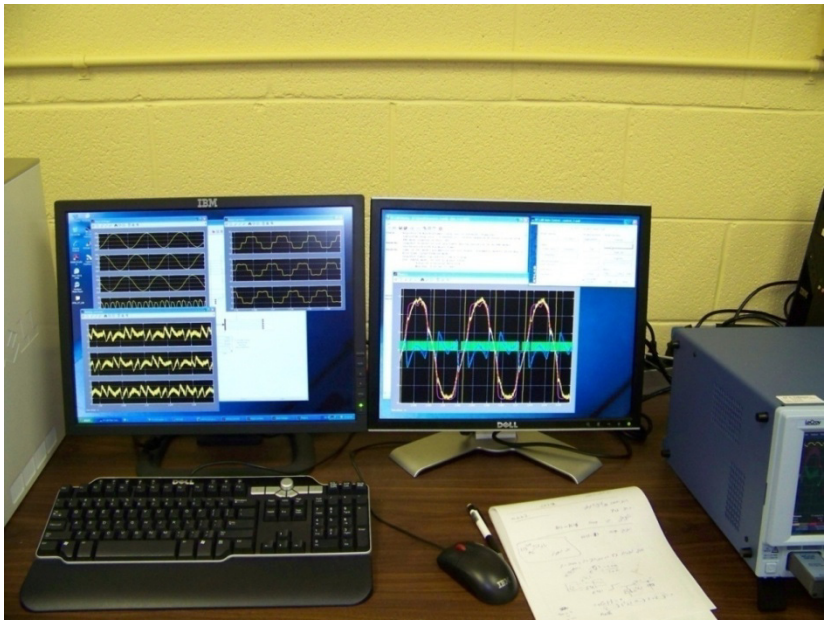
Non-linear load

Equipments:



Real-time Simulator
Probes
Patch panel
Three phase power Inverter

RT-Lab Interface



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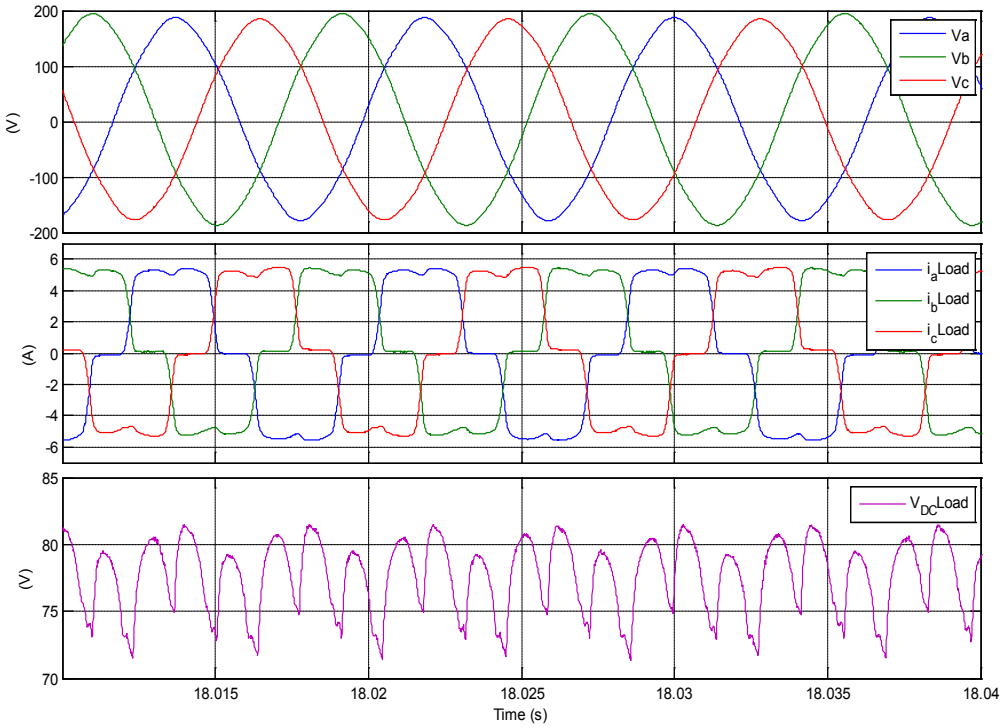
Real-time results of the PHIL:

- *Instantaneous non-active power compensation*

  Instantaneous voltages and currents:



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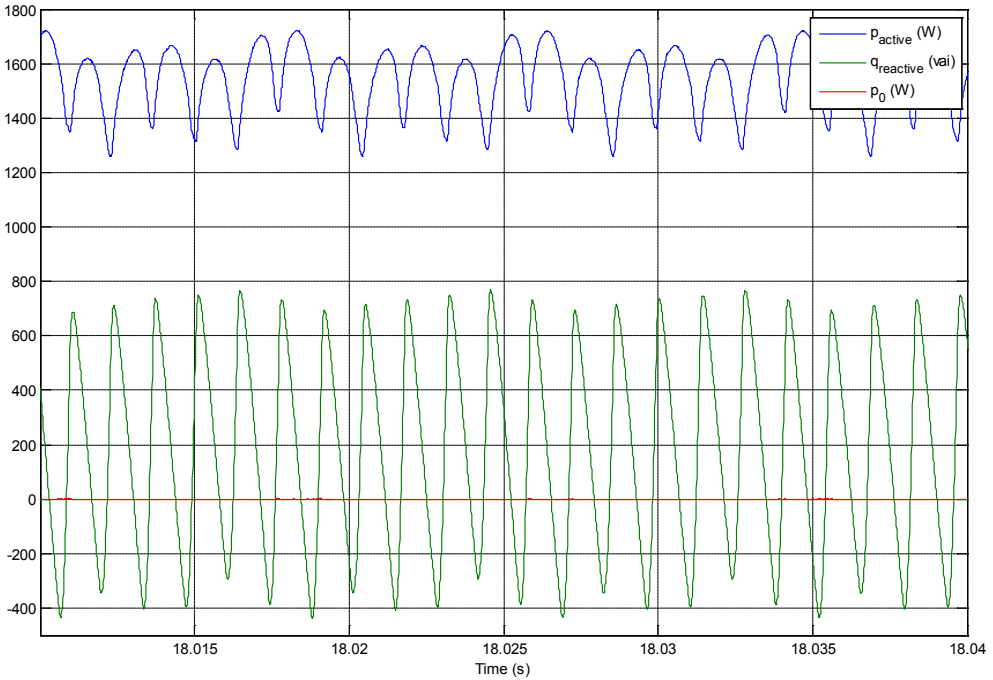
Real-time results of the PHIL:

- *Instantaneous non-active power compensation*

  Instantaneous active, reactive, and zero-sequence powers:



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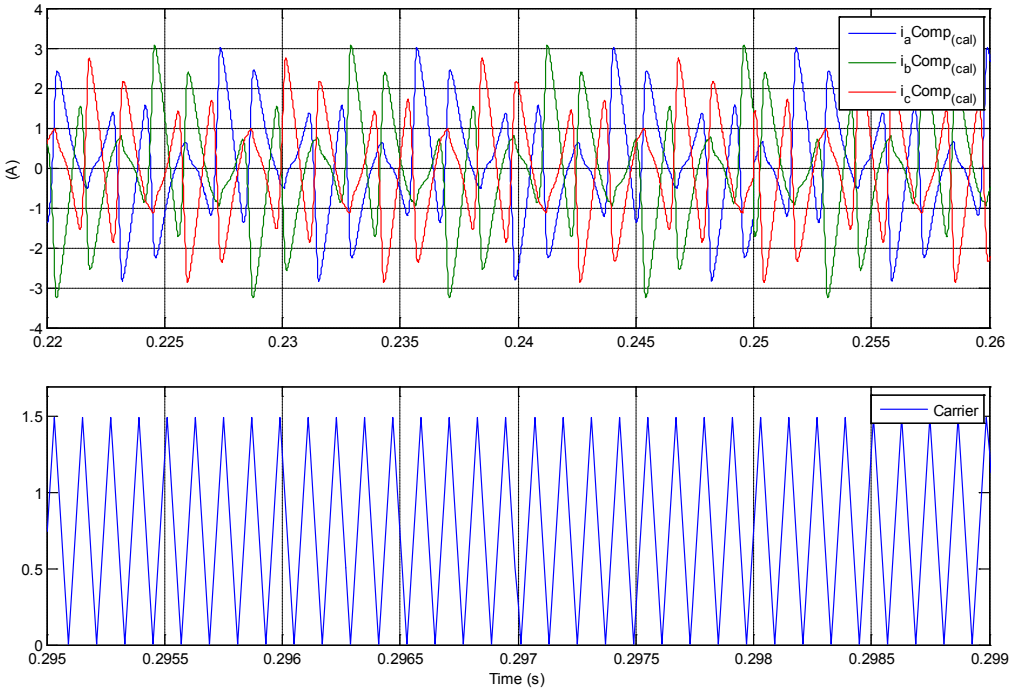
Real-time results of the PHIL:

- *Instantaneous non-active power compensation*

  Instantaneous calculated compensating currents, carrier (8.33 kHz):



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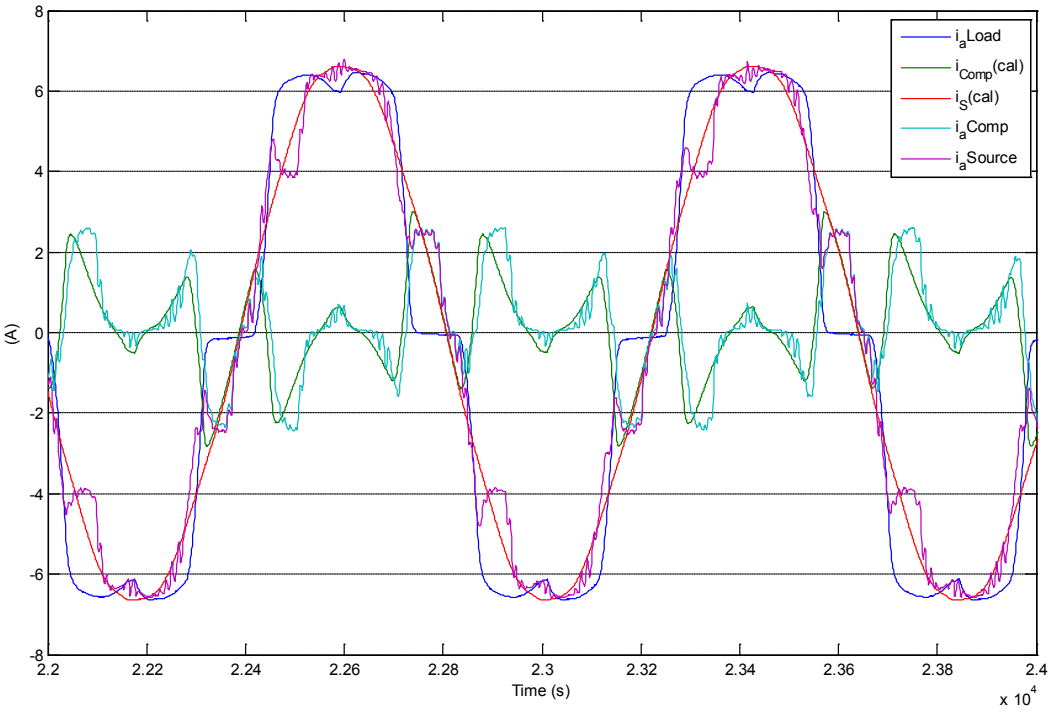
Real-time results of the PHIL:

- *Instantaneous non-active power compensation*

  Instantaneous load, source, compensating, and calculated currents:



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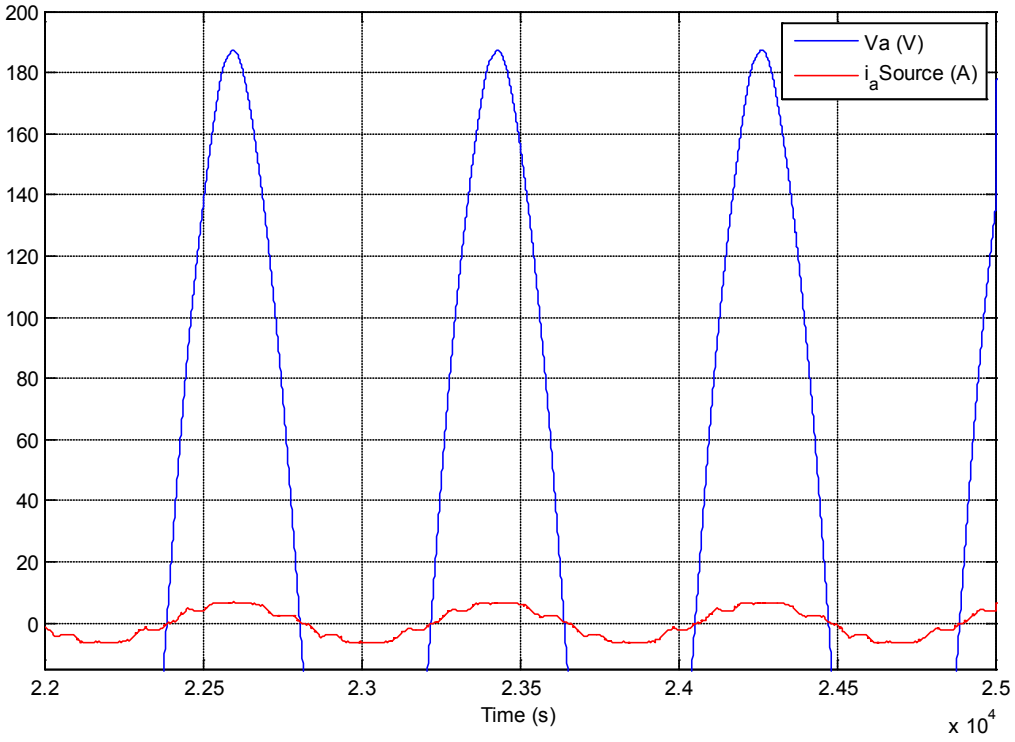
Real-time results of the PHIL:

- *Instantaneous non-active power compensation*

  First phase (“a”) source voltage and current after compensation :



Conclusion:

- ✓ This paper describes active filters built around a commercial inverter.
- ✓ The Opal-RT real-time simulator was used to implement a real-time controller based on the *p-q* theory to have a powers Hardware in the loop system (PHIL).
- ✓ Data were acquisitioned instantaneously and results were analyzed.
- ✓ Despite the use of a PWM in this paper, currents produced by the inverter have had exactly the same shape as the calculated compensating currents.
- ✓ By means of the real-time test, the powerfulness of active filters based on the instantaneous theory was illustrated, as well as the capabilities of the real-time simulator was demonstrated.

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Thank you

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