Advanced Control of Microgrids

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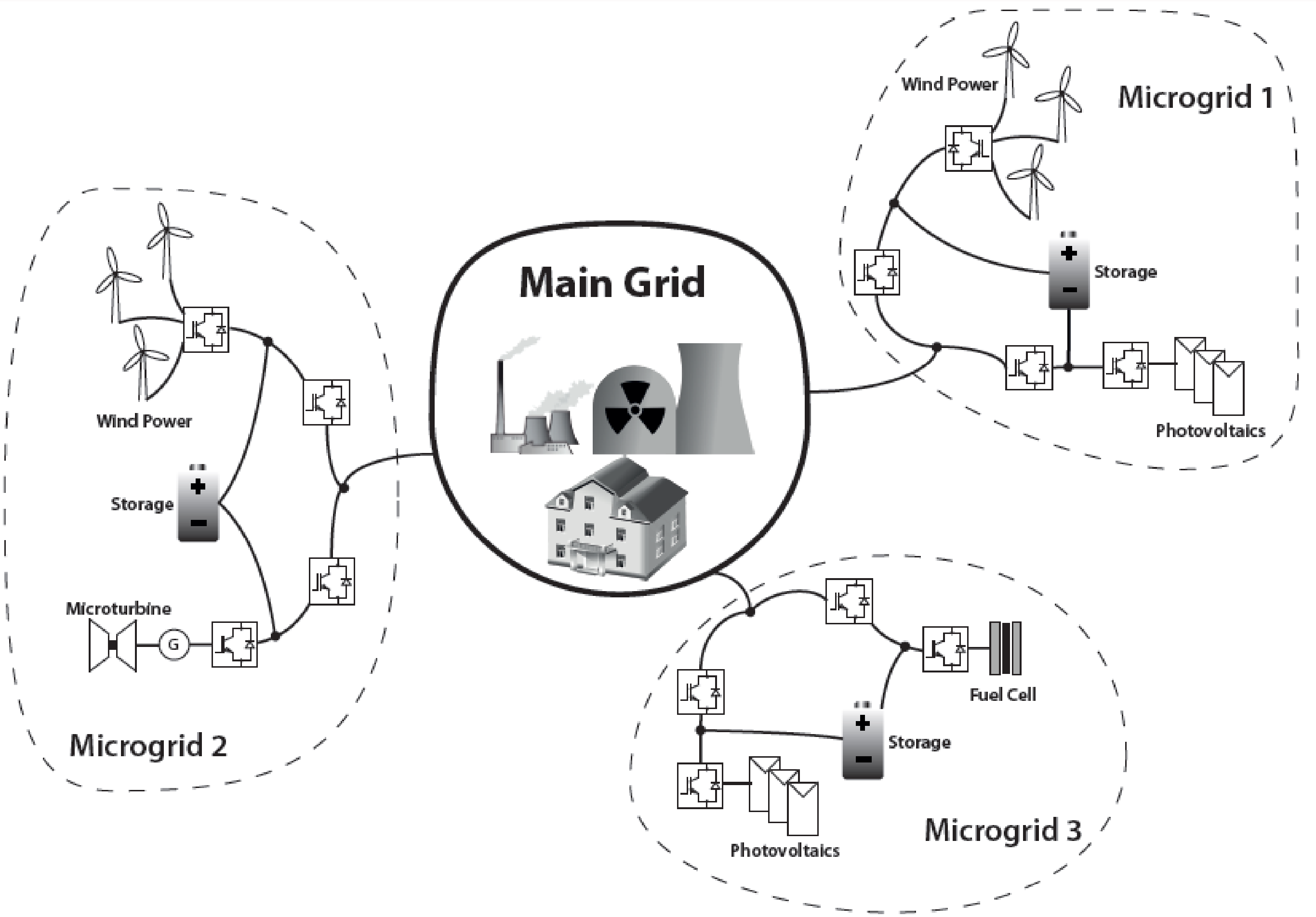
This presentation is a summary of the following paper:

- B.Bahrani , M. Saeedifard, A. Karimi, A.Rufer, “A Multivariable Design Methodology for Voltage Control of a Single-DG-Unit Microgrid,” accepted for publication in the IEEE Trans. on Industrial Electronics.

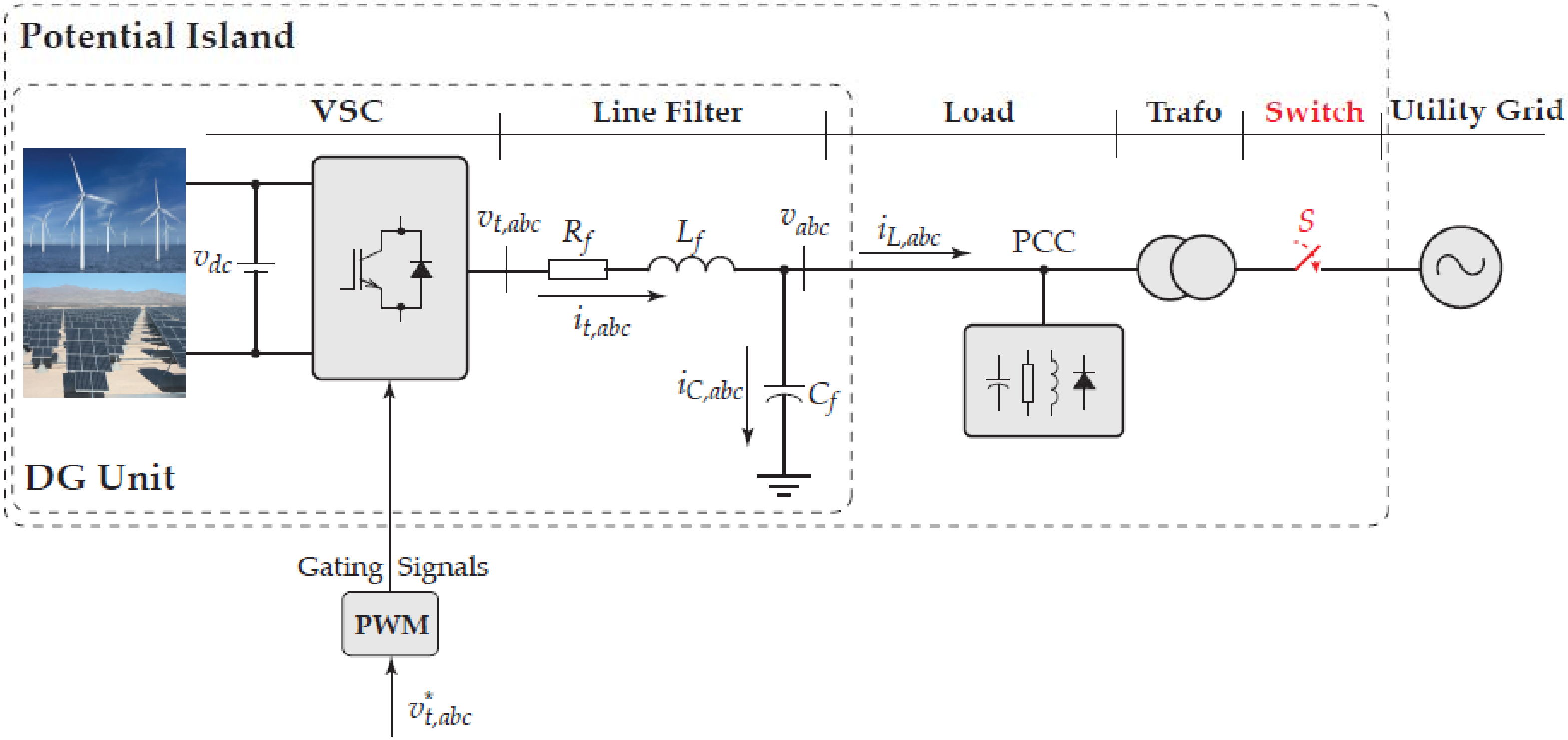
Outline

- Introduction
- Statement of the Problem
- The Proposed Multivariable Controller
- Experimental Results
- Conclusions

Introduction



Introduction



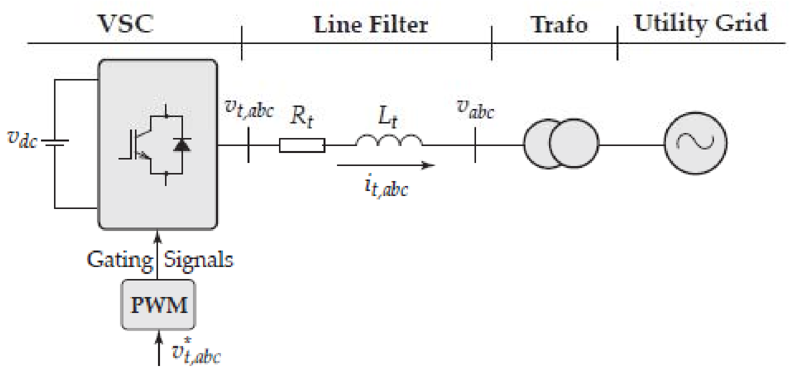
Introduction

- To design controllers, the model of the to-be-controlled system is essential.

Parametric Models

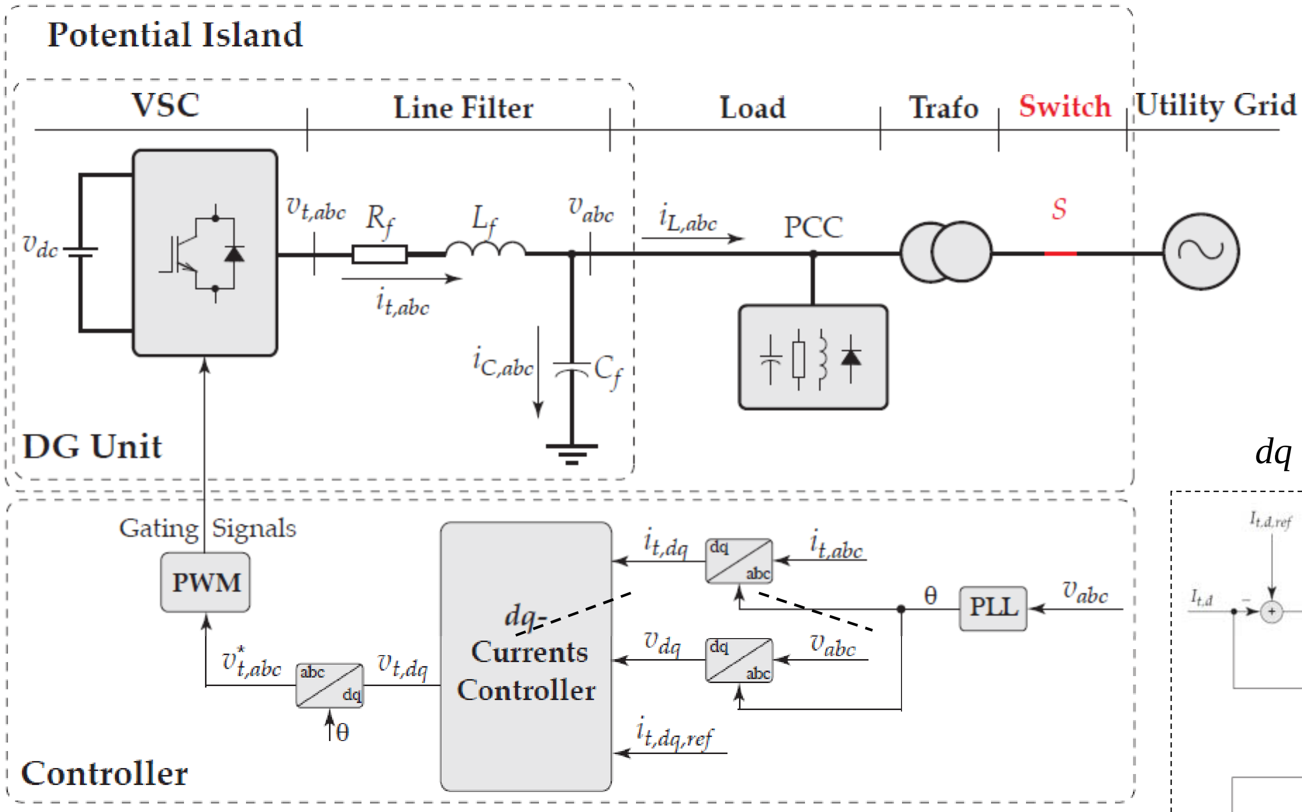
Unable to precisely reflect system dynamics

Subject to measurement errors

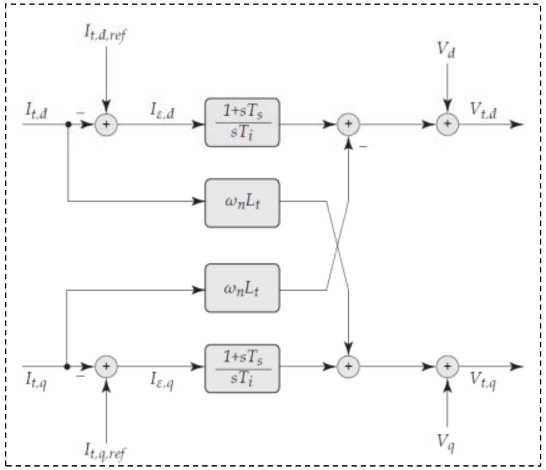


Introduction

- Current Control of a Grid-connected Microgrid

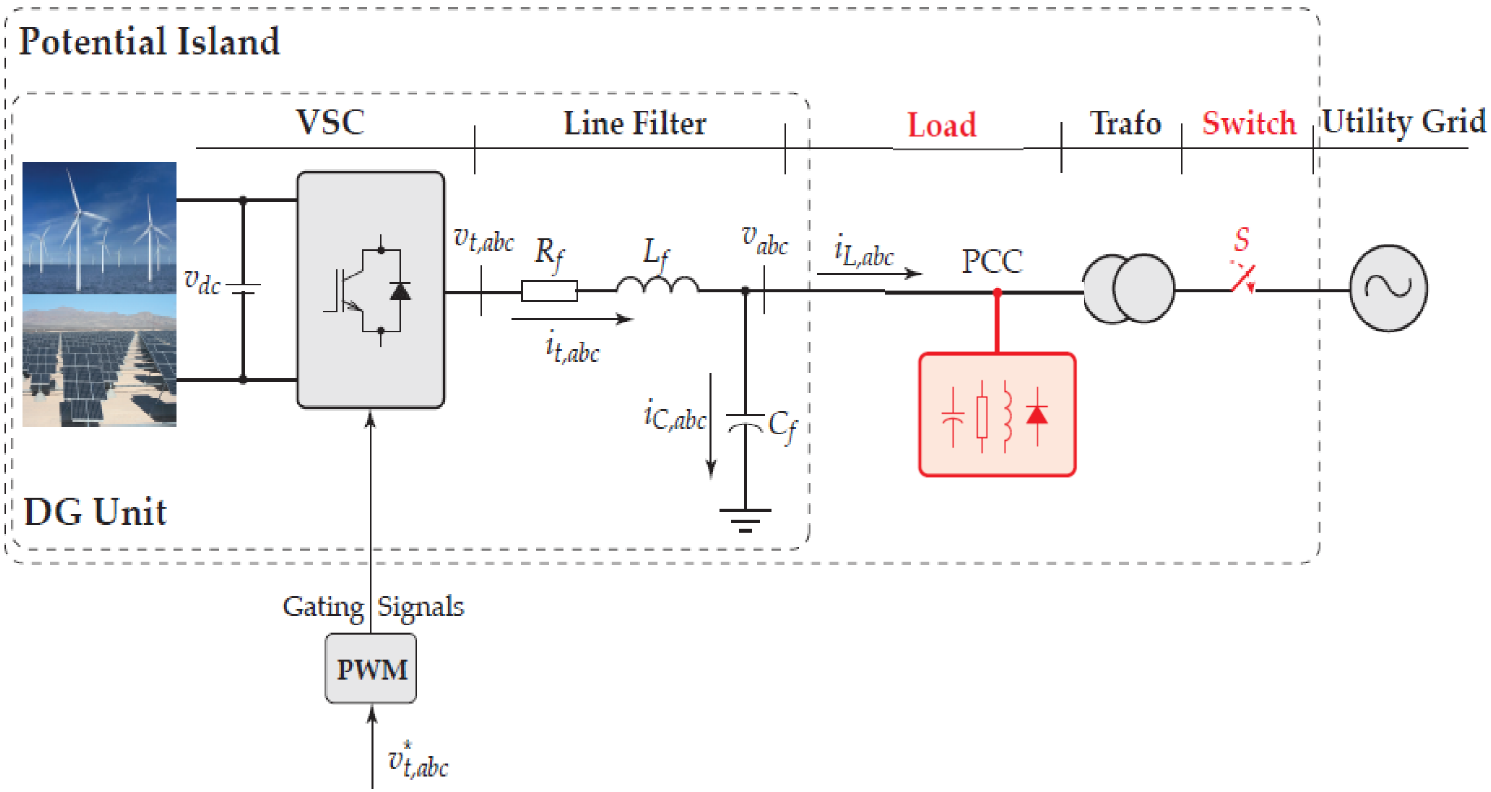


dq Current Controllers



Statement of the Problem

- Robustness issues to uncertainties in the load parameters
- Distortion of the load voltage in presence of harmonically polluted loads



The Proposed Multivariable Controller

- The proposed design approach, initially proposed in [1], relies on shaping the open-loop and closed-loop transfer functions of the system through convex optimization.

- The design procedure consists of three steps:

  Step 1. Determination of the (family of) spectral or nonparametric model(s) of the system

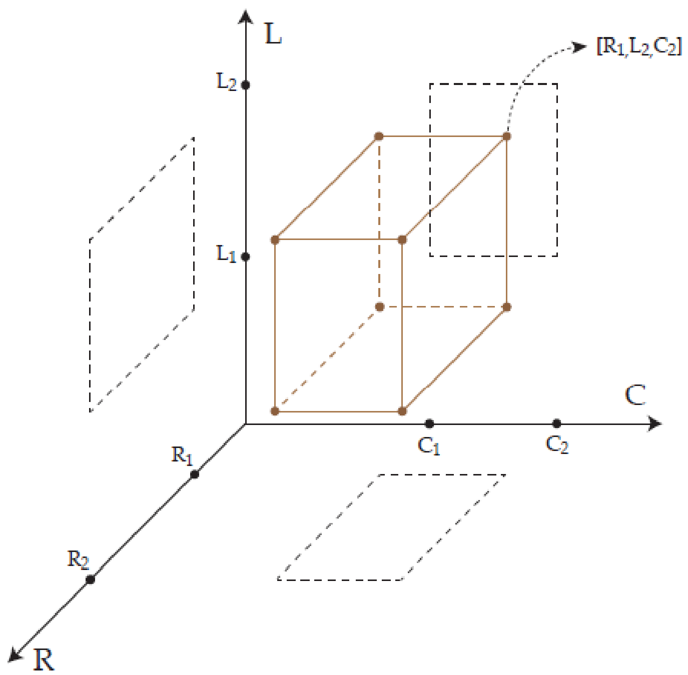
  Step 2. Determination of the controller class

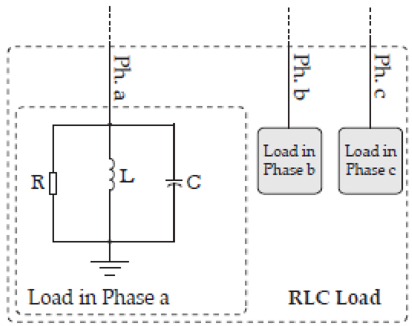
  Step 3. Determination of the controller coefficients

[1] - A. Karimi and G. Galdos, "Fixed-order H1 Controller Design for Nonparametric Models by Convex Optimization,“ Automatica, vol. 46, num. 8, 2010.

The Proposed Multivariable Controller

Step 1. Determination of the (family of) spectral or nonparametric model(s) of the system





$6\Omega < R < 600\Omega$

$25mH < L < 50mH$

$200\mu F < C < 400\mu F$

The Proposed Multivariable Controller

Step 1. Determination of the (family of) spectral or nonparametric model(s) of the system

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \underbrace{\begin{bmatrix} G_{i,11} & G_{i,12} \\ G_{i,21} & G_{i,22} \end{bmatrix}}_{\mathbf{G_i}} \begin{bmatrix} V_{t,d} \\ V_{t,q} \end{bmatrix}$$

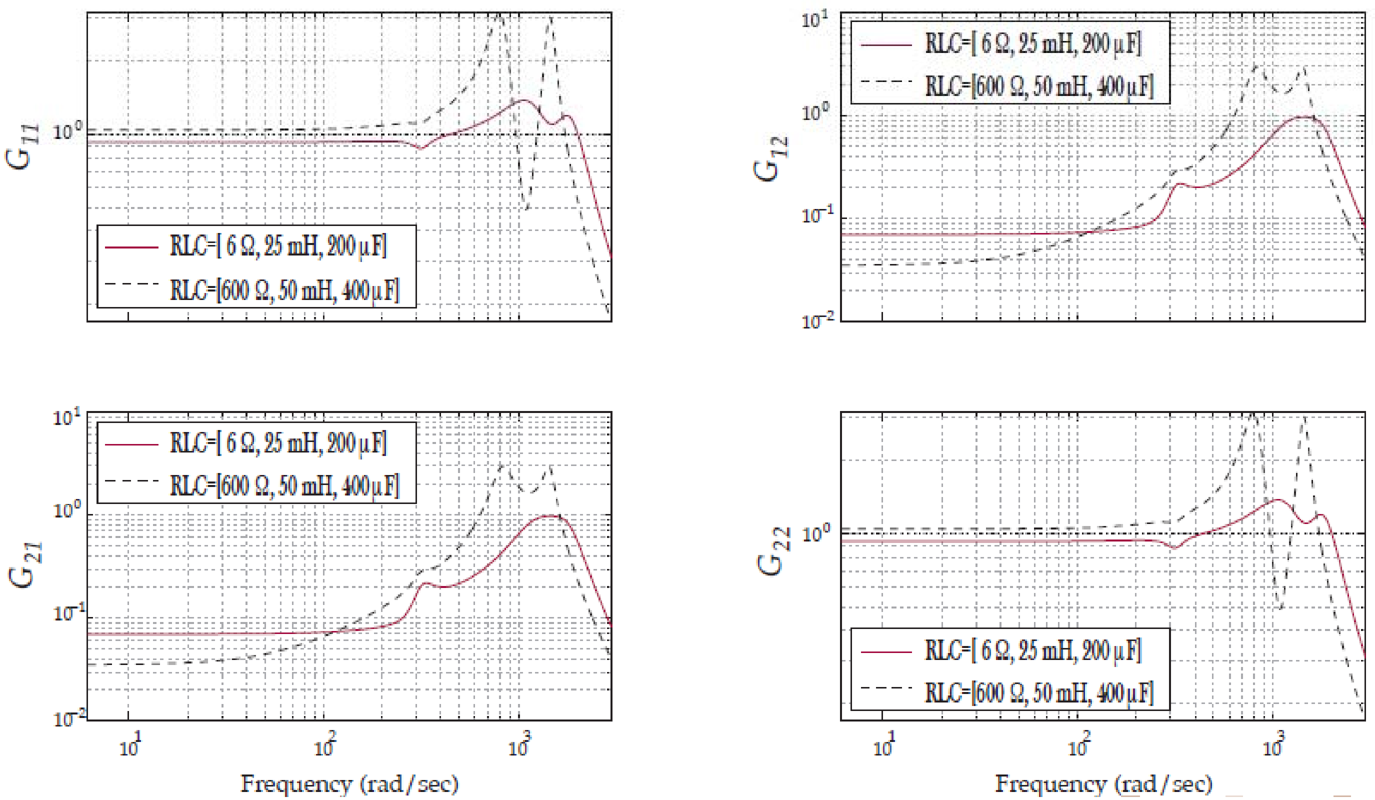
$$G_{i,11}(j\omega) = \frac{\mathscr{F}(v_d)}{\mathscr{F}(v_{t,d})} \quad \text{and} \quad G_{i,21}(j\omega) = \frac{\mathscr{F}(v_q)}{\mathscr{F}(v_{t,d})}$$

$$G_{i,12}(j\omega) = \frac{\mathscr{F}(v_d)}{\mathscr{F}(v_{t,q})} \quad \text{and} \quad G_{i,22}(j\omega) = \frac{\mathscr{F}(v_q)}{\mathscr{F}(v_{t,q})}$$

$$\mathscr{G} = \{\mathbf{G_i}(j\omega); i = 1, ..., 8; \forall \omega \in \mathbb{R}\}$$

The Proposed Multivariable Controller

Step 1. Determination of the (family of) spectral or nonparametric model(s) of the system



The Proposed Multivariable Controller

Step 2. Determination of the class of the controller

$$\mathbf{K}(z,\rho) = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}, \text{and therefore, } \mathbf{L}(j\omega,\rho) = \mathbf{G}(j\omega)\mathbf{K}(j\omega,\rho)$$

- **Multivariable-Proportional Integral (PI)-Resonant Controller**

$$K_{21}(z) = \frac{\rho_4+\rho_5 z^{-1}}{1-z^{-1}} + \rho_6 \frac{b_1 z^{-1}+b_2 z^{-2}}{1+a_1 z^{-1}+a_2 z^{-2}}$$

The Proposed Multivariable Controller

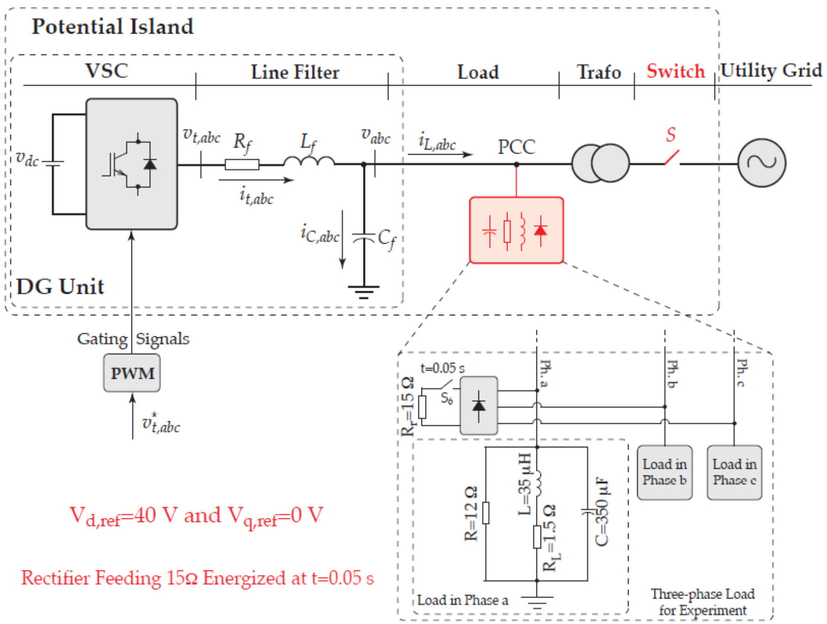
Step 3. Determination of the controller coefficients by loop-shaping

The open-loop shaping the system with a family of $\mathscr{G}$ *is* carried out by the following minimization

$$\min_{\rho} \sum_{i=1}^{m} \| \mathbf{L_i}(\rho, j\omega) - \mathbf{L_D}(j\omega) \|^2, \qquad \mathbf{L_D}(s) = \begin{bmatrix} \frac{\omega_{c1}}{s} + \frac{\omega_{c2}}{s^2+2\zeta\omega_h s+\omega_h^2} & 0 \\ 0 & \frac{\omega_{c1}}{s} + \frac{\omega_{c2}}{s^2+2\zeta\omega_h s+\omega_h^2} \end{bmatrix}$$

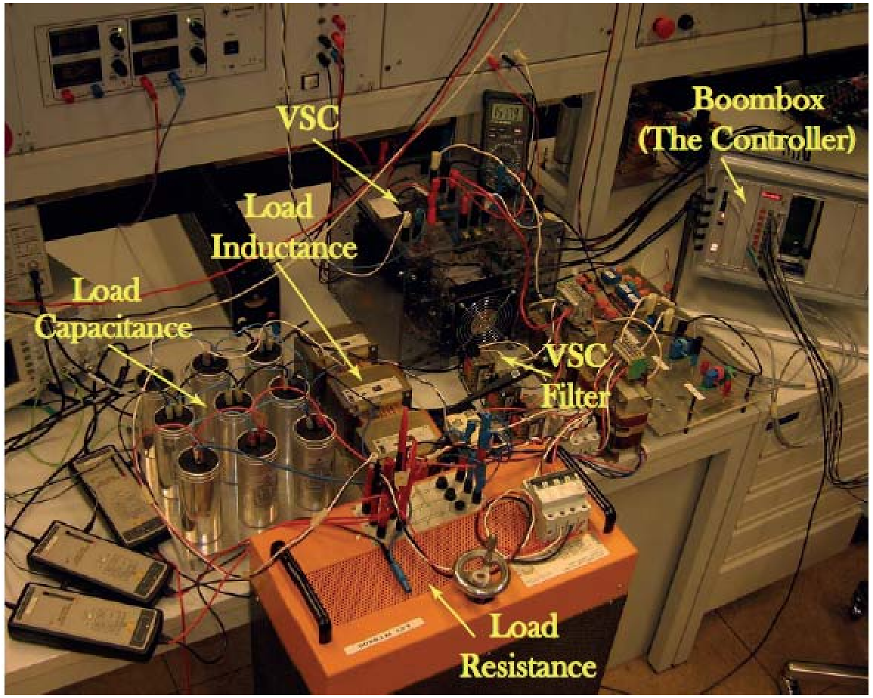
Experimental Setup

Nonlinear Resistive Load Change

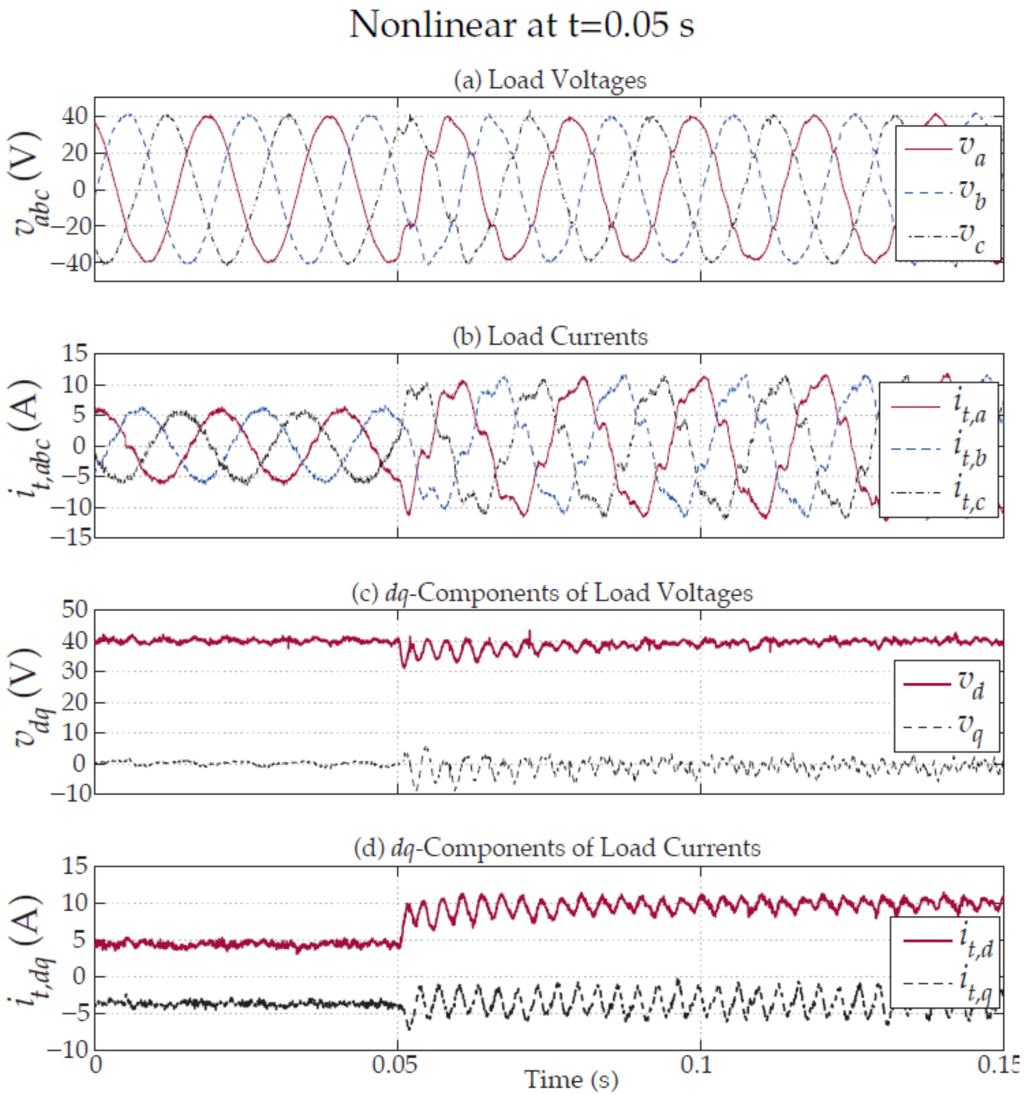


$V_{d,ref}$=40 V and $V_{q,ref}$=0 V

Rectifier Feeding 15Ω Energized at t=0.05 s



Experimental Results



Conclusions

- A voltage controller for islanded microgrids have been proposed.
- The proposed controller provides satisfactory dynamic performance and robustness in the presence of nonlinear loads.