Advanced Control of Microgrids

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This presentation is a summary of the following paper:
Outline

• Introduction
• Statement of the Problem
• The Proposed Multivariable Controller
• Experimental Results
• Conclusions
Introduction
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- To design controllers, the model of the to-be-controlled system is essential.
Introduction

- Current Control of a Grid-connected Microgrid
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

The Proposed Multivariable Controller

Step 1. Determination of the (family of) spectral or nonparametric model(s) of the system
The Proposed Multivariable Controller

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

\[
\begin{bmatrix}
V_d \\
V_q
\end{bmatrix}
= 
\begin{bmatrix}
G_{i,11} & G_{i,12} \\
G_{i,21} & G_{i,22}
\end{bmatrix}
\begin{bmatrix}
V_{i,d} \\
V_{i,q}
\end{bmatrix}
\]

\[
G_{i,11}(j\omega) = \frac{\mathcal{F}(v_d)}{\mathcal{F}(v_{i,d})} \quad \text{and} \quad G_{i,12}(j\omega) = \frac{\mathcal{F}(v_q)}{\mathcal{F}(v_{i,d})}
\]

\[
G_{i,21}(j\omega) = \frac{\mathcal{F}(v_d)}{\mathcal{F}(v_{i,q})} \quad \text{and} \quad G_{i,22}(j\omega) = \frac{\mathcal{F}(v_q)}{\mathcal{F}(v_{i,q})}
\]

\[\mathcal{G} = \{G_i(j\omega); i = 1, \ldots, 8; \forall \omega \in \mathbb{R}\}\]
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

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

- 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 $G$ is carried out by the following minimization

$$\min_{\rho} \sum_{i=1}^{m} \| L_i(\rho, j\omega) - L_D(j\omega) \|^2, \quad L_D(s) = \begin{bmatrix} \frac{\omega_c1}{s} + \frac{\omega_c2}{s^2 + 2\zeta\omega_h s + \omega_h^2} & 0 \\ 0 & \frac{\omega_c1}{s} + \frac{\omega_c2}{s^2 + 2\zeta\omega_h s + \omega_h^2} \end{bmatrix}$$
Experimental Setup

Nonlinear Resistive Load Change

Potential Island

VSC Line Filter Load Trafo Switch Utility Grid

DG Unit

Gating Signals

PWM

\[ V_{d,ref}=40 \text{ V and } V_{q,ref}=0 \text{ V} \]

Rectifier Feeding 15Ω Energized at \( t=0.05 \text{ s} \)

Load Inductance

Load Capacitance

VSC Filter

Load Resistance

Boombox (The Controller)
Experimental Results

Nonlinear at $t=0.05$ s

(a) Load Voltages

(b) Load Currents

(c) $dq$ Components of Load Voltages

(d) $dq$ Components of Load Currents
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.