Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 100 (2016) 375 – 387

Energy Procedia

3rd International Conference on Power and Energy Systems Engineering, CPESE 2016, 8-12 September 2016, Kitakyushu, Japan

Robust Multivariable Microgrid Control Synthesis and Analysis

M. Naderi, Y. Khayat, Y. Batmani, H. Bevrani*

Smart/Micro Grids Research Center, Dept. of Electrical and Computer Eng., University of Kurdistan, PO Box 416, Sanandaj, Iran.

Abstract

In this paper, an islanded microgrid is modelled as a linear multivariable dynamic system. Then, the multivariable analysis tools are employed. The generalized Nyquist diagram and the relative gain array are used respectively for the stability assessment and solving the paring problem among the inputs and outputs. Droop control dependency on the X/R ratio of the microgrid DERs is recognized and its type is proposed using the relative gain array concept. Robust stability, nominal performance and robust performance requirements are evaluated in order to a better understanding of the system dynamics. Finally, three different controllers including H_∞, H_2 and sequential proportional-integral-derivative controls are designed and compared.

Peer-review under responsibility of the organizing committee of CPESE 2016

Keywords: Microgrid; RGA; Generalized Nyquist; Robust performance; H_∞ control; H_2 control, Multivariable system.

1. Introduction

With the advent of small-scale power plants in the vicinities of distribution systems, some issues like huge losses related to bulk fossil power plants and transmission lines [1–3], construction cost of large generation units, dramatically decreased [4]. On the other hand, a number of environmental benefits such as clean and green environmentally advantages of distributed energy resources (DERs), are the other promising solutions of small-scale power plants and distributed generations (DGs) [5]. These new micro power plants, known as microgrids, can be connected or islanded from the legacy grids. Their improved efficiency, reliability, utilization of clean and various renewable energy resources, and expandability have been gained popularity of these networks more and more [6]. However, different dynamic properties of such systems, impressed the power system dynamics totally, and has

**E-mail address:* bevrani@ieee.org

Peer-review under responsibility of the organizing committee of CPESE 2016
doi:10.1016/j.egypro.2016.10.191

raised some crucial considerations at the integration of DGs with various energy resources [7]. Distributed generations with DC-output, e.g., PV arrays, energy storage elements and fuel cells, are generally connected to the AC microgrid distribution network by grid interface converters [8] such as voltage-source converters (VSCs). All of these cause some challenges in control and stability of microgrids, especially during islanded operation mode due to low or no inertia, nonlinear and wrapped dynamics, intermittent wind power and photovoltaic outputs, etc. [9].

The above mentioned issues motivate researchers to figure out detailed models of microgrids and DGs. Currently, surveys of the microgrid modelling and stability are mostly focus on the mathematical analysis and modelling of the microgrid to improve stability. Detailed consideration is paid to the small signal and transient stability analysis [10–16].

However, due to the intermittent nature of DERs and their uncertainties, it has encouraged many of researchers to design controllers based on the robust control strategies as powerful methodologies to achieve robust stability and performance in the presence of uncertainties [17]. Robust control strategies guarantee robust stability and provide desired performance specifications such as excellent transient response and zero steady-state error despite any type of un-modelled uncertainties in the system dynamics and possible perturbations and distortions [18].

This paper presents multivariable robust control strategies based on H_∞ and H_2 theorems for two connected VSC-coupled DG units that simultaneously supply a resistive load in the islanded operation mode. The mathematical equations of the studied system develops a dynamic model of two DERs and their common load in *dq* rotating frame, and presents a systematic approach for system recognition from the controllability and observability point of view. Also, for the obtained dynamic model, the generalized Nyquist stability criterion, and input-output sets selection are outlined. Finally, in order to enumeration of robust stability and performance needs, a standard control framework for robust control synthesis considering both structured an unstructured uncertainties are represented.

The rest of this paper is organized as follows. Section 2 presents the microgrid modelling using Park transformation. In Section 3, microgrid analysis as a multivariable system is presented. The uncertainty determination is presented in Section 4. In section 5, robust stability and performance requirements are given, robust H_∞ and H_2 controllers are designed and some simulations are performed.

2. Microgrid modelling using Park transformation

The schematic block diagram of the considered microgrid is depicted in Fig. 1 (a). In order to find a linear model of the microgrid, each DER is considered as a VSC with a static dc link, and the VSC is modeled by a controllable three-phase sinusoidal voltage source. The VSC output filter, transformer and line between the VSC and point of common coupling (PCC) are modeled by an equivalent inductance and an equivalent resistance. The load is considered as a common resistive in the PCC. Fig. 1 (b) shows the equivalent single-line diagram of the microgrid.

In order to find a linear time invariant (LTI) model of the microgrid, the most commonly method is converting the three-phase circuit equations to the *dq0* frame using Park transformation [19–22]. Park transformation converts three-phase voltages and currents to their *dq0* components, respectively. This transformation can be represented as follows:

$$\begin{bmatrix} f_d \\ f_q \\ f_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ -\sin(\theta) & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}, \tag{1}$$