Stabilizing plug-and-play regulators and secondary coordinated control for AC islanded microgrids with bus-connected topology

Stefano Riversoa, Michele Tuccib,*, Juan C. Vasquezc, Josep M. Guerrerod, Giancarlo Ferrari-Trecatea

a United Technologies Research Center Ireland, 4th Floor, Penrose Business Center, Penrose Wharf, Cork, Ireland
b Dipartimento di Ingegneria Industriale e dell’Informazione, Università degli Studi di Pavia, Italy
c Institute of Energy Technology, Aalborg University, 9220 Aalborg, Denmark
d Automatic Control Laboratory, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

HIGHLIGHTS

• Distributed control scheme for guaranteeing stability in Islanded microGrids (ImGs).
• Modular procedure for designing Plug-and-Play controllers in bus-connected ImGs.
• Automatized update of the primary layer when units plug in/out. Stability ensured.
• Definition of a secondary layer for bus voltage tracking and reactive power sharing.
• Feasibility of the proposed control design framework validated through experiments.

ARTICLE INFO

Keywords:
Distributed control
Secondary control
Plug-and-play design
AC islanded microgrid
Reactive power sharing
Voltage and frequency control

ABSTRACT

This paper presents a distributed hierarchical control architecture for voltage and frequency stabilization and reactive power sharing in AC islanded microgrids. In the primary control layer, each generation unit is equipped with a local regulator for voltage and frequency stability acting on the corresponding voltage-source converter. Following the plug-and-play design approach previously proposed by some of the authors, whenever the addition/removal of a distributed generation unit is required, feasibility of the operation is automatically checked by designing local controllers through convex optimization. The update of the voltage-control layer, when units plug-in/-out, is therefore automatized and stability of the microgrid is always preserved. Moreover, local control design is based only on the knowledge of parameters of power lines and it does not require to store a global microgrid model. In this work, we focus on islanded microgrids with bus-connected topology and enhance the primary plug-and-play layer with local virtual impedance loops and secondary coordinated controllers ensuring bus voltage tracking and reactive power sharing. In particular, the secondary control architecture is distributed, hence mirroring the modularity of the primary control layer. We validate primary and secondary controllers by performing experiments with both linear and nonlinear loads, on a setup composed of three bus-connected distributed generation units. Most importantly, the stability of the microgrid after the addition/removal of distributed generation units is assessed. Overall, the experimental results show the feasibility of the proposed modular control design framework, where generation units can be added/removed on the fly, thus enabling the deployment of virtual power plants that can be resized over time.

1. Introduction

Islanded microGrids (ImGs) are autonomous energy systems composed of the interconnection of Distributed Generation Units (DGUs) and loads. In view of their capability of supplying loads in absence of a connection to the main grid, ImGs provide a flexible solution for bringing power to remote areas or islands [1–7]. The growing interest in ImGs is also motivated by microgrids that normally operate in grid-connected mode and that can transfer to islanding mode for two main reasons [8]. The first one is the so-called preplanned islanded operation, i.e. if any events in the main grid are presented (such as long-time voltage dips or general faults among others), islanded operation must

* Corresponding author.
E-mail address: michele.tucci02@universitadipavia.it (M. Tucci).

http://dx.doi.org/10.1016/j.apenergy.2017.08.110
Received 31 March 2017; Received in revised form 6 June 2017; Accepted 12 August 2017
Available online 24 August 2017
0306-2619/ © 2017 Elsevier Ltd. All rights reserved.
be started. This can be done by disconnecting the microgrid from the main grid by means of a static transfer switch. As this is a decision taken by the microgrid, it can be safe. The second cause of switch from grid-connected to islanding mode is the non-planned islanded operation: if there is a blackout due to a disconnection of the main grid, the microgrid should be able to detect this fact by using proper algorithms, otherwise it could damage other equipment or injury people that is arranging the grid "upstream".

From a practical point of view, ImGs find application as parallel Uninterruptible Power Supply (UPS) systems, in which modular UPS systems can operate in parallel, thus requiring accurate power sharing and good level of frequency/voltage regulation [9]. Another example of real-world application for ImGs is the parallel operation of battery-based inverters, also named line-interactive UPS systems [10,11]. These units (whose interconnection forms an ImG) can be very far way from one another; in this case, power sharing is necessary to avoid the discharge of a battery unit over another.

Self-sufficient and flexible generation islands also promote the deregulation of the energy market and they have been advocated as a key component of future smart power systems [12].

One of the key issues of ImGs is scalability, i.e. how to add and remove DGUs without compromising the safe operation of the whole system. This problem is not trivial, as voltage and frequency stability must be guaranteed by regulating the Voltage-Source Converter (VSC) of individual DGUs. Furthermore, in order to make online computations grow nicely with the ImG size, decentralized control architectures (where each DGU is equipped with a local regulator) must be used [13-15]. Since each local controller measures variables of the corresponding DGU only, the plugging-in or -out of a DGU can easily destabilize the whole ImG if the control layer is not properly updated [16]. In order to overcome this critical issue, in [1,16] the authors present a methodology for designing local primary regulators to allow Plug-and-Play (PnP) operations [17,18] while preserving voltage and frequency stability of the overall ImG. The PnP approach has several advantages in terms of safety and scalability. First, if a DGU issues a plug-in/unplugging request, a local automatic test (involving only the
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات