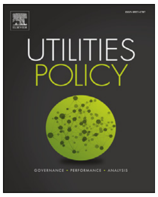
Utilities Policy xxx (2017) 1–9

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup



Optimizing energy management and control of distributed generation resources in islanded microgrids

Mohammad Abedini [a], [*], Moein Abedini [b]

[a] Department of Electrical Engineering, Ayatollah Broujerdi University, Broujerd, Lorstan, CT 06516, Iran
[b] The School of Electrical and Computer Engineering, College of Engineering, University of Tehran, Tehran 1439957131, Iran

ARTICLE INFO

Article history:
Received 14 December 2015
Received in revised form
13 August 2017
Accepted 13 August 2017
Available online xxx

Keywords:
Droop controller
Islanded
Optimization
Cost function

ABSTRACT

A new problem formulation for islanded microgrids (MG) is introduced and developed by employing a multi-objective function approach where the objectives include: i) fuel consumption cost, ii) voltage stability index, and iii) total voltage variation). A hybrid optimization algorithm is proposed to solve the proposed algorithm by combining the harmony algorithm (HS), mutation, and crossover operators of the genetic algorithm (GA). To find the best solution for the non-dominated results, a fuzzy logic method is employed. The performance of the proposed approach is compared with those of the other optimization and non-optimization methods in MG using 33-bus test network in a MATLAB environment. The obtained results show that the proposed algorithm is capable of: i) significantly reducing the islanded MG customer interruptions and ii) improving the islanded MGs stability. In addition, selecting appropriate parameters of droop facilitate the successful implementation of the islanded MG concept in distribution systems.

1. Introduction

Distributed generation resources (DGs), emerging from the utilization of renewable energy resources (RES) in distribution networks, come in different types including: i) controllable, e.g., diesel generators, fuel cells and micro-turbines, and ii) uncontrollable, such as wind turbines and photovoltaic systems. DGs along with the energy storage systems, controllers, loads, and communication systems provides a small low-voltage system, known as a microgrid (MG), which is widely regarded as a significant and essential part of modern distribution network development (Momoh and Reddy, 2016).

Among various factors influencing the behavior of MGs, optimal sizing, location, and operation of DGs are of particular interests in the power-grid optimization literature. Although research in finding optimal sizing and siting of DGs in a MG is well developed in references (Fetanat and khorsaninejad, 2015) through (Reddy, 2017) discussion of the optimal operation of DGs is ongoing. In reference (Campoccia et al., 2008), a NSGA-II algorithm is applied for the optimal location of RES-based DG.

To find the optimal operation of the autonomous MG with and without droop control, the use of a central controller is vital, as noted in references (Oyarzabal et al., 2005) and (Vasiljevska et al., 2012). The research reported in reference (Basu et al., 2012) looks at power dispatching among DGs using an evolutionary algorithm. In reference (Reddy, 2017), a hybrid algorithm optimization is provided to solve generation scheduling in a MG, including renewable resources. In references (Moradi et al., 2015a) and (Reddy and Lho, 2015), heuristic algorithms to optimize the location and size of DGs and voltage regulators in distribution systems are studied. In reference (Reddy et al., 2013), a market clearing process for wind integrated thermal system for energy and spinning reserve procurement is provided.

Despite the substantial contributions of the above studies in the area of power-grid optimization, a review of the literature reveals that few studies have looked at the optimal operation of DGs along with their optimal location. This paper addresses this gap and presents a novel hybrid optimization method to find an optimal operation of an autonomous MG simultaneously. The operation is optimized by identifying the optimal droop gain parameters of DGs. The optimization problem is formulated in terms of a multi-objective problem to minimize the fuel consumption of DGs and improve the voltage profile and stability of MG subject to operation and security constraints. A hybrid algorithm, referred as HS-GA, is

---

* Corresponding author.
E-mail addresses: m_abedini_dr@yahoo.com (M. Abedini), m.abedini@ut.ac.ir (M. Abedini).

http://dx.doi.org/10.1016/j.jup.2017.08.003
0957-1787/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Abedini, M., Abedini, M., Optimizing energy management and control of distributed generation resources in islanded microgrids, Utilities Policy (2017), http://dx.doi.org/10.1016/j.jup.2017.08.003

developed to solve the optimization problem.

The rest of the paper is organized as follows. First, the background of the problem definition is considered. Then, the problem formulation outline is developed for use in the solution algorithm. Finally, numerical results and implications are comprehensively addressed.

MGs can be operated in either grid-connected or autonomous modes (Mitra et al., 2006). In the grid-connected mode, voltage and frequency of the MG are dictated by the grid and thus the MG only controls the interchange of electrical power with the grid (Lasseter and Piagi, 2004). In the autonomous mode, where there is no link between MG and the main grid, the MG control is responsible for retaining both the frequency and voltage regulation, and thus the power generated by the MG needs to meet its local demand. To share power among DGs, a proper control method is required to manage the supply of the MG's load. Under such conditions, there are two control methods: centralized and decentralized. The centralized control method is too costly because of the need to provide a remarkable data transferring and a reliable communication link to swap power division signals among DGs (Li and Shi, 2012; Geem et al., 2001). Because of this, the centralized control methods sound to be appropriate for small-scale MGs where DG units are close together.

In the decentralized method, the load is shared among DGs with the use of droop controller characteristics and local measurement (frequency and voltage variations). Although decentralized methods provide a proper voltage regulation in PCC, there are some drawbacks with their use, including: i) voltage drop in some buses, ii) lack of minimizing power generation costs to the MG, and iii) lack of dispatching reactive power generation among DGs (based on DG characteristics). To cope with these drawbacks, tuning DG droop parameters is of particular usefulness. MGCC might be employed to make such tuning possible. In this paper, a combination of MGCC with a decentralized control method is established to solve the optimal power-sharing problem of DGs. MGCC is employed to provide optimum DGs' droop parameters and a decentralized controller is used to operate with the optimal droop parameters.

2. Problem formulation

The main challenge is how to find the optimal operation and static characteristics of DGs to i) reduce fuel cost of DG units (f_1), ii) improve voltage stability index (f_2), and iii) reduce total voltage variation (f_3), subject to constraints. These three objective functions can be mathematically formulated as a minimization problem,

$$Minimize\left\{\begin{matrix} f_1(i,k) \\ f_2(i,k) \\ f_3(i,k) \end{matrix}\right\} \tag{1}$$

where i is the bus number, representing DGs location, and k represents the static characteristics, including: i) frequency, ii) voltage references, and iii) static droop gains as follows:

$$k=\left\{\omega_i^*,\left|V_i^*\right|,s_{pi},s_{qi}\right\}\quad i\in N_{dr} \tag{2}$$

A Fuel Cost of DG Units

Fuel consumption cost can be given by,

$$f_1=\sum\nolimits_{i=1}^{n_{DG}}P_{DG_i}{*}C_i(P_{DGi}) \tag{3}$$

B Voltage Stability Index (VSI)

Using Fig. 1, VSI index based on (Charkravor, 2001) can be calculated by,

$$\begin{aligned}VSI(i+1)=|V_i|^4-4\left[\hat{P_{i+1}}X_i-\hat{Q_{i+1}}R_i\right]^2\\ -4\left[\hat{P_{i+1}}R_i+\hat{Q_{i+1}}X_i\right]^2|V_i|^2.\end{aligned} \tag{4}$$

where V_i is voltage of node i. Here VSI is utilized to compute the stability of a MG line as illustrated in Fig. 1. For the stable action of MG, VSI should be positive in microgrid buses. To improve VSI, (4) should be maximized and thus accordingly the following should be minimized:

$$f_2=\frac{1}{VSI(i+1)}\quad i=1,2,\ldots,NB. \tag{5}$$

C Total Voltage Variation (TVV)

To uniform voltage in MG, TVV index can be given by,

$$f_3=\frac{\sum_{i=1}^{NB}|1-V_i|}{NB} \tag{6}$$

D Constraints

There are two main limitations in the optimization problem: equality and inequality. Equality limits include nonlinear load-flow equations that can be obtained by (Moradi and Abedini, 2012).

$$P_{gi}=P_i+V_i\sum_{j=1}^{NB}V_jY_{ij}\cos(\delta_i-\delta_j-\theta_{ij}) \tag{7}$$

$$Q_{gi}=Q_i+V_i\sum_{j=1}^{NB}V_jY_{ij}\sin(\delta_i-\ \delta_j-\ \theta_{ij}) \tag{8}$$

In addition, inequality limits include i) voltage, ii) thermal, and iii) power generation that are described as follows:

i) *Voltage Limit:* The limit of voltage magnitudes in MG buses can be mathematically expressed by,

$$V_{\min}\le V_i\le V_{\max} \tag{9}$$

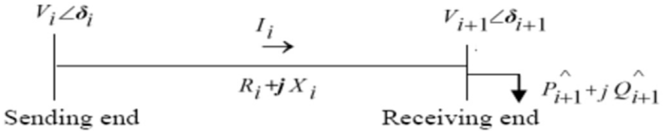


Fig. 1. One-line diagram of MG line.

Please cite this article in press as: Abedini, M., Abedini, M., Optimizing energy management and control of distributed generation resources in islanded microgrids, Utilities Policy (2017), http://dx.doi.org/10.1016/j.jup.2017.08.003