Integration of distributed energy resources into low voltage grid: A market-based multiperiod optimization model

Elahe Mashhour *, S.M. Moghaddas-Tafreshi

Faculty of Electrical Engineering, K.N. Toosi University of Technology, Seyd Khandan, P.O. Box 16315-1355, Shariati, Tehran, Iran

**Article info**

Article history:
Received 21 May 2009
Received in revised form 4 September 2009
Accepted 18 October 2009
Available online 25 November 2009

Keywords:
Distributed energy resources (DER)
Micro grid

**Abstract**

This paper develops a multiperiod optimization model for an interconnected micro grid with hierarchical control that participates in wholesale energy market to maximize its benefit (i.e. revenues-costs). In addition to the operational constraints of distributed energy resources (DER) including both inter-temporal and non-inter-temporal types, the adequacy and steady-state security constraints of micro grid and its power losses are incorporated in the optimization model. In the presented model, DER are integrated into low voltage grid considering both technical and economical aspects. This integration as a micro grid can participate in wholesale energy market as an entity with dual role including producer and consumer based on the direction of exchanged power. The developed model is evaluated by testing on a micro grid considering different cases and the results are analyzed.

© 2009 Elsevier B.V. All rights reserved.

**1. Introduction**

The share of distributed generators (DG) in the power system generation is increasingly grown up and eventually the micro grids are in progress. Micro grids contain low voltage distribution network with DER, i.e. DGs, controllable loads and storage devices. These systems can be operated in non-autonomous way, if interconnected to the main grid, or in autonomous way, if disconnected from the main grid [1,2].

In control strategies of micro grid, there are several levels of decentralization that can be possibly applied ranging from the fully decentralized approach to a hierarchical control [1,3].

According to the fully decentralized approach, the main responsibility is given to the controllers of the micro generators that compete to maximize their production in order to satisfy the demand and probably provide the maximum possible export to the grid taking into account market prices [1–4]. This approach is based on the multi-agent technology and provides effective solutions for a number of specific operational problems in controlling micro grids [2,4].

In order to achieve the full benefits from the operation of micro grids, it is important that the integration of the micro sources into low voltage grids and their relation with the medium voltage grid will contribute to optimize the general operation of the system [1,5]. To achieve this goal, the hierarchical (centralized) control of micro grid is proposed for which three control levels are distinguished [1,3,6,7]:

1. Distribution management system (DMS);
2. Micro grid central controller (MGCC);
3. Local controllers (LC), which could be either micro source controllers or load controllers.

DMS is responsible to manage and control the distribution area comprising several feeders including several micro grids. The main interface between the DMS and the micro grid is the MGCC. It is the main responsible for the optimization of the micro grid operation, or alternatively, it simply coordinates the local controllers, which assume the main responsibility for this optimization. The lower control level consists of the LC that control DERs.

According to the relevant literature, many studies are performed about optimizing the operation of micro grid. In [2,4], operation of micro grid under decentralized control strategy is discussed. The studies of [8–13] are agreed with centralized control of micro grid. In [8,9], optimizing the operation of an autonomous micro grid is performed for 1-h time interval. The authors of [10] optimize the operation of an autonomous micro grid over 24-h time interval, however, there is no link between successive hours. In other words, the optimization problem can be separately solved for each time interval. This link is created in [11] by taking into account the minimum up/down time limits for DG units. Moreover, the electrochemical storage is incorporated in the optimization model by adding the limits of minimum and maximum states of charge of the battery to the constraints, which is insufficient for modeling the storage. In the context of the electrochemical storage, there are two