

Centralized Control for Optimizing Microgrids Operation

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Abstract—Microgrids are low-voltage (LV) distribution networks comprising various distributed generators (DGs), storage devices, and controllable loads that can operate either interconnected or isolated from the main distribution grid as a controlled entity. This paper describes the operation of a central controller for microgrids. The controller aims to optimize the operation of the microgrid during interconnected operation, i.e., maximize its value by optimizing the production of the local DGs and power exchanges with the main distribution grid. Two market policies are assumed including demand-side bidding options for controllable loads. The developed optimization algorithms are applied on a typical LV study case network operating under various market policies and assuming realistic spot market prices and DG bids reflecting realistic operational costs. The effects on the microgrid and the distribution network operation are presented and discussed.

Index Terms—Demand-side bidding (DSB), distributed generation, markets, microgrids, optimization, renewable energy sources.

I. INTRODUCTION

THE DEREGULATED energy environment, among other effects, has favored the penetration of distributed generation (DG) sources connected near the energy consumers at the medium-voltage or low-voltage (LV) side of the distribution network. These sources comprise several technologies, such as diesel engines, microturbines (MTs), and fuel cells either in combined heat and power (CHP) operation or purely for electricity production, photovoltaics (PVs), small wind turbines (WTs), hydro turbines, etc. The capacity of the DG sources varies from few kilowatts to 1–2 MW.

The coordinated operation and control of DG sources together with storage devices such as flywheels, energy capacitors, batteries, and controllable loads such as water heaters and air conditioners is central to the concept of microgrids [1], [2]. Microgrids mostly operate interconnected to the main distribution grid, but also islanded, in case of external faults. From the grid's point of view, a microgrid can be regarded as a controlled entity within the power system that can be operated as a single aggregated load, and given attractive remuneration, even as a small source of power or ancillary service supporting the network. From a customer's point of view, microgrids similar to traditional LV distribution networks not only provide their thermal and electricity needs, but in addition, enhance local reliability,

reduce emissions, improve power quality by supporting voltage and reducing voltage dips, and lead to lower costs of energy supply. It is clear that, in order to achieve these benefits, it is important to provide a coordinated decision-making process, so as to balance demand and supply coming both from the DG sources and the medium-voltage (MV) distribution feeder.

This paper focuses on the functionalities of the microgrid central controller, which is responsible for the optimization of the microgrids operation. A hierarchical control system architecture comprising three levels [2] is discussed in Section II. Two market policies, including demand-side bidding (DSB) options, are presented in Section III, and the respective optimization problems are formulated in Section IV. A typical study case microgrid [3] is presented in Section V, and results from the application of the market policies in Section VI. The study case network represents a typical LV feeder with several distributed microsources operating in realistic market conditions and the microsource bids reflect realistic operating costs. General conclusions regarding the economic impacts of this application are drawn in Section VII.

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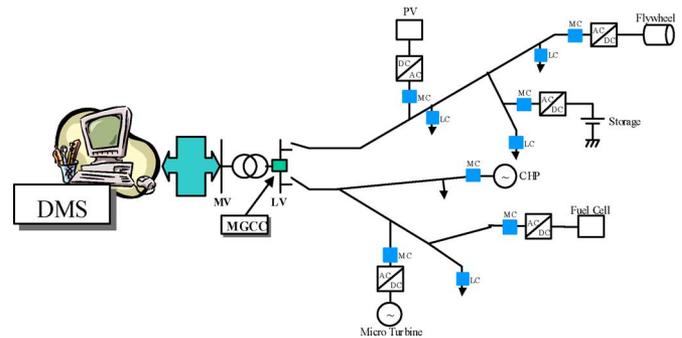


Fig. 1. Typical microgrid structure.

II. CENTRALIZED MICROGRIDS CONTROL

A typical microgrid is shown in Fig. 1. The proposed hierarchical control system architecture comprises the following three control levels, shown in Fig. 2 [2]:

- 1) local microsource controllers (MC) and load controllers (LC);
- 2) microgrid system central controller (MGCC);
- 3) distribution management system (DMS).

The MC takes advantage of the power electronic interface of the DG sources. It uses local information to control the voltage and the frequency of the microgrid in transient conditions. MCs follow the demands from the central controller, when connected to the power grid, and perform local optimization of the

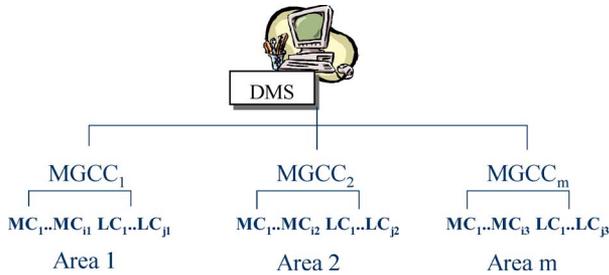


Fig. 2. Hierarchical control structure.

DG active and reactive power production, and fast load tracking following an islanding situation. Local microload controllers installed at the controllable loads provide load control capabilities following orders from the MGCC for load management.

The MGCC is responsible for the maximization of the microgrid's value and the optimization of its operation. It uses the market prices of electricity and gas and probably grid security concerns to determine the amount of power that the microgrid should draw from the distribution system, thus optimizing the local production capabilities. The defined optimized operating scenario is achieved by sending control signals to the MCs and LCs. In this framework, noncritical, controllable loads can be shed when necessary, subject to the DSB. This operation can be considered equivalent to the secondary control of the larger power system. In market terms, the MGCC might represent the functions of an aggregator or energy service provider, who acts in the interest of one or more microgrids.

Conventional approaches to DMSs need to be enhanced with new features related to the operation of microgrids connected on the feeders. The issues of islanded and interconnected operation of the microgrids and the related exchange of information with DSB are new important issues, falling outside the scope of this paper.

The information exchange within a typical microgrid is as follows: every m min, e.g., 15 min, each DG source bids for the production for the next hour in m -min intervals. These bids are prepared according to the energy prices in the open market, the operating costs of the DG units plus the profit of the DG owner, and other needs for the installation facility, e.g., space heating. For example, if a DG owner has installed a CHP unit, it may wish to provide heat demand locally at a certain period. For this period, the bids sent to the MGCC should aim at maximizing this profit by participating in the electricity market.

The MGCC optimizes the microgrid operation according to the open market prices, the bids received by the DG sources, and the forecasted loads, and sends signals to the MCs of the DG sources to be committed, and if applicable, to determine the level of their production. In addition, consumers within the microgrid might bid for their loads supply for the next hour in the same m -min intervals or might bid to curtail their loads. In this case, the MGCC optimizes the operation based on DG sources and load bids, and sends dispatch signals to both the MCs and LCs. Fig. 3 shows the information-exchange flow in a typical microgrid operating under such conditions.

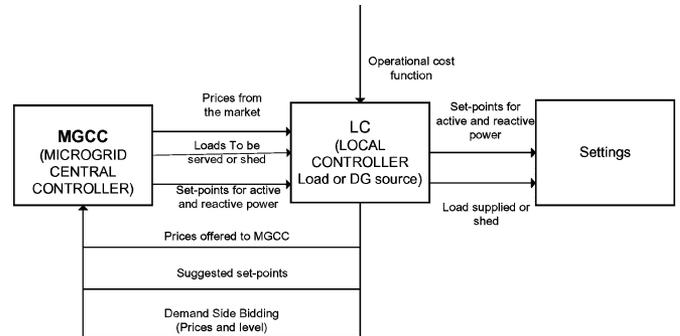


Fig. 3. Information exchange flow between MCs and the MGCC.

The optimization procedure depends on the market policy adopted in the microgrid operation. In the following section, two possible market policies are described.

III. PARTICIPATION IN ENERGY MARKETS

A. Market Policies

In the first policy, the MGCC aims to serve the total demand of the microgrid, using its local production, as much as possible, without exporting power to the upstream distribution grid. For the overall distribution grid operation, such a behavior is beneficial, because at the time of peak demand, when energy prices in the open market are high, the microgrid relieves possible network congestion by partly or fully supplying its energy needs. From the consumers' point of view, the MGCC minimizes the operational cost of the microgrid, taking into account open market prices, demand, and DG bids. The consumers of the microgrid share the benefits of reduced operational costs.

In the second policy, the microgrid participates in the open market, buying and selling active and reactive power to the grid, probably via an aggregator or similar energy service provider. According to this policy, the MGCC tries to maximize the value of the microgrid, i.e., maximize the corresponding revenues of the aggregator, by exchanging power with the grid. The consumers are charged for their active and reactive power consumption at the open market prices. The microgrid behaves as a single generator capable of relieving possible network congestions not only in the microgrid itself, but also by transferring energy to nearby feeders of the distribution network.

B. Demand-Side Bidding

It is assumed that each consumer has low- and high-priority loads allowing him to send separate bids to the MGCC for each of their types. In our application, it is assumed that each consumer places bids in two levels reflecting his priorities. "Low" priority loads can be satisfied in periods of lower prices (shift) or not be served at all (curtailment). A similar approach can be used for more than two bid levels reflecting more precisely the consumer's priorities. Two options are considered for the consumers' bids.

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