

# Management of Microgrids in Market Environment

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**Abstract** — Restructuring of power markets has helped in the penetration of Distributed Generation (DG) in the electricity networks. The Microgrid, a LV network that usually operates interconnected with the main MV network but in case of emergency can run autonomously, is a suggested structure for the co-ordination of the DG sources. In this study, the control approaches followed, possible market configuration as well as security issues addressed within the MICROGRIDS project framework are discussed and show that Microgrids can be a future paradigm of a power system

**Index Terms**— MicroGrids, Distributed Generation, Markets, Renewable Energy Sources, Wind Power, PV, Demand side bidding

## I. INTRODUCTION

THE deregulated energy environment, among other effects, has favored a gradual transition from centralized power generation requiring long transmission and distribution facilities to Distributed Generation (DG) sources connected at the Medium Voltage or Low Voltage side of the Distribution Network [1]. These DG sources comprise several technologies, such as Diesel Engines, Micro Turbines and Fuel Cells either in CHP operation or purely for electricity production, Photovoltaics, small Wind Turbines, etc. The capacity of the DG sources varies from few kW's to 1-2 MW's.

The coordinated operation and control of DG sources together with storage devices, such as flywheels, energy capacitors and batteries, and controllable loads is central to the concept of Microgrids. Microgrids can operate interconnected to the main Distribution grid, or in an autonomous way, if disconnected from the main grid, 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 [2] and, given attractive remuneration, as a small source of power or ancillary services supporting the network. From a customer point of view, Microgrids similar to traditional LV distribution networks

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 potentially lower costs of energy supply

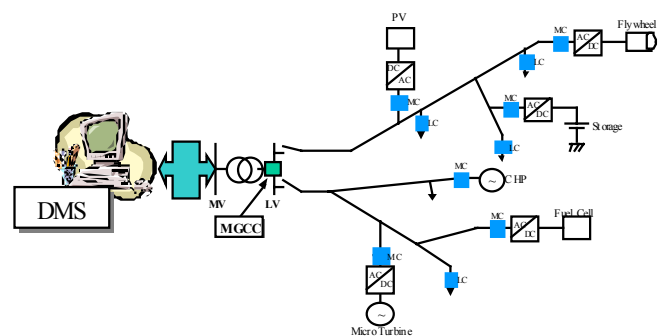


Fig 1 A typical Microgrid

Within the Microgrid a small energy market can operate. Which units will produce and at what level, if they are regulated, is the result of an optimization procedure that aims to maximize the value of the Microgrid. Suggested market policies within the Microgrid and control strategies to optimize this operation are explicitly described in [3]. According to these policies the DG sources bid for their production and a Central controller decides which bids will be accepted. In this paper the Control strategies, the Market environment of operation within the Microgrid considering demand side management aspects, as well as security issues concerning Microgrids are presented

## II. TYPICAL CONTROL STRATEGIES FOR MICROGRIDS

In a typical Microgrid three control levels can be distinguished, as shown in Fig. 1 [4].

- Distribution Network Operator (DNO) and Market Operator (MO).
- Microgrid System Central Controller (MGCC)
- Local Controllers (LC), which could be either Micro Source Controllers or Load Controllers.

The Distribution Network Operator (DNO) is responsible for the operation of medium and low voltage areas in which more than one Microgrid may exist. In addition, one or more Market Operators (MO) is responsible for the Market function

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of the specific area. These two entities do not belong to the Microgrid but they are the delegates of the main grid.

The main interface between the DNO/MO and the Microgrid is the Microgrid Central Controller (MGCC). The Microgrid Central Controller, may assume different roles ranging from the main responsibility for the maximization of the Microgrid value and optimization of its operation to simple coordination of the local controllers

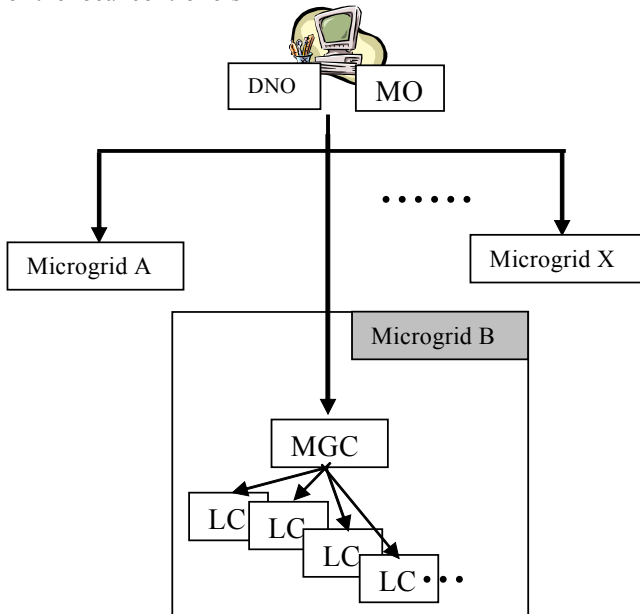


Fig 2 The architecture of Microgrid control

The lower level of control consists of the Local Controllers (LC). The LCs control the production or storage units and some of the local loads. Depending on the control approach, they have certain level of intelligence. In a centralized operation they just receive set-points from the MGCC and in a decentralized model they make decisions locally. Of course in any approach there are decisions that can be made only locally, for example for voltage control, the LCs do not need the coordination of the MGCC and all necessary calculations are performed locally

In the centralized control approach, the Local Controllers (LC) follow the orders of the MGCC, during interconnected mode of operation, and have the autonomy to perform local optimization of the micro source active and reactive power production, and switch to fast load tracking following transition to islanded operation. Based on DG bids and using high-level optimization software, the MGCC provides set-points to the DG sources and decides on serving controllable, low-priority loads. In the decentralized approach, the main responsibility lies with the controllers of the DG sources [4]. These compete to maximize their production in order to satisfy the demand and probably provide the maximum possible export to the grid taking into account current market prices. Furthermore the local controllers take all the appropriate decisions to ensure safe and smooth operation of the device or the load they are controlling.

Some key functions of the Central Controller are:

- Provide the individual power and voltage set-point for each local controller
- Ensure that heat and electrical loads are met
- Ensure that the Microgrid satisfies operational requirements of the distribution system.
- Maximize the operational efficiency of the micro sources

For this purpose the MGCC may be equipped with the following functions

- Simple Forecasting (short term) of load and power production capabilities.
- Economic Scheduling
- Security Assessment
- Demand Side Management (load curtailment)

### III. MARKET ASPECTS

#### A. Market Policies

Within the Microgrid a small internal market is expected to operate in order to optimize the operating cost of the Microgrid. In [3] a decentralized control approach is described where the local controllers compete one other to optimize the operation of the Microgrid using decentralized software approach with intelligent agents based on FIPA software approach.

In a more centralized control approach two market policies have been considered.

1. Microgrid serving the needs of its own consumption only, requesting zero reactive power from the grid, this is equivalent to the “good citizen” model, and
2. Microgrid buying and selling active and reactive power to the grid supporting its operation, this is equivalent to the “ideal citizen” model.

In the first case, the MGCC tries to minimize the energy costs for the whole Microgrid. In the second case, the MGCC tries to maximize the value of the Microgrid, maximizing the gains from the power exchange with the grid. In both cases, the active and reactive power demand, the market prices for buying active and reactive power, the bids of the micro-sources and the various network constraints are considered. In addition, load curtailment bids can be included in the optimization routine. Results using a typical Microgrid[5] and prices from Amsterdam Power exchange [6] have shown that savings up to 21.56% for a daily operation can be obtained for high prices periods[3].

#### B. Demand Side Management

The topic of Demand Side Management has also been addressed as a method to reduce the demand in periods of high prices or shed the less important loads in order to operate the most critical ones. Moreover, some loads such as water heater, air conditioning, washing machines can be controlled so that the total demand profile is altered according to economic criteria

Two approaches have been followed. The load curtailment approach in which the loads are not met at the specific operating period and the load shift approach where the loads are shifted to a later period when the prices or the operating conditions are more favorable. A simple algorithm for this

purpose has been incorporated within the MGCC software taking into account the demand side bids in order to decide which loads will be curtailed or shifted increasing the benefits for the end-users up to 34%.

Additionally, a more sophisticated algorithm for load curtailment and load shift taking into account the number of connected controlled devices that can be controlled has been developed. For these loads, a future connection moment is proposed so that the minimum discomfort is taken for the customers. Results from case studies have been presented in [8]

### *C Security issues*

Finally, security issues are treated, as far as the ability of the system for a seamless transition from interconnected to islanded mode of operation. Regarding steady state security, the adequacy of the committed units including load curtailment possibilities is considered in the centralized control approach, so that if it is possible to meet the demand of the critical loads, the necessary DG sources are operating for this purpose. Neural Networks that provide on line dynamic security assessment capabilities of the Microgrid operating state have been developed taking into account the dynamic characteristics of the DG sources and storage devices[7].

## IV. CONCLUSIONS

The above analysis shows that the development of control functions and the study of security issues of a Microgrid can help so that distributed generation is not passively connected in the Distribution Networks but operate in a intelligent way that can increase reliability of supply and decrease the operating costs.

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