Hierarchical Frequency Control Scheme for Islanded Multi-Microgrids Operation

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***Abstract*—This paper presents a new hierarchical approach to deal with the problem of controlling frequency and active power generation of a medium voltage network comprising several microgrids and distributed generation sources operated in islanded mode.**

The hierarchical approach described here should be cost effective and capable of dealing with large numbers of distributed microsources and performing tasks related to coordinated frequency control.

***Index Terms*—Distributed generation, microgrid, frequency control, hierarchical control.**

I. Introduction

THIS paper presents a new hierarchical approach to deal with the problem of controlling frequency and active power generation of a Medium Voltage (MV) network comprising several microgrids and Distributed Generation (DG) sources operated in islanded mode.

A microgrid consists of a Low Voltage (LV) feeder with several microsources, storage devices and controllable loads connected on that same feeder (Fig. 1), including a local communication system and a hierarchical control structure managed locally by a MicroGrid Central Controller (MGCC).

The new concept of multi-microgrids is related to a higher level structure, formed at the Medium Voltage (MV) level, consisting of several LV microgrids and DG units connected on adjacent MV feeders. The possibility of having a large number of controllable microgrids, DG units and MV loads under Demand Side Management (DSM) control requires the use of a hierarchical control scheme that enables an efficient control and management of this kind of system. These concepts are being developed under the EU financed More-Microgrids Project.

In this paper it will be demonstrated how an intermediate managing control structure – the Central Autonomous Management Controller (CAMC) – can be used to accomplish some management tasks in this kind of multi-microgrid system, namely frequency control in case of MV network islanding and also load-following in islanded operation. The CAMC would relate to the Distribution Management System (DMS), under the responsibility of the Distribution System Operator (DSO). In fact, the CAMC may be seen as one DMS application which is in charge of one part of the distribution network that depends from one HV/MV substation (Fig. 2).

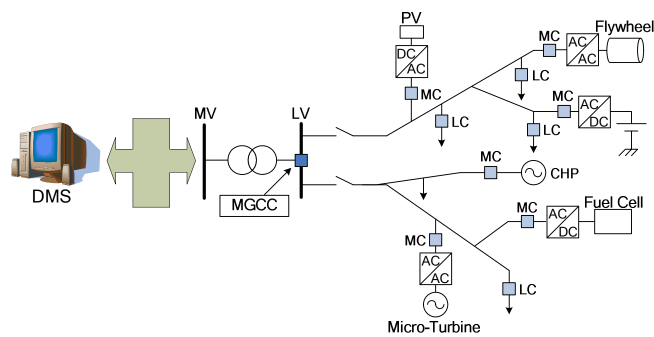

Fig. 1. Microgrid concept. The MV network would include several of these LV microgrids.

In order to test this concept, a dynamic simulation platform was developed exploiting *Eurostag v4.2* and *MATLAB* software packages.

This kind of change in the control paradigm for MV networks will require substantial modifications to the standard practice for distribution networks management. Currently, DG is typically disconnected during faults and MV islanded operation is not usually allowed, which could make this new control approach unfeasible. Therefore, protection and automation systems need to be adjusted or developed to allow MV islanded operation and, with that, all the related potential benefits.

II. Hierarchical Control

A. Introduction

The suggested hierarchical control system can be represented by the block diagram in Fig. 2. It will be shown how to possibly implement the Level 2 and Level 3 control autonomously, without any intervention from the DMS.

The CAMC will be the entity from where the commands for production change will be originated. The CAMC does not need to know the specific microgrid constitution as each of the microgrids is controlled and somewhat “hidden” by the corre-

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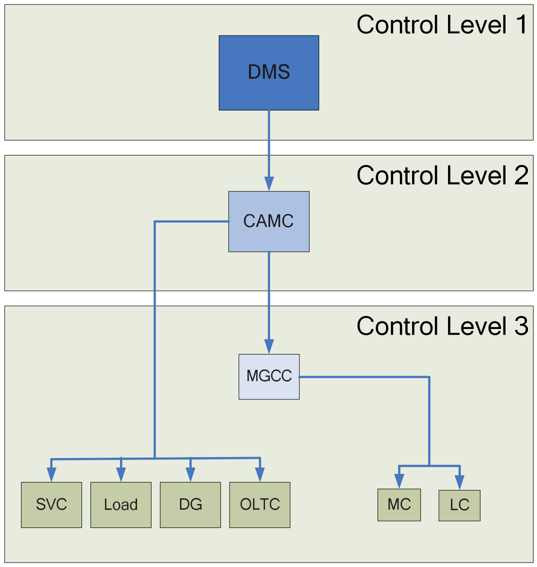

Fig. 2. Hierarchical control scheme. The implementation considered here only focuses on control levels 2 and 3.

sponding MGCC. However, the CAMC will still be able to perform control actions directly over other DG units, usually of bigger size than the ones under MGCC control.

The CAMC will react to power system frequency changes, in a way similar to the one implemented in regular Automatic Generation Control (AGC) functionalities [1]. The power generation change requested to the production system in case of frequency variation will be derived from the system frequency through a PI controller. Then, an economical allocation algorithm will distribute this power change among all the power generation units and MGCCs under CAMC control but only if they are willing, at that point in time, to participate in frequency regulation.

Each of the MGCCs will also allocate the generation request among its subordinate micro-generation units. Some of these do not usually have regulation capabilities (e.g., PV or wind generation, due to limitations in primary resource availability) and will not, in principle, be asked to change power generation.

This kind of decentralized control requires regular exchange of information among all intervening elements. As it is expected that this kind of information exchange will be subject to some delays that may not be negligible, such delays were included in the simulation.

The reason behind the choice of using power setpoint variations and not absolute power setpoints is related to the assumption that there could be a higher order control system, either automatic or manual, that would independently adjust microsource or DG output to setpoints other than the system optimal ones. At one end of the spectrum, this "control system" could eventually be the microsource individual owners who would adjust microsources, for instance, according to their heating needs. Therefore, it is assumed that the CAMC would only act if strictly needed and would not try to globally change setpoints in order to achieve a near optimum point of operation of the system.

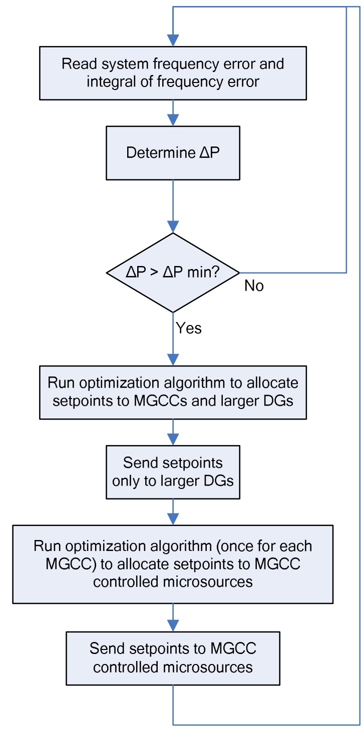

Fig. 3. Implementation flowchart. This procedure runs once each period T_s.

B. Control Details

The CAMC continuously samples the system frequency in order to identify if control actions are needed. However, it is not feasible to send control setpoints in real time to every MGCC and other DG. Because of this constraint, due mainly to communication systems limitations, the CAMC will react to system frequency changes every time interval T_s (sample time).

Therefore, each time T_s, the frequency error and the frequency error integral will be used to determine the additional power (1) to be requested to the available distributed generation under CAMC control. It should be noted that this additional power can have negative values if the frequency rises over its rated value. This way, the CAMC can respond to other disturbances, such as load loss while in islanded mode, commanding the distributed generation to reduce power output.

$$\Delta P = \left(K_P + K_I \frac{1}{s} \right) \times \left(f_{rated} - f \right) \tag{1}$$

If this required power variation is smaller than a specified threshold (i.e. the frequency is sufficiently close to its rated value) no action will be taken, as it is considered unnecessary.

On the other hand, if this required power variation is large enough, it will be necessary to determine how to distribute the power requests through the available sources. The unitary generation costs for each of the sources (MGCCs and other DGs) are used for this purpose.

The optimization is based on standard linear optimization techniques (2). In order to avoid globally changing setpoints

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