Defining Control Strategies for Analysing MicroGrids Islanded Operation

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Abstract—**The main objective of this paper is to present the development of microsource modelling and the definition of control strategies to be adopted to evaluate the feasibility of operation of a microgrid when it becomes isolated. Normally, the microgrid operates in interconnected mode with the MV network, however scheduled or forced isolation can take place. In such conditions, the microgrid must have the ability to operate stably and autonomously. An evaluation of the need of storage devices and load-shedding strategies is included in the paper.**

Index Terms—**Power system dynamic stability and control; Renewable energy sources and storage devices; Integration of distributed generation in the main grids.**

I. INTRODUCTION

THE need of reducing CO_2 emissions in the electricity generation field, recent technological developments in the microgeneration domain and electricity business restructuring are the main factors responsible for the growing interest in the use of microgeneration. In fact, the connection of small generation units – the microsources (MS), with power ratings less than a few tens of kilowatts – to Low Voltage (LV) networks potentially increases reliability to final consumers, brings additional benefits for global system operation and planning, namely regarding investment reduction for future grid reinforcement and expansion. In this context, a MicroGrid (MG) comprises a LV network (for example covering an urban area, a shopping-centre or even an industrial park), its loads and several small modular generation systems connected to it [1].

Examples of MS technologies to be used when building a MG include renewable power sources, such as wind and photovoltaic (PV) generators, microturbines working on gas or bio-fuels and different types of fuel-cells, and also storage devices (such as flywheels or batteries).

The MG is intended to operate in two different operating conditions:

- Normal Interconnected Mode – the MG is connected to a main MV network, either being supplied by it or injecting some amount of power into the main system.
- Emergency Mode – the MG operates autonomously, in a similar way to physical islands, when the disconnection from the upstream MV network occurs.

It will not be common to find fully controllable synchronous units in a MG, which are normally responsible for voltage and frequency control in conventional power systems. The majority of MS to be installed in a MG are not suitable for direct connection to the electrical network due to the characteristics of the energy produced (DC power in fuel-cells and PV generators or high frequency AC power in microturbines). Therefore, a power electronic interface (DC/AC or AC/DC/AC) is required. For instance, in [2] a control scheme based on droop concepts to operate inverters feeding a standalone system is presented.

In this paper the droop concept for inverter control is further explored in different modes of operation. Two inverter control schemes are combined in order to demonstrate the feasibility of a seamless transition from Normal Interconnected Mode to Emergency Mode under specific conditions, as well as the possibility of stably operating a MG in islanded conditions. In order to achieve this goal, the potentialities of the *MatLab*® *Simulink*® environment and its libraries (mainly the *SimPowerSystems* toolbox) were employed in order to develop a simulation platform suitable for identifying MG control requirements and evaluating the MG dynamic behaviour under several conditions. Different MS technologies coexist and are operated together in the simulation platform. Controllable and non-controllable sources as well as the disconnection of non-essential loads are used in order to guarantee the continuity of electric supply in a LV area after scheduled or forced loss of the upstream MV network connection.

This research is being developed within the framework of an EU R&D project with the objective of studying the problems that challenge the integration of large amounts of different MS in LV grids and involves several institutions and companies [3].

II. MICROGRID ARCHITECTURE

The control of the MG is based on a hierarchical control architecture in order to assure a robust operation [3]. Consequently, a MicroGrid Central Controller (MGCC) is installed at the LV side of a MV/LV substation managing in an upper level the MG operation through several crucial

This work was supported in part by the European Commission within the framework of EU Project MicroGrids, Contract No. ENK-CT-2002-00610.

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management functions, both technical and economical. At a second hierarchical level each MS and storage device is locally controlled by a Microsource Controller (MC) and each electrical load or group of loads is controlled by a Load Controller (LC). A communication infrastructure must also be provided in order to guarantee information exchange between the MGCC and the other controllers. A typical MG structure is shown in Fig. 1.

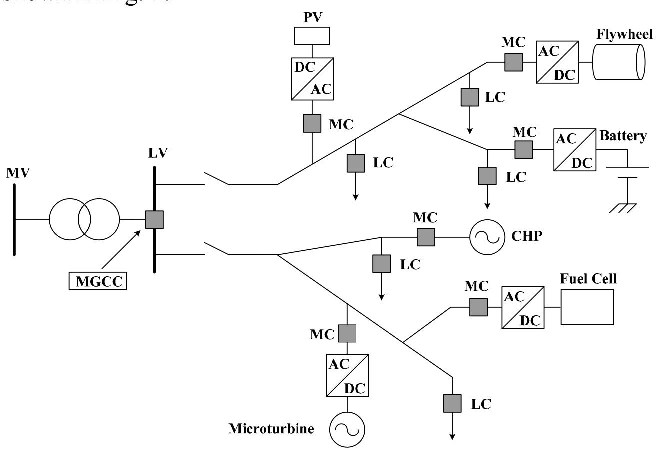

Fig. 1. MG control architecture

The interaction between the control devices is as follows: the MGCC promotes adequate technical and economical management policies and provides set-points to LC and MC. LC will act based on an interruptibility concept and MC are responsible for the control of the MS active and reactive power production levels.

It is important to understand that the amount of data to be exchanged between the several network controllers is small, as it includes mainly messages with set-points to LC and MC, as well as information requests sent by the MGCC to LC and MC about the active and reactive powers and voltage levels. Another important factor that eases the establishment of the communication infrastructure is the small geographical span of the MG.

The communications system can use either Power Line Communication, which presents some interesting characteristics for this type of network, or explore other type of access such as Wireless Communication (a rapid-growing technology).

III. Dynamic Models

The analysis of MG behaviour requires the development of a set of dynamic models able to simulate the response of the MG under several conditions. For this purpose, MS and storage devices, together with control systems, have been modelled.

Inverter modelling is an important issue, especially regarding operation control, thus deserving careful analysis and detailed implementation.

A. Microsource Modelling

The MS models developed within the project include photovoltaic arrays, wind generators, microturbines and a fuel-cells. Concerning storage devices, flywheel systems and batteries have also been modelled [4].

For illustration purposes only details on the dynamic model developed for the Solid Oxide Fuel-Cell (SOFC) are given next. The fuel-cell includes a Fuel Processor that converts the used fuel in Hydrogen, a Power Section, where chemical reactions take place, and a Power Conditioner that converts DC to AC power. The SOFC model adopted assumes several simplifications, such as: fuel gases are considered to be ideal, it is sufficient to define only one single pressure value in the interior of the electrodes, the temperature in the fuel-cell is presumed to be always stable, only ohmic losses are considered, assuming that the working conditions are far away from the upper and lower extreme values of current, and the Nernst equation is assumed to be applicable. The complete model can be seen in the block diagram in Fig. 2.

The state variables used to model the fuel-cell behaviour are the reaction current (I^r_{fc},) the hydrogen input flow (q^{in}_{H2}) and the partial pressure of the reaction components - p_{H2}, p_{O2} and p_{H2O} - respectively hydrogen, oxygen and water.

The full dynamic model description for the adopted SOFC can be found in [5] and [6].

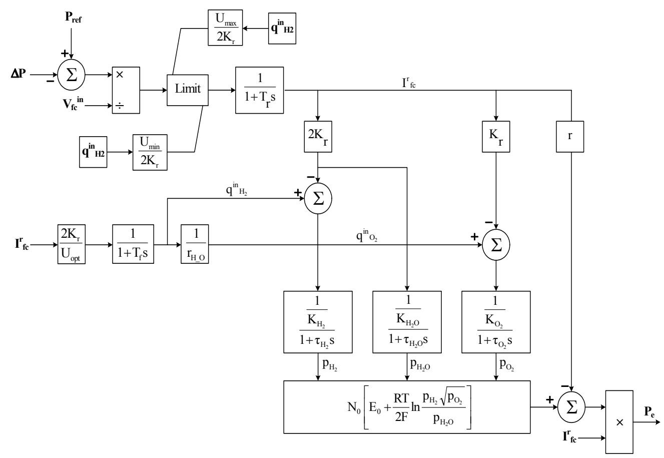

Fig. 2. SOFC block diagram model

A GAST dynamic model was adopted for the microturbines primary unit, since they are small simple-cycle gas turbines, [5]. Both high-speed single-shaft units, with a compressor and turbine mounted on the same shaft as the electrical synchronous machine, and split-shaft units using a power turbine rotating at 3000 rpm and a conventional induction generator connected via a gearbox, were modelled. The single shaft unit requires an AC/DC/AC converter to connect the unit to the grid. The wind generator is considered to be an induction machine directly connected to the network and represented by fifth-order model available in *MatLab® Simulink®*. Concerning the PV generator, it was assumed that the array is always working at its maximum power level for a given temperature and irradiance. It is basically an empirical model based on experimentation results as described in [7].

B. Storage Devices Modelling

Storage devices like flywheels and batteries are modelled as constant DC voltage sources (taking into account the time

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