MicroGrid Laboratory Facilities

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***Abstract*—Within the frame of the European project "Microgrids" several test set-ups have been installed or enlarged at different laboratories. Three of them are presented in this contribution: a specially designed single phase system of the NTUA with agent control software, the DeMoTec at ISET, which is a general test site for DER and the flywheel test rig, design by UMIST. These three sites allow the tests of different components, control strategies and different storage technologies. Though this contribution is aimed at the presentation of the facilities themselves, some test results are included.**

***Index Terms*— laboratories, DER, battery inverter, flywheel, wind turbine**

I. Introduction

Within the frame of the European project "Microgrids" several test set-ups have been installed or enlarged at different laboratories. Three of them are presented in this contribution: a specially designed single phase system of the NTUA with agent control software, the DeMoTec at ISET, which is a general test site for DER and the flywheel test rig, design by UMIST. These three sites allow the tests of different components, control strategies and different storage technologies. Though this contribution is aimed at the presentation of the facilities themselves, some test results are included.

II. Test Faclitiy at NTUA

This contribution presents the laboratory-scale microgrid system, which has been installed at the National Technical University of Athens. The microgrid comprises two PV generators, battery energy storage, controllable loads and a controlled interconnection to the local LV grid. Both the battery unit and the PV generators are connected to the AC grid via fast-acting DC/AC power converters. The converters are suitably controlled to permit the operation of the system either interconnected to the LV network (grid-tied), or in stand-alone (island) mode, with a seamless transfer from the one mode to the other.

A. System description

The composition of the microgrid system is shown in Fig. 1, along with a photo of the actual installation. It is a modular system, comprising a PV generator as the primary source of power, as well as a second small PV module, added recently. The addition of a small WT is also planned for the immediate future. All microsources are interfaced to the 1-phase AC bus via DC/AC inverters. A battery bank is also included, interfaced to the AC system via a bi-directional PWM voltage source converter. The microgrid is connected to the local LV grid, as shown in Fig. 1.

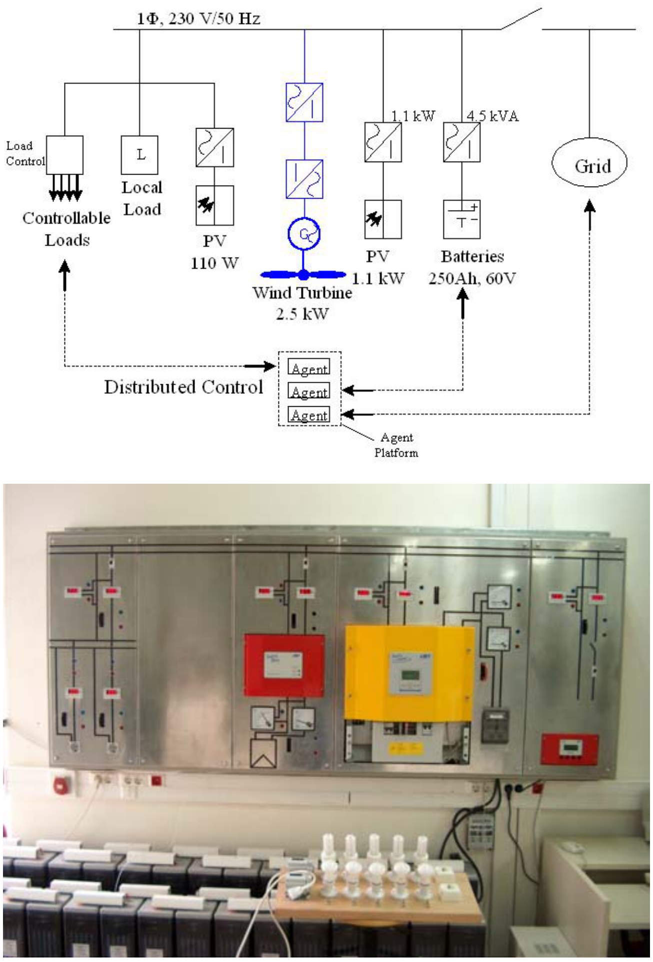

Fig. 1: Layout and set-up of NTUA system

The central component of the microgrid system is the battery inverter, which regulates the voltage and frequency when the system operates in island mode, taking over the control of active and reactive power. The battery inverter operates in voltage control mode (regulating the magnitude and phase/frequency of its output voltage), acting as a "grid-forming" unit, when the microgrid operates in island mode, i.e. setting the voltage and frequency of the system. When the microgrid operates in parallel to the grid, in which case the

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latter defines the operating frequency and voltage, the inverter operates as a “grid-following” unit.

The grid-connection scheme after upgrading the controllers is shown in Fig. 2. In the above configuration, the transfer from island to grid-tied mode and vice versa is controlled by the switch K5, which enables (or not) the “Diesel synch. input” to detect the grid voltage presence and thus give the appropriate order to the switch K3. In this new scheme, the transfer from one mode of operation to the other is now uninterruptible.

However, there is still no function implemented for the fast detection of public grid failures and subsequent isolation of the microgrid. That is, at present, the transfer from interconnected to isolated operation is seamless provided that the grid has not failed. A fast measurement and detection system is therefore required to enable the timely isolation of the system in case of abnormal grid conditions.

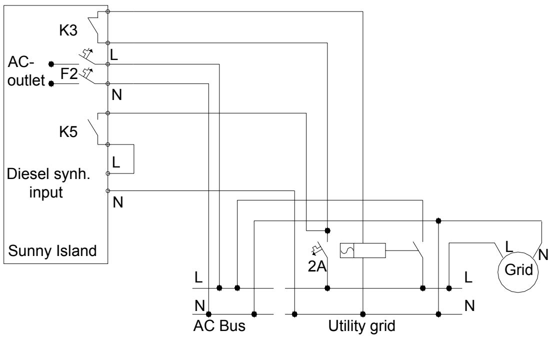

Fig. 2: Grid connection scheme of NTUA system

B. MultiAgent System for MicroGrid Operation

In this section, the capabilities offered by MultiAgent System (MAS) technology in the operation of the MicroGrid are presented. The use of MAS technology can solve a number of specific operational problems:

· The small DG (Distributed Generation) units have different owners, so centralized control is difficult. Several decisions should be taken locally.

· Lack of dedicated communication facilities.

· Microgrids will operate in a liberalized market, so the decisions of the controller of each unit concerning the market should have a certain degree of «intelligence».

The local DG units besides selling power to the network have also other tasks: producing heat for local installations, keeping the voltage locally at a certain level or providing a backup system for local critical loads in case of a failure of the main system. These tasks reveal the importance of the distributed control and autonomous operation.

1) The Agents in the Jade platform

In application that was developed for the Microgrids MAS there are 4 kinds of agents:

· Production Unit: This agent controls the Battery Inverter of the Microgrid. The main tasks of this agent are to control the overall status of the batteries and to adjust the power flow depending on the Market Condition (prices).

· Consumption Unit: This agent represents the controllable loads in the system. It knows the current demand and makes estimations of the energy demand for the next 15 minutes. Every 15 minutes it makes bids to the available Production Units in order to cover the estimated needs.

· Power System: This agent represents the Main Grid to which the Microgrid is connected. According to the Market Model presented before, the Power System Agent announces to all participants the Selling and the Buying price. It does not participate in the market operation since it is obliged to buy or sell any amount of energy asked for (as long as there areno security issues for the network)

· MGCC: This agent has only coordinating tasks and more specifically to announce the begining and the end of a negotiation for a specific period and to record final power exchanges between the agents in every period.

C. Controllable load

For the effective cooperation of the MAS technology with the microgrid a controllable load is required, which will be linked to the Consumption Unit agent. The Consumption Unit agent will have measurements in order to estimate the consumption and to make more realistic bids. Furthermore this agent will have the ability to control the load and to limit it according to the market status or the MicroGrid security considerations. So a controllable load scheme has been implemented, as described below.

This section describes the controllable MicroGrid load, which is implemented using various load types and a relay panel, controlled either manually or by a PLC (Programmable Logic Controller) or a PC-Card.

The relay panel is connected to a 25-pin parallel port, to facilitate the connection of the control panel to the PLC or a PC Card. Controlling each relay via the parallel port, the respective load is controlled independently. The panel is sufficient for controlling up to eight different loads of rated current up to 16A.

In order to permit the direct control of the panel from a PC Card or a PLC, secondary 5 to 24 V DC relays are first used to drive the 230 V AC relays, which subsequently control the loads.

D. Monitoring and control system

Using the form of communication described above, two monitoring and control systems were implemented, developed in WinCC and LabView environment. These systems provide, first of all, measurements from the battery and the PV – inverters (voltage, current and frequency of the inverters, state of the batteries etc.). In addition, they can alter the “idle” frequency (f0) and voltage (u0), as well as the corresponding “droop” values (Section 2.3). In this the active and reactive power output of the battery inverter can be regulated. Furthermore, the grid synchronization can be also controlled.

Fig. 3: WinCC control panel

III. DeMoTec

The DeMoTec promotes design, development and presentation of systems for the utilization of renewable energies and the rational use of energy. ISET and the University of Kassel's Institute for Electrical Energy Technology (IEE) have joined forces with companies and other research institutions to perform experiments and demonstrate the state of the art. The latest R&D findings and products, which are mainly related to the generation or consumption of electrical energy, are demonstrated.

A supply technology, which allows series-produced modules from different manufacturers to be assembled together, is presented. By working closely together with companies, ISET develops the basic systems functions required and contributes to the standardization of interfaces. In order to guarantee the suitability of the components, whole supply systems are set up in DeMoTec and compatibility tests are per-formed. ISET also checks and optimizes power supply systems with dynamic load profiles and long-term tests, in order to improve reliability.

DeMoTec mainly focuses on electrification with renewable energies using modularly expandable and grid-compatible hybrid power supply systems. A step-by-step expansion of such power supply systems is demonstrated for applications in developing countries, starting with small isolated systems and progressing to grid connected power supply units. The supply units may be connected via a flexible crossbar distributor.

Remote monitoring and control systems are developed and presented in DeMoTec, which allow the economic operation of such modularly structured supply systems – e.g. by independent power producers (IPP).

To investigate basic issues of distributed generation in interconnected grids, currently additional low-voltage distribution grids, grid simulators and corresponding decentralized generators are being set up.

A DeMoTec master display is being used to monitor the operations of a widely dispersed wind power plant system, which comprises about 80 representatively, selected systems throughout Germany. In this master display, moreover, the remote monitoring of remote isolated systems in Greece and Spain as well as the control of active low-voltage grids can also be demonstrated.

For investigations in the test field a portable energy container can be used. With its PV-diesel hybrid system the operation of small wind mills at an island grid and the evaluation of the monitored data are possible.

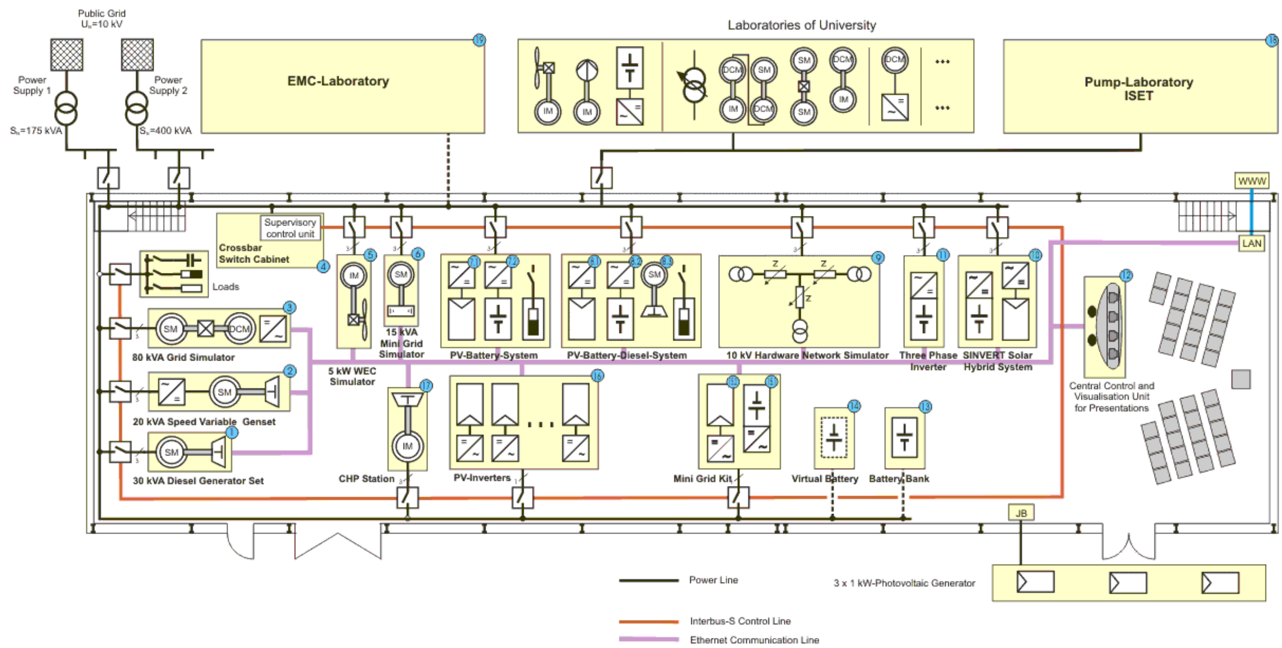

Fig. 4: Layout of DeMoTec facility at ISET

The total available generation capacity is approximately 200 kW. All generators and loads can be connected via a central crossbar switch cabinet to a local grid. Up to three independent grids can be realized simultaneously. These grids may be coupled via a medium voltage network simulator to study the effect of interconnected micro-grids. Control of the connection of the components to the grid, data acquisition, and visualization is managed by a professional software for visualization and industrial process control. The communication needed for this purpose is done via an Interbus-S control line. Extra space is available to integrate custom devices on request.

In order to enable a common control of the generators and to enable a monitoring of the operating states of the system a Supervisory Control and Data Acquisition System (SCADA) for the laboratory network was developed. XML-RPC was selected as communication protocol between the generators, the communication is done via a separate Ethernet communication line.

Fig. 5: View of DeMoTec at ISET

IV. Flywheel Installation at UMIST

Fig. 6 illustrates the hardware topology used in the UNIVERSITY OF MANCHESTER Microgrid/Flywheel energy storage laboratory prototype. The overall system is nominally rated at a 20kVA, although the flywheel and power electronics are rated much higher (100kW).

The immediate work for 2005 has involved the development of control systems for real time control of the Microgrid hardware, using the Simulink/dSPACE control environment.

The design build and commission of the laboratory Microgrid hardware/flywheel energy storage system is now complete.

V. Acknowledgment

We would like to express thanks to the European Commission for their support in the MicroGrids-project ENK5-CT-2002-00610.

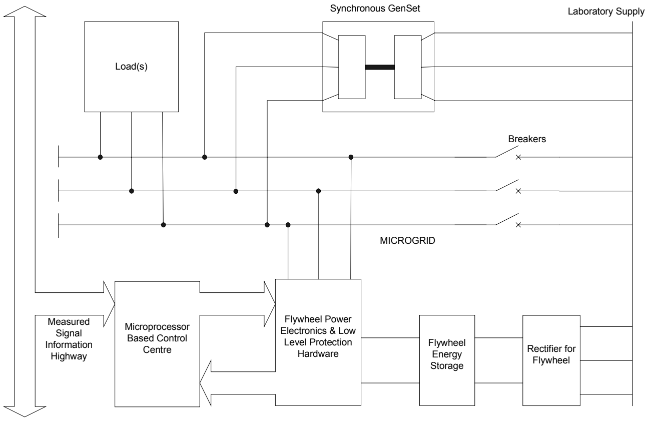

Fig. 6: MicroGrid Layout Schematic at UMIST

Fig. 7: View of flywheel installation

VI. References

VII. Biographies