POWER QUALITY MEASUREMENTS IN MINI-GRIDS INCLUDING PHOTOVOLTAIC UNITS AND BATTERY STORAGE

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1. INTRODUCTION

Autonomous power systems with penetration from renewable energy sources such as photovoltaic units and wind turbines form a very attractive solution for the electrification of remote areas away from the main grid [1]. However, the fluctuating nature of both the generation from renewable sources and the load profile, the existence of power electronic interfaces used for the connection of these sources or energy storage devices as well as the inherent low system inertia, can cause a series of operational problems. These problems are related to the quality of power supplied to the end user and the system stability and efficiency.

The CRES Hybrid Power Plant has been constructed, in the framework of EU projects, for the investigation of ways to cope with these problems in the case of mini grids with high penetration of RES generators. In the following, a presentation of this system is performed, with emphasis on the architecture of the recently upgraded SCADA application. In the framework of the European project “DISPOWER” a series of experiments, for the evaluation of the hybrid system operation under various load control strategies, is in progress. CRES is collaborating with Econnect Ltd. which has provided controllers for the experiments. Some preliminary results regarding the operation of these controllers are presented and discussed.

2. SYSTEM DESCRIPTION

A schematic representation of the power system is shown in Fig.1. As it can be seen it consists of a 4.4 KWp PV unit connected to the grid through an inverter, a 40KWh battery storage unit connected to the grid through a power electronic converter, a 12.5KVA diesel-generator and a load unit.

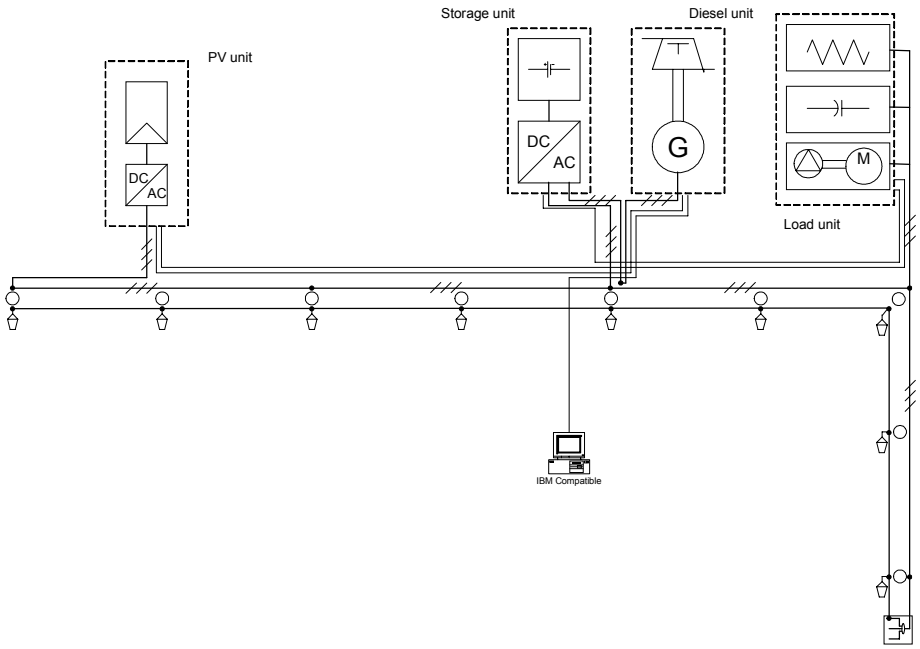
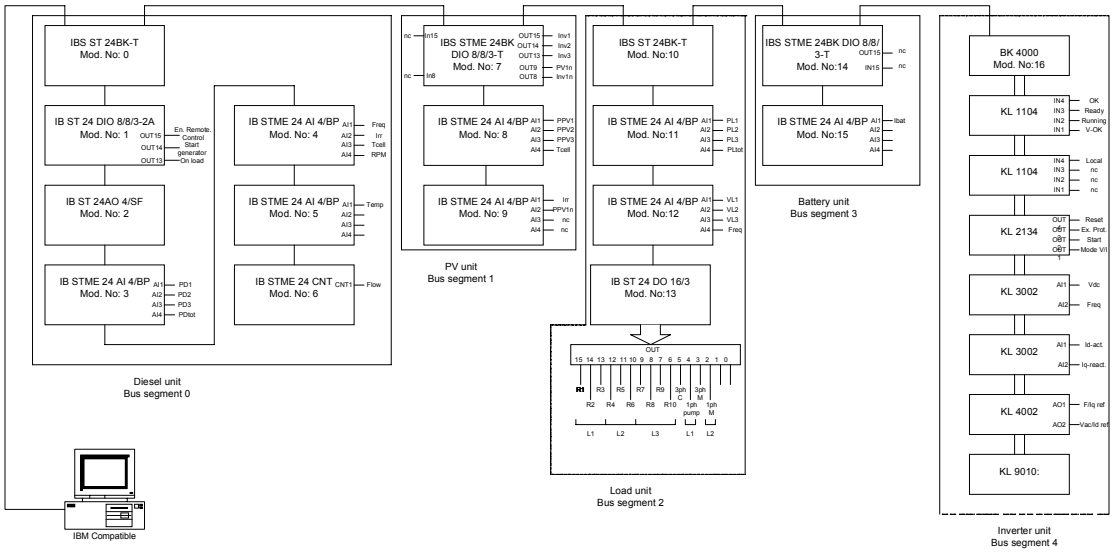


Fig.1.Hybrid Power Plant layout.

The supervisory control system, developed in Labview 6.1 environment, offers the following capabilities:

- Grid monitoring, through the collection of measurements and information about the hybrid system components as well as meteorological information.
- Switching of the power components.
- Automatic operation of the hybrid power system according to a prescribed strategy.

The communication interface between the power system units and the supervisory control system is Interbus. Interbus is a serial bus system for transmitting data between control systems (e.g. programmable logic controllers, personal computers etc) and spatially distributed input/output units to which sensors and actuators are connected. A schematic diagram of the Interbus communication network is shown in Fig.2 .



Interbus-s new configuration (2/2002)

Fig.2. Interbus Configuration.

3. DESCRIPTION OF THE SUPERVISORY CONTROL SYSTEM STRUCTURE

The main software entities of the Supervisory Control System are the OPC Server and the OPC Client. At its lowest level, the OPC server is an I/O driver that can interchange data with the connected physical device (Interbus controller board). When running, the server reads the file once and opens the communication path to the controller board via the driver. Data is read by the controller board and written to the cache of the OPC server. Write access to output variables is distributed to the individual communication processes by the cache and is transferred to the hardware. The OPC client is implemented in Labview using datasocket technology. In order to be able to monitor the harmonic pollution caused by the presence of the power electronic inverters, an energy analyzer has been placed in the load side. This instrument supports the Modbus RTU communication protocol and the Supervisory Control application uses the Lookout OPC Server in order to communicate with it.

4. EXPERIMENTAL RESULTS

In the framework of “Dispower” project, Econnect has developed Distributed Intelligent Load Controllers (DILCs) with communication capability [2]. This capability is

challenging for applications where the power generating devices operate in isochronous mode. Six of these controllers with the appropriate communication interface have been installed in CRES Hybrid Power Plant and different control algorithms have been implemented in order to evaluate their benefits. One of the control objectives was to improve the efficiency of the diesel genset in the face of variations in the power demand caused by the load profile and PV unit. For this reason, a control algorithm has been developed, according to which the DILCs are shedding or connecting their loads in order to keep the diesel generator power equal to 6 KW. The plots in Fig.3A and Fig3B depict some preliminary results from the algorithm testing. As it can be seen, the algorithm operates in a satisfactory manner, since every time the consumer load increases or decreases, the DILC load is controlled and the generator power is driven to the reference value of 6 KW. From a power quality point of view frequency variations are very low, but this is not the case for voltage. Every time that the DILCs are activated, a transient with an overshoot of about 10Volts appear because of the load switching. This effect will be smoothed through the increase of the number of DILCs and their connection with smaller controllable loads. In addition, the battery inverter will be introduced in the grid in order to further improve the power quality of the system.

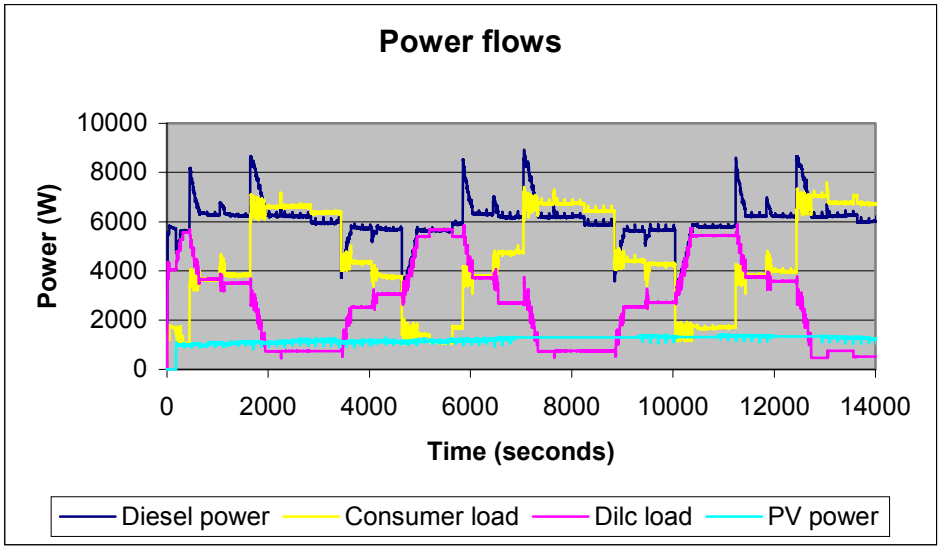


Fig.3A. Experimental results.

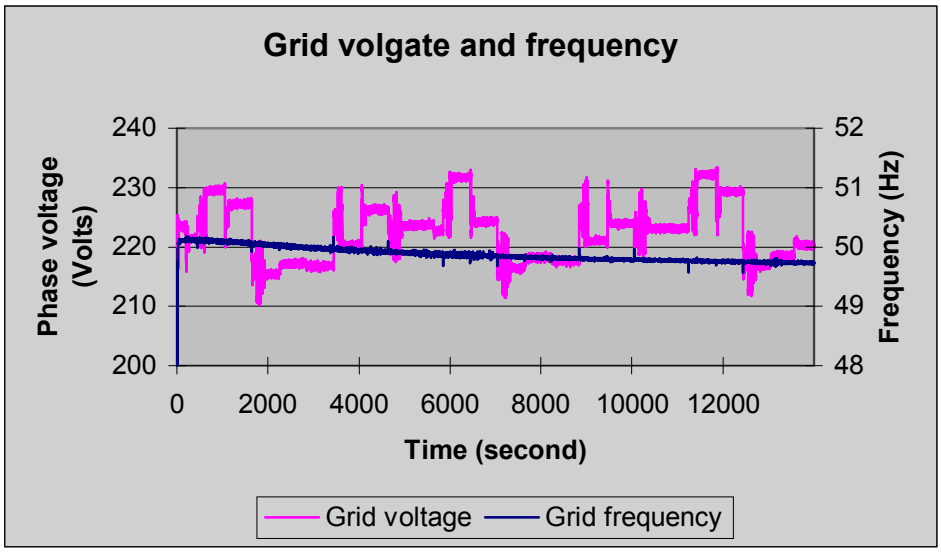


Fig.3B. Experimental results.

5. CONCLUSIONS, FURTHER WORK

A supervisory control application based on OPC technology has been developed for the monitoring and control of the CRES Hybrid Power Plant. This application provides the ability for a detailed evaluation of different control strategies applied in order to optimize the operation of such systems. In the framework of the "Dispower" project, the CRES Hybrid Power Plant will be connected to the public grid. Because of this task, the installation of new equipment (synchronization and protection devices) and the necessary augmentation of the Supervisory Control capabilities (diesel generator control and monitoring of variables at the connection point) are currently in progress.

REFERENCES

[1] Tselepis Stathis, "Electrification Study in Remote Areas with Stand Alone P.V. Systems", Publishable Report for the E.C. project: "Modular Stand-Alone PV Plants for Decentralised Electrification (PV MODE)", Contract No.: JOR3-CT98-0244, CRES, Athens, Greece, September 2001.

[2] Williamson I., Kemsley R., Taylor P., Rollinson D., Tselepis S., Neris A., "Intelligent load control strategies utilising communication capabilities to improve the power quality of inverter based renewable island power systems",", Proceedings of the International Conference: RES for Island Tourism & Water, Crete, Greece, 26-28 May 2003.