Educational Model of a Smart Urban District

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***Abstract**: Sometimes the smart notion is narrowed to the smart metering. Practically the smart phenomenon means a philosophy how to build and operate the power network. In this project we developed a laboratory panel where the different elements of the smart electrical grid is demonstrated, as the power quality meter, the audio and radio frequency ripple control, smart meter, renewable energy generation (PV). The smart grid model can show the operation of the microgrids, so a local balance manager controls the equality of the load and generation. The panel was mounted by the students of the Obuda University.*

***Keywords**: Microgrid; Smart Grid; Smart Devices; Power Quality Monitor*

1 Educational Tasks

At the Power System Department of Óbuda University the new power phenomenon are taught by different laboratory models, as

- Photovoltaic Generation
- Wind turbine
- Pumped storage hydro plant
- Microgrid
- Fuel-cell

The models were developed with the help of the students. The next item will be the new wall board for the demonstration of the Smart Grid theorem. The smart grid defined by the following capabilities:

- Fault recognition before spread over the fault
- Prevention instead of recovery actions
- Local solutions for the system problem

- Distributed measurement, fast communication, auto diagnosis, actions for the stability
- Adaptive protections
- Self healing, auto reconfiguration
- Developed visualisation for control purposes
- Active cooperation with the small energy producers
- Less viability against the external disturbances
- Better power quality
- Integration of more distributed renewable generation
- Better fit to the electricity market
- Better utilisation
- Condition dependent maintenance

In the table model we are going to demonstrate the following smart features:

- Island operation
- Internal generation
- Demand Side Management
- Load/Generation visual monitoring
- Feed back to the utility net
- Load-Generation balance control
- Audio frequency ripple control
- Radio frequency ripple control
- Smart metering
- On-the-line measurements
- Power Quality monitoring

2 The Model

To introduce real off-the-shelf industrial equipments we mount in the model the next Smart oriented products:

- Landis+Gyr E450 multi-energy smart meter
- As home display we use Landis+Gyr ecoMeter EU V1.0
- To show the operation of the Audio frequency Ripple control - RCR 131 HKV

- Radio frequency Ripple control Landis & Gyr FTY243
- Power Standards Lab's PQub**e** - Power Quality and Energy Monitor/Analyzer that detects sags, dips, swells, interruptions and impulses

2.1 The Balance Manager

The load manager acts autonomously – as in the real power system. It demonstrates the No.1. rule of all power systems (small or huge, DC or AC) that the load and generation must be in equal range (see Fig. 1). The status of the individual load elements (households) or generators are indicated by LEDs.

The DC model has external feeding (the "utility network") and has real own PV generation. The power system's automatic balance restoration is solved by a simple bridge electronics that senses the balance deviation by comparators and through relays switches more load or generation (see Fig. 2).

The basic feed in is limited by a small power supply unit. In case of overload some generation capabilities turned on (PV source) or consumption units are turned off. The switches are delayed due to evade the non wanted oscillations. The power situation is changed if the external ripple signal turns on/off some devices or some of the load units are manually switched (see Fig. 3).

The power balance is indicated through a voltage meter. It demonstrates the changes in the consumptions and also the need for the continuous balance restoration. In case of network independent island operation mode the single consumer caused deviation is greater, the operation runs in wider voltage range.

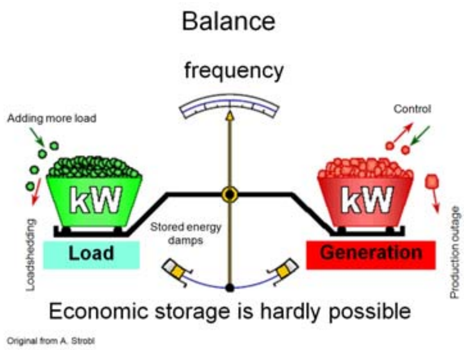

Figure 1
The balance of the AC power system

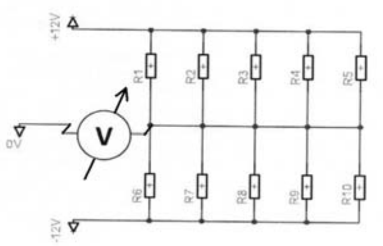

Figure 2
The balancing electronics senses the load deviation

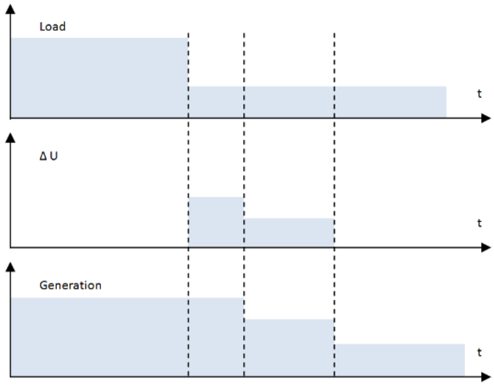

Figure 3
Operation in case of load drop

2.2 The Ripple Control

In Hungary the on-the-power-line operation 183 and 213 Hz audio frequency ripple control devices operate for 30 years supporting the demand side management. Now there are projects for the change of the robust power electronic devices into Long Wave radio frequency controlled devices. Both are switching relays (and loads) in our model. The ripple signals come from the utility net and from the "air" – as a hardly predictable external event.

Figure 4
Landis+Gyr radio frequency ripple control receivers

Figure 5
The DS-40 amorphous panel

2.3 The Small Scale Renewable Generation

On the roof of the building are many PV panels. One of them real-time produces energy in our DC model. This is a DS40 type amorphous panel produced by Dunasolar company. The 40 W panel's free run voltage is 62,2 V, operation voltage is 44,8 V. The solar panel brings a really actual and independent element into the power balance measurements because it depends on the actual weather.

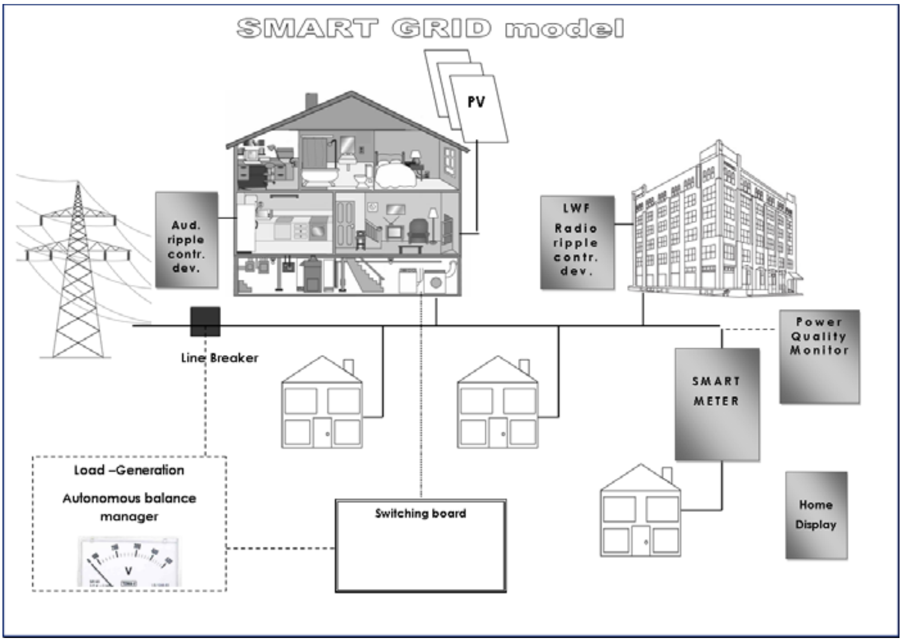

Figure 6
The 1 m times 1,5 m Smart Grid model

2.4 The Smart Meter

The meter demonstrates the digital energy metering and also the Power Line Carrier communication. The PLC operation can be measured by oscilloscope and special tester too. Additional load can be connected to measure real and greater loads. This flexible advanced electricity meter integrates a multi-energy data collector, a remote two-way communication node and a powerful interface to enable end-user interaction. The intelligent devices makes harmonic distortion effect (PLC, Audio Frequency ripple control) that measured by the Quality monitor.

Figure 7
Landis+Gyr E450

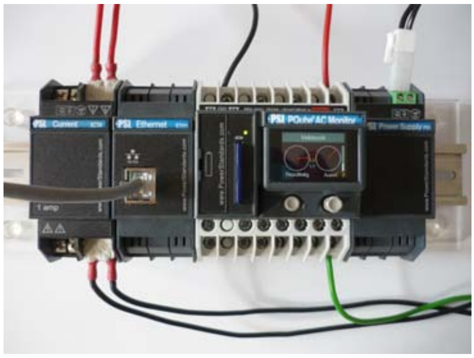

Figure 8
PQube quality monitor device

2.5 The Power Quality Monitoring

The different power quality features are well defined but the traditional monitor devices require special download and evaluation software, so the information stayed secret knowledge of professionals. A new trend makes common all these information. PQube device monitors the Voltage dips, swells, and interruptions, waveforms, over-frequency and under-frequency events, Voltage and current unbalance and RMS Flicker. Calculates, draws and stores RMS graphs, complete energy information data set, daily, weekly, monthly trends, Load duration curves. These values are directly sent to Spreadsheets, Pictures, Text, XML and/or HTML summaries. It is made for non professionals and produces event report automatically in commonly readable form. The data can be transferred through internet or SD memory card.

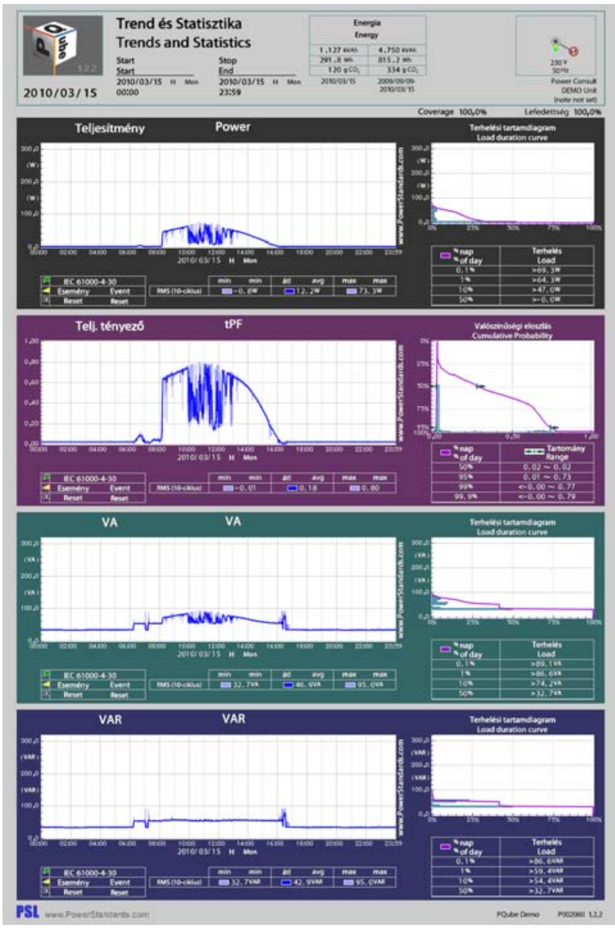

Figure 9
PQube daily power trend statistics of a PV metering

2.6 The Home Display

One of the objectives of the smart metering directive is to make obvious the load customs for all energy customers. Having knowledge about the correlation of the consumption, tariffs, weather situation, market situation the user have the possibility for the self control and voluntarily self limitation of the consumption. The new smart function, the smart display helps the user to control the actual load, informs about the price, makes possible the energy conscious behaviour. It helps the sustainable and semi-green energy production. The home display is a radio frequency controlled easily readable visualisation tool that can participate in other regional information broadcast too as catastrophe alarm or weather information.

Figure 10
Inhome Display Unit – ecoMeter

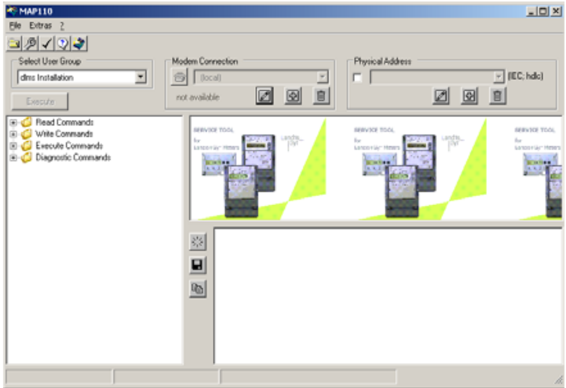

Figure 11
Measurement download and evaluation software

3 Educational Scenarios

The smart philosophy is a common product of the world leading scientists, utilities and gauge producers. In the general high level education this information must be spread over for education the mass of the professionals will work with this matter. From the vendors through the different utilities and the energy consumer institution and offices till the telecommunication side there is an increasing demand for employees with practical knowledge about the smart network.

With the help of this laboratory tool many different lab exercises can be defined. The following features can be taught by this demonstration panel:

- Smart Grid philosophy
- Operation of the Smart Grid
- Demand Side management, ripple control
- Smart metering, smart meter device
- Power quality monitoring
- Smart communication (Audio- and Radio frequency, Power Line carrier, Ethernet/internet)
- Device specific evaluation software tools, etc.

Conclusion

The realisation of this model has been started and planned to be finished in the middle of 2010. The tool is prepared by handwork of students. The work is supported by Metsys Ltd. There are other running ZigBee investigation projects, so in the future some ZigBee controlled devices could be appeared in this panel too. The Smart devices operate locally as part of a great wide area system. Another direction of the future development is the technical cooperation with far away institutions to demonstrate the distributed data collection, evaluation and control – through internet.

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