GREEN CAMPUS – ENERGY MANAGEMENT SYSTEM

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ABSTRACT

The aim of this paper is to describe and discuss about the main objectives and functions of the Energy Management System (EMS) of the Green Campus Smart Grid (GCSG). The main objectives of the Green Campus Smart Grid project are to realise fully functional smart grid (SG) environment, to demonstrate the functions of the smart grid and to function as a test platform for further smart grid related research.
The EMS is responsible for controlling the smart grid devices and applications connected to the smart grid environment. By gathering the information from these devices to the EMS database, it can optimise the operation of the devices by accessing single database? and increase energy efficiency of the smart grid. The database also serves research purposes by offering access to long term data of the devices connected to the smart grid environment.

INTRODUCTION

The smart grid concept is well known method to diminish the unwanted effects of increasing energy consumption, distributed generation installation, energy efficiency, power supply reliability and power quality [1]. However, this creates new challenges in power balancing and protection [2]. While the average load level of a micro grid environment decreases, the power balancing becomes more challenging. The effect of load variation increases in smaller micro grids, while the base load in larger micro grids diminishes the effect. Hence, utilising an energy management system in smaller micro grids like households is mostly recommended for efficient and stable power balancing. However, this requires more intelligence from the electric devices connected to the household for the EMS to be able to control the devices.
The Green Campus Smart Grid is a smart grid environment project in Lappeenranta University of Technology in Finland to implement, research and to demonstrate smart grid functionalities in real low voltage customer network [3]. The overall objective of the Green Campus project is to promote and improve energy efficiency in a campus environment. Several demonstration projects will be developed and used to achieve this objective. The demonstration projects are designed around the following three main areas of Green Campus research and development:

- efficient use of energy and resources leading lower energy use and CO2 emissions
- optimized utilization (reduction) of the grid and generation capacity, and
- everyday energy efficient behaviour of staff and students.

Utilising the low voltage customer network simulates a detached house with three phase customer connection. The main concept of the Green Campus Smart Grid is illustrated in Fig. 1.

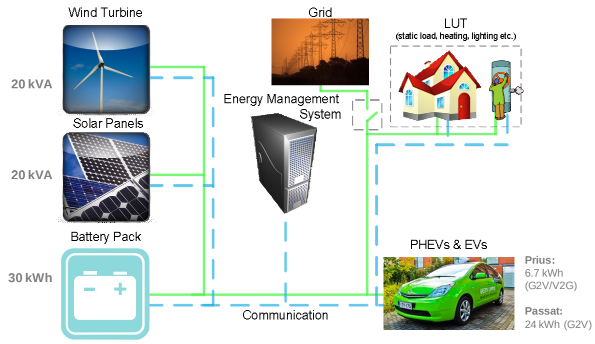

Fig. 1. The simplified structure of the Green Campus Smart Grid.

The main components of the Green Campus Smart Grid are distributed generation, controllable loads, electric vehicles and the energy management system. These smart grid devices and applications are connected to a feeder switchboard to allow accurate measurement and control of the appliances. A switchboard also allows easy disconnection of the smart grid from the distribution network in case of a distribution network fault.
The main communication is implemented with optical fibre network, installing separate fibre for the most important of the devices to ensure the undisturbed communication during disturbance in the distribution system. Part of the communications also operates in the existent university local area network (LAN) in a virtual layer, including only irrelevant smart grid appliances.
The EMS is one of the most essential parts of the smart grid to enable typical? smart grid functions. The EMS is

responsible for gathering data from the smart grid appliances and to process it to optimise the functions of the smart grid. The optimisation can be based for example on the load curve (peak smoothing), price signal (electricity cost minimization) or island operation.

Depending on the optimisation scheme, the EMS can send predefined commands to the various SG-devices. However, the EMS requires a common interface protocol to be able to communicate with different types of devices by using the same command structure. Different types of devices can have various commands and the EMS must be able to identify the device type and the available commands for that specific SG-device.

ENERGY MANAGEMENT SYSTEM

The EMS is a core of Green Campus Smart Grid environment. All the necessary data needed in control and optimization of smart grid operation is processed in the EMS. The EMS in GCSG has a SQL-based (Structured Query Language) database to store the data of all SG-devices. The database includes also information about estimated load curves, stationary loads connected to the SG, priority of the loads, weather forecasts and other necessary data for controlling the smart grid.

However, unlike the typical case where the database structure is constructed in advance, the data of the SG-devices are inserted to the database by the interfaces of the SG- devices. The interfaces are responsible for creating the database structure for the specific SG-devices and identifying the device type for the EMS, removing complex database structure construction for unique SG-devices from the EMS and allowing it to concentrate to the optimisation and control of the smart grid.

In addition to this, different devices can have different communication protocols by default (Control Area Network, ProfiBus, etc.). Hence, the interfaces must be custom made for each of the SG- devices, but since the interface between the EMS and the SG-device is based on the common communication protocol, the EMS does not need any software modifications when installing new additional SG-devices. The only exception is installing a device which has no predefined type class.

In addition, the interfaces of the SG-devices can insert additional information about the devices into the database and accept custom commands from external control clients. The additional data are irrelevant for the EMS but can be used for research purposes. The information in the database can be accessed with an external client, exploiting additional data and giving custom commands to the SG- devices. The concept of the communication structure of the Green Campus Smart Grid is illustrated in Fig. 2.

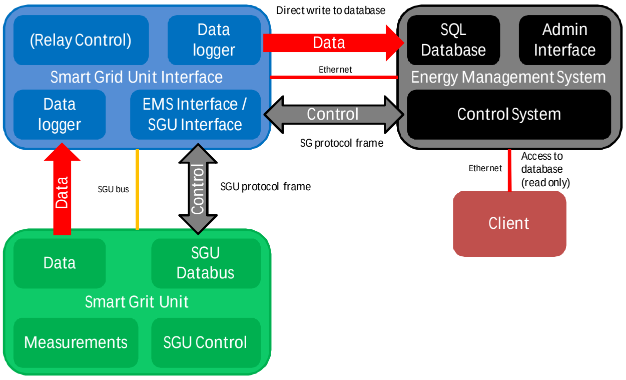

Fig. 2. The concept of the communication structure of the Green Campus Smart Grid.

Communications

The physical communication network is implemented with optical fibre, the most important SG- devices having the fibre installed from the device to the EMS. The usage of the existing information network within the university is minimised for securing the smart grid communication network operation.

The communication protocol (SG-protocol) between the EMS and the SG-device interface is uniform to all devices. However, the SGU interface protocol (SGU protocol) between the SGU interface and the SG-device depends entirely of the SG-device. The PHEV (Plug-in Hybrid Electric Vehicle) has an integrated Smart Grid interface

Table 1. Required background data from different types of SG-devices (x = not available, v = available, - = unknown).

‘ID	TYPE	STATUS	POWER	RATED POWER	SOC	ENERGY	<DATA>
00xxx	Load	x	x	v	x	x	-
10xxx	Controllable load	v	x	v	x	x	-
20xxx	Distributed generation	v	v	v	x	x	-
30xxx	EV	v	v	v	v	v	-
31xxx	EV with V2G	v	v	v	v	v	-
40xxx	Energy storage	v	v	v	v	v	-
50xxx	<Specific device>	-	-	-	-	-	-
…	…	-	-	-	-	-	-
yyxxx	…	-	-	-	-	-	-

which can be modified, but the wind turbine interface, which is implemented by Profibus, is defined by the manufacturer. Even though this requires heavy customisation from each of the SGU interfaces, it also enables uniform communication method between EMS and the SGU interface and allows the full usage of the SG-devices via SG protocol. The basic data required by the EMS are presented in Table 1.

The data required by the EMS for optimisation depends from the type of the SG- device. The information about the status and the rated power is enough to optimise the usage of controllable load, but the EMS requires more information for instance from the electric vehicle (EV) like time of the next estimated departure to be able to optimise charging.

Possible commands for optimisation are predefined by the ID of the SG- device. The two first digits specify the type of the SG-device and the last three numbers gives the SG-device a unique identifier. The ID number is hexadecimal, enabling connecting 4094 different SG- devices of same type.

The data from the SG-device are gathered by the SGU interface and directly updated frequently to the SQL database in the GC server. If the SGU interface does not find any record of previous updates of its specific SG-device, it will create a new row for the predefined ID number of the appliance. The connection to the SQL database is created and maintained by the SGU interface. However, the status of the SG-device is confirmed with a TCP/IP connection.

The TCP/IP connection operates as a control gateway between the EMS and the SG- device. The SGU interface opens a TCP/IP connection to the EMS, identifying itself for the EMS and creating the possibility for the EMS to give control commands to the SG-device. The EMS creates a stack of open connections linking the correct ID for each of the connections. Hence, the EMS can recognise the available SG-devices and control and give commands only to a specific appliance or broadcast a command for all of the SG-devices. Furthermore, the EMS can cross-check the connection, noticing communication line faults or unintentional disconnections of the SG-device and react accordingly.

Information network

Even though the Green Campus Smart Grid fibre optics LAN is installed separately from the existing university network, the two networks is connected each other via GC server. The GC server is a rack server, typically used in data centres. Server is configured to mirror data to multiple hard discs and to perform sequential full backup. The power input is ensure by the uninterruptible power supply (UPS), which maintain server and fiber optics grid switch fully operative up to half an hour during disturbance in the grid.

The most important SG-devices has a separate communication network between the appliance and the GC server via separate switch, but connecting SG-devices is also possible utilising the existing university network LUT LAN. The university network has VLAN (Virtual Local Area Network) for staff members and creating new VLAN for the Green Campus allows easy installation of SG-devices within the existing access points in the university.

The separate VLANs enable secure communication between the EMS and the SG-devices, but the common LAN also allows access to the GC server from the staff VLAN. Hence, the information gathered by the appliances can be accessed by the staff members for research purposes. In addition, the information in the GC server can be also accessed outside of the university LAN using a suitable client.

However, the system has also admin clients for advanced utilisation of the SG-devices. With the admin client, it is possible to give direct commands to the specific SG-devices. Hence, the optimisation algorithm can be bypassed for researching particular behaviour of the SG-device. The scheme of the information network of the Green Campus Smart Grid is presented in Fig. 3.

Control principle

The information required by the EMS to effectively optimise smart grid varies by the type of the SG-device. The load control optimisation can be made mostly based on the status and rated power of the SG-device concurrent with the measurements from the main switchboard. However, higher level optimisation requires more information from the SG-devices and an ability to forecast the consumption based on other information.

For efficient optimisation, the EMS have to take into account weather forecast, EVs driving pattern forecast, load forecast, load measurements and indoor temperature measurements. Also the load priority has to be reckoning with. In addition, the EMS can obtain external control signals like price signal from the electricity retailer or load signal from the DSO (Distribution System Operator). Some of the information is applied by the SG-devices or other services, but the load forecast and EVs driving pattern forecasts is created by the EMS. All the information is implemented in the SQL database in different tables. Therefore, the same information what the EMS optimisation algorithm uses is accessible by the info clients.

The optimisation can be based on several methods. The main optimisations are load curve, price signal and island mode optimisations. However, the EMS can also optimise the smart grid based on energy storages, extending their life time or using more of the capacity.

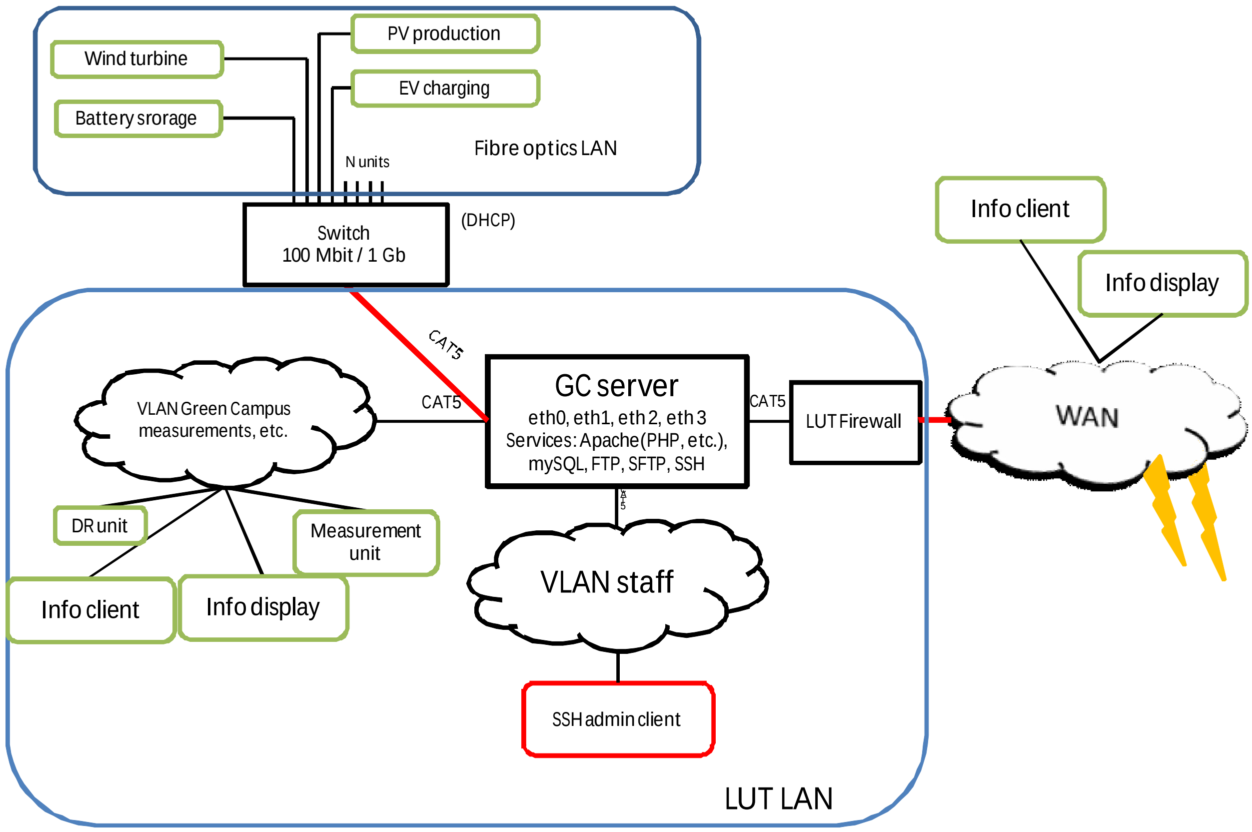

Fig. 3. The scheme of the Green Campus Smart Grid information network.

The load curve optimisation is mainly used for reducing consumption peaks and load transitions, shifting consumption or prioritises certain loads. Price signal optimisation responses to electricity price alteration, reducing or increasing the consumption accordingly and island mode optimisation aims only for sustaining the micro grid in balance.

CONCLUSIONS

In this paper, the Green Campus Smart Grids Energy Management Systems structure and main objectives and functions are presented. The GCSG main objective is to serve as a demonstration grid of smart grid concept and research platform in low voltage customer network.

By utilising individualised interfaces for the smart grid appliances in the GCSG environment, received information and control possibilities for single SG-device can be maximised. The SGU interfaces also enable using common protocol between the EMS and the SG-devices.

Type based ID numbers for smart grid appliances allow easy implementation of additional SG-devices without making any changes to the EMS software. The EMS can also control specific appliance and verify communication connections with the help of the unique ID numbers.

The SG-devices are connected to GC server via GC VLAN in existing university LAN or via optical fibre specifically installed for the appliance. With the SQL database and TCP/IP connections, the EMS is able to optimise the information from the SG-devices and send commands to achieve the wanted optimisation target. Optimisation method can be based on load curve, price signal or island mode optimisation.

The aim of the GCSG project is to form a smart grid environment with ability to implement distributed generation, electric vehicles and controllable load. Furthermore, main objectives are also to be able to interact with these smart grid elements, enabling effective optimisation of the smart grid and possibility detach from the distribution grid sustaining itself for a period of time.

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