Effectiveness Analysis of Microgrid Modules

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***Abstract*- This article describes the microgrid under development at TUT and its links to the distribution network with an electric car. The components of of the microgrid and the modules of the microgrid cost in terms of power and volume are analyzed.**

I. Introduction

Microgrid development in the Department of Electrical Drives and Power Electronics at TUT has been planned to be completed in several years. Previous ideas and plans in this field are described in earlier papers [1], [2], [3] and [4]. This article describes the latest plans for furtherance of the development works resulting from fast advances in the field of microgrid and insufficient resources. Recent developments described in this article also include the charging system for an electric carthat allows bidirectional energy flow between the electric car and the microgrid.

First, the article describes the composition and work principles of the microgrid, followed by an analysis ofthe effectiveness of the basic parts of this microgrid. Effectiveness analysis of the parts enables us todraw conclusions of the effectiveness of the whole microgrid. However, it is not possible to analyze the effectiveness of the whole microgrid altogether because of no microgrid of a similar structure available for comparison.

II. Composition of the Described Microgrid

Figure 1 shows the structural schema of the microgrid described. For clear comprehension, power circuits are plotted with bold lines.

The microgrid described consists of an AC switchboard that connects the microgrid with the distribution network. There are meter-controllers before and after the AC switchboard indicated with the index PG and the order number, the task of which is to measure active and reactive energy, voltage, current, harmonics and etc. Meter-controller PG1 is also capable of measuring the direction of energy flow.

Energy accumulator of the microgrid depicted in Fig. 1 consists of a bidirectional power converter, a DC switchboard, and a stationary battery with the BMS (Battery Management System). The bidirectional power converter can convert three-phase AC current to DC current and conversely. Battery BMS controls the conditions of each battery element, also battery charging and discharging.

Charging post for electric cars is implemented to connect the microgrid with the electric car. As different from other components of the microgrid, it is meant for use by ordinary users, being located separately from other parts of the microgrid. The charging post is supplied from the AC switchboard and also from the DC switchboard, allowing charging of the electric cars with AC or DC current. Naturally different connectors to different sorts of current are available in the charging point.

In addition, the microgrid also contains a microcontroller, switch, GSM-modem, server computer and developer computer. These components are intended to control the microgrid and the band, composing together a controlling device of the microgrid.

Control devices UPS provide uninterruptible power only for the control devices.

III. Work Principle of the Described Microgrid

In normal circumstances the microgrid can be supplied power from the distribution network directly or through other buildings, i.e. the School of Economics and Business Administration Building and Library. Connections with other TUT buildings already exist, so this project will secure better provision of power supply to the microgrid. The connections are described in detail in [1].

The AC switchboard distributes the incoming energy from the distribution network. The protection and switching apparatus of the connected lines is also mounted in the AC switchboard. Feeders 3 and 4 are in the AC switchboard in reserve, to enable new energy supplies and consumers be added.

Energy metering from the distribution network and moving in the microgrid is conducted with a meter-controllers PG that sends the measured information through the switch to the server computer.

In normal conditions the charging post is supplied energy from the distribution network through the AC switchboard and the meter-controllers PG 3 and also through PG2 and the bidirectional power converter and the DC switchboard. At the same time the stationary battery is charged, elements charging of this battery is controlled by the BMS.

If is possible, at blackout in the distribution network energy is supplied from the connections with other buildings of TUT. The working regime of the rest of the microgrid remains the same.

In case of blackout in the distribution network, and when it is impossible to supply energy from other connections, energy flow from the energy accumulator to other consumers of the microgrid is established. At that time, connections with other buildings are interrupted. If in this situation an electric car with fully charged batteries is connected to the microgrid, energy to the consumers of Power Engineering Building is additionally supplied from these electric car batteries.

All microgrid control is automatic. Control programs are in the microcontroller and in the server computer. Messages concerning interruptions in the microgrid are sent to the developers through the GSM modem.

To decrease the needed inputs/outputs of the microcontroller, all devices that need data connection and are capable of direct connection to the switch, are connected directly to the switch.

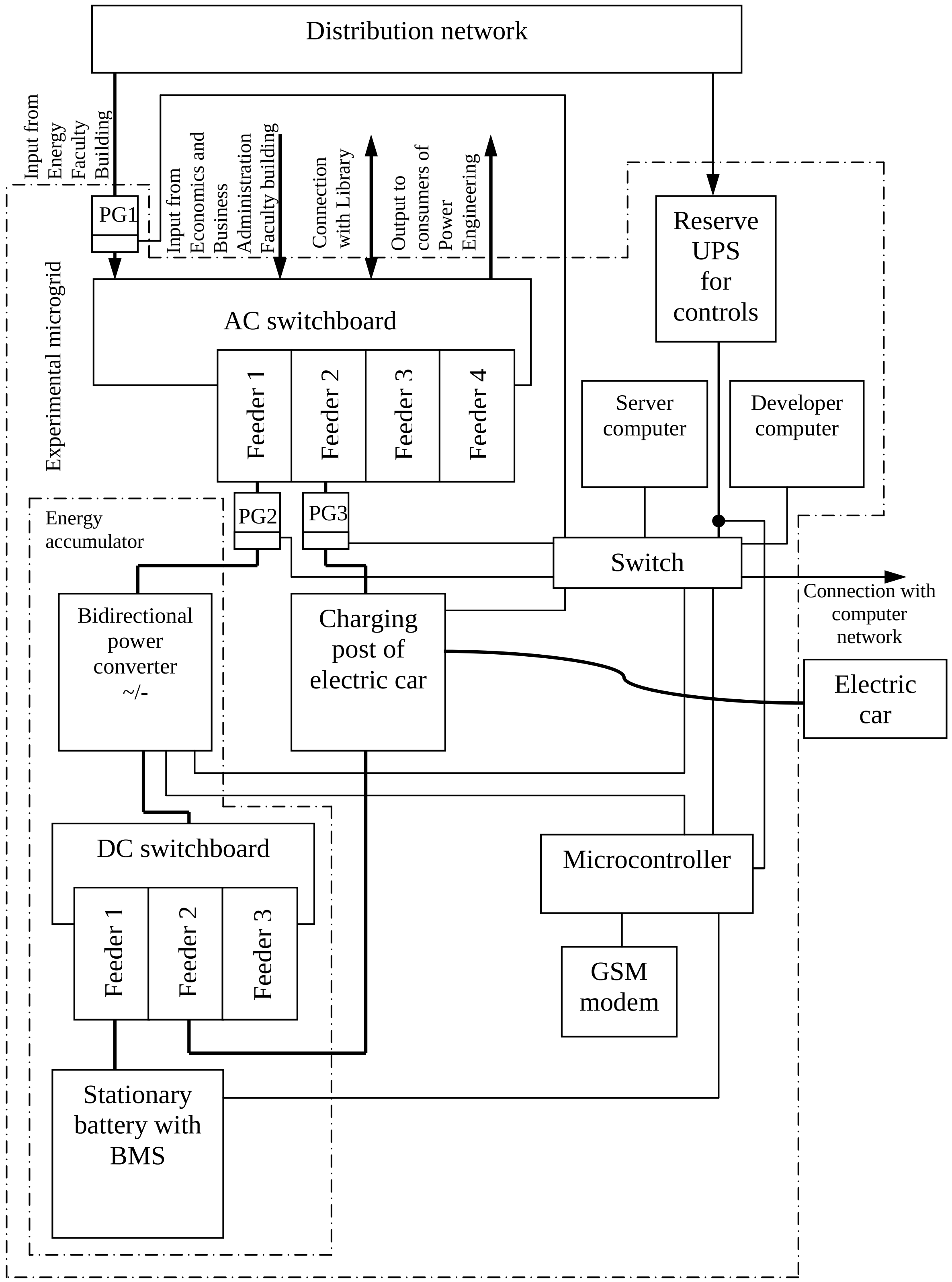

Fig. 1. Structural schema of the experimental microgrid.

Installation of the programs to the server computer, monitoring of microgrid functioning, and if necessary, also correcting work of the microgrid are performed through the developer's computer. However, the developer's computer is not required to be connected with the microgrid at all times, unlike the server computer.

Since the computers that are controlling the microgrid, switch and microcontrollers must have uninterruptible power supply, those devices are connected through the reserve UPS that in normal circumstances are supplied power from the distribution network.

IV. EFFECTIVENESS ANALYSIS OF MICROGRID MODULES

In this article valuable means module cost per some precise technical unit.

All attributes that are important to the user of the microgrid are valuable.

For the user the attributes of the microgrid are valuable: better power supply ability as compared with the distribution network; sufficient power; capability of working with islanded mode; capability of working with other microgrids that work according to the same principles (if interconnections exist) and capability of exchanging energy between the grids; capability of enlarging the microgrid easily; capability of compensating reactive energy; capability of securing of energy metering; capability of keeping important data, especially energy saving data; possibly high universality; as low weight, volume and price of the system as possible; ergonomic design of the system; and as high efficiency as possible.

The following components of the microgrid described in sections II and III valuable to users are analyzed:

- Cost of microgrid stationary battery per energy stored in the battery
- Cost of bidirectional power converter per power unit of this converter
- Cost of bidirectional power converter per volume unit

Effectiveness of the components is considered in this article because these indicators are comparable with other similar indicators. However, today's whole microgrids are not comparable because of their substantial differences.

Cost of the microgrid components described in this article, the basis of the effectiveness analysis, is approximated in Table I Table II shows important technical data.

TABLE I
COST OF MICROGRID DEVICES

Device	Cost [€]
Meter-controller PG1with driving panel	6780
Meter-controllers PG2 and PG3	4800
Bidirectional power converter	22900
Li-ion battery and BMS	12650
Microcontroller	2430
Switch	1170
Computer	1300
UPS	540
Other devices and materials	3080
Summary:	55650

TABLE II
IMPORTANT TECHNICAL PARAMETERS OF THE MICROGRID

Parameter	Value
Voltage and frequency of microgrid	~3L 230/400V 50Hz
Max current inputs from distribution network	250 A
Energy of stationary battery	18,4 kWh
Power of bidirectional power converter	25 kW
Cubature of bidirectional power converter	774dm^3

As can be seen from data in Tables I and II, the cost of a stationary battery per energy unit stored in this batteries 12650/18.4=687.5 €/kWh.

According to literature [5] ordinary lead acid battery cost per stored energy unit is between 38…212€/kWh and for Li-ion battery between 605…1512€/kWh.

Also, data in Tables I and II show that the cost of a bidirectional power converter per power unit is 22900/25=916 €/kW.

Cost of the same bidirectional power converter per volume unit is 22900/774≈30 €/dm^3.

The effectiveness of a bidirectional power converter is compared with a power converter EPV25TP-TR produced in China, calculated on the basis the data from the source [6]. Those indicators are as follows: cost per power unit is 8964/25≈359 €/kW; cost per volume unit is 8964/825≈11 €/dm^3.

Indicators of the bidirectional power converter WE-SFUP [7] from the company Gustav Klein GmbH & Co are as follows: cost per power unit is 64800/150=432€/kW; cost per volume unit is 64800/2000≈32€/dm^3.

Cost of the bidirectional power converter Power Star [8] per power unit is 2997/6≈500€/kW, cost per volume unit is 2997/260≈12€/dm^3. Cost per power unit of another bidirectional power converter [9] with power of 18 kW from the same company is 10034/18≈557€/kW, and cost per volume unit of the same power converter is 10034/353≈28€/dm^3.

V. CONCLUSIONS AND FUTURE WORK

As this research was limited, the most important values of the microgrid in terms of user emphasis were analyzed taking into account the information available. The analysis was faced with difficulties to acquire information on price whereas companies showed their unwillingness to publish their price information.

As a result of the analysis it is clear that the indicators of the planned battery are sufficient. But the indicators of the bidirectional power converters are worse than those of other bidirectional power converters.

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