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THE CONCEPT OF A PROSUMER ELECTRICAL INSTALLATION STRUCTURE IN A MODERN BUILDING

Abstract
This article presents the concept of a smart electrical installation of a prosumer type, designed for modern buildings, especially for civic buildings. This installation can be considered as an element of smart power grids. The external institution plays a special role in the proposed structure in the form of an outsourced energy service provider.

Key words
smart electrical installation, power management, prosumer installations, BMS

Introduction
Today, in a modern building, the role of the electrical installation is not limited only to reliable and safe delivery of electricity to receivers. Equally important is the manner in which the installation works, it should ensure comfortable operating, and above all, fulfill the postulates of rational use of energy. The matters related to the rational use of energy in the context of the issue of electricity supply are discussed in [1]. These goals assumed for the electrical installation can be realized using building automation techniques. The issue of using electricity in the aspect of building revitalization in terms of improving energy efficiency was discussed in [2].

Installation components should react to the changing external and internal factors of a structure, affecting the control of the power receivers. The ability to take optimum actions in response to stimuli defines the "smartness" of an installation in a smart building. The provisions relating to this type of structure are summarized in [3]. At present, the concept of a smart building is extended by the aspect of energy autonomy [4]. According to the directive [5], after 2020, buildings with very low energy demand that are covered at least partially from renewable sources (RES), should be put into use within the European Union. By 2020, about 15% of the energy produced in Poland is expected to come from RES. To meet this requirement, each renovated and newly activated building should have installations providing at least 13% of renewable energy consumption [6].

At present, the creation of an energetically self-sufficient building is not a technical problem, but rather an economic one. Thanks to the decreasing cost of installing RES appliances and unrelenting energy prices, these solutions can become profitable in the future. As pointed out in [7], virtually every power grid can be transformed into a prosumer structure that combines energy consumption with production. The literature mainly presents the concepts of prosumer installations, predestined for residential purposes, such as in [8]. When becoming a prosumer, an energy efficient, smart building, equipped with a power management system can co-create smart power grids. A simulation of this structure is presented in [9].

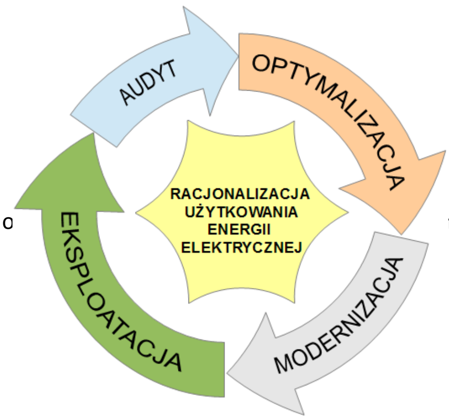
Smart installation
The elements forming a modern smart electrical installation can be divided into:
- Objects like energy receivers (work devices), energy sources (own micro-generation, aggregates, UPSs, energy storage systems, power grid connection);
- Sensors that gather information on the current installation status, internal and external factors and user expectations (connectors, buttons, sensors, detectors);
- Actors such as executive devices, being in direct control of work objects;
- Wiring;
- Elements facilitating supervision over the installation and the security measures.

The following can be used as a medium for the transmission of control and measurement signals [10]:
- A dedicated structural cabling network (including a teleinformatic network);
- 230V power supply installation wires;
- Wireless technologies.

The core of the smart installation is the BMS (Building Management System), which includes the terms BMCS (Building Management and Control System) and BM (Building Management), whereas these concepts refer to a complete control and supervision system.

The BMS system combines the elements of the BAS (Building Automation System) or the BACS (Building Automation and Control System) and the TBM (Technical Building Management), which is also called the SMS (Security Management System). The BACS automation functions ensure the efficiency of control functions for the installation, equipment and any building subsystems, rationally adjusting their power consumption to current requirements [3]. The BMS can be an important part of the building's energy consumption information system [11]. The structure's administrator may have access to professional and independent studies of the building's energy consumption profile compared to other similar buildings in the world. This will allow for the identification of abnormal energy consumption. The next step in using the energy management system may be to prevent users from wasting energy.

It should be noted that for the users to achieve long-term benefits, it is not enough to implement the *BMS* on its own. An improperly configured energy management system can even contribute to an increase in energy consumption [12]. Such a system should be subject to regular audits and optimization, according to the latest developments and technical knowledge. This is due to unavoidable changes in usage, the need to adapt to new trends, user needs, and tenant changes. Cyclical successive stages, such as auditing, performance optimization based on audit results, modernization, and proper operation of electrical installations using the *BMS* are elements that make up the process of rational use of electricity (Fig. 1).



Rys.1. The cycle o n an e

Audyt – Audit; Optymalizacja – Optimization; Modernizacja – Modernization; Eksploatacja – Exploitation; Racjonalizacja użytkowania sieci elektrycznej – Rationalization of the use of the power grid

The concept of the internal power grid of a modern building

Below is an overview of the internal structure of the power grid of a modern building[2]. The complete structure should apply especially in larger buildings and civic buildings. The whole consists of subsystems (modules) that create distributed and centralized structures. A centralized structure includes a superordinate electric power control system and a system of power supply for the installation from a distribution system (SEE). Other subsystems form distributed structures that encompass the entire building. The task of the whole is optimal and rational use of the electricity coming from the SEE and internal micro sources of power (Fig. 2). This task is realized through algorithms within the control automation, based on the idea of an intelligent building.

[2] This concept was created during the implementation of the project „Naukowcy dla gospodarki Mazowsza" ("Researchers for the Mazovian economy"), co-financed by the European Union under the ESF.

Not all modules must be present in a particular structure, the criterion for their application is rationality (economic, technical and reliability reasons). In full configuration, the building plays an active role of a prosumer in the electricity market.

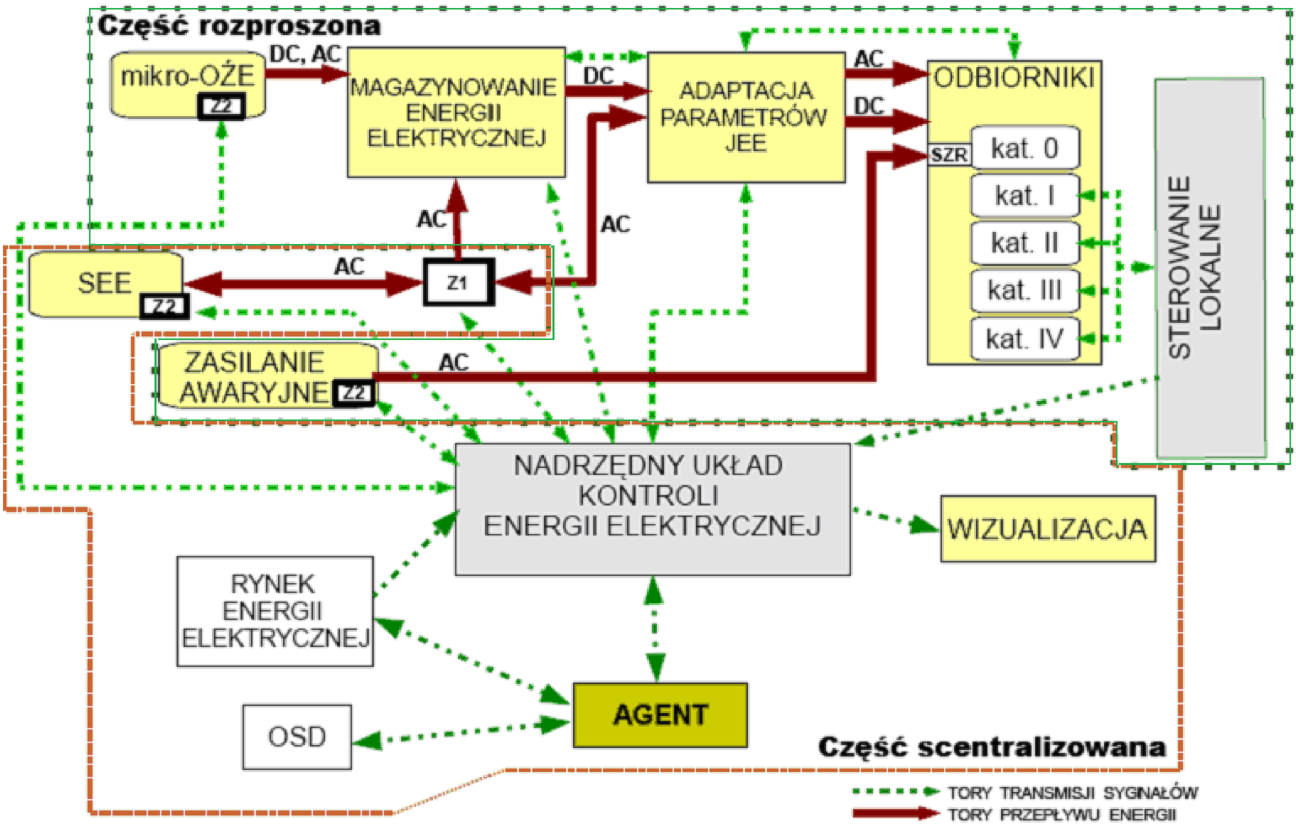


Fig. 2. The structure of the internal power grid of a modern building
Source: The author's own study

szona – Dis- ; mikro-OŹE – maga- energii – power stor- adaptacja jee – adapta- parameters; eceivers; kat. :erowanie lo- – local ınie emergency y; Nadrzędny ıli energii el- uperordinate :rol system; wizualizacja – visualiza-tion; rynek energii elektrycznej – electric power market; część scentralizowana – central-ized part; tory transmisji sygnałów – signal trans-mission tracks; tory przepływu energii – en-ergy flow tracks;

The following describes the individual modules that make up the grid structure.

Agent

An agent is a service-oriented institutional structure that oversees the exploitation and correct operation of all systems, with the ability to intervene in the settings and algorithms of the superordinate power control system on an ongoing basis, to continuously optimize the system and ensure the rational use of energy in the building. Changes can be made based on information coming from the electricity market and customer suggestions. The agent has the power to control category IV receivers by shutting down or running them remotely according to the demand control program (DSM), flexible tariffs, or in conjunction with an electricity distribution grid operator (OSD). By accessing the parent control system, the agent can remotely control all of the system components, including micro sources, that are adapted to this.

The role of an external agent can be played by a company employing a small number of specialists, suitably qualified in the field of energy auditing, energy efficiency, energy use rationalization, power engineering and ICT systems, programs and market analysts. This is a business niche for small and medium-sized enterprises (SMEs) from the services sector. A company with more installations in buildings can aggregate its position in the energy market by creating virtual deliveries and even virtual power plants, gaining a stronger position in the local con-tracting, balancing, or system services market. A company of this type may also offer other electric energy services, becoming a kind of a broker of energy services and an intermediate between the prosumer and the OSD.

Basic tasks:

- Supervision, exploitation, maintenance of the installation;
- Supervision of control systems;
- Forecasting (of energy prices, production from micro sources, user behavior);
- Analysis of electricity consumption and production;
- Cyclical optimization of the BMS;
- Active participation in the energy market - positioning (e.g. stock exchange, system services);
- Creating and controlling virtual receivers and virtual power plants;
- Cooperation with the OSD;
- Making settlements;
- Offering comprehensive (rational) energy use services.

Receivers
Each energy receiver in the installation should be assigned with a set of attributes related to the supply method, the sensitivity to the reliability and quality parameters of the electrical system operation, the possibility of generating power disturbances and the nature of the work, including the energy consumption profile.

Based on attribute values, receivers are assigned to the appropriate categories. The characteristics of individual categories are acceptable power outage durations and the type of automation controlling the receiver (Tab. 1).

Table 1. Categories of receivers

Category	Acceptable power outage	Control automation
0	Unacceptable	Own
I	< 1 s	Local
II	> 1 s	Local
III	> 1 s	Local, Central
IV	> 1 s	Local, Central, Agent
N	> 1 s	None (only manual)

Source: The author's own study

Due to the rationalization of energy consumption, the use of category "N" receivers should be eliminated.
The receiver control automation can be local (signals from limited space, such as a single room, floor), central (signals from the central unit, based on information from the whole structure), or internal (dedicated to specific devices). Some receivers can be controlled by an external agent. Due to the rational use of energy, priority should be given to control signals, in descending order: manual, agent, central and local automation.

Energy sources
Energy sources are small-power (micro-RES) power generators, utilizing renewable energy or recovering energy from the building, often lost as a byproduct of the processes, activities, and behavior taking place during the exploitation of the structure. Examples of technology include photovoltaic systems, solar collectors, small windmills, cogeneration systems, Stirling engines, and energy recovery systems from moving parts of equipment or from emitted heat.

The installation should be connected to the power distribution grid and then a connector and a possible transformer would be included in the system. Depending on the required reliability of the building's power supply, one or two mutually complementary lines can be provided, integrated with the SZR (Samoczynne Załączenie Rezerwy - Automatic Reserve Activation), which in the event of a loss of power from the primary line will automatically switch to the reserve track.

Emergency power supply system
The task of the emergency power supply system is to ensure the continuity of the supply for sensitive (class "0") receivers in the event of a power outage coming from other sources or insufficient energy resources from the ongoing production from the micro-RES. The emergency power supply can be, depending on the need or economic account, a power generator, a large UPS unit, or a UPS-generator tandem.

This system can be coupled to a storage system for the energy produced in one's own micro sources. It can be used in the case of oversupply of the energy generated in relation to the current demand, and when it is not viable to resell it to the grid, or when the electricity supplied from the grid is clearly cheaper and it is cost-effective to retrieve it from the system while running the storage modules. An energy storage system can be created by rechargeable batteries within UPS devices or, for example, using superconducting coils, supercapacitors, batteries (Zn-Br, lead-acid, lithium-ion). The choice of technology is determined by the individual economic account.

System of adaptation of quality parameters of electricity (jee)
The purpose of the system is to adjust the supply voltage parameters of the receivers to the level they require and, in addition, eliminate interference and the possibility of them being distributed along the building's installation to improve the quality of electricity. Another purpose is to install AC and DC circuits.

Some receivers, especially those with electronic components, are normally supplied with DC power, so when there are many it is reasonable to create a separate DC power supply. This eliminates the unnecessary degrees of transformation and equipment, such as converters, power supplies, and rectifiers. The power electronics that make up this system can dynamically improve the quality of the electricity supplied from the grid and from unstable micro sources, and reduce the inactive power dissipation through compensation when a reduction of the current module affects the voltage stabilization. The jee adaptive system can include high harmonic filters (active and passive), active current converters (PFCs), rectifiers, inverters, capacitor banks with thyristor controlled capacitors, passive power converter sources, symmetrizers, conditioners, stabilizers, and soft-start circuits.

Z1, Z2 Connections systems
The systems consist of, respectively:

- A three-state switch, allowing only charging from the energy storage systems grid, only powering the receivers from the grid (through the adaptation of the jee parameters), simultaneous charging from the energy storage systems grid, and the receivers through the jee parameters adaptation system;
- Connector systems enabling the activation of a power supply of a building from a power grid through a connector or from own micro sources (micro-RES).

Local control systems
This is a system consisting of physical amounts sensors and it transmits information to the central system and to individual device controllers, which provide control based on programed algorithms, allowing to rationalize the electricity consumption of the receivers. The system creates the first local layer of automatic control of the distributed intelligence type. Intelligence manifests itself in the ability of controllers in the installation to respond to changing external and internal environmental factors, based on programed settings.

Superordinate electricity control system in the building
This system covers the functionality of the building's electricity management system and plays an overriding role in relation to the Local Control System. It has up-to-date and historical measurement information about the state of the building with the ability to predict behavior. Based on special algorithms, it controls the devices and receivers in the building, optimizing and rationalizing the electricity consumption in a holistic manner. Thanks to higher priority of the control signals, it can affect the use of receivers (classes III and IV), regardless of local control. Based on information about electricity prices, the system makes decisions about how to power the building, increasing or decreasing energy demand from the grid, by regulating the connectors within the Z1 and Z2 systems, and by allowing the return of the energy produced (micro-RES) or stored in the energy storage system to the power grid. If the storage system is also acting as an emergency power supply, the superordinate control system monitors the charging of energy containers with the energy from the grid and/or own sources. The manner of choosing the route of energy inflow is based on a programed algorithm, taking into account the criteria of rationality (technical, reliability and economic). The superordinate system can archive, report and visualize data, including an "energy mirror" function.

Electricity flow tracks
A system of electric wires and cables, separating, receiving from internal sources and the grid, and supplying electricity to receivers or grids, consists of an AC power supply and a dedicated DC power supply.

Signal transmission tracks

The signal transmission tracks are used to transmit measurement information, status signals and control signals. Different technologies can be used, including hybrid solutions such as separate structured cabling, wireless transmission, and power transmission tracks.

Summary

The electrical installation of a modern building should evolve towards an autonomous micro-grid, which can interact with the power engineering system within a smart grid (the concept of buildings included in the Smart Grid network: B2G - Building to Grid). It will then be possible to create a network of co-operating small-scale energy sources. Installations equipped with a monitoring and remote reading system can be rationally and efficiently managed. This requires planning and carrying out organizational changes in the management of the national power engineering system, improving infrastructure, and introducing flexible tariffs.

The concept of the power grid structure of the building has been presented, highlighting the specific role of the element supervising the functionality of the whole system in particular objects. This solution creates the concept of a new business model for the power engineering services industry, predestined for the small and medium enterprises sector.

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THE CONCEPTION OF PROSUMER ELECTRICAL SYSTEM IN MODERN BUILDING

Abstract
The article presents the concept of a prosumer intelligent electrical system for modern buildings, especially for public buildings. This system can be treated as an element of smart grids. A special role in proposed structure comes in an external establishment providing electric power services by outsourcing.

Key words
Intelligent electrical system, energy management, prosumer installations, BMS