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ANN–supported control strategy for a solid oxide fuel cell working on demand for a public utility building

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ABSTRACT

The idea of control strategy of SOFC operating to meet demand of a public utility building was presented. The strategy was formulated with the support of Artificial Neural Network. The network was used to predict the demand for electricity. The calculations were carried out on the example of a building of the Institute of Heat Engineering Warsaw University of Technology. The control strategy is influenced by various factors depending on changes in market conditions and operating characteristics of the cell. We can define different objective functions eg: working for own needs, for maximum profit and maximum service life. The article presents a simulation of SOFC operation for demand profile of the IHE building from the selected time period.

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Introduction

In the face of ever more increasingly stringent standards for greenhouse gas emission electricity producers are forced to seek more and more sophisticated technologies [1,2]. One solution of this problem can be distributed generation, e.g. a biogas [3–5] fueled internal combustion engine [6] is a promising alternative for a small–scale biogas based distributed stationary power generation applications [7]. Until now research on the work of distributed sources covered almost exclusively electrical issues [8–14], including: the impact of disturbances, grid synchronization, and more. While issues related to long-term behavior of distributed sources are poorly researched.

The topics for distributed generation and its impact on energy systems is currently being tested in centers around the world. The development of this area is crucial to the promotion of many so-called clean technologies and this development will force the transformation from prediction procedures to scenario techniques [15]. [8] described what effect has the development of distributed sources on the reliability of the energy system and specifies conditions that must be fulfilled. It was noted that distributed generation can cover customers own needs and could activate their participation in the market game of supply and demand.

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According to [8,9,15,16] we can distinguish following distributed sources: fuel cells; gas turbines; piston engines; Stirling engines; CHP systems based on gas turbines and reciprocating engines [17]; small hydroelectric plants; wind power plants; solar thermal systems (indirect method) [18,19]; photovoltaic systems (direct method); geothermal plants; systems using biomass and waste, tides, marine currents, wave energy and heat.

The article [9,16] analyzed the performance of these devices in terms of technology, economy, operation and environment as well as their impact on the power system. As a result, it was noted that there is a need to build an IT system to manage these sources.

A comprehensive description of distributed generation can be found in Ref. [20]. It concerns on technical integration with the power system, economic aspects, impact of legal issues on distributed generation and also contains a SWOT analysis.

[21] investigates the possibility of the development of distributed energy in Poland as well as agriculture energy. According to the author of [21] these types of generation should be developed in Poland.

Most work related to distributed generation refers to electrical problems and related to cooperation of source with the power grid [9,10].

Production of electricity in DC microgrids using distributed sources was discussed in Ref. [22]. Micrograds were also the subject of [23,24] which highlighted the mutual covering needs for heat and electricity by prosumers. However [25], discusses islanding operation of generators in microgrid. Issues relating to microcogeneration can be found in Refs. [26–30].

The work of the network itself and transmission of electricity in distributed systems were studied in Refs. [10,11]. In contrast, the behavior of a network with connected to it distributed sources in case of emergencies–in Ref. [12].

The work of the CHP (with microturbine and heat storage system) located in Sapporo City University was presented in Ref. [31].

The article [32] describes the impact of changes from parallel to serial connection in the local system of hot water supplying using distributed sources. The proposed solution was to change heat exchanger to heat accumulator in each building to reduce the installed power of sources working on the tested system. Similar topic been dealt with in Ref. [33].

[34] describes the use of heat pumps in the virtual power.

CHP systems using biomass gasification was presented in Refs. [35–38]. In turn [39], investigated the possibility of controlling multiple distributed sources via the Internet and in Ref. [40]—common work of distributed sources in economic terms.

Systems consisting of solar thermal collectors, photovoltaic panels and internal combustion engines fueled with natural gas were the topic of [17]. The simulator of acting in real time connection of distributed source to the power grid was described in Ref. [13].

The work of distributed sources from the point of view of their power and efficiency as well as abilities to operate in cogeneration was presented in Refs. [41,42].

Energy storage is also an important issue of distributed generation. The energy can be stored in many different ways, for example: by using batteries [43–48], flywheels, pumped storage power plants, in the form of hydrogen [45–49], in compressed or liquid air.

Most of the available studies on distributed generation does not contain information on long-term operation of such sources or strategies of its control which takes into account changing market conditions.

Theory

Fuel cell

Distributed generation in recent years has gained importance as an economically viable solution for small power installation, especially as a source of energy for distant locations and without the possibility of connecting to the grid. According to a this trend, fuel cells: polymer exchange membrane fuel cell [50,51], molten carbonate fuel cell [52–58] and solid oxide fuel cell [59,60] are now considered as a competitive alternative to conventional sources [61]. Due to the high operating temperature SOFC and MCFC do not require the use of expensive metals (platinum) as anode catalysts [62,63].

Therefore, the fuel cell degrades rapidly at each start-up and turn off it should operate on the maximum life—continuously. To obtain a reasonable profit or minimize costs cell should not be oversized. Which results in that during the high demand electricity must be supplied from the network or using another source. After analyzing the load of the building under consideration it was assumed that the nominal power of the cell will reach 25.7 kW. This power has been chosen so that a technical minimum of the cell (60% of load) was the minimum power requirement for the analyzed building. In the situation if demand would fall below assumed previously value excess electricity from SOFC [64,65] operating at its technical minimum should be sold to the grid in order to avoid switching off the cell.

The curve presented in Fig. 1 was replaced by the following equation:

$$\eta = -0.3711 \cdot P_{rel}^2 + 0.8421 \cdot P_{rel} \quad (1)$$

where: η—actual (momentary) electrical efficiency of the fuel cell, P_{rel}—relative power.

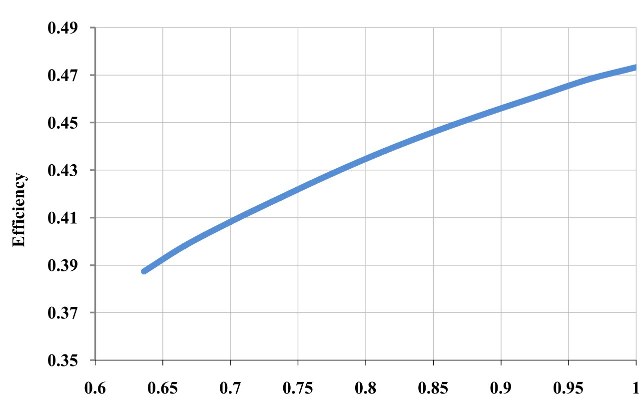

Fig. 1 – Characteristics of SOFC.

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