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DEMAND SIDE MANAGEMENT OF POWER: TECHNOLOGY AND INCOME

From Polish patent application No P.384716 we know the device for measuring the consumption of electrical energy, which allows a supplier and a recipient for the current electrical energy consumption measure reading and the measurement data collecting. In this paper we present the method of energy consumption control and measure. The method realizes the model of the power modes, developed by the authors. We present a proposition of business model for income generation, too.

Keywords: *power modes, DSM, smart metering, energy sufficiency, power modes model, smart grids, distributed control, hierarchical control systems, smart metering and control.*

Даріуш Бобер, Яцек Кеншик

УПРАВЛІННЯ ПОПИТОМ НА ЕЛЕКТРОЕНЕРГІЮ: ТЕХНОЛОГІЇ І ДОХОДИ

У статті описано, що в Польщі було запатентовано прилад (номер патенту P.384716) для вимірювання витрат електричної енергії, який дозволяє одночасно постачальникам і одержувачам вимірювати енергоспоживання і збирати необхідні дані. Представлено метод контролю і вимірювання енергоспоживання. Метод реалізує модель різних режимів енергоспоживання, розроблену авторами. Також представлено бізнес-модель для збільшення доходів.

Ключові слова: *режими енергоспоживання, управління попитом, інтелектуальні вимірювання, достатність енергії, моделі режимів енергоспоживання, інтелектуальна енергосистема, розподілене управління, системи ієрархічного контролю, інтелектуальний облік і контроль.*

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УПРАВЛЕНИЕ СПРОСОМ НА ЭЛЕКТРОЭНЕРГИЮ: ТЕХНОЛОГИИ И ДОХОДЫ

В статье описано, что в Польше был запатентован прибор (номер патента P.384716) для измерения расхода электрической энергии, который позволяет одновременно поставщикам и получателям измерять энергопотребление и собирать необходимые данные. Представлен метод контроля и измерения энергопотребления. Метод реализует модель различных режимов энергопотребления, разработанную авторами. Также представлена бизнес-модель для увеличения доходов.

Ключевые слова: *режимы энергопотребления, управление спросом, интеллектуальные измерения, достаточность энергии, модели режимов энергопотребления, интеллектуальная энергосистема, распределенное управление, системы иерархического контроля, интеллектуальный учет и контроль.*

Demand side management. Electric energy consumption is subject to equation of power balance (1), where power demanded by consumers P_{EC} is balanced by power of generators P_G and where aspects of power looses ΔP_{SL} and power grid cooperation with neighbor's grids P_{EX} are included too. In stable, this equation is quite easy to be maintained, but it is obvious that the processes occurring in the power grid are dynamic (Gladys and Matla, 1999; Paska, 2005):

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$$P_G + P_{EX} + P_{EC} + \Delta P_{SL} = 0. \quad (1)$$

In the situation where there are no economic or technical conditions to increase a level of power supply (usually by infestation into new generators or/and into transmission grids), the side of power demand has been taken into consideration (Kapron, 2007; Kiedrowski and Zabludowski, 2012).

There are many methods to encourage consumers of electric energy to reduce their demand (Bober, 2009b; Gladys and Matla, 1999; Szkutnik, 2010; Sroczan, 2007). The most radical are: total switching off, or a little bit, so called "circular switching off/on". In those methods, users are totally devoid of power, with the all consequences of this forced situation (Bober, 2009a; Gabrysiak, 2004; Gladys and Matla, 1999; Malko, 2006), or to reduce nuisance of electricity lack – the operator use a circular limitation, by switching off one distribution grid for some time, and after that time switching it on and off the next one. This methods are used only in an emergency situation (Malko, 2006; Paska, 2005).

More friendly methods for customers are the ones with a common denominator of energy prices (Bober, 2007, 2009a, 2009b; Paska, 2005; Sroczan, 2007), where by preferential prices in dedicated time or/and date, customers are enlisted to migrate their energy consumption from the peak loads (where prices are high) into the valleys (where prices are low) (Bober, 2007; Gladys and Matla, 1999).

In the second group of methods of power demand side management, the presented model of the power modes and its business model are written in.

Model of the power modes. The power modes model is defined as extraction of the state-of-art of consumers powering (Bober, 2008a, 2008c; Bober and Kapron, 2010). Currently consumers are powered with no possibility to diverse quality parameters of energy consumed (Gladys and Matla, 1999; Malko, 2009). In the most they have no choice to be powered or to be not in lack of electricity situations (Gabrysiak, 2004; Paska, 2005). The model of power modes is defined to resolve that issue.

The model allows distributing electricity consumer powering into some kind of dedicated virtual channels, where "a part" of consumed energy E is associated with a quality parameter q:

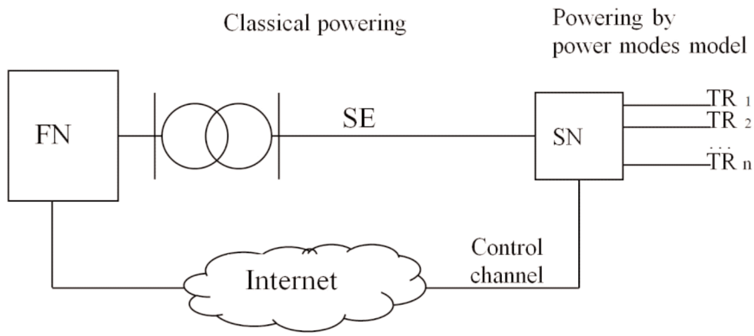
$$TR = g(E, q). \quad (2)$$

The quality parameter q described some individual principles of each power mode TR and the conditions (energy price, hours of access, degree of reliability etc.) of energy consumption by the stuff powered in the power mode. So, the described households could be powered by 3 power modes: protected power mode TRp, standard power mode TRs and economic power mode TRe. The energy consumed by households in the new model (2) will be the sum of the modes:

$$E = E_{TRp} + E_{TRs} + E_{T\,\mathrm{Re}}. \quad (3)$$

This concept is illustrated on Figure 1.

The model of power modes (Bober, 2008c) is similar to another concept of the power consumption distribution – the "UPS model" (Sroczan, 2007), where the author also proposes to separate some individual power lines in commercial buildings and to control them individually according to the energy price and energy sufficiency. The power modes model is a more universal one, designed for any type of electricity consumers.



FN – provider node, SN – customer node, SE – classical power lines.

Figure 1. **The power modes model; logical data are transmitted via electronic channel** *(Bober, 2008c)*

System for measurement and control of electrical energy consumption. Some systems for measurement of electrical energy consumption are known and they are in use till now, e.g. systems for measurement one-phase AC presented in (Gladys and Matla, 1999; Sroczan, 2004). From the Polish patent application No P.384716 (Bober, 2008b) we know the device for measuring the consumption of electrical energy, which allows a supplier and a recipient for the current electrical energy consumption measure reading and the measurement data collecting. This process of data collection is independent of access to common IT systems and the location of measure point (Bober and Kapron, 2009). The invention in its embodiment is presented on Figure 2, in the schematic view of the key elements.

The system for measurement and control of electrical energy consumption has n separated tracks TR_1, TR_2, TR_3, ..., TR_n, preferably 3 tracks, which are connected with powering line *L1* through controllable current relays P_1, P_2, P_3, ... P_n, which are controlled by microprocessor-based data collection and processing system*3*. The microprocessor-based data collection and processing system*3* has a feedback channel*4*, which is the communication channel to exchange data with an external operator through the IP protocol. The microprocessor-based data collection and processing system*3* is connected to the electronic systems LE_1, LE_2, LE_3, ... LE_n for measuring the consumption of electrical energy at each track TR_1, TR_2, TR_3, ..., TR_n individually, the microprocessor system of control and data records has an *LCD* screen*6* to display actual information of the system for measurement and control of electrical energy consumption status and has a set of buttons*7* for interacting with user by displaying context menu on the *LCD* screen*6*, and the supply of power to the tracks TR_1, TR_2, TR_3, ..., TR_n is controlled either manually using the buttons PR_1, PR_2, PR_3, ..., PR_n or automatically via the microprocessor-based data collection and processing system*3* by switching on/off the controllable current relays P_1, P_2, P_3, ..., P_n.

The operation of the system to measure and control consumption of electric energy is such that a single powering line *L1* is split into n separated tracks TR_1, TR_2, TR_3, ..., TR_n, preferably 3 tracks, and with each track of secondary side there is assigned a quality parameter which informs about a power mode of electric energy the track is powered. Each of the tracks TR_1, TR_2, TR_3, ..., TR_n of secondary side is indi-

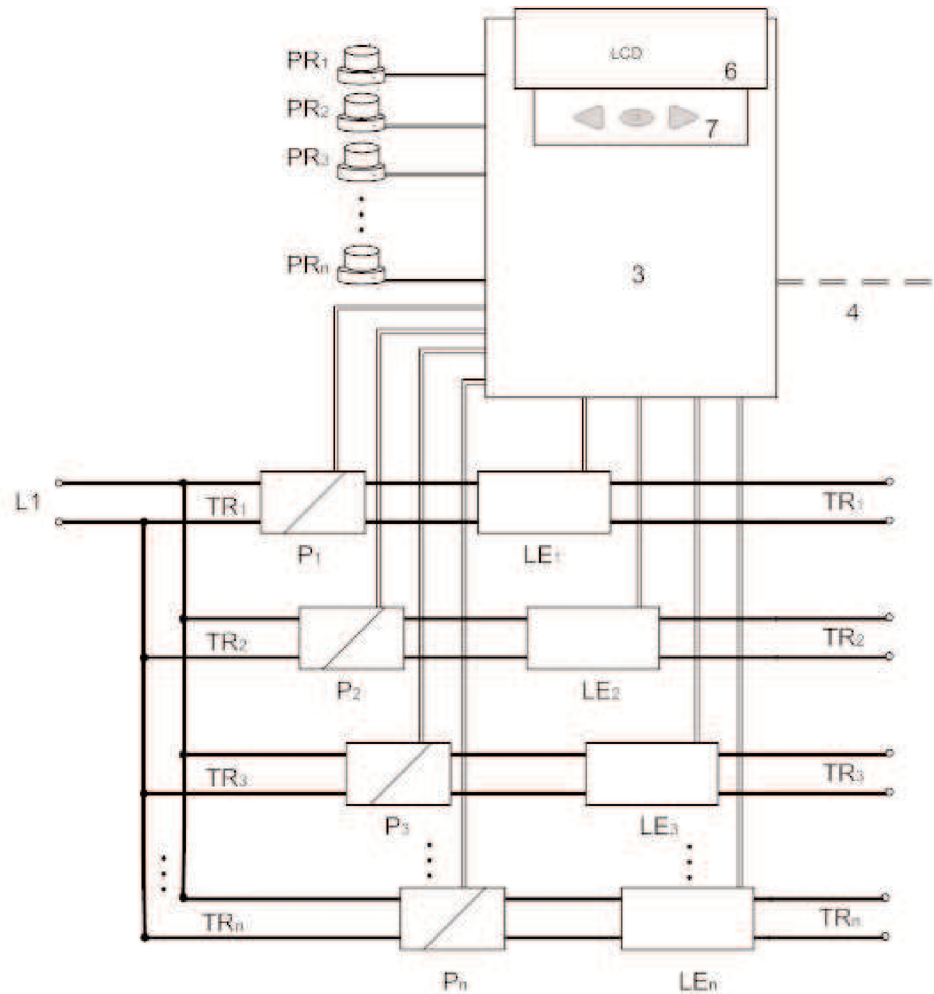


Figure 2. **The diagram of system for measurement and control of electrical energy consumption** *(Bober, 2008b)*

vidually measured by the electronic systems LE_1, LE_2, LE_3, ..., LE_n for measuring the consumption of electrical energy, and the measure data are recorded in persistent memory located inside the microprocessor-based data collection and processing system*3*. The microprocessor-based data collection and processing system*3* records the measure data of electrical energy consumption of each of *n* tracks separately and stores this data both: cumulatively and with precision to the desired step of integration. The communication channel*4* to exchange data with an external operator through the IP protocol allows for two-way communication, from the system unit to external operator and back (Janicek, 2004). The electronic messages are exchanged in scalable structures of *XML* files. Such form of communication ensures uploading measurement data containing information of the electric energy consumption at each track TR_1, TR_2, TR_3, ..., TR_n in direction to external operator, and, in the feedback direction, downloading the data describing the values of quality parameters assigned to individual tracks TR_1, TR_2, TR_3, ..., TR_n, and other data significant in the energy management process for large numbers of customers equipped with the systems to measure and control consumption of electric energy. The system to measure and control consumption of electric energy initializes a communication transaction with remote operator in desired step of replication time, every time there are processed exchange the measure data of electric energy consumption for a period since the last successes transaction of communication and there are downloaded values of the quality parameters sets. The microprocessor-based data collection and processing system*3* parses the downloaded data and takes interpretation of quality parameters values and basis of that data the microprocessor-based data collection and processing system*3* takes control over the availability of power supply into individual tracks TR_1, TR_2, TR_3, ..., TR_n of secondary side by switching on/off the controllable current relays P_1, P_2, P_3, ..., P_n, which control the availability of power supply of correspondent tracks TR_1, TR_2, TR_3, ..., TR_n. The system to measure and control consumption of electric energy allows for manual control of power supply into individual tracks TR_1, TR_2, TR_3, ... TR_n of secondary side independently of the communication channel*4* to exchange data is available or not. This is realized by buttons PR_1, PR_2, PR_3, ..., PR_n for manual control, which manage the state of controllable current relays P_1, P_2, P_3, ..., P_n. The buttons PR_1, PR_2, PR_3, ..., PR_n switch on/off a correspondent controllable current relays P_1, P_2, P_3, ..., P_n and in this way control the availability of power supply of correspondent tracks TR_1, TR_2, TR_3, ..., TR_n of the secondary side. The system to measure and control consumption of electric energyhas an *LCD* screen*6* to display actual information about electrical energy consumption of each tracks TR_1, TR_2, TR_3, ..., TR_n of secondary side and some important information of the system to measure and control consumption of electric energy status are displayed there too. Moreover, the system to measure and control consumption of electric energy has a set of buttons*7* for interacting with users of the system by displaying the context menu on the *LCD* screen*6*.

Business model for income generation. In the previous chapter we described the method of how the system to measure and control consumption of electric energy interoperates with master system of power provider. Although, there is a mechanism of central coordination of energy consume in this method, but this mechanism is not mandatory. The consumers' independence couldn't be limited by the proposed method.

So how, the consumers will cooperate with the "power off" communicates, delivered via electronic channels? The model of power modes (2) makes assumption that only a part of the consumers will agree to reduce the level of their electric energy consumption. They will reduce energy consumption for some individually preferred time, and they switch off some electrical receivers. That means the power modes model determinate some kind of platform of business information exchange rather than the platform for data acquisition and control.

The power modes model allows for interoperation between power providers and clients. Provider distributes the actual prices of energy unit in each mode, and the well-informed consumer decides (himself or his intelligent computer system does that) which devices should work under the current conditions of powering.

If we assume, that the parameter q in the power modes model definition (2) describes a risk ρ of power limitations. The risk will be the lowest in the protected power mode ρ_{TRp} (4). The risk ρ_{TRp} of no electricity in this mode is much lower than in the standard mode. The highest risk ρ_{TRe} of power limitation is in the economic mode.

$$\rho_{TRp} << \rho_{TRs} < \rho_{TRe}. \quad (4)$$

An increased degree of energy security in the protected mode *TRp* means that even under the situation of power deficit in the power system, the devices powered in that mode will have ensured the continuity of energy supply. This privilege is accompanied by the increased level of the energy price in the protected mode ρ_{TRp}:

$$\rho_{TRp} >> \rho_{TRs} > \rho_{TRe}. \quad (5)$$

And the consumers who decide to power their devices in the economic mode will pay the lowest price ρ_{TRe}, but they should calculate the risk of power limitations (4).

The proposed business model would work even in old buildings, where there is no chance for general renovation, or the owners are too old to operate with advanced technology. For them, to implement the proposed model, the minimum is to install an intelligent measure unit, with functionality described in the previous chapter. For them the information on prices could by displayed by classic media, e.g. TV. A proposition of the graphical information with current power modes prices, displayed on the screens of TV sets is presented on Figure 4.

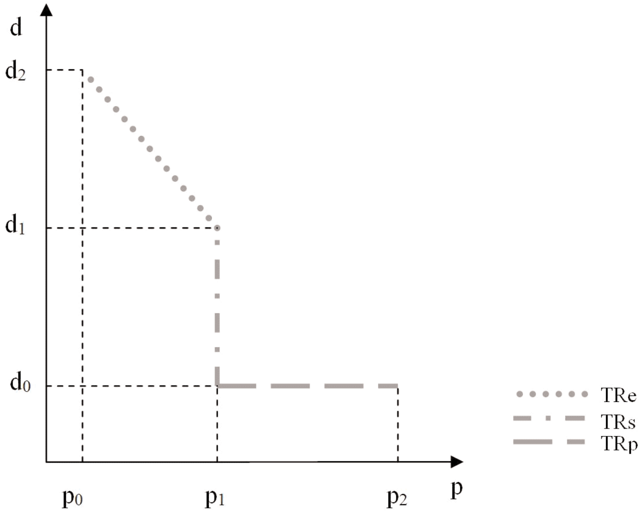


Figure 3. **The proposed model of energy price in the power modes**

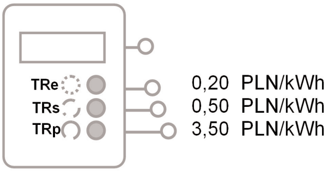


Figure 4. **A proposition energy prices in each power mode**

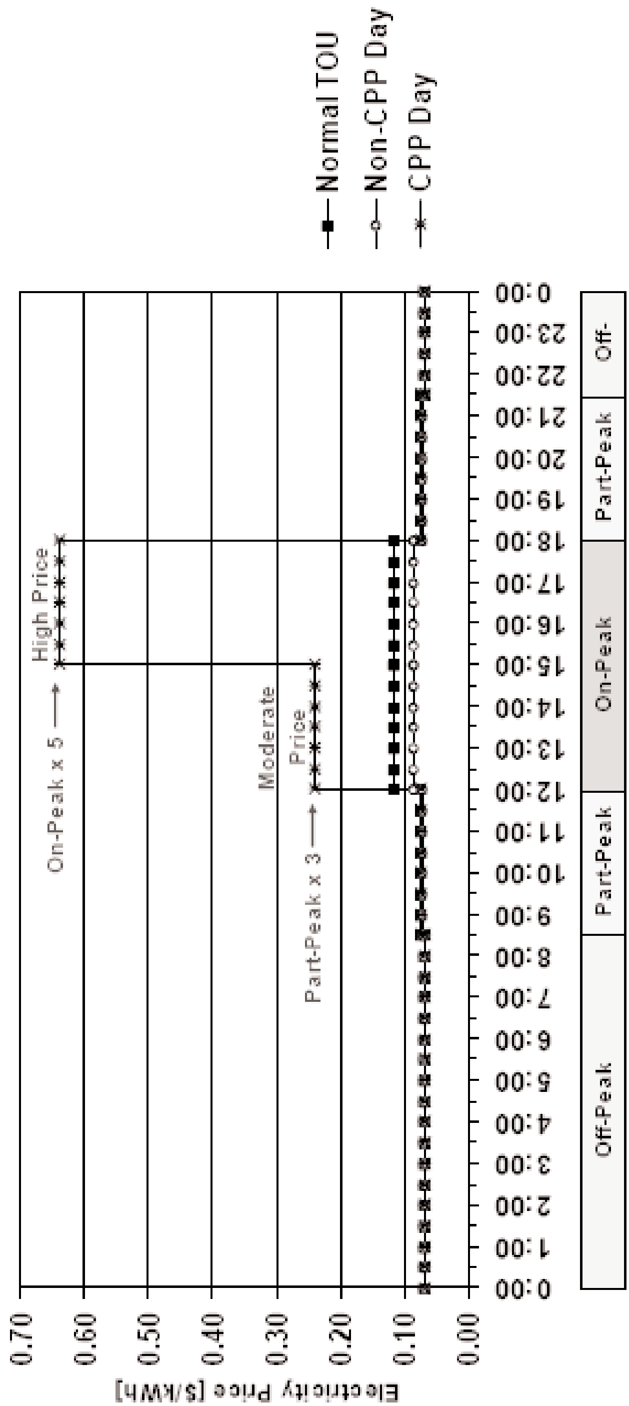


Figure 5. **Critical price peak, a possible effect of real time prices** *(Piette at al., 2006)*

The measure unit, which works offline, will archive the history of the consumer behavior. The final price of energy will be calculated by retrospection, after the history of measures will be manually downloaded by a collector.

The bases for the thesis that customers would like to cooperate with energy suppliers upder the presented busines model is the fact that after the automated metering infrustrusture (AMI) implementation (Billewicz, 2007; Janicek, 2004; Malko, 2009; Szkutnik, 2010), it is rather possible that suppliers will offer the electric energy in a real time prices (see Figure 5), like it has been done in the USA (Piette at al., 2006). Then the proposed model of price (and energy) distribution into the power modes is more operable for customers. They can choose in which mode they will power their receivers, and if the price of some mode will be unacceptable, this mode will be switched off.

Conclusion. The positive effect of the invention is that the system for measurement and control of electrical energy consumption allows for separation, from a uniform power line on the primary side, to n tracks at the secondary side, preferably 3 tracks, which are qualitatively different from each other and thus allows for practical implementation of the new method of electrical energy supply by power modes.

The customers of electric energy would knowingly participate in demand side management of the power system. By choosing the economic power mode customers make the declaration on the part of their energy consumption which can be reduced in situation of power limitation. The same mechanisms would be used by suppliers to balance the power.

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