

Design of marketing system of control by energy consumption modes at the retail power market

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Abstract – The methods of managing the modes of electric load for structural levels of the power system were examined. The effectiveness of marketing approach of forming the energy efficient modes of power consumption in transformed model of power market were proved. The levels of segmentation of the retail power market were grounded, the relevant criteria for consumers' segmentation considering their specifics of power consumption mode regulation were determined. The significance of criteria was proposed to consider in calculation of differentiated prices.

Key words – power market, market segment, mode of power consumption, criteria for segmentation, differentiated prices system.

I. Introduction

Reformation and liberalization of national power market of Ukraine stipulate urgency of creation of effective mechanism of management by the modes of energy consumption for providing of permanent balance of demand and supply at the market of electric energy (EE).

Therefore, the special actuality is acquired by the increase of effectiveness of methods of purposeful management by electricity load over time at all level of electrical power system (EPS).

II. Analyzing of recent researches

Researches [1-4] devoted to equalize daily schedule of electrical loads (SEL), focused on only one specific area or a separate method and, as a result, does not give the tool of complex influence on all groups of consumers at power market.

So, in [2] the shown efficiency of management SEL of industrial consumers by a technical and technological method, and in [3] were proved to efficiency of priority-step method of equalizing SEL. In [4] were marked that for the management by daily demand at the retail power market (RPM) it is necessary to attract technical and technological, information and propagandistic, economic and others methods. A considerably anymore effect from these methods can be expected at their complex application at all level of EPS - from elementary power consumers to united power system (UPS) as a whole.

In the conditions of transition of power market of Ukraine from a «unique buyers (pool) market» to competition «bilateral agreements and balancing market» [5], where the long-term forecast demand on electric

energy (EE) will be based on the analysis of control by energy consumption in accordance with technology of production; and clarification of the expected demand with the contracted deliveries based on the medium-term prognoses of the modes energy consumption on next days (spot market), and current demand and supply on power in the real time accord at the balancing market. A base price on EE for every separate consumer will be formed on market principles of maximal concordance of demand and supply on EE in the real time.

In such a market model, are increasing the role of marketing of control the supply and demand for power market [6, 7]. Thus, subsequent perfection of needed both system of the segmentation of the RPM, so and pricing on EE.

III. Purpose of work

Justification of levels of segmentation of the RPM, selection of adequate criteria for segmentation, development of the flexible pricing systems in under uncertainty and associated marketing levers for create energetic efficiently mode power consumption at all levels of EPS.

IV. Material and results of research

For the effective work EPS it is necessary permanently to support the EE balance in the real-time mode; the complex of the managing actions directed simultaneously at all structural levels of EPS (Fig.1) will be facilitate that.

For the first level will take production operation, because it integrates separate consumers and electrical equipment involved in investigated period of time SEL.

As the second level may be accepted the technological process which summarizes the power consumed by operations.

On the 3-rd level is considered a separate consumer with the commercial account EE is examined, as market unit for energy companies (EC).

The nodular substation is the 4-th local level of EPS, which feed on completely absolutely different, but territorial near consumers.

The 5-th level are formed 26 EC, which conduct independent economic and financial activity on production, transmission and distributing of EE.

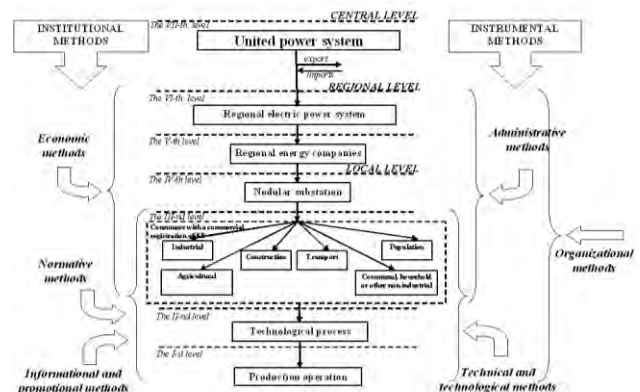


Fig. 1. The methods of control SEL on the structural levels of the EPS

The 6-th level is formed by 8 regional EPS, which are interconnected interstate lines of electricity transmission.

At the highest, 7-th level of UPS, territorial limited by the scopes of Ukraine aggregate of power-stations, power systems and other objects of power, which are incorporated by the centralized management for providing of the general balance of EE.

It should be noted that determining forming influence on the SEL of EC is played by 1-3 levels EPS, as every higher level integrates power $P_E(t)$ of lower level, and his SEL is superposition of the SEL of inferior constituents [8].

Therefore forming SEL of UPS and EC it follows to begin $P_E(t)$ of 1-3 levels with the management by power. (For example, equalizing SEL of separate consumers, on principle of superposition, leads to equalizing the graphic EC in resulting).

For every level EPS it follows to find the most effective levers of influencing by determination of priority of application of methods of adjusting of control by energy consumption and selective sensitiveness of levels of hierarchical to EPS structure to each of methods of influencing, which is determined by the degree of financial, technical, ecological, social or other expediency.

For to manage use of the electricity rationally using instrumental methods of direct effects and indirect effects of institutional methods (Fig. 1), which create conditions for stimulation of regulation [8].

Technical and technological methods [9] are most applicable for the 2-th level.

The organizational method of equalizing of resulting is SEL, by the mutual change of his constituents in the cooperative store of loadings for the concerted implementation of the total graph of loading of cooperative store on the whole [5], for example mutual change of the graphs of two technological processes, two separate enterprises, regional EC and others like that. A method can be applied at some structural level EPS – from 1 to 6.

The use of administrative methods is expedient then, when a market mechanism and economic facilities adjusting appear insufficient or operate not enough quickly. For example, is the forced disconnection of consumers of 2 and 3 categories, correction of the seasonal counting out of time, limitation of day's demand, etc.

Normative methods are substantiating specific values of expense of energy and carry out the control after their observance. A method can be applied at 1-5 level.

Informational and promotional methods include measures on popularization of aims and maintenance of adjusting (for example is idea of power independence of Ukraine, power marking of products, etc.).

Economic methods use the aggregate of financial and economics' instruments which purposefully influence on volumes and processes of energy consumption; thus, the role of main regulator is carried out by a price on EE [7]. More effectively all economic methods can be applied at 3-6 level.

Development of market relations in energy requires introduction of marketing approaches to work with consumers on the basis of segmentation at power market. The successfully conducted segmentation will allow: to take into account the specific of consumers of different segments at forming of the differentiated price policy; to

promote flexibility of management by the modes of energy consumption; to multiply exactness of prognostication of level and character of demand on EE for support of permanent energy balance [7].

Segmentation of the RPM and the formation system of differentiated prices (SDP) rationally conduct according to six levels for the RPM segmentation (Fig. 2):

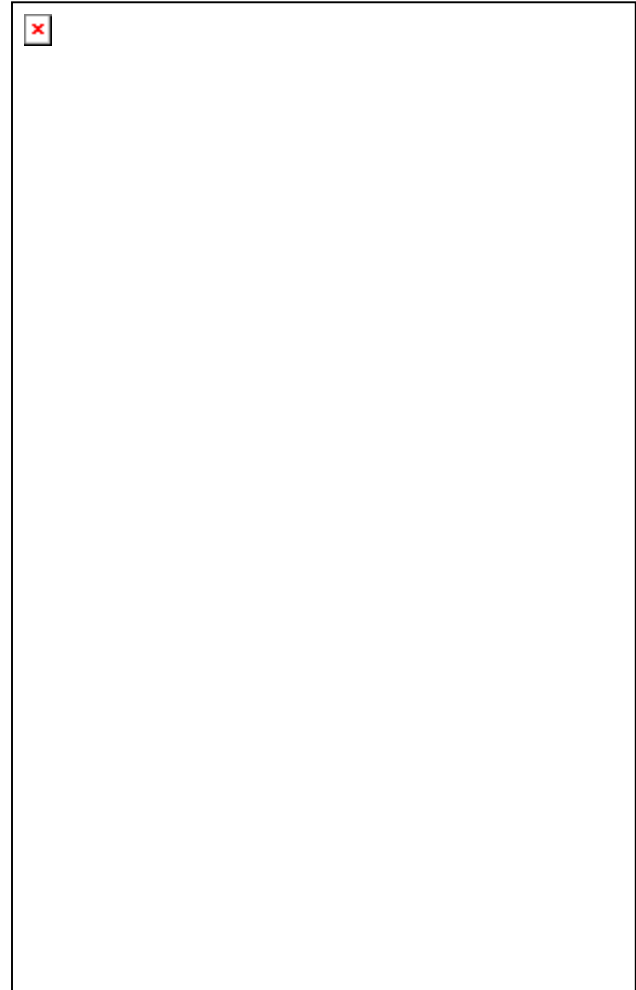


Fig. 2. Segmentation of consumers the RPM on 5 levels in accordance with the criteria $X_1 - X_5$.

The **I-st** level is segmenting the degree of impact of consumer's SEL on SEL of UPS;

The **II-nd** level of segmentation is done by separating consumers of energy (CE) on the uneven mode power consumption during the day;

The **III-rd** level of segmentation CE - the ability regulatory mode over time;

The **IV-th** level of segmentation CE - the financial and economic situation of the consumer;

The **V-th** level of segmentation CE - amount of power consumption.

In accordance with the foregoing, it is possible to offer 5 main criteria for segmentation of the RPM:

– as the 1-st criteria adopt the impact of CE is appropriate generalized indicator X_1 , which is functionally dependent on two coefficient:

$$X_1 = f_1 (K_{KOP}^C, \eta), \quad (2)$$

where K_{KOP}^C – is coefficient of mutual correlation SEL of separate EC and the SEL of UPS, in that K_{KOP}^C characterizes the measure of coincidence of their forms, $\eta = P_{CE,i} / P_{OEC,i}$ – is coefficient of influencing of certain EC on common consumption of the electric power UPS in the i -th period of time, $P_{CE,i}$ – is level of power of certain EC in the i -th period of time, $P_{OEC,i}$ – is level of the general power UPS;

– as the 2-nd criteria adopt degree of irregularity mode power consumption of CE is appropriate generalized indicator X_2 , which is functionally dependent on two coefficient:

$$X_2 = f_2(K_{3T}; K_{HP}; K_{\phi}), \quad (3)$$

where K_{3T} – filling factor of SEL; K_{HP} – coefficient of inequality; K_{ϕ} – shape factor of SEL;

– as the 3rd adopt the ability of regulatory mode applicable at the time generalized index X_3 :

$$X_3 = f_3(\gamma^{MAX}; \tau), \quad (4)$$

where $\gamma^{MAX} = \Delta W^{MAX} / W^{MAX}$ – is relative potential ability EC to decrease energy consumption in the spades area SEL of UPS, ΔW^{MAX} – is potential diminishment of energy consumption in the peak area due to the purposeful adjusting of the mode of energy consumption, kW·h, W^{MAX} – is initial volume of energy consumption in the peak area, kW·h, τ – is value of the maximally possible change SEL in time, h;

– as the 4th criterion of the financial and economic state of the consumer we will adopt the index X_4 :

$$X_4 = f_4(\beta; I_{OPII}; \varphi), \quad (5)$$

where $\beta = V_{EC} / V_C$ – is degree of the economic personal interest of consumers in the management by demand on EE, which is determined by the particle of charges on its payment V_{EC} in the general charges V_C , $I_{OPII} = I_{\Phi AKT} / I_H$ – is level of payment of the consumer for EE, $I_{\Phi AKT}$ is actual payment of consumer for electric power for the certain interval of time (month or year), I_H is size of necessary payment by an consumer in obedience to the actual volumes of energy consumption, φ is dynamics of payment in time (monthly, quarterly and others time);

– as the 5th criterion on the quantitative indexes of energy consumption we will apply the index X_5 :

$$X_5 = f_5(\omega_{CI}^3; \omega_{CI}^I; b), \quad (6)$$

where ω_{CI}^3 is volume of the EE consumption for a winter regime day, ω_{CI}^I is volume of the EE consumption of a summer regime day, $b = \prod_{i=1}^n (b_i)^{1/n}$ – is rate of growth of volumes of the EE, relative units, b_i – is the common consumption EE in the i -th period of year, n is amount of years which calculations are conducted for.

Segmentation of the national power market in accordance with 5 main criteria $X_1 - X_5$ provides a basis for forming of individual SDP in every segment (Fig.2).

For today the CE majority works with the coefficient of the correlation $K_{KOP}^C \rightarrow 1$, causing uneven available SEL of UPS. Therefore, segment $0 \leq K_{KOP}^C \leq 1$ is major for UPS in terms of regulation.

Inasmuch at forming of segments is present a linguistic vagueness, which complicates the relevant ranging of values of criteria, and also stipulates uncertainty of expert in ranking near values of criteria, it is necessary to carry

out segmentation with the use of theory of fuzzy logic. For evaluation variables were selected three linguistic terms (L -"low", M -"medium" and H -"high") of the trapezoidal membership functions.

Thus, in the segment with $0 \leq K_{KOP}^C \leq 1$ were formed the three subsegment with the following membership functions:

– for L:

$$\mu(X_L) = \begin{cases} 1, & X \leq X_{cL} \\ \frac{Xd_L - X}{Xd_L - X_{cL}}, & X_{cL} < X < Xd_L \\ 0, & X > Xd_L \end{cases} = \begin{cases} 1, & X \leq 0,2; \\ \frac{0,4 - X}{0,2}, & 0,2 < X < 0,4; \\ 0, & X > 0,4. \end{cases} \quad (7)$$

– for M:

$$\mu(X_M) = \begin{cases} 0, & X < Xa_M; \\ \frac{X - Xa_M}{Xb_M - Xa_M}, & Xa_M \leq X < Xb_M; \\ 1, & Xb_M \leq X \leq Xc_M \\ \frac{Xd_M - X}{Xd_M - Xc_M}, & Xc_M \leq X \leq Xd_M; \\ 0, & X > Xd_M. \end{cases} = \begin{cases} 0, & X < 0,2; \\ \frac{X - 0,2}{0,2}, & 0,2 \leq X < 0,4; \\ 1, & 0,4 \leq X \leq 0,6; \\ \frac{0,8 - X}{0,2}, & 0,6 \leq X \leq 0,8; \\ 0, & X > 0,8. \end{cases} \quad (8)$$

– for H:

$$\mu(X_H) = \begin{cases} 0, & X < Xa_H \\ \frac{X - Xa_H}{Xb_H - Xa_H}, & Xa_H \leq X \leq Xb_H \\ 1, & X > Xb_H \end{cases} = \begin{cases} 0, & X < 0,6; \\ \frac{X - 0,6}{0,8 - 0,6}, & 0,6 \leq X \leq 0,8; \\ 1, & X > 0,8. \end{cases} \quad (9)$$

The interval $[Xa; Xd]$ is optimistic assessment parameter and that spacing $[Xb; Xc]$ is pessimistic.

On the first stage, consumers with most values K_{KOP}^C among which most influential there are consumers with greater η get out from this segment. For the economic stimulation CE to reformation of the mode, for them SDP-1 is developed, using K_{KOP}^C and η in the formulas of calculation of the maximum values $C_{MAX,1}$ and $C_{MIN,1}$ [4].

The part of CE will avail SDP-1, realizing the proper adjusting; for other CE it is necessary to involve the 2th, more deep level of segmentation (fig. 2). For this purpose, from the segment of $3 \leq 0 \leq K_{KOP}^C \leq 1$ consumers are exposed, with the most uneven graph of energy consumption; from these CE form the segment of the II-nd level and develop for them the special SDP-2 in the function X_2 .

On the next stage is selected consumers with high ability of the γ^{MAX} adjusting of own SEL. The CE search is carried out at first, able to decrease «peaks» loading; from these CE the separate segment of the III-rd level is formed, and for remaining ($\gamma^{MAX} = 0$) research is conducted of possibility of additive change of them SEL in time. On the basis of the offered criteria and develop for them special SDP-3 in the function X_3 . For creation at the consumer of high motivation it is necessary to adjusting, that the range of differentiation of price was proportional to the index of γ^{MAX} or τ . Then, correlations of extreme values of prices for the subsegments of the III-rd level.

Among remaining CE from the segment expose those, which can manage SEL, but not enough explained to the management and is conducted the IV-th level of

individual segmentation on the financial and economic personal interest.

An economic sensitiveness to differentiation of prices depends on the financial and economic personal state of consumers. For example, for those consumers, at whom charges on payment of SEL are relatively insignificant, motivation it is necessary to strengthen by the special SDP-4.

For CE, at which payment for electric power (V_{EC}) arrives at 50...70% from general charges, does possibility of even the insignificant EE price abatement cause substantial interest, but for CE with $V_{EC} \leq 15\%$ question of economy of charges on EE is not priority. With the purpose of increase of the personal interest of the last, by us the individual are grounded for each CE $C_{MAX.5}$ and $C_{MIN.5}$, coming the condition of their break-even activity from [4].

As the transition to deeper levels of segmentation appropriate to comply with the ratio $C_{MIN.1} > C_{MIN.2} > C_{MIN.3} > C_{MIN.4} > C_{MIN.5}$ and, respectively, $C_{MAX.1} < C_{MAX.2} < C_{MAX.3} < C_{MIN.4} < C_{MIN.5}$, allowing to strengthen the CE stimulation.

Thus, implementation of marketing approaches to the CE segmentation and establishment of individual SDP in most degree stimulates CE to the management by the own modes of energy consumption and energy saving.

Conclusion

1. Differentiation 6 methods of management after the degree of their influence on SEL of each of 7 structural levels of the EPS allow to select basic (primary) and auxiliary (secondary) among them, and also promote forming energy efficiency of modes of energy consumption.

2. Determined of levels of segmentation and account of values of criteria of the RPM segmentation at the calculation of the differentiated prices allow to stimulate consumers to forming of the energy efficiency graph of the electric loadings.

Application of theory of fuzzy logic promotes exactness of differentiation CE with the near values of criteria of segmentation.

References

[1] V.P. Rozen and M.V. Prokopets', "Vykorystannya vnutrishnykh rezerviv tekhnolohichnykh protsesiv pry keruvanni rezhymamy elektrospozhyvannya promyslovykh pidpryyemstv" ["The use of internal resources processes in control the electric power in industry"], *Avtomatyziatsiya vyrobnychykh protsesiv*, no. 1(22), pp. 26 – 30, Jan. 2006.

[2] B.S. Serebrennikov and K.G. Petrova, "Upravlinnya rezhymom elektrospozhyvannya promyslovykh spo-

zhyvachiv z vykorystannyam tekhnolohichnoho resursu" ["The control of the electric power consumption of the industrial enterprises with the use of the technological resource"], *Elektrotehnika ta elektroenerhetyka – Electrotechnics & Electroenergetics*, no. 1, pp. 70 – 76, Jan. 2013.

[3] B.S. Serebrennikov and K.G. Petrova, "Udoskonalennya kryteriyiv priorytetno-krokovoho metodu rehulyuvannya elektro-spozhyvannya" ["Improving the criteria of priority-step method regulation of consumption power"], *Elektrotehnika ta elektroenerhetyka – Electrotechnics & Electroenergetics*, no. 1, pp. 65 – 69, Jan. 2012.

[4] B.S. Serebrennikov and K.G. Petrova, "Formuvannya dynamichnykh tsin na elektroenerhiyu zalezno vid nerivnomirnosti hrafiku elektrospozhyvannya" ["Formation of dynamic electricity prices depending on uneven schedule power consumption"], *Enerhetyka ta elektryfikatsiya – Energetics & Electrification*, no. 10, pp. 18 – 23, Oct. 2012.

[5] A.V. Prakhovnyk and O.V. Kotsar, "Keruvannya rezhymamy elektrospozhyvannya v umovakh zaprovadzhennya v Ukraini rynku dvostoronnnykh dohovoriv ta balansuyuchoho rynku" ["Control power consumption modes in implementing market in Ukraine bilateral contracts and balancing market"], *Enerhetyka ta elektryfikatsiya*, no. 2, pp. 42 – 52, Feb. 2010.

[6] Ye. Krykavs'kyy, N. Kosar and L. Moroz, *Marketynh enerhozabezpechennya [Marketing of energy supply]*. Lviv: Lvivska politehnika Publ., 2001.

[7] V.H. Herasymchuk and B.S. Serebrennikov, "Marketing pricing policy at the electric power market" in *Proceedings of the 5th International Scientific Conference "Marketynh ta lohistyka v systemi menezhmentu"* [Marketing and Logistics in system of management]. Lviv: Lvivska politehnika Publ., 2004. pp. 60-61.

[8] B.S. Serebrennikov and K.G. Petrova, "Differenciacija metodov upravlenija jelektropotrebleniam po strukturyum urovnjam jelektrojenergeticheskoy sistemy" ["Differentiation of method management power consumption by structural levels of electric power system"], *Energoberezhenie•Energetika•Energoadit – Energy saving • Energy • Energy Audits*, no. 6 (112), pp. 21 – 28, Jun. 2013.

[9] K.G. Petrova and S.V. Serebrennikov, "Ranzhuvannia metodiv upravlinnia rezhymamy elektrospozhyvannia za ekspertnoiu otsinkoiu" ["Ranking methods of control mode of power consumption according to expert estimates"], *Enerhetyka i avtomatyka – Energy & Automation*, no. 2 (16), pp. 1–6, 2013. [Online]. Available: http://nbuv.gov.ua/j-pdf/eia_2013_2%2816%29__14.pdf. [Accessed Jun, 2013].