LOAD CURVE SHAPING USING DSM OPTIONS

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Abstract - This paper presents results from the energy market research connected with demand-side management programmes. On the basis of achieved results, conditions and possibilities of introducing a DSM programme could be formulated. Activities considered in the research have been connected with energy storage and tariff incentives. Those options could allow to achieve a preferred shape of the load curve from the local utility and a customer's point of view. Analysis of possibilities of application of those options has been based on a special measure and opinion poll researches. The surveys were aimed to describe the load profile and preferences of customers from a residential sector. Achieved results have determined conditions and possibilities of introducing initially selected DSM programmes in the chosen part of a local energy market in Poland.

Keywords - demand-side management, load curve, local energy market, end-user, utility

I. INTRODUCTION

Transformation of the Polish energy sector was one of the main reasons for energy to be treated by the utilities as regular consumer goods. Management in the competitive circumstances also requires new utilities' attitude to the energy trade and distribution. In the new conditions of activity, utilities should pay more attention to effectiveness and reliability of the management process. From the economic and technical point of view the main purpose of the utility is to increase the profitability and to decrease a risk of an energy distribution and trade services. It is also necessary to take into consideration customer's requirements and preferences (low energy bills, high quality of service).

Taking into account a peculiarity of an energy market and utility products special tools in the management process should be used. One of those techniques is demand-side management (DSM). Considering the requirements of the Polish energy law (tariffs, competition market, justified costs), utilities should aggregate reliable data for preparing their own price structure and future strategy. Utility, obligated by the domestic energy law regulation[1], has to include also DSM options in their load managing process. Those kinds of actions also allow energy distributors, operating at the competitive energy market, to keep their customers closer to the company. From the utility perspective DSM actions should allow to control load growth (especially peak load) and alter shape of the load curve. Thanks to DSM it is possible to satisfy end-user needs. Those kinds of programmes could bring benefits also for a non-participants, i.e. society, environment.

Successful implementation of these activities depends on tailoring DSM programmes to individual customer profile and needs. Because of different customer attitudes, a problem of costs and profits sharing that is connected with DSM programmes implementation, the application of load control options should be supported by careful research of energy demand structure and customer preferences [6]

II. PROGRAMMES FOR LOAD CURVE SHAPING

Programmes presented in the paper are connected with basic DSM techniques:
- peak clipping,
- valley filling and load shifting.

In authors' opinion those techniques could be realised by the following options:
- electrical energy tariff incentives,
- controlling heat storage on a customer level,
- electrical energy storage on a substation level.

It was supposed that thanks to those actions it is possible to shape a load curve and to achieve a preferred, from the utility perspective, load profile in the separated part of the local energy market. All of chosen activities aim to shift a load from tariffs peak periods to off-peak periods (Figure 1).

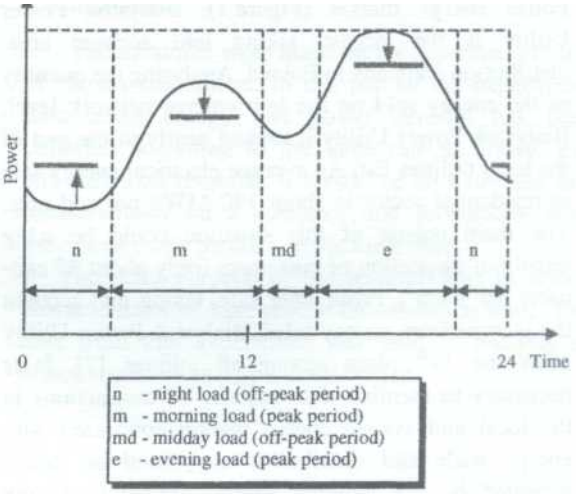

Figure 1. Simplified load profile with tariff periods

[1] Act *Energy low,* 10.04.1997

The first initially chosen DSM programme assumes that through diversification of energy prices in tariff system it is possible to influence on the load profile. The idea of the following option is based on controlling of heat storage devices, which are used by customer from the residential sector. The idea of that action consists of adjusting the time of use heat storage devices to tariff time structure. The third option uses battery energy storage. Through that programme it is possible to control and change power demand profile (profitable, from the utility perspective). Furthermore, use of BES should increase distribution ability of the local utility (power delivery with minimum and justified costs) [1].

In order to evaluate possibilities of application of those options, special measure and opinion poll researches were carried out. Data achieved from that research could be used in process of formulation of conditions and possibilities of introducing DSM programmes in the local energy market.

The paper presents the key effects of a main part of survey which have been done. It should be also underlined that number of DSM programmes prepared and applied in Poland, practically two, are practically not significant comparing with the number of similar activities introduced by western utilities. So there is no any special know-how base connected with those kinds of programmes, which are taking into account conditions of the evaluating energy market in Poland.

III. PLACE, PURPOSE AND RANGE OF RESEARCH

It was supposed that DSM programmes considered in the experiment would be analysed from perspective of a local utility. Therefore a research was carried out in the separated part of a local energy market. Regional branch of the Bialystok Power Utility operates on the chosen part of the local market[2]. That company is a one of 33 local utilities operating at the Polish energy market (Figure 1). Bialystok Power Utility is the largest, taking into account area, distribution company in Poland- Analysing the quantity of the energy sold on the low voltage network level, Bialystok Power Utility is ranked nearly at the end of the local utilities list. An average electrical energy sale in residential sector is about 190 MWh per end-user. The main reason of this situation could be a big territorial dispersion of customers (only about 23 end-users per 1 km^2). From other side, taking into account the income from energy sales, Bialystok Power Utility takes the 17th place among all utilities [7]. It is necessary to mention that majority of transactions in the local and system energy market connected with energy trade and distribution are based on prices accepted by the national energy regulator. At the present stage of the energy sector transformation, majority of customers are not allowed to choose a supplier. Therefore it is impossible to say that Polish energy market is truly competitive market. From DSM point of view, features of the energy market play a basic role in the process of application and estimation of those kinds of activities.

Figure 2. Territorial structure of trade & distribution of energy sector in Poland

The regional utility branch, where the research was carried out, operates on the 421 km^2 area and serves about 127.000 users (about 300 end-users/km^2). This regional branch is the biggest urban branch in the Bialystok Power Utility. The majority of customers of that branch are from the residential sector (88,8%). The energy usage of this group is about 30% of the total energy sales in the chosen branch. Only about 11% of the end-users belong to the commercial and industrial sector. There is no customers connected to the 100 kV networks in the chosen division.

Taking into account an idea of initially chosen programmes and specification of the regional branch, research should be carried out first of all among customers from the residential sector. Polish tariff system gives utilities the possibility to account end-users from that sector according to two-period tariff and one-period tariff[3].

The basic analysis of electrical energy usage in the residential sector indicated that energy demand of customers counting for the energy according to G12 tariff is almost two times higher than the rest of consumers from this group. The basic figures about those tariffs are given in the Table 1. Price of the electrical energy in two-period tariff is strictly dependent on time of usage. According to an idea of multi-period tariff system it should be an incentive for the customer to shift a load to a valley period.

[2] Utility should be treated as an energy trade and distribution local company (an abbreviation from Polish *ZE).*

[3] In Polish tariff system Gil is used as a symbol of one-period tariff, G12 is used for two-period tariff for the customer from the residential sector

Table 1. Comparison of tariff charges in the residential sector (customers with 1 -phase meters)

Type **of** main **tariff charges**	**Type of tariff**		
	Gil	**G12**[4]	
	nvenly four how	peak period	valley period
Fixed distribution costs (per month), *[USD]*	0,22	0,75	
Variable distribution costs, *[USD/MWhJ*	32,91	37,91	4,67
Electrical energy rate of charges, *[USD/MWh]:*	37,70	39,93	29,40
Total eostgf electrical energy. *[USD/MWh]*	**70,61**	77,84	**34,07**

Authors decided to choose for the survey customers, which are accounted for the energy according to G12 tariff. It was supposed that customer choosing that type of tariff is willing to control the energy demand more other customers. The other reason to choose a residential sector is because of the number of customers and number of DSM programmes designed for this group.

The additional criterion was the place of the potential respondent's residence. This research was designed for consumers living in detached houses. It should also be stressed out that in Polish circumstances the number of heat storage devices in that kind of houses is bigger than in other areas of user's residence. Taking into consideration the chosen DSM options, those two criterions allow to separate very absorbing, form research aim perspective, group of respondents.

The most important part in the process of DSM programme preparation is identification and analysis of the actual and future end-user needs. According to the initial assumptions of the experiment and specification of chosen options it was necessary to make a research in the two basic fields:

- load research (energy demand characteristic on the end-user and substation level),
- opinion poll research (analysis of the customer preferences and survey of households usage of devices for the heat storage).

Data collected in the measurement part of an experiment allowed to prepare individual load curves and to examine a way of electrical energy usage by the users from the G12 tariff group. Thanks to this research it was also possible to control (identify) an influence of present tariff system (price-time structure) on the behaviour of end-users.

In the process of customers' selection, besides mentioned above two criterions, the additional principle was also used. The measurement experiment was carried out among users connected to 3-phase LV network and with monthly energy usage of minimum 50 kWh. It was supposed that the customers connected to this kind of networks probably use more energy-consuming equipment than others do. That additional criterion allowed to separate consumers with insignificant energy demand. The basic structure of the measurement research is given in the Figure 3.

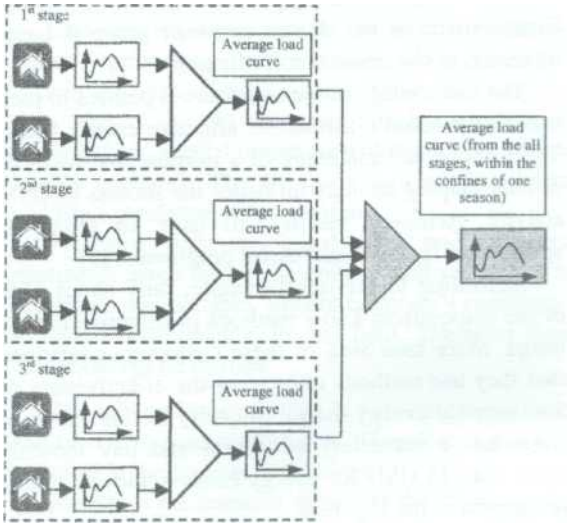

Figure 3. Simplified structure of data collection used in the process of load profile preparing

In the measurement research (3 stages in the winter and 3 stages in the summer season) 75 household were examined.

The second part of the measurements was focussed on research of load profiles on the 15/0,4 kV substation level. The basic criteria of substation selection were:

- high concentration of end-users from the G12 tariff group,
- technical and safety aspects of registers installation.

The measures were made on the separated circuits of chosen substations. In this part of the experiment, data about energy and power demand has been collected according to the same rule as above, e.g. end-user load research. It should be also stressed that measurements on a customer and substations level have been made parallel, in the same time.

The main purpose of the research was to obtain characteristics of load profile on substation level. The data from that experiment was used in analysis of effectiveness of energy storage option.

[4] According to that tariff the price of the energy during peak period time (from 6 a.m. to 1 p.m. and from 3 p.m. to 10 p.m.) is higher than out of that period (from 10 p.m. to 6 a.m. and from 1 p.m. to 3 p.m.)

IV. POTENTIAL PARTICIPANTS AND CIRCUMSTANCES OF DSM PROGRAMMES APPLICATION[5]

Results from the study could be a good base for creation of potential participants' image. Knowledge of the potential participant's preferences could be useful in an identifying the most successful option from technical and economic point of view. Characteristic of the chosen customer group is based on results of the opinion poll research.

The basic image of the end-users is pointed to their knowledge about a method of effective energy usage. The level of understanding of a purpose and methods of load shaping strongly influence the success of DSM activity. Achieved results will have an effect on selection of the most successful programme [5J.

According to the questionnaire, only about 46% of the respondents know methods of effective energy usage. More than 80% of these customers confirmed that they use methods improving the effectiveness *of* an electrical energy usage. Majority in this group of users has a secondary education and pay monthly more than 18 USD for energy bills. Achieved results are shown in the Figure 4.

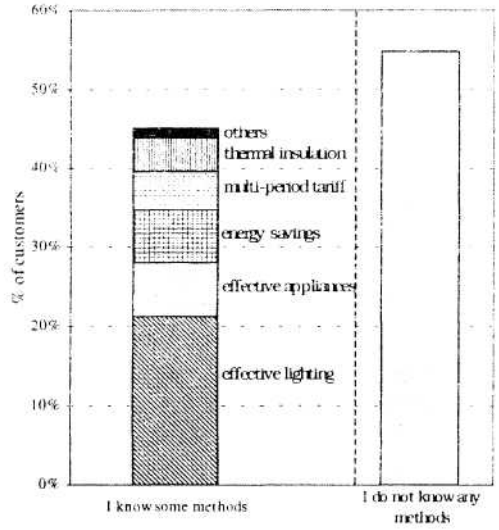

Figure 4. Methods increasing effectiveness of electrical energy usage - in customer opinion

On the top of the users' list is an effective lighting, a replacement of existing devices with more effective takes the second place. A multi-period tariff is well-known method of load shaping only for 11 % of customers, which have been aware of some energy savings method. This result is unanticipated because all of respondents are accounted for the energy according to that kind of tariff.

The one of most important issues of the study was to evaluate market saturation with heat storage devices. Taking into consideration that part of the survey it is necessary to stress a one of the requirements of the former tariff system. Customers interested in accounting for the electrical energy according to the tariff G12 had to own storage appliances in their households. The existing tariff system does not require this kind of conditions.

The research indicates that only about 80% *of* potential participants use storage devices, including a hot water supply and an electric storage furnace. Only 4% of those customers use electric heating systems in their households (Figure 5).

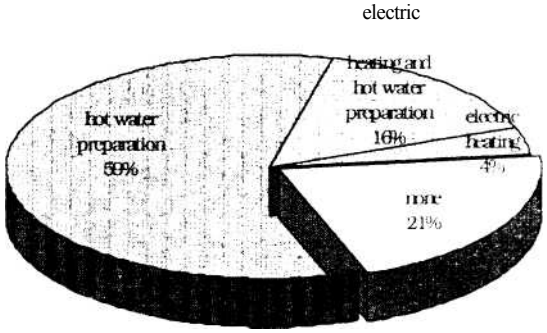

Figure 5. Households saturation with heat storage devices

Results of the research revealed that households from the selected part of regional utility branch are relatively poorly saturated with heat storage de\ ices.

Thanks to poll survey, it was also possible to determine a type of devices used for water heating by the respondents (Figure 6).

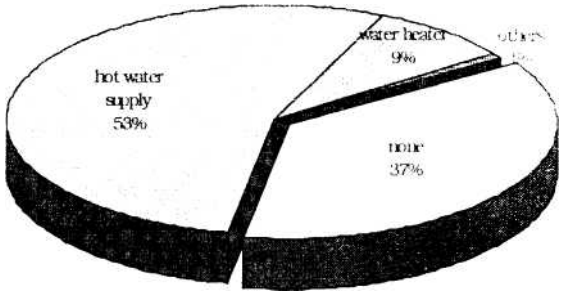

Figure 6. Devices for water heating in the households

The majority of these appliances are hot water supplies (52,4%) allowing shifting heat storage from the peak to a valley period. But number of these devices in the analysed part of local energy market is relatively low taking into account purpose of DSM programmes, e.g. load curves shaping.

Taking into account the main purpose *of* applying two-period tariffs (increasing demand for the energy in the valley period and reducing in the peak period) authors expected higher level of this factor.

In addition to the information about participants' knowledge from load management area and household saturation with heat storage devices, it is purposeful to present an influence of the tariff system on end-user behaviour.

Results concerned the customers which have been interested in DSM programme participation only

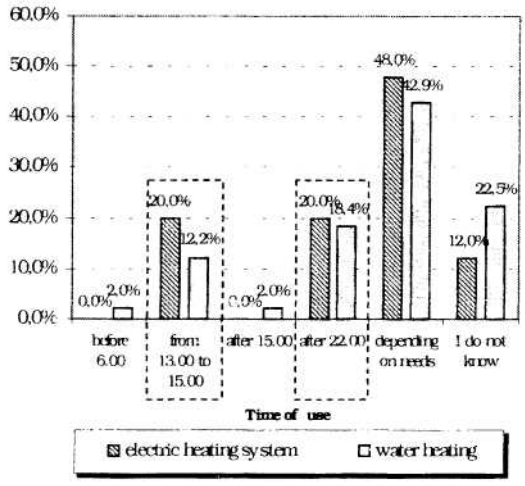

Figure 7. Heat storage devices time of use (declared by respondents)

According to customers' answers, more than 40% of them use the mentioned above devices contrary to the two-period tariff regulations, Energy usage depends on customer needs - the most common respondents' statement given in the questionnaire. Only 20% of examined respondents switched those devices on during the low price period (Figure 5).

These observations were compared with results of the load research. In order to examine these questionnaire answers, time of peak load demand was checked. Achieved results are shown in Figure 6a and 6b. Load 'measurements, carried out on the end-users level definitely confirmed results from the opinion poll.

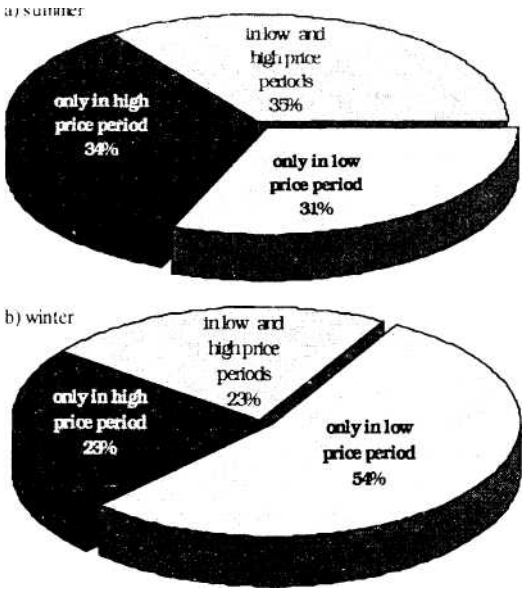

Figure 8. Time of peak load demand (in summer and winter period)

Presented graphs show that only 31 % of customers intensify electric appliance usage during the low-price period. This situation is positively, from the utility point of view, changing during the winter. It is probably connected with more intensive usage of heat storage devices.

Data survey indicates that DSM programme participants do not want to *or* are not able to reduce energy demand during the peak period. It also shows that the incentives of the existing tariff system are not strong enough to influence the customer's behaviour (energy usage).

Load profiles of the end-users from examined group indicate that application of DSM option is purposeful from the utility point of view.

The very important role in the process *of* second option application (heat storage) plays a control system. Analysis of those systems shows that only less than 50% of devices are controlled by any systems. Among them, special timers control about 139r of heat storage appliance. The rest of devices use thermostats and hand regulators of temperature.

Presented data are based only on customers' statements given during the opinion poll research. The researcher was not able, without customer's permission. to control real situation in that field. Therefore those data could not be verified.

The key problem of DSM is participation in costs and of course potential benefits. Therefore it was also included in the opinion poll survey.

Results of the research show that the bigger group of the potential participants has a monthly domestic income from 75 to 125 USD per person. Durring interview respondents very often openly declared lower income than they probably have. Therefore could be stated that the monthly family income of part of customers probably is between 125 and 175 USD (Figure 9a).

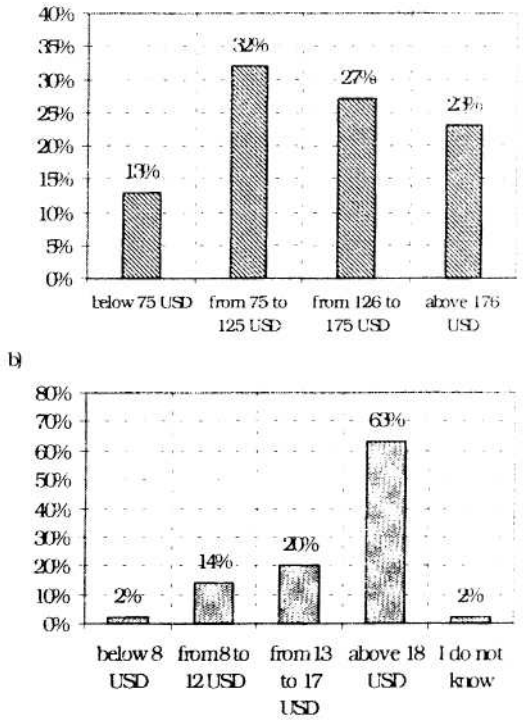

Figure 9. Monthly domestic income (a) and monthly expenditures on electrical energy (b)

The majority of potential participants spend on electrical energy more than 18 USD (Figure 9b). It could be connected with a natural susceptibility to reducing their expenditures. But it should be also mentioned that potential financial savings might cause different user's behaviour, e.g. purchasing a new electrical appliance, increasing energy demand [2].

In the close connection with domestic income *of* end-users and their expenditures on electrical energy is participation in costs of DSM options.

Among 78% of customers interested in participation in DSM programmes, about 76% (65% of all examined customers) gave their assent to cover a part of programme costs. In order to evaluate the potential amount of a customer subsidy, a hypothetical situation was presented.

It was supposed that during the first year of DSM programme operation, it is possible to save about 75 USD on electrical energy expenditures. In those circumstances about 34% users were willing to spend on the programme less than 25 USD. Customers from that group pay more than 15 USD per month for the electrical energy usage. Almost 26% of respondents would spend on that project from 25 to 75 USD. It is necessary to underline, that majority of that customers also pay more than 25 USD per month for the electrical energy usage. In addition, more then 40% of those customers use electrical heat systems in their houses. Only 5% of respondents were able to spend more than 75 USD for that purpose.

Eagerness to participate in costs of DSM programmes was compared with the monthly income of those end-users. The income of consumers spending on that programme less than 25 USD is lower than 75 USD (per person in a household). Opinion poll results show that the amount of subsidy depends on the customer's financial status (earnings).

V. RECOMMENDATION OF DSM PROGRAMME FOR LOAD CURVE SHAPING

Presented results of the research were the base for recommendation of DSM programme, which could be the most profitable for its participants. Selection of the programme was also based on following factors:

- preferences of a customer (potential participants), technical possibility of application,
- potential economic effectiveness.

The key result of the research is evaluation of the DSM option, which would be accepted by potential participants. The results of received user's answers are given in a Figure 8. That graph shows the rank of the most popular activities chosen by customer (three from seven options) among options submitted in the questionnaire.

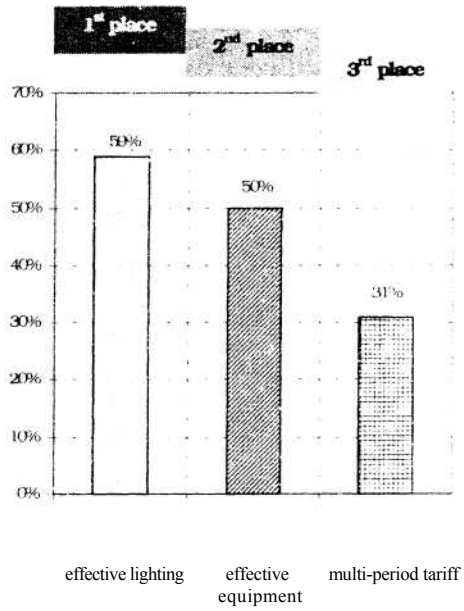

Figure 10. Rank of DSM programme

The most popular and most interesting (profitable) activity for the respondents is installation of the effective lighting. Comparing the achieved results (see Figure 3 and 8) the basic conclusion could be drown: customers are mainly interested in well-known programmes. It also should be underlined, that producers promote an idea *of* an effective lighting. There were also made a special scientific project *PELP* (Programme of Effective Lighting Promotion' on the Bialystok Power Utility territory of operation. The programme was sponsored by United Nation Development Global Environmental Facility.

The second option chosen bv respondents is also connected with change of the household devices. The last position on that ranking is taken by multi-period tariff. Only 31% of consumers classified that option on the third place. Achieving data in these two last positions of the rank show the bigger customer's indecisiveness comparing with the top of rhe list. These results also confirmed that customers are interested in well-known activities with visible and comprehensible effects.

Main pros and cons arguments of examined in the experiment DSM options are given in the Table 2. Presented results of analysis determined a final recommendation.

Arguments presented in Table 2 definitely show that the first and the third option could be the most attractive from utility perspective. Activities related to central controlling of heat storage devices by the local utility were not chosen at all. Authors are of the opinion that applying this kind of DSM option is possible in co-operation with end-users. Lack o! customer's interest is the second significant reason io reject the proposal of the DSM options connected with peak load modelling on the end-user level by controlling the heat storage devices. Only 8% of boiler users have been interested in usage this method for a load curve shaping. Among users of electric heating. *the number of interested* end-users has been significantly bigger (20%).

Table 2. Pros & cons arguments of DSM options application

DSM option	Arguments	
	Pros	Cons
. Load shaping with tariff incentives	— unfavourable from the utility point of view load profile — low investments costs	- Regulation of energy prices - lack of acception and lack of knowledge of potential profits - necessity of modification in metering system
. Heat storage control on end-user level	— customer willingness in that programme participation — end-users susceptibility for participation in programme costs — usage of heat storage devices in households - unfavourable from the utility point of view load profile	- relatively low level of usage of heat storage devices in households - low level of usage of control systems - demands of short period of investment pay off - low level of interests
Energy storage option on local utility level	- high daily diverse of load demand on the end-user level - high factor of load diversity — interference in customers behaviour and their metering system is not required	- relatively high capital expenditures - lack of experience in that field new technology in Polish conditional

In addition these customers are not interested in change of a heating or control system. Only 30% of potential participants are willing to change their systems. But none of them is interested in a modern electric heating with a control system.

In this context the utility operation market is not sufficiently saturated with such appliances. This is the main reason to reject the initially considered option connected with heat storage devices. It was acknowledged that because of low saturation level applying this option (controlling heat storage devices) could bring distributors worse effects than it had been supposed.

Application of this option in other part of a local energy markets (other local utility) could give better effects. It is because of high diversity of heat storage devices usage and diversity of load profiles.

Presented rank and characteristic of load demand should be a strong incentive for the utility to change present tariff system. But on the present stage of the energy sector transformation, modification of this system needs acceptance of the national regulator (energy market authority). Utility in these circumstances could be not enough convinced and motivated for using a new tariff structure for a load curve shaping.

Results show that the option connected with battery energy storage (BES) applied on the distributor level in those circumstances could be more effective and well grounded. Taking into consideration from a one hand achieved results connected with separated part of the local energy market and on other hand nation-wide trends BES option could be strongly recommended.

Analysis of economic effectiveness of BES was based on results of the measurements, carried out on the 15/0,4 kV level. Due to a range of the paper, authors decided to present only the main outputs and conclusions from that part of research. Analysis of that option is widely presented in 13]. Achieved load characteristic has been used in estimation of parameters of hypothetical BES installation. According to LCP method, effectiveness of BES option was compared with traditional option, e.g. option concentrated on modernisation of power network. Polish forecasts of electrical energy demand indicate that during next ten years usage of the energy in Poland will visibly increase. It was supposed that BES could cover an increasing demand in tha part of the local market during next ten years. Thanks to BES option is it possible to:

- reduce the peak load,
- reduce the energy demand in peak periods,
  avoid a costs of power network investment (modernisation of 15/0,4 kV substation)[6].

These effects contacted with ioad curve shaping could bring utility measurable benefits:

- direct tariff profit - thanks to diversity of energy prices during the di.v and reduction of the peak load,
- profits resulting from postponing the moder nisation of 15/0,4 kV substation.

NPV and IRR were used as basic criteria in a study of economic effectiveness of BES option [4]. Achieved results of the analysis of DSM and traditional option including those rates are given in Figure 11.

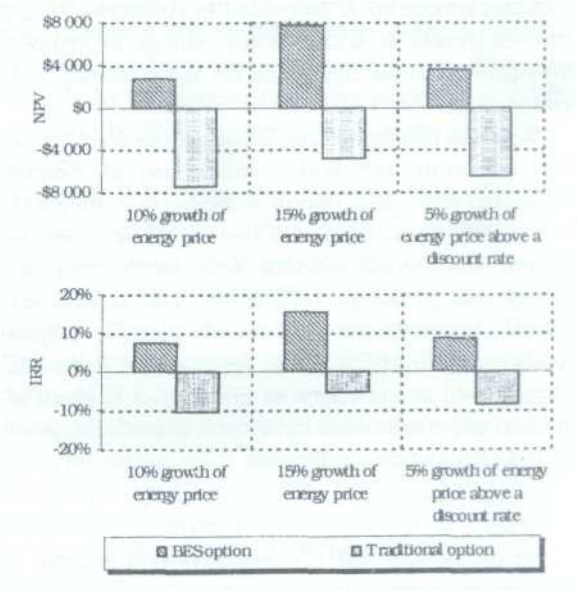

Figure 11. Economic effectiveness rates of DSM and supply-side option [3]

[6] Necessity of substation modernisation will appear because of forecasting growth of electrical energy usage

The analysis was carried out taking present and predicted conditions of Polish energy market into consideration. On the present stage of transformation of Polish energy sector it is difficult to precisely predict trends of energy prices. Therefore three scenarios of price changes were taken into account in the study. The level of growth in the first scenario is agreed with average yearly regulation of electrical energy prices.

Research and simulations, carried out by authors, proved that BES installation could be more effective than traditional approach. Changes of economic conditions in Poland and technology progress in the battery energy storage area could improve rates of effectiveness of DSM options.

The nation wide research and practical applications prove effectiveness of the battery energy storage in the power system [1]. It seems that well-known technology and potential technical and economic benefits could be a good incentive for Polish utilities to apply BES in the power network.

VI. CONCLUSIONS

Results described in this paper indicate that information about DSM activities and related programmes is not sufficiently popularised. Consumer's lack of knowledge (know-how) in that field strongly influences the success of DSM programmes implementation. This situation indicates the necessity of applying by energy distributor marketing actions (promotion) together with popularising DSM option among their customers. Those results show also usefulness of those kinds of surveys for the distributors (energy services companies).

DSM actions could be treated in conditions of full competitiveness as a chance for utilities to improve their position in the energy market and a relation with customers.

Research connected with DSM options seems to be very interesting from both scientific and commercial points of view. It is worth noticing that Bialystok Technical University, as the first scientific centre in Poland, has started research with an experimental battery energy storage installation. The surveys are carried out within the confines of scientific project sponsored by State Committee for Scientific Research. The aim and characteristic of this project is given in the next paper submitted by authors in proceedings of TELMARK Discussion Forum.

VII. ACKNOWLEDGEMENT

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