

Dynamical demand response method

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Abstract

In this paper authors suggest method of dynamic demand response to consumers of the municipal sector. The electrical grid scheme with adjustments for the application of the dynamic demand response method is described. Results of simulation on Matlab/Simulink are given. Moreover advantages of the method for consumers and energy supply organization are given.

Keywords: dynamic demand response, demand response, smart grid, aggregator, load curve

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1. Introduction

Calculations before connecting consumer to the power grid are made. The calculations allow to create a functioning network able to meet the specified requirements. However in the calculations the load is not always taken as an adequate value, that leads to inconsistencies between a designed grid and power actually flowing through it. In most cases, the calculated load is greater than the actual load, as a result there are underloaded networks and equipment. Especially in solving such problems the situation is aggravated by the unevenness of typical daily load curves.

Electrical energy consumption in the task of analysis, management and development of the energy sector is an electric power system regime integral indicator. Typical consumers load curves are highlighted: municipal load, industrial type load (coal mining, oil refining, ferrous metallurgy, non-ferrous metallurgy, heavy engineering, motor vehicle industry, woodworking, food production, etc.), public building load, street and area lighting and others.

Nowadays, in the world research connecting with “smart grid” is being conducted. A smart grid is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid. Network and equipment load management through consumption control (demand response) refers to the key tasks are solving in the “smart grid” area.

Demand response is a change in the power consumption of an electric utility customer to better match the demand for power with the supply. Electric energy cannot be easily stored, so utilities have traditionally matched demand and supply by throttling the production rate of their power plants, taking generating units on or off line, or importing power from other utilities. There are limits to what can be achieved on the supply side, because some generating units can take a long time to come up to full power, some units may be very expensive to operate, and demand can at times be greater than the capacity of all the available power plants

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put together. Demand response seeks to adjust the demand for power instead of adjusting the supply.

In this paper, for analysis municipal load curve is considered for the example of a consumer located in Novosibirsk city. If you know the load curve configurations, it is possible to evaluate the amount of underused power energy using the formula:

$$W_n = \left(t \cdot P_{\max(\%)} - \sum_{i=1}^{24} P_{i(\%)} \right) \cdot \frac{100}{t \cdot P_{\max(\%)}} \quad (1)$$

t – number of hour, $P_{\max(\%)}$ – maximal power in percent, $P_{i(\%)}$ – consuming power at i-th hour in percent.

For the case presented in Figure 1, one third of the available energy per day is underused as marked by the shaded area.

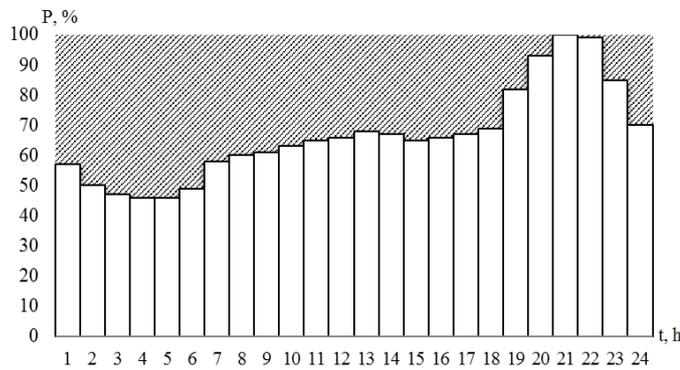


Figure 1. Novosibirsk city consuming municipal load curve (shaded area is underused power energy)

To increase the network and equipment loading and profit of an energy supplying organization it is necessary to solve the load curve optimal completing problem.

2. Scheme and model

2.1. Scheme

For the optimization model developing a simple scheme (figure 2) was chosen. It is assumed that the power source is a huge power system connected via step-down transformer with transmission line with six branch lines (consumers).

Consumer can work in power energy markets that involved consumers with a regulated load. Both independently and by the help of specialized legal entities – demand response aggregators. Such organizations need is due to the fact that retail consumers are not wholesale power energy market subjects and are not involved to its structure and usually do not know the marker rules. In this case the unit consumer capacity may be too low and the number of consumers too large for market work management organization. Aggregators combine regulating capabilities of several consumer into a larger unit that meets the requirements for the amount of unloading put on the market. And act as dealer between consumers and power energy markets. In addition

aggregators can equip consumers with the necessary equipment to reduce consumptions, advise on the unloading technology, develop optimal participation plans for consumers in demand response, etc. Independent companies or energy sales organizations may act as aggregators.

The proposed method suggests an increasing in load curve density by selling free power and energy to consumers, which are limited by agreement, but they need power and energy. It is required to modify the electrical grid circuit and add two rungs: the first is the aggregator (control rung) and the second is the analyzer (accessorial rung). Also each consumers needs to install a so-called “the second socket” that is an externally controlled input switch and a meter. The modify scheme is shown in figure 3.

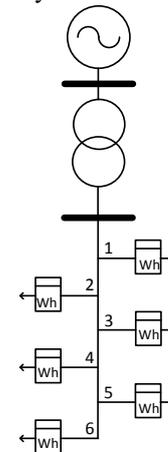


Figure 2. Power system circuit

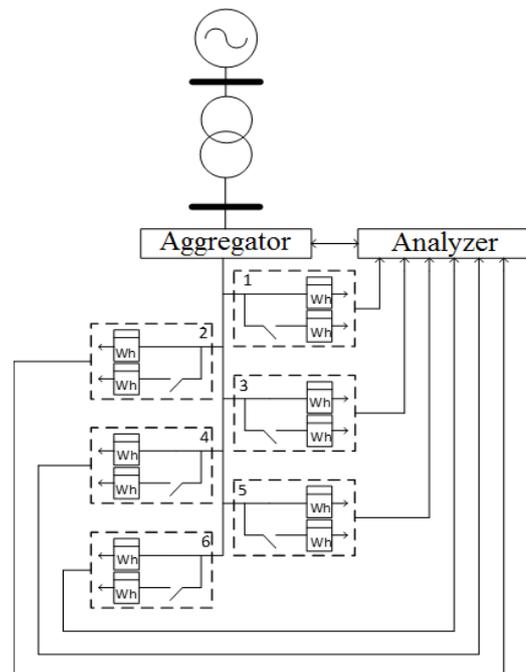


Figure 3. Changed power system circuit

In figure 3 is a diagram of an electrical network that corresponds to the dynamic demand response method proposed by the authors. The “analyzer” rung makes

measurements of the network electrical parameters. The networks load is enumerated with results based on measurements. i.e. power and energy of each consumers are summed, free power and energy amount at each time point are enumerated. The “aggregator” rung is legal entity. According to the results that come from the “analyzer” rung an “public sales” are realized between consumers for the rights to purchase free power and energy which is supplied by “the second socket”.

2.1. Model

Implementation of calculations for the scheme is performed on Matlab/Simulink. The model is based on the electrical network (figure 4), but consumers have the following features: the first and the second are guaranteed to be supplied with electricity in accordance with their load curves (figure 5), but the third and the fourth consumers are supplied with electricity only if it is possible.

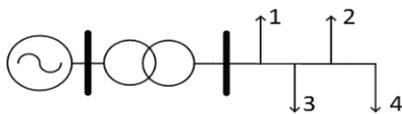


Figure 4. Power system electrical circuit

For the first approximation, it is assumed that the power of the third and the fourth consumers is required to be the same at every hour of the day. In addition, to enumerate the priority the cost of the unit of power for the third and the fourth consumer is set.

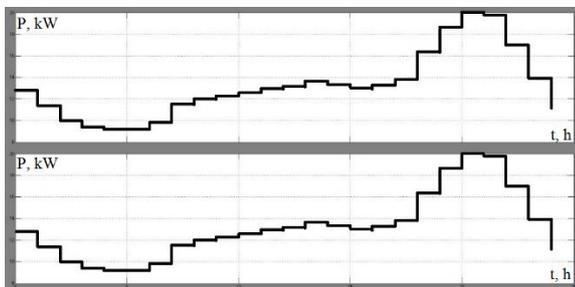


Figure 5. The first and the second consumers load curves

In figure 6 shows the graphs that display: the remaining power after the first and the second consumers energy supplying; the remaining power after the third and the fourth consumers energy supplying (if it is possible); the third and the fourth consumers load curves.

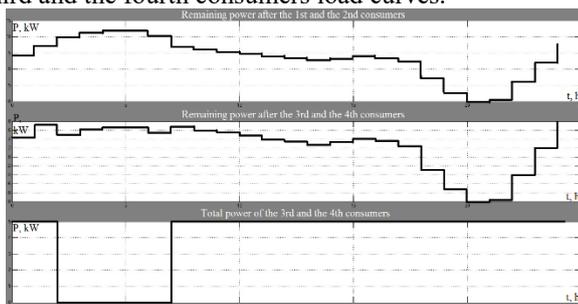


Figure 6. The graphs of calculation results

In this case, the source power is not enough even to supply the first and the second consumers, but there are a time points when the third consumer switch on. Therefore if we increase source power or change the configuration of the consumers load curves, then the method of dynamic demand response may be applied.

In figure 7 shows graphs: remaining power after the first and the second consumers supplying; the remaining power after the third and the fourth consumers energy supplying (if it is possible); the third and the fourth consumers load curves. It can be seen that this case is possible, since the first and the second consumers are supplied and at the same time, there are times points at which the third consumers switch on, as well as the third and the fourth consumers together.

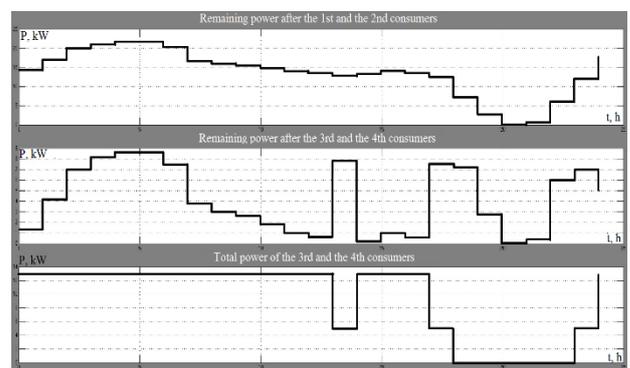


Figure 7. The graphs of calculation results

In figure 8 shows graphs of calculation results after priority changing.

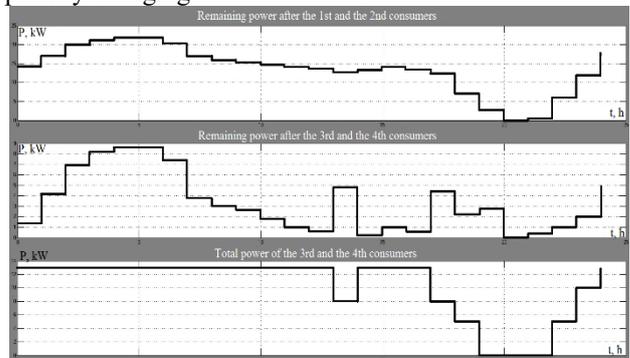


Figure 8. The graphs of calculation results

Results show that the tasks put in the beginning on extra supply of power and energy for consumers are completed, and it is proved that such approach is possible.

3. Method application advantages

There is load node with a load curve, which is shown in figure 9. It is required to calculate the electricity consuming cost in accordance with this load curve for the second and the third price brackets. Next, we need to straighten the load curve (figure 10), calculate the cost of consumed energy and compare the results with the previous one.

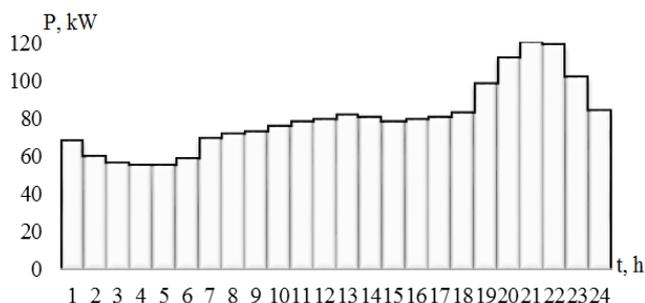


Figure 9. Origin load curve

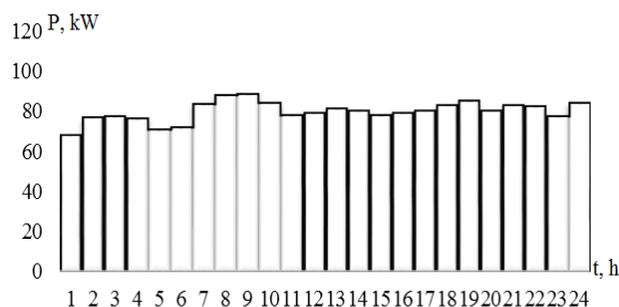


Figure 10. Straightened load curve

If consumer is in the second price bracket, it should pay for the electricity according with two-zone or three-zone tariff. All tariffs are given in table 1.

Table 1. Electricity tariffs

The indicator	Unit of measurement	Validity	From 01.01.2018
			to 30.06.2018
Price (tariff)			
Tariff, differentiated by time zones			
Two-time zone			
Daytime zone	rub/kWh	07:00 - 23:00	2,78
Nighttime zone	rub/kWh	23:00 - 07:00	1,91
Three-time zone			
Peak zone	rub/kWh	07:00 - 10:00, 17:00 - 21.00	2,98
Half-peak zone	rub/kWh	10:00 - 17:00, 21.00 - 23.00	2,42
Nighttime zone	rub/kWh	23:00 - 07:00	1,91

Based on the results of the calculations it can be concluded that the application of the developed method leads to the action of consumer with a more even load

curve, so that the consumer has an economic benefits if it is not in the first price bracket. All results are shown in table 2.

Table 2. Calculation results

Price bracket	2 (two-zone)		2 (three-zone)		3	
Load curve	Before	After	Before	After	Before	After
Total, rub	8492,7	7168,2	8339,4	7315,9	7455,6	6204,1
Benefit, %	15,6		12,3		16,8	

The most common price brackets among municipal consumers and small organizations are the second and the third. Moreover, the second price bracket is divided into a two-zone and three-zone tariffs. When the load curve is aligned a significant benefit is came for each price bracket. It indicates the ability of enterprises or municipal consumers to save on electricity. The greatest benefit of 16.8% is came when using the third price bracket.

4. Conclusion

As a result, authors proposed correcting mechanisms for market relations. It is suggests to add two intermediate rungs “aggregator” and “analyzer”, which allow to implement dynamic demand response as part of the concept “demand response” in “smart grid”.

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