Price-Dependent Electricity Consumption as a Tool of Risk Management of Non-Payment for Electric Energy by Industrial Enterprises

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ABSTRACT

The growth of indebtedness of industrial enterprises operating in conditions of economic instability for consumed electricity and the sanctions imposed by the energy supplying organizations for late payments, determine the urgency of the problem of managing the risks of non-payment for energy from industrial enterprises. The article is devoted to the description of the method developed by the authors for managing the risks of non-payment of industrial enterprises for consumed electricity, based on the principles of price-dependent electricity consumption. Based on the study of the mechanism of formation of the cost of electricity purchased by industrial enterprises in the wholesale and retail electricity markets, special methods were proposed to control each component of the cost of electricity: electrical energy, electrical power, electricity transmission services. It justifies the need to develop options for operating modes of industrial equipment, such as nominal load mode, load limiting mode, technological minimum load, in order to effectively implement and use price-dependent power consumption in crisis conditions. Modeling scenarios of price-dependent demand management for power consumption is made on the example of a machine-building enterprise and the calculation and component-wise analysis of the economic effect of price-dependent management and the factors influencing its formation are carried out. The developed method allows you to effectively manage the risks of non-payment of industrial enterprises for electricity, as well as minimize the risks of restricting the supply of electricity to industrial facilities and disruptions in the operation of industrial equipment.

KEYWORDS:

price-dependent electricity consumption, crisis management, non-payment for electricity, restriction of electricity consumption, demand schedule management, energy tariffs, demand for electricity consumption, electric power, electricity transmission service.

FOR CITATION:


1. INTRODUCTION

Over the past decade, industrial enterprises in Russia were functioning in the conditions of continuous economic instability caused by the impact of the economic crisis, introduction of sanctions and increasing competition on international markets. The recent Federal Law ‘On amendments to certain legislative acts of the Russian Federation on taxes and duties’ envisages the increase of the base rate of the value added tax from 18% to 20% from January 1, 2019. The latter will lead to decreasing stability of operational activity of many industrial enterprises, which can cause delays in payments for raw material and consumed energy resources.

Electric power is the basic energy resource and is used in the primary and support production processes of the enterprise as well as for heating, water supply and lighting. The practice of functioning of industrial enterprises in Russia in the crisis periods indicates that the available financial resources are primarily allocated to wages and purchase of materials and, as a residual, to payment for energy resources.

Over 1990–a, many industrial enterprises did not pay for energy resources (10 years of Federal Law FZ-35 ‘On electric energy’, [s.a.]. In OAO RAO UES, 2012), their debt to RAO UES exceeded 50% of the cost of supplied electric and thermal energy (Energy Workers, 1994). The situation improved slightly after the reform of electric energy industry and tightening of the payment discipline. Nevertheless, today a number of economic entities still have a considerable debt to energy suppliers. According to Russian Federation Federal Statistics Service, as at December 2017 consumers’ debt to energy suppliers was 821 bn Rubles. The population is responsible for only 20% of the indebtedness. For the most part, debtors are providers of housing and communal services and industrial enterprises.

Table 1

<table>
<thead>
<tr>
<th>Sanctions for non-payment for energy resources</th>
<th>Retail electricity market</th>
<th>Wholesale electricity market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normative acts regulating the procedure of payment for consumed electric power</td>
<td>(Ordinance, 2012)</td>
<td>(Annex No 16, 2019)</td>
</tr>
<tr>
<td>Schedule of payment for consumed electric energy (power)</td>
<td>• 30% of the cost of electricity till the 10th of the current month • 60% of the cost of electricity till the 25th of the current month • the rest till the 18th of the next month after the billing one</td>
<td>1% of the cost of electricity till the 25th of the current month 2% of the cost of electricity till the 10th of the current month 40% of the cost of electricity till the 25th of the current month 4% of the cost of electricity till the 10th of the current month 14% of the cost of electricity till the 10th of the current month 1% of the cost of electricity till the 25th of the current month 2% of the cost of electricity till the 10th of the current month 40% of the cost of electricity till the 25th of the current month 4% of the cost of electricity till the 10th of the current month 14% 21% 28% of the month. For various cost components: electric energy, electric power, transmission services, balancing market, dates are established within the mentioned periods</td>
</tr>
<tr>
<td>Penalty for non-payment for consumed electric energy</td>
<td>• 1/10 of the refinancing rate for every day of the delay (or 21.7% per annum)</td>
<td>• Bank guarantee issued by the authorized bank • guarantees of the electric power suppliers on the wholesale market • security payment • sureties of the electric power suppliers on the wholesale market • elimination of a group of electricity supply points on the wholesale market • exclusion from the regional membership of the electricity wholesale market</td>
</tr>
<tr>
<td>Sanctions for long-term non-payment for consumed electric energy</td>
<td>• limiting the enterprise’s electricity consumption to the level of technological norms • terminating the energy supply contract with the enterprise</td>
<td>• Bank guarantee issued by the authorized bank • guarantees of the electric power suppliers on the wholesale market • security payment • elimination of a group of electricity supply points on the wholesale market • exclusion from the regional membership of the electricity wholesale market</td>
</tr>
<tr>
<td>Organizational implications in case of long-term non-payment for consumed electric energy</td>
<td>• Absence of technological possibility of electricity consumption • Absence of technological possibility of electricity consumption on the conditions stipulated in cases of non-contractual electricity consumption • Purchasing electric energy on considerably excessive tariffs</td>
<td>• Bank guarantee issued by the authorized bank • guarantees of the electric power suppliers on the wholesale market • security payment • elimination of a group of electricity supply points on the wholesale market • exclusion from the regional membership of the electricity wholesale market</td>
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Fig.1. The share of expenditures on electric power in the product cost structure of Russia's main industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum production</td>
<td>35%</td>
</tr>
<tr>
<td>Machine tool-building</td>
<td>12%</td>
</tr>
<tr>
<td>Mining and metalurgy</td>
<td>9%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>5%</td>
</tr>
<tr>
<td>Heavy machinery</td>
<td>4%</td>
</tr>
<tr>
<td>Chemistry and petrochemistry</td>
<td>4%</td>
</tr>
</tbody>
</table>
Among industrial enterprises, the most persistent debtors are the energy-intensive industries, which have a considerable share of electric energy in their product cost structure. Therefore, development of anti-crisis measures for management of payments for electricity is of great strategic significance for them. In machine tool-building, the share of the cost of electric power in the product cost structure is 12%, in mining and metallurgy 9%, in manufacturing – 5% (Figure 1).

To tighten the payment discipline, the following measures are undertaken:
- tightening of the payment schedule;
- increasing penalties for late payments;
- limiting electricity supply in case of late payments (Ordinance, 2012; Federal Law, 2015);
- introducing sanctions for non-payment on the legislative level (Table 1).

Non-payment for electric power leads to considerable risks of electric power cost rising and risks that its supply to the enterprise can be limited, risks of production stopping, failure to implement the product output plan, failure to fulfill commitments before the customers.

The sector-specific peculiarities of majority industrial enterprises functioning require them to maintain some of the technological processes even if products are not manufactured: heating and ventilation, hot and cold water supply, wastewater disposal, lighting and alarms. Some of the enterprises are under obligation to supply energy resources generated by them to the population connected to their power grid. Steelmaking, chemical and petrochemical production, some kinds of manufacturing industries do not envisage halting the production process; otherwise it takes a lot of time to relaunch the production and/or change the essential equipment.

Experiencing the conditions of financial instability and having substantial debts to energy supplying organizations, some enterprises, mainly machine-building, resort to extreme measures: reduce the number of working shifts, temporarily withdraw energy-intensive equipment from service in order to reduce the debt burden by reducing the energy consumption.

Considering the mentioned economic and technological specifics, the majority of industrial enterprises require sustainable operation of primary and support equipment even in the conditions of economic crisis. The need to manage the risks of non-payment for electric energy is evident for ensuring operation of industrial enterprises in the conditions of economic instability; in particular, at the expense of reducing relevant expenditures.

In view of the foregoing, we have developed recommendations on reducing the costs of electricity for industrial enterprises in the conditions of economic instability. To manage the risks of non-payment, it is expedient to use a mechanism of price-dependent electricity consumption: consumers manage their own demand for electrical energy in the energy market with a view to reduce expenditures on electricity (Dzyuba, Solovieva, 2013; Solovieva, Dzyuba, 2014).

### 3. METHODOLOGY OF THE STUDY

The cost of electric power purchased by the industrial enterprises at the wholesale and retail markets consists of three main components (Fig. 2):

\[
S_{\text{e}} = S_{\text{p}} + S_{\text{m}} + S_{\text{l}}
\]

where \(S_{\text{e}}\) is the cost of electric energy in Rubles; \(S_{\text{p}}\) – cost of electric power in Rubles; \(S_{\text{m}}\) – cost of electricity transmission services in Rubles.

#### 4. ‘COST OF ELECTRIC ENERGY’ COMPONENT

The cost of electric energy reflects the unit costs of the energy system to generate electricity in every hour of the day. The calculation of the amount of obligation to pay for electric energy is defined as a product of prices for electric energy differentiated by hours of the calculation period and individual amount of hourly electricity consumption of specific consumer.

\[
S_{\text{e}} = \sum_{t} (W_{t} \times C_{t})
\]

where \(W_{t}\) is electric energy consumed by an industrial enterprise from an energy system in hour \(t, \text{kWh}\); \(C_{t}\) – price for electric energy differentiated by hours of the calculation period in relation to the volume of electric energy supplied in an hour of the calculation period, Rubles/kWh.

For the participants of the wholesale market – hourly market price for the day ahead, for the participants of the retail market – non-regulated price for electric energy differentiated by hours of the calculation period, for the territories of the East Integrated Power System – regulated price for electric energy differentiated by hours of the calculation period.

The example of hourly energy prices at the wholesale energy market of the Leningrad region from 17th to 23rd of July 2017 (fig. 3) demonstrates a considerable diurnal volatility and a significant spread between the prices of the right minimum load and at the hours of daily maximum of the power system.

In a period of economic crisis, price-dependent management of electricity costs should lie in the redistribution of volumes of electricity consumption to the time when it is economically beneficial. Then, industrial enterprises will save up to 70% of the costs of this component or up to 30% of the total costs of electric energy. When developing options to optimize the electric load schedule, it is necessary to take into account technological parameters of production and energy market parameters. It is worthwhile to identify the range of price-dependent management of electric load hourly schedule basing on projected hourly prices for electric energy. The methodology for projecting prices for electric energy suggested by us is described in other papers in more details (Solovieva, Dzyuba, 2013; Solovieva, Dzyuba, 2017a).

#### 5. ‘COST OF ELECTRIC POWER’ COMPONENT

Cost of electric power reflects the payment for the readiness of the energy system to generate electricity in the needed volume in a certain period of consumption. The obligation to pay for electric power is calculated as a mean value of the power consumed by an enterprise in the hours coinciding with the hours of the daily maximum of electricity consumption of the regional power system over the working days of the billing month (Annex 13.2, 2019).

\[
S_{\text{p}} = \frac{F_{\text{p}} \times C_{\text{m}}}{n_{\text{m}}} \sum_{t} W_{t} \times \frac{1}{n_{\text{m}}}
\]

where \(F_{\text{p}}\) is the obligation for purchasing power by an industrial enterprise in the month \(m\); \(C_{\text{m}}\) – the price of power purchased by an industrial enterprise in the month \(m\); \(W_{t}\) – hour of the combined peak demand for a federal entity where the enterprise is buying energy in the hour \(t\) of the working day in the month \(m\); \(n_{\text{m}}\) – number of the working days in the month \(m\); \(T_{\text{p}}\) – intervals of peak load planned hours approved by the System Operator of the Unified Energy System of Russia.

Figure 4 shows the intervals of the planned peak load hours approved by the System Operator of the Unified Energy System of Russia for the first price zone of the wholesale market for 2018, Figure 5 – the hours of the combined maximum demand of the Leningrad region power system over the working days in 2016.

Price-dependent management of electricity costs in the period of economic crisis, in our view, should lie in shifting of electricity consumption from the regional power system peak time, which can enable the industrial enterprises to reduce costs of electric energy up to 33% comparing with the initial costs. The range of price-dependent management of electric load hourly schedule is appropriate to identify basing on the projected peak time of the power system; respective proprietary methodology is described in other papers in more details (Dzyuba, 2014; Solovieva, Dzyuba, 2014).
6. ‘ELECTRICITY TRANSMISSION SERVICES COST’ COMPONENT

The cost of electricity transmission services reflects the payment for the use of the electricity grid infrastructure for the transportation of electric energy generated by the power plants to the end users. Consumers can use price-dependent management of electricity costs only if they use a two-part tariff to pay for energy. The electricity transmission services cost is calculated according to the formula (Ordinance, 2012):

\[ S = S_{\text{t.c.}} + S_{\text{m}} \]  

(5)

where \( S_{\text{t.c.}} \) is the cost of electricity transmission services according to a two-rate tariff taking into account the technology costs (losses) in the electricity grid in the month \( m \), kWh.

\[ S_{\text{t.c.}} = T_{\text{m}}^{\text{t.c.}} \times V_{\text{m}} \]  

(6)

where \( T_{\text{m}}^{\text{t.c.}} \) is the tariff rate for electricity grid maintenance in the month \( m \); \( V_{\text{m}} \) is the value assumed for the calculation of the payment obligations for electricity grid maintenance in the month \( m \).

\[ V_{\text{m}} = \frac{\max(W_{\text{hr}}}^{\text{max}})}{m} \]  

(7)

where \( \max(W_{\text{hr}}}^{\text{max}}) \) is the maximum value of energy consumption in the period of intervals of planned peak load hours \( T_{\text{p}} \) approved by the System Operator of the Unified Energy System of Russia, for a working day of the month.

Fig. 5. The hours of the combined peak demand of the energy system of Leningrad region over the working days in 2016 (Administrator, [s.a.])

The cost of electricity transmission services is differentiated by levels of powering voltage: HV (high voltage, 110 kV and higher), MV1 (first medium voltage, 35 kV), MV2 (second medium voltage, 20-1 kV), LV (low voltage, 0.4 kV and lower) (Order, 2004). The lower voltage level, the higher is the electricity transmission services tariff. Consequently, for the HV level the percentage of costs for electricity transmission services is 36%, and for the LV level – 51% (Fig. 6).

The results of the analysis of cost formation mechanism for every component of electric energy expenditure are presented in the Table 2. It is evident that the cost of every component depends on the hourly schedule of electricity consumption of a specific enterprise \( W_{\text{hr}} \), which is mathematically described by a respective system of equations.

Fig. 6. The structure of electric energy tariff for industrial enterprises by voltage levels

\[ S_{\text{m}}^{\text{t.c.}} = T_{\text{m}}^{\text{t.c.}} \times V_{\text{m}} + S_{\text{m}} \]  

(8)

where \( T_{\text{m}}^{\text{t.c.}} \) is the tariff rate to pay for the technology costs (losses) in the electricity grid in the month \( m \).

\[ S_{\text{m}} = \frac{f(W)}{m} \]  

(9)

7. PRACTICAL IMPLEMENTATION

The structure of energy consumption of any industrial enterprise is described by the electricity consumption graphs of separate production and support facilities, i.e. workshops, buildings, furnaces, mills, etc. As a rule, the bulk of the energy demand is concentrated on separate units of energy-intensive facilities, which are part of the unified production process or a value chain. The energy demand of separate energy-intensive entities forms the group (combined) graph of energy demand of an industrial enterprise (Fig. 7).

Price-dependent management of electricity costs is carried out by way of managing configuration of the work of separate energy-intensive production facilities that have impact on the amount of

<table>
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<th>Table 2</th>
<th>Mechanism of forming energy cost components</th>
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<tr>
<td>Cost component</td>
<td>Cost forming principle</td>
</tr>
<tr>
<td>Electric energy</td>
<td>Energy consumption in the period of power system maximum demand</td>
</tr>
<tr>
<td>Electric power</td>
<td>Energy consumption in the hour of daily power system maximum demand</td>
</tr>
<tr>
<td>Energy transmission services</td>
<td>Irregular energy consumption in the period of the peak load hours</td>
</tr>
</tbody>
</table>
obligations to pay for the electric energy costs components of the industrial enterprise. The size and range of adjustments are determined by specific economic conditions (Table 3).

With a view to reduce the electricity costs, regulation of electric load schedules can be carried out within a relatively short control range, at around ±20% of the nominal electricity consumption load (Baev, Solovieva, Dziuba, 2017); if there are risks connected with limiting of power supply to the enterprise and shutdown of primary production equipment, price-dependent load regulation is admissible within a wider range, up to reducing power consumption of some production facilities to 100% of the nominal load.

In a crisis period, the model of price-dependent management of electricity costs at industrial enterprises has many constraints: the internal ones include technological and organizational possibilities to shift the work schedule of production equipment, external ones – established deadlines to fulfill the output plans, economic possibilities of the environment to use hourly electricity tariffs to reduce the electricity consumption costs within the required range.

With regard to price-dependent management of energy consumption, industrial enterprises should consider a number of factors:

- ensuring economic efficiency of shifting primary and support production personnel to the second shift and overnight regime, working on weekends and holidays;
- compliance with the conditions of technological viability of production equipment exploitation when the work load is reduced to load limitation mode and to minimum safe output;
- consideration of parameters of technological processes in one production chain with the equipment, through which the price-dependent management is carried out;
- consideration of logistical processes and stock when changing the work schedule of technological processes;
- implementing a system of operational accounting and control of parameters of energy demand, parameters of calculating the economic effect of price-dependent management of electricity costs;
- harmonization of the system of accounting and modelling of the processes of price-dependent management of electricity consumption and production process control system;
- ensuring the possibility of flexible management of the parameters of price-dependent electricity consumption management;
- consideration of parameters of increasing cost of purchasing other energy resources (for example, natural gas) in case of redistribution of the production equipment work schedules.

### Table 3: Options of operating schedules of equipment at an industrial enterprise

<table>
<thead>
<tr>
<th>Operating schedule of an enterprise</th>
<th>Description of the equipment operation</th>
<th>Equipment load in the periods of planned peak load hours of the power system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal load mode</td>
<td>The schedule of production equipment in base load for plan execution</td>
<td>80-100% depending on specific production plans and the work of related production lines</td>
</tr>
<tr>
<td>Load limitation mode</td>
<td>The schedule of production equipment in load limitation mode for plan execution</td>
<td>25–80%</td>
</tr>
<tr>
<td>Minimum safe output</td>
<td>The schedule of production equipment in a mode to maintain viability of enterprise engineering systems without product output</td>
<td>0-25% depending on technological features of production</td>
</tr>
</tbody>
</table>

With the aim of a more detailed analysis, the operating schedules of an industrial enterprise are divided into operational modes (Fig. 8, 9).

![Overall graph of electricity consumption of the enterprise](image1)

![Unit of overall electricity consumption of the industrial enterprise](image2)

![Taking into consideration electricity consumption of separate production facilities of the enterprise](image3)

![Building 1, Mill 1, Workshop 1, Workshop 2](image4)

![Fig. 7. Example of forming a group combined electric load graph for industrial enterprises](image5)

![Fig. 8. Hourly graph of the nominal load mode of the work of equipment of the industrial enterprise in April 2017](image6)

![Fig. 9. Changing the parameters of hourly graphs of electricity consumption of an industrial enterprise from the nominal load mode to the load limitation mode and to minimum safe output on the example of a working week](image7)
In crisis periods, enterprises that need to maintain production and support processes face the risks of non-payment to energy supplying companies. The legislation of the Russian Federation in force related to electricity envisages severe sanctions against industrial enterprises for violating payment discipline, which determines the need to manage the risks of non-payment for electricity during a crisis.

The analysis of mechanisms of forming the cost of electricity purchased by industrial enterprises at wholesale and retail energy markets indicated that the enterprises on their own can manage all the components of the cost of purchased electric energy: the cost of electric energy, the cost of electric power and the cost of transmission services. Management of expenditures on every cost component is carried out by varying their own hourly electricity demand schedule with due regard for parameters formed by the wholesale and retail market regulators and mechanisms of flexible formation of hourly prices for electricity supply.

The suggested classification of load modes determines the possibilities to apply the tools of price-dependent management of electric energy consumption in various economic conditions of the activity of enterprises. The management of electricity demand schedules in a crisis period differs from management in basic operation period by the depth of regulating such schedules. We have suggested the ranges of price-dependent management of load graphs to the levels 'load limitation mode' and 'minimum safe output mode', which enables the enterprises to considerably reduce the expenditures for purchased electricity and the non-payment risks in the future.

Using the example of electricity consumption of a machine-building enterprise in the Leningrad region, by modelling the options of price-dependent management of electricity consumption load schedules, we showed the possibility to reduce the obligations to pay for electricity when maintaining the same total monthly volume of electricity consumption. In the load limitation mode, obligations to pay for electricity were reduced by 41%, in the minimum safe output mode – by 63%, which underscores the effectiveness of the suggested method.

The systematization of factors impacting the effectiveness of price-dependent management of electric energy consumption in a crisis enables us to assess more precisely the appropriateness and efficiency of the measures taken and avoid inaccuracies and mistakes in the management process.

The developed method of price-dependent management of electricity consumption allows to efficiently manage the risks of non-payment for electricity by industrial enterprises in a crisis; minimize the risks of forming a debt to energy suppliers and non-payment for electricity by industrial enterprises in a crisis; increase the financial stability indicators and sooner overcome crisis situations.

The results of calculation of expenditures on electricity for the modelled options of load graphs are presented in Table 4. In three options, the total monthly volume of power consumption is equal and amounts to 3 465 180 kWh. For the 'nominal load mode' option, the obligation to pay for electric power is 9.2161 MW/month, obligation to pay for electricity transmission services is 9.9080 MW/month. For the 'load limitation mode' and the 'minimum safe output options' the component of payment obligation for electric energy was decreased by 46 and 73% respectively, the component of payment obligation for electricity transmission services decreased by 50 and 75% respectively. Meanwhile, the average cost of purchasing the component 'electric energy' went down just by 3 and 7% respectively since the electric load was redistributed to peak periods of weekdays as well, which led to buying electric energy for peak prices of the weekends.

The decrease of the mentioned components led to reducing both overall costs of electricity consumption and tariffs to purchase electric energy for the enterprise: in the 'load limitation mode' option – by 41%, in the 'minimum safe output option' – by 63%, or by 9.483 227 and 14 493 877 Rubles respectively.

After shifting to the load limitation mode or minimum safe output mode, the enterprise has an opportunity to reduce the debt for the previous period, settling it at the expense of funds saved, or reduce the risks of non-payment for power in the future. Reduction of expenditures on electricity while keeping the same output levels will enable the enterprise to raise the financial stability indicators and sooner overcome crisis situations.

The ultimate economic effect of price-dependent management of load graphs should be calculated considering the change of shifts, increase in costs of lighting during night and evening shifts.

However, if the expenditures of the enterprise on electricity are large, the significant organizational measures, in the majority of cases, will be economically viable.

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