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Efficiency of the Determined Model of Power Consumption by Nonlinear Closed Slow-Response Production

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Abstract. It is impossible to predict energy consumption without sufficient degree of accuracy for power-consuming nonlinear inertial industries at change of technological parameters. This problem is solved by the simplified and determined model based on the equations of material balance of streams for substance.

Introduction

Conditions of the energy market force the enterprises to look for scientific approaches to determination of volumes of the energy consumption, its prediction and planning. Especially this problem is particularly acute for power-consuming industries. It is obvious that the solution of such a task requires development of the tools based on the knowledge of production and modern information technologies. [1, 2]

Production energy consumption depends entirely on its character and an operating mode. For linear discrete productions electricity consumption is in direct ratio to production output. Energy consumption models are mostly based on statistical data and they are widely used. However for a number of the nonlinear inertial closed productions and nonlinear multi-nomenclature productions such an approach is not always right.

The modern market offers a wide choice of raw materials for energy producing of various qualitative structures and prices. New types of raw materials with higher or lower content of the drawn substance cause a strong effect on technological parameters of the energy production process. In this case, even skilled experts cannot predict what transitional processes on the power of material streams and duration can arise upon transition to other modes. Energy consumption of all production will change. Therefore the solution of a problem of forecasting of energy consumption has to be based on the determined models of production [3, 4].

Modeling

The power-consuming industry of alumina by Bayer possesses all the features described above. Alumina is a technical oxide of aluminum and it is used as a raw material for electrolytic receiving metal of aluminum. It is produced on large-capacity process production lines in the most widespread way of Bayer. The development of the model was based on the following facts:

Hydro chemical alumina production way of Bayer, by itself, carries the pronounced nonlinear, inertial and closed character (reverse flows are ten times bigger than direct once, buffer tanks are small). Therefore experience shows that the model based on statistics is not applicable in this case.

For this production the simplified determined model of its energy consumption was created, and it was based on the equations of material balance of streams of substances in a production ring with the description of expenses of the electric power per unit of volume of each stream. Expense of the electric power was calculated by means of a ratio:

$$W = K_e \cdot \sum_{i=1}^{16} K_{ie} \cdot F_i , \qquad (1)$$

Kie – coefficients of energy consumption allocated along a hydro-chemical ring (kWt-h/units F), their values were defined by capacities of drives, pumps, mixers, etc., *Ke* - the correction coefficient reflecting a share of unconsidered electric power consumption.
Volumes of streams have been calculated by the systems of the nonlinear algebraic equations of material balance described as follows:

$$\sum_{i=1}^{16} L_{ij} A_i G_i F_i = 0 \quad \sum_{i=1}^{16} N_{ij} B_i G_i F_i = 0 \quad \sum_{i=1}^{16} H_{ij} G_i F_i = 0 \quad \sum_{i=1}^{16} I_{ij} F_i = 0 \quad \sum_{i=1}^{16} I_{ij} D_i F_i = 0 \quad M_i = 1.645 \frac{B_i}{A_i}, \qquad (2)$$

where Fi- material streams in units of volume measure, Gi-the contents in a firm phase, Ai – concentration in liquid phase Al_2O_3, *Bi* – similar to the caustic soda (Na_2O_k), D-density of a stream, M – the so-called caustic module of solution, Lij, Nij, Hij, Iij - reflect specific nonlinear transformations for each i-stream in an entrance (exit) of j-block, including a sign (positive for entrance and negative for an output stream).
Dynamics of solution decomposition was modeled at assumption about ideality of process of hashing of a hydrate pulp in the decomposer. Therefore the volume of V_D of each n-wow ideal device and their quantity of N_D in a chain became parameters for identification of model for achievement of identical duration and a form of the transition processes received by means of model and observed by experts in practice in the sum at the exit of several parallel strings of consistently working decomposer. The changes of temperature existing in practice of regularity along strings of devices were approximated by square dependences.
As a result the model of each n-wow device was described by system of the differential equations:

$$\begin{aligned}
&F_{n-1} = F_n + 0.53 \cdot V_Д \cdot V_{P n} \cdot G_n^*, \qquad G_n^* = 1 - \frac{G_n}{2.43}, \\
&V_Д \frac{d}{dt} \cdot G_n = F_{n-1} \cdot G_{n-1} - F_n \cdot G_n + 1.53 \cdot V_Д \cdot V_{P n} \cdot G_n^* \\
&V_Д \frac{d}{dt} \cdot G_n^* \cdot A_n = F_{n-1} \cdot G_{n-1}^* \cdot A_{n-1} - F_n \cdot G_n^* \cdot A_n - V_Д \cdot V_{P n} \cdot G_n^* \qquad (3) \\
&V_Д \frac{d}{dt} \cdot G_n^* \cdot B_n = F_{n-1} \cdot G_{n-1}^* \cdot B_{n-1} - F_n \cdot G_n^* \cdot B_n \\
&V_{P n} = -U_D K_1(B_n, T_n) K_2(X_{S0}, S_{S0}) \frac{(A_n - A_E(B_n, T_n))^2}{A_E(B_n, T_n)^2},
\end{aligned}$$

where F_n – a consumption of a hydrate pulp at the exit of n-go of the device, G_n - the contents in it are strongly hydrated, A_n - the contents in the liquid phase Al_2O_3, B_n - the contents in the liquid phase Na_2O_k, – the speed of decomposition of solution in the device, K_1, K_2 – the nonlinear functions considering dependence on concentration of B_n reagent and temperature of T_n in the device, the content X_{SO} and surface of S_{SO} of seed hydrate particles, A_E – equilibrium concentration of Al_2O_3, – the nonlinear function B_n and T_n. In addition, the model contains the description of dynamics of work of the generalized buffer capacity and the block automating identification of model under the demanded technological mode.
The described model contains systems of the nonlinear algebraic and differential equations which was resolved with use of numerical methods. The modeling error assessment was based in the following way: on an interval of time at 100 o'clock the global error of the decision was not more than 3%.

Values of energy consumption of aluminous production at the set modes and characteristics of change of its energy consumption at spasmodic change of technical parameters were observed and described. Some of them are presented in fig. 1.

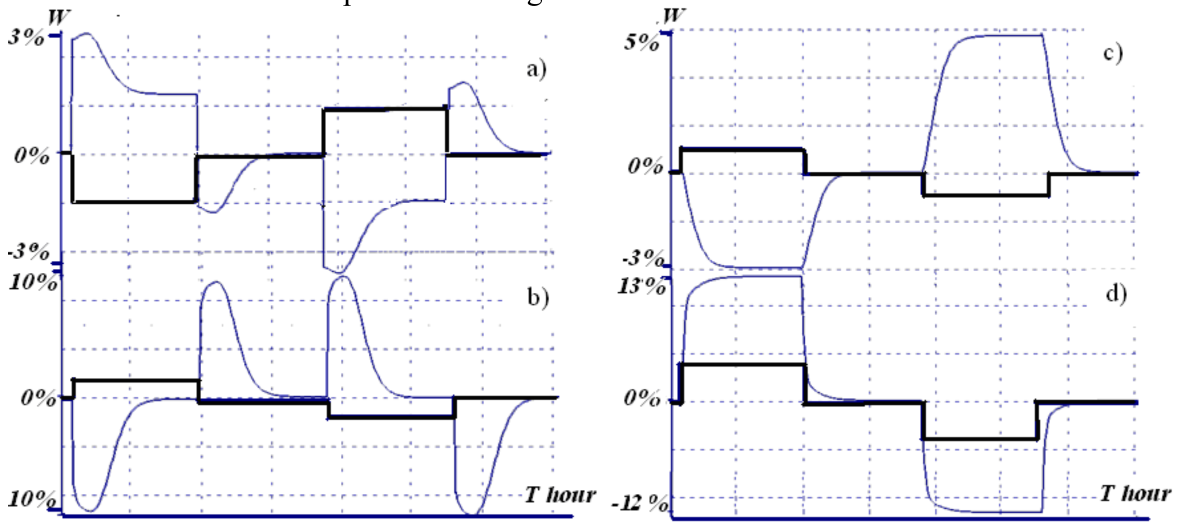

Fig. 1. The reaction of power consumption changes W of alumina production at sudden change of technical parameters (the black chart) regarding the nominal values: content of seed hydrate (a), B5(b), area of seed hydrate(c), M3(d). Division value of the x-axis is 54 hours.

Solution of Efficiency

The stable technological mode is represented by relatively small changing of technical parameters, which represent general concentration characteristics of streams of technological repartitions, electricity consumption at maintenance at the demanded level. For plants of average power near 200MWt the volume of the consumed electric energy and power for the next year with monthly breakdown and hourly specification is specified in an annually updated contract for purchase of the electric power.

In the process of energy consumption planning adjustment of hourly volumes, can be made on condition of observance the regulations of information exchange established by the contract between the enterprise and the supplier of the electric power. The energy supplier should be compensated for the cost of deviations of the actual hourly volumes.

Consumers of the retail market with the attached power more than 750 KWt (to whom also the considered production concerns) with the interval or integrated account pay besides the cost of planned consumption the cost of the specified deviations counted on a formula:

$$S_d = \sum_{i}^{m} S_i^d \ , \qquad (4)$$

where S_i^d - the cost of deviations of the actual volume of electricity consumption from i specified in the contract for an hour, m-a number of hours of the settlement period, are usually a month.

Let's calculate the effect from use of the offered tools at change of one of the technological parameters(1.33rubles/KWt-hour). Thus we will consider that for this nonlinear inertial production at change of technological parameters transitional process completely comes to an end in 5 days, and value of energy consumption for its assessment will be established in 2 days. Therefore it is necessary to calculate the cost of deviations of the actual volume of electrical deviation consumption from contractual on an Eq.4.

At change of the M3, the aluminate module, for +5% has an increase in energy consumption by 13% (see fig. 1). We will assume that according to the term of the contract of delivery of the

electric power, the enterprise will be obliged to pay excess (or decrease) of power consumption in the following order: if the difference is more than 2% and less than 5%, at the price is 50% higher contractual, if the difference is more than 5% and less than 10%, the 75% higher contractual energy consumption will exceed more than 10% rather than the contractual volume, for 100%.
We assume that two days are enough time to determine the new level of energy consumption and that the transfer of the new request to the energy supplier. If planned energy consumption 200 KWt/h, in two days the enterprise has to pay to the power supplying organization in addition besides previously calculating obligations under the contract of delivery of the electric power the cost of deviations of the actual consumption equals 13 081 545 Rubles, calculated by formula (4). Data on calculation at change of the M3, aluminate module for +5% are consolidated in table 1.

Table 1. Energy consumption and cost of deviations from its contractual volume

Hours	First 24 hours		Next 24 hours		Cost with application Tools [Rubles]	
	Energy consumption [MWt/h]	Cost of deviations (excess) [Rubles]	Energy consumption [MWt/h]	Cost of deviations (excess) [Rubles]	First 24 hours	Next 24 hours
1	200.000	0.0	224.889	311 088.8	276 660.0	311 088.8
2	200.000	0.0	225.194	311 511.5	276 660.0	311 511.5
3	200.000	0.0	225.5	311 934.2	276 660.0	311 934.2
4	203.333	0.0	225.806	312 356.8	281 271.0	312 356.8
5	206.667	142 941.0	225.844	312 410.6	285 882.0	312 410.6
6	210.000	145 246.5	225.883	312 464.4	290 493.0	312 464.4
7	213.333	221 328.0	225.922	312 518.2	295 104.0	312 518.2
8	216.667	224 786.3	225.961	312 572.0	299 715.0	312 572.0
9	220.000	228 244.5	226	312 625.8	304 326.0	312 625.8
10	220.306	304 748.7	226.039	312 679.6	304 748.8	312 679.6
11	220.611	305 171.4	226.078	312 733.4	305 171.4	312 733.4
12	220.917	305 594.0	226.117	312 787.2	305 594.0	312 787.2
13	221.222	306 016.7	226.156	312 841.0	306 016.7	312 841.0
14	221.528	306 439.4	226.194	312 894.8	306 439.4	312 894.8
15	221.833	306 862.1	226.233	312 948.6	306 862.1	312 948.6
16	222.139	307 284.7	226.272	313 002.4	307 284.7	313 002.4
17	222.444	307 707.4	226.272	313 002.4	307 707.4	313 002.4
18	222.750	308 130.1	226.272	313 002.4	308 130.1	313 002.4
19	223.056	308 552.8	226.272	313 002.4	308 552.8	313 002.4
20	223.361	308 975.4	226.272	313 002.4	308 975.4	313 002.4
21	223,667	309 398.1	226.272	313 002.4	309 398.1	313 002.4
22	223.972	309 820.8	226.272	313 002.4	309 820.8	313 002.4
23	224.278	310 243.5	226.272	313 002.4	310 243.5	313 002.4
24	224.583	310 666.1	226.272	313 002.4	310 666.1	313 002.4
	Total in two days the cost of deviations: 13 081 545[Rubles]				Total: 14 705 770 [Rubles]	

As a result, the enterprise has to pay 26 361 225.3 Rubles. If the schedule of change of energy consumption had been provided in advance, the cost of the electric power would make only 14 705 770 (Rubles). The economic effect of use of the offered tools makes:

26 361 225.3 – 14 705 770.1 = 11 655 455.2 (Rubles)

Summary

The received model of the energy management considered and similar productions can be used for drawing up schedules with monthly breakdown and hourly specification that is required for electric power supply contracts.

The developed tools will allow calculating energy consumption size at various parameters of production in advance, and dynamics of its change upon transition to the new mode that will allow building schedules of hourly power consumption in time and by that to reduce its cost.

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