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CURRENT ENERGY BUDGET OF AN ENTERPRISE

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Abstract. Energy budget shows production volumes and energy consumption for the certain period of time as well as fuel storage, auxiliary power consumption, losses in utilities, energy sources consumption in structural units and depending on areas of operations [1, 2].

1 Introduction

Thus, it is of vital importance to develop approaches towards energy budget calculation for short period of time. This issue has a great value in case of development potential, plotting graphs of product transportation and fuel supply, assessing possibilities of energy resources demand coverage for severe conditions e.g. winter peak and summer low load, repair and maintenance schedule, specific climatic conditions (waterflood, hurricane, fallout and etc.), anthropogenic and natural disasters [5-9].

It is evident that energy budgets of any period should be based on the same methodological framework and database. The structure and content of balance items, collection, and calculation and correction techniques of energy budget base elements should be arranged.

2 Calculation of current energy budget

Calculation of current energy budget is based on reinforced concrete plant energy budget.

Figures 1 and 2 show pie charts of energy resources consumption structure in the plant's subdivisions (fractions of the whole).

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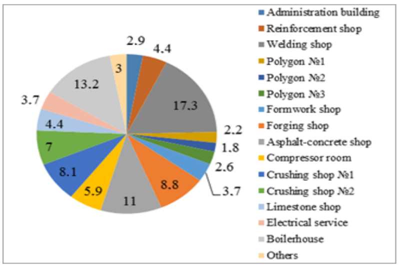

Fig. 1. Electrical energy consumption, %.

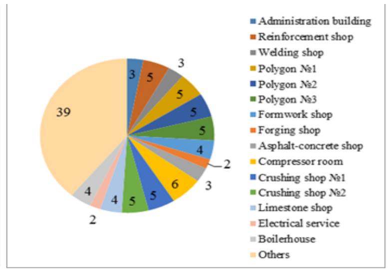

Fig. 1. Water consumption structure, %.

Current energy budget for short period of time supports financial, commercial, logistic, organizational and other branches' basis of controlling [3].

Average calculations of assigned year energy consumption are not difficult if we do not consider short periodical energy budgets structure perturbations:

$$A_t = \int_0^t P_t \cdot dt \cdot \frac{A_{\text{year}}}{N_t} \cdot \Delta t, \tag{1}$$

where P_t – current power, kW, A_{year} – annular consumption, kilowatt hour, T – basis time duration, hour, Δt – current period duration, hour, N – number of equal current time intervals per one year [4]. In case of known plant energy consumption per one year (40000 Ths. kilowatt hour) average short periodical consumption volumes will be calculated as follows.

There is actual difference between energy resources use for short period of time and average for one year. Thus it is necessary to adjust temperature, social, process and other factors. Element value adjustment should be done in the following way:

$$A_k = A_{av} \cdot (1 + k_1 \cdot k_2 \cdot k_3 \cdot k_4), \tag{2}$$

where A_k – current element value, A_{av} – average element value, k_1 – correcting factor considering energy resources volumes of operating days and holidays, k_2 – correcting factor considering demand's increment between start and end of the year; k_3 – correcting factor considering energy resources consumption depending on air temperature, k_4 – correcting factor considering energy resources consumption between heating and non-heating seasons.

Energy consumption ratio of holidays and operating days with correcting factor k_1 approaches 0.5:1. This ratio between holidays and operating days for one week reinforced concrete plant operation equaled 0.55:1.18. In relation to year average plant measurements level showed following k_1 values (Table 1).

Table 1. Correction factor k_1.

Correction factor k_1, relative unit	Electrical energy	Thermal energy	Gas	Water
Operating days	1.15	1.1	1.07	1.12
Weekends and public holiday	0.55	0.75	0.825	0.7

Correction factor k_2 considering demand's increment between start and end of the year is defined as:

$$k_2 = 1 + k_{\text{in}} \cdot \frac{i}{365}, \tag{3}$$

where $k_{in} = 0.02 \div 0.04$ – average incremental growth of demand equal 2 – 4% per year, I – number of the date starting from 1st of January.

Air temperature correction factor k_3 describes energy resources incremental growth with air temperature lower than +10^{0}C in relation to average temperature for same period of many years. In some cases, temperature may be close to zero degrees. Temperature reference scale origin is shifted to the point of – 100 ^{0}C to avoid division by zero. Then:

$$k_3 = \frac{100 - \Theta_d}{100 - \Theta_{av}}, \tag{4}$$

where Θ_d – desired air temperature of design day, ^{0}C, Θ_{av} – average long-term temperature of this day, ^{0}C.

Correction factor k_4 characterizes energy resources consumption between heating and non-heating seasons. It is important to include this factor into calculations because there is a great difference in heat and fuel consumption for both seasons.

Centralized annual heat and fuel consumption comprises the following:

$$Q = Q_{heat} + Q_{\text{hws}} + Q_{pr}, \tag{5}$$

where Q_{heat} – heat consumption for heating, Gcal, Q_{hws} – hot water supply, Gcal, Q_{pr} – heat consumption for process requirements, Gcal.

Thermal energy for heating Q_{heat} is supplied only during heating season, hot water supply Q_{hws} – all year round, and Q_{pr} according to operational program. In calculations hot water supply system volume in comparison with heating accounts for 10 – 12 %. Throwing away Q_{pr} due to its uncertainty, we may assume that:

$$Q = Q_{heat} + Q_{\text{hws}} = Q_{heat} + 0.12 Q_{heat} = 1.12 Q_{heat},$$

$$Q_{heat} = \frac{Q_{heat} + Q_{\text{hws}}}{1.12} = 0.89 \cdot (Q_{heat} + Q_{\text{hws}}),$$

$$Q_{heat} = \frac{Q_{heat} + Q_{\text{hws}}}{1.12} = 0.89 Q.$$

Daily average heat transmission for heating volume during heating season is:

$$q_{\text{av}}^{heat} = \frac{0.89 Q}{235} = 3.79 \cdot 10^{-3} Q,$$

and hot water supply all year round:

$$q_{\text{av}}^{hws} = (1 - 0.89) \cdot \frac{Q}{365} = 0.29 \cdot 10^{-3} Q.$$

Daily heat supply during heating season:

$$q_{day} = 3.79 \cdot 10^{-3} Q + 0.29 \cdot 10^{-3} Q = 4.08 \cdot 10^{-3} Q,$$

and during non-heating season:

$$q_{day} = 0.29 \cdot 10^{-3} Q.$$

Correspondingly, the correcting factor k_4 during heating and non-heating seasons is equal to:

$$k_4 = 4.08 \cdot 10^{-3} \cdot 235 = 0.9588,$$

$$k_4 = 0.29 \cdot 10^{-3} \cdot 130 = 0.0377.$$

This correcting factor for electrical energy and water supply can be taken as 1.

3 Experimental results

Correction factors for other periods of time are defined the same way. Table 2 shows correcting factors' values for accepted design conditions.

Table 2. Correcting factors' values.

Current period	k_1, k_o – operating days, k_h – holidays				k_2	k_3	k_4 heat and fuel	
	Electrical energy	Thermal energy	Gas	Water			Heating season	Non-heating season
Hour k_o k_h	 1.15 0.55	 1.1 0.75	 1.07 0.875	 1.12 0.7	$1+k_{in}\cdot\frac{i}{365}$	$\frac{100-\Theta_d}{100-\Theta_{av}}$	0.9588	0.0377
Day k_o k_h	 1.15 0.55	 1.1 0.75	 1.07 0.875	 1.12 0.7	$1+k_{in}\cdot\frac{i}{365}$	$\frac{100-\Theta_d}{100-\Theta_{av}}$	0.9588	0.0377
Week	$\frac{k_o \cdot n_o}{7}+\frac{k_h\cdot(7-n_o)}{7}$				$1+k_{in}\cdot\frac{i}{52}$	$\frac{100-\Theta_d}{100-\Theta_{av}}$	0.9588	0.0377
Month	$\frac{k_o \cdot n_o}{n_a}+\frac{k_h\cdot(n_a-n_o)}{n_a}$				$1+k_{in}\frac{j}{12}$	$\frac{100-\Theta_d}{100-\Theta_{av}}$	0.9588	0.0377
Heating season	$\frac{k_o \cdot n_o}{n_a}+\frac{k_h\cdot(n_a-n_o)}{n_a}$				$1+k_{in}\frac{n_a}{365}$	$\frac{100-\Theta_d}{100-\Theta_{av}}$	0.9588	0.0377
Non-heating season	$\frac{k_o \cdot n_o}{n_a}+\frac{k_h\cdot(n_a-n_o)}{n_a}$				$1+k_{in}\frac{n_a}{365}$	$\frac{100-\Theta_d}{100-\Theta_{av}}$	0.9588	0.0377

*Foot-note: k_o – operating load factor, k_h – weekend and public holidays load factor, $k_п$ – increment load factor of the whole year, Θ_d – desired temperature of period, Θ_{av} – average temperature of period, *i* – day number of the year, n_o – operating days number of period, *j* – week number starting from the beginning of the year, n_a – day quantity of the period, *e* – month number starting from the beginning of the year.

4 Conclusion

Current energy budget calculation represents simple computational task. Experience of current energy budget use for energy consumption and energy saving control allows to plan energy sources volume for different short periods of time more accurately, to calculate faults, to determine energy performance factors in terms of the year for fixed points based upon development prospect (or other side – production curtailment) and etc.

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