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METHODOLOGIES

FOR CALCULATION OF ELECTRICITY FOR ANCILLARY AND INTERNAL NEEDS OF "VOROTAN HYDRO POWER PLANTS CASCADE"

"Vorotan Hydro Power Plants Cascade" CJSC

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METHODOLOGIES
FOR CALCULATION OF ELECTRICITY FOR ANCILLARY AND INRERNAL NEEDS OF "VOROTAN HYDRO POWER PLANTS CASCADE"

1. General Provisions

1. The amount of electricity used for ancillary and internal needs of “Vorotan HPPs Cascade” serves as a guidance for control and planning of the actual (measured) amount of that consumption, as well as for improvement of the operating mode of electricity consumers.

2. Calculations are carried out based on analytical method, considering operating mode of each consumer one by one. The calculation of electricity used for ancillary needs of substations is carried out within each settlement period (month, year).

3. Within the framework of these Methodologies for calculation of electricity used for ancillary and internal needs of “Vorotan HPPs Cascade”, the operating mode of consumers shall be selected to meet the following requirements:

    a) ensure adequate technical status of all equipment installed in buildings and structures, under normal operation mode;
    b) ensure operation of all equipment installed in buildings and structures by applying advanced - modern methods;
    c) implementation of technical-organizational measures aimed at energy saving.

2. Composition of Electric Consumption Appliances for Ancillary Needs of Hydro Power Plants

The electric consumption appliances, which ensure necessary operation mode of equipment in the process of electricity generation and transformation, are classified as electric consumption appliances for ancillary needs of hydro power plants.

The electric consumption appliances for own needs at hydro power plants shall not include consumers classified as appliances for internal needs (see part 3).

The list of electric consumption appliances for ancillary needs at hydro power plants includes the following electricity consumers:

1. Hydraulic structures

   - engines of machines maintaining reservoir, HPP outlet, water collector basin and other structures;
   - lighting of reservoir and heating of rooms of buildings at the reservoir structures.

2. Pressurized reservoir

   - engines of machines maintaining pressure diversion and trash gathering devices;
   - engines of machines maintaining pressure front net (dam)and gate;
   - lighting of pressure diversion and heating of buildings at its structures;
   - heating of dam and gates.

3. Buildings of HPPs

   - electric engines of HPP building's water offtake and water pumping from hydroelectric generators flowing channel operating within the regulating system;
   - electric engines of HPP's oil and compressed air shop, generators excitation system and fire control system of the HPP building;
   - electric engines of penstock gates opening-closing mechanisms and lifters (elevators, cranes, hoists and other);
   - electric engines of mechanisms and machines of electric welding, electric tools, hydro-mechanical and electro-technical equipment repair shops;
   - lighting, heating and ventilation of all rooms/premises of HPP building, as well as distribution facilities and lighting of HPP area.

4. HPP substation

   - cooling of transformers and autotransformers;
   - feeding of operative and control circuit, charging-subcharging devisces of storage batteries (in substations of operative alternating current);
   - heating of driver and oil breaker chambers, air collectors;
   - heating of drivers of separators and couplings;
   - electric motors of automatic machinery of synchronous condenser's auxiliary devises, oil circulation and suction pumps;
   - heating of electric energy meters in unheated rooms;
   - heating and use of drivers of under load voltage regulation converters
   - communication and telemechanics devices;
   - lighting of substation area;
   - technical losses of electricity in intra-network elements of a plant are calculated according to the "Methodologies for calculation of unavoidable technical losses of electricity in 110 kV and higher voltage networks" and

attributed to the WEM entities in compliance with the "Temporary methodologies for accounting for electricity (capacity) in the Power Sector of Armenia".

3. Composition of Electric Consumption Appliances for Internal Needs of Hydro Power Plants

1. Electric consumption appliances, which ensure consumption of electricity by non-production subdivisions, necessary for maintenance of the main activity, but do not directly relate to the technological process of electric energy generation and conversion at HPPs, are attributed to the group of HPPs internal needs.

2. The list of HPP electric consumption appliances for internal needs comprises the following consumers:

   - motor-vehicle park;
   - equipment and material, fuel storages;
   - administrative buildings, including separate service buildings of various importance: training centers; library, medical center, residential buildings, specialized laboratories, shelters, fire fighting and military protection buildings;

Electric consumption for internal needs of HPPs does not include:

   - Electricity consumed by the organizations having separate balance under administrative subordination of hydro power plant (repairing-mechanical, ferro-concrete structures, wood-working and testing factories, specialized constriction and mantling organizations, specialized constructive and design organizations);

   - Electricity consumed for heat, water supply and lighting for workers' towns, personnel involved in repairing and operation activities, separate residential buildings, canteens, dormitories, hotels, clubs, hospitals, kinder gardens, resting areas and other premises.

4. Calculation of Electricity Used by Electric Consumption Appliances for Ancillary and Internal Needs of HPPs

1. Calculation of electricity used for ancillary and internal needs shall be conducted separately, for each month or a year, including the following:

   - energy consumption necessary for heating of installed buildings and structures (premises);
   - electric energy consumption for lighting;
   - electric energy consumption for power equipment.

2. For calculation of electric energy consumption necessary for heating of ancillary and internal needs of buildings and structures, it is necessary to take into account climatic conditions. Calculation, presented in the Methodologies, is provided on an annual basis and for "mild" climatic zone, which is considered basic for Armenia.

   In these Methodologies the territory of Armenia is segregated into 4 climatic zones according to the altitude above sea level:

   I climatic zone - 1800 m. and higher;
   II climatic zone - 1700-1800 m;
   III climatic zone - 1100-1700 m;
   IV climatic zone - up to 1100 m.

Information necessary for calculation of electric energy consumption for heating of ancillary and internal needs of "Vorotan HPPs Cascade" CJSC is presented in table 1, based on the location of Cascade's separate entities by climatic zones.

The amount of necessary heat:

$$Q=[(F_w + F_c)K_w + F_l K_l](t_n - t_{est}) \quad (W), \tag{1}$$

where:

F_w - total area of external walls of the construction (m^2),

F_c - total area of ceiling (m^2),

$F_{ťáõë}$ - total surface of windows (m^2),

K_w - heat conductivity factor of the construction wall (is selected from reference books [1]) (W/ $m^2 \cdot K$),

K_l - heat conductivity factor of constructions' windows (is selected from reference

books [1]) (W/ $m^2 \cdot K$),

t_n - required standard temperature inside of the construction (18^0 C),

t_{est} - average temperature of heating season within the RoA territory, estimated by meteorological service.

The amount of electricity necessary during the heat season in case of electric energy heating:

$$W^h(I) = QT(I) \cdot 10^{-3} \text{ (kWh)}, \qquad (2)$$

where: T(1) - duration of the heat season for the given climatic zone.

The amount of electricity necessary during the heat season is divided based on months by the following formula:

$$W^h_{month} = K2(I,J)W^h(I) \text{ (kWh)}, \qquad (3)$$

Where: K 2 (1,J) - factor-relative unit (r.u.), which takes into consideration the portion of electricity used for heating based on months and climatic zones

I- number of the climatic zone;
J- name of the months of the year.

K 2 (1,J) – the value of the factor is taken from Table 2.

The annual amount of electricity necessary for heating:

$$W^h_{year} = \sum_{i=1}^{n} W^h_{month} \text{ (kWh)}, \qquad (4)$$

Where: n – number of months in a year.

3. For calculation of electric energy consumption necessary for artificial lighting of ancillary and internal needs of buildings and structures, the amount of luminous flux of lamp (lamps) is determined:

$$\Phi = \frac{100 E_l k_s S Z}{N h} \quad \text{(Lumen)}, \qquad (5)$$

where: E_l - the lowest provided light (Lux),

S - lighting area (m^2),

N - number of lamps,

η- use factor (%),

k_s - safety factor, which takes into account the fact of decrease of the luminous flux during the operation

Z - direction factor.

Amount E_1 is equal to [2]

$$El = \begin{cases} 50\ lux, & for\ corridors, \\ 50 \div 200\ lux, & for\ production\ buildings, \\ 300\ lux, & for\ work\text{-}rooms. \end{cases}$$

Direction factor. [2]

$$Z = \begin{cases} 1.15, & for\ incandescent\ and\ mercury\ lamps \\ 1.1, & for\ fluorescent\ lamps. \end{cases}$$

Safety factor. [3]

$$k_{å} = \begin{cases} 1.3, & for\ incandescent\ lamps, \\ 1.5, & for\ fluorescent\ and\ mercury\ lamps \end{cases}$$

The use factor relating the size of the building is taken into account by -i- indice of the premises:

$$i = \frac{AB}{h(A+B)}, \qquad (6)$$

Where: A, B, h - corresponding length, weight and height of premises (m).

If i>5, then i =5. If A:B $\geq$ 10, then i =B/h.

For different types of lamps based on –i-, η-the values of the usage factor are determined in compliance with the walls, ceiling, as well as reflection factors of the floor area and reference book.

In accordence with Φ value, nearest standard lamp form the tables provided in the reference book is selected, the limen-lux can be differentiated from the calculated value in the amount of $-10 \div +20\%$.

The amount of designed load for artificial lighting for the buildings is the following:

$$P_{est} = P_{in} K_d \text{ (kWh);} \quad (7)$$

Where:

$P_{in} = \sum P_i$ - Total designed capacity of lamps

K_d - Demand factor

P_i - Nominal capacity of the selected lamps.

Demand factor. [2]

$$K_d = \begin{cases} 1, & \textit{for emergency and} \text{ external lighting,} \\ 0.95, & \textit{for propduction buildings,} \\ 0.9, & \textit{for admin istrative} \text{ buildings,} \\ 0.6, & \textit{in} \text{ storages.} \end{cases}$$

To calculate annual average consumption of electricity the number of the working hours of artificial lighting should be determined.

Number of working hours with artificial lighting:

$$T = t(A - a) \quad \text{(h),} \quad (8)$$

where: t - number of daily working hours with artificial lighting ,

A - total number of days in a year,

a - number of non-working days.

Annual amount of electricity consumption for artificial lighting:

$$W^{l}_{year} = P_{est} T \quad \text{(kWh):} \quad (9)$$

4. For calculation of annual amount of electric energy consumption, necessary for ancillary and internal needs of power equipment, we will have to calculate the average capacity of electric consumption appliances during the shift with the highest load:

$$Pav = K_u P_{nom} \quad \text{(kW),} \quad (10)$$

where: K_u - use factor (is selected from reference books) [4]),

P_{nom} - nominal capacity of consumers.

Monthly amount of electric energy consumption is calculated by this formula:

$$W^{\mathrm{p}}_{\mathrm{month}} = P_{\mathrm{av}} t_{\mathrm{month}} \quad \text{(kWh)}, \tag{11}$$

where: t_{month} – number of working days of a given consumer:

Annual amount of electric energy consumption:

$$W^{\mathrm{p}}_{\mathrm{year}} = \sum_{i=1}^{n} W^{\mathrm{p}}_{\mathrm{month}} \quad \text{(kWh):} \tag{12}$$

5. Annual electric energy consumption for ancillary and internal needs:

$$W_{\mathrm{year}} = W^{\mathrm{h}}_{\mathrm{year}} + W^{\mathrm{l}}_{\mathrm{year}} + W^{\mathrm{p}}_{\mathrm{year}} \quad \text{(kWh).} \tag{13}$$

Table1

Altitude above sea level of entities of "Vorotan HPPs Cascade" CJSC, estimated average temperature and duration of heating season.

#	Climatic zone	Heating season			
		average temperature, ℃	duration, days	beginning	end
1	I climatic zone (1800 m. and higher)	-2.1	209	10.10	7.05
2	II climatic zone (1700-1800 m.)	-2.1	196	15.10	29.04
3	III climatic zone (1100-1700 m.)	0.0	179	24.10	21.04
4	IV climatic zone (up to1100 m.)	0.5	146	18.10	13.04

Table 2.

Allocation of premises' annual electricity consumption by months

Name of factor	Climatic zone	Months (J)												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
K2(I, J)of premises heating	1	0.148	0.134	0.148	0.144	0.033	0	0	0	-	0.101	0.144	0.148	1
	2	0.158	0.143	0.158	0.148	0	0	0	0	0	0.082	0.153	0.158	1
	3	0.173	0.156	0.173	0.118	0	0	0	0	0	0.039	0.168	0.173	1
	4	0.212	0.192	0.212	0.089	0	0	0	0	0	0	0.083	0.212	1

Note:

In table 2, amount of K2 (I, J) is calculated in the following way:

K2 (I, J) = T (J) / Ti (I),

Where: T (J) –number of days in heating month,
Ti (I) –average annual number of heating days.
Amounts of T (J), Ti (I) are taken from table 1, for the corresponding climatic zones.