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RESEARCH VARIANTS OF AIR ACCUMULATING POWER STATION CONSTRUCTION AND THEIR SUBSTANTIATIONS

There had been offered variants of construction of the small air heat-sink power station suitable for research of processes in it. The design procedure of key parameters of this research station is presented.

***Keywords**: energy-saving, wind-power engineering, heat-sink power station, air storage.*

1. Introduction

Papers [1, 2] show the prospects of the wind accumulating power stations construction (WAPS), variants of air storages, schemes of complex application and mathematical models of evaluation of their economic efficiency, as well as the formulated problems to be solved in this sphere of researches. The consideration of the problem of AHPS construction requires research the processes which take place in the particular elements of this class of electric power accumulators, their mutual interaction and to determine the materials which characteristics will correspond to operating conditions in interaction with these processes.

Since the experience in constructing of AHPS hasn't been acquired yet and there haven't been published the scientific articles numerous enough to investigate the problem in the sphere of construction engineering it is necessary to construct a small AHPS to research the processes characteristics of the air accumulation of electrical energy and the influence of the processes on the construction materials used for manufacturing of the construction elements

This paper introduces several variants of AHPS constructions and methods of its parameters' assessment. Using one of the variants any research institution interested in the processes of air accumulation of electrical energy could build such AHPS on its research ground without any considerable financial losses.

2. Variants of air storages for research AAPS and evaluation technique of their parameters

Let's consider three variants of air storage:

1). Hollow metal cube with internal volume $V_1 = 1\,m^3$ to boost the air up to pressure $P_1 = 23{,}1\,MPa$.

2). Hollow metal parallelepiped with internal volume $V_2 = 4\,m^3$ to boost the air up to pressure $P_2 = 4{,}1\,MPa$.

3). Hollow ferroconcrete parallelepiped with internal volume $V_3 = 60\,m^3$ to boost the air up to pressure $P_3 = 0{,}2\,MPa$.

The realization of the first of these variants allows to use a receiver of the air high-voltage switch from the substation of $750\,kV$, the realization of the second variant allows to weld the table steel to the parallelepiped with the length and width in $2\,m$ and height in $1\,m$, reinforced by the angle bar and the channel bar. For the third variant to be realized one can dig out a hole of $10{,}5\,м \times 3{,}5\,м \times 2{,}25\,м$ where a reinforced concreted gutter of the size 10m x 3m x 2m then to be concreted using encasement and armature concrete. The gutter is to be covered with the reinforced concreted slabs armor-clad at joints with metal welded to the necessary metal blocks at the definite points.

Using a well-known formula [3] —

$$E_i = V_i(P_i - P_{at}) = V_i \cdot \Delta P_i, \quad i = 1,2,3, \tag{1}$$

let's calculate the energy reserve in each air storage air full with set pressure.

Inserting into the formula (1) the meaning of the atmosphere pressure $P_{am} = 0{,}1\, M\Pi a$ and the meaning of the pressure and volume for each of the above mentioned variants of air storages, we'll find out the energy reserves are

$$E_1 = 23\, MJ, \quad E_2 = 16\, MJ, \quad E_3 = 6\, MJ. \tag{2}$$

Considering the results (2) we see that increasing pressure, one and the same volume of energy can be stored in the air storage of the smaller sizes. It should be noted however, that in the reinforced concreted air storages the pressure shouldn't be increased by more than 0,2 MPa as the reinforced concrete is known to be damaged under the higher pressure and cyclic loading.

Let's calculate the air mass in each of suggested variants of air storage, which is to take place under the maximum pressure.

For this purpose we'll use the rule of Boyle-Mariotte (3) taking into consideration that the air in both cases is of the same temperature:

$$P_i \cdot V_i = P_{at} \cdot V_i^{at} = 0{,}1 \cdot V_i^{at}, \quad i = 1,2,3, \tag{3}$$

where V_i^{at} – air volume in an atmosphere after releasing from the air storage.

Substituting values of corresponding parameters from all the three resulted above air storage variants in the formula (3) we receive:

$$V_1^{at} = 231\, m^3, \quad V_2^{at} = 164\, m^3, \quad V_3^{at} = 120\, m^3. \tag{4}$$

But if to consider that during the releasing of air from the air storage into the atmosphere, the air will last until the pressure is higher than that in the atmosphere, the real "wind" will be formed with the air volume E_{ip}^{am} which can be found from the correlation

$$V_{ip}^{at} = V_i^{at} - V_i, \quad i = 1,2,3. \tag{5}$$

Substituting the output data and the results (4) in the formula (5) we find

$$V_{1p}^{at} = 230 m^3, \; V_{2p}^{at} = 160 m^3, \; V_{3p}^{at} = 60 m^3. \tag{6}$$

From physics we know

$$M_i = \rho_{at} \cdot V_{ip}^{at} = 1{,}2 \cdot V_{ip}^{at}, \quad i = 1,2,3, \tag{7}$$

where ρ_{at} – air density under the atmospheric pressure which equals $1{,}2\, kg/m^3$, and M_i – air mass in the i-th air storage variant which will create "wind" during the air releasing. Substituting results (6) in correlation (7) we shall receive

$$M_1 = 276\, kg, \quad M_2 = 192\, kg, \quad M_3 = 72\, kg. \tag{8}$$

3. Research AAPS structure and evaluation technique of its parameters

Research AAPS functional structure it suggested to choose in a variant schematically presented in figure 1 with the elements: 1 – air storage (accumulator), 2 – regulator of pressure, 3 – diffusion cell, 4 – wind engine, 5 – electric generator, 6 – stop valve, 7 – compressor, 8 – compressor electric drive, 9 – power supply system, 10 – electric power consumer, 11 – control-measuring and adjusting equipment.

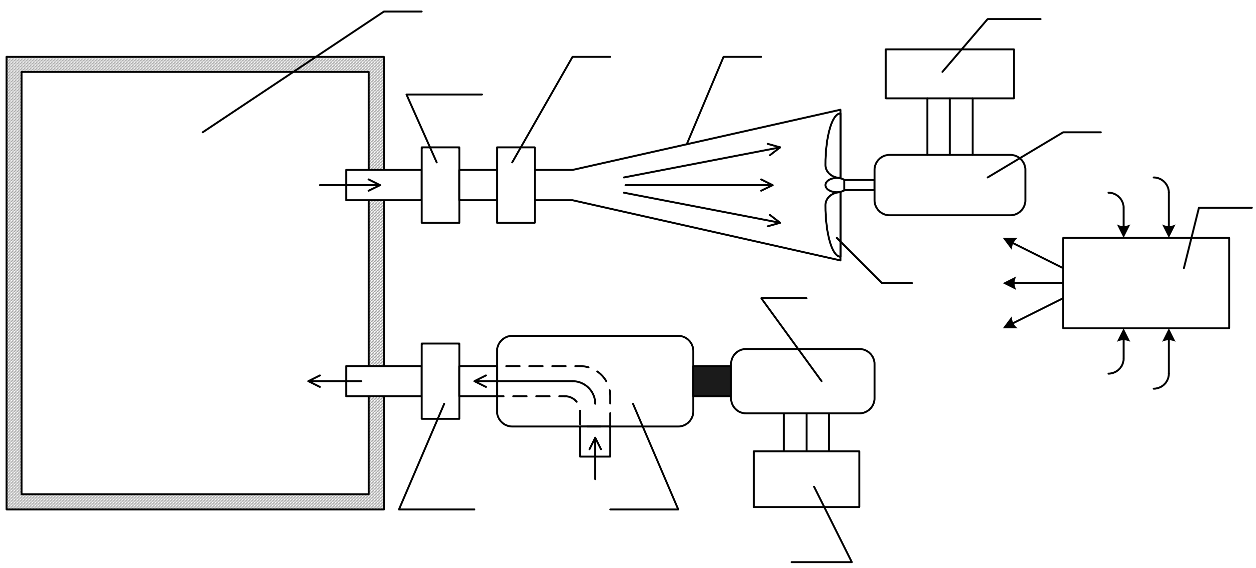

Fig. 1. Research AAPS functional structure variant

It’s evidently that in case of AAPS work synchronization processes research with the electrical power system, the elements 9 and 10 will be combined and represent the same busses of electric network substation.

It should be noted that we concentrate our attention on AAPS functional structure from which the air accumulation basic technological processes of the electric power and transformation of the compressed air energy into the electric power are easily traced. In this paper the problem of the AAPS elements equipment with the particular control-measuring and regulating devices is not considered as first, this is the subject matter of the other paper, and, secondly, its list and an implementation aria are determined by subject under research.

The algorithm of AAPS functioning (the structure of which is shown in fig.1) in case of the combination of the elements 9 and 10, will be as follows: since the surplus of electric energy and pressure in air storage 1occurs to be lower than the set one, the usage of the adjusting equipment 11 and the electric drive 8 puts into operation the compressor 7 which will force the air in the air storage 1 until its pressure become equal with the set. When this balance is reached, the regulating equipment 11 sends the command to the stop valve 6-K and to the switch of the electric drive 8 of compressor 7. In the result the compressor is disconnected and the air access channel in air storage is blocked. During the air boosting into the air storage 1 and after the finishing of this process the stop valve 6-B holds the channel blocked.

When the electric power deficiency appears in an electric power system, the adjusting equipment 11 sends the signal on the stop valve 6-B, the compressed air release channel from air storage 1 to diffusion cell 3 opens. The stream of air which is formed by diffusion cell 2 acts on the wind engine 4 where the compressed air energy turns into the mechanical energy of wind engine shaft rotation. The wind engine 4 transfers the mechanical energy of rotor shaft rotation to the rotor of the electric generator 5 in which the mechanical energy turns into electric energy which, in turn, is supplies to the electric power system. This process lasts until the pressure in air storage 1 becomes equal to the atmosphere pressure or the electric power deficiency in electric power system disappears. During the process of air release from the air storage 1, the pressure in diffusion cell 3 is kept constant by means of a pressure regulator 2. This process can be stopped by the signal of the adjusting equipment which will fulfil the set program.

The main regime of AAPS parameters is the power $N = f(\nu, D)$ in watts which it can develop on a wind engine shaft with wind wheel diameter D (in meters) with different speeds (in meters per second) of the wind stream which rotates the wind engine.

The paper [4] suggests the calculating the maximum possible value of capacity N by means of formulas

$$N_{\max} = \frac{2}{3} v \left[\frac{8}{9} \left(\rho_{at} \frac{v^2}{2} \right) \right] \pi \left(\frac{D}{2} \right)^2 = 0{,}279 v^3 D^2 \ (W). \tag{9}$$

Table shows the discrete values of wind engine power dependence on the seven values of the wind wheel diameter, and the three values of wind stream speed calculated on the basis of formula (9).

Table

Set of values of lattice function $N_{\max} = f(v, D)$ in watts

$v\,(m/s) \backslash D\,(m)$	**0,1**	**0,5**	**0,75**	**1**	**2**	**5**	**10**
7	0,956	23,92	53,88	95,7	382,8	2392	9570
10	2,79	69,75	157	279	1116	6975	27900
15	9,42	235,4	530,1	941,6	3766	23540	94162

Now we will find relationship between the volume V_{ip}^{at} of air which will leave the air storage into an atmosphere through diffusion cell with the diameter D, speed v from which air will pass through this diffusion cell and the interval of time t necessary for the air volume to leave the air storage provided that the regulator of pressure during all this interval of time will support the constant pressure in the diffusion cell.

Starting from a condition of indissolubility of an air stream in diffusion cell it is possible to write

$$V_{ip}^{at} = \nu \left(\pi \frac{D^2}{4} \right) t, \quad i = 1,2,3, \tag{10}$$

from which

$$t = \frac{4V_{ip}^{am}}{\nu \pi D^2}, \quad i = 1,2,3. \tag{11}$$

For the chosen (during the table construction) seven values of diffusion cell diameter D and three values of air stream speed v in diffusion cell during the meeting with a wind wheel of the diameter D for each working air volume V_{ip}^{at}, $i = 1,2,3$ using the formula (11) it is possible to find 21 values of time interval t during which AAPS will work in a mode of energy generation.

For example, if $V_{1p}^{at} = 230\ m^3, v = 10\ m/s,\ D = 1\ m$ so substituting these values of parameters in the formula (11) we will receive $t = 29\ s$. And if at same the volume and speed we take $D = 0{,}5\ m$ or $D = 0{,}1\ m$ we will receive accordingly $t = 116\ s$ or $t = 2929\ s$.

From these examples we can see that reducing the diffusion cell diameter and the wind wheel diameter we can essentially increase the time of AAPS functioning in a generation mode. But it should be noted that the wind engine power thus will essentially fall and will accordingly make up $279\ W$, approximately $70\ W$ and nearby $3\ W$ (see tab. 1).

These are, of course, the theoretical calculations. On practice the parameters will differ a little from those calculated, therefore we suggest to build the research AAPS to research all these divergences and formulate the adequate variants of the obtained mathematical models.

4. Conclusions

1. There had been grounded the expediency and perspective of the research AAPS construction with comparatively small but available for the research work volumes of air storages.
2. There had been suggested several variants of air storage and the AAPS functional structure.
3. There had been developed the evaluation techniques of AAPS main parameters and shown specific examples of their using.

REFERENCES

1. Mokin B. I. Ecologic and economic aspects of AAES creation // VISNYK of Vinnytsia Polytechnical Institute. – 2006. – №5. – C. 95-103.

2. Мокін Б.І. Системи еколого-економічного управління // Зб. матеріалів XIII Міжнародної конференції з автоматичного управління «Автоматика-2006». – Вінниця: «УНІВЕРСУМ-Вінниця». – 2006. – С. 109-113.

3. Чепурний М.М., Ткаченко С.Й. Основи технічної термодинаміки. – Вінниця: «Поділля-2000». – 2004. – 352 с.

4. Ветроэнергетика / Под ред. Д.Рензо: Пер. с англ. под ред. Шефтера Я.И. – М.: Энергоатомиздат. – 1982. – 272 с.

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