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PNEUMATIC ENERGY BATTERY FOR PRIVATE SOLAR POWER

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***Summary* -** the article deals with the accumulation of energy for the conditions of a farming business like greenhouse, etc.. For the very beginning, the main applicable methods of energy storage are considered and mutually compared. The main attention is given to gravity and mechanical storage ways. The basic principles of energy accumulation and storage for these forms of energy and the back conversion into electrical energy are indicated for the conditions of farms. Theoretical regularities of the air pressure stabilization time in the receiver under the constant supply are obtained for different environmental parameters and the receiver operating conditions. The obtained patterns make it possible to justify the operation mode of the gas storage device, its design parameters and give the preconditions for the selection of pneumatic shut-off and control valves, as well as electric generators.

The tasks are set for the technical implementation of the energy complex. As the further work basis the authors see the expanding of the parameter list for the regularity for the pressure stabilization time determination taking into account temperature fluctuations during charging and discharging of a gas storage device and the influence of air parameters on the performance efficiency.

Keywords: renewable energy, energy storage, energy storage gas.

Introduction. One of the main problems of alternative energy is the unevenness of its receipt from renewable sources [8]. The sun shines only during the day and in cloudless weather. Wind speed is also unstable. Additionally the demand for electricity is not constant, and depends on a large number of unpredictable factors and some others scarcely predictable for a long period [6, 7]. Taking into account that electric energy has such a feature, that the generated amount of the energy must be consumed and the difficulties with the accumulation of the large volumes of electric energy, the problem arises how to match the electric power generation and consumption. This task is realized in practice with the different ways of the energy accumulation implementation and to solve many technical problems for it is actual for the great variety of the energy power generators and different power consumers [3, 8, 10].

The article will discuss the energy accumulation for conditions of the farm private business with crop production like greenhouses with a need to ensure reliable energy supply for the technological process. The solving of the task is complicated by the fact that the electrochemical storage usage is impossible due to the temperature fluctuations and the complexity of the storage location features [3, 8]. Additionally, the installation gasoline and diesel generators accompanied by products of combustion emissions, noise and the complexity of the operation.

Analysis of recent research. There are 6 main forms of energy: gravitational, mechanical, thermal, chemical, electromagnetic and nuclear. Now there are artificial batteries for the energy of the first five forms [3, 7, 9]. Let us consider how these forms of energy could be accumulated, stored and converted into electricity in the conditions of the farms.

In the gravitational energy accumulators at the stage of energy storage the load rises up accumulating potential energy and at the right time it falls down, returning this energy for possible usage. The use of solids or liquids as a load contributes to the very specific type of design [9]. An intermediate position among the mentioned types is occupied be the usage of bulk solids (sand, lead shot, small steel balls, etc.) as energy accumulating body.

The mechanical energy storage devises are characterized by the movement of individual bodies or their particles. These include the kinetic energy of the linear or rotational motion of the body, the energy of deformation during bending, tension, twisting, compression of elastic bodies (like springs, etc.) [3]. There are such types of mechanical drives: gyroscopic (energy is stored in the form of kinetic energy of a rapidly rotating flywheel); gyroresonance (represent the same flywheel, but made of elastic material), etc. [9].

Among mechanical drives with usage of elastic forces it is necessary to consider a bit more attentively the ones with usage of the spring [9] and gas as accumulating media [2, 5, 9]. The spring-based mechanical drives (ones that use the compression and straightening of the spring, providing a large flow rate and energy input per time unit) require a complex and material-intensive mechanism for fixing the spring. On the contrary, the gas-based mechanical drives (the compressed gas is fed into a turbine that directly performs the necessary mechanical work) are simpler for the technical implementation and operation.

Based on the literature analysis, communication with scientific and practical experts, it was decided to focus on the gas mechanical storage devices [4, 5]. This approach allows us to get a double product: electrical energy and water (as it condenses in the tank, because the moist air is compressed from the greenhouse and cooled during the night) besides with the possibility of the direct consumption of the compressed gas for possible technological implementations.

A promising technology for creating energy reserves is air compression due to available energy at a time when there is no immediate need for it. Compressed air is cooled and stored under the pressure 60-70 atmospheres [2]. If it is necessary to consume the stored energy, the air is extracted from the storage ring, heated, and then supplied to a special gas turbine, where the energy of compressed and heated air rotates the turbine, turning the shaft connected to an electric generator delivering the electricity to the power system [2, 4].

It is not new way to solve the energy production-consumption problem. Gas storage devices are used in transport [10], robotics [1] and industrial energy sectors [2, 3, 6]. Various algorithms have been developed for the technical and economic justification of the design and operation modes of such energy-storage plants. There are developed standard modules, like ones of the Matlab library with the Simulink environment [4, 5, 7]. For the business connected with the cultivation of closed soil there are many natural (air composition, external influences) and anthropogenic (technological equipment, asocial behavior of workers, vandalism, low work culture, etc.) factors that require a detailed review of the design choice and economic substantiation of the effectiveness of the use of gas energy storage.

Purpose of the article. To get a mathematical model allowing to determine the time of pressure stabilization of the receiver with the atmospheric pressure in, dependence of the environmental parameters.

Research materials. It is necessary to consider the physics of the processes that occur in gas storage devices to achieve the goal of the article. This is complex and multi-parametric task. For the very beginning, let’s determine the time for stabilization of the air pressure in the receiver with a constant supply of external air

$$t = \frac{|\Delta m|}{\vartheta} \quad (1)$$

where |Δm| – the mass difference for the air in the tank under atmospheric pressure and actual pressure in the tank, kg;

υ - air supply rate to the container, kg / s;

With use of the reference data for the air physical properties at certain values under the pressure P (Pa) and temperature T (K) using the Mendeleev-Clapeyron equation, it’s possible to determine the weight of air in the tank of the volume V (m^3) according to the given parameters:

$$m = \frac{V\mu}{R}\left(\frac{P}{T}\right) \qquad (2)$$

where R – universal gas constant, R=8,31 J/(mol·K);

μ - molar mass of air, accept the molar mass of dry air μ=28,96 g/mol.

Therefore, as follows from expression 2, the weight of air in a closed volume under altered (m_2) and atmospheric (m_1) pressure should be be calculated as:

$$m_2 = \frac{V\mu}{R}\left(\frac{P_2}{T_2}\right) \qquad (3)$$

$$m_1 = \frac{V\mu}{R}\left(\frac{P_1}{T_1}\right) \qquad (4)$$

Introducing the constant:

$$D = \frac{\mu}{R} = \frac{29\cdot 10^{-3}}{8{,}31} = 3{,}5\cdot 10^{-3}\ \left[\frac{kg\cdot mol\cdot K}{mol\cdot J} = \frac{kg\cdot K}{J}\right], \qquad (5)$$

$$t = \frac{D\cdot V}{\vartheta}\left|\frac{P_1}{T_1} - \frac{P_2}{T_2}\right| = 3{,}5\cdot 10^{-3}\cdot\frac{V}{\vartheta}\left|\frac{P_1}{T_1} - \frac{P_2}{T_2}\right|, \qquad (6)$$

In the particular case, pressure equalization will be carried out if the atmospheric temperature and the temperature inside the vessel are equal, i.e. $T_1 = T_2$, and the expression 6 takes the form

$$t = 3{,}5\cdot 10^{-3}\cdot\frac{V}{\vartheta}\frac{|P_1 - P_2|}{T}, \qquad (6)$$

For an example and the simplification of further calculations let's accept: receiver volume V = 1 m^3, atmospheric pressure P_2 = 100 kPa. Under the precondition that the air in the greenhouse is dry the receiver will charge and discharge at the same temperature. Accepted assumptions could be easily implemented for the laboratory conditions. In such a way, theoretical data are obtained for the stabilization time under constant atmospheric pressure (fig. 1) and under the constant ambient temperature (fig. 2).

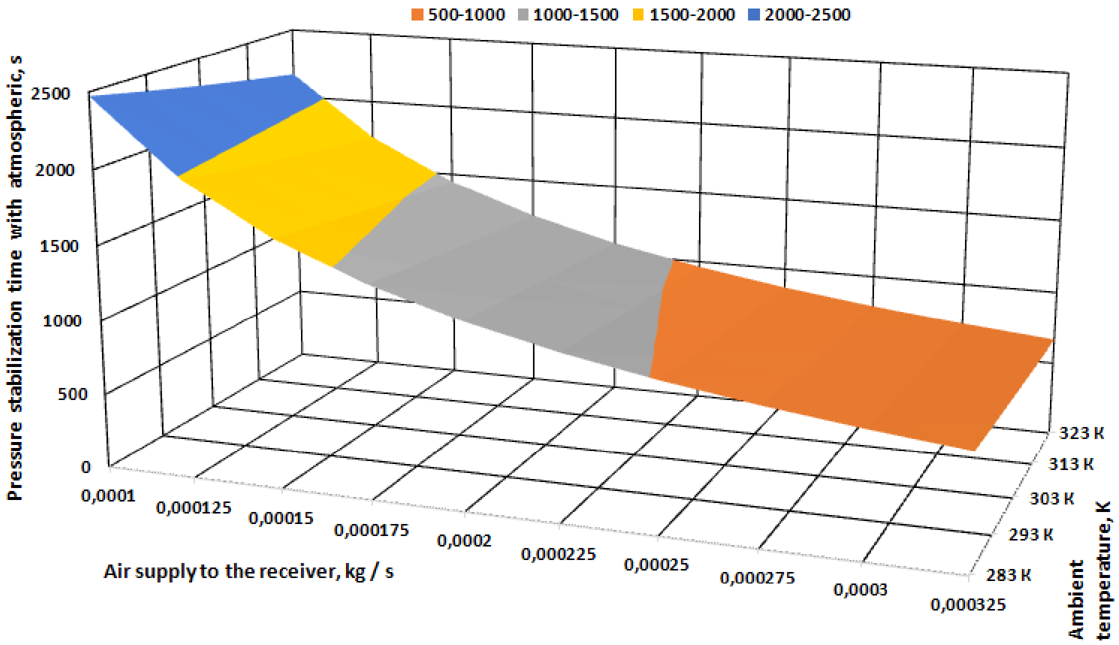

Fig. 1. Receiver pressure stabilization time under atmospheric pressure at various ambient temperatures (P_2 = 120kPa)

The accepted conditions hardly could be fulfilled for the real plant in operation as it is obvious that the temperature of the receiver will change as well as the humidity of the air in greenhouse and both the factors should not be neglected. Under the usage of the stored energy in the receiver under the calm weather (if one's plant is equipped with wind generators) or in the dark (for plant with solar energy generation), the temperature factor will contribute to the receiver pressure change up to the end of the filling time. Humidity would contribute to the condensation of moisture at the bottom of the receiver and it means technical complication for the flow of air to the turbine.

Analysis of the graphs shows that it is better to store energy in a gas storage device under low temperatures, taking into account the temperature fluctuations during the discharge of the storage device. Ambient temperature significantly affects the time of the receiver pressure stabilization (Fig. 1), which contributes to a qualitative analysis of the operating modes of the converter of the gas kinetic energy into the another type of energy. The influence of the receiver pressure on the equalization time with atmospheric pressure (Fig. 2) has more linear character and it's good for the future usage to justify the design and the calculation of the receiver mechanical characteristics.

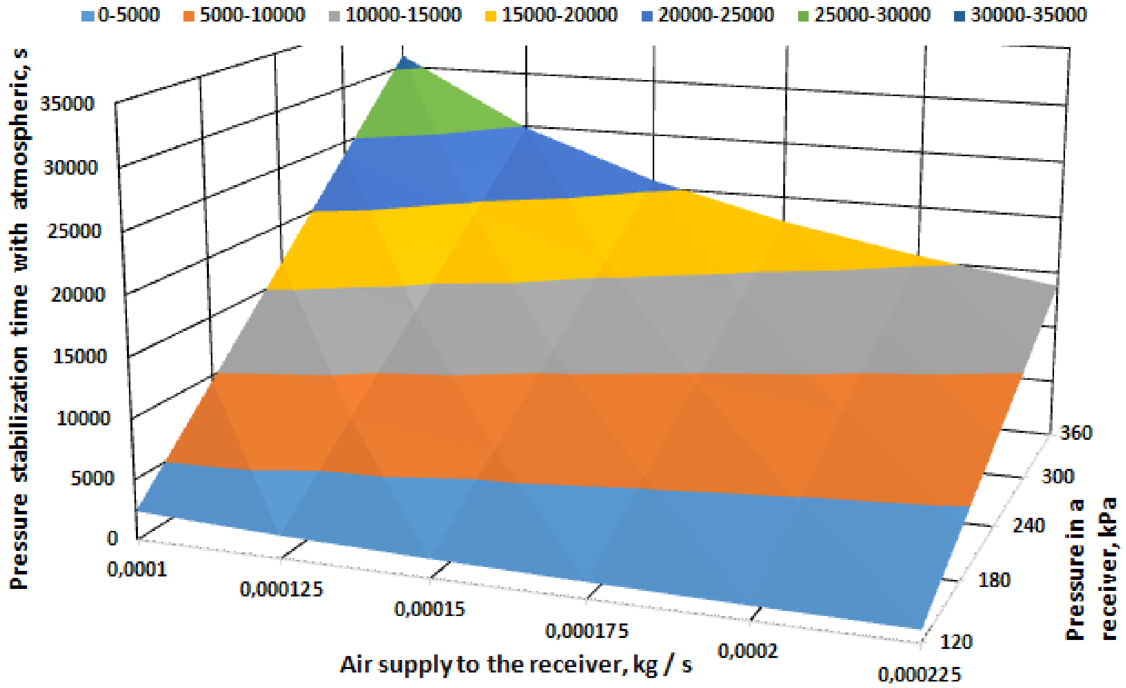

Fig. 2. Receiver pressure stabilization time under the different atmospheric pressures and different ambient temperature T = 293K.

Discussion

Theoretical regularities are obtained for the receiver air pressure stabilization time under the constant supply from the environmental parameters and under given receiver operating conditions. The indicated regularities make it possible to justify the operation mode of the gas storage device, its design parameters and lay the foundation for the selection of pneumatic shut-off and control valves.

For the technical implementation of this approach, it is necessary to solve the following tasks:

- expand the list of parameters for the determining of the pressure stabilization time taking into account temperature fluctuations during the charge and discharge of a gas storage device, the influence of air parameters on work efficiency;

- study the technical and technological possibilities of the accumulator efficiency increasing (under possible heating and cooling of the receiver);

- study the quantitative and qualitative indicators of the process of moisture condensation during the gas storage operation under the conditions of closed ground structures.

It could be seen as the proposed methodology is something like a “step backward” in the scientific approach to solving the tasks, but this is necessary measure that was determined by the multifactor nature and multiparametrical features of the introducing renewable energy sources into the technological processes of private greenhouse facilities as autonomous energy systems.

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ПНЕВМАТИЧЕСКАЯ БАТАРЕЯ ДЛЯ СОЛНЕЧНОЙ ЭНЕРГЕТИКИ В УСЛОВИЯХ ЧАСТНОГО БИЗНЕСА

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Аннотация – в статье идет речь о накоплении энергии в условиях частного бизнеса – растениеводства закрытого грунта. Рассмотрены основные методы накопления энергии. Самое большое внимание уделено гравитационным и механическим накопителям. Указаны основные принципы накопления и хранения в этих формах энергии и дальнейшее преобразование в электрическую в условиях фермерских хозяйств. Получены теоретические закономерности времени стабилизации давления воздуха в ресивере при его постоянной подаче от параметров окружающей среды и заданных условиях работы ресивера. Полученные закономерности позволяют обосновать режим работы газового накопителя, его конструктивные параметры и закладывают основы выбора пневматической запорно-регулирующей арматуры, а также электрогенераторов.

Поставлены задачи для технической реализации энергетического комплекса. В основе дальнейшей работы находится задача расширения перечня параметров в закономерности определения времени стабилизации давления (учесть колебания температур при заряде и разряде газового накопителя, влияние параметров воздуха на эффективность работы).

Ключевые слова: возобновляемая энергетика, накопитель энергии, газовый накопитель энергии

ПНЕВМАТИЧНА БАТАРЕЯ ДЛЯ СОНЯЧНОЇ ЕНЕРГЕТИКИ В УМОВАХ ПРИВАТНОГО БІЗНЕСУ

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Анотація – в статті йдеться мова про накопичення енергії в умовах приватного бізнесу - рослинництва закритого ґрунту. Розглянуто основні методи накопичення енергії. Найбільшу увагу приділено гравітаційним і механічним накопичувачам. Вказані основні принципи накопичення і зберігання в цих формах енергії та подальше перетворення в електричну в умовах фермерських господарств. Відзначено, що роботи по даному напрямку вирішують досить широке коло завдань, але в рослинництві закритого ґрунту в умовах приватних господарств є безліч природних (склад повітря, зовнішні впливи) та антропогенних (технологічне обладнання, асоціальна поведінки працівників, вандалізм, низька культура праці) чинників, які вимагають детального перегляду методик вибору конструкції і економічного обґрунтування ефективності застосування газових накопичувачів енергії.

Метою роботи є отримання математичної моделі, яка дозволить визначити час стабілізації тиску ресивера з атмосферним залежно від параметрів навколишнього середовища.

Для того, щоб досягти мети статті необхідно розглянути фізику процесів. Для визначення часу стабілізації тиску повітря в ресивері при постійній подачі зовнішнього повітря визначена маса повітря в ємності заданого обсягу при певній температурі та тиску. Для цього використано рівняння Менделєєва-Клапейрона. Для вирішення практичного прикладу прийнято ряд умов: повітря в теплиці сухе, зарядка і розрядка ресивера відбувається при однаковій температурі.

Отримано теоретичні закономірності часу стабілізації тиску повітря в ресивері при його постійній подачі від параметрів навколишнього середовища і заданих умовах роботи ресивера. Це дозволить обґрунтувати режим роботи газового накопичувача, його конструктивні параметри, а також закладають основи вибору пневматичної запірно-регулюючої арматури та електрогенераторів.

Поставлені завдання для технічної реалізації енергетичного комплексу. В основі подальшої роботи знаходиться завдання розширення переліку параметрів в закономірності визначення часу стабілізації тиску (врахувати коливання температур при заряді і розряді газового накопичувача, вплив параметрів повітря на ефективність роботи).

Ключові слова: поновлювана енергетика, накопичувач енергії, газовий накопичувач енергії.