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Hybrid System for Using Renewable Sources of Energy for Local Consumers in Agriculture

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Abstract: The dynamics of total consumption of electric and thermal energy in agriculture and in the whole country is considered in the study. The analysis of developments in the field of solar and bioenergetics their current state and possible directions of research on the use of RES in livestock production is given. A mathematical model of a hybrid energy supply system based on a photo-solar-bio energetic installation is developed which makes it possible to reduce the energy intensity of agricultural production. Experimental results of studies of the effectiveness of the proposed hydro breeding system are presented.

Key words: Hybrid energy supply system, the mathematical model, photovoltaic, biogas and helium plant, supply

INTRODUCTION

At present, the contribution to the world energy of photovoltaic installations is small: their total capacity is 5,000 MW, i.e., 0.15% of the energy supplied by other sources. However, solar energy and the production of photovoltaics are intensively developing. In 2000, the annual production of photocells in the world amounted to 260 MW and in 2010-1700 MW (Elistratov and Aronova, 2009). The annual growth rate for the last 5 years is 30%. Leading countries: USA-60 MW, Japan-80 MW, Germany-50 MW. The total area of solar water heaters (solar collectors) in the world exceeded by incomplete data 21 mln. m^2 while the annual production of solar collectors exceeds 1.7 mln. m^2.

Lead countries: Japan-7 mln. m^2, the united states 4 mln. m^2, Greece-2.0 mln m^2 (Elistratov and Aronova, 2009). Over the last 10 years, the generation of electricity from the photomultiplier has increased by 25% per year. In Japan, in absolute terms, it reached 833 MW in Germany-353 MW in the US-153 MW. The cost of this electricity is still too high: 1 kWh costs 20-25 cents while the price of electricity produced by the CHP plant is 4-6 cents on coal, 5-7 cents on natural gas, 6-9 cents on biofuel (Elistratov and Aronova, 2009). The cost of electricity production based on photomultipliers for greece in areas with daily solar radiation from 4-4.9 kW/h/m and an average annual output of 33.3-41.6 MW·h is from 0.122-0.152 euro/kW·h that when the electricity tariff of 0.13 euros/kW·h making solar energy competitive (Fantidis *et al*., 2013).

MATERIALS AND METHODS

Methodical basis of the research was the methods of mathematical analysis, mathematical physics, used in the construction of mathematical models. Methods of mathematical statistics, economic and mathematical methods, target (normative) prediction methods for determining the scales of energy consumption of the investigated objects were also used. In the study of heat fluxes, it is advisable to use the method of step-by-step simulation of the selected subsystems and elements of the hybrid installation using enlarged models. Such models allow to calculate the integral characteristics of heat exchange processes (values of medium-volume temperatures, mean heat fluxes). In the future, these models will be called models with lumped parameters, in contrast to models with distributed parameters that take

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into account the spatial distribution of temperature fields. Practice has shown that for these models it is advisable to build fairly general models and develop universal software that allows solving a wide range of specific technical problems (Fantidis *et al*., 2013; Eltamaly *et al*., 2014; Giaouris *et al*., 2015; Guangya *et al*., 2015). Proceeding from the theory of heat exchangers, the following assumptions are accepted: the temperature of the coolant flow is assumed to be the same throughout the pipe section there are no internal heat sources in the heat carriers, the storage capacity of the heat exchanger walls can be neglected, the heat capacity of all elements and heat carriers is constant, the heat exchange between the elements of the system is characterized by the average values of the heat transfer coefficients and heat transfer. Mathematical modeling of heat fluxes in a hybrid plant is implemented in accordance with a specific plan which is usually presented in the form of a diagram (graph) that maps the order of execution of the basic logical operations and computing procedures.

The result of thermodynamic analysis is the design of initial physical representations in the form of a conceptual model representing the heat supply object (installation or technological process) in the form of an extended thermodynamic system. In the process of identifying the structure of an object, it is necessary to distinguish the characteristic elements of objects in it. For them the equations of thermal balances are compiled, the totality of which is considered as the physical basis of the analytical model of the thermal regime of the object.

Physical macroscopic quantities characterizing the state of a thermodynamic system are parameters of its state. Thermal conductivity, heat capacity, density and viscosity are the thermo physical parameters of substances from which the individual elements of the object are composed. Geometric dimensions are the constructive characteristics of the object under study. All physical quantities used for mathematical description. Thermo physical process can be divided into 2 groups-variables and constants. In turn, the variable physical quantities are divided into independent and dependent. Independent parameters include the state of the environment. The heat flux from the solar collector is a controlled variable value (regulating effect).

Dependent variables are unknown (sought) quantities. These usually include the parameters of the state of the individual elements of the object under study. For example, the required values may be the substrate temperatures in the bioreactor and the water in the heat exchanger-helioc collector circuit. They carry information about the energy (thermal) state of the object. The task in this formulation is characteristic for technological processes and is solved within the framework of an unsteady thermal regime. For the hybrid plant, the substrate temperature in the bioreactor is set. Accordingly, as one of the unknown variables, the thermal power of the solar collector and the heat output of the gas boiler are taken. In this case, they are dependent output variables and the temperature in the bioreactor is an input independent variable.

The solution of the problem in this formulation can be carried out within the framework of both stationary and non-stationary thermal conditions of technological equipment or structures. In the first case, it reduces to determining the calculated thermal power of the solar collector and the gas boiler, in the second-the law of the time variation of the temperature of the heat carriers. Dependent variables, as unknown (sought-for) quantities, are considered in the form of output. In this case, the input independent variables and constants are the initial data in the problem being solved.

Types of small power systems using renewable energy sources: Modern small power system can be divided into 2 types (Eltamaly *et al*., 2014; Bhandari *et al*., 2015): small power supply system connected to a central low-voltage networks to-torye operate only on alternating current; small stand-alone power system are not connected to a central low-voltage networks, operating as a constant and the alternating current. They allow you to create simple and reliable in operation, eco-wide autonomous power supply system of small farms distant from the centralized grid-term. Modern small power system have improved following hattics: ensuring high peak overloads, voltage-stabilized output of the summation of different energy sources, ensuring quality requirements for elec-tricity and uninterrupted power supply.

Hybrid systems based on renewable energy sources: To create energy-efficient small power systems are widely used Hybrid Systems Based on Renewable Energy Sources (HSRES) which are divided into the following types:

- HSRES consisting of a photomultiplier and wind energy installations (wind turbines) (Eltamaly *et al*., 2014; Giaouris *et al*., 2015; Li *et al*., 2014; Kumar and Bhimasinguk, 2015)
- HSRES consisting of a photomultiplier, wind turbines and micro hydro (Hossain *et al*., 2015)

- HSRES consisting of a Solar Collector (SC), Ground Heat Exchanger (GHE), the Heat Pump (HP) and a Gas Boiler (GB) (Kim *et al*., 2013)
- HSRES consisting of a PV, wind turbines, micro hydro, micro turbines and diesel-generator (Bhandari *et al*., 2015)

HSRES allow you to create an effective low power system that can be is use to rural electrification. In this case the following requiretion of the rural consumer must, be considered: simplicity of design, reliability, power quality, efficiency, electrical safety, conformity to the nature of the electrical load of electrical type and technology of farms.

Photovoltaic installations: The analysis in the field of photovoltaic systems research revealed the following promising results of research (Matchanova *et al*., 2015; Hill *et al*., 2011). In UK, McKenna and Thomson (2014) analyzed changes in demand for PMT capacity from 1 up to 4 kW shows the change in power generation, depending on the demand and prices on it during the day from 11.8-14.3 euro cents kW/h. The study of the international solar energy institute (Uzbekistan) (Matchanova *et al*., 2015; Anarbaev *et al*., 2008; Abdurakhmanova *et al*., 2012; Sosnina *et al*., 2015) presents the results of experimental studies of the mode of autonomous solar photo-thermoelectric setup for mobile objects of low power. According Bhandari *et al*. (2015) electricity generation by renewable energy mix in the US rose from 11% in 1993-13% in 2011, for the period until 2040 is expected to increase to 16%. The total amount of renewable solar energy resources account for 1% of biomass from waste-4%, hydro-63%, wind energy 23%. The Poznan University of Technology (Poland) (Frydrychowicz and Bugala, 2015) presents an analysis of different mathematical models to determine the power of solar radiation and justified choice of the modified model to improve the accuracy of calculations for the central polish conditions. The Technical University of Denmark (Juamperez *et al*., 2014) results of modeling the integration of photovoltaic systems and methods of smoothing the voltage rise in the network, depending on the degree of integration of 10-60% and presented the preliminary results of research and three-phase systems to increase the efficiency of the PMT. In Turkey, Abbasoglu and Babatunde (2015) investigated various methods of modeling in the analysis of performance PMT. For conditions in Cyprus shows the results of simulation of the PMT output 5.76 kW, the average deviation of the actual volume of electricity production from the simulation results was 5.3 ... 9.3%. The (Yilmaz and Ozcalik, 2015) analyzes of construction costs and operation of the PMT output of 500 kW and the prospects for new investments. Huang *et al*. (2015) developed a model for predicting the production of electricity FEU taking into account possible fluctuations of power depending on the weather forecasts are updated every 3 h. Tsai *et al*. (2015) described charger for photovoltaic energy conversion. Cucchiella *et al*. (2015) analyzed the economic feasibility of investments in photovoltaic systems of various capacities (200 and 400 kW and 1 MW and 5) in the Italian market. Sant'Anna *et al*. (2015) studied systems with a low concentration of solar radiation to photomultiplier with concentrators and without conditions for moderate and tropical regions of Brazil. Prepared increase power generation of about 31.3%. Valencia and Poja (2015) represented by mathematical analysis of the sliding track for maximum demand controller mode photovoltaic systems with a single-stage controller. Experiments confirmed the effectiveness of the proposed solutions. Jelle (2015) shows the results of analysis of the development of integrated structures of various photovoltaic cells with an efficiency 12.5...17.7% and a specific capacity of 93.2 of 142.6 W/m^2. In the UK in 2006, the local photovoltaic system 1300 PMT used homes (Hill *et al*., 2011).

Hill *et al*. (2011) showed that local helio systems use of solar water heaters which are connected to the Boiler batteries. Helio system widely used for example in the UK, in 2006, 78,000 units were used and by 2020 the government planned Uwe-lichit their number to 1.3 mln. (Hill *et al*., 2011). Nallusamy *et al*. (2006) presented the results of investigations is work solar collector system-boiler at heating water to 70°C with a water circulation rate in the loop 2, 4 and 6 kg/min, the efficiency of the system -0.49 (Nallusamy *et al*., 2006). Fooladi and Taheriani investigated helio system, efficiency was 0.28-0.58 (Fooladi and Taheriani, 2010). Chung presented a circulation pump bellows to solar system (Han-shik *et al*., 2012).

Bio-gas installations: An analysis of research in the field of biogas plants revealed the following promising results. Tomislav and Neven conducted economic analysis of the effectiveness of the central croatia in the conditions of the bioenergy plant capacity to 100,000 tons/year. It was found that the range of >15 km, the cost of transportation of the waste is >3.5 euros/tonne of waste and does not pay shipping. In Germany, Eikmeyer *et al*. (2013) conducted a research on the effectiveness of disinfection

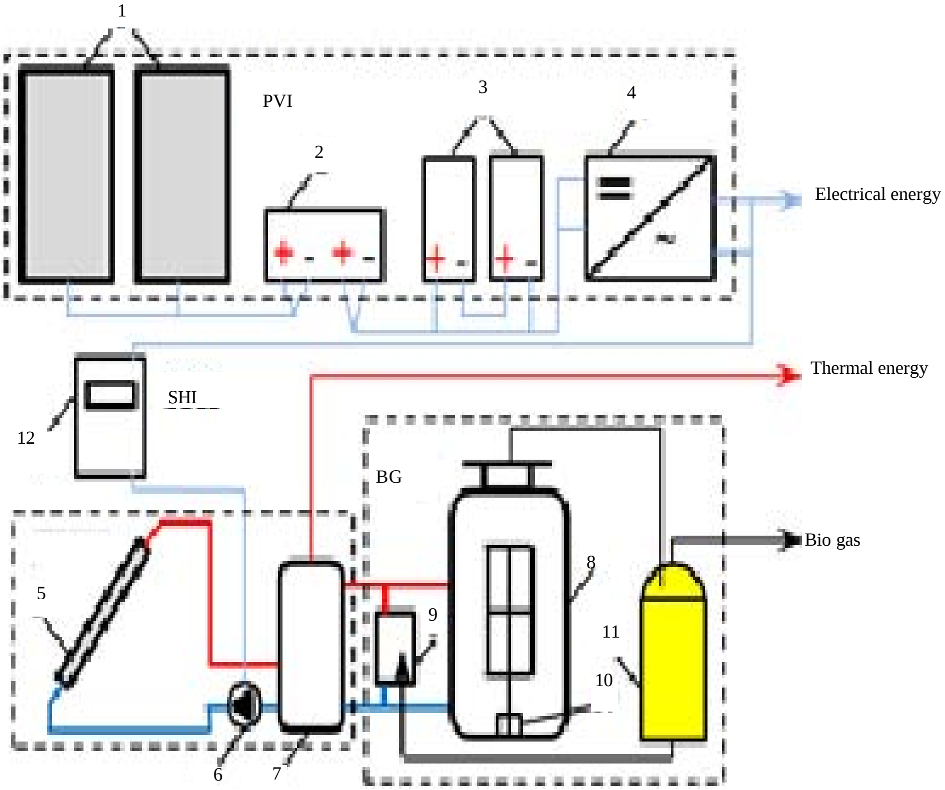

Fig. 1: The hybrid power plant for autonomous energy farm farms ho-electric, thermal energy and biogas based renewable energy

in the biogas plant different species of pathogenic bacteria (dysentery, botulism, meningitis, etc.). The results show a high degree of decontamination-1·10-20 (Eikmeyer *et al*., 2013). Binner *et al*. (2011) showed the efficacy of exogenous cellulose as an additive. Marousek (2013) led the development of a biogas plant with 2 reactors: reactor disinfection biowaste steam and high pressure reactor. Denmark Gavala developed an efficient biogas technology ammonox positive results were obtained. Zairi *et al*. (2014) studied the work of anaerobic bioreactor company Puxin, bacteriological analyzes made to determine the extent of waste decontamination, examined the intensity of selection of biogas with different acidity of the substrate. In Turkey, Sridevi *et al*. (2015) studied the chemical composition of the fertilizer. In Austria, Weedermann *et al*. (2015) developed optimal bioenergy systems. In Romania, Wan *et al*. (2013) we investigated the dynamics of release of biogas and other parameters parameter for 70 days.

The Hybrid Power Plant (HPP): In developing the HPP must take into account the specifics of livestock, namely: a large amount of manure and other waste requiring disposal in biogas. On the basis of our research analysis created a hybrid power plant for secu-cheniya processes animal three types of energy: electricity, thermal energy and biogas. HPP consists of a PV instalation, the solar heating instalation and bio gas instalation. These parameters are selected in accordance with the nature of the electrical load, electrical type and species of animals (Eltamaly *et al*., 2014; Giaouris *et al*., 2015) (Fig. 1).

The design of HPP consists of solar panels 1, controller 2, block accumulative-ditch 3, 4 inverter, solar collectors 5, 6, circulation pump, storage tank, boiler 7, 8 bioreactor, gas boiler 9 and the gas tank 10. The scheme of control and automation based on a programmable microprocessor located in 11 control panel. HPP provides processes farms and other types of farms electricity and heat as well as biogas. Construction HPPs can generate three types of energy which reduces the energy consumption of the production of agricultural products and solves the problem of autonomous power.

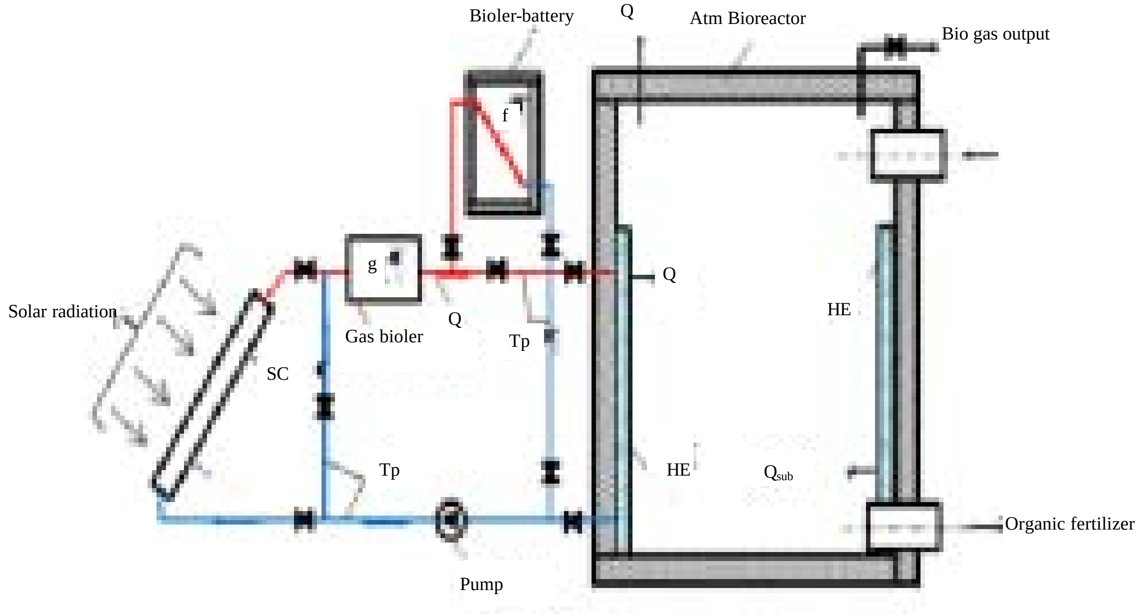

Fig. 2: Structural model of HPP and BI; SC: Solar Collector; GB: Gas Boiler; B: a Bioreactor; BA: boiler-battery; HE: Heat Exchanger; TP: Technological Pipelines; H: the pump; Pc: solar radiation; Q: the heat flow from the SC and GB; Q_{sub}: heat flow, re-giving to the substrate; q_{atm}: heat losses to the environment

RESULTS AND DISCUSSION

HPP modeling components: The efficiency of the hybrid installation depends largely on the thermal regime of its components: solar heating instalation, bioreactor, battery-boiler and gas boiler. The required temperature conditions of the process of anaerobic digestion of biomass in the bioreactor is provided with thermal energy coming from solar collectors. To operate bioreactor BU during periods of receipt of solar radiation-tion is understudy-gas boiler using biogas.

The structural model of the HPP and Bio reactor is shown in Fig. 2. They include: solar collector (HG1 heat generator), the Bioreactor (B) with a Heat Exchanger (HE), gas boiler with biogas (Heat Generator HG2), circulation pump (H) Technological Pipelines (TP) and boiler-accumulator for hot water.

For the mathematical model, the following assumptions: the body temperature of the solar collector equal to the temperature of water in it; body temperature of the bioreactor the temperature of the substrate therein; water temperature distribution along the length of the linear solar collector; heat transfer processes occurring between the individual areas of the model, characterized by the average within each region the values of heat transfer coefficients. The thermal model can be represented as separate areas: BR-a Bioreactor; SC-Solar Collector; GB-Gas Boiler and BB-Boiler-Battery.

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$$Q_c = q_c F_{sc} \eta_o \tag{1}$$

Where:

q_c = Average solar flux density entering the solar collector surface (W/m^2)

F_{sc} = Solar collector area (m^2)

η_{oeff} = Effective optical efficiency of the solar collector

Heat loss Q^{met} u for heating metal elements solar collector during $d\tau$:

$$Q^{met} = C^{met}_{sc} \frac{dt_{hc}}{d\tau} \tag{2}$$

Total heat capacity of the metal elements of the solar collector, J/°C; heat loss through the walls of the solar collector:

$$Q_{hc}^{loss} = k_1(t_{sc} - t_{env}) + k_2(t_{sc} - t_{env})^2 \tag{3}$$

Where:

k_1; k_2 = Coefficients of heat loss the solar collector
t_{sc}; t_{env} = Means the temperature of the heated water in the solar collectors and the environment (°C)

Heat loss Q_{gas} for heating metal elements gas-fired boiler during $d\tau$:

$$Q_{gas} = C_{gas}\frac{dt_{sc}}{d\tau} \tag{4}$$

where, C_{gas}, the total heat capacity of metal elements gas boiler, J/°C. Heat loss through the thermal insulation of the gas boiler is defined by Eq. 5:

$$Q_g^{loss} = K_g F_g(t_{sc} - t_{env}) \tag{5}$$

Where:

K_g = Coefficient of heat transfer through a gas boiler wall (W/m)
F_g = The outer surface area of the thermal insulation of the boiler (m^2)

The heat flow to the heat exchanger in the bioreactor:

$$Q_{heat} = G_{cir}\, c_{cp}\,(t_{sc} - t_{env}) \tag{6}$$

Where:

G_{cir} = Circulating water flow solar circuit (kg/sec)
c_{cp} = The specific heat of water (J/kg·°C)
t_w = Water temperature (°C)

$$Q_c = Q^{met} + Q_{Sc}^{loss} + Q_{gas} + Q_g^{loss} + Q_{heat} \tag{7}$$

$$\frac{dt_{hc}}{d\tau} = \frac{F_{sc}}{(C_{hc}^{met} + C_g^{loss})}[q_c\eta_{oeff} - k_1(t_{sc} - t_{env}) - k_1(t_{sc} - t_{env})^2] - C_{cir}\, c_{cp}\,(t_{sc} - t_{env})$$

$$\frac{dt_{env}}{d\tau} = \frac{1}{C_{heat}^{met}}[C_{cir}\, c_{cp}(t_{hc} - t_{env}) - K_{heat}\, F_{heat}(t_{tenv} - t_{sub})]$$

$$\frac{dt_{sub}}{d\tau} = \frac{1}{\left(C^{bio} + C_{sub}\right)}[K_{heat}\, F_{heat}(t_{tenv} - t_{sub}) - K_{bio}\, F_{bio}(t_{sub} - t_{env})]$$

Where:

F_{sc} = Solar collector area (m^2)
q_c = The average solar flux density entering the gelionagrevatelya surface (W/m^2)
η_{oeff} = The effective optical efficiency gelionagrevatelya
t_p = Average temperature
K_{heat} = Coefficient of heat transfer through walls (W/m^2)
C_p = The total heat capacity solar collector
C_{cir} = Expenses solar circuit water (kg/sec)
$C^{met=}$ = The total heat capacity of the heat exchanger metal structures (J/°C)
F_{heat} = External surface area of the heat exchanger (m^2)
t_{sub} = Substrate temperature within the bioreactor (°C)
C^{bio} = The total heat capacity of steel structures bioreactor (J/°C)
C_{sub} = Specific substrate heat capacity (J/kg·°C)
K_{bio} = Coefficient of heat transfer through the wall of the bioreactor (W/m^2)
F_{bio} = The outer surface area of the bioreactor (m^2)

The system of Eq. 8 consists of streams $F_k q_c \eta$ of solar energy absorbed as well as heat loss and flow rate $G_{\text{в}}$ in the solar circuit, caused by forced circulation. Expressing one variable over another and performing some conversion, semi-cpm second order differential Eq. 9:

$$\frac{d^2t_f}{d\tau^2} + (a_1 + b_2)\frac{dt_f}{d\tau} + (a_1b_2 - a_2b_1)t_f = a_3b_1 + a_1b_3 \tag{9}$$

Where:

$$a_1 = \frac{K_pF_p + G_{\text{в}}c_{\text{в}}}{C_p};\ a_2 = \frac{G_{\text{в}}c_{\text{в}}}{C_p}$$

$$a_3 = \frac{F_pq_c\eta_{on}}{C_p};\ b_1 = \frac{G_{\text{в}}c_{\text{в}}}{\left(C_f^{MK} + C_f^{m\text{в}}\right)}$$

$$b_2 = \frac{K_fF_f + G_{\text{в}}c_{\text{в}}}{\left(C_f^{MK} + C_f^{m\text{в}}\right)};\ b_3 = \frac{K_fF_ft_{oc}}{\left(C_f^{MK} + C_f^{m\text{в}}\right)}$$

Solving the differential Eq. 9, we obtain an expression for the temperature of the water in the boiler-battery:

$$t_f = C_1e^{k_1\tau} + C_2e^{k_2\tau} + C_0 \tag{10}$$

Where:

$$C_0 = \frac{a_3b_1 + a_1b_3}{a_1b_2 - a_2b_1};\ C_1 = -\frac{k_2\left(t_{f0} + C_0\right)}{k_1 - k_2};\ C_2 = \frac{k_1\left(t_{f0} - C_0\right)}{k_1 - k_2}$$

$$k_{1,2} = -\frac{\left(b_2 + a_1\right)}{2} \pm \sqrt{\frac{\left(b_2 + a_1\right)^2}{4} - \left(a_1b_2 - a_2b_1\right)}$$

An expression that describes the dynamics of change gelionagrevatelya temperature is as follows:

$$t_p = \frac{1}{b_1}\left(\frac{dt_f}{d\tau} + b_2 t_f - b_3\right) = \frac{1}{b_1}[(k_1 C_1 + b_2 C_1)e^{k_1\tau} + (k_2 C_2 + b_2 C_2)e^{k_2\tau} + (b_2 C_0 - b_3)] \quad (11)$$

From the expressions Eq. 10 and 11, it follows that the main factors affecting the leadrank and temperatures are t_p and t_f and density of solar radiation q_c the area nagrevate F_p and water consumption $G_в$. The aim was to identify the nature and influence on the constancy F_p and $G_в$ other factors t_p and t_f determine the optimum range of their values. The system (Eq. 8) differential Equation was solved numerically using MathCAD program.

In taking the following as the main source of data: the mass of heated process water m_{water} = 400 kg; K_f = 1.24 W/m^2·°C; F_f = 3.3 m^2; q_c = 700 W/m^2; K_p= 7 W/m^{2o}C; τ_c = 25200 sec or 7 o clock. The calculation were carried out at the following values: F_p = 4;6;8 m^2 G = 0.5-10 1/min. The calculation results are shown in Fig. 3.

$$1 - t_p = f_1(G_в) \text{ at } F_p = 8\ m^2$$

$$2 - t_p = f_2(G_в) \text{ at } F_p = 6\ m^2$$

$$3 - t_p = f_3(G_в) \text{ at } F_p = 4\ m^2$$

$$4 - t_f = f_4(G_в) \text{ at } F_p = 8 m^2$$

$$5 - t_f = f_5(G_в) \text{ at } F_p = 6 m^2$$

$$6 - t_f = f_6(G_в) \text{ at } Fp = 4 m^2$$

Analysis of the graphs shows that for small values $G_в$ of solar collector has bo-lee high temperature, even though the value is low. This is considerable-governmental heat loss through the surface of the solar collector. By increasing $G_в$ the heat removal process intensification occurs as a result of decreases and increases. However as can be seen from Fig. 3 when $G_в$>5 1/min process of improving first slows and then almost stopped. It is therefore recommended as optimum take the following values: $G_в$ = 4.5 l/ min.

From Fig. 3 it follows that when F_p = 4 m^2 t_f = 41.5°C, F_p = 6 m,^{2} t_f = 5.12°C and when F_p = 8 m^2, t_f = 56.8 °C. Given that, firstly, the cost of the collectors is quite high (\$80-200 m^{-2}) and secondly, in this case, an increase F_p of 6-8/m^2 gives a small (5-6°C) increase t_f due to increased heat loss, the an optimal value of is recommended F = 6 m^2.

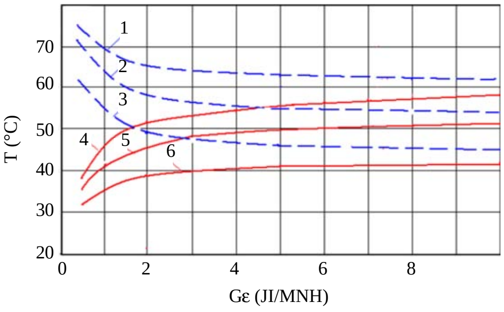

Fig. 3: Changes in water temperature in the boiler-battery and solar collectors for different values of the area of the solar collector and the water flow in the solar circuit

The developed mathematical model Eq. 11 with the allows you to calculate the thermal conditions, optimize the solar collector and the costs of circulating water in the re-liokonture. If the solar water heating takes place from 10 a.m. to 17 p.m., the water in the boiler, the battery heats up to a temperature of 41.5-56.8°C, depending on the value of total solar collector show mercy. Calculations show that during the heating of one ton of water saving electrical energy ranges from 35-50 kW·h and annual savings 3000-4500 kW·h.

Modeling PV panel: When simulating a photomultiplier, it is necessary to determine the optimum mode of charging the battery, depending on the load schedule of the process equipment. For charging, the time interval between the maximums of the load is used. Let us consider how the charge time and the number of cycles between the load maxima on the battery capacity affect by Weinel. The graphical dependence of the charge current of the recharge time on the value of the capacity of the preliminary discharge is shown (Elistratov and Aronova, 2009). The pre-discharge means the capacity of the battery that was consumed before starting the charge from the solar panels (before sunrise, etc.). Based on the a ctual duration of the load minima, the charge time interval is determined. The capacity of the preliminary discharge is determined by the following relationship:

$$Q_{cap} = I_{ch} t_{ch} + I_{ch} = I_{ch}(t_{ch} + 1) \quad (12)$$

Where:

I_{ch} = The charging current
t_{ch} = The charge time

The charge capacity Q_{ch} is expressed by the relation:

$$Q_{cap} = I_{ch} \times t_{ch} \quad (13)$$

Solving Eq. 13 with respect to the charge current, we obtain:

$$I_{ch} = \frac{Q_{cap}}{t_{ch}+1} \quad (14)$$

If we substitute the expression Eq. 14 in to Eq. 13, then we obtain:

$$Q_{cap} = \frac{Q_{ch} t_{ch}}{t_{ch}+1} = Q \cdot \alpha \quad (15)$$

Where:

$$\alpha = \frac{t_{ch}}{t_{ch}+1}$$

The power consumption of electrical equipment in the first cycle is covered by the initial capacity of the battery. This part of the electricity can be determined from the load schedule as a sum:

$$\sum\sum A = \sum P_1 t_1 + P_2 t_2 + P_3 t_3 \quad (16)$$

Where:

t_1 = Operating time of the milking plant
P_2 = Electric power consumption by a forage crusher
t_2 = Working time of the feed crusher
P_3 = Electric power consumption by a fecal pump
t_3 = Operating time of the fecal pump

Naturally, ΣA is part of the capacity of the battery and therefore, in the future can be written as ΔQ_1. For-cycles of operation, the expended capacity of the battery can be written:

$$\Delta Q_n = \Delta Q_1 (\beta^{n-1} + \beta^{n-2} + \beta^{n-3} + ... + 1) \quad (17)$$

where, β = (1-α), multiply and divide expression Eq. 6 by (β-1), we obtain:

$$\Delta Q_n = \frac{\Delta Q_1 (\beta^n - 1)}{\beta - 1} \quad (18)$$

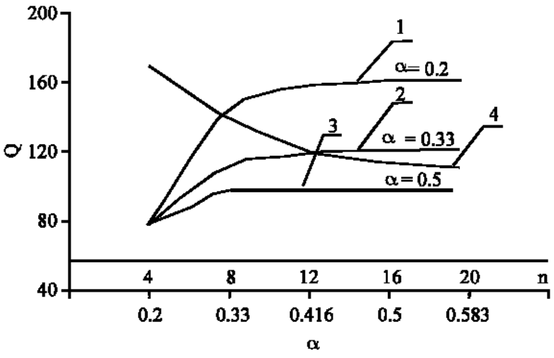

Fig. 4: Dependencies of battery capacity on the number of recharging cycles Q = f1 (n) at; 0.5; 1-dependences 1-3 and on the coefficient α Q = f 2 (α), the dependence 4

Substituting the value β = (1-α) into the expression Eq. 17, we obtain:

$$\Delta Q_n = \frac{\Delta Q_1 \left[1 - (1-\alpha)^n\right]}{\alpha} \quad (19)$$

The obtained expression Eq. 18 makes it possible to determine the capacity of the photomultiplier battery as a function of the number of operating cycles of the process equipment and the sub-charge time in each cycle. An example of calculating Q_n the dependence of s on the number of cycles and the time of recharging is given in Fig. 4.

Analysis of Eq. 18 and graphical dependencies (Fig. 4) shows that depending on the number of recharging cycles, the battery capacity asymptotically approaches the limit value which is determined by the ratio.

The photomultiplier consists of 24 solar panels 1, a power of 200 W, a total power of 4.8 kW, 20 gel batteries 2 a capacity of 200 Ah a control panel 3 which houses a controller an inverter and a control scheme for automation based on A programmable microprocessor an electricity meter, ammeters and voltmeters. The solar collector consists of an evacuated solar collector 4 with heat pipes, an aperture area of 5.7 m^2 and a storage tank 5 with a capacity of 250 L, a circulating pump 6. The consists of a bioreactor 7, a heat exchanger 8, a combined agitator 9 with an electric drive 10 a gas boiler eleven.

The dynamics of the diurnal variation of the coolant temperatures in the solar collector of hybrid power station, water in the boiler-heat accumulator and outside air is shown in Fig. 5 and 6.

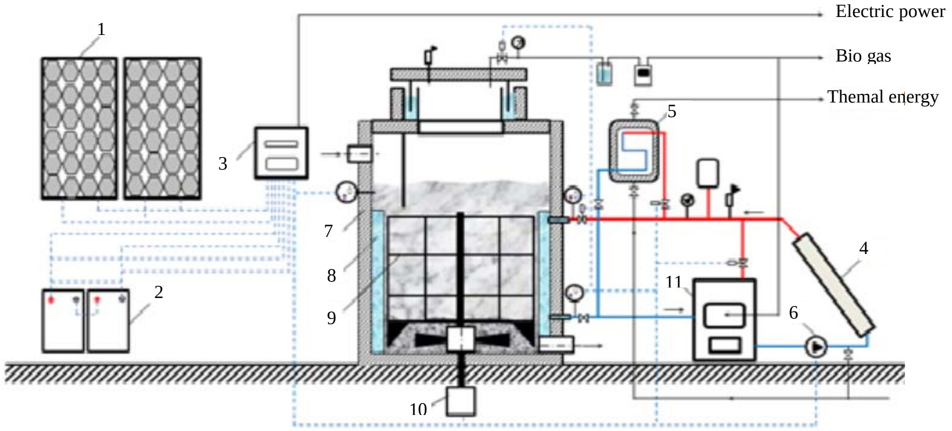

Fig. 5: Schematic diagram hybrid power plant

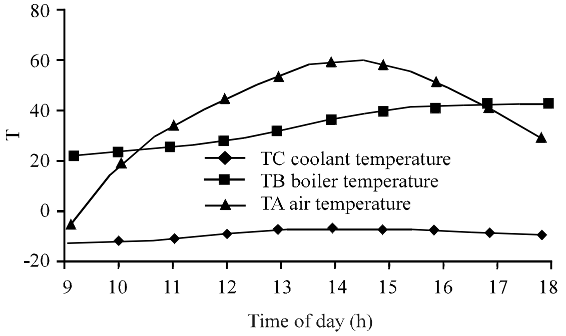

Fig. 6: Dynamics of the diurnal change of the coolant temperatures at the inlet and outlet of the collector, water in the boiler-heat accumulator; T_c: temperature of the coolant at the inlet and outlet of the solar collector; T_B: average temperature of water in the boiler-heat accumulator; T_A: outdoor temperature

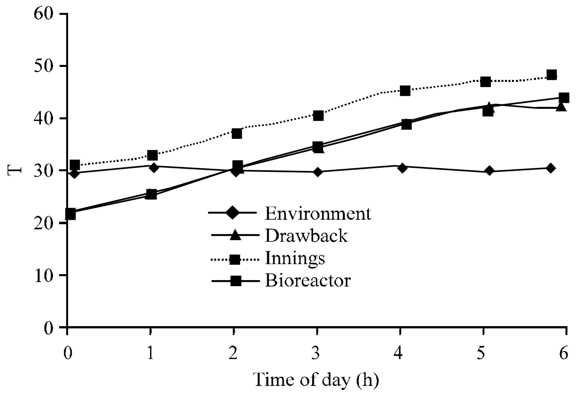

Fig. 7: Dynamics of the diurnal change of coolant temperatures at the inlet and outlet of the gel collector and substrate in the bioreactor (September 2015)

Analysis of experimental data shows that on January 15, 2015, the outside temperature changed within -13 to 7°C in clear weather, the solar collector heated the water in the heat storage tank from 24-44°C while the efficiency factor was 0.56. March 13, 2015 the temperature in the boiler-heat accumulator was 50°C, efficiency the installation rose to 0.65. July 3, 2015, the water in the boiler-heat accumulator was heated to 70°C in clear weather and fluctuations of T.v within 26-31°C efficiency -0.7.

The study of the degree of cooling of the heated water in the boiler-heat accumulator showed that its temperature dropped from 44-40°C, 17 h on January 15-9 h on January 16, so the cooling rate of water is 6°C/day. The dynamics of temperature changes in the coolant in the circuit is shown in Fig. 7. After starting the substrate is heated by the heat energy from to an average temperature of 48°C for 5 days and then this temperature is maintained throughout the test period. The amount of useful thermal energy obtained from the with heating 6 tons of substrate in the is 189 kW·h.

The volumes of daily generation of useful electricity by the components of the HPP in the period from January-July 2015 are: from the PV 13.5; 27 and 36 kW·h/day electricity, from solar collector 12.0; 21 and 28 kW·h/day of thermal energy from the biogas 10; 21 and 21 kW·h/day of electricity from biogas in the gas generator (Fig. 8). In total, the power generation of the power plant was respectively, 35.5; 69 and 85 kW·h/day which fully meets the needs of the technological equipment of a dairy farm for 20 cows and a rural house.

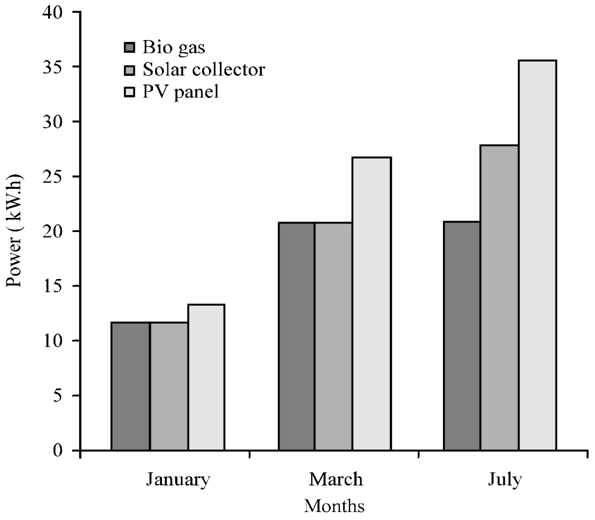

Fig. 8: Generation of electrical, thermal energy and electricity from biogas

CONCLUSION

The developed mathematical model of a helioheating installation from a biogas plant allows us to calculate the thermal regimes, optimize the parameters of the solar collector and the circulating water flow in the solar circuit. As calculations have shown when one ton of water is heated, the saving of electric energy is from 35-50 kW·h and the annual saving is 3000-4500 kWh.

The developed mathematical model of a photo of an electrical installation allows one to determine the capacity of a PV battery, depending on the number of operating cycles of the process equipment and the recharging time in each cycle. An analysis of the shown calculations of the photovoltaic system shows that, depending on the number of charge cycles, the capacity of the battery pack asymptotically approaches the limiting value

REFERENCES

Abbasoglu, S. and A.A. Babatunde, 2015. Evaluation of field data and simulation results of a photovoltaic system in countries with high solar radiation. Turk. J. Electr. Eng. Comput. Sci., 23: 1608-1618.

Abdurakhmanov, A.A., K.K. Zainutdinova, M.A. Mamatkosimov, M.S. Paizullakhanov and G. Saragoza, 2012. Solar technologies in Uzbekistan: State, priorities and perspectives of development. Appl. Solar Energy, 48: 84-91.

Anarbaev, A.I., R.A. Zakhidov and R.R. Avezov, 2008. Schematic and parametric optimization of solar fuel boiler installations. Appl. Solar Energy, 44: 20-23.

Bhandari, B., K.T. Lee, G.Y. Lee, Y.M. Cho and S.H. Ahn, 2015. Optimization of hybrid renewable energy power systems: A review. Intl. J. Precis. Eng. Manuf. Green Technol., 2: 99-112.

Binner, R., V. Menath, H. Huber, M. Thomm and F. Bischof *et al.*, 2011. Comparative study of stability and half-life of enzymes and enzyme aggregates implemented in anaerobic biogas processes. Biomass Convers. Biorefin., 1: 1-8.

Cucchiella, F., I. D'Adamo and P. Rosa, 2015. Industrial photovoltaic systems: An economic analysis in non-subsidized electricity markets. Energies, 8: 12865-12880.

Eikmeyer, F.G., A. Rademacher, A. Hanreich, M. Hennig and S. Jaenicke *et al.*, 2013. Detailed analysis of metagenome datasets obtained from biogas-producing microbial communities residing in biogas reactors does not indicate the presence of putative pathogenic microorganisms. Biotechnol. Biofuels, 6: 49-49.

Elistratov, V.V. and E.S. Aronova, 2009. Solar photo energy technologies for electric power consumers. Appl. Solar Energy, 45: 143-147.

Eltamaly, A.M., K.E. Addoweesh, U. Bawa and M.A. Mohamed, 2014. Economic modeling of hybrid renewable energy system: A case study in Saudi Arabia. Arabian J. Sci. Eng., 39: 3827-3839.

Fantidis, J.G., D.V. Bandekas, C. Potolias and N. Vordos, 2013. Cost of PV electricity: Case study of Greece. Solar Energy, 91: 120-130.

Fooladi, F. and H. Taheriani, 2010. Experimental study of a multi-tube ICS solar water heating system in mild climates. Appl. Solar Energy, 46: 20-28.

Frydrychowicz, J.G. and A. Bugala, 2015. Modeling the distribution of solar radiation on a two-axis tracking plane for photovoltaic conversion. Energies, 8: 1025-1025.

Giaouris, D., A.I. Papadopoulos, S. Voutetakis, S. Papadopoulou and P. Seferlis, 2015. A power grand composite curves approach for analysis and adaptive operation of renewable energy smart grids. Clean Technol. Environ. Policy, 17: 1171-1193.

Guangya, Y.A.N.G., F. Marra, M. Juamperez, S.B. Kjaer and S. Hashemi et al., 2015. Voltage rise mitigation for solar PV integration at LV grids. J. Mod. Power Syst. Clean Energy, 3: 411-421.

Han-shik, C., W. Ju-sik, S. Yong-han, K. Jun-hyo and J. Hyo-min, 2012. Experimental assessment of two-phase bubble pump for solar water heating. J. Cent. South Univ., 19: 1590-1599.

Hill, F., H. Lynch and G. Levermore, 2011. Consumer impacts on dividends from solar water heating. Energy Effic., 4: 1-8.

Hossain, F.M., M. Hasanuzzaman, N.A. Rahim and H.W. Ping, 2015. Impact of renewable energy on rural electrification in Malaysia: A review. Clean Technol. Environ. Policy, 17: 859-871.

Huang, C.M., S.J. Chen, S.P. Yang and C.J. Kuo, 2015. One-day-ahead hourly forecasting for photovoltaic power generation using an intelligent method with weather-based forecasting models. IET. Gener. Trans. Distrib., 9: 1874-1882.

Jelle, B.P., 2015. Building integrated photovoltaics: A concise description of the current state of the art and possible research pathways. Energies, 9: 21-21.

Juamperez, M., Y.A.N.G. Guangya and S.B. Kjær, 2014. Voltage regulation in LV grids by coordinated volt-var control strategies. J. Mod. Power Syst. Clean Energy, 2: 319-328.

Kim, Y.J., N.S. Woo, S.C. Jang and J.J. Choi, 2013. Feasibility study of a hybrid renewable energy system with geothermal and solar heat sources for residential buildings in South Korea. J. Mech. Sci. Technol., 27: 2513-2521.

Kumar, Y.P. and R. Bhimasingu, 2015. Renewable energy based microgrid system sizing and energy management for green buildings. J. Mod. Power Syst. Clean Energy, 3: 1-13.

Li, C., R. Wang, Y. Hu, R. Zhou and M. Liu et al., 2014. Towards automated provisioning and emergency handling in renewable energy powered datacenters. J. Comput. Sci. Technol., 29: 618-630.

Marousek, J., 2013. Pretreatment of sunflower stalks for biogas production. Clean Technol. Environ. Policy, 15: 735-740.

Matchanova, N.A., N.K. Zhuraeva, A.M. Mirzabaev and D. Dzhumabaev, 2015. Solar photothermoelectric installation for cooling of low_power mobile objects. Geliotekhnika, 2: 63-66.

McKenna, E. and M. Thomson, 2014. Demand response behaviour of domestic consumers with photovoltaic systems in the UK: An exploratory analysis of an internet discussion forum. Energy Sustainability Soc., 4: 13-13.

Nallusamy, N., S. Sampath and R. Velrag, 2006. Study on performance of a packed bed latent heat thermal energy storage unit with solar water heating system. J. Zhejiang Univ. Sci., 7: 1422-1430.

Puksec, T. and N. Duic, 2012. Economic viability and geographic distribution of centralized biogas plants: Case study Croatia. Clean Technol. Environ. Policy, 14: 427-433.

Sant'Anna, V.R.D.S., M.A. Egido, A. Ribeiro and A.C.F. Ferreira, 2015. Photovoltaic systems with and without radiation concentrators for temperate and tropical regions. Energies, 8: 12505-12529.

Sosnina, E.N., O.V. Masleeva and E.V. Kryukov, 2015. Comparative environmental assessment of unconventional power installations. Therm. Eng., 62: 539-546.

Sridevi, V.D., T. Rema and S.V. Srinivasan, 2015. Studies on biogas production from vegetable market wastes in a two-phase anaerobic reactor. Clean Technol. Environ. Policy, 17: 1689-1697.

Tsai, C.T., Y.C. Kuo, Y.P. Kuo and C.T. Hsieh, 2015. A reflex charger with ZVS and non-dissipative cells for photovoltaic energy conversion. Energies, 8: 1373-1389.

Valencia, P.A.O. and C.A.R. Paja, 2015. Sliding-mode controller for maximum power point tracking in grid-connected photovoltaic systems. Energies, 8: 12363-12387.

Wan, S., L. Sun, J. Sun and W. Luo, 2013. Biogas production and microbial community change during the Co-digestion of food waste with chinese silver grass in a single-stage anaerobic reactor. Biotechnol. Bioprocess Eng., 18: 1022-1030.

Weedermann, M., G.S. Wolkowicz and J. Sasara, 2015. Optimal biogas production in a model for anaerobic digestion. Nonlinear Dyn., 81: 1097-1112.

Yilmaz, S. and H.R. Ozcalik, 2015. Performance analysis of a 500-kWp grid-connected solar photovoltaic power plant in Kahramanmaras. Turk. J. Electr. Eng. Comput. Sci., 23: 1946-1957.

Zairi, M., A. Aydi and H.B. Dhia, 2014. Leachate generation and biogas energy recovery in the Jebel Chakir municipal solid waste landfill, Tunisia. J. Mater. Cycles Waste Manage., 16: 141-150.