Autonomous power installation with complex power effective electroproviding

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Application of natural gas for ensuring heat and electricity is actively applied in many settlements of the Russian Federation and is the most favorable resource. Networks of distribution of natural gas don't cover all volume of consumers and the question of accession to networks to become more and more sharp in view of a constant gain of again formed complexes of the housing estate remote from the cities and megalopolises, and consequently and from network communications.

Alternative of leading of network gas is the device of the autonomous (personal) gasification, capacities resumed by liquefied gas. This method involves big financial expenses which have a big payback period, occupy part of elevated and underground space of the expensive earth, and also demands attention regarding maintenance and that periodic replenishment of the tank by the liquefied gas, as private use is important, attracts the raised expenses on transportation.

The technology of application of the liquefied gas for the centralized providing with energy resources of a complex of building remote from network energy resources is considered in this work, the economic-mathematical model of the first approach of the concept of the device of the settlement, allowing to determine the cost of received energy and equipment payback periods is offered.

1. Relevance of work

Now the term «energy efficiency» is treated as rational use of energy resources, however sense and the importance of this definition was beyond recommendatory measures and began to be the requirement. Confirmation to that is introduction in action of the Federal law of the Russian Federation of November 23, 2009 N

261-FZ "About energy saving and about increase of power efficiency and about modification of separate acts of the Russian Federation" [1] the international standard in the field of ISO 50001 energomendzhment, and also the developed draft of the state standard specification P 50001 standard "Systems of power management. Requirements and application guide". Thus, in Russia, as well as in other developed countries, energy saving is one of strategic tasks without which decision in the near future it is possible to meet difficulties, and it is possible and with problems [2-5].

Thus, in the construction industry of Russia it is necessary to set the priority direction effective use of the fuel and energy resources (FER) and the made energy, having changed a classical abutment of accumulation of volumes of their extraction and production which manages much more expensively, than introduction of actions for its savings [6-7]. The important reason of squandering of TER is inefficient, and sometimes even irrational consumption of energy in the sphere of housing and communal services, in the construction sphere and in the sphere of the industry [8-9].

In the Russian Federation one of the most demanded type of natural resources is natural gas. Natural gas is applied as fuel, having advantages before firm and liquid fuel, thus warmth of its combustion is higher and it doesn't leave waste (ashes). Natural gas is widely applied on thermal power plants, in boiler installations and industrial furnaces, and also has broad application in automobile equipment. However at all obvious advantages of gas and gasification as a whole there is a number of the shortcomings one of which is leading of communications to the end user. It is rather labor-intensive process which demands big financial investments.

Application of natural gas for ensuring heat and electricity is actively applied in many settlements of the country and is the most favorable resource. Unfortunately networks of distribution of natural gas don't cover all volume of consumers and the question of accession to networks to become more and more sharply in view of a constant gain of again formed complexes of the housing estate remote from the cities and megalopolises, and consequently and from network communications [10-13].

Now in the large cities, the cities of federal value – St. Petersburg and Moscow territorial and land resources, and cost of the remained spots of possible building incredibly are almost completely settled, and in some areas are absent at all [14]. In this regard development of area of the city in which low building is mainly applied very actively develops – new settlements and inhabited massifs are created. On the average again erected housing estates are calculated on 50-100 households about 250 sq.m., but also complexes consisting of 800-900 households with a specific area about 100 sq.m. meet also. And it is impossible to forget about need of construction of objects of infrastructure without which complex activity is impossible. It is also necessary to consider need for gasification of the existing settlements which are unevenly remote from larger settlements and communications to which there is no technical capability of connection to networks of distribution of energy resources, or the cost of connection is incommensurably high. According to data on population census of 2010 in the territory of the Russian Federation 19126 rural settlements, among which 2771 settlements with a number of living less than 500 people and 5568 settlements numbering from 500 to 1000 people are located. According to the data presented on a site of the leading gas magnate [2] - "JSC Gazprom is the only producer in Russia and the exporter of the liquefied natural gas and provides about 5% of world production of LNG. ", also the following information which in the case under consideration can become a bright example is given in this resource: "The cooperation agreement between JSC Gazprom and Administration of the Nenets Autonomous Area is signed in 2006. The agreement on gasification – in 2010. ", in March, 2013 "The parties discussed a question of development of gasification of the region. The draft of the General scheme of gas supply and gasification of the Nenets Autonomous Area is developed. Now it undergoes coordination procedure. In the current year the company plans to direct on gasification of the district of 100 million rubles". Thus, it is necessary to draw a conclusion that process of leading of network natural gas process long (at complex development can make some years), but also expensive [15-18].

Existing alternative is the device of the autonomous (personal) gasification, capacities resumed by liquefied gas. This method involves big financial expenses which have a big payback period, occupy part of elevated and underground space of the expensive earth, and also demands attention regarding maintenance and that periodic replenishment of the tank by the liquefied gas, as private use is important, attracts the raised expenses on transportation [19-21].

In this work the technology of application of the liquefied gas for the centralized providing with energy resources of a complex of building remote from network energy resources will be considered. Besides, the cost of received energy will be calculated and the equipment payback period is defined.

2. Short review and research problem definition

The significant contribution to the solution of the theory and practice of autonomous power installations was brought by the following scientists: Nikolaev Valentin Georgiyevich, Onishchenko Sergey Vladimirovich, Sotnikova Xenia Nikolaevna, Isanova Anna Vladimirovna, Vikulin Denis Yuryevich, Ivanov Anton Aleksandrovich, etc. [22-26]

Nikolaev V. G. in the work used the complex of methods including pilot studies, computer modeling, mathematical modeling with elements of mathematical statistics, functional and cost the analysis. I carried out functional and cost the analysis of the experimental "solar" building with the autonomous system of power supply (ASPS). For minimization of expenses of energy during the work of pump installations Nikolaev V. G. solved a number of optimizing tasks with development of essentially new methods of determination of optimum parameters of the pump equipment and ways of management of. Confirmation of expediency of management by systems of water supply and optimization of their work on more difficult example is received [22].

Onishchenko S. V. gave statistics of the countries of leading power consumers. It conducted complex researches of effective architectural and planning and constructive solutions of power effective residential buildings on the example of the house of farmstead type with the autonomous system of power supply (ASPS) on the basis of solar energy in climatic conditions of the South of Russia. In its work features of individual application of ASE are considered and compared to application in complex building of the settlement consisting of similar houses of farmstead type. It investigated methods and the ways of space-planning and constructive decisions providing increase of thermal efficiency of the building; development of the experimental building with active solar system on the basis of photo-electric solar modules [23]. Isanova A. V investigated increase of efficiency and a choice of rational parameters and working hours of heatpump stations for systems of heating and hot water supply century. She developed mathematical model of heatpump station for system of heating and hot water supply. The model includes the equations describing influence of efficiency and temperatures of condensation of a working body of thermal pumps, temperatures of a low-potential source of warmth, heat carrier temperature in system of heating and hot water supply for work of thermal station. On the basis of mathematical model about use of a method of consecutive approximations in the form of the regular and singular theory of indignations I received analytical dependences of temperatures of condensation of working bodies of the thermal pumps, minimizing fuel consumption, from thermal and mechanical parameters of thermal pumps and external power sources. I revealed influence of efficiency of thermal pumps on the minimum fuel consumption and the rational scheme of their connection. I developed a technique of determination of parameters and working hours of heatpump station. The technique is based on mathematical model and analytical dependences [24].

Vikulin D. Y. investigated automation of design of systems of monitoring of energy efficiency of buildings, constructions at their reorganization in SAPR of construction objects. He developed complex monitoring of buildings, constructions for maintenance set or level increases энергоэффективностити and the version of the power passport for the personal computer [25]. Ivanov A.A. was engaged in modeling and justification of systems of gas supply of settlements, I developed scientific bases of calculation and design of distributive systems of gas supply of rural settlements. It conducted a pilot research and mathematical modeling of thermal efficiency of household gas-using appliances, developed mathematical model of justification one - and two-level settlement systems of gas supply, developed a technique of a choice and justification of optimum parameters and circuit decisions of settlement systems of gas supply, developed economic-mathematical model of justification of a rational scope one - and two-level systems of gas supply at gasification of rural settlements [26].

Thus, despite large volume of the scientific researches devoted to this subject, use of systems of a heat supply at simultaneous introduction of a complex of systems of monitoring and management engineering systems for settlements of cottage type so far isn't offered. By results of the short review need of systematization and updating of all conducted researches was revealed and the research objective was formulated: Creation of autonomous power installation complex power supply of the cottage settlement, providing the most effective power consumption [27]. For achievement of this purpose it is necessary to solve the following problems:

- to define economic feasibility of use of power installation using the liquefied hydrocarbonic gas as an initial energy resource, in the considered scale
- definition the optimum constructional and planning decision providing the maximum efficiency at distribution of energy resources on internal networks of the settlement.
- to provide energy saving and economy of energy resources, by scientific and reasonable optimum operation of regulators of temperature.

3. Development of autonomous power installation with complex power effective electroproviding

Now exist a big variety of schemes of gas supply:

1. From the high-level network. This method doesn't oblige the end user to carry out capacious engineering works on equipment selection, however leading of the main gas to the end user has the following stages:

1.1. Receiving Specification (removal of technical restriction)

1.2. Order of the project of the gas pipeline (if technically possible and specification)

1.3. Coordination of the project with the state instances and owners of the gas pipeline

1.4. Gas pipeline laying, with involvement of the competent authority exercising technical supervision

1.5. Delivery of object of the state commission, with all corresponding bureaucratic delays

1.6. Conclusion of the contract for maintenance

1.7. Implementation of balancing and commissioning

1.8. Conclusion of the contract for supply of gas

In case the area of the heated room more than 300 sq.m. it is necessary to put calculation about requirement of gas.

Thus, the method isn't technically difficult and doesn't demand acquisition of the expensive equipment, however demands a large number of organizational works at the expense of what in the Russian conditions can have huge term of realization, and also we don't accept in settlements which are removed from the highway, or in a case when connection to the highway is required to be coordinated with several areas of municipal authority, process can be dragged out for decades [28-33].

2. Alternative of leading of **network gas is the device of the autonomous (personal) gasification**, capacities resumed by liquefied gas. This method involves big financial expenses which have a big payback period, occupy part of elevated and underground space of the expensive earth, and also demands attention regarding maintenance and that periodic replenishment of the tank by the liquefied gas is important that as individual use, attracts the raised expenses on transportation [34-37].

3. **Autonomous gas supply of the cottage settlement in a complete set with reservoir installation**. Unites in itself both specified options – is network distribution of the liquefied hydrocarbonic gases (LHG). It is possible to refer simplicity and the organization period to advantages, however has also following shortcomings: it is incomparable high cost in comparison with natural gas, it is necessary expensive the equipment for gas processing (the copper, a plate), is necessary the qualified technical control [38]. Autonomous gasification of cottage settlements is very slow and difficult because coordination of many papers is required, including, have to participate and local authorities, besides demands from consumers of big participation - the List of data and documentation for design and autonomous gasification of the cottage settlement:

3.1. With each owner of the house, in the settlement, the document confirming the right of possession on property of a site, or the lease contract (if the person rents the house) is required;

3.2. Production of copies with accurate designation of borders of each site, with a mark of surveyors (in a certain territory, an individual landscape).

3.3. Without fail, the registered survey on the scale of 1:500 or 1:200;

3.4. The document confirming geological research of soil of a site;

3.5. From local administration, construction license;

3.6. Accurate design assignments of autonomous gasification;

3.7. Specifications, on service and supply of gas (the organization has to have a license for such types of work);

3.8. The plan of a task on which the exact location of the gas pipeline is specified;

3.9. Passports, certificates.

Analog are the block thermal power plants working at natural gas.

On the basis of studying of existing techniques and systems of the centralized gas supply of the settlement in which there is a leading of the natural or liquefied hydrocarbonic gas to a household, definition of characteristics of the equipment, drawing up the nomenclature of the equipment, for determination of the demanded amount of financing, determination of technological features and the conclusion about shortcomings of these techniques is offered the following scheme:

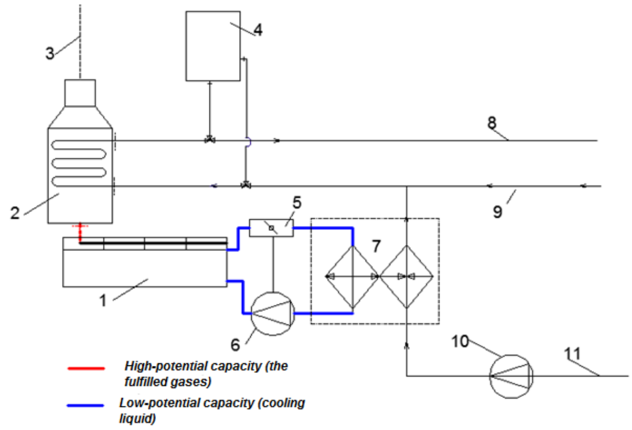

Fig. 1. Standard scheme of utilization of warmth

1 - diesel generator; 2 – copper utilizer; 3 – exhaust pipeline; 4 – tank accumulator of heating water; 5 – thermostat; 6 – centrifugal pump; 7 – economizer; 8 – water supply pipe in the heat carrier; 9 – return pipe; 10 – pump; 11 – pipe for giving of outside water

The considered scheme demands performance of a complex of organizational and technical and economic-mathematical actions. Namely, first of all it is necessary to construct economic-mathematical model of the first approach of the concept of the device of the settlement – to make the integrated structure of object for which it is necessary to define characteristics and to establish electricity and heat consumption in various time of day, and in a various season, to calculate specific indicators, for the purpose of further application and definition of optimum views of settlements on the basis of uniform, integrated criterion of an assessment of efficiency of use of this technology.

4. Research model

It is offered to consider option centralized heat and power supply of the cottage settlement, by the liquefied hydrocarbonic gas (LHG) use as initial power source from which the electric power is generated, and the thermal arising thus is used for heating.

First of all from the liquefied hydrocarbonic gas (LHG) it is necessary to receive electric energy, in volume providing consumption of the considered cottage settlement on 800 households * 3,5 kW consuming on the average, having used thus emitted thermal energy for the purpose of its further use for heating. Thus, the problem of increase of power efficiency is solved and negative influence of generating installation on environment comes to naught. There are two methods of an assessment of efficiency of the systems similar by the offered:

1. The exothermic analysis or the analysis of operability of a working body (it is directed on determination of economic efficiency)

2. Warmth efficiency (WE) method – the most convenient for a complex assessment.

The external thermal balance of the heatpower plant, as we know, looks like:

$$\dot{Q} = P + \dot{Q}_{ex},$$

where in the left part of the written identity there is the thermal capacity entered into installation at combustion of fuel, P – so-called capacity on an engine shaft (turbines, the piston engine, etc.). The second composed in the right part – the thermal capacity lost, according to the second beginning of thermodynamics, in "a cold source". Here the thermal capacity lost, for example, in the cooling system enters. Correct expression:

$$\eta := \frac{P}{\dot{Q}}$$

represents efficiency (efficiency) of installation. For modern thermal cars $\dot{Q}_{ex}$ value is close to efficiency of a cycle of Carnot. Size fluctuates within 50% (The engine of external combustion) … 70% (aviation gas turbines).

In connection with the told there is an important engineering problem of utilization of "secondary" thermal power $\dot{Q}_{ex}$. Problematical character of a task that componentsc $\dot{Q}_{ex}$ (for example, the capacity of a stream of exhaust gases and a stream of the cooling environment) have different thermal potential (or working capacity - an exergy) and, as a result, with various efficiency are realized.

So, for example, temperature of a stream of exhaust gases makes from 400 … 450C (The engine of external combustion) and 600 … 700°C (gas turbines). Such high-potential stream is easily utilized, for example, in the steam generator. Temperature of a stream of cooling liquid seldom exceeds 100 … 120C that creates problems with heat exchangers recuperators (big dimensions and low temperature pressures turn out) [39]. Except other, use of warmth of cooling liquid in heat exchangers leads to emergence in the pressure head cooling system of knots of division and connection of streams, i.e. to additional losses of a pressure [40].

The measure of use of warmth is estimated at TSU by warmth efficiency

$$KQ := \frac{P + \alpha \dot{Q}_{ex}}{\dot{Q}},$$

where $\alpha \leq 1$ – coefficient of completeness of utilization. Let $\alpha=0$ (warmth isn't utilized). Then $KQ=\eta$. If all secondary warmth is utilized, i.e. $\alpha=1$, то $KQ=1$. Obviously:

$$KQ = \eta + \alpha \ 1 - \eta \ .$$

In modern installations the efficiency of warmth reaches 95% (Engeniering Control, USA). Expression:

$$h_0 = 1 - \frac{h}{KQ} = \frac{a(1- h)}{h + a(1- h)}$$

represents a measure of utilization of warmth. If $\alpha=0$, that the measure of utilization of warmth is equal 0. If all warmth is utilized, $\eta_0=1-\eta$.

The major technical and economic task consists in determination of optimum value of a measure of utilization of the warmth, warmth delivering at most an efficiency KQ with restriction on time of payback of capital investments on the installation, having the set efficiency η.

At the heart of model gas-turbine installation (GTI) which develops electric energy lies, consuming environmentally friendly and most economic natural gas. In too time of GTI develops comparable part on the volume of the thermal energy which rational use is capable to reduce considerably losses (50-70%), thereby having increased efficiency of GTI more than twice.

$$Q_t = Q_{ex} + Q_{выб},$$

Where $Q_{выб}$ - heat loses, $Q_{выб} = 0{,}7\,Q$, that makes about 50-70%

$$\eta = \frac{A}{Q_t} \approx 0{,}3(\max)$$

Used warmth allows to receive the following:

$$Q_{им} = A + (Q_t - A) \times (0{,}5...0{,}7) = 0{,}3Q_t + 0{,}7Q_t 0{,}6 = 0{,}72Q_t$$

$$WE = \frac{Q_{им}}{Q_t} = 0{,}72$$

For development of 1 kW/hour of electricity of GTI spends about 15 kg of air. At the exit the fulfilled air has temperature about 500 degrees. Using water it is possible to receive thermal energy which can be directed further on heating or can be to be used in the industrial purposes.

Novelty consists in use of the converted aviation turbine. This turbine non-vibro-action that gives it a number of advantages at definition of a place of its arrangement. Besides, for this turbine it is possible to use the easy base that also adds a number of advantages – demands considerably smaller financial expenses for integration and it is capable to expand (opens opportunity) the geographical range of placement.

It is necessary to refer ability of the turbine to technical features instantly and considerably to raise loading. During the work in a standard mode loading about 30%.

Besides, for service to this turbine special attention regarding technical and engineering service doesn't demand.

5. Conclusions

Economic feasibility of use of power installation using the liquefied hydrocarbonic gas as an initial energy resource, in the considered scale is defined

The scheme offered in the present article proposes the optimum constructional and planning solution providing the maximum efficiency at distribution of energy resources on internal networks of the settlement

The economic-mathematical model of the first approach, allowing to define optimum values of a measure of utilization of the warmth, warmth delivering at most an efficiency is developed KQ with restriction on time of payback of capital investments on the installation, having the set efficiency η.

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