Economic valuation of biogas production in Russia

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Abstract. The purpose of the study is to get a detailed idea of the economic efficiency of the construction of the designed biogas plant. Carried out technical-economic evaluation of feasibility and economic efficiency of application of the developed technological scheme of biogas plant on the example of a pig-breeding complex with the number of pigs - 1500 heads. Capital expenditures for construction and installation of main and auxiliary equipment amounted to 15.21 million Russian rubles, the discounted payback period of 8 years and 8 months. The amount of discounted cash flow on an accrual basis at the end of the design life of 20 years can be found in future researches. The widespread use of the proposed scheme of biogas plant at large pig enterprises in Russia will significantly reduce the problem of recycling and storage of production waste, which will have a positive impact on the ecology of Russia, while increasing the autonomy and profitability of the energy complex.

1. Introduction

The processed substrate after the biogas plant is fed to the separator. It separates the fermentation residues into solid and liquid fractions.

The biogas obtained is an energy source for the production of electricity and heat. Gas turbines and piston engines are used to convert biogas. The principle of operation of these technologies is similar. Energy is converted into mechanical energy of rotation and further in the generator it is converted into electrical energy. Heat energy is produced as a by-product. Both technologies are roughly in the same price range and have similar levels of performance. For the production of electricity, asynchronous generators are mainly used, less often synchronous generators.

An asynchronous generator is nothing more than an AC squirrel-cage motor powered by a public grid. If it operates at a speed greater than that of the engine, it generates electricity that can be supplied to the public grid. At the same time, it consumes a certain amount of electricity (reactive current) for magnetic activation of the network. Thanks to the activation of the network, the number of revolutions is stabilized within certain limits, depending on the power of the generator.

Asynchronous generators are cheap and undemanding in operation. The main disadvantage of asynchronous generator is that in case of disappearance of current in the network, it can not generate electricity, and thus is not suitable for use as an emergency generator.
2. Literature review

Synchronous generators are self-activated, they are arranged in such a way that they can also generate electricity even without connecting to the network. The current required to create a magnetic field is supplied from a small auxiliary generator located on the shaft and the armature winding in the rotor. For synchronous generators, the number of revolutions must be synchronized with the mains frequency. For this purpose, the biogas engine must be equipped with a speed controller. After a certain power of 45 to 50 kW, synchronous generators are as expensive as asynchronous generators [1].

The purpose of the generator is not only to generate electricity, but to use as efficiently as possible the excess heat generated by the engine. In winter, this does not cause any problems, especially in small farms, because in addition to the fermenter heating is still required for the house and livestock buildings [2].

With the increasing size of biogas plants, not only in summer but also in winter there is a large excess of heat. Part of the excess heat is used to maintain the temperature of the fermenter, but often most of it is "utilized" by means of an emergency cooler. As an emergency cooler, a plate heat exchanger is used, corresponding to the power of the engine with a fan operating from the network and controlled by a thermostat located outside the technical room [3,4].

Fuel for microturbines can be natural gas, diesel fuel, associated petroleum gas containing hydrogen sulfide and many other types of hydrocarbons with different calorific value. The gas pressure acceptable for microturbines starts from 0.02 bar. Regular booster compressors are used to raise it to operating values [5,6].

3. Results and discussion

The microturbine from the manufacturer includes:

- microturbine;
- recuperator;
- heat exchanger-water / exhaust;
- power electronics (rectifier, inverter, filter);
- air cooling system for power electronics;
- automatic control system of the microturbine;
- control panel;
- rechargeable battery.

For the calculated installation, the microturbine is suitable for the parameters:

- electric power: 30 kW;
- output voltage: 380-480V, 3 phase;
- amperage: 40-46 amp;
- output current frequency: 50-60Hz;
- electrical efficiency: 26-30 %;
- electrical load range: 1-100%;
- thermal power: 1.7 kW per 1 kW of electricity;
- coolant outlet temperature: (water) 95°C.

The size of the gas tank for a biogas plant is determined by the volume of biogas production and the process of its consumption. In the production of biogas only thermal energy is selected such a volume of storage that it provides storage of daily output.

With cogeneration and generation of electric energy only, it is possible to manage with a much smaller gas tank, it is sufficient to take 20-50% of the daily gas production by the station, if the
installation works round the clock with a full load. Irregularity in the consumption of thermal energy in this case can be compensated by the use of accumulator tanks [7,8].

General technical requirements for biogas plants are that plastic gas tanks are used to collect biogas in simple, combined installations, where plastic is coated with an open container serving as a reactor, or a separate plastic gas tank is connected to the reactor.

Steel gas tanks are divided into low (0.01-0.05 kg/cm$^2$), medium (8-10 kg/cm$^2$) and high (200 kg/cm$^2$) pressure gas tanks.

Low pressure steel gas tanks are justified only in the case of a long distance (at least 50-100 m) from the installation to biogas devices. In other cases, the use of a cheaper plastic gas tank should be considered. The cost of installation and construction of equipment and facilities take 30% of the cost of equipment [9,10].

We determine the capital costs for the construction of a biogas plant, thousand Russian rubles:

$$K = (K_m + K_{mm} + K_g + K_n + K_{mb} + K_c + K_k \cdot 1.3)$$ (1)

where $K_m$ is the cost of a 60 m$^3$ digester (railway tank) - 2100 thousand Russian rubles; $K_{mm}$ is the cost of a mechanical stirrer installed in a methane tank is 70 thousand Russian rubles; $K_g$ is the cost of a gas tank with a volume of 30 m$^2$ - 950 thousand Russian rubles; $K_n$ is the cost of the ONL pump is 86 thousand Russian rubles; $K_{mb}$ is the cost of the separator SOSH-175 - 600 thousand Russian rubles; $K_c$ is the cost of the Capstone 30 microturbine is 4000 thousand Russian rubles.

$$K = (2100 \cdot 2 + 70 \cdot 2 + 950 + 86 + 600 + 55 + 173 + 4000 + 500 + 1000) \cdot 1.3 = 15210$$

On the basis of the above described and made calculations, we assume that the designed biogas plant will have a separate plastic low pressure gas tank with a volume of 30 m$^3$.

4. Conclusion

After separation, the processed substrate is sent to the lagoon. Lagoons are used for receiving fermented substrate from flow installations and further storage.

Their volume should ensure the storage of the material during the non-growing period, the time when plants do not consume nutrients, depending on climatic conditions and plant culture, this period lasts approximately 6-7 months.

In most newly designed biogas plants, the lagoon is covered with either a hard surface or a film cap to prevent nitrogen losses and capture resulting from biogas fermentation [11,12].

Capital costs for the construction of a biogas plant consists of the costs for the construction of tanks, purchase and installation of methane tanks, cogenerators, agitators, auxiliary equipment, automation systems and project development [13,14].

Current operating costs of a biogas plant consist of depreciation, payroll, contributions to insurance funds for each employee, repair costs.

The presented feasibility study allows to get a detailed idea of the economic efficiency of the construction of the designed biogas plant [15,16].

There is technical-economic estimate of feasibility and economic efficiency of application of the developed technological scheme of biogas plant on the example of a pig-breeding complex with the number of pigs - 1500 heads.

Capital expenditures for construction and installation of main and auxiliary equipment amounted to 15.21 million Russian rubles, the discounted payback period of 8 years and 8 months. It is proof the researches that was written before [17,18,19].
The widespread use of the proposed scheme of biogas plant at large pig enterprises in Russia will significantly reduce the problem of recycling and storage of production waste, which will have a positive impact on the ecology of Russia, while increasing the autonomy and profitability of the complex.

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