The complex mobile independent power station for the recreational areas

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Abstract. There are many problems with energy supply and waste water utilization of recreational areas associated with increased environmental requirements and restrictions. These areas include the Baikal Lake, there are many settlements and tourist campings around. The use of traditional energy and wastewater systems at these sites is problematic. In the result of the our research a complex mobile independent power station was developed, which will allow to solve the above problems. This installation includes renewable energy equipment, which allows to receive electricity and heat energy, as well as utilize the wastewater.

1. Introduction

For energy supply and sewage treatment of villages in the countryside, cottage settlements and even separate buildings it is necessary to build additional energy and sewage treatment plants, with associated complex design work. In most cases, after deterioration or obsolescence of these stations and related life support systems [1], it is necessary to carry out major repairs and reconstruction or conservation, followed by the construction of new stations. It is also impossible to move them with reusing in case of a decrease in the number of subscribers of these stations. Not to mention the fact that the use of traditional energy often has environmental consequences. This is especially concerns the recreational areas, like The Baikal Nature Territory in the Irkutsk Oblast, Zabaykalsky Krai and Republic of Buryatia.

For example, the Listvyanka settlement is located on the shores of the Baikal Lake, is included in the water protection zone and is one of the main tourist centers on the Baikal. In this settlement, the main source of thermal energy is the coal boiler, which produces carbon dioxide, polluting the air of the village and the slag that needs to be utilized. The negative impact of carbon dioxide is monitored by environmental organizations and regularly charge fees for emissions of harmful substances into the atmosphere. Also there is the problem of transportation and storage of coal fuel in the settlement. The nearest storage point is located 10 km from the boiler house, which forces them to carry out continuous fuel transportation and the corresponding financial costs, as well as the subsequent increase in the heat energy tariff [2].

The use of renewable energy sources [3]-[18] can solve many of the above problems, but even they alone cannot solve the problems of mobility and dependence on external factors.
2. Renewable energy sources

The attractiveness of solar energy is resulted from a number of circumstances: solar energy is available at every point on our planet, it is an environmentally friendly source of energy, allowing to use it on an ever-increasing scale without a negative impact on the environment, besides it is an almost inexhaustible source of energy that will be available over millions of years. However, this technology has such disadvantages as a strong dependence on weather conditions and geographic location. At the same time, the Baikal Lake is located in a zone with good insolation rate.

Table 1 presents the calculation of the number of solar collectors, required for the partial removal of the load from the boiler plant in Listvyanka, namely, for the local school and two five-story residential buildings. This calculation was carried out in the framework of the preparation of solutions for the boiler plant technical retrofit. In the data presented in Table 1, it can be seen that the calculation was made with the duration of daylight and the average for 22 years the number of cloudy days in the area under consideration. This significantly affects the performance of the solar system. In this calculation, the SUN 1 solar collector, developed and patented in INRTU, was used [19].

| Table 1. Calculation of the solar heating system for the Listvyanka settlement. |
|---------------------------------------------------------------|
| Jan. | Feb. | March | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Year |
|------|------|-------|------|-----|------|------|------|------|------|------|------|------|
| 31   | 28   | 31    | 30   | 31  | 30   | 31   | 30   | 31   | 30   | 31   | 31   | 365  |
| Duration of month, days |
| Monthly average solar energy values falling on an optimally oriented surface, kW·h/m²·day |
| 2,92 | 4,37 | 5,55  | 5,83 | 5,62| 4,89 | 4,01 | 4,00 | 4,17 | 3,67 | 2,86 | 2,33 | 4,19 |
| Amount of cloudy days |
| 4,3  | 2,6  | 3,1   | 4,5  | 6,6 | 8,1  | 11,1 | 9,5  | 7,7  | 5,6  | 5,6  | 5,3  | 74,0 |
| Average sunny day duration, hours |
| 3    | 5    | 6,7   | 7,4  | 8,6 | 8,8  | 7,8  | 7    | 6,1  | 4,9  | 3,1  | 2    | 5,9  |
| The total value of solar energy per month, kW·h/m² |
| 77,99| 111,00| 154,97 | 148,68| 137,21| 107,04| 79,87| 86,04| 93,09| 93,18| 69,87| 60,00| 1218,40 |
| The average hourly value of solar energy per month, kW·h/m² |
| 0,97 | 0,87 | 0,83  | 0,79 | 0,65| 0,56 | 0,51 | 0,57 | 0,68 | 0,75 | 0,92 | 1,17 | 0,71 |
| Hourly heat load on hot water supply, kW/h |
| 70,00| 70,00| 70,00  | 70,00| 70,00| 70,00| 70,00| 70,00| 70,00| 70,00| 70,00| 70,00| 70,00 |
| Daily heat load on hot water supply, kW/day |
| 910,00| 910,00| 910,00  | 910,00| 910,00| 910,00| 910,00| 910,00| 910,00| 910,00| 910,00| 910,00|
| Required solar collectors performance, kW/h |
| 303,33| 182,00| 135,82  | 122,97| 105,81| 103,41| 116,67| 130,00| 149,18| 185,71| 293,55| 455,00| 155,11 |
| The average monthly SUN 1 solar collector performance, kW/h |
| 1,19 | 1,07 | 1,01  | 0,96 | 0,80| 0,68 | 0,63 | 0,70 | 0,83 | 0,91 | 1,13 | 1,42 | 0,87 |
| Required number of SUN 1 solar collectors |
| 255  | 171  | 134   | 128  | 133| 153  | 186  | 186  | 179  | 203 | 260  | 320  | 178  |

In result of the calculations, the required number of solar collectors was established - 203 pcs. This number of solar collectors will allow to fully cover the calculated daily heat load on the hot water supply system of the buildings under consideration in period from February to October and from 60 to 80 % of the load in period from November to January. At the same time in February, March, April,
May and September, the excess heat can also cover part of the heat load of the heating system of the buildings.

There is an area where it is possible to place 203 solar collectors, which will provide the thermal energy for the school and houses in the immediate vicinity of the boiler plant. However, unfortunately, this area is not enough to supply power to a larger number of buildings in Listvyanka. Using solar heating, it is necessary to have an additional, more stable source of heat supply, which in this case will be the boiler plant of Listvyanka. But in many settlements and campings located in the coastal areas of the Baikal Lake, there is no such source for various reasons, starting with inaccessibility and fuel logistics problems, and ending with financial difficulties. Not to mention the environmental restrictions mentioned above. It is also not always possible to carry out centralized power grids in all settlements and campings.

As for electrical energy, solar panels have exactly the same dependence as solar collectors. Wind turbines also have a strong dependence on the weather and air speed.

In connection with the foregoing, the use of hybrid energy sources is very promising. As a result of our research, the complex mobile independent power station was developed, which includes several autonomous energy sources, as well as the function of wastewater treatment.

3. The complex mobile independent power station
The power station developed by us is designed to provide full power supply of various facilities, located even in remote areas, reduce dependence on centralized energy supply systems, reduce fossil fuel consumption, improve the ecological situation in urban areas and solve industrial and municipal sewage treatment problems. It is also suitable for use in recreational areas. It can be used in almost any types of building and does not require additional design and construction work. This unit can be used as a primary, secondary or temporary energy source. It can also be easily moved from one subscriber to another and integrated into the existing energy supply systems of a building [20].

\[ \text{Figure 1. The power station draft: } SP – \text{ solar panel; } WT – \text{ wind turbine; } IN – \text{ inverter; } DG – \text{ diesel generator; } MFC – \text{ microbial fuel cell; } WTP – \text{ wastewater treatment plant; } UVWT – \text{ ultra-violet water treatment; } HP – \text{ heat pump; } IB – \text{ indirect boiler; } EH – \text{ electric heater; } P – \text{ pump; } TV – \text{ thermostatic valve; } TS – \text{ temperature sender; } HE – \text{ heat exchanger; SC – solar collector.} \]
As shown in Figure 1, the mobile independent station includes a solar panel \( SP \) and a wind turbine \( WT \), which allow to get electricity from the sun and wind, and an \( \text{accumulator} \), which allows to accumulate electricity generated by energy sources. To obtain electrical energy, in case of adverse weather conditions the station contains a diesel generator set \( DG \).

To obtain thermal energy in the power station, it contains the solar collector \( \text{SUN 1} \ SC \), which was previously mentioned. A distinctive feature of this collector is the meander-shaped heat-receiving tubes that allow to increase the heat transfer medium temperature at the outlet of the collector and its efficiency, enhanced rear insulation and double frontal glass, which increase the thermal insulation characteristics of the collector. That's why this collector can be used at a lower outdoor temperature. Heat pump \( HP \) also allows to receive thermal energy from the ground heat or water. It is also possible to install an air heat pump. Modification of the heat pump may allow it to be used as an air conditioner in the summer. Indirect boiler \( IB \) allows to get a supply of water, and the electric heater \( EH \), integrated into it, allows to maintain the temperature of the stored water.

The station includes an independent plant for water treatment of the \( WTP \) with an ultra-violet treatment unit \( UVTU \), which allows the power station to expand its functionality and solve the problem of waste utilization in recreational areas. The sediment obtained from the \( WTP \) will be used as the source of the microbial-fuel cell \( MFC \). The new integrated control system will simplify the operation of this plant, as well as improve its overall efficiency.

4. Results of the study and conclusion

The developed complex mobile independent power station designed to provide full power supply to various objects, even located in remote areas, and to reduce dependence on centralized power supply systems. At the same time, it significantly increases the reliability of uninterrupted heat and power supply from centralized life support systems. In addition, it reduces the consumption of fossil fuels, which makes it possible to greatly improve the ecological situation and solves the problems of utilization industrial and municipal wastewater. It is proved that it is especially suitable for use in recreational areas.

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