Automation based on renewable energy sources in the Trans-Baikal Territory

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Abstract. This work is devoted to the study of the prospects for the development of renewable energy in the Trans-Baikal Territory. Solar and wind energy are considered. For calculations, 3 settlements of the Trans-Baikal Territory were selected. The solar energy inflow has been calculated for the three positioning systems. A comparison of the efficiency of solar and wind power plants has been made. The calculation of the payback period for solar power plants has been completed.

1. Introduction
This article examined the prospects for the development of renewable sources of the Trans-Baikal Territory, in particular solar and wind energy. Prospects will be assessed by the payback period of solar and wind power plants. For the assessment, 3 settlements were selected. 1. The city of Chita, which is the administrative center of the Trans-Baikal Territory. 2. Chara village, one of the northernmost settlements. 3. The town of Borzya, one of the southern settlements of the region.

2. Solar energy
The solar power plant used in the calculation has a rated power of 1000W. It includes 6 solar panels Delta SM 200-24 M (24V / 200W) [1] with a total cost of 39120 rubles, a single-phase inverter Sofar 1100TL-G3 1100VA [2] costing 29670 rubles, which includes a maximum power point controller tracking (mppt). The total cost of the solar power plant, including wires and protective equipment, will be: 73480 rubles. The solar panels will be installed on the ground (pole-mount), in an open space free from natural and artificial shading [9, 10]. As a positioning system, consider static, static with a seasonal change in the angle of inclination and a system with a two-axis tracker.

Solar insolation throughout the year is shown in Table 1 [3].

Based on the data obtained, the highest annual solar insolation in all 3 settlements is observed at Latitude - 15 °. In the case of a static tilt system, the greatest efficiency will be observed at Latitude - 15 ° from March to September, and Latitude + 15 ° from October to February.

The use of a Dual-axis solar tracker also significantly increases solar energy inflow. The greatest increase in its use is observed in the summer. The maximum increase was recorded in the village of
Chara in June (+ 39.5%). Based on these data, we calculate the amount of solar energy per day using the formula:

\[ E = k_l P_{sb} \]

(1)

Where \( P_{sb} \) – solar battery rated power;
\( k_l \) – insolation coefficient.

The results obtained are presented in the form of Figure 1 – Figure 6.

| Region | Solar panels Tilt angle | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Chita  | Horizontal | 37.04° (Lat-15°) | 2.36 | 3.54 | 5.18 | 5.72 | 5.9 | 5.7 | 5.16 | 4.78 | 4.27 | 3.47 | 2.41 | 1.95 |
|        | Vertical | 67.04° (Lat+15°) | 2.71 | 3.81 | 5.12 | 5.02 | 4.68 | 4.38 | 4.06 | 3.99 | 3.94 | 3.57 | 2.7 | 2.27 |
|        | Dual-axis tracker | 41.9° (Lat-15°) | 2.92 | 4.32 | 6.39 | 7.42 | 7.99 | 7.61 | 6.68 | 5.89 | 5.09 | 4.11 | 2.91 | 2.45 |
|        | Dual-axis tracker | 56.9° (Lat) | 2.17 | 2.94 | 4.28 | 4.36 | 3.69 | 3.13 | 3.06 | 3.17 | 2.99 | 2.91 | 2.26 | 1.52 |
|        | Dual-axis tracker | 71.9° (Lat+15°) | 3.04 | 4.06 | 5.2 | 5.06 | 4.95 | 4.54 | 4.15 | 4.23 | 4.31 | 3.82 | 3.05 | 2.62 |
|        | Dual-axis tracker | 56.9° (Lat) | 2.9 | 3.98 | 5.34 | 5.54 | 5.66 | 5.27 | 4.77 | 4.73 | 4.59 | 3.87 | 2.96 | 2.48 |
|        | Dual-axis tracker | 71.9° (Lat+15°) | 3.04 | 4.06 | 5.2 | 5.06 | 4.95 | 4.54 | 4.15 | 4.23 | 4.31 | 3.82 | 3.05 | 2.62 |
|        | Dual-axis tracker | 56.9° (Lat) | 2.9 | 3.98 | 5.34 | 5.54 | 5.66 | 5.27 | 4.77 | 4.73 | 4.59 | 3.87 | 2.96 | 2.48 |
|        | Dual-axis tracker | 71.9° (Lat+15°) | 3.04 | 4.06 | 5.2 | 5.06 | 4.95 | 4.54 | 4.15 | 4.23 | 4.31 | 3.82 | 3.05 | 2.62 |
|        | Dual-axis tracker | 41.9° (Lat-15°) | 2.61 | 3.71 | 5.23 | 5.76 | 6.16 | 5.83 | 5.23 | 5.03 | 4.63 | 3.72 | 2.71 | 2.22 |
|        | Dual-axis tracker | 56.9° (Lat) | 3.29 | 4.6 | 6.47 | 7.46 | 8.43 | 7.84 | 6.78 | 6.27 | 5.57 | 4.41 | 3.3 | 2.84 |

**Table 1. Solar insolation.**
Based on the data received, we will calculate the annual output.
Thus, the total output for the year will be as it shown in Table 2:

| Region | Positioning method | Total energy production, Watt×h×year |
|--------|--------------------|---------------------------------------|
| Chita  | Fixed Tilt         | 1841904                               |
|        | Seasonal Tilt      | 1890060                               |
|        | Dual-axis Tracker  | 2329428                               |
| Chara  | Fixed Tilt         | 1672740                               |
|        | Seasonal Tilt      | 1715472                               |
|        | Dual-axis Tracker  | 2136288                               |
| Borzya | Fixed Tilt         | 1929576                               |
|        | Seasonal Tilt      | 1988172                               |
|        | Dual-axis Tracker  | 2456508                               |
When calculating the payback period, you need to take into account the losses arising during the operation of solar panels, as well as losses during energy conversion. The former include: dust and other types of pollution, losses due to heating of solar panels, losses due to aging of photovoltaic cells, losses due to darkening of the panel by external objects. The second are: The efficiency of the mppt controller, the efficiency of energy conversion by the inverter.

In this model, the solar panels were installed on the ground, which makes it possible to keep them clean. The loss due to darkening will also be equal to 0. The loss due to heating can be calculated using the formula [4]:

\[ k_T = (1,2T_e - 25\,^\circ C)k_{PR}, \]

Where \( T_e \) – Air temperature;
\( k_{PR} \) – power loss due to heating (0.5).

According to [3] and [5], the air temperature in all settlements, even in summer, is not sufficient for the appearance of losses due to overheating of solar panels.

Losses due to aging are assumed to be 5%.

The declared efficiency of the mppt algorithm of the selected inverter is > 99.9%. The energy conversion efficiency is 97.2% [2, 11].

Thus, the total losses in the production and conversion of energy will be: 5 + 0.1 + 97.2 ~ 8%.

Then the payback period can be calculated using the formula:

\[ PP = \frac{0.92P_w n}{1000C}, \]

Where \( P_w \) – total produced power, Watt\times h \times \text{year};
\( C \) – total project cost.
\( n \) – electricity tariff for the settlements under consideration;

The results are shown in Table 3.

| Region | Positioning method | Payback period, years. |
|--------|-------------------|------------------------|
| Chita  | Fixed Tilt        | 10.3                   |
|        | Seasonal Tilt     | 10.1                   |
|        | Dual-axis Tracker | 16.5                   |
| Chara  | Fixed Tilt        | 11.4                   |
|        | Seasonal Tilt     | 11.1                   |
|        | Dual-axis Tracker | 18                     |
| Borzya | Fixed Tilt        | 9.8                    |
|        | Seasonal Tilt     | 9.6                    |
|        | Dual-axis Tracker | 15.64                  |

3. Wind energy

According to the study [6], as well as [3] and [7], it can be concluded that the average wind speed in all areas of the Trans-Baikal Territory is not high enough to be recouped. Let's carry out the calculation based on the SWG EW1000 wind generator with a capacity of 1000 watts. The average rate of each month for the city of Chita is used as input data (Figure 7).
Let us construct a graph of power generation using the power curve of the selected wind generator [8] and compare it with the power generation of a solar power plant of the same power (1000 W.).

The results are presented in Figure 8.

4. Conclusion
Based on the study, we can conclude that solar energy has good development prospects. Calculations show that the payback period of a solar station in almost ideal conditions, with an electricity tariff of 4.2 rubles per 1 kWh, will be at least 9.6 years. At the same time, for convenience and clarity, such a tariff was also applied to the village of Chara, despite the fact that tariffs for rural settlements of the Trans-Baikal Territory the tariff is 2.94 rubles per 1 kWh at the moment. In this case, the payback period will be at least 15.8 years. A seasonal adjustment system, in this case, increases energy production by 2.5-3%. When using a two-axis tracker, the payback period is almost doubled, despite a good increase in the collected solar energy. This is due to the high cost of the two-axis tracker itself (from $ 1000 and more). It should be borne in mind that when installing solar panels on a roof (roof mounting), the power loss will be higher, which is associated with dust and pollution of the panels. Also, with this setting, the panels will get hotter than when mounted on the ground (pole mount) [4]. It is also worth noting that since 2019, Russia has adopted a law on microgeneration, thanks to which the owners of private SPPs can sell surplus generated energy to the general network at wholesale prices.

It was also concluded that the wind energy potential of the Trans-Baikal Territory is small.
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