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CALCULATION OF A COMBINED WIND AND SOLAR POWER PLANT FOR A PUMPING STATION IN THE REPUBLIC OF KARAKALPAKSTAN

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Abstract. This work presents analysis of the schemes of connection of wind power plants to renewable energy sources shows that in modern conditions, the most effective circuits are microgrid circuits that are self-sufficient, i.e. in normal, steady-state modes, there is no current in the connection line to the central network. This eliminates and reduces power transmission losses from the central grid, as well as increases the reliability of power supply to consumers. The development of such microgrids (virtual power plants) corresponds to the trend of development of distributed energy in our republic.
Consider, as an example of, the distribution of capacities of a combined power plant, which includes wind and solar installations providing electricity in pumping stationsin the city of Nukus.

Introduction. Renewable energy sources (wind and Solar) are unmanageable by humans, so we must strive to ensure that electricity consumption is linked to its receipt. This is a feature of the calculations of the design of power supply based on renewable energy compared with traditional power supply.
Having analyzed the meteorological data and the expected loads in the Nukus, let's assume that in winter, summer and autumn the specific wind power is more consistent with the load at the input to the pumping station than the density of solar radiation, and vice versa in spring. Such weather conditions are typical for Karakalpakstan. Based on this, wind is accepted as the main source of energy. Since calm days are observed throughout the year, wind energy needs to be duplicated. In this regard, solar radiation is taken as an auxiliary source. However, direct solar radiation also does not happen every day and is absent at night. This makes it necessary to accumulate energy for periods of simultaneous absence of wind and Solar renewable energy sources, as well as to provide power for their own needs.
Thus, the following energy sources are accepted for the power supply of the pumping station:

- wind;
- solar radiation;
- batteries (reserve).

The power supply is carried out as follows. If there is wind, then a DC machine charging batteries is rotated from the wind wheel. If there is no wind or the wind wheel is turned off in an unacceptably strong wind, then the battery is powered by a photo power plant, a wind turbine and a power generator can also work simultaneously.

From the batteries charged in this way, the direct current through the inverter is converted into alternating current, which is supplied to the load - household appliances at home.

Determination of the power of power plants

The power of wind power plants is one of the most important characteristics determining the reliability of the power supply system.

The power of the wind power plant (wpp) should be sufficient to power the electric receivers at home and charge the batteries of such capacity, which is sufficient to power the electric receivers on calm days (up to four days).At the same time, it should be borne in mind that during a calm period, batteries can be charged from a photovoltaic power plant (PPP). Obviously, the total power of wind power plant (wpp), photovoltaic power plant (PPP) and batteries should be minimal at the same time.Thus, the justification of the power of power plants is a task that can be formulated as follows - to determine the power of wind power plant (wpp), photovoltaic power plant (PPP) and battery capacity sufficient for uninterrupted power supply at home.

Results and Discussion.

Choosing a wind turbine

We calculate the gross potential of wind energy in the selected area:

$$E_{WF_i} = \sum N_{WF}(V) \cdot t(W) \cdot 8760 \quad (1)$$

where: N_{WF}– specific gross power of the wind flow,

V–wind speed,

t(W) –differential repeatability of wind speed.

The specific power of the wind flow passing through 1 m^2 of cross-section is given by the formula:

$$N_{WFi}(V) = 0{,}5 \cdot \rho \cdot V^3 \, (W/m^2) \quad (2.)$$

where: ρ -specified air density, under normal conditions: ρ=1,226kg/m^2.

The results of the calculations are summarized in Table 1

Calculation of the gross potential of wind energy in the northern part of Karakalpakstan for two wind turbines BRIZ – 5000 (5 kW) and wind turbine – 1500 (power 1.5 kW)

Table 1

V, m/s	t(V)%	N_{WF} Vt/m^2	E_{WF}kW*h/m^2*year	Es^{TEX},MW*h/km*year,V^np(m/s).	
				5kW BRIZ-5000	1,5kW WTD-1500
0.5	31.9	0.0788	0.11	-	-
2.5	29.8	9.8438	64.2	-	75.43
4.5	17.7	57.409	400.5	261.3	261.3
6.5	8.8	173.01	866.9	391.5	391.5
8.5	4.4	386.9	1267.6	437.7	437.7
10.5	1.6	729.3	1073.3	-	285.77
12.5	2.3	1230.5	3097.7	-	-
14.5	1	1920.6	2438.8	1198.8	-
16.5	2.1	2830	8590	-	1623.6
19	0.4	4321.2	2876	-	-
	Σ	11659	20675	2289.3	3075.3

Consequently, the average specific gross power of the wind flow is

$N_{WF}^{val}=E_{WF}^{val}/T=20675/8760=2360\ W/m^2$.

Analyzingtheabove, wechoosea 1.5 kWwindturbine.

The main technical characteristics of which are given in Table 2.

Table 2 Characteristics of the VT-1.5 wind turbine.

Table 2

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Name of the parameter	VT-1.5 kW
Power at the AB terminals at a wind speed of 12 m/s	1,5 kW
Maximum power at a wind speed of 15 m/s	1,7 kW
Initial operating wind speed	2,5 m/s
Storm wind speed	50 m/s
Rotor diameter	2,8 m
Number of blades	3
AB voltage	24 W
Recommended batterycapacit	215 Ah
Weight without mast	45 kg
Mast height	14 m
Service life	15 year
Temperature range	-40 +60°C

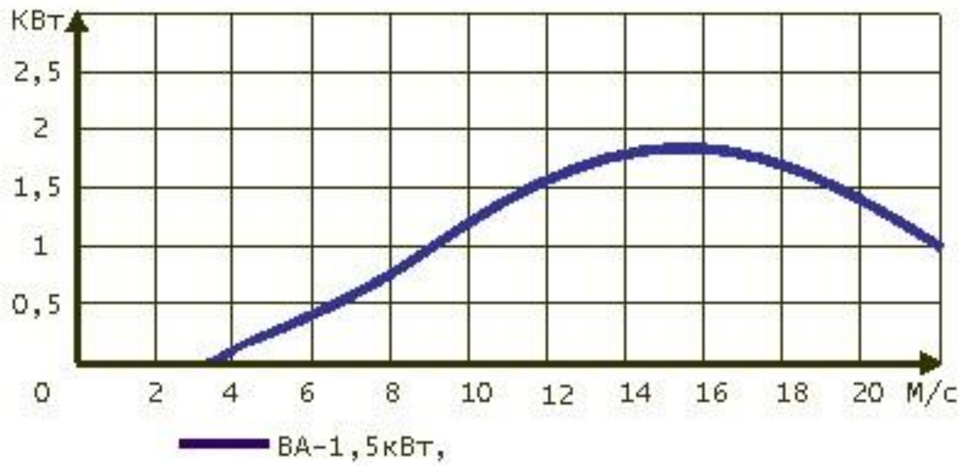

Fig. 1. Dependence of the power of the wind turbine on the wind speed.

Table 3. Design features of the wind turbine

Table 3

Storm protection –	removing the rotor from the wind
Orientation to the wind direction –	weather vane
Blade material –	Polyester fiberglass
Connection of the generator to the rot –	without gearbox
Generator –	contactless, synchronous with permanent magnets Nd-Fe-B
Type of mast –	steel pipe with stretch marks

From the load graph, we see that in the range of wind speeds up to 3 m/ s and from 25 m/ s, the power of the wind turbine is zero.Summing up according to Tables 4.2 and 4.3 all ti(V_i) values for0 □ V_i□□2,5m/s andV_i□□25m/s we get the downtime of the wind turbine during the year:

t_{td}=8760*(0,319)=2794 hours/year.

The energy generated by the wind turbine during the year E_{WTD}^{year} (kWh) is calculated according to the formula:

$$E_{WTD}^{year} = \sum_{i=1}^{k} N_{WTD}(V_i) \cdot t_i(V_i) \cdot T_{year} \qquad (3)$$

The calculation results are presented in Table 4.

E_{WTD}^{year}energy characteristics WTD: □ WTD(V) and□ N_{WTD}(V)

Table 4

Vi, m/s	ti, %	E_{WTD},kW	E_i, kW*h	E_{WTD}^{year},kW	□ N_{WTD},kW	□□$_{WTD}$, %
1	2	3	4	5	6	7
2.5	29.8	0.05	130.5	0.07	0.02	71.4
4.5	17.7	0.2	310	0.428	0.228	46.7
6.5	8.8	0.4	308.3	1.29	0.890	31
8.5	4.4	0.95	203.23	2.45	1.5	38.8
1	2	3	4	5	6	7
10.5	1.6	1.45	203.23	5.18	3.73	28
12.5	2.3	1.65	332.4	9.18	7.53	18
14.5	1	1.7	312.7	14.32	12.62	11.87
16.5	2.1	1.7	312.7	21.1	19.41	8.05
19	0.4	1.7	59.16	32.23	30.53	5.27
	Σ		2171.7			

Summing up all the values $E_i$we get,thatE_{WTD}^{year}=2171,7kWh/year, then the number of hours of useWTD E_{WTD}^{ud}=1,5 kW will be equal to

h= 2171,7/1,5=1448h.

The total number of wind turbine operating hours per year will be equal to: $h_{WTD}=T_{year}-t_{td}$= 8760–2749 =5965h.

The specific installed capacity is equal to

$$N_S^{UD} □ 1{,}85 □ V_{nom} \quad (4)$$

$$N_S^{UD} □ 1{,}85 □ 12^3 □□ 3196{,}8\,kW/km^2$$

Based on the values obtained E_S^{TEX} andN_S^{UD}calculate the number of hours of use of the specific installed capacity of wind turbines per 1 km^2

$H_p = E_S^{TEX} / N_S^{UD}$ =3075300/3196,8 =962h.

Battery capacity selection

To calculate the battery capacity , use the formula:

$$E_a = \frac{W_a}{U_a} \quad (5)$$

where: E_a – battery capacity,Ah;

U_a – battery voltage, B.

W_a – daily estimated electricity consumption, Wh.

$$E_a = \frac{32150}{24} = 1340\ A \cdot h$$

We choose a lead acid battery of the brand 6ST190A;

We determine the required number of batteries:

N=1340/190=7 pieces.

The charge of lead acid batteries is carried out In two stages: currenti_1 □□0,1□ C_{AB}Bthe passage of time $t_1$before the onset of gas formation,and then with a smaller current i_2□□0,5□ $i_1$during the time t_1= 2 – 3h.

Total battery charge time (AB):

1

$$T = t_1 + t_2 = \frac{C_{AB} \cdot 0{,}5}{i \cdot \text{n}_{AB}} + t_1 \quad (6)$$

where: C_{AB}=770 A*H –containerAB ; i =68A – charging current,

□$_{АБ}$□□0,8 - KPDAB,

$$T = \frac{1340 \cdot 0{,}5}{68 \cdot 0{,}8} + 2 \approx 14{,}5\ h.$$

Calculation of the powerof a photovoltaic installation

As already mentioned above, the **photovoltaic installation** is an auxiliary energy source and its power goes to charge the AB, therefore, knowing the required charging time of the AB, we can determine the required power of the **photovoltaic installation.**

$$T = \frac{C_{AB} \cdot ET \cdot U}{t_{cht}} + t_1 \quad (7)$$

where: C_{AB}–container AB,

ET – discharge ratio AB,

U– voltageAB,
t_{cht}– charging time AB.

$$W = \frac{1340 \cdot 0{,}5 \cdot 24}{14{,}5} = 1109\ {}^{W \cdot h}/_{d}$$

Let's determine the time with which the photovoltaic installation works with rated power:

$$t_{nor} = \frac{E_\beta^2}{P_{pp}} \quad (8)$$

where: E^2_β–average daily arrival of solar radiation, W/h.
P_{pp}–arrival of peak power W per m^2
t_{nor}= 3000/1000 =3h/day.
Now we can determine the power that needs to be developed in a day:

$$P = \frac{W}{t_{nor}} = \frac{1109}{3} = 370\ W$$

We choose a photomodule of the brand FSM –30-12, with a peak power of 30 watts.

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Hence the required number of models:
n= 370/30 12 pieces
Thus, the parameters of the renewable energy system are as follows:

The main source of wind turbines, $P_в$= 1,5kW;
Additional source of photovoltaic installation, P_C= 0,36kW;
Reserve, batteries 6CT190AE$_a$=7*190 =1340A h.

Calculation results

Based on the results of the calculation from 2018 to 2022, the following conclusions can be drawn.

1. In the Republic of Karakalpakistan, wind and sun are the most promising of the well-known renewable energy sources.

2. For reliable autonomous power supply at home with a total design load P=1,85 kW the most expedient is the integrated use of a wind turbine, a solar installation and a battery reserve in a combination of 1.5 kW, 0.36 kW and 1340 Ah, respectively.

3. When introducing environmentally friendly renewable energy sources on the pumping station in Nukus city the ecological situation in the region will significantly improve.

4. Installations based on renewable energy for the power supply of pumping stations are quite economical and have an acceptable payback period, since there is no need for power supply from the central network.

Conclusions.

1.The analysis of connection schemes of wind generators and solar power plants is carried out-parallel with the main network in the Nukus (on the example of pumping stations).

2. A comparative analysis of the schemes of combined power plants and their connection to central electric networks using renewable energy installations shows that modular schemes of power plants allow summing and distributing energy flows from generating sources and implementing effective methods of managing these processes.

3. In this paper, an analysis of the schemes of connection of renewable energy power plants to the pumping station which is located in the Nukus. As an example, a technical solution for the use of renewable energy for the power supply of pumping stations in the republic of Karakalpakstan in Nukus city is proposed. In the process of development, a combined photo-wind turbine for the power supply of the pumping station is calculated.

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