Scientific and technical basis for the implementation of combined technologies using solar and wind energy in the conditions of Turkmenistan

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Abstract. The article discusses issues related to uninterrupted power supply to settlements that are not connected to the central power supply system. The use of combined systems of photovoltaic solar and wind power plants in the conditions of Turkmenistan is explained in details and the importance of designing combined systems for power generation is proved. A software method is also proposed for the reliable execution of design and calculation works of combined plants in a short time. An analysis is given of the possibility of accumulating excess electricity generated during the day in accumulator batteries. The reasons for the need to use a combined system of photovoltaic solar and wind power plants are being carefully studied.

1. Introduction
Power energy sector of Turkmenistan is a key sector of our national economy and provides the other sectors of the country to operate. This, in turn, is a clear indication that the energy sector has great advantages. At present, the energy system not only satisfies the needs of domestic consumers, but also export of electricity to neighboring countries on a contractual basis.

Turkmenistan's natural weather and geographical location are considered to be particularly favorable for the widespread use of solar energy, and there is a wide range of opportunities for the active use of solar radiation in the industrial and electric fields for electric and thermal energy.

According to scientific sources, the duration of sunlight in Turkmenistan is 2500-3100 hours per year, in the summer season, i.e. in June duration of sunny days is 16 hours per day, and 8-10 hours in the winter season, in December.

Wind energy is a form of discovering solar energy today. As a result of the sun radiation, the earth's surface heats unequally. As a result, it causes the formation of air flow. The surface of the water and the area covered by the cloud is heating up slowly, and the surface of the area that is not shaded is heating up quickly by the sun. The air flow over the hot area heats, rises up and creates a low
pressure zone. The air in the high-pressure zone changes its position in the low-pressure zone, resulting in the formation of wind [5].

About 40% of Turkmenistan's territory is considered to be suitable for the use of wind energy. It is more convenient to use wind energy in the northwestern districts, where the average annual wind speed is above 4 m/s. The northern coast of the Caspian Sea has a high specific power of air flow amount of which is 110-135 W/m².

The wind energy potential is considered very high in the Balkan and Kopetdag gates and its rate is above of 150 W/m². The specific wind power between the central provinces and the northern border is not more than 100 W/m². In total, the wind energy potential is 5.5 billion tonnes of conventional fuel.

Based on the information provided, the use of compatible technologies to convert solar and wind energy into electricity, once again confirms that the issue of uninterrupted supplying of consumers with electricity, that is considered harmless and safe for the environment, will be even more important in the future.

The advantages of compatible power stations include:

- Reliable supply of consumers with electricity.
- Supply that the output voltage in the independent electrical system does not change.
- No voltage change in the system and rise of deviations.
- The possibility of expansion of a combined power plant (station).
- Ensuring environmental regulations in the field of environmental protection.
- Reduction of maintenance during the continuous operation of the combined power plant (10-15 years).
- Increase in the efficiency coefficient of the combined power plant as a result of the optimal combination of various sources of its energy supply, i.e. solar energy and wind energy at the same time.

There are a number of complex issues related to the introduction of this system into production and its effective use. For this, in the installation of a solar photovoltaic station, it is necessary to take into account change of sun radiation by time and seasons in the determined geographical space, as well the different value of consumption of generated electricity by consumers. Determination of rates of sun radiation intensity, and defining technical and economic indicators of project's are purposeful and remain as one of the important issues. Also, in order to select the location of the installation of wind power structures in a geographically defined area and to evaluate wind energy reserves, first the annual average wind speed (in different heights) in the area where the project will be carried out, annual and daily wind direction, repeating wind speed, the problems of defining minimum and maximum wind speed have to be solved.

2. Materials and methods

Combined systems based on renewable energy sources are now being used to ensure the safe supply of electricity to villages, small farms and other consumers away from the central power supply system, as well as to collect the surplus electricity generated in one place, it also remains to be an economically viable solution in overcoming the problems rose by high over load in the use of renewable high-power energy. Renewable energy sources are one of the most promising areas for addressing key issues in energy security and environmental protection [4].

In order to ensure sustainable development in economic sectors of Turkmenistan, the development of alternative energy will not only diversify the reserves of fuel and energy, but also reduce the emissions of carbon dioxide and introduce advanced technologies into the energy sector. "The State Program of Energy Saving for 2018-2024" and the Concept of development of "Altyn Asyr" Turkmen Lake region for 2019-2025 are adopted for the purpose to carry out the work of using renewable energy sources, the introduction of innovative technologies, the use of modern types of energy-saving equipment and materials in the social system. According to the plan of work to be carried out within
In order to ensure the qualitative reliability of the tasks ahead, at the Scientific Production Center of Renewable Energy Sources of the State Energy Institute of Turkmenistan software entitled as "Digital system of designing photoelectric solar power station" was developed and actively used in design works. The developed "Digital system of designing photoelectric solar station" software has enabled the accurate and short-term execution of calculations in the design works of photovoltaic stations.

With the help of software, certain pre-existing formulas were used in project’s calculation works. The data obtained from this software were also compared with the data obtained from the measurements at the photovoltaic solar power plant, which allows the production of 2 kW of energy, made by Canadian Solar company, which is installed in the State Energy Institute of Turkmenistan. The results showed that the program was working correct. Only efficiency of the inverter is taken into account in calculations of electrical installations of the system. If there is a independent power supply, then the system of mandatory batteries must be taken into account, i.e. the efficiency of the batteries (equals to the ratio of the discharge voltage to the charge voltage), efficiency of the controller and inverter also must be taken into account. In result, for a system consisting of n-photovoltaic panels, the average value of the energy produced during the day in i-month can be determined by the following formula [2]:

$$E_{adv} = \eta_{inv} \cdot \eta_{pv} \cdot \eta_{cons} \cdot S_n \cdot N_n \cdot E_i \cdot (U_{dc}/U_{ch})/10^3$$

(1)

Where: $E_{adv}$ - average amount of energy produced per day in i-month, kW·h; $\eta_{inv}$ - efficiency of the inverter; $\eta_{pv}$ - efficiency of photoelectric panel; $\eta_{cons}$ - efficiency of the controller; $S_n$ - the area of one of the photoelectric panels; $N_n$ - number of photoelectric panels; $E_i$ - incidence of sunlight at specific place in i-month, kW·h/m²/day; $U_{dc}$ - battery discharge voltage, V; $U_{ch}$ - battery charging voltage, V.

The status of wind in the region, the ongoing natural process and the detailed information on the conversion of wind energy into electricity remain important for conducting calculations at the sites where wind power plants will be designed. This scientific work proposes a software method for performing calculations to select locations for the installation of wind power plants and to evaluate wind energy resources.

The average wind speed per year can then be determined by the following formula [4; 6]:

$$V_{av,year} = \frac{1}{12} \sum_{i=1}^{12} V_{month}$$

(2)

Where: $V_{month}$ - the average wind speed per month, m/s.

The vertical profile of the wind flow is determined by the following formula:
\[ V_{h2} = V_{h1} \left( \frac{h_2}{h_1} \right) \cdot m \]  

(3)

Where: \( V_{h1} \) - wind speed, measured at a height of 10m, m/s; \( V_{h2} \) - wind speed at \( h_2 \) height; \( m \) - level indicator, for Turkmenistan this value is equal to 0.2 (RF-0.2; US-0.18).

3. Results

Average amount of the electrical energy that will be produced in months by solar panels inclined along the optimal \( \beta \)-angle of the transverse plane of a 7 MW photovoltaic solar station (figure 1). Data on the intensity of the average sunshine falling on differently \( \beta \)-angle inclined solar panels according to the transverse plane for cities located in the provinces of Turkmenistan were used [3]. Based on these data, the data obtained as a result of the calculations carried out on the Altyn Asyr Turkmen Lake were included (table 1).

![Figure 1. Performance of a solar station with capacity of 7 MW by months, at the optimal angle \( \beta \) of the transverse plane, by months (kW-h).](image1)

![Figure 2. The average amount of electrical energy that will produce a wind power plant in one day, by month, (kW-h).](image2)

| No. | Provinces of Turkmenistan | Location of the meteorological station within the province | Geographical latitudes, \(^\circ\) (in degrees) | Optimal tilt angle \( \beta \), in degrees | Average intensity of solar radiation falling to optimal inclined solar panel per year, kW∙h/m\(^2\) |
|-----|-----------------|-------------------------------|------------------|------------------|----------------------------------|
| 1.  | Ahal            | Ashgabat                      | 37.9             | 58.3             | 36                               | 1825.455                        |
| 2.  | Mary            | Mary                          | 37.6             | 61.8             | 36                               | 1897.407                        |
| 3.  | Lebap           | Turkmenabat                   | 39.1             | 63.6             | 36                               | 1875.814                        |
| 4.  | Dashoguz        | Dashoguz                      | 41.8             | 59.8             | 31                               | 1855.527                        |
| 5.  | Balkan          | Altyn Asyr Turkmen lake       | 40.44            | 56.47            | 40                               | 1819.882                        |

Table 1. Calculations performed on Altyn Asyr Turkmen
According to the data obtained from the meteorological station in the regions of Turkmenistan for the period 2004-2018, on the basis of the measurements on the Turkmen Lake Altyn Asyr for the period 2019-2021, the average wind speed values for the provinces and Lake Altyn Asyr were determined (table 2).

**Table 2.** the average wind speed values for the provinces and Lake Altyn Asyr

| No | Provinces of Turkmenistan | Location of the meteorological station within the province | Geographical latitudes, ° (in degrees) | Average wind speed, m/s | The average annual electricity generation of two wind power plants with a nominal capacity of 1.5 MW, MW·h |
|----|---------------------------|----------------------------------------------------------|----------------------------------------|-------------------------|-------------------------------------------------------------------|
| 1  | Ashgabat                  | Ashgabat                                                 | North latitude 37.9, Eastern longitude 58.3 | 5.1                     | 0.16                                                              |
| 2  | Ahal                      | Derveze                                                  | North latitude 40.10, Eastern longitude 58.24 | 5.1                     | 0.16                                                              |
| 3  | Mary                      | Mary                                                     | North latitude 37.6, Eastern longitude 61.8 | 4.95                    | 0.14                                                              |
| 4  | Lebap                     | Turkmenabat                                              | North latitude 39.1, Eastern longitude 63.6 | 5.7                     | 0.22                                                              |
| 5  | Dashoguz                  | Dashoguz                                                 | North latitude 41.8, Eastern longitude 59.8 | 6.6                     | 0.34                                                              |
| 6  | Balkan                    | Balkanabat                                               | North latitude 39.5, Eastern longitude 54.4 | 6.6                     | 0.34                                                              |

Data obtained on the results of the scientific work can be used in the assessment of wind energy reserves for the regions of Turkmenistan and the region of "Altyn Asyr" Lake and in determining the location of wind power plants.

4. **Discussion**

As can be seen from the results obtained, the combined system has the capability of adjusting overnight and seasonal changes, improving the reliability of the system and reducing consumption of accumulated energy in the system, also the capability of balancing power to combine renewable energy sources [7]. Ultimately, the combined use of solar and wind energy in the area under consideration will allow uninterrupted power supply to consumers under any weather conditions throughout the year.

5. **Conclusion**

Thus, the following conclusions can be drawn:

- It has been determined that the use of combined systems based on renewable energy sources is a priority if villages and consumers are decentralized and away from the central power supply system.
- With the help of a combined system, the possibility of eliminating the problem of high loads depending on the use and climatic conditions of the large capacity of renewable energy sources and ensuring the accumulation of surplus electricity is studied.
- The great potential of Turkmenistan's climate for the use of renewable energy sources has been studied and it has been determined that a compatible system will be more effective in selecting the sites to be built.
- In accordance with the long-term plan for the development of small and medium-sized businesses away from the central power system, the choice of centralized power supply of compatible technologies in the construction of modern villages, the creation of new livestock and poultry complexes has been determined as expedient.

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