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This volume contains publications based on the results of the travelling conference "DeEn_CA: Industry 4.0 for Renewable Energy and Energy-saving Technologies for Central Asia" hold March 11th till 18th at several universities and research institutes of Kazakhstan and Kyrgyzstan. The conference was devoted to problems communication technologies applied to the area of energy production systems from renewable sources. The research results can be of interest for researchers and development engineers, who deal with development and deployment of sustainable energysystems.

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Content

A Concept for a Self-Sufficient Off-Grid and Backup Solutions for Power Supply and Grid Stabilization in Rural Areas with Wind-Solar-Hydropower for Central Asia

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Keywords: Decentralized Energy Systems, Central Asia, PV Systems, Micro-Wind-Power Stations, IIoT.

Abstract: The purpose of this work is to present a concept how to realize a decentral energy-efficient and self-sufficient energy supply system, consisting of a wind-photovoltaic (PV) or PV- micro-hydro power plants for a stable local energy supply. This comprises of subsystems for controlling the energy flows between power generators and consumers, sensor networks for keeping energy balance and to predict failures in particular subsystems (so called predictive maintenance), and optimization of energy demand tailored to remote areas in Central Asia. The energy production of this self-sufficient system shall be based on regenerative energy sources only such as wind, hydro and photovoltaic. The system will be supported by an appropriate energy storage system with, e.g., lithium ion or lead-gel or even lead-acid batteries. This study presents a higher-level management system based on IIoT networks and machine learning methods which control the individual energy generators (wind, hydro and photovoltaic) together with the connected consumers (load management) to avoid peak loads and to trigger suitable processes in case of energy surplus or deficiency. The dimensioning of each subsystem has to consider specific local energy demands and specific climate conditions with dedicated forecasting and machine learning methods.

1 INTRODUCTION

Due to the existing high occurrence of fossil energy resources in the Central Asia region, especially in Kazakhstan, Turkmenistan and Siberian part of Russia, the integration of renewable energy sources in the energy mix of Central Asia played in the recent past a minor role. Currently, the share of renewable energy in Kazakhstan is about 1 % [1]. However, the kazakh government has the ambitious goal to increase the share of removable energy to 50 % by 2050 [1] and to improve the supply infrastructure in rural regions. In this scenario renewable energies gain is of essential importance. In the neighbouring country Kyrgyzstan the share of renewable energies is much higher than in Kazakhstan. This is due to the dominance of large hydropower plants in Kyrgyzstan. However, the construction of such huge hydro-power plants causes also essential ecological damages. Besides this, in Central Asia, the distribution of the energy in rural arears is still an unsolved issue due to, e.g. very long distances and an overage grid structure. About 70 % of the total grid losses are within the voltage range of 0,4-10 kV – the dominant distribution technologies to the small settlements of the region. With this in mind, it is important to note that about 43 % of Kazakhstan's population (equals to approx. 7,7 million inhabitants) and 70 % of Kyrgyzstan's (equals to approx. 4 million inhabitants) live in remote villages [1]. In the Siberian region of Russia this portion is even higher than 80 % [2]. So, uninterrupted and stable energy supply in rural areas is one of the major goals of the governments of lots of central Asian countries, especially Kazakhstan and Kyrgyzstan. Therefore, there is consensus among politicians, local administrations and experts that decentralized energy production, e.g., based on small wind turbines (WT) or micro-hydro power plants (µHPP) combined with photovoltaic (PV) plants will play a central role in the near future. Small villages in rural areas are currently either cut off from a stable power supply or they operate diesel generators. The energy supply with renewable sources of those villages has a strategic priority of the Central Asian governments and has potentially an economic and ecological impact in this region. This challenge represents an opportunity to jointly transform the energy sector in Central Asia into a sustainable and environmentally friendly energy economy.

The energy supply of rural areas with decentralized energy solutions saves costs of complex infrastructure such as for installation and maintenance of complex power lines to remote villages. However, decentralized energy solutions require a very precisely coordinated energy management, which is real-time capable and fail-safe. Not only individual energy generators, including short-term storage must be considered but also the consumers side must be taken into account here.

In order to make this economically viable, however, further innovative methods must be developed and implemented. This paper presents a basic concept and first technical ideas of the development of such decentralised systems. These ideas have been already presented to the scientific audience at a travelling conference titled “Industry 4.0 for Renewable Energy and Energy-saving Technologies for Central Asia”, held in March 2019 in the cities Astana (now Nur Sultan), Karaghandy, Oskemen, Almaty in Kazakhstan, Bishkek and Osh in Kyrgyzstan. After an intensive discussion with players from academy, energy research centers, with representatives of ministries and local municipal administrations, energy providers, and grid operators, a concept of decentral energy systems based on renewable energy have been elaborated. The following sections present the main ideas of a decentral energy system or known as DeEN_CA *system (**DE**central **EN**ergy system for **C**entral **A**sia*).

2 OBJECTIVES

The overall aim of the DeEn_CA system is to realize local energy-efficient and self-sufficient energy supply systems, which consists of wind and PV or PV and micro-hydro power plants with a nominal power between 10 and 100 kW. This includes systems for controlling the energy flow between power generators and consumers, sensor networks to predict failures in all subsystems, known as predictive maintenance, and optimization of energy demand of the location. The energy production in the developed system will be realized completely from regenerative energies sources such as wind, hydro and photovoltaic and will be supported by an appropriate energy storage system with, e.g., lithium-ion batteries or lead-gel or even lead acid batteries. A high-level management system shall be used to control the individual energy generators together with the connected consumers, e.g., loads like milking aggregates cooling systems or small production machines. This allows to avoid peak loads and to trigger suitable processes in case of energy surplus or deficiency. A successful implementation is linked to further objectives and sub-goals considering the initial situation. The objectives are:

- Adaptation of small water turbines (WT) for operation under harsh climatic conditions and the optimization of the local energy gain under the conditions in Central Asia;
- Adaptation of PV modules for large temperature fluctuations and optimization of the energy yield of PV systems with new concepts such as bifacial PV modules under the climatic conditions in Central Asia (local irradiation conditions, high albedo absorption potential due to diffusion and reflections of snow-covered surfaces, low module operating temperature);
- Optimization of the charge and discharge process of lithium-ion or lead-acid batteries to extend their operational life time at the specific climatic conditions at the target area.
- Increasing of reliability and durability of the components such as power electronics and batteries by means of prioritized energy supply to air conditioning of the central container, de-frosting of the PV modules and de-icing of the wind turbine mechanics;
- Operation of communication systems, software implementation to control small scale decentralized energy supply systems, and adaptation of power generation to the needs of consumers, e.g., considering short- and mid-term weather forecast;
- Sensor support system with interconnection by other subsystems via Industrial IoT means to implement a predictive maintenance paradigm;
- Construction of weatherproof computer systems based on one-chip systems, operation of communication systems considering local regulatory frequency restrictions and under harsh conditions such as temperature range from -55 °C to + 45 °C. A conceptual view of such a DeEn_CA system is shown in Figure 1 below.

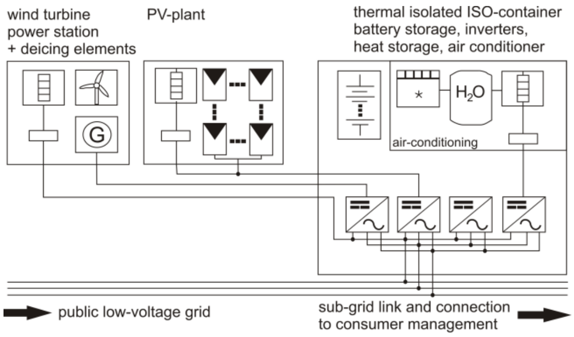

Figure 1: Overview of a DeEn_CA system with wind and photovoltaic, batteries and inverters.

3 CONCEPT AND PROPOSED APPROACH

To reach the project's objectives we propose to construct a few pilot systems in several places across Kazakhstan and Kyrgyzstan, which differ significantly from each other according to the local energy sources, climatic conditions and the customer needs. A previous study will collect specific data of each location such as energy demand, weather data and the local infrastructure to select the best solution. With the collected data and experiences, we will create an energy supply and consumption chain for agriculture in rural areas. This will clearly add value to small farmers and thus trigger a positive socio-economic reaction in the area towards the ecological and sustainable cultivation of rural areas in Kazakhstan and Kyrgyzstan.

As a typical consumer in Kazakhstan we consider a medium-sized dairy farm with about 100-200 cows and with a few attached residential houses. Depending on the season, usually such a dairy uses two to three times a day an electrical milking machine. In addition, a local refrigerating storage house to preserve the milk is used. These consumers have a certain energy demand, which can be adapted to the needs and the current weather conditions and thus it would be possible to reduce the size of the energy storage. Furthermore, the electrical lighting of the farm and the residential building will be realized with the same system.

3.1 Wind power plants

Two different types of wind turbines will be built. One adapted wind turbine with a classical horizontal axis design as provided e.g. from enbreeze GmbH or other German manufacturers and at the same site a wind turbine with a vertical rotor system. This type of wind turbine is developed by Prof. Bolotov, AUPET (Almaty) for very cold regions with dominance of multi-modal winds [3]. Thus, valuable results can be gained during the project to investigate the best wind turbine structure for providing an optimized yield and high reliability under the specific wind conditions of Kazakhstan.

3.2 Photovoltaic power plants

The aimed project will also consider to emerge PV technologies to increase the potential energy yield and the reliability in respect to the climate and geographical conditions at the installation sites. The very high temperature differences and irradiation properties over the north-south expansion of Kazakhstan shift the requirements on the installed PV modules for a more accurate dimensioning. High amount of snow can on one hand force damages on the module due to high weight but on the other hand snow can increase the energy yield due to its high reflectivity. So, we will use framed glass-glass PV modules to increase the reliability and bifacial PV modules to increase the energy yield. Bifacial PV modules use not only the in-plane irradiance on the front but also the reflected irradiance from the ground. Section 4.2 shows simulation of a bifacial PV system for different locations in Kazakhstan and Kyrgyzstan and a comparison to standard monofacial PV modules.

4 METHODS AND RESULTS

4.1 Requirements of the wind turbine system

Wind turbines with power ranges of 5 to 30 kW will be basically used. Especially, a 15 kW wind turbine will be redesigned mechanically and electronically, whereby the mechanical design and construction will be adapted to geographical requirements at the target area. Due to harsh climatic conditions it is not possible to use existing wind turbine solutions without region-specific adoptions. In addition, we want to investigate alternative solution to protect moving parts and electronics against icing and compare them to conventional solutions such as heating of the rotor blades, which are economical not feasible. Therefore, appropriate test trials in a climate chamber will be carried out to simulate long-term reliability. In addition, R&D work will be carried out when integrating the WT to the energy-management system.

The electronics and the rotor head control will be realized by IIoT sensor networks. The detected environmental/weather and technical/yield data from the system will be used for machine learning methods to predict electricity generation and demand on consumer site in short (minutes till hour) and medium-term (days). Those methods shall increase system efficiency and predictive maintenance options for essential components.

4.2 Simulation of PV energy yield at five specific location in Kazakhstan and Kyrgyzstan

4.2.1 Meteorological data

To estimate and compare the PV energy yield we have choosen five different location across five different climate zones in Kazakhstan and Kirgizstan. In Kazakhstan Nur-Sultan (former Astana) has a temperate continental climate (Dfb), Almaty has a warm continental climate (Dsa) and Ceyfullino represent a cold desert climate (BWk). Ceyfullino takes on special relevance as it is located in an agricultural isolated region in the desertic part of the country, therefore, it is qualifying for the established consumers' profile of the project. In Kyrgyzstan we have choosen Bishkek with a temperate mesothermal climate (Csa) and Osh in the high-mountain region of the country which represent a cold semi-arid climate (BSk). For comparison, we have choosen our own PV test filed at Anhalt University (Köthen, Germany) [4] which represent a moderate continental climate (Cfb) at the same latitude as Nur-Sultan. Table *1* shows an overview of all selected location with their geographical coordinates, climate zone and the optimal tilt angle for PV modules.

Table 1: latitude, longitude, optimal tilt angle and climate zone [5] of different locations in Kazakhstan, Kirgizstan and Germany.

Location	Latitude	Longitude	Optimal Angle	Climate Zone
Nur-Sultan (Kz)	51,1°N	71,4°E	38°	Dbf
Almaty (Kz)	43,2°N	77,0°E	35°	Dsa
Ceyfullino (Kz)	45,0°N	64,9°E	38°	BWk
Osh (Kg)	40,5°N	72,7°E	31°	BSk
Bishkek (Kg)	42,8°N	74,6°E	35°	Csa
Anhalt (D)	51,2°N	12,0°E	36°	Cfb

Figure 2 shows the yearly global irradiation at optimum tilt angle and azimuth (blue bars), rear-side in plane irradiation (yellow bars) together with the average ambient temperature (grey line) of the chosen locations in Kazakhstan, Kyrgyzstan and Germany.

Locations with high latitudes, such as Nur-Sultan, have a low irradiation tendency, whereas south located ones are prone to high irradiation such as Ceyfullino. The yearly global irradiation in Nur-Sultan is about 1350 kWh/m²/a and at Ceyfullion 1800 kWh/m²/a [6]. The average ambient temperature of the five locations is between 4 °C in Astana and 22 °C in Osh. However, the temperature range of the PV module can be between -50 °C to 60 °C at night and day, respectively.

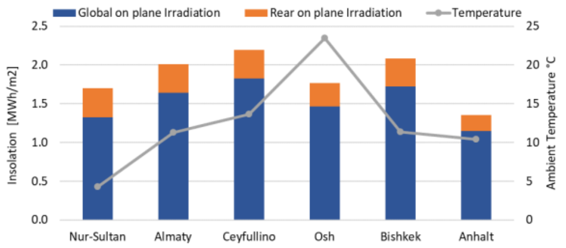

Figure 2: Yearly global irradiation at optimum tilt angle and azimuth (blue bars), surface rear irradiation (yellow bars) and average ambient temperature (grey line) of the locations in Kazakhstan, Kyrgyzstan and Germany.

In order to simulate the energy yield of bifacial module it is important to have information of the so-called Albedo at the given location. As per definition Albedo is the diffuse reflectivity of a horizontal surface which is defined as the ratio of the reflected irradiance by the surface and the received irradiance. Since the simulation of the bifacial PV module energy yield requires the in-plane rear-side irradiance. We need to consider the rear/front side irradiance ratio α at a given incidence angle [7], [8].

The influence of rear-side ratio is relevant for the consideration of energy generation of bifacial modules. The rear-side generates a significant addition to the front-side irradiation, particularly in winter due to intensive snowfalls in central, north and west of Kazakhstan. Thus, locations in the north that usually expose a higher number of snow days, like Nur-Sultan, are strongly beneficiated than locations in the south as Osh. However, seasonal variation such as due to vegetation can influence α. At Ceyfullino, located in a desert has seldom snow events during the year but the rear-side ratio can be higher due to local soil.

Due to the leak of rear-side irradiance data in metrological data in this study we consider α measurements of similar climates.

Figure 3-bottom shows the histogram of α for Anhalt and Vermont (continental climate) together with the mean (μ), the median and the standard deviation (σ). In the moderate climates such as Anhalt α is wider distributed around the mean value while in the temperate continental climate at Vermont we see two maxima in the distribution. One around 0.2 which represent the summer month and around 0.7 which represent the winter months with snow cover. Figure *3* shows instead the monthly mean value of α in a boxplot diagram. Seasonal variation could be observed at Anhalt due to the change of vegetation. In summer the grass turns from green to yellow/grey. Sandia_VT shows higher α values in winter due to snow. The ground is covered with snow from November to March. The high fluctuation is due to the fact that sometimes the snow melts and the substrate is visible. However, snow refreshes quick and therefore no long-term soiling issues are observed. Other location in desert climates show α of 0.2 to 0.4 without any seasonal variations [7].

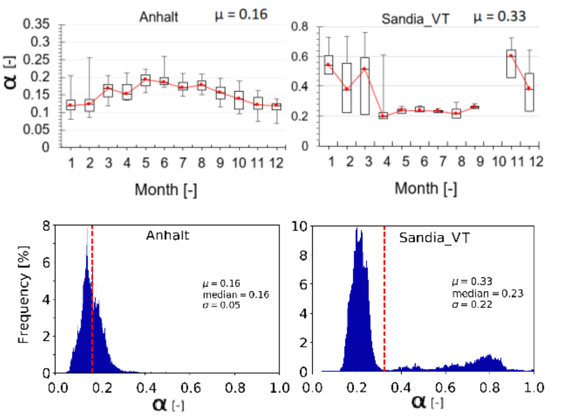

Figure 3: Seasonal variation, monthly average of rear/front side ratio (top), (bottom) Histogram of α together with mean (μ), median and the standard deviation (σ), (Sandia_VT: no data for October) [7].

Base on this study we assumed the number of days with snow and calculate the rear-side irradiance at the given location. The yellow bars in Figure 2 represent the calculated rear-side irradiation.

4.2.2 Bifacial energy yield simulation

Based on the above described metrological data we have simulated a 24 kWp PV system for all five locations using PVsyst version 6.86 [9]. In order to show the benefit of bifacial modules the simulation is carried out with monofacial and bifacial PV modules. Both module types consist of the same cell technology but the monofacial module consists of a white backsheet instead of a transparent one.

Figure 4 shows the monthly energy yield at Nur-Sultan (top) and Bishkek (bottom) together with the monthly irradiation. The grey bars show the energy yield of the monofacial PV modules and the orange bar the bifacial energy gain, i.e. the sum of both represent the specific energy yield of the bifacial modules. The red line represents the font-side irradiation while the blue line the total irradiation, i.e. sum of front and rear-side.

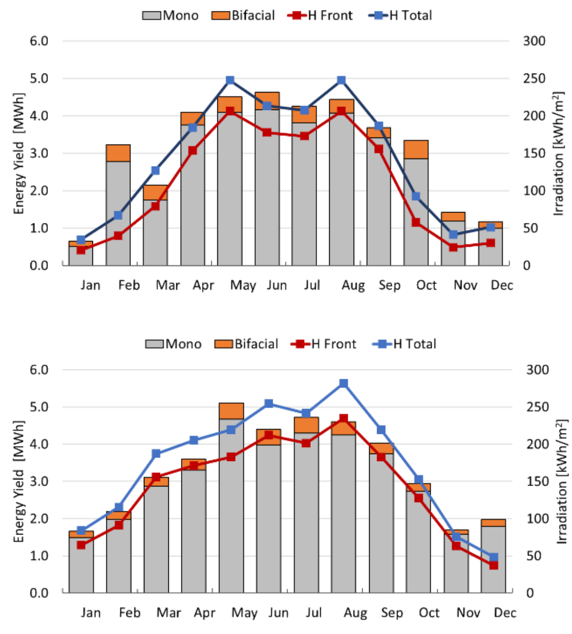

Figure 4: Monthly simulated energy yield for monofacial and bifacial PV modules together with front and total (front+rear-side) irradiation for Nur-Sultan (top) and Bishkek (bottom).

With a 24 kWp PV system consist of monofacial PV modules at Nur-Sultan the simulated energy over the year is about 34 MWh/a. This correspond to a specific energy yield of 1390 kWh/kWp. If instead of monofacial modules bifacial modules are used the energy yield is about 37,5 MWh/a or 1564 kWh/kWp. This is a gain of 12.4 % by using the same installation area and mounting structure. In the spring and summer months from April to September the energy gain is in average 9 %. Due to the snow cover in the winter months from October to March the energy gain is in average 20% in respect to the monofacial modules.

At Bishkek we calculate a yearly energy yield of about 37 MWh/a (1530 kWh/kWp) for the monofacial and 40 MWh/a (1670 kWh/kWp) for the bifacial, respectively. This is a gain of about 9%.

Due to the temperate mesothermal climate the gain is rather constant over the year with about 9%.

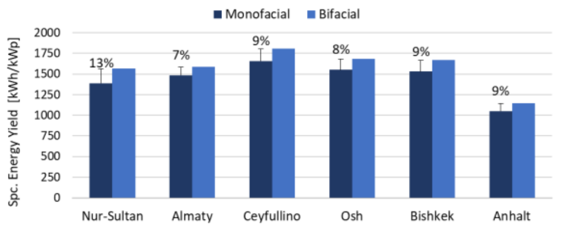

Figure 5: Yearly specific energy yield of a PV systems with monofacial (blue) and bifacial PV modules (dark blue) at six different locations in Kazakhstan, Kyrgyzstan and Germany.

Figure 5 shows yearly specific energy yield of a PV system with monofacial (blue bars) and bifacial PV modules (dark blue bars) at the six presented locations. It is clear visible that the energy yield increases with higher irradiation potential. Compared to Anhalt (Germany) all locations in Kazakhstan and Kyrgyzstan show a higher PV energy generation, e.g., Astana has about 23 % higher PV potential as Anhalt. This due to higher irradiation in winter month, more clear days and lower temperatures. In general, at all location the yearly bifacial gain is about 9%. For the northern region it is a bit higher due to the snow in the winter.

During the project we will carry out detailed measurement of the pilot system in order to improve energy yield simulation and optimize the energy management of the DeEn_CA systems.

5 CONCLUSIONS

We showed concept of a solution for energy-efficient and self-sufficient energy supply system in rural areas in Kazakhstan and Kyrgyzstan based on a combination of either wind-PV or µHP-PV combination. We believe that such small power decentral systems for very local demands in the radius of some hundred meters are economically feasible and can play as game-changers for the live in rural regions of Central Asia and Siberia. The presentations at the said travelling conference in March 2019 in Kazakhstan and Kyrgyzstan as well as in June in Almaty to experts in agriculture and energy sector of Kazakhstan, Kyrgyzstan and Tajikistan have proven the high relevance of implementation of such a system

The photovoltaic potential is at least 20 % higher than in Germany. Bifacial PV modules can enhance the energy yield be at least 9% by using the same amount of installation area and mounting structure.

In a next step we are aiming at establishing of a strong consortia of research institutions along with corporate players to perform necessary applied research, tests and adoption of the industrial systems for implementing a field setup in a context of a suitable funding program in Central Asia.

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We would like to acknowledge all our partners in Kazakhstan and Kyrgyzstan.

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To the Question of Development Perspective of Kyrgyz Republic Electric Power Industry with Using of New Innovative Renewable Energy Technologies

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Keywords: Traditional energy, Renewable energy, Solar, Losses, Tariffs, Approach, Method, Grid.

Abstract: This paper shows the possibilities of renewable energy application in Kyrgyz Republic. Among them are solar, wind, biomass, etc. Scientific studies show that existing power industry has already exhausted its resource. Kyrgyz system is economically inefficient. The fundamentally new approach to the organization of power supply technology, based on the use of modern IT technologies is proposed. In the future, the creation of such systems is very promising, especially for countries with large territories or mountainous countries. Today it is necessary to seriously consider the future development of the power supply system, taking into account advanced renewable energy technologies. To solve the set tasks and implement them, it is necessary to provide these studies with finances and investments. In this regard, the Kyrgyz Republic has developed and adopted a Law on Renewable Energy providing for certain preferences for investors and ensuring the return on investments. The paper suggests reducing of energy losses, increasing of transparency and parallel development of RES in Kyrgyz Republic.

1 INTRODUCTION

The intensive direction of searching for additional energy sources in the background of reducing the reserves of traditional energy resources like oil, gas, coal, etc. and global environmental problems has led in recent decades to the use of new innovative and environmentally friendly technologies of renewable energy (RES) conversion (solar, wind, biomass, etc.).

Already today we can say with confidence that the future of energy is renewables. The practice of recent years shows that the pace of the introduction of new capacities for energy supply using renewable energy sources is at the most advanced positions in the world [5, 6, 10]. In recent 5-10 years, there has actually been a revolutionary transformation in the issues of receiving and transmitting energy using renewable energy sources, which leads to the need for a fundamental revision of modern power supply technologies and building networks entirely on new innovative principles.

2 CURRENT ENERGY SITUATION IN KYRGYZSTAN

Scientific studies of scientists in the field of electric power industry show that modern electric power industry, as a way of centralized production, transmission and distribution of energy, has already exhausted its resource and in its development comes to a standstill [1, 2]. As known, the existing centralized power supply systems for reliable customer support are based on increasing the generating capacity taking into account the peak power coverage. This can be well demonstrated by the example of the functioning of the Kyrgyz energy system. Total installed capacity of all generating stations of the Republic is 3940 MW, while the average annual output is 14,7 billion kWh. In fact, to generate such a quantity of electricity, the installed capacity of 1700 MW is sufficient. This says that the utilization rate of generating stations does not exceed 43 %, i.e. unused reserve is 2240 MW. Of course, in such situation, there is no need to talk about the economic efficiency of the system. That is, such a system is not consistent already in the near future.

Of course, with all this we must not forget that this is due to the need to ensure the reliability of the supply of electricity to the consumer. So the seasonal change in electricity consumption in some years exceeded 2 or more times [7, 9]. The main electricity generation in the Republic is mainly carried out at the expense of hydropower stations, and their mode of operation is closely related to water resources, and they, in turn, are related to the provision of agricultural land with water, not only our Republic, but also neighboring countries like Uzbekistan and Kazakhstan. With this in mind, the functioning of the existing power supply system of the Republic is experiencing even greater difficulties. From this we can conclude about the need to find new ways to provide consumers with electricity, eliminating the shortcomings of the existing system.

3 SMART GRID APPROACH

In recent years, the so-called smart micro grid systems have been actively developing in the world. This is a fundamentally new approach to the organization of power supply technology, based on the use of modern IT technologies using self-restoring smart grids, built not on increasing capacity, but directly on supplying the consumer with the necessary electrical energy. The construction of such systems has become possible due to the development of renewable energy technologies that ensure the most efficient operation of the electrical network with distributed parameters. It is a network with small generating capacities, interconnected to local and centralized networks, providing not only production, but also energy consumption. Moreover, the whole system is connected into a single intellectual, self-organizing and controlled network, providing the most efficient and reliable supply of electricity to the consumer. Such a system ensures maximum utilization of generating stations, due to minimum distances for energy transmission, minimizes technological and technical losses in grid, ensures the most efficient and optimal system operation due to the presence of consumer and producer feedback, through the use of computer control software and modern adaptive monitoring-measuring equipment equipped with elements of artificial intelligence.

In the future, the creation of such systems is very promising, especially for countries with large territories or mountainous countries, where there is a rather low density of consumers. The location of consumers in remote foothill and mountainous areas, where their provision of electricity by building traditional power lines is an unjustified luxury.

The Kyrgyz Republic is related to such type of mountainous country. Therefore, today it is necessary to seriously consider the future development of the power supply system, taking into account advanced renewable energy technologies.

Elements of such “Smart Grid” systems are already piloted in practice in the USA, Japan, Western Europe and other developed countries [1, 3]. The use of power supply technologies with the use of renewable energy allows to take into account the daily load of each individual consumer, up to the individual appliance, which provides a more efficient power supply. Here, the criterion of reliability is not the input power, but the total daily need for electricity.

Such systems provide a balance between production and energy consumption by virtue of the above structural control of the system in automatic mode. It should be noted that the synchronization system of generating devices of different types by their nature is being simultaneously solved. That is, it is possible to simultaneously connect to work as solar installations, micro hydro, wind turbines or other generating devices [1, 2, 4].

The presence of low density of electricity consumers, territorial dispersion, economic inefficiency of providing them with electricity, by laying lines of electric transmissions, especially in the foothill and mountainous terrain of our Republic, makes it very relevant to conduct scientific research in this area and develop practical recommendations for building the development strategy of the Republic’s fuel and energy sector.

In addition to the above objective reasons for the development of the use of renewable energy in the Republic there is another reason. This is non-proper extraction of traditional energy resources like coal, oil, gas, which we are forced to import from other countries for currency. Kyrgyzstan is rich in RES resources [8], whose potential is able to provide more than 50 % of the country's energy needs in the fuel and energy sector. The accumulated practical experience of using these energy sources shows that the solar installations, the energy of small mountain streams, and the energy of biomass, wind power and others can be used quite effectively in the Republic to obtain both thermal and electrical energy [8].

However, it should be said that for a successful integrated solution to the problem of power supply, the availability of new technical solutions and the introduction of new innovative technologies that use the most advanced IT technologies and automatic control systems are not enough. As modern practice shows, these are necessary but not sufficient conditions. To solve the set tasks and implement them, it is necessary to provide these studies with finances and investments.

4 REDUCTION OF LOSSES

Today in the world there are a lot of financial institutions, various funds of public associations, government agencies, large corporations ready to invest in promising renewable energy projects. But they all want one - guarantee return on investment and the availability of relevant legislation in the country.

In this regard, the Kyrgyz Republic has developed and adopted a Law on Renewable Energy (2012) providing for certain preferences for investors and ensuring the return on investments [11].

Unfortunately, practically adopted law did not work. Over the past 7 years, not a single project in the field of renewable energy with the attraction of foreign investors has been implemented. As a pilot project, only the Small Hydropower Project implemented by a local entrepreneur was implemented. But unfortunately, this experience was not successful. So when concluding an agreement between a supplier and a distribution energy company, there were disagreements related to the payment of the difference in the cost of electricity to the supplier.

Energy companies spoke in favor of the impossibility of financially covering this difference at the expense of their activities and initiated in the Parliament of the Kyrgyz Republic a review of the Law on Renewable Energy Sources and the establishment of other incentive coefficients.

As practice has shown, despite the rather high stimulating factors adopted in the Law on Renewable Energy (for solar photovoltaic stations the multiplying factor was assumed to be 6), no investor was involved in the implementation of the project on renewable energy in the past period. This suggests that the coefficients in and of themselves do absolutely nothing and their changes, provided for in the new law in the direction of decreasing, absolutely will not change anything. Apparently the reason is still in the other. If we put aside all the technical issues, the lack of regulatory and technical documentation for connecting renewable energy generating stations to centralized networks, the lack of mechanisms for compensating the difference in electricity tariffs, etc., then we can see other more weighty reasons that exist in the existing system functioning of the Republic's fuel and energy complex, hindering the successful attraction of investments in energy projects of renewable energy sources. It is clear that one of the main reasons why investments in the energy sector are not attractive is low electricity tariffs.

The second reason is the low efficiency of the fuel and energy complex. Previously, we showed that the existing system, due to the prevailing circumstances and the existing technological scheme, provides only 43 % of the workload of generating stations, i.e. more than 50 % of the equipment is practically idle and does not bring any benefit.

Finally, it is quite a high losses of electricity for its transportation and distribution. In Figure 1 the diagrams of electrical losses in Kyrgyzstan are compared with other foreign countries are provided.

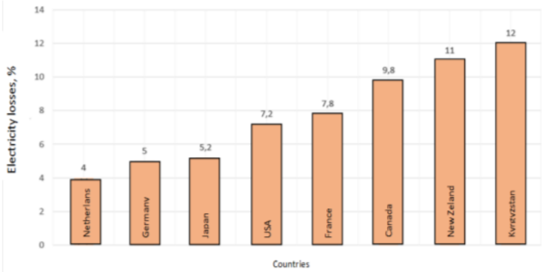

Figure 1: Diagrams of power losses.

As you can see, the percentage of losses is quite high and this is the Achilles heel, which radically negates the efficiency of the power supply system and the impossibility of its independent recovery from this situation.

Let us try to assess how this factor affects the attraction of foreign investments and why the position of electric companies is against introducing multiplying factors into the law. To do this, consider the current situation in the energy sector and analyze the objectivity of the approval of energy companies about the impossibility, with electricity tariffs, to repay the difference in the cost of electricity generated stations operating on renewable energy. If you follow the chronology of increasing the capacity of power plants in the Republic (Table 1), you can see that in almost 100 years from 1919 to 2019, the total capacity reached 3940 MW.

Table 1: The chronology of increasing the capacity of power plants in the Republic.

Years	Cap. (MW)
1917	0,485
1941	19,6
1951	61,9
1961	261,794
1971	908,149
1981	2770,65
1991	3075,65
2001	3315,65
2017	3940

And the most active period was the time interval from 1970 to 1991, i.e. during the period of the Republic in the USSR. Moreover, for these 21 years, the capacity was put into operation at almost 2,5 thousand MW, which is more than 62 % of the total installed capacity today. During the years of independent existence of Kyrgyzstan as a sovereign state (27 years), only 18 % of the total installed capacity was introduced, which is only 813 MW. What it says is that the pace of introduction of new capacities has decreased significantly and the reasons for this are the previously listed factors, including the fact that this industry is not attractive to investors. What can we say about the pace of implementation in the fuel and energy complex of new innovative technologies for the use of renewable energy? Earlier, we showed that during the whole period of existence of independent Kyrgyzstan, not a single industrially significant project on RES, and even when the law on RES was adopted, the situation has not changed.

Suppose that the pace of implementation of additional capacity will remain the same as over the past 27 years. Assume the growth of these capacities will be at the expense of the introduction of traditional generating stations and stations operating on renewable energy sources (20 %) Then you can easily calculate that on average about 30 MW of total capacity should be entered annually, of which the capacity of RES stations will be 6 MW. We intend to adopt an overestimated 20 % share of electricity generation at renewable energy stations, in order to further more clearly show the inconsistency of the assertion that it is impossible to cover the difference in tariffs of traditional stations with renewable energy stations. Actually, of course, given the experience of introducing renewable energy in recent years, most likely these values of the commissioned annual capacity of renewable energy stations will be significantly lower.

Based on the assumptions made, we will calculate the possible generation of annual electrical energy when the solar power is set to 1 MW and then we will determine it by simple multiplication for a power of 6 MW.

Determine what percentage of the total annual output will be the production of PV station with a capacity of 6 MW with (1). It is known that the average annual duration of sunshine in the Republic varies between 2800 hours a year. Then PV station at the rate of 1 MW will generate

$$Q = N_\tau = 1 \cdot 2800 = 2800 \text{ MWh} \qquad (1)$$

For a power of 6 MW 16800 MWh respectively.

Of the total annual output of the fuel and energy complex 14,7 billion kWh the share of PV station output with a capacity of 1 MWh will be in percent 0,02 %, for 6 MW respectively 0,12%.

We have previously shown that, on average, in the Republic, the loss of electric energy in the networks is 12 %. Let’s calculate how much electricity and money the energy companies lose as a result of this, if we take into account that the annual production of electricity amounts to 14,7 billion kWh, the calculations will be carried out with the established tariffs for electricity energy of 0,77; 2,16; 2,24 KG soms per kWh In this assessment, no division was made into categories of consumers paying for different tariffs, the calculation was made in the offer, when all consumers pay for different tariffs. This approach allows you to make a qualitative assessment of the potential losses of electricity and losses of income of energy companies, depending on the % of the existing electrical losses in the networks.

Table 2 shows the results of the calculations made.

The corresponding designations of the columns of the above-stated table means.

1 - Indicators of electrical losses in percent;

2 - The corresponding annual energy losses at various percentages, bln. kWh;

3, 4, 5 - Average annual losses of the electric power complex of the Republic, expressed in million soms with corresponding electricity tariffs of 0,77 soms; 2,16 som; 2,24 som. In other words, how many electric companies annually lose financial resources due to losses in the networks;

6 - This column shows what percentage of the corresponding total losses of the fuel and energy sector of the country is at a loss of 1 MW of installed PV power and 6 MW respectively (column 7).

Table 2. The results of calculations of losses of electricity and incomes of energy companies depending on the losses of electricity in networks.

Loss perc.	Electricity losses, billion kWh	Financial losses of companies, mln soms			Percentage of losses	
%		0,77 som	2,16 som	2,24 som	At 1 MW	At 6 MW
1	2	3	4	5	6	7
1	0,147	113	317	329	2,08	11,5
2	0,294	226	635	658	1,02	5,7
3	0,441	339	952	987	0,68	3,8
4	0,588	452	1264	1316	0,51	2,85
5	0,735	565	1586	1645	0,41	2,28
6	0,882	678	1903	1974	0,34	1,9
7	1,029	791	2220	2303	0,29	1,6
8	1,176	9,04	2537	2632	0,25	1,42
9	1,323	1017	2854	2961	0,22	1,26
10	1,47	1130	3171	3290	0,20	1,14
11	1,617	1243	3488	3619	0,18	1,03
12	1,764	1356	3805	3948	0,17	0,95

The data in Table 1 represented in the form of the corresponding diagrams (Fig. 2) and (Fig. 3).

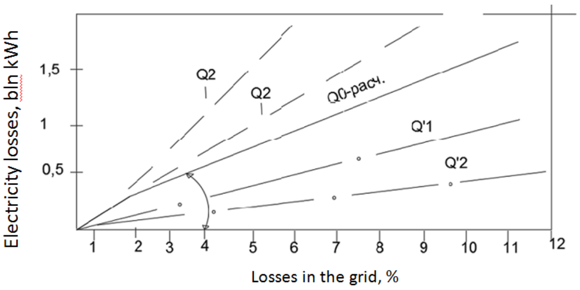

Figure 2: Diagrams of changes from different percentages.

From the obtained diagram it can be seen that the dependence of electric power losses in networks linearly depends on its percentage value.

Moreover, the intensity of losses is the higher, the greater the generation of electricity, i.e. in the zone where $Q_2 > Q_1 > Q_{0calc}$ losses will grow more intensively than in the zone where $Q_{0calc} > Q_1' > Q_2'$.

That is, in other words, if the angle of inclination of a straight line to the horizon is an angle α, then we can write:

$$Q_l = tg\alpha \cdot K, \qquad (2)$$

where Q_l - losses of electricity, K - percentage of losses in the networks. The value of K is the value of the maximum average annual values of energy losses of the considering system (%).

Thus, it can be seen that for the case under consideration, when the annual energy production in the Republic is 14,7 billion kWh, the value of $tg\alpha$ will be 0,147, and it is a constant value, that is, taking into account the latter in general terms can be written (2):

$$Q_l = \frac{Q^y \cdot K}{100}, \qquad (3)$$

where Q^y - the average annual electricity generation.

The dependence obtained allows us to determine the amount of electric power losses in networks with known values of its average annual output.

The diagram in Figure 3 shows the changes in the financial losses of energy companies, from the loss of electric power, due to the loss of electricity in the networks at the existing tariffs.

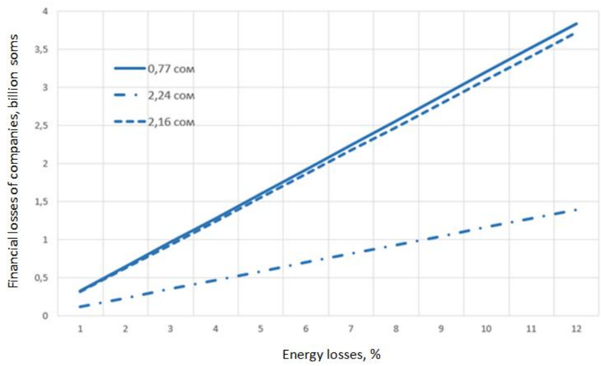

Figure 3: Diagram of financial losses of energy companies depending on losses in the grid.

From the obtained diagrams presented in Figure 3, it can be seen that the qualitative picture of the change in the financial losses of power companies depending on the losses in the networks is similar to the diagram shown in Figure 2. Therefore, analogously to (3), we can write down:

$$C_l = \frac{Q^y}{100} \cdot C \cdot K, \qquad (4)$$

where C_l - is the cost of electrical losses, som; C - tariff for 1 kWh of electricity.

If we use (4), we can easily determine how much money an electric company can save, or in other words say, will get additional profit while reducing losses. Reduction of losses by 1% with appropriate rates are shown in Table 3 (column 3).

Now let's calculate what amount the energy companies should pay annually to the electricity supplier from PV, resulting from the difference in tariffs, determined by the adopted law of RES. Accordingly, for PV with an installed capacity of 1 MW the annual generation of electricity, as shown earlier, will be 2,8 million kWh. For 6 MW - 6,8 million kWh respectively.

The price of payment for traditional power plants, respectively, at different rates, with an installed capacity of 1 MW are given in Table 3 (column 3), and at 6 MW Table 3 (column 6).

Considering that we have not made a division of the number of consumers into the corresponding categories according to paid tariffs. For a qualitative presentation of the existing picture in the Table 3 shows the obtained values for the average tariff (1,72).

The value of the necessary payment for PV energy according to the Law of Renewable Energy should be considered with a factor of 6. Calculations for 1 MW are given in Table 3 (column 4), for 6 MW (column 7).

The annual value of payments of the energy company to the electricity supplier from the PV will be nothing more than the difference in the amount of payment received to the electricity supplier from PV with the value of payment to the traditional supplier at the established traditional tariff. The values of the calculations for 1 MW are given in Table 3 (column 5) and respectively for 6 MW (column 8).

Table 3: The results of calculations of the cost of electricity for the traditional system and PV.

#	Tariffs, Som	Cost of electric power tradition. at 1 MW (million som)	The cost of electric energy PV 1 MW, (million som)		Cost of electric power tradition. at 6 MW (million som)	The cost of electric energy PV 6 MW, (million som)	
			Δ	C		Δ	C^1
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0,77	2,156	13	10,9	12,93	77,6	64,7
2	2,16	6,05	36,3	30,2	36,3	217	180,7
3	2,24	6,27	37,6	31,3	37,6	225,6	188
Av.	1,72	4,8	28,8	24	29	177,6	148

The data Table 3 for clarity presented in the form of histograms in Figure 4.

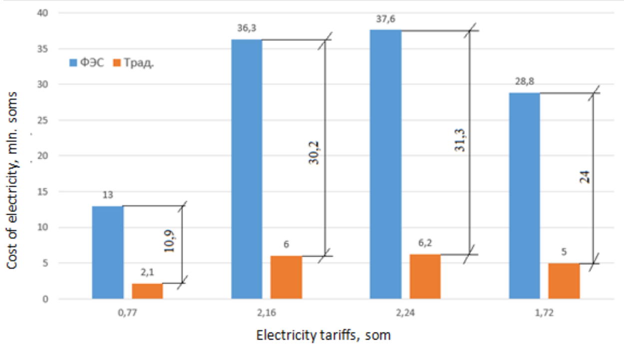

Figure 4: Comparative diagrams of electricity costs for traditional and PV grids at installed capacity of 1 MW.

Thus, from the presented data and diagrams, it can be seen that for an installed capacity of 1 MW, utility companies must pay the supplier annually, depending on the relevant tariff 10,9, 30,2, 31,03 million soms. If we take the average tariff, then, respectively, 24 million soms. For the chosen power of 6 MW, respectively, these values will be 6 times higher – 64,7, 180,6, 188 million som and 144 million averaged.

Previously, we raised the question at the expense of what means of the power company should cover this difference. To do this, go back to the Table 2. It can be seen that if the energy companies reduce their losses by at least 1 % per year, they will receive additional funds in the amount of 113 million soms (with 0,77) 317 million soms and 329 million soms, respectively, at tariffs 2,14 som and 2,24. At the average tariff of 252,8 million soms.

Then, taking into account the data Table 3 it can be calculated that energy companies, while reducing their electric power losses in the networks by 1%, can respectively compensate for the difference in tariffs for PV for about 10,5 years by receiving additional profit.

Thus, given the current situation in the electric power industry and existing tariffs, if we introduce PV with a capacity of 1 MW and reduce losses in general for all electric companies by 1% without any consequences, they can pay the difference in tariffs to the supplier of PV with the accepted ratio of 6 10,5 years and at the same time not a penny without raising the existing tariffs.

For the installed power of the PV of 6 MW, respectively, we get 1,7 years.

It should be said that all the calculations presented here are based on the electricity tariffs that exist today, the average annual output and in the proposal that the rate of increase in generating capacity will remain the same as the last 27 years, i.e. each year it is assumed to build up about 30 MW. Moreover, of these 30 MW, it is assumed that 20 % will be increased at the expense of PV, which accordingly amounted to 6 MW.

The above calculations were made for the case of a possible reduction of losses by only 1%. In reality, if you look at world experience, losses can be reduced to 6-8% as was done in developed countries like Germany, USA, Japan, i.e. for our Republic, this is approximately a reserve of 4-5 %, which makes it possible to cover the difference without increasing tariffs for a period of 7-9 years. Of course, this does not mean at all that everything will be exactly like this, but under the conditions we adopted, such an expected result is possible.

5 CONCLUSIONS

Thus, if we generally talk about the strategic development of the electric power industry of the Republic and its main implementation mechanisms, then the following should be said:

- The existing power supply system, which has a coefficient of utilization of power plants below 50% and is built on the principles of providing peak power to the consumer, is not consistent and is not economically justified;
- Already today, it is imperative to search for completely new innovative ways to provide consumers with electricity based on new grid design principles;
- The Kyrgyz electric power industry has rather large prospects in improving the innovative attractiveness of renewable energy projects and reserves in their financial support.
- At the first stages of improving the power supply system in the Republic, it is necessary to maximize the introduction and provision of parallel operation of generating stations on renewable energy sources with traditional centralized networks using the elements of the Smart Grid.

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Comparative Analysis of Some Types of Renewable Energy Sources

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Keywords: Energy Supply, Non-Traditional Renewable Energy Sources (NRES), Biomass, Wind Installation, Electricity, Heat Supply, Solar Energy, Installation, Low-Power Water Flows, Organic Fuel.

Abstract: The article discusses the current state and possibilities of using renewable types of energy in Kyrgyzstan. The efficient assessment is given for using of non-traditional renewable energy sources. The main advantages of using the energy in the national economy are also indicated in the given article. The problem of introduction and use of alternative energy sources, the factors that impede the widespread introduction of new types of facilities in the country are analyzed. On the base of reviewed material, the conclusions are formulated to improve the situation on using renewable energy sources.

1 INTRODUCTION

At present day, the supply of consumers by electricity, heat and other types of energy has become one of the factors, showing the level of social, technical and economic development of any country. Its absence or deficiency directly affects the vital activity of the population, industrial establishments and other organizations.

In this connection, the question of saving and maximally rational consumption of energy resources in production, everyday life and social security is in the first place. It is safe to say that energy saving is one of the global problems of our time.

The Kyrgyz Republic has sufficient proven reserves of hydrocarbons: coal – 1,34 billion tons, oil – 11,5 million tons, gas 6,54 billion cubic meters. [1]. In addition, Kyrgyzstan, as one of the Central Asian countries, has a huge potential of renewable energy (solar energy, wind energy, biomass energy, etc.) and a significant hydro power potential of watercourses (hydro energy – 81 billion kwh/year. [2]. Electricity is one of the basic sectors of the economy of the Kyrgyz Republic and an important factor in its development is small energy, which includes non – traditional types of energy. In this aspect, Kyrgyzstan has already been defined as a country that has developed strategy of the energy sector, which is engaged in legislative activity for its legal protection, attracts investments to improve work in this direction. However, it is the development of renewable energy that allows us to solve the most important tasks at the moment:

- Increasing the reliability of power supply and economy of fossil fuel;
- Solving problems of local energy and water supply;
- Improving living standards and employment of local population;
- Ensuring sustainable development of remote areas in the desert and mountain zones;
- Enhancing the country’s commitment in fulfilling international agreements on environmental protection.

Potential energy resources of the NRES of the Republic, which are actually available at the current level and development of techniques and technology, are 840 million tons of fuel equivalents in a year. Thanks to scientific and technical progress, electric and thermal energy can be extracted locally, directly on site, using renewable energy sources (RES). It will not adversely affect the environment, because the energy of solid and liquid fuels is not used [1].

Up to now, there has undertaken a small practical study of the potential of renewable energy (their immediate share in the country’s energy balance is less than 1 %). There are various reasons for this, the main one being the lack of an effective economic incentive mechanism for using of renewable energy [2].

The use of renewable energy “dictates” the very natural specifics of Kyrgyzstan, since almost 90% of the total area of the country is covered by mountains. The majority of the population, almost 60%, lives in rural areas; in the foothills and mountain areas, where the delivery of traditional fuels is very difficult. It makes profitable useof local autonomous systems of renewable energy sources that do not require connection to existing electrical networks [3]. We will analyze some types of renewable energy sources based on the factors indicated below:

- Energy potential;
- Ease of maintenance;
- Portability (mobility);
- Economic efficiency and payback period;
- Impact on the environment.

2 ENERGY POTENTIAL

2.1 Wind energy

The total annual energy potential of wind flows in Kyrgyzstan is 2 billion MWh per year.

The potential of wind energy in the regions of the republic is different. The average annual specific energy of the wind flow is from 170 to 1300 kWh / m^2. Comparing the needs of small objects for electric energy with wind inventory data shows that the wind energy potential is sufficient and can be successfully used to cover the needs for energy [3, 4].

Analysis of the wind flow features showed that more than 50 % of wind flows in Kyrgyzstan fall on light wind and calm, 30-40% on light wind (2-5 m/s) and the rest on moderate and fresh wind (6-10 m/s) [3, 4].

On a large part of the lowland and foothill zones, where the main low-power consumers are located, wind energy potential is low. In the same zones where the winds are blowing at a speed of 8-12 m/s, with high energy potential, consumers are practically absent. That’s why, the development of small wind energy (1-10 kW unit) seems to be promising, and, first of all, for the supply of electricity to remote low-power autonomous consumers located in the foothill and mountain regions [3-4].

2.2 Biomass energy

Local biomass sources include biomass from livestock and straw cultivation, the potential using is estimated at 9,732 thousand TJ per year. However, the level of their use is extremely low and is usually limited to the heating of residential premises with dry manure (kizyak). The estimated energy potential of agricultural biomass available for use is more than 12,0 thousand TJ per year [5].

2.3 Solar energy

Due to its favorable geographical location and climatic conditions, the territory of Kyrgyzstan receives an average of 4,64 billion MWh of radiant solar energy per year, or 23,4 kWh per 1 square meter, although there is a regional change in the intensity of solar radiation. A significant difference in the thermal energy coming from the sun is made by the mountain relief, which characterizes 90 % of the country’s territory.

The technical annual potential of solar heating plants under these conditions can reach 1,7 million MJ [3, 4, 6].

2.4 Energy of low-power water flows

The total hydropower potential surveyed in the territory of the republic is 172 rivers and streams with oxen consumption from 0,5 to 50 cubic meters m/s, more than 80 billion kW / h per year. Experts believe that now there is the possibility of building 92 new small hydropower plants with a total capacity of 178 MW and an average annual output of up to1.1 billion kW / h of electricity. 39 previously existing small hydropower plants with a total capacity of 22 MW and average annual output of up to 100 million kW/h of electricity can be restored [2]. One of the factors of hydropower development should be the reconstruction and building of small hydropower plants, as the centralized system of power supply requires the large capital investments.

3 PROSTATE MAINTENANCE

3.1 Wind energy

Maintenance of low-power wind installation of generators does not require much experience and profound technological knowledge from the user, the knowledge obtained in the form of consultation is sufficient. Regular maintenance, as well as the use of modern technologies – allows not only to extend the period of trouble-free operation, but also to avoid unintended downtime of wind turbines [3, 4].

The repairing works of blade and parts is performed by specialists who have received specialized training in working with composite materials (fiber and epoxy resins) and parts replacement.

3.2 Biomass energy

During the operation of biogas plants (BGP), the daily dose of fresh manure loading and its periodic introduction into the installation are of great importance. Loading dose is a variable value and depends on various subjective - objective factors. The daily dose should be introduced into the reactor not entirely, but gradually, in equal portions at single intervals of 4-6 times per day. The load portion must be heated. The use of BGP, which is considered to be the simplest in its design, in contrast to other sources of renewable energy requires more attention during operation, reliable fastening of all parts of the installation. Replacing the material in the installation requires a person to be attached to it, monitoring the condition and maintaining the required temperature of the organic material. This whole procedure will be easy for a farm or a family with a large number of members, but not for families that mostly work in the fields.

3.3 Solar energy

The solar maintenance, regardless of their number, is extremely simple and reduces to periodic (just a few times a year, with the exception of snowy days) surface cleaning, which can be done by everyone, regardless of qualifications and professional skills. You should also take into account the fact that the strength of tempered glass, which is covered with panels, is so great that it can withstand large hail (up to 2,5 cm in diameter), therefore, it is rather difficult to damage or damage the panel. At the same time, maintenance of solar panels is much simpler than heating and air-conditioning systems, which today are present in almost every private house.

3.4 Energy of low-power water flows

For maintenance of micro HPSs, special knowledge is not required, as they have a simple structure consisting of a base, a water wheel, a generator and an electrical panel.

After installation, micro HPS can operate autonomously for a long time. Repair can be reduced to the replacement of component parts.

4 PORTABILITY (MOBILITY)

4.1 Wind energy

Wind turbine must be installed permanently, because it can be up to several meters high and have a lot of weight, so there is no possibility for its constant movement. To move the wind turbines, it must first be disassembled in parts, then move it to the right place and disassemble it again. The above works on the transfer and installation of equipment can be performed only by specialists in this field.

4.2 Biomass energy

Biogas plant with a large reactor volume is installed above the ground. The reactor is attached to the ground with a concrete surface and is not subject to movement. Carrying a biogas plant will require special equipment and specialists in this field. A lot of efforts can be spent on the movement of biogas plant and this can take indefinite time specialists.

4.3 Solar energy

Solar energy converters - installation can be installed almost anywhere. To move the solar installation doesn’t require specialists. As solar plants usually have a small weight, the movement can’t be carried out by a non-specialist person who doesn’t belong to this area; and also it doesn’t require time and physical assistance.

4.4 Energy of low-power water flows

Hydroelectric power plants are installed stationary, in the stream of the water flow.

However, if necessary, it is possible to disassemble the installation into separate component parts with subsequent transfer to a new location

5 ECONOMIC EFFICIENCY AND PAYBACK PERIOD

The following table 1 shows the data on capital investments, costs and payback periods of installations [3, 4, 6, 7].

Table 1: The data on capital investments.

n/n	Kind of energy	Specific capital investment, $/kW	Cost of installation on1 kWh, cent/kW	Payback period (year)
1	Wind power	600-1200	4-5	5-7
2	Biomass energy	700-1600	8-9	3-7
3	Solar power	1500-2500	2-16	3-6
4	Energy of low-power water flows	700-1000	3-4	2-7

As can be seen from the table, the economic indicators and payback periods of the above types of energy have on average similar data.

6 ENVIRONMENTAL IMPACT, SAFETY

6.1 Wind energy

Environmental problems associated with the construction and commissioning of wind power facilities may include noise and vibration, soil erosion and threat to biological species, including habitat change and impact on wildlife, deterioration of water quality, and impact on visual perception. [3, 4].

Studies conducted by experts in this field have shown that for low-powered wind installations the above problems practically do not exist, and are not the greatest harm for ecology and fauna. Noise during operation of low voltage generators with low-power generators is hardly noticeable.

Using the wind generators reduces the annual emissions into the atmosphere thousands of tons of carbon dioxide, sulfur oxide, nitrogen oxide. It affects the rate of decrease of the ozone layer, accordingly to the rate of global warming. In addition, they produce electricity without using water, which will reduce the exploitation of water resources, and without burning traditional fuels, and this reduces the demand and prices for fuel.

Wind turbine is dangerous to life and the environment, only when exposed to external factors and the device breaks (blades).

6.2 Energy biomass

As far as the degree of fermentation, i.e. decomposition of organic matter, reaches 30-40 % and because of it, the decomposition of biologically unstable organic compounds occurs mainly, the sludge is devoid of the smell characteristic of the original substrate [5].

The hygienic effect of anaerobic fermentation is primarily due to heat exposure for a certain length of time. For the destruction of individual pathogens required in each case a certain minimum temperature and the minimum duration of their stay at this temperature [5].

During the operation of the equipment, there may be consequences and malfunctions. The consequences can be a gas leak. Using of open flames to detect gas leaks is prohibited, as it is explosive. Gas pipes must be regularly checked for leaks and protected from damage.

6.3 Solar energy

In comparison with other types of energy, solar energy is the most pure in ecological attitude. The use of solar collectors is the most promising for reducing social tensions, as the huge potential of solar energy, in combination with relatively low capital investment and operating costs in the future, can cover 50 % of the republic's needs for thermal energy. However, it is practically impossible to completely avoid the harmful effects of solar energy on humans and the environment, if you take account of the whole process chain from obtaining the required materials to energy production.

6.4 Energy of low-power water flows

MicroHPS practically doesn’t harm the ecology environment. However, the generated voltage of 220 V can be dangerous to humans, and therefore it is necessary to follow the safety regulations when working with electrical equipment.

CONCLUSION

Kyrgyzstan together with the traditional energy (HPS, CHE), at this time is developing electricity and heat supply on the base of non-traditional sources of energy. With for that purpose, the government promotes the programs of NGOs of international organizations, establishes the Agency for the development of non-traditional types of energy, and adopts laws to promote and protect the interests of people engaged in non-traditional energy sources. This contributed to the emergence of interests from legal and private individuals on the use of objects of non-renewable sources of energy. In addition, the geographical feature (the complexity of laying electrical lines, the location of consumers at large distances from each other), territorial features (delivery of energy from neighboring countries and high prices) also have an impact on increasing demand for non-renewable sources of energy.

The use of renewable energy sources in Kyrgyzstan as well as throughout the world has its advantages:

- Independent of the central power system, its own source of electrical and thermal energy;
- Long shelf life of installations;
- Economic benefit (low cost per unit of energy);
- Minimal environmental impact;
- the use of local materials for the construction of power plants;
- Ease of maintenance of power plants;
- A relatively unlimited amount of energy.

In addition, each type of renewable energy has its advantages in different areas of the country: for hot and warm southern areas biogas plants (excellent fermentation effect), micro hydro (maximum use of time) and solar plants for heat and electricity; the use of wind energy for the northern regions, which give a large efficiency in contrast to the southern regions. But this does not mean that the use of other types of renewable energy does not make sense.

The reason for the inefficient use of renewable energy in Kyrgyzstan can be explained by the following reasons:

- Lack of interest: poor public awareness; high cost of electrical energy, technical illiteracy in the use of power plants; geographical distance from energy resources.
- Weak promotion of products on the market by business structures: a limited number of assortments of renewable energy; no technical support for the operation of power plants; small return of the spent means.
- Technical and technological unpreparedness of the country: the use of morally and physically obsolete technologies and technology, lack of qualified specialists (technicians, craftsmen).

These problems can be solved by holding seminars, trainings, consultations and visual advertisements, inviting the necessary specialists, perhaps even from abroad. Production of plants such as micro hydro, wind turbines (wind power plant), biogas plants, and solar thermal converters does not require high technology. The industry of the Kyrgyz Republic is able to master the production of these installations in regional centers, as well as industrial cities.

The calculations show that the renewable energy sources are quite competitive, as their cost is 1,5-4 lower in comparison with the traditional energy sources. One of the advantages of installations using renewable energy sources is that they don't require significant maintenance costs, in most cases they are less than 3-5% of the equipment cost. The organization of the production of converters of alternative renewable energy will create additional jobs. Integrated use of renewable energy will help to improve the life of inhabitants of mountainous and foothill regions, and to solve a number of problems associated with the migration of people to cities and abroad. Alternative energy supply will help preserve the ecosystem of the Kyrgyz Republic and reduce the negative impact of human activity on the environment. It will help to preserve the balance of rational recovery of the health of glaciers, which are a source of moisture, energy and stability in the Central Asian region.

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Improvement of the Work of a Small Derivative Hydro-Electrostation by Water Treatment by Hydrocyclones

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Abstract: The relevance of the study lies in the fact that in the common derivation schemes of hydroelectric power plants, protection against bottom and bottom sediments is carried out in water inlets, and water is cleaned from dangerous fractions of sediments in sedimentation tanks. The costs for the construction of a sump are very significant and sometimes make up 20-35 % of the investments in the construction of hydroelectric power stations. In our opinion, it is possible to reduce these costs by using modern types of hydrocyclones instead of sumps and filters used to purify water for cooling generators. The purpose of the work is to increase the efficiency of small hydropower plants by improving the site of water treatment. The research method is the use of guidelines for the preparation of technical documentation for energy production and technological complexes of hydroelectric power stations and thermal power plants and the testing of a water treatment unit and a technical water supply system. The results obtained: a feature of a new technical solution to improve a small hydropower plant was established. Unlike the existing ones, it has a complex clarifier for water purification replaced by an effective hydrocyclone. The hydrocyclone is also installed on the cooling unit of the hydrogenerator. Due to this, a simplification of the design of hydroelectric power stations, increasing the degree of water purification is achieved. The results of calculating the design parameters of hydrocyclone assemblies and testing them in laboratory and production conditions are presented. It has been established that replacing the bulky reinforced concrete sump of existing hydropower plants with simplified design hydrocyclone sand traps reduces the cost of building a water treatment unit from 30% (existing) to 7%. This allows you to expand the scope of development of a small hydroelectric power station, especially in mountain conditions.

1 INTRODUCTION

It is well known that hydropower is the most widespread in practice and technologically advanced industry in renewable energy sources [1-5].

Unlike other ecologically safe renewable sources such as the sun, wind, small hydropower practically does not depend on weather conditions and capable to provide steady supply of the cheap electric power to the consumer.

The main stimulating factors for the construction of small hydropower plants are [6]:

- constant renewability of water resources;
- minimal environmental impact;
- low cost of electricity compared with thermal power plants;
- significant savings in mineral fuels;
- improvement of household conditions and labor of people;
- low capital intensity, short investment cycle.

Articles [7-9] show that broad prospects are revealed before small (100 - 1000 kW) and mini-hydroelectric plants (up to 100 kW), especially when using them in foothill and mountain regions. The efficiency of such a power plant can significantly increase if it is used in conjunction with other types of renewable sources, for example, wind power or solar power plants.

As operation experience of a hydroelectric power station demonstrates, the technical condition and reliability of hydroturbine equipment affect the efficiency of their operation, especially the power characteristic [10-12]. In the presence of mechanical impurities in the feed water, hydraulic units are often subjected to abrasive wear. Abrasive wear of turbines leads to a significant drop in their efficiency, and consequently, to a decrease in the power and power output of a hydroelectric power station, to a reduction in the service life of hydro turbine equipment [13-18].

In the widespread derivational schemes of hydroelectric power stations, the protection of hydraulic units from bottom and bottom sediments is carried out in water receivers, and purification of water from hazardous fractions of mechanical impurities is carried out in sedimentation tanks [15].

In common HES derivation schemes, the protection of hydraulic units from bottom and bottom sediments is carried out in water intakes, and the water is cleaned from dangerous fractions of mechanical impurities in septic tanks [6, 20].

However, the cost of the construction of the sump, due to its cumbersome design, are very significant and sometimes make up 20-35 % of the investment in the construction of a hydropower plant [6]. Therefore, the feasibility of building a hydropower plant with a settling tank should be justified by special technical and economic calculations. For this, the cost of installing a settling tank is usually compared with the cost of cleaning the structures from sediment and repairing turbines that will be required if the construction of the settling tank is abandoned. periodic removal of sediment deposited in the sump.

These problems to reduce capital investments in construction and the cost of operating a hydropower plant, in our opinion, can be eliminated by using the energy of the watercourse through the diversion channel (pipeline) to separate mechanical impurities from water using hydrocyclones. In this case, the construction of bulky settlers is no longer necessary [21].

2 DESCRIPTION OF THE DEVELOPMENT AND METHODOLOGY OF THE INVESTIGATION

The small derivational power station developed by us includes a hydrocyclone water treatment unit 1, a building of hydroelectric power station 2, a hydroturbine 3, a generator 4, a hydrocyclone 5 for a cooling unit of the generator and a suction tube 6 (Figure 1) [19].

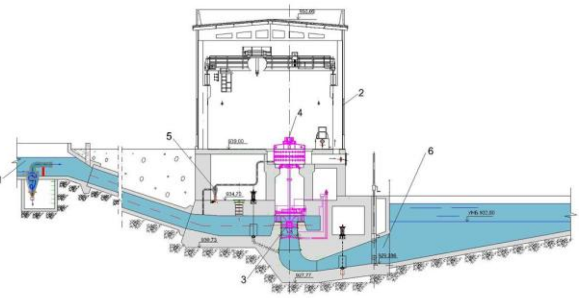

Figure 1: Design diagram of the small derivational power plant with hydrocyclone water treatment unit.

In Figure 1 shows 1-hydrocyclone water treatment unit; 2-building of hydroelectric power station; 3-hydroturbine; 4-generator; 5-hydrocyclone for the cooling unit; 6-suction pipe.

The water purification unit consists of hydrocyclones with a receiving chamber and a drainage pipe, a threshold, a manhole and a sand pipe. The threshold set inside the derivation channel is provided in order to ensure the full flow of water with mechanical impurities into the receiving chamber of the hydrocyclone. Therefore, the threshold height must be at least the height of the cylindrical part of the hydrocyclone.

To fully ensure the required water flow, a parallel arrangement of hydrocyclones is provided for (Figure 2).

When a hydropower plant is in operation, water with mechanical impurities, moving at the expense of the velocity head in the channel, gets tangentially into the hydrocyclone and is cleared of solid components. Purified water through the upper drain pipe, located in the direction of flow of fluid, flows back into the channel and is fed to the working nozzles of the turbine.

Figure 2: Parallel arrangement of hydrocyclones in the hydroelectric diversion channel.

Mechanical impurities captured in a hydrocyclone, mainly in the form of fine sand with diameters greater than 0,05 mm, are ejected into a heap by a sand extraction pipe.

The height of the sand mass accumulation at the sand hole within 1/3 of the height of the conical part of the hydrocyclone and the opening of the sand removal line is adjusted using an automatic controller of a simple action.

The initial data for the calculation of a hydro-cyclone unit of a small hydroelectric station are taken: the flow of water passing through the hydro-cyclone - Qn and the pressure drop at the entrance to the hydro-cyclone and its output - Nn, as well as the content of suspended particles before cleaning - γ. [21].

Based on the results of the analysis, it was revealed that in order to use computer simulation data, the numerical model must be verified by a physical experiment. Therefore, numerical analyzes of the processes were carried out on the basis of the STAR CCM + 6,04 software package using the results of experimental studies.

This study includes the calculation of the flow lines of the velocity of particles of a liquid in a hydrocyclone, the trajectory of movement of solid particles, pressure drop, and the efficiency of separation of liquid and solid particles.

The result of the study made a prediction of the degree of water purification, depending on the physical properties of the fluid, the flow rate at the inlet and the geometric parameters of the hydrocyclone.

From the experiments performed in the laboratory were initially known: inlet pressure Pвх = 1100 kPa; speed v = 0,3844 m/s; fluid flow Q = 173 l/min = 2,88 kg/s;

For the numerical calculations of this problem, the geometry was chosen with the following characteristics:

- Dimensions of the hydrocyclone: the area of the entrance area is 0,075 m^2, the area of the output area is 0,0153386 m^2, height is 1,1 m, the area of waste particles is 0,007 m^2.
- The grid is selected according to a multifaceted scheme to provide a balanced solution to complex. And also the model of a prism-grid layers is used to generate orthogonal prismatic grids with a wall border. This layer of cells is necessary to improve the accuracy of the solution of the flow movement. Surface meshes are a discrete representation of the geometry of the individual areas that will be used to generate volumetric meshes. It consists of faces (triangles) and vertices and connects all surfaces of the geometry. A total of 70898 cells and 397585 surfaces are used to implement the calculation.

In the three-dimensional motion simulation under consideration, it was assumed that the flow is stationary, i.e. does not depend on time, the density of water and particles of contaminated liquid are constant, and the flow of water is incompressible.

Due to the fact that the fluid movement is two-phase, we can use the Lagrange multiphase model, i.e. phase 1 - water, phase 2 - particles of mechanical impurities.

In the simulation of turbulence, the Navier-Stokes differential equation is used, where the averaging process can be considered as temporary for stationary states and averaging the set for repeated transition situations and the continuity equation. The boundary and initial conditions were selected on the basis of experimental data.

The Reynolds (1) are written in the form:

$$\rho\frac{\partial \bar{u}_j \bar{u}_i}{\partial x_i} = \rho \bar{f}_i + \frac{\partial}{\partial x_i}\left[-\bar{p}\delta_{ij} + \mu\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right)(1)\ \overline{u'_i u'_j}\right].$$

Then, the continuity (2):

$$\frac{\partial \rho}{\partial t} + \operatorname{div} \rho \mathbf{v} = \frac{\partial \rho}{\partial t} + \rho \operatorname{div} \mathbf{v} + \mathbf{v} \operatorname{grad} \rho = (2)$$

At the inlet of the hydrocyclone, the velocity of the supplied suspension was 0,38 m/s, and the initial pressure was 1100 kPa. At the outlet, the state of purified water met the expected requirements for the degree of purification.

The results of pressure on a symmetric section of a hydrocyclone show that the outlet pressure drops to 550 kPa. This is in the permissible errors coincide with the subsequent experimental data.

The change in pressure in a hydrocyclone is characterized by the model shown in Figure 3.

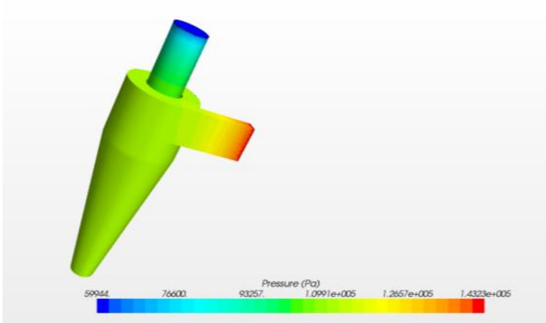

Figure 3: Pressure change in a hydrocyclone.

The ratio of the amount of water and particles of contaminated liquid in the calculation is in the order of 3:1. In Figure 4 shows the proportion of particles and their distribution in the hydrocyclone by weight. It turned out that the maximum fraction of particles is at the entrance (0,35) and approximately 0,05 at the exit.

Due to the fact that during the operation of a hydrocyclone, centrifugal forces exert a significant effect on mechanical particles and the difference in the densities of the components considered the position of the particles under various possible modes of operation. The established features are to a certain extent characterized by the model solution shown in Figure 5.

In the future, it is planned to consider models for establishing the optimal operating modes of a hydrocyclone with changes in the properties and states of the studied phases of the medium.

The main technological parameters and the rational mode of operation of the proposed water treatment unit were established according to the results of tests on a specially constructed laboratory installation (Figure 6). [21].

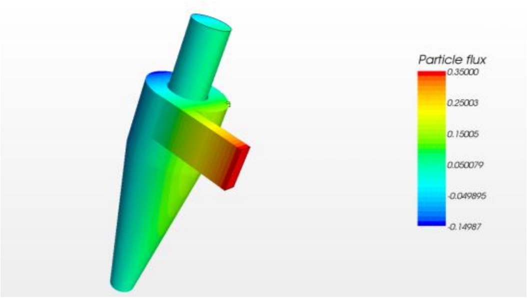

Figure4: Mass fraction of mechanical particles.

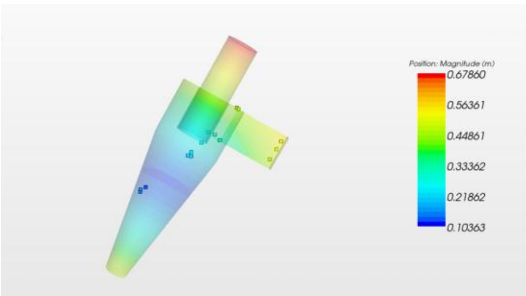

Figure 5: The location of the dirt particles in the hydrocyclone.

On the first table the main part of the research facility was located, based on the centrifugal pump 1,5 KM with step-by-step power control, parameters of the pressure hydrocyclone and a hydroturbine.

To change the operating mode, we used valves, electronic pressure sensors installed at the assembled units of the hydraulic unit, and also an electronic flowmeter. Under the table there was a container for circulating water supply, into which liquid is supplied from the suction pipe of the small hydroelectric power station.

Figure 6: Laboratory installation for studying the parameters of hydroelectric power stations with a hydrocyclone.

On the second table was installed a personal computer with a program for monitoring the work of the bench installation and a communication cabinet with controls and measurements, as well as a module for connecting sensors to a personal computer.

On the basis of the above theoretical assumptions and the calculation procedure, the following dimensions were calculated for the manufacture of experimental industrial samples (Table 1).

Table 1: The main dimensions of the projected hydrocyclones.

Options	GC-700 (node 1)	GC-500 (node 2)
Diameters, mm:		
Cylindrical part	700	500
The inlet nozzle	90*330*65	70*200
Drain connection	200	100
Sand hole	50	32
Angle, taper, degree	30-35	20
Height of cylindrical part	380	250
Taper height	1185	750
Diameter of the air column	52	45
Minimum particle size	0,05	0,05
Maximum particle size	3,75	2,75

3 RESULTS OF THE INVESTIGATION

As a result of the test, it was found that when the pressure at the inlet of industrial sample of the hydrocyclone changes within 0,025 ... 0,045 MPa, an increase in the flow rate of liquid through the discharge pipe from 5,78 l/s to 57,5 l/s is observed, and through the sand hole - up to 4,42 l/s (Table 2).

As can be seen from the graphical dependences Qout = f (Pout) and Qin = f (Pin) (Figure 7), the maximum flow rate of the hydrocyclone through the drain (57,5 l/s) is provided at an inlet pressure of 45 kPa, when the valve on the pressure line is open to the full cross section. The pressure loss in the hydrocyclone chamber at the same time is 22 ... 35 kPa.

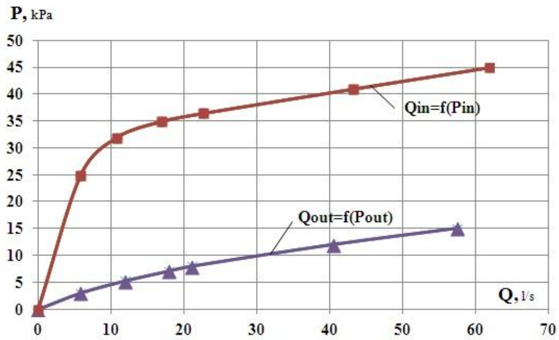

Figure 7: Graphic dependences Qout = f (Pout) and Qin = f (Pin).

During the tests, by changing the diameter dp from 10 to 25 mm, the concentration of the ground mass was reached with a ground weight consumption of 0,73 ... 0,77 kg / s and a density of up to 1,843 t/m^3) significantly increases the density of the condensed mass, however, this leads to clogging of the discharge opening (Table 3).

In the established mode, the clarified water density was equal to 1,009 ... 1,05 t / m3, and the degree of purification - 91 ... 97%. The minimum particle size was 0,05 mm, and the maximum particle size was 3,75 mm.

The choice of the location of the designed hydrocyclone gritters, as well as the replaced septic tanks, is provided within the head node or on the main (diversion) channel taking into account the geological and topographical conditions, the approach of water to the water treatment unit.

Table 2: Discharge characteristic of a hydrocyclone at pressure mode.

Pressure, kPa				Consumption, l/s		
At the entrance of a hydrocyclone, Pin	On the sink of a hydrocyclone, Pout	On the sand hole of a hydrocyclone, Ppo.	At the entrance of a hydrocyclone, Qin	Through the discharge of a hydrocyclone, Qout	Through the sand hole of a hydrocyclone, Qpo.	
25	3,0	2,0	5,83	5,78	0,05	
32	5,3	4,0	12,26	12,0	0,26	
35	7,1	5,0	18,64	18	0,64	
36	8,0	6,0	22,72	21,1	1,62	
41	12,0	8,0	43,27	40,5	2,77	
45	15,0	10,0	61,92	57,5	4,42	

The required type of hydrocyclone is made on the basis of a technical and economic comparison of the construction and operational parameters of the water treatment unit, taking into account the presence of a sufficient hydraulic slope of the water supply path and the free flow of water necessary to separate the two-phase liquid.

Table 3: These tests for determining the degree of water purification with a mechanical impurity in a hydrocyclone.

Pressure at the inlet of a hydrocyclone, kPa	Density of liquid and pulp, t/m3		Degree of cleaning, %
	clarified water	condensed water	
20	1,020	1,520	91
30	1,009	1,680	92
40	1,025	1,720	94
50	1,031	1,745	96
60	1,035	1,780	97
70	1,040	1,800	97
80	1,034	1,843	96
100	1,050	1,840	94

In view of the fact that the designed sand trap will be installed on the bottom of the diversion channel, its main parameters should ensure optimal operation of the channel and hydroelectric turbine of the hydroelectric station.

The water turbine system is selected at the maximum head taking into account the set operating conditions and the range of pressure change at the hydroelectric power station.

For the calculation and design of hydrocyclone sanding units, the same parameters for water and pollution should be specified as for sedimentation tanks. The hydraulic size of particles, which must be isolated to provide the required cleaning effect, is determined at the required height of water layer. The main design value of the hydrocyclones is capacity for purified water and degree of purification. Water productivity *(Qhc)* can be calculated by (3) taking into account the diameter of hydrocyclone *Dhc:*

$$Q_{hc} = 0{,}785 q_{hc} D_{hc}^2 \quad (3)$$

Based on the total amount of water *Qw* supplied, the number of hydrocyclone working units is determined: *N = Qw / Qhc.* After the designation of the devise diameter and determination of their quantity, basic parameters of the hydrocyclone were established.

The angle of inclination of the generatrix conical part of the hydrocyclones in each specific case is set depending on the properties of the precipitate being precipitated. The main components and parts of hydrocyclones can be made of steel and plastic materials.

In view of the fact that hydrocyclones of considerable diameter (700-1000 mm) are analogous to ours, they are installed in those nodes of the technological scheme in which it is necessary to process volumes of contaminated water at the size of the boundary grain separation 0,4-0,5 mm, within these limits. With low productivity and the need to separate sand of small size (0.2-0.4 mm), as in the case of cooling water in the node of technical water supply of hydroelectric power stations, hydrocyclones with diameters within 350-500 mm are recommended.

The hydropower plant under consideration is designed in accordance with the target program “Creation of a basis for serial production of renewable energy sources in Kazakhstan of world level” (BR05236263, National Academy of Sciences, Kazakhstan).

CONCLUSIONS

It has been established that the hydrocyclone method for trapping mechanical impurities has a number of significant advantages over other methods of water purification, in particular from a settler:

- simplicity of hydrocyclone design, adjustment, operation, installation
- and high service life of the water supply unit;
- high degree of purification from abrasive mechanical particles;
- slight loss of liquid through the sand nozzle - up to 2-3 %;
- lack of an autonomous pump and drive, because works due to the drop of the derivation channel or pipe.

If it is needed they can be replaced with new ones or restored during the operation of the small hydroelectric power station.

Approved in production conditions, prototypes of the hydrocyclone water supply unit with a diameter of 700 mm showed the degree of water purification from mechanical impurities to 96-98 %. The installed capacity of one used hydroelectric power station is 3-10MW. Annual power generation reaches 4,0 – 5,0 million KW.

Replacing the bulky reinforced concrete clarifier of existing hydroelectric power stations with hydrocyclone sand traps of simplified construction reduces the cost of building a water treatment unit from 30 % (existing) to 7 %. , which were calculated by comparative assessment of the sump and the proposed hydrocyclone unit. This allows you to expand the volume of development of small hydropower plants, especially in mountain conditions.

The main consumers of development are energy services, interested in non-traditional energy sources and private organizations.

The economic effect of using the proposed technology of water supply of a hydroelectric unit of a small hydroelectric power station is achieved through the replacement of an expensive sedimentation tank and complex filters for water purification on hydrocyclones. Achievements of a stable operating mode of the hydrounit and associated main hydroelectric power station nodes without special stops contribute to reducing the loss in power supply to 15-20 %.

The technical novelty of the development is confirmed by patent of the Republic of Kazakhstan No. 25130,2014. Originality and effectiveness of the solution is marked by a certificate and a medal of the World Intellectual Property Organization (WIPO). The current model of the proposed hydroelectric power station was demonstrated at

EXPO-2017 (Astana, Kazakhstan) and was approved by specialists.

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Wind Turbine Reliability: A Brief Review

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Abstract: Energy plays an important part in the economic growth and the socio-economic development. With the increasing global energy demand and the depletion of fossil fuels renewable energy like wind energy have become not only an important source of clean energy but also important of a nation's energy security. The wind turbine industry as a result is rapid developing with a global capacity of approximately 230 GW and is expected to increase five times by 2020. As this industry is becoming more commercial manufacturers are incorporating technologies from other fields which are proven into the wind turbines. However, these technologies are sometimes not appropriate for the wind turbines, which then lead to high failure rate. Despite this issue there exits only a number of many studies on the reliability on the wind turbines. Hence, this paper aim is to provide a review on wind turbine and its sub-components reliability, providing an overview of components failure rate and downtimes.

1 INTRODUCTION

Since the first oil crisis in 1973, interest in renewable energy is growing and the industry has made positive advances since the protocol Kyoto 1997 where collective reduction in greenhouse gas emission were consented and numerous developments in this sector was encouraged by governments across the globe.

The wind energy industry has unquestionably responded. In 2009 about 39% of new capacity installed within EU was wind turbines [2] and in 2012 it provided nearly more than 6% of the region's electricity [3]. The world wind energy capacity was approximately 237 gigawatts (GW) in 2011 and has been doubling energy 3 years, and is projected to rise to at least 1000 GW by 2020 as per one forecast [4].

Due to the rapid development of the wind turbine (WT) industry, its design has evolved through time, with the aim of producing energy more efficiently and cost effectively. Therefore, WT manufacturers have explored different design topologies, such as horizontal or vertical axis of rotation and downward or upward placement of rotor, and also considered changes in smaller components like brakes and blade tips or using different control strategies. [5]

As the manufacturers are trying to make WT more commercial, they have looked into technologies in other fields which are proven, in many cases, components can be taken off the shelf. However, in some instances, due to insufficient knowledge of the WT operational condition, results show lower reliability than anticipated. For example, despite the commerciality of gearbox, in WT high failure rates are obtained. [5]

To study the reliability of WT there are not enough sources through time. There exits only a number of databases with failure information such as LWK [6] and WMEP [7] in Germany, Windstats Newsletter in Denmark [8], VTT in Finland and Elforsk in Sweden [9].

These are some of the data that have been used to study the reliability of WTs. Nevertheless, besides failure rates there are other aspects that are important to consider such as downtime by failures [9,10], effects of wind speed [11] and icing [12] on reliability. This paper therefore aims to provide a brief overview of WTs.

2 COMPONENTS OF WT

The main components of the typical WT are found in Fig. 1 [13]. Propelled by the wind, the blades are connected to the rotor hub which transmits mechanical energy by the low speed shaft through the gearbox to the highspeed shaft that is linked to the generator. The low speed shaft is held by the main bearings, and the gearbox regulates the speed. The yaw system that rotates the nacelle, is used for the alignment to the direction of the windspeed. Power going into the wind turbines are controlled by a pitch system that is mounted in each blade and also act as an aerodynamic brake. For the control of the pitch, brake and yaw systems, a meteorological unit may be used that provides weather data.

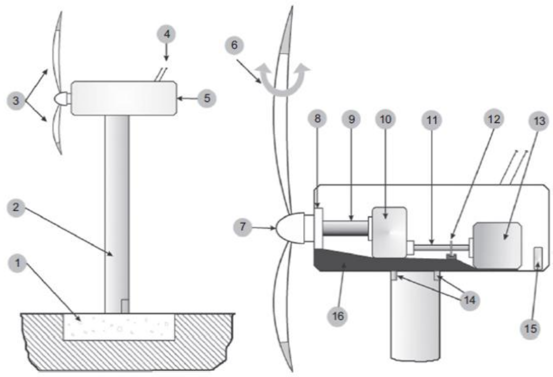

Figure 1: Components of WT: 1-base; 2-tower; 3-blades; 4-meteorological unit; 5-nacelle; 6-pitch system;7-hub; 8-main bearing; 9-low speed shaft; 10-gearbox; 11-high speedshaft; 12-brakesystem; 13-generator; 14-yaw system,15-converter, 16-bedplate. Drivetrain= 9-11 [13].

3 WT PERFORMANCE AND RELIABILITY

Through many years of research, scientists had developed numerous models for the estimation of the performance of WT system. A brief review of performance evaluation methods is discussed here.

Abderrazzag [14] investigated the performance of a grid connected wind farm during 6 years operation and reported variation in wind speed and energy production on a monthly and annual basis for the whole examined period. Another study by Castro Sayas and Allan [15] proposed a probabilistic model of a wind frame taking into consideration the complex nature of the wind, the spatial wind speed correlation and the failure and repair process of WT. A study by Dokopoulos et al. [16] proposed an approach for predicting the economic performance and reliability of autonomous energy systems consisting of diesel generators and wind energy converters (WECs) based on the Monte Carlo-based method.

Billinton and Guung studied the capacity generation associated with wind energy, using a sequential Monte-Carlo simulation and showed that the contribution of WECs to the reliability performance of a generating system is highly dependent on the site wind condition [17]. A sequential Monte-Carlo simulation technique, proposed by Billinton et al. [18] is based on an hourly random simulation for the appropriate evaluation of a generating system including WECS.

Besides, an advanced model, developed and proposed by Kariniotakis et al. [19], which is based on recurrent high-order neural networks for the prediction of the power output profile of a wind park. Holcher [20] presented new storm regulation software, which helps to stabilize the grid during a storm wind and permits additional energy yield. This can subject less stress to the converter as a result of the switch off and start up process at high wind velocities which are avoided, along with their associated load peaks. For the evaluation of short-term wind power fluctuations and their impact on electric power systems, Wan et al. [21] presented statistical properties of the data collected and discussed the results of data analysis. Additionally, through the examination and comparation of regression and artificial neural network models, Shuhui et al. [22] estimated the wind turbine power curves.

Camporeale et al. [23] proposed an electronic system for testing the performance of wind turbines. The main aim of this system is to increase the accuracy in the measurements of speed and torque for each steady-state point of the turbine characteristic power curve. Skiha et al. [24] suggested the steps that can be taken by the government agencies in order to ensure the desired growth of the wind industry in the country and to meet the technical challenges faced by the wind industry. Also, with regards to improving the performance of the wind farm, suggestion on the appropriate selection of the wind electric generator with an optimum rated wind speed was made.

WT life is typically for around 20 years and its failures are commonly predicted and assumed to follow a bathtub curve [25] (Fig. 2). Therefore, reliability of a system is its or its component capability to complete its required task under a certain condition at a defined period of time.

Tanver et al. [25] showed data from Germany and Danish turbines in their periods of early life and their period of usefulness, respectively. They failed to find any appropriate data for wear out periods as the WTs were relatively new and the WT that lose reliability tend to be taken out of service before wear out. In addition, a study reported that the early periods of failure of a WT appear to be getting longer [26].

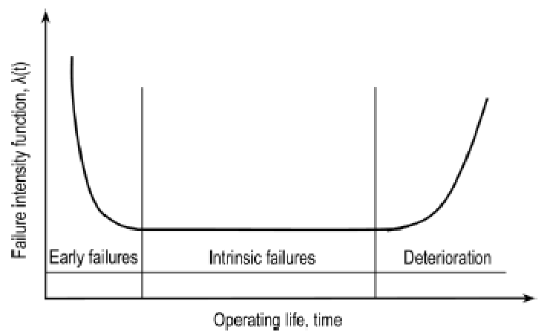

Figure 2: The 'bathtub curve' illustrating the reliability variation throughout the life of repairable machinery [13].

However, the typically reported average failure rate of the turbine per year is (1) [27],

$$f = \frac{\sum_{i=1}^{I} N_i}{\sum_{i=1}^{I} X_i T_i} \quad (1)$$

where, f is the failure per turbine per year, N_i is the number of failures, T_i is the time interval (I in total of 1 year each one), X_i number of wind turbines reported.

Similarly, the downtime is the time in which the WT is not operating dur to a fault, typically comprised of time for diagnostic failure, accessing the mechanism, gathering repair equipment's and spare parts and repairing and restarting the WT. This can be calculated by (2) [27],

$$d = \frac{\sum_{i=1}^{I} d_i}{\sum_{i=1}^{I} X_i T_i} \quad (2)$$

where, d is the failure per hour per turbine per year, d_i is the lost productive hours, T_i is the time interval as a result of failure and X_i number of wind turbines reported.

4 FAILURE OF WT COMPONENT

There have been several studies conducted for the collection of reliability data, some of them including Germany, Sweden, Denmark and Finland. The data in all studies is presented in different forms, for instance, downtime distributions (%), failure rates as failures per turbine per year, failure distributions, downtime as hours lost per component. Also, factors such as types of WT, weather condition and location are also taken into account.

Tanver et al. [28] presented a correlation between weather, location and reliability of the WT due to the speed of wind. His later study [29] showed that there that is a stronger link between the temperature and humidity; weather conditions and failure rate on the reliability of the turbine than the wind speed.

Ribrant and Bertling [30] studied WT failure rate in Germany, Sweden and Finland. The failures data obtained for Germany was between 2003 and 2005 from 865 WTs, between 4% and 7% of the total. Failure rate was about 2.40 per turbine, mainly due to the faults in the sensors, hydraulic, electrical and control systems. Data for Sweden were collected between 2000 and 2004 from approximately 625 WTs ranging from 500-1500 kW. The average failure rate per turbine per year was about 0.4, newer WTs more than 1 MW had higher failures and most failures were in sensors, blades/pitch and electrical system [30-31]. Studies of about 72 WTs in Finland were done. The failure rate obtained was 1.38 per WT per year, mostly due to the blades/pitch, the hydraulic system and the gears. Overall, failures were common in sensors and blade, electrics, control and hydraulic systems in all countries. Gearbox failures accounted for the largest downtime in Sweden and Finland, followed by the control system in Sweden and blades/pitch in Finland. In Germany, generator failure accounted for the largest downtimes followed by gearbox.

McMillan and Ault [32] showed with Windstats data from Germany that the generator, rotor, main bearings and gears account for about 67% of downtime per failure. Similarly, Spinato et al. [33] analysed data from Winstats data [34] over a period of 11 years from Germany (WSD) and Denmark (WSDK). Along with this data, the study also studied data from Schleswig Holstein in Germany (LWK) [35]. From the findings, electrical systems had the highest failure rate, while gearbox led to the largest downtime per failure. Besides, larger WTs experienced higher failure rates [33] and higher costs [36].

Average failure rates of WT components are shown in Fig. 3 [13, 30, 31, 33, 37]. It can be seen that the control system, blades/pitch and electrical system have the cumulative highest failure rate, while Gears, yaw system, brake, generator are in the medium cumulative failure rate. The other components such as the drivetrain have low failure rate.

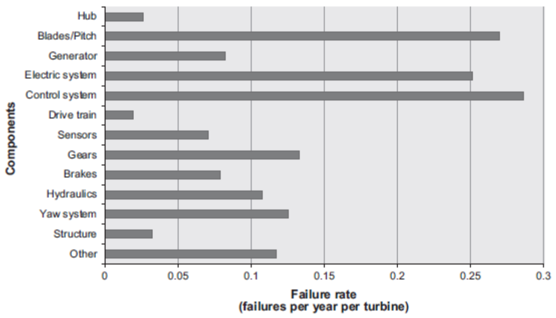

Figure 3: Average failure rate of WT components [13, 30, 31, 33, 37].

Bussel and Zaaijer [37-38] in a study presented that the blades have the highest failure rate of 0.72. Also, their work showed that the control system had failure rate per turbine per year in Germany of 0.66, but from the previous study by Ribrant and Bertling [30] it was about 0.40. Compared to Finland, Denmark or Sweden, electrical system in Germany fail more frequently [37], which could be due to the use of more electrical components in the WTs. None of the authors could find statistics or did not consider the failure rates of other components besides the ones described above, for instance, Spinato et al. [33] considered the failure rate of blades and hub combined as the rotor failure rate.

A different way of observing these studies from Germany, Sweden and Finland [31] is to look at the results as failure rates against hours lost per failure for each of the different components shown in Fig. 4. It should be noted that the hours lost per failure were obtained form downtime per turbine per year divided by failures per turbine per year.

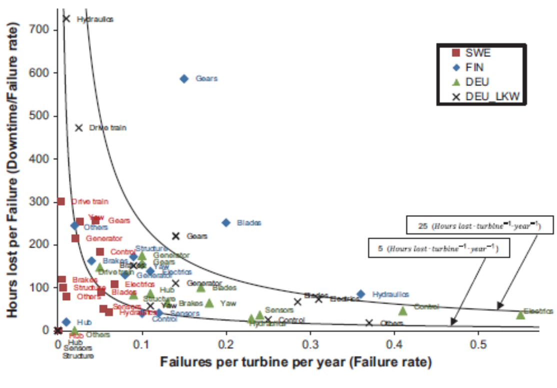

Figure 4: Rate of failure vs. hours lost per failure: Sweden (SWE), Finland (FIN) and Germany (DEU) [13, 30, 31, 33].

Also, the two curves superimposed on the plot are lines of equal downtime of 5 and 25 hours lost/turbine per year, which is just to ease the identification of components failure frequencies or the downtimes per failure.

5 CONCLUSION

- Between different studies the reported failure rates and downtimes of the generators, brakes, sensors, hubs, yaw system and structure do not vary much. The exception is the gearbox, blades and hydraulics;
- Most frequently cited components that experience failures are blades, electrical and control systems, while gearbox, blades and generator are considered to have the highest downtime;
- Gears, blades or hydraulics are considered to be the most problematic components affecting the reliability of WT, as the combination of failure rate and downtime per failure results in a high overall downtime.

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Some Methods for Assessing Wind Energy Resources of the South of Kyrgyzstan

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Keywords: Renewable Energy, Wind Energy, Geo-Information Systems, Kyrgyz Republic.

Abstract: The article discusses the creation of geographic information systems (GIS), which allow you to quickly and in detail analyze various alternatives based on the available geographically-related information for assessing the consequences of plant design options in a given wind power industry with the goals of ensuring sustainable development of the region. This mainly relates to energy facilities and systems that use wind energy sources, with their high spatial and temporal irregularity and variability. In accordance with the tasks that determine the necessary design parameters, the requirements for the initial physical-geographical, climatic, metrological, wind energy resources and energy-ecological potential information necessary for creating a GIS database arise. Estimates of wind energy and its distribution over the territory is hampered by the limited amount of energy potential in time and space. With the help of GIS, energy, economic, environmental, social issues and climate change mitigation opportunities can be solved on the basis of wind power plants, and their resources, environmental benefits, goals and objectives on scientific and methodological foundations in the field of wind power for the implementation of state programs of Kyrgyzstan for energy supply in the region.

1 INTRODUCTION

The Kyrgyz Republic is one of the states with huge renewable energy potential. First of all, it is the energy of the sun and watercourses, wind energy and biogas. The calculations of experts show that potentially renewable energy sources in Kyrgyzstan can replace up to 50,7% of the need for fuel and energy resources consumed by the republic today [1].

Use of renewable energy sources to the republic is “dictated” by natural specificity. Almost 90% of the total area of the country is occupied by mountains. Most of the population (more than 60%) lives in rural areas in the foothills and mountains, where access to traditional fuels is difficult [2]. This makes it advantageous to use local autonomous renewable energy systems that do not require connection to existing electrical networks. The use of wind power plants for power supply of such consumers will be much cheaper. The lack of good roads in the mountains, their insufficient length and branching makes the delivery of traditional fuel and energy resources (coal, gas, fuels and lubricants, etc.) very expensive. For poor, low-powered and autonomous consumers, such expensive fuel will not be affordable. In this situation, renewable energy is the only available opportunity for villagers to solve energy problems.

2 METHODS FOR ASSESSING WIND ENERGY RESOURCES

The potential of wind energy in the regions of the Kyrgyz Republic is different and varies depending on the speed from 0,8 to 6 m/s [3]. Estimation of wind energy potential, based on generalized statistical data of weather stations and methods for calculating wind reserves based on known average annual wind speeds, made it possible to establish that the Republic wind potential is 49,2 105 ton of fuel. An analysis of the specific power of the wind flows in Kyrgyzstan shows that it varies within fairly large limits. According to annual data, it is 40-180 W/m^2, and monthly – 30-230 W/m^2, the average – 100 W/m^2. The average annual specific energy of the wind flow varies from 170 to 1300 kWh/m^2. Their mean monthly values, as a rule, do not exceed 50-60 kWh/m^2. Analysis of the data shows that for large-scale and medium-scale wind power, the dispersion of indicators makes it possible to use only 17-22% of the potential wind power resources to be economically justified. However, a comparison of the need for small objects in electrical energy with the data of the wind inventory shows that for this type of consumers the wind energy potential is sufficient and can be successfully used to cover their energy needs. According to estimates, out of 2 billion kWh per year of the gross potential of the energy of wind flow in Kyrgyzstan, no more than 140 million kWh are technically justified, no more than 4 million kWh can be considered economically viable for development. This is due to the specific conditions of the distribution of the wind rose in the highland regions. Analysis of the wind flow features showed that over 50% of all Kyrgyz winds fall on light winds and calm, 30-40% on light winds (2-5 m/s) and the rest on moderate and fresh winds (6-10 m/s).

From the meteorological data, the average wind speed in the foothill areas of the Osh region reaches up to 20 m/s, which indicates the possibility of large-scale use of wind power installations. According to regulatory data, if the wind speed is in the range of 4,5 to 20 m/s, then these figures are considered sufficient for the introduction of wind power plants in these areas.

In Table 1-6 shows the average monthly and annual wind speed, repeatability of wind directions (in %) per year, average monthly and annual wind speeds at different hours of the day, the number of days with strong wind (15 m/s), the probability of wind of different speeds in directions in %, wind speed for 2017 for the city of Osh. The most densely populated valleys with an average annual wind speed are summarized and given in Table. 7

Table 1: Average monthly and annual wind speed, m/s.

Osh	I	II	III	IV	V	VI	Year
	1,9	2,1	2,3	2,4	2,8	3	2,3
	VII	VIII	IX	X	XI	XII	
	2,5	2,4	2,4	2,4	2	1,8	

Table 2: Repeatability of wind directions (%) per year.

Direction	N	NE	E	SE
Osh	6	6	5	8
Direction	S	SW	W	NW
Osh	45	5	14	11

Table 3: Average monthly wind speed at various hours of the day, m/s.

Osh		I	II	III	IV	V	VI
	1	2,3	2,4	2,4	2,8	2,9	3,4
	7	2,2	2,4	2,3	2,4	2,8	2,9
	13	1,5	2	2,8	3	3,2	3
	19	1,7	1,4	1,5	1,5	2,3	2,7
		VII	VIII	IX	X	XI	XII
	1	3	3	2,8	2,9	2,2	2
	7	2,6	2,4	2,4	2,3	1,9	2
	13	3	3	3,1	2,9	2,1	1,7
	19	1,5	1	1,3	1,6	1,5	1,6

Table 4: The number of days with strong winds (15 m/s).

Osh	I	II	III	IV	V	VI	Year
	0,9	0,4	0,6	1,8	1,9	3,2	0,9
	VII	VIII	IX	X	XI	XII	
	1,4	0,2	0,1	0,2	0,2	0,4	

Table 5: The probability of wind of various speeds in the directions, %.

Osh	Speed, m/s	N	NE	E	SE
	0 – 1	3,2	2,8	3	3,4
	2 – 5	3,06	3,2	2,6	4,3
	6 – 9	0,07	0,2	0,2	0,14
	> 10	-	0,01	0,1	0,02
	Speed, m/s	S	SW	W	NW
	0 – 1	18,1	2,4	4,9	4,36
	2 – 5	25,6	2,5	6,9	6,6
	6 – 9	0,57	0,2	0,94	0,07
	> 10	0,05	0,07	0,15	0,01

On a large part of the flat and foothill zones, where the main low-power consumers are located, its energy potential is low. In zones where there are winds with high energy potential and wind speeds of 8-12 m/s, consumers are practically absent. Therefore, it seems promising to develop small wind energy (1-10 kW units) and, first of all, for the power supply of low-energy autonomous consumers located in decentralized foothill and remote mountainous areas.

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Table 6: Wind speed in Osh for 2017.

2017 year	Month					
	Jan.	Feb.	March	April	May	June
I decade	0,64	0,65	0,89	0,94	0,79	0,9
II decade	0,76	0,81	0,77	0,99	0,93	0,92
III decade	0,75	0,81	1,08	0,87	0,87	0,71
Month average	0,72	0,75	0,92	0,93	0,86	0,84
Month maximum	5,5	6,63	8,32	9,19	8,18	13,53
	July	Aug.	Septem.	Octob.	Novem.	Decem.
I decade	0,9	0,85	0,60	0,54	-	-
II decade	0,7	0,76	0,64	0,59	-	-
III decade		0,68	0,62	0,58	-	-
Month average	0,8	0,76	0,60	0,57	-	-
Month maxi-mum	6,94	8,42	6,10	7,0	-	-

Note: The wind speed is defined in m/s. The maximum wind speed is an instantaneous value (gust).

Table 7: Average annual wind speed.

№	Name of the observed areas	The number of days in a year a strong wind of 10-25, m/s	Average annual speed, m/s
1.	Sary - Tash	7	2,5
2.	Dzantyk	45	3,5
3.	Daroot - Korgon	14	2,6
4.	Kyzyl - Dzhar	9	2,4
5.	Gulcho	2	0,8
6.	Ozgon	5	1,6
7.	Osh field	10	2,3

All of the above factors indicate the urgent need to develop a wind energy inventory. To systematize the characteristics of the wind situation in a particular region for the purpose of its efficient energy use, as a rule, a wind energy cadastre is developed, which is a combination of upper-air and energy characteristics of the wind, allowing determining its energy value, as well as appropriate parameters and operating modes of wind energy installations. The main characteristics of the wind energy inventory are:

- Average annual wind speed, annual and daily wind speed;
- Speed repeatability, types and parameters of velocity distribution functions;
- Maximum wind speed;
- Distribution of wind periods and periods of energy lag by duration; - specific power and specific wind energy;
- Wind energy resources of the region.

The most convenient way to use the wind energy cadastre is the development of a geographic information system (GIS) “Wind Energy Cadastre of Kyrgyzstan”.

The final task of the developed GIS technology is the formation of a benevolent information environment for the user a visual map.

The data can be used by end users, whether it is an investor or a farmer, a person engaged in farming, animal husbandry, bee keeping. Why install wind turbines in a particular area, the area with what power type wind turbines, the interested person can find the answers through the global network.

If the GIS inventory is multi-component either includes the wind, the sun's biomass, the flow of the rivers, this makes it possible to estimate the energy potential as a whole, it also makes it possible to predict the climatic conditions, the weather, the yield, of a particular region or area.

3 CONCLUSION

As the studied experience shows, one of the obstacles in the practical use of renewable energy technologies is the low public awareness of the possibilities of these technologies and technical illiteracy in the installation and operation of equipment. Therefore, it is extremely important to conduct educational work among the population to disseminate information about these technologies.

Mapping of wind - energy resources would give a preliminary assessment of measures to reduce emissions in the energy sector from the use of wind turbines from one meter square.

GIS will allow assessing the competitiveness of the projects considered regarding quotas in the region and rank them according to the degree of attractiveness to investors.

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Design and Practical Evaluation of the PVT Concentrator System Concept

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Keywords: PVT System, PV System, Concentrators, Thermal Performance.

Abstract: The purpose of this work is to propose a novel and effective photovoltaic-thermal hybrid solar system (PVT) with thermal and electrical output for small households. Such design allows the use of standard industrial photovoltaic modules in areas with low solar irradiation. The base of the system is a parabolic solar concentrator that increases the density of an irradiation flow on the photovoltaic module surface. To prevent the system from damage caused by overheating, redundant thermal energy can be used in a house heating system or should be removed by a cooler, boiler, etc. The proof of concept has been realized as a standalone PVT system with thermal and electrical output and successfully tested under natural conditions.

1 INTRODUCTION

Nowadays, the public consciousness is growing the conviction that the energy of the future should be based on large-scale use of solar energy, and in its most diverse manifestations. The sun is a huge, inexhaustible, safe source of energy. The growth rates of wind and solar energy in the world have been 30% or more for several years, which exceeds the growth rates of traditional coal and gas energy by an order of magnitude.

Reducing the cost of electricity production is possible in two ways: decreasing the cost of a solar battery and improving the efficiency of energy collection.

The implementation of the first method of possible ways [1]:

- Cost of production reduction - the creation of automated production plants;
- Cheaper silicon by replacing monocrystalline silicon by polycrystalline and multicrystalline silicon;
- Replacement of silicon by other materials, such as gallium arsenide.

As for the second method, you can increase efficiency [2]:

- Using tandem installations, multilayer photodetector at heterojunctions, although this increases the cost;
- Using a double-sided photoelectric converter, this significantly increases efficiency;
- Various concentrations are added, which are accompanied by an increase in generated energy, and accompanied by an increase in temperature, which negatively affects the efficiency;
- Introduced a tracking system for the sun.

2 DESCRIBE OF PVT SYSTEM

The installation is a hybrid system that converts solar energy into electricity and heat (Fig. 1). The sunlight falling silicon photovoltaic modules are converted into electricity. Production of heat occurs at the expense of the cooling of photovoltaic modules.

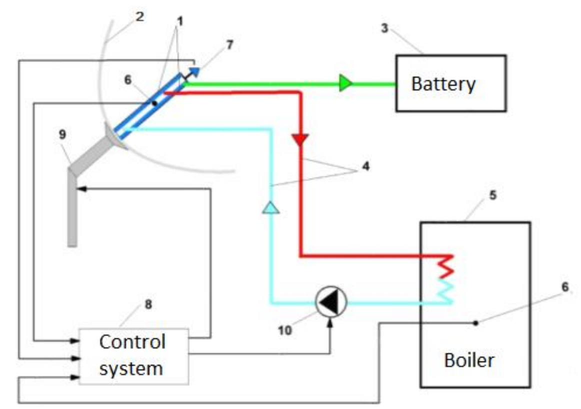

Figure 1: PV concentrator system with a heat sink: 1 is PV module, 2 is Concentrator, 3 is Accumulator Battery, 4 is Copper Tubes, 5 is Boiler, 6 is Temperature Sensors, 7 is Sensor of Tracking System, 8 is Control System, 9 is Rotating device, 10 is Pump.

The low concentrator is added to the system to increase energy production. The concentrator is a parabolic reflector.

Coming radiation flux falls on the concentrator and is reflected on the photovoltaic module. The plane of the solar module is located perpendicular to the flow of the reflected radiation. Direct light is not incident on a photovoltaic module.

The photovoltaic module consists of the two panels arranged in parallel to each other. The area between the photovoltaic modules is filled with the liquid. The photovoltaic modules are cooled by the liquid flow at the same time the liquid is heating.

The concentrator consists of two parabolic reflecting surfaces. The concentrator can be made of any material that meets the economic and operational tasks, such as metal or plastic with a reflective coating [2].

To increase the energy production is added in the low reflective concentrator. The concentrator provides increased density of the incoming solar energy flow in 2-3 times, thereby increasing the efficiency and the production of electricity. Also because of the increase in incoming solar flux on the surface of the PV module is heated; which leads to loss of efficiency and, when heated to a temperature above 130 °C, delamination or deterioration of elements of ohmi contacts photocells [1, 2].

The cooling system is a typical thermal solar system. Any liquid with a high specific heat capacity, such as glycol, mineral oil or water, can be used as a coolant. The easiest and most affordable option is water. Water is pumped from the bottom and moved upward by the pump. A configuration of cooling system is coil.

The control system consists of the several subsystems that control individual units. Harmonization of all subsystems is based on a microcomputer BeagleBon. Power for BeagleBon will be provided directly by PV modules as well as other sensors. The microcomputer will form a database of system and save it. That will optimize the system.

Management of PV: Battery control will be based on the MPPT-controller.

The system orientation to the sun is realized on the basis of the active tracking system [3]. The active system determines itself the position of the sun and issues a control signal to correct the position. Accordingly, the passive system works according to given astronomical data on the position of the sun during the day. Passive system is less effective on cloudy days.

The solar tracking system based on the photoelectric sensor. In our system we use three photovoltaic inverters A, B and C [4].

Control cooling system. The subsystem monitors the temperature of the coolant at the inlet and outlet of the solar panel [5, 6].

If the temperature difference at the inlet and outlet is less than the minimal value (approximately 5°), the pump power is decreased; if greater than the maximum value, it is increased (approximately 20°).

Authors see a prospect for alternative energy usage for small villages and private houses in distant and remote terrain (example, villages in a taiga, and houses of forestry officers in national parks).

3 THE MATHEMATICAL MODEL OF PVT SYSTEM

Numerical modeling of a PV concentrator system is designed with the help of Simulink/MatLab and is presented in [7]. MatLab works with matrix data and enables to create a custom calculated program. Simulink implements the principle of visual programming: the user uses the library to construct the model, configures the solver and calculation step.

The electrical model is based on the double exponential model of the photovoltaic cell. The model for the proposed range of the equivalent circuit elements, irradiance and temperature as model inputs, with the corresponding values of voltages, currents, and power as outputs is presented [8].

The voltage is set by uniformly time-varying signals. The current values are calculated for a definite voltage value at each step. The temperature effect is taken into account when modeling the photocurrent and diode saturation current [9]. Possible differences in the parameters of the diodes in the equivalent circuit are taken into account, as they have a significant impact on open-circuit voltage and power output.

The thermal model bases on the transfer of heat from hot to cold bodies. The model takes into account the heat flow from the heat protective glass flow and heat energy directly to the photovoltaic cells [10, 11]. In the thermal part of the calculated temperature value transmitted to the module and the electric part, wherein on the basis of this temperature is determined by the operating current and voltage.

4 THE FIELD TEST FOR PVT SYSTEM

The field experiment was conducted. The experimental results have shown efficiency of the installation. A great influence on the electrical output has a minimal deviation from the direction of the sun (Fig. 2).

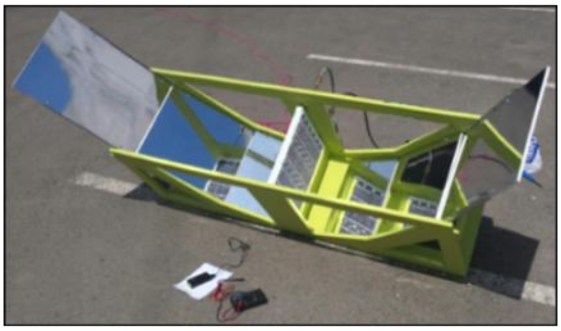

Figure 2: The concept of PVT system with concentrator.

The temperature of the photovoltaic modules was measured prior to testing and was 22 °C, which corresponds to the ambient temperature (Fig. 3).

At the first stage, the heating time of the entire system on a sunny, clear day was monitored using a concentrating system (Fig. 4 and Fig.5).

The temperature of both PV modules is the same (Fig. 4 and Fig. 5) since the concentrator reflects the same stream of sunlight and has an identical design. The tracking system also provides accurate position to the sun, which ensures the equality of energy that comes to each concentrator. Therefore, thermograms for only one module will be given below.

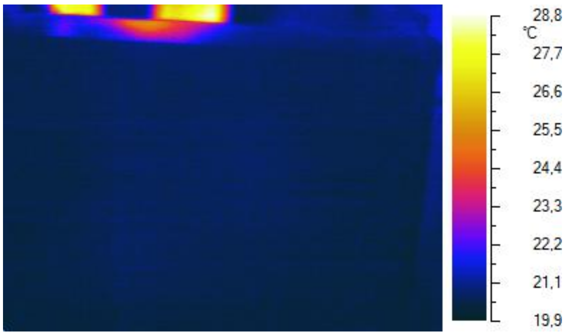

Figure 3: PV module in the initial state. Module temperature is equal to ambient temperature.

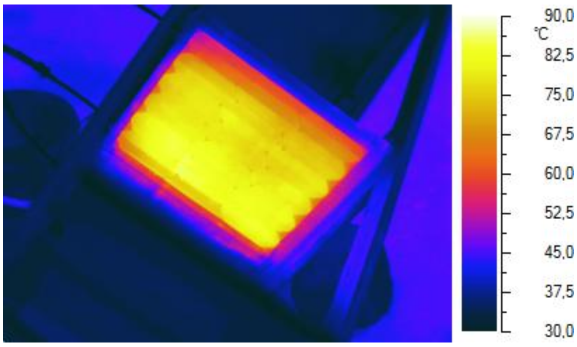

Figure 4: Operating, without cooling: Side A– 10 minutes.

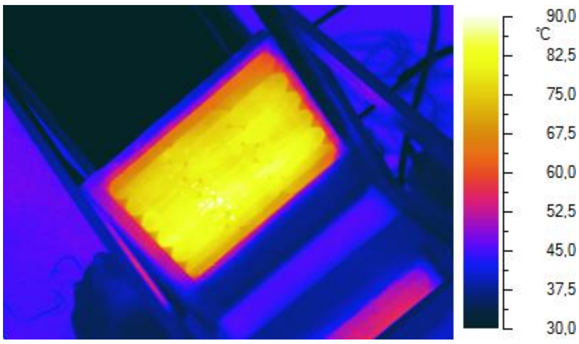

Figure 5: Operating, without cooling: Side B– 10 minutes.

At the second stage, the cooling system was connected, and observations were made on the quality of the cooling system (Fig. 6-8).

After the cooling system has been operating for 10 minutes (Fig. 6), the heating of the module has slightly decreased.

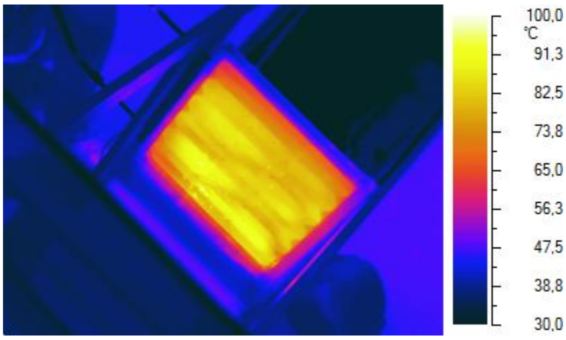

Figure 6: Operating with cooling: side A: Cooling - 10 minutes.

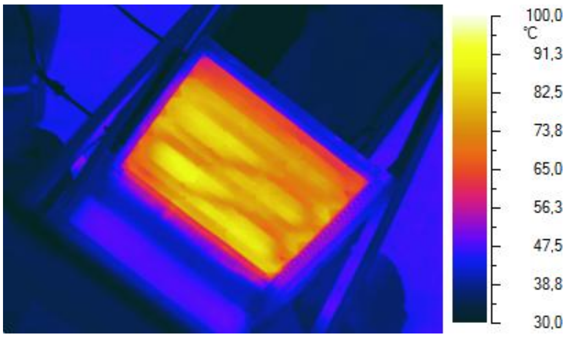

Figure 7: Operating with cooling: side A: Cooling - 15 minutes.

After the cooling system had been running from 15 minutes (Fig. 7), the heating of the module decreased. Maximum cooling is achieved in the zone of direct contact of the cooling tubes with the module. For better cooling, it is necessary to increase the area of this contact.

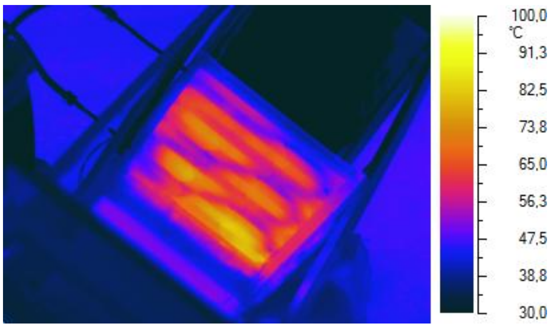

Figure 8: Operating with cooling: side A: Cooling - 50 minutes.

After the cooling system had been operated for 50 minutes (Fig. 8), the system went into balance. The temperature level of the modules remains the same. The average temperature is about 50°C, this mode of operation does not lead to the destruction of the module structure and significant energy loss.

As a result of the field experiment, it was revealed that this system works. The heating of the PV modules surface with a 2-times concentration of solar radiation occurs quickly. Achieving a temperature that is dangerous for a photovoltaic device at a temperature of 90 °C occurs within 10 minutes (Fig. 3-5). When the temperature setting to 60 ° C, power generation decreased by 8,2% and at a temperature of 90 °C decline in power output is 18%. When the cooling is turned on there is a significant cooling (about 30 °C).

According to the results of the experiment can be said that the cooling system is functioning well. To increase the cooling uniformity in the design can be changed or to add absorber, as well to augment the number of turns of the coil. It is possible constructive change of the system to provide more uniform cooling.

5 PVT OPERATION MANAGEMENT

The management system provides for the collection of information about the PVT system, the processing of information and the issuance of control actions. The central control unit is the BeagleBone Black mini-computer. The control system controls the orientation of the sun and cooling.

The priority of the cooling system is to keep the panel temperature below 60 ° C. At the same time, if possible, the system will circulate in the system to ensure its heating for the consumer.

The priority of the tracking system is the accuracy of the orientation of the position of the sun for uniform and maximum energy production by each concentrator.

The system loop control algorithm is shown in Appendix.

First, the temperature sensor is read and the temperature t0 of the photovoltaic panel is calculated. The mode of operation of the pump is selected depending on what range is the temperature of the panel. For example, if the panel temperature is below 40 °C, cooling is not required and the pump is turned off. When the temperature rises, the pump speed automatically begins to increase, which provides more intensive cooling of the photovoltaic panel.

After performing the control and temperature adjustment, the program proceeds to the execution of the system positioning algorithm. The solar tracking system based on the photoelectric sensor [4]. In our system we use three photovoltaic inverters A, B and C (Ipv_1 is signal A, Ipv_2 is signal B, Ipv_3 is signal C). Two obverse of elements A and B define the position of the sun; the third rear element (C) accepts influence of scattered radiation. The signal of the received element C is subtracted from signals of the elements A and B. The device compares the signals and then generates a control signal to the motor (whether to east or to west), which directs the solar battery. The maximal signal from the rear element returns the solar module to its original position at sunrise

6 CONCLUSION

The proposed solution is a novel and effective PVT system aimed to use in small households as an electrical and thermal source.

To increase the efficiency of the PVT system, several methods have been applied:

- Solar tracking has been used to achieve smooth and highest straight irradiation.
- The parabolic solar concentrator has been used to increase the amount of incoming solar irradiation. As the negative impact such method leads to overheating of the PV module surface.
- The cooling system has been used to remove redundant and dangerous heat from the PV module surface and used in the house heating system.
- Control and monitoring system has been implemented under BeagleBone Black microcomputer. Such a platform is relatively cheap, flexible and easy to deploy.

The proof of concept has been implemented and tested under natural conditions. Experimental results show that usage of the proposed combined PVT system with an included parabolic concentrator and cooling system leads to a significant rise of the converting solar energy.

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APPENDIX

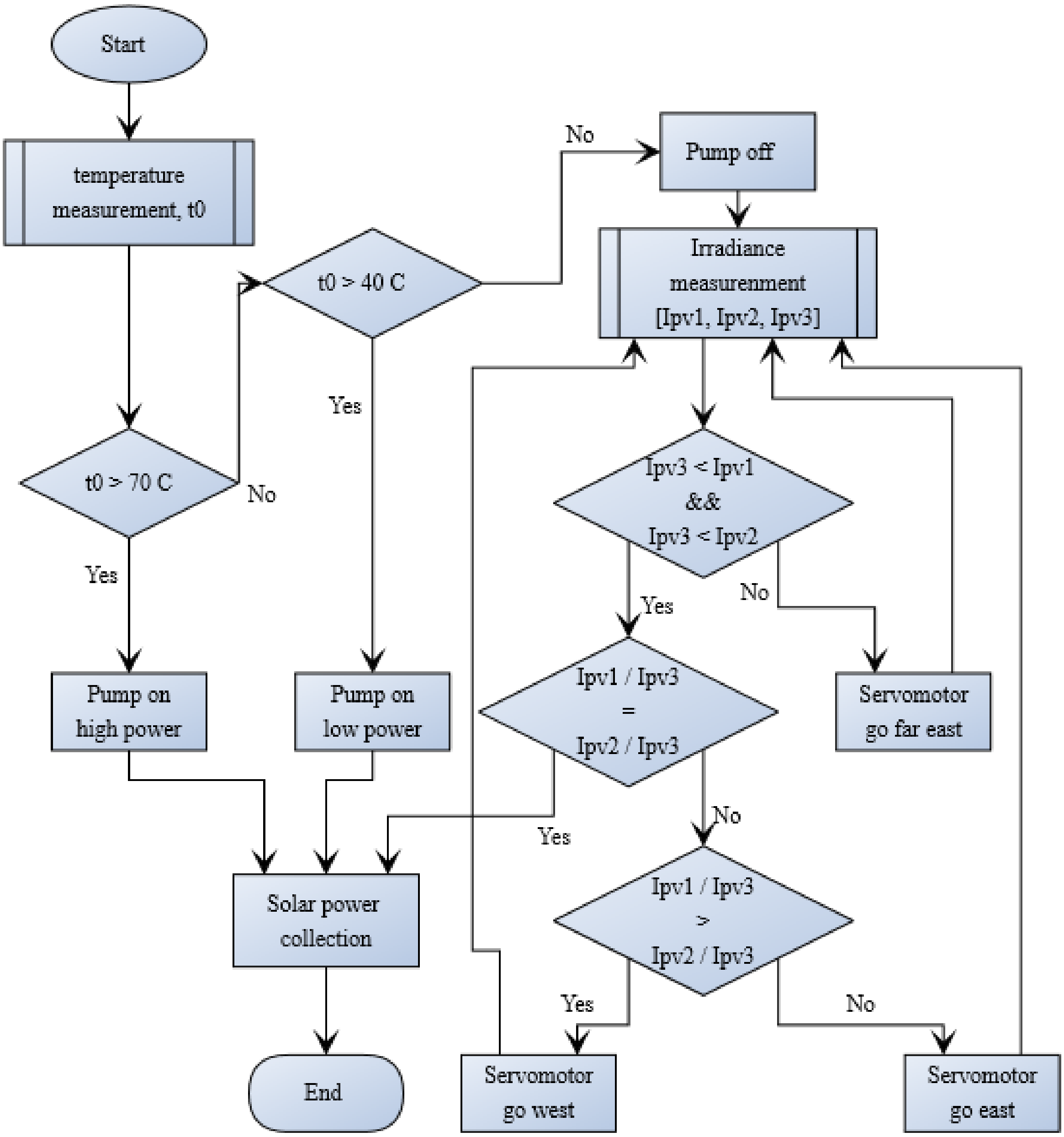

Figure A: Algorithm of PVT operate cycle.

Analysis of Increasing Efficiency of Gas Turbines by Using Absorption Refrigerator (AR)

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Keywords: Ambient Air Temperature, Air Cooling Efficiency, Gas Turbine, Gas Turbine Power Plant.

Abstract: The paper presents an analysis of the gas turbine power plant's (GTPP) operation. It is shown that in summer the efficiency of GTPP is significantly reduced due to the high air temperature on the inlet of the compressor. In the summer, the efficiency and, accordingly, the production of electric energy is reduced due to high temperatures of the ambient air. This article presents an analysis of the possibility of increasing the efficiency of the gas turbine engine. The analysis shows that the use of absorption refrigerator (AR) in hot periods of the year, in which the outside air temperature exceeds 20 degrees is the optimal solution. The analysis showed that the use of AR allows to increase efficiency and specific heat consumption by 3 %, capacity by 14 % (5,5 % annually) MW and reduce fuel consumption by 2,5-3 %. The experience of modernization of gas turbine unit (GTU) is available, for the installation of AR it will be required about 2500 million tenge (6000 US dollars). Taking into account the economic effect of 740 million tenge, a simple payback period for the introduction of air cooling systems at GTPP will be about 4 years.

1 INTRODUCTION

The prospect of using gas turbines at an industrial facilities in Kazakhstan compared with other types of heat engines [1] is associated with their high energy intensity, autonomy, which does not require additional energy. The efficiency of the gas turbines depends on a large number of factors. One of the most important elements of the gas turbine is air compressor. In most cases, 50 % of the output of the turbine is consumed by a compressor connected by a single shaft in a gas turbine.

Under normal conditions, the air content of the gas-air mixture reaches 98 %. In the warm period of the year, the thermo physical properties of air changes. An increase in temperature and a reduction in air density lead to a decrease in the electric power of the gas turbine unit [2-18, 21] which increases in the specific fuel consumption.

Cooling of the inlet air can compensate these negative factors. The main methods of cooling are following: the use of evaporative coolers, fine dispersion of air behind the filter and the use of refrigeration machines - the latter allows you to obtain the maximum depth of cooling.

The authors [2] studied the influence of temperature decrease on the compressor suction to 12 °C. The results showed that the use of cooling increases the generation of electrical energy in the case of evaporative systems by 27,5 %, in the case of chillers by 32,11 %. The study [3] of reducing the temperature at the suction of GTU compressors used in the production of propane by 1 °C and increased the production of electrical energy by 0,53 %, and the thermal efficiency by 0,22 %. With a decrease in the air temperature at the inlet of compressor from 40 to 15 °C, propane production rises by 245 barrels per day or 40 m^3/day, which leads to savings of 18 thousand dollars a day. The payback period according to [3] is 8,5 months with 100 % use of these installations.

The results of studies [4] showed that at an ambient temperature of 37 °C, cooling by absorption coolers led to an increase in the production of electrical energy to 25,47 %, and a thermal efficiency of up to 33,66 %, which reduced the cost of electrical energy by 13 %. The use of evaporative coolers increased power by 5,56 % andefficiency by 1,55 %.

The authors of [5] showed that at a temperature before the turbine is equal to 1700 K, a compression ratio of 23 and an ambient temperature of 313 K with the use of vapor compression coolers, the generation of electrical energy increased by 18,4 %, and the efficiency increased by 4,18 %. However, it is noted that in geographic regions with low relative humidity and low temperatures, the preferred scheme is the use of vapor compression units

The authors [6] presented a new type of coolers, which is called indirect evaporative cooling system. This system is a humidifier and a vapor compression unit. At 45 °C the use of this cooler led to an increase in power by 15 % and efficiency by 9 %. The use of these chillers with mechanical chillers (dry cooling towers) resulted in a power increase of power by 7,81 % and an efficiency by 2,24 %. But the latter have a higher cost, which increases the payback period.

Articles [7-8] present the results of the study of evaporative coolers at the inlet to gas turbine plants with steam injection. The results showed that by using the evaporative coolers, the efficiency of the turbine increased by 6,91 %, and the electric power by 16,42 % for simple cycles, and for the combined-cycle plant, the power increased by 17,34 %.

In addition to these authors, there are many different ways to increase the efficiency of the turbine, by reducing the air temperature at the entrance to the gas turbine unit [9-15]. Especially interesting the use of ammonium-water absorption cooler in [13]. Energy and exergetic analyzes showed that the heat station produced an additional 9440 kW of energy, thereby increasing the thermal efficiency by 1,193 % and the exergy efficiency by 1,133 %. In winter time, the increase in power does not exceed 400 kW.

The article analyzes the operation of the GTPP at an industrial facility. All data are taken from the equipment passports and the results of the energy analysis.

2 ANALYSIS OF POWER GENERATION

The main purpose of GTPP is the supply of electric energy, the excess amount of electric energy is intended for export. According to 2017, electricity for production needs is 75 %, and electricity exports are 25 %.

There is no system for utilizing the heat of exhaust gases after GTU. In the design documentation of the power plant, it is stipulated that in the future the system of using the heat of exhaust gases after turbines should be introduced.

3 ANALYZED AIR COOLING SYSTEM

Cooling with a secondary coolant (cold water). This cooling is combined with energy conservation systems or with cooling heat exchangers, the refrigerant into which is supplied directly from the chiller. Unlike direct refrigerant cooling, these systems consume the energy of the pumps. Due to the fact that the piping of the direct cooling systems is low (due to the standard chiller size), and the cold water circulates in the channels under low pressure more freely in comparison with the primary refrigerant, the system is practically protected from leaks. In addition, it is easy to install, maintain and operate. Such systems are most preferably used in GTUs operating in the base mode for a long period of time.

As the source of heat, AR uses the heat of the exhaust gases GTU, steam or hot water. The AR scheme is shown in Figure 1.

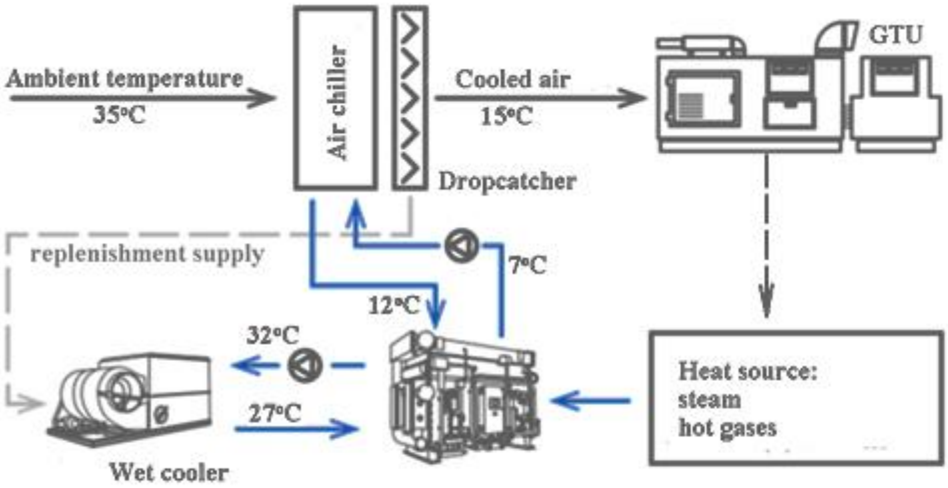

Figure 1: Structural scheme of AR.

4 MATHEMATICAL MODELING

A gas turbine is a heat engine that converts chemical energy of the fuel into potential energy and after that potential energy into a mechanical energy. Depending on what is installed on the turbine shaft, this can be electrical energy or mechanical compression energy of the compressor. The gas turbine consists of three main elements: an air compressor, a combustion chamber and a gas turbine itself. The principle of the gas turbine operation is as follows: from the atmosphere, the air is taken up by the compressor, after which it is supplied to the combustion chamber at elevated pressure, where liquid or gaseous fuel is simultaneously supplied from the gas compressor. In the combustion chamber the air is divided into two streams: one stream in the amount necessary for combustion enters the fire tube, the second flows around the flame tube from the outside and is mixed with the combustion products to decrease from the temperature. The combustion process in the chamber occurs at an almost constant pressure.

The gas, obtained after mixing and combustion, enters the gas turbine, expanding, completing the work, then discharging into the atmosphere (Fig. 2).

Unlike the steam-turbine unit, the GTU's useful power is 30-50 % of the turbine's power. The useful power fraction can be increased by increasing the gas temperature in front of the turbine or by lowering the temperature of the air sucked in by the compressor. In the second case, the work required to compress the air in the compressor is reduced.

In mathematical modeling, Water Steam Pro program [22] was used, which allows to calculate the parameters of gases, in particular air and combustion products. Before the analysis, the results obtained by the program were compared with the passport data of gas turbine units. The results are shown in Figure 3. The error in the data does not exceed 4%, which indicates a sufficiently reliability.

The calculation of gas turbine units main parameters, such as efficiency, power were calculated according to [4, 22-27].

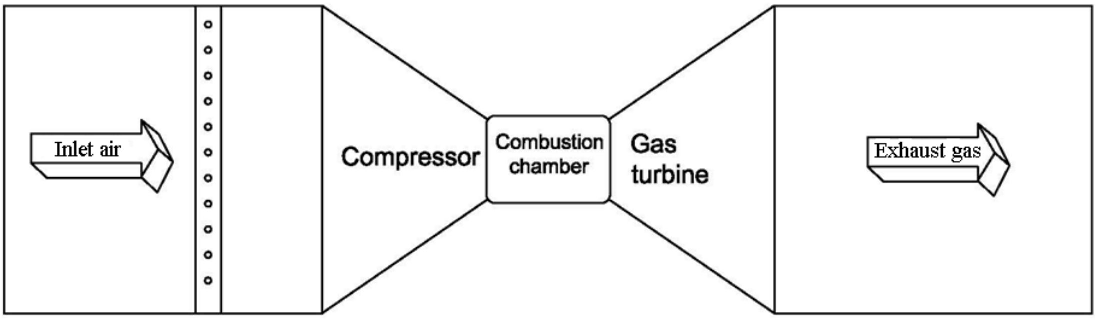

Figure 2: Schematic diagram the gas turbine.

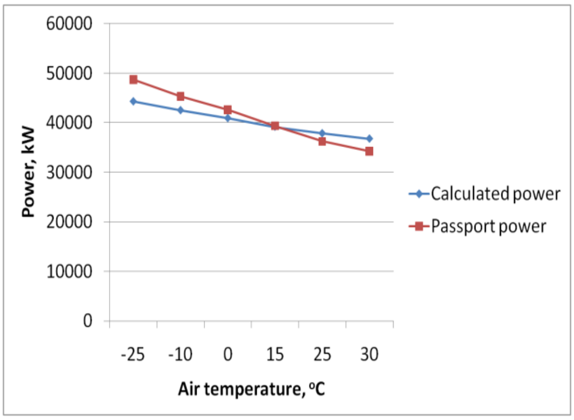

Figure 3: Approbation of the program for calculations.

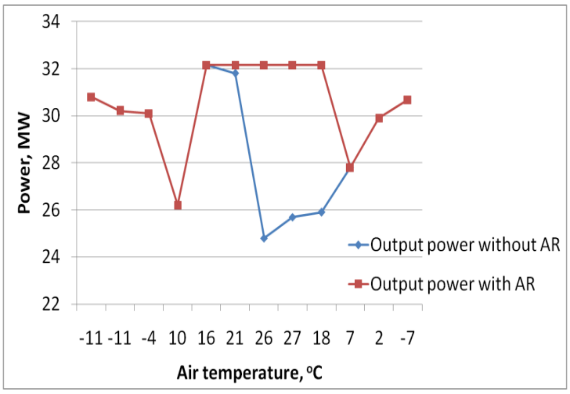

Figure 4: Power depending on air temperature.

5 RESULTS

Figure 4 presents an analysis of the power calculation for various real statistics on the outdoor air temperature in Western Kazakhstan, where gas turbine plants are operated. It can be seen from the graphs that when the temperature rises above 21 degrees there is a significant drop in power up to 7 MW. This is due to the increase in air temperature, which leads to an increase in the specific operation of the compressor.

Figure 4 shows that when AR is used, it is possible to reduce the temperature at the compressor inlet to an optimum of 15 °C. This allows to significantly increase turbine power. Taking into account the fact that AR does not need high power, this circumstance indicates a great potential for implementation. In the hottest period, the power difference is 7 MW, which is a significant indicator.The average increase in power in hot period is 14 %, the average annual increase in power is equal to 5,5 %.

Figure 5 shows the dependence of the efficiency of GTU on the outside air temperature. As can be seen from the figure, in the hot months, there is a significant reduction in efficiency up to 3 %. This is particularly noticeable in the range 21-18 ° C. The use of AR allows a significant increase in efficiency in a hot period of time. In the rest of the time, it is assumed that AR will be shut off or else cold will be used elsewhere.

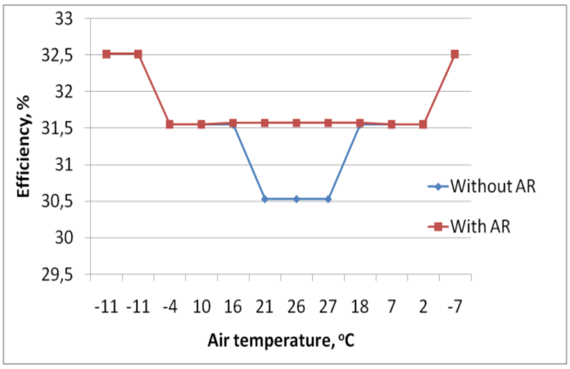

Figure 5: Dependence of efficiency from ambient air temperature.

Figure 6 shows the dependence of the specific heat consumption on energy production. As can be seen from the graphs, the presence of AR allows a significant reduction in the specific heat consumption. In the hot period between 16 and 18 degrees, the average heat consumption is reduced by 3 %.

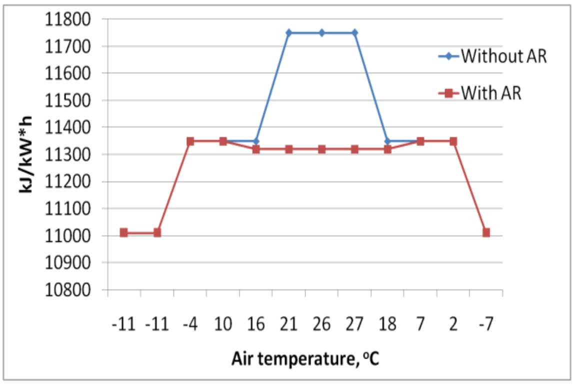

Figure 6: Specific heat consumption.

Reducing the specific heat consumption leads to a significant reduction in fuel consumption (Fig. 7). In hot months, the difference is 2,5-3 %. Considering the number of hours that fall for a hot period of 2160 hours, the annual fuel economy is 14,2 thousand m^3.

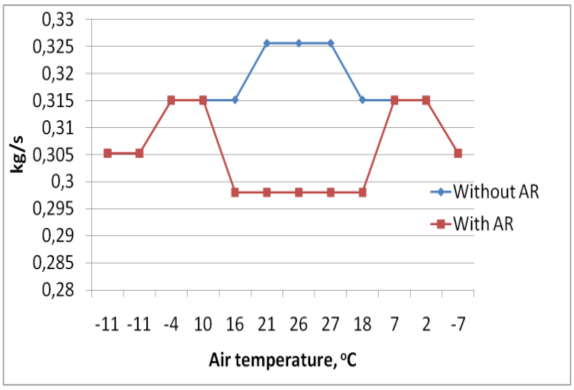

Figure 7: Fuel consumption per second.

6 ANALYSIS OF THE POSSIBILITY OF INCREASING THE EFFICIENCY OF GTTP

As the temperature increases, the specific heat consumption increases, which in turn leads to a decrease in the efficiency by 4 %. This negative factor can be eliminated by cooling the air supplied to the gas turbine.

For climatic conditions of the Republic of Kazakhstan, the period of demanded air cooling at the entrance to the turbine will be the end of April - September, that is, about 150 days. If we assume an average power increase of 14 %, then the additional power will be:

$$\Delta P = P_{guar}*0,14*150*24 = 504\ P_{guar} MWh$$

Let, for example, the guaranteed capacity of four operating turbines P_{guar} = 147 MW, then an additional GTPP will be produced in a year:

$$\Delta P_{annual} = 147*0,14*150*24 = 74088\ MWh$$

Taking the cost of electricity at the level of 10 tenge (3 US cents) per kWh, we will get an economic effect at the level of:

$$E_{annual} = 74088*10 = 740880 \text{ thousand tenge (1949684 US dollars)}$$

At the same time, for the life cycle of the air cooling system (about 30 years), the GTPP will additionally generate about 1270,000 MWh of electric energy.

7 CONCLUSION

The analysis shows that the use of AR in hot periods of the year, in which the outside air temperature exceeds 20 degrees is the optimal solution. The analysis showed that the use of AR allows to increase efficiency and specific heat consumption by 3%, capacity by 14 % (5,5 % annually) MW and reduce fuel consumption by 2,5-3 %. The experience of modernization of GTU is available, for the installation of AR it will be required about 2500 million tenge (6000 US dollars). Taking into account the economic effect of 740 million tenge, a simple payback period for the introduction of air cooling systems at GTPP will be about 4 years.

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