International Journal of Engineering Trends and Technology Volume 68 Issue 12, 43-47, December 2020
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V68I12P208

Increasing Energy Efficiency and Reliability of Electric Supply of Low Power Consumers

N.N. Sadullaev[1], U.T. Mukhamedkhanov[2], SH.N. Nematov[3], F.O. Sayliev[4]

[1]*Professor, Bukhara Engineering Technology Institute, Bukhara, Uzbekistan,*
[2]*Professor, Tashkent State Technical University, Tashkent, Uzbekistan.*
[3,4]*doctoral student, Bukhara Engineering and Technology Institute, Bukhara, Uzbekistan,*

nasullo68@mail.ru, m-ulugbek@mail.ru, mrshuxa@mail.ru

Abstract – *In the article, a principle construction "hybrid" is a source of electric power consisting of wind power installation with a mechanical store of Energy, the solar panel with battery in common working with an electric network. The method of estimating the Energy of efficiency of the objects eating from several energy sources is offered. It is proved the efficiency of application of such source of the electric power low power consumers. It is proposed to use the coefficients used in assessing industrial enterprises' energy efficiency in assessing the efficiency of using alternative energy sources. It also offers a low-speed axial generator designed for the wind turbine. The use of an axial generator in wind power plants reduces the gearboxes' cost in the system and allows efficient use of the available energy flows. Hybrid systems consisting of alternative energy sources are a key factor in improving the reliability of power supply to remote areas. Improving the reliability of power supply allows improving the region's socio-economic situation, developing small business and private entrepreneurship.*

Keywords – *Hybrid, wind power installation, solar panel, mechanical store of Energy, energy efficiency, reliability of electro supply, the low power consumer, an alternative energy source.*

I. INTRODUCTION

One of the urgent problems of the electric power industry in the world is the uninterrupted power supply to consumers, especially in rural consumers, where power supply interruptions often and for a long time occur. One way to solve this problem is to install low-power alternative sources of electricity for these consumers, which will increase the reliability of the power supply and improve the environment.

Today, many scientists in the world conduct a lot of research in the field of intelligent networks. For example, Gaynanov D.A., Kashirina E.S., Khabirova Y.F. About the effective ratio of traditional and renewable energy sources in Russia's electric power industry [1]. The article considers the task of determining the effective ratio of the use of traditional and renewable energy sources and building predictive estimates of the development of the electric power industry in the Russian Federation.

U. A. Tadjiev, E. I. Kiseleva, M.U. Tadjiev, R. A. Zakhidov. Features of the formation of the wind flow over Uzbekistan's territory and opportunities for its use for electric power: Part 2.[2] The article provides estimated Energy, mechanical, and cost indicators of promising wind power plants suitable for use in various Uzbekistan regions, taking into account differences in wind conditions, terrain orography, and synoptic factors.

B. Urishev. Microgrid Control Based on the Use and Storage of Renewable Energy Sources[3]. The article describes the technological and functional schemes for controlling microgrid objects based on wind and photovoltaic plants using pumped-storage power plants and a new device for controlling low-power power plants.

J.O. Izzatillaev, Yusupov Z. Short-term Load Forecasting in Grid-connected Microgrid.[4] The article describes the Integration of Distributed Energy Resources (DER) into the main network should consider the influence of many factors. One of them is to determine the electrical load in the Microgrid. Creating a feasible and efficient Microgrid based on predicted load power is more relevant. The article analyzes the forecasting of electric energy consumption in microgrids and analyzes the applicability, advantages, and disadvantages of short-term forecasting methods of energy consumption. Two methods - group data processing (GMDH) and artificial neural networks (ANN) are used to determine short-term load prediction.

Zhukov V.V., Shmelev A.V., Mikheev D.V. Assessment of the influence of poorly formalized factors on energy facilities' reliability indicators [5]. The article discusses the effective operation of intelligent electronic devices and fiber optic cables, which are used in the formation of modern energy facilities and their reliability indicators, depend on changing external working conditions. In this regard, the urgent problem is assessing the impact of poorly formalized factors on the reliability indicators of energy facilities elements, which are not taken into account in traditional methods of calculating reliability as the object of study adopted digital substation (DSP).

The article published the results of a study conducted on a micro-grid in a remote village in India. The micro-grid controls the micro-grid output parameters in real-time depending on several external environmental factors in the research. The energy storage system's charge status in the micro-grid, the load schedule, and the Energy flows in the distributed energy resources are analyzed and controlled using Arduino microcontrollers. Arduino microcontrollers' use in real-time modes of power flows leads to simplification and low cost of the system [6].

In recent years, Uzbekistan has adopted a number of legislative acts on developing alternative energy, and it is widely introduced in all sectors of our economy. Diversification of energy sources based on renewable sources allows saving energy resources, increasing the reliability of power supply to consumers, and improving the environmental situation. Another promising direction for the development of the electric power system is creating "smart" grids, one of the tasks of which is the diversification of energy sources of energy system objects. These circumstances determine the relevance of research to create effective alternative energy sources based on renewable energy. At present, the production of electricity from renewable energy sources is more expensive than traditional sources of Energy. Therefore, when using renewable energy sources, we must first pay attention to the energy efficiency indicators of consumers.

Improving Energy Efficiency in Low Power Consumers in Rural Areas

In the modern world, the level of electricity supply is the main factor in developing the country, improving the socio-economic situation of the population. In many countries, especially Uzbekistan, the level of connection to electricity or electricity supply reliability is very low in remote areas, far from the centralized power grid. Ensuring employment of these regions' population and improving the economic situation is the most pressing issue of increasing the reliability of the power supply. In many countries of the world, many scientific studies have been carried out to improve the reliability of power supply in remote areas [1].

A number of problems in the power supply negatively affect the increase in the power supply's reliability. One of the most common problems is the increase in network losses due to the low voltage network's excessive lengthening. In addition, profitability is declining due to the high cost of building the transmission line and purchasing transformers. Due to network operation deficiencies, some industries experience low resilience to natural disasters and equipment failure in the network [2].

At the end of 2016, about 24% of the world's electricity was generated from renewable energy sources (RES). In 2017, this figure increased to 2.5 percent (that is, 26.5 percent) [3]. RES, especially wind, hydropower, and solar energy, are primarily important for designing clean and sustainable energy systems [4]. Fortunately, these areas tend to be rich in renewable energy sources, so it's worth exploring local renewable energy resources to generate much-needed electricity. Energy availability and use are one of the key drivers of a country's assets and growth, in addition to traditional energy sources (including sources that produce more than 2.5 million barrels of crude oil and 2.175 billion tons of coal and coal per day, as well as 187 trillion cubic feet of natural gas reserves) [5].

Micro-network is a group of distributed energy sources and electricity consumers that can be used autonomously or integrated into a centralized network. Connection or disconnection from the network is carried out following the economic and technical requirements. In such a network, the task is to provide consumers with a reliable power supply quickly. To accomplish this task, the system will need to diversify various independently distributed energy sources, analyze detailed data on consumers and energy sources, and perform several other steps. Micro-grid can be designed in three different ways depending on the grid voltage: DC micro-grid, AC / DC hybrid micro-grid, AC micro-grid.

Depending on the application, micro-grids can be divided into connected microgrids, isolated (standalone, islanding) types of microgrids.

Microgrids are divided into 2 types depending on the management method: centralized and decentralized. With a centralized management method, the data is analyzed, and only one operator makes a decision. With a decentralized control method, each local area network is monitored and managed through its control system. Based on a standard developed by the Institute of Electrical and Electronics Engineers for microgrid management, the IEEE 2030.7 standard was developed.

For a microgrid to be reliable and flexible, it must consist of many distributed, independently controlled energy sources within the grid. A microgrid's installed capacity can vary from several kilowatts to megawatts (from 100 kW to 10 MW) [6]. But to date, all states have set standards for capacity, reliability, and similar sized microgrids based on their capabilities.

Low power consumers in rural areas are small enterprises for building materials, agricultural processing products, services, educational institutions, public facilities, etc. The main problem of these facilities is power outages and the inability to expand production due to lack of energy sources. This issue is especially relevant for farms located in remote places from the electric network. An effective solution to improving energy efficiency and reliability of power supply is to diversify the source of electricity, i.e., the introduction of "hybrid" energy sources, consisting of several alternative sources [4], [5], [6].

The climatic conditions of our Republic do not allow the efficient use of wind power plants. Due to the weak and unstable flow of Energy from these sources, the obtained alternating current electricity at the generator output becomes impossible to use [7]. Therefore, this Energy is usually used through accumulation in the form of direct current Energy and then in the form of a variable using inverters, which leads to a rise in price and a decrease in the efficiency of these plants. The efficiency of these machines can be improved by using wind power plants (wind turbines) with a vertical axis of rotation, as well as more rational planning of the operating modes of these sources, i.e., generate electricity only after the accumulation of Energy by renewable sources. The use of energy storage systems in renewable energy systems leads to an increase in the reliability of the electricity supply. These articles[8,9] assess the efficiency of using compressed air energy, supercapacitors, and lithium-ion backup systems, as well as the use of this system in wind energy storage. The creation of monitoring of energy flows of hybrid energy systems allows, will increase the efficiency of the use of renewable energy sources. This article develops a new strategy for dealing with uncertainties in wind energy forecasting for energy storage systems. This factor allows for the efficient use of wind flows and wind power devices[10].

II. MODELING AND EXPERIMENTAL PART

At the Department of Power Engineering, a "hybrid" energy source for low-power consumers, consisting of several sources and energy storage devices, working in conjunction with the electric network, was developed. An electric power supply consists of a wind turbine with a mechanical drive, a solar panel to the battery, an inverter and, as well a microcontroller and to switch sources (Fig. 2). A wind turbine includes a three-blade wind turbine on a mast with flanges and an axial synchronous low-speed generator with permanent magnets (Fig. 3).

Based on the data from the meteorological station installed in the building of the Bukhara Institute of Engineering and Technology, was studied the energy production of the area where the wind turbine and solar PV panels will be installed. The following graphs show the wind speed and the energy flux per square meter of solar radiation.

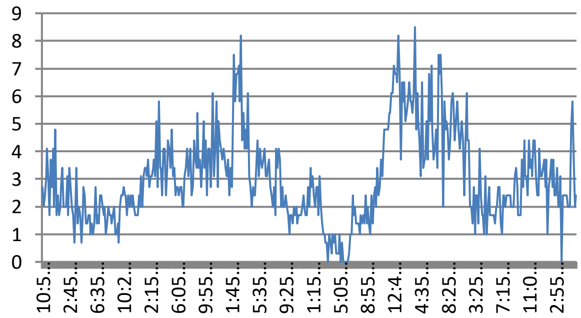


Fig. 2 Wind speed in 11-15.02.2019

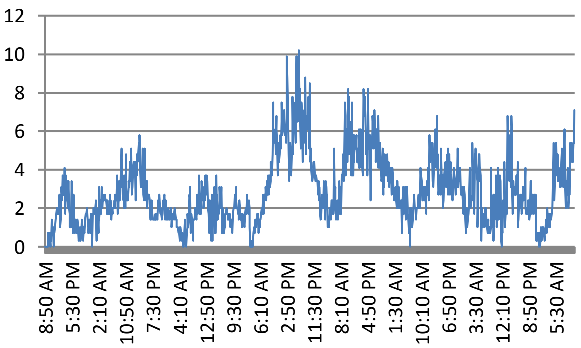


Fig. 3 Wind speed in 28.03.2020

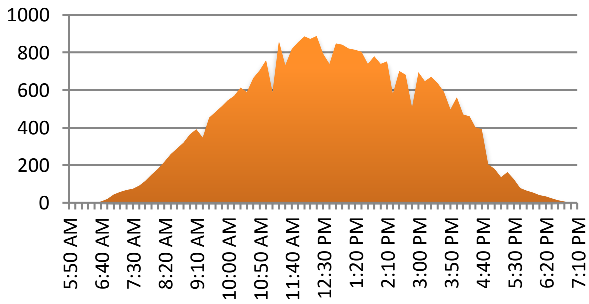


Fig. 4 solar light in 30.03.2019 (W/kv.m)

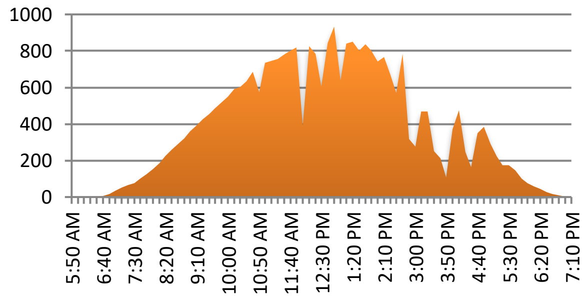


Fig. 5 Solar light in 31.03.2019 (W/kv.m)

A vertically oriented wind power station requires a minimum of space for placement, is absolutely harmless due to the absence of radiation, vibration and noise load [10], [11], [12], [13], [14], [15], [16], [19].

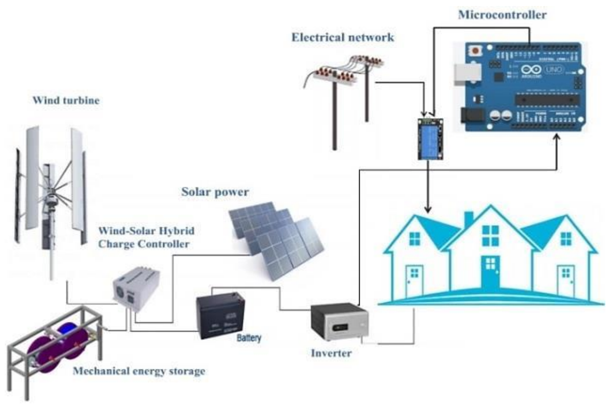
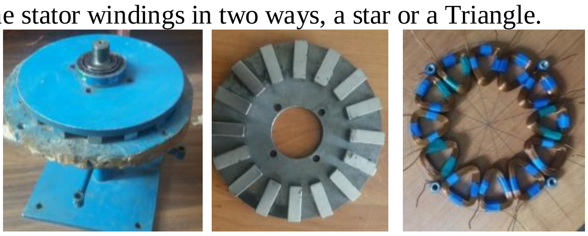


Fig. 6 The Structure of "Hybrid" Electric Power Source.

Fig. 7 Experimental Vertical Wind Power Installation

One of the major advantages of a vertically - oriented wind generator is independent of its "pointing" at the direction of the wind. The optimal profile of the wind wheel blade allows achieving wing efficiency close to ideal, regardless of wind direction [10, 11, 20, 21]. Moreover, the rotor speed is limited only by the force of the airflow. The controller- conversion system, combined with the gearbox, allows you to charge the battery at the lowest RPM. This makes it possible to consume previously generated Energy during a period of calm[17, 18].

Figure 4 shows the rotor and stator of the axial generator used in a vertical wind generator. This axial generator is designed with the power of a wind blade in mind. The generator stator has three phases, 4 windings in each phase. To change the output voltage, you can connect the stator windings in two ways, a star or a Triangle.



a) b) c)

Fig. 8 Appearance of the Generator (a), Rotor (b) Stator (c)

The magnetic flux generated in the generator depends on the size of the permanent magnets and the induction of the magnetic field. This expression looks like this:

$$\Phi_{\text{мах}} = B_g W_m L_m; \tag{11}$$

EMF generated in the generator stator is determined by the following expression [10]:

$$E_f = \frac{\sqrt{2}\mathrm{q}\pi\kappa_{\mathrm{W}}\Phi_{\text{мах}}\mathrm{n}\pi p\mathrm{N}}{120} = \frac{\sqrt{2}\mathrm{q}\pi\kappa_{\mathrm{W}}\mathrm{B_g W_м Ln\pi pN}}{120}; \tag{12}$$

Here: p – is the number of polar pairs of permanent magnets; q – is the number of rods in one phase; κ_W – filling ratio (0.95); N - number of turns at one-second winding; n is the rotation speed of the magnetic field; $W_м$ – permanent magnet width; $L_м$ –permanent magnet length; B_g –the magnitude of the magnetic field induction between two magnetic airstrips.

A virtual model of the axial generator (fig-) was created in order to conduct experiments on the axial generator and create an efficient generator based on optimal dimensions in the future. The virtual model was created by Ansys Maxwell.

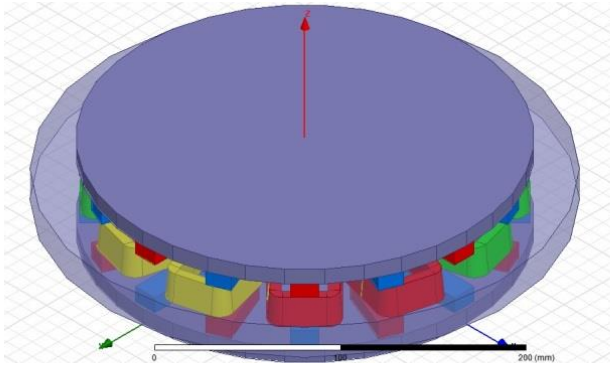


Fig. 9 A virtual model of a low-speed axial generator, the Ansys Maxwell.

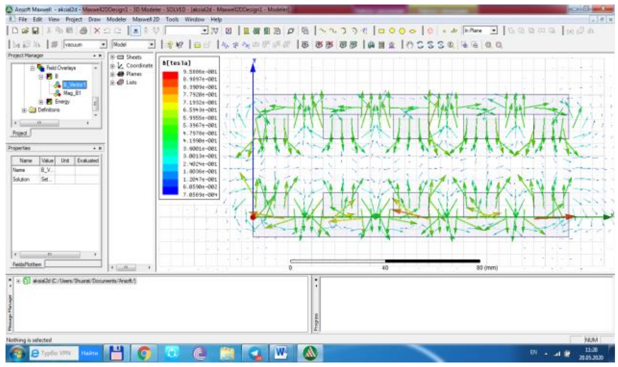


Fig. 10 Generation of magnetic induction vectors in an axial generator designed by Ansys Maxwell.

III. CONCLUSION

1. A "hybrid" electric power source has been developed, consisting of a wind power installation with a mechanical energy storage device, a solar panel with an accumulator, working together with the electric network. A method has been developed for a comprehensive assessment of the electrical efficiency of an industrial low-power facility based on a generalized electrical efficiency indicator.

2. A method has been developed for a comprehensive assessment of the electrical efficiency of an industrial low-power facility based on a generalized electrical efficiency indicator.

3. A generalized indicator of the enterprise's electrical efficiency has been developed by the method of normalizing indicators, characterizing the enterprise's electrical efficiency with a single generalized indicator.

4. The procedure for ranking generalized indicators and values of weight coefficients is justified, taking into account the influence of these indicators on the overall indicator of electric efficiency of an object.

ACKNOWLEDGEMENTS

We thank the rector of the Bukhara Engineering Technological Institute N.R. Baraka for his support in the development of science and working conditions.

REFERENCES

[1] D.A. Gaynanov, E.S. Kashirina, & Y.F Khabirova. On an Effective Ratio of Conventional to Renewable Energy Sources in the Russian Electric-Power Industry. Russian Electrical Engineering, 89, (2018) 9-12, doi:10.3103/S1068371218010030.

[2] U.A. Tadjiev, E.I.Kiseleva, R.A. Zakhidov. Features of the formation of the wind flow over the territory of Uzbekistan and opportunities for its use for electric power: Part 2. Applied Solar Energy, 50 (2014) 265–272, doi:10.3103/S0003701X14040161.

[3] B. Urishev. Microgrid Control Based on the Use and Storage of Renewable Energy Sources. Applied Solar Energy, 54 (2018) 388–391, doi: 10.3103/S0003701X18050201.

[4] J.O. Izzatillaev, Yusupov Z. Short-term Load Forecasting in Grid-connected Microgrid. 7th International Istanbul Smart Grids and Cities Congress and Fair, (ICSG 2019), 71–75, ,doi:10.1109/SGCF.2019.8782424.

[5] Zhukov, VV, Shmelev, AV & Mikheev. DV An Evaluation of the Effect of Weakly Formalized Factors on the Reliability Index of Power Facilities. Russian Electrical Engineering, 89 (2018) 332-339, doi:10.3103/S1068371218050140.

[6] M.Veeramani, J.Prince Joshua Gladson, C.K.Sundarabalan, J.Sanjeevikumar. An Efficient Microgrid Management System for Rural Areas using Arduino. International Journal of Engineering Trends and Technology (IJETT), 40(6), (2016) 335-341. doi: 10.14445/22315381/IJETT-V40P254

[7] S.V.Kiseleva, O.S. Popel, A.B. Tarasenko, R.R. Avezov. Efficiency estimation for the grid-tie photovoltaic stations construction in some regions of Central Asia and Transcaucasia. Applied Solar Energy, 53 (2017) 306–311, doi:10.3103/S0003701X17040090.

[8] Karuna Nikum, Rakesh Saxena, Abhay Wagh. Performance Analysis of Battery Banks with PV-Wind Connected Hybrid Distributed Power System. International Journal of Engineering Trends and Technology (IJETT), 29(4) (2015) 177-182 . doi: 10.14445/22315381/IJETT-V29P233

[9] Biks Alebachew Taye. Design, Modeling, and Control of Standalone Photovoltaic System for Rural Electrification in Ethiopia using MATLAB. International Journal of Engineering Trends and Technology, 66(3) (2018): 184-190. doi: 10.14445/22315381/IJETT-V66P227

[10] N.Sivasankar, Dr.KR.Devabalaji. Comparative Analysis of Non-Isolated Three port converters for Solar and Energy Storage Integration. International Journal of Engineering Trends and Technology 68(7) (2020) 73-77. Doi: 10.14445/22315381/IJETT-V68I7P211S.

[11] Oh, E. Rolling based energy storage system operation strategies considering wind power forecast uncertainty. International Journal of Emerging Trends in Engineering Research. 7(11), (2019), , 708-714. doi: 10.30534/ijeter/2019/497112019

[12] N.N. Sadullaev, M.B. Bozorov, Sh.N. Nematov. Research of efficiency of functioning of system of electro supply of the enterprise by method multi-criteria analysis. Journal of Electrical and Electronic System, 2 (2018) 27–30.

[13] N.N. Sadullaev, A.B. Safarov, Sh.N. Nematov, R.A. Mamedov. Statistical Analysis of Wind Energy Potential in Uzbekistan's Bukhara Region Using Weibull Distribution. Applied Solar Energy, 55 (2019) 126–132, doi:10.3103/S0003701X19020105.

[14] N. N. Sadullayev, A. B. Safarov, Sh. N. Nematov, R.A. Mamedov, and A. B. Abdujabarov. Opportunities and Prospects for the using Renewable Energy Sources in Bukhara Region. Applied Solar Energy, 56(4) (2020) 291–300. doi: 10.3103/S0003701X20040106

[15] Y.C. Lima, W.T. Chonga, F.B. Hsiaob. Performance Investigation and Optimization of a Vertical Axis Wind Turbine with the Omni-Direction-Guide-Vane. Procedia Engineering, 67 (2013) 59–69, doi:10.1016/j.proeng.2013.12.005.

[16] F. Jacek, Gieras, Rong-Jie Wang, Maarten J. Kamper. Axial flux permanent magnet brushless machines. Kluwer Academic Publishers.: Dordrecht, (2004) 189-211.

[17] Jinyi Li, Yang Cao, Guoqing Wu, Zifan Miao, Jiawei Qi. Aerodynamic stability of airfoils in a lift-type vertical axis wind turbine in the steady solver. Renewable Energy, 111 (2017) 676–687, doi:10.1016/j.renene.2017.04.057.

[18] A. Dilimulati, T. Stathopoulos, M. Paraschivoiu. Wind turbine designs for urban applications: A case study of shrouded diffuser casing for turbines. Journal of Wind Engineering & Industrial Aerodynamics. 175 (2018) 179–192, doi:10.1016/j.jweia.2018.01.003.

[19] E. Kurta, H. Gorb, U. Doner. Electromagnetic design of a new axial and radial flux generator with the rotor back-irons. International journal of hydrogen energy, 41 (2016) 7019–7026, doi:10.1016/j.ijhydene.2016.02.034.

[20] N.N. Sadullaev, A.B. Safarov, Sh.N. Nematov, R.A. Mamedov. Research on Facilities of Power Supply of Small Power Capability Consumers of Bukhara Region by using Wind and Solar Energy. International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 8(9S2) (2019) pp. 229-236. doi:10.35940/ijitee.I1047.0789S219.

[21] Patent US6740989 05/25/2004.

[22] Patent RU2390654C1 04.24.2009.