IOP Conf. Series: Materials Science and Engineering **791** (2020) 012053 doi:10.1088/1757-899X/791/1/012053

Algorithm and program for calculating the facility's power supply system based on photovoltaic modules

E A Bekirov, M M Asanov and D V Polyanovsky

Electrical Energy and Electrical Engineering Department, V.I. Vernadsky Crimean Federal University, Academician Vernadsky Ave., 4, Simferopol, 295007, Russia

E-mail: asanov.m.m@cfuv.ru

Abstract. The popularity of renewable sources in design of the facility's energy supply system is mainly due to their environmental safety. They are the sources of the so-called "clean energy", the production of which is not accompanied by harmful emissions into the atmosphere. Renewable energy plants are complex systems with a large number of interconnected elements. Their design requires the solution of a number of problems, which include the selection of the functional, technical and technological structure of the system. The power plants components parameters depend on many factors, including the system's installation location characteristics, the consumers operating mode features, the system components compatibility with each other. Design automation of power plants based on renewable sources will help reduce the workload on the designer during the system development, thereby will promote wider use of such sources in facility's energy supply systems. In this work, the authors developed an algorithm and a program based on it for designing a facility's power supply system with photovoltaic modules as an energy source. The program allows user to select the necessary system components based on databases; evaluate the system effectiveness depending on the facility location; calculate the selected power supply system cost. When simulating the system operation a check for the input data correctness is made to exclude possible errors.

1. Introduction

The share of energy generated by renewable sources in the energy systems of a number of countries is constantly growing. According to statistics, for 5 years from 2013 to 2017 the growth in renewable sources capacity in the world amounted to about 610 000 MW, and energy production over the same period increased by 1 149 633 GWh [1]. Therefore, at the end of 2017, energy production by renewable sources in the world amounted to 6 190 948 GWh, which is 25% within the global power generation mix. Norway is the world leader in this area, where at the end of 2017 the share of energy produced by renewable sources was 97.8%. In Russia, this indicator for the same period amounted to 17.5% [2].

The power plants based on renewable energy sources popularity growth is connected not least with the desire to reduce the negative impact of humanity on the environment. UN Secretary General Antonio Guterres called climate change "the main issue of our time" [3]. According to the results of the UN Climate Action Summit, which took place on September 23, 2019 in New York, 65 countries and major sub-national economies committed to reduce greenhouse gas emissions to zero by 2050, and another 70 states announced that they would either expand their national action plans by 2020, or have already begun this process [4]. A number of countries and private companies have announced a significant increase in financing activities to promote the renewable energy sources use.

Power plants based on renewable energy sources are complex technical systems, and their design requires solving a number of problems. The difficulty lies in choosing the functional, technical and technological structure of systems with renewable sources. It is necessary to form a general structural and functional model of a power plant at the initial design stage, which is determined by a number of factors, including resource capabilities of a given region, consumer characteristics, and system components compatibility. In addition, the project feasibility should be evaluated from a technical and economic point of view [5-7].

The above mentioned problems, the growing popularity of power plants based on renewable sources caused the need for their design automation, as well as evaluating effectiveness of such systems at the initial development stage. For this purpose, a number of programs have been developed and are successfully used [8-10].

The first of the considered applications for modeling a renewable energy system is the Solar Advisor Model (SAM). It was developed by the National Renewable Energy Laboratory in collaboration with Sandia National Laboratories in 2005 for U.S. Department of Energy's Solar Energy Technologies Program. It is designed to predict energy production and estimate its cost for renewable energy systems connected to a common network, depending on the selected configuration and installation location. As the energy sources can be selected solar cells, including those with solar energy concentrators, wind turbines, solar systems, geothermal systems, biomass combustion systems, etc. The program allows user to interact with external models made in Excel and TRNSYS. In addition, SAM has its own scripting language, which makes it possible to write your own program to control the simulation, change the values of the input signals and write information to text files [8, 9, 11, 12].

HOMER (Hybrid Optimization of Multiple Energy Resources) software was developed by U.S. National Renewable Energy Laboratory for modeling the operation of low-power energy systems connected to the common network and isolated. Together with such systems functioning analysis, HOMER allows user to evaluate its installation and operation costs. The simulated system can provide energy to both electric and thermal loads, powered by photovoltaic modules, wind power, small hydropower, biomass power, reciprocating engine generators, microturbines, fuel cells, batteries, and hydrogen storage. The main tasks of HOMER are simulation, optimization and sensitivity analysis. In the simulation process, the program analyzes the operation of a given system to assess its development and cost. In the optimization process, the program analyzes a number of different systems in order to find the only one that fully meets the requirements set by the user, as well as that has lowest price. In the sensitivity analysis process, the program evaluates how sensitive the output is to the changes in input. At the same time, the user himself sets those input variables, which values will change. According to the available data, the program searches for the most optimal system configuration taking into account the accepted assumptions [9, 13, 14].

The Renewable Energy Technologies Screen was developed by the Government of Canada and is designed to evaluate the effectiveness, the ability of several sources to work together, and to analyze the energy production of the selected sources. The program allows user to work with a number of databases, including climate database from NASA ground stations and satellites. It is possible to integrate cost, benchmark, hydrology, and other databases. RETScreen makes it possible to analyze the entire working cycle of the selected project in order to evaluate the effectiveness of its work anywhere in the world under any environmental conditions [9, 15].

There are number of software that simulates the systems with renewable energy sources operation. Among them, the following programs used to analyze the energy systems based on photovoltaic cells can be noted:

- Photovoltaic systems (PVSyst) is used to analyze, simulate operation and evaluate the size of the system [9, 16];
- PV*SOL is used for dynamic analysis of the system, which includes energy storage, with the 3D visualization possibility and detailed analysis of the panels shading [17];
- Solarius PV allows user to analyze the work and evaluate the economic component of systems with a large equipment database and the ability to 3D visualization [18];

- Solar Pro simulates the systems operation, including ones with a dual axis Sun tracking system, with the assessment of shading and 3D visualization [19].

2. Materials and Methods

The aim of this work is to create an algorithm and a program based on it, allowing simulating the operation of a photovoltaic system with the ability to evaluate its technical and economic characteristics.

When developing the program, the choice was made in favor of VisualBasic.NET, which now is one of the most popular programming languages. Despite the existing shortcomings and the fact that it is very inferior in popularity to C ++, Java, C #, VisualBasic.NET functionality does not differ much from the programming languages listed above.

The main feature of VB.NET is its object orientation. VisualBasic.NET itself is a full-fledged object-oriented language that supports polymorphism, static typing, inheritance, and operator overloading. The object-oriented approach gives user the opportunity to solve the problem of developing the scalable, flexible and extensible applications [20].

Another difference between VisualBasic.NET and the standard Visual Basic is the use of the modern .NET platform.

Let us single out the main, in our opinion, VisualBasic.NET properties:

- Various languages support. This environment supports several languages C#, F#, C++, VB.NET, as well as languages that are tied to .NET, for example: Delphi.NET. The developer can choose the language that is suitable to him. It became possible thanks to the Common Language Runtime (CLR), which is the basis of the .NET platform. All code in any of the listed languages is compiled into an assembly in the CIL (Common Intermediate Language).
- Cross-platform. The .NET system is a portable platform. For example, the latest version of the platform at the moment is NETFramework 4.8 is supported on most modern Windows OS (Windows / Vista / 7/8 / 8.1). In addition, thanks to the Mono project, user can create applications that will continue to work on other OSs of the Linux family, including Android and IOS mobile systems.
- Large class library. Another feature of .NET is a single class library for all supported languages. During any application development process using VB.NET, in any event, interaction with the .NET class library takes place.
- Lots of auxiliary technology. .NET has a whole stack of technologies that can be applied when writing various applications. For example, ADO.NET technologies and the Entity Framework platform are designed to work with databases; WPF technology is used for the development of graphic programs with a rich interface; Windows Forms is used for the simplest applications; ASP.NET is used to create websites or web services.

As described above, VisualBasic.NET code compiles into applications or assemblies with exe or dll extensions in the Common Intermediate Language. Then, after the application starts, JIT compilation (Just - In - Time) is done into machine code, which is then directly performed. At the same time, since the launched application can be large and have many instructions, only part of the application that is being accessed will be compiled. When accessing other parts of the code, the system will also be compiled from CIL to machine code. The already compiled part of the application is saved until the program terminates. It is necessary in order to increase program performance, increase speed and perform instant computing functions.

3. Results

Authors developed an algorithm and program that allow calculating any autonomous power supply systems based on solar panels for any facility. The block diagram of the algorithm is shown in figure 1.

The program development began with the libraries analysis, preparation of windows, forms, and buttons. A power supply system components database was made: solar panels, batteries, inverters, diesel generators, as well as a database of cities– system installation location data. The first version of the program had a small selection of cities and minimal interaction with databases.

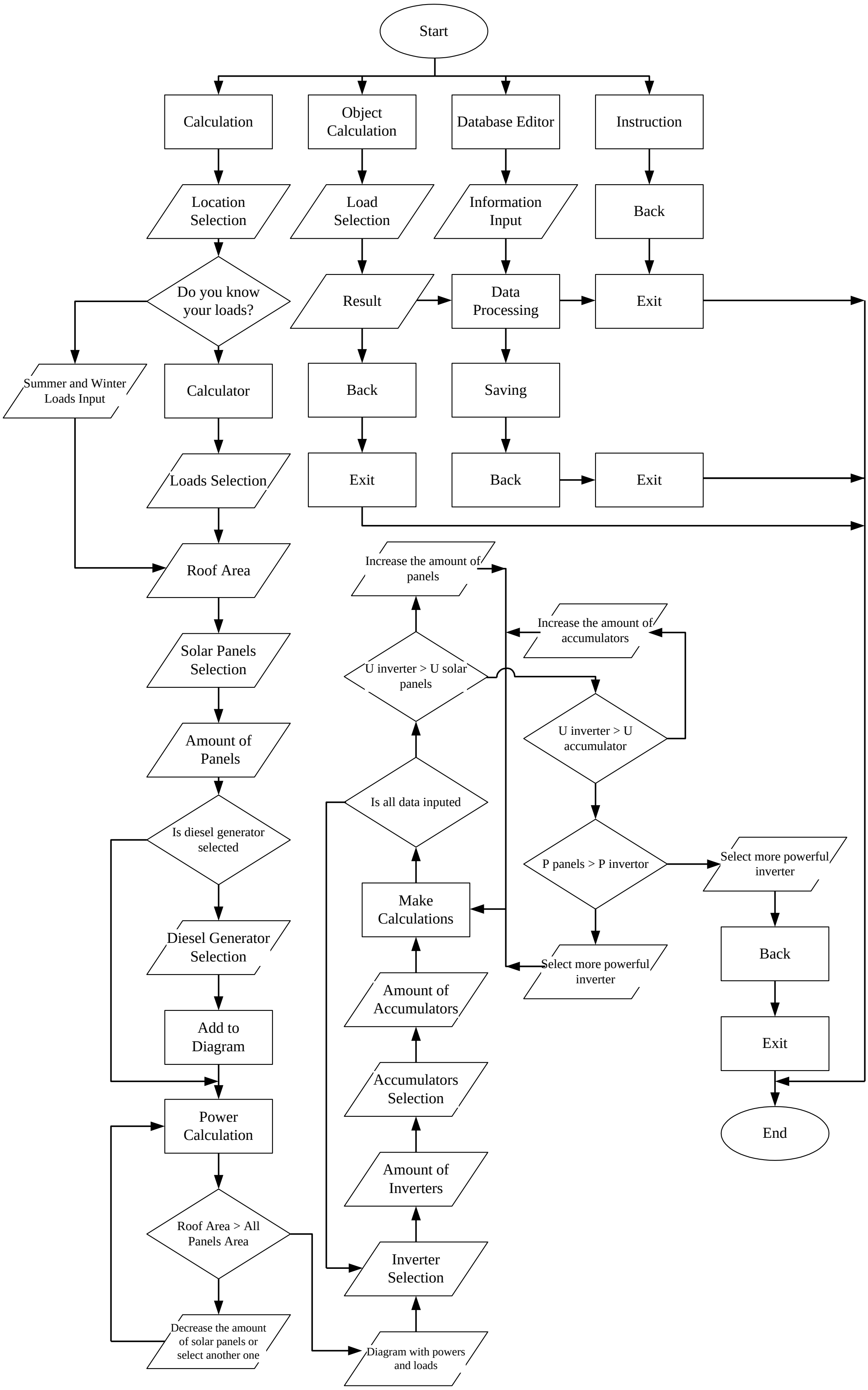

Figure 1. The developed algorithm of the described program.

IOP Conf. Series: Materials Science and Engineering **791** (2020) 012053 doi:10.1088/1757-899X/791/1/012053

Subsequent versions provided more information, the input information was checked for errors, the access to additional sources of information was opened to the user, and a slight simplification for information input was made. In addition, a calculator was developed, which allows user to select their own loads, indicate their power, operating time. The program itself makes further calculations based on input information. The user menu is shown in figure 2.

Figure 2. User interface of a start menu.

The user has two options for interacting with the program - performing a simple calculation of the house with ready-made solutions for solar energy systems or a detailed calculation of the facility power supply.

In the first case, the user must specify the required number of his devices by pressing the appropriate buttons, after which the program will automatically select the appropriate power system (figure 3).

Figure 3. User interface of the facility power supply system simple calculation menu.

If the user needs to perform a more detailed calculation, he needs to choose the location, in which the system will be installed, indicate his daily loads in winter and summer. If daily loads are unknown, there is a special calculator, which helps user to specify this information. The program saves entered data for further plotting.

The next step is the selection of power system components (solar panels, inverters, batteries and diesel generators) from a database created in Microsoft Access. Firstly, the necessary solar panels and their number are selected, after which the data is saved. When user clicks the "Calculate power" button, a graph will be built showing loads in winter and summer. Seasonal loads on the graph are marked with the corresponding color; an annotation is indicated on the right of them.

User can choose a diesel generator, if necessary. For this, user must click on the "Add diesel generator" checkbox, after which a list of diesel generators available in the database with their parameters appears. To select a suitable generator, must click on the "Add Generator" button.

The next step is the inverter selection. The inverter power, as known, depends on the solar panels power, and must exceed it in order to withstand the load that goes through it. The selection is made from the table, while the number of inverters is also indicated. After the data is recorded, the user receives information about the inverters power; and user proceeds to the batteries choice.

After selecting the batteries from the corresponding table and their number, the system itself determines the capacity and displays the result on the screen (figure 4).

When all the data is selected, user must click on the "Calculate" button, and a confirmation message will appear. Pressing the "Yes" button will start checking the entered data. If all the criteria and conditions are correct, the system will display a message "Calculation completed!", otherwise an error message will be displayed. In this case, it is necessary to change the data according to the specified information (figure 4).

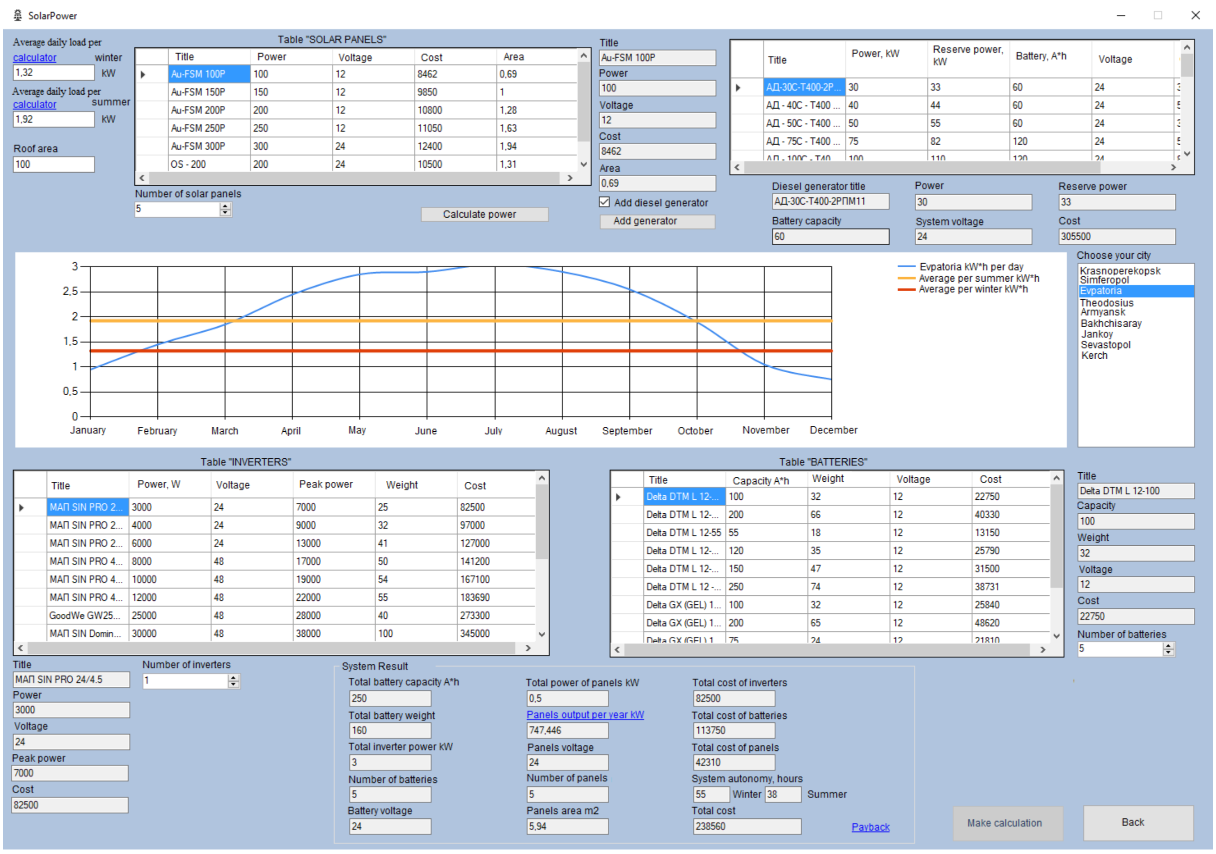

Figure 4. User interface of the facility power supply system detailed calculation menu.

IOP Conf. Series: Materials Science and Engineering **791** (2020) 012053 doi:10.1088/1757-899X/791/1/012053

Based on the calculated data, the “System Result” window will appear, in which the following data will be listed:

- total battery capacity;
- total mass of batteries;
- number of batteries;
- battery voltage in accordance with the connection method;
- total power of inverters;
- total power of the panels;
- voltage of panels;
- number of panels;
- panel production for the year;
- area occupied by panels;
- total cost of inverters;
- total cost of batteries;
- total cost of panels;
- total amount;
- autonomy of the system for winter and summer.

The program has a database editor, in case there is a need to remove something from the database or add a new element (figure 5). If necessary, user can call the instructions for working with the program.

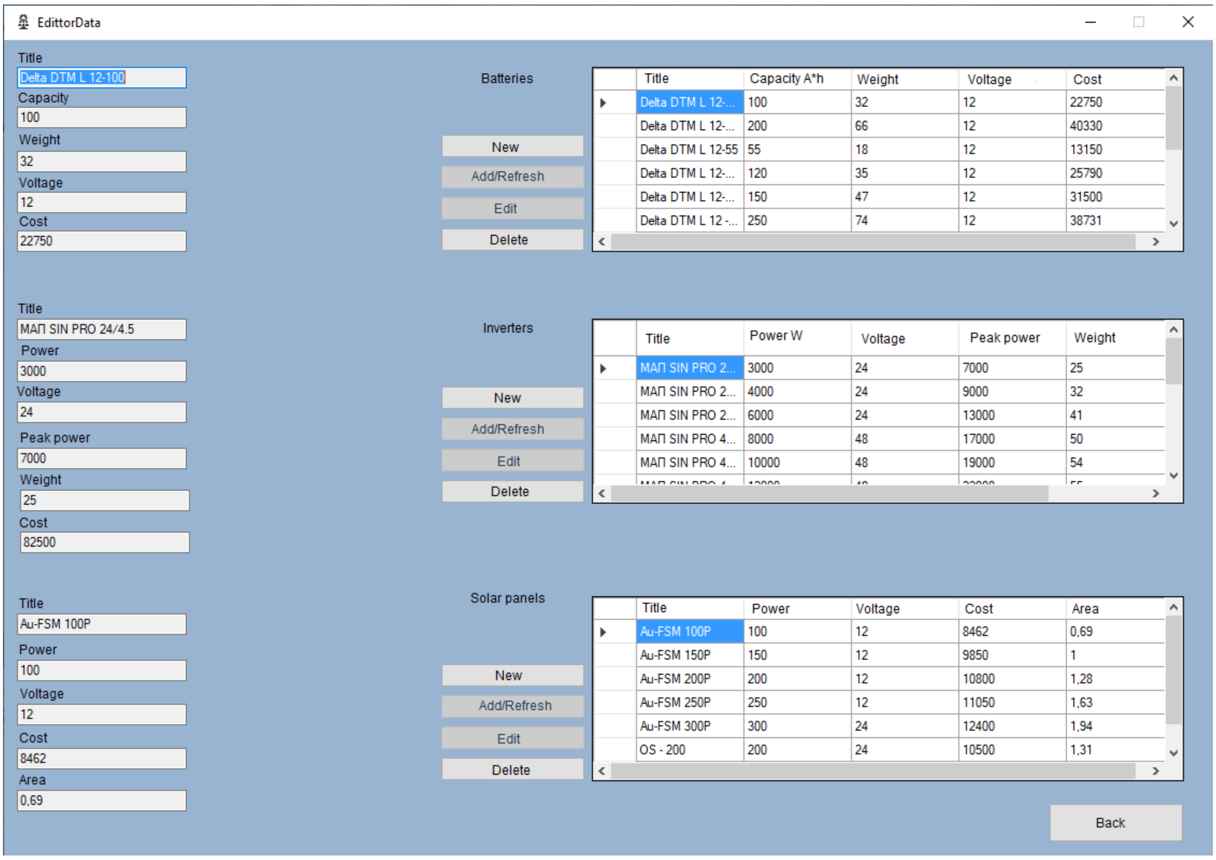

Figure 5. User interface of a database editor.

4. Conclusion

As a result of the study, the authors developed an algorithm and a program that implements it, used to automate the design process of a facility's power supply system based on photovoltaic modules. VisualBasic.NET was chosen as the program language, which, thanks to a number of advantages, makes it possible to successfully realize all of the set goals with low human and machine resources. The developed software solves a number of problems faced by the power supply system's designer. In particular, it helps to calculate the facility load, facilitates the selection of system components and their parameters, inputs the selected facility location characteristics, checks the entered results correctness to eliminate errors when modeling the system. As a result of calculations based on the entered data, among other, the program gives information about the selected system components and their quantity, their cost and the whole system cost, as well as the power production of the system in summer and winter. The software also includes detailed operating instructions.

References

[1] Whiteman A, Esparrago J, Elsayed S, Rueda S, Arkhipova I and Escamilla G 2019 *Renewable Energy Statistics* (Abu Dhabi: IRENA) URL https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jul/IRENA_Renewable_energy_statistics_2019.pdf
[2] Global Energy Statistical Yearbook 2018 URL https://yearbook.enerdata.net/2017/renewables/renewable-in-electricity-production-share.html
[3] Climate Action Summit 2019 URL https://www.un.org/en/climatechange/
[4] Climate Action Summit. Closing Release URL https://www.un.org/en/climatechange/assets/pdf/CAS_closing_release.pdf
[5] Trubaev K P 2018 Study of Power Dependence of Wind Power from Wind Speed *J. Phys.: Conf. Ser* **1066** 012026
[6] Zubova N V and Rudykh V D Optimization of power output for a wind turbine using methods of artificial intelligence *IOP Conf. Ser.: Mater. Sci. Eng.* **552** 012034
[7] Zaliskyi M, Petrova Y, Asanov M and Bekirov E 2019 Statistical data processing during wind generators operation *Int. J. of Electrical and Electronic Eng. & Telecommunications* **8** 33-8
[8] Gurupira T and Rix A 2017 PV simulation software comparisons: PVSYST, NREL SAM and PVLIB *SAUPEC 2017* (Stellenbosch: University of Stellenbosch)
[9] Umar N, Bora B, Banerjee Ch and Panwar B S 2018 Comparison of different PV power simulation softwares: case study on performance analysis of 1 MW grid-connected PV solar power plant *Int. J. of Eng. Science Invention* **7** 11-24
[10] Ringkjob H-K, Haugan P M and Solbrekke I M 2018 A review of modelling tools for energy and electricity systems with large shares of variable renewable *Renewable and Sustainable Energy Reviews* **96** 440-59
[11] Blair N, Dobos A P, Freeman J, Neises T and Wagner M 2014 *System Advisor Model, SAM 2014.1.14: General Description* (Denver: NREL)
[12] NREL System Advisor Model (SAM) URL https://sam.nrel.gov/
[13] Farret F A, Simoes M G 2006 *Integration of Alternative Sources of Energy* (New Jersey: John Wiley & Sons)
[14] HOMER Energy URL https://www.homerenergy.com/
[15] Natural Resources Canada URL https://www.nrcan.gc.ca/energy/retscreen/7465
[16] PVSYST Photovoltaic Software URL https://www.pvsyst.com/
[17] Valentin Software URL https://www.valentinsoftware.com/en/products/photovoltaics/ 57/pvsol-premium
[18] Solar Design Software URL https://www.accasoftware.com/en/solar-design-software
[19] Laplace Systems URL https://www.lapsys.co.jp/english/products/pro.html
[20] Grundgeiger D 2002 *Programming Visual Basic NET* (Sebastopol: O'Reilly)