World Applied Sciences Journal 24 (Information Technologies in Modern Industry, Education & Society): 117-125, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.24.itmies.80023

Solar Energy System Design and Feasibility Study Support System

Daria Olegovna Malanina, Anton Pavlovich Tyukov,
Maxim Vladimirovich Shcherbakov and ValeryAnatolievich Kamaev

Volgograd State Technical University, Volgograd, Russia

Submitted: Aug 7, 2013; **Accepted:** Sep 18, 2013; **Published:** Sep 25, 2013

Abstract. Technical and economic development of renewable energy sources and the number of their use possibilities is increasing every year. Engineering companies for the solar energy systems design require design key processes automation. Company equipment suppliers want to increase sales market. Solar power plants customers have a low awareness in this area. To solve these problems, we developed a method that allows you to improve key performance indicators in the decision-making process on the solar energy systems design. The method is based on the analysis of three design parameters: technical, economic and natural ecological. The feasibility study is performed using the developed comprehensive analysis method, including intuitive methods and knowledge bases. Natural and ecological analysis is operates based on the production rules model and provides information on the possible impact of construction on the environment and the impact of the environment on the solar power plant capacity. We implemented the algorithm part on the equipment selection. The results of the algorithm are corresponding to the reference values.

Key words: Photovoltaic solar plant · Solar power plant design · Feasibility study · Solar stations · Alternative energy · Photovoltaic sizing

INTRODUCTION

Total world energy consumption for the period from 1990 to 2007 is increased by 40%. According to forecasts, from 2007 to 2035, energy consumption growth will increase by another half. According to AS MARKETING analysts, the market volume of alternative energy key technologies in 2018, compared with 2008 will increase nearly 3 times (while the growth will be 64%) [1]. In March 2007, European Union leaders set objectives program entitled "20 20 20", under which by 2020 three tasks should be performed: by 20% increased energy efficiency of the EU industry, carbon dioxide emissions reduced by 20% from those of 1990, a 20% increased energy consumption share in the EU, produced by renewable energy sources (RES) [2]. There is an increase in the number of solar power plants (SPP) of low, medium, high capacity. An example of a large capacity plant is ActivSolar project of 100 MW capacity in Ukraine, near the village of Perov, Crimea. [3] The combined capacity of the German SPP has increased from 1.1 GW in 2004 to about 19 GW by the beginning of this year [4]. The value of the investment costs for the SPP construction for the period 2010 - 2012 is decreased on average by 45% by reducing the main elements cost [5].

At the same time, the majority of power plants were built in Russia during the Soviet Union days and require major repair or complete replacement. Maintaining stations in operating condition is carried out due electricity tariffs rising. This is indicated by electricity prices tariffs review, produced by the CIS Executive Committee of the Electric Power Council. The average rate increased from 3.54 to 7.79 U.S. cents/kWh for the period from 2006 to 2011. [6] Company "Hevel" completes the creation of solar module production capacity of 130 MW. This will reduce the time and equipment delivery cost. Due the production development, a number of large-scale projects for the SPP introduction in Russia is planned: land has been allocated in the Stavropol Krai (Kislovodsk), in the Altai region (v. Kosh Agach), obtained in Dagestan [7]. In Russia, the volume of investment in the power up to 2030 will amount to 572-888 billion U.S. dollars in 2007 prices.

Corresponding Author: Malanina, Volgograd State Technical University, Lenin avenue, 28, 400005, Volgograd, Russia.

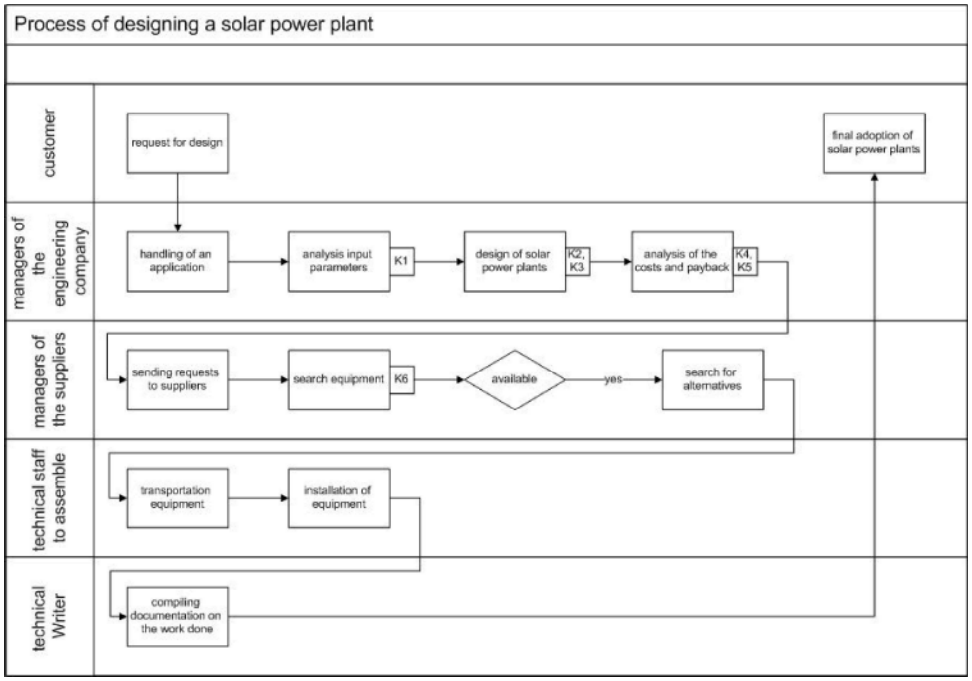

Fig. 1: Business process map

This paper reviews existing studies that provide full or partial problem solution. Authors also suggest their solution to the solar energy systems design and feasibility support: solution methods and automated system, based on developed methods are described.

Contribution on the papers is in the following:

We Analyze:

- Factors influencing on decision-making and the investment effectiveness in the solar power stations construction;
- The process of design and documentation for the solar power plants design;
- The documentation process Key Performance Indicators to allocate steps that need automation;
- Optimization methods for solar power plant necessary equipment calculation;
- Existing solutions amongst Web-based systems;
- We propose a method to improve key performance indicators in the solar power plants design decision-making process. The method allows to carry out feasibility study, especially considering the projected solar power station location featuresand influence of it on environment.
- An algorithm for automated analysis of the investment effectiveness in the solar power stations construction is developed.

Background: The authors analysed the solar power plants design process. According to the analysis results, business process map was designed, it shown in Figure 1.

Key performance indicators:

- K1 input parameters analysis time (meteorological data collection, construction site data, etc.). Unit of measure: hour.
- K2 solar power plant design time. Unit of measure: hour.
- K3 Design calculation error rate. Unit of measure: %.
- K4 Cost price and profitability calculation time. Unit of measure: hour.
- K5 Cost price and profitability calculation error rate. Unit of measure: %.
- K6 Equipment for the specified characteristics selection time. Unit of measure: hour.

For today, considerable knowledge and experience are accumulated, related to the renewable energy technologies implementation. However, there is no information and the economic base in the form of modern information systems, based on the knowledge, allowing effectively select, design and implement RES [8]. The 4 main components are separated, that describe the entire RES design and implementation process [8]:

Table 1: A comparative analysis of methods

Criterion	Intuitive	Numerical	Artificial intelligence
Used information	The average statistical data on insolation, solar panel characteristics, power consumption, equipment losses	The time series of meteorological data, longitude and latitude, the power, panel and battery characteristics	Required power, longitude, latitude, ambient temperature, the number of autonomous days, averaged insolation data, panels, inverter, batteries characteristics.
Panel characteristics calculation	Yes	Yes	Yes
Battery capacity calculation	Yes	Yes	Yes
Inverters characteristics calculation	No	No	Yes
Output power calculation	No	Yes	Yes
Taking into account the construction cost	No	Yes	Yes
Taking into account natural and ecological factors	Yes (accounting panels heating losses)	No	Yes (panels heating losses, absorption of insolation reflected from the ground)
Reliability analysis	No	Yes (LOLP, LPSP)	Yes (more LPSP)
Calculation complexity	Basic calculations / 5	Formulas + modelling / 10	Formulas + artificial intelligence methods / 9

- Technical;
- Natural and ecological;
- Engineering and geologic;
- Economic.

Analysis of Methods for Problem Solution: Comparative analysis of the methods showed that the intuitive methods give a rough estimate without analysing system reliability and are suitable for applications where detailed weather information are not available. Intuitive methods are suitable for rapid assessment and easy to use. Numerical methods are more accurate, but are applicable only if the detailed information on the insolation is available.

Analysis of the Effectiveness Include:

- Analysis of the developed capacity (accounting insolation, temperature, humidity, dust);
- Impact on the environment analysis, during construction and operation (dust-noise-pollution, public safety and public health, water and natural resources, etc.);
- Analysis of the construction site suitability for the solar power plants installation (soil, access to roads, terrain, natural phenomena, etc.);
- Calculation of the solar power plant size and parameters;
- Selection of equipment on specified characteristics;
- Calculation of solar energy system cost and payback;
- Analysis of possible operating costs.

System Concepts:

- Problem Statement, requirements and limitations.

The authors propose a method to support the design and techno-economic analysis of solar energy systems, which allows you to create a report that includes an all design process components analysis: technical, economic, natural-ecological and engineering-geological.

The method consists of three parts: technical, economic, natural-ecological.

The technical part is a comprehensive method based on the arrangement of the existing methods. Carried out calculation of capacity and other equipment characteristics, their optimal combination with the geographical location, economic costs threshold and solar energy plant construction area. The genetic algorithm operates on the basis of the synthesized method, consisting of the intuitive equipment composition design.

The economic part is based on the cost of the project and on calculating investment project payback indicators.

The natural-ecological part is the analysis of climatic, environmental, regulatory parameters. This part is the knowledge base and is based on the production rules model.

This concept could be used as a subsystem of energy management system [9, 10].

System Interaction Scenario Description: On the basis of the questionnaire received from the station customer, weather and geological conditions of the area, the system determines power plant ability to install, its technical parameters (number and type of equipment, the scheme and installation principles, compliance of equipment to accepted standards) and economic parameters, such as the total cost of the project, payback time, net present value (NPV).

Relying on the object location, system receives information about the level of insolation, climatic conditions (rainfall, wind, extreme temperatures, cloud cover), natural and geographical indicators (seismicity, topography, nearby water bodies, type of soil), construction conditions (the possibility of transportation).

The system then calculates the output power, essential equipment, the wiring and installation of solar power plant especially under specified conditions (type of panels, the view and the principle of fixing angle plates, etc.) necessary for the preparation of the work carried out by the construction site.

As a result of the algorithm the user receives a report presented in the document for printing. The report includes: a feasibility study of the project, a set of specific solutions for installation, evaluation studies on socio-economic, natural, geographical and climatic characteristics of the item construction, environmental friendliness.

Description of the Input-Output Data Streams: Table 2 shows the basic input parameters of the algorithm used at different stages [11, 12].

The output data of the algorithm are:

- Descriptive data on the impact on the environment:
- Noise, dust, vibration pollution
- Data on the zoogeography
- Data on phytogeography
- Data on the waters
- Distance from settlements
- Descriptive data on the suitability of the construction site
- Relief
- Natural phenomena
- Soil
- Distance from roads
- The power loss due to the number of cloudy days, overheating, dust
- Necessary works for operation (removal of dust, snow)
- A set of equipment
- The model and the number of solar panels
- The model and the number of controllers
- The model and the number of inverters
- The model and the number of cables
- Number of panels rows
- The number of panels in a row
- The panels angle
- Output power
- Energy production (by month)
- Wiring diagram
- The results of the reliability analysis
- The cost and payback
- Cost of equipment
- Cost of installation
- Cost of service in operation
- Net present value
- The payback period
- IRR
- Cash flow (forecast)

Table 2: The input parameters of the algorithm

Parameter	Source of data	Parameter	Source of data
Longitude	customer	Dustiness	Meteorological data Internet source
Latitude	customer	Soil type	Soil map
Area	customer	Landform	Relief map, Internet sources
Budget	customer	Localities	Localities map, Internet sources
Direct insolation	Internet sources or calculation	Landmarks	Map of landmarks, Internet sources
Diffuse insolation	Internet sources or calculation	Zoogeographical data	Zoogeographical map
The number of cloudy days	Meteorological data Internet source	Phytogeography data	Phytogeography map
The air temperature	Internet sources of meteorological data	Inverter efficiency	Equipment technical documentation
Air humidity	Meteorological data Internet source	Size, efficiency, capacity of solar power panels	Equipment technical documentation
Inverter cost	Equipment technical documentation	Battery capacity	Equipment technical documentation
Controller cost	Equipment technical documentation	The price of electricity	Normative base
Panels cost	Equipment technical documentation	Statistics of natural disasters	Internet source

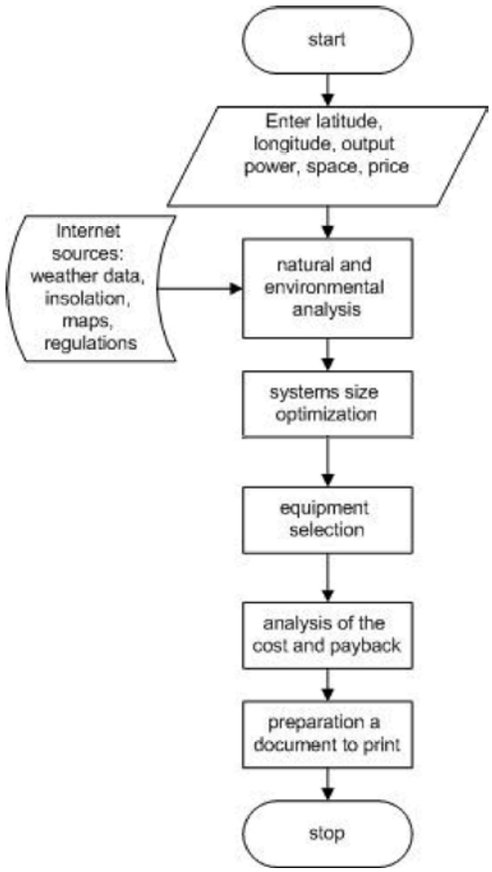

Fig. 2: Algorithm flowchart

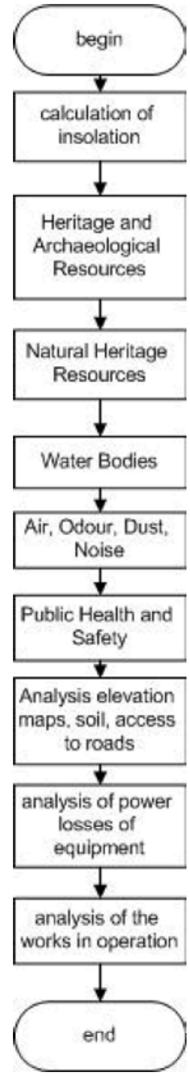

Fig. 3: Block "natural and environmental analysis" flowchart

Description of the Proposed Algorithm: Figure 2-4 shows the algorithm flowchart.

The algorithm receives user input on the budget, the location and capacity of the station. These data, as well as data from internet sources, arrive in analysis unit of natural environmental conditions. This block make first calculation of insolation and the solar panels optimum angle selection, then the analysis of the impact on the environment and concludes with an analysis of environmental impacts on the projected solar power plant. Dust analysis provides information about the need for cleaning panels, for example in plains and deserts. The next stage of the algorithm is to analyze the size and power of the photovoltaic system. At the initial stage, via an intuitive method assessment analysis is performed, allowing to know approximate number and capacity of solar panels and other equipment. The input data is received on the insolation, the required power. The next step of the algorithm is to compile a list of options for filling the available space for building solar panels of all types. At the output there is a list of options for the solar panels design in accordance with the available construction area. If the power for the area corresponds to the desired, then the algorithm proceeds to a more accurate estimation of parameters. At this stage, the analysis using the knowledge base is performed. Result is a set of parameters for solar panels, inverter, controller. In the next block, a designed system reliability analysis is performed. Further there is a filtering of the selected panels at the lowest price taking into account the fact that the total cost of the selected solar panels should not exceed 80% of the customer total budget, available for the solar power plants construction. The result of filtering is 3 best options to fill the available space for development in terms of the required capacity and the minimum price expended for the SPP construction. The results of this unit comes to the equipment selection for the suppliers

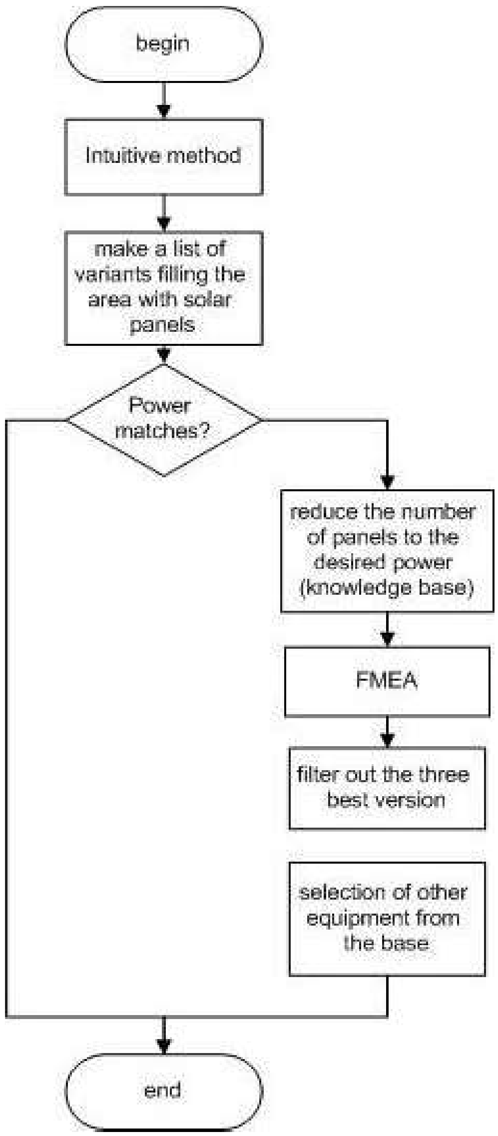

Fig. 4: Block “systems size optimization” flowchart

database specified characteristics. Further, an analysis of cost and payback isperformed. The final step is the layout of the document to be printed, containing a feasibility study and the effects description.

System Design: Authors propose the automated system concept based on the developed method functioning, which generates a knowledge-based SPP equipment manufacturer’s database, available for data analysis. The data are taken from ready Internet sources, search engines programs. The system distributed by SaaS model [13,14].

Figure 5 shows a components diagram of the designed automated system in the notation of UML.

The system is developed in the programming language C # using ASP.NET MVC4.

Figure 6 shows a use-case diagram of developed part.

Algorithm the system displays an algorithm result and the user is taken to a page "Result" with the results of selecting the best configuration of SPP equipment in three concepts, allowing him to choose one of the favorite equipment combinations.

Figure 7 shows the Web-based Application main page with the questionnaire.

After filling in the input parameters, developed algorithm starts working. The algorithm results are the 3 best equipment configurations shown in Figure 8.

Case Studies: Developed part of designed system testing and the equipment selection algorithm were based on the following input data:

- Price=8000 $, Space=200 square meters, Power = 3000 Watts.
- Price=10000 $, Space=500 square meters, Power = 300 Watts.

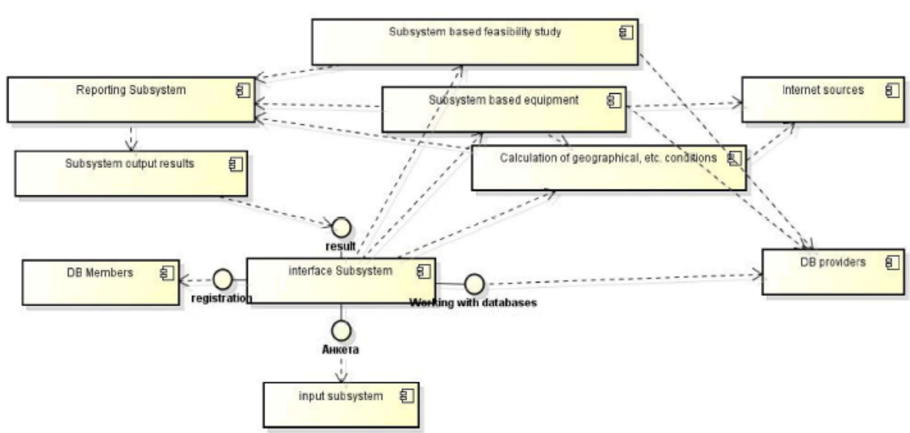

Fig. 5: Component diagram

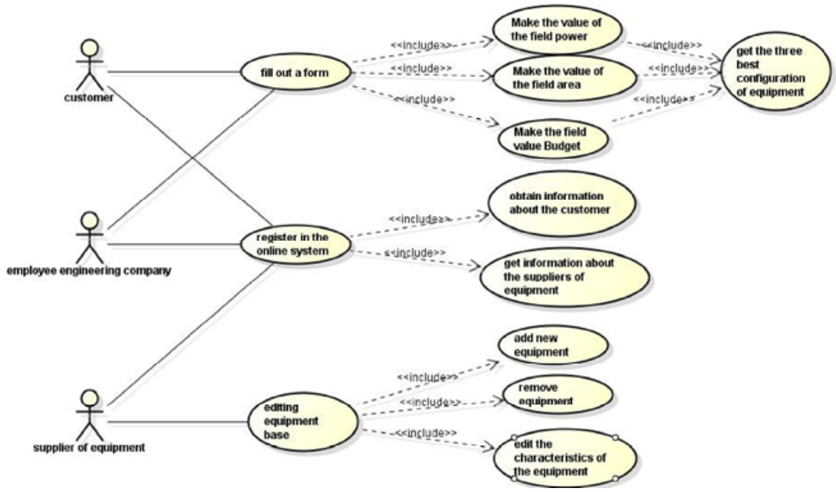

Fig. 6: Use-case diagram in UML notation

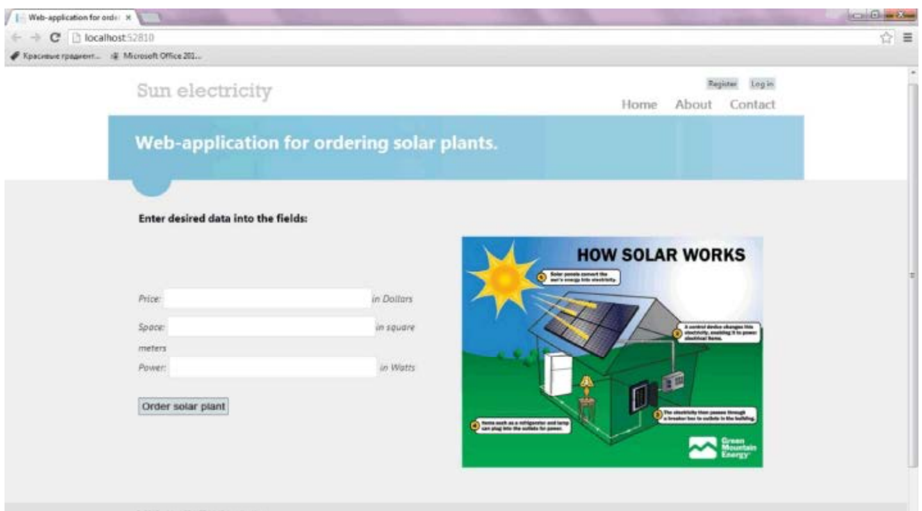

Fig. 7: Web-Based Application main page

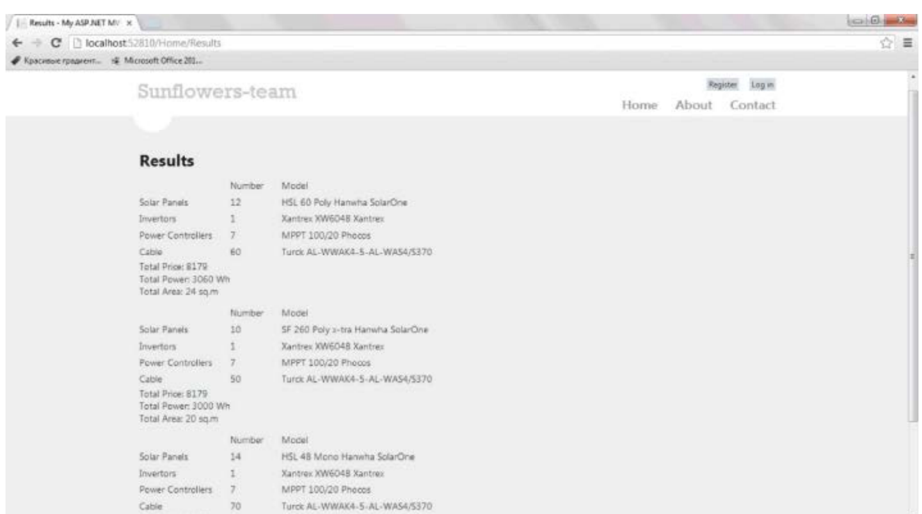

Fig. 8: Page with the algorithm output

Table 3: Results of the program

Inputs	Results of the program	Assessment expert
8000 $	HSL60 Poly Hanwha SolarOne x12	SF260 Poly x-tra Hanwha SolarOne x10
200 sq.m	Xantrex XW6048 x1	Xantrex XW6048 x1
3000 Wt	Phocos MPPT 100/20 x7	Phocos MPPT 100/20 x7
	Turck AL-WWAK4-5-WAS4-/S370 x60	Turck AL-WWAK4-5-WAS4-/S370 x50
	Total Price: 8179	Total Price: 8179
	Total Power: 3060	Total Power: 3000
	Total Area: 24sq.m	Total Area: 20sq.m
10000 $	SF260 Poly x-tra Hanwha SolarOne x2	HSL48 Mono Hanwha SolarOne x2
500 sq.m	Xantrex XW6048 x1	Xantrex XW6048 x1
300 Wt	Phocos MPPT 100/20 x1	Phocos MPPT 100/20 x1
	Turck AL-WWAK4-5-WAS4-/S370 x10	Turck AL-WWAK4-5-WAS4-/S370 x10
	Total Price: 5921	Total Price: 5917
	Total Power: 340	Total Power: 430
	Total Area: 2sq.m	Total Area: 2sq.m

The result of the work is presented in Table 3 and compared with the expert reference values, calculated for the same input data.

The comparison revealed that the program result may differ by solar panel selected model, which leads to a slight deviation in price and performance. In general, the study results match for the task stated. With the help of the designed system developed part, authors were able to improve one of the key performance indicators of the solar power systems design and construction, that is, to reduce the K2 indicator "Solar power plant design time".

CONCLUSION

Review of existing automated systems and solar energy systems design methods has shown that while there is no universal multi-criteria method to completely cover the design process and provide optimal results without the need to reduce the optimality of one of the parameters. We designed a method that supports all aspects of the solar power plants design, the use of which automates the engineering companies activities in the solar power plants design. This method allows to improve the key performance indicators of the solar power plants design process. We implemented equipment selection for the designed station. The implemented part results corresponding to expert reference values.

ACKNOWLEDGMENTS

Authors would like to thank RFBR for support of the research (Grants #12-07-31017, 12-01-00684). Authors like to thank Oleg Olshansky for supervisory support of research, Dmitriy Makeev for creating the web-site.

REFERENCES

1. Kazantsev, T.V., 2008. Analytical announcement of the Russian and global solar energy market. AS Marketing.
2. Böhringer, C., T.F. Rutherford and R.S.J. Tol, 2009. THE EU 20/20/2020 targets: An overview of the EMF22 assessment. Energy Economics, 31: 268-273.
3. Energy fresh. The 10 largest solar power plants in the world. Data Views 6.06.2013 www.energy-fresh.ru/photos/?id=48 and pid=465.
4. Power efficient Russia. Global prospects of solar energy.Data Views 6.06.2013 energosber.info/articles/alternate/71797/.
5. Smart Grid future energy. Swiss researchers predict a reduction in price of solar power by 2020. www.smartgrid.ru/novosti/v-mire/shveycarskie-issledovateli-prognoziruyut-udeshevlenie-solnechnoy-energetiki-lish-k/.
6. Tariffs for electricity and fuel prices in the CIS countries. Review (Issue 35), 2012. The Executive Committee of the CIS Electric Power Council.
7. Hevel Solar, Politics of LLC "Hevel". Data Views 6.06.2013 www.hevelsolar.com/press/news/.
8. Moskalenko, Y.S., A.V. Andrukhin and A.V. Yamshanov, 2007. The principles and features of the intelligent information systems development for selection and implementation of renewable energy sources. Vologdinsky readings, 62: 72-75.
9. Khatib, T., A. Mohamed and K. Sopian, 2013. A review of photovoltaic systems size optimization techniques. Renewable and Sustainable Energy Reviews, 22: 454-465.

10. Belmili, H., N. Matidji and O. Badaoui, 2009. Sizing a (photovoltaic / wind) Hybrid System. Fourth International Congress on Renewable Energy and the Environment (CIAL), http://www.cere-tunisia.com/administrateur/article/CERE_WC_3.pdf.
11. Lopez, M., M. Ll Sidrach-de-Cardona, 2009. A simple model for sizing stand alone photovoltaic systems. Solar Energy Materials and Solar Cells, 55: 199-214.
12. Yang, H., Z. We and L. Chengzhi, 2009. Optimal design and techno-economic analysis of a hybrid solar–wind power generation system. Applied Energy, 86: 163-169.
13. Jallouli, R., L. Krichen, 2012. Sizing, techno-economic and generation management analysis of a stand alone photovoltaic power unit including storage devices. Energy, 40: 196-209.
14. Rajkumar, R.K., V.K. Ramachandaramurthy and B.L. Yong, 2011. Techno-economical optimization of hybrid pv/wind/battery system using Neuro-Fuzzy. Energy, 36: 5148-5153.