Optimization complex systems of renewable energy sources (RES) based on computer program "VizProRES" (Russia)

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Abstract

The approach to an application creation for calculation and optimum unit commitment of the integrated energy system based on the renewable energy sources is examined in the article. The optimization is based on the consideration of multifactor mathematical model representing a "black box". The result of the present model examination is the creation of an application for calculation of efficient energy system with the equipment definition and the installed power of each type of RES. The performance criterion is the minimal production cost of 1kW*h of energy by the integrated system of RES on average per year. The special feature of the application is a strict lock-on on future RES energy complex location and with regard to stochastic climatic characteristics (wind speed, insolation and temperature).

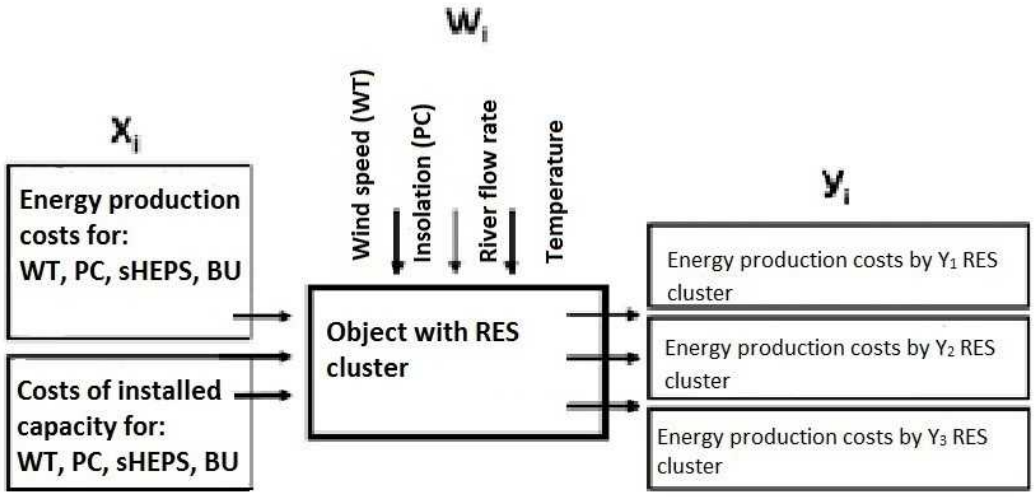
Key words: renewable energy, renewable energy sources (RES), RES optimization.

Nowadays more than 12% of all the energy in Europe is produced by renewable energy sources (RES). 15 years ago this index was less than 0,1%. However, despite increase of volume, the production cost of 1kW*h of electric energy by RES is high and requires the search of new solutions for increasing a competitive ability in relation to conventional sources.

To increase the efficiency of integrated energy systems based on the RES, the work on equipment definition and capacity optimization is in progress worldwide. The similar problem is solvable through the variety of mathematical models of energy systems and the relevant software, for example, «Homer» (USA) [1], «RETScreen» (Canada) [2] or Skelion [3].

Setting of the problem

The purpose of the product under development is to calculate and select the optimal RES equipment definition of integrated energy system with regard for the second moment of distribution (dispersion of production cost of kW*h). The search is implemented by the consideration of multifactor mathematical model representing a "black box" – object with RES complex (cluster) (see pic. 1).



Pic.1. Scheme of multifactor discrete mathematical model of RES cluster

In practice the purpose of multifactor experiment is to determine dependence for a discrete stochastic model:

$$y = f(x_1, x_2, \ldots, x_k) \qquad (1)$$

The problem is the selection of x_k with the "minimum risk" and minimum production cost of 1 kW*h at the following constraints:

$$x_0 + x_1 + x_2 + \ldots + x_n = 1; \qquad x_0 r_0 + x_1 m_1 + \ldots + x_n m_n = A;$$

$$A < r_0; \qquad x_i \geq 0, \quad i = 0,1,\ldots,n$$

A – an acceptable level of the average cost of 1 kW*h, produced by the RES cluster ($A < r_0$).

$m = M(Y/a) = x_0 r_0 + x_1 m_1 + x_2 m_2$ - an average cost of energy, produced by RES cluster in a unit time;

r_0 – a direct operating cost of disel generator in a unit time (includes the equipment cost as well as cost of handling labor);

$Y/a = x_0 r_0 + x_1 Y_1 + x_2 Y_2 + \ldots + x_n Y_n$ – an energy cost, produced by cluster in a unite time (it is a random variable, whereas the first component on the right is not random).

As the target function of the mathematical model of RES cluster was taken the quadratic function from $x_1, x_2, \ldots, x_n$ of the following type:

$$D(Y/a) = \sum_{i=1}^{n}\sum_{j=1}^{n}\sigma_{ij}x_i x_j \Rightarrow \min, \qquad (2)$$

where x_i – a fraction of the installed capacity of each type of renewable energy sources, included in RES cluster;

Y/a – an energy cost, produced by cluster in a unite time;

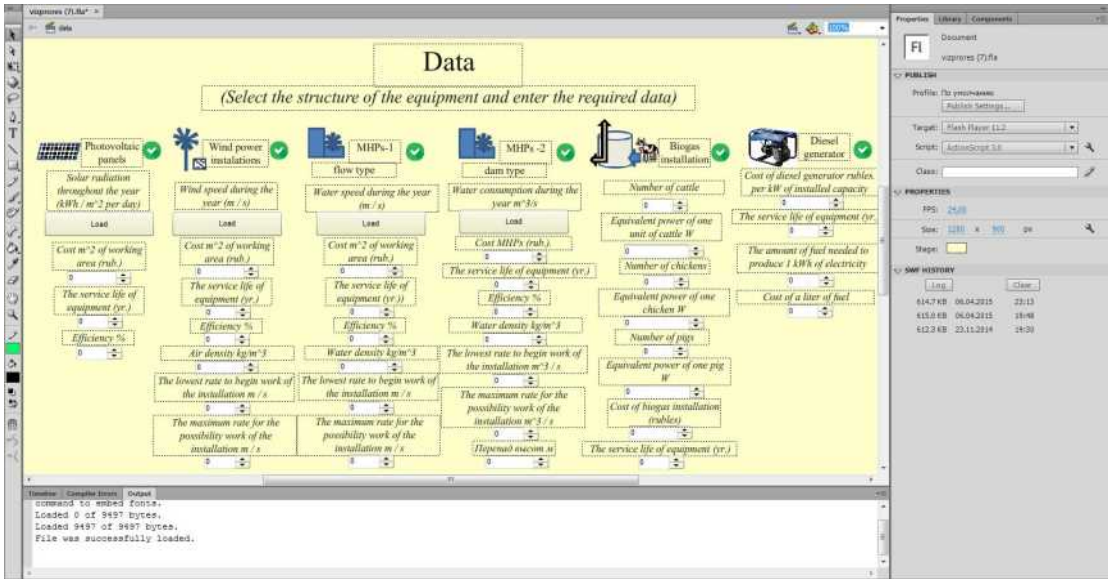
σ_{ij} - a sample covariance, calculated on sampling collection for Y_i, Y_j.

This is the convex-programming problem, which can be solved using the "finding solutions" module in Excel. The result is a vector ($x_0, x_1, \ldots, x_n$), setting an effective RES cluster equipment definition. As applied to the RES cluster this is a solving for optimum of fraction capacity balance x_{DG}, x_{WT}, x_{PC}, $\ldots x_n$.

Optimality criterion is the minimal production cost of kW*h electric energy by all types of the equipment per year [4].

Functional characteristics of "VizProRES":

The application for RES optimum unit commitment "VizProRES" is made in "Adobe Flash Professional CS6" in programming language Action Script 3.0. [5] and is exported to the "EXE" format for the start convenience on any computer. The runtime environment is presented in the pic.2.



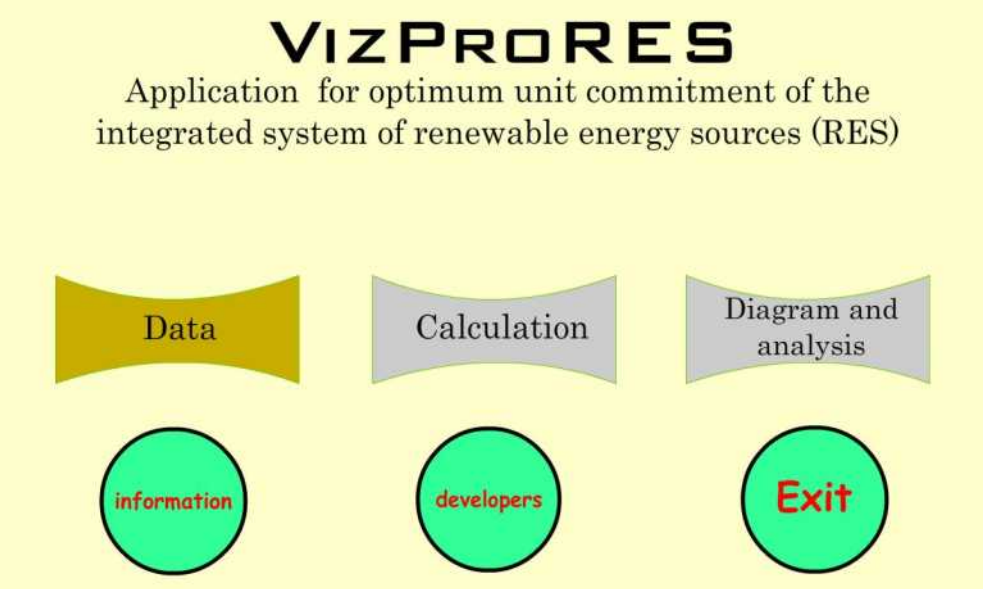
Pic.2. Runtime environment "Adobe Flash Professional CS6"

The "VizProRES" application makes it possible to choose the effective RES equipment complex including wind turbine (WT), photoelectric converter (PC), small hydro-electric power station (sHEPS), biogas unit (BU) and disel generator (DG), as well as to calculate the ideal installed capacity of each element and for the given location.

Application operation description

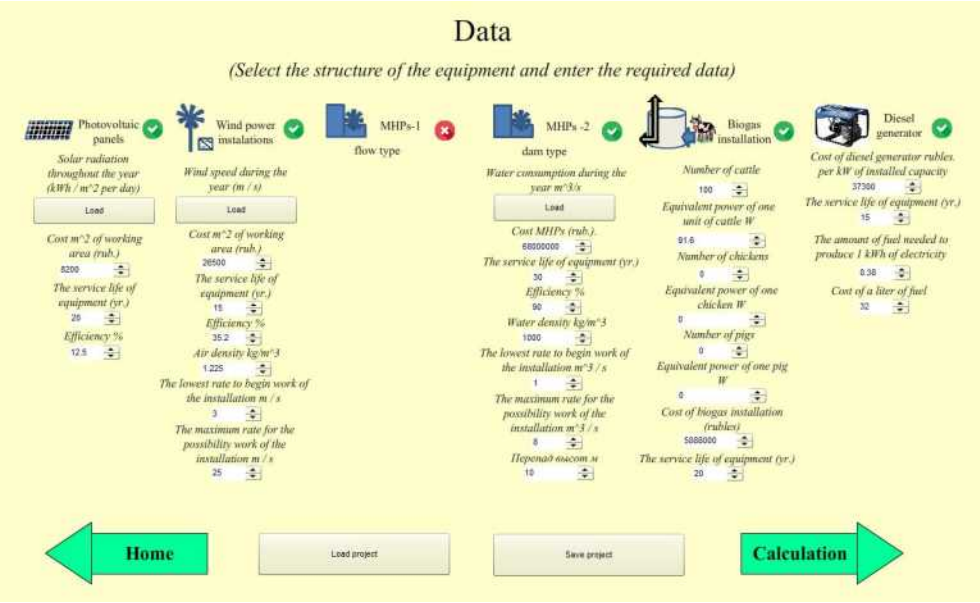
At application start appears a start screen as presented in the pic.3. To data input is necessary to activate the relevant field, upon which opens a user-friendly input window (pic.4). The user may choose types of equipment and characteristics. To download daily data per year of sun

insolation, wind speed, water consumption from a pond, river flow rate, in a relevant field is necessary to input data from a ".txt" file, which contains previously created database.



Pic. 3. The application start screen "**VizProRES"**

In "**VizProRES"** there is an ability to store the selected data and download of previously input information [5] by pressing the icon "Save the project" or "Download the project".

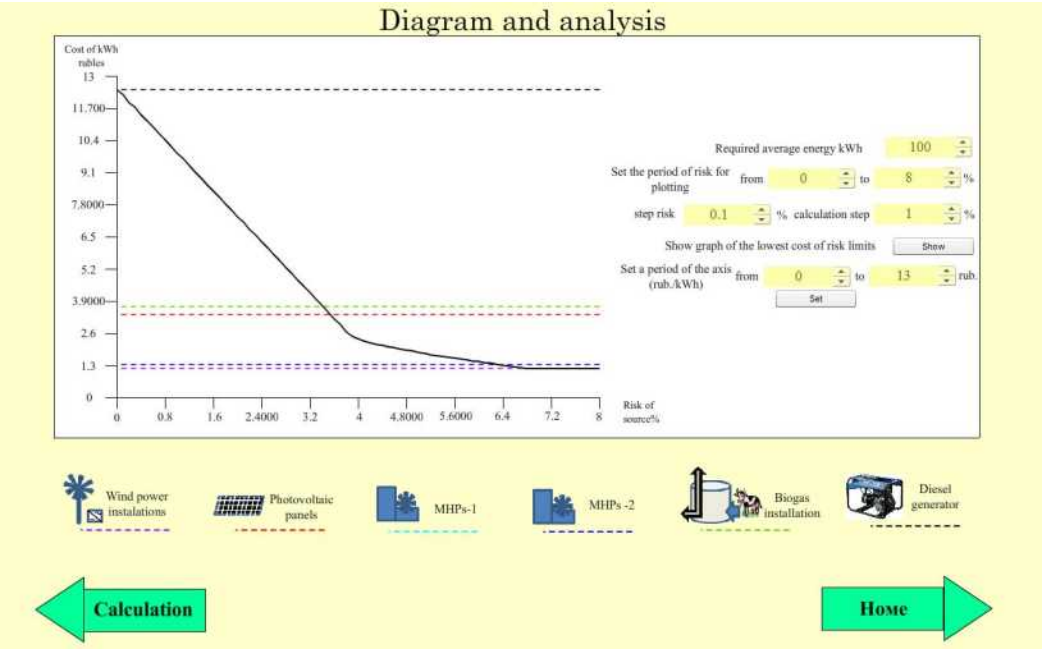


Pic. 4. Raw data input window

The calculation window opens after the input of all the necessary data [6].

Search of optimum RES complex is made by computer blind search of all the possible choices resulting in finding a point corresponding to a minimal production cost of kW*h of electric energy. The determined parameters of RES complex are displayed in text fields.

In “Diagrams and analysis” window (pic.5) is made a construction of the diagram of kW*h total cost dependence of calculated equipment definition on its risk in %. Can be chosen the diagram range on the “risk” and “cost” scales, the calculation step and risk step.



Pic. 5. Window “Diagram and analysis of RES equipment definition”

The “Risk” parameter displays an irregularity of energy production during a year. The higher is the “risk” parameter the higher is the irregularity of energy production. Zero-risk is possible with only risk-free energy sources, such as disel generator or biogas unit, which energy production is constant in time.

Conclusions:

1. The analytical model of efficiency of RES complex system makes it possible to improve the RES cluster on equipment definition and minimum-cost criterion of 1 kW*h production.
2. Usage of the mathematical model of second moment of distribution (dispersion) makes it possible to increase the accuracy of calculation of the optimum RES equipment definition to 20-25%.
3. The choice of the optimum RES type definition with the help of “VizProRES” makes it possible to bring down equipment capital costs and to increase the reliability of consumers electricity supply.

Reference index:

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