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SYNERGETIC MODELLING OF THE RUSSIAN FEDERATION'S ENERGY SYSTEM PARAMETERS[1]

The energy system in any country is the basis of the whole economy. The level of its development largely determines the quantity and quality of economic entities, periods of economic growth, fall and stagnation. A high percentage of the power-deficient municipalities in the Russian Federation shows the substantive issues in this sphere that carries a threat to the energy security of the state.

One of the promising trends for enhancing the energy security is the renewable energy sources (RES). Their use has the obvious benefits: it provides electricity to power-deficient and inaccessible areas, contributes to the introduction and spread of new technologies, thus solving the important social and economic problem. At that, it is important to determine the optimum ratio using of the recovery of renewable and conventional energy sources (CES). One of the main challenges in this regard is to build a model that adequately reflects the ratio of renewable and conventional energy sources in the Russian energy system.

The paper presents the results of a synergistic approach to the construction of such a model. The Lotka-Volterra model was the main instrument used, which allowed to study a behavior pattern of the considered systems on the basis of the simplified regularities. It was found that the best possible qualitative "jump" in the Russian energy sector was in 2008. The calculations allowed to investigate the behavior of the Russian energy system with the variation of the initial conditions and to assess the validity of the targets for the share of electricity produced through the use of renewable energy in the total electric power of the country.

Keywords: renewable energy sources, energy system, targets, synergetic approach

The analysis of the state of the renewable sources' field in the Russian Federation

The basis for the increase of energy security in the majority of countries appears to be introduction and use of renewables, which is the core of a new technological mode along with the most recent technologies. The renewable energy sources offer some advantages in comparison with the conventional ones:

1) respect for the environment (absence of emissions, conservation of the planet balance, the absence of extra emission of carbonic acid and etc.);
2) reproducibility (inexhaustibility of resources);
3) availability to a user (possibility to get energy in hard-to-reach places of dwelling);
4) possibility to use the land, which is not adjusted for economic aims;
5) possibility to use the land for both economic and energetic aims at the same time.

A practical mastering of RES positively influences the socioeconomic status of the government as a whole owing to the fact that it favours the development of small and medium-sized businesses and the creation of new working places.

Along with advantages, there are also some disadvantages, which can be subdued with technological development in the future:

— low energy density;
— the existence of increased noise and vibration (for instance, wind power);
— unsteady, probabilistic character of the flow of energy (production only at the moment of existence of energy source);
— the necessity for accumulation;
— the necessity for reservation (for solar and wind energy).

Basic indicators of the state of renewable world energy (Table 1) show that the volume of the annual investments in 2004–2013 increased 7-fold, but for all that, the investment peak was in 2011 and maximum of general established power of the electric power stations on the basis of RES in the world (not including hydropower) in 2013 was 560 GW at average annual rate of growth 21,2 %.

[1] Original Russian Text © D. A. Gaynanov, O. G. Kantor, E. S. Kashirina, 2015, published in Ekonomika regiona [Economy of Region]. — 2015. — No 4. — pp. 357–369.

Nowadays, the leaders in renewable energy are China, USA, Germany, Spain, Italy and India (Table 2).

The Russian Federation lags behind the top countries in the generation of the wind and solar energy. According to the World Wind Energy Association (WWEA), in 2013, Russia with its index of 16.8 MW took the 69th place in the world in accordance with the total capacity of the wind power stations. Speaking about the solar energy, it should be noted that based on the estimates of the German Advisory Council on Global change, by 2100, the Sun will be a dominant source of the energy on the planet. For this reason, the solar energy is regarded as the most perspective direction of RES in many countries, it is actively supported and rapidly developed. In Russia, some changes were made in this direction: in 2010, the first photovoltaic power plant was launched in the Belgorod region with 100 kW power and in autumn 2014 Kosh-Agach solar power station was opened for an experimental run in the Republic of Altai.

According to the indices of hydropower capacity, the Russian Federation leaves behind many countries including Germany, India, Italy and Spain but at the same time gives way to Mexico, Indonesia, the Philippines and so on. However, the larger part of the world community only views as

Table 1

Global Trends in Renewable Energy Developments

Indicator	Year									
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
New investment in renewable energy, billion USD per year	30	40	55	104	130	161	227	279	249	214
Renewable power capacity (not including hydro), GW	99	116	136	163	180	250	315	395	480	560
Countries with policy renewable energy targets, units	45	52	—	68	75	85	109	118	138	—

Source: Renewables 2014 Global Status Report. Renewable Energy Policy Network for the 21st Century. Retrieved from: http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf.

Table 2

The Installed Capacity of Generating Facilities Running on RES in Top Six Countries and Russia, GW

Type of power	Country						
	China	USA	Germany	Spain	Italy	India	Russia
Bio-power capacity	6.2	15.8	8.1	1	4	4.4	1.2
Geothermal power capacity	~0	3.4	~0	0	0.9	0	0.08*
Hydropower capacity	260	78	5.6	17.1	18.3	44	46.7**
Solar power capacity	19.9	13	36	7.9	17.6	2.3	~0
Wind power capacity	91	61	34	23	8.6	20	0.02***
Total (including hydro)	378	172	84	49	49	71	48
Total (not including hydro)	118	93	78	32	31	27	1.3
Share of a global volume of renewable energy capacity (including hydro), %	24.23	11.03	5.38	3.14	3.14	4.55	3.08
Share of a global volume of renewable energy capacity(not including hydro), %	21.07	16.61	13.93	5.71	5.54	4.82	0.23

Source: Renewables 2014 Global Status Report. Renewable Energy Policy Network for the 21st Century. Retrieved from: http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf.

* Source: BP Statistical review of world energy 2014. Retrieved from: https://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf.

** Source: Annual report of Public Joint-stock Company "RusHydro" 2013. Retrieved from: http://www.rushydro.ru/upload/iblock/4ec/RusHydro_26–06.pdf.

*** Source: World Wind Energy Association (WWEA). Retrieved from: http://www.wwindea.org.

RES the energy produced in the small-scale HPP's and its part in hydropower industry in the country is 1.6 %.

Such state of the renewable energy in the country is explained, firstly, by the provision of its own fossil fuel reserves, and, secondly, by the fact that to the RES problems were not been paid enough attention for a long time, which resulted in the absence of a governmental regulatory mechanism and the lack of its support.

It should be mentioned that the oil and gas resources are not unlimited, and the exploration of new fields demands large expenditures. Different research of the energy in Russia show that more than 50 % of the territorial units in the country are energy-deficient, and therefore, there is a problem of the internal energy security. Regardless of the fact, the conventional fuels will continue to have a leading role in the grid of the country for years to come; RES should be observed as an important element, the use of which corresponds to the principle of stable development and promotes a rational use of existing resources.

In this connection, the problem of the recuperation of renewables and conventional energy sources reduced to the determination of an optimum correlation of their utilization has the special relevance. The solution of this problem accounting for the complexities of the system should be carried out on the basis of mathematical modeling. One of the main tasks is to build a model that reflects the correlation between RES and CES in an energetic system of the Russian Federation. The existence of such model should supply not only detection of established tendencies in the energy industry of Russia, but also provide a possibility to value the consequences from impacting it. The development of such model is the subject of this paper.

Synergetic Approach to Research Energy Systems

The grids are complicated systems, which are defined by openness, purposefulness, dynamic and hierarchy. The complication of the grids is explained by the existence of a great number of elements interacting with each other, such as electric power stations, substations, electric and heating, etc. Openness, purposefulness, dynamic of the grids specified with their embeddedness in socio-economic system of different levels (in accordance with the territorial and administrative features), their functioning is realized uninterruptedly in accordance with the economic, social and political reality, and directed to attain the definite aims on a scale of both separate areas and the government as a whole. The hierarchy of the grids is explained by its multi-level structure. For example, the power-grid

Table 3

The Comparison of the Cybernetic and Synergetic Approaches

Characteristic	Cybernetics	Synergy
Definition	The science about self-regulation in grids [2, P. 17]	The science about self-organization in grids [2, P. 47]
The object of inquiry	Stable, directed, self-regulating systems [3, P. 143]	Open, nonlinear, non-equilibrium, dissipative system [3, P. 143] (closed systems are examined like private, limited in time and space, conceptually built cases of self-organization, which are characterized with linear processes)
The subject of inquiry	The processes of direction	The conformity and mechanisms of self-organization [4]
The back coupling	The direction by the system is realized with the help of circuit of a negative back coupling [1, P. 17]	Taking into account of positive and negative back coupling (negative back coupling obstruct the changes and development, positively is responsible for the development) [5, P. 3]
Incidental influences	The development of the system under the influence of these factors is not considered [6]	Observed like a source of development
The results of development of the system	Balanced state	Different trajectories [7] (balanced state in systems is observed in a limited dimensioned factor) [8, P. 64–68]

of Russia consists of seven united power grids, which, in turn, include about 20 regional grids according to the geographical features, respectively.

In the context above-mentioned, the use of specific methods, including cybernetic and synergetic, is implied in the mathematical description of the grids. The main task of the cybernetic approach in the investigation of systems is to study how should the processes be operated, and the synergetic approach is to study processes of systems' self-organization. The comparative analysis (Table 3) of two approaches shows that the synergetic method is wider that led to its choice as the basic instrument in the context of a real investigation.

The Lotka — Volterra Model: Description and Use

The synergy being an interdisciplinary science it allows to use one and the same model for objects of the different nature. Within the limits of synergetic science, the set of basic mathematical models was worked out, where the Lotka — Volterra models of interspecific struggle were included. A great interest from the side of scientists was shown because of the expedient assumptions and obtained conclusions from this model. The main advantage is the realization of qualitative features of the system behavior with the help of simplified dependencies.

The Lotka — Volterra models are widely used in the different spheres of science: in work of chemical kinetics [9] and dynamics of microbe elements [10], process modeling of species' formation [11] and activity of neurons [12], in mathematical economics [13], in astrophysics [14], in hydrodynamics [15], in description of social and economic interactions [16–21].

In 1910, an Italian researcher A. Lotka on the basis of analysis of a the system of differential equations predicted the possibility of oscillations in chemical systems. In 1920, V. Volterra, being interested in vibrations of harvesting of fish in the Adriatic Sea, deduced the system of ordinary differential equations, which described the interaction of the population. The results, which were obtained independently from one another, were identical. For this reason, the model described as a system of differential equations (1) was named the Lotka — Volterra equations [22, p. 24]:

$$\begin{cases} \frac{dx}{dt} = x(a - by), \\ \frac{dy}{dt} = y(-c + dx), \end{cases} \tag{1}$$

where x — the number of prey; y — the number of predators; a — a coefficient of prey birth rate per a unit time in absence of predators ($y = 0$); $-c$ — a coefficient of predators death rate per a unit time in absence of prey ($x = 0$); b, d — a coefficient describing the effectiveness of victims' consumption by the predators; $a, b, c, d > 0$.

As a basis of the Lotka — Volterra models, the following assumptions were accepted:

— the population of prey reproduces exponentially (in accordance with the Maltus law $\frac{dx}{dt} = ax$) if a predator is absent;

— the population of predators exponentially dies out ($\frac{dy}{dt} = -cy$) if a prey is absent;

— there is a linear dependence between the total quantity of prey, consumed by predators, and the quantity of both populations;

— the summands, proportional to multiplication xy, are observed like a transmutation of an energy source into another energy (the result of a meeting of both populations consists of decreasing the speed of growth dx/dt of prey quantity into quantity xy, proportional to the quantity of the predators) [23];

— other factors that could have an affect on the dynamic of the population are absent (the limit of resources of prey and predators, the effect of predators' saturation and so on).

V. Volterra, learning relations "predator — prey", came to the conclusion [24]:

1) variation of the number of two kinds of individuals is periodic;

2) the average value of the number of two kinds of individuals does not depend on the initial conditions, if only the coefficient of growth and the coefficient of rapacity are the same;

3) if they try to kill both kinds of individuals at the same time, then the average value of the number of consumed individuals will increase, and the number of consuming individuals will lessen.

The key for the model (1) is the coefficient of rapacity, and V. Volterra wrote about this the following: "...They grow together with rapacity and with the voracity of the second type, and they lessen when the first kind of individual has more means of protection" [24]. That is why the basis of the model became the trophic function, which described the individual ration of a predator. By definition, the individual ration is the quantity of prey, consumed by the predators per unit time. A traditional form of the trophic function is the dependence of individual ration of a predator P, but only from the population density of prey x, i.e. $P = P(x)$. The simplest case of a trophic function is a linear dependence $P(x) = mx$, which was used in the Lotka—Volterra model. Such dependence was used when almost all victims became the prey of a predator. If the coefficient part k which was obtained from biomass of prey's energy is spent on reproduction, and the other part is spent to support basal metabolism, model (1) takes the following form:

$$\begin{cases} \dfrac{dx}{dt} = ax - mxy, \\ \dfrac{dy}{dt} = kmxy - cy. \end{cases} \qquad (2)$$

The Lotka—Volterra model has some disadvantages. From a mathematical point of view, the model is rough (in the V. I. Arnold's terminology) and conservative so that even small changes of parameters can lead to the qualitative changes in the trajectory of decisions. From a biological point of view, a disadvantage is the absence of factors influencing the dynamic population (the limitation of resources of prey and predators, the effect of predator' saturation and so on). But nevertheless, the model (1) allows to describe the difficult systems of different natures with the help of simple rules, and the effectiveness of this method was proved [25–30].

The Model of Renewable and Conventional Energy Sources' Use

As a basic model of using conventional and renewable energy sources, the model (2) is used. The electricity generation from RES is associated with victims and indicated x, and the electricity generation from CES is predators and marked y. Summand ax in the first equation of model (2) shows the growth of electricity generation from RES without CES: evidently, we could expect an increase of electricity generation from RES in proportion to the quantity of electricity already produced. The summand $-cy$ in the second equation is explained in the following way. The absence of RES practically implies the disappearance of a competitor for producers of electricity from CES, which can continue to get the same profit, increasing the price and reducing the volume of produced electricity.

The summand, proportionate to multiplication xy, shows the increase of electricity generation from the connection of both kinds of sources. Considering that electricity generation from CES is more popular and yields lower costs (Table 4) for customers, supposing that a customer has a choice and prefers electricity from CES that negatively influences increase of x, and, on the contrary, positively influences increase of y. For all that, the volume of consumption, which the producers of electricity from RES "lose", evidently should be provided with the electricity from CES. It allows to get a parameter $k = 1$.

Table 4

A Cost Value of Electricity Production in the Russian Federation in 2007, [31, 32]

A sort of electro power station	A cost value, cent/kWh
Thermoelectric power station	2.5–5.5
Atomic power station	≤2
Medium and big hydroelectric station	≤1
Small hydroelectric station	2.5–4.3
Biomass power station	4.5–14
Wind power station	16–22
Geothermal power station	13–15
Solar power station	53.5–57.2
Tidal power station	17–20

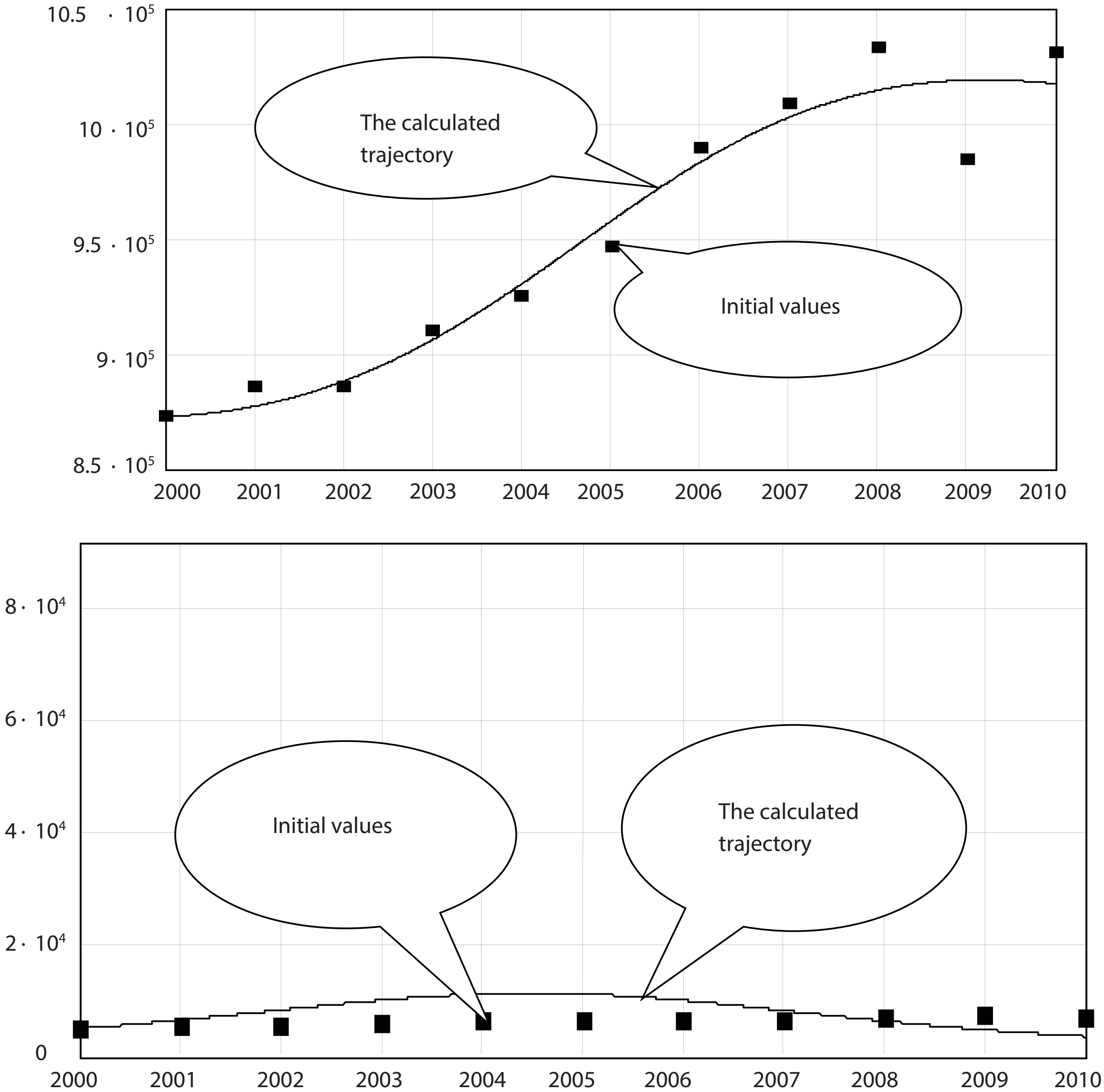

Fig. 1. *The trajectories of electricity generation from CES (on the left) and RES (on the right)*

The calculation of parameters of the model of the RES and CES use was made on the basis of a datum of official statistic accounts of the Russian Federation (Table 5).

The direct calculations were made with the help of the mathematical package Mathcad, that allowed to get the following values of required parameters: $a = 3.9956$; $m = 0.000004$; $c = 0.0172$. So, the model of utilization of RES and CES can be shown on the following form:

$$\begin{cases} \frac{dx}{dt} = 3.9956x - 0.000004xy, \\ \frac{dy}{dt} = 0.000004xy - 0.0172y. \end{cases} \quad (3)$$

A good precise model (3) confirms average errors of approximation $A_y = 1.094\%$; $A_x = 1.094\%$ (fig. 1).

The model (3) allows to value the current state of the energy system (find in what position it is at the present moment), predict its behavior by taking into account different initial conditions and come to know its more effective variants of traditional and alternative energy sources utilization.

The synergetic approach suggests that in the process of its development, which consists of cyclical repeated levels of evolution and a leap, the system always changes from a stable condition to unstable and vice versa. The different types of traffic in the environment of equilibrium (conditions) correspond to the different types of equilibrium conditions. Most practical works in synergy are directed to find stable positions of the system and study the behavior of the system close to the equilibrium point.

Table 5

The Electricity Generation in the Russia, mln kWh

Year	Electricity generation from RES	Electricity generation from CES	The total electricity generation	The share of electricity generation from RES,%
2000	4550.7	873249.3	877800.0	0.52
2001	4788.2	886511.8	891300.0	0.54
2002	5021.7	886278.3	891300.0	0.56
2003	5362.7	910937.3	916300.0	0.59
2004	5982.1	925917.9	931900.0	0.64
2005	5892.2	947191.2	953083.4	0.62
2006	5929.4	989864.5	995793.9	0.60
2007	6027.5	1009306.0	1015333.5	0.59
2008	6460.2	1033919.0	1040379.2	0.62
2009	6750.9	985228.6	991979.5	0.68
2010	6320.1	1031709.0	1038029.1	0.61

* Bezrukih, P. P. (2013). Sostoyanie i perspectivy ispolzovaniya vozobnovljaemykh istochnikov energii v mire [State and prospects for using the renewable energy in the world]. Moscow: IMEMO RAN Publ. Retrieved from: http://old.imemo.ru/ru/conf/2013/13122013/BEZRUCH_13122013.pdf (date of access: 16.03.2015).

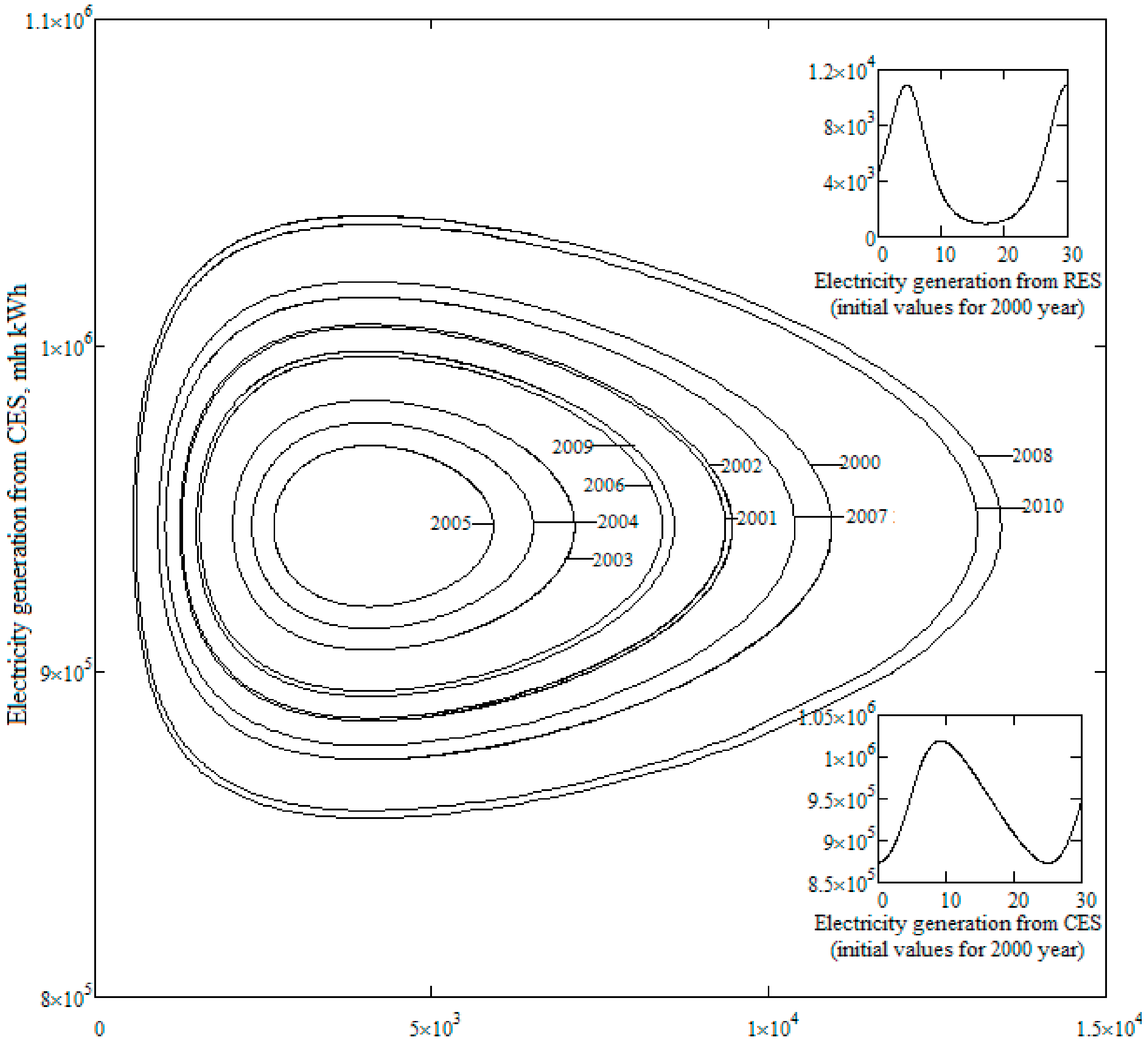

Fig. 2. *Phase plot for model (3) and time trajectories*

On the basis of the system (3), an equilibrium point can be defined, which is calculated from the condition:

$$\frac{dx}{dt} = 0; \quad \frac{dy}{dt} = 0. \tag{4}$$

The model (3) has 2 critical points: the first—$x = 0$, $y = 0$—the production of energy is absent and that is why it is not interesting for investigation, the second— $x = \frac{a}{m} = 944300$, $y = \frac{m}{m} = 4065$ —is a special point inside of the phase curves or the center (Fig. 2). The phase trajectories in an environment of the center are closed curves, appropriate for initial values for 2000–2010. Close to the center, continuous waves were observed. The beginning of the negative back coupling is the result of a decrease in electric energy production on the basis of non-renewable sources, the growth of electricity from RES can be observed. As far as an equilibrium point is stable, only a strong fluctuation (for instance, great volume of investments in renewable energy, presentation of different encouraging methods by the government) can lead to a qualitative leap and change the structure of energy industry in Russia.

The conclusion made by V. Volterra according to the model "predator—prey" is true in the case of the system (3).

The research of the model (3) shows that the energy system of the Russian Federation from 2000 to 2005 tends towards an equilibrium point (corresponding to the trajectory of the Fig. 2). Then, some distancing was observed from the point. Maximum separation from an equilibrium point was in 2008. This year was the best period to make a qualitative leap in the electric power industry of the Russian Federation. However, the government did not make any measures; therefore, the energy system came back to "comfortable" (stationary) state.

This conclusion is confirmed by statistics (Table 5): the value of produced electricity from different sources of energy in Russia was close to an equilibrium point. In different years, a relative deviation of electricity produced from RES and CES was from 0.3 % to 9.5 % and from 11.9 % to 66.1 %, respectively. As mentioned above, it can be explained by sufficient sources of traditional energy sources and mechanisms that are not worked out because of insufficient support of the renewable energy by the government.

Model Application of Renewable and Conventional Energy Sources' Use

The developed model (3) can be used for purposes of forecasting and setting the target indicators. In the USA, the detailed prognoses of the dynamic of heterogeneous energy indicators considering RES till 2020 were made in 1996–1998 [33]. In Russia, the RES prognoses are not developed, the target indicators of their development have appeared recently.

For the first time, the target indicators for the development of RES on the state level were identified in "Increasing of the energetic effectiveness of electro energy on the basis of utilization of renewable energy sources till 2020" (it was confirmed by the order of the Government of the Russian Federation from the 8th of January 2009 № 1-p)[2]. In accordance with the documents, the total sum of RES was planned to increase (without large-scale HPP's) in power generation of the country in 2010, 2015 and 2020 till 1.5 %, 2.5 % and 4.5 % accordingly. However, the time showed that planned reference point was hard-hitting. That is why the order of the government of the Russian Federation from the 28th of May 2013 № 861-p[3] introduced some additions and corrections to the document mentioned above (Table 6).

In 2014, in accordance with the corrected and approved state program of the Russian Federation "Energy efficiency and energy development", it had been targeted to increase the percentage of RES in the energy balance of the country by 2020 up to 2.5 % instead of the previously chosen 4.5 % in 2009[4] (Table 7).

Within the limits of the developed model (3), an investigation was made under the influence of a change in initial conditions on the behaviour of the energetic system in Russia. In this way, the variation of the share of electricity from RES in 2010 (Table 8) to the total volume of produced electricity fixed

[2] Sobranie zakonodatelstva Rossiyskoy Federatsii [Collection of laws of the Russian Federation]. (2009), 4, 515.

[3] Sobranie zakonodatelstva Rossiyskoy Federatsii [Collection of laws of the Russian Federation]. (2013), 23, 2931.

[4] Sobranie zakonodatelstva Rossiyskoy Federatsii [Collection of laws of the Russian Federation]. (2009), 4, Art. 515.

Table 6

National Targets for Renewable Electric Capacity (MW) and Expected Volume of Electricity Production from Renewables (GWh)

Types of power stations	MW/ GWh	Year							Sum total
		2014	2015	2016	2017	2018	2019	2020	
Wind power stations	MW	100	250	250	500	750	750	1000	3600
	GWh	219	547.5	547.5	1095	1642.5	1642.5	2190	7884
Solar power stations	MW	120	140	200	250	270	270	270	1520
	GWh	136.7	159.4	227.8	284.7	307.5	307.5	307.5	1731
Hydro power stationsunder 25 MW	MW	18	26	124	124	141	159	159	751
	GWh	46.4	69.6	324.6	324.6	371	417.4	417.4	1971
Total	MW	238	416	574	874	1161	1179	1429	5871
	GWh	402	776.5	1099.9	1704.3	2321	2367.4	2914.9	11586

Table 7

The Implementation of Renewable Energy Sources

Index	Year							
	2013	2014	2015	2016	2017	2018	2019	2020
The share of electricity generated by renewables in total volume of electricity generated (excluding hydropower plants over 25 MW), %	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5
The capacity of power-generating facilities running on RES (excluding hydropower plants over 25 MW), MW	—	238	416	574	874	1161	1179	1429

Table 8

The Results of the Model Extrapolation (3) Assuming Variations of the Data from 2010 as The Initial Values*

Index	The share of electrical energy produced from RES in the entire volume of production, %				
	0.62	1.0	1.5	2.0	2.5
RES, million kWh					
– initial value	6320.1	10380.3	15570.4	20760.6	25950.7
– minimum value for the total cycle	606.1 ***(0.058 %)***	376.8 ***(0.036 %)***	168.1 ***(0.016 %)***	66.0 ***(0.006 %)***	24.6 ***(0.002 %)***
– maximum value for the total cycle	13090.0 ***(1.26 %)***	15480.0 ***(1.49 %)***	19570.0 ***(1.89 %)***	24040.0 ***(2.32 %)***	28730.0 ***(2.77 %)***
CES, million kWh					
– initial value	1031709.0	1027648.8	1022458.7	1017268.5	1012078.4
– minimum value for the total cycle	857300.0	842000.0	819100.0	797500.0	777600.0
– maximum value for the total cycle	1037000.0	1055000.0	1082000.0	1108000.0	1133000.0
Periodicity, year	26.0	27.0	28.5	30.5	32.5

* — the share of electrical energy is marked with Bold Italic, produced from RES, towards to the total volume of the production electricity.

at the level of 1038029.1 million kWh (Table 5). The increase in the share of electricity from RES yields the following effects:

— spread in values of electricity produced from the RES and CES rises, which indicates that the energy system of the Russian Federation moves away from its steady state; there is an evident breach of the harmonic nature of the oscillations, which can be evaluated as a factor that positively influences the increase in the number of possibilities for a change of the current structure of grid;

— the duration of cycles — the predicted periods in the development of the energy system of the Russian Federation — increases;

— spread in values shorten between the maximum amount of electricity from RES as a share of the entire volume of produced electricity, and the analogous initial value expressed in percent. According to the data from 2010, these values differ by 2.03 times (1,26 %/0,62 %), and with the share of RES in a total volume of produced electricity of 1 %, 1.5 %, 2 % and 2.5 % this ratio becomes 1.49, 1.26, 1.16 and 1.11 times, respectively.

The results of the last conclusion can be evaluated as the basis for the target indicators' development. Indeed, an increase in the share of electricity produced from RES in the total volume of generated electric energy is related to the growth of investments in this field of electric power industry. It is obvious that investment projects on a scale of the country become more attractive the better outcomes they can lead to [34]. In this case, firstly, the positive outcome is expressed in a possible increase in the growth in the RES-produced electricity. In case of investments into the RES-based power production with an increase of its share in the total volume of electricity generated in the country up to 1 % (Table 8) the maximum effect will amount to 0.49 % (1.49 %–1 %), and in the case of its share getting up to 1.5 %, 2 % and 2.5 % — 0.39 %, 0.32 % and 0.27 %, respectively.

Matching the planned investments with suggested outcomes favours the growth of validity of decisions made. It should be noted that the results of the calculations and the drawn conclusions presented above confirm expediency of corrections of the target values of the share of RES in 2014 in the country's energy balance[5], according to which, by 2020 this share index should reach 2.5 % instead of 4.5 % expected in 2009.

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