About Controllability in the Energy Sector. Including the Global One. Problems, Possible Solutions and Prospects

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Article

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Abstract: Efficient or at least rational use of energy resources is a problem that occupies an overwhelming number of people in modern society – from major scientists and politicians to journalists and schoolchildren who have a poor understanding of the basic laws of physics.(the knowledge of politicians in this area is also sometimes doubtful). At the same time, the main focus of the discussions is on the resource base, possible waste and consequences. According to these features, they want to see the future of energy. However, the division of "energetik" follows different principles. On the one hand, these are thermal, nuclear and hydropower sources. On the other – wind and solar energy. Obviously, this separation is not only related to the renewable resources or the absence of consequences for the environment and humans. If we do not touch on geopolitical problems. which are not the subject of this article, it is obvious that the main dividing feature of these types of energy production will be their controllability. The theory of automatic control (TAC) is one of the most complex modern sciences that has been developing for many years to solve precisely the problems of energy Now, when considering energy problems, this science is most often not remembered. Maybe because the most active participants in the discussions don't know much about it? Or is this situation beneficial to someone? How efficiency and controllability are related to some problems with controllability in the "household" energy sector, which concerns almost every inhabitant of the planet and in the global energy sector, this article is devoted to

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1. Introduction

In three energy production technologies - thermal, nuclear and hydropower, the problem of controllability, in general, has been successfully solved.

In RES - wind turbines and solar battery parks -. has virtually no rational solution. It should be noted that this is of little concern to the supporters of these "power engineers". Suffice it to mention that in advertising and popular publications and materials [1,2], controllability problems are never mentioned (!!!).

Meanwhile, controllability of processes is a quality that creates civilization and it is very dangerous to ignore it. At the same time . obviously, the fact that the problem has been solved in the traditional energy sector has contributed to a superficial attitude towards it in the "new energy. In the first part of the article, the author will consider in more detail the controllability of processes at the "household" level - in automatic heating systems, which he encountered during practical cooperation with energy companies. In the second, an assessment is made of possible solutions to controllability problems in alternative energy fields, which, in the author's opinion, are of undoubted interest to a wide range of readers.

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2. About control problems in domestic power engineering.

Automatic heating systems are one of applications of high-professional automatic control theory in normal life. Modern smart home appliances are able to efficiently control air temperatures in separate premises, large buildings and structures. There are many variants of such systems[3–8]. The most widely used are systems for regulating the temperature of a heat transfer agent depending on the temperature of the outside air[9] (Figure 1).

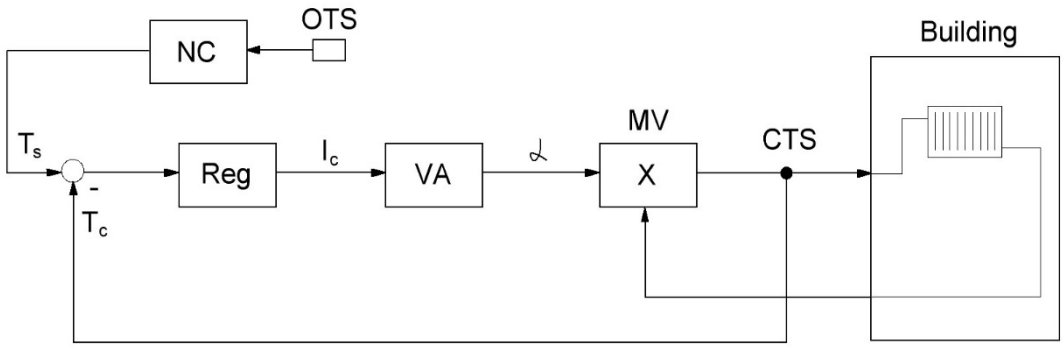

Figure 1. Functional diagram of a system with a mixing valve.

In such systems, depending on the temperature of the outside air measured by the sensor OTS - non-linear converter NS generates the setpoint temperature. Reg - system regulator, which forms the control I_c and for the valve actuator; VA, which turns MV - mixing valve so that the temperature of the mixed hot and cold heat transfer medium, which is controlled CTS, is close to the specified value. In this case, the temperature of the hot coolant must be somewhat greater. The maximum temperature required for heating. In such systems, it would have failed to provide complete controllability of the processes. The accuracy and speed of modern automatic control systems (ACS) are such that it is not difficult to obtain stable, accurate ACS for heating buildings. But most often, due to the dynamic characteristics of the building to be heated and the regulator, the processes for regulating the temperature of the heat-transfer agent are oscillatory, with a significant amplitude of 7 -10° C (Figure 2).

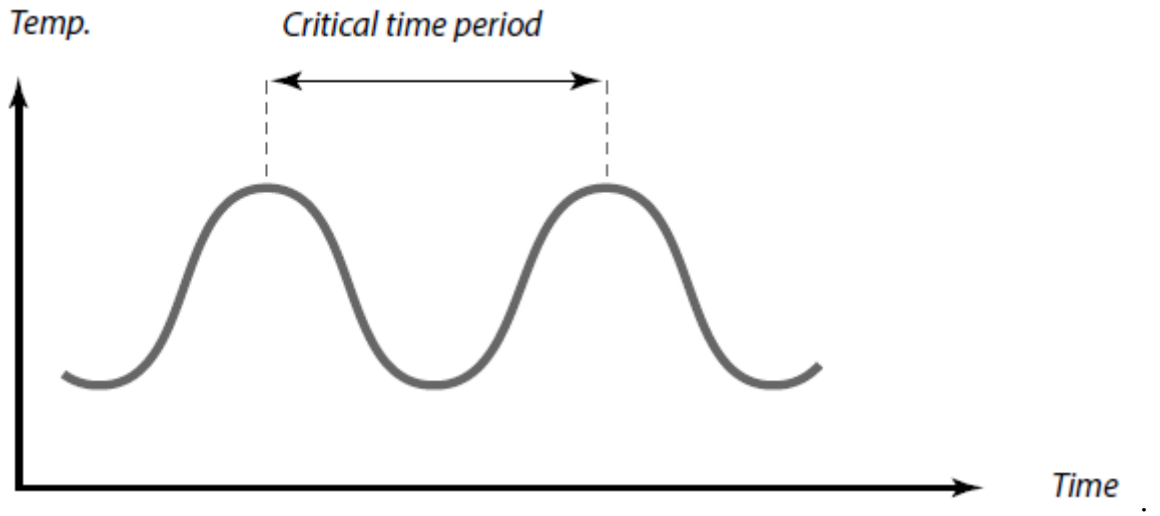

Figure 2. Figure on page 74 in the Danfoss ECL Comfort 210\310 manual[9].

This fluctuation does not affect the comfort of people in these buildings, and the equipment of "smart" complexes, for all its intelligence, considers these fluctuations to be a normal mode of operation.

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One of the important features of oscillatory processes is this loss of controllability and accuracy of the ACS . As can be seen from Fig2 . the heating system, maintaining an average temperature of the coolant equal to the temperature of the task (this is how ACS work), allows oscillatory processes and the ACS cannot regulate instantaneous temperature values "inside" these fluctuations. What does such a loss of controllability lead to ? Consider further…

It should be noted that equipment manufacturers also do not consider such modes to be emergency. The instructions do not contain any instructions for their correction.. Much more attention is paid to optimization modes , for example . "priority of hot heat supply" or "regulation of the temperature of the reverse coolant", [9] which form external temperature control circuits in the boiler or at the entrance of the heated building and which are completely unusable with the fluctuation of the control processes in the internal circuit of the coolant.

In recent years, attempts to apply a variety of sources of resources – wind power, solar power sources and solar heating, etc. - have been frequent in modern "smart" homes.

In such "multidimensional" systems, it is advisable to use neural network technologies for regulators, but even in them the task of synthesizing correct dynamics, that is, with minimal oscillation, turns out to be relevant.

Therefore, let's return to heating systems with automation, which have been produced and used for a long time, have been well studied and do not contain any "pitfalls", as it seems to engineers and residents of houses - "consumers" of such systems.

Many companies produce equipment for such systems, the largest of them are Danfoss (Denmark), Honeywell (USA), Viessmann (Germany), ARIES (Russia). The instructions for this equipment also do not require the exclusion of such modes from operation. So on the page there is a recommendation for "optimizing" the control processes, and nothing says whether to eliminate these fluctuations or at least reduce their amplitude, how to do it, what they lead to and what their appearance and parameters (amplitude and frequency) depend on.

This circumstance is quite difficult to explain, based on the provisions of the theory of automatic control (TAC)[10], which considers stability and the absence of oscillation in transients to be the main scientific problem.

Control theory applied to thermal power engineering is a fairly well–developed field. Most often, simplified "linear" methods of ACS analysis are used in works on heat supply automation. Little attention is paid to the more complex, but also closer to reality, nonlinear TAC and its methods. Obviously, heating systems are secretly considered "simple" systems for TAC.

The monograph [11], which is very detailed for TAC heat supply methods, discusses approaches to the construction of a heat supply ACS that have developed over several decades not only in Russia. but also in other countries. A lot of attention is paid to the problem of sustainability. At the same time , the authors do not go beyond the linear TAC . That is, they consider all systems as linear

A lot of attention is paid to the method of selecting the parameters of regulators. providing a certain margin of stability. This technology . developed in the 60s, it is quite cumbersome. It is valid only for dynamic objects of a certain structure and completely "falls apart" if there is at least one non-linear link in the heating system. There are almost always such links in the systems. In the same book, in the section on real automation tools, nonlinear actuating relays are indicated.

In this section, the authors "forget" about the method of synthesis of stable processes and explain that ACS with such links are necessarily oscillatory. At the same time, nothing is said about the possibility of changing the amplitude of vibrations by applying the method of analysis of nonlinear ACS – the harmbalance method. This method allows you to select the parameters or correction structure that will provide self-oscillation with minimal amplitudes and the most convenient frequency in the initial control system, that is, its use will make the self-control of the ACS minimal. As a rule , even the resources of standard regulators are sufficient for this operation .Similar solutions are given in the works [13], where they are described in detail and justified ..

One can only guess whether the sections of nonlinear TAC are really very difficult for companies implementing ACS in heat supply or it is beneficial to someone.

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The research conducted over 15 years by a group of specialists from SUSU and NPF Vostok-Zapad (Chelyabinsk, Russia) was aimed at studying the causes of fluctuation of heat supply processes[12–15], the possibility of their correction and assessing the impact of the quality of dynamic processes of coolant regulation on the final characteristics of automatic heat supply systems.

3 About the causes of oscillation

We note several theoretical provisions on the controllability and stability of automatic control systems.

From the point of view of classical TAC, oscillation is the ultimate stability of the ACS. In this case, the oscillation in the sauna is determined by the amplitude of the oscillations. From the point of view of stability theory, oscillatory processes with any amplitude have the same evaluation as systems with extreme stability.

But from the point of view of controllability, systems with small and larger amplitudes have significant differences, since they cannot ensure the accuracy of regulating the output variable (in this case, the temperature of the coolant) above the amplitude of these fluctuations. From this point of view, it is advisable to reduce the amplitude of vibrations in the ACS as much as the dynamics of the elements and the structure of the ACS allow. All this fully applies to heating systems. The causes of oscillation in the automatic heating systems presented on the pattern 1 are several, the excretions two, most essential. Widely used elements of such systems are mixing valves with electric drives.

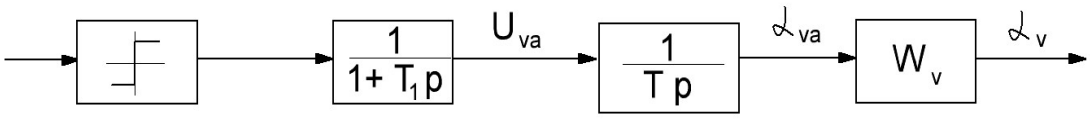

Figure 3. The structural diagram of the valve drive of an unregulated type.

In Figure 3, a diagram with an unregulated type regulator, the signal supplied to the valve electric motor has only two values , the temperature of the heat transfer medium changes by the position of the mixing valve, ie the angular position of the output shaft of the valve reduction gear.

Such a link, which is built into the structure of the ACS, helps to disrupt the stability and controllability of the heating system.

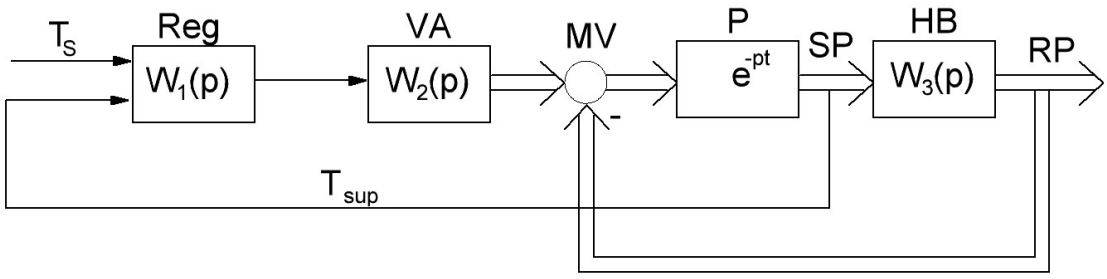

Figure 4. Structural diagram of valve actuator with positioning.

Mixing circuits form feedbacks that complicate the structure of the ACS. At the same time, pipelines and heated buildings are dynamic links with great inertia or pure lag. Even in a "simplified" form, these schemes (Figure 4) have a significant "potential" of oscillation.

In such a structure, it is difficult to obtain asymptotic stability. But it is possible to change the amplitude of self-oscillations by applying the harmonic balance method in nonlinear systems, as shown in [12–15] A mixing valve operating at one speed, taking into account mechanics – from the point of view of TAC - is a relay link with complex dynamics , which in any closed control system greatly contributes to oscillation by selecting the parameters of the regulator by this method.

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In heating systems, unlike electromechanical ACS, fluctuations in the temperature of the coolant are not a clear sign of a malfunction. This explains the "tolerance" to such regimes of many recommendation documents and instructions.

Let's consider the effect of oscillatory processes on energy consumption in ACS.

Direct losses from oscillation are very difficult to calculate. it is widely believed that these losses only affect the operation of the valve actuator . that is, they are minimal. At the same time , it is not taken into account that cold and hot water are mixed in boilers and heating circuits , the oscillatory processes of temperature changes and the speed of movement of the coolant certainly require energy consumption , But in this case we will take into account only those resource costs . which are necessary to compensate for the loss of controllability of heat supply processes due to oscillation.

4. Problem analysis

In order to. in order to fully control the average temperature of the coolant, it is necessary that its maximum temperature reaches a value that takes into account the amplitude of the oscillations. That is, it is necessary to "overheat" the coolant in the boiler relative to the temperature required by the heating conditions for the amplitude of fluctuations.

With an oscillation amplitude of 7-10 degrees C, this excess will be up to 10% of the resources needed to heat the coolant in the boiler. In the absence of oscillation, there is no need for overheating in the coolant and the maximum temperature of the coolant may exceed the required one by 1-2 degrees.

5. Solution option

Pilot operation of self-propelled guns with a minimum amplitude of oscillations.

Experimental studies of the heating system of a residential complex. In the power complex of a large residential area consisting of a boiler room with three boilers, three heat supply circuits and one hot water supply circuit, standard ("factory") parameters of ECL-210 regulators were installed for 10 years, which regulated the temperature of the coolant with an amplitude of 7-10 degrees (Figure 6)

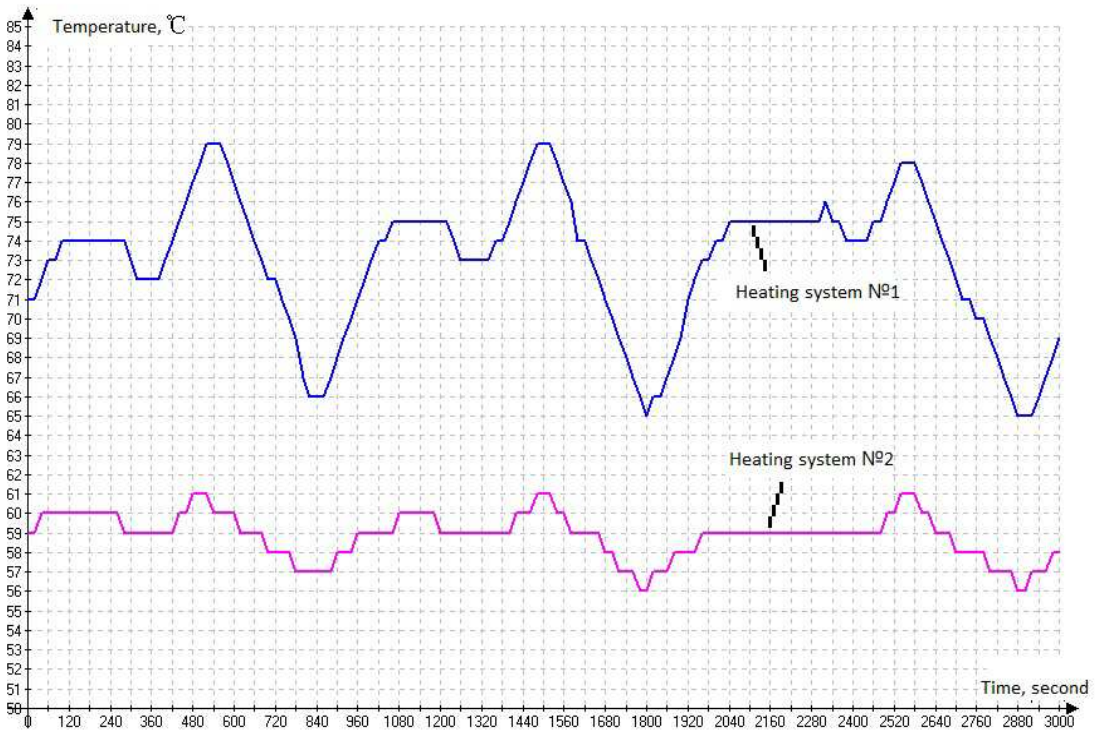

Figure 6. The processes of changing the temperature of the coolant in heating circuits with the parameters of the regulators recommended by the instructions.

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In 2016, by optimizing the parameters of the regulators, described in detail in [12,13], it was possible to achieve a significant reduction in the amplitude of the oscillations – up to 0.5 ℃, with a period of 1-2 minutes (Figure 7). At the same time, the regulators themselves were identified and it was found that they have a differentiation channel necessary for the correction of self-oscillations. Thanks to the strengthening of this channel . as well as reducing the pause in the control pulses , it was possible to solve the problem of reducing the amplitude of self - oscillations and the uncontrolled zone of the ACS

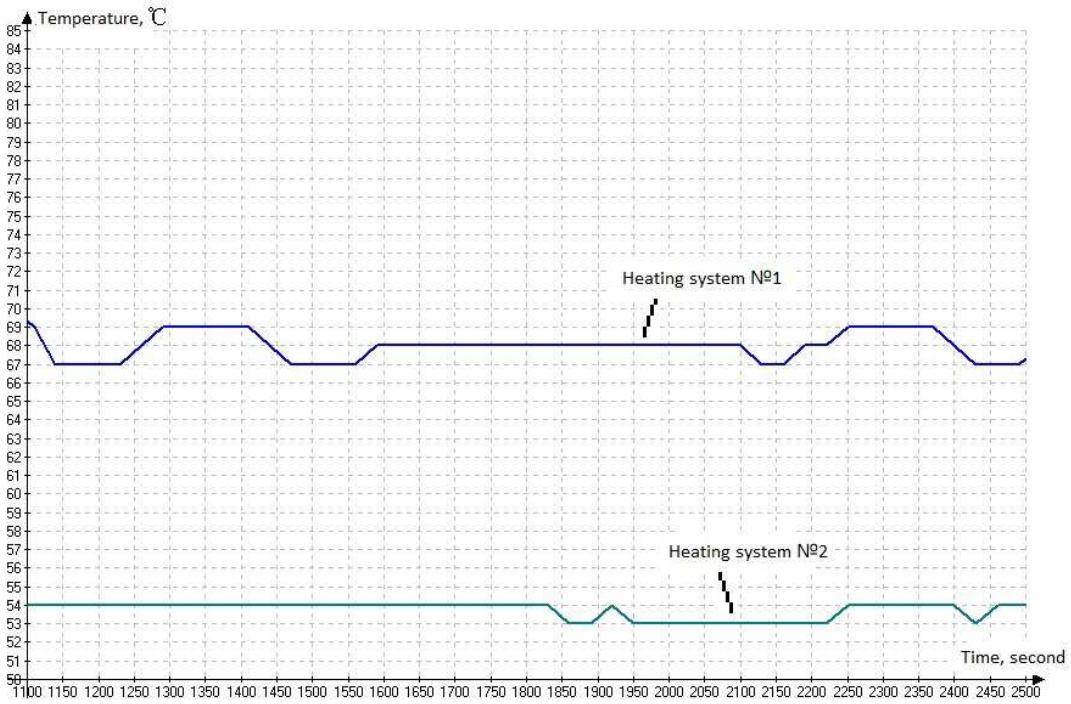

Figure 7. Processes in the same circuits after optimization of parameters. PD – controller.

For several years, observations and comparisons of the effectiveness of regulatory systems have been carried out

Because the weather conditions – the temperature of the outside air is rarely repeated in long stretches . a trend methodology was proposed, according to which plots of 7-10 days were allocated in the graphs, during which the weather seemed to change or gas consumption schedules were similar.

6. Discussion of the results

Graph (Figure 8) shows that at identical external temperatures-in periods from 10 to 16 and from 18 to 24 gas flow rate on corrected system is less, and in period from 16 to 18, at considerably lower temperatures in 2015, gas flow is single. Gas flow rate decreased by 7 -10% on average. High efficiency of automatic heating systems with minimal fluctuation of processes is confirmed by all comparisons. [16]

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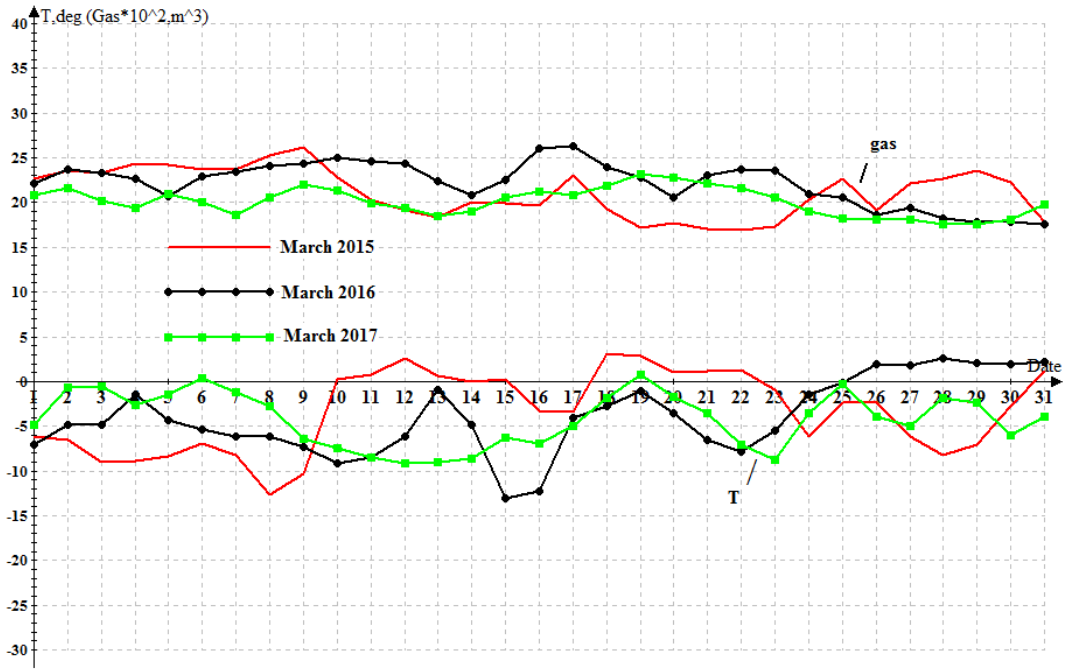

Figure 8. Graphs of gas consumption and outdoor air temperature by months (March (2015, 2016, 2017)).

However, despite the obvious advantages of the regulation processes with a minimum oscillation amplitude, the proper attention is not paid to their synthesis, and the broad practice of introducing automatic heat supply regulators does not contribute to the adequate attention of the controllability of the heat supply processes, which leads to loss of resources.

When implementing the proposed method for adjusting regulators, it is possible to save up to 10% of resources, while 2% of the total world 's energy balance is a proportion of the entire renewable energy, the introduction of which requires shoe investments, and reduced amplitudes of heat carrier oscillations – only the use of TAC methods.

Is society's dislike of complex theory so great, or does someone benefit from a different direction of energy development?

In the discussion on the problems of the future of energy, and, consequently, of the entire civilization, very little attention is paid to the problem of controllability, leaving this problem to specialists. .at the same time, there is no room in advance for their opinions in the initial questions.

7. Discussion of the manageability problem

The role of controllability of processes in the global energy sector.

In the global discussions on the energy of the future, the problems of controllability are decisively ignored by the most active participants[17,18]. Perhaps this is due to the fact that they do not know the theory of automatic control well? A complex, professional science that has developed historically specifically for energy management in the first place.

As mentioned above, the three traditional energy systems are very well controllable - thermal, carbon energy, nuclear and hydropower.

In these power plants, energy flows are regulated at each stage - in thermal power plants, processes in boilers, turbines and power generators are regulated In nuclear power – in reactors, boilers, turbines and generators, in hydropower, water flows and processes in generators are regulated. That is , all energy flows . which electric generators convert into electrical is rigidly regulated .

Thanks to this controllability , unified powerful power grids in Europe , Russia , America and China have become possible

When low-power wind turbines and solar battery parks are connected to these controlled, powerful and stable power grids, the system chooses whether to leave them connected or turn them off if their parameters are very different from the required ones. At the same time, a system based on controlled generation by 80-90% does not lose its operability both with and without renewable sources.

But how will a system consisting of unmanageable elements and complexes behave by 90 or 100 % ? Stabilization of such complexes will require very complex and expensive equipment with an excess of the total installed capacity required by several times – that is, a multiple excess of investment compared to controlled generation..

It is impossible to provide such regulation only in the wind turbines themselves. The main obstacle is the instability of the wind itself. No more than 25-30% of the wind energy flow can be used by regulating the electrical parameters of electric generators to compensate for these problems, that is, it is impossible to provide the required parameters of electricity with great efficiency. It is very difficult to assemble one powerful and stable structure from such separate structures, It may require more resources. what will be saved on renewable energy at the expense of resources.

Along with the low wind speed, poor controllability of renewable energy sources is a very significant problem of wind generation.

Let us also recall the problem of low wind speeds.

The wind speed used in wind generators is 20-30 rarely 40 m/s. When the diameter of the blades of wind turbines is 20-30 m , the rotation speed is 5-10 rpm. Maximum 20 m/min. The rotation speed of generators at traditional stations is 100-1000 times higher. The cost, dimensions of generators and switching equipment for comparable electrical capacities of low-speed and low-voltage wind generators, by definition, will be hundreds of times higher and nothing can overcome this initial difference.

The only way out that is real today for creating energy systems from renewable energy sources is the introduction of storage systems, which are also very expensive, which occupy significant spaces (supermachoviki) or which are difficult to dispose of (batteries).

There is also a question for systems with storage devices, the need to generate 2 times more energy consumed in order to accumulate it during the period of energy production. Aren 't these problems with poor handling of RES obvious ? or is it beneficial for someone not to notice them?

Another perspective is to use any electricity from wind turbines and solar panels and not strive to adjust it to the standards of networks. That is, to create local power systems. Will this process be followed by further decentralizations – industry, economy, politics, information exchanges??

The consequence of this technology is the decentralization of energy, which is possible in principle, but the consequences of which for the whole way of life would not like to predict.

It is not difficult to predict other problems that will arise over time or may arise, but which are completely ignored by the participants of the discussions.

If the winds stop carrying air masses along their traditional routes, won't it change the climate with unpredictable consequences? Or will the loss of sunlight by the earth's surface, which will be absorbed by solar panels, affect the processes in the soil and will it be possible to change them again??

There is a lot of talk about hydrogen energy. It will have full controllability . since hydrocarbons will simply be replaced by hydrogen . which can be burned without carbon release. But where to get the hydrogen from?

If out of the water, then – I suggest a "mental" experience – look at the school globe. With a radius of 30 cm . A layer of blue paint 0.2 mm is the depth of the ocean on a globe scale. The radius of the Earth along the equator is 5-6 thousand km. And the depth of the ocean is 3-4 km. How long will this ocean last us?

And how much water should be consumed in the ocean to cause irreversible consequences for nature – 0.01% or less.

We do not recall at all in this article about the problems of resources for creating the same wind turbines and solar panels – for example, rare earth metals needed to create batteries and accumulators also need to be extracted from the earth's interior. only it is much more difficult and dangerous than

extracting oil or gas . . We are also not talking about the fact that wind turbines are very complex structures and they need to be constantly and professionally serviced, spending considerable resources.

These problems are somewhat different than manageability - they are often mentioned in discussions and are not the subject of this article. Problems of controllability in the energy sector . as we can see, they manifest themselves both in specific everyday issues and in global ones, ignoring them both there and there leads to tangible problems. which you may not notice, but which will be very sensitive.

9. Conclusion

The experience of modern civilization, which is about 5,000 years old, very clearly shows that it is possible to destroy, under the guise of the best wishes, the largest achievements very quickly

Our descendants will nostalgically recall the times when all the problems of raw materials in the energy sector were solved at the expense of fossils or river flows, or uranium with endless stages of processing.

Of course, there are still problems in the energy sector, but it is better for humanity to solve them using only scientific and technical solutions.

The theory of automatic control is of course a very professional science, it is difficult to demand that it be understood by politicians, schoolchildren and journalists who are sincerely worried about the future of energy. But it would be nice to listen at the same time to specialists who are almost inaudible.

Our ancestors used only natural renewable energy sources for almost 5000 years. The shortcomings of this energy were made up for by the slave labor of millions of people -this labor was not only the basis of the prosperity of the authorities. but it must also be recognized as a condition for the survival of mankind.

Steam engines appeared 300 years ago . 160 – electricity that created the modern world

Do we want to go back? Is the dislike of complex sciences so great, or is it beneficial to someone?

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