THE MODELING TECHNOLOGIES EVOLUTION FOR FOSSIL POWER PLANT SIMULATORS

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ABSTRACT

One of the main thesis of different simulator vendors is that all good simulators are arranged internally more or less in the same way. It is not the truth. The article describes and compares 3 generations of simulation technologies for fossil power plants.

INTRODUCTION

This article is devoted to the consideration of different technologies for developing the models of fossil power units used by development engineers in the world. Depending on the used technologies for developing these models the authors distinguish the three generations of simulators for fossil power plants. The main features of models of each generations are described below.

One of the main thesis, which, as a rule, the development engineers of different companies uphold, consists of the fact that all good simulators are arranged more or less in the same way. Therefore the question, where to place the order for a simulator, consists for the Customer mainly of the price and the personal preference.

SIMULATORS WE ARE SPEAKING ABOUT

First of all, we must mention, which simulators are involved here.

The persons of different specialties are engaged in the electricity production. It is clear that all of them must be trained, and the different specialists must be trained in the different way and with the different means of training.

In this article it is a question of training means for the boiler and turbine operators.

The professional skill of operators includes as minimum the two main components:

- Theoretical knowledge, for example, the knowledge of maintenance manuals
- Skill (or practical skills) to control the power unit.

In this article we don't concern the theoretical knowledge, while we discuss only the simulators, the main goal of which is the training of practical skills.

Now the following question is natural: which practical skills of operators should be trained? It is evident, for example, that the operators need the practical skills including the motor ones and for working with control system installed at the unit – it can be either the traditional automatic control system (ACS) with operating board or the modern DCS. In this case, even if ACS covers completely all the regimes of equipment operation, while this completeness is realized far from always, and even if the ACS utilization factor is high, the situations appear frequently in the real operation, when the operator must make decisions on controlling the power unit and to carry out them in operation under conditions of rigid limit of time. This skill must me trained.

It should be noted beforehand that many development engineers of simulators, which can be used in the best case for training the operators to work with ACS, try to persuade the potential customers that if the simulator can be used for training to work with ACS, it can be used the more so for training the operators to control the power unit in the complicated technological situations. But it is not the same in reality.

WHAT DETERMINES THE INSTANTANEOUS VALUES OF PARAMETERS IN A REAL LIFE

Before describing the different technologies for simulating the dynamic processes it is necessary to give to the reader, which is far from dynamics problems, the explanation, what determines the instantaneous values of different physical parameters in the real physical system.

We take for it the example. Let us have a cold room, where we have just switch on a heating device. What determines the air temperature in this room in 1 minute? In 5 minutes? In other time?

It is clear that the more powerful are the heating device, the warmer is in the room in 1 minute and in 5 minutes. Thus, a temperature in the room depends in each moment on the "consumption" of coming heat. We put intentionally the word "consumption" relatively to heat in quotation marks, because we don't speak in such way about heat in our everyday life, though just this word defines the essence of matter.

And what is when a small hinged window pane or even the window are open in the room. It is evident that the temperature in room will be in 1 minute less than in the first case, but by how much less, it depends on the fact, what is open – the small hinged window pane or the window itself.

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Thus, really the temperature in the room depends in each moment of time on imbalance of the flows of coming and leaving heat.
On what else does the temperature in the room depend in 1 minute after beginning of heating from? That is evident that it depends on the initial temperature in room. On what else? From the sizes of the room itself – than less is the size of room, the quicker it is heated with the same heating devices. It means that the less is the size of room, the warmer will be in it in 1 minute after beginning of heating with the same other conditions.
Thus, if to use the more formal language, the air temperature in a room is an integral of the flows of coming and leaving heat. The integration rate depends on the room sizes in the reversed proportion and more formally – on the general heat capacity of the room.
We considered the question of temperature. The same judgments and conclusions are applied to pressures, but in the case flows are a consumption of substance. The pressure in some point of real physical system is the integral of imbalance of coming and leaving substance. The coefficient at integral is inversely proportional to the inner volume (capacity) of the given point.
It will be shown furthermore that the application of these ideas to the development of power units models was the serious step forward in the technology of simulating fossil power plants.

GENERATIONS OF SIMULATORS

In this Chapter three generations of simulators are determined on the basis of approach used for the creation of object models, and their characteristics are given.

Simulators That Include A Model Directly Reproducing The Known Processes Of The Object

For simulators of the first generation (S1G) the models are constructed on the basis of known static and dynamic characteristics of the object. In the most cases the experimental data obtained directly at the operating object are the source of these characteristics. The off-line calculation methods can be sometimes used to obtain some characteristics. For example, in the past for some simulator projects in Russia the curves of transient response were first calculated on the basis of so called “Normative method of calculating the dynamic characteristics of one-through boilers”, while then the model was developed on the basis of these transient response curves. On the whole the model is constructed as a software system, which reproduces the known regimes and processes of the object. In this case the model structure reproduces primarily the structure of channels, which link the input effects with the outlet variables. In essence the object becomes the black box: its technological structure and design characteristics, which lie in the basis of how it works, remain outside the model frameworks. The dynamic characteristics, on the reproduction of which the model is based, are usually treated as the linear ones. In the very insidious cases the coefficients of transfer functions approximating them put in a dependence on some parameter that is considered to be a decisive one, for example, on the load. It is natural that the principle of superposition is used for calculating the reactions on a combination of inlet effects. This principle can apply to any linear system. The intermediate regimes and processes, for which the experimental (or off-line calculated) data are absent, are realized by means of an interpolation. The regimes and processes outside the region of known data are obtained by using an extrapolation.
The essential advantages of such models are:

- a problem of securing the solution stability is practically absent, because the number of feedback’s is minimal; it allows to carry out the calculations with the relatively large steps in time, i.e. with the small expenditure of computer time, and it reduces substantially the demands of calculating capacity of computers used for simulation;
- a possibility to separate strictly the work on development models between the specialists of different professions: some of them determine the characteristics and construct the scheme of channels, while the other ones reproduce these scheme and characteristics in the computer; the latter specialist – mathematicians and programmers – must not at all understand the technology and physics of the processes.

On the other hand this approach has some essential shortcomings:

- low accuracy being the result, first of all, of the fact that the substantially nonlinear object (the power unit is a perfectly such object) is reproduced as a linear one and, secondly, due to the fact that any initial characteristics obtained in experiments on a real object are known to have not a high accuracy;
- low reliability of the processes, which can be reproduced with such model for the intermediate (interpolation) regimes and especially those coming outside the frameworks of experimental data (extrapolation), in particular, for the start-ups;
- such model can’t be constructed for the object, for which the experimental characteristics haven’t been determined, i.e. for the object being in the stage of design, construction or mounting.

The result of low model’s accuracy and reliability consists of the fact that the thermal and mass balances are quite often not fulfilled in them, and the users first of all define this shortcoming.

Simulators That Include A Model Based On Conservation Equations With Coefficients Obtained From An Experiment

The recognition of fact that the models must be constructed directly on the basis of physical laws, which define the functioning of real object, became a significant step ahead in the area of developing the models of power units. First of all, they are the laws of conservation of energy (heat), mass and momentum. For example, the application of laws of conservation for developing the models has obtained in the USA the name of application of «the main principles». They are the same laws, which we spoke about in the previous chapter.
The laws of conservation are mathematically written as the differential balance equations. The heat balance is described by an equation, where the time derivative for temperature or heat content is proportional to the difference between the consumption’s of heat supplied and

removed from the working medium. The temperature itself, or heat content, is calculated by integrating this difference (imbalance).
The heat balance equations are written for all components and working media under consideration, for example, for steam flowing through the superheater bank, flue gases given the heat to this bank, metal of bank tubes and so on.
The mass balance can be described by an equation, where the time derivative of pressure is proportional to the imbalance of flow rates of supplied or removed working medium (steam and/or water, flue gases etc.). The pressure itself is calculated by integrating this imbalance.
The object is already not a black box in the model based on the set of differential balance equations. As the equations are written for the interconnected object's components, the structure of balance equations and their interconnection reflect the structure of object's components.
The principal questions are: how to determine the heat consumption or flow rate of working medium (steam, water, gases) being present in the balance equations as well as to determine the coefficients of derivatives, from which the dynamics of processes in simulator depends.
We will consider it on the example of heat balance equation for the metal of bank tubes of platen superheater of a boiler (not taking into account the metal distribution along the wall length and thickness):

$$M \cdot c_m \; dt_m/d\tau = \alpha_{out} S_{out} (T_g - T_m) - \alpha_{in} S_{in} (t_m - t)$$

where M is a metal mass of bank tubes,
c_m is a specific heat of metal
α_{out} is a coefficient of outside heat transfer (from gases to metal)
S_{out} is a heating surface on the gas side
α_{in} is a coefficient of inside heat transfer (from metal to steam)
S_{in} is a heating surface from the steam side
T_g is a temperature of flue gases (average)
T_m is a metal temperature (average)
t is a steam temperature (average)
τ is a time.
The difference between the heat flow from gases to the outer metal side (usually that is a heat supplied to metal) and the heat flow from inner metal side to steam (usually that is the heat removed from metal) is written in the right side of equation. The flows link this equation with balance equations of other components:

- balance of gases heat in the area of platens, where the same flow that is outer for metal is the heat removed from gases;
- heat balance of steam, where the heat flow that is inner for metal is the heat supplied to steam.

The calculation of these flows during simulation represents some difficulties. First of all, it concerns the determination of heat transfer coefficients and especially the coefficient of heat transfer from gases to metal. The problem consists of the fact that in the area of platens there are both heat transfers by radiation (due to the high gases temperature) and convection (due to the velocity of gases motion). The heat transfer coefficient for each kind of these heat transfers depends on the composition of flue gases, their temperature, the geometric characteristics of platens and gas duct etc.
The accurate calculation of these heat rates for all operating regimes of boiler could be fulfilled on the basis of formulae and recommendations of the widely known in Russia "Normative method of thermal calculation of boiler plants", which contains for it all necessary recommendations. However, this procedure is very complicated and demands a large number of initial design data.
It is much easier to determine these rates from the experimental data obtained at the real object. It is possible to see that these two heat flows for metal (supplied and removed ones) are equal in a steady mode of power unit operation. It is quite simple to calculate the heat flow to steam for a steady mode of the real unit, if the steam flow rate and pressure as well as the steam temperature before and after platens are known. All these parameters are measured, as a rule, on all power units. If a development engineer has the information for some steady modes, he can try to invent an approximating function for calculation of heat flows from gases to metal and from metal to gas depending on some parameters really measured at the power unit. For example, it is possible to construct the approximation function depending on the gases temperature in some point of gas path, where the gases temperature is measured at the real power unit. In our case it is not obligatory if this gases temperature were the gases temperature in the platens area, because there is a correlation between the gases' temperatures in the different points of gas path. At last it is possible to approximate not the heat flows themselves, but to make the approximation of heat transfer coefficients from gas to metal and from metal to steam on their base. Then it should be necessary to calculate in simulator the heat flow by multiplying the "supposed" value of heat transfer coefficient obtained on the basis of approximation procedure by the heat transfer surface and the temperature difference.
The same approach can be also used for another components of boiler and turbine.
It should be specially spoken about the coefficient of derivative, on which the dynamic properties of metal temperature in the area of platens (in our example) in the model will depend. In its physical sense this coefficient represents the general heat capacity of platen metal. The basic meaning of this heat capacity, which should be adjusted in the dynamic calculations depending on the current metal temperature, can be determined on the basis of detailed analysis of initial design and constructive data.
Another method consists of the simple using as adjusting coefficients the coefficients of derivatives in the balance equation (not only for the heat and not only for the metal). For any particular transient process (unloading, shut-down, cold start etc.) by changing and adjusting these coefficients you can realize the dynamic properties of power unit, which correspond to Customer's understanding or interpretation of how the power unit works. Of course the customer's understanding is based upon his experience. I.e. again the coefficients of model equation are determined on the basis of experimental data.
The coefficient of derivative can be tuned to satisfy the customer's interpretation if some static parameters (heat transfer coefficients, temperature differences, heat fluxes themselves) are calculated very accurately. Some authors call it the separation of static and dynamic problems

(while the nature “solves” these problems jointly – as the only problem).

We call the simulators using the models of such type as the second generation simulators (S2G). They have the substantial advantages before S1G, first of all because they reproduce in much more details the object’s structure and the physics of processes. The balance of heat and mass in all components and in the model on the whole is brought together in principle. It is easier to obtain the initial information from the real power plant, which the development engineer of S2G is using in the development, than for S1G, for which the much higher accuracy is required. It is here mainly a question of information on the static (steady state) and dynamic regimes of equipment operation, which can be obtained in some cases without the special tests of equipment – by the method of passive experiment.

However the same shortcomings are inherent in these models as in the models S1G:

- uncertainties in the accuracy and reliability of reproducing the unsteady regimes, for which the experimental data are absent (for start-ups, for not expected modes etc.)
- difficulties in developing such model for the object, which has no working prototype
- etc

These shortcomings are the result of the fact that in developing such models as well as the models S1G, though to a lesser degree, the development engineers come «from processes to processes» - from the processes that in one way or the other are fixed at the real object, to the processes, which are implemented on the model. Such models are quite convenient for the simulator development engineers, because in developing them they are responsible not for the model adequacy in any processes and regimes of objects, but for its adequacy only in the regimes, the data for which were received from Customer. The main goal is to satisfy the Customer’s expectations. There appears to be the main reason, why the majority of simulators’ development engineers not only in Russia, but in the world are still developing S2G.

Simulators That Include A Model Based On Balance Equations With Coefficients Obtained From Design Data

The static and dynamic characteristics of real power unit are determined by a large number of factors, which can be arbitrarily divided in the following groups:

- main design parameters of equipment that are chosen in the design stage and are subject to the accurate evaluation such as:
  - values of heating surfaces in the different zones of boiler,
  - cross section for gas passing through the different zones of boiler,
  - amount and design parameters of high-pressure heaters and low-pressure heaters,
  - metal mass of separate components of equipment
  - etc
- Parameters generalizing some set of made design decisions, which are at the design stage not subject to the accurate calculation for the concrete equipment; however basing on the designs the values of such parameters can be preliminarily evaluated on the basis of statistical data generalization for the similar equipment; the preliminarily estimates can be later adjusted after the completion of mounting and the putting the equipment into operation; for example, such parameters include:
  - rate of use for different heating surfaces
  - thermal resistance of insulation
  - height of flame in furnace
  - etc
- Outside factors not depending on the design parameters of power unit such as:
  - Composition of fuel coming at the present moment (for example, in some moment of time the fuel may have the elaborated moisture content or the boiler can operate with the mixture of different fuels)
  - Ambient air temperature
  - Temperature of cooling water
  - etc
- Factors depending on the distinctions of power unit maintenance such as:
  - Degree of heating surface contamination in boilers, of tubes in condenser etc
  - Value of air suctions in the different boiler elements and in the turbine condenser,
  - etc

The operator interprets the properties of power unit through automatic control system installed on the object. Therefore the additional factors effecting on the perception of power unit properties by a man are:

- properties of measuring transducers and special features of their mounting,
- Properties of DCS

To take into account all these factors is so difficult, when the simulator is developed. It is also one of the reasons, why the technology of developing the models S2G was for a long time the main technology for developing the power unit models.

However the technologies has to evaluate, and it was necessary to make the next principle step. The result of this step was the technology of developing the models for simulators of the third generation (S3G).

The main features of modeling technology S3G are the following:

1. The modeling is based on the so called main principles:
   - laws of balancing heat, mass and momentum,
   - equations of water, steam and gaseous mixtures equations,
   - criteria equations of heat transfer
2. The united system of differential and algebraic equations, which describes its behavior in all operating regimes (from the cold start-up initial state till the nominal state of unit operation with full load) is constructed for the power unit being modeled.
3. **All coefficients** of this system of equations are directly of indirectly determined on the bases of **design data** of modeled object.

4. The values of a main amount of coefficients in these equations (no less than 95% from them in accordance with our estimation), which depend on the design equipment parameter that are subject to the accurate estimation, can be precisely calculated. These values are determined at the initial stage of simulator development and are the final ones. It means that the development engineer doesn't change the values of these coefficients in the process of adjustment and testing. A case represents the exception, when the mistake is found in determining some coefficient.
5. The values of statistically estimated and generalized parameters are evaluated. The coefficients in equations, which depend on them, are calculated by means of these values. In Russia the statistical evaluation of generalized parameters for boiler plants are taken from "Normative method for calculating boiler plants". For example, there are the statistical estimates of heat loss in environment, air flows in flue gases in the regenerative air heaters, rate of use for the heating surfaces in gas ducts of the boilers of different type and so on.
6. The method of statistical evaluation is also used for the factors depending on the special features of power unit operation.
7. If necessary, the values of statistically estimated parameters are furthermore corrected.
8. The external factors effecting on the equipment behavior must be for the models S3G the boundary conditions, which can be effectively changed in the process of operation. It means, for example, that a start-up of unit can be begun at S3G with the usual fuel and finished with a wet fuel.

An example of statistically estimated coefficient is the coefficient connecting the heat loss in environment with the difference of current metal temperature and ambient air temperature. If it will be so in future that within the frameworks of simulator and with these coefficients the power unit is cooled quicker or slower than in reality, the coefficients are corrected in the corresponding side - and nothing more.

The technology S3G makes the following important steps in comparison with S2G:

- the calculations of heat flows, water and steam flows in all regimes of modeled equipment operation are carried out on the basis of accurate formulas, and no approximation is used
- the heat capacities and inside volumes of all elements of power unit are taken correctly into account; in this case their values are not used as the adjusting coefficients for achievement of the necessary dynamic characteristics; the object model works directly with the initially calculated specific quantities of metal and the inside volumes of all power unit elements

Due to all above mentioned, S3G has the following important consumers' properties:

- sufficiently accurate reproduction of **any** static regime of equipment operation; for example, a special testing of a few S3G installed in training center of Moscow 26-th power plant showed that the discrepancy of values of the main static parameters of power unit operation at the simulators and at the similar regimes of real equipment operation falls in the measurement error
- sufficiently accurate reproduction of **any** dynamic regime of equipment operation
- there is a possibility to train the personnel to power unit start-ups from **any** thermal conditions
- the models S3G allow to Customer to pay attention on the potential problems of measuring devices of real objects (transducers, thermocouples) or real DCS, because if a parameter of a steady mode in simulator and real object are not coincided, in many cases just the parameter in simulator is correct, while there is a problem at the real power unit either with the DCS or with the measurement devices

It is reasonably safe to say that S3G go not from the processes to the processes, as S1G and S2G do, but they go from the design data to the processes. The task of S3G development engineer consists of the fact to model correctly on the basis of design data the static and dynamic properties of separate elements, which form the power unit (furnace, platen superheater, pipeline, turbine valve, condenser, high- and low pressure heaters etc.); and then any variant of start-up, correct or not correct, can be reproduced in simulator from any thermal condition by natural way without the additional adjustments of simulator.

In fact the S3G is more than just a tool for training of beginners. In addition it is a tool for increasing the skill of the most experienced and skilled operators. They can test here any situations, which rarely occur. An adequate and explainable reaction will be in the result.

There is a sufficiently simple method for Customer to understand, either the development engineer creates S3G or not. As a result of development of simulator the Customer will receive in the best case S2G, if the development engineer:

- asks as the initial data for modeling from Customer the information on dynamic properties of real object, but not only the design data
- drag the specialists of Customer to the development of simulator before the moment of beginning its tests

COMPARISON OF THE SIMULATORS OF DIFFERENT GENERATIONS

The models S1G are still used by the developer engineers, for which the creation of simulators is not the main professional activity. These models can be used for the following purposes:

- connection with a model of real DCS for the debugging of relatively simple DCS components and training of operator for working with these components
- initial training of the beginners, for which it is still early to fulfill at simulator the complex regimes and which can not yet evaluate the adequacy of simulator model

The S2G is a serious step ahead to the quality of modeling in comparison with S1G. As a rule the developers of S2G simulators are professionals in the field.

At present the most part of commercially developed simulators are the S2G simulators. The S2G allows to achieve the acceptable quality of technological process modeling with its careful implementation in the case, if the main goal of training is formulated in such way:

- the training is limited by some multitude of beforehand defined operations
- the training is begun from the beforehand coordinated initial conditions (for example, the unloading of power unit from 100 to 70%, the power unit start-up from the beforehand agreed initial conditions)
- the training is carried out by the beforehand known scenarios (the unloading of power unit from 100 to 70% must be fulfilled only by the beforehand determined way)

Many development engineers of S2G are proud by the fact that they drag the Customer's specialists to the simulator development at the early stages of the development and that they use the data from the real object. They declare that it is the only way to approach the simulator to the real power unit.

Reading this description of simulators' generations, somebody from S2G development engineers can assert the following:

- All leading development engineers develop S3G. Only the procedure of determining the same coefficients in the same equations is different.
- The practice showed that there is a possibility to determine the same coefficients on the basis of static and dynamic properties of the power units.

Is it so? The equations of S3G models operates on the concept of metal mass (and by means of mass the heat capacity of this metal is calculated for the current temperature of metal) of not heated boiler surfaces: headers, by-pass tubes etc. The concrete values of mass for all such elements (for example, the by-pass tubes before the 1st injection, the supply headers, a header of the 1st injection, the outlet header and so on) are calculated in S3G by development engineers on the basis of design data, and they are placed in the model. Due to the distribution of object in the space, the not heated element has an independent meaning, and its mass can't be simply added to the mass of heated element. It is impossible to determine separately the mass of heated and not heated surfaces on the basis of experimental dynamic properties of boiler: unlike the direct problem of determining the sum by the items the reverse problem of division of sum to the items has no solution. Therefore, if a simulator development engineer is using in the process of model development the dynamic data from object or if he attracts the Customer's specialists to the development of simulators before the tests, it means that such simulators use the ***other*** equations in comparison with S3G. For example, these ***other*** equations unlike the S3G equations don't take into account the distribution of specific amount of metal along the spatial coordinate. To our knowledge, practically nobody from the leading world producers of simulators for fossil power plants even don't ask the Customer to present the detailed data on the not heated surface of boiler. It means that their equations don't take into account the heat storage in metal of these surfaces.

THE PRESENT STATE OF THE ART IN THE WORLD SIMULATOR ENGINEERING

The Russian company "Power plant simulators" takes the leading positions in Russia in the area of development of simulators for training the operators of boilers and turbines due to the development of S3G.

In January 2004 the specialists of company took part in the annual conference "Fossil Simulation and Training", which was organized within the frameworks of "2004 Western Simulation MultiConference" by International Society for Computer Simulation (SCS). A lot of leading world simulator vendors participated in the conference.

The Russian company "Power plant simulators" has demonstrated at this Conference the abilities of its simulators and made a plenary report.

The main subject of Russian representatives' report was the technology of developing models for S3G, which is successfully used by this Russia company at the Russian market already for more that 10 years. More than 20 simulators were developed by this technology and are used successfully in Russian electric power industry. What is more, it is exactly due to the high quality of models the simulators of this Russian company were chosen as the basic software for organizing the International competitions of professional skills of fossil power plants operators - Cyberthon. These competitions have been twice successfully organized in the beginning in Republic of South Africa and then – in Russia. It is planned to carry out in October of 2004 the next international competitions of professional skills of fossil power plants operators - Cyberthon-2004.

At the discussion, which took place at the Conference "Fossil Simulation and Training"-2004 after the report of Russian representatives, it was evident that no one companies participated in the Conference is ready today to develop a simulator for fossil power plant on the basis of design data as it was done by company "Power plant simulators". All of them demand the intensive participation of Customer's specialists in the process of developing simulator from the beginning. In fact it means that all of them are developing only S2G.

Why does the simulator engineering stop at the boundary of S2G? Is it possible that the leading world producers were not able to create the simulation technologies for S3G? Certainly they could do it. But the conditions in the simulator engineering industry were developed in such way that the technology of creating S2G was extremely convenient for the development engineers including as well from the commercial point of view. And the Customer knew nothing that was better. It was explained to Customer that there was no other way for developing the qualitative simulator. IAEA (International Atomic Energy Agency) helped unintentionally to the simulator development engineers in this problem: IAEA made a decision that each nuclear power plant has to have s simulator. It signified that the power plant has not only to spend money for simulator, but it has in addition to be pleased with this simulator (if the simulator is not suitable for training the personnel, it is formally impossible to maintenance the nuclear power plant). The development engineers explained to Customer that if the situation has been formed, when the Customer was interested essentially in

the quality of simulator more than the development engineer itself, the Customer has to help to the development engineer to create a good product. So the Customer really became the coauthor of simulator. Using it the development engineer shifted to the Customer a responsibility for the simulator quality: the Customer provides its own engineers and presents the regimes, while the development engineer makes in essence “all you wish”.
Gradually such approach has migrated from the nuclear power plants to the fossil ones, because the Customers from fossil power plants were constantly “educated” that the experience of developing the simulators for nuclear power plants was the most advanced in the world.
In fact the transfer to S3G means for development engineer that he takes all the responsibility for himself. In this case the Customer keeps away from the development, and its natural role of outside critic of simulator quality is returned to him. Who needs in such responsibility, if the Customer doesn’t require it?
About 10 years ago, when the favorable scientific-research contacts between Russia and West were begun, the “advanced” technologies of developing S2G prevailing in the world came in Russia and mainly in the nuclear power industry. The situation is natural in the world, when the same companies that specialized in simulators for nuclear power plants receive the large contracts and develop also the simulators for the fossil power plants. There is another situation in Russia: the leading Russian producers of simulators for NPP have yet not managed to develop no one serious simulator for a fossil power unit or power plant. One of the reasons consists of the high prices, with which these development engineers got used to work (if a nuclear power plant is obliged to have a simulator in any case, it is possibly to increase the price). However we believe that the question concerns not only the price. First S3G began to appear in Russia approximately in the same time, and from year to year the more and more power engineers know that these simulators are of very high quality.

CONCLUSIONS

To get a next contract for simulator, the development engineers bring forward often as the evidence of their successful activity the examples of other “successful” projects claiming that the Customer was pleased with its simulator. The situation in simulator engineering, when “the Customer is pleased”, convinces little somebody. There are many reasons, why a Customer can be pleased with simulator. The different people can be pleased on the side of the same Customer. For example, a chief manager of a power plant can be pleased in public with simulator, while the ordinary operators can be not pleased. The chief manager can be pleased in public, because he paid money for the simulator and, he can’t confess that these expenditures didn’t justify the expectations. Another reason, why somebody can be pleased with the available S2G, simply because he was not familiar with a S3G.
The conclusion that S3G use the **different equations** and the **different technology** for simulating the power unit in comparison with S2G, which was substantiated above in this article, can explain many things:

- why the situation is practically unbelievable, when an operator of high class, which is well acquainted with some S3G, can be not pleased with it and at the same time to be pleased with some S2G
- why it is possible successfully to carry out with S3G the competitions of professional skills of fossil power plants operators including the international ones and suggesting to the participants to fulfill the most complicated tests continuing for hours; the different teams of operators fulfill in these tests the hundreds of different control operation in the different sequence, while the simulator reacts adequately on all their actions
- etc

To order of a S2G instead of a S3G can be justified from the viewpoint of Customer only in a case, if the S2G simulator is in few times cheaper than the S3G, because the customers’ qualities of S3G and S2G simply cannot be compared.
At present according to our understanding of the situation, no one leading world simulator vendor for fossil power plants except of Russian company “Power plant simulators” has not even declared that he has been developing a S3G. Even if somebody will start today to change his own technology of simulation to S3G, he needs a few years for creating the necessary software and for development his first S3G.

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AUTHOR BIOGRAPHIES

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