

Comparison of mathematical models of power generation equipment in transient process simulation in energy systems

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Abstract. *The aim of this study is to develop approaches for improving the efficiency of transient characteristic modeling of a nuclear power plant (NPP) unit by approximating dynamic processes using first- and second-order functions. This will reduce the simulation time for combined energy systems, which include power generation sources with different physical operating principles (NPPs, thermal power plants, hydroelectric power plants, wind farms, etc.). This work is aimed at ensuring the selection of a simulation model of equipment that best meets the goals of future research, including the development of new approaches to controlling the structure and parameters of power generating sources, which will contribute to the efficient operation of power systems.*

Keywords: *automatic control system, identification, classification, efficiency criteria, mathematical model.*

Introduction

In energy systems, accurate modeling of transient processes is crucial for ensuring system stability and reliability. One of the key aspects of such modeling is representing power generation equipment using mathematical models. Different types of equipment, such as synchronous generators, wind turbines, and solar panels, require specific models to capture their dynamic behavior during transient processes.

When comparing mathematical models of power generation equipment, it is important to consider factors such as accuracy, computational efficiency, and ease of implementation. For example, detailed physical models can provide a high level of accuracy but may be computationally intensive, making them less practical for real-time simulations. On the other hand, simplified empirical models may offer faster computation times but can compromise accuracy under certain operating conditions.

Thus, the selection of mathematical models for power generation equipment in energy system simulations is a critical decision that can impact the accuracy and reliability of transient process modeling. By carefully evaluating the trade-offs between accuracy and computational efficiency, researchers and engineers can choose the most suitable model for their specific application.

The research object is a simulation model of a

nuclear power plant unit. This study addresses the problem of adequately describing and analyzing transient processes in models of thermal and electrical equipment to improve power management methods and energy system stability. The primary objective is to approximate the dynamic characteristics of a nuclear power plant unit using first-, second-, and third-order differential equations, which allows for optimization of the control process and ensures accurate system dynamics representation. This will contribute to enhancing the efficiency of power plants, ensuring stable electricity supply to consumers, and improving methods for analyzing reactor system performance.

The study includes a simulation of a nuclear power plant unit at various load levels, allowing an investigation into how the order of the differential equation describing the dynamic properties of the control object affects the quality of power generation/consumption balance maintenance in the energy system. The obtained results indicate that first-order equations provide a fast and simplified system analysis; however, such models are unsuitable for describing certain operating modes of the equipment, such as short-circuit conditions in the electrical grid. For emergency conditions, high-order nonlinear models must be used. This paper considers only transient processes corresponding to the normal operation of energy systems.

During the study, the effectiveness of approximation was evaluated by comparing the actual reactor characteristics with simulation results. Criteria for assessing approximation accuracy were

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developed, considering indicators such as system response speed, regulation stability, and model consistency with real data. The research results indicate that at high power levels, second-order functions provide a more accurate representation of dynamic processes, while for medium and low power levels, first-order functions are more effective.

The obtained research results can be applied to optimize the power regulation process in energy systems, improve the accuracy of modeling the dynamics of power plants, and enhance energy system management strategies. The use of first- and second-order function approximations allows for a balance between analysis speed and system description accuracy, which is essential for ensuring the reliability and efficiency of power plants under modern conditions.

Objectives for achieving the research goal:

- Obtain NPP unit acceleration curves for the "setpoint – electrical power" channel at different load levels.
- Compare the accuracy of approximation using first- and second-order functions.
- Develop criteria for evaluating approximation efficiency to determine the optimal power regulation method.
- Provide recommendations for using first- and second-order functions in reactor system modeling.

These objectives aim to ensure the selection of a simulation model that best meets the needs of future research, including the development of new approaches to managing the structure and parameters of power generation sources, thereby contributing to the efficient operation of energy systems.

1. Statement of the problem

One of the key tasks in analyzing the stability, reliability, and efficiency of modern energy systems is their adequate simulation modeling. In this context, understanding the principles of building such models, their accuracy, and efficiency in representing the system's dynamic behavior under external or internal disturbances is crucial.

Mathematical models of power generation equipment are developed to represent the processes of electricity generation, transmission, and distribution while considering the physical, chemical, and mechanical properties of the equipment. The most common models include synchronous generators, asynchronous machines, renewable energy sources, energy storage systems, and other energy system elements. Each model is

tailored to a specific level of detail and the problem it aims to solve. For example, models of synchronous generators are typically based on equations of electromagnetic induction, rotor dynamics, and control systems [1].

Transient processes in the power system, such as short circuits, load changes, or reserve activation, require high modeling accuracy to adequately predict their consequences. Both simplified linear models, which allow for a quick assessment of system behavior under minor disturbances, and nonlinear models, which account for complex interdependencies among system elements, are used for this purpose. Nonlinear models, such as state equations that consider magnetic circuit saturation, enable highly accurate process modeling but require more computational resources [2].

The increasing demand for energy-intensive equipment and the uneven energy consumption throughout the day necessitate more precise power regulation methods that consider the dynamic changes in reactor system parameters. Additionally, modern energy systems face challenges related to equipment aging, which limits their ability to respond quickly to load changes. Insufficient model accuracy or incorrect approximation methods can lead to power regulation errors, oscillations, and, in some cases, emergency situations in the power system. Therefore, selecting an appropriate model is crucial for ensuring the stability of the energy system's operation.

Model comparisons are conducted based on several key criteria: accuracy in representing physical processes, computation speed, versatility (i.e., the ability to model various scenarios), and compatibility with other energy system models. For example, models of electrical equipment, such as transformers and power transmission lines, need to account for transient oscillatory processes caused by the simultaneous presence of inductive and capacitive properties. On the other hand, the large masses of metal, water, and technological limitations on the rate of power changes in power units act as low-pass filters for these transient processes, complicating the overall model [3].

Another aspect of model comparison is their ability to work with real-world data. Energy systems increasingly use machine learning-based models to analyze real-time data, such as load indicators, voltage, or frequency. At the same time, classical physics-based models remain relevant due to their transparency and the ability to conduct precise engineering analyses [4].

2. Materials and Methods

2.1. Application Areas of First- and Second-Order Mathematical Models

In the field of energy systems, the use of simulation models is crucial for understanding and predicting the behavior of complex systems. One common approach is to model these systems using differential equations of various orders. By comparing simulation models based on differential equations of different orders, researchers can gain valuable insights into the dynamics of energy systems. [5]

Higher-order differential equations allow for a more detailed representation of system dynamics, accounting for nuances that might be overlooked in lower-order models. However, these models can be more computationally intensive and may require more data for accurate parameter estimation. On the other hand, lower-order differential equations provide a more simplified representation of the system, making them easier to analyze and implement. Although they may not capture certain complexities, they can still offer valuable information about the overall behavior of the energy system. By comparing simulation models based on differential equations of different orders, it is possible to determine the most suitable approach for a specific application. [6] This comparative analysis is essential for deepening the understanding of energy system operations and improving the accuracy of predictive models.

First-order models are widely used for rapid and simplified system response analysis. They describe the transient process using a transfer function of the form:

$$W(s) = \frac{K}{Ts + 1},$$

where K - is the gain coefficient, and T - is the system time constant. These models are quite effective for describing systems with homogeneous dynamic characteristics; however, their accuracy may decrease when modeling complex or multifactorial processes. They are applied when the system dynamics are characterized by:

1. A single dominant storage element (e.g., boiler water temperature or steam pressure).
2. The absence of significant oscillatory processes.
3. An exponential transient process without oscillations.

Advantages of First-Order Models:

- Simplicity of calculations.
- Useful for rough system estimation when precise behavior is not critical.

- Suitable for stable, slow-changing processes [7].

A system described by a first-order differential equation under random disturbances has the following characteristic features:

1. Application area:
 - Suitable when the system dynamics under random disturbances are determined by a single dominant storage process, such as the thermal inertia of a boiler.
 - A weak influence of random disturbances on system parameters (up to 10%) allows neglecting the interaction of complex processes.
2. Stability:
 - A first-order system is always stable if the time constant $T > 0$.
 - Small-amplitude random disturbances decay rapidly according to an exponential law.
3. Frequency Response:
 - A first-order system exhibits low-pass filtering properties: disturbances with frequencies higher than $1/T$ are effectively attenuated (their amplitude decreases), while low-frequency disturbances pass almost unchanged.
 - Frequency response:

$$|H(j\omega)| = \frac{K}{\sqrt{T^2 \omega^2 + 1}}.$$

Second-order models provide a more accurate description of reactor system dynamics by considering a greater number of parameters. They use a transfer function of the form:

$$W(s) = \frac{K}{T_2^2 + T_1 s + 1}, \quad (1)$$

where T_1 and T_2 are time constants characterizing different aspects of the system dynamics [8]. If the condition $T_1 < 2T_2$ is met, the system exhibits oscillatory properties; otherwise, it behaves as an inertial second-order system. For convenience in analyzing the properties of an oscillatory system, its transfer function is rewritten in the form:

$$W(s) = \frac{K}{T^2 s^2 + 2\zeta Ts + 1}.$$

The parameter ζ is called the damping coefficient. If $\zeta > 0$, the system behaves as an inertial system [9].

By incorporating second-order dynamics, these models are better suited for analyzing complex transient processes, though they require more

computational resources. Second-order models are used when the system exhibits:

- The presence of two interacting storage elements.
- Oscillatory dynamics or damped transient processes.
- A significant influence of the damping coefficient ζ on the nature of the transient process.

Advantages of Second-Order Models:

- Accounts for complex dynamic processes.
- Suitable for systems with oscillations or inertia.
- Provides a more accurate model for control optimization.

A system described by a second-order differential equation under random disturbances has the following characteristic features:

1. Application:

- Used when the system has two interrelated dynamic variables (e.g., pressure and turbine rotational speed).

- Important in the presence of interactions between accumulation processes or when oscillatory dynamics are present.

2. Stability:

- Stability depends on the damping coefficient ζ and the signs of the roots of the characteristic equation.

- When $0 < \zeta < 1$, the system exhibits damped oscillations, which may be amplified under random disturbances (resonance effect) [10].

3. Transient process:

- If the condition $0 < \zeta \ll 1$ holds, the system exhibits damped oscillations; if $\zeta = 0$, oscillations do not decay; when $\zeta > 1$, oscillations are absent.

- In the presence of random disturbances, a second-order system may experience frequency resonances if the disturbance matches the natural frequency ω_n .

4. Frequency characteristics:

- A second-order model filters random disturbances more effectively depending on damping.

Table 1

Comparison of First- and Second-Order System Properties

Characteristic	First Order	Second Order
System Complexity	One dominant process	Two interrelated processes
Oscillations	None	Presence of oscillations depends on system parameters and external influences
Control Objectives	Maintaining slowly varying parameters	Controlling processes with inertia or oscillations
Examples of Technological Equipment	Steam pressure after a boiler, steam temperature	Turbine rotational speed, power converters

Table 2

Comparison of First- and Second-Order Transfer Function Criteria

Criterion	First-Order Transfer Function	Second-Order Transfer Function
Stability	Always stable ($T > 0, T > 0$)	Depends on the ratio between coefficients T_1 and T_2 (damping coefficient ζ). Resonance is possible.
Noise Sensitivity	Suppresses high-frequency random disturbances	May amplify noise at frequencies close to the resonance frequency
Frequency Filtering	Suitable for low-frequency disturbances	Suitable for tasks with resonances and a broad frequency spectrum
Transient Response	Exponential	Damped oscillations or critical damping ($\zeta = 1$)
Application	Systems with a single accumulation process (e.g., thermal inertia)	Systems with two interacting processes (e.g., pressure and velocity)
Effectiveness with Random Disturbances	Effectively suppresses small-amplitude noise ($< 10\%$)	Requires consideration of resonance frequencies when filtering random disturbances

- Frequency characteristics:

$$|H(j\omega)| = \frac{K}{\sqrt{(2\zeta T\omega)^2 + (1 - T^2\omega^2)^2}}$$

- Resonance frequencies (ω_r) may amplify random disturbances if the disturbance frequency is close to the damped natural frequency.

The main principle of using these models is to determine the parameters K, T, T1, and T2 to ensure the best match between the approximation model and the data obtained from real-world or simulation experiments. Numerical approximation methods, such as the least squares method, are used for this purpose.

3. Results and Discussions

To obtain the dynamic characteristics of a nuclear power plant (NPP) unit, this study utilizes a simulation model [11]. This model enables the simulation of transient processes at various load levels and serves as a reference for analyzing approximation using first- and second-order functions. The model parameters were selected according to the typical characteristics of a VVER-1000 NPP unit, and the simulation time was set to 24 hours, allowing for the consideration of both short-term and long-term parameter variations.

During the simulation, the impact of different load levels on transient processes was studied, the accuracy of the approximation was analyzed, and the effectiveness of each method was evaluated. First-order models proved effective for rapid analysis of systems with low parameter variability, while

second-order models provided a more accurate representation of complex processes due to the greater number of parameters taken into account.

The obtained results allow conclusions to be drawn regarding the feasibility of using different approximation methods depending on the operating conditions of reactor systems and the required level of accuracy. This forms the basis for developing optimal strategies for managing the dynamics of energy systems, improving their efficiency and stability [12].

The reference simulation model describes the main processes occurring during power changes and allows for the study of the system's response to external disturbances, specifically the given electrical power of the power unit.

The developed model includes the following key components:

1. Power Input Subsystem:

- Specifies the power level as a percentage of the nominal value.
- Generates a control signal that determines the power level the system needs to reach.

2. Reactor Unit Subsystem:

- Accounts for reactor parameters, including inertia, time delays, and behavior under variable load conditions.
- Includes the dynamic properties of the turbine and circulation pipelines between the reactor and steam generators, as well as steam pipeline characteristics.
- Incorporates key technological regulators that maintain critical operational parameters of the reactor unit within normal operating conditions.

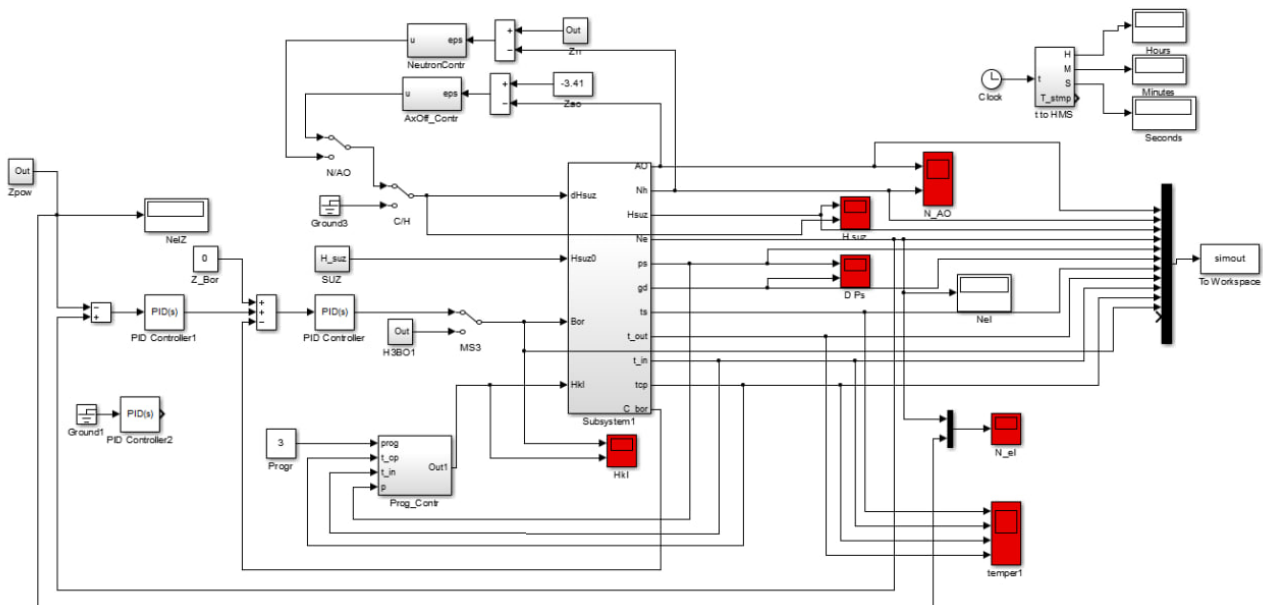


Fig. 1. Simulation model of a power unit from a WVER-1000 reactor

3. Measurement Module:

- Records the reactor's output power (as a percentage of the nominal value).
- Monitors other system characteristics, such as settling time, maximum deviations, and operational stability.

The model was built considering real operating conditions of reactors, with its parameters adjusted to match the typical characteristics of reactor systems.

For the study, load levels ranging from 80% to 100% of nominal power were selected, allowing for an assessment of system behavior across a wide range of operating modes. The simulation time was set to 24 hours to account for both short-term fluctuations and long-term dynamic changes.

To ensure adequate modeling, the following aspects were considered:

1. The system's response to a sudden increase or decrease in load.
2. The system's ability to stabilize after external disturbances.
3. The settling time required to reach the specified power level after changes in the system.

The model also includes the capability to simulate external disturbances, such as sudden load changes. This enables the study of the system's response under real operating conditions. Special

attention is given to how the system reacts to these disturbances, how quickly the power stabilizes, and how accurately the model represents the reactor's dynamic processes.

Due to its structure and capabilities, the Simulink model serves as a powerful tool for studying transient processes in a reactor system. To run the reactor simulation in Simulink, multiple power levels were defined using the Zpow block. These levels range from 80% to 100% of nominal power, allowing for an assessment of system behavior under different load conditions. Each level is set as an input signal that simulates real-world operational conditions of the energy system.

The simulation time is set to 24 hours to enable the analysis of both short-term fluctuations and long-term power variations. During the simulation, the output parameter N_{el} (electrical power) is recorded as a function of time, allowing for the evaluation of the system's dynamic characteristics. After running simulations for each power level, the results are analyzed to construct transient response characteristics of N_{el} over time. These graphs form the basis for approximating dynamic processes using transfer functions.

Fig. 2 illustrates the transient response corresponding to a step change in load from 100% to 80%, both in the direction of decrease and increase.

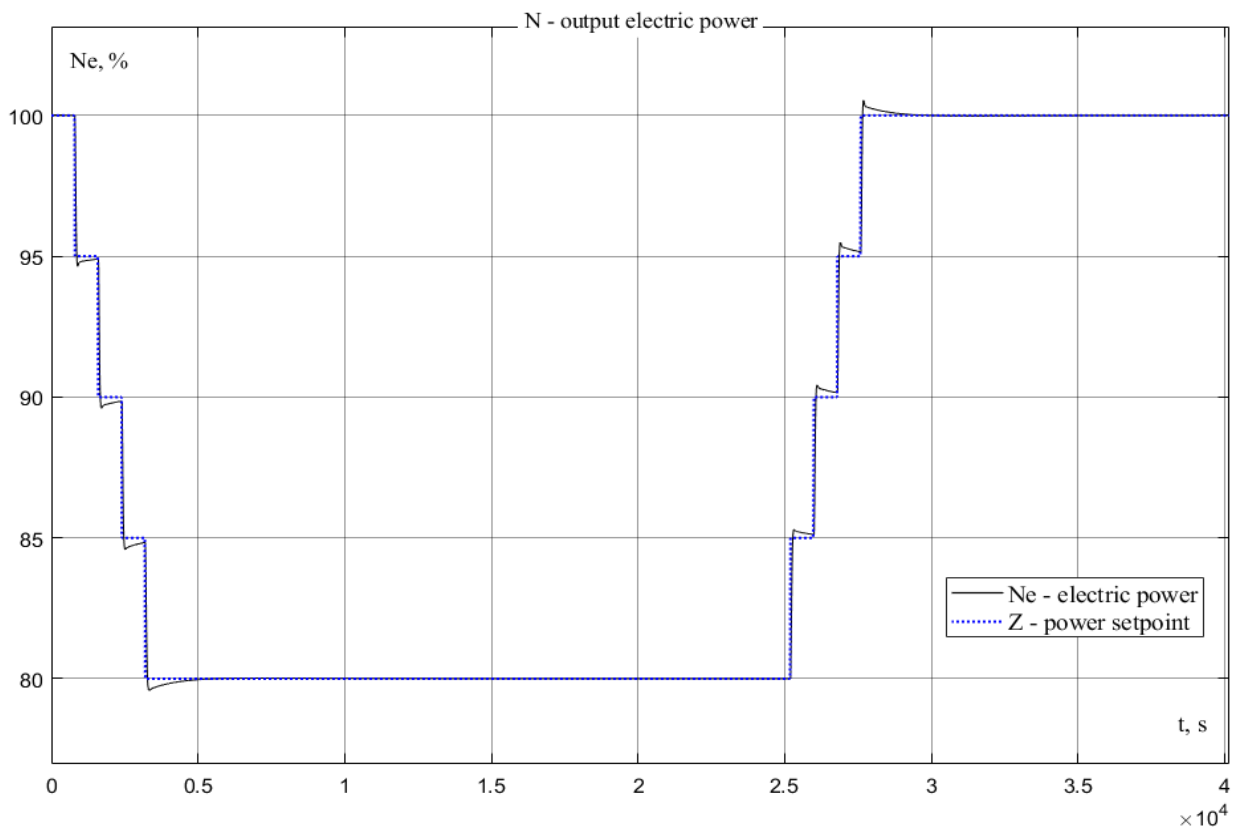


Fig. 2. The process of changing the power unit capacity depending on the task

For the approximation procedure, the given process was divided into separate segments, which were approximated using first-order transfer functions, second-order transfer functions without delay, second-order transfer functions with delay, and third-order transfer functions.

The simulation and approximation results are presented in Fig. 3 and Fig. 4. A summary of the comparison results is provided in Table 3.

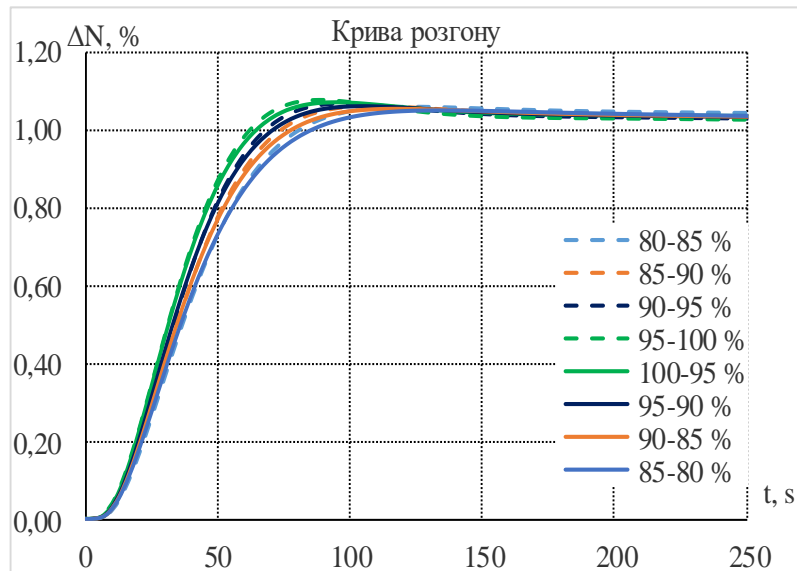


Fig. 3. Step response of a NPP power unit when changing the load controller task at $\Delta Z_{Ne} = \pm 5\%$ for different load levels

As can be seen from the acceleration curve graphs, even when the load regulator is in operation, the power unit, as a power control object, has nonlinear properties depending on the load level at which the disturbance occurs. However, the presence of an automated power unit control system allows us to minimize these nonlinearities.

All eight acceleration curves were approximated by four types of models: 1st-order

inertial link with delay, 2nd-order inertial link without delay, 2nd-order inertial link with delay, and 3rd-order inertial link without delay. The results of the approximation are shown in Fig. 4 and Fig. 5 and summed up in Table 3.

Depending on the power, the time constant of the approximated model ranges from 18 s at maximum load to 30 s at minimum load. This dependence is shown in Fig. 4.

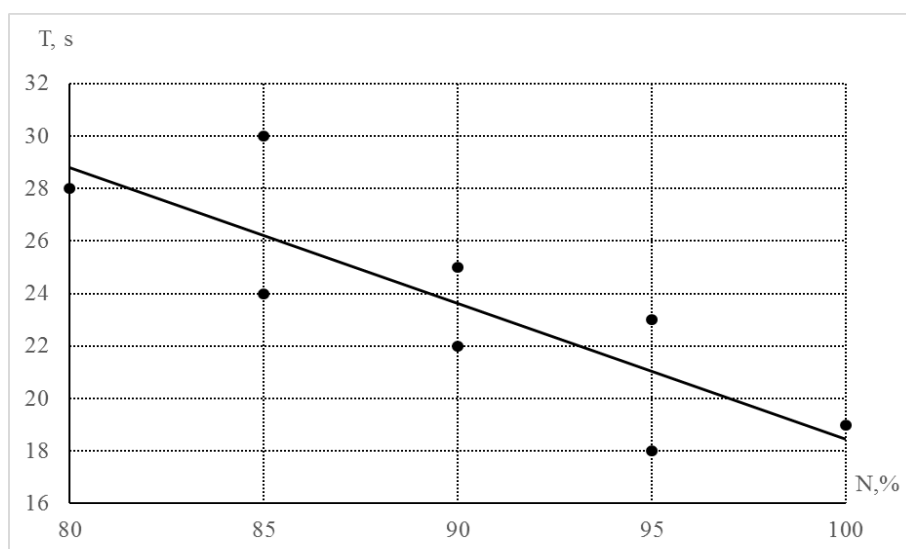


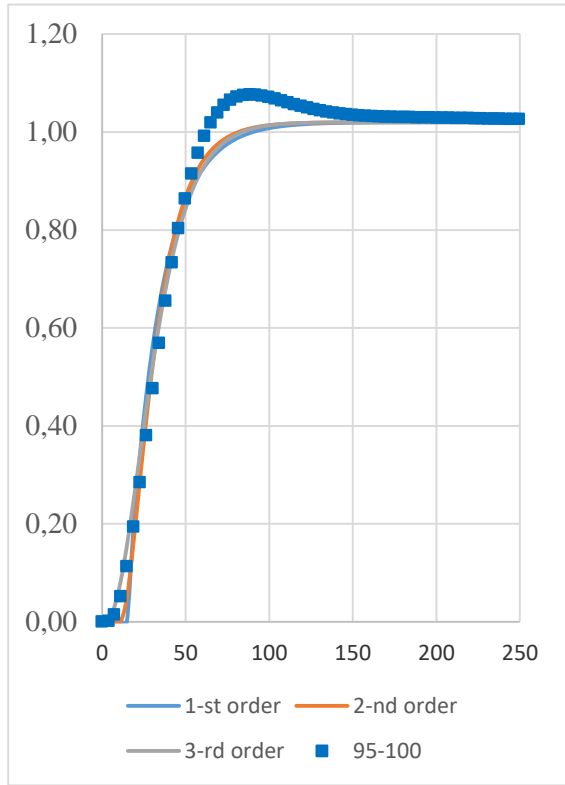
Fig. 4. Dependence of the time constant of the approximated model on the power level

Fig. 5 shows two extreme cases, the worst and the best, of the acceleration curves. In the worst case, even a second-order model describes the properties of the control object with a large error. In the best case, the 1st order model describes the properties with sufficient accuracy. In this case, the difference between the models is observed only in the initial part of the graph. Later on, the graphs practically coincide.

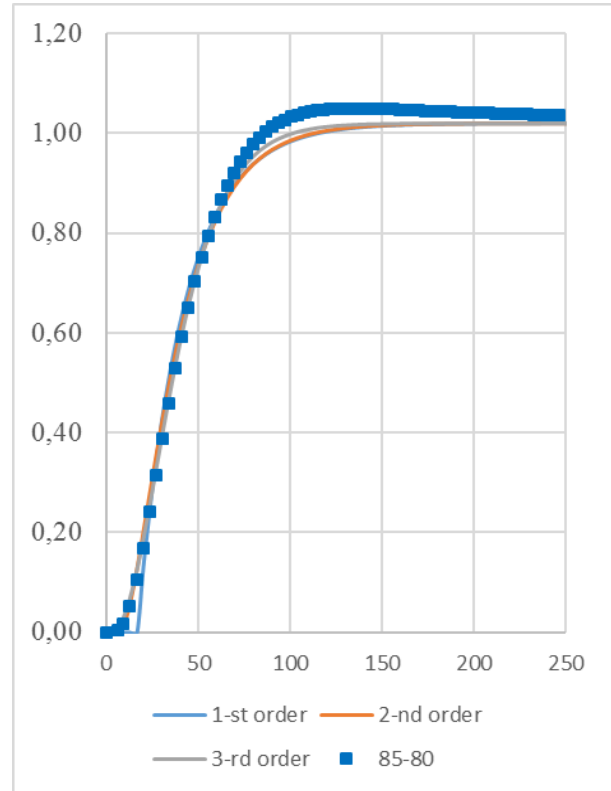
The approximation models are compared with each other using the sum of squared deviations between the simulation model and the approximation model:

$$S = \sum (y - y_m)^2 .$$

Table 3 shows the numerical values of the sum. The number of the acceleration curve corresponds to the number of the graph in Fig. 3.



a)



b)

Fig. 5. The result of approximation of the worst (a) and best (b) step response of a NPP power unit

Table 3

Comparison of Approximation Results for the Power Unit step responses

Ramp Response Curve Number	Sum of Squared Deviations S			
	First-Order Model with Transport Delay	Second-Order Model without Transport Delay	Second-Order Model with Transport Delay	Third-Order Model
1	0,144	0,193	0,109	0,081
2	0,140	0,194	0,089	0,085
3	0,144	0,183	0,087	0,074
4	0,104	0,145	0,079	0,052
5	0,107	0,160	0,063	0,052
6	0,110	0,176	0,070	0,067
7	0,130	0,217	0,097	0,097
8	0,152	0,226	0,104	0,112

This table summarizes the approximation accuracy for different transfer function models by evaluating the sum of squared deviations for each ramp-up curve. As expected, the best result in terms of approximation accuracy is obtained with the 3rd order model. On the other hand, it turned out that the 2nd order model without delay describes the object even worse than the first order model with delay. In addition, in the worst case (curve 8), the 2nd order model approximation was more accurate than the 3rd order model. Based on the calculation results and the practice of calculating industrial regulators, we can conclude that there is no significant difference between the 1st, 2nd, and 3rd order models considered. That is, the decision on the structure and order of the model should be made based on the degree of detail of the system being modeled.

Conclusion

In the modeling of regulation processes in thermal and electrical power systems, the choice between first-order and second-order differential equations plays a significant role. First-order differential equations describe systems where the rate of change of the state depends only on the current state and external influences. These equations are relatively simple and allow for analytical solutions, which facilitates the analysis and synthesis of control systems. Such models are particularly useful in the early stages of design when there is a need for a quick evaluation of the system's basic dynamic properties and preliminary calculations. The application of first-order models is also justified when the system's dynamics are straightforward and do not require consideration of inertia or oscillatory processes.

On the other hand, second-order differential equations take into account not only the rate of change of the state but also acceleration, allowing for the modeling of systems with more complex dynamics, including oscillatory processes and inertia effects. These models are necessary for the accurate description of systems where significant delays or oscillations are present, such as in modeling synchronous machines in electrical power engineering. However, the use of second-order equations complicates the mathematical model, requires more complex solution methods, and increases computational costs. Additionally, the identification of parameters for such models may be complicated due to the need for precise experimental data and complex calibration procedures.

In the context of thermal power systems, where processes often exhibit relatively slow dynamics and can be approximated without considering high-

frequency oscillations, first-order models simplify the analysis and development of control systems. This helps reduce development costs and simplifies the implementation of control algorithms. However, when it is necessary to account for more complex dynamic effects, such as resonance phenomena or interactions between different subsystems, the use of second-order models becomes inevitable to ensure the adequacy and accuracy of the modeling.

Thus, the choice between using first-order or second-order differential equations in modeling regulation processes in thermal and electrical power systems depends on the required accuracy, the complexity of the system's dynamics, and the available resources for developing and implementing the models.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

Financing

The study was conducted without financial support.

Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

References

1. Brezovec, M., Kuzle, I. and Krpan, M. (2022) 'Detailed mathematical and simulation model of asynchronous generator', *Journal of Energy - Energija*, 64(1-4), pp. 102-129. <https://doi.org/10.37798/2015641-4147> (PDF).
2. I.A. Razzhivin, A.A. Suvorov, R.A. Ufa, M.V. Andreev, A.B. Askarov, The energy storage mathematical models for simulation and comprehensive analysis of power system dynamics: A review. Part i, *International Journal of Hydrogen Energy*, Volume 48, Issue 58, 2023, Pages 22141-22160. <https://doi.org/10.1016/j.ijhydene.2023.03.070>.
3. da Silva, L. T. F. W., Tomim, M. A., Barbosa, P. G., de Almeida, P. M., & da Silva Dias, R. F. (2023). Modeling and Simulating Wind Energy Generation Systems by Means of Co-Simulation Techniques. *Energies*, 16(19), 7013. <https://doi.org/10.3390/en16197013>

4. Xie, Zhijun & Zhang, Dongxia & Hu, Wei & Han, Xiaoqing. (2024). Power System Transient Stability Preventive Control via Aptenodytes Forsteri Optimization with an Improved Transient Stability Assessment Model. *Energies*. 17. 1942. <https://doi.org/10.3390/en17081942>.
5. Yuanshi Zhang, Amin Mohammadpour Shotorbani, Liwei Wang, Behnam Mohammadi-Ivatloo. (2021) Distributed Secondary Control of a Microgrid With a Generalized PI Finite-Time Controller. *IEEE Open Access Journal of Power and Energy - Vol. 8*
6. M. Nagendra, Ch. Naga Sai Kalyan & R. Srinivasa Rao. Comparison of SMES and RFB Performance in Combined Voltage and Frequency Regulation of Multi Source Power System. *Control Applications in Modern Power Systems (EPREC 2023)* pp 91–107
7. Yavorskyi Oleksandr, Tarakhtii Olha, Maksymov Maksym, Kryvda Viktoriia. A model of a gas turbine unit with concentrated parameters for analyzing patterns of dynamic properties. *Energy Engineering and Control Systems, Volume 9, Number 2, 2023*, p. 105 - 118
8. Yavorskyi, O., Tarakhtii, O., Zhukovskiy, V., Panin, V. (2024). Analysis of the distribution of gas turbine unit operation modes as a tool for improving the stability of the power system. *Technology Audit and Production Reserves*, 6 (2 (80)), 50–57. <https://doi.org/10.15587/2706-5448.2024.320229>
9. D. Bouskela, “Modeling and simulation of complex ThermoSysPro model with OpenModelica: Dynamic Modeling of a combined cycle power plant,” in *Proc. 12th Int. Modelica Conf.*, Prague, Czech Republic, May 2017, pp. 407–414.
10. Kryvda, V., Maksymov, M., Zubak, V., Ivaneiev, A., Ryaboshapka, R. (2024). Development of the model and improvement of the method of automated control of steam turbine parameters to minimize the power imbalance in the energy system to increase its efficiency. *Technology Audit and Production Reserves*, 5 (1 (79)), 00–00. <http://doi.org/10.15587/2706-5448.2024.314219>
11. Kryvda, V. I., Zubak, V. V., Maksymov, M. M. (2024). Model for maintaining the operability of the power system under conditions of its imbalance. *Electrical and Computer Systems*, 40 (116), 13–24. <https://doi.org/10.15276/eltecs.40.116.2024.2>
12. Goldrin V. M., Chervonenko I. I., Zbyskyi V. S., Brodych R. A., Slonevskiy O. G. Participation of Ukrainian NPPs in Frequency and Power Control in the Integrated Power System: Analysis of the Problem and Ways of Solution. "State Enterprise State Scientific and Technical Centre for Nuclear Radiation Safety Nuclear and Radiation Safety 1(85).2020

Порівняння математичних моделей енергогенеруючого обладнання при моделюванні перехідних процесів в енергосистемах

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Анотація. Метою роботи є розробка підходів до підвищення ефективності моделювання перехідних характеристик енергоблоку АЕС шляхом апроксимації динамічних процесів функціями першого і другого порядків. Це дозволить зменшити час моделювання комбінованих енергосистем, які складаються у тому числі з енергогенеруючих джерел з різними фізичними принципами роботи (АЕС, ТЕС, ГЕС, ВЕС, тощо). Це дозволить забезпечити надійність та стабільність роботи енергосистеми, а також оптимізувати управління джерелами електричної енергії. Ця робота спрямована на забезпечення вибору такої імітаційної моделі обладнання, яка найбільшою мірою задовольняє меті майбутніх досліджень, у тому числі розробці нових підходів до управління структурою та параметрами енергогенеруючих джерел, що сприятиме ефективному функціонуванню енергетичних систем.

Ключові слова: система автоматичного керування, ідентифікація, класифікація, критерії ефективності, математична модель.

Отримано 18.02.2025

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