Chapter 7
Features and Application of Deterministic Analytical Modeling

ABSTRACT

The main subject of discussion is deterministic analytical modeling, including its features and possible applications. The first section discusses the general organization of analytical modeling and presents its main implementation in the direction of deterministic, stochastic, and combined approaches. The second section deals with the use of mathematical approximations as an apparatus for discrete model investigation, presenting two sub-parts: the analytical approximation with a mathematical description and the application of analytical modeling in the study of power electronic converter. The next two sections are devoted to the application of graphs and Petri nets for the realization of deterministic models and their investigation, with presenting selected examples for illustration. The last section of the chapter discusses pseudo-stochastic analytical modeling, which is a deterministic variant of the description of processes that are stochastic in nature. This part makes a transition to the stochastic approaches in the next chapter.

1. GENERAL ORGANIZATION OF ANALYTICAL MODELING AND APPROACHES

Analytical modeling is related to creating a mathematical model of the studied object to represent its physical properties in a selected mathematical system (Hazır, 2015). For this purpose, two main sets of parameters are considered (Figure 1) – of the input impacts $\{X_i\}$ and of the output reactions $\{Y_j\}$, and the mathematical description of the object is most often a system of equations.

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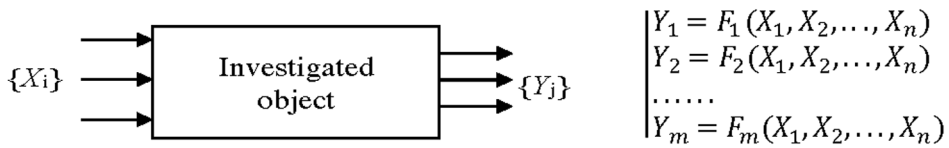
Figure 1. Analytical model defining



The advantages of analytical modeling are determined by the requirements for precision in formulating the mathematical relations, assumptions, and approximations. In this reason, analytic dependencies are strictly provable and imply analytic credibility. Analytical models have a great cognitive value because they allow an arbitrary combination of the analyzed parameters. In addition, they are characterized by a minimum complexity of calculations, because for their solution known numerical methods and approaches are usually applied.

The disadvantages are primarily associated with the influence of the subjective factor when defining the mathematical description, which can lead to an overly simplified image of the real object due to the introduction of unjustified simplifications and approximations. As a rule, the creation of an analytical model is associated with certain assumptions – for example, independence of individual factors, linear approximation of dependencies, instantaneous transitions, etc. However, they must be well thought out and justified in order not to violate the adequacy of the model process.

Computer systems and processes have characteristic features that enable the successful application of analytical modeling. For example, in the investigation of cloud services (Antonelli et al., 2020), edge and fog computing (Pereira et al., 2021), machine learning (Nai-Zhi et al., 2022), etc. Research framework for computer systems engineering and modeling is proposed in (Kurniawan, 2019), which is based on service-oriented architecture (SOA) principles. The framework is designed to develop model-based computing systems for process analysis and optimization. A summary of the main features of computing is presented below.

- Regardless of the discrete nature of the structure of computer devices and systems, the processes taking place in them are of a stochastic nature.
- The competition between the active processes for occupying the free resource and their service is oriented to the theory of mass service (queuing theory).
- Computer processes are characterized by Markov properties.
- When studying the computer parameters, average values for the estimates are usually sought, which implies stationarity of the processes.

The development of an analytical model follows the generalized technological scheme, and a simplified adaptation of the procedure is shown in Figure 2.