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Functioning of an Intelligent System on the Example of the National Power Demand System

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Abstract. This publication includes a concept and research results regarding the search for regularity in the functioning of an intelligent system using the example of a system for forecasting national power demand. The research employs the ARX regression machine learning method to derive models of the functioning of the electricity forecasting system. The study uses actual values of electricity generated by both uniform and non-uniform domestic electricity systems as input quantities, and forecasted national power demand as the output values from January 2023. The main aim of the research was to obtain several hourly models and several monthly models to demonstrate changes in selected system parameters and to show whether, and what changes occur in the direction of increasing the system's independence, enhancing the system control level, etc. The research methodology also employs, in addition to the machine learning method, the method of control theory and systems. At the same time, an example of obtaining a model of the national system demand for electric power using the ARX machine learning method, which was transformed into state space model, whose matrix elements were used to interpret the correctness of changes in the intelligent system.

Keywords: Degree of internal organization, Electric Power Demand system, Forecasting demand for electric power, Intelligent systems, MATLAB and Simulink environment, Regression machine learning methods, System control level.

1 Introduction

Intelligent systems, which include The power system as a unmanned factory and its subsystems such as the National Power Demand system (NPD system) are modeled to study their quality on models, not on systems, as well as learn their regularities and use them in the control and development of the system and its subsystems. In Annexes 1 and 2 to the document entitled Poland's energy policy until 2040 regarding applications from prognostic analyzes for the energy sector [9-10]. The need for a more precise forecasting of the demand for power and electricity was noted and was indicated, among others, that in recent years many different assessment methods have been developed, which generally indicate a relatively large change in the structure of power and electricity production in Poland in perspective until 2040. It was indicated in the document, among others, that these changes concern in particular the increase in the power of the achievement of production sources from the value of 47.3 GW in 2015 and 46 GW in 2018 to the value appropriate in the year: 2030 - 59 GW (increase by approx. 58.0%) and up to 72 GW in 2040 (increase by approx. 93.0%).

2 Modeling of the National Demand for Electric Power

In these studies, modeling was carried out using the ARX machine learning method (also known as the identification method) [11-18] on the example of the National Power Demand system in order to obtain a discrete parametric model determined as ARX using numerical data regarding electricity production by a uniform domestic electricity system (marked as JWCD) [GWH], which were adopted as 24 input quantities and data on the demand for electric power in the national power system [MW], which were adopted as individual output quantities [19]. Modeling was carried out in the MATLAB and Simulink environment using such program libraries as System Identification Toolbox (SIT) and Control System Toolbox (CST) [20] system with a discreet model of the NPD system marked as ARX. This model was then pulled by obtaining a continuous parametric model of the NPD system marked as TH, and this was converted to a continuous state space model marked as SS. Detailed transformations and obtained results were included in the previous work of the authors [11, 12].

It can be noted, among others, that the national demand for electric power is a multi Input Multi Output system, hence the obtained model is a type model, even where the output size is the hourly streams of the daily domestic demand for electric power, and in the input sizes in the presented tests the hourly total generation of the uniform system designated as JWCD. At the same time, research on system modeling is also carried out, which in addition to the daily total generation of electricity by uniform JWCD units in the inputs to the NPD system are also the hourly size of the total generation of non -uniform units marked as nJWCD.

It is assumed that the output quantities are delayed by one day in relation to the output size [11-12]. As a result of regressive machine learning, the NPD system is obtained, which for the purposes of testing the internal degree of organization of the system and the level of control is also obtained as a model of variable states. The research experiment included in this publication uses a numerical example regarding the NPD system for numerical data recorded from January 1, 2023 to January 31, 2023 with a measuring period of 31 days and one day progress (daytime days) [19]. Example of a course of data on electricity production between 1 and forecasting the power demand for 24 is shown in Fig. 1.

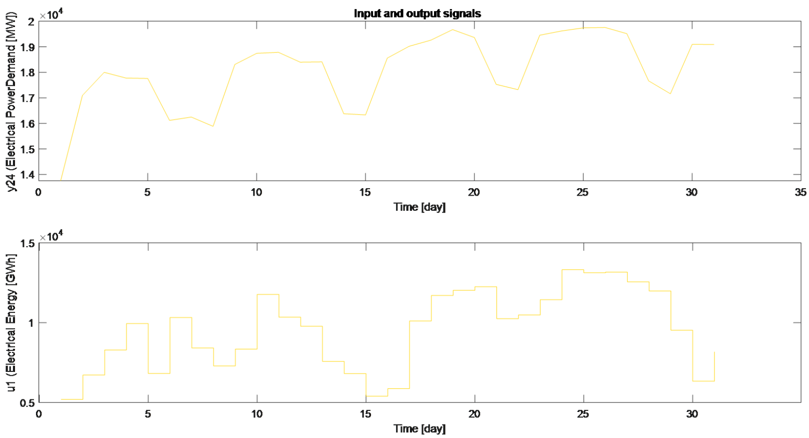

Figure 1. Course of data on: upper chart - real demand for electric power for 24:00 (output from the electrical power demand system) in January 2023 [MW]; Lower chart - real electricity production by JWCD [GWH] units. Source: own study using the MATLAB and Simulink and SIT environment [19-20].

Course of data on: upper chart - real demand for electric power for 24:00 (output from the electrical power demand system) in January 2023 [MW]; Lower chart - real electricity production by JWCD [GWH] units. Source: own study using the MATLAB and Simulink and SIT environment [19-20].

As a result of regressive machine learning, hourly models of the NPD system were obtained as discrete and continuous parametric ARX and as discreet and continuous state space model marked as SS. As a consequence, an important issue was to obtain changes in components of matrix **A**, **B**,**C**,**D** and **K** model variables of the NPD system, the changes of which show the state of independence of the system, the level of its control, etc., as well as, among others own values and the location of the elements on the plane of the complex variable s.

3 Methodology of research in the field of NPD system modeling

3.1 Description of the research process

Due to the assumed main purpose of the research, including the adopted detailed goals and the complexity of research in the field of regression machine learning, the designed research process for work [15] consists of eight stages of activities, namely:

1) For the purposes of conducting studies and research in the field of modeling nd meta-modeling of the NPD system, a comparative modeling study with a structure should be developed: modeled system, type of modeling, including used identification methods, data used for input and output modeling, forecasting horizon, tests (matching the model to the system, this is a matching to real data), used measures, obtained forecast results (including types of errors and their value) including IT calculations, etc.

2) In order to conduct experiments, it was necessary to analyze the processes occurring in the NPD system, as well as obtain recorded numeric data in individual hours of the day, and preliminary procedures had to be carried out on numerical data.

3) In order to obtain a catalog of NPD system models and carry out identification experiments using numerical data listed in NPD system in the MATLAB and Simulink environment using the Systems Identification Toolbox (SIT) [20].

4) Due to the need to improve the parameters of the MPD system model, you should choose architecture and method of artificial learning neural network in the MATLAB and Simulink and Deep Learning Toolbox (DLT) environment and conduct possibly neural learning experiments [20], in order to improve the quality of the regression model, which was shown in number examples, among others in the following work [21-23].

5) It is necessary to obtain information about the degree of internal organization of the system which is the NPD system and obtain information about the control level occurring in it, which is associated with the need to conversions parametric models of discrete ARX to parametric models continuous TH, and those on continuous state space model (marked SS model) in order to obtain a matrix catalog **A**, **B**, **C**, **D** and **K** appearing in the space states [21-23].

6) The quality of the model should be carried out in relation to the NPD system, which requires, among others determining: discrepancies, absolute and relative errors and, e.g. map, as well as the effectiveness of NPD system models, system efficiency and intensity and their models, and also requires examination of the sensitivity of the model of the NPD system [14-15].

7) The discussion of the obtained test results should be conducted and the conclusions indicate to what extent the target goal and detailed goals were achieved, as well as directions of further research, which requires setting MAPE errors and reference to them currently received in this respect in the electricity.

3.2 Selected modeling results of the NPD system

In accordance with the adopted methodology, the NPD system modeling was conducted in p. 3 using the regression machine learning method for the system with 24 inputs on information on produced electricity from the uniform NPD system and with one output regarding the demand for electric power for selected characteristic hours of the day (MISO models), this is for the hour: 3:00, 6:00, 9:00, 12:00, 12:00, 12:00, 18:00, 21:00 and 24:00.

Recreation parametric models discreet and continuous MISO models for the above mentioned hours of day were obtained using hourly numerical data from the month of January 2023 available on the PSE Operator website, which was then transformed into continuous state space models. Selected results of detailed tests regarding these models were included in author's work [17-18].

At that time, attention was paid to the need to check how much changes:

- degree of internal organization of the NPD system, and especially the correctness resulting from coded information in values and in the structure of matrix **A**,

- the level of control of the NPD system, and especially the correctness resulting from coded information in values and in the structure of matrix **B**, and similarly in the values and structure of other matters appearing in the variable models of the state, primarily in the **C** and **K** matrix, because the D matrix is of zero values.

For this type of need to conduct research in the field of the National Power System (KSE), attention has already been drawn to, among others at work [14], and then in the scope of the next day system functioning on TGE S.A. in work [15] and the National Power Demand system in work [11-12].

These research results are a continuation of research in the NPD system, in particular in the scope of parametric and structural changes of the NPD system, which results from changes in the value of elements of individual matters occurring in individual daily models of variable state variables, including in the own values resulting from individual **A** elements, this is the matrix of the process, and thus the internal way of organizing the system.

4 Models of the Electric Power Forecasting system

Therefore, as already mentioned on p. 3 as a result of regression machine learning, hourly parametric models were obtained discrete and continuous MISO, as well as hourly discreet and continuous state space models of the system states using the MATLAB and Simulink environment with the library of programs entitled. Identification Toolbox and Control System Toolbox [20], while modeling uses data on the demand for electrical power from January 2023 obtained from the part of Polish electricity networks S.A. [19]. As a result of modeling using regression machine learning, hourly parametric models (continuous and discreet) and hourly state space models of the NPD system were obtained, while in this publication their presentation was limited to eight characteristic hours of day, and, for example, for the presented data from January 2023 for 24:00 received:

1) Discrete parametric model marked ARXr202301h24441-Fig. 2 (with an accuracy of almost 100)%, MSE error = 7.845 e-23) characters:

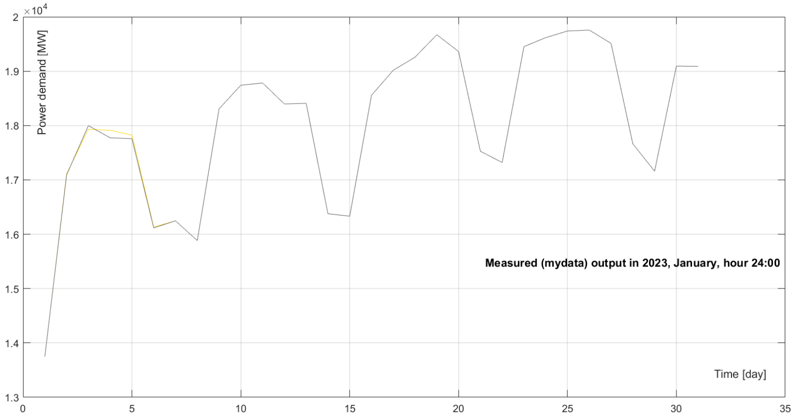

Figure 2. The course of changes in electrical power for 24:00 (output from the ARXr2023m01h24 model and output from the National Power Demand system) in January 2023. Source: own study using the MATLAB and Simulink and SIT environment [19-20].

$$A(z) \cdot y(t) = B(z) \cdot u(t) + e(t), \tag{1}$$

where:
$A(z) = 1 - 0.8411z^{-1} - 0.4568z^{-4}$,

$B1(z) = -0.2561z^{-4}$,

$B2(z), B3(z), ..., B8(z), B10(z), B12(z), B17(z), B19(z), B21(z), B23(z) = 0$

$B9(z) = -0.4942z^{-1} - 0.4832z^{-2} - 0.2336z^{-3} - 0.5143z^{-4}$,

$B11(z) = -0.05373z^{-3}$,

$B13(z) = 0.3275z^{-1} + 0.3513z^{-2} - 0.05662z^{-3} - 0.4014z^{-4}$,

$B14(z) = -0.2308z^{-2} + 0.3589z^{-3} + 1.259z^{-4}$,

$B15(z) = -0.4239z^{-1}$,

$B16(z) = -0.2693z^{-1} - 0.2122z^{-2} - 0.08817z^{-3} - 0.2796z^{-4}$,

$B18(z) = 0.1025z^{-2}$,

$B20(z) = 0.9415z^{-1}$,

$B22(z) = -0.696z^{-4}$,

$B24(z) = -0.5468z^{-1} + 0.6153z^{-2} + 0.01764z^{-3} + 0.9827z^{-4}$ z - time delay opertor.

2) Continuous state space model designated as SSR2023m01 - see: Fig. 2 (with an accuracy of akmost 100)%, MSE error = 5.603 e-23) characters:

$$\frac{d\mathbf{x}_i}{dt} = \mathbf{Assr2023m01h24} \cdot \mathbf{x}(t) + \mathbf{Bssr2023m01h24} \cdot \mathbf{u}(t) + \mathbf{Kssr2023m01h24} \cdot e(t), \quad (2)$$

$$\mathbf{y}(t) = \mathbf{Cssr2023m01h24} \cdot x(t) + \mathbf{Dssr2023m01h24} \cdot \mathbf{u}(t), \quad (3)$$

where:

$$\mathbf{Assr2023m01h24} = \begin{bmatrix} -1.752 & 4.553 & -4.948 \\ 0.105 & -1.84 & 3.53 \\ -0.242 & -0.003 & -1.358 \end{bmatrix},$$

$$\mathbf{Bssr2023m01h24} = \begin{bmatrix} 2.14 & 2.01 & -0.96 & -2.10 & -1.82 & 3.84 & -1.08 & -0.36 & ... & 1.11 \\ 0.105 & -1.84 & 2.57 & 2.73 & 1.81 & -3.08 & 1.12 & -2.33 & ... & -0.28 \\ -0.242 & -0.003 & -0.38 & -0.65 & 0.88 & 3.01 & -1.98 & -0.53 & ... & -1.33 \end{bmatrix},$$

$$\mathbf{Cssr2023m01h24} = \begin{bmatrix} 1.00 & -0.79 & 1.09 \end{bmatrix},$$

$$\mathbf{Dssr2023m01h24} = \begin{bmatrix} 0.00 & 0.00 & 0.00 & ... & 0.00 \end{bmatrix}.$$

$$\mathbf{Kssr2023m01h24} = \begin{bmatrix} 1.31 \\ -1.31 \\ 0.16 \end{bmatrix}.$$

5 Results of the National Power Demand System changes test during the day

Elements of the matrix of the internal organization system (designated as **A**) when limiting its dimension to 3 x 3 for the eight characteristic hours of the day (i.e. for 3:00, 6:00, 9:00, 12:00, 15:00, 18:00, 21:00, 24:00) for January 2023, set in Table 1, and the changes of individual elements of the matrix were shown in Fig. 3 [20].

Analysis of parametric changes of matrix elements **Assr2023m01h24** showed, among others, that the daily changes were not significant, but there was, for example, an increase in the value of a11 and a21 elements and the decrease in the value of elements a12 and a33. However, the value of the a31 element basically remained at the same level.

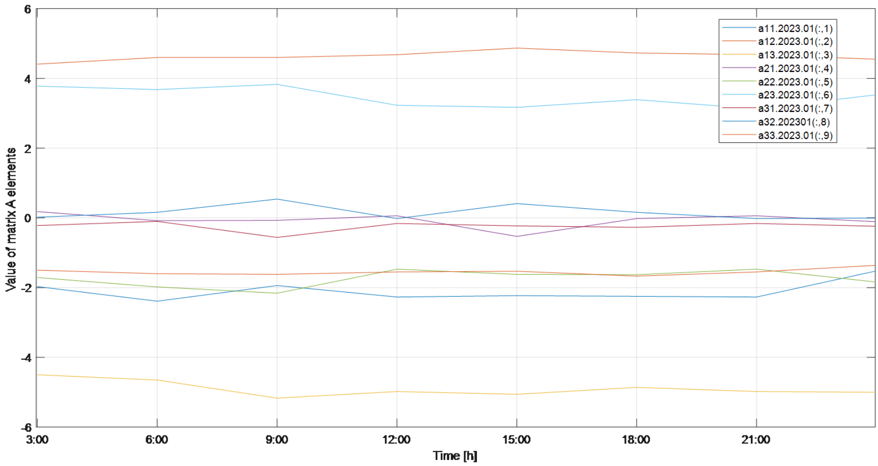

Figure 3. Medium - length changes in the value of **Assr2023m01h24** matrix elements and determined for January 2023. Source: Own study using the MATLAB and Simulink environment as well as SIT and CST libraries [19-20].

In addition, changes in the elements of B, C and K matrix were examined by placing the values of selected elements in Table 2, and the course of their hourly changes at: Fig. 4 - for b11 element of the **Bssr2023m01h24** matrix, Fig. 5 - for the c11 element of the **Cssr2023m01h24** matrix (the D matrix were with elements witch values were zero), Fig. 6 - for the k11 element of the **Kssr2023m01h24** matrix.

Table 1. Values of matrix components **Assr2023m01h24** in the variable model of the status of the Electric Power System in characteristic hours of day. Source: own study in the MATLAB and Simulink environment using SIT and CST [19-20].

Hour/aij	a11	a12	a13	a21	a22	a23	a31	a32	a33
3:00	-1.97	4.41	-4.50	0.18	-1.71	3.78	-0.22	0.02	-1.50
6:00	-2.39	4.60	-4.65	-0.08	-1.98	3.68	-0.10	0.16	-1.60
9:00	-1.94	4.60	-5.17	-0.07	-2.16	3.83	-0.56	0.54	-1.62
12:00	-2.27	4.68	-4.98	0.06	-1.47	3.23	-0.16	-0.02	-1.55
15:00	-2.23	4.87	-5.06	-0.53	-1.62	3.17	-0.23	0.41	-1.53
18:00	-2.25	4.73	-4.86	-0.02	-1.63	3.39	-0.27	0.16	-1.67
21:00	-2.27	4.68	-4.98	0.06	-1.47	3.13	-0.16	-0.02	-1.55
24:00	-1.52	4.55	-5.00	-0.11	-1.84	3.53	-0.24	-0.003	-1.36

Table 2. Values of selected elements of **Bssr2023m01h24** , **Cssr2023m01h24** and **Kssr2023m01h24** matrix occurring in variable state space models of Electric Power Demand system. Source: own study in the MATLAB and Simulink environment using SIT and CST [19-20].

Element\Hour	3:00	6:00	9:00	12:00	15:00	18:00	21:00	24:00
b11 of Bssr2023m01h24 matrix	1.41	1.33	1.75	1.89	1.84	2.23	1.89	2.14
c11 of Cssr2023m01h24 matrix	1.13	1.43	1.26	1.17	1.43	1.28	1.17	1.00
k11 of Kssr2023m01h24 matrix	2.83	0.49	1.25	3.49	0.75	-0.04	3.49	1.31

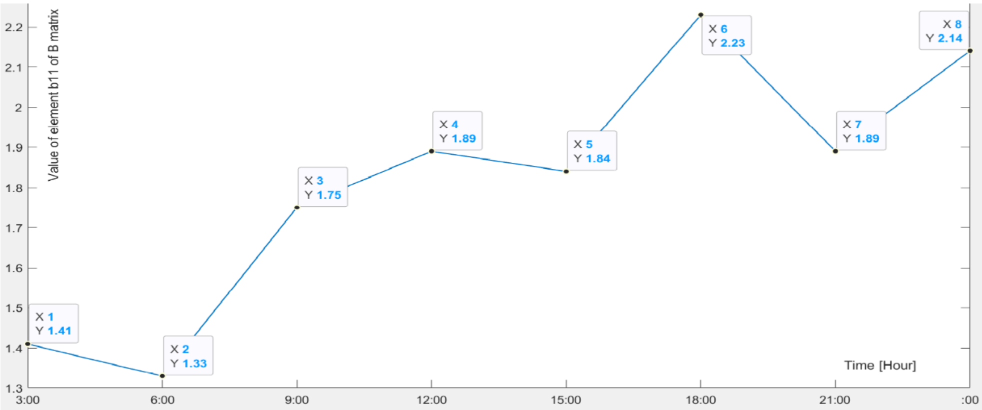

Figure 4. Changes in the value of the element b11 of **Bssr2023m01h24** matrix occurring in the variable state space model of the Electric Power Demand system. Source: own study in the MATLAB and Simulink environment using SIT and CST [19-20].

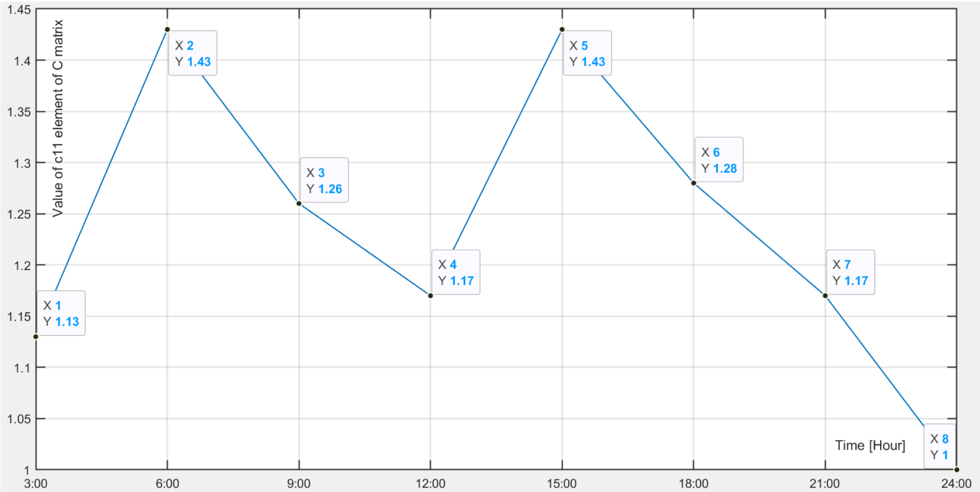

Figure 5. Changes in the c11 value of the **Cssr2023m01h24** matrix occurring in the variable model of the status of the Demand for Electric Power System. Source: own study in the MATLAB and Simulink environment using SIT and CST [19-20].

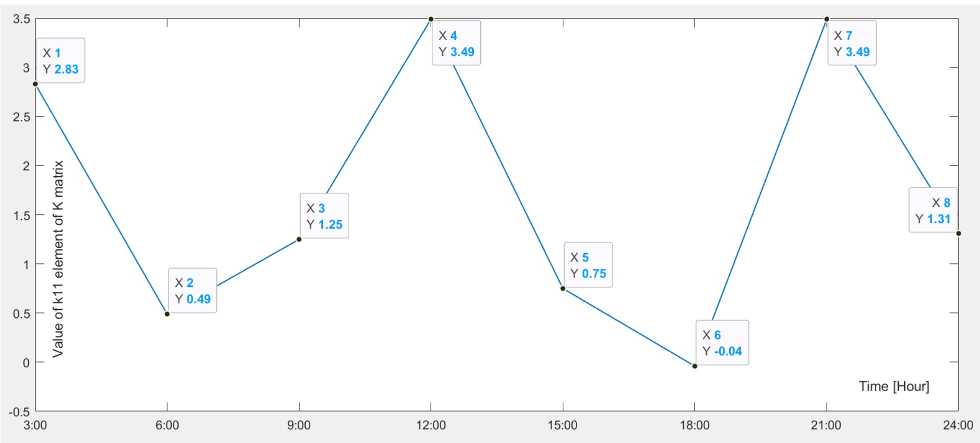

Figure 6. Changes in the value of the k11 element of the **Kssr2023m01h24** matrix in the state space model of Electric Power Demand system. Source: own study in the MATLAB and Simulink environment using SIT and CST [19-20].

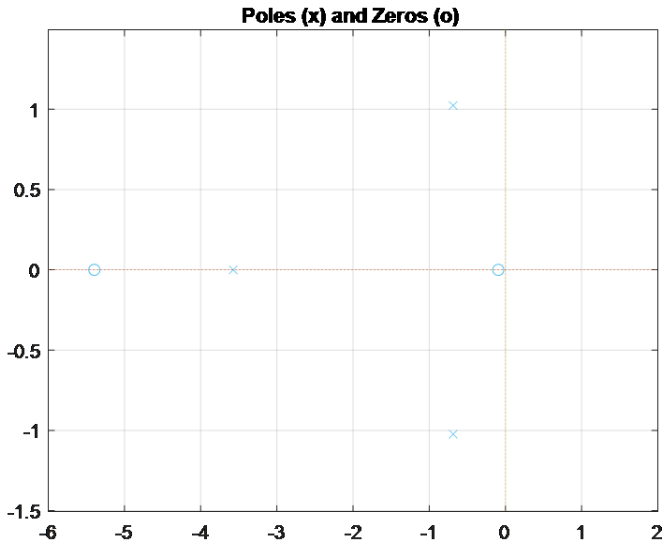

Figure 7. Zero and pole in the state space model of the Electric Power System for the u1-y18 subsystem occurring in the variable state model for hour 18:00. Source: Own study in the MATLAB and Simulink environment using SIT and CST [19-20].

Table 3. Own values determined on the basis of the **Assr2023m01h24** matrix in individual state space models. Source: own study in the MATLAB and Simulink environment using SIT and CST [19-20].

Hour	Eig-1	Eig-2	Eig-3
03:00	-3.7060 + 0.0000i	-0.7379 - 1.0036i	x
06:00	-1.2432 + 0.7314i	-1.2432 - 0.7314i	-3.2873 + 0.0000i
09:00	-3.0130 + 0.0000i	-1.1741 + 0.6358i	-1.1741 - 0.6358i
12:00	-3.4605 + 0.0000i	-0.9146 + 0.9536i	-0.9146 - 0.9536i
15:00	-1.2383 + 0.9527i	-1.2383 - 0.9527i	-2.9004 + 0.0000i
18:00	-0.8419 + 1.0838i	-0.8419 - 1.0838i	-3.8727 + 0.0000i
21:00	-3.4605 + 0.0000i	-0.9146 + 0.9536i	-0.9146 - 0.9536i
24:00	-3.5737 + 0.0000i	-0.6860 + 1.0233i	-0.6860 - 1.0233i

6 Conclusions and directions of further research

This publication includes the main elements of the research methodology and selected results regarding the intelligent system on the example of the National Power Demand system for electric power using regressive machine learning. Numerical research was limited to testing the intelligent system functioning in the period of January 2023, taking into account 24 inputs representing hourly electricity production in a uniform NPD system, and at the output the demand for power in the selected day of the day, which was a total of eight characteristic hours, this is: 3:00, 6:00, 9:00, 9:00, 12:00, 15:00, 18:00 and 24:00.

Parametric models of the NPD system MISO discrete model were obtained, as well as discrete and continuous models in the state space model, which is characterized by the matrix of the internal organization of process **Assr2023m01h24** (with a deliberately limited dimension to the size of 3 x 3 in order to present on the number of more transparent research methodology in number), and thus with three sizes of variables.

However, the control matrix is matrix **Bssr2023m01h24**, which as a consequence of the above mentioned. The assumptions are 3 x 24 with the process control values in a stimulating or inhibitory manner, which was shown in this publication only on the example of changes in element b11 (similarly only changes in the value of the c11 element for of the **Cssr2023m01h24** matrix and of the k11 element of the **Kssr2023m01h24** matrix, the value of elements dij of the **Dssr2023m01h24**matrix were of zero value).

The research is continued. Subsequently, research for 48 input quantities will be carried out, taking into account the heterogeneous NPS (nJWCD) system and the demand for electrical power in the remaining months of 2023. Ultimately, an important issue will also be an important issue to propose the measurement indicators of the degree of system intelligence, which requires comparative research for all months 2023, and maybe even a few years. In this respect, achievements regarding research results in the field of security and preventive automation [24] as well as the possibility of using many methods in control and systems [6] are already important in publications.

Changes in the order of **A** matrix **Assr2023m01h24** mutual relations between the elements of the matrix and, for example, during the year 2023 in the study of changes in models received for individual months of the year. Also important will be changes in matrix **Bssr2023m01h24**, and even a **Cssr2023m01h24** matrix from the point of view of changes in the control level and compounds of the NPD system with the environment. The first important research and attempt to interpret their initial interpretation were shown in this regard.

Due to the complexity of the subject of changes taking place in the power electricity during the transformation in Poland, Europe and the world, the methodology and practical examples presented in the publication respond to the current demand for methods of modeling complex systems using artificial intelligence methods, including using machine learning methods [25].

References

1. J. Tchórzewski, R. Marlęga, Smart Village as an action system supporting people with special information and communication needs, Studia Informatica. Systems and Information Technology, Vol. 1(30)2024, pp. 49-65.
2. W. Agustiono, Smart Villages in Indonesia in the Light of the Literature Review, 2022 International Conference on ICT for Smart Society (ICISS), Bandung, Indonesia, pp. 1-5, 2022.
3. E. Anastasiou, S. Manika, K. Ragazou, I. Katsios, Territorial and Human Geography Challenges: How Can Smart Villages Support Rural Development and Population Inclusion? Social Sciences, 10(6), pp. 1-15, 2021.
4. K. Bilewicz, Smart metering. Inteligentny system pomiarowy (in Polish), PWN, Warszawa, pages 278, 2012.
5. K. Bokun, J. Nazarko, Smart villages concept. A bibliometric analysis and state-of-threat literature review, Progress in Planning, 100765, ELSELVIER, April 2023, Article in Press, pp. 1-23.
6. S. P. Mohanty, H. Thapliyal and R. Bajpai, Consumer Technologies for Smart Cities to Smart Villages, 2021 IEEE International Conference on Consumer Electronics, Las Vegas, NV, USA, pp. 1-1, 2021.
7. T. Thaj, M. Delsy, K. Haritha, B. Martin and G. Karthika, Smart Village Monitoring and Control Using PLC and SCADA, 2021 International Conference on Innovative Computing, Intelligent Communication and Smart Electrical Systems (ICSES), Chennai, India, 2021, pp. 1-7.
8. S. Wu et al., Evaluation of Smart Infrastructure Systems and Novel UV-Oriented Solution for Integration, Resilience, Inclusiveness, and Sustainability, 2020 5th International Conference on Universal Village (UV), Boston, MA, USA, 2020, pp. 1-45.
9. Ministerstwo Klimatu i Środowiska, Polityka energetyczna Polski do roku 2040, Załącznik do uchwały nr 22/2021 Rady Ministrów z dnia 2 lutego 2021 r. (in Polish), in English: Poland's energy policy until 2040, annex to Resolution No. 22/2021 of the Council of Ministers of February 2, 2021.Warszawa 2021.
10. Ministerstwo Klimatu i Środowiska, Zał. 2 do PEP do roku 2040 pt. Wnioski z analiz prognostycznych dla sektora energetycznego (in Polish), in English: Annex 2 to PEP until 2040 Applications from prognostic analyzes for the energy sector, Warszawa 2021.
11. J. Tchórzewski, W. Nabiałek, R. Marlega, "Modeling an Intelligent System Using Regression Machine Learning on the Example of the Electric Power Demand System", (Extended Abstract), [in:] Niewiadomski A., Wawrzyńczak-Szaban A. (ed.): Proceedings of the 2nd Conference on Intelligent Systems and Information Technologies. Logic, Knowledge, and Reasoning in Intelligent Systems. Extended abstracts (2024), Siedlce, UPH w Siedlcach, pp. 106-113.
12. J. Tchórzewski, W. Nabiałek, M. Demiańczuk, Regression Machine Learning of an Hourly Model of National Electric Power Demand System, IEEE Digital Library, PAEE, Kościelisko (2025), pp. 1-5.
13. A. Zimmer, A. Englot, Identyfikacja obiektów i sygnałów. Teoria i praktyka dla użytkowników MATLABA in Polish), in English: Identification of objects and signals. Theory and practice for MATLAB users, PK (2005), Kraków, pages 239.
14. J. Tchórzewski, Rozwój systemu elektroenergetycznego w ujęciu teorii sterowania i systemów (in Polish), in English: Development of the power system in terms of control theory and systems, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, pages 190, 2013.
15. R. Marlęga, Identyfikacja i metaidentyfikacja systemu zarządzania Towarową Energią Elektryczną (in Polish), in English: Identification and metaidentification of the Electricity Management Management System rozprawa doktorska pod kierunkiem dr hab. inż. Jerzego Tchórzewskiego oraz dr hab. inż. Arkadiusz Jurczuka (promotor pomocniczy) na Wydziale Inżynierii Zarządzania PB, Białystok 2022, pages 238.
16. J. Tchórzewski, Metody sztucznej inteligencji i informatyki kwantowej w ujęciu teorii sterowania i systemów (in Polish), Wydawnictwo Naukowe UPH, Siedlce, pages 343, 2021.

17. R. Marlęga, “Hourly identification and simulation of the TGE SA Day-Ahead Market system”, Control and Cybernetics, Vol. 51 (2022) No. 4, pp. 523-555.
18. R. Marlęga, “A methodology of identification and metaidentification research on the example of Day Ahead Market System, Studia Informatica. Systems and Information Technology”, Vol. 2(27)2022, ss. 109-137.
19. Polskie Sieci Elektroenergetyczne SA, Wielkości podstawowe raportów dobowych z pracy KSE (in Polish), in English: The size of basic daily reports from KSE work, https://www.pse.pl/dane-systemowe/funkcjonowanie-kse/raporty-dobowe-z-pracy-kse (access: 2021-2025).
20. MATLAB and Simulink with toolboxes such System Identification Toolbox and Control System Toolbox, MathWorks, https://www.mathworks.com [access: 1992-2025].
21. J. Tchórzewski, Systemic Neural Modeling of Hourly Power Demand in the National Power System, IEEE Digital Library, PAEE, Kościelisko 2024, pp. 1-5.
22. R. Marlęga, “Correction of the parametric model of the Day-Ahead Market system using the Artificial Neural Network”, Studia Informatica. Systems and Information Technology, Vol. 1(26)2022, pp. 85-105.
23. J. Tchórzewski, „Model neuronalny 24-godzinowego jednoczesnego zapotrzebowania na moc z wyprzedzeniem dobowym w KSE” (in Polish), in English: Neuronal model of 24-hour simultaneous demand for a daily power in KSE, Przegląd Elektrotechniczny (2025), R. 101 Nr 2, pp. 228-232.
24. W. Rebizant, Metody inteligentne w automatyce zabezpieczeniowej (in Polish), Prace Naukowe Instytutu Elektroenergetyki, in English: Intelligent methods in protection automation, Seria Monografie Nr 29, (93), OW PWr., Wrocław, pages 168, 2004.
25. I. Filipiak, W. Milczarski, Energetyka w okresie transformacji (in Polish), in English: Power engineering in the period of transformation, WN PWN (2023), Warszawa, pages 295