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Adaptation of selected aspects of deterministic chaos for long-term forecasts of peak power demand for Poland

Streszczenie. *Publikacja dotyczy innowacyjnej techniki konstruowania długoterminowych prognoz zapotrzebowania na moc szczytową oraz na energię elektryczną brutto dla całego kraju na przykładzie Polski. Metoda ta bazuje na rozkładzie kanonicznym wektora zmiennych losowych (ang. CDVRM). W pracy opisano problematykę doboru scenariuszy zmiennych objaśniających do modelu prognostycznego. Ponadto przedstawiono koncepcję wykorzystania równań Prigogine'a oraz elementów teorii chaosu zdeterminowanego. Opisane koncepcje zostały zweryfikowane poprzez wykonanie prognoz dla Polski do roku 2040.* ***Techniki konstruowania długoterminowych prognoz zapotrzebowania na moc szczytową oraz na energię elektryczną brutto dla całego kraju na przykładzie Polski***

Abstract. *The paper presents an innovative technique of constructing long-term forecasts of peak power demand and gross electrical energy demand for an entire country on the example of Poland. The method is based on the Canonical Distribution of the Vector of Random Variables Model (CDVRM). The study also focuses on the problem of choosing the optimum explanatory variables scenarios for forecasting models. The concept of using elements of the deterministic chaos theory based on Pregogine's logistic equation has also been described. The ideas discussed have been verified in the process of making long-term forecasts for Poland up to the year 2040.*

Słowa kluczowe: elektroenergetyka, zapotrzebowanie mocy szczytowej, długoterminowa prognoza, teoria deterministycznego chaosu, .
Keywords: electrical power engineering, peak power demand, long-term forecast, deterministic chaos theory.

Introduction

The Polish power engineering sector is currently facing a great challenge. It has to satisfy the rapidly increasing demand for electrical energy, whereas most assets for centralized heat and electric energy production require modernization. At the same time new regulations are being introduced by the European Union and many countries all over the world. The regulations are aimed at the limitation of climate changes and guaranteeing energy supplies. In the case of development planning, forecasts concerning energy supply and demand need to be made for very long time spans. A typical situation, where long-term forecasts are required, concerns decisions on the development of national systems of energy acquisition and supply. Decisions of that kind can only be made rationally on the basis of the most credible long-term forecasts of energy and power demand for national power engineering systems. Making a correct forecast for the whole system is a difficult task, which requires a lot of experience, knowledge and intuition.

Modelling electrical energy systems takes time and requires knowledge in different fields such as mathematics, physics, IT science, power engineering, economics and energy policies [2, 6, 9, 10, 13, 14, 20]. It is a complex operation which requires appropriate methods in order to avoid mistakes, which may occur at any stage of constructing the model. To arrive at a correct forecast the situation must first be modelled. Using a model to solve real life problems helps in formulating assumptions about the behaviour of the genuine system, which is seldom available for experiments. Due to the specific significance of electrical energy as a product, research concerning the energy sector is of key importance to maintain proper functioning of the economy. Large fluctuations in the prices of energy carriers, as well as unstable energy supplies affect the economy of any country.

European Union member states use many complicated models encompassing power engineering, economics and environmental issues that facilitate comprehensive modelling and forecasting of the development of the energy system [20]. Some of the best known models recommended by the European Commission include: **World Energy Model (WEM)** - The model is used to make detailed long-term energy forecasts for particular sectors and regions. Predictions for areas, regions and entire countries are prepared on this basis. **PRIMES** - **Model** The model was developed as part of a series of scientific programmes of the European Commission conducted since 1994. The model was used to prepare the European Outlook Program on Energy and Emission. **POLES Model** - The model resulted from cooperation between the following European scientific institutions: CNRS (France), UPMF University, Enerdata and IPTS (European Commission Research Centre, Spain).The above mentioned institutions coordinate research on global long- term energy forecasts. **Green-X Model -** The model was developed by the Energy Economics Group (EEG) at the Technological University in Vienna as part of the scientific project „Green-X – obtaining optimal promotion strategies to increase the amount of renewable energy sources on the dynamic European market of electrical energy". It was a European scientific project financed as part of the Fifth Framework Programme of the European Commission for Scientific Research.

The above mentioned models are used for planning the development of the system. However, the complexity of the models coupled with the requirement of collecting extensive data basis regarding economic, technical and social issues make their exploitation impossible. Scientific research carried out for several years at the Faculty of Electrical Engineering of the Częstochowa University of Technology resulted in the creation of the Canonical Distribution of the Vector of Random Variables Model (CDVRM). This is a far less complicated tool and may be successfully used in selected issues regarding the planning of the development of the system. The model was published in several scientific monographs [2, 10, 11] and renown scientific journals [1, 12, 14]. The model has been implemented at the PSE company, a transmission system operator in Poland. The model was used for long-term final electrical energy demand forecast in an electrical power engineering system.

The present paper suggests one of the methods of long-term prediction of peak load for Poland on the basis of results obtained from the CDVRM.

Long-term forecast of gross energy demand in Poland using the CDVRM

According to [7, 8] the Polish Energy Policy uses a single variate forecast until the year 2030 that was

assessed as true to life up to the year 2015 and doubtful in the years 2020-2030, due to the dynamic increase in demand according to [5, 6, 9].
Forecast for final energy demand in the year 2030 predicts a rise of approximately 29% in comparison to 2006 [8]. Dynamic growth of renewable energy sources will ensure a 15% share in the use of RES in final energy structures. This surge means an increase of 21% in demand for initial energy. The growth is expected to take place after the year 2020.

The expected high price of permits for greenhouse gas emissions of about 60 Euros causes a decrease in the use of hard coal (by about 16,5%) and brown coal (by about 23%), with a simultaneous increase in the use of gas (by about 40%). In the total demand for primary energy, 12,4% will account for renewable energy, while 6,5% will come from nuclear energy in 2030. The forecast predicts a growth of final demand for electrical energy from 111 TWh in 2006 to 172 TWh in 2030. This gives an increase in gross energy demand from 151 TWh in 2006 to 217 TWh in 2030.

Taking into consideration the above comments and opinion voiced by both governmental and scientific circles it would be advisable to attempt to verify electrical energy and peak power demand forecasts made for Poland, but this time for a longer period than has so far been done, that is stretching beyond the year 2040. Such a forecast has been made using the CDVRM. Selected aspects of the forecast are described below.

Input data of the model

Rapid advancement in energy technologies makes forecasts rather uncertain. The future of electricity systems remains volatile and research into this matter is definitely worthwhile.

For the purpose of the planned experiment forecasts prepared for the PSE were used. The forecast was prepared basing on the CDVRM implemented at the PSE. The model had the following explanatory variables.
The external explanatory variables creating the pace of development in Poland as a result of external factors (energy policy of the EU, pace of development of EU member states, economic development/crisis, social and environmental factors in the EU) for European members of the OECD. The variables included:

- total primary energy consumption in Btu;
- total net energy consumption in TWh;
- total CO_2 emission connected with the consumption of energy in millions of tonnes;
- energy intensity in Btu/USD_{2005}.

Explanatory internal variables creating the pace of development in Poland as a result of internal factors (government policies regarding the economy, economic development/crisis in Poland, social and environmental factors). The variables included:

- population given in millions;
- GDP in current prices given in millions of PLN;
- Added value in industry, in current prices given in millions of PLN;
- Added value in remaining sectors of the economy in current prices given in millions of PLN;
- Total primary energy consumption in PJ;
- Total CO_2 emission connected with energy consumption given in millions of tonnes;
- Energy intensity in Btu/USD_{2005};
- Loss and balance sheet differences (transfer loss and distribution of electrical energy) given in GWh;
- Direct energy consumption in industry given in GWh;
- Direct energy consumption in other recipients given in GWh.

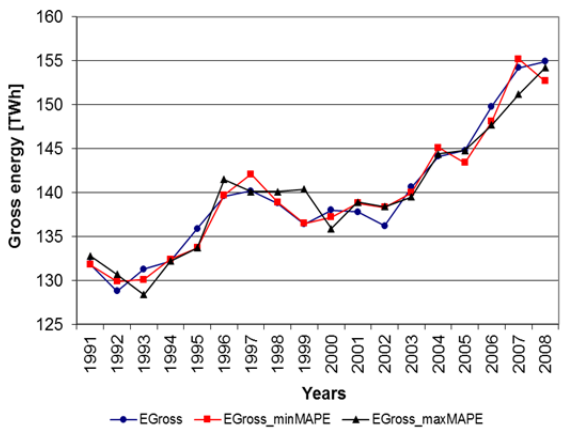
Annual gross consumption forecast for the National Electricity System was obtained from the CDVRM. The model was constructed for a basic scenario. The scenario used assumptions made by the American agency EIA for the prediction of dynamics of economic progress in OECD countries. Forecasts for explanatory variables, which influence development in Poland up to the year 2040 were made using the population forecast for Poland up to the year 2035 [16]. For the remaining explanatory variables, data from publicly available international papers was used, such as *World in 2050* prepared by PricewaterhouseCoopers [19], as well as forecasts made for particular countries [8, 17, 18].

Calibration of the CDVRM

Making calculations for all possible options of choosing potential explanatory variables may be difficult or even impossible to perform in a reasonable period of time. Due to the above fact it is essential to search for other methods which would facilitate the reduction of combinations, and at the same time make it possible to find combinations of variables that meet the condition of optimality. In the described experiment, Hellwig's method was used, which is explained in [2, 10, 11].

The method limited the number of variables to a minimum, but did not affect the model's properties and precision. In order to examine the model's properties and determine its parameters (calibrations) trials were performed with the ten best combinations of explanatory variables selected using Hellwig's method. Results showing how the model matched with empirical data are presented in Fig.1.

Fig.1. Real-life courses and courses selected during the calibration



of the CDVRM in the gross energy demand forecast for the National Electricity System for the best and worst combinations of the order of variables chosen using Hellwig's method in terms of MAPE. Where: EGross – Real values of gross energy demand for Poland in the years 1991-2008; EGross_minMAPE – gross energy demand values obtained from CDVRM for Poland in the years 1991-2008 with the smallest MAPE tracking errors; EGross_maxMAPE – obtained from CDVRM values of gross energy demand for Poland in the years 1991-2008 with the largest MAPE tracking errors

Validation forecasts were made for the years 2009 – 2012. Results for the best and worst versions in terms of compatibility with MAPE for real life data are show in Table 1.

Table 1. Validation forecasts for gross electrical energy for the National Electricity System from 2009 to 2012. Where: EGross – Real values of gross energy demand for Poland; EPOL-Gross-L – gross energy demand values obtained from CDVRM for Poland with the smallest MAPE tracking errors; EPOL-Gross-H – gross energy demand values obtained from CDVRM for Poland with the largest MAPE tracking errors

Years	EGross	Gross energy forecast			
		EPOL-Gross-L	MAPE	EPOL-Gross-H	MAPE
	[TWh]	[TWh]	[%]	[TWh]	[%]
2009	148,72	157,00	5,57	167,80	12,83
2010	154,98	159,00	2,59	162,70	4,98
2011	157,90	158,95	0,66	166,87	5,68
2012	157,01	163,12	3,89	174,32	11,03
Medium errors			**3,18**		**8,63**

Forecasts of external explanatory variables for Poland up to the year 2040

The forecast for gross annual electrical energy demand in the National Energy System made using the CDVRM for a basic scenario. Assumptions accepted by the EIA on the forecast of dynamic economic growth in OECD countries were used in the scenario. Fig.2 and Fig.3 present scenarios for selected external explanatory variables that may affect demand for electrical energy and power in the Polish power energy system.

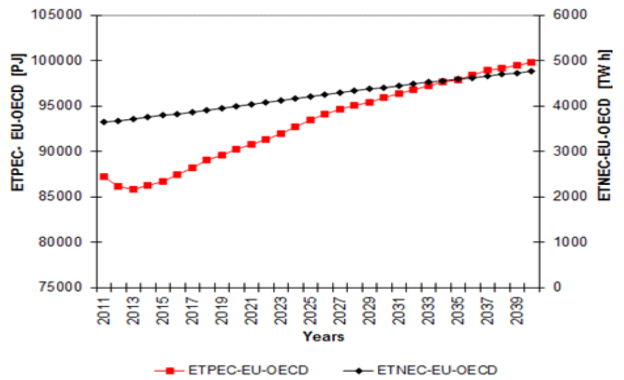


Fig.2. Forecasts based on the EIA assumptions concerning primary energy demand and net electrical energy production by European OECD countries up to 2040. Where: ETPEC-EU-OECD - total primary energy consumption in [PJ]; TNEC-EU-OECD - total net energy consumption in [TWh]

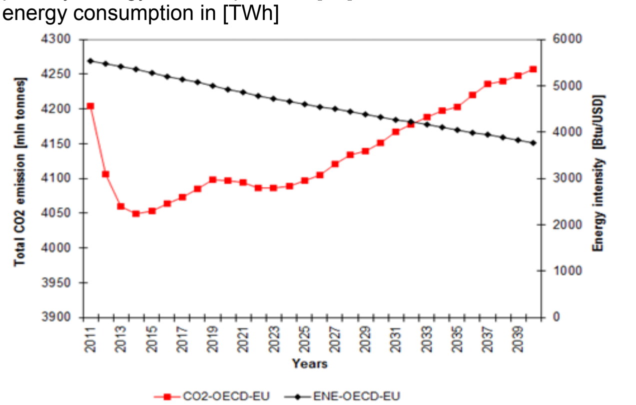


Fig.3. Forecasts based on EIA assumptions concerning CO_2 emissions and energy consumption in European OECD countries up to 2040. Where: CO2-OECD-EU – Total CO_2 emission connected with the consumption of energy in millions of tonnes; ENE-OECD-EU – energy intensity in Btu/USD_{2005}

Forecasts of internal explanatory variables for Poland up to the year 2040

The forecasts of internal explanatory variables creating the pace of development in Poland up to the year 2040 were made using data from the publicly available forecast of the Polish Statistical Office concerning population forecasts for Poland up to the year 2035 [16]. In order to standardize the time span of the forecast, the last five years of the forecast were approximated with the second degree polynomial up to the year 2040. The function was: $y=-0{,}0021x^2+0{,}0495x+38{,}29$.

The original GDP forecast was made basing on data from the document *World in 2050* prepared by PricewaterhouseCoopers [19], where authors estimate, among others the GDP for Poland in comparison to other countries. The document assumes that GDP in Poland will increase by 3% per year up to 2030. Then, by about 2.5% up to the year 2050. Using similar assumptions, an original forecast was drawn up for Poland up to 2040.

In the document *Polish Energy Policy up to the Year 2030* in enclosure no. 2 *Fuel and Energy Demand Forecast up to the Year 2030* [17] it is expected that industry added value will decrease to 19,3% in 2030, while in other sectors it will remain on a similar level with only a slight increase in services, from 57,6% in 2010 to 65,8% in 2030. Assuming similar expectations an original forecast was made for the industry added values together with other sectors up to 2040 (see Fig.4).

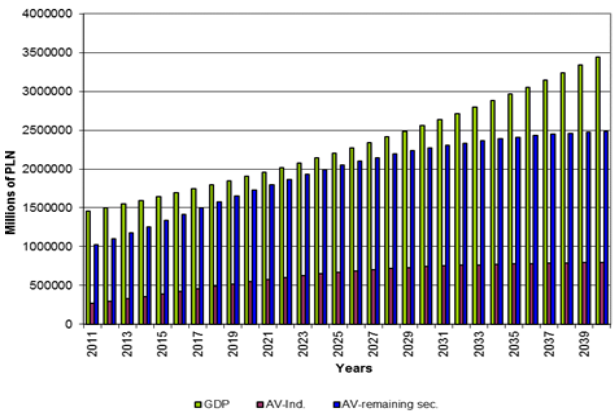


Fig.4. GDP forecasts for Poland, industry value added including other sectors up to the year 2040. Where: GDP – GDP in Poland; AV-Ind. – Added value in industry; AV-remaining sectors. – Added value in remaining sectors

Governmental plans assume a fall in energy intensity from 73,1 [toe/m PLN_{2007}] in 2010 to 33 [toe/m PLN_{2007}] in 2030. If a similar pace of decrease prevailed in 2040, we would achieve a fall in energy consumption to 64% in comparison to the year 2011. Maintaining these trends would mean lower energy intensity levels in 2040 than those predicted for Europe by EIA. It is expected that primary energy demand will increase by 21% by the year 2030. If the rate of increase does not change primary energy will grow by about 30% in 2040.

Long-term forecasts of gross energy power demand in the year 2040 for Poland

Annual gross consumption forecast for the National Electricity System was obtained from the CDVRM. The model was constructed for a basic scenario.

Results of forecasts for gross electrical energy demand in Poland given in three options: basic (Gross), low (Gross-L) and high (Gross-H), (see Fig.5).

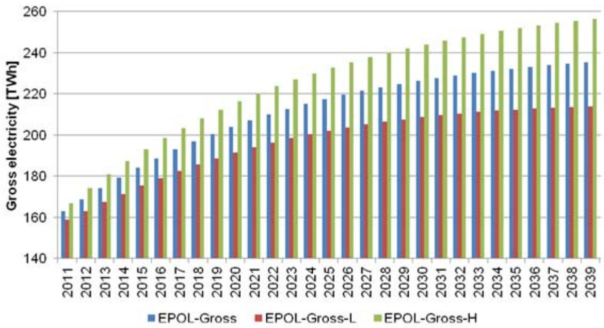


Fig.5. Gross electrical energy forecast for Poland in three options up to the year 2040, where: EPOL-Gross – Forecast of gross energy demand for Poland according to a basic scenario; EPOL-Gross-L – Forecast of gross energy demand for Poland according to a low scenario; EPOL-Gross-H – Forecast of gross energy demand for Poland according to a high scenario.

Long-term forecasts of peak power demand in Poland

One of the fundamental load levels that characterizes the annual load variation is the average annual load level expressed in (1).

$$(1) \qquad m_r = \frac{P_{r\,śr}}{P_r} = \frac{A_r}{T_r \cdot P_r} = \frac{T_{rs}}{T_r}$$

where: A_r - annual labour; $P_{r\,śr}$ - annual average load; P_r - annual peak load; T_r - time of duration of the year (8760 h); T_{rs} - time of use of peak power.

If A_r and m_r are known, then it is easy to calculate annual peak load P_r. This is a useful feature in the case of long-term forecasting, because having an energy forecast and relevant data connecting the annual load with other indicators derived from energy and power in the system it is possible to obtain a forecast for annual peak load and peak loads for other seasons. An additional benefit of such a method is the control of forecasting variables, as it is clear from formula (1), an annual load level in the system must be restricted to the range from 0 to 1.

An arrangement of recipients, where there are both quantitative and structural changes has a different work and load increase. It is for this reason that we distinguish two parameters defining annual increase. These are the relative annual energy increase and the relative annual power increase expressed by (2) and (3) respectively.

$$(2) \qquad \alpha_A = \frac{A_r}{A_{r-1}} - 1$$

$$(3) \qquad \alpha_S = \frac{P_r}{P_{r-1}} - 1$$

where: A_r, A_{r-1} – annual labour in the year r and $r-1$, respectively; P_r , P_{r-1} – peak load in the year r and $r-1$.

The average static arrangement of recipients reflects the set of recipients between the beginning and the end of a given year, from which the quantitative increase was eliminated.

In literature [2, 10, 11] the derivation of the formula determining the static value of the annual load level is also given for an average set of recipients in a year as expressed in (4).

$$(4) \qquad m_r^{stat} = \frac{A_r^{stat}}{T_r \cdot P_r^{stat}} = \frac{A_r}{T_r \cdot P_r} \cdot \frac{1+\frac{\alpha_A + \alpha_S}{2}}{1+0{,}54 \cdot \alpha_A}$$

The parameter is expressed as an arithmetic mean from the annual static load level indicated for a set of recipients from the beginning and from the end of a given year.

Adaptation of Prigogine's equation for long-term forecasts of peak power demand in Poland

The method based on Prigogine's equation referred to in numerous papers on forecasting [2, 3, 4, 10] is based on the non-linear logistic equation taken from Paper [15] which describes the development of an examined population (excluding deaths) as expressed in (5).

$$(5) \qquad X_{n+1} = X_n \left[1 + R\left(1 - \frac{X_n}{K}\right)\right], \quad X_n \geq 0,$$

where: X_n, X_{n+1} – the cardinality of population at moments $n=t$, $n+1=t+\tau$; R – growth rate coefficient; K – level of development; τ – interval between a pair of values X_n, X_{n+1}.

Examining in numerous experiments the process described by the equation (5) we can arrive at five types of behaviour of X_{t+1} depending on the value of the R coefficient and the K/X_{t0} relation at moment of start [2, 10]. The five types of X_{t+1} behaviour are:

1. asymptotic monotonic convergence to K – system equilibrium;
2. convergence to K with oscillations;
3. bifurcation;
4. jump to K in the first step;
5. chaotic course (including impossible events $N_{t+1}<0$).

Table 2 and Fig.6 below show the process according to changeable levels of development achieving four types of population behaviour depending on the growth of the R coefficient and the K/X_{t0} relation at the starting moment.

Table 2. Example of a process described by Prigogine's Equation depending on R coefficient and K/N_{t0} relation. Where: RU – system in equilibrium; O – convergence to K with oscillations; BI – bifurcations; CH – chaotic course

$\frac{K}{X_{to}}$	R=1	R=1,5	R=2,0	R=2,5	R=3,0
10	RU	0	0	BI	CH
5	RU	0	BI	BI	CH
2.5	RU	0	BI	0	CH

The presented model may be used to describe the development of mass processes involving human life and actions. They have a naturally existing limit, that is the level of development or saturation K, to which the value of parameter X_n tends for as long as there is no change in the value of the level.

In the case of human population K increases when there is a large number of young people in reproductive age, or a decrease in population typically occurring in times of war, great epidemics, famine or ecological disasters. In economic life changes in K depend on many factors like demography, politics, natural resources, recession, economic policies etc.

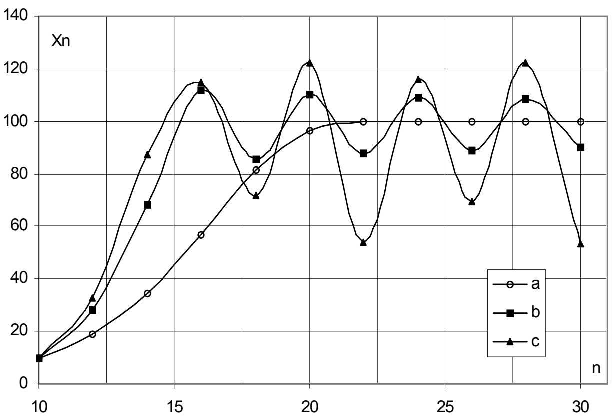


Fig.6. Prigogine's Logistic Model. K=100. a) R=1, b) R=2, c) R=2,5. Source: [2, 10]

In the case in question the adaptation of the model seems to be justified, because the annual forecasted load of system $\hat{Y}$ has a natural level of advancement, which cannot be greater than 1. Due to the above fact, it is sufficient to select, using appropriate optimization tools, the R coefficient in order to ensure the entire system is in equilibrium. The growth rate coefficient may be generated by iteration from historical statistical data in a way minimizing the tracking error. For the obtained R and K coefficients, the forecasting equation for the annual static system load is shown (6).

$$\hat{m}_{r\,t+1}^{stat} = \hat{m}_{r}^{stat}\left[1 + R\left(1 - \frac{\hat{m}_{r}^{stat}}{K}\right)\right], \tag{6}$$

$$m_r \geq 0$$

This results in an annual peak expressed by (7).

$$\hat{P}_{r\,t+1}^{stat} = \frac{1}{T_r}\frac{\hat{A}_{r\,t+1}^{stat}}{\hat{m}_{r\,t+1}^{stat}} \tag{7}$$

where: $\hat{A}_{r\,t+1}^{stat}$ - annual gross electrical energy static forecast for Poland at moment *t+1*; $\hat{m}_{r\,t+1}^{stat}$ - average annual load level static forecast at moment *t+1*;
T_r - year duration (8760 h).

Due to the fact that we are exploiting static statistics selected for National Electricity System [KSE] (not taking into account annual increases in power and energy), the gross energy for KSE is computed according to procedures [2, 10] to obtain static value. This involves choosing a certain scenario for the future annual increase of power and energy.

On the basis of the history of the process the changes in increases were examined from 1994 to 2012, (see Fig.7).

During the construction of a static parametric model, two forms of future power and energy increases were examined and adopted. The method is shown in Fig.8 and Fig.9.

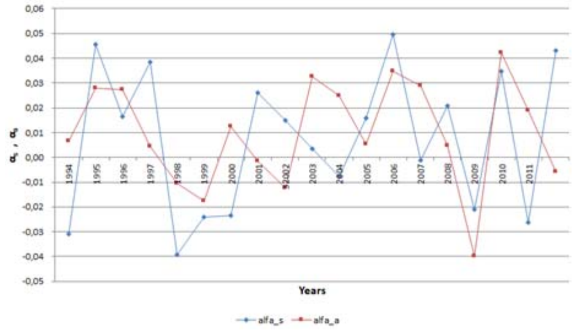


Fig.7. Annual changes in increases of power and energy for the National Electricity System (KSE) in the years 1994-2012

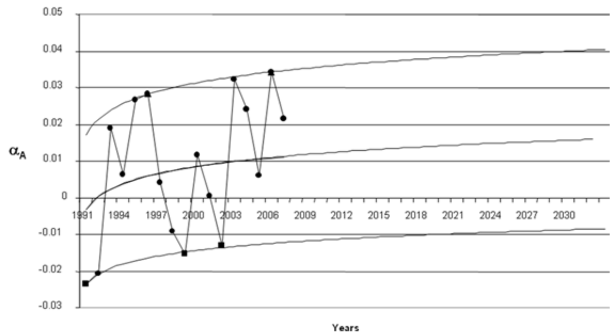


Fig.8. Forecast construction of annual energy increases for KSE

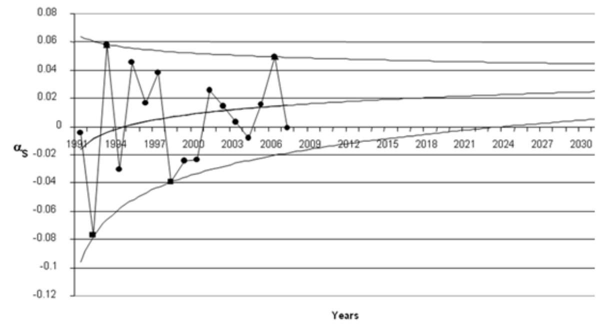


Fig.9. Forecast construction of annual power increases for KSE

The first method implied an average pace of change in the future plotted on the basis of the examined historical period from the past. In that case $\alpha_{A,sr}$=0,0096 and $\alpha_{S,sr}$=0,0071. In the second instance, on the basis of an analysis of changes in increases of power and energy a forecast was suggested according to functions (8) and (9).

$$\alpha_A(t) = 0{,}0051\ln(t) - 0{,}0032 \tag{8}$$

$$\alpha_S(t) = 0{,}011\ \ln(t) - 0{,}016 \tag{9}$$

Where: t - the next time interval.

Transforming the formula according to [2, 7, 8] we switch to dynamic values expressed by (10).

$$\hat{\mathrm{P}}_{\mathrm{r}\ \mathrm{t}+1} = \hat{P}_{r\,t+1}^{stat}\left(1 + \frac{\hat{\alpha}_{\mathrm{A}} + \hat{\alpha}_S}{2}\right) \tag{10}$$

Forecasts of peak power demand for Poland up to the year 2040 - case study

In order to remain pragmatic when making long-term forecasts it is essential to calibrate the model basing on historical data (fixing structural parameters of the model for an optimal historical period for which there is a set of complete explanatory variables). Establishing the base year, for which a set of required data may be obtained is a complex task when it concerns macroeconomic forecasting, as is the case in the present paper. For the purpose of the study the year 1990 was chosen as the base year, while the calibration period lasted from 1990 to 2008.
Validation forecasts of peak power demand for Poland were made for the years 2009 – 2012. Results for the best and worst versions in terms of compatibility with MAPE for real life data are shown in Table 3.

Table 3. Validation forecasts for peak power demand for Poland from 2009 to 2012. Where: Pr(D) – Dynamic forecast of peak power demand for Poland according to a basic scenario (Gross); Pr-L(D) – Dynamic forecast of peak power demand for Poland according to a low scenario (Gross-L); Pr-H(D) – Dynamic forecast of peak power demand for Poland according to a high scenario (Gross-H)

		Forecasted power peaks					
Years	***Pr***	***Pr(D)***	***MAPE***	***Pr-L(D)***	***MAPE***	***Pr-H(D)***	***MAPE***
	[MW]	[MW]	[%]	[MW]	[%]	[MW]	[%]
2009	24 594	24 221	1,52	23 996	2,43	25 819	4,98
2010	25 449	25 984	2,10	24 604	3,32	27 196	6,87
2011	24 780	26 839	8,31	26 187	5,68	27 491	10,94
2012	25 845	27 700	7,18	26 780	3,62	28 619	10,73
Medium errors			**4,78**		**3,76**		**8,38**

Results of forecasts for peak power demand in Poland for static and dynamic value given in three options: basic (Gross), low (Gross-L) and high (Gross-H), (see Fig.10 and Fig.11).

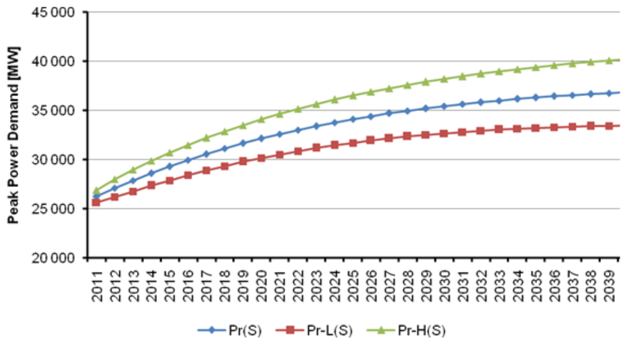


Fig.10. Peak power demand forecast for Poland up to the year 2040 -static value, where: Pr(S) – Static forecast of peak power demand for Poland according to a basic scenario (Gross); Pr-L(S) – Static forecast of peak power demand for Poland according to a low scenario (Gross-L); Pr-H(S) – Static forecast of peak power demand for Poland according to a high scenario (Gross-H)

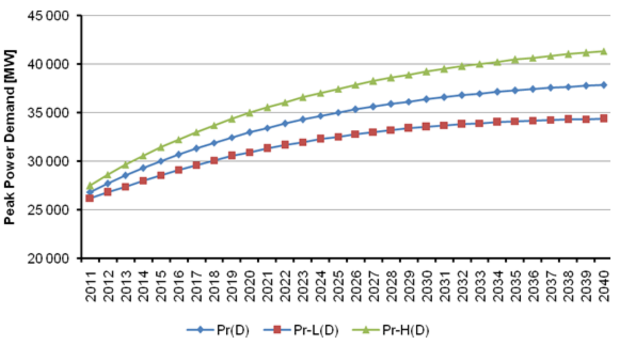


Fig.11. Peak power demand forecast for Poland up to the year 2040 -dynamic value. Where: Pr(D) – Dynamic forecast of peak power demand for Poland according to a basic scenario (Gross); Pr-L(D) – Dynamic forecast of peak power demand for Poland according to a low scenario (Gross-L); Pr-H(D) – Dynamic forecast of peak power demand for Poland according to a high scenario (Gross-H)

Conclusions

In a situation where energy technologies change at a fast pace there are no detailed visions for the development of power engineering. All forecasts are highly uncertain. No scientific research is able to eliminate the uncertainty of the future of electricity systems. It therefore seems necessary to create various scenarios of what may probably occur in the future.
In order to check the reliability of their forecasts the authors compared the results they obtained with forecasts made by the ARE [Energy Development Agency].
In the case of gross electrical energy demand for Poland, results of the base option are considered feasible to achieve under conditions laid out in the present paper.
The method described in the subchapters of the present paper makes it possible to generate long-term forecasts, which in the last prediction year – 2040 may amount to 235,8 TWh in the base option, 214,1 TWh in the low option and 257,5 TWh in the high option. The authors consider the base option defining gross electrical energy demand for Poland at a level of 235,8 TWh as realistic.
The forecast made by ARE for gross electrical energy demand for Poland and the KSE peak power demand forecast were taken as a benchmark. The forecasts were then compared with the authors' predictions in the last prediction year of 2040. The comparison showed the forecasts were almost identical.
The authors predict that the gross demand for electrical energy for Poland will be 235,8 TWh, while ARE forecasts give 237,7 TWh. The authors' forecasts for gross electrical energy demand for Poland covering the period from 2014 to 2031 is on average 12% higher than the forecast proposed by ARE.
The peak power demand forecast for Poland made by the authors in the dynamic option in the last prediction year 2040 is higher than the ARE forecast by 611,7 MW and amounts to 37857 MW. In the static option the forecast for peak power demand for Poland was 36859 MW and was lower than the ARE prediction by 387 MW.
To assess the reliability of the prediction we can look closely at the physicality of processes governing changeability of loads in an electrical energy system. One of the commonly used measures for calculating the degree of changeability is the mean annual load of the system.
The measure combines annual system energy and peak load. Analysing this measure shows that in the history of the process in the years 1990-2010 there is a clear linear trend.

Assuming a similar mean annual load increase in the forecasted period, it is visible that predictions made by the authors are closer to the linear trend.

When the difference between the ARE forecast and the authors' forecast was analysed it was shown that the authors' prediction up to the year 2030 diverges from the trend by an average of 0,03%, and the ARE forecast by about 1,8%. Whereas in the period 2031 to 2040 the difference is 0,8% (authors') and 4,8% (ARE).

In the construction of the model rules of parsimony should be applied. According to these rules explaining certain phenomena implies simplicity. This means opting for models based on the fewest number of assumptions and parameters. Simpler models are less likely to be excessively matched and therefore reduce the occurrence of a generalization error. In long- term models certain issues should be dealt with at the right time in order to minimize risk and avoid inaccuracy of the forecast. These include:

- Creating various scenarios of input data;
- Appropriate preparation of data obtained from the energy sector, that is using unified statistics approved by international institutions;
- Using forecasts prepared by certified institutions;
- Validating the forecast to update and correct presented data. (Janus coefficients J^2 calculated ex-post basing on errors for a sampling period of 6 years are below unity, which proves that the CDVRM is an effective tool for long-term forecasting);
- The Theil coefficient I^2=0,0009 determined for an eight-year trial period of the CDVRM indicates its high quality. Coefficients of I_1^2=49,7% and I_2^2=46,2% inform us that the CDVRM correctly forecasts the mean value of the process, and that the predicted variable is similar to the real variable, which means the model forecasts accurately;
- Selecting forecasting models with the fewest possible number of explanatory variables which are able to adequately explain the variance of the examined process.

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