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DEVELOPMENT OF A COMBINED METHOD FOR FORECASTING ELECTRICITY CONSUMPTION OF AN INDUSTRIAL ENTERPRISE LLC EVROSNAR

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Abstract: The scientific article discusses methods to improve the accuracy of forecasting electricity consumption by industrial enterprises on the example of the company Evrosnar. The influence of weather conditions on the accuracy of forecasting is analyzed.

Keywords: forecasting methods, regression, correlation analysis, generalized indicator, daily power consumption schedule, expert methodology, enterprise energy balance, regression analysis, software package, relative forecast error, weather effects, correlation coefficient.

1. Introduction.

The task of planning and forecasting energy consumption is of great importance in the electric power industry. Increasing the accuracy of electricity consumption forecasting is related to the transition to market relations between wholesale market entities, as well as responsibility for the results of forecasted actions. Electric load forecasting is an important aspect in economic and technical issues. Timely information about the upcoming load allows us to choose the optimal mode of system operation. The accuracy of load forecasting results has a significant impact on the operation of the power complex in the electricity market. Forecasting is an important factor in drawing up a power balance in the power system and influences the choice of operating parameters and the calculation of electric load. The power balance is necessary to ensure the stable operation of the power system. If the balance is not respected, the quality of electricity deteriorates (there is a deviation from the required frequency and voltage values). This also affects another element of the electrical complex - the operation of consumers. The accuracy of the forecast allows to optimize the operation of the entire electrical complex [1,2,3,4].

Foreign scientists Kudrin B.I., Vedernikov A.S., Voronov I.V., Afanasiev V.N., Hoffman A.V., Makolyuev V.I., Startseva T.B., Baker A.B., Goop D.V., Bunn D.V. who contributed much to development of forecasting models. To a large extent, these

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studies cover only short-term forecasting issues, without looking at medium-term forecasting problems [5,6].

2.Methods.

The term "forecasting method" is used very widely, from the simplest calculations to the procedures of multistage expert surveys, and as a way of theoretical and practical action.

The reliability of a forecast directly depends on the use of calculation methods and models. Currently, there are a significant number of different methods and models for making power consumption forecasts. But 15-20 methods are practically used as the main forecasting methods. Different forecasting methods are used for short-term and long-term forecasting, which are oriented to different tasks and use specialized databases [7,8].

Various types of classification of forecasting methods are presented in the modern literature.

The proposed method of combined prediction taking into account all external factors affecting the accuracy of the prediction. After conducting a correlation analysis of indicators, the generalized indicator of consumption forecast is determined.

3.Results and discussions.

It is noted that this should be approached individually, in particular, based on a comprehensive analysis of the enterprise itself. Take the example of EUROSNAR, located in Jondor district of Bukhara region. Using this data, we try to make a forecast for the whole year. Let's select the consumption for 2015-2017 and compare the resulting forecast to 2018.First, let's draw a graph of electricity consumption for the 2015-2017 months. As you can see from the graph, the company's energy consumption is seasonal rather than linear. We can observe an increase in consumption in the fall and winter and a decrease in the spring and summer. The analysis and forecasting of energy consumption is carried out with the software package STATISTICA of USA production.

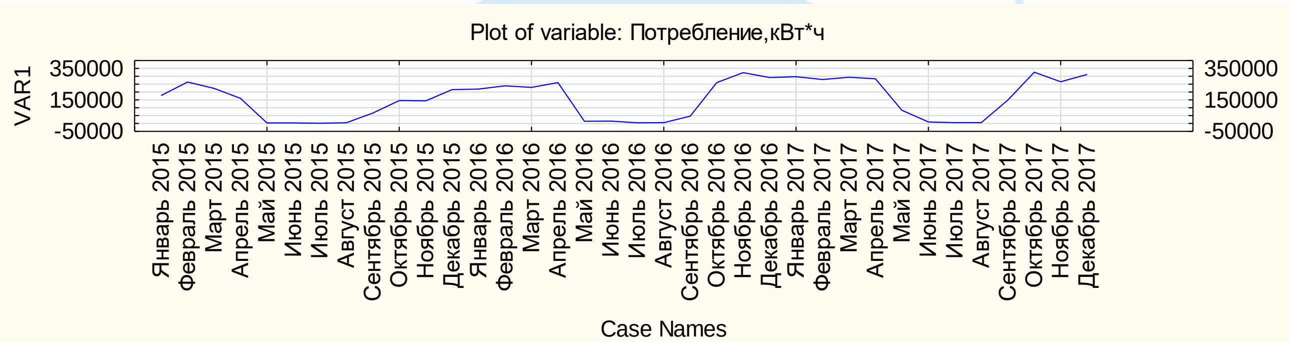

Figure-1. EUROSNAR electricity consumption in 2015-2017.

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Lag	Autocorrelation Function (Spreadsheet3) Потребление,кВт*ч (Standard errors are white-noise estimates) Auto-Corr.	Std.Err.	Box & Ljung Q	p
1	0,711303	0,159952	19,7755	0,000009
2	0,326095	0,157651	24,0540	0,000006
3	-0,092382	0,155315	24,4078	0,000021
4	-0,412028	0,152944	31,6653	0,000002
5	-0,563644	0,150535	45,6849	0,000000
6	-0,500367	0,148087	57,1016	0,000000
7	-0,403687	0,145598	64,7890	0,000000
8	-0,182750	0,143066	66,4207	0,000000
9	0,052053	0,140488	66,5580	0,000000
10	0,288343	0,137862	70,9325	0,000000
11	0,488066	0,135185	83,9673	0,000000
12	0,580156	0,132453	103,1524	0,000000
13	0,395599	0,129664	112,4607	0,000000
14	0,117938	0,126814	113,3256	0,000000
15	-0,181562	0,123899	115,4730	0,000000

Figure-2. Correlation analysis of EUROSNAR electricity consumption for 2015-2017.

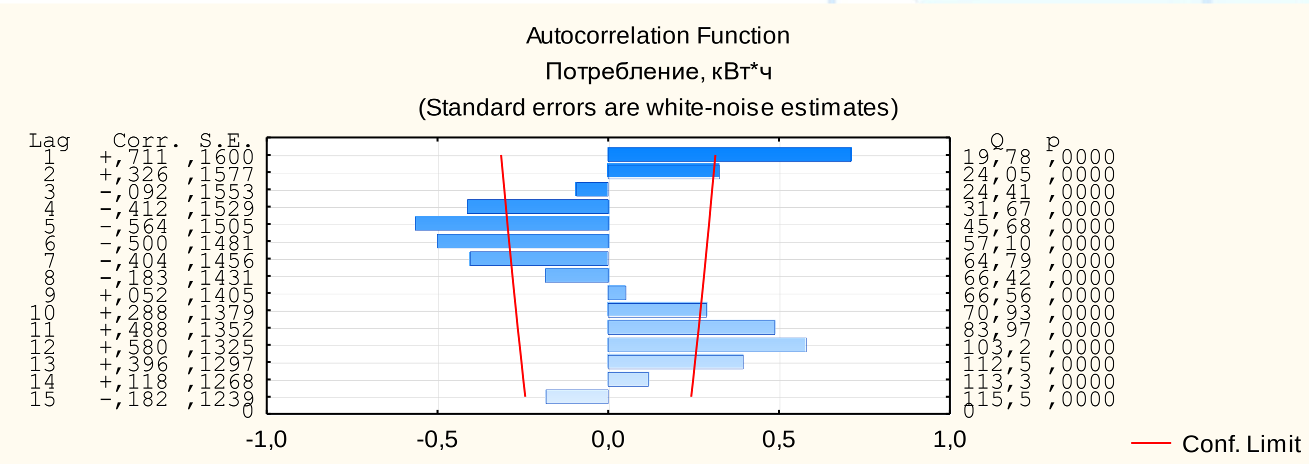

Figure-3. Graphical representation of the correlation analysis

To determine the seasonality, we will conduct a correlation analysis of electricity consumption by the company in 2015-2017. Let's make a correlation matrix of the data.

As you can see from the graph, there is seasonality in the data presented. There is also a trend. This can be seen in Figure 3. Later we get a seasonal dissociation. Let's identify the trend and cycle and predict consumption for 2018.

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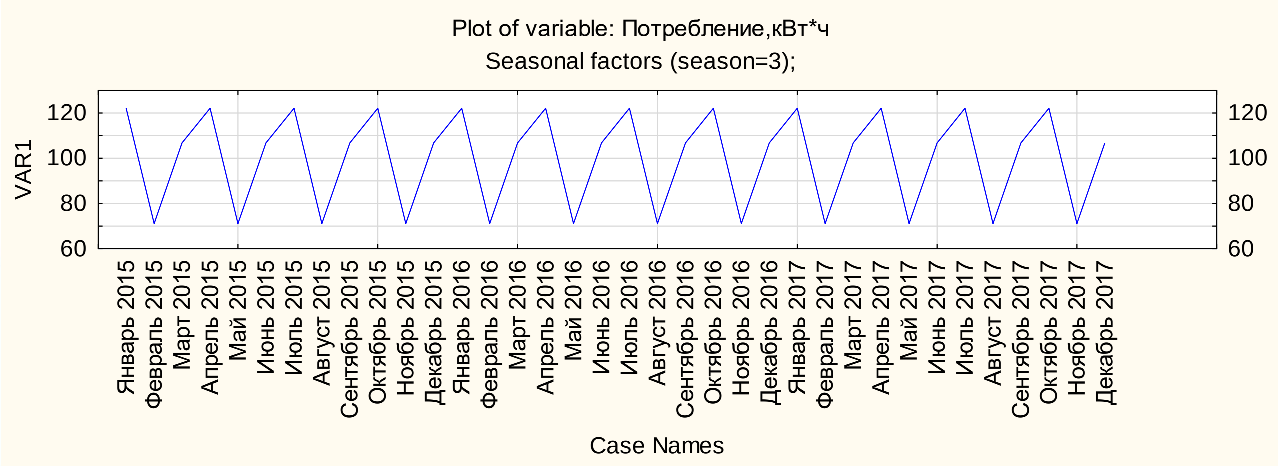

Figure 4. There is a trend in the indicators

Next, check the percentage of deviation or error 9,4%.

We can conclude that the amount of electricity consumed by the enterprise is very inconsistent, which makes the forecast of electricity consumption for 1 year unacceptable in practice.

It can be concluded that the forecasting of the enterprise's activity for the year is not used in practice because of the large percentage of deviations.

Let's set another problem. Let's try to forecast electricity consumption for six months. That is, for July-December 2018. To do this, we analyze the consumption. To increase the studied data, let's record the data on the daily consumption of electricity by the enterprise for January-June 2018. Work with additional 91 data.

Seasonal Decomposition: Multipl. season (3) (Spreadsheet3)
Потребление,кВт*ч

Case	Потребления,кВ	Moving Averages	Ratios	Seasonal Factors	Adjusted Series	Smoothed Trend-c.	Irreg. Compon.
Январь 2015	178056,0			122,0875	145843,0	263760,7	0,552937
Февраль 2015	263456,0	221656,0	118,8581	71,1078	370502,2	241854,8	1,531920
Март 2015	223456,0	215656,0	103,6169	106,8047	209219,2	198043,0	1,056433
Апрель 2015	160056,0	129184,3	123,8974	122,0875	131099,4	133043,2	0,985390
Май 2015	4041,0	56046,0	7,2101	71,1078	5682,9	55337,0	0,102696
Июнь 2015	4041,0	3507,7	115,2048	106,8047	3783,5	18353,9	0,206144
Июль 2015	2441,0	3907,7	62,4669	122,0875	1999,4	10730,2	0,186333
Август 2015	5241,0	24841,0	21,0982	71,1078	7370,5	30501,6	0,241643
Сентябрь 2015	66841,0	72641,0	92,0155	106,8047	62582,4	71799,0	0,871634
Октябрь 2015	145841,0	118960,7	122,5960	122,0875	119456,2	122080,4	0,978504
Ноябрь 2015	144200,0	168680,3	85,4871	71,1078	202790,7	165951,0	1,221991
Декабрь 2015	216000,0	193000,0	111,9171	106,8047	202238,3	203077,7	0,995866
Январь 2016	218800,0	224933,3	97,2733	122,0875	179215,8	226143,6	0,792487
Февраль 2016	240000,0	229600,0	104,5296	71,1078	337515,6	246319,0	1,370238
Март 2016	230000,0	243333,3	94,5205	106,8047	215346,3	216336,0	0,995425
Апрель 2016	260000,0	168266,7	154,5166	122,0875	212962,1	162550,3	1,310130
Май 2016	14800,0	96666,7	15,3103	71,1078	20813,5	81789,5	0,254476
Июнь 2016	15200,0	11600,0	131,0345	106,8047	14231,6	34842,8	0,408452
Июль 2016	4800,0	8666,7	55,3846	122,0875	3931,6	13501,1	0,291206
Август 2016	6000,0	19109,0	31,3988	71,1078	8437,9	38610,7	0,218538
Сентябрь 2016	46527,0	104175,7	44,6621	106,8047	43562,7	114785,1	0,379515
Октябрь 2016	260000,0	210175,7	123,7060	122,0875	212962,1	213237,5	0,998708
Ноябрь 2016	324000,0	292000,0	110,9589	71,1078	455646,1	291922,8	1,560845
Декабрь 2016	292000,0	304666,7	95,8425	106,8047	273396,2	314042,9	0,870570
Январь 2017	298000,0	290000,0	102,7586	122,0875	244087,3	310834,0	0,785266
Февраль 2017	280000,0	290666,7	96,3303	71,1078	393768,3	302892,6	1,300026
Март 2017	294000,0	286000,0	102,7972	106,8047	275268,7	271200,1	1,015002
Апрель 2017	284000,0	220666,7	128,7009	122,0875	232620,1	209754,4	1,109012
Май 2017	84000,0	126000,0	66,6667	71,1078	118130,5	124282,3	0,950501

Seasonal Decomposition: Multipl. season (3) (Spreadsheet3) | Seasonal Decomposition: Multipl. season (3) (Sp

Figure-5. Breakdown of indicators after regression analysis.

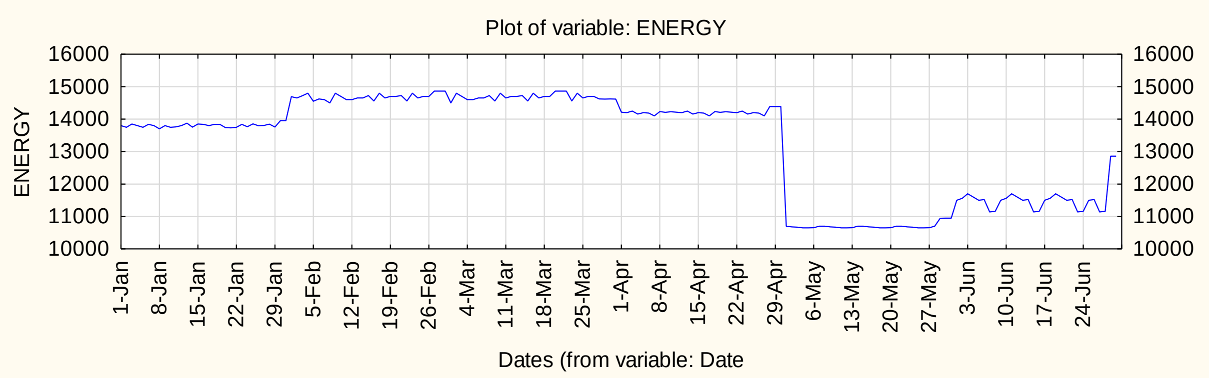

Figure-6. EVROSNAR daily electricity consumption in 2018

Autocorrelation Function (Spreadsheet4)
ENERGY
(Standard errors are white-noise estimates)

Lag	Auto-Corr.	Std.Err.	Box & Ljung Q	p
1	0.977548	0.073518	176.802	0.00
2	0.956685	0.073315	347.078	0.00
3	0.935329	0.073111	510.747	0.00
4	0.916019	0.072906	668.609	0.00
5	0.895919	0.072701	820.472	0.00
6	0.875995	0.072496	966.482	0.00
7	0.857919	0.072289	1107.327	0.00
8	0.840122	0.072083	1243.166	0.00
9	0.820101	0.071875	1373.356	0.00
10	0.801329	0.071667	1498.377	0.00
11	0.781522	0.071458	1617.989	0.00
12	0.762187	0.071249	1732.425	0.00
13	0.741303	0.071039	1841.317	0.00
14	0.722630	0.070829	1945.407	0.00
15	0.703608	0.070618	2044.681	0.00
16	0.685115	0.070406	2139.372	0.00
17	0.666111	0.070194	2229.425	0.00
18	0.647127	0.069981	2314.936	0.00
19	0.628206	0.069767	2396.015	0.00
20	0.609103	0.069553	2472.708	0.00
21	0.588340	0.069338	2544.706	0.00

Figure-7. Correlation analysis of EUROSNAR electricity consumption

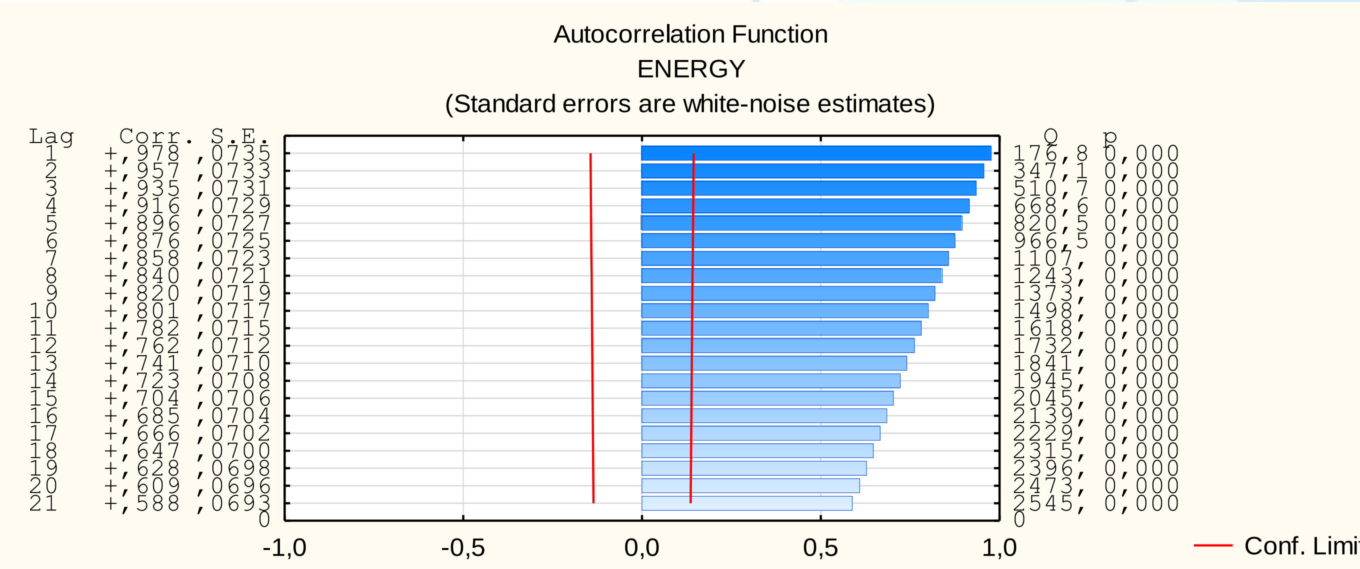

Figure-8. Graphical representation of the correlation analysis

The calculation showed a deviation of 9.3 percent. Let's try to predict Eurosnar electricity consumption for 1 month.

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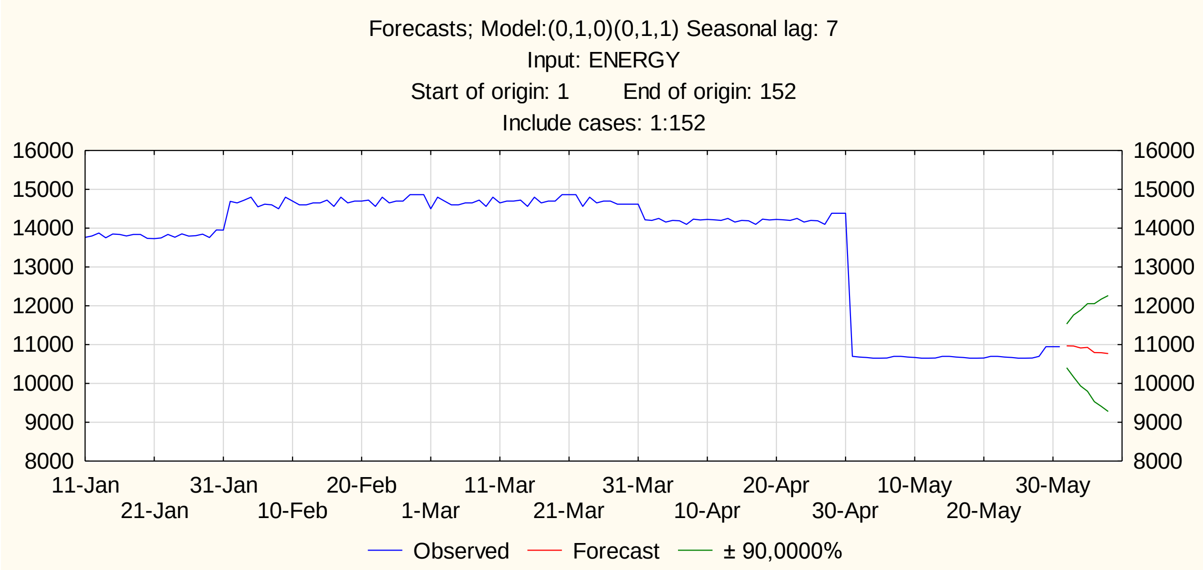

Figure-9. Predicted results. Maximum and minimum values of the functions.

We choose the daily consumption for January-March and forecast for April 2018. In addition, we take into account weather conditions (temperature, humidity, wind speed). First, let's perform a correlation analysis and determine the correlation coefficient. You can see that there is very little correlation between electricity consumption and wind speed. You can ignore them. Let's create two graphs

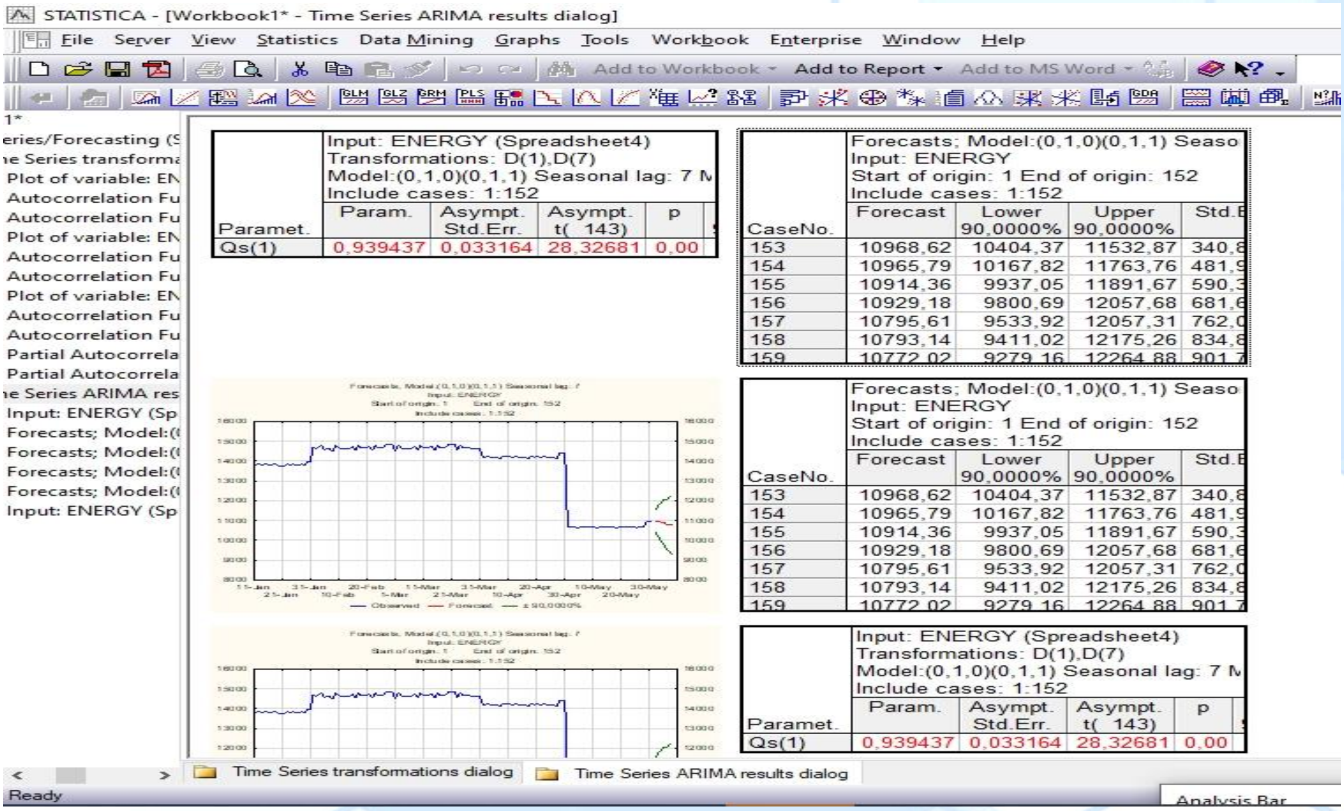

Figure-10. Regression calculation

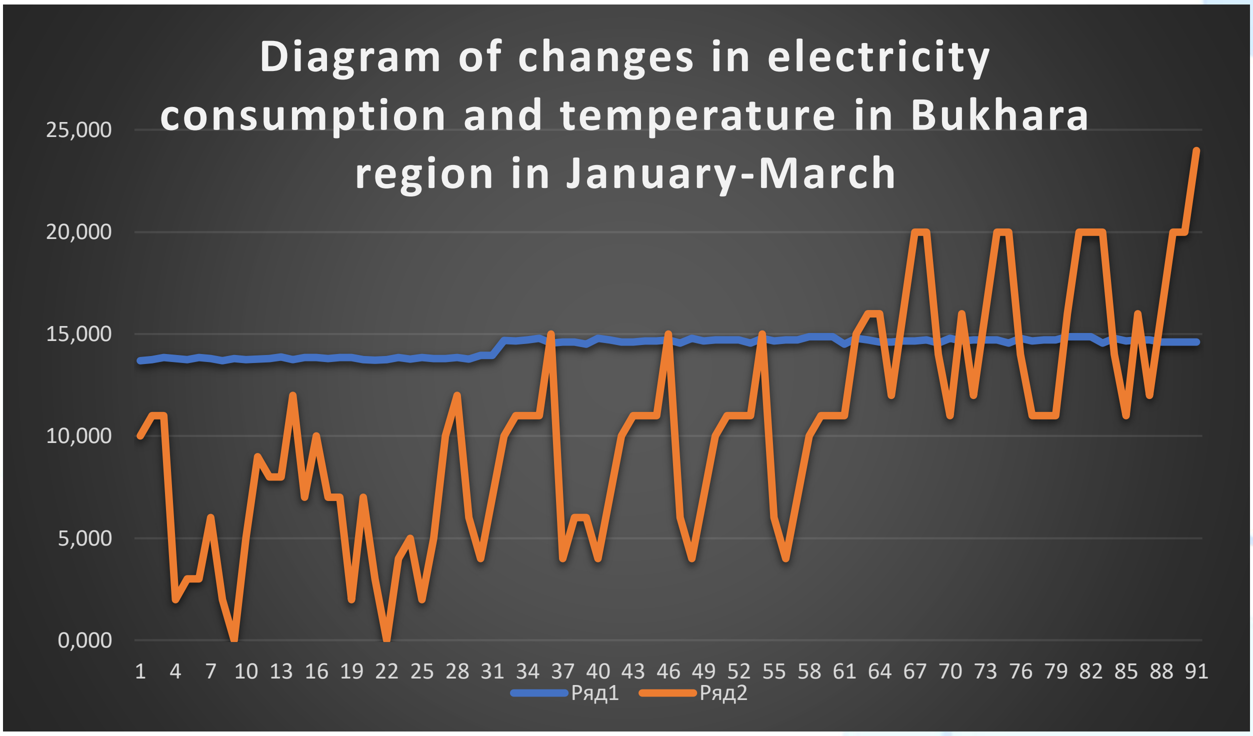

Figure-11. Diagram of changes in electricity consumption and temperature in Bukhara region in January-March

Let's calculate the regression of power consumption with regard to temperature

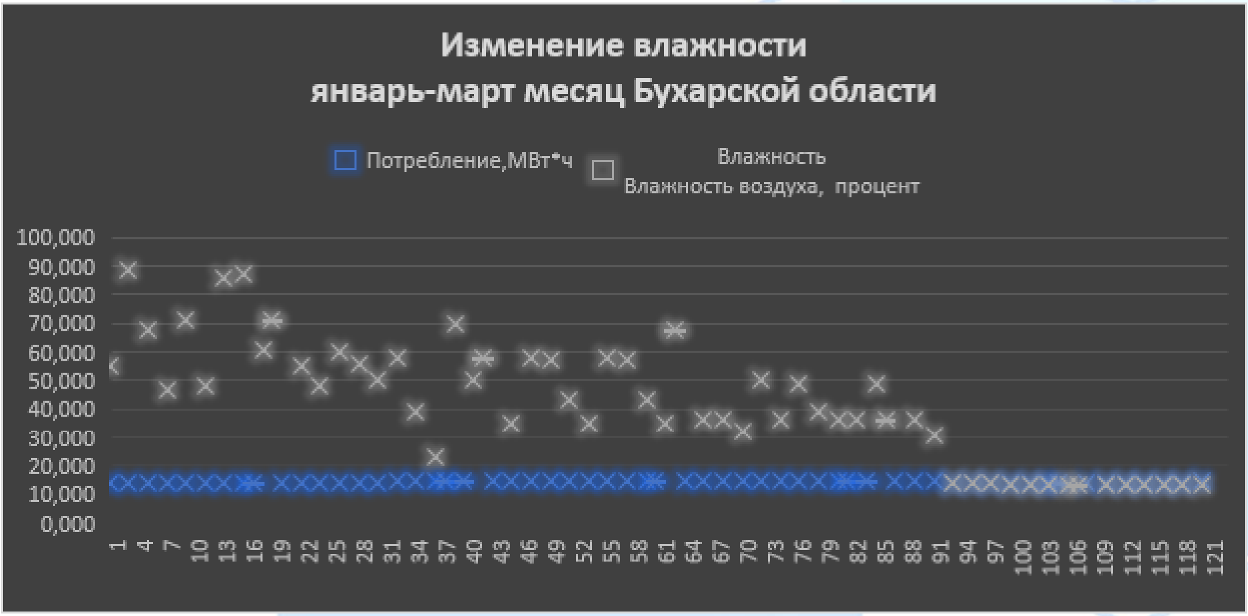

Figure-12. Changes of humidity in Bukhara region in January-March

Let's calculate the forecast of electricity consumption, taking into account the effect of temperature in April, summarize the data and write it in the Table-1.

Table-1.
Weather-adjusted forecast

Forecast	M-I (MWt)	deviation (MWt)	%
True energy consumption	426,419	0	0
Predictive temperature effects	455,5	29,081	6,8
Impact of humidity	403,363	-23,056	5,4
Composite indicator	429,432	3,013	0,7

The generalized forecast indicator consists of the average of temperature and humidity effects

$$P = \frac{Pt+Ph}{2} \qquad (1)$$

Where, **P**-generalized forecast of electricity consumption, **Pt**-forecast taking into account the effect of temperature on electricity consumption, **Ph**-forecast taking into account the effect of humidity on electricity consumption. It showed a deviation of 1 percent on average, which is good.

4. Discussion and Conclusion.

1. Using the mathematical apparatus of regression analysis allows us to obtain an error of less than 3% in electricity consumption for a number of months: March, April, May, June, July and December. The regression equation should include electricity consumption and an increase in ambient temperature in the same month last year.

2. Averaging the results obtained by exponential equalization and regression analysis methods usually reduces the RMS error, but has unacceptable errors when predicting electricity consumption over several months.

3. The combination of using regression equations and functional relationships between electricity consumption in different months increases the percentage of forecast accuracy.

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