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Seasonal Analysis of Electricity Consumption in Rajasthan

Abstract

Electricity consumption plays a very vital role in economic development. The forecasting of electricity demand is fundamental leading factor for efficient planning because electricity is commodity which cannot be stored as it should be generated as soon as it is demanded .Therefore it becomes more important to have reasonably accurate estimates of electricity use in different seasons over any year in particular. Accurate forecasts lead to substantial savings in operating and maintenance costs, and Analysis of time series datafor forecasting purpose involves the identification of patterns that exist in the data. For many time series dependence of the particular monthly and quarterly data on alternating seasons exists. In many economic phenomena more or less seasonal variation occurs. If the time series is periodic and this pattern may include trend, seasonality, cyclicality and random variability. In this research paper we have monthly data of electricity consumption (in average MW) , from January 2004 to December 2015 .

On the basic of these data seasonality is tested using Holt –Winter's method. Using this method monthly consumption of electricity is forecasted. Using chi-square and paired t- tests the goodness of fitted model is tested.

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Introduction

Although electricity demand is assessed by accumulating the consumption periodically. It is almost considered for monthly, hourly, daily, weekly, and yearly periods. According to Edward kozlow (2015) sources reveal that one of the most strategic management tasks of water supplying companies is water consumption prediction. This consumers' demand forecast is done using several, specially designed models whichgenerate data necessary for planning forthcoming operational activities.

Review of Literature

The authors have proposed previously a solution, wherein hourly water consumption is determined by trend analysis and harmonic analysis and now continue the research on prediction methodsenabling effective forecasts with the applications of Holt-winter method and analysis resultsshow that further investigation are necessary to improve to prediction performance in long time period. Subsequently Vinko Lepojević, Marija Anđ elković-Pešić (2011) predicts theelectricity consumption in the area covered by Elektroistok Ltd Nis during the periodNovember 2011 - October 2012. For the purposes of these forecasts, Holt-Winters method and appropriate seasonal regression models were used.

The Holt-Winters (HW) methods estimate three smoothing parameters was introduced byauthors B.Arputhamary, Dr.L.Arockiam (2016) it associated with level, trend and seasonal factors. The seasonal variationcan be of either an additive or multiplicative form. Also in this paper, Performance Improved Holt-Winters (PIHW) prediction algorithm is proposed and the results demonstrate that aconsiderable reduction in forecast error (Mean Square Error) can be achieved in the proposedmodel compared to Holt-Winters (HW) model.Another researcher Odame Owiredu Emmanuelet al (2014) investigated the use of maternal healthcare facilities is an important indicator of the impact ofthe free maternal healthcare policy aimed at improving health status of pregnant women inGhana. This study investigated the pattern of quarterly assisted deliveries at Komfo AnokyeTeaching Hospital (KATH), Kumasi, Ghana from 2000 to 2011. The Holt Winters multiplicative and additive forecasting models were considered.

Objectives of the Study

1. To test the seasonality of consumption of electricity.
2. To forecast the consumption of electricity.

Research Methodology and Data Source

The objectives of this study were to test seasonality and to forecast the monthly consumption of electricity precisely. For fulfilment of these objectives we used the following methods.

Testing Seasonality in Consumption of Electricity

To test the seasonality the data were arranged monthly for all the years then we computed the average for months for all the year, then average of all the average was computed i.e.

$$X_{bar} = 1/n*(\sum_{i=1}^{n} Xi)$$

Finally, for the seasonal indexi^{th}quarter /month was computed by expressing the respective averages as of the overall average. This method is based on the assumption that the given time series is independent of the trend and cyclic variations.The χ2 goodness-of-fit test was used to test the seasonality. This is relatively popular for detecting seasonality because of its simple mathematical theory, which makes it easy to calculate and understand (Hakko, 2000). The test is based on whether the empirical data can be a sampleof a certain distribution with sampling error as the only source of variability (McLaren, Legler, &Brittenham, 1994). This test requires a sample from apopulation with an unknown distribution function F(x) and a certain theoretical distribution function $F_0(x)$. Although there is no restriction on the underlying distribution, usually the hypothetical distribution is a uniform distribution.For seasonality studies, the frequency O_i, i = 1, 2,…, k is the observed valueat the i^{th} season, while the frequency E_i, i = 1, 2,…, k is the expected cell frequencyat the i^{th} season. Under the null hypothesis that there is no seasonal effect (i.e., $F_0(x)$is a uniform distribution), then $E_1 = E_2 = \ldots = E_k$ and the statistically uniform distribution), then

$$\chi 2 = \sum_{i=1}^{n} \frac{(Oi - Ei,)^2}{Ei},$$

Under the hypothesis H_o = There is no significant seasonal component in the time series data V/s H_1 = There is significant seasonal component in the time series data, is asymptotically distributed as χ2 with v = k − 1 degrees of freedom (Horn, 1977).

Forecasting the Consumption of Electricity

Holt-Winters additive method was used to forecast. Holt (1957) and winters (1960) extended Holt's method to forecast to capture seasonality. The Holt-Winters seasonal method comprises the forecast equation and three smoothing equations — one for the level (ℓ_t), one for the trend (b_t), and one for the seasonal component (s_t), with corresponding smoothing parameters α, β∗ and γ. We used m to denote the frequency of the seasonality, i.e., the number of seasons in a year. For example, for quarterly data m=4, and for monthly data m=12.There are two variations to this method that differ in the nature of the seasonal component. The additive method is preferred when the seasonal variations are roughly constant through the series, while the multiplicative method is preferred when the seasonal variations are changing proportional to the level of the series. With the additive method, the seasonal component is expressed in absolute terms in the scale of the observed series, and in the level equation the series is seasonally adjusted by subtracting the seasonal component. Within each year, the seasonal component will add up to approximately zero. With the multiplicative method, the seasonal component is expressed in relative terms (percentages), and the series is seasonally adjusted by dividing through by the seasonal component. Within each year, the seasonal component will sum up to approximately m. The component form for the additive method is given

$$\hat{y}_{t+h|t} = \ell_t + hb_t + s_{t+h-m(k+1)}$$
$$\ell_t = \alpha(y_t - s_{t-m}) + (1-\alpha)(\ell_{t-1} + b_{t-1})$$
$$b_t = \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1}$$
$$s_t = \gamma(y_t - \ell_{t-1} - b_{t-1}) + (1-\gamma)s_{t-m},$$

Here k is the integer part of (h−1)/m, which ensures that the estimates of the seasonal indices used for forecasting come from the final year of the sample. The level equation shows a weighted average between the seasonally adjusted observation (y_{t-st-m}) and the non-seasonal forecast ($\ell_{t-1} + b_{t-1}$) for time t. The trend equation is identical to Holt's linear method. The seasonal equation shows a weighted average between the current seasonal index, ($Y_t - \ell_{t-1} - b_{t-1}$)and the seasonal index of the same season last year (i.e., m time periods ago).The equation for the seasonal component is often expressed as

$$s_t = \gamma*(y_t - \ell_t) + (1-\gamma)s_{t-m}.$$

If we substitute ℓ_t from the smoothing equation for the level of the component form above, We get

$$S_t = \gamma* (1-\alpha)(y_t - \ell_{t-1} - bt - 1) + [1-\gamma*(1-\alpha)]\mathbf{S}_{t-m}$$

Which is identical to the smoothing equation for the seasonal component we specify here,with γ = γ∗(1−α). The usual parameter restriction is 0≤γ∗≤1, which translates to 0≤γ≤1−α.

The data were taken from Rajasthan state electricity board and Rajasthan Vidyut Vitran Nigam(RVVN) .

Statistical Analysis

Objective 1

To test seasonality, we processed our datato get estimates of seasonal relative for each monthand found our results using the online resource available athttp://home.ubalt.edu/ntsbarsh/Business-stat/ otherapplets/ SeasonalTools.htm for the raw data that are given in Table 1.

Table -1

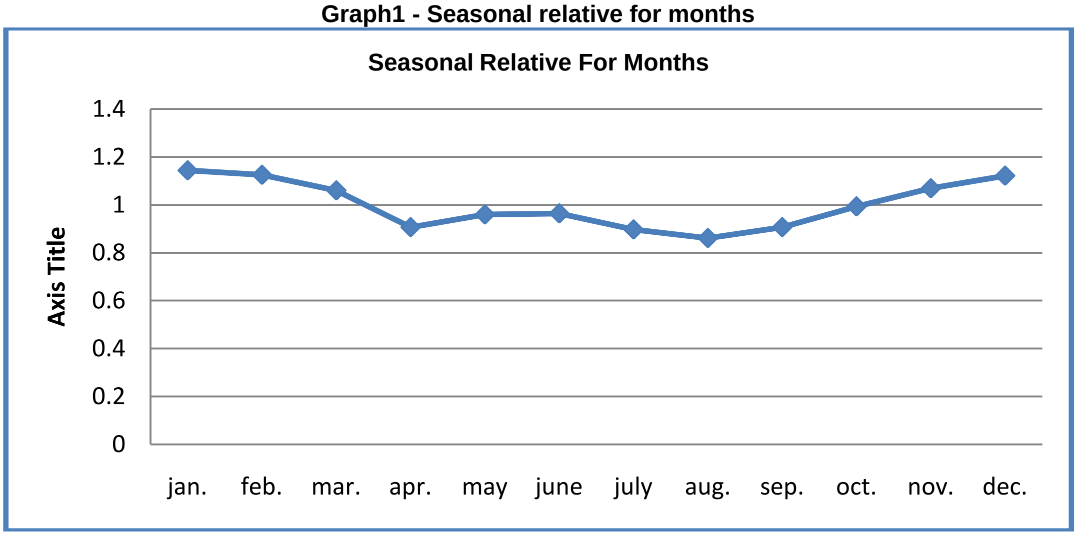
Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug.	Sep.	Oct.	Nov.	Dec.
2004	867.4	871.3	844.5	676.5	700.8	682.2	549.4	603.3	627.3	736.4	822.6	827.1
2005	916.8	877.1	862.1	782.6	784.9	771.5	783.7	625.5	789.5	739.4	874.4	906.6
2006	977.2	979.0	868.5	785.3	834.3	850.7	723.9	867.1	760.9	852.3	935.9	936.3
2007	1001.2	942.9	859.9	805.0	879.0	828.8	801.3	754.2	816.9	917.1	980.8	992.9
2008	1104.6	1105.6	1082.9	894.4	958.9	942.4	842.2	910.9	893.2	981.9	1076.3	1094.6
2009	1223.2	1219.7	1108.4	887.5	925.3	888.4	959.0	900.5	960.6	1103.3	1187.1	1190.3
2010	1348.7	1259.6	1304.7	1054.8	1103.6	1088.7	1026.3	1053.6	1130.2	1230.0	1261.4	1349.0
2011	1537.4	1491.8	1499.5	1215.5	1243.8	1202.5	1097.8	997.7	1026.2	1284.3	1189.0	1376.4
2012	1538.7	1590.6	1554.9	1288.3	1350.2	1342.3	1241.4	1153.2	1055.1	1232.4	1463.9	1522.2
2013	1727.4	1558.2	1679.8	1329.2	1389.8	1493.6	1392.5	1219.4	1251.0	1537.2	1583.8	1683.9
2014	1822.5	1843.0	1679.9	1416.4	1597.7	1534.5	1372.9	1281.5	1659.9	1424.2	1652.1	1818.6
2015	1944.2	2010.8	1492.4	1551.7	1661.6	1866.5	1762.7	1683.7	1717.9	1862.8	1932.8	2003.3

The data were entered in the tool given by Dr. Hossein Arsham (The Wright distinguished Research Professor at the University of Baltimore).After entering time series correctly in the matrix, then we got monthly seasonal index.

Table 2 – Seasonal relative

Month	Seasonal Relative	Month	Seasonal Relative
Jan	1.143	Jul	0.896
Feb	1.125	Aug	0.860
Mar	1.059	Sep	0.906
Apr	0.906	Oct	0.993
May	0.959	Nov	1.068
Jun	0.963	Dec	1.121

Graph1 - Seasonal relative for months



For Testing Seasonality based on seasonal relative we used the test for seasonality and get the following result.

χ^2 =11.24 and P-Value = 0.423

This shows that there is no significant seasonal component in the time series data. Hence we may conclude that the monthly consumption of electricity has no seasonal effect.

Objective 2

To forecast the monthly consumption of electricity he Holt-Winters additive method was employed.

Table 3 - Holt-Winter's Forecast Additive Model

Holt-Winter's Forecast Additive Model							
S.No.		Alpha	0.266				
		Beta	0.056				
	Original data	Gamma	1.201			MSE	10967.09
	Yt	lt	bt	St	Ft	Et	Et*Et
1	867.36			133.30			
2	871.28			137.22			
3	844.48			110.42			
4	676.46			-57.60			
5	700.81			-33.25			
6	682.24			-51.82			
7	549.40			-184.66			
8	603.26			-130.80			
9	627.30			-106.76			
10	736.41			2.35			
11	822.60			88.54			
12	827.08	734.06	-3.66	93.02			
13	916.79	744.51	-2.87	180.10	863.70	53.09	2818.74
14	877.13	741.18	-2.89	135.69	878.87	-1.74	3.02
15	862.13	741.86	-2.69	122.25	848.71	13.42	179.99
16	782.57	766.02	-1.18	31.42	681.57	101.00	10201.08
17	784.92	779.02	-0.38	13.75	731.60	53.32	2843.38
18	771.53	790.53	0.29	-12.42	726.83	44.70	1998.49
19	783.69	838.02	2.95	-28.19	606.16	177.53	31516.06
20	625.48	818.45	1.68	-205.44	710.18	-84.70	7173.37
21	789.52	840.38	2.82	-39.65	713.38	76.14	5797.83
22	739.38	814.97	1.23	-91.22	845.55	-106.17	11272.98
23	874.38	808.13	0.78	61.78	904.74	-30.36	921.98
24	906.62	810.15	0.85	97.16	901.93	4.69	22.03
25	977.24	807.31	0.64	167.89	991.09	-13.85	191.94
26	979.00	817.35	1.17	166.85	943.64	35.36	1250.05
27	868.50	799.31	0.09	58.55	940.77	-72.27	5222.99
28	785.34	787.30	-0.60	-8.66	830.81	-45.47	2067.81
29	834.32	795.71	-0.09	43.60	800.46	33.86	1146.77
30	850.65	813.55	0.92	47.03	783.21	67.44	4548.70
31	723.85	797.88	-0.01	-83.22	786.29	-62.44	3898.31
32	867.10	870.90	4.10	36.65	592.42	274.68	75449.97
33	760.92	855.21	2.99	-105.25	835.35	-74.43	5540.45
34	852.31	880.89	4.27	-16.01	766.97	85.34	7282.97
35	935.93	882.23	4.10	52.08	946.93	-11.00	121.10
36	936.25	873.77	3.39	55.53	983.49	-47.24	2231.38
37	1001.20	865.50	2.74	129.24	1045.05	-43.85	1922.50
38	942.94	843.74	1.36	85.63	1035.09	-92.15	8491.70

39	859.94	833.47	0.70	20.03	903.64	-43.70	1909.93
40	804.97	828.71	0.39	-26.76	825.51	-20.54	422.07
41	878.97	830.77	0.49	49.12	872.70	6.27	39.33
42	828.76	818.09	-0.25	3.38	878.28	-49.52	2452.54
43	801.33	835.57	0.74	-24.42	734.61	66.72	4451.06
44	754.22	804.74	-1.03	-68.01	872.97	-118.75	14100.84
45	816.92	835.21	0.74	-0.84	698.46	118.46	14033.08
46	917.05	861.77	2.20	69.58	819.94	97.11	9430.67
47	980.82	881.19	3.17	109.17	916.05	64.77	4195.64
48	992.87	898.44	3.96	102.23	939.88	52.99	2808.06
49	1104.62	921.81	5.05	193.56	1031.64	72.98	5325.61
50	1105.57	951.61	6.45	167.67	1012.49	93.08	8663.30
51	1082.94	985.93	8.02	112.45	978.09	104.85	10993.98
52	894.40	974.60	6.93	-90.92	967.19	-72.79	5298.00
53	958.90	962.45	5.85	-14.11	1030.65	-71.75	5147.96
54	942.42	960.52	5.41	-22.41	971.68	-29.26	856.09
55	842.18	939.52	3.93	-111.97	941.52	-99.34	9867.59
56	910.93	952.88	4.46	-36.73	875.44	35.49	1259.68
57	893.18	940.51	3.51	-56.65	956.50	-63.32	4009.35
58	981.89	935.58	3.03	41.64	1013.60	-31.71	1005.32
59	1076.27	946.19	3.46	134.27	1047.79	28.48	811.10
60	1094.62	961.02	4.10	139.90	1051.88	42.74	1826.45
61	1223.24	982.28	5.07	250.46	1158.68	64.56	4168.37
62	1219.65	1004.54	6.04	224.63	1155.02	64.63	4176.93
63	1108.39	1006.68	5.82	99.55	1123.02	-14.63	214.01
64	887.47	1003.43	5.31	-120.98	921.58	-34.11	1163.78
65	925.25	990.29	4.27	-75.26	994.62	-69.37	4812.59
66	888.43	972.30	3.01	-96.19	972.15	-83.72	7008.73
67	959.03	1000.75	4.45	-27.63	863.34	95.69	9156.54
68	900.51	987.13	3.43	-96.63	968.47	-67.96	4618.68
69	960.62	997.66	3.83	-33.11	933.91	26.71	713.60
70	1103.29	1017.49	4.73	94.66	1043.13	60.17	3619.87
71	1187.08	1030.35	5.19	161.24	1156.49	30.59	935.87
72	1190.26	1039.48	5.41	152.96	1175.44	14.82	219.77
73	1348.69	1059.07	6.21	297.47	1295.35	53.34	2844.80
74	1259.55	1057.21	5.75	197.87	1289.91	-30.36	921.82
75	1304.67	1100.76	7.88	224.84	1162.52	142.16	20208.07
76	1054.75	1126.48	8.89	-61.85	987.66	67.09	4500.90
77	1103.64	1146.94	9.54	-36.90	1060.12	43.52	1894.30
78	1088.67	1164.03	9.97	-71.18	1060.29	28.38	805.37
79	1026.30	1142.07	8.17	-133.45	1146.37	-120.07	14415.77

80	1053.58	1150.23	8.17	-96.66	1053.61	-0.03	0.00
81	1130.20	1159.70	8.24	-28.78	1125.29	4.91	24.09
82	1229.97	1159.27	7.75	65.90	1262.61	-32.64	1065.22
83	1261.40	1149.24	6.75	102.31	1328.25	-66.85	4469.22
84	1349.01	1166.64	7.35	188.27	1308.96	40.05	1604.40
85	1537.36	1191.51	8.34	355.55	1471.47	65.90	4342.20
86	1491.84	1224.88	9.75	280.82	1397.72	94.12	8858.22
87	1499.48	1245.26	10.35	260.11	1459.47	40.01	1601.11
88	1215.49	1261.39	10.67	-42.70	1193.76	21.73	472.37
89	1243.80	1274.36	10.80	-29.29	1235.17	8.63	74.56
90	1202.49	1282.10	10.63	-81.31	1213.98	-11.49	131.93
91	1097.80	1276.39	9.71	-187.64	1159.28	-61.48	3779.90
92	997.66	1235.10	6.84	-265.68	1189.44	-191.78	36779.15
93	1026.23	1192.23	4.04	-193.53	1213.16	-186.93	34941.79
94	1284.29	1202.15	4.37	85.40	1262.17	22.12	489.37
95	1189.01	1174.66	2.57	-3.29	1308.83	-119.82	14357.47
96	1376.39	1180.13	2.73	197.87	1365.50	10.89	118.68
97	1538.69	1182.94	2.74	355.80	1538.41	0.28	0.08
98	1590.55	1218.66	4.60	390.16	1466.50	124.05	15389.06
99	1554.85	1242.26	5.67	323.11	1483.37	71.48	5110.02
100	1288.27	1270.01	6.91	30.49	1205.23	83.04	6895.05
101	1350.20	1304.19	8.45	61.11	1247.64	102.56	10519.08
102	1342.25	1342.13	10.11	16.45	1231.34	110.91	12301.82
103	1241.41	1372.67	11.26	-119.95	1164.60	76.81	5899.20
104	1153.17	1393.21	11.78	-234.90	1118.24	34.93	1219.80
105	1055.12	1363.43	9.44	-331.33	1211.47	-156.35	24444.34
106	1232.37	1312.80	6.06	-113.70	1458.26	-225.89	51027.88
107	1463.92	1358.31	8.28	127.46	1315.57	148.35	22008.01
108	1522.20	1355.35	7.65	160.63	1564.46	-42.26	1785.54
109	1727.44	1365.30	7.78	363.41	1718.80	8.64	74.73
110	1558.24	1318.57	4.71	209.49	1763.23	-204.99	42022.28
111	1679.84	1332.17	5.21	352.60	1646.39	33.45	1119.11
112	1329.24	1327.11	4.63	-3.55	1367.86	-38.62	1491.71
113	1389.75	1330.91	4.58	58.38	1392.84	-3.09	9.57
114	1493.61	1373.16	6.70	141.31	1351.94	141.67	20069.62
115	1392.46	1415.11	8.69	-3.13	1259.92	132.54	17566.77
116	1219.39	1431.91	9.15	-208.03	1188.90	30.49	929.82
117	1250.97	1478.61	11.26	-206.84	1109.72	141.25	19950.66
118	1537.22	1532.69	13.68	28.24	1376.17	161.05	25936.02
119	1583.79	1522.43	12.33	48.10	1673.83	-90.04	8106.53
120	1683.88	1531.70	12.15	150.49	1695.38	-11.50	132.25

121	1822.50	1521.31	10.88	288.71	1907.27	-84.77	7185.29
122	1843.04	1559.15	12.40	298.82	1741.68	101.36	10273.43
123	1679.90	1506.61	8.74	137.33	1924.15	-244.25	59656.73
124	1416.38	1489.98	7.31	-87.65	1511.80	-95.42	9104.24
125	1597.71	1508.47	7.94	95.43	1555.68	42.03	1766.86
126	1534.47	1483.64	6.10	32.68	1657.72	-123.25	15191.30
127	1372.85	1459.49	4.39	-103.39	1486.61	-113.76	12940.95
128	1281.54	1470.71	4.78	-185.39	1255.86	25.68	659.50
129	1659.85	1579.51	10.64	137.95	1268.65	391.20	153036.50
130	1424.18	1538.51	7.73	-142.93	1618.39	-194.21	37717.12
131	1652.10	1561.59	8.59	99.01	1594.34	57.76	3336.17
132	1818.61	1596.23	10.06	236.80	1720.68	97.93	9590.49
133	1944.20	1619.37	10.80	332.07	1895.00	49.20	2421.08
134	2010.82	1651.93	12.02	370.94	1928.99	81.83	6696.09
135	1492.42	1581.83	7.40	-134.89	1801.28	-308.86	95395.68
136	1551.66	1602.54	8.15	-43.51	1501.58	50.08	2508.22
137	1661.59	1598.85	7.48	56.18	1706.12	-44.53	1983.07
138	1866.48	1666.81	10.89	233.16	1639.01	227.47	51742.40
139	1762.68	1727.79	13.71	62.63	1574.31	188.37	35483.23
140	1683.71	1775.43	15.62	-72.93	1556.11	127.60	16282.13
141	1717.86	1734.91	12.46	-48.14	1929.00	-211.14	44579.31
142	1862.79	1816.06	16.33	84.77	1604.44	258.35	66743.41
143	1932.77	1832.76	16.35	100.22	1931.40	1.37	1.87
144	2003.33	1827.15	15.11	164.02	2085.91	-82.58	6818.96

After forecasting, the reliability of forecasted values was tested using paired sample test.

Table 4- Paired Samples Statistics

Paired Samples Statistics			
	Mean	**Std. Deviation**	**Std. Error Mean**
Original data	1206.45	338.63	29.47
Forecast data	1196.96	339.19	29.52

Table 5 – Paired Samples Test

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Original data - Forecast data	9.49	104.69	9.11	-8.53	27.52	1.04	131	.299

The results show that there is no significant difference in forecasted and original data (t=1.04, P<0.05), hence we may conclude that the Holt-Winter's Forecast Additive Model was fit for forecasting the monthly consumption of electricity.

Conclusion

The aim of any economyis to reduce the consumption of electricity and increase production. Graphic presentation of the seasonal relative shows that consumption of electricity follows a seasonal pattern in which consumption are higher at the beginning of the year and then fall from February to April and remain low until around September, afterward consumption start to climb again, though it was not statistically significant (χ^2 =11.24 and P-Value = 0.423) that means that little or no real evidence was shown against the null hypothesis.It is highly required to continue research on electricity demand prediction methods, a particular challenge for mathematical forecasting models being here longterm forecasts based on correctly selected sets of input data. This seems from the fact that aside from the random nature of electricity consumption, these methods should also taken in account of many additional factors. The results presented in this paper confirm that the Holt-Winters method can be effectively used for electricity demand forecasting and designing controllers for electricity supply in order to optimize the costs of maintaining electricity supply at the desired level.

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