International Journal of Engineering &Technology, 7 (1.8) (2018) 201-203

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Solar and Wind Power Forecasting with Optimal ARIMA Parameters

M. Veda Swaroop[1]*, P. Linga Reddy[2]

[1]M.Tech Student, Electrical and Electronics Department, K.L.E.F (deemed to be) University, Green Fields, Vaddeswaram
[2]Professor, Electrical and Electronics Department, K.L.E.F (deemed to be) University, Green Fields, Vaddeswaram
**Corresponding author E-mail: vedaswrp@gmail.com*

Abstract

The solar and wind renewable energy sources are gaining popularity to encourage green energy into the power system. The cost of generation of solar and wind energy sources are decreasing and competing with conventional coal-based generation. Therefore, it is very important to integrate these renewable sources into the power system. Integrating Solar and wind energy sources require to solve the uncertainty problem. Both the solar and wind energy generation is uncertain and not controllable. In this paper, sliding window optimal ARIMA forecasting algorithm is proposed to solve the uncertainty associated with solar and wind sources. The proposed forecasting method is used on the data collected from National Renewable Energy Laboratory website.

Keywords: *ARIMA; Forecasting; Renewable energy integration; Solar power; Wind power.*

1. Introduction

Conventional power plants use fossil fuels to generate power. They are not environment-friendly and release harmful gases into the atmosphere. In developing countries like India, the energy demand is increasing. At the same time, the importance of renewable energy sources is gaining popularity to encourage green energy into the power system. The governments are also providing subsidies to install renewable sources like solar panels on rooftops and wind turbines. Large-scale solar power plants and wind power plants are being constructed in many countries. The solar and wind energy generations are not controllable and there is uncertainty in the amount of power generation. Therefore, it is very important to study the uncertainty challenge in integrating these sources into the power system.

To address the uncertainty, the gas power plants, pumped hydro energy storage, hydel power plants, compressed air energy storage system, diesel plants and other energy storage options such as battery energy storage systems[1] are used. All these solutions have limitations like storage capacity, financial problems, non-availability at all times etc. Forecasting is a feasible solution to address the uncertainty problem. In time series statistical forecasting methods, ARIMA (p, d, q) model is used for forecasting. Where p is an autoregressive parameter, d is differencing parameter and q is moving average parameter. Typically, Box-Jenkins method is followed to find p, d and q parameters[2]. This method is usually difficult to understand and find the correct parameters. In this paper, sliding window optimal ARIMA (p, d, q) forecasting algorithm for finding optimal p, d and q parameters is proposed. The proposed method is used to forecast solar and wind powers.

2. Sliding Window Optimal ARIMA (P, D, Q) Forecasting

This method is used for short-term forecasting. The proposed algorithm is developed using MATLAB software. Historical data is required to forecast using ARIMA method. The algorithm for the proposed method is as follows.

1. Read the historical data.
2. Perform Kwiatkowski-Phillips-Schmidt-Shin (K.P.S.S) test[3][4] in MATLAB on the historical data. If K.P.S.S test returns zero then go to next step. If the test returns one then difference the historical data and perform the test on differenced data. Repeat this procedure until the test returns zero. Here d parameter is no. of times historical data are differenced.
3. After finding d parameter. For a given range (0 to 3) of p and q parameters, perform Akaike's Information Criterion (A.I.C) test[5][6] on all combinations of ARIMA (p, d, q) models estimated on historical data.
4. Choose the ARIMA (p, d, q) models without errors.
5. The model with least A.I.C value is found.
6. The forecast is generated for the model.
7. Update the historical data with new measured data and go to step 1.

The sliding window forecasting procedure can be graphically represented as shown in the following Fig.1.

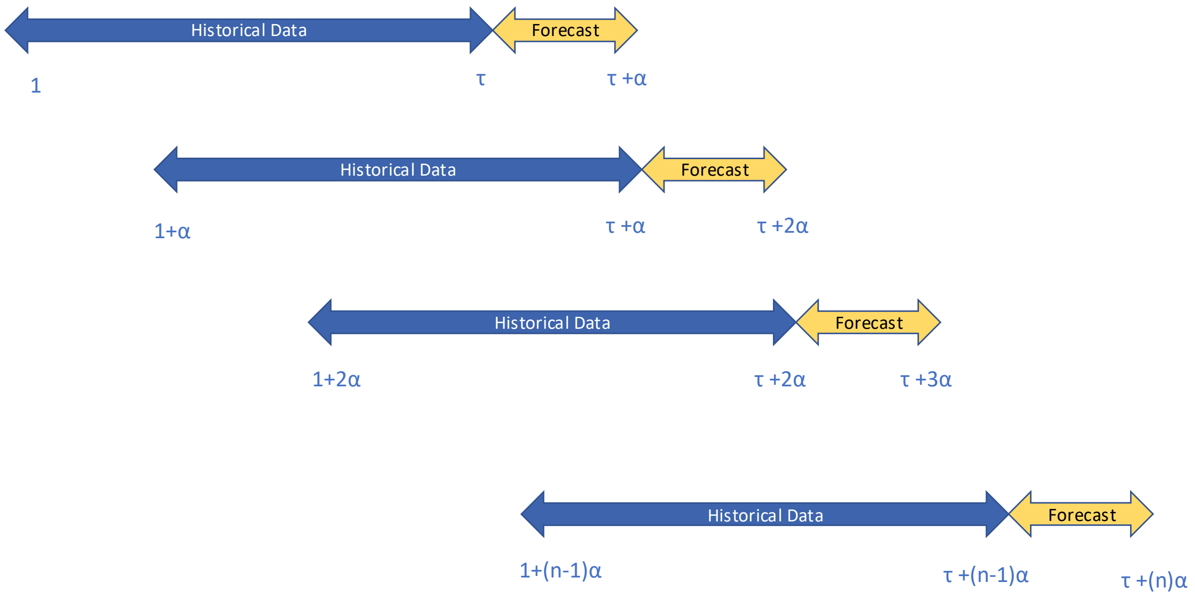

Fig.1 Sliding Window Forecasting procedure

1 to τ is the time series historical data up to the time τ which is called window area. Where 'α' is the forecast horizon. τ + α is the forecast generated after time τ. Now the historical data is updated with measured data and the window is moved to generate next forecast. This process is repeated until nth forecast is obtained.

3. N.R.E.L System Data:

Measured Solar and Wind powers data are available online on National Renewable Energy Laboratory (N.R.E.L) website[7][8]. The data used to test the proposed method is a 5-minute interval solar and wind power data. The 5- minute interval data is averaged to 15-minute interval data[9]. 24 hours historical data is used as window area. The proposed method is used to forecast solar and wind powers for next 15 minutes. The sliding window forecasting procedure is followed to obtain next 24-hour forecasts.
The measured solar and wind powers and the forecasts obtained are shown in the following table.

Table 1: Measured and forecasted solar, wind powers

s.no	Measured solar power (MW)	Solar power forecast (MW)	Measured wind power (MW)	Wind power forecast (MW)
1	0	8.48E-07	11.965	12.44823
2	0	-5.9E-07	12.57833	12.06382
3	0	3.05E-07	13.329	13.14353
4	0	-1.9E-08	14.047	13.74013
5	0	1.2E-07	13.81833	14.19278
6	0	2.09E-07	13.468	13.45073
7	0	1.11E-07	13.581	13.61355
8	0	-6.1E-08	15.327	14.41304
9	0	1.37E-07	16.78467	16.64501
10	0	1.82E-07	16.31333	16.8013
11	0	-1.8E-07	17.01967	16.44764
12	0	1.27E-07	16.30467	17.57494
13	0	-3.1E-07	15.07467	15.675
14	0	5.29E-07	13.48967	13.90521
15	0	-6.1E-07	14.60867	14.27028
16	0	9.82E-07	14.47933	14.77751
17	0	-1.4E-06	14.26667	14.35199
18	0	2.68E-06	14.10267	14.19608
19	0	-3.5E-06	14.09267	14.14608
20	0	5.53E-06	14.19967	14.11737
21	0	-8.2E-06	14.14767	14.30799
22	0	1.26E-05	13.70533	13.97709
23	0	-1.9E-05	13.495	13.42077
24	0	2.79E-05	13.404	13.46408
25	0	-4.6E-05	13.07233	13.133
26	0	5.48E-05	13.06033	12.99245
27	0	-0.00014	12.72333	12.80708
28	0	-6.9E-07	12.817	12.53759
29	0	-0.00078	13.527	13.15395
30	0	-0.00173	14.21967	13.97939
31	0	-0.00819	14.16967	14.53919
32	0	-0.03309	13.10367	13.76904
33	0.566667	-0.08834	12.05733	12.56132
34	10.53333	1.629255	11.092	11.55848
35	16.4	20.98739	10.47967	10.55908
36	19.8	22.16291	10.48833	10.30965
37	21.86667	23.87153	10.101	10.4238
38	22.33333	24.28888	9.146667	9.226947
39	23.46667	23.08045	8.137333	8.733481
40	23.93333	24.18248	7.342	7.273068
41	23.8	24.12955	6.843667	6.99661
42	23.03333	23.50738	6.027667	6.339628
43	21.93333	22.35732	5.139333	5.337273
44	20.8	21.53294	4.318	4.589064
45	19.7	20.24318	3.459	3.621639
46	19.4	19.04771	2.591333	2.780752
47	18.13333	19.47076	1.960333	2.067859
48	18.1	17.01098	1.325	1.459037
49	17.26667	17.8138	0.940667	0.570793
50	18.36667	18.39375	1.61	1.219203
51	18.86667	18.86994	2.469333	2.10135
52	19.8	19.76743	3.031667	2.844482
53	20.4	20.60904	3.533667	3.269509
54	20.53333	20.44719	3.896667	3.812514
55	23.06667	21.08301	3.967667	3.936521
56	22.96667	24.76323	3.942333	3.948825
57	23.23333	23.28722	3.822333	3.711283
58	22.43333	22.78074	3.729	3.64505
59	22.33333	21.52657	3.670667	3.404474
60	21.83333	22.49199	4.294667	3.74645
61	21.06667	21.62567	5.031667	4.616431
62	19.83333	20.93979	5.497667	5.116705
63	17.8	18.12779	5.737667	5.423599
64	15.5	16.35824	5.741	5.744714
65	11.83333	13.05997	5.595333	5.600045
66	4.666667	7.812623	6.092	5.772525
67	0	-7.27166	6.896667	6.571583
68	0	-0.94548	6.793	6.882246
69	0	-0.06714	8.233667	7.250945
70	0	-0.05638	9.328667	9.803069
71	0	-0.05448	9.681	10.61415
72	0	-0.32235	13.38533	10.89242

73	0	-0.05587	15.825	16.55948
74	0	-0.05587	15.278	16.49905
75	0	-0.05587	14.06933	14.72051
76	0	-0.0503	12.689	13.13423
77	0	-0.0503	11.31667	12.05678
78	0	-0.0503	10.718	10.44663
79	0	-0.04994	11.91433	11.37874
80	0	-0.0503	14.23567	12.89536
81	0	-0.0503	17.231	16.77933
82	0	-0.0503	16.899	19.00919
83	0	-0.05587	14.652	14.49184
84	0	-0.0503	15.16333	14.99914
85	0	-0.05587	15.01	14.88409
86	0	-0.05587	15.12333	15.64803
87	0	-0.0503	15.238	14.57128
88	0	-0.0503	16.198	16.89021
89	0	-0.05587	15.321	16.13585
90	0	-0.07735	14.56567	14.48466
91	0	-0.03327	13.92767	14.67458
92	0	-0.0503	13.56033	13.37701
93	0	-0.0503	15.64833	12.95258
94	0	-0.05587	18.249	17.65477
95	0	-0.05587	17.529	18.98587
96	0	-0.0559	16.003	15.46713

By observing the above table, the forecasted values are closer to the actual measured values. The solar and wind forecasted powers and the measured powers are graphically represented in figure 2 and figure 3.

4. Results

24-hour historical data is taken from N.R.E.L website and the next 24-hour data is forecasted using the proposed method with a forecast horizon of 15 minutes. To evaluate the performance of the proposed method, the percentage error in power per day for solar and wind forecasts are calculated and are shown in table 2.

Table 2: Percentage error in power per day

Forecast Type	Percentage error in power per day
Solar power forecast	-0.2383 %
Wind power forecast	-0.0956 %

The percentage error in power per day of solar and wind powers forecasted using proposed method are -0.2383% and -0.0956% respectively.

5. Conclusion

Solar and wind energy integration into power system is gaining popularity to decrease carbon emissions. The main challenge to integrate these sources is the amount of power generated is uncertain. Currently, available solutions to address the uncertainty problem have limitations. In this paper solar and wind, short-term forecasts are used to solve the uncertainty problem. Sliding window optimal ARIMA (p, d, q) method is proposed for forecasting. The forecasts are developed using the data collected from NREL website and the performance of the proposed method is evaluated.

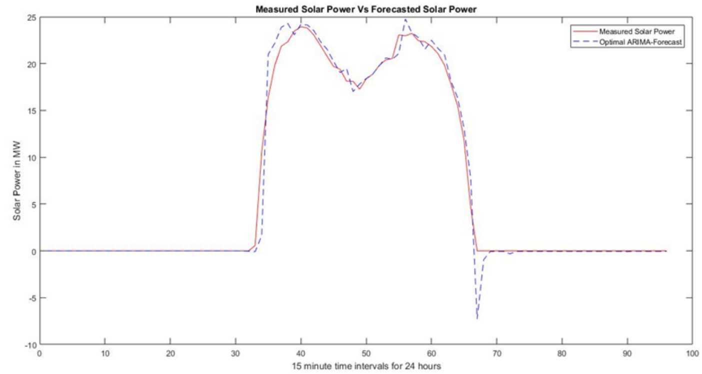

Fig.2 Measured and forecasted Solar power

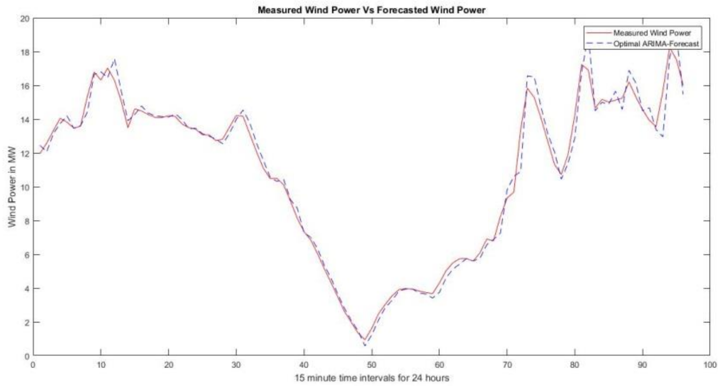

Fig.3 Measured and forecasted Windpower

The measured and forecasted solar, wind powers presented in Table: 1 are graphically plotted and are shown in figures 3 and 4. The x-axis is 15-minute interval time periods for 24 hours. The y-axis represents measured and forecasted powers in megawatts (MW).

References

[1] M. Beaudin, H. Zareipour, A. Schellenberg, W. Rosehart, Energy Storage for Mitigating the Variability of Renewable Electricity Sources, Energy Storage Smart Grids Plan. Oper. Renew. Var. Energy Resour. 14 (2014) 1–33. doi:10.1016/B978-0-12-410491-4.00001-4.

[2] D. Van Der Meer, G.R.C. Mouli, G.M.E. Mouli, L.R. Elizondo, P. Bauer, Energy Management System with PV Power Forecast to Optimally Charge EVs at the Workplace, IEEE Trans. Ind. Informatics. 14 (2018) 311–320. doi:10.1109/TII.2016.2634624.

[3] D. Kwiatkowski, P.C.B. Phillips, P. Schmidt, Y. Shin, Testing the null hypothesis of stationarity against the alternative of a unit root, J. Econom. 54 (1992) 159–178. doi:10.1016/0304-4076(92)90104-Y.

[4] KPSS Test, available online: http://in.mathworks.com/help/econ/kpsstest.html, last visit:22.04.2018

[5] H. Akaike, A New Look at the Statistical Model Identification, IEEE Trans. Automat. Contr. 19 (1974) 716–723. doi:10.1109/TAC.1974.1100705.

[6] A.I.C Test, available online: http://in.mathworks.com/help/ident/ref/aic.html, last visit:22.04.2018

[7] NREL Solar dataset, available online: https://www.nrel.gov/grid/solar-power-data.html, last visit:22.04.2018

[8] NREL Wind dataset, available online: https://www.nrel.gov/grid/wind-integration-data.html, last visit:22.04.2018

[9] a. Sfetsos, C. Siriopoulos, Time Series Forecasting of Averaged Data With Efficient Use of Information, IEEE Trans. Syst. Man, Cybern. - Part A Syst. Humans. 35 (2005) 738–745. doi:10.1109/TSMCA.2005.851133.