POWER PREDICTION OF WIND POWER TURBINE USING AUTOREGRESIVE MODEL AND MARKOV CHAIN

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Abstract: This paper deals with prediction of electrical power from wind power plants. In first part of this paper, there are described basic principles of wind power prediction. Numerical and statistical prediction methods are described with more details, as they are modelled in second part on particular example. Second part uses real output power data from offshore wind power plant located in Czech Republic. Tested methods are Autoregressive numerical method and Markov chain model. Obtained results are statistically processed and evaluated.

Keywords: wind power plant prediction, wind power simulation, statistical prediction

1. INTRODUCTION

Number of wind turbines and total installed power in Europe raises significantly. Wind energy as a uncontrollable source brings certain instabilities into electrical grid. Electricity transmision problems have already occurred in recent years and it is still a dangerous issue for grid stability. Possibilities of wind power plant regulation are narrow, but for electrical grid dispatching is also very important a knowledge of future expected power. This brings need of accurate and reliable prediction. It is not difficult to create basic prediction model, but it is not essential, to run prediction with a sufficient accuracy.

2. PREDICITON MODELING

There are many ways how to predict generated power from wind power plants. Fields of this modelling principal can be categorized as follows [1]:

- Numerical methods
- Statistical methods
- Meteorological forecasting
- Local measuring network
- Neuron network algorithms and combinations

Each category brings its own needs and requirements and can also lead to different reliability.

2.1. NUMERICAL METHODS

Numerical methods use power or wind speed measurement from simulated power plant. On this data are applied regression functions, which can be optimized for achieving better results.

Usual problems are caused by measurement low sampling or failure. It is common, that wind speed fluctuates and power can change many times in a minute. This cause, that changing trends and wind fluctuations cannot be cached on time. These difficulties bring significant inaccuracies and make this kind of prediction very unreliable.

Possibility of improvement can be seen in installing special on-line measuring system, which will significantly raise price for prediction system.

For numerical prediction are typical following models [1]:

- Autoregressive model (AR)
- Autoregressive moving average (ARMA)
- Autoregressive integrated moving average (ARIMA)

Autoregressive model

This particular model is useful for basic one or multiple steps ahead prediction. Regression function is generally polynomial, however satisfying result are obtained also by simple linear model.

If we have discreet sequence of ordered couples $[x_1,y_1]$, $[x_2,y_2]$, …, $[x_n,y_n]$ and we do expect, that following value in time x_{n+1} is given by equation (1) [4].

$$y_{n+1}(x_{n+1}) = p_0 + p_1 \cdot x_{n+1} + p_2 \cdot x_{n+1}^2 + \ldots + p_k \cdot x_{n+1}^k + \varepsilon \,, \tag{1}$$

where ε is white noise, p_0, … , p_k are polynomial coefficients and $k \leq n$. Polynomial coefficients can be calculated by method of least squares, which brings following matrix equation (2) [4].

$$x = \left(A^T \cdot A\right)^{-1} \cdot A^T \cdot b \,, \tag{2}$$

where matrix A, and vectors x and b are

$$A = \begin{bmatrix} 1 & x_1 & x_1^2 & \ldots & x_1^k \\ 1 & x_2 & x_2^2 & \ldots & x_2^k \\ . & . & . & \ldots & . \\ . & . & . & \ldots & . \\ 1 & x_n & x_n^2 & \ldots & x_n^k \end{bmatrix},\ x = \begin{bmatrix} p_0 \\ p_1 \\ . \\ . \\ p_k \end{bmatrix},\ b = \begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_n \end{bmatrix}. \tag{3}$$

Other more developed methods ARMA and ARIMA are based on same principals using also moving average statistical process.

2.2. STATISTICAL METHODS

Statistical methods prediction needs long term measured data. These data are at first point analyzed and later used for functional synthesis. Statistical methods interpret occurred scenario and identify possible future development including particular probabilities.

Statistical methods can be [2]:

- Markov chain
- Markov switching autoregressive (MSAR)
- Hidden Markov model (HMM)
- Grey Markov model
- Viterbi Algorithm

It is also important to note, that use of numerical methods with statistical modelling is also usual.

Markov Chain

Markov chain is a discrete time stochastic method, where following step is given by current step and transition matrix. Contrary to AR model, following step is not dependent on previous states. Transition matrix (4) is created according to statistically processed historical data of predicted function. In line i and row j is value $p_{i,j}$, which represents a probability that function, which currently occurs in state i will get in next step to state j [5].

$$P = \begin{bmatrix} p_{1,1} & p_{1,2} & p_{1,3} & \cdots & p_{1,n} \\ p_{2,1} & p_{2,2} & p_{2,3} & \cdots & p_{2,n} \\ . & . & . & \cdots & . \\ . & . & . & \cdots & . \\ p_{m,1} & p_{m,2} & p_{m,3} & \cdots & p_{m,n} \end{bmatrix} \tag{4}$$

2.3. CREATED MODELS

For simulation was used data from 2 MW off-shore wind power plant. Data were obtained as 10 minutes values of output power and prediction horizon was set to one step, which means 10 minutes ahead. Length of simulation was one year. It was selected deterministic forecasting represented by output power values.

For simulation were used two models. First model is simple autoregressive model (AR) with parametric optimization. Second is simple Markov chain model, with minor improvement changes. Results from both models were compared together and statistically evaluated.

As autoregressive model is modest and very simple to use. It requires only couple of values at the beginning [1]. On the other hand Markov is much more demanding. In Markov chain model is necessary to create transition matrix [2, 3]. This requires past data more preferably captured from longer time period. In this case was used data from previous year.

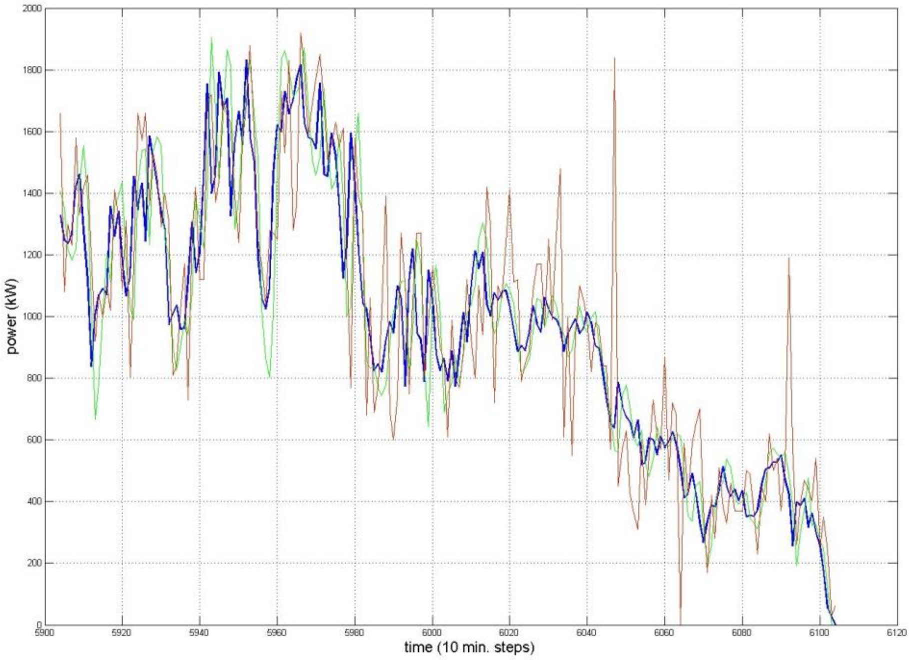

Figure 1: Prediction model sample (measured data are given by blue line, green line represents autoregressive model, red line represents Markov chain model).

Difficulty of AR is held in parametrical settings. Prediction with bad parameters can bring very inaccurate results. Finding acceptable settings is not so difficult, but it is time demanding to find optimal setup. Interesting could be also idea of different parameter setups for particular exemplary weather conditions.

deviation	>50 %	>20 %	>10 %	>5 %
Autoregressive m.	0,13 %	4,32 %	17,61 %	38,05 %
Markov chain m.	0,35 %	6,08 %	21,55 %	45,80 %

Table 1: Percentage of all cases, where deviation were greater than 50 %, 20 %, 10 % and 5 %

Autoregressive model has reached better results than Makrov chain. Variance of AR was only 8,19 % of maximum value and variance of Markov chain was 10,02 %. Another difference is shown by deviations greater than 5 %. This has occurred at rate of 38,05 % for AR, but for Markov chain model in 45,80 % of all cases. More detailed comparison are shown in table 1.

3. CONCLUSION

In this paper were described methods for power prediction from wind power plants. From methods mentioned were described two of them and tested on real data. According to results was in our particular simulation more accurate autoregressive model. Markov chain has brought in our case grater deviation. However these results are obvious, both models can be developed and after further modification they can bring more satisfying results.

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