# CUTTING WIND GENERATOR POWER CHART PEAKS TO MITIGATE POWER FORECAST ERROR

**Kaupo Toom[1], Kuno Jurjenson[1], Tauno Juhanson[2], Andres Annuk[1]**
[1]Estonian University of Life Sciences; [2] Eesti Energia AS
kaupo.toom@emu.ee

**Abstract.** Under certain circumstances, the transmission system operator (TSO) can face the need to reduce the power output of the wind parks. In a market based setup the wind power producers will normally pay for the balancing costs of wind power. Therefore, the more accurate the forecast of wind power, the lower the balancing costs for the wind power producers will be. From a socio-economic perspective, better forecasting will reduce the total generation costs due to the more optimal dispatch of power plants. The operators of the wind parks integrated into the transmission network are responsible for presenting a 24h-forecast of their output power to TSO. The real wind power differs from the forecast one. This difference needs balancing by the rest of the energy system. In the Estonian conditions, it means the regulation of the capacity of oil-shale-fuelled power plants which induces an accelerated wear, additional emissions and fuel consumption of the power plants. The reason why wind park output power is particularly difficult to forecast at wind speeds of 6-10 $m \cdot s^{-1}$ is due the fact that electricity generation of wind turbines changes markedly between these speeds.

**Keywords:** wind park, wind power, forecast error, production charts.

## Introduction

Fluctuations in wind capacity are balanced by power plants of fast regulated output, such as gas turbines and hydro power plants, or storage facilities such as pumped-storage hydro power plants and compressed air power plants. The conventional fossil fuel based thermal power plants are not easy to use for balancing large capacities of wind power, and nuclear power plants are totally unsuitable in this respect. In the territory of Estonia, the resources available for balancing the wind power by oil-shale power plants are becoming exhausted, and the same is true about the hydro power plants in Latvia. The fastest way to provide for the additional fast regulated capacity is to establish gas turbine plants and a pumped-storage hydro power plant in the further future.

TSOs are authorised to reduce wind park production peaks, which they occasionally also resort to in extreme conditions, when the balancing required cannot be achieved by other measures [1]. It can be presumed that the need for cutting off peak loads is increasing fast. In Estonia, the first reserve plant of 120 MW in capacity will be erected as late as 2013, and by this time, even the most conservative forecast suggests that the capacity of wind parks will have been increased to about 590 MW [2]. The method of cutting off production chart peaks could be applied systematically to correct forecast errors, whereas the energy cut off might be applicable for heat energy production in boiler houses.

## Materials and methods

The capacity produced by power plants at any given moment of time must be equal to the consumption capacity. With a conventional fossil fuel based energy system the power balance is well maintained. The accuracy of consumption capacity forecast is high enough and it is by these charts that the output of thermal power plants is adjusted. On the contrary, the stochastic fluctuations in the wind park output power may have amplitude as large as tens of megawatts per minute, which may result in emergency situations for the network if the need for forecast is neglected. The reason why generation is particularly difficult to forecast at wind speeds of 6-10 $m \cdot s^{-1}$ is due the fact that electricity generation of wind turbines changes markedly between these speeds.

Forecasting wind power as accurately as possible is important to wind power producers bidding in their production in an electricity market as well as to the system operator. In a market based setup the wind power producers will normally pay for the costs of balancing the wind power. Therefore, the more accurate the forecast of wind power, the lower will the balancing costs to the wind power producers be.

As a rule, wind park capacity is predicted for 24 h ahead. The time span of 24 hours enables to plan the necessary changes to the reserve capacities. Nevertheless, the wind power forecast is bound to involve some error. The forecast error (FE) (1) is estimated by two main methods: Root Mean Square

Error (RMSE) and Mean Absolute Percentage Error (MAPE) (2) [3]. In this paper we also report on the use of Mean Percentage Error (MPE) (3).

$$FE = \frac{1}{n}\sum_{t=1}^{n} P_a - P_f \ , \tag{1}$$

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{P_a - P_f}{P_a}\right| \cdot 100 \,, \tag{2}$$

$$MPE = \frac{1}{n}\sum_{t=1}^{n}\frac{P_a - P_f}{P_a} \cdot 100 \,, \tag{3}$$

where $P_a$ – actual wind park output power;
$P_f$ – predicted wind park output power.

While MPE shows the polarity of error, MAPE expresses the range of it. It is reasonable to use MPE for estimating the polarity of forecast error in the short time intervals of data-series. The MAPE values may vary significantly, but an average of 20 % can be achieved [4].

For the estimation of the forecast error of wind generators output power we used the production chart of Aulepa Wind Park as of 2009 and the forecast data chart of average power data for 1-hour time intervals. Aulepa Wind Park includes 13 WinWind WWD-3 3 MW wind generators with the total capacity of 39 MW. For the purpose of generalization we use the proportional unit of power, p.u.

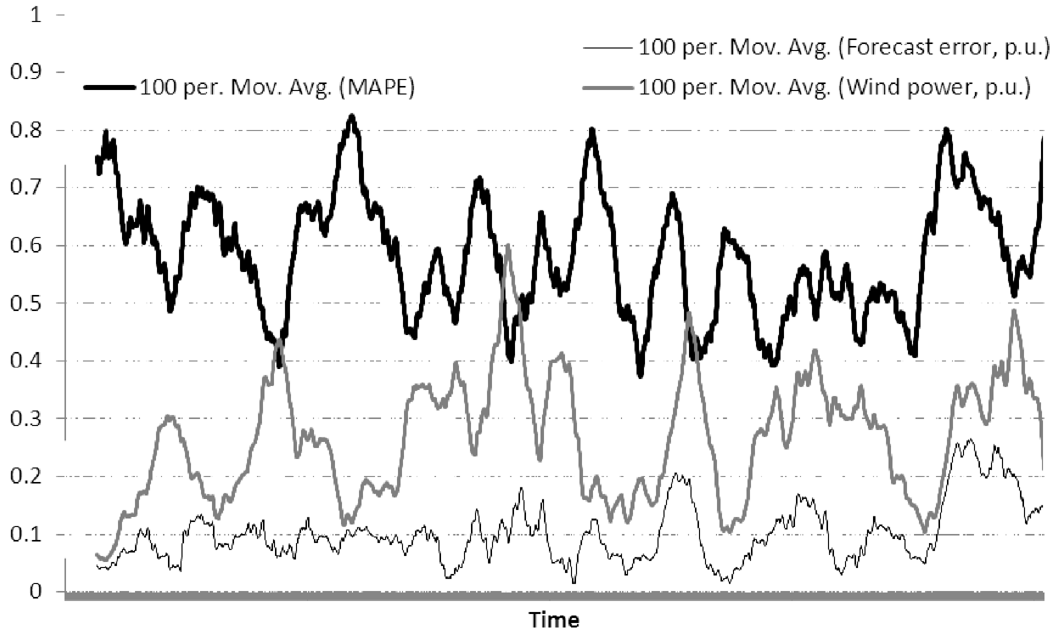


Fig. 1. **Aulepa Wind Park production chart with forecast error and MAPE chart (01.08.2009-31.12.2009)**

Figure 1 presents the production chart of Aulepa Wind Park in proportional units of power and the corresponding forecast errors in percentages. The average MAPE was 0.588 and average forecast error was 0.135. We can see from the figure that the larger the wind park output power, the smaller turns MAPE, and vice versa. The forecast error increases as the wind park output power increases. Figures 1 and 2 display a 100 period Trendline Moving Average to facilitate the trend observation. The average wind speed in the period of time 1.8.2009–31.12.2009 was 4.4 m·s$^{-1}$.

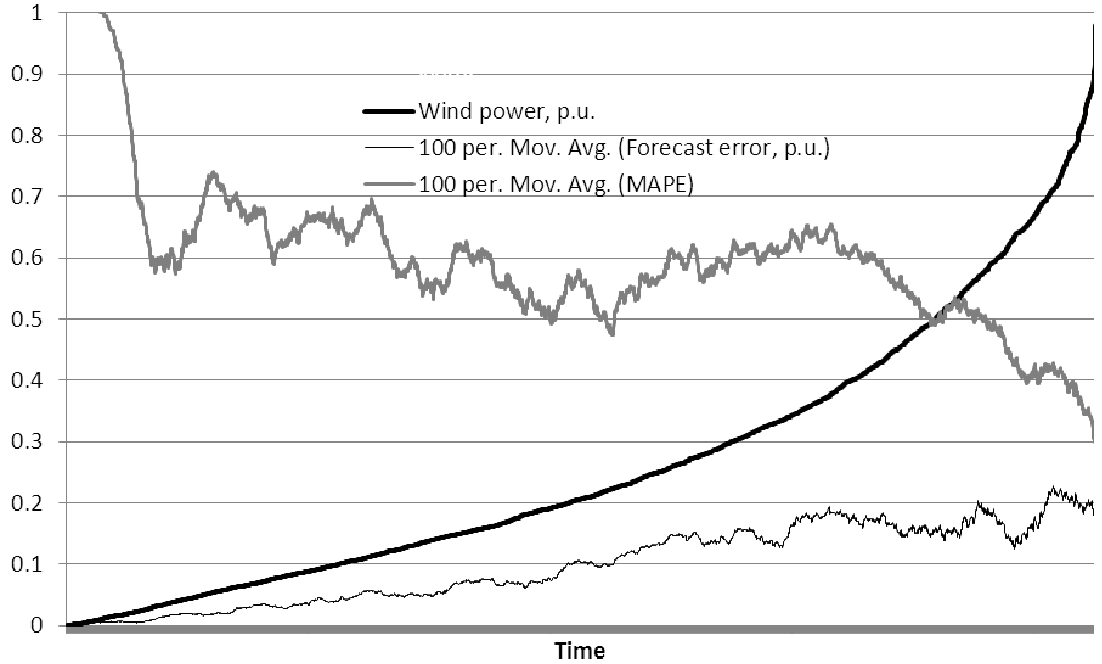


Fig. 2. **Sorted increasing wind power in Aulepa Wind Park with forecast error and MAPE chart (1.8.2009-31.12.2009)**

Figure 2 presents the cumulative output power of the wind power plant to give a better explanation of trends. MAPE is decreasing significantly if the wind power is greater than 0.45.

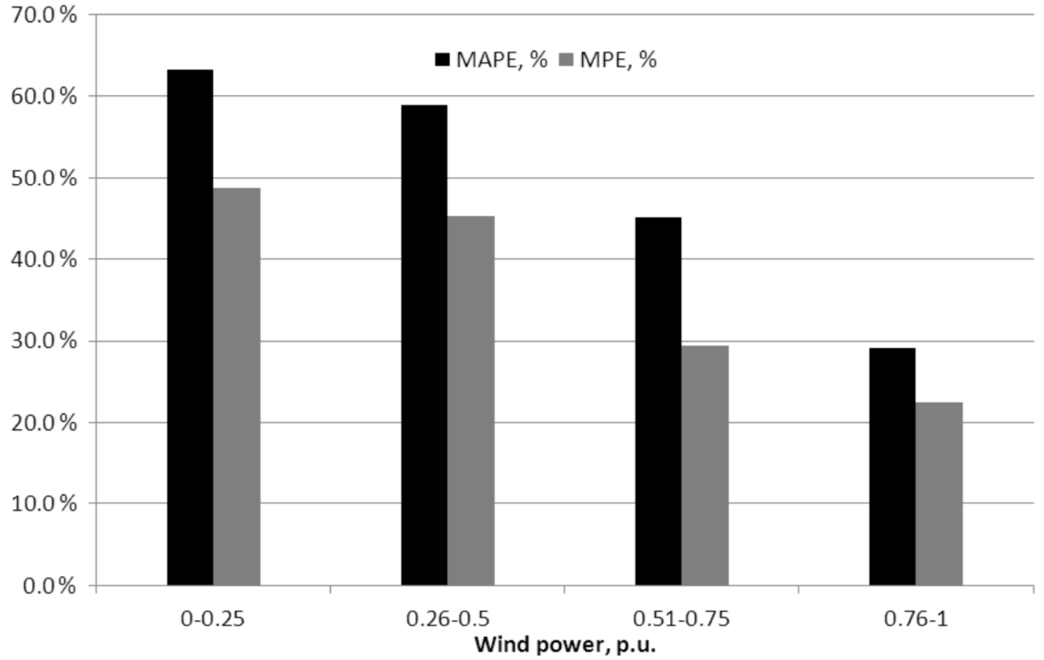


Fig. 3. **MAPE and MPE of proportional power in Aulepa Wind Park (01.08.2009-31.12.2009)**

Figure 3 shows by periods of time that MAPE and MPE values are higher at the lower output power of the wind park. This also means that cutting off production chart peaks makes MAPE and MPE increase.

**Results and discussions**

The results of cutting off production chart peaks on different levels are given in Table 1. The cut off energy, forecast error, MAPE and MPE are calculated on different cutting levels. The forecast error decreases when cutting off production chart peaks. MAPE and MPE do not change significantly. The average forecast error in Aulepa Wind Park without cutting was 0.135.

Table 1

**Cutting off production chart peaks**

| Cutting level, % | Cut off energy, % | Forecast error, p.u. | MAPE, % | MPE, % |
|---|---|---|---|---|
| 30 | 67.6 | 0.077 | 62.8 | 49.2 |
| 40 | 52.4 | 0.098 | 62.7 | 48.9 |
| 50 | 38.5 | 0.112 | 61.9 | 47.7 |
| 60 | 25.9 | 0.123 | 61.1 | 46.5 |
| 70 | 13.8 | 0.130 | 60.0 | 45.6 |
| 80 | 5.5 | 0.134 | 59.3 | 45.0 |

The average forecast error in Estonia is about 0.13. For example, in Germany and Denmark the forecast error is about 0.08-0.10 [5]. This is due to bigger total wind park output power and developers have more experience in prediction.

During this period of time (see Fig. 4), the average MAPE of Estonian wind generators is 51 % if the maximum wind park output power was 127 MW and the maximum forecast error was 45 MW within the given period [6]. The figure also shows that for a long period of time, the forecast error is more than 30 MW. All over Estonia there are similar trends to those of Aulepa Wind Park given in previous figures.

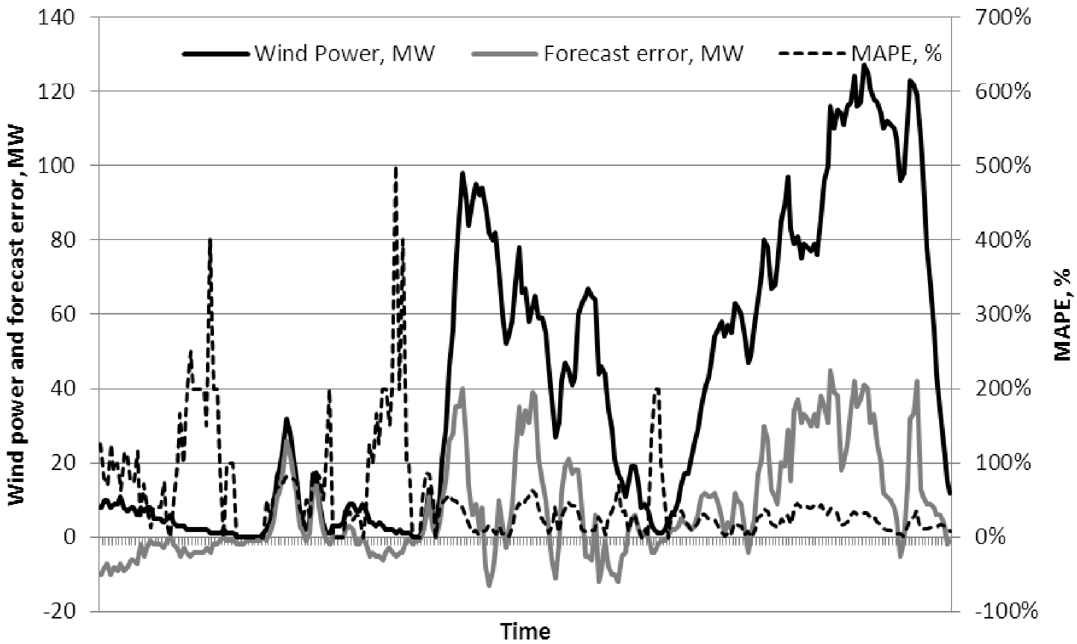


Fig. 4. **Summary of wind power production, forecast error and MAPE in Estonia (20.01.2011-30.01.2011)**

In the analysis of the performance of wind turbines it is feasible to apply the concept of the coefficient of maximum (or nominal) power usage [7] that may be described as

$$k_m = \frac{W_m}{P_m \cdot t_n} \cdot 100, \tag{4}$$

where $W_m$ is energy produced by the wind turbine in the time period $t_n$, and $P_m$ is the maximum power (sum of the nominal power of the wind turbines). Here, $P_m t_n$ is the energy amount that would have been produced by all the generators working at nominal power for time $t_n$. During this time period at Aulepa, the coefficient of nominal power usage was 26 %. This is the average result in Estonian wind parks.

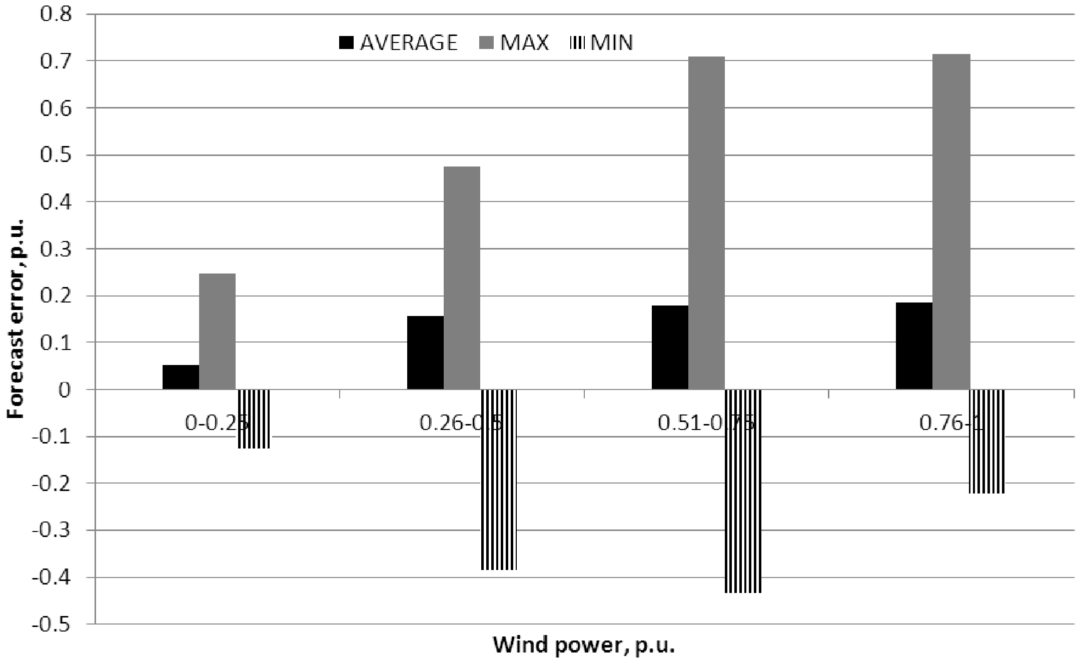


Fig. 5. **Forecast error in p.u. by periods of time**

Figure 5 shows that there are greater forecast errors if the wind park output power exceeds 0.5. The most and the greatest forecast errors (even up to 0.71) were at the wind park output power being 0.5-0.8 or at the wind speed being about 9-11 $m \cdot s^{-1}$.

## Conclusions

1. According to the measurement data in Aulepa Wind Park, the average MAPE was 58.8 % and the average forecast error was 0.135.
2. The higher the wind park output power, the lower becomes MAPE, and vice versa. The forecast error increases as the wind park output power increases.
3. During the period of time 01.08.2009–31.12.2009 at Aulepa, the coefficient of nominal power usage was 26 %. This is an average result in Estonian wind parks.
4. The forecast error decreases as the production chart peaks are cut off. MAPE and MPE do not change significantly.
5. The most and the greatest forecast errors could be observed when the wind park output power was in the range of 0.5-0.8.

## References


1. Lepa J., Annuk A., Kokin E., Põder V., Jürjenson K. Energy production and consumption charts in energy system. Oil Shale 26(3S), 2009, pp. 309-318.
2. Eesti elektrisüsteemi tootmisseadmete piisavuse aruanne 2009. Elering OÜ. Tallinn. 20 p. (in Estonian) [online] [30.01.2011]. Available: http://www.elering.ee/index.php?id=546.
3. Rosen J., Tietze-Stöckingen I., Rentz O. Model-based analysis of effects from large-scale wind power production. Energy 32(4), 2007, pp. 575-583.
4. Agabus H., Tammoja H. Wind power production estimation through short-term forecast. Oil Shale 26(3S), 2009, pp. 208-219.
5. Wind power in Estonia. Elering OÜ. 2010. [online] [30.01.2011]. Available: http://www.elering.ee/uploads/media/Uuring_-_Tuuleenergia_systeemi_yhendamine.pdf
6. Planned and actual generation of windparks. [online] [30.01.2011]. Available at: http://www.elering.ee/index.php?id=524%2520%2520%2527&L=1.
7. Annuk A., Tammoja H., Agabus H., Toom K., Tamm T. Possibilities for Correcting Forecast Errors by Cutting off Production Chart Peaks. Agronomy Research 8(1), 2010, pp. 25-32.