Integration of Wind Power into the Danish Power System

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Overview

Using renewable energy sources widespread in the future's energy production, is essential, in order to mitigate those expected negative external environmental, economic and social effects which can be derived from the use of fossil fuels. Wind energy is already a major player in the Danish electricity market with an ambitious goal to pursue 50% of the electricity market by 2020. Besides the economic and social concerns, Denmark places emphasis on investing in wind energy mainly to diminish the CO2 emission of the energy sector.

This paper examines the economic impacts of increasing integration of large-scale wind power to the existing electrical grid, by examine the marginal cost of electricity generation and the marginal cost of CO2 reduction.

Method

In this empirical research, a cost minimization problem was considered in order to introduce how the increasing wind penetration level would have an effect on the cost of electricity generation in the Western Denmark region. Using the results of this optimization problem we study how the cost of CO2 emission reduction would have changed, taking into consideration different optimal wind power penetration scenarios – besides the baseline case, 35%, 50% and 75% wind penetration 'optimized' scenarios have been examined.

In the paper we use the grid management model to minimize the yearly total cost of generating electricity from different energy source used power plants, while the electricity demand is met by the supply in every hour. The model takes into consideration the variable costs of power supply, and optimizes the output from the different fuel based power plants – such as natural gas, oil, coal and biogas plants – to minimize the total cost. The hourly based electricity demand and wind power production data, and the cost related data have been gathered for the year 2010.

Results

The results show that the total amount of electricity output would decrease by more than 16% at the 35% 'optimized' wind scenario, compared to the baseline scenario – the wind power penetration were identical in both cases, but the operation of fossil fuel power plants was optimized in the 35% 'optimized' wind scenario. However, due to the increased share of electricity generated by coal fired, the total CO2 emission would increase by 4.6%. Furthermore, when the 50% and 75% wind penetration scenarios have been compared to the 'optimized' 35% wind scenario, a slight increase in electricity output – 1.2% and 7.9%, respectively – was found which was due to the increased number of hours of wind oversupply. Moreover, comparing the CO2 emission value of the 50% and 75% wind penetration scenarios to the corresponsive value of the 35% 'optimized' scenario, a significant decrease occurred; the CO2 emission has been reduced by 14.1% and 31.6%, respectively, which is the result of the decreased share of the usage of fossil fuel generators from the total.

The marginal cost of electricity generated has increased by 55.5% and 123.6%, comparing the cost of MWh generated in the 50% and 75% wind penetration scenarios to the 35% 'optimized' wind scenario, due to the high installation cost of wind turbines. Moreover, the marginal cost of reducing one ton of CO2 emission has increased by 560 Danish kroner (around 72 euro) to 614 Danish kroner (around 79 EUR).

Conclusion

The operation of non-wind generators has been optimized and due to their low operation and maintenance and fuel costs, the coal fired power plants have been determined as base-load generators. Thus, the total CO2 emission generated by non-wind generators is higher, than it would have been in a case when the base-load was provided by a more diverse generation mix. However, the significant increase in wind power penetration resulted in a significant decrease in electricity output of fossil fuel power plant, thus in a substantial CO2 reduction. Taking into consideration the high installation cost of wind turbine, the marginal cost of electricity generation has increased significantly. Interlacing the high wind installation cost and the decreasing CO2 emission, the marginal cost of reducing CO2 emission has increased significantly, as well.

References

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