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BALANCING WIND ENERGY IN THE GRID: AN OVERALL, TECHNO-ECONOMIC AND COORDINATED APPROACH "WINDBALANCE"

R. BELMANS, W. D'HAESELEER, G. PALMERS, J.-C. MAUN.

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FINAL REPORT PHASE 1

SUMMARY

BALANCING WIND ENERGY IN THE GRID: AN OVERALL, TECHNO-ECONOMIC AND COORDINATED APPROACH

"WINDBALANCE"

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Promotors

Ronnie Belmans
Katholieke Universiteit Leuven (K.U.Leuven)
(ESAT-ELECTA)

William D'haeseleer
Katholieke Universiteit Leuven (K.U.Leuven)
(TME)

Geert Palmers
3E

Jean-Claude Maun
Université Libre de Bruxelles (ULB)

Authors
R. BELMANS, W. D'HAESELEER, G. PALMERS, J.-C. MAUN.

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BELGIAN SCIENCE POLICY

BELGIAN SCIENCE POLICY

Rue de la Science 8
Wetenschapsstraat 8
B-1000 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person: Igor Struyf
+32 (0)2 238 35 07

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The general objective of the WindBalance Project is to identify technical and market barriers limiting the wind power potential in Belgium. By analysing these limits, solutions are put forward to increase the share of this renewable energy source in the Belgian power system.

In the first phase of the project, a market simulator was developed for a single wind farm (Task 4). This market simulator may serve as a tool for determining the prices that wind power yields in the different markets under different market conditions and depending on the predictability of the wind power output. The simulation tool was developed as follows:

- Market design and regulation concerning the delivery of electricity and ancillary service in Belgium were inventoried. Special attention is given for regulation affecting wind power and these rules form the set of boundary conditions for the simulation tool (Task 1).
- The feasibility to deliver power at market conditions for wind power operators was described statistically. The stochastic distributions of wind power production and wind power prediction errors are the input for the simulation tool (Task 2).
- As an approximation, prices at power markets are considered not to be affected by wind power. The stochastic distributions of prices on the different markets (over-the-counter, day-ahead, intra-day, balancing market) serve as the second main input for the simulation tool (Task 3).

The market simulator is designed to calculate the value of wind energy when traded on the power exchange market. This is performed by combining time series of wind power output and market prices taking into account production deviations (imbalances) and imbalance tariffs. The average value of wind power can be determined and is called the "Fixed Price OTC Equivalent" as this value can be compared to the fixed price negotiated in over-the-counter(OTC)-contracts. This simulator is a valuable support for both parties in the negotiations of OTC-contracts. Moreover, the tool provides a base for an objective analysis of the real market value of wind energy under different market conditions.

The simulator can perform long term predictions of the market value of wind power and can be used to evaluate investments. Since the simulation tool allows easy adjustment of input time series and input parameters, it can also be used to assess the value of wind energy on different markets. Depending on the input, different kinds of evaluations are possible, e.g. the value assessment of short-term wind power predictions (day-ahead or intra-day).

Different configurations for wind power generation are researched (turbine, farm, park). For a single turbine, the fixed OTC-value for 2009 is calculated as € 66,3 per MWh. The prediction error (RMSE) is around 16% which leads to a loss in income of 18% due to the charged imbalance tariffs. The value may be improved with 20% when aggregating wind generation over large areas and submitting this as one nomination.

Different nomination strategies are researched including the value of accuracy improvements concerning forecasting. For a wind farm of 8 MW, the OTC-value is determined at € 68,5 per MWh when using state-of-the-art prediction tools. This value increases to 72,1 Euro per MWh when using intra-day markets to adapt nominations to newer predictions. The prediction error decreases from 15,5% to 9,2%.

In the second phase of the project, the constraints of the total wind power capacity in Belgium is studied. Step by step, a model is build to evaluate the limit of the wind power potential in Belgium. In a first part (Task 5.1) three major assumptions are taken into account:

- Only the control zone of the Belgian TSO, Elia, is considered which contains Belgium and a part of Luxemburg.
- Network constraints and potential grid bottlenecks are not considered. This is a reasonable assumption when considering the control zone of Elia and only and a limited amount of wind power.
- All available power plants in the Belgian power system are used in a cost-optimal way to cover demand in the same control area. As a consequence, the effect of the liberalised market, with several active generators, is initially not considered. Generation units are deployed in the most cost-optimal way, as if they would be operated by one central party.

Under these assumptions, the technical upper limit for wind can be determined by the capacity of the other available generation units to set off the fluctuations in the wind energy production. Overestimation of the wind power production needs to be balanced by flexible generators. An amount of "spinning reserves" is required at all times, which is concretised by a minimum amount of available capacity in the system for every hour. These reserves can be used to meet discrepancies between demand and supply. Negative forecast errors or underestimations of the wind power output can be resolved by curtailing the output of the wind turbines if needed to restore system balance. This possibility increases the technical barrier for wind power.

However, within Belgium, the potential of other generation units to balance the intermittent output of wind farms is limited. This barrier could be relieved by considering the whole of Europe in a second task (5.2), while still making abstraction of potential grid bottlenecks. Now, Belgium is not considered as an island anymore and interactions with the rest of Europe are discussed. It is concluded that aggregation of wind power over larger areas increases the smoothing effects of uncorrelated wind speeds and prediction errors.

The assumption that no bottlenecks are present in the Belgian and European grid is clearly an enormous simplification of reality. Therefore, in Task 6, this assumption is dropped and grid constraints are added to the model. This is expected to reduce the maximal potential for wind capacity. The maximal amount of wind power which can be integrated in the grid can be quantified using a reliability assessment analysis.

The core of the risk assessments study is a load flow analysis that establishes all the active and reactive power flows in the network branches, for a given state of consumption and generation. Two options have been analysed to perform the study :

1. Using MatPower, a package of Matlab functions specially dedicated to run power flow & optimal power flow calculations.
2. Using other software providing other services as unit commitment, contingency analysis, Monte Carlo simulations, etc.

The core of the risk assessment analysis is the "processing", which is composed of three modules: a hydro and thermal unit commitment as well as load flow calculations. However, in order to run effectively, this processing part needs to handle a high number of input data which are prepared upstream in the "pre-processing" part. Finally, output data are processed in the "post-processing" part in order to obtain the needed results. Figure 1 represents the different modules.

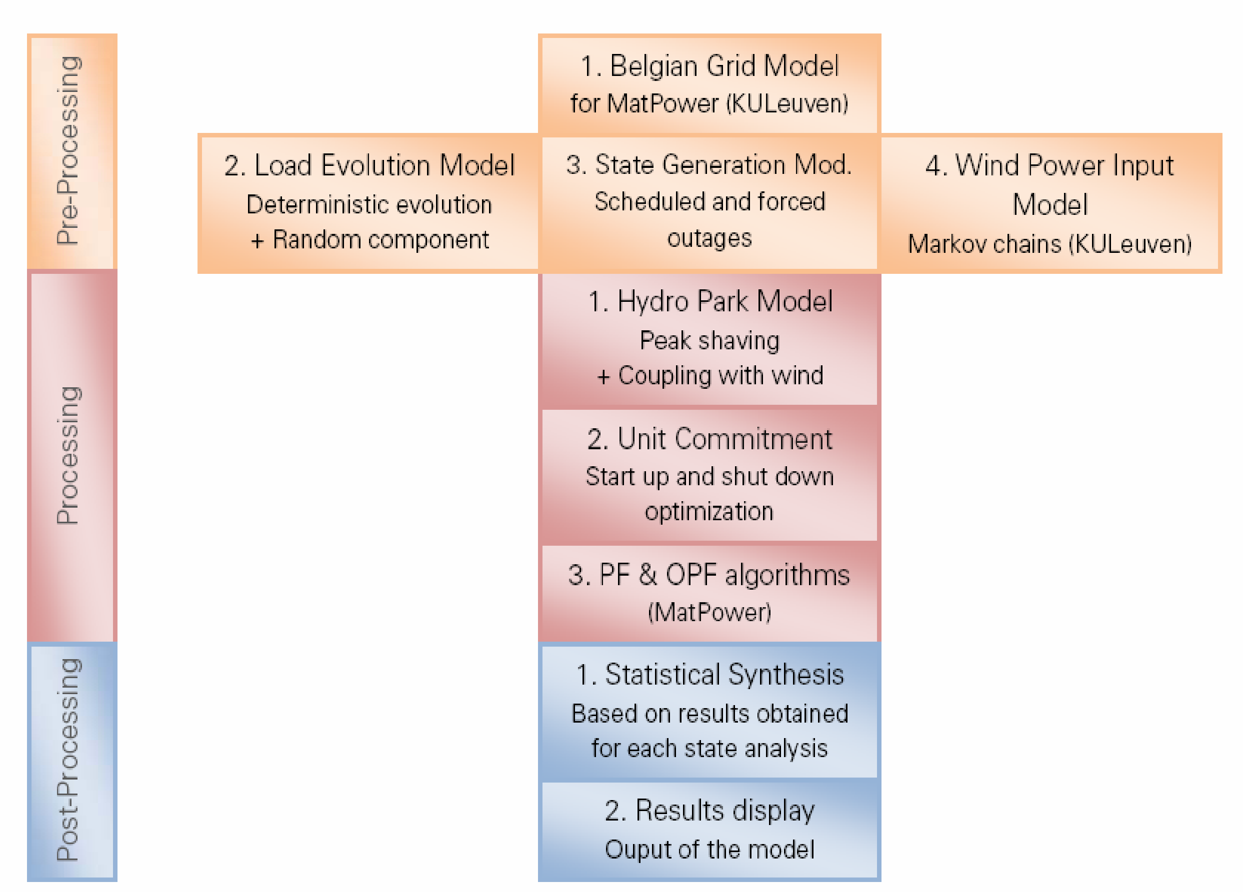

Figure 1: Schematic overview of model implementation