Temporal & Energetic Downtime Losses and its Influence on Wind Farm Economics

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Summary

The work introduced here addresses the assessment of production losses of operating wind turbines. The discussion is based on a comparison of two different methodologies to estimate the energetic losses of wind turbines proposed by IEC on its Technical Specification 61400-26-2.

Introduction

Losses of income in connection to operational downtimes are the nightmare of most wind farm operators. The analysis of the operational behaviour of several wind turbines over the years has shown that downtime losses are likely higher in months of high wind speeds, and/or in months immediately following periods of high speeds. The general question however is how to determine these losses in terms of kWh and the consequent lost of income in connection to the downtimes. The technical specification IEC 61400-26, released by the International Electrotechnical Commission is a relatively new reference addressing this question. The technical specification is composed by two parts: The IEC 61400-26-1 dealing with the estimation of the time based availability of wind turbines, and the IEC 61400-26-2 dealing with the estimation of a production based availability. The first part of the technical specification has been issued in November 2011, and the second part is still on a draft. Its first edition is expected to be issued by the middle of 2013. The IEC proposes different methods for the assessment of production losses. This paper discusses two of these methods.

The IEC 61400-26-1

The first part of the technical specification IEC 61400-26 concerns the estimation of the time based technical availability of wind turbines. The proposed method clearly distinguishes between operational and technical availabilities. The key parameter distinguishing the technical to the operational availability is the amount of available hours.
The amount of available hours taken into account when determining the operational availability of a wind turbine includes the downtimes related not only to a technical standby or scheduled and unscheduled maintenance but also the monthly hours under which the design characteristics (wind speed, electrical specifications, etc.) of the turbine were not given at the site. The technical availability instead is determined taking into account the total generating time (full and partial performance) added to the amount of hours under which the turbines were stopped by a technical standby or in connection to a requested shutdown. The total of available hours includes as well the time related to design characteristics out of the specification range. In this sense, the operational availability reflects exclusively the amount of effective energy generation hours. The technical availability the amount of hours under which the turbines were available to generate energy, but did not because of external influences (suspend operation, force majeure events, etc.), programmed maintenance, or because the design specifications were not given at the site. In view of these differences, the estimation of the technical availability must be deeply understood before conclusions regarding the operational status of a turbine can be taken.

The IEC 61400-26-2

The second part of the IEC 61400-26 deals with the estimation of the production based availability of wind turbines. The key parameter is the estimation of the lost production in connection to operational downtimes. The lost production is given by the difference between the potential production and the actual production. Most of the problems related to the assessment of the performance of a wind turbine are linked to the estimation of production in periods of downtime. Recognizing this difficulty, the IEC proposes two different methodologies for the estimation of the potential production of a turbine: A specific power curve and wind speed method, and a power based method.

Roughly speaking, in the specific power curve and wind speed method, the available wind speed for generation is determined either by nacelle anemometer measurements, by upstream measurements (e.g. LIDAR) or by measurement masts installed at the site. The power curve applied on the estimation of production might be the manufacturer’s specific power curve of the turbine to the site, or the “real” power curve of the turbine determined with historical information on production when this has been operating at full performance.

The second method proposes the estimation of the potential production of a stopped wind turbine taking into account the average production of other wind turbines operating in its surroundings. Depending on the site characteristics, all the turbines of a wind farm might be used as a comparison reference, or only the turbines operating at more similar conditions.

The next section discusses the results of a test of both methods. The first test was based on the operational data of 9 turbines installed since January 2008 at a site in Asia. The second test relied on the performance data of 35 wind turbines operating since January 2009 at a site in Europe.

Specific Power Curve and Wind Speed Measurements Method

The power curves used in the estimation of the potential production of the turbines in connection to the given downtimes were determined based on the 10 minutes resolution power data from their SCADA system. The information on the wind speed was based on the nacelle anemometer measurements. Fig. 1 summarizes the main results. All in all, the wind farm had downtimes losses around 7% over the whole operational period. When comparing the mean wind speed curve to the bars displaying the downtime losses, it can be seen that months with high wind speeds, e.g. April 2008 are linked to high losses. The effect of the turbines operating at high rotational rates over a long period is seen again on the downtime losses of May 2011, a month immediately following a period of wind speeds above the average in April 2011. The advantage of the proposed method to estimate the production losses of an operating wind turbine is in first place the associated costs, since no additional equipments at the site other than the turbine itself are necessary. In this sense, this method is suitable to all wind tur-
bines operating at a site, independent from their location, being also appropriated to wind farm sites with only a few turbines. The disadvantages are clearly linked to the inaccuracy on the wind speed measurements from nacelle anemometers. In addition to that, the estimation of a reference power curve based on historical information on production requires from the turbines a long period of operation under full performance, being therefore not suitable to the first operational months of a wind farm.

**Power Based Method**

The second method proposed by the IEC to assess the production availability of wind turbines has been tested on a wind farm with 35 turbines relying on about 4 years of operating data. The potential production of the turbines out of operation has been estimated with a reference factor determined by the averaged production of all the other operating turbines. The results are shown in Fig. 2. According to the assessment, this wind farm had downtime losses averaging 4% over the whole operational period. Like in the previous example, months with wind speeds above the average had the highest losses (e.g. December 2009). March 2009, a month with an average wind speed almost 26% above the mean wind speed over the overall operational period has been followed by downtime losses slightly above 10%. One of the main advantages of this method is clearly the independency from wind speed measurements. In addition to that, the reference potential production determined through this method is less sensitive to turbine aging, deterioration, wake effects, etc., since all these effects are already reflected on the data from the nearby turbines. The disadvantage is that the method does not take into account local variations of wind speed, being therefore unsuitable to wind farms on complex terrain. To build an accurate average production factor, the method requires also a minimum of reference turbines operating at full performance, what might be problematic to relatively new wind farms.

**Impact of Downtime losses on the Economics of a Wind Farm**

The analysis of downtime losses has been complemented by an evaluation of the impact of these losses on the economical performance of a wind farm. The investigation was based on the comparison of the average Debt Service Coverage Ratio (DSCR) associated to different production scenarios. The DSCR is given by the ratio between the net operational income of the wind farm to its debt service (repayment parcel + interest) over the considered reference period. Since the net income is directly proportional to the energy production of the turbines, the losses in association to the downtimes are immediately reflected on the DSCR\(^1\). In the wind energy business investors and/or financing institutions traditionally refer to a target DSCR as a measure of the economic performance of a determined project. Since this ratio is dependent from the debt level of the project, a fixed target (e.g. 1.24) is reached adjusting the debt to equity parcels. Fig. 3 presents the evolution of the DSCR assuming four difference scenarios of production. The blue line is the evolution of the DSCR assuming a reference production scenario, the red and the green curves refer to respectively 7% and 8% losses scenarios. The violet curve refers to the evolution of the DSCR assuming 10% of losses.

The reference scenario of production has an average DSCR meeting the proposed target of 1.24. In this case, the project leverage is equivalent to 75%-25% (75% debt to 25% equity). Once the reference production is reduced by 10%, the average DSCR falls to 1.15. To meet a target of 1.24, the leverage has to be adjusted to 70%-30%, what is equivalent to an increase of 5% in the parcel of equity.

These results confirm that the economics of a wind farm projects are very sensitive to production losses. It is important to remind however, that this analysis had a mere exercise character assuming away several important issues like the payment of

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1 The net income has been estimated taking into account general cost assumptions such as capital costs amounting to 1.3 Million Euro/MW, a reference feed in tariff of 0.09 Eurocent/kWh, interest rate on the debt of about 4.75%, etc.
performance guarantees, coverage of losses through insurance, etc. On the top of that, the analysis assumes a steady increase of operational costs, not taking into account extra expenses related to the replacement of parts or in connection to eventual measures to improve the performance of the operating turbines.

Conclusion

The methodologies proposed by the IEC to the estimation of the time and production based availabilities of wind turbines lighted up a relative frequent subject of discussions between manufacturers and wind farm operators. With the technical specification 61400-26, all involved parties are now able to speak the same language when discussing the performance of operating turbines. Downtime losses are difficult to manage. The adjustment of the predictive maintenance schedule to periods of likely low wind speeds is one of the most applied strategies to reduce downtime losses. To be worth, a careful analysis of the historical of production from the turbines is the first step. The evaluation of the ware rate of key components is a relevant practice to improve the efficiency of the procurement of spare parts and smooth the losses in connection to unscheduled repairs. The use of Condition Monitoring Systems associated to a periodical technical inspection of the turbines might be therefore valuable strategies. Nevertheless, in view of the complex design character of a wind turbine, the failure of components operating at high rates cannot be always avoided. In this sense, there is still a strong need for further investigations.

References