Managing and Mitigating Wind Farm Operational Risks

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Introduction
Operation of wind farms is a business with clear risk exposure to meteorological, engineering and technological factors. The purpose of this article is to highlight these risks, their effects on wind farm operations and possibilities to mitigate the impact.

The stakeholders
Unlike the development phase, wind farms operations are often carried out by external stakeholders. Finance investors such as pension funds, investment funds, insurances, banks, etc. play a major role in the investment in wind farms. They usually have little technical background of wind farm operations or the energy business in general. Their motivation is usually to invest in a relatively well predictable and stable
cash flow that wind farm projects can provide. Going by the increasing investment requirements - to the tune of 100-million USD, the wind business clearly needs players with high investment capabilities.

**Risk classification**

From an investor’s perspective, risks of wind farm operations can be generally classified in two categories:

i. Revenue Shortfall
ii. Unexpectedly high operational cost.

The diagram below shows the main issues in the operation of wind farms leading to these two major risks.

![Figure 1: Wind Farm performance and its main risks](image)

A combination of these issues or sometimes even a single occurrence of an operational problem could lead to poor performance of the wind farm investment. From an investor’s perspective, this poor performance leads to reduction of available cash flow which affects the payment of investment dividend.

**1. Shortfall of revenue**

On an individual wind farm, shortfall of revenue leads to dramatic reductions in cash flow over the whole lifetime of the wind farm. Shortfall of revenue is caused by reduced electricity generation linked to:

**Meteorological issues**

a) **Too optimistic resource assessments**

Wrong energy yield predictions (usually too optimistic) are leading to substantial shortfall of revenue. Since the possibilities of mitigation are low in such cases of overestimated wind resources, the problem of cash flow shortfall usually continues over the whole lifetime of the project. Mitigations used in such cases usually target the finance structure of the project.

Energy yield assessments have to be considered the highest risk of wind farm operation as state of the art software is easily available, being used by developers, independent consultants etc. Hundreds of studies are performed every week throughout the world. It turns out especially astonishing knowing that the costs of energy yield assessments are typically represented with below 0.1% of the whole investment sum.

Mitigation to this risk must be addressed in the very beginning when ordering and reviewing the relevant energy yield assessments. Both investor and the financing bank should critically review - in-house or with external experts- the results of the underlying energy yield assessments in order to avoid future surprises.

b) **Site Conditions vs. Turbine Type**
Several wind farms around the world are operating with unsuitable or at non-optimized turbine types. This has been found to lead to massively lower production compared to optimized selection. The reasons for use of sub-optimum equipment are partly linked to poor knowledge about the wind conditions at the given site and the long licensing procedures that force wind farm owners to use outdated technology.

c) Other Site Conditions

Wind speed is the key factor when considering meteorological effects of wind farm risks. Besides, all further variables that needs to be considered when planning wind farms such as turbulence at the site, wind shear, wake effect, vertical components etc. lack regularly care. Each of those variables have diverse effects on wind turbines- either by influencing the average wind speed, affecting the output of the wind farm or by influencing the load to which the turbine is exposed to. Increased loads will impact the wear and tear of each component and add to operation and maintenance costs.

As such wind resources have a double impact to the economics of the wind farm- on the income and on the expenditure side of the Cash Flow.

Case 1: Especially when facing complex terrain such effects might have material impact to the wind farm performance. We have experienced various wind farms operating in mountainous regions with high components of vertical winds, turbulence etc. Those are causing damages to main bearings in one case and, in another case, made the blade tip touch the tower, breaking thus blades due to such underestimated vertical components of winds. Due to the high value of the components and the long standstill times, each exchange of component had a major financial impact to the operation of the wind farms.

Mitigation possibilities

Having in mind the huge impact of wind resource to the performance of the wind farm, to the cost for O&M, lifetime of the wind farm etc. at the moment of investment decision it should be ensured that a high quality engineering process has been conducted throughout the whole planning process. Such process should include a site adequate wind measurement campaign and independent, high quality energy yield assessments.

It is highly recommended for investors to request own energy yield assessments, performed on basis of the wind measurement in order to verify the whole wind farm planning and identify possible sources of risks before hand. Such assessments can prevent investors from u profitable investments that might stay in the books for more than one decade.

In complex terrain and / or layout constraints, wind sector management should be carefully implemented, monitored and if necessary adopted during the operation phase in order to not exceed the acceptable loads for the wind turbine.

Technically induced shortfall of revenue

Wind farm performance is always connected to two variables: availability and performance of the selected wind turbine technology. And the below are the main reasons leading to poor performance of wind farms:

- Low technical availability of the wind turbines;
- Non fulfillment of the contractual power curve;

a) Low availability

Probably the most relevant indicator of performance after the average wind speed of an operating wind farm is the availability of wind turbines during the year of operation. High availability is key to achieving operational success. When operating wind farms today, availability rates of 98% should be the target. Lower availability rates over longer periods are normally a clear indicator of low reliability of the wind turbine technology and problems during the erection and commissioning process and will continue to influence the wind farm performance, unsuitable wind turbine type to the site conditions or poor performance of the O&M team.

In order to ensure high availability rates, reliable turbine technology that fits the site conditions and a sound O&M concept need to be secured. Assessing O&M concept calls for management of various factors such as 24/7 surveillance, reaction time, trained and experienced O&M personnel, spare parts and components logistics and concepts for preventive maintenance from longer downtimes. Such a setup...
should also include a sound transition from installation and commissioning of the wind turbine to the O&M phase. There have been various cases where mistakes in the installation/commissioning of the wind farm have led to significant availability shortfall, underperformance, exceeding loads to the turbines or even putting the technician’s security in risk when performing standard maintenance work.

**Mitigation strategies**

Low availability can be addressed with careful selection of the implemented technology. However, due to fast development in the turbine development, it is to some degree not possible to assess the outcome of new turbine types or developments.

Once the technology has been selected, supervision of the implementation of the wind farm and careful O&M management including predictive maintenance to the main components will further reduce downtime and enable the owner to have a good wind farm performance.

**b) Power performance**

The market value of a wind turbine is reflected in the individual power curve, as it is the predominant economical determination of a wind turbine. Besides the importance of the power performance of the wind turbine to the economic success of the wind farm operation, a relatively high number of operators still believe in its fulfillment and do not perform power curve verifications once the turbines have been installed.

Power curve verifications will give evidence on whether the contractual power curve is achieved by the installed wind turbine or lacking in its fulfillment. It can be seen from two perspectives: a formal perspective of achieving the power curve according to the contractually agreed conditions. Furthermore, the objective of power curve verification is to identify even smaller deviations from the contractual power curve enabling the investor to negotiate reassessments of the installation or other mitigations with the turbine manufacturer independent of any contractual obligation.

**Case2:** After installing 2 wind farms with the same turbine manufacturer, an operator realized that one of them was underperforming. The approach of the owner to address this situation was to perform power curve verifications for both wind farms. The results are shown below. Here a significant deviation from the contractual power curve can be identified in the bins until reaching rated power.

Although the verification confirmed that both wind farms were operating within the agreed contractual parameter, the results of the PC verification supported the owner in negotiating the improvement of performance with the manufacturer.

Power performance of wind turbines can be reduced due to various events. One of the key events in the lifetime of a wind farm is obviously the installation and commissioning process. Having passed over mistakes in the installation/commissioning process, turbines might operate with reduced performance, lower availability and usually higher loads—so having a direct effect on the lifetime of the wind turbine or component. But also further events like changes in the operational software or changes in operational parameters can heavily influence the power performance of wind turbines.
Case 3: In another case was linked to mistakes in the installation & commissioning of the wind farm. Having corrected several installation problems, the power curve—here only measured with the wind turbine SCADA, could be changed as follows:

2. Increased cost of operation

As discussed above, revenue shortfall is clearly the most relevant risk to the performance of a wind farm investment. However significant increase of operating costs might heavily affect the cash flow of operating projects. In single cases, increased cost of operation turns out as dramatic as the shortfall of revenue. Especially when looking at markets with low remuneration rates, the economics of wind farm projects are very tight. For this reason, an optimized management of operational cost is essential to succeed in the operation.

The most tangible part determining the success of a wind farm in terms of operational costs are the O&M and repair cost. Generally wind farm owners experience high O&M and repair costs from two sides:
- Cost forecast and repair reserves are not adequate and sub-estimated at the moment of acquisition/start of operation of the wind farm;
- Even relying on a realistic O&M/repair forecast, the selected technology requires repair cost that are
higher than the benchmark. The first reason can be addressed through reasonable care during the investment phase. The second problem is rather hard to assess beforehand and usually hits the operator with two effects:

- Low availability of the wind farm—thus lower electricity generation and
- Unforeseen increase of cost which can lead, in extreme cases, to claims between the manufacturer and the operator.

Mitigation strategies

Again, as seen above, high quality engineering from the very beginning of the wind farm planning is crucial for a successful wind farm operation and pays off—especially when facing critical situations. Close follow-up by the owner from taking over of the wind farm through end of warranty inspections and regular follow-up inspections, data analysis of the CMS and SCADA data and active management of the maintenance activities would be the tools to enable the owner to reduce the risk of unforeseen cost for repair and/or substitution of the wind turbine or individual components.

Serial component damages

An extreme case of increased operational cost is from serial damages to components of the wind turbine. Even high quality providers of wind turbines are facing such cases of serial damage to components. When facing discussions between the various involved parties—usually the owner and the manufacturer—Root Cause Analysis to identify here as one of component breakage is crucial to defend the owner interest based on documentary assessments, inspections and usually assessment of the environmental conditions. Performing such kind of third-party witnessing enables the owner to argue objectively with the manufacturer about damages and respective liability. For such kind of assessments, specialized teams are setup for the questionable component.

Conclusion

In order to reduce risk of shortfall of revenue:

- High quality engineering from the very beginning of wind farm planning until installation;
- Reliable technology to be selected for the site;
- Skilled and experienced teams for installation and operation and maintenance;
- Continuous follow-up of operation through periodic turbine inspections, verification of operational data, etc.

Finally wind farm operations require an active management. In spite of this, risks will still exist but the indicated measures should enable the operators to considerably reduce risk.

About UL-DEWI

Combining technical expertise with many years of in-depth industry experience, the DEWI Group (a UL company) offers global, one-stop wind energy services to turbine manufacturers, component manufacturers, project developers, utilities and other companies within the sector. The DEWI Group helps stakeholders—developers, investors and operators—to identify the critical aspects related to wind farm projects through comprehensive one-stop services, individually tailored and flexibly delivered. Worldwide we have completed more than 270 Due diligence projects, 1,610 power curve measurements & wind measurements and More than 3,630 energy yield assessments in over 30 countries.

UL-DEWI’s due diligence team supports the various stakeholders, banks, investors, operators in wind farm and PV projects with the aim to identify and evaluate technical project risks. UL-DEWI offers due diligence services for the complete life cycle of a project, with verification processes precisely tailored to the needs of the client.

- In the project development stage: Classic project review during investment or financing decisions;
- During implementation: Monitoring of construction work, acceptance tests and financial controlling;
- During operation: Inspection of the wind turbines or individual components, analysis of operating data.

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