The Total Return Hedge – An approach to overcome the limits of index hedging
1.1 Weather hedging in the energy industry

• In ‘traditional’ energy markets like
  - natural gas supply for heating purposes
  - power supply for air conditioning
    weather is also an important driver for profitability, however there the demand side is affected.

• In these markets weather derivatives are a standard tool for risk management, for example hedging out risk of a warm winter with put options on Heating Degree Days (Europe) or hedging out risk of a cool summer with call options on Cooling Degree Days (US).

• In both markets this business has become a billion € respectively USD business.

=> What is the reason for the success of weather derivatives in these markets?

• Managing risk with weather derivatives allows for cash flow stabilization as it makes profits more plannable.

• In temperature the basis risk, means the difference between the unwanted deviation in income and the payout provided by a professional structured weather derivative is very small, which means the hedge works almost perfectly.

• Reason for this is that in temperature driven energy markets the correlation between temperature and energy consumption is very high and well defined by so called sigmoid functions (they literally exist for each location and consumer group and simply need to be aggregated to give a large wholeseller the basis for his hedging programme).

=> Sounds all great but now let’s turn to the world of renewables and particularly wind
1.2 Wind power generation

- Wind power generation is besides solar and hydro power generation the generation with lowest fuel cost, zero.

- In many markets its generated MWhs are heavily subsidised which make it an interesting investment opportunity (However this currently changes, at least in Germany).

- As a result traditional finance structure of wind projects is highly leveraged, often about 80% debt + 20% equity and certainly investors want to make sure that they get their money back.

- Most important influence factor for cash flow is wind speed with its well known natural volatility, however there are also parameters to be considered, like
  - grid constraints
  - planned or unplanned outages
  - administrative measures like turn-offs due to bird protection etc.
  - short term nomination requirements with penalty systems

- This creates uncertainty about cash flow from power sales and thus a very conservative evaluation approach of lenders.

- If investor’s comfort level could be increased more investments could find sponsors.

- To increase investor’s comfort level one needs to make this exposure manageable.

- Before it can be managed it must be exactly defined.
The reinsurance industry owns wind assets, has operators under contract, insures the industry against weather and all other perils and also has a deep understanding of finance.

Whilst they do not have the detailed operational knowledge of an operator they have much better know how to take and manage all the risk involved than any individual participant along the value chain of wind generation.
MARKET DEVELOPMENT: EEG 2017 (onshore)
• More and more markets transfer their fixed feed-in tariffs into more market oriented models (e.g. Germany)
• From 2017 on tenders will apply for new installations (2.800 MW/a)
• With the EEG 2017 Germany establishes an annual auction system with limited maximum capacity and a system of reduced regional different subsidy factors.
• Investors need to bid for new installations with the lowest bids come first until tender is closed

Before EEG 2016 largest risk was risk of lack of wind which could at least be mitigated with index hedges. One only had to care about volume risk because the generous feed-in tariffs guaranteed a sound margin.

EEG 2016 introduces the ‘reference location’ based FIT system which finally depends on governmentally authorized wind expertises and is subject to review only every 5 years. Depending on location subsidies are cut by up to 40% (see next slide). So in the much more competitive auction environment investor’s risk is increased beyond the ‘normal’ volume and basis risk and plannability of future cash flows becomes even more important.

Wind index hedges with a contract duration of 5 years and longer are already available, however challenge of basis risk still needs to be solved.
New German Feed in Tariff System according to EEG 2017 (onshore) ‘penalizes’ high quality wind locations and fosters low quality wind locations. Idea is to reach a better regional distribution of installations and thus reduce pressure on the grids.
1.5 Wind speed: volatility and trend: Germany

- Investment decisions based on data until 1995 have not created the expected results.
- It looks rather that there is a trend of decreasing wind speed.
- As a result producers started to look for financial protection particularly against lack of wind (but also excess wind).
- So far only protection on basis of weather station observations or reanalysed data have been available, both leaving clients with basis risk.

Estimated annual volatility of wind is 10 – 20%
1.6 Wind speed: volatility and trend: Turkey

- In other markets it looks similar, partly even higher volatility but also phenomena of general decreasing wind speed.
- As new projects are most vulnerable to cash flow variations in the first years the incorporation of wind hedges might have been proven to be a good idea.
2.1 Index Hedging

Traditional risk mitigation approach are weather derivatives which are based on Wind Production Indices. A Wind Production Index is based on measured wind speed and theoretical power curve. The wind production index (WPI) created thereof is calibrated towards historical production (if available) and provides a proxy for actual production.

\[
WPI = \left[ \sum_{i = \text{January 1st}}^{\text{December 31st}} P(\bar{v}_i) \right] \times 24\text{h} \times \text{No. of Turbines} \times \text{Efficiency Factor}
\]

\[
P(\bar{v}_i) = \text{Turbine Power Curve} \quad \bar{v}_i = \text{Hourly Average Wind Speed (m/s)}
\]
2.2 Index Hedging (Refinements)

First one needs to distinguish whether the wind park to be hedged is already in operation or not. The first case is the easier one, the second one is rather difficult but will become particularly relevant in Germany with the EEG 2017.

- In both cases one uses reanalysed data for turbine’s exact geographical coordinates which is calibrated towards turbine axis height.
- One needs to consider wake factors from inside the park (other turbines) as well as outside (e.g. landscape specifics). They certainly also depend on prevailing wind direction.
- Finally a theoretical production curve is established which only variable is reanalysed wind speed at turbine axis height.
- For existing wind parks the theoretical production curve will be calibrated towards the historical production.

With wind parks not yet in operation it is much more difficult to build a proper index hedge.

- One needs to have trust in the wind expertise which even when elaborated for the best might prove to be wrong.
- All technical assumptions like wake factors finally etc. are only assumptions.
- The very important calibration of the theoretical (park) power curve to the observed production is not possible.
- Best approach is to compare with production data of somehow comparable parks.
3. Hedging Instruments available (1)

- The Wind Production Index (WPI) as defined on page 10 with wind speed as only variable is the ‘Underlying’ of the Hedging Instrument.

- For the WPI there is a defined strike volume expressed in [MWh] which normally is equivalent to the financially minimum required generation of the park, e.g. P(80) or P(85)

- It is important to stress that this is approach hedges the actual theoretical power generation calculated with contract formula in [MWh].

- The buyer of a wind production index put option is indemnified with positive difference between the agreed index strike level and the actual theoretical power generation calculated with observed or reanalysed wind speed.

- Alternatively operator or investor might also enter into a swap agreement which comes along with reduced premium (in extreme cases down to zero).
### 3. Hedging Instruments available (2)

<table>
<thead>
<tr>
<th>Structure Type</th>
<th>Put Option on power generation index (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underlying</td>
<td>Wind Production Index</td>
</tr>
<tr>
<td>Wind Park</td>
<td>Turkey</td>
</tr>
<tr>
<td>Longitude</td>
<td>26° 45' 26.1&quot;</td>
</tr>
<tr>
<td>Latitude</td>
<td>41° 05' 12.2&quot;</td>
</tr>
<tr>
<td>Buyer</td>
<td>Client</td>
</tr>
<tr>
<td>Seller</td>
<td>Risk Taker</td>
</tr>
<tr>
<td>Risk Period</td>
<td>January 1, 2017 until December 31, 2019</td>
</tr>
<tr>
<td>Turbine Type</td>
<td>20 x Vestas V126/3300 (3.3 MW)</td>
</tr>
<tr>
<td>Efficiency factor</td>
<td>0.95</td>
</tr>
<tr>
<td>Turbine axis height</td>
<td>127 m</td>
</tr>
<tr>
<td>Hourly Wind speed vi</td>
<td>Average hourly wind speed in m/s at turbine height level</td>
</tr>
</tbody>
</table>

#### Wind Production Index WPIA

\[
WPI = \left( \sum P(\frac{\nu}{\nu}) \right) \times 24h \times 20 \times 0.91
\]

whereby: \( P(\frac{\nu}{\nu}) \) = Turbine Power Curve and \( \frac{\nu}{\nu} \) = Hourly Average Wind Speed (m/s)

- **Wind Production Index Strike WPI**: 120'000 MWh
- **Tick Size**: 73 €/MWh
- **Payout Formula**: \( \text{Max}(0; (\text{WPI} - \text{WPIA}) \times \text{Tick Size}) \)
- **Payout Limit**: 292'000 €
- **Premium**: [to be discussed]

#### Turbine Power Curve \( P(\nu) \)

<table>
<thead>
<tr>
<th>m/s</th>
<th>kW</th>
<th>m/s</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>30</td>
<td>13</td>
<td>3'300</td>
</tr>
<tr>
<td>4</td>
<td>179</td>
<td>14</td>
<td>3'300</td>
</tr>
<tr>
<td>5</td>
<td>397</td>
<td>15</td>
<td>3'300</td>
</tr>
<tr>
<td>6</td>
<td>711</td>
<td>16</td>
<td>3'300</td>
</tr>
<tr>
<td>7</td>
<td>1'150</td>
<td>17</td>
<td>3'300</td>
</tr>
<tr>
<td>8</td>
<td>1'723</td>
<td>18</td>
<td>3'300</td>
</tr>
<tr>
<td>9</td>
<td>2'484</td>
<td>19</td>
<td>3'300</td>
</tr>
<tr>
<td>10</td>
<td>3'090</td>
<td>20</td>
<td>3'300</td>
</tr>
<tr>
<td>11</td>
<td>3'290</td>
<td>21</td>
<td>3'300</td>
</tr>
<tr>
<td>12</td>
<td>3'300</td>
<td>22</td>
<td>3'300</td>
</tr>
</tbody>
</table>
4. Limitations of index hedging

WIND PARK GENERATION
• The actual physical generation of the wind park is measured by the grid operator.
• This energy amount determines the payout for the operator or investor.

BASIS RISK
• The BASIS RISK risk is the risk that there is a difference between actual Wind Production Index and actual Wind Park Generation.
• Its root causes are manifold and its magnitude varies from wind park to wind park.
• The traditional approach is that basis risk is left completely with operator / investor.
• Investor’s point of view might be that even in case one tries to mitigate the largest risk (weather) the current hedging tools do not allow basis risk removal
• As wind power index derivatives already reduce the margin whilst providing only a proxy hedge many investors shy away from using them. This is different to other areas with few or no basis risk like temperature / natural gas sales.

➢ The fact that most risk takers in the renewables area have a very good view on most components of basis risk raises the question whether this is an efficient approach.
BASIS RISK DEFINITION
• Deviation between the value of the Wind Production Index and Actual Power Generation.

TURBINE AVAILABLES
• A wind turbine has in every time unit two possible technical availability conditions, it’s either available or unavailable to produce power. The availability status is measured on a continuous basis by the Condition Monitoring System inside the turbine which is turbine manufacturer’s property (see also separate page about availabilities)

POWER CURVE
• There are variations even in same turbine type
• Depend on turbine’s production tolerances
WIND DIRECTION AND TURBULENCES
• Traditional weather derivatives refer to wind speed only
• Wind direction counts for 40% of a wind farm’s output
• Turbines have flexibility regarding wind direction but it’s difficult to predict and park is designed for major wind direction

SHADING EFFECTS
• Are known from the park design and should be considered in the Wind Production Index

WEAR AND TEAR
• Function of turbine’s age and maintenance, has strong influence on technical availability

![Wear and Tear Diagram](image)

- a) Periodical maintenance
- b) Condition related maintenance
- c) Outage (and possible consequent damages)
5 Basis Risk – Root Causes and Conclusion (3)

ADMINISTRATIVE CUT OFFS
• Grid Constraints
• Bird Protection measures

MARKET PRICE CONSIDERATIONS
• Negative Power Prices and other cut-off incentives

CONCLUSION
• Basis risk obviously has a couple of dimensions, for its understanding and possible coverage one needs to look at the world of availabilities as well as turbine’s Condition Monitoring System (SCADA data)
  ➢ A turbine is only able to produce if it’s technically available
  ➢ If it is not available for whatever reason ever it can’t produce
  ➢ However even if it is available it might not necessarily produce at all or what it would be expected to at a given power curve
  ➢ Reasons for this being manifold, e.g. weather, technical or economic considerations
• For a risk taker becoming comfortable with a total return hedge one would need to be able to quantify this whole complex and put a value to it
6.1 Approach to an ‘ideal’ solution: The total return hedge

THE APPROACH

• The final aim would be a ‘Total Return Hedge’ which would guarantee for a defined period a minimum (fixed) cash flow for a given investment
• Given the nature of the business on the one side there will always remain some necessary caveats on side of risk taker
• In addition there are particularly technical details in which risk taker relies on third parties' knowledge
• On the other side investor needs to make sure that risk taker understands the industries’ best practices, e.g. that there are situations where it makes sense to switch off turbines although they would be available
• So let’s look what would need to be hedged and how one could close the gap
6.2 The World of Availabilities (1)

1. Scheduled Maintenance

2. Predictive maintenance

3. Emergency maintenance

4. Technical availability

5. Time based availability guarantee (for 5 years)

6. General wind availability

7. Energetic Availability

8. Energetic based availability guarantee

9. Transmission Availability

10. Administrative Measures (bird protection etc.)

11. Market price based considerations (e.g. § 51 EEG)

12. Output
6.2 The World of Availabilities (2)

1. Scheduled Maintenance

2. Predictive maintenance

3. Emergency maintenance

4. Time based availability

5. Time based availability guarantee (for 5 years)

6. General wind availability

7. Energetic Availability

8. Energetic based availability guarantee

9. Transmission Availability

10. Administrative Measures (bird protection etc.)

11. Market price based considerations (e.g. § 51 EEG)

12. Output

See separate slide
AVAILABILITY OF WIND
• Usual pricing approach with reanalysed data.

TIME BASED AVAILABILITY
• Percentage of period in which a turbine is technically able to generate power. In a year with 365 days 100% correspond to 8,760 hours.

AVAILABILITY GUARANTEE
• Is normally issued for 5 or more years after installation but refers to TIME BASED AVAILABILITY. However relevant for client is ENERGETIC AVAILABILITY. Both Siemens and Vestas say they offer yield based guarantees but it sounds vague and details are not disclosed.

TECHNICAL AVAILABILITY OF TURBINE
• Identify status codes / availability groups which are still under (technical) warranty.
• Choose the remaining acceptable ones, exclude others from coverage.
• If no more warranty in place choose all acceptable ones and exclude others from coverage.
• Historical calculation of turbine's availability (use data from same turbines installed elsewhere if park is new).
• Considering aging process of turbine.
ENERGETIC AVAILABILITY

- Relationship between actual realized power generation and theoretical possible power generation at prevailing wind conditions. This means that technical non-availability at low wind speed has no or only small influence on energetic availability whilst at high wind speed the influence is larger. Energetic availability is a better economic indicator than time-based availability.

- Simultaneous analysis and future simulation of AVAILABILITY OF WIND and TECHNICAL AVAILABILITY OF TURBINE.

MAINTENANCE

- Consider maintenance plan in technical availability calculation.
- Production put needs to include operator's obligation for a reasonable maintenance policy according to industry standards ('condition related maintenance').
- Industries best practice needs to be considered.

Source: Iberdrola, EWEA 2013
### 6.3.1 Pricing Approach for the Risk Factors – Availabilities (3)

<table>
<thead>
<tr>
<th>Availability Group XX</th>
<th>Parameter Value</th>
<th>Turbine technically able to produce?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status Code 1</td>
<td>INFORMATIONAL, WARNING OR STOP</td>
<td>yes or no</td>
</tr>
<tr>
<td>Status Code 2</td>
<td>INFORMATIONAL, WARNING OR STOP</td>
<td>yes or no</td>
</tr>
<tr>
<td>Status Code ...</td>
<td>INFORMATIONAL, WARNING OR STOP</td>
<td>yes or no</td>
</tr>
<tr>
<td>Status Code n</td>
<td>INFORMATIONAL, WARNING OR STOP</td>
<td>yes or no</td>
</tr>
</tbody>
</table>

- Availability are determined by availability groups which themselves consist of an array of status codes.
- For each turbine this array of status codes is continuously monitored. Each status code has assigned possible parameter values (e.g. INFORMATIONAL, WARNING OR STOP) which are linked to certain conditions or thresholds.

n x yes => Turbine is **technically available** according to this Availability group

(<n) x yes => Turbine is **technically unavailable** according to this Availability group
Availability for each turbine is continuously measured at the end of the risk period one gets a table of the monthly availability of each turbine:

By adding availabilities over the turbines one gets the parks total monthly availability during the risk period (measured in hours or percentage):
Reason for grouping Status Codes in Availability Groups becomes obvious here:

<table>
<thead>
<tr>
<th>Turbine Type</th>
<th>Status</th>
<th>Code</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Warning</td>
<td>0</td>
<td>System faultless</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>1001</td>
<td>Manual stop</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>1005</td>
<td>Availability - low wind</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>1007</td>
<td>Remote stop - Owner</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Warning</td>
<td>1022</td>
<td>Local, scheduled service work</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Warning</td>
<td>1023</td>
<td>Local, ad-hoc / repair work</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Warning</td>
<td>1024</td>
<td>Local, customer / guest visit</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>1115</td>
<td>Strong Twr. Vib. (SS stopped)</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>7102</td>
<td>Hyd oil temperature error</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>7106</td>
<td>Pitch pump. time too long,stop</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>7110</td>
<td>Hyd. oil temp. sensor error</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>7111</td>
<td>Hyd. for crane/cover activated</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8000</td>
<td>Windspeed too high to operate</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Warning</td>
<td>8108</td>
<td>FT1 Sonic wind sensor error</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Warning</td>
<td>8114</td>
<td>FT1 Configuration error</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8131</td>
<td>Pri. Windspeed &lt; expect, icing</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8135</td>
<td>Pri. Windspeed Range err, icing</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8136</td>
<td>Sec. Windspeed &lt; expect, icing</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8180</td>
<td>Pri. Windspeed Range error</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8184</td>
<td>Pri. FT sensor turbulence error</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8185</td>
<td>Many Anemometer activations</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8187</td>
<td>Many Wind Vane activations</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8230</td>
<td>Ice detection: Low torque</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8234</td>
<td>Ice detection: No cut in</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8801</td>
<td>Blade de-icing active (stop)</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Stop</td>
<td>8802</td>
<td>Blade de-icing active (idle)</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Informational</td>
<td>9995</td>
<td>Data communication unavailable: Turbine - ParkPC (Modem)</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Informational</td>
<td>9996</td>
<td>Data communication unavailable: Turbine - ParkPC</td>
</tr>
<tr>
<td>Siemens SWT-2.3-101</td>
<td>Informational</td>
<td>9997</td>
<td>Data communication unavailable: Turbine - Breeze</td>
</tr>
</tbody>
</table>

- System faultless, Status Warning, Turbine Available (=1)
- Low wind speed, Status Stop, Turbine Available (=1)
- High wind speed, Status Stop, Turbine Available (=1)
- Blade de-icing, Status Stop, Turbine Unavailable (=0)
- Data communication unavailable, Status Informational, Turbine Available (there is even literature available about this status code) (= unknown)
6.4 Example for Status Codes (2): Example Vestas V90 2 MW

There are also different Status Parameters for identical Status Codes so all very generator specific (e.g. Status Code 0 INFORMATIONAL VERSUS WARNING)

<table>
<thead>
<tr>
<th>Turbine Type</th>
<th>Status</th>
<th>Code</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Informational</td>
<td>0</td>
<td>Turbine OK</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>30</td>
<td>Internal sublogic error</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>76</td>
<td>PitchC pos:Â° vel:Â°/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>79</td>
<td>Max. Yaw error: Â°</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>79</td>
<td>Max. Yaw error: 239.1Â°</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>83</td>
<td>B Ctrl:34.59V P.Vel:0Â°/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>83</td>
<td>B Ctrl:35.31V P.Vel:0Â°/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>83</td>
<td>B Ctrl:34.14V P.Vel:0.1Â°/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>84</td>
<td>C Ctrl:V P.Vel:Â°/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>102</td>
<td>Emergency circuit open</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>144</td>
<td>High windspeed: m/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>144</td>
<td>High windspeed: 25 m/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>144</td>
<td>High windspeed: 25.1 m/s</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>151</td>
<td>High temp. Gen bearing 2:177Â°C</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>176</td>
<td>Error on all wind sensors</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Warning</td>
<td>178</td>
<td>Def. fuse, lightn. prot. (F9-11)</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>182</td>
<td>Feedback = 0, yawing CCW 0</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>187</td>
<td>Q8 open, US12 UL12</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>189</td>
<td>Feedback = 1, Brake</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>3621</td>
<td>Converter Disconnected in Prod</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Warning</td>
<td>3624</td>
<td>Tower nat frequency test not done</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>3630</td>
<td>PrevCabTwCode: CabTwCode:</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>3633</td>
<td>Yaw System Stopped</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>3656</td>
<td>Conv Charge Failed</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Informational</td>
<td>4185</td>
<td>Unknown status code</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>4917</td>
<td>RotorTachSpdSigErr.400.15</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Stop</td>
<td>4917</td>
<td>RotorTachSpdSigErr.400.12</td>
</tr>
<tr>
<td>Turbine type: Vestas V90 2MW</td>
<td>Informational</td>
<td>9997</td>
<td>Data communication unavailable: Turbine - Breeze</td>
</tr>
</tbody>
</table>

Turbine OK, Status Informational, Turbine Available (=1)

High wind speed (with Speed), Status Stop, Turbine Available (=1)

Converter disconnected in production, Status Stop, Turbine Unavailable (=0)

Data communication unavailable, Status Informational, Turbine Available (there is even literature available about this status code) (= unknown)
6.5 What should be in and what should be out of scope?

<table>
<thead>
<tr>
<th>Influence area</th>
<th>Risk Factor</th>
<th>Coverage</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside operator</td>
<td>Availability of wind</td>
<td>In scope</td>
<td>f(wind speed)</td>
</tr>
<tr>
<td>Outside operator</td>
<td>Technical availability of turbine</td>
<td>In scope</td>
<td>f(outage)</td>
</tr>
<tr>
<td>Outside operator</td>
<td>Energetic availability of turbine</td>
<td>In scope</td>
<td>f(wind speed, technical availability)</td>
</tr>
<tr>
<td>Outside operator</td>
<td>Deviations of wind expertise and actuals</td>
<td>In scope</td>
<td>f(wind speed, long term)</td>
</tr>
<tr>
<td>Partly with operator</td>
<td>Maintenance</td>
<td>Might be partly in scope</td>
<td>f(warranty, trade off wear &amp; tear vs. technical availability)</td>
</tr>
<tr>
<td>Outside operator</td>
<td>Power Curve Deviations</td>
<td>Out of scope</td>
<td>Turbine manufacturer</td>
</tr>
<tr>
<td>Outside operator</td>
<td>Administrative measures</td>
<td>Out of scope</td>
<td>n.a.</td>
</tr>
</tbody>
</table>
Due to the different technologies of different turbine one needs to define for each turbine type which status codes are covered or not. Particularly in the area of predictive maintenance this requires very specific know how. Complexity is added by phenomena like power curve deviations within the same turbine type.
6.6 Conclusion re insurability

- A total return hedge might be very desirable for the renewables industry, however a parametric style production hedge at whatever level is quite a challenge for the risk takers of this world.

- Reason not only that particularly in the area ‘available but not producing for any reason’ there are lots of combinations which might need to be excluded in a traditional insurance approach but should not be excluded if considering best industry experience (particularly in the area maintenance).

- Although they own assets the know how about best industry practice is not necessarily with the risk takers of this world as they outsource their asset operations to third parties.

- So an ideal solution would be a business set-up in which a third independent party is involved which
  - makes sure that risk taker understand what they insure and receive the necessary information including data to make them comfortable with taking the risk.
  - monitors that investor conducts ‘best market practices’ when operating his plants.
  - acts as independent calculation agent / claims settlement manager for the settlement process.
6.7 Approach to an ‘idea solution’ with a Calculation Agent

- Calculation Agent
- Investor
- Asset
- Risk Taker

**Input Components:**
- Fixed Investment [€]
- Revenue from power generation [€]
- WPI Hedge Payoff [€]

**Output Components:**
- Revenue from power generation – Hedge Margin [€]
- Best practice monitoring and settlement

**Flow of Information:**
- Calculation Agent 
  - Input from Investor 
  - Input from Asset 
  - Input from Risk Taker

- Investor 
  - Input from Asset 
  - Input from Calculation Agent 

- Asset 
  - Input from Calculation Agent 
  - Input from Investor 

- Risk Taker 
  - Input from Calculation Agent 
  - Input from Investor 
  - Input from Asset
6.8 Product Development: Munich Reinsurance Group is looking for a pilot client to set up the product

1. Ideally a brownfield project with sufficient historical data available (including original wind expertise).

2. Openess in the structuring process would be necessary.

3. Calculation agent would be involved in the structuring process from the beginning (idea would be an operator who manages about 250 MW within Europe).

4. Incentive for pilot client would be not only getting a new kind of cash flow protection but also at the utmost competitive risk transfer price.
6.9 Data to be provided by client (as a starting point)

1. Technical details of wind park
2. Wind expertise
3. Historical production if available
4. Array of availability groups, status codes and availabilities including their history
5. Risk engineering report if available
6. Information about coverages (warranties, insurances) still in place (to be filtered with the status codes)
7. Maintenance Plan

On request a non disclosure agreement will be signed.
Thank you!

Contact:

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