Power Performance
Optimisation

Optimise your turbine
performance

Data accuracy **impacts** your turbine performance.

A wind turbine controller is in many ways the brain of the turbine. The effectiveness of the controller is highly dependent on the accuracy of the data it receives. The more accurate the data, the better the adaptation of the turbine to its climatic conditions.

The two main input signals that determine a wind turbine's performance are the wind speed and the wind direction in front of the turbine's rotor. It is these inputs signals that allow the turbine to optimise its yaw alignment, pitch angle and rotor speed. This in turn, impacts the turbine loads and energy production. The more upwind the turbine is aligned, the smaller the load impact and the greater the energy output.

Algorithms that improve wind measurements

Today, most wind turbines measure wind speed and wind direction via sensors located on the nacelle behind the rotor. These measurements differ from the wind speed and wind direction in front of the rotor due to the turbulence created by the rotor and the nacelle. Algorithms are used to convert the measurements from the wind sensors into estimations of the actual wind speed and wind direction in front of the rotor.

The algorithms improve the adaptation of the wind turbine to the site conditions through continuous correction factor calculations for wind speed and wind direction measurements. The correction factors applied in the algorithms are based on prototype turbine measurements. They are naturally sensitive to obstacles in front of the turbine, the alignment of the sensors, and site-specific conditions such as complex terrain. It is for this reason, that an upgrade of these software algorithms to actual site conditions of the turbine is beneficial for asset owners.

Power Performance Optimisation

Vestas continuously develops innovative solutions that make wind turbines even more effective. Vestas PowerPlus® product range targets performance optimisation of turbines already in operation. As part of Vestas PowerPlus®, we offer software upgrades that can increase your wind turbine's annual energy production by up to 1.5%*. We call this Power Performance Optimisation.

The smart software algorithms that Vestas has developed for Power Performance Optimisation improve wind measurement estimates. Ultimately, this leads to an optimisation of the pitch angle and the yaw alignment of the turbine. Furthermore, the algorithms allow for smarter use of power boosts and for the turbine to exploit low air density conditions.

*Dependent on wind and site conditions

Are you looking to **maximise** the output of your operating wind assets?

The software upgrades available under Power Performance Optimisation address the Partial Load Area of a turbine's power curve and increase the energy capture when the turbine operates below rated power. In practice, we achieve a more effective turbine performance by optimising each wind turbine's default software settings to its unique site and climatic conditions. The individual software features of Power Performance Optimisation facilitate this in three different ways:

Optimise pitch angle, rotor speed and yaw alignment

The first two software upgrades, Wind Speed Estimator and Adaptive Wind Sensing, work to optimise the accuracy of wind speed and wind direction measurements. This is achieved through the introduction of smart algorithms that automatically and continuously correct the measurements. In turn, this increases the accuracy of a turbine's pitch angle, rotor speed and yaw alignment without impacting its loads.

Wind Speed Estimator: Wind speed is commonly measured via sensors located on the nacelle behind the rotor. These measurements differ from the wind speed in front of the rotor due to turbulence created by the blades and the nacelle. The software estimates the wind speeds in front of the rotor in order to minimise the impact of the turbulence. This is achieved by calculating the wind speed from the turbine's blade pitch, rotor speed and power readings. The optimised wind speed measurements allow

for setting the optimal pitch angle of the blades and speed of the rotor to the actual wind conditions on the site for a greater power output.

Adaptive Wind Sensing: The software evaluates and improves the accuracy of the turbine's yaw alignment. This is achieved through automatic and continuous self-calibration based on the peak power of the turbine. The software also minimises uncertainties associated with the site and the default settings of the wind sensors. The result is a greater upwind alignment of the turbine according to the specific site and its climatic conditions. Ultimately, this contributes to a greater wind capture and a greater energy production.

Optimise operation at higher thrust levels

The third software feature, Variable Thrust Limiter, optimises the operational strategy of the turbine according to the site-specific turbulence.

Variable Thrust Limiter: The software is an inbuilt control feature in Vestas wind turbines, which allows the turbines to operate at defined thrust levels. During manufacturing, the software settings are predefined according to the turbine variant's design envelope. The retrofit upgrade to the Variable Thrust Limiter targets operating turbines that exhibit available load margins in their design envelope. The upgrade allows the inbuilt thrust levels to be scaled according to the actual site conditions. De-

Impact of Power Performance Optimisation on the power curve

Power

Normal power curve ■
Power performance optimisation ■

Wind speed
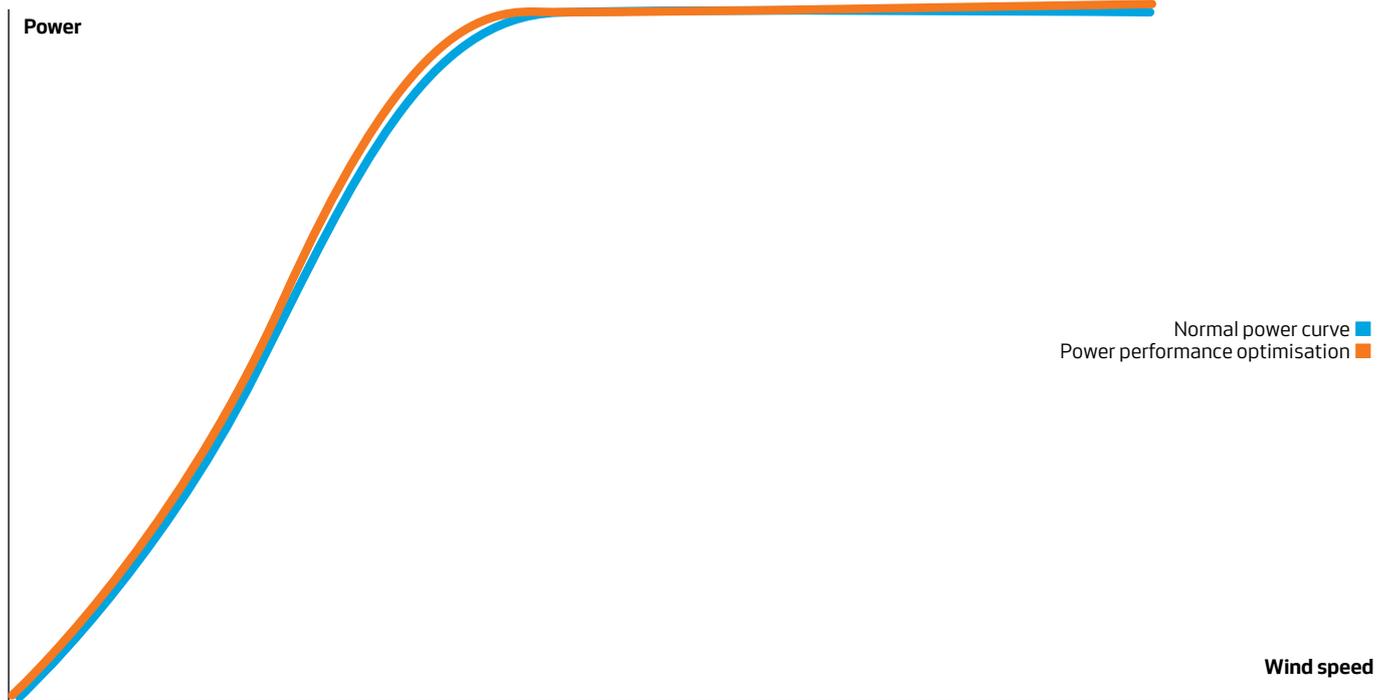
Power Performance Optimisation can provide up to 1.5% increase in annual energy production. The performance upgrades as part of the Power Performance Optimisation portfolio target performance improvements on the slope of the power curve in partial load operation.

pending on the specific site turbulence, the software enables the turbines to operate at higher thrust levels by adjusting the pitch angle without exceeding their design loads.

Optimise the turbine's boosting periods

The fourth software upgrade, Extended Power Boost, lengthens the time in which the turbine's power is boosted.

Extended Power Boost: The software is an inbuilt control feature in Vestas wind turbines. The default software allows the turbine to boost 5% of its nominal power for five seconds when it reaches rated wind speed. The Extended Power Boost software prolongs the boosting period up to 200 seconds. In this way, the feature improves the power performance of the turbine by boosting its rated power for longer intervals. The duration of the extended boost depends on the available load margins of the turbine.

Availability of Vestas' Power Performance Optimisation:

V80-1.8/2.0 MW® *
V90-1.8/2.0 MW® *
V90-3.0 MW® **
V100-2.0 MW®
V110-2.0 MW®
V112-3.45 MW®
V117-3.45 MW®
V126-3.45 MW®

* Requires controller upgrade to VMP Global. Variable Thrust Limiter is not available for this variant.

** Requires controller upgrade to VMP Global. Variable Thrust Limiter and Extended Power Boost are not available for this variant.

No load impact

Wind Speed Estimator and Adaptive Wind Sensing increase the accuracy of a turbine's pitch angle, rotor speed and yaw alignment **without impacting its loads.**

Fast and accurate **validation** of performance data

DNV-GL certified

Vestas has developed a thorough, DNV GL certified, Toggle Validation analysis for validating performance improvements.

When installing a retrofit upgrade on a wind turbine, it is important to assess its impact and expose any potential risks involved. This is why we perform a site and turbine specific analysis and provide you with a business case calculation prior to any Power Performance Optimisation project. This enables you to make a well-informed decision, while increasing the certainty of your return on investment.

We upgrade when it makes economic sense for you

The business case includes an estimation of the increase in annual energy production that can be expected from the software upgrades. This means that we only install Power Performance Optimisation on sites where it makes economic sense for the asset owner.

Following the installation and the successful operation of the upgrades, the estimated annual energy production is validated against the actual performance improvements. Vestas has developed a thorough, DNV GL certified, Toggle Validation analysis for this specific purpose.

Toggle method provides fast, accurate validations

Toggling offers an accurate validation of on-slope software performance upgrades like Power Performance Optimisation. Vestas' Toggle Validation uses live production data. Intervals where the upgrade features are turned on are compared to intervals where the upgrades are turned off.

Compared to traditional target reference methods, which normally takes 12 months, our method brings the validation period down to just 4-6 months. This allows for a significantly faster validation of the production gains of the upgrade features.

Today, we have validated the increase in energy production on more than 40 projects with more validation results for newer features such as Extended Power Boost and Variable Thrust Limiter under way.

Validated results
show clear increases
in energy production

0.8%
AEP
increase

Country: Sweden
Turbine type: V112-3.3 MW
Upgrade: Wind Speed Estimator, Adaptive Wind Sensing

Vestas estimated an increase in annual energy production of 0.6%. The actual increase in annual energy production was 0.83%.

0.5%
AEP
increase

Country: United Kingdom
Turbine type: V90-2.0 MW
Upgrade: Wind Speed Estimator, Adaptive Wind Sensing

Vestas estimated an increase in annual energy production of 0.36%. The actual increase in annual energy production was 0.54%.

0.8%
AEP
increase

Country: Sweden
Turbine type: V112-3.3 MW
Upgrade: Wind Speed Estimator, Adaptive Wind Sensing

Vestas estimated an increase in annual energy production
of 0.6%. The actual increase in annual energy production
was 0.78%.

0.5%
AEP
increase

Country: Poland
Turbine type: V112-3.3 MW
Upgrade: Wind Speed Estimator, Adaptive Wind Sensing

Vestas estimated an increase in annual energy production
of 0.6%. The actual increase in annual energy production
was 0.5%.

About the wind farm

Located in Heilbronn-Franken near Künzelsau, Bürgerwindpark Hohenlohe GmbH was found in 1999 by the entrepreneur Friedrich Hertweck. The turbines were the first to be commissioned in the region and run as a citizen project. The wind farm has 861 citizen shareholders and 14 citizen-owned wind turbines.

Increasing
energy capture
on V126-3.3 MW
in Germany

A citizen owned wind park in Germany was looking for ways to further optimise the energy production of its asset. Benjamin Friedle, CEO of Bürgerwindpark Hohenlohe GmbH, was involved in the process from the beginning. His main role was to determine which aftersales upgrade the wind farm should invest in. The decision fell upon Vestas Power Performance Optimisation. Benjamin Friedle explains why:

"We decided to implement Vestas' Power Performance Optimisation on six of our V126-3.3 MW turbines. Vestas had both the capabilities and the track record to prove the upgrade actually worked. With the upgrade, we could maximise the return on our investment for the benefit of our citizen shareholders."

Decision based on reliable data

For Benjamin Friedle and Bürgerwindpark Hohenlohe GmbH, it was important to understand, what return on investment could be expected from the upgrades. Vestas provided a site and turbine specific analysis together with an estimation of 0.69% increase in annual energy production and a detailed business case calculation for this purpose. These were not only very helpful, but also highly accurate, Benjamin Friedle recalls.

"Vestas provided an estimate of the increase in annual energy production that we could expect from the upgrades. This was an important factor in our evaluation of the upgrades and our investment. Following the implementation of the software

upgrades, we conducted our own internal assessment of the energy gains, which confirmed the estimates provided by Vestas."

A recommended upgrade

One year after the implementation of the upgrades, Adaptive Wind Sensing and Wind Speed Estimator have successfully been running on the six turbines. Together, they have enabled further optimisation of the turbines' yaw alignment, pitch angle and rotor speed for greater energy capture.

"The upgrade completely met our expectations. We can thoroughly recommend the software upgrade to other wind turbine owners"

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