Guaranteed performance gains and efficiency improvements

Upgrading Vestas V47-660kW

Newly developed controller system enables increased Annual Energy Production up to 6.1% and safe turbine lifetime extension

Thousands of Vestas V47-660kW turbines have been installed around the world since its introduction in 1997. With the first turbines nearing their end of design life, a consideration that turbine owners face is whether to continue operations.

Since many turbines are in conditions that allow for safe continued operations, turbine owners are looking for alternatives to decommissioning that do not end their stream of income. Operating a turbine beyond its design life imposes new requirements for O&M and turbine control, while offering an attractive opportunity to implement performance upgrades.

Vestas and Mita Teknik have developed an upgrade package to implement the latest production enhancement innovation to existing Vestas V47 turbines. The upgrade consists of three components:

- A hardware and software controller upgrade
- Vestas PowerPlus™ performance improvements
- Vestas LifePlus™ life extension solutions

This paper includes a technical presentation of the upgrades and demonstrates their value by showing performance gains and how the life extension solutions are validated and certified by DNV-GL.

In short; the controller upgrade is expected to deliver a performance gain of up to 2.5%, based on a combination of achieved results of controller upgrades on Vestas turbines and preliminary test results. The PowerPlus™ upgrades are expected to deliver 5.6% improvement in IEC-1 conditions, by implementing Power Uprate and Extended Cut Out.

Quick Facts: Controller Retrofit

- Improve annual energy production by 0.5-2.5%[1] through more efficient turbine operations
- Upgrade turbine performance with Vestas PowerPlus™ and increase AEP by up to 5.6%[1]
- Reduce OPEX through remote access and flexible performance management
- Extend turbine lifetime with Vestas LifePlus™ and benefit from improved spare parts availability

[1] Actual AEP improvement is depending on site- and turbine-specific conditions

Controller upgrades enable more efficient wind resource capture and remote operations

The controller system is essential to ensure efficient energy production. Performance management is improved by integrating single turbines into a network. This is enabled by cutting-edge hardware and software innovations based on Mita Teknik's WP3500 MK II controller system.

By integrating turbines in a network, operators and utility companies can control parameters such as curtailment and power quality. These parameters can be managed directly via SCADA or dedicated park control systems. Remote access to operational data and operating parameters enhances optimization of operating expenses, for example through enabling onsite tasks to be performed remotely.

A uniform family of controller enables the controller upgrade to be implemented across different turbine types. By using the same basis, the interfaces are kept identical. The interfaces include HMI, I/O and SCADA interfaces.

Multiple communication protocols are embedded in the controller system and enable full compatibility with SCADA and third-party add-ons. In addition to the proprietary MPP protocol these include Open MPP, TCP and IEC61400-25. The protocols are installed separately from the control system so that existing and new features can be added without changing firmware or the turbine control program.

The controller uses a modern processor capable of processing large amounts of data for statistical calculations, performance monitoring and applying advanced aerodynamic control algorithms. With this processor, the controller system is adequately equipped to perform complex tasks typically performed by large MW-turbines only.

Through advanced aerodynamic control algorithms and a new yaw position sensor, the turbine can improve its wind capture. The result is a significant increase of the annual energy production.

Verified improvement of turbine efficiency with the new controller upgrade

The indicated efficiency improvement through upgrading the controller is based on simulated power curves. The efficiency gains are currently being validated in field tests.

The measurement campaign is using two test sites, each including at least one test turbine with the controller upgrade and one reference turbine with the original Vestas VMP® controller. Data is collected by logging equipment installed on the test turbines. The equipment operates at a 10Hz frequency.

The two sites are located in flat terrain with a prevailing wind direction and a limited wake effect. In addition to sensor checks and outlier removal, only data from when both turbines showed similar operational characteristics, is utilized.

The test turbines include three V44-600kW turbines and two V47-660kW turbines in Denmark.

The V44-600kW is included in the field test study because of the high degree of similarity with the V47-660kW (i.e. same VMP controller software) and because identical controller upgrades and advanced algorithms are implemented. The V44-600kW test report is verified by using actual production data from the past four years. The verification indicates an improved annual energy production of 0.5%.

Although the data collection and fine-tuning campaigns for the V47-660kW are not completed, we can present indicatory results. The specific site shows an improved annual energy production of 2.5%.

How Vestas SiteCheck® is used to assess load margins of existing turbines

The V47-660kW turbines are designed for IEC-1A conditions that include high average wind speeds (22.4 mph). However, many V47 turbines are sited below their design conditions, resulting in load margins. Load margins include a factor of safety and indicate the strength of the structure compared to the loads it is designed for. These margins can be utilized to increase power production or extend turbine lifetime.

To assess the potential of the load margins for individual turbines, Vestas performs a detailed loads analysis. The analysis is based on models developed in Vestas SiteCheck® and includes a turbine-specific evaluation of loads and design life impact. In addition, a calculation to determine the annual energy production potential is conducted.

The load analysis compares the turbine's conditions during operation against original design conditions. By using simulation models, Vestas SiteCheck® can predict the impact of performance upgrades to the design life of a turbine or can calculate how many years a turbine can operate beyond its original design lifetime. The purpose of this analysis is to ensure no load margins are exceeded and to guarantee safe turbine operations.

The Vestas SiteCheck® methods and analysis models are validated and certified by independent certification body DNV-GL in accordance with the 'IEC 61400-1 ed. 3' guidelines.

Enhance the nominal power with Power Uprate

Power uprating is a well-known concept in the energy industry. The purpose of uprating is to enhance the nominal output of power sources. Vestas developed Power Uprate to increase the nominal power of its existing fleet and is now making it available for Vestas V47 turbines.

Temperature management of the turbine is necessary to implement Power Uprate without exposing the turbine and major components to failure risk. Until now, it has not been possible to manage temperatures in V47 turbines adequately. Installing the controller upgrade enables the Vestas V47 to be uprated to 710kW with safe temperature settings and avoid component overheating.

The nominal power of the Vestas V47 can be increased from 660kW to 710kW, as illustrated in Figure 1. In IEC-1 conditions the annual energy production can be improved by 4.5%.

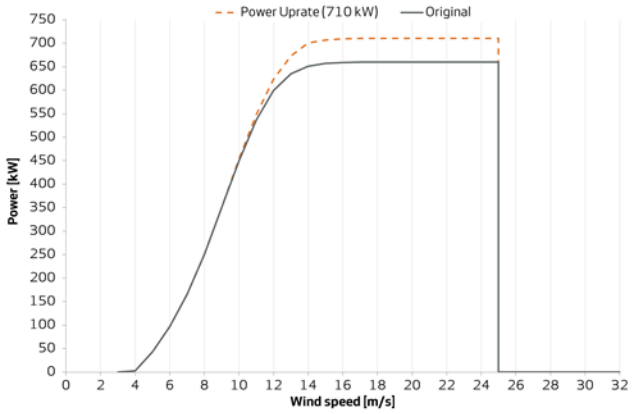

Figure 1 Power curve for Power Uprate on the Vestas V47

Increase operating range with Extended Cut Out

Extended Cut Out allows turbines to operate at wind speeds that exceed the standard cut-out wind speed. The standard certified cut-out wind speed is a balance between maximum energy capture and increased loading. At the cut-out wind speed, the turbine will cease production in order to protect against high loads to the structure of the turbine.

The cut-out point is determined by a 100 second exponential average. This average is used to prevent frequent production starts and stops, which not only causes stress on the turbine's drivetrain and additional wear and tear, but also impacts grid connections. Once the wind speeds reduce to a 100

second exponential average at or below the re-cut in set point, a start-up will be initiated.

If the cut-out wind speed is exceeded, the turbine will increase pitch until the turbine is in an idle state. While ceasing production, it is important to prevent so-called 'back-latching'. If the torque is reduced too quickly, the teeth inside the gearbox will have load on the wrong side of the teeth which can damage the gearbox.

For the Vestas V47-660kW the cut-out wind speed can be increased from 56 mph to 63 mph (see Figure 2), resulting in a production gain of 1.1% in IEC-1 conditions. In addition, implementing Extended Cut Out reduces impact of the hysteresis gap, which is the lag between pausing production at cut-out wind speeds and resuming production at cut-in wind speeds. The threshold of this lag is built in the turbine controller algorithms to prevent repeated production start-stops.

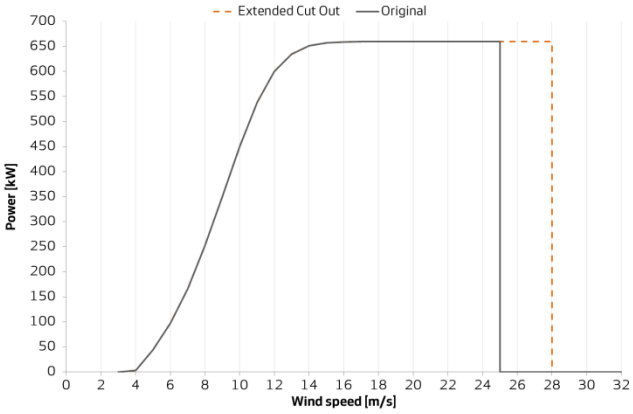

Figure 2 Power curve for Extended Cut Out on the Vestas V47

The availability of Vestas PowerPlus™ upgrades is depending on site- and turbine-specific analysis.

Increased power performance validation of Power Uprate and Extended Cut Out

The validation of performance gains is conducted through a direct comparison of actual before and after power curves. Actual data comparison relies on the nacelle-mounted anemometer to measure wind speeds and displays the effect of the Power Uprate and Extended Cut Out performance upgrades.

Operate turbines beyond the design lifetime with Vestas LifePlus™

The first Vestas V47 turbines are nearing the end of their original design life of 20 years. Vestas is now introducing LifePlus™ life extension solutions to this turbine. The solution allows V47 turbines to operate beyond original design life and fleet owners to benefit from additional years of revenue.

Vestas evaluates the remaining lifetime of each turbine based on a site-specific analysis of actual and design loads. By using simulation models to project turbine operations beyond the design lifetime, critical components can be monitored and, if necessary, identified for replacement. The comparison between actual and design loads can reveal if, and which critical components need to be replaced to enable a lifetime extension solution.

Vestas – Your fleetwide lifetime service partner

If you would like to learn more about how the new control system, PowerPlus™ performance upgrades and LifePlus™ life extension solutions can benefit your business, please contact your local Vestas Services office.

References

http://www.dnvgl.com/news/new-dnv-gl-standard-and-service-specification-for-lifetime-extension-of-wind-turbines-61059

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