POWER CURVE

Analysis of Vortex Generator upgrade of GE 1.5s on Atsumi wind turbine site, Japan.

1. Introduction

Figure 1 shows a site map of Atsumi together with the locations of the wind turbines.

Figure 1. Atsumi Site Map

The upgraded turbines at the Atsumi wind turbine site, Japan are turbines 2, 4 and 7.

Turbines 2 and 4 are marked with a red circle on Figure 2. Turbine 7 stands away from the other upgraded turbines as indicated on Figure 1.

Figure 2. Site picture from Google Earth.

2. Benchmark method

Our preferred benchmark method is the Side-by-Side method where the power signals of an upgraded and a reference turbine are compared before and after VG installation. This method requires that SCADA data is time synchronized (typically by a park controller) but unfortunately this precondition is not satisfied as the Atsumi wind farm does not have a park controller.

Thus the benchmark method used in this analysis is power curve comparison where the pre- and post- VG installation power curves are compared. This method is generally accepted but holds a somewhat higher uncertainty compared to the side-by-side method due to anemometer precision.

3. Filtering and procedure

The raw SCADA data provided amounts approx. 12 months before (baseline data) and approx. 6 months after upgrading (test data). The baseline period span from 01-10-2016 to 17-10-2017 and the test period span from 19-10-2017 to 08-04-2018. VG's were installed 18-10-2017. For turbine 2 the baseline period is adjusted to span from 01-01-2017 to 17-10-2017 due to repair work done on the turbine.

The analyzed power data is 5-1500 kW to exclude data points where the turbines are out of service. Data points where the turbines are in curtailment have been filtered out as well. Furthermore data points with wind speeds larger than rated wind speed (13,5 m/s) have been excluded in the AEP calculation as the VG's only have an effect below rated power. After filtering approx. 60 % of the raw data is left for analysis which is a statistical acceptable amount.

The Weibull shape and scale parameters used was 3.16 and 8.96 respectively and have been found utilizing MATLAB to fit a Weibull distribution on the provided wind speed data in the span 3-13.5 [m/s]. The fitted Weibull parameters correspond to an average wind speed of approx. 8 [m/s].

4. Individual turbine results

Figures 3-8 shows the power curve of the given turbine both before and after the VG installation date, together with a scatter plot showing power data points. The scatter plots show some outlying data points after filtering marked with green in Figure 3. Since the number of outliers are limited and occurs in both the baseline- and test period they will not affect the result.

Turbine 2:

Figure 3 and 4 show that the power curve is shifted to the "left " after VG installation

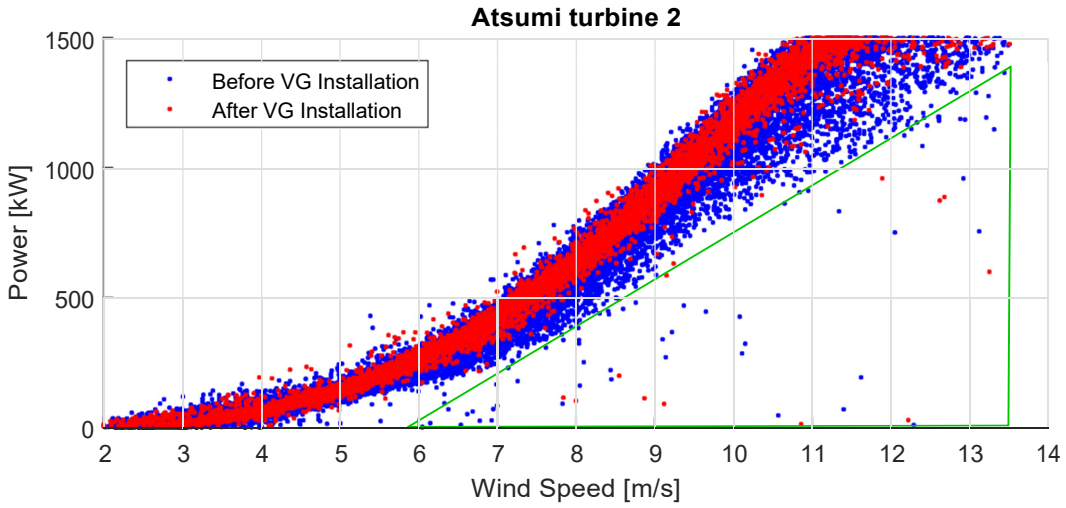

Figure 3. Scatter plot of Turbine 2

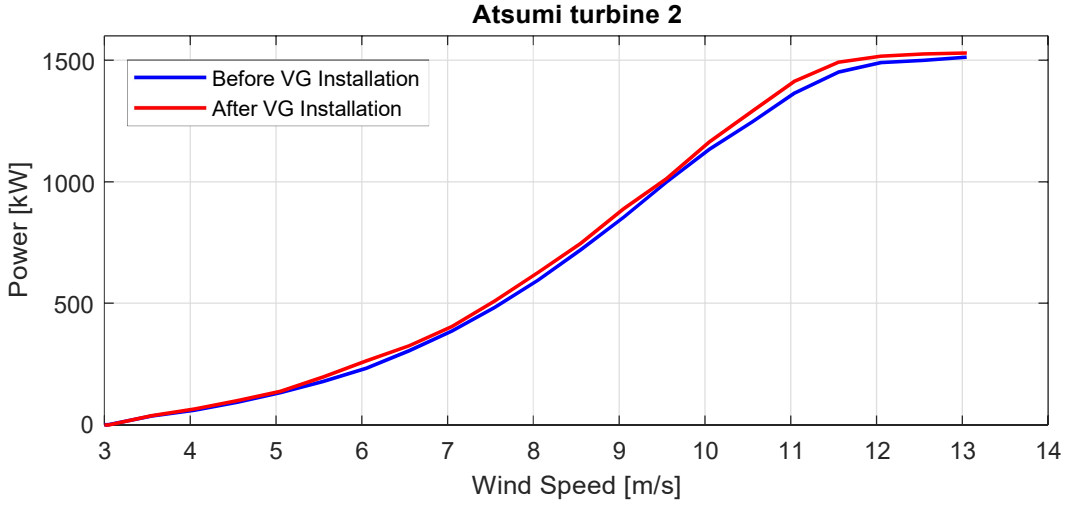

Figure 4. Power curve of Turbine 2

Converting the power change through the measured wind distribution (Weibull distribution) an AEP improvement of 3.7 % is found for turbine 2.

Turbine 4:

Figures 5 and 6 show that the power curve have been lifted after VG installation.

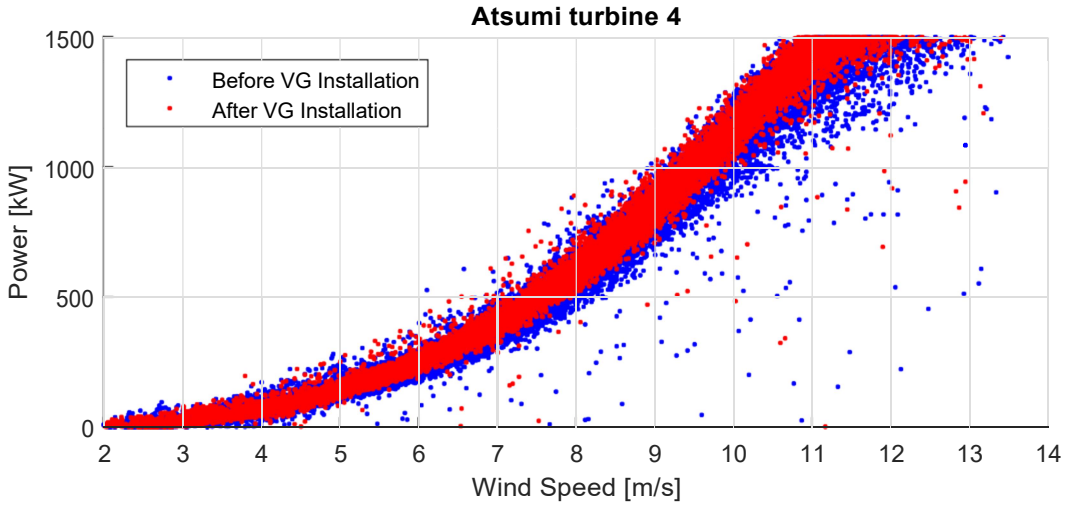

Figure 5. Scatter plot of Turbine 4

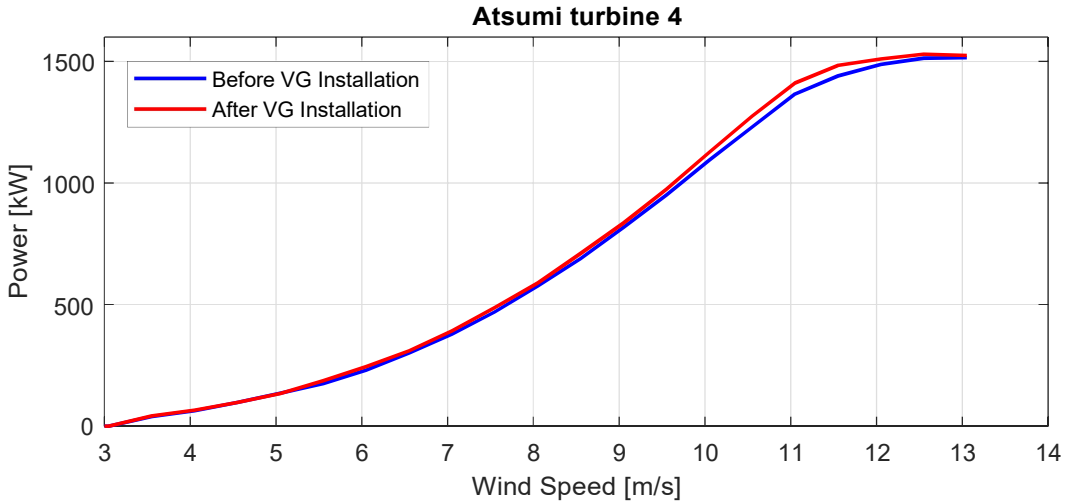

Figure 6. Power curve of Turbine 4

Most significant improvement is in the span 10-12 [m/s] resulting in an AEP improvement of 2.8 % for turbine 4.

Turbine 7:

Figure 7 and 8 show that the power curve have generally been ”lifted” after VG installation.

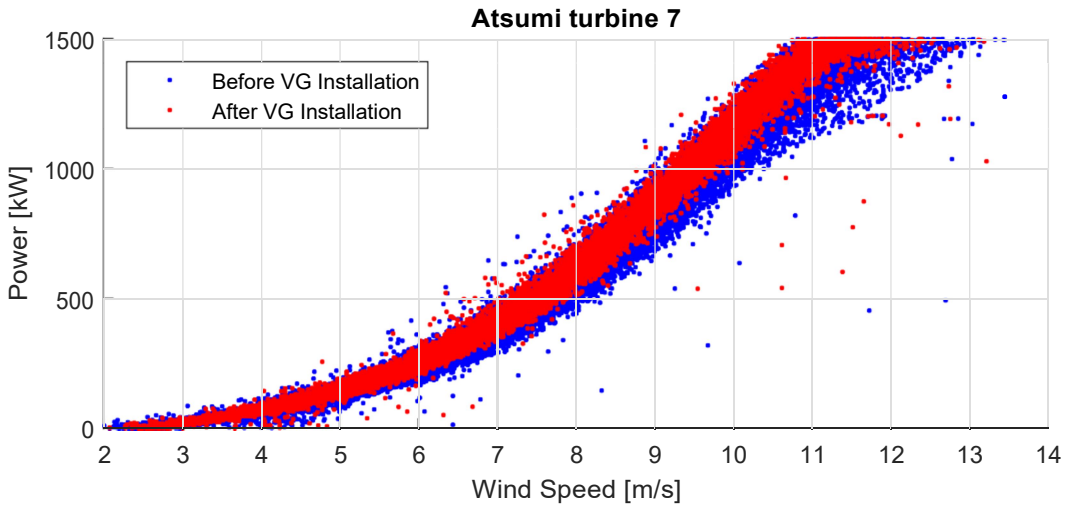

Figure 7. Scatter plot of Turbine 7

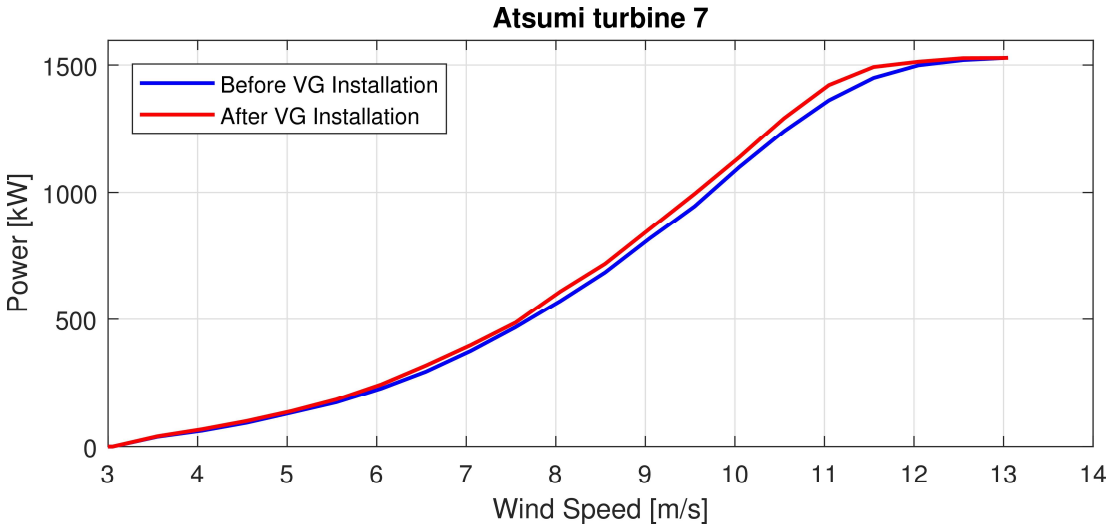

Figure 8. Power curve of Turbine 7

Resulting AEP improvement is 4.1 % for turbine 7.

5. Conclusion

Results after approx. 12 months baseline data and approx. 6 months of test period data:

Turbine	AEP Change
Atsumi2	3.7 %
Atsumi4	2.8 %
Atsumi7	4.1 %
Average	3.5 %

For Atsumi 7 WTGs an average +3,5% AEP is equal to approx. 1.0 GWh more production per year.