# Field Implementation of coordinated Control of wind farms

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## Abstract

Real time field implementation of wind farm coordinated control strategies is presented. Two 2MW turbines from the Le Sole de Moulin Vieux (SMV) wind farm are used for this purpose. The farm is equipped with state of the art LiDARs for measuring wind characteristics, up to a frequency of 1Hz. Simulations are performed using WindPRO for wake effects prediction. Optimised curtailment strategies are simulated with a farm controller for estimating optimum curtailment settings of the upstream turbine. Analysis of the field data shows that a gain of up to 11.5% is possible in downstream turbine production, using a hard curtailment strategy by reducing power of the upstream turbine by about 17%. The combined production of the two turbines decreased with the hard curtailment strategy, indicating that the upstream turbine must be optimally curtailed for avoiding any production loss.

To the best knowledge, this is the first practical implementation of LiDAR based coordinated control.

## Objectives

1. Practically implementing coordinated control in an operating wind farm using LiDARs.
2. Developing **curtailment strategies** based on **$C_P$** and **Yaw angle** for farm production maximisation.
3. Comparing simulation results with results based on real-time field data.

## Motivation

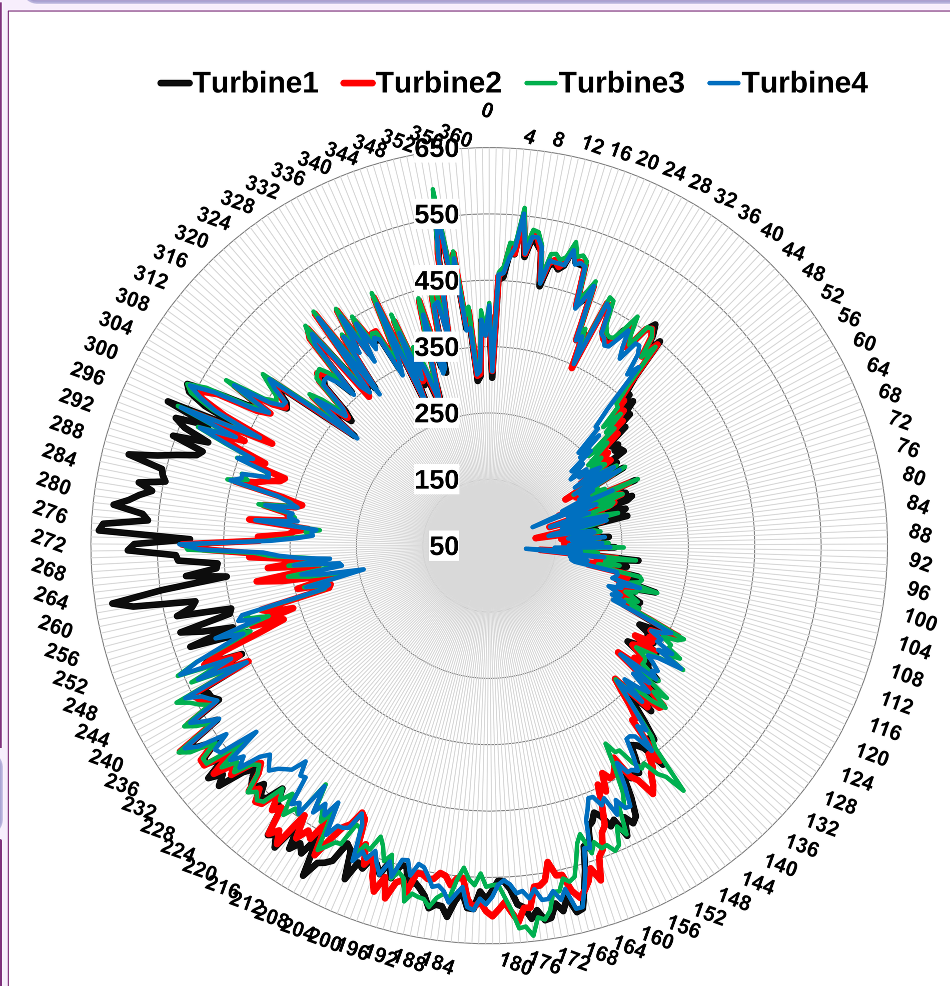


Figure 1a: Average power (kW) in all directions for the first four turbines at 8 ± 0.5 m/s (SMV Wind Farm)

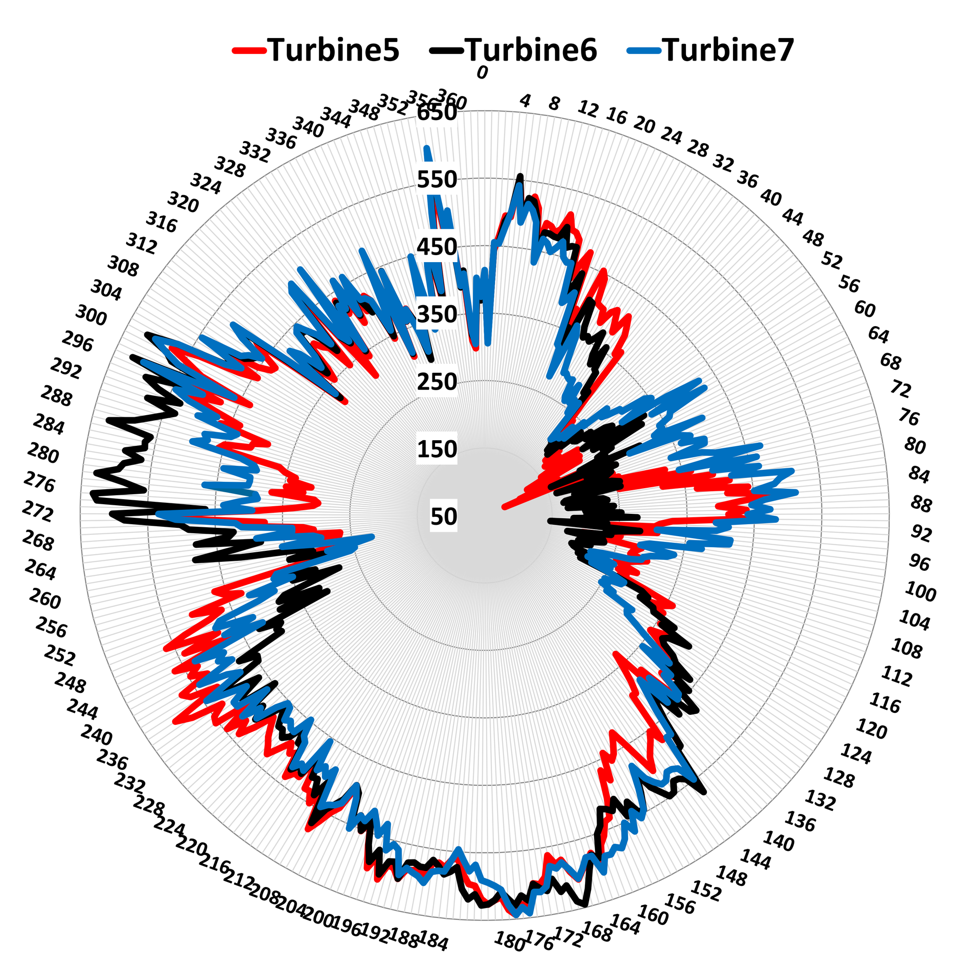


Figure 1b: Average power (kW) in all directions for the last three turbines at 8 ±0.5 m/s (SMV Wind Farm)

## Methodology and Experimental Setup

Table 1: Two steps hard curtailment strategy implemented on the upstream turbine, applied in full wakes and near-full wake conditions (180° to 220°)

| if 180° ≤ Wind Direction ≤ 220° |
|---|
| Step1:<br>if<br>1200kW ≤ Power of upstream turbine ≤ 1500 kW<br>then<br>curtail upstream turbine to 1200 kW |
| Step2:<br>if<br>1600kW ≤ Power of upstream turbine ≤ 1900 kW<br>then<br>curtail upstream turbine to 1600 kW |

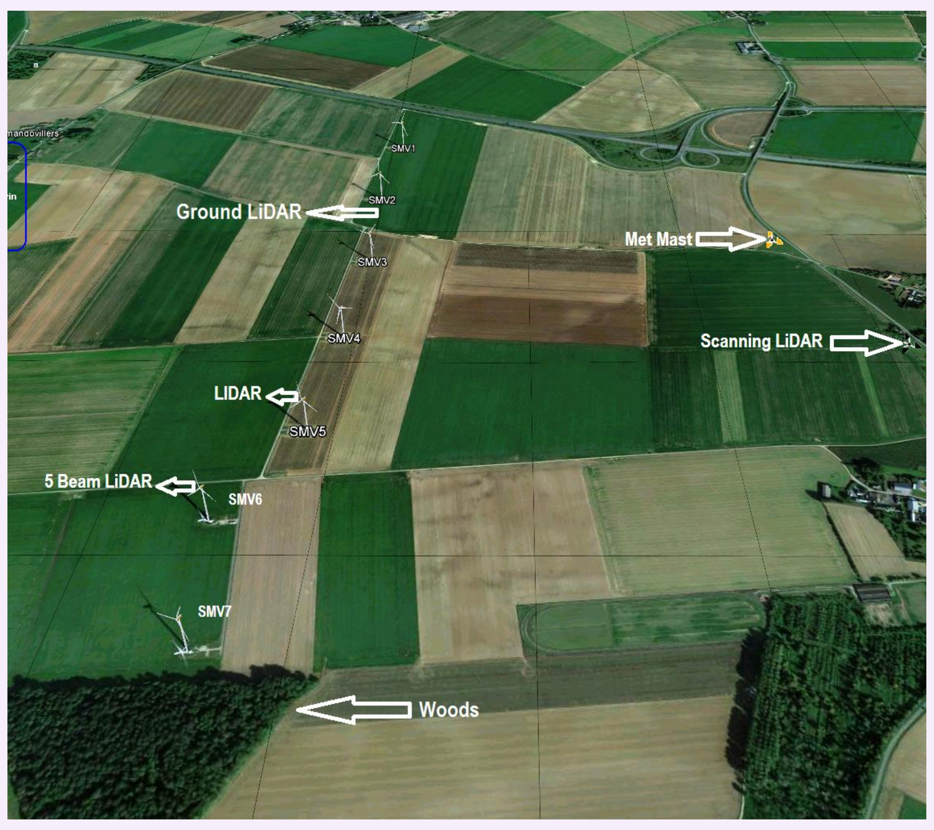


Figure 2: SMV wind farm layout and experimental setup (LiDARs) source: (Google earth) [1]

Figure 3: Leosphere 5 beam LiDAR mounted on top of the upstream turbine. The LiDAR can provide data with a frequency of up to 1Hz

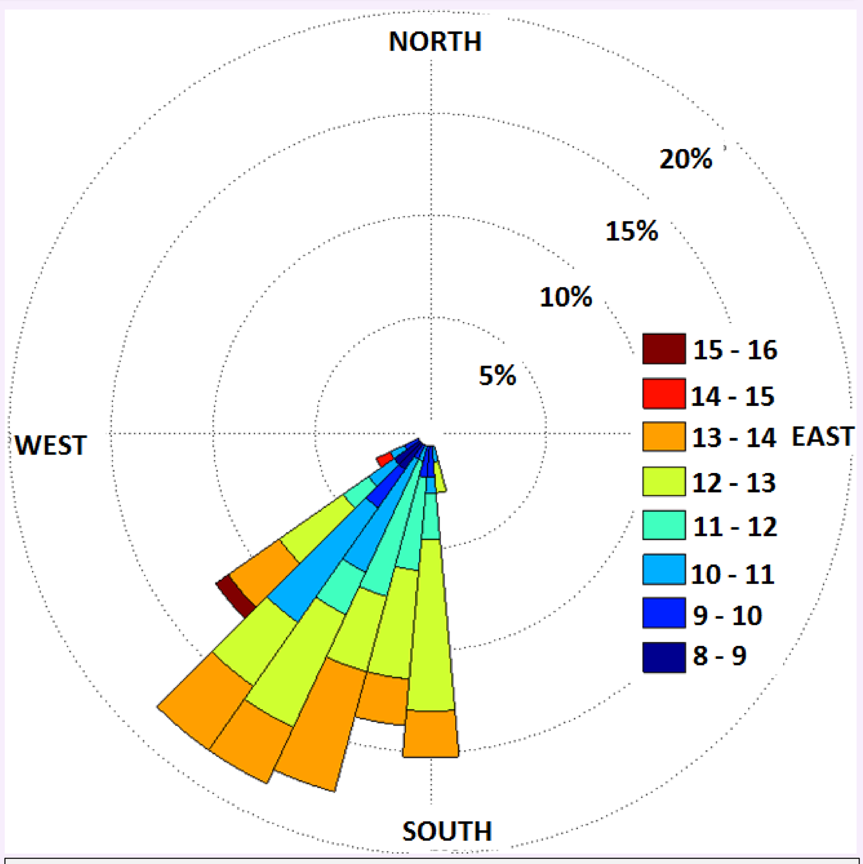


Figure 4: Wind conditions when the upstream turbine was curtailed as per the strategy in Table 1

## Data and Results

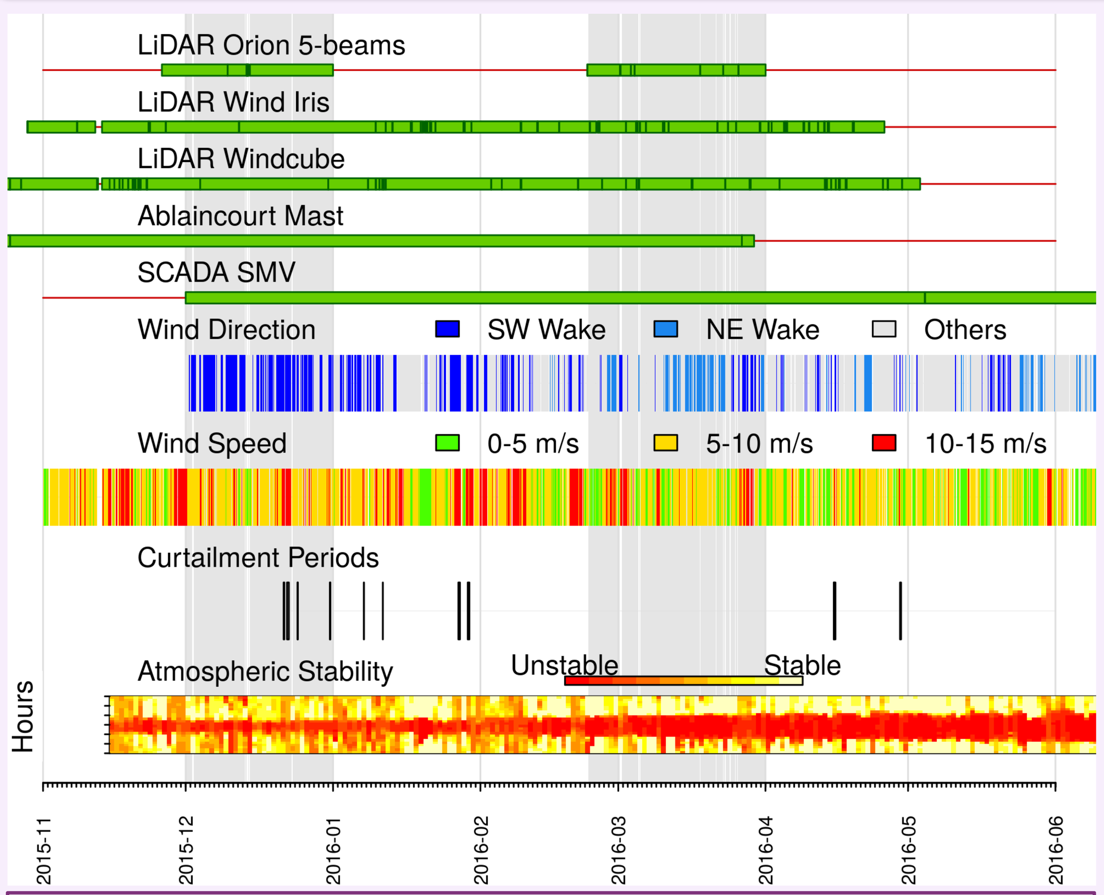


Figure 5: Availability of data from different sources

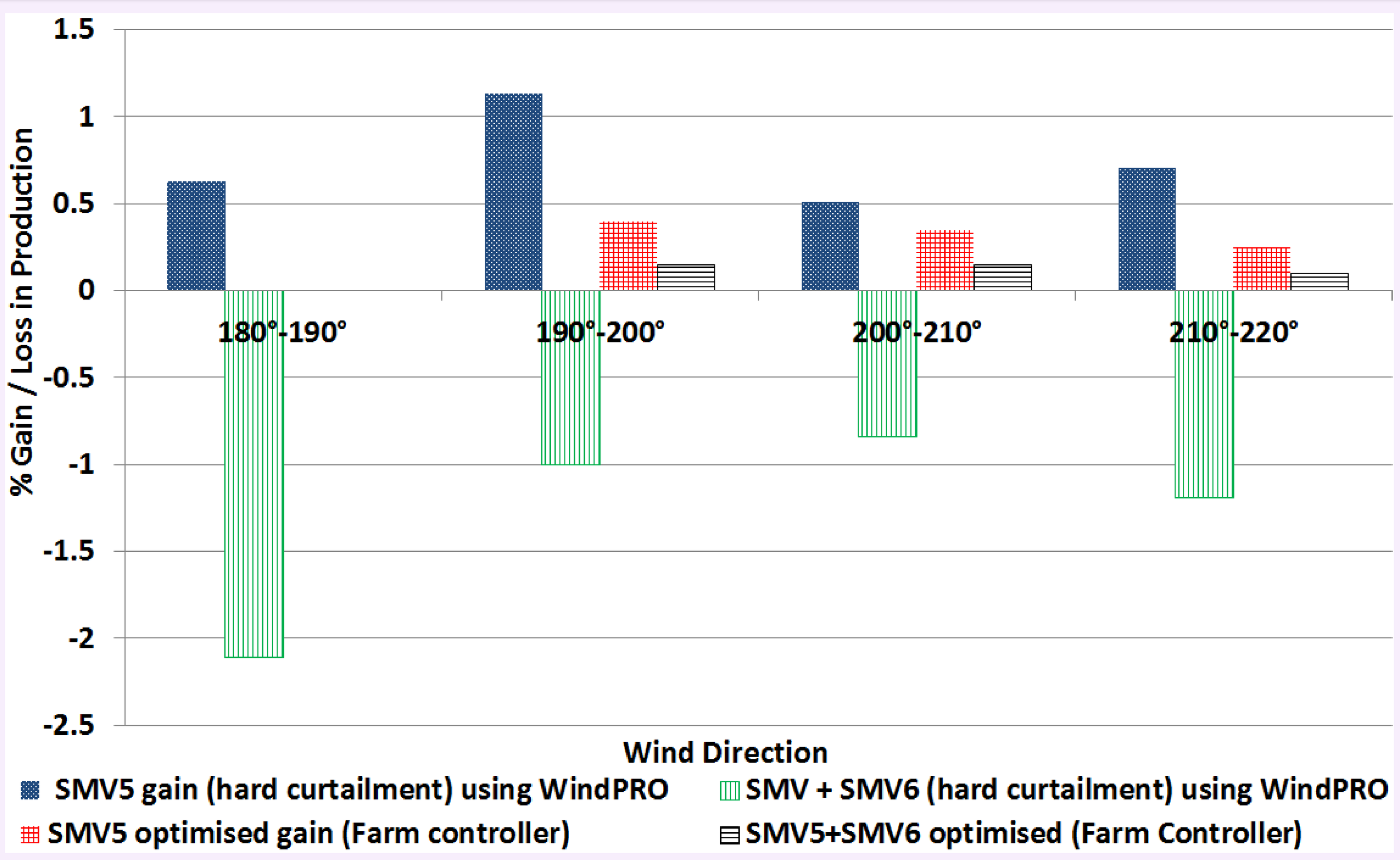


Figure 6: Results based on Simulations with WindPRO and the farm controller developed in [2]

Table 2: Impact of the upstream turbine (SMV6) Curtailment on the SMV wind farm in different wind direction

| Turbine(s) | 180° – 220° | 190° – 210° | 200° – 210° | 200° – 220° |
|---|---|---|---|---|
| SMV6 | -17.5 | -17.1 | -18.6 | -19 |
| SMV5 | 4.5 | 11.5 | 11.5 | -0.7 |
| SMV4 | 3.5 | 4.9 | -0.9 | -1.5 |
| SMV3 | 2.0 | 2.3 | -0.3 | -0.5 |
| SMV2 | 1.6 | 1.9 | 0.2 | 0.2 |
| SMV1 | 2.6 | 2.7 | 0.5 | 0.6 |
| SMV5+SMV6 | -8.1 | -5.6 | -6.4 | -10.9 |
| Farm | -0.7 | 0.4 | -1.9 | -3.4 |

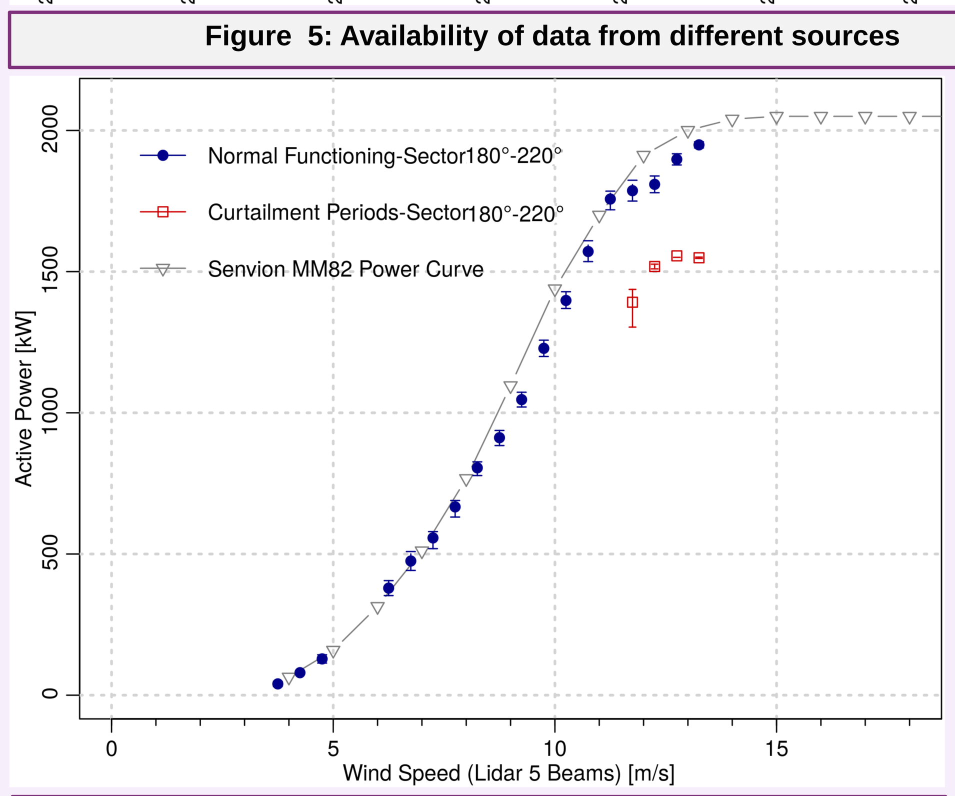


Figure 7: SMV6 (upstream turbine) power curve during normal and curtailed operations

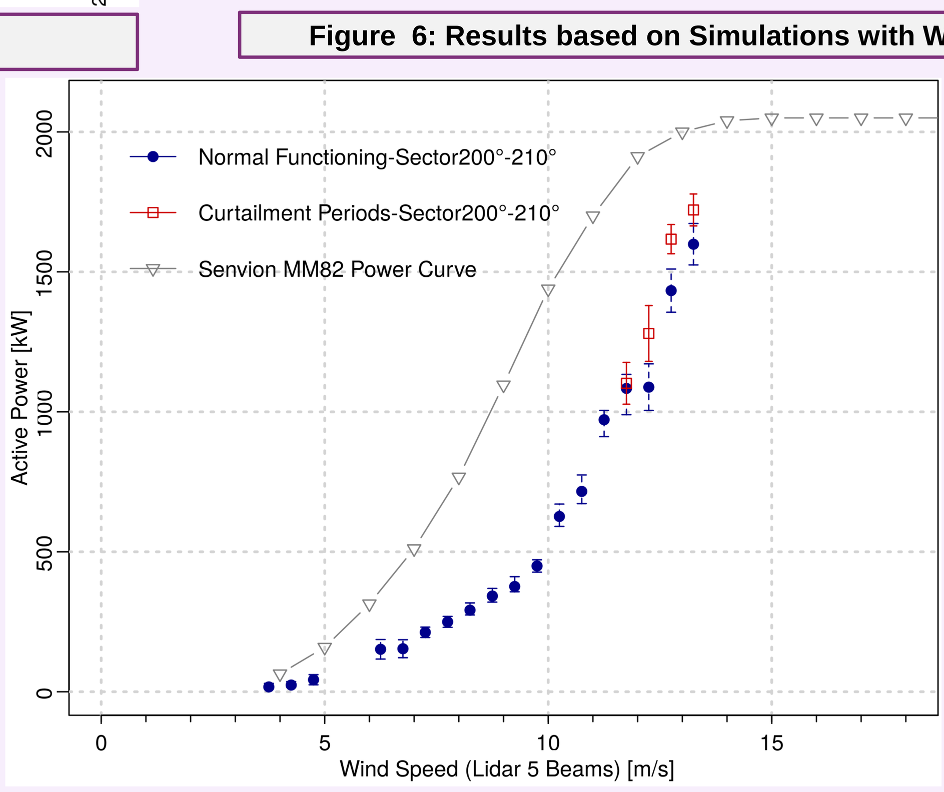


Figure 8: SMV5 (downstream turbine power curve) in full wake conditions, during normal and curtailed operations

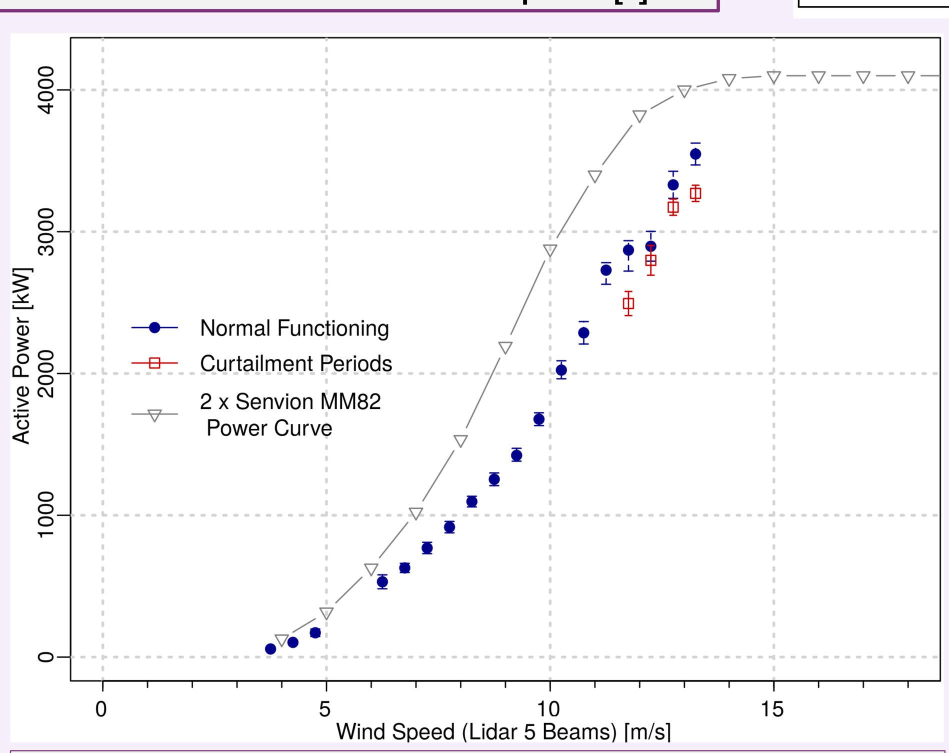


Figure 9: Combined power curve of SMV5 and SMV6

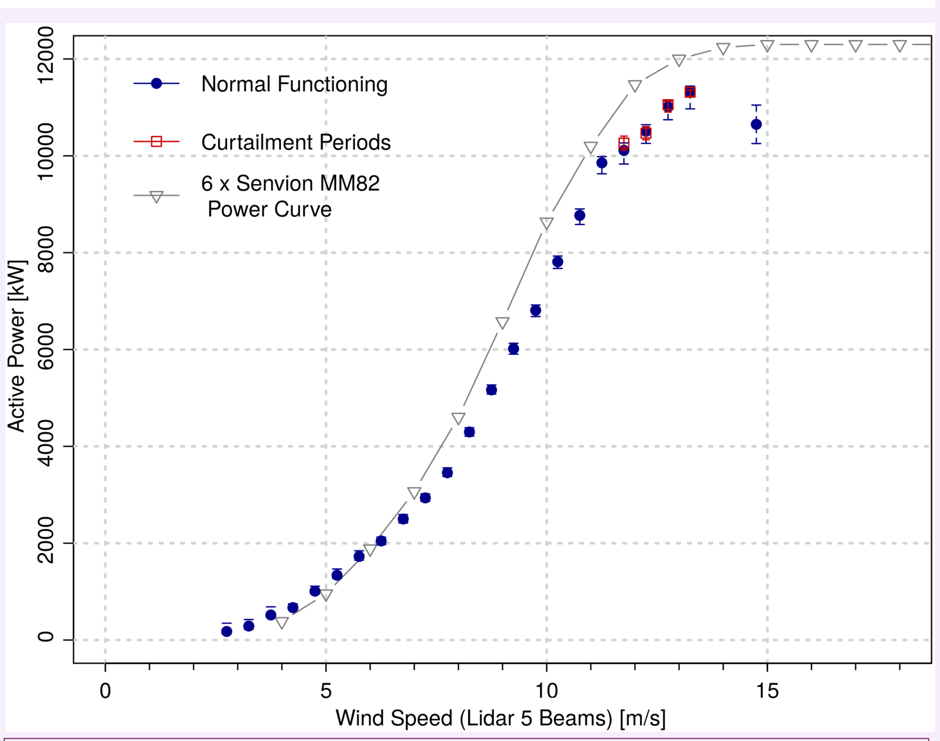


Figure 10: SMV Farm production in normal and curtailed operations.

## Conclusions

- Preliminary results of the CP -based curtailment campaign from the SmartEOLE project are presented.
- Practical implementation of coordinated control of wind farms (in the SMV wind farm) with modern LiDARs is presented.
- Production increase of up to 11.5% was observed for downstream turbines production with the field data.
- Overall the downstream turbines in the farm benefited from curtailing the upstream turbine
- The decrease in combined production of SMV5 and SMV6 turbines confirmed the importance of optimised control strategies.
- It is concluded that coordinated control of wind farms is beneficial for overall gain and production maximisation of downstream turbines.

## References

1. www.google.com/earth/
2. T. Ahmad, N. Girard, B. Kazemtabrizi and P. C. Matthews, *Analysis of two onshore wind farms with a dynamic farm controller*, in EWEA, Paris, France, 2015

## Acknowledgments

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