Open-Source and DevOps for WindPower

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Energy transition example: Marseille

Today: 3 x 8.4 MW

Floating Turbine

Source: Google maps

Source: openstreetmaps

Source: Wikipedia WindFloat Prototype
Wind power more important than solar here in EU, stats from open data. Source: Global stats visualization & local forecast | Kaggle
But.. When something goes wrong?

Fault notification processing:
- 2 days
  - Tech expert reads report

Fault inspection time:
- 2 weeks
  - Get team to inspect fault

Order the right components:
- 6 weeks
  - but maybe longer

Plan & execute repairs:
- 2 weeks

Typical service intervention: 10 weeks
- \$125,000
  - Lost revenue for 3.5 MW turbine
  - Based on downtime, standard capacity factor, energy price

Example from the field

Intervention is a major issue, having the spare parts at the right time saves money!!!
Monitoring and predicting

**WHAT?**
- Failure classification based on gearbox and bearing expertise
- Repair solution

**WHERE?**
- Spare parts location
- Turbine location

**WHEN?**
- Reaction horizon
- Spare parts availability
- Technician availability

Data collected and analyzed

Weibull model to predict failures occurring / spares order

\[
F(x) = \begin{cases} 
0 & \text{for } x < 0, \\
1 - e^{-(x/\beta)^\gamma} & \text{for } x \geq 0.
\end{cases}
\]

Model verified on test data, Eventual outliers discussed with domain experts

\[ R^2 = 0.95 \]
Fast return to operation

Wind turbine data → Cloud integration → Production data

Prescriptive maintenance

SEE ➔ THINK ➔ ACT
The evolution of maintenance

Data analysis with open-source software allows more and more sophisticated maintenance.
ZF Wind Power Digitalization tech stack

- python
- pandas
- LIFELINES
- pytest
- docker
- Azure DevOps
- OPENSHIFT
- JFrog Artifactory
- databricks
Desired Outcome from data analysis

- **Reduced downtime**
  by having the right parts at the right time

- **Reduced costs**
  by optimizing the stock levels

- **Reduce unplanned maintenance**
  with proactive planning

- **Avoid consequential damage**
  by addressing reoccurring failure modes
Realized improvements in pilot study

- 50% decrease in alert processing effort
- 60% decrease in unplanned field inspections
- 85% decrease in lead time to repair
- 0.4% increase in AEP at park level
Conclusions

• Fragmented value chain conversely affects wind energy efficiency

• Data insights and prompt communication has a big positive impact:
  - Reduced alert processing effort
  - Prescriptive maintenance
  - Lead time to repair decreased
  - Increased overall efficiency

• Good results could be achieved using open-source software running either on premises or in the cloud

• DevOps practices allowed the pilot project success
Thank You!

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Spare parts optimization

Consumed Lifetime

- SCADA Data
- Digital Model
- Consumed Lifetime

Remaining Lifetime

- ZF Service Intervention Data
- Classification based on Domain Knowledge
- Remaining Lifetime

Gearbox Expertise
Failure Modes & Solutions

Spare Parts Recommendations

External Service Intervention Data