
RECOMMENDED KEY PERFORMANCE INDICATORS FOR OPERATIONAL MANAGEMENT OF WIND TURBINES

17.01.2019 EERA DeepWind'2019, Trondheim

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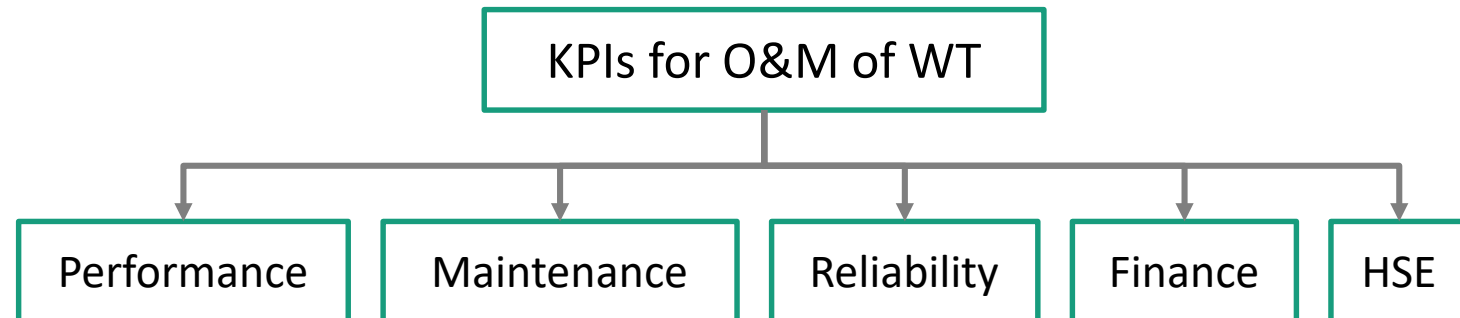
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KPIs: What are we talking about?

Key Performance Indicator(s)

- Objectively describe the performance of an observed unit
- Provide information as a decision support
- Are repeatedly evaluated (monthly, quarterly, yearly ...)
- Should be SMART

- Specific
- Measurable
- Achievable
- Relevant
- Time-bound



Motivation and Scope

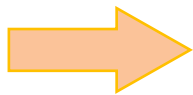
Situation in the wind industry (O&M)

- Various standards are available (e.g. IEC 61400-25)
- KPIs are commonly used
- Used KPI systematics and definitions vary heavily



Drawbacks

- Additional effort (design, implementation, ...)
- Cross-company benchmarks aren't possible
- Hinders communication and knowledge building
- Makes contracts more complicated



Scope of this work

- Identify and prioritize commonly used KPIs
- Collect and review various definitions
- Propose a set of recommended KPIs including unified definitions

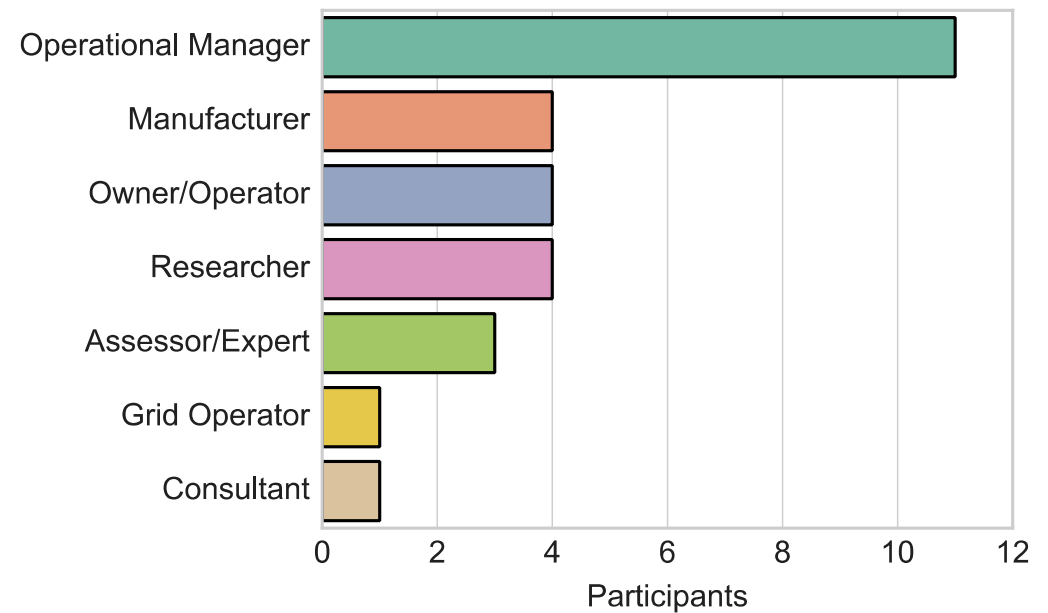
Survey on KPIs

- Survey is part of a standardization task within the FGW e.V.
- 34 different KPIs were considered in the survey
- Survey was open 4th October 2017 till 1st November 2017

What did we ask?

- Is the KPI used in your company?
- Which definition is used?
- Which data serves as a basis?
- How important is the KPI?

Who participated?



HSE- and Finance KPIs

HSE-KPIs

KPI	Answers	Use	Importance (1-5)	Abs. Importance
Total accident rate	5/5	4/5	3.7	14.8
Total lost time occupational illness frequency	5/5	3/5	2.7	8.1
Fatal accident rate	5/5	2/5	4	8
Recordable injury rate	5/5	2/5	3.5	7
Energy demand per employee and year	5/5	0/5	0	0
Pollutant release per employee and year	5/5	0/5	0	0

Finance-KPIs

KPI	Answers	Use	Importance (1-5)	Abs. Importance
EBITDA	9/9	5/9	4	20
Maintenance costs	9/9	5/9	3.6	18
Operational expenditures (OPEX)	9/9	4/9	4.4	17.6
Levelized cost of energy (LCOE)	9/9	3/9	3.7	11.1
Debt-service coverage ratio (DSCR)	9/9	2/9	5	10
Free cash flow to equity (FCFE)	9/9	2/9	4.5	9
Break-even price of energy (BEPE)	9/9	1/9	4	4
Loan life coverage ratio (LLCR)	9/9	0/9	0	0

Low importance
in the survey



- HSE- and Finance-KPIs are not discussed in detail in this work
- But: Most participants in the survey had a technical background
- Further work on HSE- and Finance-KPIs is required

Performance KPIs

KPI	Answers	Use	Importance (1–5)	Abs. Importance
Power curve	20/20	19/20	4.5	85.5
Wind conditions	20/20	16/20	4.5	72
Average wind speed				
Wind speed distribution				
Wind direction distribution				
Average wind speed/site assessment				
Full-load hours	20/20	18/20	3.5	63
Energy consumption	20/20	16/20	3.1	49.6
Capacity factor	20/20	13/20	3.7	48.1
Data availability	20/20	11/20	4.1	45.1
Remote-resets	20/20	5/20	3.2	16
Site quality				
No. of telecommunication interruptions				
Forecast fulfillment				
Operating hours				
Specific yield				
Market value factor				

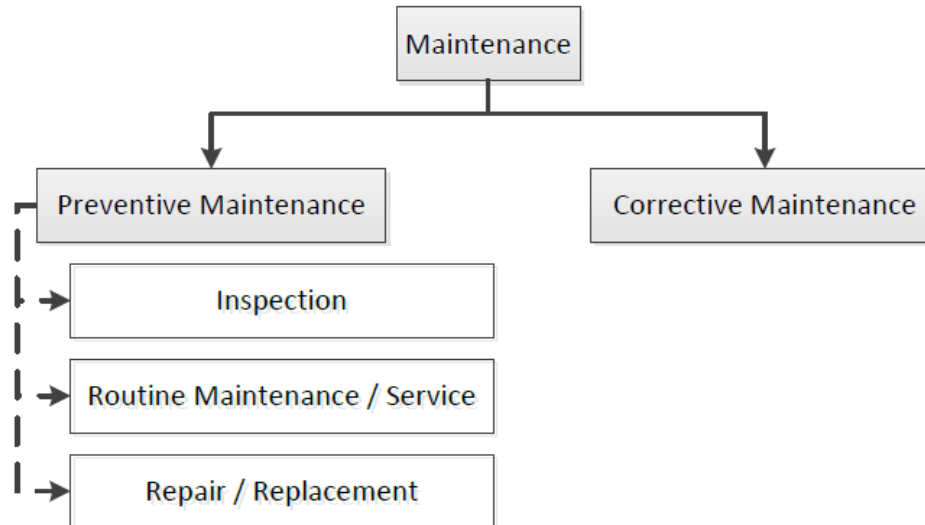
- Power Curves are the most important tool for performance assessment
- Operators use various metrics to describe the wind conditions
- Many more performance KPIs were suggested

Maintenance KPIs

KPI	Answers	Use	Importance (1–5)	Abs. Importance
Time-based availability	16/16	16/16	4.7	75.2
Production-based availability	16/16	12/16	4.1	49.2
Production ratio				
Yield losses by cause				
Monetary-based availability				
Maintenance tasks	16/16	7/16	4	28
Preventive maintenance tasks	16/16	7/16	3.3	23.1
Number of routine maintenance tasks				
Number of inspections/visual inspections				
Number of repairs				
Reactive maintenance tasks	16/16	7/16	3.3	23.1
Risk priority number (RPN)	16/16	1/16	5	5

- KPIs are defined in IEC 61400-25/26
- A new availability definition will be introduced
- Further categorization for maintenance tasks required

Maintenance KPIs – Maintenance Tasks



Structure to categorize maintenance tasks by the maintenance type and activity according to BS EN 13306 and BS EN ISO 14224

Reliability KPIs

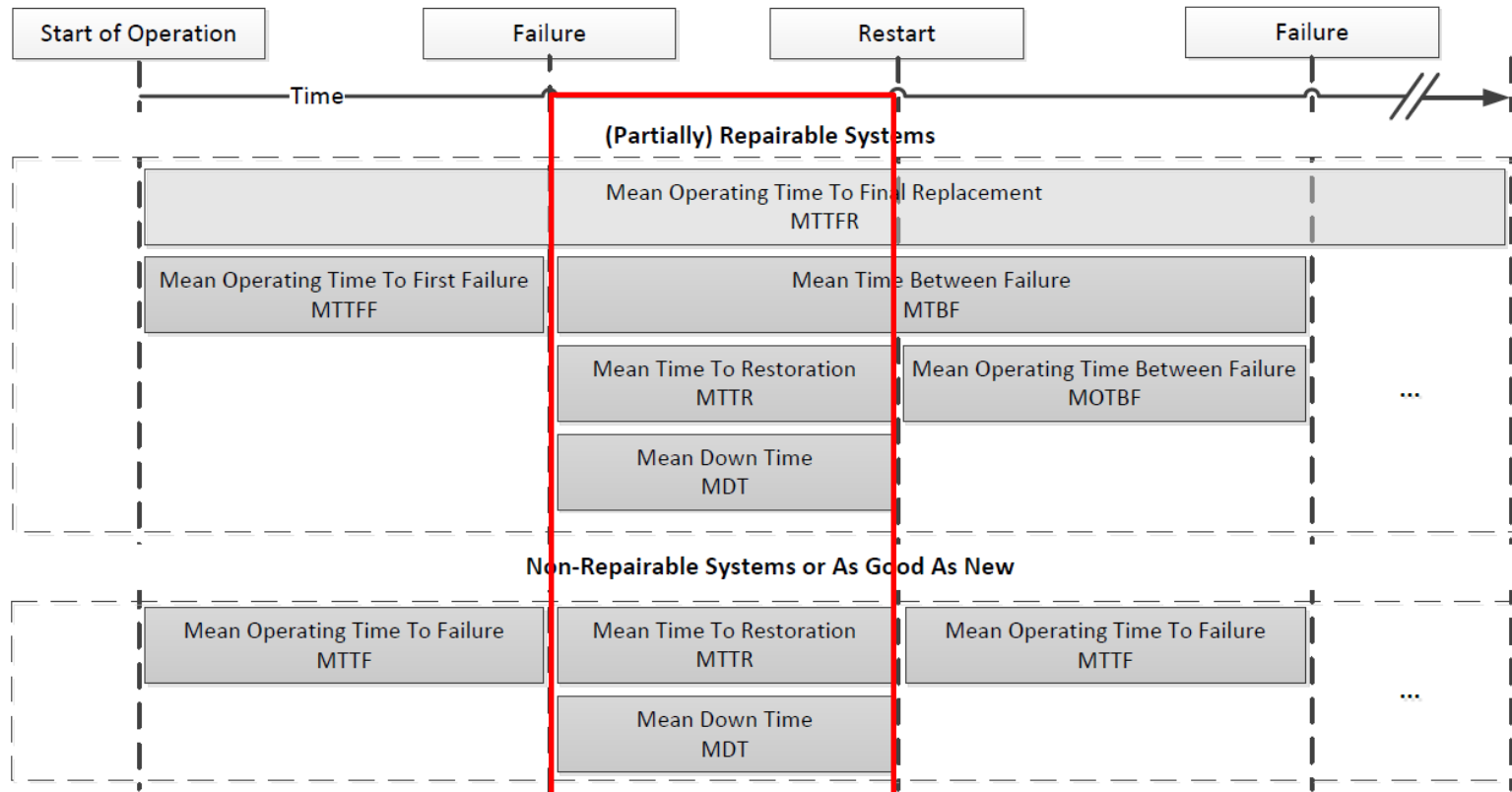
KPI	Answers	Use	Importance (1–5)	Abs. Importance
Failure rate	10/10	8/10	3.6	28.8
Mean time between failures (MTBF)	10/10	7/10	3.6	25.2
Mean time to repair / restoration (MTTR)	10/10	7/10	3.3	23.1
Mean down time (MDT)	10/10	6/10	3	18
Mean operating time between failures (MOTBF)	10/10	5/10	3.2	16
Mean operating time to failures (MTTF)	10/10	5/10	2.8	14
Repair rate	10/10	3/10	2.3	6.9

- Reliability Mean Time Measures are sometimes tricky to differentiate
- Different standards use different naming rules
- MTTR or MTTRes? MTBF or MOTBF?



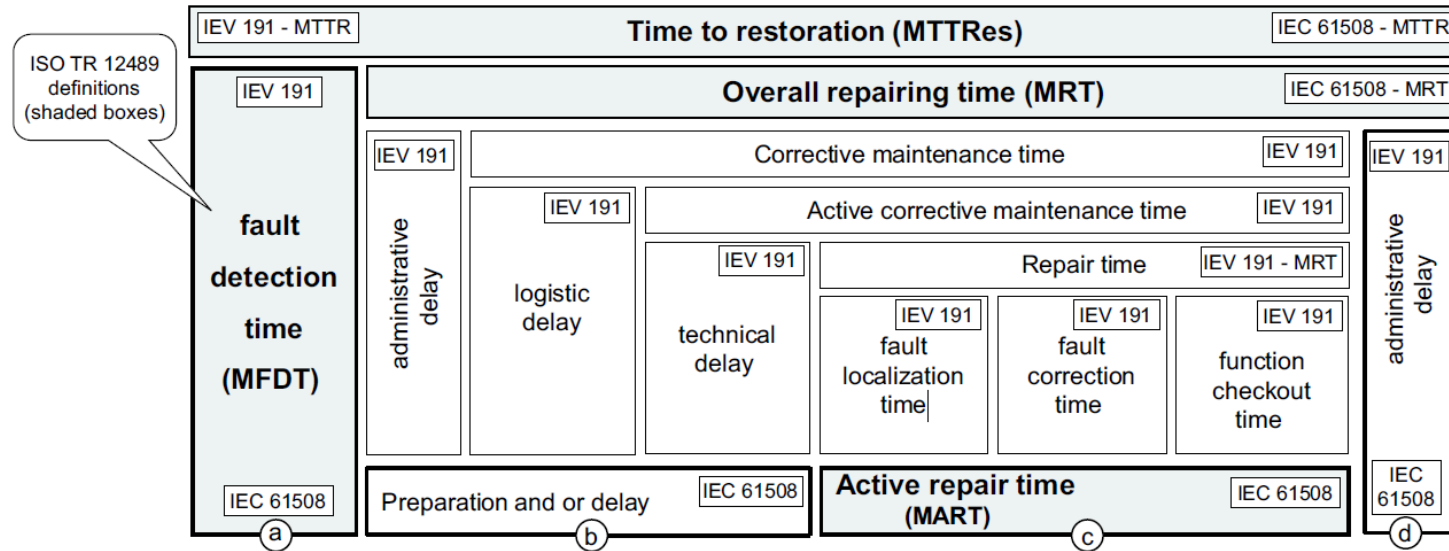
Unified definitions and naming rules are essential to avoid misunderstandings and mistakes

Reliability KPIs – Reliability Mean Time Measures



Reliability mean time measures for (partially) repairable and non-repairable systems according to ISO and IEC standards.

Reliability KPIs – Reliability Mean Time Measures



Taxonomies of MTTR subcategories from ISO/TR 12489

Conclusion and Outlook



Conclusion

- Many KPIs and many varying KPI definitions are in use
 - Performance KPIs are most important for operational managers
 - Current situation can lead to confusion
 - A unified set of KPIs makes life easier for everyone
 - An international technical guideline would be beneficial
- Make use of unified KPI definitions!

Outlook

- Starting point for committee work on a technical guideline (FGW e.V.)
- The current list is not complete, further KPIs will be developed
- Further topics like aggregation or uncertainties of KPIs have to be addressed.
- A detailed review of HSE- and Finance-KPIs is still required

DISCUSSION



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