SYNTHESIS PROCESS
OF A NEW WISPER LOAD SPECTRUM

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Bernard Bulder - ECN
Denja Lekou, Pantelis Vionis - CRES
Rogier P.L. Nijssen - WMC
Theo Kramkowski, Holger Söker - DEWI

1 RECOVERY AND ADAPTATION OF WISPER SYNTHESIS

Within the research work performed in the OPTIMAT BLADES project it has been agreed to set out for establishing a new WISPER load spectrum and test sequence. The NEW WISPER spectrum / sequence shall reflect up to date’s wind turbine technology and be the base for further material and component testing. NEW WISPER shall be based on the most recent real life measurements available to the project.

This document presents the discussion amongst the participating partners on the appropriateness and the possible need for adaptation of the process used when establishing the NEW WISPER spectrum/sequence.

1.1 *Discussion on the WISPER Synthesis Procedure*

All partners of TG1 were requested to assess the procedure used to establish the old WISPER load standard as laid out in the comprehensive report by Ten Have NLR in 1992 [1]. In this assessment needs for adaptation of the process to today’s engineering requirements and to today's wind energy technology standard are to be compiled in the list below. Also characteristics to be preserved shall be stated in such a list.

Pos.	Originator	Step	Description	Decision
1	TUD	Format	NEW WISPER shall have the same format as that of the old WISPER/X i.e. a fixed sequence of load reversal points on a discrete amount of levels	Agreed – Methodology of how to derive the fixed sequence to be adapted
2	ECN	Rainflow Counting	64 load level shall be maintained	Agreed
3	ECN	Input (Load) data	Flapwise or flatwise bending i.e shall the pitch angle be considered or not	Flatwise bending moments are to be considered i.e. within the blade coordinate system – no consideration of pitch angle required.
4	TUD	Rainflow Counting / Data Handling	Data handling according to IEA recommendations on fatigue assessment to be checked	All partners have participated in a rainflow benchmarking: techniques are reasonably well aligned to have each partner use their own rainflow counting procedures.
5	TUD	Wind data	Wind and load data shall originate from the same measurements	Discarded: wind speed distribution shall be common to all data bases and wind turbulence levels are to be selected for each data base individually to achieve best possible coverage of wind speed spectrum.
6	DEWI	Wind data	Shall a the assembly process assume an IEC class 1 wind distribution	Wind speed distribution shall be common to all data bases: either IEC class 1 / 2 or according to a real year long measurement (can data from NLR exercise be recovered?)
7	DEWI	Wind data	Shall the “low cycle” fatigue approach i.e. sequential selection of per-operation-mode-load-matrices according to a sequence of 10-minute wind speed averages. Shall / can we obtain this sequence from NLR Alternative: go through wind speed distribution bin by bin and linearly extrapolate the per-bin-load-rainflow-matrix	In addition to the bin by bin linear superposition and extrapolation of the binwise load rainflow matrices the low cycle approach according to IEC 61400-13 (Appendix) shall be applied. (see procedure outline below)

8	TUD	Input (Load) data	Use of computer simulations to obtain load data for	Use of computer simulated loads has been

			a large variety of design solutions (e.g. turbine concept, # of blades...) and external / operation characteristics (e.g. complex terrain-, wind farm-, offshore- operation)	discarded in the second meeting June 2002 at RISO
9	TUD / ECN	Input (Load) data	Necessity to incorporate edgewise loading	Incorporation of edgewise loading discarded can better be addressed in static amplitude tests
10	DEWI	Normalisation level	Shall the normalisation scheme be preserved (normalisation by "once-per-1000-rev. Level")? Should we normalise with respect to power (e.g. by span of average loads at 20% and 80% of rated power)	A normalisation scheme using span of average loads at 20% and 80% of rated power has been suggested (see below)
11	DEWI	Truncation and Omission	Truncation and omission practice to be confirmed	Matter of actual synthesis: truncation most likely does not apply , ommission will be necessary to cut down on cyclic content of the rainflow counts
12	DEWI	Reduction of cyclic content	Procedure is somewhat unclear at this point	To be

Table of Work Group Inputs And The Decisions Met on The Individual Issues

1.2 *NEW WISPER Synthesis Procedure*

The base line for the set up of a new procedure for a NEW WISPER test load sequence is threefold:

- Standard techniques as used by the participating partners and laid out in the existing standards (here IEC 61400-13) shall be used to make use of best and established practice and to ensure acceptability in the wind turbine industry.
- Simplicity and transparency of the synthesis process shall be achieved.
- In order to maintain confidentiality of the data used the participating work group members shall supply processed data only.

The following outlines the suggested synthesis process in detail:

1.2.1 Turbine Description (all partners):

The turbine represented in the data bases used shall be described by the following parameters:

- Rotor diameter
- Rated power
- Power control
- Rotor speed, maximum (two speeds?, speed range)
- No. of blades
- Rotor position (upwind / downwind)
- Hub height
- Prototype / serial production turbine

1.2.2 Site Description (all partners):

The site represented in the data bases used shall be described by the following parameters:

- Topography
- Sector of load measurements
- Mean turbulence in sector

1.2.3 Data selection from the capture matrix (all partners):

The data base shall be given by a IEC 61400-13 capture matrices of 10-Min time histories for normal power production and transient operation. The subsequent steps are to be taken:

- Pick turbulence bin with the widest wind speed coverage.
- Add data of turbulence bin above and below, resulting in a turbulence bin of 6% width.
- Substitute missing data from other turbulence bins and report such substitution.
- Copy data from highest wind speed bin up to the 25m/s bin.
- Identify transients of starts and stops at cut in and cut-out (above rated) wind speed.
- Identify transients of rotor speed switching (low to high / high to low rpm) if applicable.

1.2.4 Normalisation of flatwise bending (all partners):

In order to be able to combine the loads measured on various machines with different designs a normalisation of the load level is required:

- Derive wind speeds at 20% and 80% rated power from bin averaged power curve (interpolation).
- Determine difference in the bin averaged mean flatwise bending at the above wind speeds (interpolation).
- Normalise all flatwise and edgewise bending loads by the above difference.
- Report normalised maximum and minimum values of instantaneous flatwise loads (normal power production or transient operation) to DEWI

The largest values of all turbines will set the limits for the Rainflow counting into a 64 x 64-bin-matrix

The reported normalized minima and maxima are:
CRES min : -1 max: +6
ECN min: -2 max: +4
DEWI min: -3 max: +5
Hence the range to chose is minimum: -3 and maximum: +6

1.2.5 One year wind speed time history of 10min mean (ECN,DEWI - all partners)

For determination of the low cycle fatigue content and the number of starts / stops to be considered a one year wind speed time history of 10-minute-average values is to be established and reported.

For determination of the number of starts /stops / transients (all partners):

- Derive number of starts, stops and rotor speed transients from one year wind speed time history using peak/trough or level crossing counting and establishing a wind speed transition / level crossing from - to - matrix from that one year wind speed time history. The level crossing counting for the cut-in and cut out wind speeds should be done without hysteresis best before binning to avoid discretization problems – otherwise binning shall be chosen in a way that the *cut-in* threshhold falls on a bin border.

The number of starts and stops used for an individual data base is dependent on cut-in and cut-out wind speed of the individual turbine and hence shall be reported by the processing partner.

1.2.6 Annual cumulated Rainflow load spectrum (all partners)

Using the IEC class II wind speed histogram *(i.e. Weibull A= 9.59, C= 2.0)* the load spectra for the individual machines are to be derived by each data supplying partner:

- Rainflow count each flatwise and edgewise data set and add up cycles for each wind speed bin. Rainflow parameters to be defined mutually in the work group.
- Extrapolate load cycles of each wind speed bin according to the agreed on wind distribution to give cumulative duration of one year .
- Set up the annual flatwise and edgewise range / mean full cycle load matrix and cumulated range spectrum.

1.2.7 Normalisation of cyclic content (rotational speed) (all partners):

As rotational speed of the turbines varies a normalisation in this respect is required:

- Derive number of rotor revolutions per year from the cumulated edgewise range spectrum.
- As a *reference constant rotor speed 16rpm* have been defined in the group.
- Normalise Rainflow counts by the factor: reference annual rotor revolutions/ annual no. of rotor revolutions

1.2.8 Add low cycle loads for each turbine (IEC / RISOE proposal) and transient loads (all partners):

To account for the low cycle fatigue loading the IEC / RISOE approach is adopted:

- Arrange a sequence of maximum and minimum normalised flatwise loads according to one year wind speed time history. For each 10 minute interval throughout one year the maximum and minimum normalised flatwise loads of all load time histories in the respective wind speed bin are to be selected and added to a sequence.
- Rainflow count the above sequence into a range / mean full cycle load matrix (using the Rainflow parameters as selected for step 1.2.6.
- Add cycles to normalised annual flatwise Rainflow matrix
- Rainflow count the selected start / stop / rotor rpm transients into a range / mean full cycle load matrix (using the Rainflow parameters as selected for step 1.2.6. *The number of starts and stops to be used must be taken from step 1.2.5*
- Rainflow count the selected emergency stop transients into a range / mean full cycle load matrix (using the Rainflow parameters as selected for step 1.2.6.). *The number of emergency stops per year to be considered has mutually been defined to be 40.*
- Add Rainflow counted cycles of the above no. of starts, stops and rotor rpm transients per year to above matrix

1.2.9 Compose flatwise Rainflow summatrix of all turbines (ECN,DEWI)

- Add flatwise Rainflow matrices of all turbines and devide by the total number of (min. number of cycles > 1)
- Derive annual range pair spectrum
- Apply omission of small cycles (e.g. 25% of full range = 16 bins)

Result: Reasonable small no. of cycles for material testing

1.2.10 Get Sequence from Rainflow matrix (ECN, DEWI)

To obtain a load sequence from the rainflow summatrix standard fatigue equivalent techniques are to be applied (matter of investigation). A Draw peak trough sequence from flatwise Rainflow summatrix using such routine. The validity of the applied algorithm is to be proven by Rainflow counting the resulting sequence again and comparison of the result the summatrix obtained as output from step 1.2.9 (ECN, DEWI)

2 REFERENCES

[1] ten Have, A.A.: WISPER and WISPERX: Final Definition of Two Standardised Fatigue Load Sequences For Wind Turbine Blades. Amsterdam: National Aerospace Laboratory NLR, Amsterdam, The Netherlands, 1992 (Technical Publication NLR TP 91476 U)

[2] Larsen, G.; Thomsen, K.: A simple approximative procedure for taking into account low cycle fatigue loads. Paper presented at IEA-Symposium on Wind Turbine Fatigue, Stuttgart, February 1-2, 1996