Prof. Michael Schmiechen
Bartningallee 16
D-10557 Berlin (Tiergarten)
Germany

Phone: +49-(0)30-392 71 64
E-mail: m.schm@t-online.de
Website: http://www.t-online.de/home/m.schm

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Prof. Kinya Tamura
Prof. Kuniharu Nakatake

Sub: **Analysis** of **Everest** constructed test data
here: Basic analysis of **data corrected** and evaluation according to proposed rational method
Ref.: Evaluations of ISO_fin4 to fin7.mcd
Evaluations of **EVEREST**_01 **to 06.mcd**
Tamura, K.: 'An Appraisal of correction Methods ...' Trans. West-Japan S.N.A (1999) No. 97, 11-24
. Letter by Prof. Tamura dated 06.01.2001
Letters by Prof. Schmiechen dated 03./04.02.2001

Note:

This version **EVEREST_07 differs** from the preceeding version EVEREST_06 only:
1. by a more adequate notation for the averages, which have only been introduced for comparison with the results of the traditional method, but **which are not essential for the present method**,
2. by a statistical analysis of the distribution of deviations of power and speed results according to the rational evaluation of the individual runs, and
3. by additional plots of final results, interpolated and normalised values in particular.

Analysis of EVEREST constructed data

Units

Speed $kn := \frac{1852 \cdot m}{3600 \cdot sec}$

Power $W := watt$ $MW := 10^{3} \cdot kW$

Test identification TID := "EVEREST"

Constants

Length of ship $L := 213 \cdot m$ $L := \frac{L}{m}$

Diameter of propeller $D := 6.6 \cdot m$ $D := \frac{D}{m}$

Density of sea water $\rho := 1.025 \cdot 10^{3} \cdot kg \cdot m^{-3}$ $\rho := \frac{\rho}{kg \cdot m^{-3}}$

$g := 9.81 \cdot m \cdot sec^{-2}$ $g := \frac{g}{m \cdot sec^{-2}}$

Functions and subroutines

Compute left-inverse

$$\mathrm{LeftInv}(A) := \left| \begin{array}{l} r \leftarrow \mathrm{rows}(A) \\ c \leftarrow \mathrm{cols}(A) \\ s \leftarrow \mathrm{svds}(A) \\ \text{for } i \in 0..c-1 \\ \quad ISV_{i,i} \leftarrow \left(s_i\right)^{-1} \\ UV \leftarrow \mathrm{svd}(A) \\ U \leftarrow \mathrm{submatrix}(UV, 0, r-1, 0, c-1) \\ V \leftarrow \mathrm{submatrix}(UV, r, r+c-1, 0, c-1) \\ A_{inv.left} \leftarrow V \cdot ISV \cdot U^T \\ A_{inv.left} \end{array} \right.$$

Compute power

$$P_{sup}(p, N, V) := p_0 \cdot N^3 + p_1 \cdot N^2 \cdot V$$

$$P_{req}(C, V) := C_0 \cdot V + C_1 \cdot V^2 + C_2 \cdot V^3$$

Compute frequency of revolutions

$$\mathrm{Revs}(p, V, P, N) := \left| \begin{array}{l} n_i \leftarrow \mathrm{last}(V) \\ \text{for } i \in 0..n_i \\ \quad \left| \begin{array}{l} q_0 \leftarrow P_i \\ q_1 \leftarrow V_i \\ n \leftarrow N_i \\ N_{rat_i} \leftarrow \mathrm{root}\left(q_0 - p_0 \cdot n^3 - p_1 \cdot n^2 \cdot q_1, n\right) \end{array} \right. \\ N_{rat} \end{array} \right.$$

Normalise data

$$JH(V, N) := \frac{V}{D \cdot N}$$

$$KP(P, N) := \frac{P}{\rho \cdot D^5 \cdot (N)^3}$$

$$Fn(V) := \frac{V}{\sqrt{g \cdot L}}$$

$$CP(P, V) := \frac{P}{\rho \cdot D^2 \cdot (V)^3}$$

Analyse power supplied

$$
\mathrm{Supplied}(D,\rho,t,\psi_0,V_G,N,P_S) :=
\begin{array}{|l}
\text{for } i \in 0..\mathrm{last}(t) \\
\quad \begin{array}{|l}
A_{sup_{i,0}} \leftarrow (N_i)^3 \\
A_{sup_{i,1}} \leftarrow (N_i)^2 \cdot V_{G_i} \\
d_{FM_i} \leftarrow \mathrm{if}(\psi_{0_i} < \pi, -1, 1) \\
A_{sup_{i,2}} \leftarrow (N_i)^2 \cdot d_{FM_i} \cdot \cos\left(2\cdot\pi\cdot\frac{t_i}{12}\right) \\
A_{sup_{i,3}} \leftarrow (N_i)^2 \cdot d_{FM_i} \sin\left(2\cdot\pi\cdot\frac{t_i}{12}\right)
\end{array} \\
X_{sup} \leftarrow \mathrm{LeftInv}(A_{sup}) \cdot P_S \\
E_{sup} \leftarrow P_S - A_{sup} \cdot X_{sup} \\
p_0 \leftarrow X_{sup_0} \\
p_1 \leftarrow X_{sup_1} \\
\text{for } j \in 0..1 \\
\quad v_j \leftarrow \frac{X_{sup_{2+j}}}{X_{sup_1}} \\
\text{for } i \in 0..\mathrm{last}(t) \\
\quad \begin{array}{|l}
V_{F.rat_i} \leftarrow v_0 \cdot \cos\left(2\cdot\pi\cdot\frac{t_i}{12}\right) + v_1 \cdot \sin\left(2\cdot\pi\cdot\frac{t_i}{12}\right) \\
V_{S0.rat_i} \leftarrow V_{G_i} + V_{F.rat_i} \cdot d_{FM_i} \\
P_{S.rat_i} \leftarrow p_0 \cdot (N_i)^3 + p_1 \cdot (N_i)^2 \cdot V_{S0.rat_i} \\
J_{H.rat_i} \leftarrow \frac{V_{S0.rat_i}}{D \cdot N_i} \\
K_{P.rat_i} \leftarrow \frac{P_{S.rat_i}}{\rho \cdot D^5 \cdot (N_i)^3}
\end{array} \\
\left[E_{sup} \;\; V_{F.rat} \;\; V_{S0.rat} \;\; P_{S.rat} \;\; J_{H.rat} \;\; K_{P.rat} \;\; p \right]
\end{array}
$$

The harmonic current model has been introduced in accordance with the test data.

Analyse power required

$$
\begin{aligned}
\mathrm{Required}\left(V_{S0}, P_S, V_{WindR.x}\right) := \ & \text{for } i \in 0..\mathrm{last}\left(V_{S0}\right) \\
& \quad A_{req_{i,0}} \leftarrow \left(V_{S0_i}\right)^1 \\
& \quad A_{req_{i,1}} \leftarrow \left(V_{S0_i}\right)^2 \\
& \quad A_{req_{i,2}} \leftarrow \left(V_{S0_i}\right)^3 \\
& \quad A_{req_{i,3}} \leftarrow V_{WindR.x_i} \cdot \left|V_{WindR.x_i}\right| \cdot V_{S0_i} \\
& X_{req} \leftarrow \mathrm{LeftInv}\left(A_{req}\right) \cdot P_S \\
& E_{req} \leftarrow P_S - A_{req} \cdot X_{req} \\
& P_{AWind} \leftarrow A_{req}^{\langle 3 \rangle} \cdot X_{req_3} \\
& \text{for } i \in 0..\mathrm{last}\left(V_{S0}\right) \\
& \quad P_{AAir_i} \leftarrow \left(V_{S0_i}\right)^3 \cdot X_{req_3} \\
& P_{S0.vacuo} \leftarrow P_S - P_{AWind} \\
& \left[E_{req} \quad P_{AWind} \quad P_{S0.vacuo} \quad X_{req}\right]
\end{aligned}
$$

The reduction to the power required in vacuo permits direct comparison of the results of the various runs in this particular test case.

Check distribution of residua

```
Norm_distr(Sampl) := | r ← rows(Sampl)
                     | c ← cols(Sampl)
                     | for i ∈ 0..r − 1
                     |   | fract ← 2·(i + 1)/(r + 1) − 1
                     |   | distr ← fract
                     |   | Distr_i ← √2·root(erf(distr) − fract, distr)
                     |   | for j ∈ 0..1
                     |   |   A_(i,j) ← (Distr_i)^j
                     | for j ∈ 0..c − 1
                     |   Sampl_sort^<j> ← sort(Sampl^<j>)
                     | Par ← LeftInv(A)·Sampl_sort
                     | Sampl_sort.fair ← A·Par
                     | for j ∈ 0..c − 1
                     |   Par_(2,j) ← Par_(1,j)/√r
                     | [ Distr
                     |   Sampl_sort
                     |   Sampl_sort.fair
                     |   Par ]
```

Data supplied with files

$Data := READPRN("data.txt")^T$

time | course | speed over ground

$t_{File} := Data^{\langle 0 \rangle} \cdot min$ | $\psi_{0.File} := Data^{\langle 1 \rangle} \cdot deg$ | $V_{G.File} := Data^{\langle 2 \rangle} \cdot kn$

frequencies of revolution:

$N_{File} := (submatrix(Data, 0, 11, 3, 8)) \cdot min^{-1}$

brake powers measured:

$P_{S.File} := submatrix(Data, 0, 11, 9, 14) \cdot mhp$

$ni := rows(N_{File}) \quad ni = 12.00$ $\quad nj := cols(N_{File}) \quad nj = 6.00$

$i := 0 .. ni - 1 \quad j := 0 .. nj - 1$

$$t := \begin{bmatrix} 0.00 \\ 1.10 \\ 2.10 \\ 3.00 \\ 3.45 \\ 4.25 \end{bmatrix} \cdot hr$$

Time data replaced by correct values 03.02.2001

Data reorganised

$\psi_{0_j} := \psi_{0.File_j}$

$V_{G_j} := V_{G.File_j}$

$N_{10} := (submatrix(N_{File}, 0, nj - 1, 0, nj - 1))$

$N_{20} := (submatrix(N_{File}, nj, ni - 1, 0, nj - 1))$

$N := augment(N_{10}, N_{20})$

$P_{S.10} := (submatrix(P_{S.File}, 0, nj - 1, 0, nj - 1))$

$P_{S.20} := (submatrix(P_{S.File}, nj, ni - 1, 0, nj - 1))$

$P_S := augment(P_{S.10}, P_{S.20})$

Data in SI units except for time in view of further use in some mathematical subroutines, which by definition cannot handle arguments with (different) dimensions

$t := \frac{t}{hr} \quad \psi_0 := \frac{\psi_0}{rad} \quad V_G := \frac{V_G}{m \cdot sec^{-1}} \quad N := \frac{N}{Hz} \quad P_S := \frac{P_S}{W}$

Power supplied

$ni := rows(N)$ $ni = 6.00$ $nj := cols(N)$ $nj = 12.00$

$i := 0 .. ni - 1$ $j := 0 .. nj - 1$

Stacked data

$j := 1 .. nj - 1$

$S_0 := t$

$S_j := stack\left(S_{j-1}, t\right)$ $t_S := S_{nj-1}$

$S_0 := \psi_0$

$S_j := stack\left(S_{j-1}, \psi_0\right)$ $\psi_{0.s} := S_{nj-1}$

$S_0 := V_G$

$S_j := stack\left(S_{j-1}, V_G\right)$ $V_{G.s} := S_{nj-1}$

$S_0 := N^{<0>}$

$S_j := stack\left(S_{j-1}, N^{<j>}\right)$ $n_S := S_{nj-1}$

$S_0 := P_S{}^{<0>}$

$S_j := stack\left(S_{j-1}, P_S{}^{<j>}\right)$ $P_{S.s} := S_{nj-1}$

$j := 0 .. nj - 1$

Evaluation

$Res_{sup_j} := Supplied\left(D, \rho, t, \psi_0, V_G, N^{<j>}, P_S{}^{<j>}\right)$

$\left[E_{sup}{}^{<j>} \; V_{F.rat}{}^{<j>} \; V_{S0.rat}{}^{<j>} \; P_{S.rat}{}^{<j>} \; J_{H.rat}{}^{<j>} \; K_{P.rat}{}^{<j>} \; p_{rat}{}^{<j>}\right] := Res_{sup_j}$

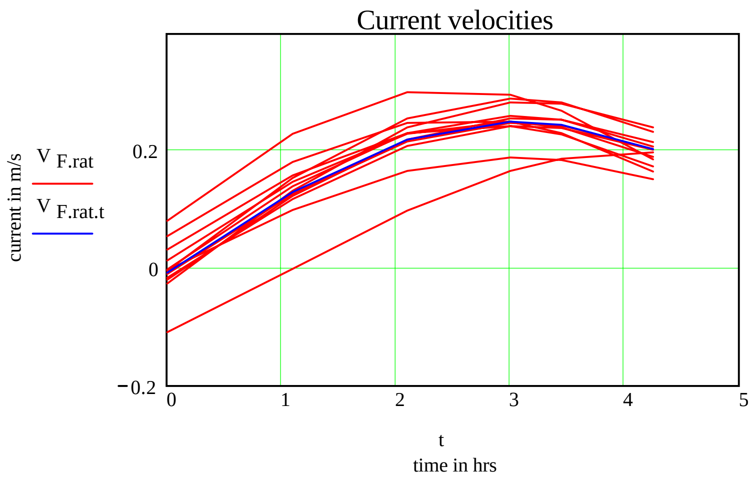
$Res_{sup.s} := Supplied\left(D, \rho, t_s, \psi_{0.s}, V_{G.s}, n_s, P_{S.s}\right)$

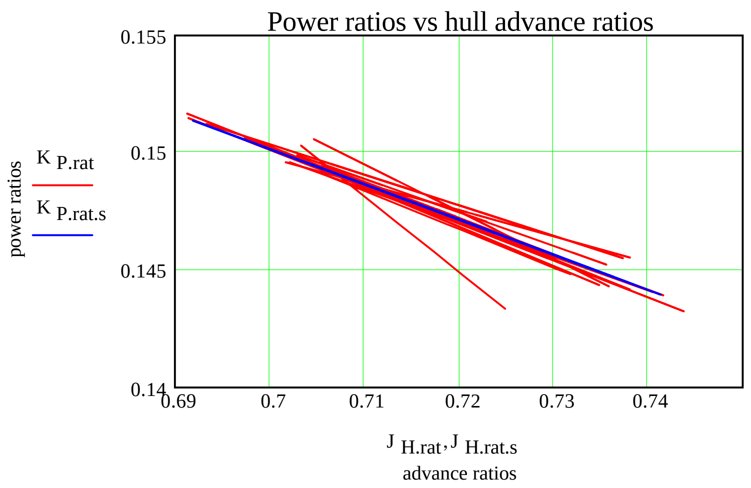
$\left[E_{sup.s} \; V_{F.rat.t} \; V_{S0.rat.s0} \; P_{S.rat.s} \; J_{H.rat.s} \; K_{P.rat.s} \; p_{rat.s}\right] := Res_{sup.s}$

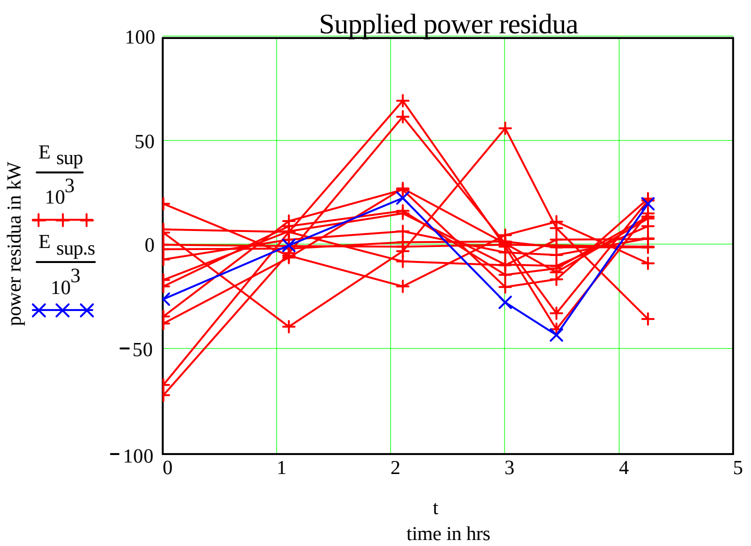
$V_{F.rat.s_i} := V_{F.rat.t_i}$

$V_{S0.rat.s_i} := V_{S0.rat.s0_i}$

Plots of current velocities
identified by rational method







These results show, that the data are not only noisy,
but that some power values are even inconsistent.

$$\frac{E_{sup}}{10^3} = \begin{bmatrix} -33.97 & 20.18 & -19.61 & 0.44 & -16.43 & -6.73 & -1.76 & -37.53 & 7.72 & 6.38 & -71.72 & -66.83 \\ 11.73 & -4.63 & 9.48 & -0.28 & 6.98 & 2.85 & -1.50 & -5.84 & 6.55 & -38.79 & -3.61 & 6.74 \\ 26.81 & -19.39 & 16.83 & -0.43 & 15.51 & 6.88 & 1.68 & 27.39 & -7.53 & -2.55 & 61.96 & 69.73 \\ -19.97 & 5.22 & -13.85 & 0.35 & -8.94 & -3.18 & 2.11 & 1.05 & -9.49 & 56.49 & 1.19 & -0.34 \\ -16.14 & 11.56 & -10.80 & 0.29 & -9.82 & -4.38 & -0.63 & -12.65 & 2.86 & 8.60 & -32.45 & -40.04 \\ 22.67 & -8.31 & 13.86 & -0.32 & 9.53 & 3.42 & -0.72 & 12.97 & 3.38 & -35.35 & 21.54 & 15.39 \end{bmatrix}$$

Relative residuals $\qquad e_{sup_{i,j}} := \frac{E_{sup_{i,j}}}{P_{S_{i,j}}}$

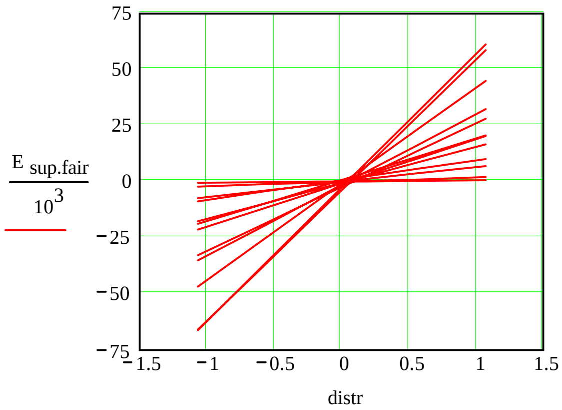
$$\frac{e_{sup}}{\%} = \begin{bmatrix} -0.54 & 0.32 & -0.31 & 0.01 & -0.26 & -0.11 & -0.03 & -0.55 & 0.11 & 0.10 & -1.10 & -1.07 \\ 0.20 & -0.08 & 0.16 & -0.00 & 0.11 & 0.05 & -0.03 & -0.10 & 0.11 & -0.65 & -0.06 & 0.11 \\ 0.27 & -0.19 & 0.17 & -0.00 & 0.16 & 0.07 & 0.02 & 0.25 & -0.07 & -0.02 & 0.60 & 0.69 \\ -0.21 & 0.05 & -0.14 & 0.00 & -0.09 & -0.03 & 0.02 & 0.01 & -0.10 & 0.59 & 0.01 & -0.00 \\ -0.13 & 0.09 & -0.08 & 0.00 & -0.08 & -0.03 & -0.00 & -0.09 & 0.02 & 0.06 & -0.25 & -0.31 \\ 0.19 & -0.07 & 0.11 & -0.00 & 0.08 & 0.03 & -0.01 & 0.11 & 0.03 & -0.29 & 0.17 & 0.12 \end{bmatrix}$$

Further analysis

Statistical analysis

Check of distributions

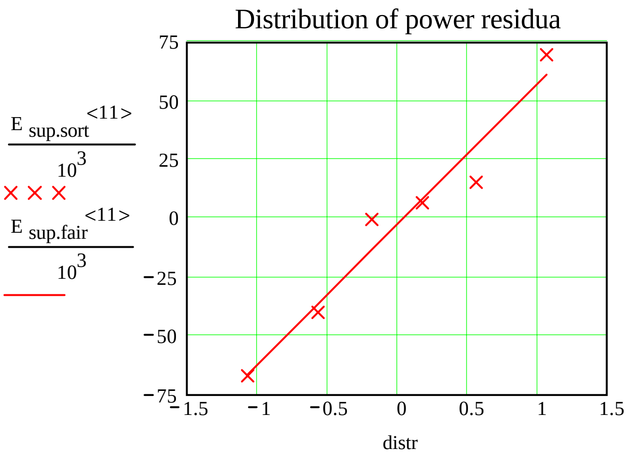
$$\begin{bmatrix} distr \\ E_{sup.sort} \\ E_{sup.fair} \\ par \end{bmatrix} := \text{Norm\_distr}\left(E_{sup}\right)$$



The data of the various runs are of very different quality.

$$\frac{E_{sup.sort}}{10^3} = \begin{bmatrix} -34 & -19 & -20 & -0 & -16 & -7 & -2 & -38 & -9 & -39 & -72 & -67 \\ -20 & -8 & -14 & -0 & -10 & -4 & -1 & -13 & -8 & -35 & -32 & -40 \\ -16 & -5 & -11 & -0 & -9 & -3 & -1 & -6 & 3 & -3 & -4 & -0 \\ 12 & 5 & 9 & 0 & 7 & 3 & -1 & 1 & 3 & 6 & 1 & 7 \\ 23 & 12 & 14 & 0 & 10 & 3 & 2 & 13 & 7 & 9 & 22 & 15 \\ 27 & 20 & 17 & 0 & 16 & 7 & 2 & 27 & 8 & 56 & 62 & 70 \end{bmatrix}$$

Detailed pictures of the distributions show,
that often the errors are not normally distributed.
As an example the distribution is being plotted
for run 11 (2 - 6), which later be excluded
from the evaluation of the power required..



According to this analysis only in the two cases 3 (1 - 4) and 6 (2 - 1)
the data show hardly any noise, but in case 6 there are systematic problems,
as far as the current is concerned.
Heavy systematic effects are also observed in the last cases 9, 10 and 11.
But despite the noise the power ratios are perfect
exept for the cases 1(1 - 2), 9 (2 - 4), 10 (2 - 5), 11(2 - 6).

Further analysis

In this test case the repeated runs with the same ship at the same current permits further analysis.

The following results suggest that the velocites are the same down and up the current.
And in fact this has been assumed in generating the test data.
For the analysis in general this step is not not necessary, even wrong!

$$V_{S0.rat.s} = \begin{bmatrix} 7.21 \\ 7.18 \\ 8.24 \\ 8.22 \\ 8.74 \\ 8.76 \end{bmatrix}$$

$k := 0 .. 2$

'Consequently' the analysis is continued with the averages

$$V_{S0.ave_k} := \frac{V_{S0.rat.s_{2\cdot k}} + V_{S0.rat.s_{2\cdot k+1}}}{2}$$

$$V_{S0.rat.s_{2\cdot k}} := V_{S0.ave_k}$$

$$V_{S0.rat.s_{2\cdot k+1}} := V_{S0.ave_k}$$

Check of current data

$$v_{S0.Errors_{i,j}} := \frac{V_{S0.rat_{i,j}} - V_{S0.rat.s_i}}{V_{S0.rat.s_i}}$$

$$\frac{v_{S0.Errors}}{\%} = \begin{bmatrix} -0.10 & 0.31 & -0.67 & 0.35 & -0.36 & 0.22 & 0.14 & 0.11 & 0.13 & 0.44 & 1.59 & -1.04 \\ 0.05 & -0.35 & 0.53 & -0.28 & 0.21 & -0.23 & 0.15 & -0.05 & -0.60 & -0.16 & -2.01 & 1.19 \\ 0.00 & 0.25 & -0.22 & 0.12 & -0.02 & 0.15 & -0.32 & -0.01 & 0.76 & -0.13 & 1.59 & -0.86 \\ -0.12 & -0.21 & -0.12 & -0.05 & -0.21 & -0.14 & 0.36 & -0.00 & -0.86 & 0.28 & -1.14 & 0.44 \\ -0.06 & -0.06 & 0.05 & -0.21 & 0.07 & -0.10 & -0.54 & -0.21 & 0.58 & -0.53 & 0.55 & -0.39 \\ -0.02 & 0.11 & -0.31 & 0.25 & -0.22 & 0.12 & 0.45 & 0.17 & -0.47 & 0.55 & 0.06 & -0.08 \end{bmatrix}$$

Check of power data

$$P_{C_{i,j}} := P_{sup}\left(p_{rat.s}, N_{i,j}, V_{S0.rat.s_i}\right)$$

$$p_{S.Errors_{i,j}} := \frac{P_{S_{i,j}} - P_{C_{i,j}}}{P_{C_{i,j}}}$$

$$\frac{P_{S.Errors}}{\%} = \begin{bmatrix} -0.54 & -0.01 & 0.18 & 0.02 & 0.03 & -0.66 & -0.23 & -0.63 & -0.10 & 0.18 & -4.28 & 0.04 \\ 0.14 & -0.14 & -0.26 & 0.50 & -0.05 & -0.16 & -0.39 & -0.25 & 0.19 & 0.13 & -0.11 & -0.03 \\ 0.15 & -0.04 & 0.31 & 0.10 & 0.22 & -0.32 & 0.21 & 0.33 & -0.65 & 0.30 & -1.73 & 1.36 \\ -0.20 & 0.31 & -0.07 & 0.26 & 0.10 & -0.19 & -0.42 & -0.08 & 0.35 & 0.91 & 0.09 & -0.03 \\ -0.25 & 0.88 & -0.15 & 0.28 & -0.04 & -0.10 & 0.39 & 0.19 & -0.30 & 0.48 & -0.20 & -0.24 \\ 0.08 & 0.30 & 0.31 & -0.02 & 0.31 & -0.22 & -0.44 & -0.03 & 0.29 & -0.34 & -0.12 & 0.07 \end{bmatrix}$$

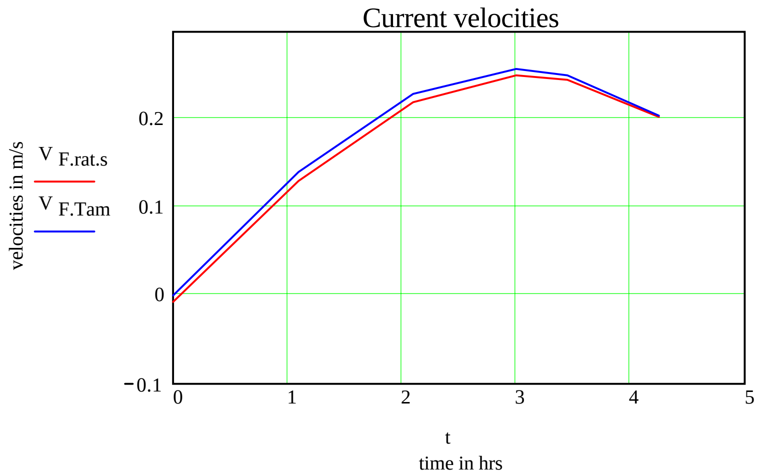
These errors indicate that the test data are not just noisy!

And in this case the data used for the construction of the test data are known,
so that further **comparison of the overall results with 'input' is possible.**

Current

$T := 12 \cdot hr$ $\quad T := \frac{T}{hr}$ $\quad A := 0.5 \cdot kn$ $\quad A := \frac{A}{m \cdot sec^{-1}}$ $\quad V_F(\tau) := A \cdot \sin\left(\frac{2 \cdot \pi}{T} \cdot \tau\right)$

$i := 0 .. \text{last}(t)$ $\quad V_{F.Tam_i} := V_F(t_i)$



$$\frac{V_{F.rat.s} - V_{F.Tam}}{A \cdot \%} = \begin{bmatrix} -2.743 \\ -3.763 \\ -3.637 \\ -2.685 \\ -1.970 \\ -0.460 \end{bmatrix}$$

Power ratios

Data at no wind and no waves

$V_{S0.Tam} := \begin{bmatrix} 14 \\ 16 \\ 17 \end{bmatrix} \cdot kn$ $\quad N_{S0.Tam} := \begin{bmatrix} 88.9 \\ 103.7 \\ 112.1 \end{bmatrix} \cdot \frac{1}{min}$ $\quad P_{S0.Tam} := \begin{bmatrix} 8207 \\ 13226 \\ 16938 \end{bmatrix} \cdot mhp$

$V_{S0.Tam} := \frac{V_{S0.Tam}}{m \cdot sec^{-1}}$ $\quad N_{S0.Tam} := \frac{N_{S0.Tam}}{Hz}$ $\quad P_{S0.Tam} := \frac{P_{S0.Tam}}{W}$

$i := 0 .. 2$

Powering characteristic identified

$$A_{Tam_{i,0}} := \left(N_{S0.Tam_i}\right)^3$$

$$A_{Tam_{i,1}} := \left(N_{S0.Tam_i}\right)^2 \cdot V_{S0.Tam_i}$$

$$p_{Tam} := \text{LeftInv}\left(A_{Tam}\right) \cdot P_{S0.Tam}$$

$$P_{Tam}(N, V) := p_{Tam_0} \cdot N^3 + p_{Tam_1} \cdot N^2 \cdot V$$

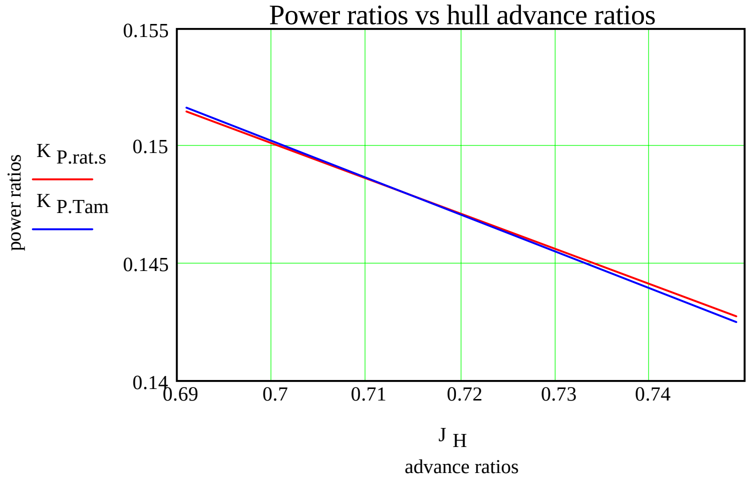
$$J_H := \begin{bmatrix} 0.691 \\ 0.749 \end{bmatrix} \qquad k_{P.Tam_0} := \frac{p_{Tam_0}}{\rho \cdot D^5} \qquad k_{P.Tam_1} := \frac{p_{Tam_1}}{\rho \cdot D^4} \qquad p_{Tam} = \begin{bmatrix} 3.34 \cdot 10^6 \\ -306195.70 \end{bmatrix}$$

$$k_{P.rat.s_0} := \frac{p_{rat.s_0}}{\rho \cdot D^5} \qquad k_{P.rat.s_1} := \frac{p_{rat.s_1}}{\rho \cdot D^4} \qquad p_{rat.s} = \begin{bmatrix} 3.28 \cdot 10^6 \\ -292283.14 \end{bmatrix}$$

$$k := 0 .. 1$$

$$K_{P.Tam_k} := k_{P.Tam_0} + k_{P.Tam_1} \cdot J_{H_k} \qquad k_{P.Tam} = \begin{bmatrix} 0.26 \\ -0.16 \end{bmatrix}$$

$$K_{P.rat.s_k} := k_{P.rat.s_0} + k_{P.rat.s_1} \cdot J_{H_k} \qquad k_{P.rat.s} = \begin{bmatrix} 0.26 \\ -0.15 \end{bmatrix}$$



Despite the inconsistencies observed, the overall results are nearly identical with the input data of the simulation.

Power required

Absolute wind speeds

$V_{WindA.10} := 10 \cdot kn \qquad V_{WindA.10} := \frac{V_{WindA.10}}{m \cdot sec^{-1}}$

$V_{WindA.20} := 20 \cdot kn \qquad V_{WindA.20} := \frac{V_{WindA.20}}{m \cdot sec^{-1}}$

Absolute wind directions

$$\psi_{WindA} := \begin{bmatrix} 0 \\ 30 \\ 45 \\ 60 \\ 75 \\ 90 \end{bmatrix} \cdot deg \qquad \psi_{WindA} := \frac{\psi_{WindA}}{rad}$$

Relative wind velocity

in longitudinal direction

$i := 0 .. ni - 1 \qquad j := 0 .. ni - 1$

$V_{WindA.x.10_j} := V_{WindA.10} \cdot \cos\left(\psi_{WindA_j}\right)$

$V_{WindA.x.20_j} := V_{WindA.20} \cdot \cos\left(\psi_{WindA_j}\right)$

$V_{WindR.x_{i,j}} := V_{G_i} + V_{WindA.x.10_j} \cdot if\left(\psi_{0_i} < \pi, 1, -1\right)$

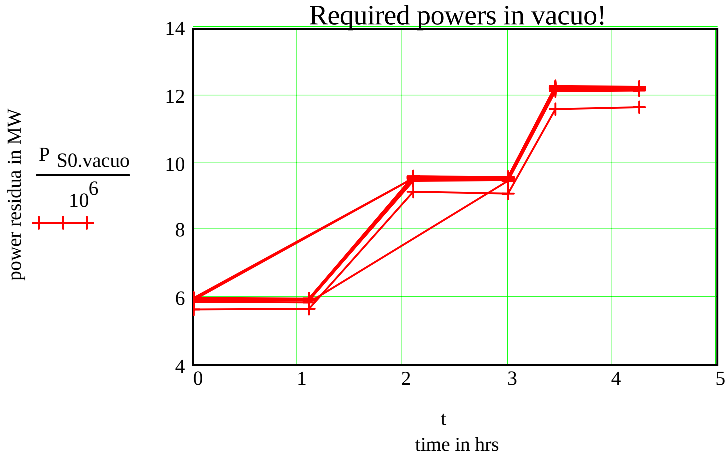
$V_{WindR.x_{i,ni+j}} := V_{G_i} + V_{WindA.x.20_j} \cdot if\left(\psi_{0_i} < \pi, 1, -1\right)$

Evaluation

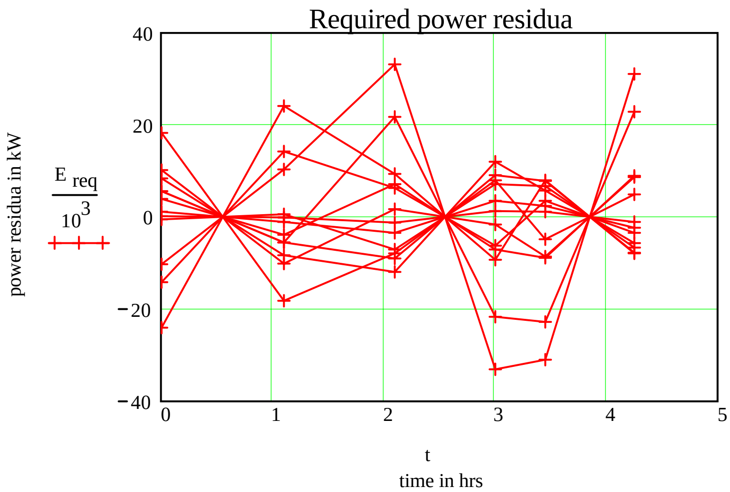
$j := 0 .. nj - 1$

$Res_{req_j} := Required\left(V_{S0.rat.s}, P_S^{\langle j \rangle}, V_{WindR.x}^{\langle j \rangle}\right)$

$\left[E_{req}^{\langle j \rangle} \quad P_{AWind}^{\langle j \rangle} \quad P_{S0.vacuo}^{\langle j \rangle} \quad C_{Res}^{\langle j \rangle} \right] := Res_{req_j}$



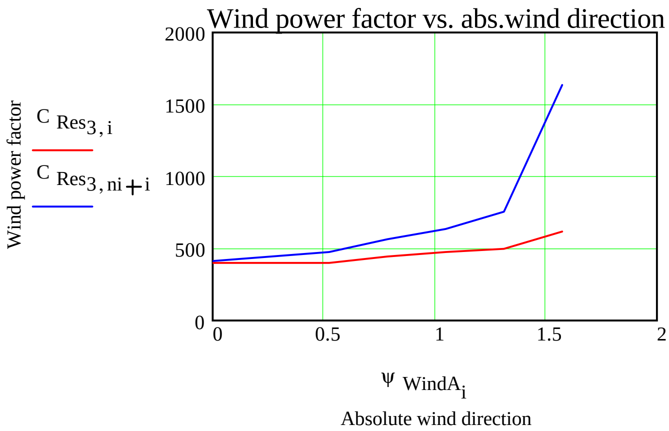
With one exception, run 11 (2 - 6), all runs provide very closely the same power required in vacuo!



$$\frac{E_{req}}{10^3} = \begin{bmatrix} -1 & 1 & 0 & -14 & 8 & 6 & 10 & -24 & 4 & 18 & 6 & -10 \\ 1 & -1 & -0 & 14 & -8 & -6 & -10 & 24 & -4 & -18 & -6 & 10 \\ -7 & -3 & -1 & 6 & -12 & -9 & 2 & 9 & 7 & -8 & 22 & 33 \\ 7 & 3 & 1 & -6 & 12 & 9 & -2 & -9 & -7 & 8 & -22 & -33 \\ 7 & 2 & 1 & 3 & 6 & 8 & -9 & 8 & -9 & -5 & -23 & -31 \\ -7 & -2 & -1 & -3 & -6 & -8 & 9 & -8 & 9 & 5 & 23 & 31 \end{bmatrix}$$

The pattern exhibited by the residua is an indication, that in simulation of the data another law has been used than in my evaluation.
So statistical analysis is not meaningful at this stage, particularly in view of the very small residua!

The intermediate step of the power in vacuo, the power required due to water resistance, is necessary due to the fact, that the coefficients of wind resistance are different depending on the wind direction, in the present investigation **stupidly** taken to be the absolute direction.



This plot shows that something is wrong with the data of the last run, as has been observed before.
Consequently the results of the last run are being excluded from the following evaluation.

Power required at no wind

In order to determine the power in still air the value at zero angle has to be taken.

$$C_{Res.Air} := \frac{C_{Res_{3,0}} + C_{Res_{3,6}}}{2} \qquad C_{Res.Air} = 403.0$$

$$P_{AAir_i} := C_{Res.Air} \cdot \left(V_{S0.rat.s_i}\right)^3$$

$$P_{S0.rat_{i,j}} := P_{S0.vacuo_{i,j}} + P_{AAir_i}$$

$$P_{S0.rat.s_i} := \text{mean}\left[\left(P_{S0.rat}{}^{T}\right)^{\langle i \rangle}\right]$$

Averages

$i := 0 .. \frac{ni}{2} - 1 \qquad j := 0 .. nj - 2 \qquad P_{S0.ave_{i,j}} := \frac{P_{S0.rat_{2\cdot i,j}} + P_{S0.rat_{2\cdot i+1,j}}}{2}$

$$\frac{P_{S0.ave}}{10^6} = \begin{bmatrix} 6.06 & 6.09 & 6.09 & 6.09 & 6.13 & 6.10 & 6.01 & 6.09 & 6.11 & 6.13 & 6.11 \\ 9.73 & 9.77 & 9.78 & 9.81 & 9.81 & 9.71 & 9.69 & 9.82 & 9.79 & 9.79 & 9.81 \\ 12.45 & 12.50 & 12.50 & 12.53 & 12.54 & 12.47 & 12.42 & 12.56 & 12.49 & 12.53 & 12.49 \end{bmatrix}$$

$P_{S0.ave.mean_i} := \mathrm{mean}\left[\left(P_{S0.ave}^T\right)^{\langle i\rangle}\right] \qquad P_{S0.ave.mean} = \begin{bmatrix} 6.09 \\ 9.77 \\ 12.50 \end{bmatrix} \circ \frac{MW}{W}$

$P_{S0.ave.dev_i} := \mathrm{Stdev}\left[\left(P_{S0.ave}^T\right)^{\langle i\rangle}\right] \qquad P_{S0.ave.dev} = \begin{bmatrix} 0.03 \\ 0.04 \\ 0.04 \end{bmatrix} \circ \frac{MW}{W}$

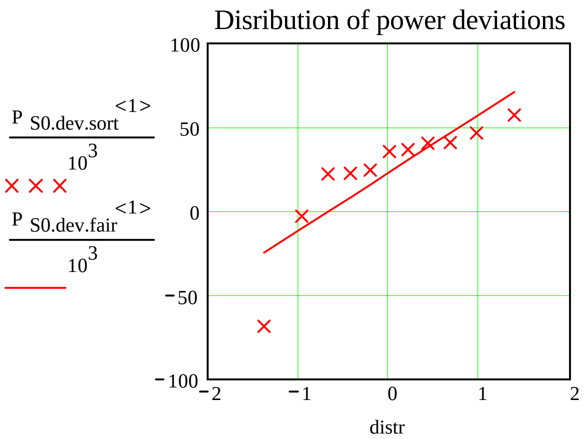
$P_{S0.95_i} := \frac{2 \cdot P_{S0.ave.dev_i}}{P_{S0.ave.mean_i}} \qquad P_{S0.95} = \begin{bmatrix} 1.10 \\ 0.88 \\ 0.64 \end{bmatrix} \circ \%$

95 % confidence interval less than 1 % for all runs, except 11 (2 - 6)!

Analysis of distribution of deviations over all runs

$P_{S0.rat.dev}^{\langle j\rangle} := P_{S0.rat}^{\langle j\rangle} - P_{S0.rat.s}$

$$\begin{bmatrix} distr^{\langle i\rangle} \\ P_{S0.dev.sort}^{\langle i\rangle} \\ P_{S0.dev.fair}^{\langle i\rangle} \\ par^{\langle i\rangle} \end{bmatrix} := \mathrm{Norm\_distr}\left[\left(P_{S0.rat.dev}^T\right)^{\langle i\rangle}\right]$$



Just an example to show that the deviations over all runs are **not** normally distributed.

Comparison with the input

$$P_{diff_i} := \frac{P_{S0.ave.mean_i} - P_{S0.Tam_i}}{P_{S0.Tam_i}}$$

$$P_{diff} = \begin{bmatrix} 0.93 \\ 0.47 \\ 0.33 \end{bmatrix} \cdot \%$$

Less than 1 % difference from input values

Mean power polynomial coefficients

$$C_{Res.mean_i} := \text{mean}\left[\left(C_{Res}^{T}\right)^{\langle i \rangle}\right]$$

$$C_{Res.mean_2} := C_{Res.mean_2} + C_{Res.Air}$$

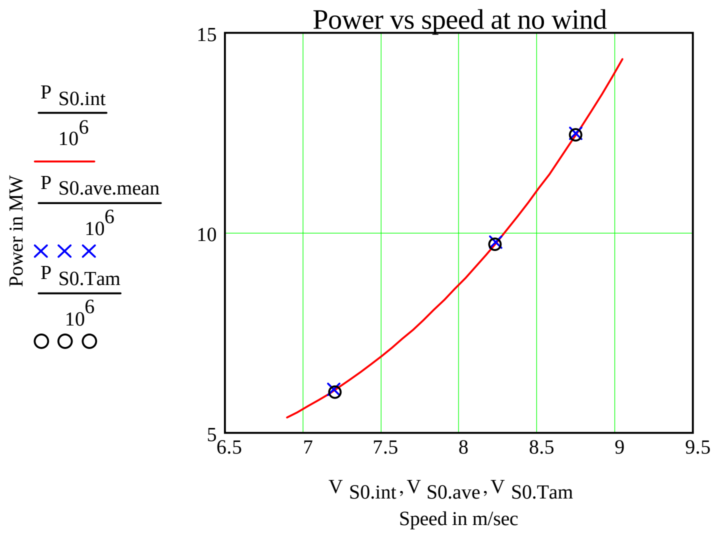
$$C_{Res.mean} = \begin{bmatrix} 3.85 \cdot 10^{6} \\ -1.07 \cdot 10^{6} \\ 90081.58 \end{bmatrix}$$

Interpolated power values

$n := 32$ $\quad k := 0 .. n$ $\quad \Delta V_{S0} := 0.3$

$$V_{S0.int_k} := V_{S0.ave_0} - \Delta V_{S0} + k \cdot \frac{\left(V_{S0.ave_2} - V_{S0.ave_0}\right) + 2 \cdot \Delta V_{S0}}{n}$$

$$P_{S0.int_k} := P_{req}\left(C_{Res.mean}, V_{S0.int_k}\right)$$



Normalised values

$$Fn_{int_k} := Fn\left(V_{S0.int_k}\right)$$

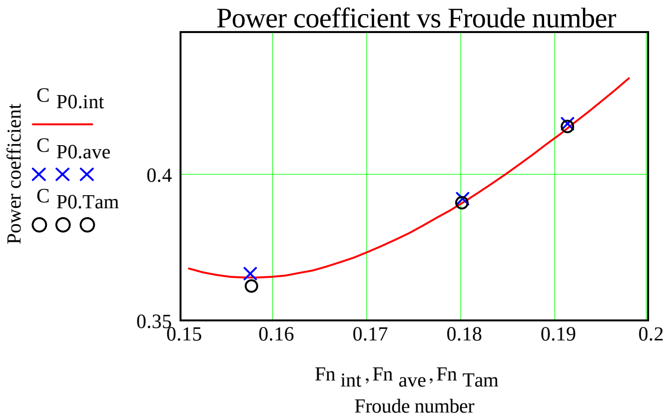
$$Fn_{ave_i} := Fn\left(V_{S0.ave_i}\right)$$

$$Fn_{Tam_i} := Fn\left(V_{S0.Tam_i}\right)$$

$$C_{P0.int_k} := CP\left(P_{S0.int_k}, V_{S0.int_k}\right)$$

$$C_{P0.ave_i} := CP\left(P_{S0.ave.mean_i}, V_{S0.ave_i}\right)$$

$$C_{P0.Tam_i} := CP\left(P_{S0.Tam_i}, V_{S0.Tam_i}\right)$$



Frequencies of revolution

$$N_{init_i} := 1$$

$$N_{S0.ave}^{\langle j\rangle} := Revs\left(p_{rat}^{\langle j\rangle}, V_{S0.ave}, P_{S0.ave}^{\langle j\rangle}, N_{init}\right)$$

$$60 \cdot N_{S0.ave} = \begin{bmatrix} 89.0 & 89.1 & 89.1 & 89.0 & 89.2 & 89.2 & 88.8 & 89.1 & 89.2 & 89.1 & 89.8 \\ 103.7 & 103.8 & 103.8 & 103.8 & 103.9 & 103.7 & 103.6 & 104.0 & 103.9 & 103.7 & 104.3 \\ 112.1 & 112.0 & 112.2 & 112.3 & 112.3 & 112.2 & 112.1 & 112.4 & 112.2 & 112.2 & 112.3 \end{bmatrix}$$

$$N_{S0.ave.s} := Revs\left(p_{rat.s}, V_{S0.ave}, P_{S0.ave.mean}, N_{init}\right)$$

$$N_{S0.ave.s} = \begin{bmatrix} 89.09 \\ 103.82 \\ 112.22 \end{bmatrix} \circ \frac{sec}{min}$$

$$N_{S0.ave.mean_i} := mean\left[\left(N_{S0.ave}^{T}\right)^{\langle i\rangle}\right] \qquad N_{S0.ave.mean} = \begin{bmatrix} 89.2 \\ 103.8 \\ 112.2 \end{bmatrix} \circ \frac{sec}{min}$$

$$N_{S0.ave.dev_i} := Stdev\left[\left(N_{S0.ave}^{T}\right)^{\langle i\rangle}\right] \qquad N_{S0.ave.dev} = \begin{bmatrix} 0.243 \\ 0.177 \\ 0.095 \end{bmatrix} \circ \frac{sec}{min}$$

$$n_{ave.95_i} := \frac{2 \cdot N_{S0.ave.dev_i}}{N_{S0.ave.mean_i}} \qquad n_{ave.95} = \begin{bmatrix} 0.55 \\ 0.34 \\ 0.17 \end{bmatrix} \circ \%$$

96 % confidence interval less than +/- 0.6 %
for all runs, except 11 (2 - 6)!

Analysis of distribution of deviations over all runs

$i := 0 .. ni - 1$

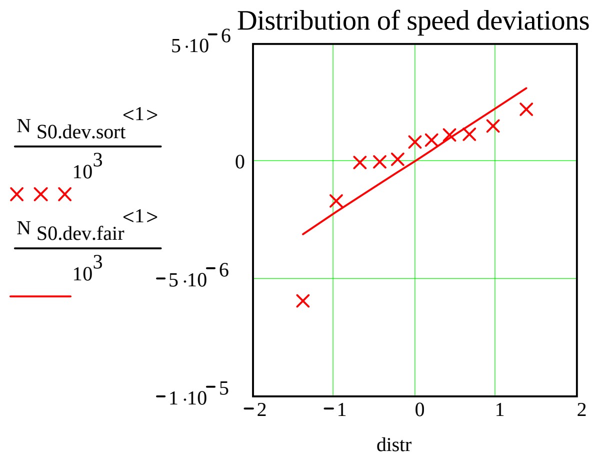
$N_{init_i} := 1$

$N_{S0.rat}^{\langle j \rangle} := Revs\left(p_{rat.s}, V_{S0.rat.s}, P_{S0.rat}^{\langle j \rangle}, N_{init}\right)$

$N_{S0.rat.s_i} := mean\left[\left(N_{S0.rat}^{T}\right)^{\langle i \rangle}\right]$

$N_{S0.dev}^{\langle j \rangle} := N_{S0.rat}^{\langle j \rangle} - N_{S0.rat.s}$

$$\begin{bmatrix} distr^{\langle i \rangle} \\ N_{S0.dev.sort}^{\langle i \rangle} \\ N_{S0.dev.fair}^{\langle i \rangle} \\ par^{\langle i \rangle} \end{bmatrix} := Norm\_distr\left[\left(N_{S0.dev}^{T}\right)^{\langle i \rangle}\right]$$



Just an example to show that the deviations over all runs are **not** normally distributed.

Comparison with the input

$i := 0 .. 2$

$$n_{diff_i} := \frac{N_{S0.ave.s_i} - N_{S0.Tam_i}}{N_{S0.Tam_i}}$$

$$n_{diff} = \begin{bmatrix} 0.21 \\ 0.11 \\ 0.10 \end{bmatrix} \cdot \%$$

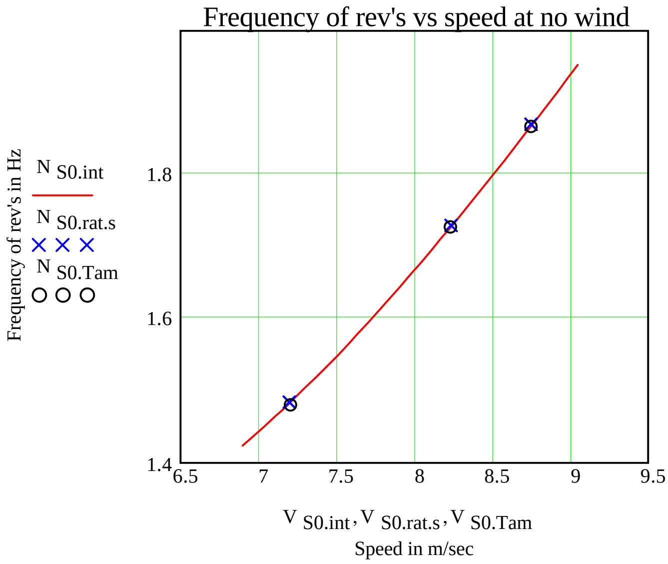
Less than +/- 0.3 % difference from input values

Interpolated values

$N_{init_k} := 1$

$N_{S0.int} := Revs\left(p_{rat.s}, V_{S0.int}, P_{S0.int}, N_{init}\right)$

$$N_{S0.ave.s} = \begin{bmatrix} 1.48 \\ 1.73 \\ 1.87 \end{bmatrix}$$

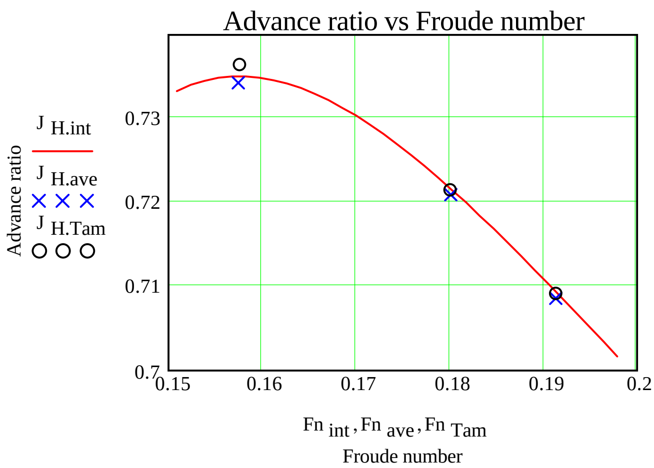


Normalised values

$$J_{H.int_k} := JH\left(V_{S0.int_k}, N_{S0.int_k}\right)$$

$$J_{H.ave_i} := JH\left(V_{S0.ave_i}, N_{S0.ave.s_i}\right)$$

$$J_{H.Tam_i} := JH\left(V_{S0.Tam_i}, N_{S0.Tam_i}\right)$$



Some Comments

The individual and the overall results concerning the power required are perfect for any practical purpose, even with the stupid wind power model adopted. But I am reluctant to adopt
a more involved model and to identify more than four parameters from only six runs, particularly from real data.
A problem is that one needs the ahead wind coefficient, which has been identified in this test case from the appropriate tests at wind from ahead and from behind. In practice one will have to identified this value accordingly, if one does not want to rely on 'laws' etc.
The individual results concerning the power supplied and the current are much less satisfactory due to poor quality of the data. In general one does not have the **excellent overall results from a large sample** as in the present test case. In practice one needs good data and, as examples have shown, usually they are good nowadays.
My suspicion is that the procedure for the construction of the data includes inconsistancies as does the traditional procedure for the analysis, as e. g. the procedure proposed in the drft standard ISO DIS 15016. I have provided evidence to that effect already at an early stage of the discussion and continued to explain this in many examples, papers and presentations all to be found on my website.
The important point of the whole procedure is that the properties of the ship can be identified without reference to model test results and other prior knowledge. A problem is the tendency towards smaller number´s of runs for reasons of costs. As I pointed out many times quasi-steady changes of state will provide all the information required. One does not even need three double runs. Maybe people will use the method as soon as they realise that its not only more convincing but also reducing their costs.

END Analysis of EVEREST constructed data