Goodness of Fit

NASPI

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Measurement (1)

Given an alternating voltage, we could

- Measure amplitude
- Measure frequency
- Measure phase relative to some other signal

Or, if we wish, we could measure all together

That is the same as solving the equation

$$x(t) = A\cos(\omega t + \varphi) \qquad (1)$$

Measurement (2)

Measurement of this kind is thus what mathematicians call a “fitting problem.”

Only in this case, the form of the equation is fixed by the physics.

As a fitting problem,

- Need multiple samples
- Min # samples = (# degrees of freedom in equation) +1
- (1) can be solved with 3 samples if no noise

Modify the equation to include ROCOF, need 4 samples

Measurement (3)

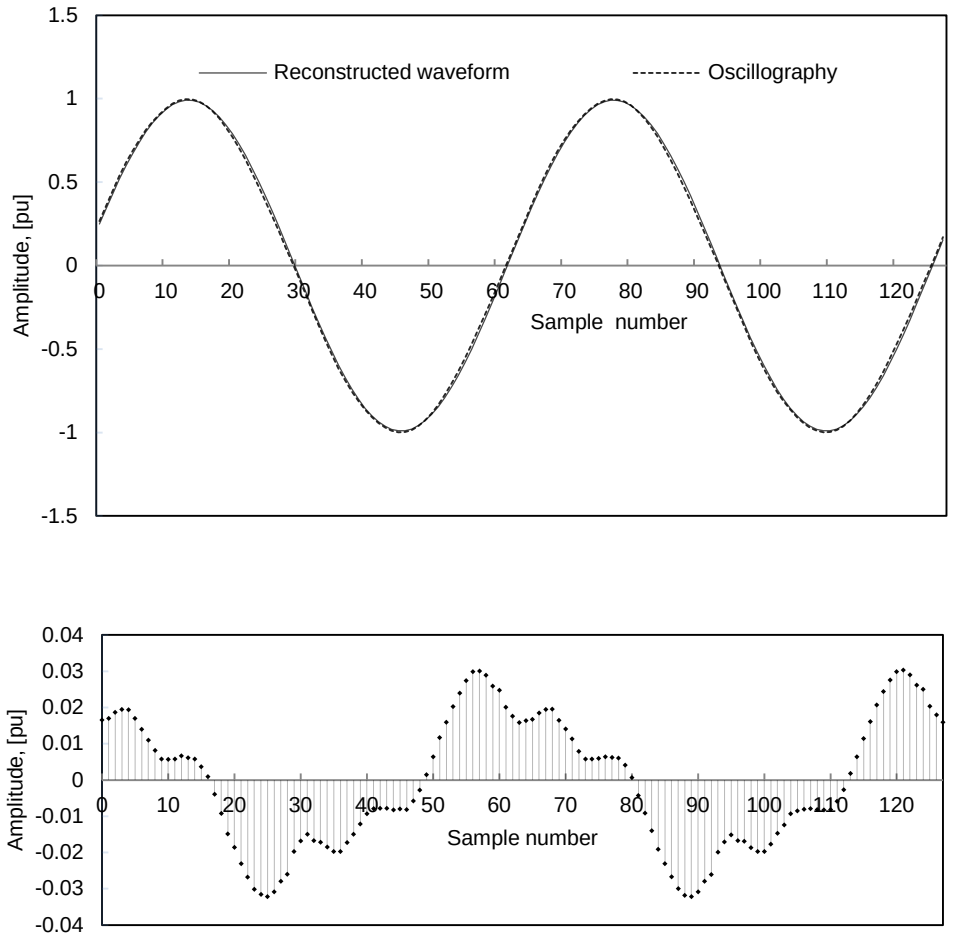
- The equation is a model: Equation (1) was a cosine model
- The *results* of the measurements are the model coefficients
- To solve as a fitting problem, one minimizes the residuals

But the measurement does not have to be made as a fitting problem to take advantage of the method*ology*

- One can find residuals, however the measurement was done
- One can look at how big the residuals are

- That is a very informative thing to do!

AEP* 345-kV data fits the equation



*Many thanks to Zak Campbell (AEP) for the data sets

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AEP data

- The residuals are few percent of the signal
- There is a fundamental-frequency component, indicating phase or timing error somewhere

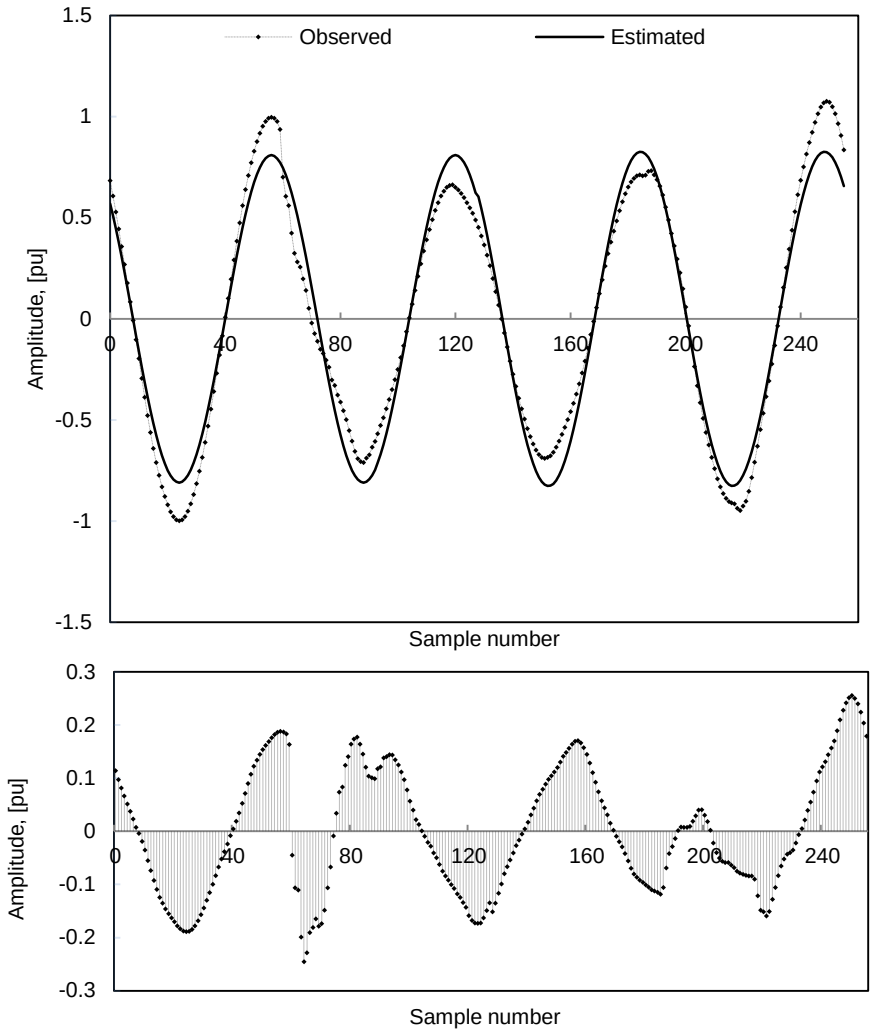
But residuals are small, indicating

the model is a good representation of the signal

- Not always the case: during fault, for example, or phase jump
- Define Goodness of Fit:

$$\mathrm{GoF} = 20\log\frac{A}{\sqrt{\frac{1}{(N-m)}\sum_{k=1}^{N}(u_k - v_k)^2}}$$

Fault response (voltage)



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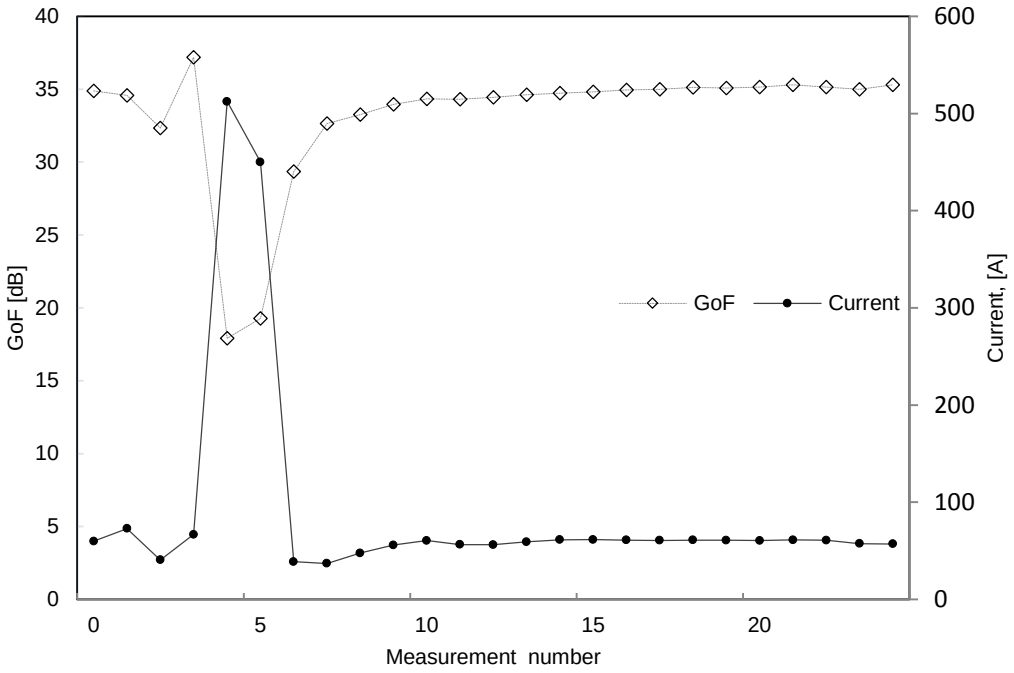
Fault response: Current & GoF



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Final Remarks

"Since the measuring device has been constructed by the observer, we have to remember that what we observe is not nature in itself, but nature exposed to our method of questioning"

The PMU answers this question:
If this signal were a cosine wave, what would the amplitude, frequency and phase be?

But the signal may not be a cosine wave . . . And GoF will tell you that without delay

W. Heisenberg, Physics and Philosophy: The Revolution in Modern Science, London: George Allen and Unwin, 1959.

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Glaucon: And the arts of measuring and numbering and weighing come to the rescue of the human understanding—there is the beauty of them—and the apparent greater or less, or more or heavier, no longer have the mastery over us, but give way before calculation and measure and weight?

Socrates: Most true.

Plato *Republic* Book X, 360 BCE