PMU Measurement and its Standardization

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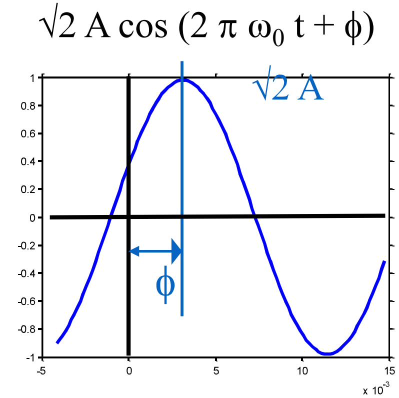
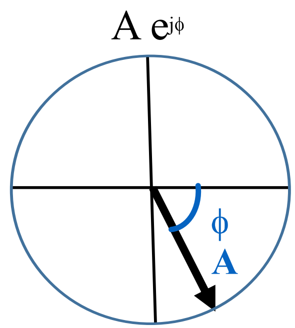
Introduction

- A phasor is the representation of sinusoidal parameters
- AC voltage and current are "mostly" sinusoidal, so we analyze power systems using phasor equivalents
- In 1980's computer relaying led to direct estimation of phasors in real-time based on a standard time reference
- Thus the ***Synchrophasor*** was born
- The first synchrophasor standard, IEEE 1344-1995, was created to establish a common basis to support and encourage development of the technology





Synchrophasor Measurement Standard development

- Synchrophasor Standard IEEE C37.118-2005 established most of the current measurement and communication practices in use
  - It was split into separate measurement and communication standards
- The present Measurement Standard is IEC/IEEE 60255-118-1
  - Covers Phasor, Frequency, & Rate of Change of Frequency
- Steady-state requirements
  - Measurement accuracy
  - Rejection of interference
- Measurement under dynamic conditions
  - Measurement bandwidth (modulation)
  - Frequency tracking (ramp) & response time (step)
- Communication latency test


IEC IEEE IEC/IEEE 60255-118-1

Edition 1.0 2018-12

INTERNATIONAL STANDARD

colour inside

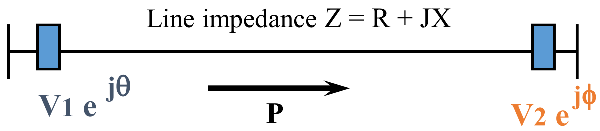
Measuring relays and protection equipment –
Part 118-1: Synchrophasor for power systems – Measurements

Can this standard be used for PMUs intended for distribution systems?

- Present standard was modeled on transmission systems
  - Experience was with measurements on transmission signals
  - Accuracies targeted toward transmission applications
  - Requirements based on transmission signals – ROCOF, noise, frequency limits, etc.
- Are distribution systems that different?
  - ROCOF & frequency are similar when connected to larger system
  - For Microgrids, deviations may be much larger
  - Noise, interference, local deviations not well documented
- Applications not well described as few deployed
  - Same problem as with transmission case
  - Mostly similar to current applications

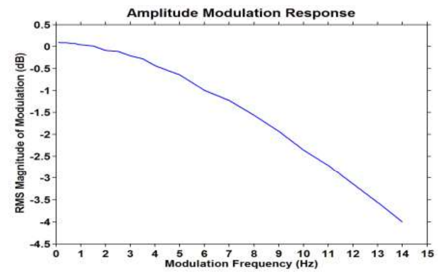
Some differences to address

- How much effect will noise and harmonics have on steady-state measurement?
  - Now we do not test with added noise
  - Harmonics are tested one at a time
- Frequency measurement spans 2 or 5 Hz
  - Will microgrids operate over wider frequencies?
- How accurate must angle measurement be?
  - For Transmission, phase angle difference relates to power flow
  - For distribution, the relation is more complex because resistance is higher and lines are shorter
- Frequency tracking is tested at 1 Hz/s max
  - Microgrids may ramp more quickly
- Measurement bandwidth is only required to 5 Hz
  - Inverters can have oscillations > 5 Hz



$$P = V_1 V_2 \sin(\theta - \phi) / X$$

$$|V_1|^2 - |V_2|^2 \approx 2(RP + XQ)$$
$$\theta - \phi \approx 2(XP - RQ)/(|V_1|^2 |V_2|^2)$$



The synchrophasor duality

- A sinusoidal signal can be very precisely determined from the phasor representation
  - The mathematical formula specifies magnitude, phase and frequency

- The Phasor value:
- Determines the sinusoidal formula:

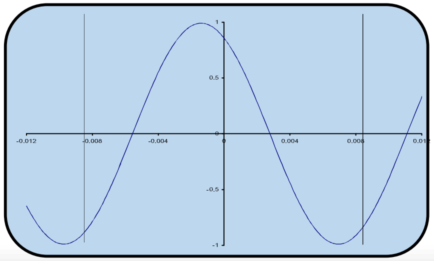
$$\boldsymbol{X}(t) = (X_m(t)/\sqrt{2})e^{j(2\pi\int g dt + \varphi(t))}$$

⇩

$$x(t) = X_m(t)\cos(2\pi f_0 t + (2\pi \int g dt + \varphi(t)))$$

⇩

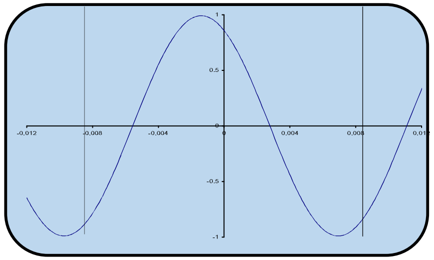
- Which generates the waveform:



- The AC waveform is precisely described by the phasor

Estimating the synchrophasor from the waveform

- Given the waveform, what is the phasor?
  - Assume it is a sinusoid, but it is only approximately
  - The phasor parameters do not exist in the waveform, we only infer them
- Observe waveform over an interval
  - A point on the waveform does not define it
  - Any interval reduces bandwidth



- Estimate a sinusoidal fit to the data:

$$x(t) = X_m(t)\cos(2\pi f_0\, t + (2\pi \int g\,dt + \varphi(t)))$$

- Pull out the phasor values:

$$\boldsymbol{X}(t) = (X_m(t)/\sqrt{2})e^{j(2\pi \int g\,dt + \varphi(t))}$$

- The phasor only approximately represents the waveform
- A standard has to accommodate these limitations

Role of Standards

- Technology support for both vendors and users
  - Vendors have a definite target for implementing requirements
  - Purchasers have a guide for specifications
  - Users know what they can expect from a product
- Standards should fulfill industry needs
  - Assure interoperability among products and outcomes
  - Provide a common basis for interfacing
  - Create a level playing field for innovation and production
- Standards should not unduly restrict technology
  - Allow for additional features and vendor development
  - Not require special functions or performance requirements not needed by most uses
  - All requirements should be testable and verifiable

IEEE PSRC WG C41 studying case for creating a synchrophasor standard

- Assess developing and anticipated distribution applications
  - Determine if the applications are mature enough to indicate data requirements
  - If so, categorize these for PMU measurement
- Analyze the signals that will be used to make phasor measurements
  - Determine the amount of noise and interfering signal content (that will limit the PMU accuracy and speed)
  - The measurement environment will indicate what qualifications are required to create a usable measurement and the tests to assure the qualifications are met
- Determine the most likely PMU performance requirements
  - Indicate tests required to prove compliance
- Make a report on findings
- WG is only providing background study, not developing a standard