The PMU standard: A fresh look

This is how 60255-118-1 begins to describe the measurement model:

4.2 Power system signal

The voltage or current in an AC power grid is modelled with the following equation:

$$x(t) = X_m(t)\cos[\theta(t)] + D(t) \quad (1)$$

where

- t is time in seconds, where t = 0 is coincident with a UTC second rollover;
- X_m is the peak magnitude of the sinusoidal AC signal;
- θ is the angular position of the sinusoidal AC signal in radians;
- D is a disturbance signal that contains additive contributions to the signal, including, but not limited to harmonics, noise, DC offset and out-of-band interference.

In then continues to describe the "synchrophasor phase angle" as:

$$\phi(t) = \theta(t) - 2\pi f_0 t$$

$D(t)$ is not used in the model, so we will ignore it.

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The 60255-118-1 model:

Rearranging and substituting yields:

$$x(t) = X_m(t)\cos\left(\omega_0 t + \phi(t)\right)$$

This is the "measurement model" for the PMU.

The problems with this are:

- A measurement model **must have constant parameters**.

  $X_m(t)$, $\phi(t)$ are undefined functions of time – they are not constant.

- The frequency in this model is constant – locked at nominal - ω_0

Source:

Bureau International des Poids et Mesures

BIPM

Guide to the Expression of Uncertainty in Measurement (GUM)

The IEC Definition of Phasor:

Area Polyphase systems and circuits / Polyphase systems of quantities

IEV ref	**141-01-01**
Symbol	θ
en	**phase** instantaneous phase argument of the cosine function in the representation of a sinusoidal quantity Note 1 – The term "instantaneous phase" is only used when the independent variable is time. Note 2 – For the quantity $A_m \cos(\omega t + \theta_0)$ the phase θ is equal to $\omega t + \theta_0$.

IEV ref	**141-01-02**
Symbol	θ_0
en	**initial phase** phase angle value of the phase of a sinusoidal quantity when the value of the independent variable is zero Note – For the quantity $A_m \cos(\omega t + \theta_0)$ the initial phase is equal to θ_0.

$A_m \cos(\omega t + \theta_0)$

the phase θ is equal to $\omega t + \theta_0$.

Note: ω is a parameter.

the initial phase is equal to θ_0.

“Constant Parameter” model:

Also in IEEE 1344 (1995)

$$x(t) = X_m \cos(\omega t + \phi)$$

Consistent with IEC definitions

Consistent with measurement requirements - i.e. constant during the measurement.

Frequency is now a parameter - Previously it was not.

Eliminates the need for the FIR filter on measurement reports. This reduces delay.

“Phase” is the entire argument of the cosine:

$$x(t) = X_m \cos\,(\underbrace{\omega t + \phi}_{})$$

$$\vartheta(t) = \omega t + \phi$$

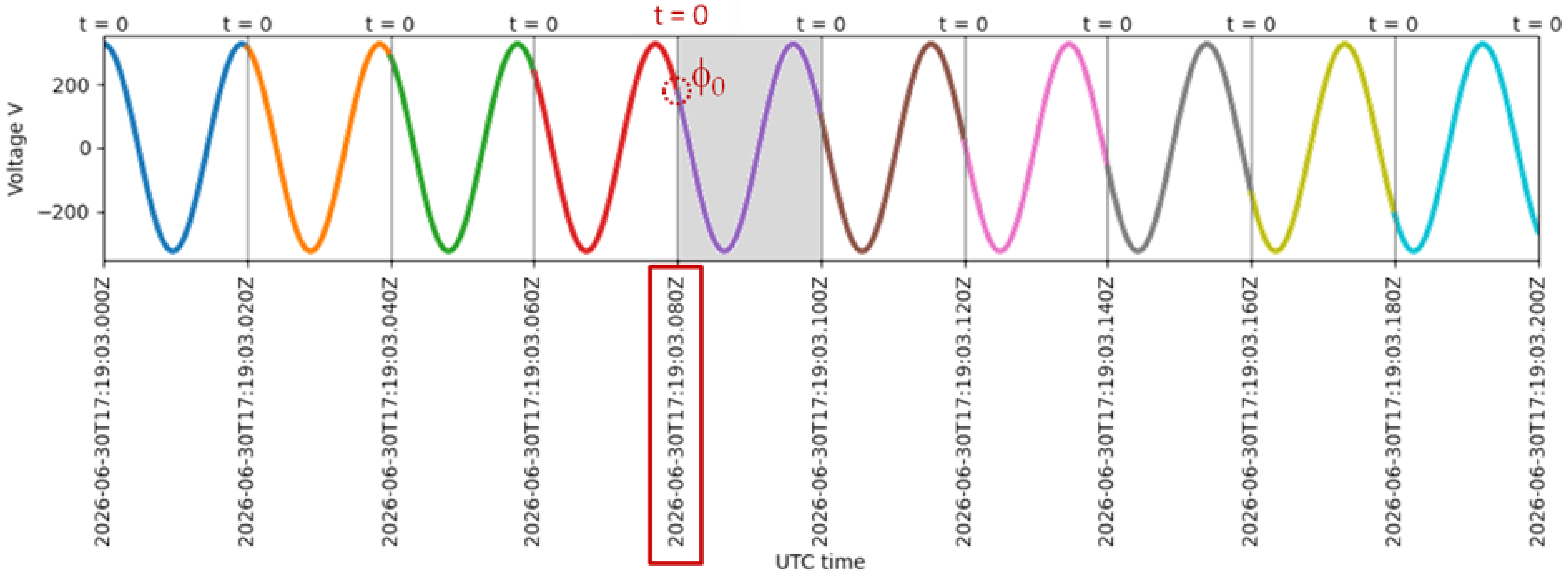
Frequency is the derivative of the phase: $$\frac{d\vartheta(t)}{dt} = \omega$$

This is not true in the present standard.
Doing this now yields ω_0 .

ϕ is the phase at time = 0

ϕ is the “initial phase” similar to the “synchrophasor phase angle”

“Time = 0” for each measurement and is linked to UTC:



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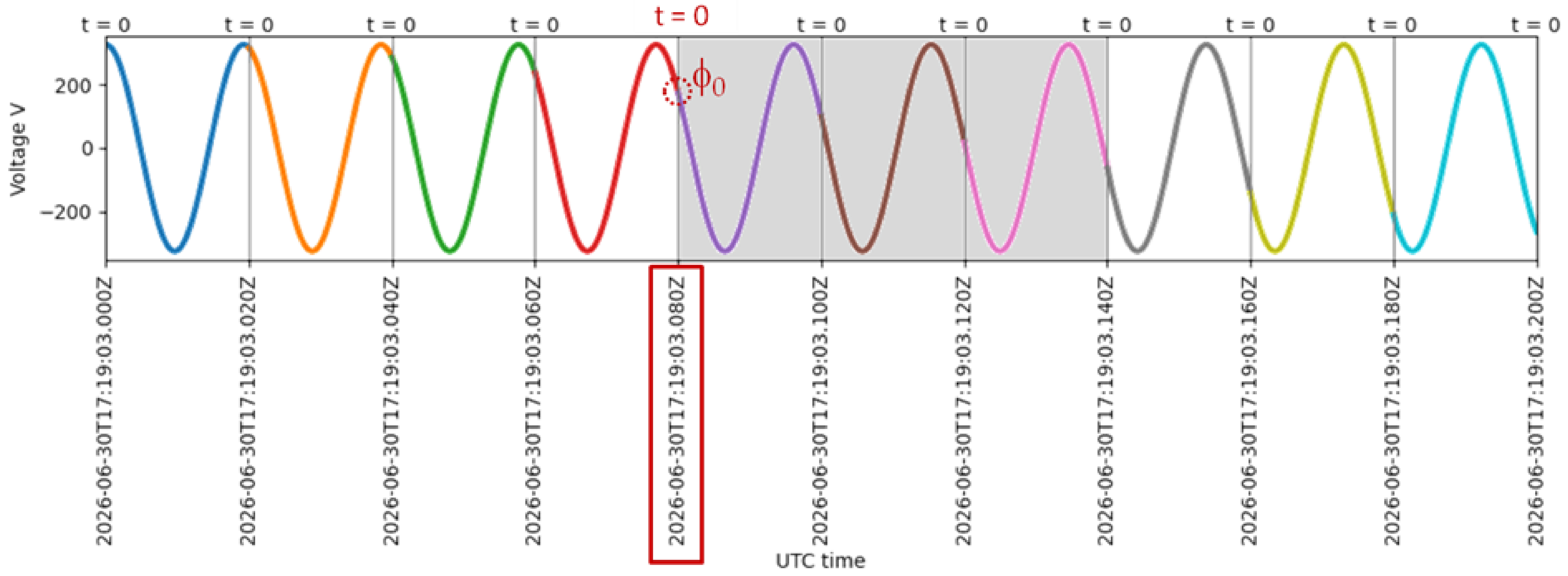

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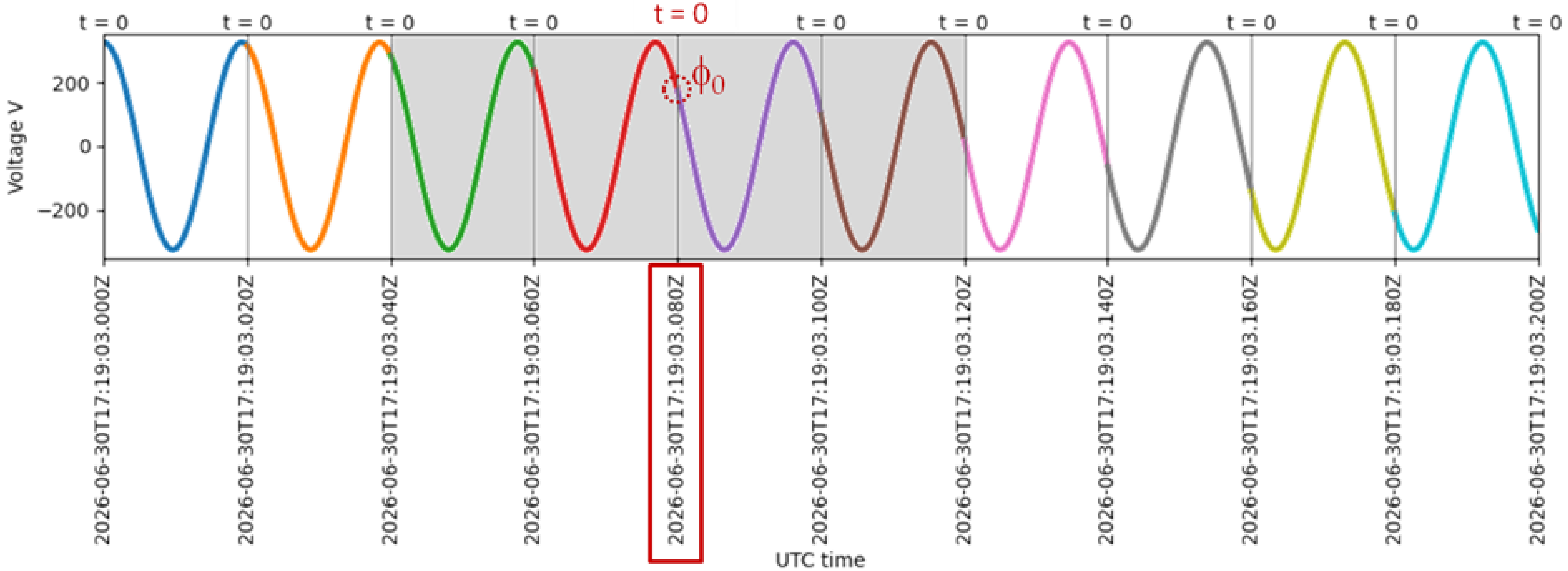

Summary:

- The phase is the entire argument of the cosine $v(t) = V\cos(\omega t + \varphi)$
- Thus, the frequency is the derivative of the phase: $\frac{d}{dt}(\omega t + \varphi) = \omega$
- The angle φ is initial phase
- The initial phase cannot change after you start a measurement

This is enough to understand why Mark Adamiak was confused when he saw what his “proto-PMU” was telling him. He said “The phasor was rotating.”

Yes. Phasors rotate, but... What he was seeing was the change in initial angle from successive measurements at times that were exactly at 16.66666 ms apart.

A case of going

BACK TO THE FUTURE

From IEEE Std 1344 (**1995**) – Page 7

If the 1 PPS signal occurs at time t_0, the measured phasor corresponding to a sinusoidal signal $v(t) = V\cos(\omega_0 t + \varphi)$ with a frequency ω_0 is $Ve^{j(\omega_0 t+\varphi)}$. For steady-state signals at off-nominal frequency ω_1, the measured phasor with time-tag corresponding to the 1 PPS instant t_0 is $Ve^{j(\omega_1 t+\varphi)}$ . . . .

$$Ve^{j(\omega_1 t+\varphi)}$$

$$v(t) = V\cos(\omega_1 t + \varphi)$$

$$x(t) = X_m \cos(\omega t + \phi)$$

Same!