

# H-I-L Testing of Phasor Measurement Unit using Mini-Full Spectrum Simulator

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MTP Stage - 1

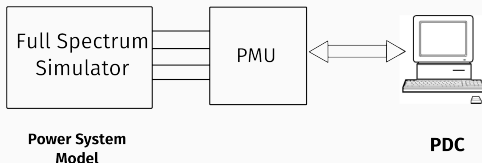
# Introduction

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# Overview

1. Theoretical background
2. Literature Survey
3. Proposed Scheme
4. Work Done
5. Plan of work

# Aim of Experiment

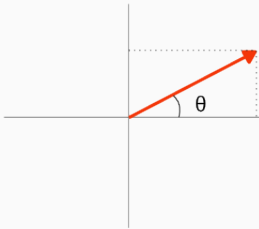


- **To test the feasibility of Full Spectrum Simulator (FSS) as well as the PMU device as per IEEE C37.118 PMU standard**
  - Implement a power system model having different test case scenarios
  - To use indigenously develop or self designed PMU hardware
  - Evaluate the performance of

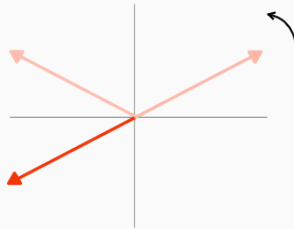
# Backgorund - Terms

**C37.118** It is a PMU standard stating the measurement provisions, performance criterion and Data communication protocol.

- **Phasors:** A complex number which represents both magnitude and angle of an AC quantity.
- **Synchrophasors:** synchronized sampling/measurement of phasor at a precise reference (time)



Phasor



Time Varying Phasor  
(Synchrophasor)

# Background - PMU Basics

PMU: It is a device which gives you an estimate of the phasor

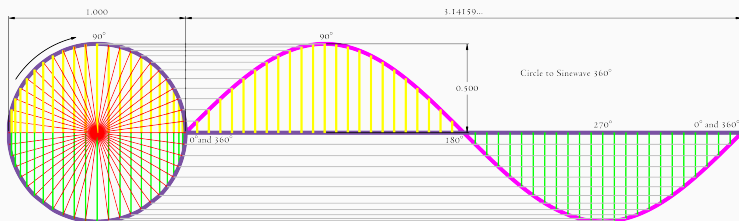


Figure 1: Sine to Circle representation [2]

**Sinuloid:**  $x(t) = X_m \cos(\omega t + \varphi)$

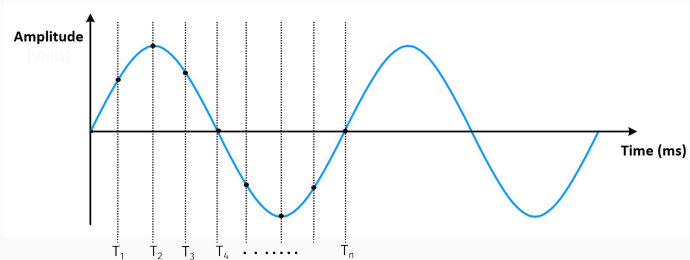
**Phasor Representation:**  $\mathbf{X} = \frac{X_m}{\sqrt{2}} \exp^{j\phi}$  or  $\mathbf{X} = X_r + jX_i$

**Frequency**  $f(t) = \frac{1}{2\pi} \frac{d\psi(t)}{dt}$

**ROCOF**  $= df(t)/dt$

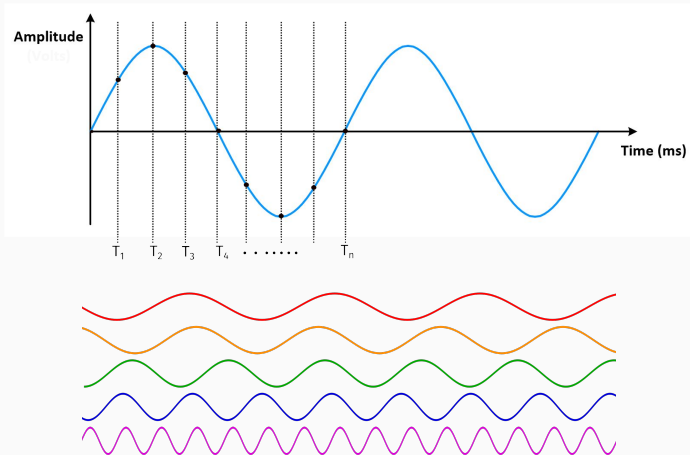
# Why Standards are required?

All previous equations are frequency dependent -  $f_0$  - Fundamental frequency



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Different make - Incompatibility



# Total Vector Error

- Two Quantities to observe - Amplitude & Phase
- Frequency dependency of the result
- we require a reference which is independent and time invariant.
- Hence **Total Vector Error (TVE)**

$$TVE(n) = \sqrt{\frac{(\hat{X}_r(n) - X_r(n))^2 + (\hat{X}_i(n) - X_i(n))^2}{X_r(n)^2 + X_i(n)^2}}$$

## Type of PMU:

- Protection Class: Time critical application, More stringent requirement
- Measurement Class: Greater precision not (very) time critical

# Types of Tests

To get the TVE, compliance test(s) are performed, recommended by C37.118

1. Steady-state compliance

- 1.1 Steady-state synchrophasor measurement requirements

- 1.2 Steady-state frequency and ROCOF measurement requirements

2. Dynamic compliance

- 2.1 Synchrophasor measurement bandwidth requirements using modulated test signals

- 2.2 Ramp of system frequency

- 2.3 Step changes in phase and magnitude

## Literature Survey

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Basically there are 3 components to any arrangement

- Device Generating Test Signal
- PMU under test
- Recording device (PDC etc.)

We will See 3 paper here, which are closest to our implementation

## Title: **Dynamic PMU Compliance Test under C37.118.1a-2014** By R. Ghiga

- Doble F6150 Power System Simulator
- Three Different PMUs
- Direct PMU - PSS interfacing
- Test Performed:
  - Amplitude Modulation: 0.9 - 1.1 PU ( 0.1 to 5 Hz)
  - Phase Modulation: 0.1 rad
  - Ampli. Step Test:  $\pm 0.1$  PU step
  - Phase Step Test:
  - Freq. Ramp:  $\pm 1$  Hz/s between (44 to 55 Hz)

IMP: Test signals are **not** time synchronised

Title:

# References



C37.118 - IEEE Standard for Synchrophasor Measurements for Power Systems



<http://westernau.com/images/Circle-To-Sine-Wave.png>



Phadke, A.G., Thorp, J.S., *Synchronized Phasor Measurements and Their Applications*, Springer US, 2008.



iPDC & PMU simulator, [ipdc.codeplex.com/](http://ipdc.codeplex.com/)



Phadake A.G., *HISTORY AND APPLICATIONS OF PHASOR MEASUREMENTS*, IEEE, 2006.



Saugata S. Biswas, Jeong Hun Kim, Anurag K Srivastava "Development of a Smart Grid Test Bed and Applications in PMU and PDC Testing" , *IEEE Conference Publications*, 2012.

Thank You