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

Rathin Dholakia

Guided By:

Prof. M. C. Chandorkar

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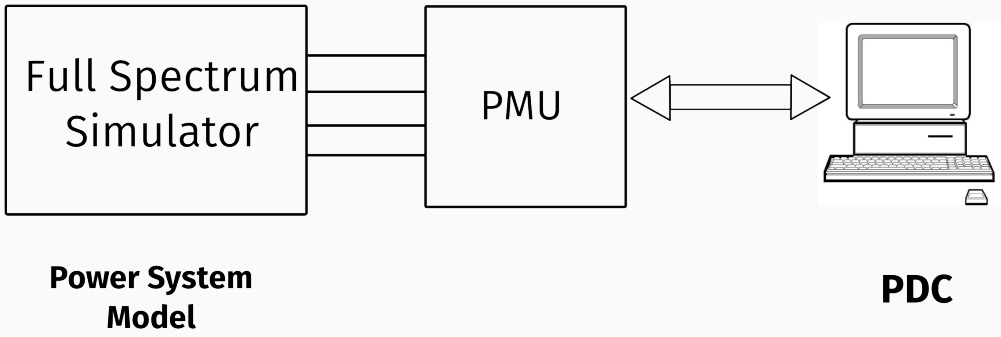
MTP Stage - 1

Introduction

Overview

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

Aim of Experiment

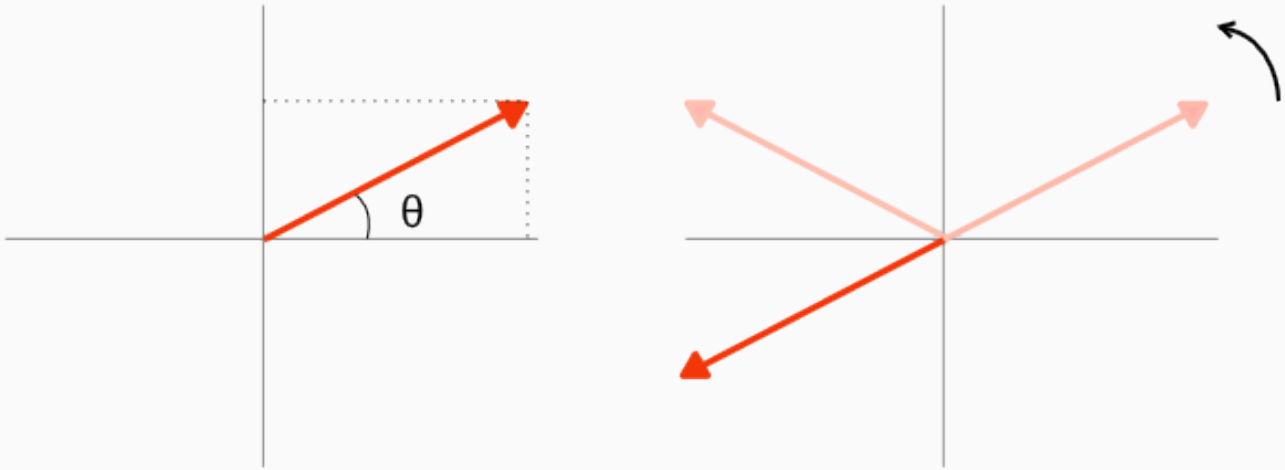


- **To test the feasibility of Full Spectrum Smulator (FSS) as well as the PMU device as per IEEE C37.118 PMU standard**
  - Implement a power system model having different test case scenarios
  - To use indigenously develop or self designed PMU hadrware
  - Evaluate the performance of

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 wich givens you an estimate of the phasor

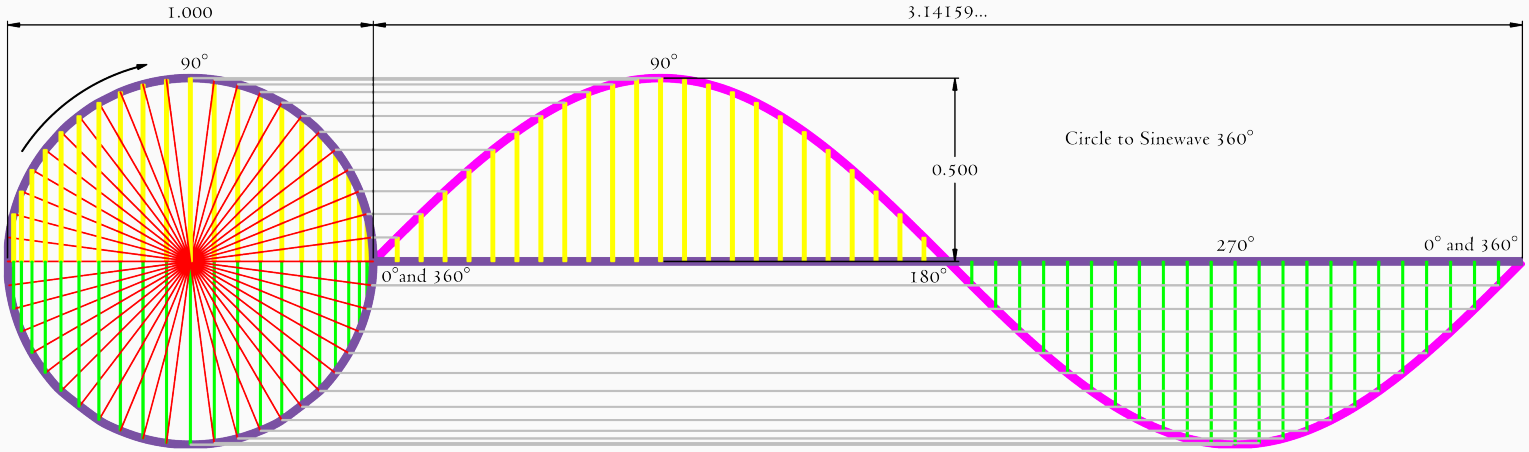


Figure 1: Sine to Circle representation [2]

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

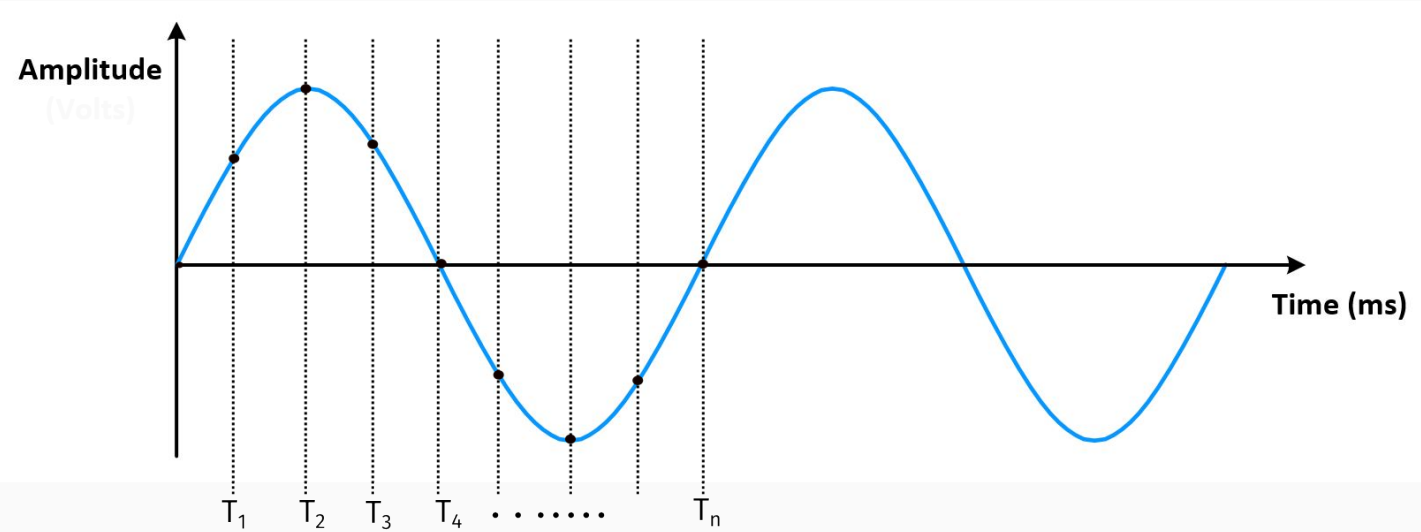
Phasor Representation: $\mathbf{X} = \frac{Xm}{\sqrt{2}} \exp^{j\phi}$ or $\mathbf{X} = X_r + jX_i$

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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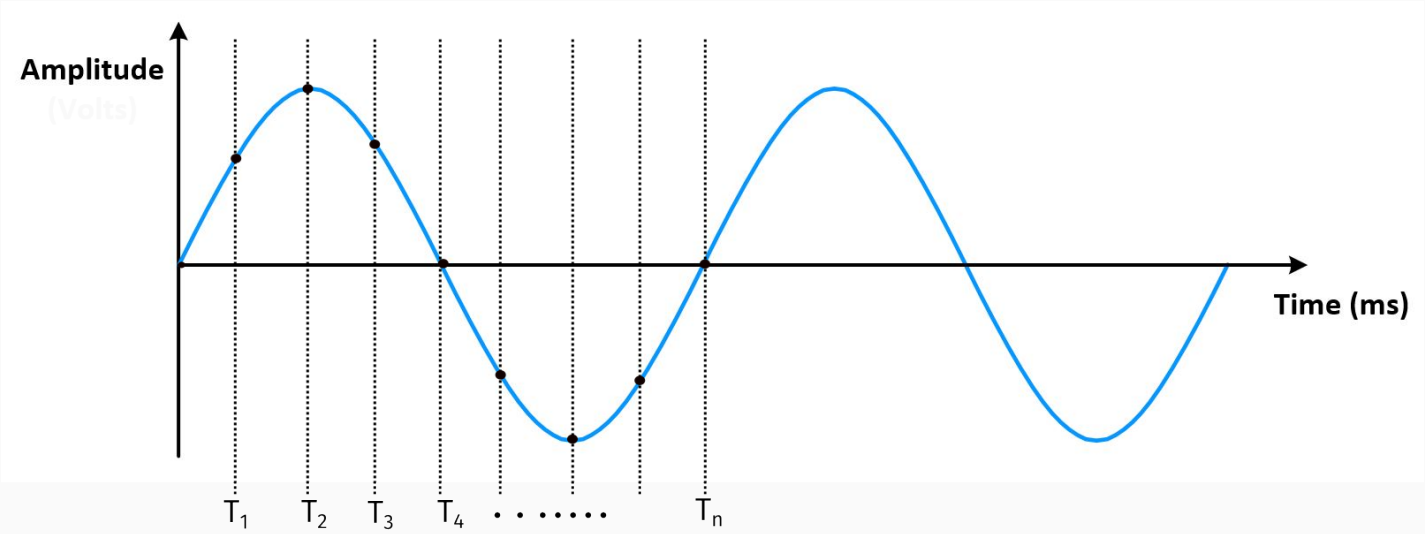
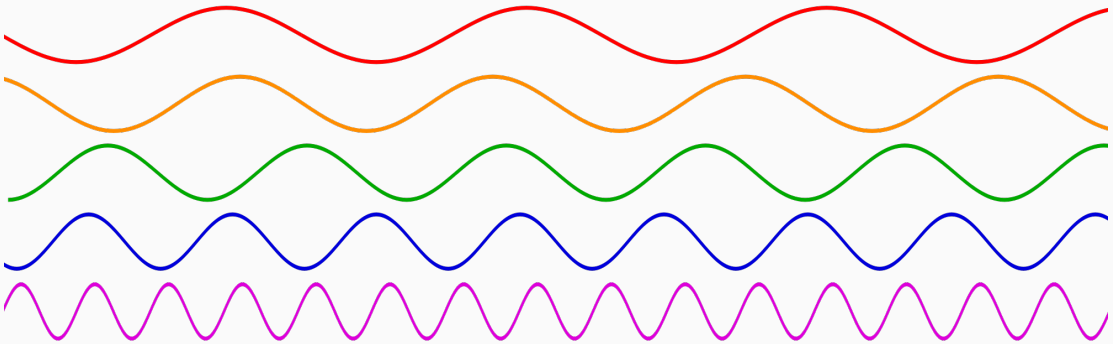




Different make - Incompatibility

Total Vector Error

- Two Quantities to observe - Amplitude & Phase
- Frequency dependency of the result
- we require a reference which is independent and time invarient.
- 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

Literature Survey

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

paper-1

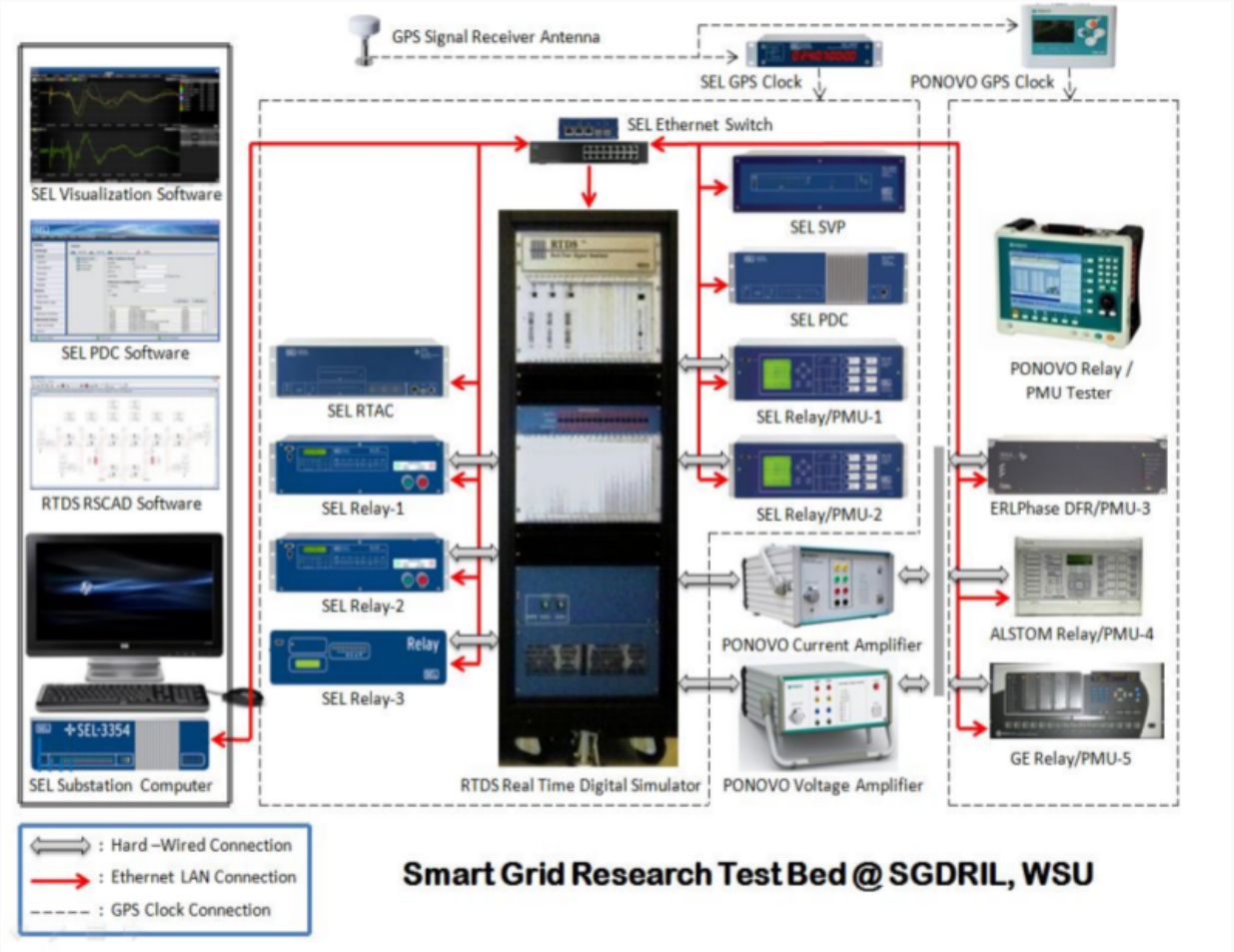
Title: **Dynamic PMU Compliance Test under C37.118.1a-2014** By R. Ghiga

- 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: **Development of a Smart Grid Test Bed and Applications in PMU and PDC Testing** By

- RTDS
- Multiple Relays/PMU
- Power Amplifier stanges



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/


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