

# PMU Model Simulation: PC37.118.1 Annex C

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**PMU Calibration**  
**Fluke Calibration**

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# Fluke / NIST PMU Calibrator Project

FLUKE®

Calibration

- A project to develop a commercially available PMU Calibration system
- Co-funded:
  - Fluke Calibration
  - NIST
- Schedule
  - Now: Seeking 2 or 3 beta partners
  - 21-24 August: Demo at NCSLI Conference, National Harbor, MD
  - 25 August: Tech paper at NCSLI
  - 1 Sept: Deliver system to NIST
  - Q1 2012: Open for commercial orders



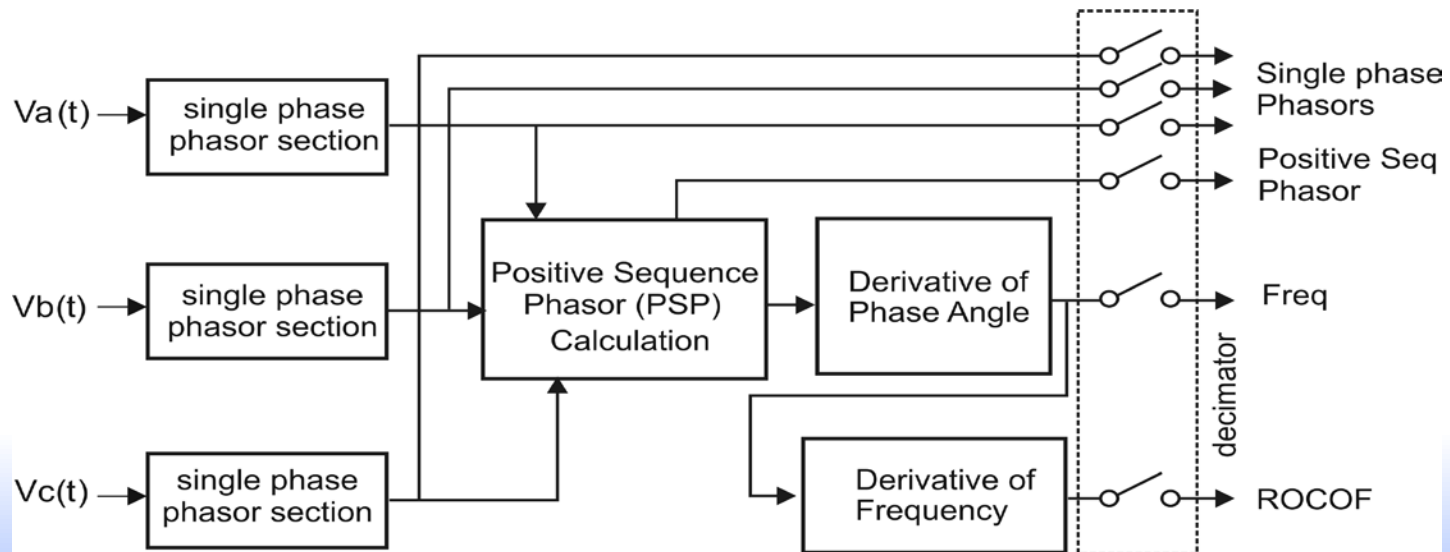
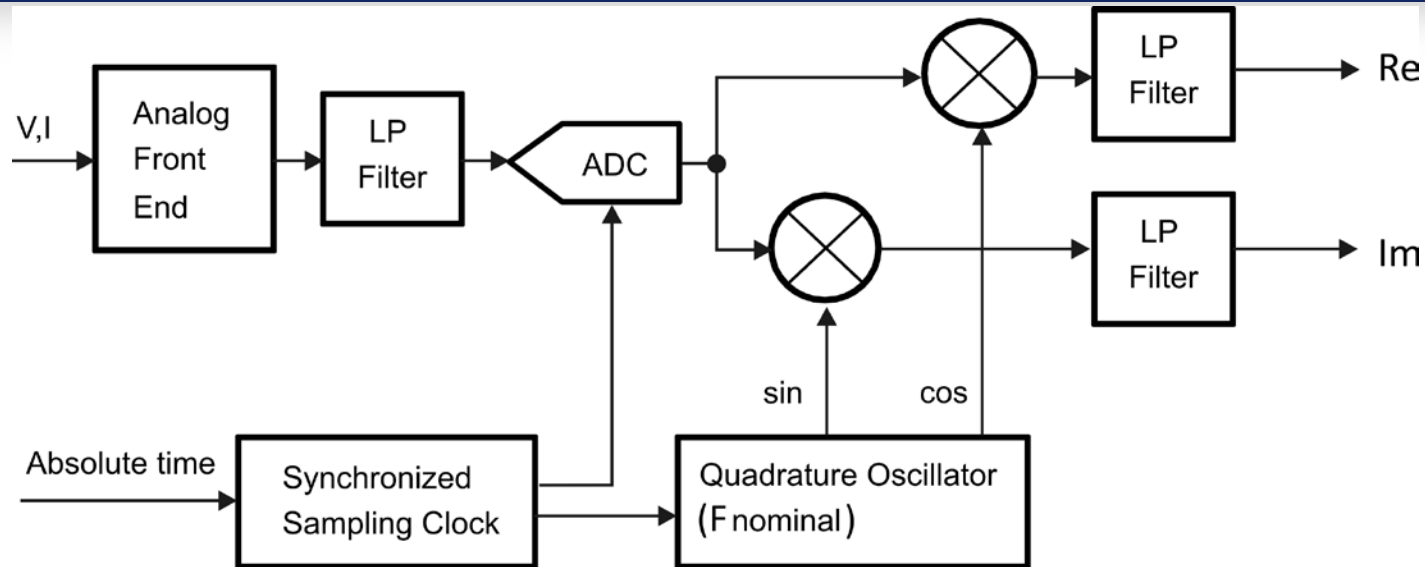
- **Developed:**

- As part of Fluke's contribution to the development of IEEE PC37.118.1
- Helps Fluke's PMU Calibrator design team understand PMU performance.

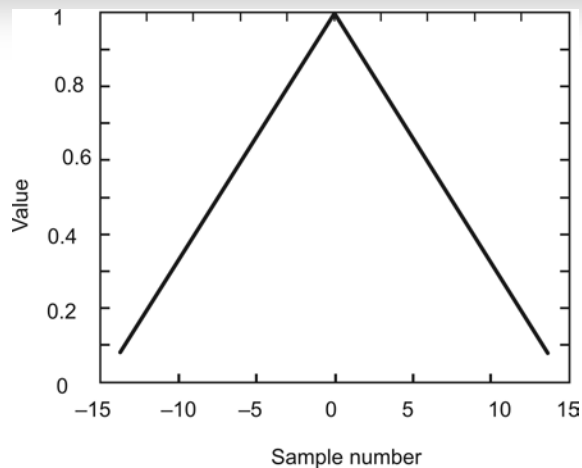
- Given to NASPI to be made freely available via the [NASPI Phasor Tool Repository](#)

- Annex C presents the reference signal processing models
  - Used to develop and verify performance requirements in PC37.118.1
  - Given for information purposes only, and
    - does not imply being the only or recommended method for estimating synchrophasors
  - Establishes common ground for
    - performance requirements
    - confirming achievability

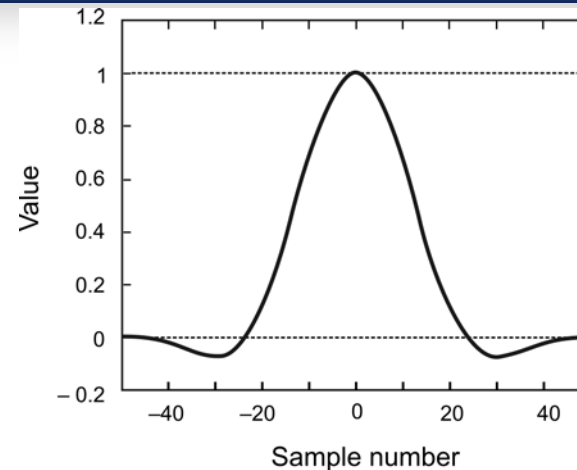
# Annex C PMU Model



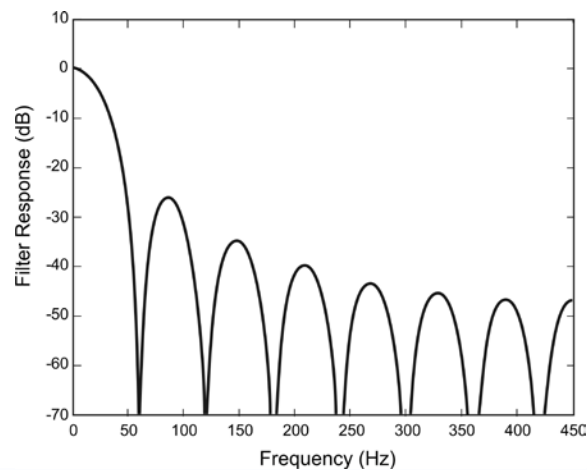
# PMU Model Filtering by Class



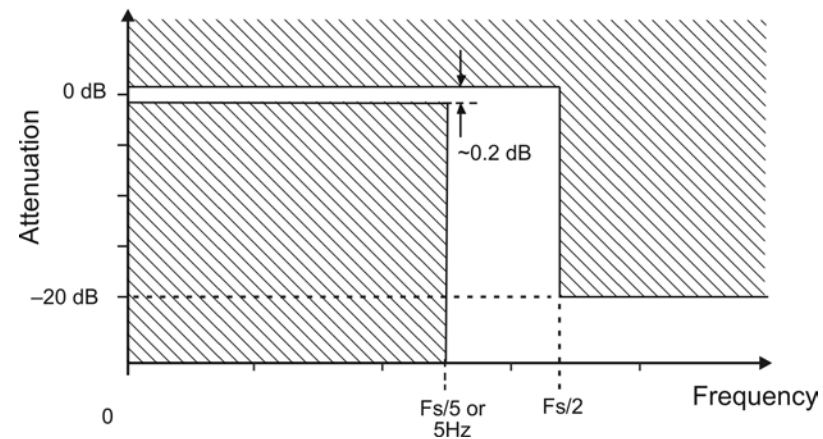
**P Class coefficients**



**M Class coefficients**



**P Class response**



**M Class response "mask"**

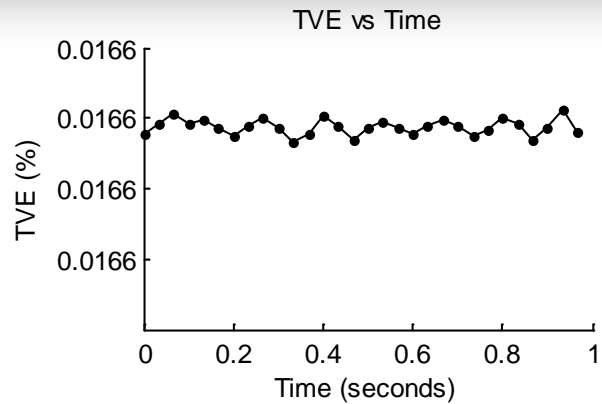
# Simulation User Interface

The screenshot shows the 'PMU Model Control Panel' window with the following settings:

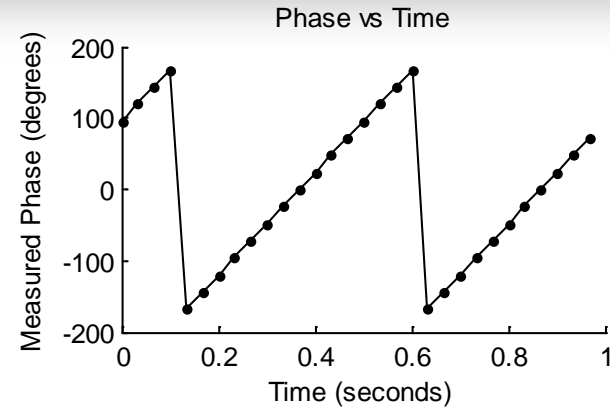
- PMU:** Sample Rate (iFsamp) 960, Reporting Rate (iFs) 30, Decimate?  yes,  no. Frequency selection:  60Hz,  50Hz,  M-Class,  P-Class.
- Input:** Input Magnitude (rXm) 0.7071, Fundamental Freq (rFin) 60, Phase Shift (rPs) 0, Ramp Rate (rRf) 0, Phase Mod Freq (rFa) 6, Phase Mod Index (rKa) 0, Amplitude Mod Freq (rFx) 6, Amplitude Mod Index (rKx) 0, Harmonic Number (iNh) 7, Harmonic Index (rKh) 0, Amplitude Step Index 0, Amplitude Step Delay 60, Phase Step degrees 0, Phase Step Delay (cycles) (iKaN) 60. A 'Generate Input' button is present.
- Simulation:** Number of Nominal Cycles to Simulate (iNcyc) 120, Settling (reports)(iNset) 10. A 'Simulate' button is present.
- Analysis:**  plot vs. Time,  plot vs. Freq. Checkboxes for:  Phase A,  Phase B,  Phase C,  PosSeq,  Theory,  TVE,  Magnitude Error,  Phase Error,  Magnitude,  Phase,  Freq,  Fe,  ROCOF,  RFe,  Step Analysis. An 'Analyse' button and  Show Sample Points are also present.

- PMU Settings
- Input Signal Settings
  - Steady State
  - Ramp
  - AM & PM Modulation
  - Step
- Simulation Settings
- Analysis Settings

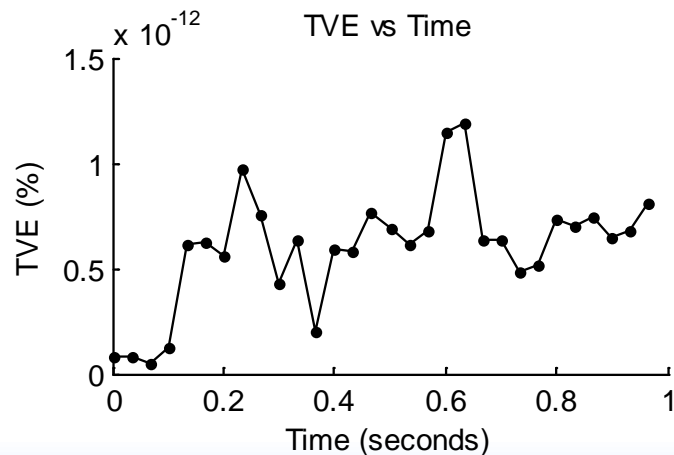
# Steady State Examples



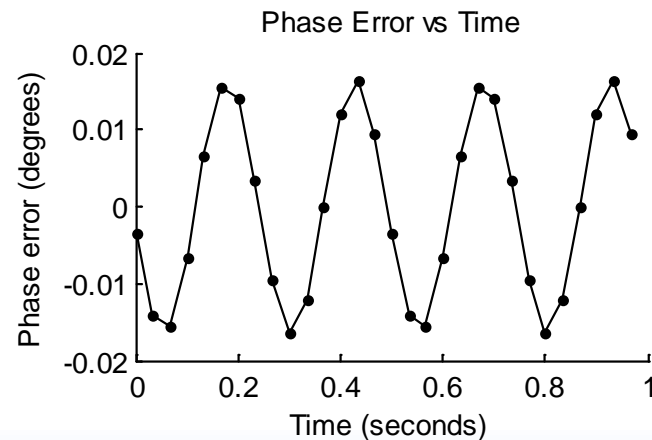
**M Class Steady State TVE**  
**60 Hz**



**M Class Steady State Phase**  
**62 Hz**



**P Class Steady State TVE**  
**60 Hz**

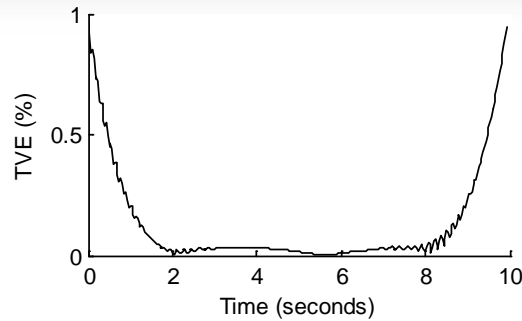


**M Class Steady State Phase Error**  
**62 Hz**

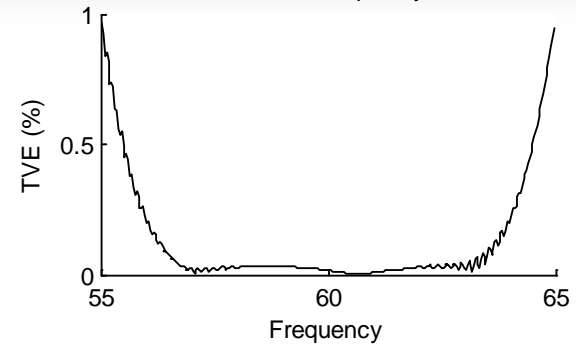


# Frequency Ramp Examples

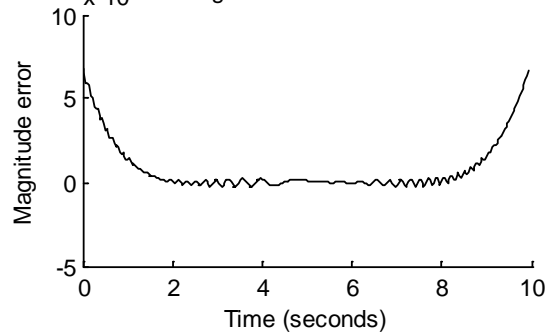
TVE vs Time



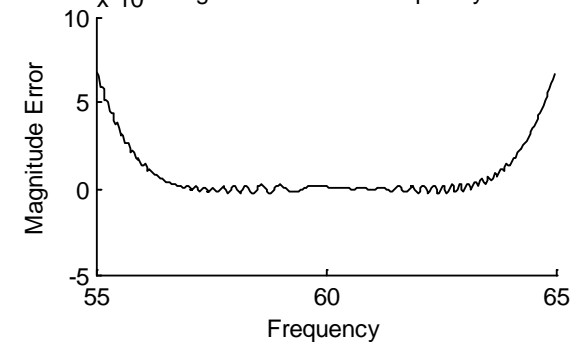
TVE vs Frequency



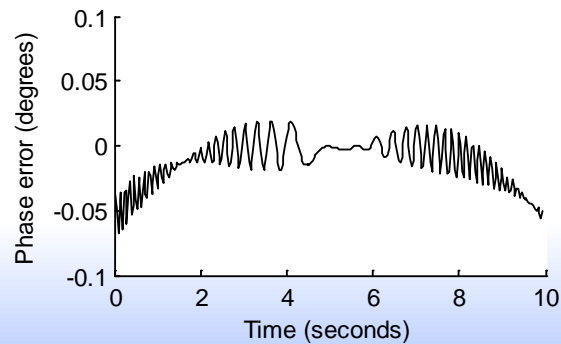
Magnitude Error vs Time



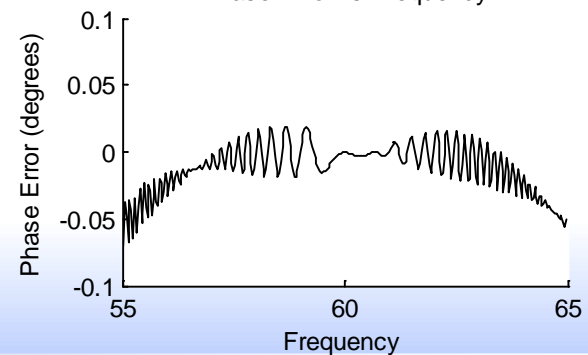
Magnitude Error vs Frequency



Phase Error vs Time

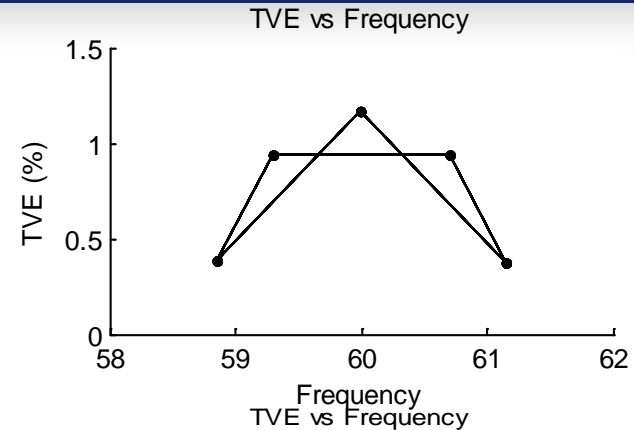
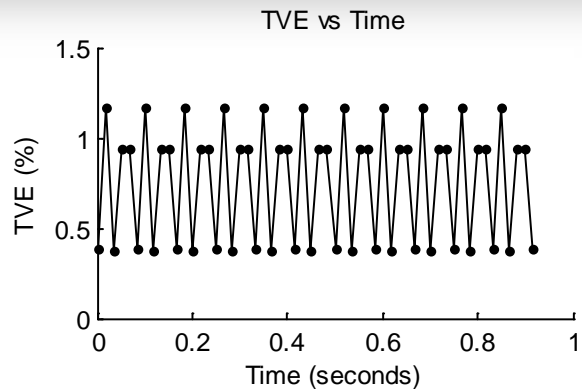


Phase Error vs Frequency

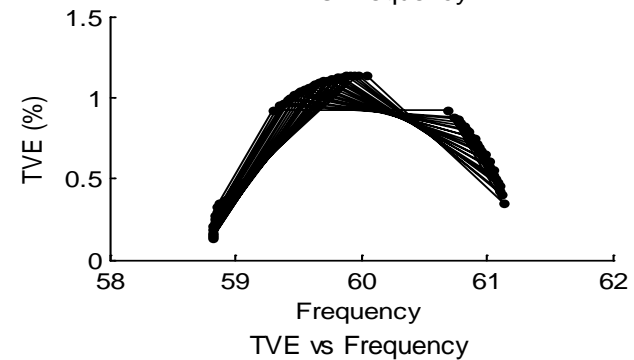
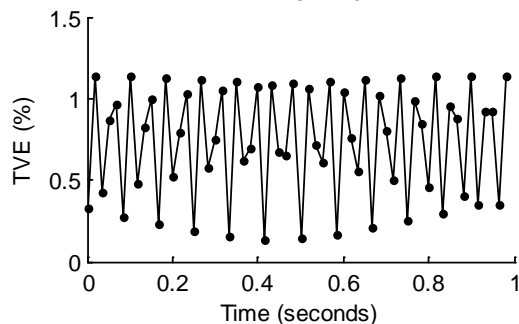


# Phase Modulation (*M Class, 60 Hz, 60fps*)

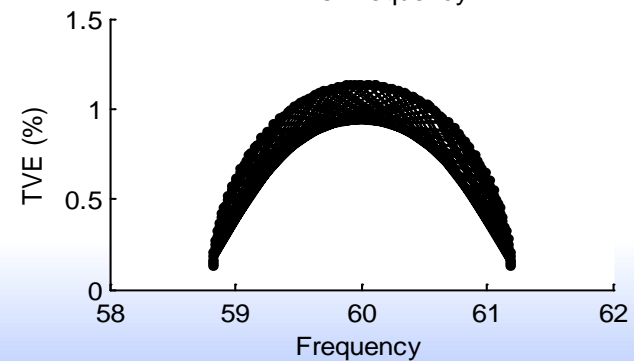
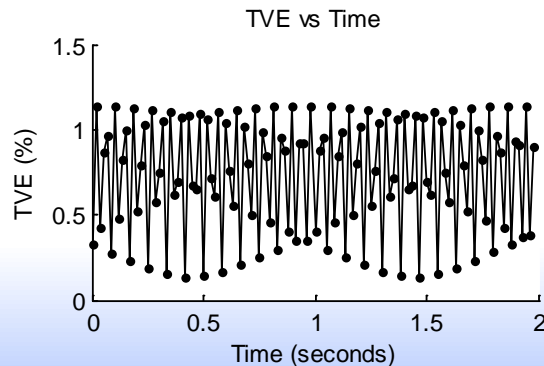
**Fa = 12Hz, Ka=0.1**



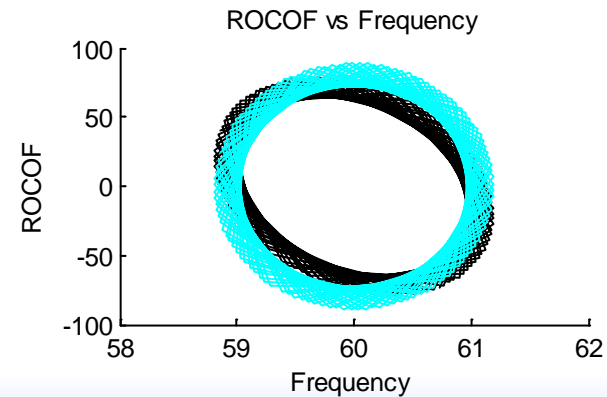
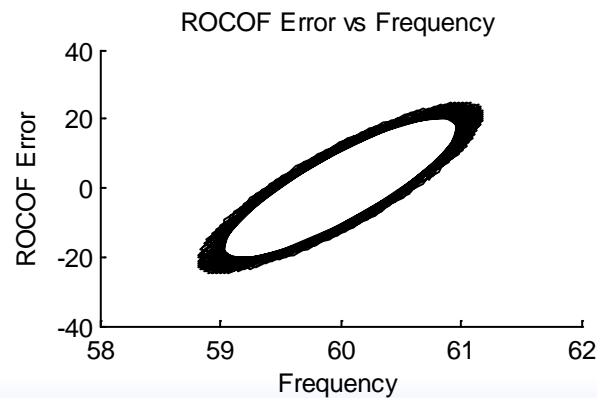
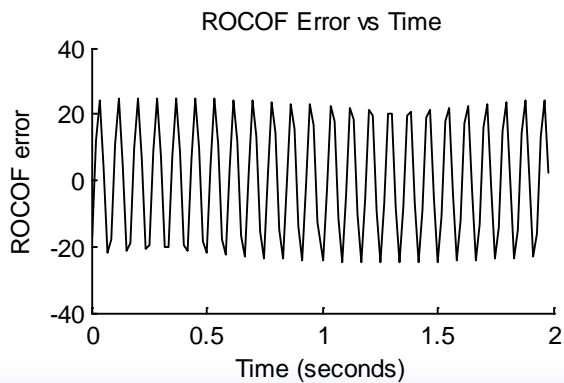
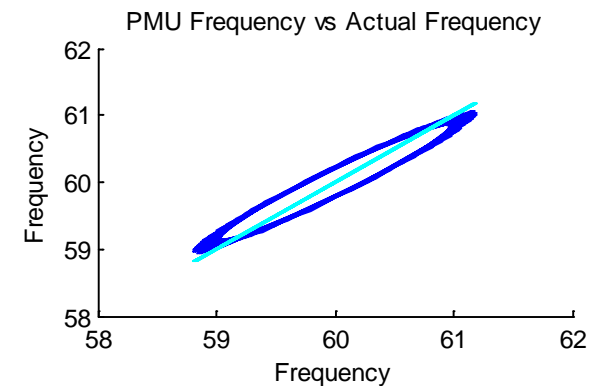
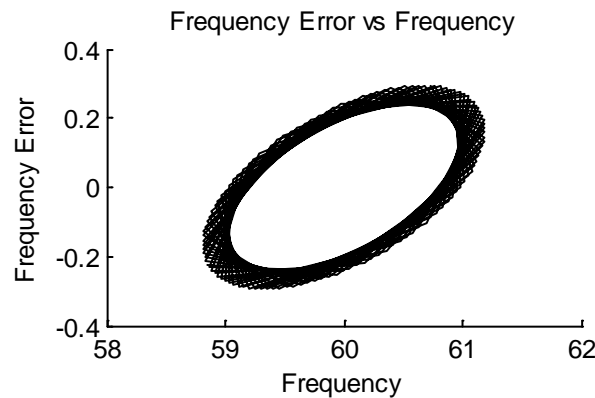
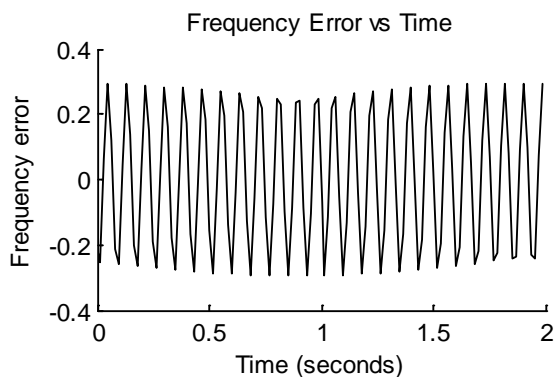
**Fa = 11.9Hz, Ka=0.1, 60 cycles**  
**Illustrates why frequency graph**  
**is helpful**



**Fa = 11.9Hz, Ka=0.1, 120 cycles:**  
**Illustrates why frequency graph**  
**is helpful**



# F, ROCOF, Fe, Rfe under Phase Modulation



**$F_s = 60\text{Hz}$ ,  $F_a = 11.9\text{Hz}$ ,  $K_a = 0.1$**

- This PMU Model Simulation will be made freely available via the NASPI Tool Repository
  - Compiled for Win32 and Win64
  - Matlab Source code is included

Thank you

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Fluke Calibration

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