Dynamic Performance Comparison and Prediction based on Distribution-level Phasor Measurement Units

Yuru Wu[1], He Yin[1], Yilu Liu[12], Shengyou Gao[3]
[1] The University of Tennessee, Knoxville [2] Oak Ridge National Laboratory
[3] Tsinghua University

Motivation

Recently, a new distribution-level PMU, Ultrahigh-resolution Synchrophasor Recorder (USR) with advanced hardware has been released.

There are two questions of interest:

- What are the key hardware to improve PMU measurement accuracy?
- How do different PMUs perform under steady-state and dynamic conditions?

Performance Prediction

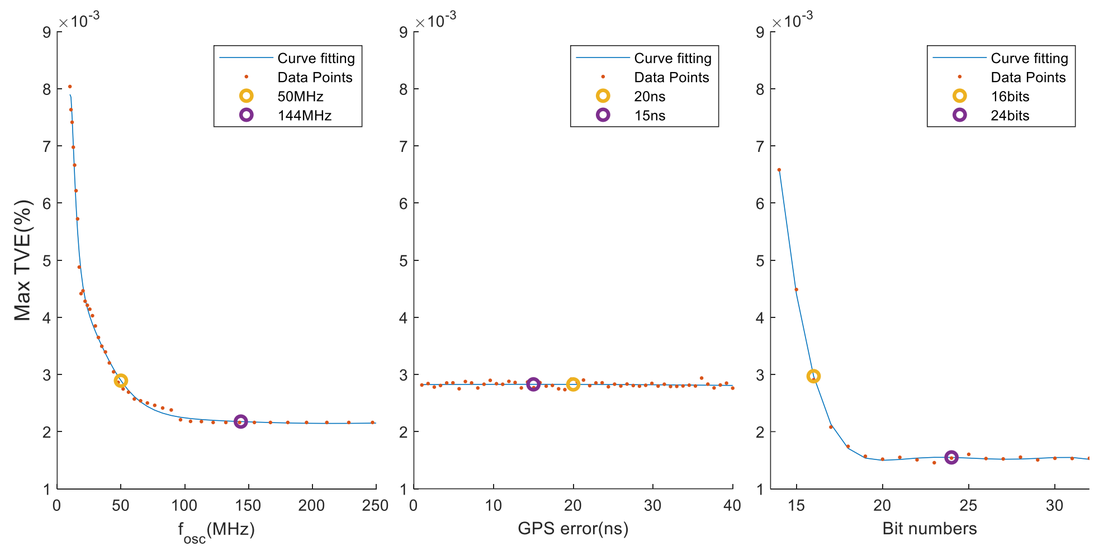
Digital samples of a steady-state signal:

$$x_D(n) = [Xcos(2\pi f(nT_s + T_{error}(n)) + \varphi)]$$

Adjusting the hardware parameters could affect the measurements of PMU.

- Oscillator frequency
- GPS timing error
- ADC sample resolution

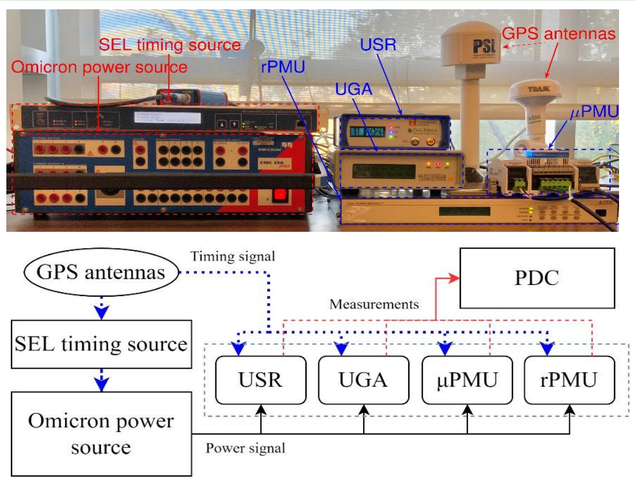
Hardware parameters	UGA	USR
Oscillator frequency	50 MHz	144 MHz
GPS timing error	20 ns	15 ns
ADC resolution	16 bits	24 bits



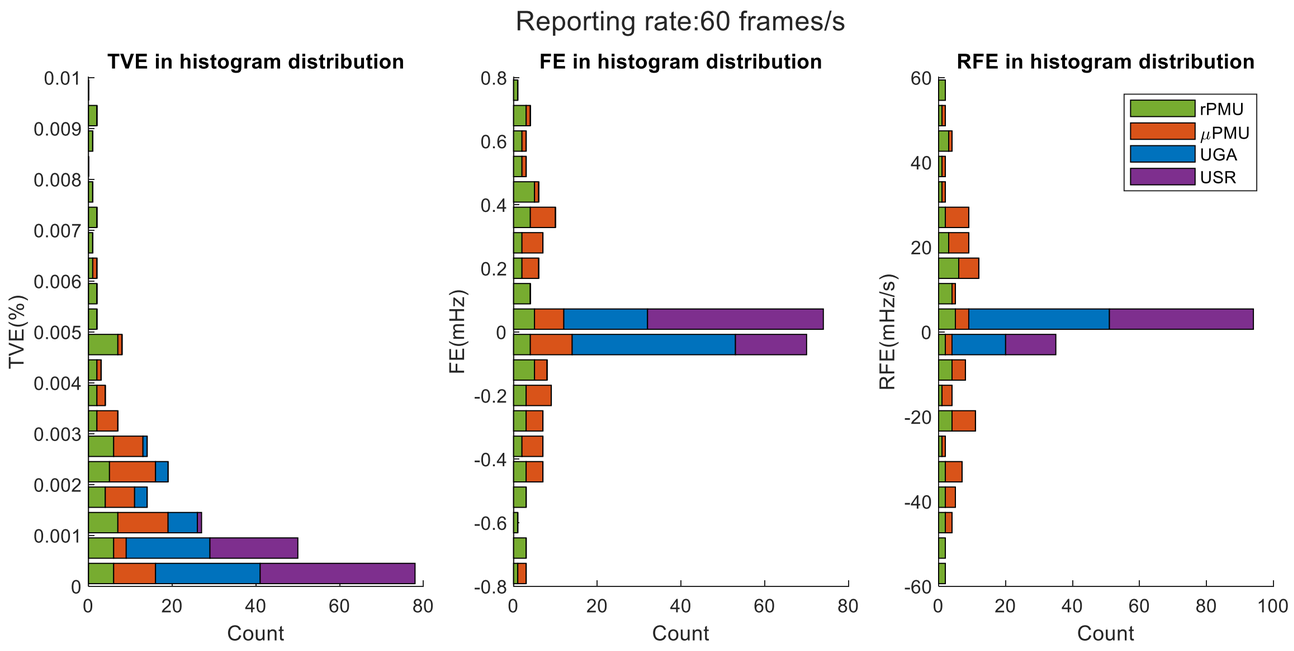
Experiment Validation

Testbench design

A power source is connected to the signal inputs of 4 distribution-level PMUs and generates different power signals according to the test scenario. The test scenarios include steady-state, frequency ramp, step change of phase and magnitude, and modulation test.

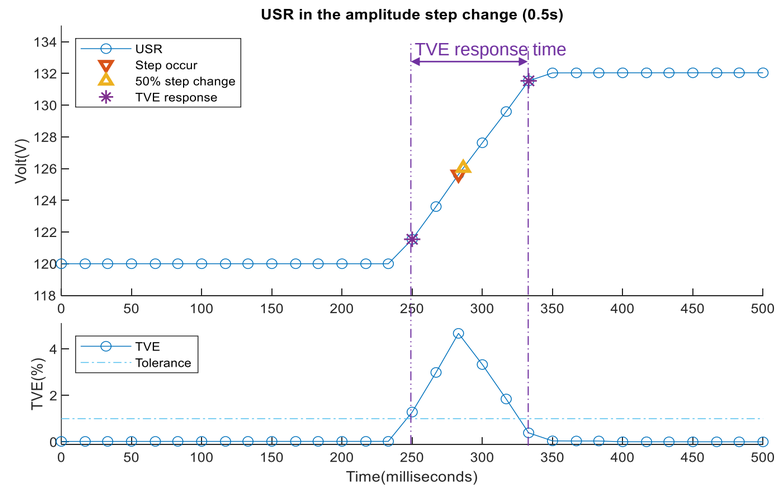


Steady-state



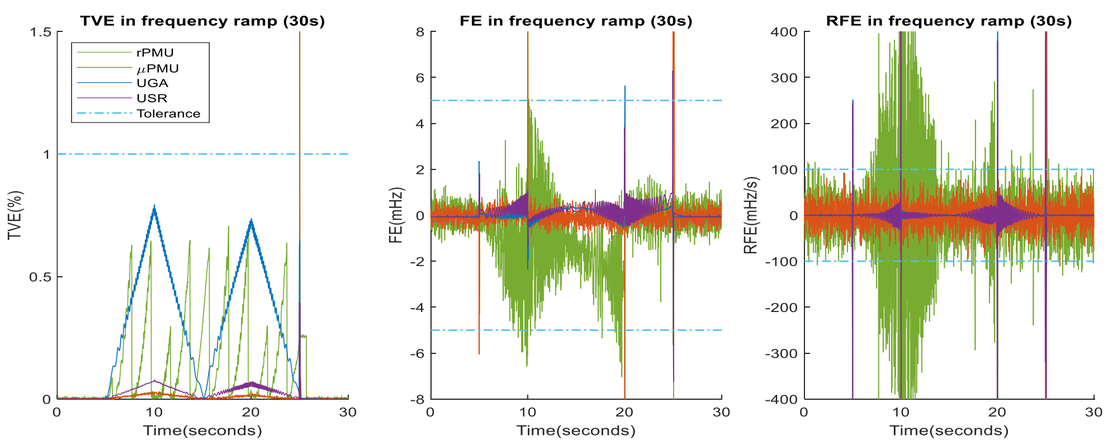
	Metrics	UGA	USR	rPMU	μPMU	PMU standard
Experiment	Max TVE(%)	2.63e-3	1.06e-3	9.13e-3	6.10e-3	<1.0
	Max FE(mHz)	0.080	0.034	0.732	0.793	<5.0
	Max RFE(mHz/s)	3.72	1.20	86.04	84.01	<10.0
Simulation	Max TVE(%)	2.82e-3	5.31e-4			

Step change

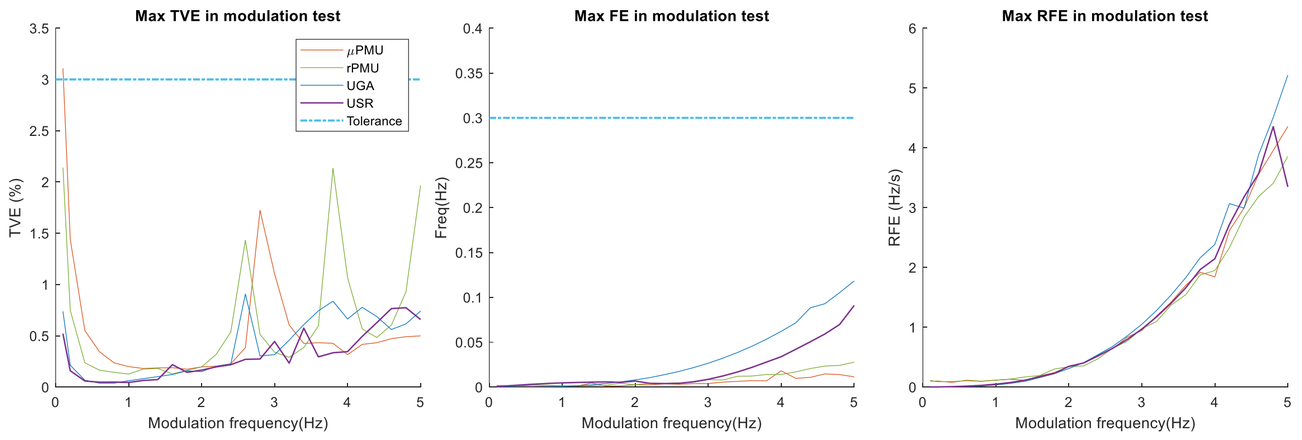


Step type	Metrics	UGA	USR	rPMU	μPMU	PMU standard
Phase angle	DT(ms)	4.60	2.21	1.64	4.16	<4.2
	RT_{TVE}(ms)	121.70	125.68	30.82	29.73	<79
	RT_{FE}(ms)	128.56	124.32	78.76	182.47	<120
	RT_{RFE}(ms)	0.16	129.66	232.52	344.22	<129
Amplitude	DT(ms)	2.38	3.40	2.55	5.10	<4.2
	RT_{TVE}(ms)	53.74	79.40	26.15	7.31	<79
	RT_{FE}(ms)	50.01	40.06	4.63	140.84	<120
	RT_{RFE}(ms)	127.84	95.07	230.21	290.52	<129

Frequency ramp



Modulation test



THE UNIVERSITY OF TENNESSEE KNOXVILLE

OAK RIDGE National Laboratory