NIST 2013 Assessment of PMU Performance (a work in progress)

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NIST
National Institute of Standards and Technology
U.S. Department of Commerce

2012/2013 PMU performance testing

- In support of continuing development of IEEE PMU performance standards, NIST sent requests to all PMU vendors to provide a sample of their PMU to be tested against the new IEEE Std. C37.118.1-2011 requirements.
  - 12 vendors responded by sending either production or prototype (pre-production) PMUs for analysis.
  - Vendors will not be identified here or in the final report.
  - Test data is given to the vendors as it becomes available.

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  - 12 vendors responded by sending either production or prototype (pre-production) PMUs for analysis.
  - Vendors will not be identified here or in the final report.
  - Test data is given to the vendors as it becomes available.
- This project allows for:
  - Understanding the PMU test requirements and limits compared to the performance of actual PMUs.
  - Continued development and refinement of the PMU test equipment at NIST.
  - Continued development and refinement of the PMUs themselves since test results are provided to the individual vendors as it becomes available.

Early results

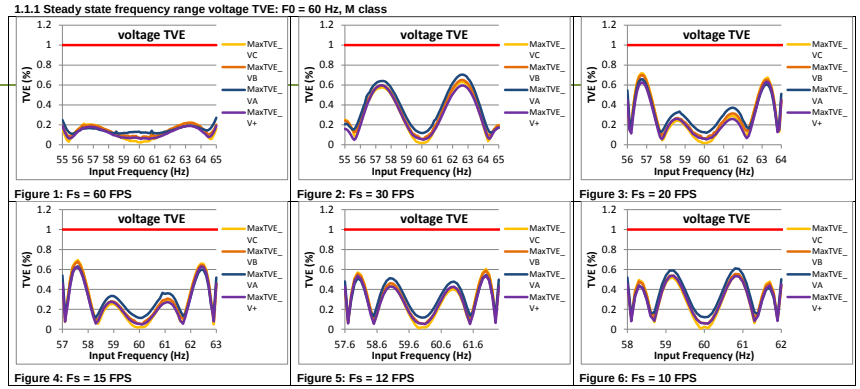
- None of the PMUs tested were able to pass all the test limits of IEEE Std C37.118.1-2011.
- Detailed results (numerical and graphical) was shared with the IEEE PSRC H11 committee members, authors of the PMU performance standard.
  - Helped the committee determine that an amendment was needed.
  - Helped the committee determine some details of the amendments themselves.
- Some vendors provided revised firmware for re-testing.

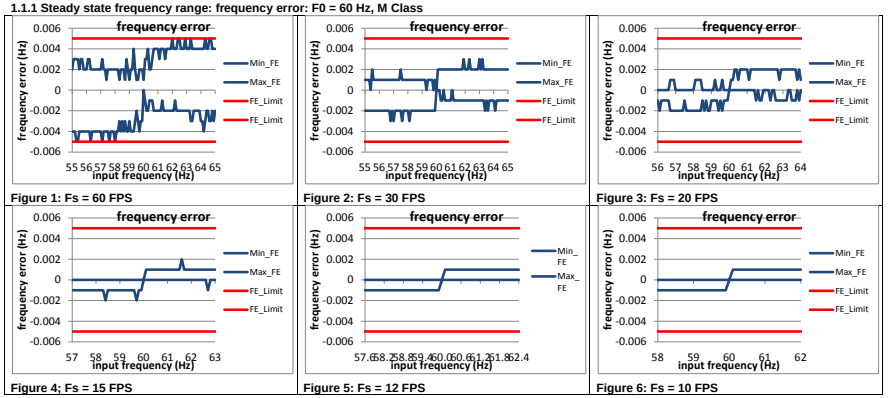
Table 1: Steady state frequency range test results

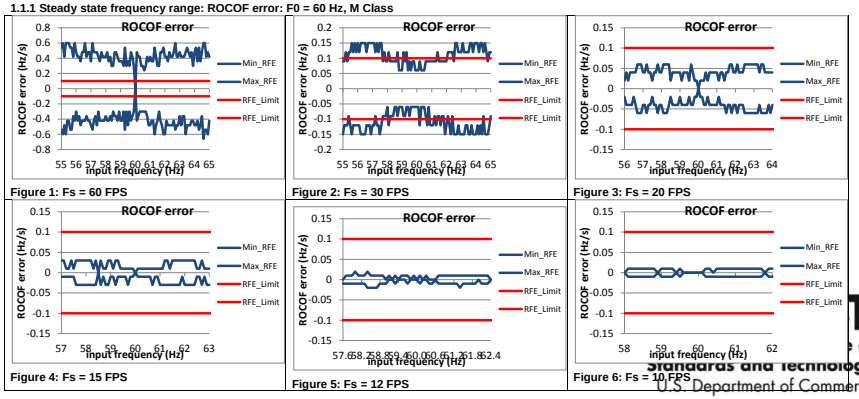
Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE	TVE	FE	RFE
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	F				P	P	F				P	P	F				P	P	F				P	P	F				P	F	F	P	F	F
PMU B	P	P	F	P	P	F							P	P	F				P	P	F				P	P	F	P	P	F	P	P	F	P	P	F
PMU C	P	F	F																						F	F	F				P	F	F	P	F	F
PMU D	P	P	P	P	P	P	F	P	P				F	P	P				F	P	P	P	P	F	F	P	P				F	P	P	P	P	P
PMU E	P	P	F										P	P	F				P	P	F				P	P	F				P	P	F			
PMU F	P	P	F																P	P	F										P	P	F			
PMU G	P	P	P				P	P	P				P	P	P				I	P	P				F	P	P									

PC37.118.1a Amendment

- All PMUs are now being re-tested against the draft amendment IEEE draft PC 37.118.1a
  - Some results are improved due to some relaxed requirements
  - Some PMU vendors have revised firmware based on the amendment and are now passing or close to passing the amended standard
  - Most PMU vendors still need to make revisions in order to pass the amended requirements

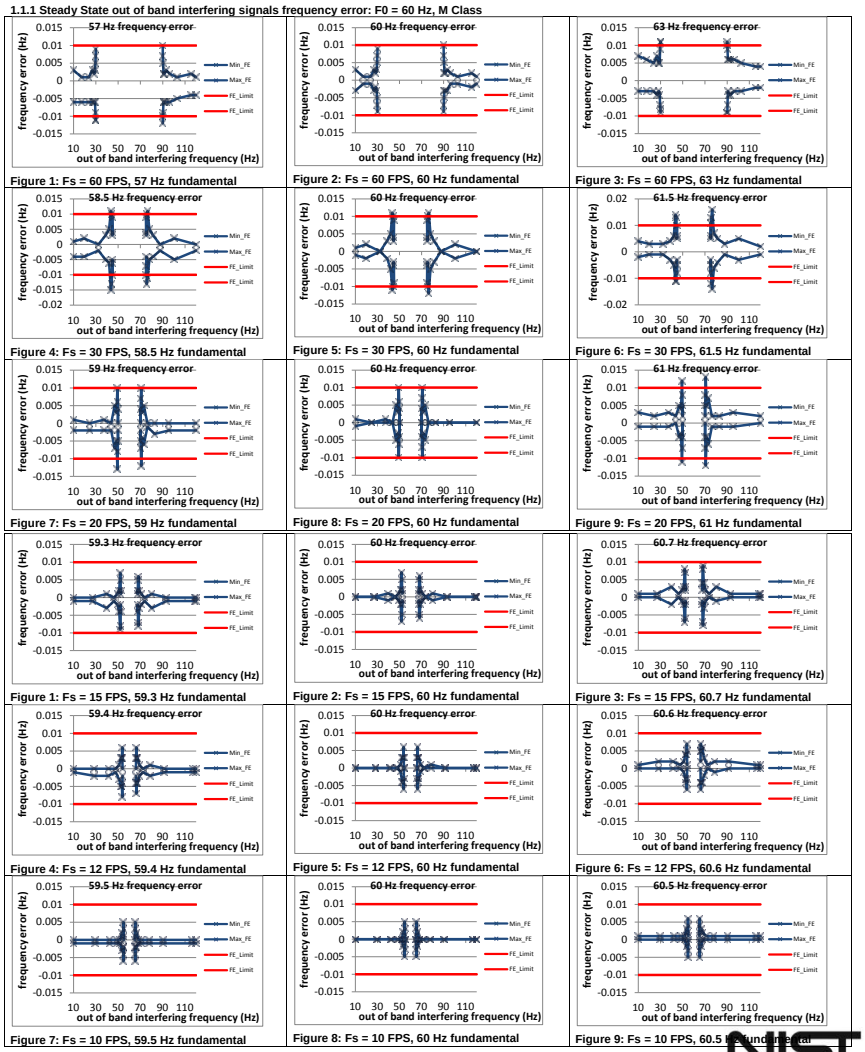






The tests and some example results

- This is NOT a presentation of the final results of the survey
  - The survey is still in progress
  - Some tests are still being developed, refined, and calibrated
    - » Calibration is the measurement of the test's uncertainty
- The survey represents the results from over 80,000 individual tests (estimated)



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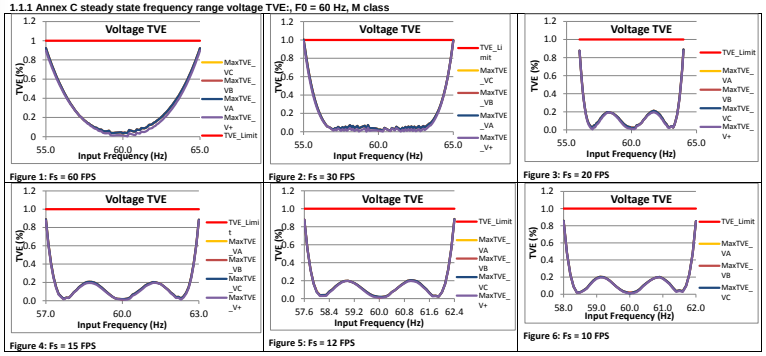
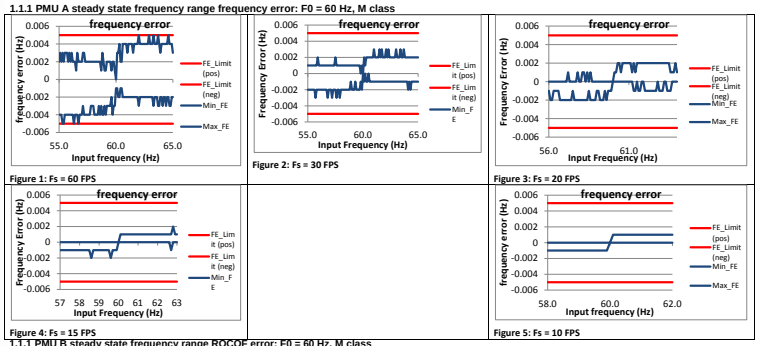
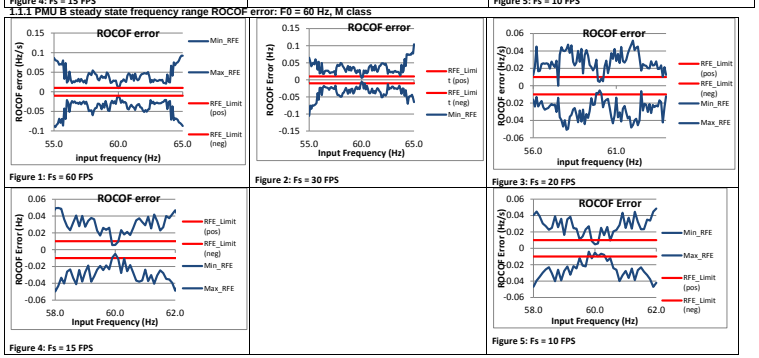
Steady State Tests

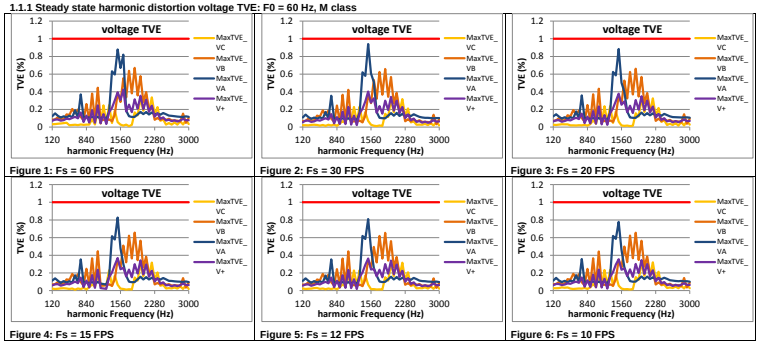
Frequency Range

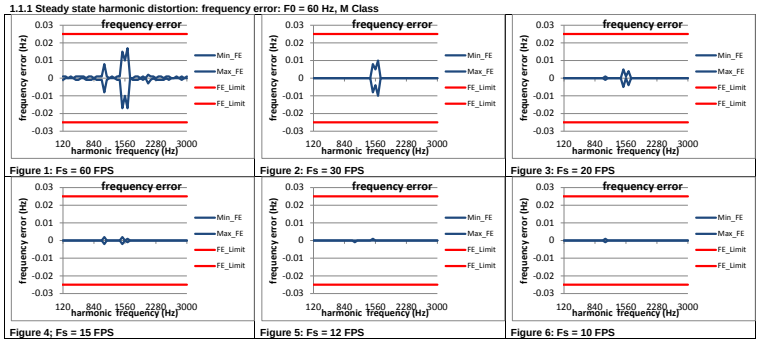


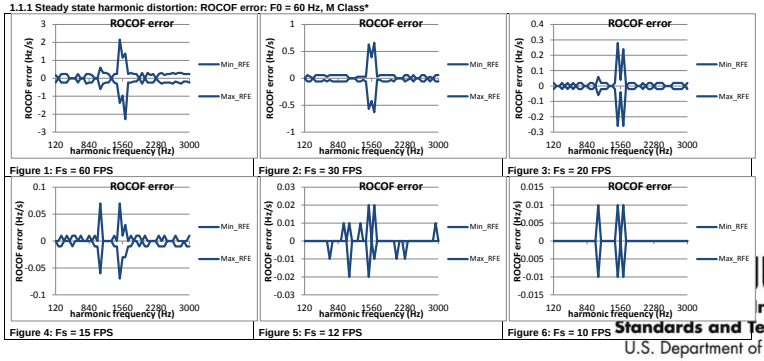




Harmonics







Steady State Tests

Interfering signals

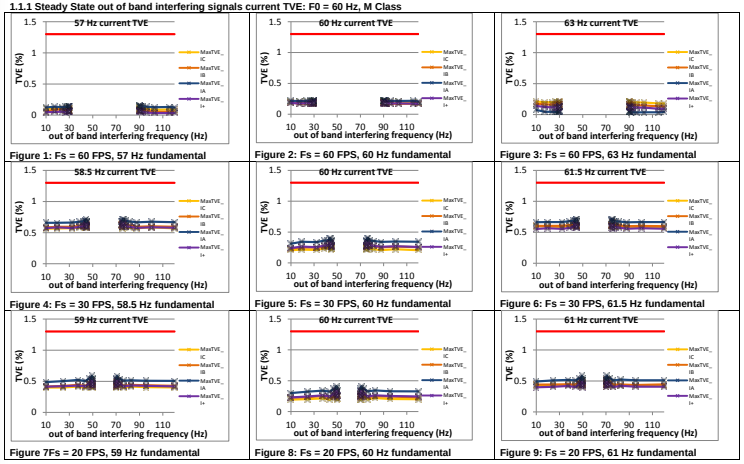


Figure 1: Fs = 60 FPS, 57 Hz fundamental
Figure 2: Fs = 60 FPS, 60 Hz fundamental
Figure 3: Fs = 60 FPS, 63 Hz fundamental
Figure 4: Fs = 30 FPS, 58.5 Hz fundamental
Figure 5: Fs = 30 FPS, 60 Hz fundamental
Figure 6: Fs = 30 FPS, 61.5 Hz fundamental
Figure 7Fs = 20 FPS, 59 Hz fundamental
Figure 8: Fs = 20 FPS, 60 Hz fundamental
Figure 9: Fs = 20 FPS, 61 Hz fundamental

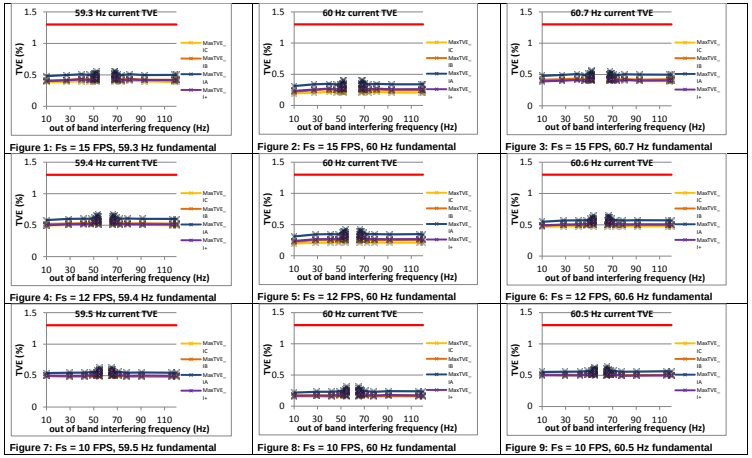


Figure 1: Fs = 15 FPS, 59.3 Hz fundamental
Figure 2: Fs = 15 FPS, 60 Hz fundamental
Figure 3: Fs = 15 FPS, 60.7 Hz fundamental
Figure 4: Fs = 12 FPS, 59.4 Hz fundamental
Figure 5: Fs = 12 FPS, 60 Hz fundamental
Figure 6: Fs = 12 FPS, 60.6 Hz fundamental
Figure 7: Fs = 10 FPS, 59.5 Hz fundamental
Figure 8: Fs = 10 FPS, 60 Hz fundamental
Figure 9: Fs = 10 FPS, 60.5 Hz fundamental

Magnitude

- All PMUs pass the steady state signal magnitude test
  - No plots were created

(note, there are no frequency error or rate of change of frequency error limits for the steady state magnitude test)

Dynamic Tests

Measurement Bandwidth (modulation)

1.1.1 Dynamic phase modulation voltage TVE: F0 = 60 Hz, M class

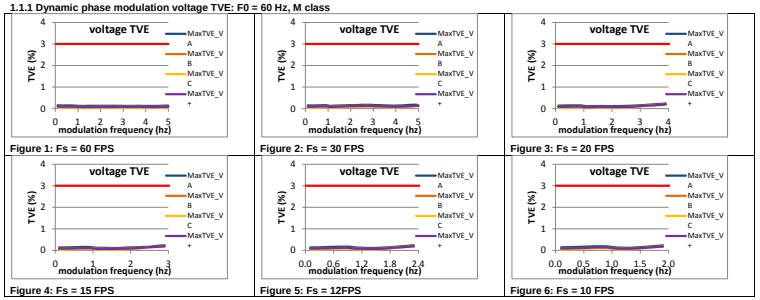


Figure 1: Fs = 60 FPS | Figure 2: Fs = 30 FPS | Figure 3: Fs = 20 FPS

Figure 4: Fs = 15 FPS | Figure 5: Fs = 12FPS | Figure 6: Fs = 10 FPS

1.1.1 Dynamic phase modulation frequency error: F0 = 60 Hz, M class

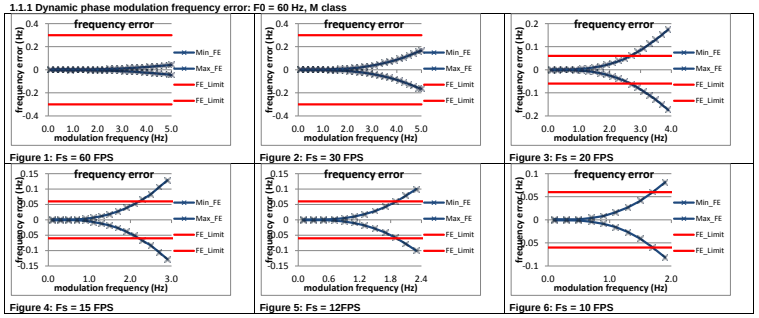


Figure 1: Fs = 60 FPS | Figure 2: Fs = 30 FPS | Figure 3: Fs = 20 FPS

Figure 4: Fs = 15 FPS | Figure 5: Fs = 12FPS | Figure 6: Fs = 10 FPS

1.1.1 Dynamic phase modulation ROCOF error: F0 = 60 Hz, M class

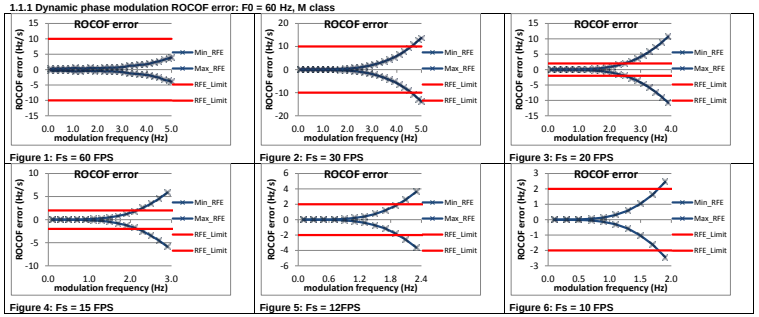


Figure 1: Fs = 60 FPS | Figure 2: Fs = 30 FPS | Figure 3: Fs = 20 FPS

Figure 4: Fs = 15 FPS | Figure 5: Fs = 12FPS | Figure 6: Fs = 10 FPS

Ramp

1.1.1 Dynamic ramp of system frequency voltage TVE: F0 = 60 Hz, M Class

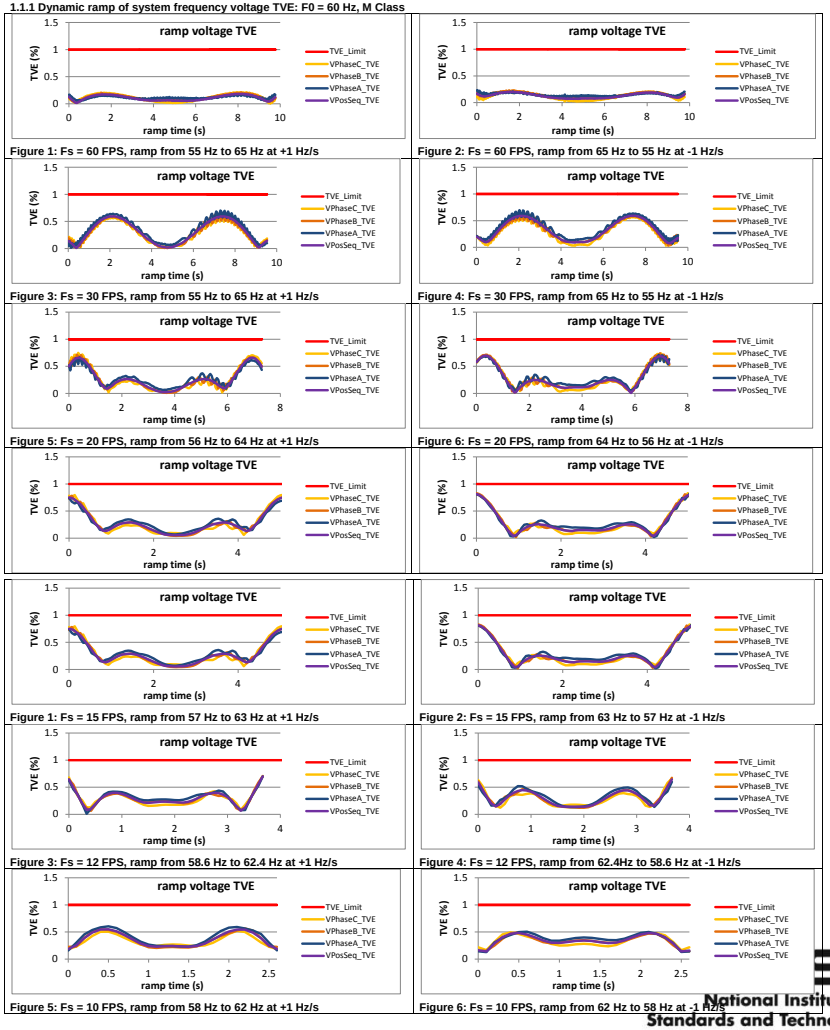


Figure 1: Fs = 60 FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s | Figure 2: Fs = 60 FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

Figure 3: Fs = 30 FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s | Figure 4: Fs = 30 FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

Figure 5: Fs = 20 FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s | Figure 6: Fs = 20 FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

Figure 1: Fs = 15 FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s | Figure 2: Fs = 15 FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

Figure 3: Fs = 12 FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s | Figure 4: Fs = 12 FPS, ramp from 62.4Hz to 58.6 Hz at -1 Hz/s

Figure 5: Fs = 10 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s | Figure 6: Fs = 10 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

Dynamic Tests

Step

1.1.1 Dynamic step change in phase current response time: F0 = 60 Hz, P Class

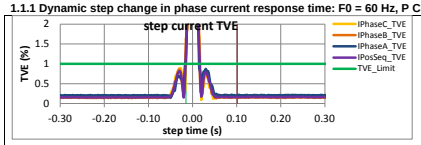


Figure 1: Fs = 60 FPS, +10 degree phase step

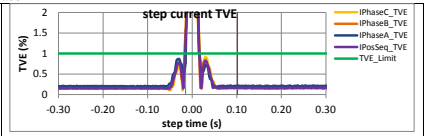


Figure 2: Fs = 60 FPS, -10 degree phase step

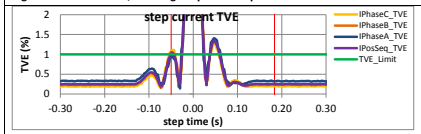


Figure 3: Fs = 30 FPS, +10 degree phase step

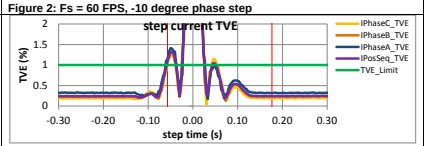


Figure 4: Fs = 30 FPS, -10 degree phase step

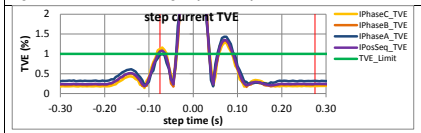


Figure 5: Fs = 20 FPS, +10 degree phase step

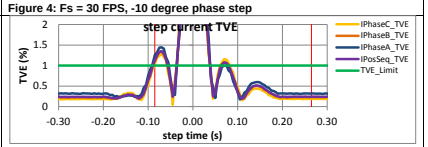


Figure 6: Fs = 20 FPS, - 10 degree phase step

1.1.1 Dynamic step change in magnitude overshoot: F0 = 60Hz, M class

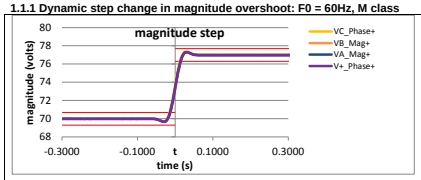


Figure 1: Fs = 60 FPS, +10% magnitude step

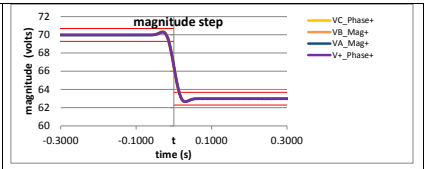


Figure 2: Fs = 60 FPS, -10% magnitude step

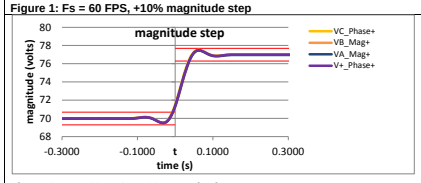


Figure 3: Fs = 30 FPS, +10% magnitude step

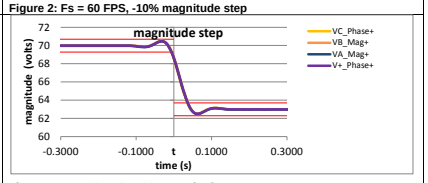


Figure 4: Fs = 30 FPS, -10% magnitude step

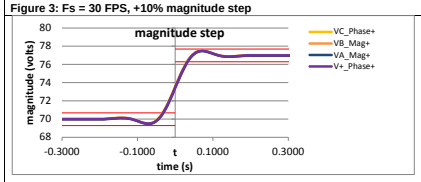


Figure 5: Fs = 20 FPS, +10% magnitude step

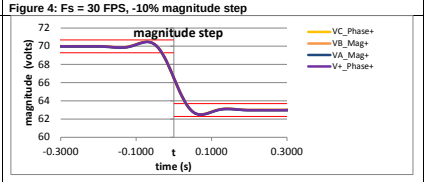


Figure 6; Fs = 20 FPS, =10% magnitude step

Measurement Latency

Test is under development

Thank you

Schedule:

- Expected completion of testing:
  January 2014 (+ 3 weeks)
- Expected publication of results as a NIST Interagency Report:
  June 2014
  - NIST IRs are available to the public.

Questions?

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