(Draft)
IEC TS62786-41: Distributed Energy Resources Connection with the Grid –

Part 41: Requirements for Frequency Measurement Used to Control Distributed Energy Resources (DER) and loads

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Motivation

- The PMU standard was the first electrical power system standard to specify requirements for frequency and ROCOF measurements in electrical power system
  - PMUs present time-stamped reports
- The importance of Frequency and ROCOF measurement in power systems is increasing
  - As will be seen in the Use Case section
- Non-time-stamped measuring systems also need a technical standard
  - An effort was made to set requirements in frequency/ROCOF relays, but it was decided that since the measurement was only used as a trigger, the work would be more appropriate elsewhere
- Distributed Energy Resources (DER) and load control was seen as having a great need of a TS for F and dF measurement, so the work was started in JWG12
- It is expected that this work will be used in other standards as well

Status of the draft

- Draft is being prepared by IES TC8, JWG-12
  - TC8: System aspects of electrical energy supply
  - JWG12: Requirements for measurements used to control DER and loads
    - linked to TC 85, TC 95, SC 77A
- The draft as been through two Committee Draft Votes (CDV)
  - A CDV is an opportunity for all national committees to provide comments on the draft.
    - Comments have been received and responded to.
- The draft is being edited now in preparation for the Draft Technical Standard (DTS) phase
  - The DTS phase is where each national committee has an opportunity to make *editorial* comments and to vote for the draft to become a Technical Standard.
- It is expected that the TS will be published in Q1 or Q2 of 2023

Scope of Draft TS 62786-41

- Characteristics of Frequency and Rate of Change of Frequency (ROCOF) Measurements
- Main use cases (related to control of DER and loads)
- Principles of functional test to evaluate the specified characteristics under steady state and dynamic conditions.
- Functional requirements
  - Note that performance limits are not specified.
  - Manufacturers shall declare the characteristics.
- Does NOT include measurements associated with time stamps (e.g. PMUs.)

What is Frequency?

- Most dictionaries and textbooks will say that it is the reciprocal of the period of a periodic waveform.
  - But what if the waveform is not so "periodic"
    - What if the angular velocity is changing?
- The PMU standard has defined frequency as the rate of change of phase.
  - But what the heck is phase?
- So a challenge before the IEC working group was to come up with a good definition of frequency whether the waveform is periodic or changing (like it does in electrical power systems.)

Clause 3: Terms and Definitions

3.2
rotating vector

representation of a sinusoidal function where a polar vector rotates at an angular velocity which may be a non-constant function of time and is expressed in radians per second.

Note 1 to entry: The radius of the rotating vector may also be a non-constant function of time.

Note 2 to entry: Rotating vectors may represent periodic or non-periodic sinusoids.

Note 3 to entry: Power system signals may be represented by a combination of signals, each represented by one rotating vector, each with various angular velocities and various radii. Each of these rotating vectors represents one component of the power system signal. (See Annex E)

Note 4 to entry: The noise component of a power system signal is not represented by a rotating vector. Noise is represented as a time series.

3.3
phase
angle of a rotating vector

Note 1 to entry: When the rotating vector is described in polar notation, the phase is the angle; when described in complex notation the phase is the argument.

3.5
frequency
rate of change of phase of a rotating vector

Note 1 to entry: If the period is a span of time, the unit of frequency is Hertz (Hz) in cycles per second.

Note 2 to entry: Frequency may be a non-constant function of time.

Clause 4: Performance Characteristics

Table 1 – Performance characteristics presented in this clause

Items	Units
Input energizing quantities	Voltage and current
Delay time	Seconds
Accuracy (declared via Maximum Absolute Error)	Hz (Frequency) and Hz/ s (ROCOF)
Resolution	Hz (Frequency) and Hz/ s (ROCOF)
Measuring Range	Hz (Frequency) and Hz/ s (ROCOF)
Operating Range	Hz (Frequency) and Hz/ s (ROCOF)
Settling Time	Seconds
Reporting Rate	1/Seconds

Clause 5: Use Cases (1 of 3)

Table 6 – List of use cases and associated requirements

Use case	Typical measuring range			Typical accuracy[a]		Typical settling time	Class that allows to fulfill the requirement
	Frequency (Hz)		ROCOF	Frequency	ROCOF		
	50 Hz system	60 Hz system					
PLL in PV power generating systems (Clause B.1)	44 to 53 Hz	56 to 63 Hz	-5 to 5 Hz/s	±10 mHz		Longer than the settling time of the voltage or current controller	C
Primary reserve (Clause B.2)				±10 mHz		200 to 1000 ms	C
Secondary reserve - frequency measurement used for centralised control (Clause B.3)				±1 mHz		1 s	D
Fast frequency-active power proportional controller with dead band (Clause B.4)				±50 mHz		100 ms	B
Fast frequency response (Clause B.5)				±50 mHz		100 ms	B

Use Cases (2 of 3)

Use case	Typical measuring range			Typical accuracy[a]		Typical settling time	Class that allows to fulfill the requirement
	Frequency (Hz)		ROCOF	Frequency	ROCOF		
	50 Hz system	60 Hz system					
Synthetic inertia (Clause B.6)			-15 to +15 Hz/s		±0.1 Hz/s	100 ms	1
Passive anti-islanding detection (Clause B.7)				±100 mHz		60 ms	A
				±30 mHz		100 ms	B
			-10 to +10 Hz/s		±0.05 Hz/s	250 ms	2
Active anti-islanding detection (Clause B.8)				±10 mHz		60 to 100 ms	C
ROCOF measurement used for centralised control (Clause B.9)			-0,03 to +0,03 Hz/s		±1 mHz/s	1 s	3
Load control with active power management (Clause B.10)				±50 mHz		100 ms	B

Use Cases: (3 of 3)

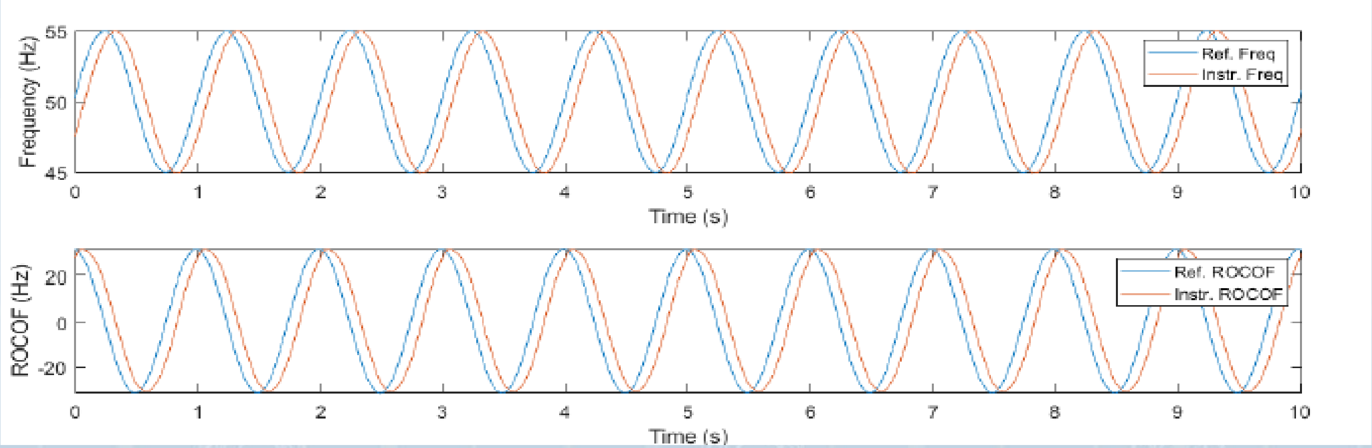
Use case	Typical measuring range			Typical accuracy[a]		Typical settling time	Class that allows to fulfill the requirement
	Frequency (Hz)		ROCOF	Frequency	ROCOF		
	50 Hz system	60 Hz system					
Self-dispatchable loads							
- Ultra fast current control				±100 mHz		60 ms	A
- Very fast current control				±30 mHz		100 ms	B
- Fast current control				±10 mHz		200 ms	C
- Disconnectable loads				±1 mHz		1 s	D
- Primary control				±1 mHz		1 s	D
- Secondary control				±1 mHz		1 s	D
- Tertiary control				±1 mHz		1 s	D
(Clause B.11)							
Underfrequency Load Shedding (Clause B.12)	43 to 53 Hz	57 to 63 Hz		±30 mHz		100 to 120 ms	B
			-4 to 4 Hz/s		±0.1 Hz/s	180 to 240 ms	2

Clause 6: Functional Tests

- The manufacturer must declare each of the characteristics required by clause 4.
- Unlike the PMU standard, there are no required performance limits.
- But the manufacturer must still provide a test report which shows verification of the declared characteristics using a standard set of functional tests.
- Additionally, there is an informative annex with optional tests of the characteristics under a variety of influencing factors.
  - Some of these may become required in future editions of the technical standard.

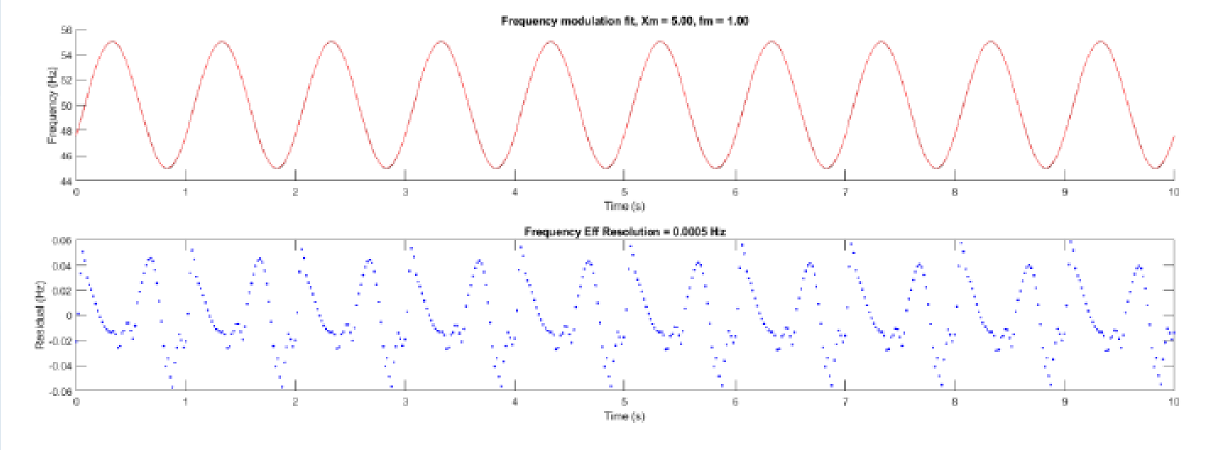
Delay time

- It is important to verify delay time first because all the following tests need to align the output with the input in order to evaluate the characteristics.
- The test method is frequency modulate the input quantity and record the input (reference) and output Frequency and ROCOF values for 10 modulation cycles.
  - A cross-correlation of the input and output Frequencies and ROCOFs will yield a lag value. The lag is the delay time



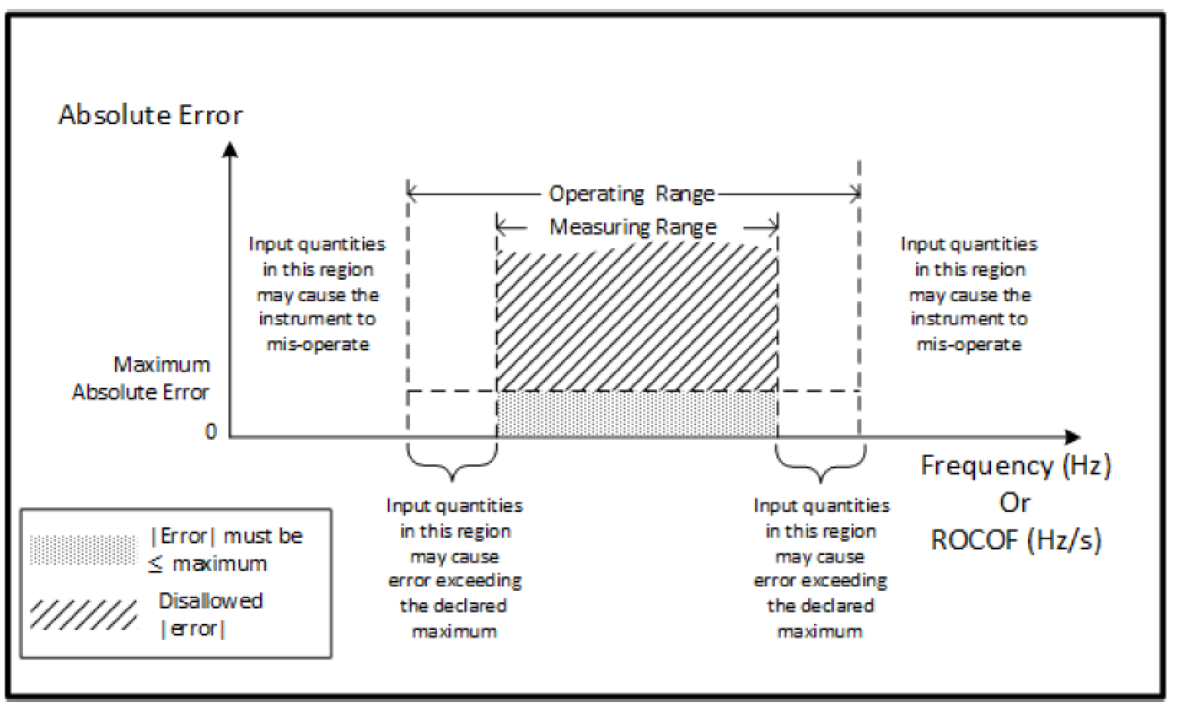
Effective Resolution

- Effective resolution takes into account the internal noise of the instrument that causes variation in the measurement
- Fit the Frequency and ROCOF data gathered during the delay time verification test to models of the Frequency and ROCOF sinusoidal functions. Determine the rms value of the residual (the noise) and divide it by the peak values reached by the FM modulated waveform. Normalize the quotient by multiplying it with the maximum value of the measuring range to determine the effective resolution.



Measuring and Operating Ranges

- The measuring range of the instrument is that range of frequency or ROCOF for which the instrument maintains less than or equal to its maximum absolute frequency and ROCOF error specification.
- The operating range of the instrument is extended beyond the measuring range, to ensure input frequency or ROCOF in the operating range does not cause the instrument to enter any form of saturation mode that requires a recovery time when the input returns into the measuring range.



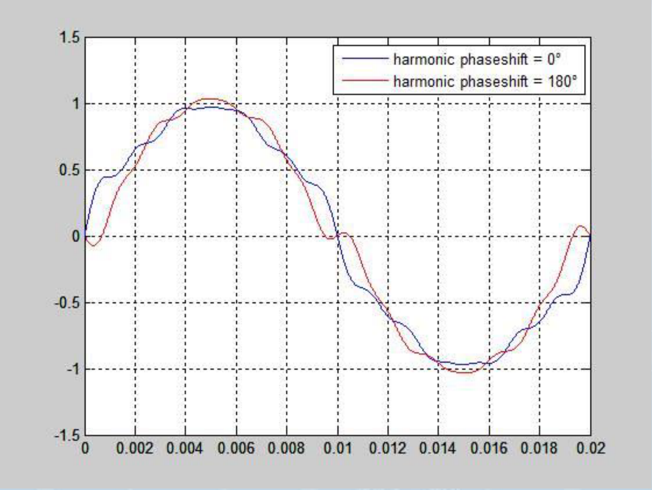
Rejection of Harmonics

- Verified using a test signal combining harmonic magnitudes as shown in the below table:

Table 7 – Input signal harmonic magnitudes

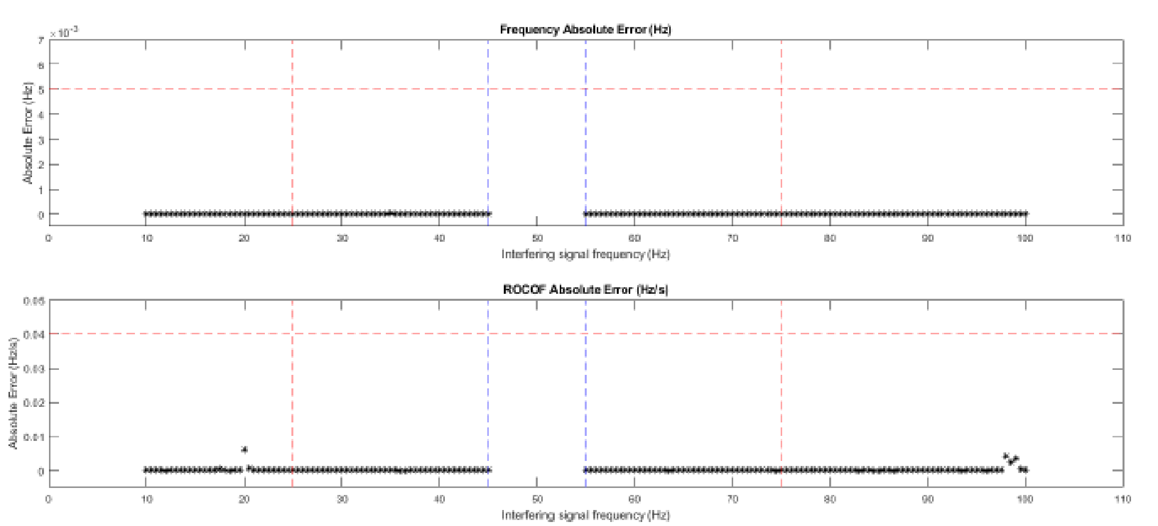
Harmonic number, h	2	3	4	5	6	7	8	9	10	11	12	13	THD
Magnitude X_h (% of X_1)	2.0	5.0	1.0	6.0	0.5	5.0	0.5	1.5	0.5	3.5	0.5	3.0	10.7

- Two tests are implemented where the harmonics are shifted by 0º and 180º. Shifting by 180º causes a double zero-crossings:



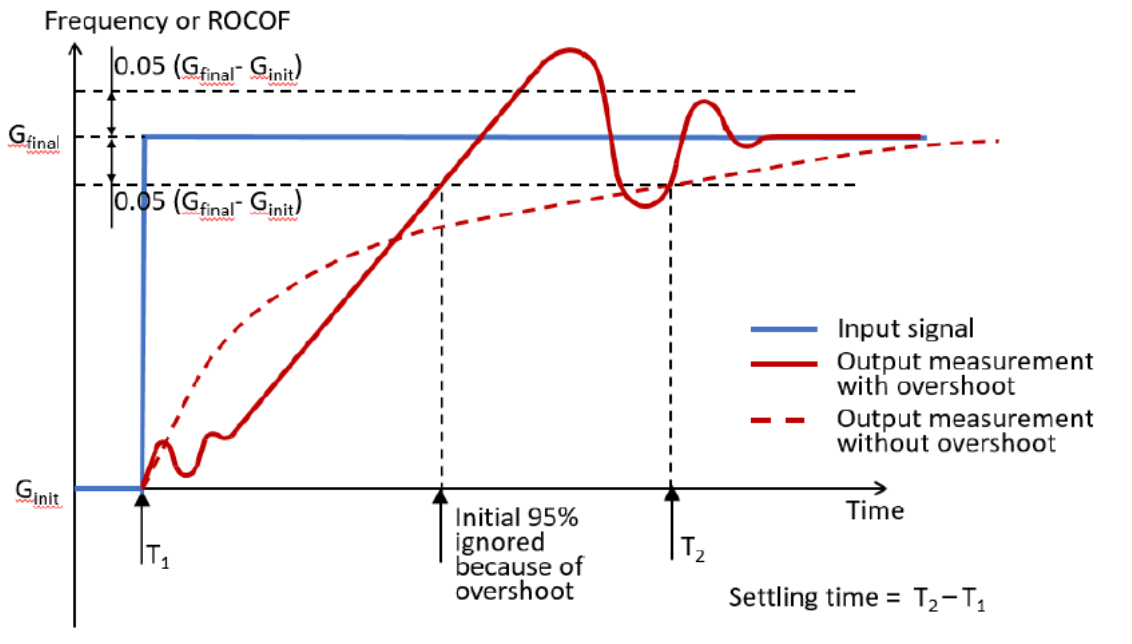
Rejection of Interfering Interharmonics

- Verified by addition to the fundamental signal component, a range of interharmonic sinewave, one at a time, with an amplitude of 0.1 p.u.
  - The range begins at 10.0 Hz and is incremented in steps of 0.5 Hz until the lower frequency of the measuring range is reached. Then from the upper range of the measuring range, incremented in 0.5 Hz steps until the second harmonic is reached.



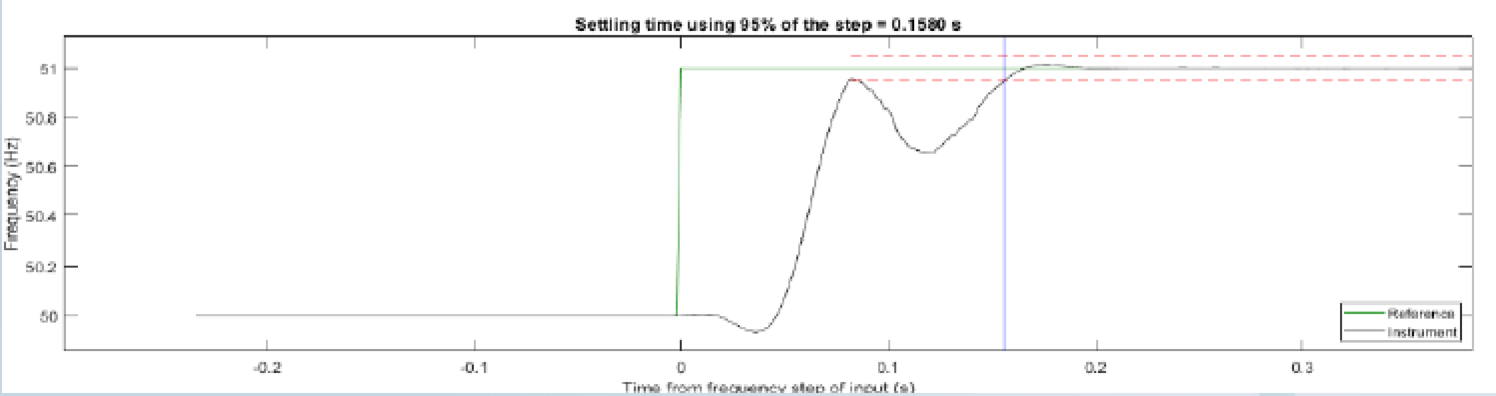
Settling Time (1 of 2)

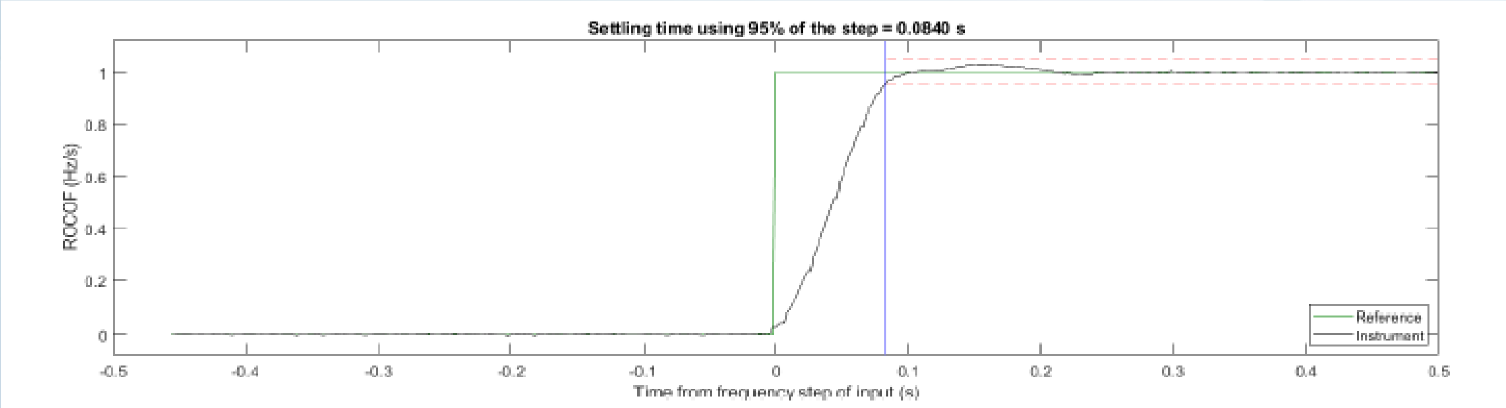
- Settling time is the duration of the time interval between the instant of the step variation of an input variable and the instant when the difference between the step response and the steady-state value remains smaller than the tolerance of the transient value
  - This is a little different from the definition used in the PMU performance standard.



Settling Time (2 of 2)

- Settling time is verified using 1 Hz steps in frequency and 1 Hz / sec steps in ROCOF (positive and negative steps)





Annex A: Measurement Classes

- *Based on use cases described in Clause 5, it is planned to group the different requirements into a few classes for frequency and ROCOF measurements in a later TS revision, either as a normative annex or as a clause associated to use case descriptions.*

Table A.1 – Measurement classes for frequency measurements

		Measurement Classes			
Frequency measurement	**Class**	**A**	**B**	**C**	**D**
	Settling Time	60 ms	100 ms	200 ms	1000 ms
	Accuracy: Maximum Absolute Error in steady state or dynamic conditions	100 mHz (Steady state & Dynamic)	30 mHz (Steady state & Dynamic)	10 mHz (Steady state & Dynamic)	1 mHz (Steady state)

Table A.2 – Measurement classes for ROCOF measurements

		Measurement Classes		
ROCOF measurement	**Class**	**1**	**2**	**3**
	Settling Time	100 ms	250 ms	1000 ms
	Accuracy: Maximum Absolute Error in steady state or dynamic conditions	0.1 Hz/s (Steady state & Dynamic)	0.05 Hz/s (Steady state & Dynamic)	0.001 Hz/s (Steady state)

Annexes

- Annex B: Description of frequency/ROCOF measurement use cases
- Annex C: Summary of requirements expressed in standards and grid codes related to frequency and ROCOF measurements
- Annex D: Maximum ROCOF to be considered on power systems in case of incidents
- Annex E: Frequency and Rotating Vectors
- Annex F: Management of frequency sudden change without discontinuity in voltage waveform
- Annex G: Step Test Equivalent Time Sampling Technique
- Annex H: Voltage and phase angle changes during transmission line faults related to the type of transformer connection
- Annex I: Influencing factors and functional tests

Thank you

- Questions?

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