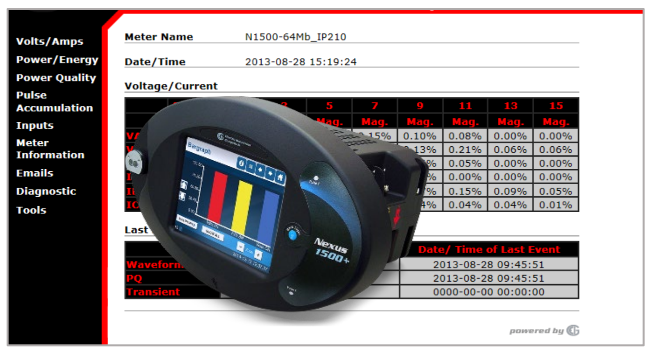
Harmonic Phase Angle Measurement and Analysis

Harmonics are introduced into an electrical system by non-sinusoidal currents, for example, those from a solar power inverter. “These current harmonics generate voltage drops and ...voltage harmonics... in the grid.[i] The calculation of harmonics is defined in the IEC 61000-4-7 standard. The phase angle of harmonics in an electrical system is a critical parameter that provides insights into the nature and origin of harmonic distortion. The phase angle, measured in degrees, indicates the displacement between the harmonic component and the fundamental frequency component of the waveform. This calculation is defined by IEC 61000-3-12, “which defines the limits of harmonic currents caused by equipment and devices with an input current > 16 and ≤ 75A per conductor. This standard is intended for connection to public low voltage networks.”[ii]

A Class A power quality meter can provide information about the cause of these frequencies by enabling harmonic phase angle analysis. Understanding and analyzing the phase angles of harmonics can be useful in the following ways:

- **Harmonic Interaction Analysis** - In systems where multiple harmonic sources are present, the interaction between different harmonic orders can lead to constructive or destructive interference, depending on the harmonic phase angles. By studying these angles, engineers can predict and mitigate potential issues arising from the interactions, such as resonance conditions that might amplify certain harmonic frequencies.



- **System Stability and Quality** - Phase angles can affect the stability and quality of the power system. For instance, in power systems with significant harmonic content, the phase angle can influence the total harmonic distortion (THD) and, consequently, the overall power quality. Understanding the phase relationships can help in designing more effective filters and control strategies to improve system stability and reduce THD.

- **Design and Optimization of Filters** - In the design of harmonic filters, whether passive or active, phase angle information is crucial. For passive filters, knowing the phase angles helps in designing the components (inductors and capacitors) to effectively tune out specific harmonics. For active filters, phase angle information is used to generate compensating currents that precisely counteract the unwanted harmonics.

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- **Source Identification** – In certain cases, phase angle information can help in identifying the source of harmonic generation. By analyzing the phase angles of harmonics at different points in the network, it is possible to trace the direction from which harmonics are being generated. This can be useful in complex networks where multiple devices and systems might be contributing to harmonic distortion.

- **Fault Analysis and Diagnostics** - Changes in the typical harmonic phase angle patterns can indicate potential problems or faults in the system. Monitoring these phase angles can help in early detection of issues such as imbalance, poor grounding, or faulty equipment, which might be contributing to abnormal harmonic levels.

In practical scenarios, such as in industrial plants, the analysis of harmonic phase angles can help in optimizing the operation of power electronic devices like variable frequency drives (VFDs), which are known to generate significant harmonics. By aligning the phase angles through proper system design and control strategies, the adverse effects of these harmonics can be minimized, enhancing the efficiency and longevity of both the drives and other connected equipment.

To utilize phase angle information effectively, accurate measurement and analysis are necessary. Advanced power quality analyzers that are certified to the IEC 61000-4-30 Class A standard, like the Nexus® 1500+ and Nexus® 1450 meters, can measure both the magnitude and phase of each harmonic component relative to the fundamental frequency. Data analysis software like the CommunicatorPQA® energy management application can be used to view and interpret the results and provide actionable insights. Refer to the following figure.

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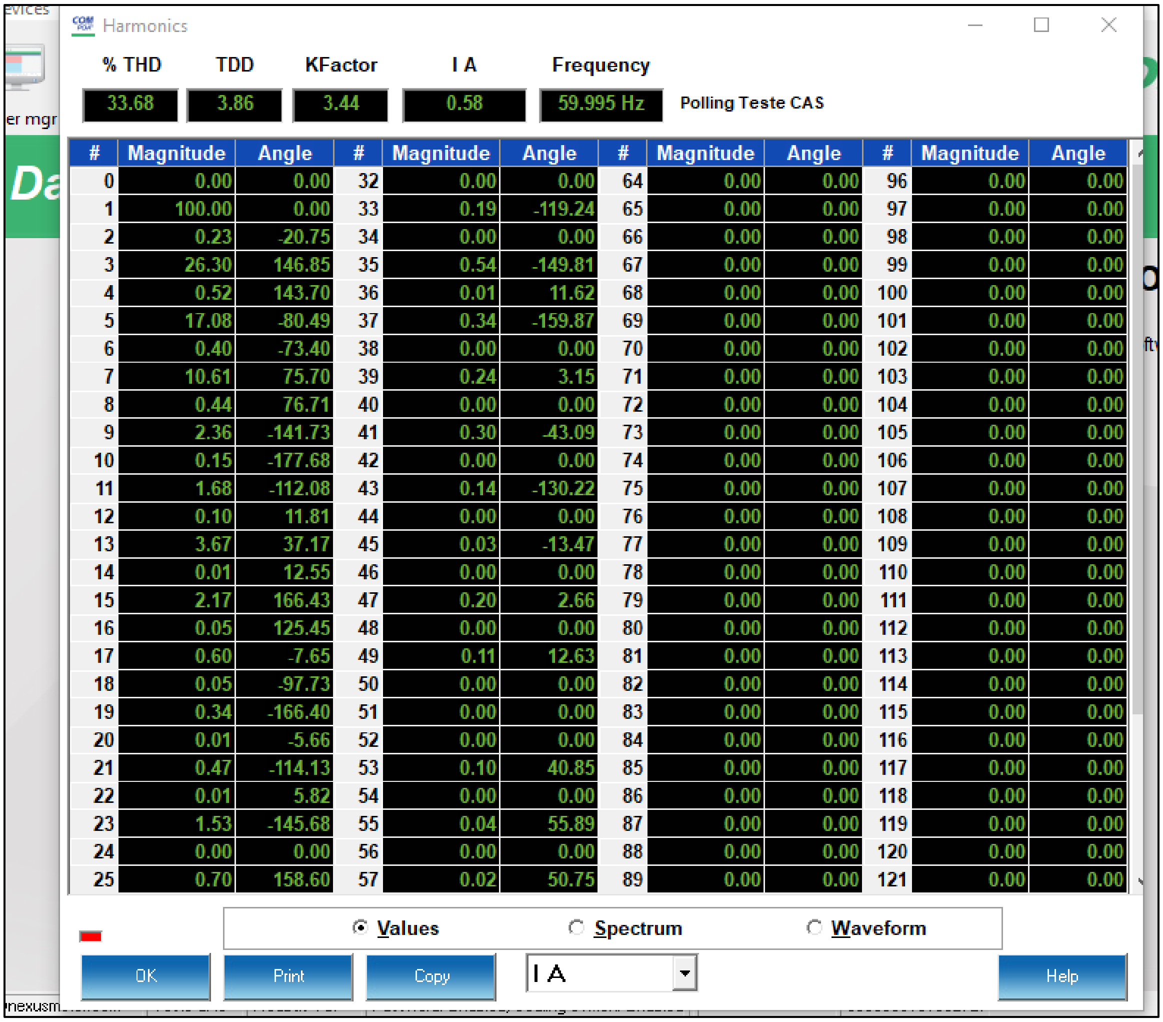

#	Magnitude	Angle	#	Magnitude	Angle	#	Magnitude	Angle	#	Magnitude	Angle
0	0.00	0.00	32	0.00	0.00	64	0.00	0.00	96	0.00	0.00
1	100.00	0.00	33	0.19	-119.24	65	0.00	0.00	97	0.00	0.00
2	0.23	-20.75	34	0.00	0.00	66	0.00	0.00	98	0.00	0.00
3	26.30	146.85	35	0.54	-149.81	67	0.00	0.00	99	0.00	0.00
4	0.52	143.70	36	0.01	11.62	68	0.00	0.00	100	0.00	0.00
5	17.08	-80.49	37	0.34	-159.87	69	0.00	0.00	101	0.00	0.00
6	0.40	-73.40	38	0.00	0.00	70	0.00	0.00	102	0.00	0.00
7	10.61	75.70	39	0.24	3.15	71	0.00	0.00	103	0.00	0.00
8	0.44	76.71	40	0.00	0.00	72	0.00	0.00	104	0.00	0.00
9	2.36	-141.73	41	0.30	-43.09	73	0.00	0.00	105	0.00	0.00
10	0.15	-177.68	42	0.00	0.00	74	0.00	0.00	106	0.00	0.00
11	1.68	-112.08	43	0.14	-130.22	75	0.00	0.00	107	0.00	0.00
12	0.10	11.81	44	0.00	0.00	76	0.00	0.00	108	0.00	0.00
13	3.67	37.17	45	0.03	-13.47	77	0.00	0.00	109	0.00	0.00
14	0.01	12.55	46	0.00	0.00	78	0.00	0.00	110	0.00	0.00
15	2.17	166.43	47	0.20	2.66	79	0.00	0.00	111	0.00	0.00
16	0.05	125.45	48	0.00	0.00	80	0.00	0.00	112	0.00	0.00
17	0.60	-7.65	49	0.11	12.63	81	0.00	0.00	113	0.00	0.00
18	0.05	-97.73	50	0.00	0.00	82	0.00	0.00	114	0.00	0.00
19	0.34	-166.40	51	0.00	0.00	83	0.00	0.00	115	0.00	0.00
20	0.01	-5.66	52	0.00	0.00	84	0.00	0.00	116	0.00	0.00
21	0.47	-114.13	53	0.10	40.85	85	0.00	0.00	117	0.00	0.00
22	0.01	5.82	54	0.00	0.00	86	0.00	0.00	118	0.00	0.00
23	1.53	-145.68	55	0.04	55.89	87	0.00	0.00	119	0.00	0.00
24	0.00	0.00	56	0.00	0.00	88	0.00	0.00	120	0.00	0.00
25	0.70	158.60	57	0.02	50.75	89	0.00	0.00	121	0.00	0.00

This screen capture from CommunicatorPQA® software shows the Harmonics Polling screen, with magnitude and angle measurements, for the Nexus® 1500+ power quality meter. The data can be copied and/or printed for analysis. Limits and alarming can also be set for current and voltage harmonics.

In summary, the use of harmonic phase angles is a sophisticated approach to managing and mitigating harmonic distortion in power systems. It provides deeper insights into the behavior of harmonics and their impact on electrical networks, leading to more effective solutions for maintaining power quality and system reliability.

For additional information on Electro Industries' power quality meters and energy management software, click the link below.
https://www.electroind.com/

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[i] "Angle Determination od voltage and current harmonics in practice," Jurgen Blum, 01/2024, accessed 12/09/2024 from https://www.a-eberle.de/wp-content/uploads/2024/02/Directionofharmonics_EN_final.pdf

[ii] *ibid*

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