ENERGY AND HEAT MEASUREMENT
A TECHNOLOGY BRIEFING

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TRENDPOINT™

*Energy and Carbon Metrics*SM

Background:
Power monitoring in data centers has moved from a luxury to a necessity as heat and power densities have risen rapidly. The principal of Management By Information (MBI) states that: You can only manage what you measure. The first tenant of MBI is: The accuracy of your measured data directly impacts the quality of your decisions.

While some may already have investments in first-generation power-strip monitoring units, it is important to understand what information is required to make proper power and heat-related decisions. There may always be a tendency to look for lower quality solutions; however, as we shall see in this paper, choosing the right monitoring solution is vital to the goal of improving and maintaining data center energy and carbon efficiency.

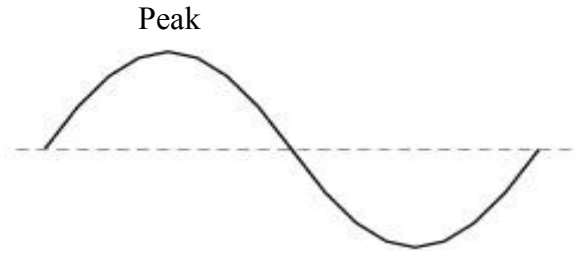
Proper Measurements
Let's begin by defining some basic power monitoring terms. First is the formula for measuring the actual wattage of power. This is expressed as follows:

Voltage x Current x Power Factor = Wattage

The continuous accumulation of wattage data is commonly referred to as the energy consumption of a device and is normally expressed in kiloWatt hours or kWh.

There are three types of measurement devices that can be used to monitor the quantity of heat measured in watts. These device types and their relationship to one another can be seen by the graphic below. We will evaluate the relationship between average metering data and RMS metering data. Peak-to-Peak is seldom used for practical purposes.

- **True RMS = .707 of Peak**
- **Average = .637 of Peak**
- **Peak to Peak = 2X Peak**

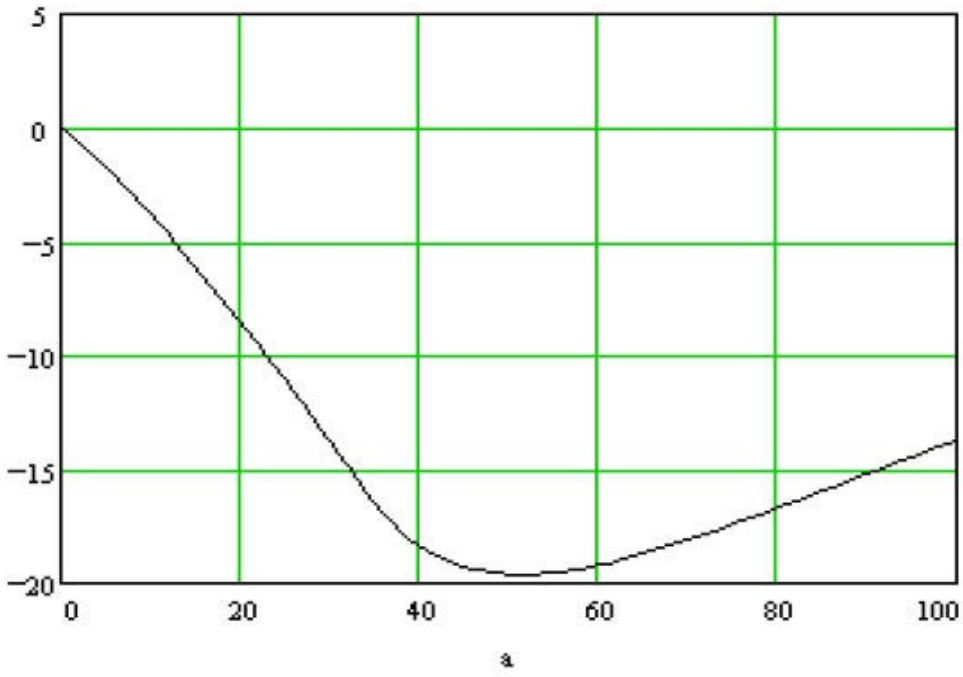


RMS stands for root mean squared. The RMS of the amperage or voltage within a circuit is calculated by taking the square root of the average the squared values for all the points measured (positive and negative) along each sine wave. True RMS data is extremely important to data center measurements as it provides the *actual heating equivalent value* for any circuit. The heating value of any circuit is expressed in watts and *must* incorporate the true RMS values for voltage, amperage and the power factor of the angle between the two. The result provides the standardized measure that is the basis for all measured electricity billing throughout the world.

The heating value of true wattage is vital to understanding the actual heat produced by any server or piece of networking equipment. It is also vital to the sizing of cooling loads in a data center. The heat loads may be correctly sized to cooling requirements through the relationship between the wattage of heat and BTU (British Thermal Units) BTU is defined as the amount of heat that it takes to change 1 pound of water by 1 degree F. Cooling system rating are generally expressed in BTU's and/or in tons (12,000 BTU) of air. The direct mathematic relationship of wattage to BTU is expressed as:

1 kWh = 3,413 BTU's of Heat

Measuring devices, such as metered power strips, often use averaging methods to calculate amperage. The use of averaging methods to measure circuit power parameters employs the fact that RMS value is 10.99% more than an average for a *pure sine wave*. However, *any waveform that is not a perfect sine wave will break the mathematical relationship between average and RMS and render an inaccurate result*. The more distorted a wave form through harmonics, the more the error and, data centers inherently have harmonics. The following curve describes the difference in average amperage or voltage vs RMS in terms of the 3rd harmonic, which has the most impact on the Total Harmonic Distortion (THD) of a sine wave.



.source: Ohio Semetronics, Inc.

This graph shows the error in percentage on the Y (left) axis vs. the 3rd harmonic on the X (bottom) scale. The error in percentage is the difference between an averaging voltage or amperage meter vs. a true RMS meter. Note that the *readings from an averaging meter source will always be less than the true RMS* meter due to harmonics. Further, the magnitude of the error is significant and approaches 20%. This error does *not* include additional inaccuracies from simple measurement error of the waveform, which can add several percentage points more to the error.

The Purpose of Power Measurements
The second item to consider before measuring amperage, voltage and wattage is the purpose for the measurement. In some cases, it may acceptable to use average measurements, even allowing a rather high error rate. However, as will be seen, in most cases, only true RMS information is reliable for use.

Types of Power Monitoring Devices in Data Centers:
Average Amps – as described, these units provide only averaged information on amps

Average Watts – these units use RMS or average amps and multiply by an averaged or estimated voltage and an estimated power factor. As we have seen, even if an RMS measure is taken for amperage, the use of average or, worse yet, estimated voltage or power factors can render such data extremely inaccurate.

Actual Watts – measure true RMS amps times true RMS voltage times the actual power factor of the angle between the RMS amperage and voltage sine waveforms.

kWh – provides sub cycle accumulation of true wattage data

	Average Amps	Average Watts	Actual Watts	kWh
Amperage Trends				
Breaker Protection				
Heat Balancing				
Energy Billing				

- Inaccurate - Acceptable - Accurate

Detailed Analysis:
- Amperage Trends - Measuring amperage trends was one of the first uses of power measurement in data centers. It is important to gather amperage information to determine when one can expect to run out of a margin of safety on any given circuit. Average amperage data with harmonics will always be lower than true RMS data, thus, will not provide an accurate picture of circuit usage. Therefore, viewing amperage trends with average amperage data will always present a picture that is distorted to the low side.

- Breaker Protection - Breaker protection cannot be accomplished well with pure amperage data, even if that is true RMS monitoring. A circuit breaker typically has one magnetic element for amperage overload, one thermal element for heat overload and a combined thermal-magnetic element that acts as a type of failsafe mechanism. Thus, in order to avoid a tripped breaker, you must monitor with True RMS amperage *and* RMS wattage of heat to understand the safety margin

that exists between the load and the breaker's trip points. Viewing amperage-only data can not protect you from a thermal overload of that breaker.

- Heat measurement. We learned earlier that the definition of RMS watts is the true heat value of a circuit. Any measurement of wattage that does not use true RMS amperage *and RMS* voltage *and* RMS power factor will yield an incorrect result. Some metered power strips employ RMS amperage and only estimate voltage and power factor. Because of the rapid change in wattage values for CPU's, basic RMS watt meters can be very inaccurate when being used to estimate actual wattage. For measuring heat values over any period of time, the accumulated quantity of power, kwh, must be employed. Kwh data is only available on billing-grade power measurement devices.

- Energy Billing. Without a true billing-grade meter chip, one can not accurately measure and therefore can not bill for energy. Most states within the US and many localities in Europe require that the sub-metered billing be provided by metering chips conforming to international electrical standards. These may include IEC 61036/60687, IEC62053-21, and IEC62053-22. Kilowatt hours are accumulated in these chips at sub cycle levels for each sine wave. According to the least square curve method, in order to achieve an accuracy of 1%, the sampling rate must be at least 10 times per cycle. Depending on whether the power is provided at 50 or 60 cycles per second, this equates to 500 or 600 samples per second as a minimum to achieve this accuracy. Thus, with circuit-based monitoring, accumulated wattage requires that the energy monitoring chips meet such speeds and standards.

Summary

The measurement of true heat and energy values in data centers is vital to improving energy efficiency. True heat values are only expressed in RMS watts. Its accumulated value, kWh forms the basis for all energy billing as well as carbon to kWh comparisons. First-generation monitoring devices employed average amperage and/or average wattage data. Average wattage is a highly inaccurate measurement and cannot be relied on to provide actual heat values or billing kWh. True RMS wattage and kWh units that measure directly at the circuit-breaker have become affordable and form the basis for quality information gathering in data centers.

About the Authors:

Robert Hunter is the founder and CEO of TrendPoint Systems. He has over 18 years experience in building, managing and maintaining data centers. Robert was previously the founder and CEO of NetBrowser Communications, the pioneering leader in web-based data center management.

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