Understanding Date Center

Power Usage Effectiveness

This Dell Technical White Paper explains how to understand Power Usage Effectiveness (PUE) and how it applies to your Data Center.

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Executive summary

Understanding how efficiently your data center operates is now, more than ever, critical to ensure cost-effective operation. Traditional methods of estimating energy efficiency are subject to gross misrepresentations of your actual performance. This paper will detail a simple and direct method to measure your energy efficiency using Power Usage Effective or PUE metric.

Introduction

Operating a data center is an ever-increasing expense for businesses as the cost of electricity continues to climb. Operating a power-efficient data center requires that special attention be paid to every link in the power delivery chain that starts from the utility grid connection, through the data center infrastructure (power conversion, backup scheme, cooling, and distribution), and connects to the server.

Traditional methods for estimating data center efficiency can lead to very inaccurate results. These methods can include taking "nameplate" or a component's rated power numbers and summing the inefficiencies of the various power and cooling infrastructure components to determine power losses.

This whitepaper will detail a more direct measurement method called the Power Usage Effectiveness or PUE that results in a more accurate representation of a data center's efficiency.

The Green Grid

The Green Grid (http://www.thegreengrid.org) is a consortium of the IT industry's leading experts, government agencies, and educational institutions whose prime focus is increasing the energy efficiency in data centers. In order to improve data center efficiency on a global scale, a common set of terms, definitions, and metrics needs to be agreed upon.

One such performance metric defined to drive awareness and to increase energy efficiency in the data center is The Green Grid's Power Usage Effectiveness or PUE. The Green Grid is proposing the PUE metric for the short term because it enables data center operators to very quickly determine their data center's energy efficiency and to compare it against a baseline of other data centers to identify any major inefficiency needs to be addressed. This quick metric identifies important issues and starts the energy improvement discussions.

Data center Power Usage Effectiveness

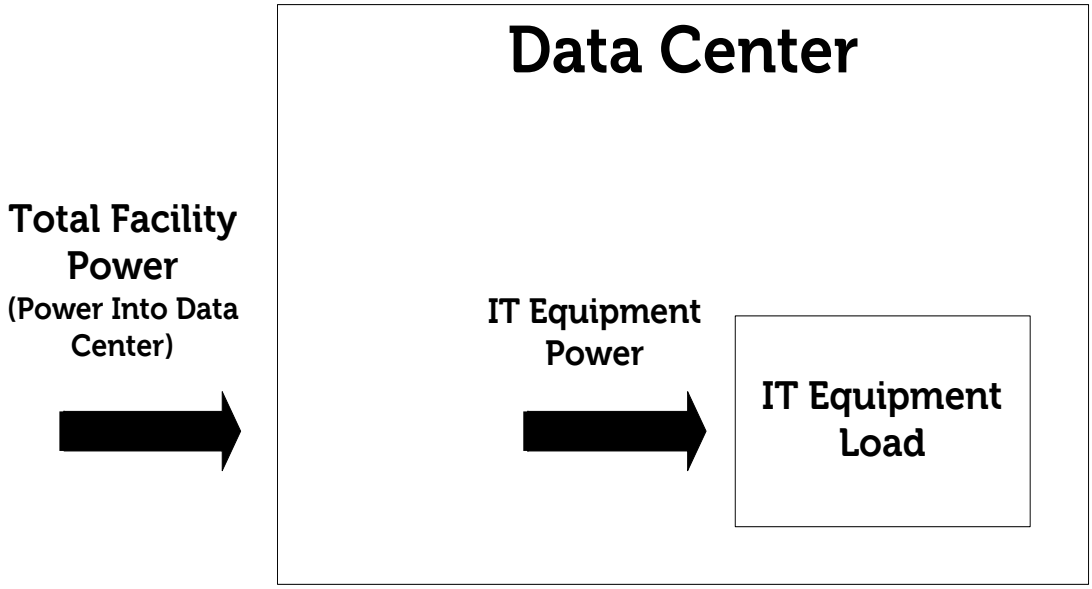
Imagine that every time you pull into a gas station to fill your car's gas tank, you start by pouring the first five gallons of gasoline directly onto the ground. At today's gas prices, you quickly see that a large chunk of your fuel cost does nothing to get you to your desired destinations. This would be the same for the operational costs of running an inefficient data center. Just as your car's miles per gallon (mpg) indicates its efficiency, your data center's PUE indicates effective use of your power bill.

The main purpose of any is data center to generate useful information technology output (work), in all its various forms. The generation of this IT output comes at no small cost, especially with the ever-increasing cost of electricity. In order to keep control of the operational costs, optimizing efficiency is critical. IT organizations can better understand energy efficiency within their datacenter by knowing how to measure its PUE.

Data centers provide an electro-mechanical ecosystem from which the IT equipment can be housed and operated. This ecosystem consumes a power overhead to operate. All the power that enters the data center does not reach the IT equipment. A fraction of power is lost along the way to support the ecosystem's overhead.

Very simply, PUE measures and compares Total Facility Power, the total data center input power, with IT Equipment Power, the portion of the power that is consumed directly by the servers, storage, and other IT equipment.

Figure 1. Power Usage Effectiveness PUE



$$PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

Total Facility Power

The total power coming from the utility provider that is used to operate the data center and power all IT equipment is the Total Facility Power. This provider includes all power conversion and distribution infrastructure, such as UPS, PDUs, and batteries that delivers power to the IT equipment. It also includes all cooling systems components; CRACS, air-handlers, pumps, and cooling towers as well as data center lighting power for the technicians and operators

IT Equipment Power

The power that reaches and specifically powers the servers, storage boxes, and other IT equipment is the IT Equipment Power. This includes the power applied to computer, storage, and network equipment. Unfortunately, it does not comprehend the individual IT equipment's power effectiveness. It should be noted here that newer servers typically operate much more efficiently than previous generations, which means for the same IT Equipment Power, operators can install and operate many more servers thus increasing the IT work output.

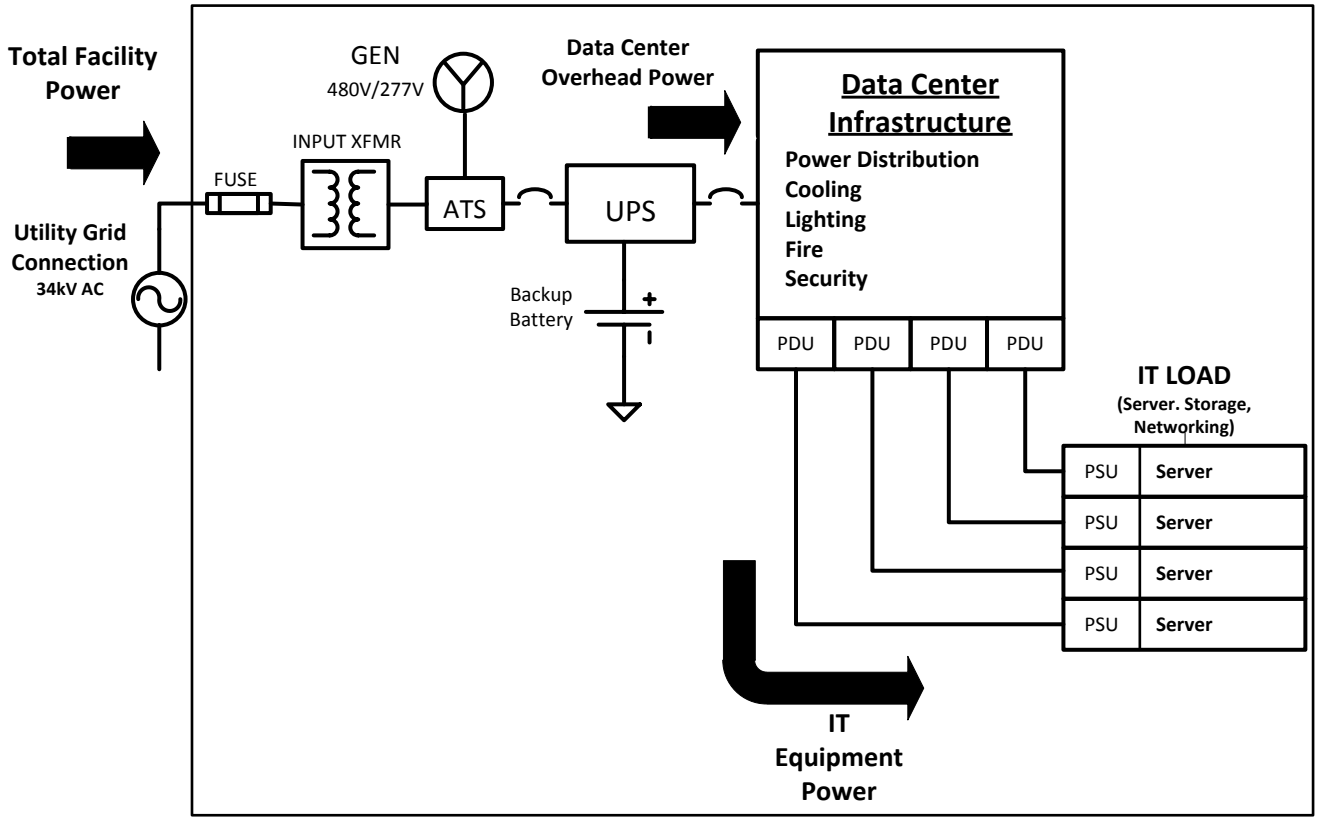
Understanding your data center's PUE

PUE calculation provides a top-level view of how efficient a data center is operating. To better understand what drives the efficiency within the data center, we have to look inside at how power is handled, converted, and distributed.

If the Total Facility Power is directly applied to the IT Equipment Load, the resulting PUE=1.0 can be achieved, but this is not realizable. That's because the power as received from the utility grid connection must be converted and distributed at voltage and current levels that can be consumed by the data center equipment.

This power conversion and distribution within the data center usually occurs in several stages with each stage having less than perfect conversion efficiency. A significant portion of the Total Facility Power being converted and distributed results in power loss as heat. Subsequently, the heat dissipated requires cooling so that the IT equipment can operate within acceptable environmental limits, which requires additional power being consumed by the data center cooling systems. There are also thermal losses associated with the operation of the cooling systems, which again adds to the loss of power from the total applied power at the data center input.

Figure 2. Data Center: Total Facility Power and IT Equipment Power



It isn't all bad news, because there are things that can be done with data center design that can maximize PUE and minimize power loss. Careful attention must be paid to selection and sizing of these power handling subsystems.

In the past, it has been standard practice to oversize or "de-rate" (to operate below the maximum specification for safe margin) the power handling and cooling subsystem components. The main impetus for this was to ensure that under worst-case loading conditions, every component is capable of handling its worst case condition. This design practice was motivated by a desire to have plenty of extra design margin or safe operating margin.

This practice inadvertently has an additive effect as you move up the power delivery/cooling infrastructure. As you move from the server to the utility grid, connecting each link in the chain adds additional worst-case loading to the stage that precedes it. This results in specifying much more capacity at the data center level than the loading capacity utilized by the IT equipment.

The negative effect of over-specifying power capacity occurs when the IT equipment load is low with respect to capacity (10-20% of capacity). This results in even lower conversion efficiencies when compared with heavier-loaded data centers. Under-utilization translates to even more losses per watt of IT load, which means the data center operator ends up paying more per watt of IT load than if power capacity is sized appropriately, typically referred to as "right sizing."

Power and workflow within a data center is a dynamic amalgamation of complex industrial electrical and mechanical systems in addition to the IT hardware, software applications, and customer usage patterns. This makes measuring actual data center efficiency quite difficult because it is hard to distill all the variables, measurement parameters, and analysis into a simple measurement and equation.

The Green Grid will be proposing a refined version of the PUE metric which they call Data Center Performance Efficiency (DCPE) which provides even greater insight into the data center efficiency. Dell will be watching their progress closely and helping to advise our customers on how to best leverage the new measurement as appropriate.

Beyond data center PUE–server-PUE

Attention to your data center's PUE is a great first step; however, operating an efficient data center does not stop there. The individual server is a critical link in this power delivery chain. Next steps include taking the same approach at the individual server level as PUE has done at the data center level. By measuring a server's power and determining how much of that power is consumed by the useful IT load work output and how much power is dissipated in the power conversion and distribution, as well as thermal management of operating the server, an equivalent metric can be used to optimize designs and reduce wasted power.

The IT Equipment Power or the input power applied to the server plug must then be converted and distributed within the server to operate the subsystem loads like the CPU and Memory. To prevent lost wattage, the server must have high conversion efficiency, technology-enabled power management capability, and low power distribution loss. This ensures more of the wattage applied at its connector makes it through to perform the actual workloads. Otherwise, this wasted power shows up as heat dissipated and consumes even more power at the data center level to maintain cooling.

What is Dell doing to optimize IT equipment power?

Dell is constantly focused on optimizing the power use of its servers to provide solutions that offer lower operating costs. Careful attention in every aspect of the server's design helps reduce power loss throughout the server. The following section highlights some of those details.

Power capacity vs. system utilization

In exactly the same way yesterday's data center designs would add up nameplate power ratings and worst-case power numbers for a safety margin, previous generations of servers would over-specify power requirements to ensure an extra safety margin.

One of the main factors that can negatively impact a server's efficiency is the difference between the power system design point and how much power the server actually uses for a given application.

In the past, it was standard practice to over-design the power subsystem. This allowed for an adequate safety margin for the combination of all worst-case conditions, including highest power CPUs, maximum configurations, IT applications, and environmental conditions. This was done to ensure that under any and all of these conditions, the power design was operating within electrical and thermal safety limits.

This was the standard design practice for decades; that is, until the cost of electricity began to sharply rise. Over-designing results in lower conversion efficiency (higher power loss) when operating at a

lighter than expected load condition. Typically, to the over-designed power subsystem, almost all IT applications were seen as light loads.

If the power subsystem is right-sized, it is better matched to the application load, the power is converted at a higher efficiency, and there will be less power loss.

Right-sized power supplies offer flexible options

Dell servers offer you the flexibility of purchasing exactly the configuration you need for your unique set of requirements. You can choose higher or lower power CPU's, more or less memory, the number of hard drives required, and more. This flexibility translates to widely varying power requirements.

This varying range in power requirements requires the server to be designed to support the maximum power requirements. Quite often the purchased configuration is not the maximum power requirement which, if not employing a properly-sized power supply unit (PSU), could lead to power over-capacity condition or an underutilized power load, wasting power and money.

By providing you the flexibility to purchase a PSU that exactly fits your unique configuration's power requirements, Dell enables a PSU right-sizing strategy resulting in major cost savings over the lifetime operation of those servers.

High efficiency PSUs – Climate Savers and 80 PLUS

Dell has been a member of Climate Savers since its inception and worked closely with the industry's leading power supply vendors to work on ever-increasing PSU conversion efficiencies. Dell continues to be an industry leader by continuing to raise the bar on power supply efficiency. In fact, Dell is the first vendor to certify a Titanium-level PSU with 80 PLUS.

Dell's portfolio provides for selecting the conversion efficiency desired. This is an important decision because of the lifetime operational costs associated with that selection. In addition to the direct power savings a higher-efficiency PSU can provide, there are additional savings through reducing the data center's thermal load and associated cooling costs.

Motherboard Power Distribution Planes

Many server subsystem loads are powered by low voltages at very high currents. In order to minimize power losses due to connecting each subsystem load to its power source, great care must be taken in the design of the motherboard. The connecting copper "islands" or planes that conduct this power must be designed with appropriate shapes and adequate thickness but also must minimize the distance between the subsystem load and its power source.

High Efficiency Power Conversion Components

Dell works closely with the leading power component vendors to develop and provide best-in-class power components and PSUs to deliver industry-leading conversion efficiencies. There is a lot of technology innovation occurring within the electrical components and circuit designs that handle power in the delivery chain.

Conclusion

Traditional methods of data center design must be replaced going forward if operators are to reach maximum efficiencies and to minimize operational expenses. Oversizing data centers results in poor operating efficiencies. The oversized data center is producing more losses and consequently requires more cost to cool for every watt of IT load generated.

Power Usage Effectiveness or PUE provides the data center operator with a quick and simple method to gage how efficient their data center is operating.

For more information, visit www.dell.com/powerandcooling.