

ENERGY LOSS MODEL FOR TIER 2 AND TIER 3 DATA CENTERS

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Abstract

Demand for energy for data centers has soared during the COVID-19 pandemic. In 2020, the demand for energy for data centers is around 1% of worldwide electricity consumption and will be 3-13% in 2030. Energy loss in data centers is the main focus of this research. An energy loss model has been constructed to investigate data center power distribution systems (PDS). The model found that the highest energy loss is from the power supply unit (PSU) of IT equipment and the uninterruptible power supply (UPS). A server upgrade to PSU 80 PLUS Titanium reduces energy loss by around 2.7 times when compared with a normal PSU. These amounts of energy loss affect long-term operating expenses over the course of the data center's lifetime. Moreover, this research compares PDS of Tier II and Tier III data centers to measure energy loss. The research results demonstrate that Tier III data centers lost approximately 1.782 times more energy through PDS than Tier II data centers.

Keywords: Energy loss model, data center, energy efficiency, power distribution system

Introduction

The Internet is a global system which intelligently connects people with information and things. Data centers support information storage and are the backbone of the digitized world which has emerged in the 21st century. Demand for Internet services has been increasing dramatically during the COVID-19 pandemic; video and audio streaming related to working from home (WFH), online learning, and online shopping continues to generate the greatest traffic of any category on virtually every network. Before the COVID-19 pandemic, data centers were energy-intensive enterprises, estimated to account for around 1% of worldwide electricity use; these trends have clear implications for global energy demand and must be analyzed rigorously (Masanet *et al.*, 2020). Masanet's study, published in the journal *Science*, notes that while there has been

an increase in global data center energy consumption over the past decade, this growth is negligible compared with the rise of workloads and hardware deployed during that time.

Data centers accounted for about 205 terawatt-hours of electricity usage in 2018, which is roughly 1% of all electricity consumption worldwide, according to the report. Up to 50% of the energy consumed by IT and communication equipment does not provide any directly useful work (Weldon, 2018). These 205 terawatt-hours represent a 6% increase in total power consumption since 2010, but global data center compute instances rose by 550% over that same period. Data centers are expected to improve their electricity intensity in a similar way as fixed access networks (FAN). This seems, however, to be not enough to cope with a 25%

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annual growth rate for global data center IP traffic. Data centers will use around 3-13% of global electricity in 2030 compared with 1% in 2010. The need to improve the efficiency of data center operations has increased due to the continued high demand for Internet transaction capacity, combined with other factors such as the evolution of IOTA and 5G technologies and smart cities, and increased competition for energy resources. This trend toward expansion has caused managers of large data centers to be more aware of the need to improve the productivity of existing facilities and consolidate excess or inefficient capacity.

The facility infrastructure of data centers and network operations centers is ordinarily overdesigned to be five times the genuine capacity. Misuse of the nameplate capacity at the start-up design stage is a result of oversizing capacity more than one-and-a-half times the ultimate actual capacity. Oversizing statistics from actual customer installations are presented. The total cost of ownership (TCO) associated with oversizing are quantified to be in excess of 30% (Rasmussen, 2012). The fundamental reasons why oversizing occurs are discussed, and architectures and methods for avoiding it are described. A power distribution system (PDS) in a data center is used as a case study to illustrate system energy loss related to oversizing. This research analyzed energy loss consumption in data centers by comparing the loss ratio of PDS between Tier II and Tier III data centers. The research results demonstrate approximately 1.782 times more energy loss in PDS for Tier III data centers than Tier II data centers. Moreover, this research analyzes the level of single PSUs and dual PSUs, subject to percent load, efficiency, and power factor (PF).

Background

Data Center Tier Classification

The Uptime Institute Tier Standard: Topology is a concept model which uses a taxonomic classification system to compare the functionality, capacity, and expected availability of site infrastructures.

This topology describes criteria which distinguish four classifications of site infrastructure topology based on increasing levels of redundant capacity components and distribution paths. This standard emphasizes definitions of the four tiers and performance confirmation tests to determine compliance with the definitions. The tier classifications define the site-level infrastructure topology required to sustain data center operations. This topology establishes four distinctive definitions

of data center site infrastructure tier classifications (Uptime, 2018), as illustrated in Figure 1: Tier 1-basic site infrastructure; Tier 2-redundant site infrastructure capacity components; Tier 3-concurrently maintainable site infrastructure; and Tier 4-fault tolerant site infrastructure (Wiboonrat, 2020).

Energy Loss

When energy is transformed from one form to another, or from one state to another, there is energy loss. Heat is one kind of energy loss which results from energy being converted to a different form. Heat energy is potentially affected by air drag or friction. Heat energy is the most easily dissipated form of energy. Usually, machines fail to limit this loss and lose some of their input energy in the form of heat which is radiated into surrounding space and therefore not part of the output energy stream, as demonstrated in Figure 2.

Losses for the data center case are shown in Figure 3. This data center can be defined as 47% efficient, based on the fraction of input power that actually goes to the IT load. On the other hand, energy losses of data center are about 53%. The most energy loss is cooling system 41% (chiller 23%, CRAC/CRAH 15%, and humidifier 3%) and 10% is power distribution system (PDU 3%, UPS 6%, and

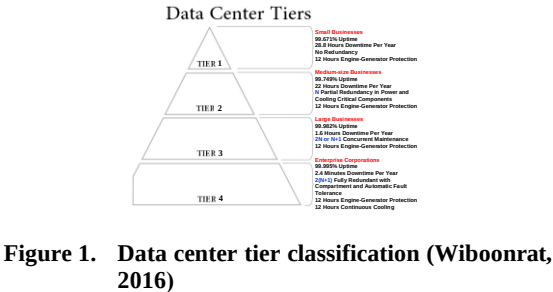


Figure 1. Data center tier classification (Wiboonrat, 2016)

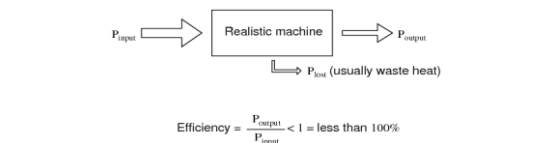


Figure 2. Waste heat as a form of energy loss

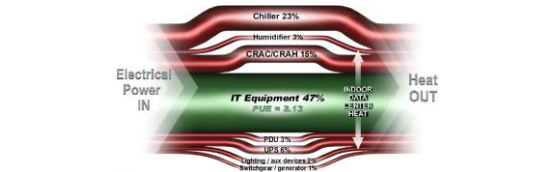


Figure 3. Useful power of the data center (Rasmussen, 2011)

switchgear/generator %). Although efficiencies can be improved, they can only be slightly increased because of the principles of thermodynamics. By the time the energy associated with electric power reaches the ICT load, it has experienced many forms of energy loss.

Figure 4 depicts a conventional PDS of a data center from the utility through a power supply unit (PSU). Moreover, it represents power loss for each piece of equipment in data center systems as follows: 2% loss in the transformer and bus bar system; 6-12% loss in the uninterruptible power supply (UPS) system; 3% loss in the power distribution unit (PDU); and 10% loss in the power supply unit (PSU). The total power loss consumption of PDS of a Tier I data center topology is around 21-27%.

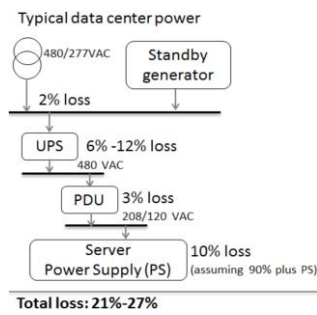


Figure 4. Typical data center power loss (Zhabelova *et al.*, 2015)

Energy Efficiency Measurement

The idea of power usage effectiveness (PUE) is to provide metrics and processes that help determine if the existing data center can be optimized before a new data center is needed. The total facility power is measured at the utility's meter to reflect the power drawn at data center entry, and IT equipment power is measured after all power conversion before reaching the IT equipment. The PUE ratio is a proportion between total facility power and IT equipment power (The Green Grid, 2007), as shown in Figure 5. The PUE can range from 1.0 to infinity. An ideal energy efficiency of PUE is 1.0, which means all power consumption is used by IT equipment. Moreover, PUE is dynamic value through the whole year of data center operations therefore PUE encourages data center operators to report the observed values of PUE.

However, the PUE equation does not show any facility efficiency or IT efficiency; therefore a new energy efficiency measurement has been proposed, called "corporate average datacenter efficiency" (CADE). This concept has been developed and supported by McKinsey & Company and The Uptime Institute (Kaplan *et al.*, 2008). CADE

measures data center efficiency including the entire facility efficiency and utilization and IT asset efficiency & utilization, as illustrated in Figure 6. CADE measures data center efficiency in five levels. Level 1 has a CADE rating of 0-5% and it is the weakest from an efficiency point of view, while a data center operating at Level 5 is maximally efficient and has a CADE rating of greater than 40%.

Root Cause Analysis

Data centers are large-scale PDS which might be viewed as a system of systems, due to the complex mesh of interconnected components and systems that have to operate seamlessly: the PDS resources are composed of the transformer, generator, automatic transfer switch, UPS and batteries, PDU, and PSU.

Transformer

The efficiency of a transformer can be defined as the output power divided by the input power. That is, efficiency = output/input. Transformers are the most highly efficient electrical devices. Most transformers have full load efficiency between 95-98.5%. Because a transformer is highly efficient, the output and input have nearly the same values; hence, it is impractical to measure the efficiency of the transformer by using output/input. A better method

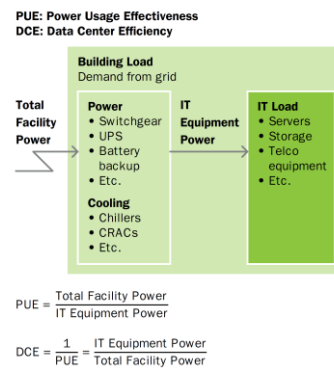


Figure 5. PUE equation (The Green Grid, 2007)

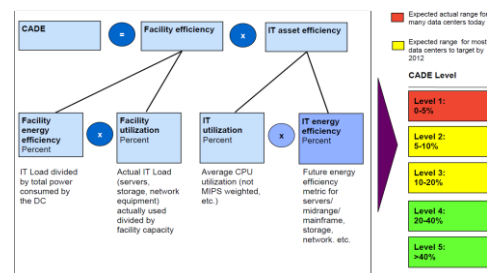


Figure 6. CADE equation (Kaplan *et al.*, 2008)

to find the efficiency of a transformer is to use $\text{efficiency} = (\text{input} - \text{losses}) / \text{input} = 1 - (\text{losses} / \text{input})$. The new technology of 2 MVA transformers is proof that the total loss is not more than 1.0% of full load (2,000 kVA) at PF = 1 (SGB, 2018).

Generator

Generator manufacturers offer ratings that exceed the requirements set forth by (ISO 8528-1, 2018) rating definitions. The data center continuous (DCC) rating is defined as the maximum power which the generator is capable of delivering continuously to a constant or varying electrical load for unlimited hours in a data center application, as shown in Figure 7.

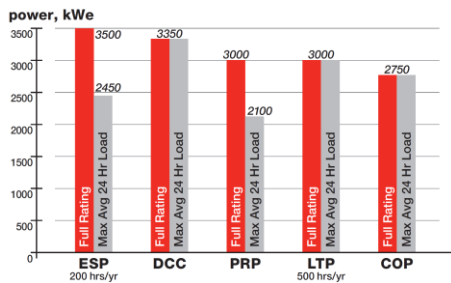


Figure 7. Generator set rating

Basically, the DCC rating is a prime-rated power (PRP) rating but without the 24-h 70% average load restriction. DCC ratings greatly simplify the engineering design process and make it easier for customers to achieve site certification from the Uptime Institute (Kaderbhai, 2017).

UPS

New energy-efficient UPSs generally range from 92-96% efficiency. However, a UPS does not always operate as efficiently as its rating suggests. Instead, its efficiency follows a curve based on the level of power capacity usage. If the UPS is operating at 100% capacity, it will run as efficiently as its rating implies. However, if the UPS is operating at a lower capacity, as most do, the equation changes. This is because a UPS loses energy in two ways: proportionally and fixed. Proportional losses occur in the form of heat dissipation and are directly tied to the size of the load. Fixed losses, however, remain constant regardless of how much current is running through the UPS. When a UPS is running a partial load, fixed losses have a more significant impact on its efficiency (Delta, 2018).

The formula for the efficiency of a power system (Panda *et al.*, 2020) is as follows:

$$(\text{Output Power} \div \text{Input Power}) \times 100 = \text{Efficiency (\%)} \quad (1)$$

The wasted or lost power within a power system, due to its inefficiencies, is calculated as follows:

$$(\text{Output Power} \div \text{Efficiency}) - \text{Output Power} = \text{Wasted Power (Watts)} \quad (2)$$

A. Using (2), the wasted power or losses can be calculated within a 1,000 kW UPS power supply that is 96% efficient, as per Table 1:

$$(1,000 \text{ kW} \div 0.96) - 1,000 \text{ kW} = 41.67 \text{ kW (wasted power)}$$

Table 1. UPS power dissipation

Static Power Dissipation in UPS System	Value	Unit
Input Parameter		
UPS Input Voltage	400	Vac
UPS Output Voltage	400	Vac
UPS Output Power	1,000	kW
UPS Efficiency	96.00	%
UPS Output Power Factor	1.00	
Input Cable Voltage Drop (Max. 5% as per IEC60364-5-52)	1.00	%
Output Cable Voltage Drop (Max. 5% as per IEC60364-5-52)	1.00	%
Other Miscellaneous Loss	0.50	%
Result Parameter		
UPS Input Current	1,504	Amp
UPS Output Current	1,443	Amp
UPS Power Loss	40	kW
Input Cable Loss	10.4	kW
Output Cable Loss	10	kW
Other Miscellaneous	5	kW
Total Static Power Dissipation	65.42	kW
Sensible Cooling Capacity Requirement	65.42	kW
	223,206	btu/hr

B. Next, as demonstrated in Figure 8, using the same 96% efficiency level, the real input and output (kW) from UPS 1,000 kW are determined:

$$(1,000.322 \text{ kW} - 959.750 \text{ kW}) \times (1.04) = 42.195 \text{ kW (wasted power)}$$

UPS Input		UPS Output	
Select current type	AC - Three phase	Select current type	AC - Three phase
Enter current in amps	1504	Enter current in amps	1443
Select voltage type	Line to line voltage	Select voltage type	Line to line voltage
Enter voltage in volts	400	Enter voltage in volts	400
Enter power factor	0.96	Enter power factor	0.96
Power result in watts	1000321.6952	Power result in watts	959750.13708
Power result in kilowatts	1000.3216951999999	Power result in kilowatts	959.7501370800001
Power result in milliwatts	1000321695.1999999	Power result in milliwatts	959750137.08

Figure 8. UPS input/output at 96% efficiency

The above calculations (A&B) demonstrate that 96% efficient power differs by 42.195 kW - 41.67 kW = 0.525 kW. This is not significantly different from the theory and real power loss. The total static power dissipation or waste is 65.420 kW, as shown in Table 1, at 96% UPS efficiency. The internal and connecting loss of 1,000 kW UPS is 65.420 kW - 42.195 kW = 23.225 kW. Imagine that this extra 23.225 kW is a large power resistor within the power supply, radiating heat and negatively affecting thermal management, component deration, and the resultant MTBF and actual field life for the UPS.

Power Supply Units (PSU)

Power supply units (PSU) transform AC power into DC for use in server circuitry; the power transformation loses some energy-this is called "heat". The efficiency of the power supply depends on its load. The most efficient loads are within the range of 50-75% utilization (Minas and Ellison, 2009). Power supply efficiency drops dramatically below a 50% load, and it does not improve significantly with loads higher than 75%. Power supply losses and the impact of rising efficiencies are reported in the CSCI certification standard "80 PLUS Titanium." as illustrated in Figure 9. PSUs rely on technology with the highest energy efficiency standard, which enables an efficiency degree of up to 96% at a level of 50% loading (Fujitsu, 2016).

80 PLUS Levels	10 % Load		20 % Load		50 % Load		100 % Load	
	Efficiency	PF	Efficiency	PF	Efficiency	PF	Efficiency	PF
Silver	75	0.65	85	0.8	89	0.9	85	0.95
Gold	80	0.65	88	0.8	92	0.9	88	0.95
Platinum	82	0.65	90	0.8	94	0.9	91	0.95
Titanium	90	0.65	94	0.95	96	0.9	91	0.95

(230 V Internal Redundant, PF = Power Factor)

Figure 9. Certification standard 80 PLUS Titanium

When comparing two power supply efficiency specifications for example, one with an 80% efficiency and another with 94% efficiency there is a tendency to think that there's only a 14% difference. However, reviewing the wasted power (as heat) between the two supplies reveals a more

dramatic difference. As a reminder, the formula for the efficiency of a power supply is

$$\text{Efficiency (\%)} = \left(\frac{\text{Output Power}}{\text{Input Power}} \right) \times 100 \quad (1)$$

and the wasted or lost power within a power supply, due to its inefficiencies, is calculated as follows:

$$\text{Wasted Power (Watts)} = \left(\frac{\text{Output Power}}{\text{Efficiency}} \right) - \text{Output Power} \quad (2)$$

1. The wasted power or losses within an 800 W power supply that is 80% efficient are determined:
 $(450 \text{ W} \div 0.80) - 450 \text{ W} = 112.50 \text{ W}$ (wasted power)

2. Next, this is compared with the same 800W power supply at 94% efficiency:
 $(450 \text{ W} \div 0.94) - 450 \text{ W} = 28.72 \text{ W}$ (wasted power)

The above calculations (1&2) demonstrate that, at 80% efficiency, power dissipates or is wasted by an additional 83.78 W internally compared with a 94% efficient unit ($112.50 \text{ W} - 28.72 \text{ W} = 83.78 \text{ W}$). Imagine that these extra 98.684 watts are a large power resistor within the power supply, radiating heat and negatively affecting thermal management, component deration, and the resultant MTBF and actual field life for the power supply.

Energy Loss Consumption Model

Based on an assumption of 5kW per rack and 400 racks per data center, the researcher investigated data center PDS to analyze energy loss in data centers by comparing the topology of PDS between Tier 2 and Tier 3 data centers, following the Uptime tier classification topology. Table 2 shows energy loss in the form of heat absorbance from three mains areas: IT equipment such as servers, storage, and network equipment; PDS themselves; and chillers, cooling towers, and CRACs. In this paper, the model concentrates only on PDS and PSUs in all IT equipment (400 racks * 11 servers =

Table 2. Energy loss in form of the heat absorbance

	Classification in Accordance with the Tier Concepts			
	Tier I	Tier II	Tier III	Tier IV
Redundancy	N	N+1	N+1	2(N+1)
Channels of Supply	1	1	1 Active, 1 Standby	2
Maintenance During Operations	No	No	Yes	Yes
Single Point of Failure	Many Failures	Many Failures	Many Failures	Not Any Failure + Fire
Fault Tolerance	None	None	Some	Yes
Diverse Fire Compartments	Not Required	Not Required	Some	Required
Heat Absorbance	220-320 W/sqm.	430-540 W/sqm.	1.070-1.620 kW/sqm.	>1.620 kW/sqm.

4,400 PSUs). This research tried to reveal why the heat absorbance of Tier 3 data centers (1.070-1.620 kW/m²) has a higher twist time than Tier 2 data centers (0.430-0.540 kW/m²).

When considering the topology of PDS, a Tier 1 data center has a single path of power distribution as shown in Figure 10(a). A Tier 2 data center has only a single path of power distribution with some redundancy critical equipment (generators and USPs) while a Tier 3 data center has two paths with some redundancy critical equipment; that is why it called “concurrent maintenance site infrastructure,” as demonstrated in Figure 10(b). A Tier 4 has full

redundancy all critical equipment and 2 paths of PDS, as demonstrated in Figure 10(c). More equipment means more energy conversion or loss in systems.

The energy loss model was constructed to analyze each piece of system-level equipment in a Tier 2 data center by applying a single line diagram from BICSI (BICSI 002, 2019). The research analyzed from many technical specs and vendors technologies subject to the power loss ratio of each equipment. Figure 11 shows PDS from the utility through server or storage PSUs: transformer loss 1-1.5%, MDB and ATS loss 0.1%, UPS loss 4-7%, PDU loss 2%, RPP loss 2%, and PSU loss 10-20%. The total loss of PDS of a Tier II data center is around 19.1-32.6%.

The research found that the most energy loss is in PSUs; therefore, in order to understand PSU energy loss, it is necessary to examine the types of server and redundant PSUs. In Tier 2, all servers are designed for a single PSU or no redundancy level (1+0) while, in Tier 3, servers are mostly designed for dual PSUs (2+0) subject to systems reliability, as shown in Table 3. The consequence of systems

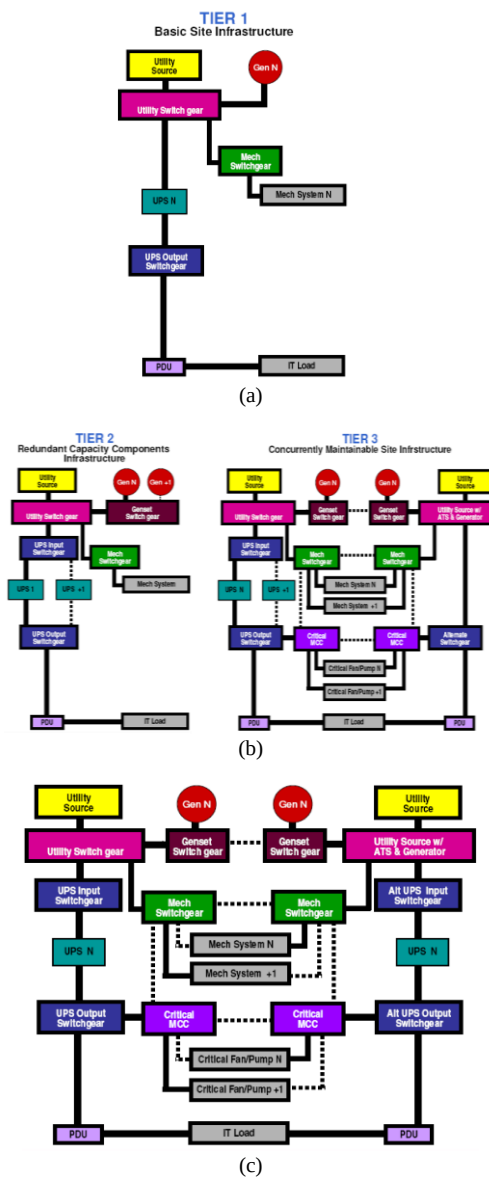


Figure 10. (a) PDS of Tier 1 data center, (b) PDS of Tier 2 and Tier 3 data Centers, and (c) PDS of Tier 4 data center

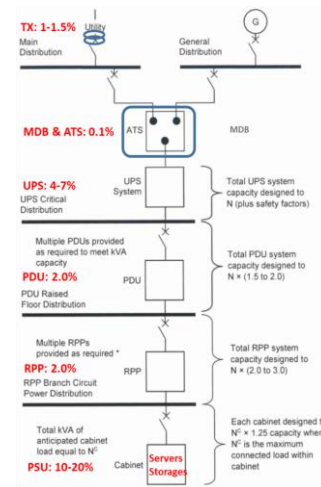


Figure 11. Energy loss consumption in data center PDU

Table 3. Redundancy modes of servers with 2 PSUs

Config	PSU 1 (W)	PSU 2 (W)	Up to Power Consumption (W)	Redundancy Level
1	450	-	450	1+0
2	450	450	450	1+1
3	450	450	802	2+0
4	800	-	800	1+0
5	800	800	800	1+1
6	800	800	1,428	2+0
7	1,200	-	1,200	1+0
8	1,200	1,200	1,200	1+1
9	1,200	1,200	2,148	2+0

reliability is a greater power loss ratio of dual PSUs. Whenever an idle server is on without load, PSUs still need to consume energy of around 30-40% of the maximum power drawn.

An estimate of energy consumption (E) at any specific processor utilization ($n\%$) can be calculated if power consumption at maximum performance (E_{max}) and at idle (E_{idel}) are known. The following formula is not accurate to a granular level, and certainly not at the single-server level. Mostly, the average processor utilization is around ($n = 30\%$).

$$E = (E_{max} - E_{idel}) * \frac{n}{100} + E_{idel} \quad (3)$$

For example, if a single PSU server has a maximum power draw of 450 W and an idle power draw of 200 W, then at 30% utilization the power draw would approximate to 275W:

$$E = (450 - 200) * \frac{30}{100} + 200 \quad (4)$$

If a dual PSU server has a maximum power draw of 802 W and an idle power draw of 356 W, then at 30% utilization the power draw would approximate to 489.8 W:

$$E = (802 - 356) * \frac{30}{100} + 356 \quad (5)$$

Energy Loss from 4,400 Servers

What is the cost of the energy loss from the Tier 2 and Tier 3 data centers illustrated in Table 4? The researcher applied certification standard 80 PLUS as a baseline for a pair to compare between Tier 2 and Tier 3 and PSU Silver & Titanium at a power loss of 50% load efficiency and 0.9 power factor (PF). The energy loss was calculated in kilowatts per hour by the average electricity cost of \$0.13 kWh. The energy loss in dual PSUs of a Tier 3 data center is almost twice that of Tier 2 in all Silver and Titanium PSUs. Investment in PSU 80 PLUS Titanium in Tier 3 reduces losses by around 2.7 times, while in Tier 2 reduces loss as the same. The energy loss per year for a Tier 2 upgrade from Silver to Titanium saves \$175,375.20, while Tier 3 saves \$312,518.61. This energy loss is a long-term operating expense which lasts as long as the data center's lifetime.

How to Improve PUE and CADE

According to Pareto's Principle, IT utilization should be addressed at the initial design stage and is key to reducing energy loss and improving the energy efficiency of equipment. PUE is a measure of power efficiency in data center IT equipment. An improvement in PUE from 1.7 to 1.3 is related

more to IT strategy, as depicted in Figure 12. Virtualization enables multiple operating systems to run on the hardware of a single physical server (utilization IT load), while containerization enables the deployment of multiple applications using the same operating system on a single virtual machine or server (reducing energy loss and increasing CPU utilization).

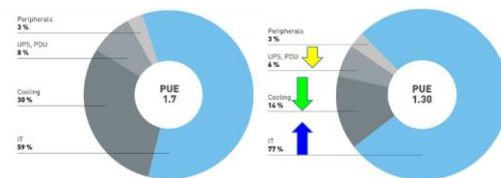


Figure 12. How to improve PUE

Table 4. Comparing PSU loss in Tier II and Tier III data centers

Data Center	Tier 2	Tier 3		
No. of Racks	400	400		
No. Servers	11	11		
450W/ Rack				
Type of PSU	Single PSU (W)	PSU-1	PSU-2	Total Dual (W)*
Power Consumption	450	450	450	802
Total	4,950			8,822
Power/Rack				
Total DC Power	1,980,000			3,528,800
Power Loss at 50 Percent Load Efficiency (PF = 0.9) kVA =				500
Silver (89)	55	55	55	98.01
Gold (92)	40	40	40	71.28
Platinum (94)	30	30	30	53.46
Titanium (96)	20	20	20	35.64
Total Loss of Silv**	242,000			431,244
Total Loss of Gold**	176,000			313,632
Total Loss of Plat**	132,000			235,224
Total Loss of Tita**	88,000			156,816
Financial loss of Silv per year (\$)	275,589.60			491,100.67
Financial loss of Tita per year (\$)	100,214.40			178,582.06

* Data from [17] ** Data Center Loss in watt/hour
The average electricity rate is \$ 0.13 kWh.

CADE makes it possible to calculate and measure data center energy-consumption-based performance and compare it with the performance of other data centers. To improve the value of CADE, some measures should be taken to improve both the IT asset efficiency and facility efficiency. The result from 4,400 energy losses shows upgrade

PSU of 4,400 reduces the power losses by around 2.7 times. If all data center operators monitor IT equipment all the time, they will understand the power loaded profile of their data center. This will be a guideline for how to adjust with IT equipment for the next time such as replace the existing PSU or recommend to the new PSU specification of IT equipment. New operations strategies need to be deployed, such as the removal of idle servers, demand management to improve IT asset efficiency, and server virtualization and consolidation. In addition, load reduction, better cabling, and efficient cooling management (hot or cool containment) can improve facility efficiency.

Discussions

From PUE equation, in Figure 5, it is not any involved with facility energy efficiency, facility utilization, IT energy efficiency, and IT utilization while on CADE has mentions about all above. CADE equation, in Figure 6, has given more details on mathematic equation on facility energy efficiency with facility utilization and IT energy efficiency with IT utilization. In this research, researcher recommend on finding out the idle servers that are not perform IT utilization or called energy losses while upgrade to premium 80 Plus UPS helps IT energy efficiency such as servers and networking equipment.

By energy loss model, Tier 3 has more energy losses than Tier 2. However, Tier 3 is designed for not only system reliability and availability but also for energy security (2N or N+1 of power distribution system and critical equipment). Now a day, most of data centers are starting designed or built with minimum Tire 3. Especially, data centers for financial and banking, credit card, social network company, Cloud service provider, and online shop requires high reliability for their services. They cannot afford downtime in their businesses.

Conclusions

The management of energy loss can save long-term operating costs in data centers. This research was conducted to analyze case studies of whole energy loss in data center power distribution systems (PDS). Based on the energy consumption of 4,400 servers, the energy loss model compares a topology of PDS between Tier 2 and Tier 3 data centers. The research model found that the highest energy loss is in the power supply unit (PSU) of IT equipment around 10-20% and the uninterruptible power supply (UPS) around 4-7%. Therefore, upgrade

standard PSU to PSU 80 PLUS Titanium is the best solution for energy efficiency while specific UPS with high power factor and high efficiency rate (ideal = 1) is the best option for long-term data center operations. A Tier 3 data center has around 1.782 times more energy loss than a Tier 2 data center. However, Tier 3 has designed for reliability and maintenance and has high reliability and availability than Tier 2. Reducing total energy loss in PSUs is key to saving more energy. The CSCI certification standard 80 PLUS Titanium advises considering a 50% server load utilization at Titanium PSU to gain 96% efficiency and a 0.9 power factor (PF). The energy loss per year for a Tier 2 upgrade from Silver to Titanium saves \$175,375.20, while Tier 3 saves \$312,518.61.

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