



Data Center Benchmarking

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Agenda

Bench-marking comparison of IT Power Loss

Static UPS Systems & Battery Storage

Yahoo! Space Park, Santa Clara, CA

Yahoo! Wenatchee, WA

Line Interactive UPS & Fly-wheel Storage

NetApp, Sunnyvale, CA

Yahoo! Quincy, WA

High Voltage AC Distribution Topology

Yahoo! Quincy, WA



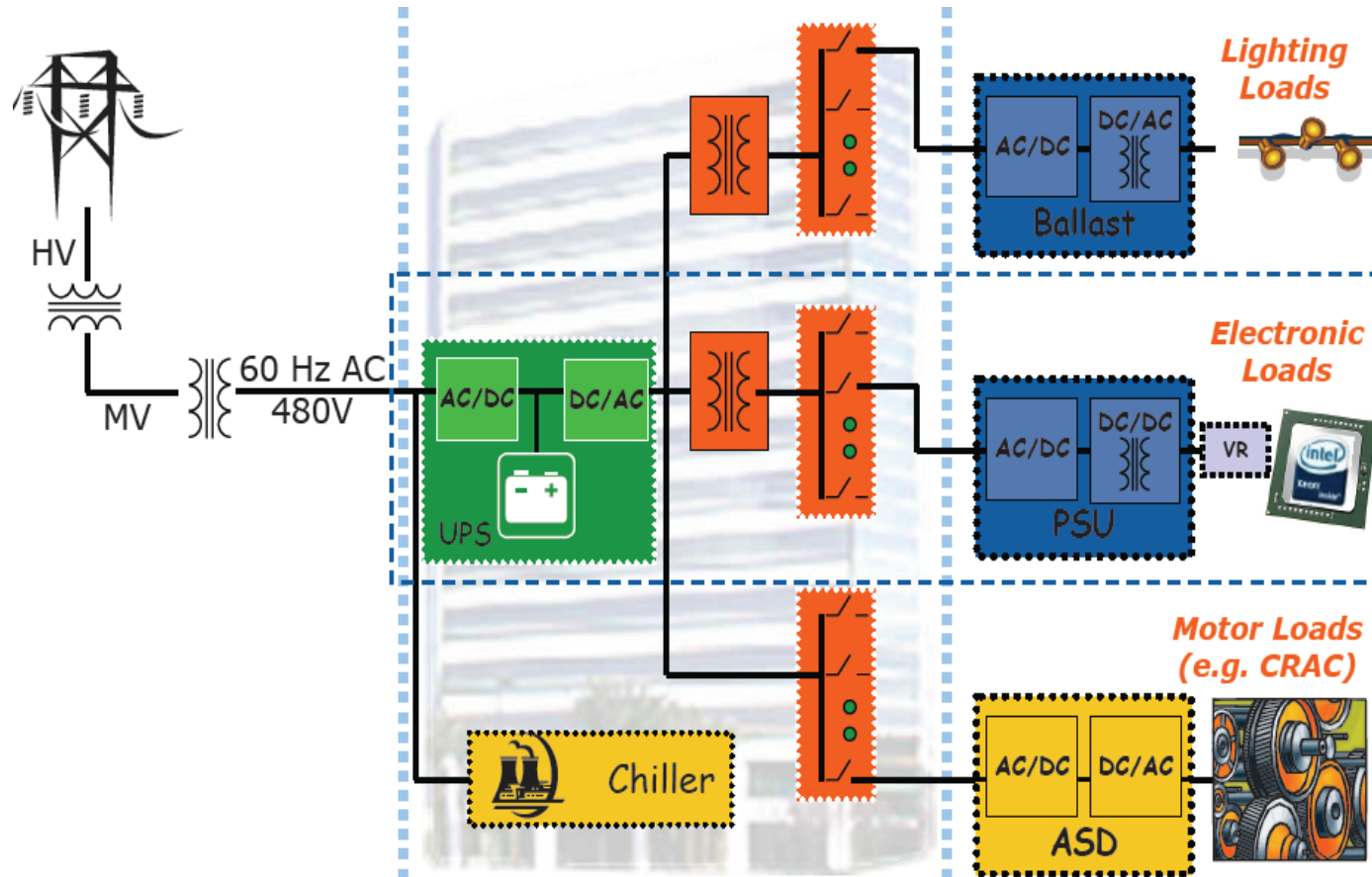
IT Power Loss Benchmarking

- Electrical power to data center used to keep IT equipment properly powered, cooled, and protected so that it can provide its useful computing
- Non-IT devices that consume data center power include transformers, uninterruptible power supplies (UPS), power wiring, the cooling system including fans, chillers and pumps and lighting
- UPS, transformers and power distribution units are in series with the IT loads as they provide the power that feeds them while the cooling system and lighting and fans are in parallel



IT Power Loss Benchmarking

- Typical IT power distribution for a data center

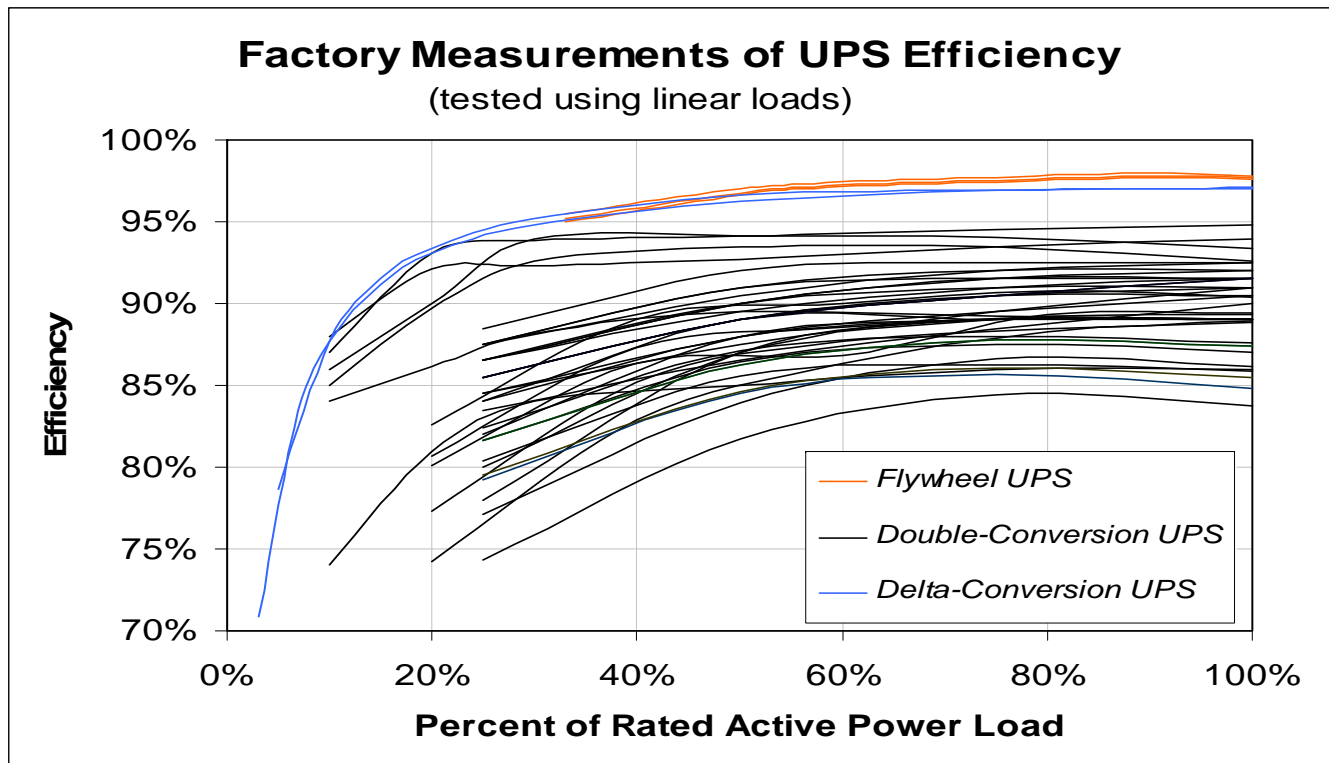


IT Power Loss Benchmarking

- If the UPS system were 100% efficient – all of the power supplied to it would reach the IT loads
- In the real world a significant amount of power is lost at each power transformation; at the building transformer, the UPS and the PDUs
- Manufacturers typically provide efficiency data for power equipment expressed as a % of power output to full-power input
- Result of using published efficiency ratings at full load is that electrical losses of real data centers are significantly higher than most users or designers anticipated
- For this reason the efficiency of static UPS systems at partial load must be considered since the efficiency curve of static UPS systems at light loads falls near zero

IT Power Loss Benchmarking

- Measurements done by LBNL illustrate that UPS efficiency for various types and sizes of UPS systems varies significantly by both the technology and the active power load



IT Power Loss Benchmarking

- The reason for difference is because actual UPS efficiency varies as a function of the IT load running on the UPS
- In most data centers which are designed with fully redundant (2N) UPS; each UPS system is typically carrying 40% of the IT load and in a (2N+1) scenario, each UPS is loaded to a maximum of 33% of full-load
- SVLG benchmarked the electrical losses of the most commonly used UPS technology, which is Double-Conversion with Flywheel UPS which based upon the prior LBNL research is the best-in-class technology recommended in the EPA report
- Compared actual UPS electrical losses in four large-scale production data centers with comparable load factors



IT Power Loss Benchmarking

- Yahoo!'s Space Park in Santa Clara is a 43,000 square foot data center with approximately 4.6 MW of IT load supported by twelve (12) Liebert 750 KVA/650 kW Multi-Module static UPS systems
- The actual UPS electrical losses are illustrated below:

UPS	kW Output	UPS Load	UPS Efficiency	kW UPS Loss	UPS Loss as % Total Power
UPS 1-1	455.0	70.0%	91.3%	43.1	0.6%
UPS 1-2	445.0	68.5%	91.8%	39.6	0.6%
UPS 2-1	362.0	55.7%	91.7%	32.8	0.5%
UPS 2-2	366.0	56.3%	93.1%	27.1	0.4%
UPS 3-1	437.0	67.2%	87.0%	65.3	1.0%
UPS 3-2	431.0	66.3%	91.7%	39.0	0.6%
UPS 4-1	381.0	58.6%	90.5%	40.0	0.6%
UPS 4-2	373.0	57.4%	88.5%	48.5	0.7%
UPS 5-1	320.0	49.2%	92.5%	26.1	0.4%
UPS 5-2	323.0	49.7%	91.8%	28.9	0.4%
UPS 6-1	339.0	52.2%	92.0%	29.5	0.4%
UPS 6-2	340.0	52.3%	92.7%	26.7	0.4%
Total	4572.0	58.6%	91.1%	446.6	6.5%



IT Power Loss Benchmarking

- Yahoo!'s Space Park data center
- The resulting annual kWh loss and cost and the estimated kWh cost savings had the data center been designed with a flywheel UPS system are illustrated below:

Static UPS Annual kWh Loss	Cost/kWh	Annual Loss Cost
3,912,526	0.10	\$408,468

Flywheel UPS Annual kWh Loss w/97% Efficiency	Cost/kWh	Annual Loss Cost
1,253,124	0.10	\$130,826

Estimated Annual kWh Savings	Cost/kWh	Annual Savings
2,659,402	0.10	\$277,642



IT Power Loss Benchmarking

- Yahoo!'s Wenatchee data center is a 22,000 square foot data center with with approximately 2.4 MW of IT load supported by eight (8) Liebert 750 KVA/675 kW Multi-Module static UPS systems
- The actual UPS electrical losses are illustrated below:

UPS	kW Output	UPS Load	UPS Efficiency	kW UPS Loss	UPS Loss as % Total Power
UPS 1-1	293.0	43.4%	77.1%	87.2	2.5%
UPS 1-2	298.0	44.1%	78.5%	81.5	2.3%
UPS 2-1	314.0	46.5%	76.8%	94.9	2.7%
UPS 2-2	320.0	47.4%	76.7%	97.2	2.8%
UPS 3-1	291.0	43.1%	76.3%	90.5	2.6%
UPS 3-2	288.0	42.7%	76.0%	91.0	2.6%
UPS 4-1	295.0	43.7%	77.5%	85.8	2.5%
UPS 4-2	296.0	43.9%	78.4%	81.7	2.3%
Total	2395.0	44.4%	77.1%	709.8	20.4%



IT Power Loss Benchmarking

- Yahoo!'s Wenatchee data center
- The resulting annual kWh loss and cost and the estimated kWh cost savings had the data center been designed with a flywheel UPS system are illustrated below:

Static UPS Annual kWh Loss	Cost/kWh	Annual Loss Cost
6,217,693	0.03	\$186,531

Flywheel UPS Annual kWh Loss w/97% Efficiency	Cost/kWh	Annual Loss Cost
829,196	0.03	\$24,876

Estimated Annual kWh Savings	Cost/kWh	Annual Savings
5,388,497	0.03	\$161,655



IT Power Loss Benchmarking

- Computer rooms 1 and 2 in Yahoo!'s Quincy data center total 40,000 square feet with approximately 3.4 MW of IT load supported by five (5) HITECH 1625 KVA diesel engine generator based UPS systems with flywheel energy storage
- The actual UPS electrical losses are illustrated below:

HITECH	kVA Input	kVA Output	KVA Loss	kW Output	UPS Load	UPS Efficiency	kW UPS Loss	UPS Loss as % Total Power
Hitech-1	867.0	794.0	73.0	790.8	48.9%	91.6%	72.7	1.3%
Hitech-2	834.0	757.0	77.0	753.2	46.6%	90.8%	76.6	1.3%
Hitech-3	814.0	790.0	24.0	784.5	48.6%	97.1%	23.8	0.4%
Hitech-4	786.0	741.0	45.0	734.3	45.6%	94.3%	44.6	0.8%
Hitech-R	588.0	460.0	128.0	455.9	28.3%	78.2%	126.8	2.2%
Total	3889.0	3542.0	347.0	3518.7	43.6%	91.1%	217.8	6.0%



IT Power Loss Benchmarking

- Yahoo!'s Quincy data center
- The resulting annual kWh loss and cost are illustrated below:

Annual kWh Loss	Cost/kWh	Annual Loss Cost
1,907,490	0.03	\$57,225



IT Power Loss Benchmarking

- The NetApp Building 11 data center is a 11,000 square feet data center with approximately 570 kW of IT load supported by two (2) Active Power 900 KVA diesel engine-generator based UPS systems with flywheel energy storage
- The actual UPS electrical losses and cost are illustrated below:

UPS	kW Output	UPS Load	UPS Efficiency	kW UPS Loss	UPS Loss as % Total Power
UPS A1	330.7	45.9%	96.3%	12.8	2.0%
UPS B1	344.3	44.2%	92.3%	26.7	4.2%
Total	674.9	45.5%	96.1%	39.5	6.3%

Annual kWh Loss	Cost/kWh	Annual Loss Cost
345,871	0.12	\$41,505



IT Power Loss Benchmarking

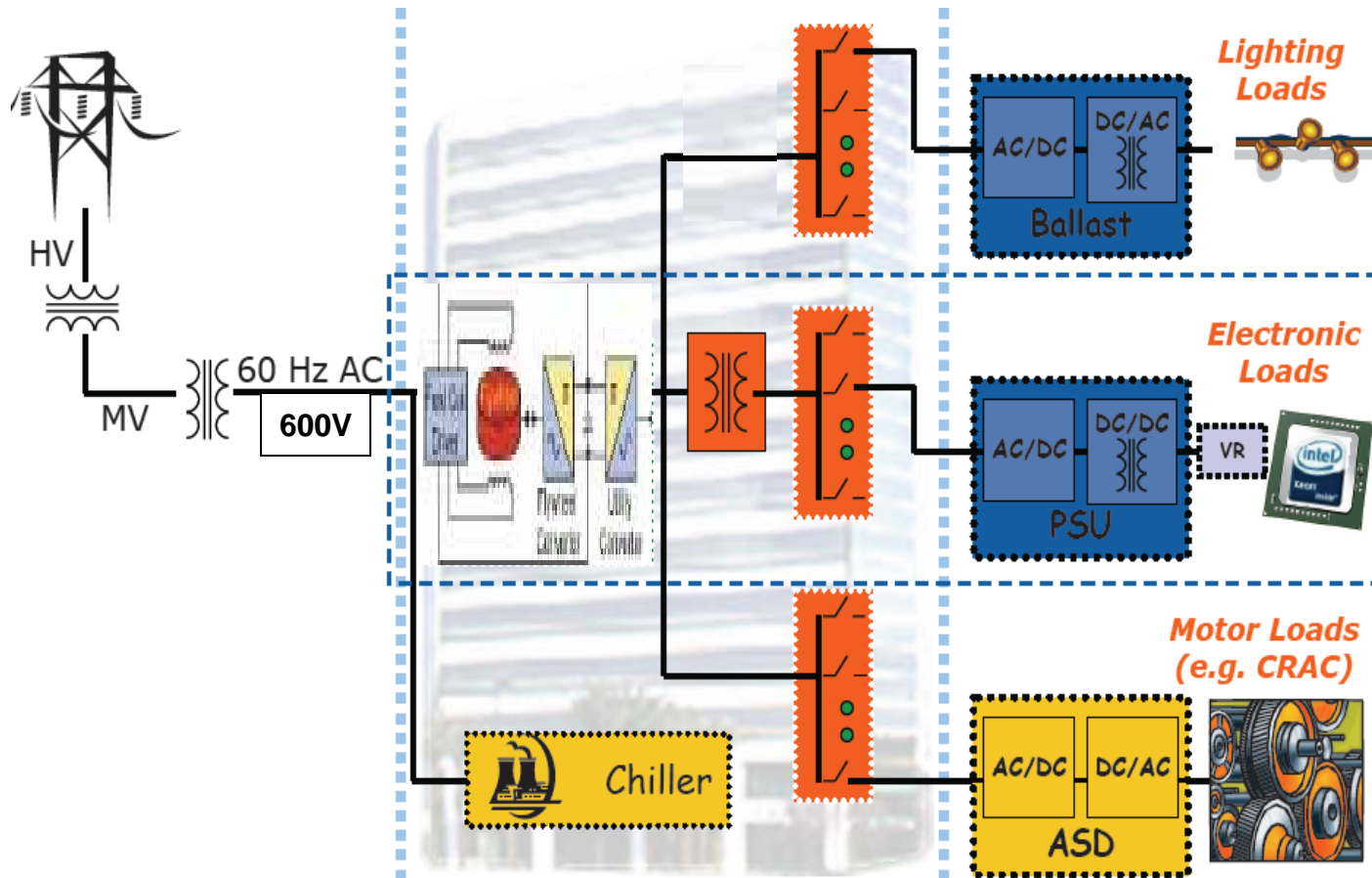
- Yahoo!'s Quincy data center
- The resulting annual kWh loss and cost are illustrated below:

Annual kWh Loss	Cost/kWh	Annual Loss Cost
1,907,490	0.03	\$57,225



IT Power Loss Benchmarking

- High voltage AC power distribution for a data center



High Voltage AC Power Distribution

- 13.2 kVA- 480 VAC Power Distribution – 208 VAC PDUs

Space Park Data Center Power			
	KVA	KW	%
480 Distribution- PDU Loss	230.2	224.5	3.3%

- 13.2 kVA- 600 VAC Power Distribution – 208 VAC RPPs

Quincy Data Center Power			
	KVA	KW	%
208V Distribution Loss	83.0	82.5	1.4%

Power Loss Savings - 1.9%



IT Power Loss Findings

- Although published full-load efficiency values for both static UPS topologies including transformer-less, double conversion UPS with lead-acid battery storage and diesel engine-generator based UPS with flywheel energy storage were similar; the actual efficiency losses varied dramatically based upon the percentage of active load on the systems
- The average Yahoo! Space Park data center static UPS electrical loss was only 6.5% because the equipment is currently being operated in the sweet spot of the static UPS efficiency curve which is greater than 60% active power load
- However, in the Yahoo! Wenatchee data center where the current IT load is only 45% of the UPS design power of the static UPS the electrical loss is 18%
- :



IT Power Loss Benchmarking

- Yahoo!'s Quincy data center is a recently opened data center with a N+1 design using flywheel technology that is currently running at 46% load for the primary UPS and 28% for the redundant UPS
- While the UPS electrical loss of 1.3% or better is higher than expected at this active load level, the requirement to keep the N+1 design and necessity to keep a low load on the redundant UPS is contributing to the data center UPS loss of 6% of total power
- Once, the IT load increases, the overall loss UPS loss as percentage of total data center power will decrease significantly
- The NetApp flywheel electrical loss of 2-4% is as expected when running at less than 50% active power load, which is below the inflection point on the flywheel UPS efficiency curve
 - > 60% active power load



IT Power Loss Benchmarking

- Electrical power costs associated with electrical losses from stand-by power systems are a large percentage of the total cost of ownership
- Since all the power that is used beyond the power needs of IT equipment is undesirable, selection of UPS systems that provide high efficiency at the active IT load at which the systems are designed to operate and using scalable solutions that can grow with IT load offer a major opportunity to reduce electrical waste and costs
- Based upon the real data centers benchmarked in this case study the potential kWh electricity savings for large scale production data centers are 25,000,000 to greater than 50,000,000 kWh over a typical 10-year life of the facility
- Due to the large amount of power and cost consumed by stand-by power systems inefficiency, reduction of UPS electrical losses should be a concern for all data center owners, as well as a significant issue of public policy