

Data Center Design Discussion

Dennis Julian, PE, ATD, DCEP

**Integrated
Design Group**
ARCHITECTURE | ENGINEERING | PLANNING₁

AFCOM Boston Symposium 2015

Learn the Do's of Data Center Design

- System selection should include review of capital and operational costs
- Discuss incentives with utilities
- Design to allow testing of equipment without affecting operating facility

2

TCO is important.

Capital cost and Operating cost

Spending a lot of additional money to improve efficiency in an area with low utility costs may not be cost effective.

Utility incentives – received \$1 million for (2) 1MW data center fit ups

Some utilities provide rebates for:

1. Energy star UPS systems
2. Efficient lighting
3. Efficient HVAC
4. Retrofits of existing systems

AFCOM Boston Symposium 2015

Learn the Don'ts of Data Center Design

- Do not equate PUE with sizing of electrical systems
- Custom vs commercial equipment can result in an 9 point improvement in RTU system PUE.
- Not all HVAC systems work everywhere

3

Electrical systems must be sized for peak PUE not annual PUE.

Improved custom equipment vs standard commercial grade can improve PUE by 9 percentage points. Change RTU with air economizer from 1.36 to 1.25 annual PUE

Design and control for dew point not relative humidity

AFCOM Boston Symposium 2015

No One Cooling System Is Best In All Locations

PUE	TRADITIONAL - 78F Return air, 35%-55% RH, 45F CHW								
	ACC with CRAH	ACC with CRAH - Airside Economizer	CRAH Econ with Adiabatic Humidifier	RTU - Airside Economizer	RTU with Adiabatic	DSE	WCC with CRAH	WCC with CRAH - Waterside Economizer	WCC with CRAH - Airside Economizer
Dallas									
Boston									
Virginia									
New Jersey									
Chicago									
San Francisco									
Santa Clara									
Phoenix									
Los Angeles									

PUE	ASHRAE A1 Hybrid - Recommended Temp, Allowable Humidity								
	ACC with CRAH	ACC with CRAH - Airside Economizer	CRAH Econ with Adiabatic Humidifier	RTU - Airside Economizer	RTU with Adiabatic	DSE	WCC with CRAH	WCC with CRAH - Waterside Economizer	WCC with CRAH - Airside Economizer
Dallas									
Boston									
Virginia									
New Jersey									
Chicago									
San Francisco									
Santa Clara									
Phoenix									
Los Angeles									

4

TRADITIONAL –
78F Return air,
35%-55% RH
45F Chilled water temperature

HYBRID –
ASHRAE recommended Class A1 input temperature of 80.6F supply air
ASHRAE allowable Class A1 humidity of 20%-80% RH.
Assumes 105F Return (25F delta T) air
60F Chilled water with temperature reset.

AFCOM Boston Symposium 2015

Operations Affects PUE and Efficiency

1. Operating all redundant equipment can maximize efficiencies.
 1. Pumps and fans save substantial energy at part loads.
2. Through SOO operate cooling systems at warm temperatures (60F+/-) with automatic setback when cooling is not adequate or humidity levels are too high.

5

Sequence of Operations (SOO) and interior conditions have the greatest effect on PUE.

Fan Laws:

1. Horsepower (HP) varies with the cube of the speed (RPM)
2. Air volume in cubic feet per minute (CFM) varies directly with RPM.

Pump Affinity Laws:

1. Brake Horsepower (BHP) varies with the cube of the speed (RPM)
2. Flow varies directly with RPM.

Example (for illustration):

A 10HP fan is required to provide the air volume required.

If two 10HP fans are operating then each does the work of ??HP?? Possibly 5HP?

ACTUALLY

Each fan provides only 1/2 of the air volume therefore by the cube law above:

$$HP1/HP2 = (RPM1/RPM2)^3$$

For a typical 1800 RPM motor: $10/HP2 = (1800/900)^3 = 8$

$HP2 = 10/8 = 1.25HP$ of power required vs 10HP.

AFCOM Boston Symposium 2015

PUE does not define cooling or power sizes

PUE is typically defined as an annual average

1. Beware of partial or lowest PUE declarations
 - PUE does not define maximum cooling capacity required.
 - PUE does not define maximum electrical needs
 - Service size
 - Generator capacity
 - Must be based on maximum electrical load on a design day

6

PUE does not equal electric service size or generator capacity. Power Usage Effectiveness (PUE) is a measure of the ratio of total data center power divided by the total IT power. PUE that is measured instantaneously is not valid to determine the total electrical power required unless it is measured at the precise peak power usage of the facility. A correctly calculated PUE uses annual averages to account for seasonal variations. It is possible for the PUE to vary from a monthly high of 1.9 to a monthly low of 1.3 (RTU system in the Northeast) with an annual average of 1.4. If the electrical service was designed based on the 1.4 PUE the service and the engine-generator system would be undersized.

Example: Assuming a 1000kW IT load:

At an average PUE of 1.4 the electrical service and generator system would be sized for 1400kW.

At the peak PUE of 1.9 the electrical service and generator system would be sized for 1900kW.

The system would be short 500kW at peak load, undersized by approximately 35%.

AFCOM Boston Symposium 2015

Hot Computer Room Temperatures

Concerns of hot ambient temperatures (104F / 40C)

1. Affect on smoke detectors (typ rated 100F)
2. Affect on sprinkler heads (Std vs Intermediate)
3. Affect on lighting systems (reduces life)
4. Affect on refrigerant based cooling systems (RTU may not operate above 95F return air)
5. Affect on cabling systems (data and power)
6. OSHA time limits for working in hot areas

7

ASHRAE recommended cold aisle temperatures of 80F and a 25F temperature rise (delta T) across the equipment will result in a hot aisle temperature of 105F.

Typical smoke and heat detectors and sprinkler heads are rated for use in 100F ambient maximum. Higher ambient temperatures may result in false activation.

Higher ambient rated detectors will provide more headroom when there is a cooling failure in the Computer room.

Typical sprinkler head rating is 135F (std) for use in a maximum 100F ambient. A minimum of 175F rated head for ambients over 100F.

Lighting ballasts and lamps affected by elevated temperatures above room temperature. Light output and ballast and LED life is reduced.

Refrigerant based systems may fail on a high head alarm for return air temperatures above 95F.

ANSI/TIA 568C.2 standard – Attenuation/insertion loss based on 20C(68F).
At 40C (104F) derate performance almost 10%

National Electrical Code bases conductor ampacity on 86F ambient temperature.
Ampacity must be reduced above this temperature.

AFCOM Boston Symposium 2015

Affect of Codes on Data Centers

1. Energy codes now specifically address data centers
2. Electrical code requirements
 1. Modular data center covered by NEC Article 646
 2. Arc flash reduction requirements for 1200A and larger CBs
 3. Ability to remove or restrict access to EPO
 4. Removal of smoke detection shutdown of air systems

8

ASHRAE 90.1-2010 and 2013 specifically address data centers.

Massachusetts has adopted the 2014 version of the National Electrical Code.

AFCOM Boston Symposium 2015

Understand EPA Generator Emissions Tiers

Generator rating – Emergency or Standby?

1. EPA Emergency rated generator
 1. Maximum of 100 hrs per year when utility is available
 2. Unlimited operation when utility is unavailable
2. EPA Non-Emergency rated generator
 1. Operating hours when utility is available limited by local jurisdiction only.
 2. Requires minimum operating loads and DEF to operate
 3. Generator shuts down if emissions out of limits.

9

- A. DEF/SCR typically required over 800kW
- B. Emissions performance affected by:
 - Properly working equipment
 - Ambient temperature
 - Viable Diesel Exhaust Fluid (DEF, i.e. Urea)
 - Must be kept cool but not freezing to extend life
 - Exhaust temperature
 - Could require load on generator up to 30% or more of nameplate
 - Could be internal load bank in generator exhaust
- C. Engine will be shut down and will require factory technician to reset if emissions fall out of tolerance.
- D. Designs must account for EPA Tier 4 restrictions on system operation:
 1. Install in warmer air environment (recirculate radiator exhaust to keep room and engine warm).
 2. Provide proper environment for DEF – cool and heat. Be aware of short shelf life of DEF.
 3. Provide quantity of DEF to match fuel capacity.
 4. Need DEF delivery arrangements to match fuel deliveries.
- E. EPA Tier 4 Certified vs Compliant
 1. Certified engines must be factory certified and can not be altered in the field
 2. Compliant engines have after market emissions controls added to meet or exceed Tier 4 requirements.
 3. Some areas have stricter requirements than Tier 4 but can not be modified in the field without invalidating the certification.
 4. May be necessary to negotiate with local EPA and Federal EPA.

UPS System Topologies

1. Transformer or transformerless design
2. Distributed or Central Static Switch
3. UPS Systems
 1. 2N
 2. N+1
 3. Distributed redundant
 4. Block redundant
 5. Iso Redundant
 6. Modified Iso Redundant

AFCOM Boston Symposium 2015

Distribution to Cabinets

1. 2N to the Cabinet
 1. One active one not active
 2. 2N UPS sources from different UPS systems
 3. 2N UPS sources from the same UPS system
 4. One UPS source, one conditioned utility source
2. Plug in Busway
3. Individual circuits to the cabinet

11

Plug in busway may not be the most cost effective in an environment where standard circuit sizes are installed for cabinets.

Short circuit rating of busways can be a concern, especially at 400V.

Busway Connection points for full load commissioning.

Busway joint maintenance. Are they maintenance free or require annual infrared scanning and tightening?

AFCOM Boston Symposium 2015

What Does It Takes to Plan the Ideal Data Center?

- Input from all stakeholders
- Design should match end user business plan
 - Risk tolerance
 - Level of efficiency
 - Billing Cost Allocations
- Consider Operational Issues and Concerns

12

A. Stakeholders:

1. Real Estate
2. IT
3. Corporate
4. Sales / marketing
5. Operators
6. End Users

B. Risk Tolerance

1. Only mission critical site
2. Large number of users – concern for reputation or productivity
3. One of many - systems are software redundant

C. Efficiency

1. Best in class efficiency
2. Corporate mandate or goal
3. Best total cost of ownership (TCO)

D. Operational

1. Is facility manned 7x24?
2. How will it be maintained? Internal or outsourced?
3. How will it be expanded and when?
4. How will it be tested and commissioned?
5. Expected growth?

AFCOM Boston Symposium 2015

What Information Should You Have Before Beginning a Design?

1. Types of deployment – single cabinet or large install
 1. Consider load ramp up
 2. Average kW per cabinet
2. IT architecture and availability requirements
 1. Environmental SLA being marketed or promised
 1. ASHRAE Allowable, Recommended, Extreme?
 2. Multi-Tenant facility?

13

A. Deployment

1. Single homogeneous user?
2. Many different system types and requirements?
3. What will be the minimum load on day 1?
4. Install all initially or have a scalable modular design?
5. Average and maximum kW per cabinet.
6. Will high density cabinets be concentrated or spread out?
7. One or separate rooms, cages?
8. Dedicated or shared infrastructure?

B. Availability requirements

1. Service level agreement (SLA) being marketed?
2. Single availability level or mixed?
3. No down time promised?
4. Temperature and humidity limits?
5. Redundancy level?
6. Efficiency/Power usage effectiveness (PUE) goal?

AFCOM Boston Symposium 2015

Learn the Do's of Data Center Design

1. Use experienced data center designers
2. Provide adequate time to design and fine tune the engineering. Don't rush design time – it will affect construction and operational costs.
3. Interactive design – Designer to explain options
4. Keep it simple and consistent

14

How do you find an experienced mission critical designer?

1. Internet?
2. References from others?
3. What qualifications and experience should they have?
4. Who should lead the project Architect or Engineer or Project Manager?

Identical data centers designed by different firms results in in over \$350k in difference in electrical costs, \$50k in fire alarm costs. Savings of \$500-\$1000 per kW

Review sizing of underground conductors. Discuss load factor. Calculations by engineer not Installer. Reference APC whitepaper: WP43v3-2011 Dynamic Power Variations in Data Centers and Network Rooms

Revit (BIM) does not cure all. Need experienced designers to do coordination. Developing a realistic 3D model requires more time and effort.

Design for arc flash to minimize operational costs. Calculations by engineer not vendor.

Use modular repeatable designs so look and feel for operations personnel is consistent.

AFCOM Boston Symposium 2015

Design the Appropriate Level of Availability

Discuss performance requirements not Tier level

1. Tier II (F2) - N+1 equipment
2. Tier III (F3) - Concurrent Maintainability
 1. Only one path is required to be active
3. Tier IV (F4) - Fault Tolerant (N after an event)
 1. Two active paths
4. ANSI/BICSI 002 level F5 - N+1 after an event

15

Tier IV fault tolerant does not mean 2N.

Tier III concurrent maintainability does not mean both power paths must be UPS.

Single corded loads in a concurrently maintainable design does not mean both power sources need static transfer switches.

AFCOM Boston Symposium 2015

Optimally Size Electrical Systems

- A 2500kVA transformer/generator only rated 3000A.
 - Why does it have 4000A circuit switchgear and feeders?
- A 3000A underground feeder
 - Why does it vary from 9 sets of 600kCMIL to 12 sets of 750kCMIL?
- A 300kVA PDU is rated for 361A at 480V.
 - Why is it fed from a 600A CB, static switch and feeders?
- A 400A MCB RPP
 - Why is it fed with a 500A CB and feeder?
- Use 100% rated equipment

16

25% - 33% oversized electrical systems.

Modern data centers operate at high power factor (pf). There is no need to size electrical systems for the typical 0.8 power factor generators are rated for since the limiting design load will be kW.

At 480V:

2000kW = 2410A at 0.8pf 2500kVA = 3012A

2000kW = 2410A at 0.95pf 2105kVA = 2537A

2500kW = 3012A at 0.8pf = 3125kVA = 3765A

2500kW = 3012A at 0.95pf = 2632kVA = 3170A

4000A = 3320kVA at 0.95pf = 3154kW

Busway concerns:

1. Annual joint infrared scanning and tightening
2. Hygroscopic - Tendency to absorb moisture if not energized and warm enough to keep dry. This moisture can lead to failure due to insulation failure.
3. Factory built with specific dimensions. Little field flexibility during installation.

Cablebus an engineered system that uses free air ratings to reduce conductors required.

AFCOM Boston Symposium 2015

Optimally Size the Building

- Power/Communications cabling above the cabinets
 - Why is a four foot raised floor necessary?
- What is the difference between a 30" raised floor and a 36" raised floor?
 - Ans: A 5 foot landing in the middle of the access ramp.
- Ceiling Benefits
 - Reduces sound levels, improves reflectivity for better lighting, lowers lighting and smoke detectors for easier maintainability, provides a return air plenum for improved cooling efficiency and a structural grid provides accessible support for cable tray, etc.

17

- A. High ceiling and raised floor heights increase building size and construction costs of not just the exterior walls but all the interior walls.
 - 1. When does a raised floor become an OSHA confined space? 4ft?
- B. CFD analysis can show that reduced volumes for the computer room still adequately cool the cabinets.
- C. Sound levels are increasing due to equipment and fan/air noise. May reach levels requiring special fire alarm annunciation and OSHA required hearing protection.
 - 1. *OSHA 1910.95(d)(1) - When information indicates that any employee's exposure may equal or exceed an 8-hour time-weighted average of 85 decibels, the employer shall develop and implement a monitoring program.*
- D. Ceiling plenum improves hot/cold air separation and increases energy efficiency.
- E. Excessive ceiling height increases construction costs and operational costs, and since the heat stratifies at the top, the air circulation is at the lower level and it provides little help as a heat sink during cooling failures due to rapid heating.
- F. Structural support built into the ceiling allows supporting cable tray, busway, etc without penetrating the ceiling.

AFCOM Boston Symposium 2015

Optimally Size Project – How Tall is Your Building?

- With a 30" raised floor, 7ft cabinet, two layers of cable tray above at 1ft spacing, 2ft clearance for sprinklers, 12ft ceiling, 3ft plenum above the ceiling and 2ft of structure totals 18.5ft....
 - Why are data center buildings so tall?
- A 25,000sf footprint equals a perimeter of 633 linear feet of wall.
 - How much can be saved by reducing the building height and/or recessing the floor? Save on interior and exterior walls.

18

Potentially save \$65,000 per foot of height.

A seven foot reduction in height could save \$500,000 in construction plus reduce operating expenses.

AFCOM Boston Symposium 2015

3 Key Things You Have Learned During this Session

1. Design can have a large impact on construction cost vs the design fee and design time saved.
2. Interior operating conditions have the largest impact on PUE.
3. Effects of hot computer room temperatures

AFCOM Boston Symposium 2015

Thank you

Dennis R Julian, PE,ATD,DCEP

Principal A/E Services

Email: djulian@idgroupaee.com

Twitter: DRJulianPE

LinkedIn: www.linkedin.com/in/dennisrjulianpe

Contact me and I will forward some articles on these topics.

**Integrated
Design Group**
ARCHITECTURE|ENGINEERING|PLANNING 20

AFCOM Boston Symposium 2015

Published articles I will forward if requested

1. 2014 Electrical Code Impact On Data Centers
2. 11 Data Center Myths and Design Issues
3. Load-on Demand Delivery Systems and Innovative Design Techniques
4. Design Considerations for Highly Reliable Electrical Systems
5. Impacts on Data Centers from the new ASHRAE 90.1-2010 Energy Standard