Life Is On | Schneider Electric

Diesel Rotary UPS (DRUPS) vs. Static UPS: A Quantitative Comparison for Cooling and IT Applications

White Paper 222

Revision 0

by Han Ming Kuang
Hng Yong Way
Sanjeet Sandhu

Executive summary

A number of published comparisons indicate that DRUPS is a superior solution for data center cooling and IT applications. The inaccurate assumptions and mistakes found in these comparisons are explained with support from third party sources. In this paper, we present a detailed quantitative comparison from a design architecture-level perspective between low voltage DRUPS and low voltage Static UPS. We consider capital expenses, energy losses, maintenance costs, footprint, and TCO using a common 2N architecture. The analysis shows the Static UPS is less expensive to purchase, install, operate, and maintain while having a slightly larger footprint.

Introduction

Some published comparisons indicate that low voltage DRUPS is a superior solution for data centre cooling and IT applications. When you consider the details of these comparisons, however, it becomes apparent that they are often misleading and do not provide a factual comparison. These comparisons often make the mistake of using very old static UPSs with very poor efficiency curves and long battery autonomy, and the comparisons do not address how redundant-type design architectures typically used in mission critical facilities today affect the analysis.

The following section lists common myths and explains them away.

Myth #1: "Higher system efficiency"

- It is often claimed that the efficiency level of DRUPSs is much better than the best Static UPSs available in the market. However, these comparisons are typically made against a UPS using the old SCR-based switching technology with a very poor efficiency curve of 92% (highest value on curve) at best.
- Common Static UPSs available in the market today can achieve up to 97.6% efficiency, which is on par or even better than the DRUPS. For example, the efficiency level for a Schneider Electric Symmetra MW, even at a partial load level of 25% is as high as 95% which is better than common DRUPS used today.
- In these misleading comparisons, efficiency at partial loads is not shown. Since UPSs in data centres almost always operate at far less than full load, having partial load comparisons would be more realistic and useful.

Myth #2: DRUPSs are equally scalable

- While a DRUPS can be scaled by adding additional units, they are usually oversized significantly to accommodate for future unknown load requirements. This is mainly due to its lack of flexibility and limited range of capacity options. In addition to being neither modular nor easily scalable, the upfront cost is also higher than a comparative Static UPS system.
- Static UPSs are more scalable and flexible given their wider range of available capacity ranges. A unit with an installed capacity much closer to the design IT load of each phase of a project can be selected. Adopting this "right-sizing" strategy, it enables data centre owners to "pay-as-you-grow" and the ability to much more easily adapt to market changes.

Myth #3: 40 - 60% space savings

- "A Static UPS takes up much more space than a DRUPS" is not entirely a true statement. And the percentage of additional space used by Static UPS vs. DRUPS is also overly inflated in most cases.
- This space comparison is often based on 15 minutes (or longer) of battery runtime for the Static UPS, which would result in a higher space requirement. This is an unfair comparison since a DRUPS can only provide about 8 – 12 seconds of ride-through time. Also note that the space calculations are usually based on VRLA type lead-acid batteries. Lithium-ion batteries use 50-80% less space than VRLA[1].
- Depending on the application and design topology used, there are cases where it is possible that the space required by DRUPSs is more than what is required for the Static UPSs.

[1] White Paper 231, *FAQs for Using Lithium-ion Batteries with a UPS*

Myth #4: No air conditioning is needed; therefore, it uses less energy

- Yes, Static UPSs need air conditioning to maintain the indoor environmental conditions needed to maximize battery life. However, the claim that using DRUPS can, therefore, save more energy than a Static UPS is misleading. This is because the comparison needs to be done in the context of the entire system used, and not simply on one element of the system. Considering the whole system, a DRUPS-based system uses MORE energy than a Static UPS system due to its higher power losses under (realistic) partial load operating conditions (< 50%).

Myth #5: "Thermal buffer" is highly complex and expensive

- It is common to use a thermal storage tank system to ensure continuous cooling when a static UPS is used. This "thermal buffer" is actually quite simple. Having a thermal buffer means having enough chilled water in the supply piping and/or in a storage tank to prevent the supply air temperatures from going too high during an outage before the backup power supplies come online to supply the cooling plants. In terms of cost, you should obviously consider the entire system cost and not just some of the system components as some of these suspect comparisons have done.

The analysis that follows in this paper addresses each of these common myths. It assumes the DRUPs and Static UPS system is being used to back up the entire data center with a 2N electrical infrastructure supporting both the IT and cooling loads, although the static UPS architecture also uses a thermal buffer system to ensure continuous cooling.

This paper offers a fact-based, "apples-to-apples", and more realistic analysis that quantifies the capital expense, total cost of ownership (TCO), maintenance costs, and footprint to ensure better informed decision-making.

Methodology and assumptions

A common 2N redundant architecture was used for this analysis (see **sidebar**). The IT load density is assumed to be 6 kW/rack (average) for 500 IT racks. This yields a total IT load of 3 MW.

In today's data centres, a challenge that some face is an increase in rack power density and higher density applications. In addition to this rise in density, ASHRAE has expanded its recommendations for thermal limits in recent years encouraging some to raise inlet air temperatures to increase economization hours. With increasing densities and/or higher temperatures in the white space, an effective thermal ride through strategy that keeps air temperatures from going too high in the event of an outage becomes more critical. This strategy ensures the data centre and critical plants are able to "ride through" the plant restart times and chiller loading time after a power failure as the generators come on line, and vice versa, when the generator is off line and grid power then returns.

The two most common strategies for maintaining cooling air during an outage adopted by data centre designers and used in this analysis are:

- Thermal storage system (buffer tank of chilled water and static UPSs for fans/ pumps/ controls)
- Entire cooling system on DRUPSs

Design assumptions summary

- 3MW IT load, 500 racks at 6kW/rack average
- Calculated cooling load - 945RT
- Water cooled chilled water system at N+1
- 8 - 15°C CHW temperature
- Canopy/ containerized type of generator
- Static UPS:
  - 2 paralleled 1600 kVA Symmetra MW UPSs at 2N for IT loads
  - 400 kW Symmetra PX UPSs at 2N for cooling loads
- DRUPs:
  - Canopy/ containerized type of low voltage DRUPS
  - 2 paralleled 2000 kVA DRUPs at 2N for IT loads
  - 1670 kVA DRUPs at 2n for cooling load
- Comparison and TCO calculation focus only on the electrical plant equipment supporting the whole data centre
- Original calculations were done in Singapore dollars and were converted to USD using a conversion rate of 1 Singapore $ to 0.7135 USD.

For the thermal storage system, the buffer tank is sized to offer 8 minutes of ride-through time before the chilled water supply temperature will begin to rise above its set point. The Static UPSs provide backup to the chilled water pumps, chiller control system, CRACs and fan coil units. This ensures this equipment continues to deliver chilled water and cold air to the data centre as well as the M&E plant during the time before backup power systems (e.g., generators) have started and begin to provide power.

The battery runtime for the Static UPSs is 5 minutes which is typical for most data centers. Note that depending on the UPS model selected, it is possible to spec a shorter runtime to reduce capital expense and save space. This 5 minute runtime specification is more than sufficient to bridge the total duration required for the generator to start, ramp up to speed, and also to account for the timing delay for the ATS switching.

In the DRUPS architecture, the entire cooling system and all IT equipment are supported by DRUPS. Remember that the Static UPS only needs to support some of the M&E plant to support the thermal ride-through process: chilled water pumps, chiller controls, CRACs, and fan coil units (FCUs). It typically takes between 8 and 12 seconds to go from a loss of utility power to completing the startup of the diesel generator within a DRUPS system.

See **sidebar** for all the design parameters and assumptions used in this analysis. Each subsection below details the comparison results on capital expense, UPS system efficiency, maintenance costs, footprint, and the 10 year TCO.

The schematic diagrams for the 2N architectures are shown below. **Figure 1** illustrates the architecture where the entire facility's IT and cooling loads are supported by DRUPS.

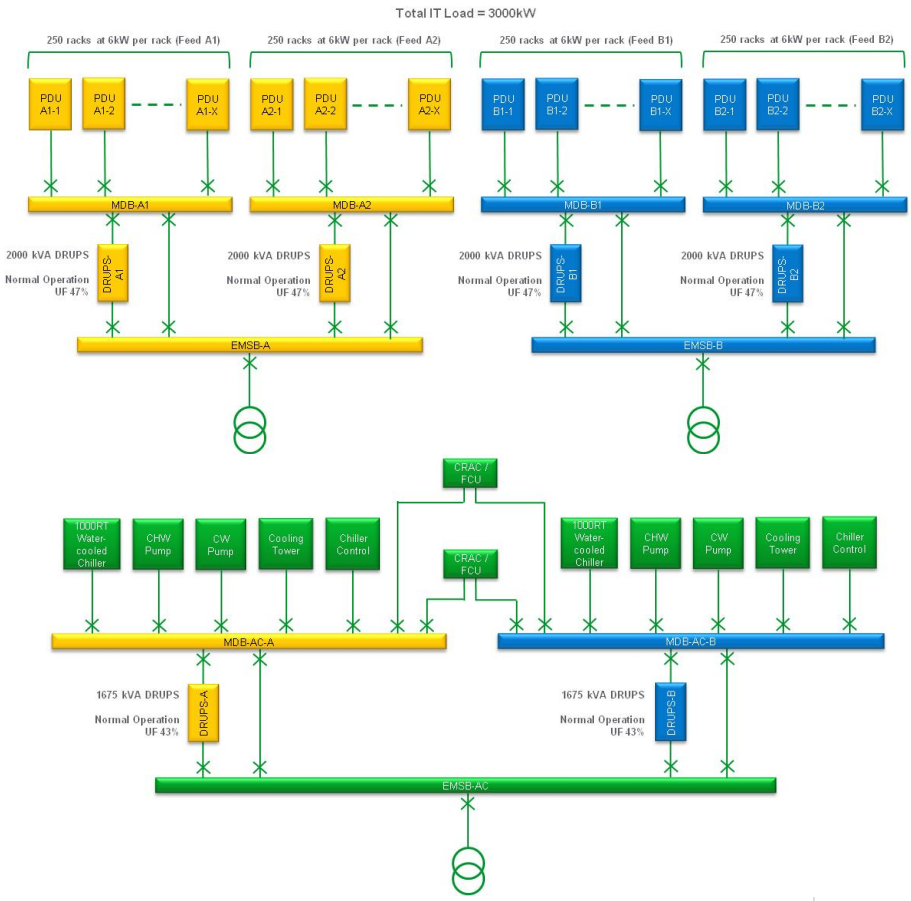


Figure 1
2N architecture using DRUPS for IT and cooling application (i.e., the full data centre)

Life Is On Schneider Electric

Figure 2 shows the architecture where a Static UPS system is supporting the IT and cooling equipment (i.e., chilled water pumps, chiller controls, CRAC and FCU). Buffer tanks are also present for storing chilled water to ensure there is sufficient cooling before the alternative power source takes over in the event of an outage.

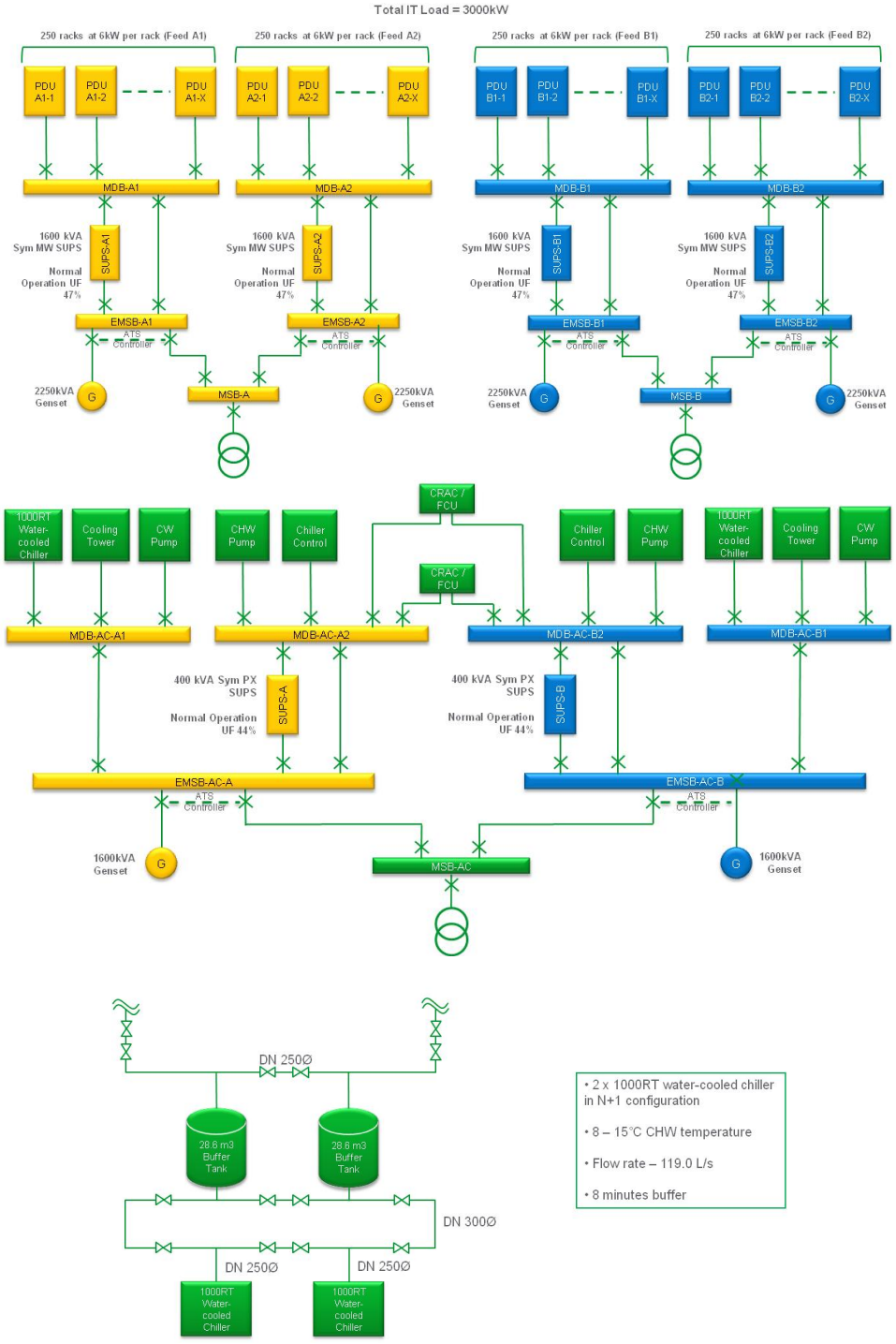


Figure 2
2N architecture using static UPS for IT and cooling application (i.e., full data centre) with buffer tanks for thermal ride through

The quantitative analysis

UPS system energy loss analysis

Given the total IT load of 3 MW, the UPS utilization factor is 47% for both DRUPSs and Static UPSs under normal operating conditions. For cooling loads, the UPS utilization factor is 43% for the DRUPS and 44% for the Static UPS under normal operating conditions as shown in Table 1.

Figure 3 illustrates the UPS efficiency curves based on one of the top DRUPS in the market against Schneider Electric's Symmetra MW Static UPS for the IT load and Symmetra PX Static UPS for the cooling load.

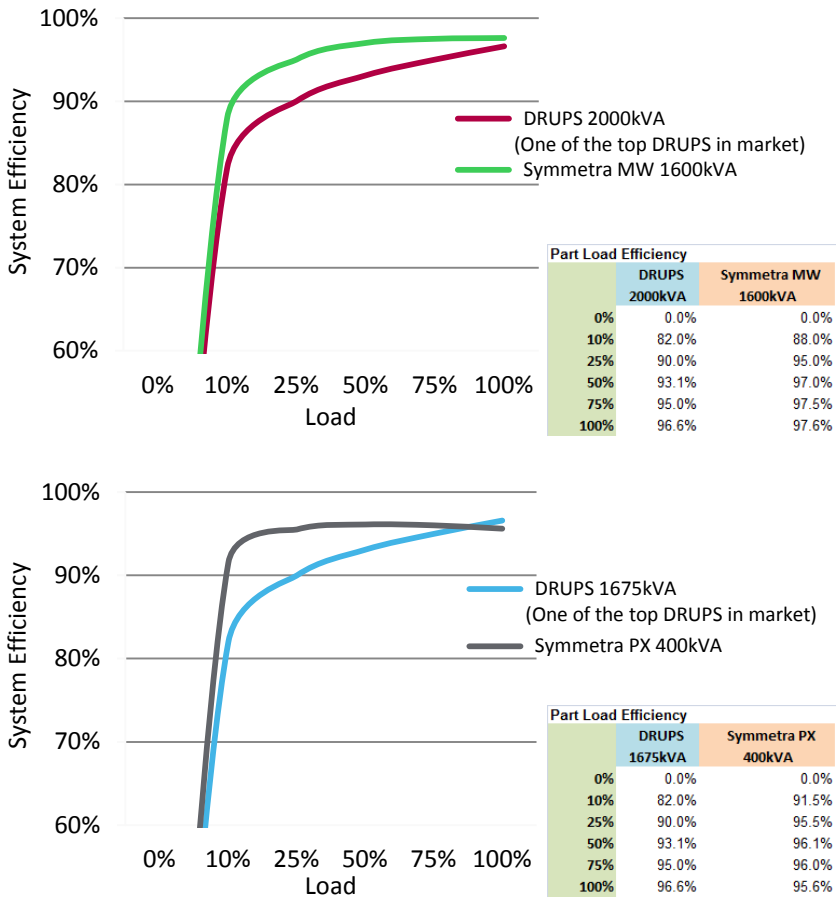


Figure 3
UPS efficiency as a function of % load

As you can see from the above figure, the efficiency of Static UPSs has improved significantly over the years especially at low load conditions. The gap between Static UPSs and DRUPSs widens substantially when the load drops below 50%, which is very common in data centres today and is, indeed, required for a 2N system.

In assuming a 2N redundant architecture and a realistic UPS utilization factor under normal operation, an efficiency comparison (total system energy losses) between DRUPSs and Static UPSs yields the following results:

The Static UPS has 68% less energy losses than the DRUPS. This has a major impact on TCO which will be shown later in this paper. **Table 1** shows the details.

UPS type	UPS load	UPS capacity	UPS loading	Part load UPS eff.	Total UPS system loss
DRUPS – IT	3000 kW	4 x 2000 kVA (1600 kW each)	47%	93%	226 kW
DRUPS – Cooling	1160 kW	2 x 1670 kVA (1340 kW each)	43%	91%	115 kW
Overall UPS system energy loss for DRUPS					341 kW
Static UPS – IT	3000 kW	4 x 1600 kVA (1600 kW each) Symmetra MW	47%	97%	93 kW
Static UPS – Cooling	353 kW	2 x 400 kVA (400 kW each) Symmetra PX	44%	96%	15 kW
Overall UPS system energy loss for STATIC UPS					108 kW

Table 1
2N topology UPS system energy loss analysis results

Footprint analysis

There is a common market perception that Static UPSs always take up much more space than a DRUPS system due to the battery storage space requirement.

However, our more detailed analysis which was based on commonly used design architecture and more realistic assumptions regarding the application showed that **the difference in footprint between the two systems is not nearly as significant as commonly thought.**

Let's take a look at the below comparison. Apart from the actual equipment dimensions, the electrical plant layout below also takes into consideration the space or access necessary for maintenance.

DRUPS System – approximately 1,128 m² (12,142 ft²)

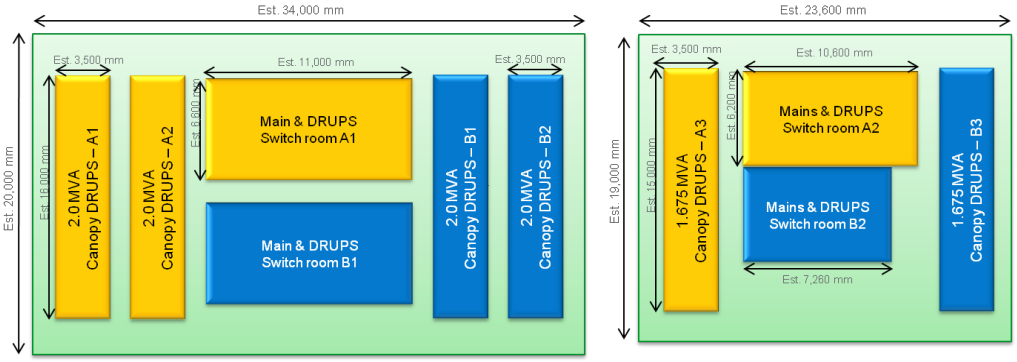


Figure 4
DRUPS – 2N topology overall plant layout (IT and Cooling loads)

Static UPS System – approximately 1,176 m² (12,658 ft²)

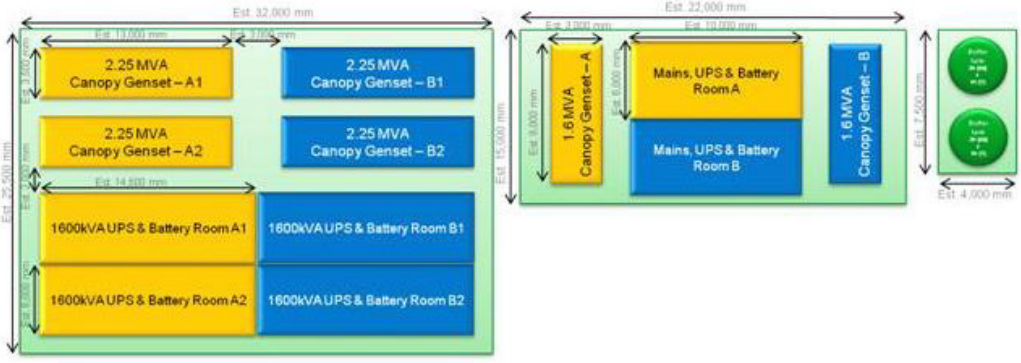


Figure 5
Static UPS with 5 min of runtime and thermal storage tanks– 2N topology overall plant layout (IT and partial Cooling loads)

Life Is On Schneider Electric

In this real world example, the Static UPS system requires only 4.3% more space than the DRUPS system. Note that this calculation even includes the area required for the thermal storage tanks.

TCO analysis

The total cost of ownership (TCO) analysis was based on a 10 year cycle, which offers a sound basis for determining the value -- cost vs. ROI -- of an investment; more than just the capital cost alone. TCO provides a more complete picture of the overall ownership cost.

This TCO analysis includes capital expenditures, comprehensive maintenance, and electricity costs over 10 years.

For Static UPS, the capital cost includes the following equipment:

- 2250 kVA prime rated canopy/ containerized generator
- 1600 kVA prime rated canopy/ containerised generator
- Main switchboards /w automatic transfer switch
- Main distribution boards
- 1600 kW Symmetra MW static UPS /w 5 min of battery runtime
- 400kW Symmetra PX static UPS c/w 6 min battery
- N+1 CRAC for UPS and battery room
- Thermal buffer tanks 2 x 28.6 m^3
- Power Distribution Unit (PDU) with isolation transformer (2% isolation transformer loss taken into ac-count)

For DRUPS, the capital cost includes the following equipment:

- 2000 kVA canopy/ containerized diesel rotary UPS
- 1675 kVA canopy/ containerized diesel rotary UPS
- Main switchboards
- Main distribution boards
- Power Distribution Unit (PDU)

Notes on TCO calculations

- Maintenance and cyclical replacement cost included for main equipment - generator, Static UPS and DRUPS
- Maintenance cost includes a 5% CAGR
- For Static UPS, battery replacement is every 5 years, so there are 2 replacements calculated in the 10 year TCO analysis
- For DRUPS, 1 engine overhaul is included in the 10 year TCO
- Potential rental gains as a result of space savings is excluded
- Decommissioning and depreciation costs were not considered

To make a simple "apples-to-apples" comparison, a discount rate was not applied to create "net present values" for future OPEX-related costs. The focus of this analysis is on the relative difference between the two architectures.

Table 2
10 yr TCO in USD for DRUPS & Static UPS excluding potential rental gains

UPS type	Capital expense	Maint. & cyclical replacement	Electricity cost	TCO for 10 years
DRUPS	$8,374,978	$3,320,600	$70,306,263	$82,001,841
Static UPS	$6,047,104	$2,484,262	$67,578,380	$76,109,746

TCO Savings (Static UPS) excluding potential rental gains over 10 years – $5,892,095 (approx 7% savings).

Based on this example, the Static UPS system costs less to purchase and install, maintain, and operate.

Table 3
2N architecture overall comparison summary

Results	Full DRUPS	Static UPS with Buffer Tanks	Static UPS % Savings
Overall UPS system energy losses	341 kW	108 kW	68.3%
Required plant floor area space	1128 m^2	1176 m^2	- 4.3%
a) CapEx	$8,374,978	$6,047,104	27.8%
b) Maintenance & cyclical replacement over 10 years*	$3,320,600	$2,484,262	25.2%
c) Electricity cost over 10 years	$70,306,263	$67,578,380	3.9%
10 yr TCO (a+b+c)	**$82,001,841**	**$76,109,746**	**7.2%**

* It should be noted that for DRUPS, all cyclical replacement/ overhaul and maintenance has to be done by the authorized dealers only. Thus, it would be more of a challenge to get a competitive quote for replacement, unlike battery for Static UPS which you can opt for any vendors as long as the technical specs fit.

Table 3 shows that a full 2N Static UPS system's electrical infrastructure supporting both the IT and cooling loads of a data centre has a 10 year TCO savings of $5,892,095 (7.2%) over a full 2N DRUPS electrical infrastructure, but at a small penalty of needing 48 m^2 additional floor space.

So if the data center in our example analysis was a collocation data center, how might the potential rental gains in the DRUPs scenario affect the overall TCO? We assumed a rough rental rate estimate of $1285/rack per month. Note that this is gross revenue and not profit.

Table 4
TCO for 10 years including rental gains

UPS type	Overall 10yr TCO	10yr Rental Gains	Total TCO including Rental Gains	Static UPS % Savings
DRUPS	$82,001,841	($2,959,400)	$79,042,441	
Static UPS	$76,109,746		$76,109,746	3.7%

For a full 2N Static UPS electrical infrastructure supporting both the IT and cooling loads of a data centre, **the overall 10 year TCO savings using a Static UPS system vs. a DRUPs system (including money earned through increased rental space in the case of the DRUPs-based architecture) is $2,932,695 (3.7% savings).**

Consideration of common plants for DRUPS in 2N architecture for full facility serving both IT and cooling

In designing a common DRUPS plant, i.e. parallel multiple DRUPS, for Data Centre that requires higher electrical power, consideration has to put into understanding the limitation of low voltage system. The highest rating of low voltage equipment is 6,300A (which yields approximately 4.36 MVA at 400V) and, therefore, you cannot have more than two 2 MVA DRUPS connected in parallel on a common electrical bus.

A way to overcome this power limitation of the low voltage system is to move to a medium voltage (MV) distribution solution. This topic is the subject of another research project at Schneider Electric and its analysis will be released in another white paper in the future.

Additional comparisons

In the Appendix, several other analyses are shown in detail to compare DRUPSs and Static UPSs under different architectures and for specific applications. These additional comparisons include:

- 2N architecture supporting IT load only
- Tri-redundant architecture supporting IT load only
- 2N architecture supporting cooling load only (to achieve continuous cooling)
- Tri-redundant architecture supporting continuous cooling load only (to achieve continuous cooling)

The results can be summarized as follows:

2N architecture supporting IT load only

Table 5
IT load only – 2N architecture summary

Results	IT on DRUPS	IT on Static UPS	Static UPS % Savings
Overall UPS system energy losses	226 kW	93 kW	58.8%
Required plant floor area space	680 m^2	816 m^2	- 20.0%
a) CapEx	$6,004,816	$4,530,012	24.6%
b) Maintenance & cyclical replacement over 10 years*	$2,222,966	$1,877,818	15.5%
c) Electricity cost over 10 years	$50,351,181	$49,748,051	1.2%
10 yr TCO (a+b+c)	**$58,578,963**	**$56,155,881**	**4.1%**

NOTE: IF you take the potential additional rental gains into account that the extra space provides, the DRUPS system 10 year TCO is 10.6% better than the Static UPS system TCO.

Tri-redundant architecture supporting IT load only

Table 6
IT load only – Tri-redundant architecture summary

Results	IT on DRUPS	IT on Static UPS	Static UPS % Savings
Overall UPS system energy losses	191kW	83 kW	56.5%
Required plant floor area space	568 m2	574 m2	- 1.05%
a) CapEx	$4,477,926	$3,219,312	28.1%
b) Maintenance & cyclical replacement over 10 years*	$1,667,224	$1,408,363	15.5%
c) Electricity cost over 10 years	$49,869,095	$49,596,000	0.5%
10 yr TCO (a+b+c)	**$56,014,245**	**$54,223,675**	**3.2%**

NOTE: With rental gains taken into consideration, the overall TCO savings is reduced slightly from 3.2% to 2.6%.

2N architecture supporting cooling load only

Table 7
Cooling load only – 2N architecture summary

Results	Cooling on DRUPS	Cooling on Static UPS	Static UPS % Savings
Overall UPS system energy losses	111 kW	15 kW	86.5%
Required plant floor area space	448 m2	360 m2	19.6%
a) CapEx	$2,369,105	$1,516,330	36.0%
b) Maintenance & cyclical replacement over 10 years*	$1,097,212	$606,131	44.8%
c) Electricity cost over 10 years	$19,230,432	$17,821,814	7.3%
10 yr TCO (a+b+c)	**$22,696,749**	**$19,944,275**	**12.1%**

NOTE: If rental gains are taken into consideration, the 88 m^2 space savings will increase overall 10 year TCO savings from 12.1% to 56.3% in favor of Static UPSs.

Tri-redundant architecture for cooling load only

Table 8
Cooling load only – tri-redundant architecture summary

Results	Cooling on DRUPS	Cooling on Static UPS	Static UPS % Savings
Overall UPS system energy losses	169 kW	29 kW	82.8%
Required plant floor area space	605 m2	536 m2	11.4%
a) CapEx	$3,584,160	$2,236,501	37.6%
b) Maintenance & cyclical replacement over 10 years*	$1,645,819	$909,197	44.8%
c) Electricity cost over 10 years	$37,633,747	$35,643,627	5.3%
10 yr TCO (a+b+c)	**$42,863,726**	**$38,789,325**	**9.5%**

NOTE: If rental gains are taken into consideration, the 69 m^2 space savings will increase overall 10 year TCO savings from 9.5% to 24.7% in favor of Static UPSs.

Conclusion

Using the common 2N architecture described above as an example, this paper demonstrated how it is important to consider the entire system and facility when comparing capital expenses, energy costs, maintenance costs, footprint, and overall TCO between one data centre backup system type and another. The analysis described in this paper clearly showed that a data centre physical infrastructure architecture employing a low voltage Static UPS system outperformed the same architecture using a low voltage DRUPS on all of these comparison points except footprint.

About the authors

Han Ming Kuang is the Data Centre Consulting and Solutions Head for DC Centre of Excellence at Schneider Electric. He has over 16 years of experience in the field of consulting engineering and project management including extensive experience in the concept and detailed design for various types of building development in particular mission critical facilities.

Hng Yong Way is the Principal Engineer for DC Centre of Excellence at Schneider Electric. He has over 13 years of experience in the area of consulting engineering, project and construction management including extensive experience in the concept and detailed design in particular mission critical facilities, institutions, residential and commercial developments.

Sanjeet Sandhu is Vice President for the DC Centre of Excellence at Schneider Electric. Sanjeet heads a team that supports the strategy and delivery of the full lifecycle of Data Centre Services that include consulting, design, project execution, assessments, software, and managed services (including critical facility operations). Sanjeet is a registered Professional Engineer in Singapore.

Resources

Comparing UPS System Design Configurations
White Paper 75

Browse all white papers
whitepapers.apc.com

Power Sizing Calculator
TradeOff Tool 1

Energy Allocation Calculator
TradeOff Tool 2

Energy Efficiency Calculator
TradeOff Tool 6

Browse all TradeOff Tools™
tools.apc.com

Contact us

For feedback and comments about the content of this white paper:

Data Center Science Center
dcsc@schneider-electric.com

If you are a customer and have questions specific to your data center project:

Contact your Schneider Electric representative at
www.apc.com/support/contact/index.cfm

© 2016 Schneider Electric. All rights reserved.

Appendix

IT load only comparison – 2N architecture

Design Parameters and Assumptions

- 3MW IT load, 500 racks at 6kW/rack
- Canopy type of generator
- Canopy type of DRUPS
- Comparison and TCO calculation focus only on the electrical plant equipment supporting the IT infrastructure only - "variable"
- M&E plant supporting lighting, general purpose power, cooling load, and other main equipment, e.g. chiller, CRAC, etc. are excluded from the case

The IT application comparison looks at the commonly adopted redundancy architectures, i.e. 2N topology. The IT load density is assumed to be 6kW/rack for 500 IT racks with a final IT load of 3MW.

Each subsection below details the results of the capital expense, UPS system energy loss, maintenance costs, footprint, and total cost of ownership (TCO) for the 2N topology. Schematic diagrams of the two 2N architectures for IT application are shown above in **Figure 1** for DRUPS and **Figure 2** for Static UPS in the earlier section of this paper.

The ride-through time for DRUPS flywheel is 8 – 12 seconds and the battery runtime for the Static UPS is a typical 5 minutes, though it can be further reduced depending on the selected UPS model.

See **sidebar** for all the design parameters and assumptions used in this analysis.

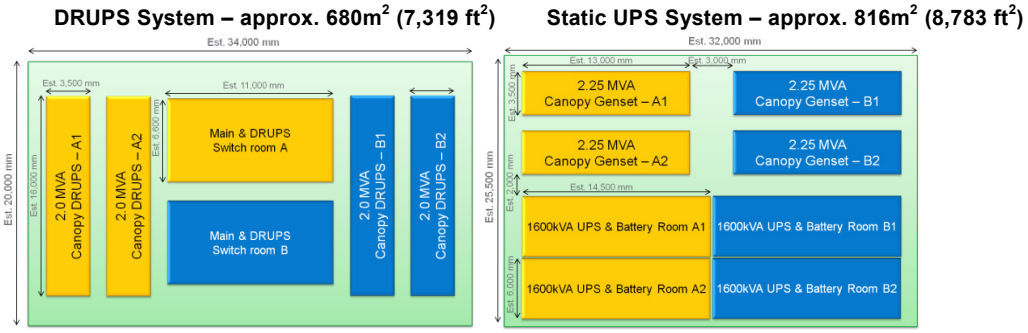
UPS system energy loss analysis

The UPS utilization factor is 47% for both DRUPS and Static UPS under normal operating conditions based on the total IT load of 3000kW with 2N topology. An energy loss comparison based on 2N topology shows the difference of energy loss between a DRUPS and a Static UPS.

Table A1
IT application – 2N architecture UPS system energy loss analysis results

UPS type	UPS load	UPS capacity	UPS loading	Part load UPS eff.	Total UPS system loss
DRUPS	3000 kW	4 x 2000 kVA (1600 kW each)	47%	93%	226 kW
Static UPS	3000 kW	4 x 1600 kVA (1600 kW each) Symmetra MW	47%	97%	93 kW

Figure A1
IT application – 2N architecture overall plant layout



UPS System TCO analysis

Notes on TCO Calculations

- Maintenance and cyclical replacement cost considered for main equipment - generator, Static UPS and DRUPS
- Maintenance cost includes 5% CAGR
- For Static UPS, battery replacement every 5 years. Total 2 replacements are included in the 10 years TCO
- For DRUPS, 1 overhaul is included in the 10 years TCO

For Static UPS, the capital cost includes the following equipment:

- 2250 kVA prime rated canopy generator
- Main switchboards /w automatic transfer switch
- Main distribution boards
- 1600kW Symmetra MW static UPS /w 5 min of battery runtime
- N+1 CRAC for UPS and battery room
- PDU with isolation transformer (2% isolation transformer loss taken into account)

For DRUPS, the capital cost includes the following equipment:

- 2000 kVA canopy diesel rotary UPS
- Main switchboards
- Main distribution boards
- PDU

Table A2
IT application – 2N topology TCO results

UPS type	Capital expense	Main. & cyclical replacement	Electricity cost	TCO for 10 years
DRUPS	$6,004,816	$2,222,966	$50,351,181	$58,578,963
Static UPS	$4,530,012	$1,877,818	$49,748,051	$56,155,881

TCO Savings (Static UPS) over 10 years – **$2,423,082** (approximately **4% savings**)

From the IT application 2N architecture analysis, it demonstrates that Static UPSs provide better overall TCO compared to DRUPSs. The negative point in the 2N architecture for Static UPS is the additional 20% space required.

However, if take rental gains from the additional 20% plant space into consideration, the 2N DRUPSs have a TCO savings of 10.6% in 10 years over the 2N Static UPSs.

In this case, for a sole IT load application the 2N DRUPSs perform better than the 2N Static UPSs.

IT load only comparison – Tri-redundant architecture

In this section, a tri-redundant design with the same assumptions for the IT load is analyzed. The same set of design parameters and assumptions were used here as in the 2N architecture. **Figure A2** and **A3** show the basic schematic diagram of the architecture

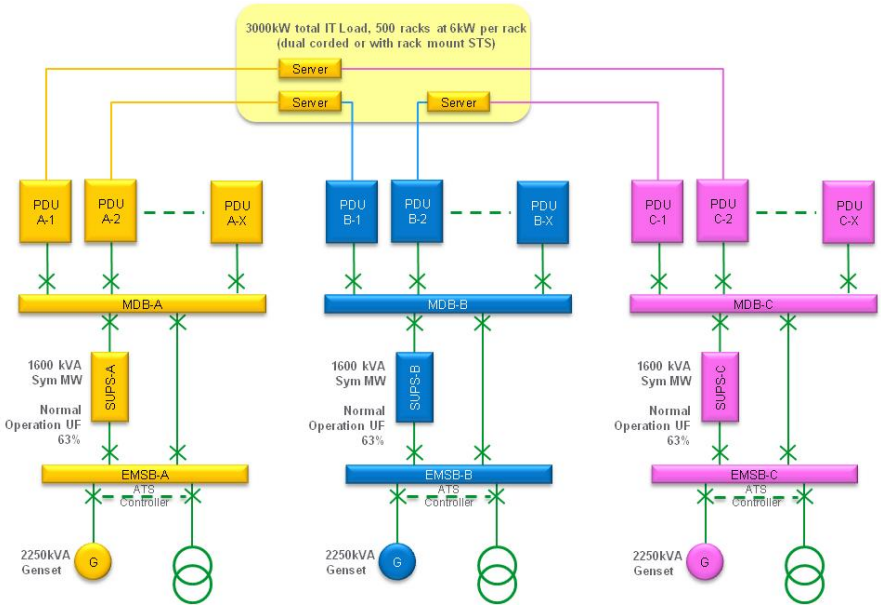


Figure A2
DRUPS, tri-redundant architecture diagram for IT application

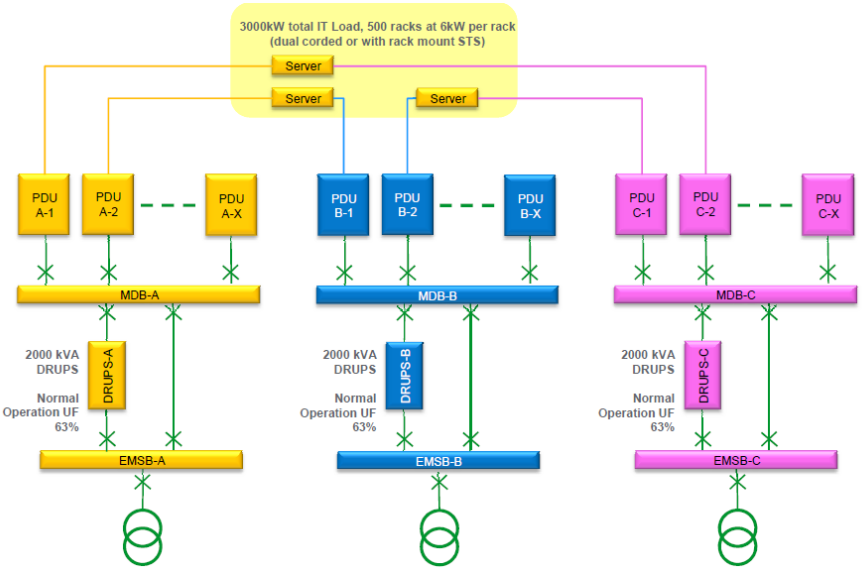


Figure A3
Static UPS, tri-redundant architecture diagram for IT application

UPS system energy loss analysis

In reference to **Figures A2** and **A3**, the UPS utilization factor is 63% for both DRUPSs and Static UPSs under normal operating conditions based on the total IT load of 3000 kW in a tri-redundant architecture.

An energy loss comparison based on the tri-redundant architecture shows the difference of energy loss between the DRUPSs and the Static UPSs.

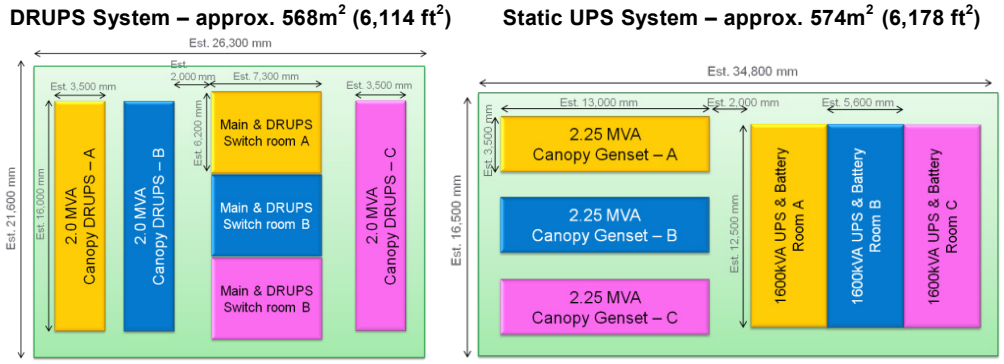
Table A3
IT application – Tri-redundant architecture energy loss analysis results

UPS type	UPS load	UPS capacity	UPS loading	Part load UPS eff.	Total UPS system loss
DRUPS	3000 kW	3 x 2000 kVA (1600 kW each)	63%	94%	191 kW
Static UPS	3000 kW	3 x 1600 kVA (1600 kW each) Symmetra MW	63%	97.3%	83 kW

Footprint analysis

For the tri-redundant architecture, the footprint difference is marginal. The Static UPSs take up 1% more space than DRUPSs.

Figure A4
IT application – Tri-redundant architecture overall plant layout



TCO analysis

TCO analysis based on a 10 year life cycle was done using the same assumptions and parameters.

Table A4
IT application – Tri-redundant architecture TCO results

UPS type	Capital expense	Maint. & cyclical replacement	Electricity cost	TCO for 10 years
DRUPS	$4,477,926	$1,667,224	$49,869,095	$56,014,245
Static UPS	$3,219,312	$1,408,363	$49,596,000	$54,223,675

TCO Savings (Static UPS) over 10 years – **$1,790,570** (approx **3%** savings)

From the analysis, it demonstrates that Static UPSs provide better values and better overall TCO compared to DRUPSs, with a marginally higher space requirement of an additional 1.05%. The overall TCO savings for 10 years is 3.2%, approximately $1.79 million.

With rental gains into consideration, the overall TCO savings reduced slightly from 3.2% to 2.6%.

Cooling load only comparison – 2N architecture

Each subsection below details the results of the capital expense, UPS system energy loss, maintenance costs, footprint, and total cost of ownership (TCO) for the 2N topology. Schematic diagrams of the two 2N topologies for IT application are shown in **Figure 1** for DRUPS and **Figure 2** for Static UPS in the earlier section of this paper.

UPS system energy loss analysis

The UPS utilization factor is 42% for the DRUPS and 44% for the Static UPS under normal operating conditions based on the total cooling load of 945RT. This is the total cooling load required for a single hall of 3MW IT load and the associated M&E plant room.

An energy loss comparison based on 2N architecture shows the difference of energy loss between a DRUPS and a Static UPS.

Table A5
Cooling load only – 2N topology UPS system energy loss analysis results

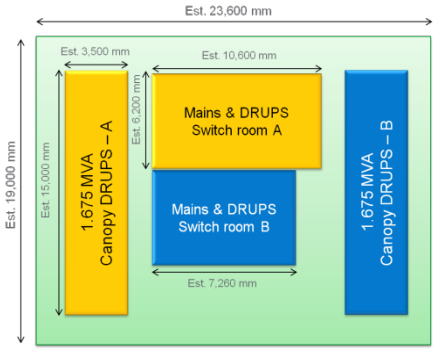
UPS type	UPS load	UPS capacity	UPS loading	Part load UPS eff.	Total UPS system loss
DRUPS	1120 kW	2 x 1675 kVA (1340 kW each)	42%	91%	111 kW
Static UPS	353 kW	2 x 400 kVA (400 kW each) Symmetra PX	44%	96%	15 kW

Footprint analysis

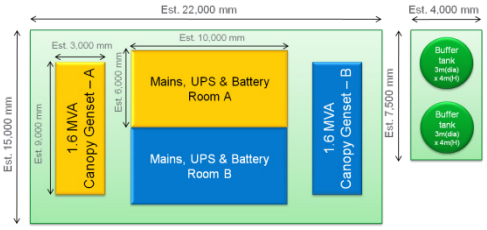
Based on a 2N architecture, the Static UPSs are more space efficient. It takes 19.6% less space compared with DRUPSs.

Figure A5
Cooling load only – 2N architecture overall plant layout

DRUPS System – approx. 448m² (4,822 ft²)



Static UPS System – approx. 360m² (3,875 ft²)



Design Parameters and Assumptions

- Calculated cooling load - 945RT
- Water cooled chilled water system in N+1,
- 8 - 15°C CHW temperature
- Canopy type of generator
- Canopy type of DRUPS
- Comparison and TCO calculation focus only on the electrical plant equipment supporting the cooling infrastructure only - "variable"
- M&E plant supporting IT load, lighting, general purpose power and other main equipment, e.g. IT UPS, etc. are excluded from the case study for simplicity - "constant"

TCO analysis

For Static UPS, the capital cost of the below main equipment are included

- 1600kVA prime rated canopy generator
- Main switchboards c/w automatic transfer switch
- Main distribution boards
- 400kW Symmetra PX static UPS c/w 6 min battery
- N+1 FCU for UPS and battery room
- Buffer tanks 2 x 28.6 m3

For DRUPS, the capital cost of the below main equipment are included

- 1675kVA canopy diesel rotary UPS
- Main switchboards
- Main distribution boards

Table A6
Cooling load only – 2N architecture TCO results

UPS type	Capital expense	Maint. & cyclical replacement	Electricity cost	TCO for 10 years
DRUPS	$2,369,105	$1,097,212	$19,230,432	$22,696,749
Static UPS	$1,516,330	$606,131	$17,821,814	$19,944,275

TCO Savings (Static UPS) over 10 years – **$2,752,474** (approx **12%** savings)

The cooling application 2N architecture analysis demonstrates that a Static UPS system provides better value and better overall TCO compared to a DRUPS system.

Notes on TCO Calculations

- Maintenance and cyclical replacement cost only considered for main equipment - generator, Static UPS and DRUPS
- Maintenance cost includes 5% CAGR
- For Static UPS, battery replacement every 5 years. Total 2 replacements are included in the 10 years TCO
- For DRUPS, 1 overhaul is included in the 10 year TCO

The TCO savings for 10 years is very substantial at 12.1% without consideration of rental gains from the space savings.

If rental gains are taken in consideration, the 88m^2 space savings will increase overall 10 years TCO savings from 12.1% to 56.3% in favor of Static UPSs.

IT load only comparison – Tri-redundant architecture

Design parameters and assumptions

Same set of parameters and assumptions as per the 2N topology with the exception of the below:

- 2 halls of 3MW IT load, 500 racks at 6kW/rack
- Calculated cooling load - 2 x 945RT

Same set of design parameters and assumptions were used here in the tri-redundant architecture where the battery autonomy for the Static UPSs is sized to offer 6 minutes to match the short ride-through time of a DRUPSs' flywheel (8 – 12 seconds) for a more accurate, "apples to apples" comparison.

The two tri-redundant architectures for the cooling application are shown in the diagram below; one used a DRUPSs (**Figure A6**) and the other used a Static UPSs (**Figure A7**).

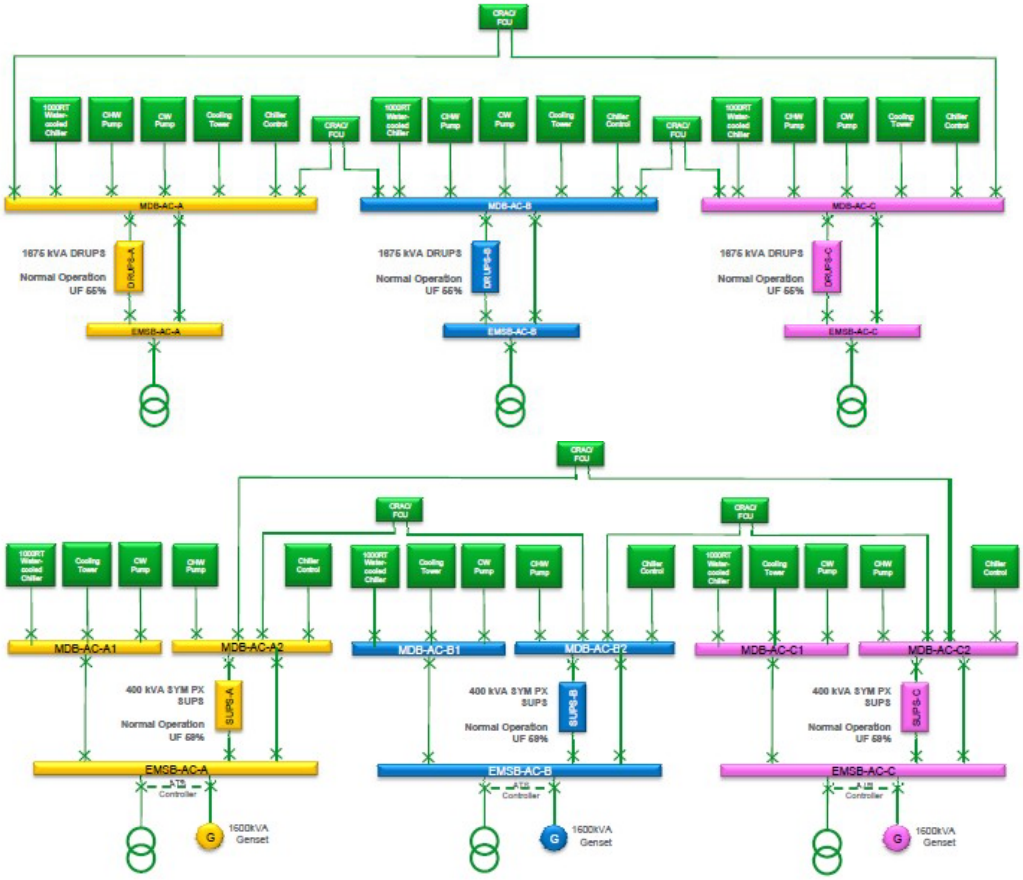


Figure A6
DRUPS – Tri-redundant architecture diagram for cooling application

Figure A7
Static UPS – Tri-redundant architecture diagram for cooling application

Life Is On Schneider Electric

Cooling application UPS system energy loss analysis

Reference to **Figure A6** and **Figure A7**, the UPS utilization factor is 55% for DRUPS and 59% for Static UPSs under normal operating conditions based on the cooling load of 2 x 945RT.

An energy loss comparison based on tri-redundant architecture shows the difference of energy loss between the DRUPSs and Static UPSs.

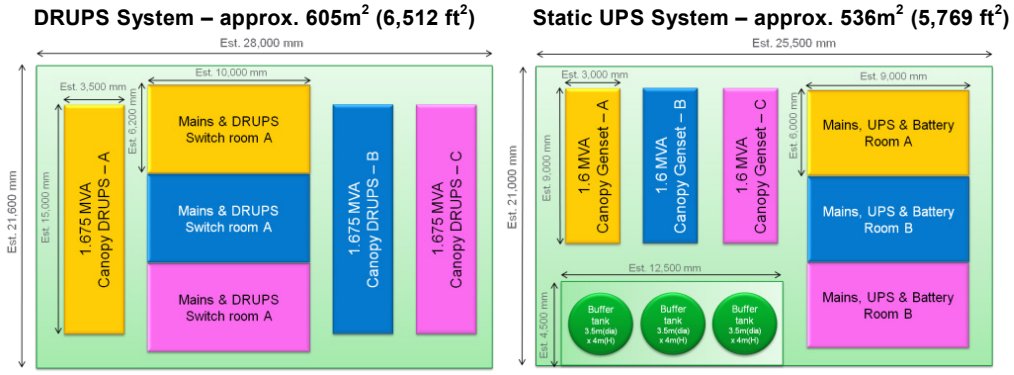
Table A7
Cooling application – Tri-redundant architecture UPS system energy loss analysis results

UPS type	UPS load	UPS capacity	UPS loading	Part load UPS eff.	Total UPS system loss
DRUPS	2240 kW	3 x 1675 kVA (1340 kW each)	55%	93%	169 kW
Static UPS	706 kW	3 x 400 kVA (400 kW each) Symmetra PX	59%	96%	29 kW

Footprint analysis

In a tri-redundant architecture, the Static UPS system is more space efficient. The area consumed by the equipment is11.4% less than a comparable DRUPS system.

Figure A8
Cooling application – tri-redundant architecture overall plant layout



TCO analysis

TCO analysis based on a 10 years cycle was done using the same assumption and parameters.

Table A8
Cooling application – tri-redundant architecture capital expense results

UPS type	Capital expense	Maint. & cyclical replacement	Electricity cost	TCO for 10 years
DRUPS	$3,584,160	$1,645,819	$37,633,747	$42,863,726
Static UPS	$2,236,501	$909,197	$35,643,627	$38,789,325

TCO Savings (Static UPS) over 10 years – $4,074,401 (approx 10% savings)

This demonstrates that the Static UPS system provides better value and better overall TCO compared to a DRUPS system. The TCO savings for 10 years is very substantial at 9.5%.

If rental gains are taken in consideration, the 69m^2 space savings will increase overall 10 years TCO savings from 9.5% to 24.7% in favor of Static UPSs.