UPS System: How Can Future Technology and Topology Improve the Energy Efficiency in Data Centers?

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Abstract: **A Data Center can consist of a large group of networked servers and associated power distribution, networking, and cooling equipment. All these applications consume enormous amounts of energy which result in a significant increase in energy inefficiency problems. One of the causes of Data Center energy inefficiency power distribution is from the uninterruptible power supply (UPS). The UPS system is an alternate or backup source of power linking between mains power supply and end critical loads in order to provide back-up power and protection for the sensitive load. This study attempts to answer the question of how can future UPS topology and technology improve the efficiency of Data Center. In order to analyze the impact of different UPS technologies and their operating efficiencies, a model for a medium size Data Centre is developed, and load schedules and worked schematics were created to analyze and test the components of each of the UPS system topologies.**

Index Terms: **Data Center, Energy efficiency, Flywheel UPS system, Static UPS system, uninterruptible power supply (UPS)**

I. INTRODUCTION

The uninterruptible power supply (UPS) system is an alternate or backup source of power, linking between mains power supply and end critical loads, to provide back-up power and to protect the sensitive load against line frequency variations [1]. The main UPS systems deployed in Data Center applications are Static, Flywheel, and DRUPS (Diesel Rotary UPS) [1]-[2]. However, the focus of this work is on the Static and Flywheel UPS systems. It analyzes the operating efficiencies of the different UPS technologies on the overall Power Usage Effectiveness (PUE) of the Data Center. The PUE is presented as a fraction whereby the total facility power inclusive of all losses is divided by the power consumed by the Data Centre IT equipment. If the PUE is equal to 1 this means a perfect efficient facility, if the given value is above 1, this means a lower facility efficiency [3]. However, the value will always be greater than 1 but the closer it is to 1 the better the Data Centre is perceived in terms of energy efficiency. Therefore, in order to analyze the different UPS technologies and their operating efficiencies a model for a medium size Data Center is developed based on a Data Center designed to provide 1500kW of cooling capacity to the Data Halls and hence support 1500kW of IT load. The electrical infrastructure topology to be adopted is configured to '2N' redundancy configuration for each of the two UPS systems technologies (Static and Flywheel), where 'N' stands for the number of UPS modules that are required to supply power to Data Center. The '2N' redundancy means the load of the Data Center is shared between two UPS systems on independent paths so that if one fails, the other will still supply the data center's critical load [4]. In addition, the entire critical load will be less than one half of the total UPS capacity installed. Computer based software programs such as the Romonet are used to offer a predictive modeling tool for the Data Center in order to evaluate how it would operate under different conditions. The system is designed in accordance with the Uptime Institute Tier 3 requirements, the Uptime Institute specify that all of the IT equipment is dual chorded or powered in that it can accept both an A and B supply from alternate sources [4].

II. DESIGN DESCRIPTION

An electrical model for a medium size Data Center is designed to provide 1500 kW of cooling capacity to the Data Halls. The Data Centre selected is assumed to be of the modular type operating on free air cooling which has been calculated to be available for 99% of the year in London based on Ashrae weather data. The designed IT load is 1500kW, which is the maximum cooling available from the mechanical systems. This, in turn, is the maximum power density of the facility. The electrical infrastructure topology adopted is configured to '2N' redundancy configuration for each of the two UPS systems technologies Static and Flywheel type. The system is designed in accordance with the Uptime Institute Tier 3 requirements. Table I outlines the loading accounted for when sizing the UPS.

TABLE I
Electrical Loading Summary for Data Center

Units	KW	KW	KVA	A	Remarks
Total IT Load	1500				
Data Center Ventilation (Fan Load)	150				
Total UPS Load		1.654	1.838	2.653	Assume P.F=0.9
Total UPS Input Load (incl. charging current & losses)		1.997	2.264	3.268	UPS charging current = 15% UPS Losses = 5%
Total Non-UPS Mechanical Cooling Load		0	1	1	Assume P.F=0.9
Total Load		1.998	2.265	3.269	

A. Static UPS system,(Double conversion Type)

The preferred static UPS technology used in this work is the Double Conversion Static UPS technology which is predominantly used in the Data Center Industry and uses insulated-gate bipolar transistor (IGBT) for power conversion [5]. The UPS selected for this design is a transformerless system and has the capability to operate in the Eco mode which is one of the several UPS modes of operation that can improve Data Center efficiency. In this UPS mode there are two main paths that can supply the load, the online (double conversion) path and the bypass path [6]. Hence the efficiency of the Static UPS has been derived measuring the UPS losses in double conversion mode, based on an 1.1MVA system around which the Data Centre in this study has been designed. As in Fig. 1, higher efficiency of 6-10% could be achieved with the Static UPS by operating it in the Eco mode.
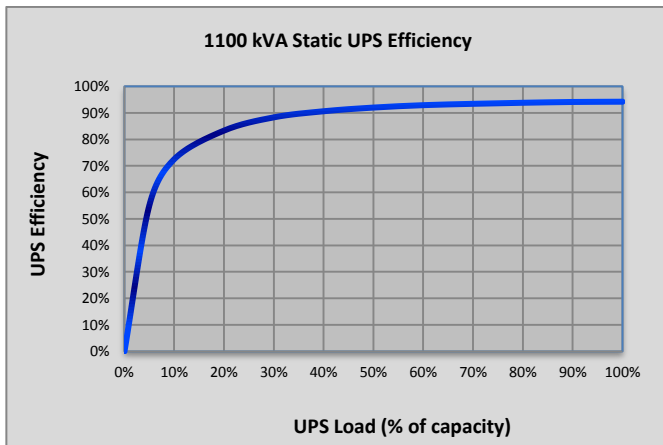

Fig. 1. Static UPS Efficiency Curve

Fig. 1 clearly indicates the efficiency of this system along the complete spectrum of loads from 5% up to maximum capacity. Considering a 2N redundancy configuration at maximum capacity, this essentially is reflected as 50% loading on the UPS at maximum capacity which would result

in losses of 8% on this Static UPS. However, large heat losses are experienced at low loading. To overcome this event, modular UPS systems such as the 1.1MVA system studied, can operate a UPS module management programmed where if the load is only 100KVA, only three of the four 225kVA UPS modules will run in double conversion, with the other module switching to double conversion immediately, if there is a load increase or power disturbance is experienced.

The system selected is scalable in blocks of 275kVA up to a maximum of 1100 kVA; the UPS requirement for the design adopted requires four UPS 1100kVA modules. Two UPS are paralleled on "A" side and the other two UPS are paralleled on side "B" for the '2N' redundancy configuration. Table II details the output findings from the Static UPS System (double conversion type) in the '2N' redundancy configuration system and the calculations undertaken for the Data Center designed to provide 1500kW of IT load.

TABLE II
Static UPS Findings in 2N Redundancy Configuration

IT Load %	100%	75%	50%	25%
Load KW	1500	1125	750	375
PUE	1.27	1.34	1.48	1.91
UPS Load	41.8%	32.1%	22.4%	12.6%
UPS Efficiency	90.88%	88.83%	85.06%	76.21%
Impact on PUE	0.11	0.14	0.21	0.41

The 2N redundancy configuration 100% loading will only ever represent a 50% loading on the site UPS as there will always be a minimum of 50% redundancy [4]-[5]. The impact this redundancy has on efficiency is shown in Table II with the UPS efficiency at 25% site load running at approximately 76.2%, i.e. 23.8% losses, and a maximum UPS double conversion type efficiency peaking at 90.88%. Fig. 2 shows the Static UPS Efficiencies in '2N' redundancy configuration at part load.
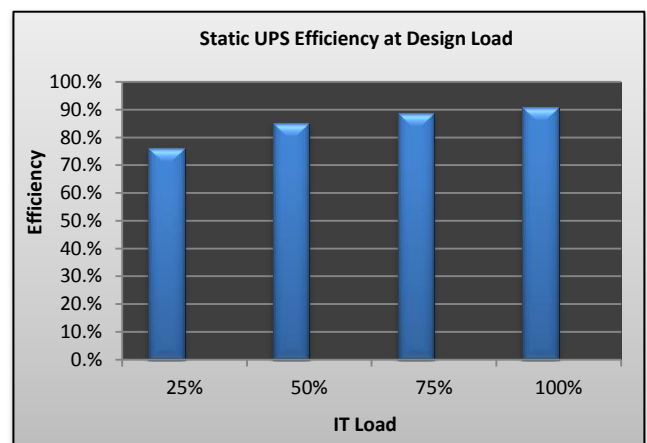

Fig. 2. Static UPS System at Part Load

B. Flywheel UPS System Type

A percentage of Data Center operators opposed to the traditional static UPS system with its requirement of large

battery capacity have embraced flywheel technology [7]. The flywheel technology performs as a 'mechanical battery' simply converting and storing electrical energy in kinetic energy. The stored energy is used in the form of electrical power when it is required during a utility outage [7]-[8]. The system that has been selected for this comparative study is a market leader in the flywheel technology that has been successfully deployed in Data Center applications. The flywheel UPS system examined is based on a design in which a 1000kVA system is composed of four 250kVA flywheels. The power electronics losses are lower than those of the double conversion Static System. Also the additional air conditioning and battery rooms requirements for Static UPS are not needed when using flywheel UPS system. The Flywheel UPS investigated provided relatively high efficiency even at low loading. Fig. 3 clearly shows that the Flywheel UPS can achieve an efficiency of 91.2% at 20% load, while in the double conversion this level of efficiency of 92% is not gained until around 50% load.
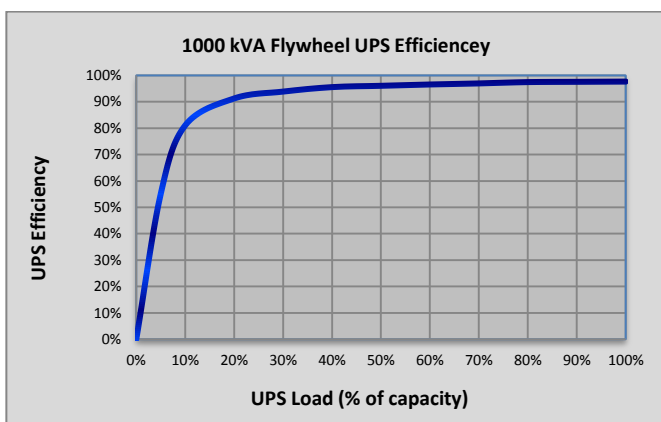

Fig. 3. Flywheel UPS Efficiency curve

In this study the UPS requirements for the '2N' redundancy configuration design require eight UPS 250kVA modules; four UPS are paralleled on "A" side and another four UPS paralleled on side "B". Table III details the output findings from the Flywheel UPS System in '2N' redundancy configuration and the calculations undertaken for the Data Center designed to provide 1500kW of IT load.

TABLE III
Flywheel UPS Findings in 2N Redundancy Configuration

IT Load %	100%	75%	50%	25%
Load KW	1500	1125	750	375
PUE	1.20	1.26	1.36	1.76
UPS Load	45.8%	35.2%	24.6%	13.8%
UPS Efficiency	95.79%	94.68%	92.40%	81.50%
Impact on PUE	0.05	0.06	0.10	0.30

Table III summarizes the results for Flywheel UPS parameters. The calculations were carried out on a '2N' redundancy configuration. The results on Table III have been measured across complete spectrum of loading on the site to enable comparison with the alternative technologies. Fig. 4

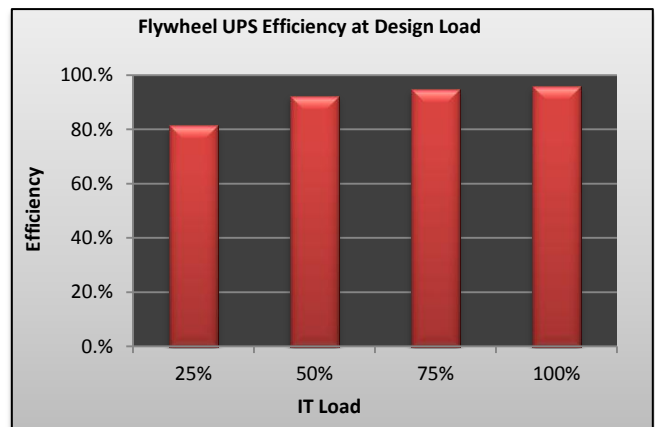shows the Flywheel UPS efficiencies in '2N' redundancy configuration at part load.

Fig. 4. Flywheel UPS System at Part Load

The efficiency profile of the Flywheel UPS is 92.40% efficiency at 50% IT load, because any system configured to operate with 100% redundancy can only ever achieve a peak loading of 50% if the load is balanced evenly across both distribution paths [4]-[7]. And that is an interesting where should result in energy savings.

III.   RESULTS AND DISCUSSION

Comparing both the Flywheel UPSs and Double Conversion Static UPSs used in the analysis, the calculations in '2N' redundancy configuration UPS efficiency show that at 50% capacity the efficiency of Flywheel technology is 92.4%, whereas the Double Conversion Static UPS only achieves 85.1%, and the efficiency of Flywheel technology at 100% capacity is 95.7%, whereas the Double Conversion Static UPS only achieves 90.8% at 100% capacity load, (see Fig. 5). Thus, the Flywheel UPS is more efficient than the Static type for the '2N' redundancy configuration.
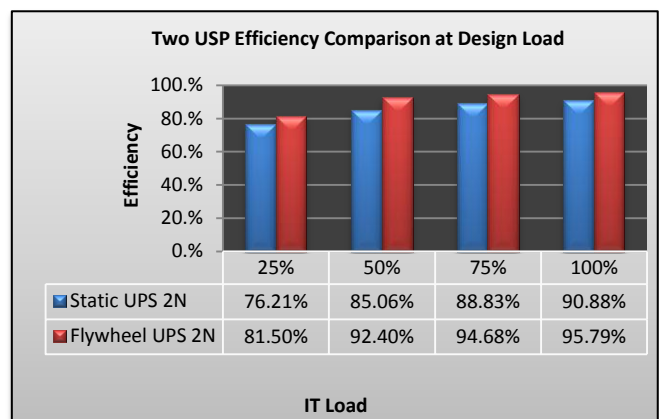

Two USP Efficiency Comparison at Design Load

IT Load	25%	50%	75%	100%
Static UPS 2N	76.21%	85.06%	88.83%	90.88%
Flywheel UPS 2N	81.50%	92.40%	94.68%	95.79%

Fig. 5. 2N configuration Efficiency Comparison between two Technologies at Design Load

IV. CONCLUSION

This study reveals, that flywheel based UPS systems, provide dramatically better efficiency across the board than conventional double-conversion UPS with batteries, based mainly on the two-step process of converting utility power from AC to DC, and then from DC to AC. This higher efficiency meets the power quality target.

ACKNOWLEDGEMENTS

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