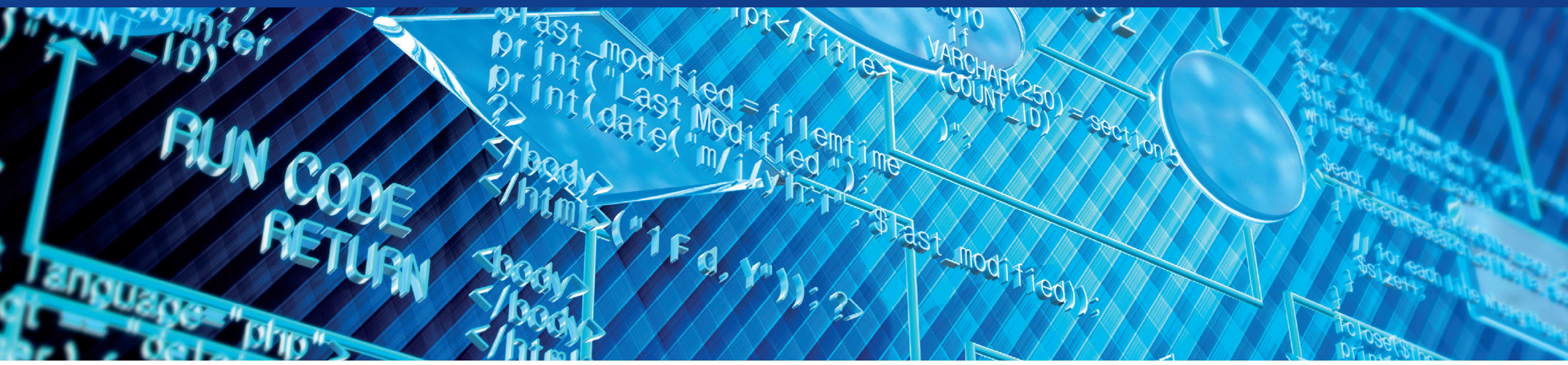
HITEC Power Protection

Diesel Rotary UPS reliability and process availability



Availability in datacenter UPS infrastructures compared

Summary

The typical characteristics of a DRUPS system are advantageous for the reliability and availability. In itself a DRUPS system is a simple concept, using a few components. This results in a higher unit MTBF figure than the more complex Static UPS systems. The Achilles heel of the Static UPS system is the standby Diesel generator set. But even leaving this component out of the calculation, DRUPS systems have a higher MTBF number due to the simple concept and low component count. End result is a higher process availability for the customer.

Content

White paper WP10-01.2
Date August 2013

1. Introduction

This document describes an availability analysis comprising a system comparison between Diesel Rotary UPS configurations (DRUPS) and Static UPS configurations (SUPS). Availability is the measure that datacenter operators will be looking for as this will determine the probability that their equipment at any certain moment is working properly.

In critical power supplies for datacenters, UPS systems play a dominant role. Commercial datacenters can for example be rated according to the Uptime Institute Tier levels[1]. The power supplies in the datacenters are a part of these evaluations. End customers are mainly concerned about the uninterrupted support for their equipment. Using the Mean Time Between Failure (MTBF) combined with the Mean Time To Repair (MTTR) one can calculate the availability of the power supply.

A UPS system must be capable of supplying the power, uninterrupted and for an “indefinite” period of time. The Uptime Institute Tier III and IV levels suggest the back-up power system in the facilities as the prime power source, where the availability of the power grid is a cheap alternative, but cannot be counted on. A DRUPS system is capable of doing so. For a SUPS system, standby diesel generator sets must be used beside the UPS and batteries, to guarantee a continuous power supply in case the grid is not available for a longer period of time.

Single UPS units will not have enough capacity to cope with the power capacity demands of a modern datacenter. Units are therefore placed in parallel. The number of units needed to cope with the demand is defined ‘N’. Dependant on the required redundancy, the UPS system is configured. The Tier level as described by the Uptime Institute can be used for that, but can also be used as point of departure to get the optimal balance between redundancy vs. CAPEX target and efficiency/maintainability vs. OPEX target.

---

[1] *www.uptimeinstitute.org*

2. MTBF figures, assumptions

MTBF figures, Static UPS (SUPS)

We see a broad range of MTBF figures and MTTR quotes for SUPS systems in published literature. The one this paper uses as a basis for the calculations is the value quoted by the System Reliability Center (38.000 hours)[2]. This institute quotes a large range, which is possible to achieve when putting single SUPS systems in parallel. We believe the lower value is most credible as this value comes very close to gathered data in 11 years of field use by Exxon[3], where, if battery failures are taken into account, the MTBF is just a little lower as mentioned (approximately 35.000 hours). Independent consultant company Uninteruptable Power Supply uses even a lower figure (20.000 hours)[4]. Other listings of single UPS systems are found at Powerkinetics bulletin (31.000 hours)[5]. Quotes of SUPS suppliers range from a staggering 2.000.000 hours (APC)[6] - although in this study battery failures are not taken into account - through 165.000 hours (Liebert)[7] - where only the hardware errors are taken into account - to 90.000 (Piller)[8] and 100.000 hours (Riello)[9].

When referred to the MTTR of SUPS systems, this is around 6 hours, although with line replaceable, hot swappable units the MTTR is claimed to go as low 30 minutes. This is very hard to support as the failures referred to are concerning the electronics and assume spare parts at site, where analysis of the failure will take up already a considerable amount of this time. This time needs to be included in the MTTR when it is to be used in availability calculations. Besides this the majority of failures will be of the battery components, of which the failure analysis will be even worse. Replacement takes considerable time as well. So although it is believed the MTTR of SUPS can be improved by hot swappable electronics, the final effect cannot lead to a factorial decrease.

MTBF figures, Diesel Rotary UPS (DRUPS)

The MTBF figure for a DRUPS system is 292.890 hours. This value is calculated by a third party consultant with a valued track record in UPS industry. This is for a single DRUPS unit without taking mains supply into account[10]. Although there are not much field listings of other rotary UPS systems in literature most rotary system suppliers quote numbers in the same range. The MTTR is assumed to be around 6 to 8 hours, depending on the nature of the problem.

---

[2] *System Reliability Center, Typical Equipment MTBF Values.*
[3] *Mean Time Between Failure (MTBF) Data Analysis of UPS, Equipment at the Exxon Chemical Plant in Baton Rouge, Louisiana Solidstate Controls Incorporated.*
[4] *Reliability of parallel redundant UPS, Uninterruptible power supplies, Whitepaper UPS 081-01-00.*
[5] *Powerkinetics Bulletin 04 http://www.powerkinetics.com.my/bulletin.htm.*
[6] *Performing Effective MTBF Comparisons for Data Center Infrastructure, APC white paper 12.*
[7] *Field MTBF Numbers: What do they really mean? White paper Liebert 2001.*
[8] *Beveiligde voedingsconcepten en varianten voor grote computer centra en industriële omgevingen. Piller Power Systems Gmbh.*
[9] *Designing Resilience Into Secure Power Systems, Leo Craig, Sales Manager for Riello Galatrek Ltd.*
[10] *Reliability Calculation for a Single Rotary UPS, Mr. H. Darrlemann of DBR Consult.*

3. Power system availability

Besides the IT equipment, also critical support systems need to be provided by uninterrupted or short interrupted power. (e.g. control, cooling and access). This will drive the power demand in medium and large sized datacenters in the range of many megawatts. A single UPS unit will not be able to provide this full capacity. Static UPS systems provide a typical capacity of 600-800 kVA in the high ranges, where the backup diesel generator sets provide around 3000 kVA in a large unit. Large DRUPS units typically are rated between 2.000 – 2.500 KVA.

In order to meet the power demand of modern datacenters one needs to parallel the single UPS units and combine the output power.

Availability of a single unit is defined:

$$\text{Avail} = \frac{MTBF}{MTBF + MTTR}$$

This can also be defined in terms of probability. Availability is the probability that the unit is working properly if probed at a random moment:

$$\text{Unit Avail} = P_{av}\,(\text{unit})$$

If we would parallel 'N' systems, all with their own availability the system availability is expressed by the following equation:

$$P_{av}\,(N, \text{system}) = \prod_{i=1}^{N} P_{av,\,i}$$

If we assume that the unit availability is equal for each system, which reasonably can be assumed if the units are of one type:

$$P_{av}\,(N, \text{system}) = P_{av}^{N}$$

The formula above shows that the system availability is less than the single unit availability. In order to achieve better system availability for power supply systems in datacenters, redundant units are added. If we add 'k' units more than the actual required 'N', the system still is capable of supporting the load, even if 'k' units would be out of operation. The availability of a system that requires 'N' units with 'k' redundancy is defined:

$$P_{av}\,(N, k, \text{system}) = \sum_{i=0}^{k} \binom{N+k}{i} P_{av}^{\,N+k-i} (1-P_{av})^{i}$$

For a Tier IV datacenter infrastructure the mathematics are straight forward. The requirement for a Tier IV infrastructure is that two separate power supply lines are available to provide the power. The UPS system consists of two subsystems (A and B). If the both lines are laid out symmetrically the power system availability of subsystem A and B are equal (assumed for this review). Whether the system is a SUPS or DRUPS system does not affect the mathematics. So both technologies use the next formula:

$$P_{av}\,(1, 1, \text{system}) = \sum_{i=0}^{1} \binom{2}{i} P_{av}^{\,2-i} (1-P_{av})^{i}$$

or: $P_{av} = P_{av,\,unit}^{\;N}$

In Tier III datacenter infrastructures we often see a 2N battery system being backed up by N+1 diesel generator sets. The 2N system on the battery will improve the system availability as there are 2 parallel lines. Essentially one has a system consisting of two subsystems of which one subsystem is redundant.

The power supply would not be secured if the backup diesel generator sets would not work. So the power system in fact is consisting of 2 subsystems that both need to work. This makes a system with N=2 (in which the systems have a different availability).

$$P_{av,\ system} = P_{av,\ battery} \times P_{av,\ Genset}$$

In which: $P_{av,\ battery} = P_{av,\ battery,\ N}^2$

With: $P_{av,\ battery,\ N} = P_{av,\ battery,\ unit}^N$

and: $P_{av,\ Genset} = P_{av}(N, 1, system) = \sum_{i=0}^{1} \binom{N+1}{i} P_{av,\ unit,\ Genset}^{N+1-i}(1-P_{av,\ unit,\ Genset})^i$

With a DRUPS system one can propose and install another configuration for a Tier III datacenter power infrastructure. An example of a Tier III certified site in the UK, London is used to define the availability formula of the DRUPS system. To comply with Tier III requirements the DRUPS design met the criterion of concurrent maintainability of the complete system. It used double output on each of the unit to feed the double distribution paths. For availability calculations it is equal to an N+2 configuration. And therefore the availability is expressed in the next formula:

$$P_{av}(N, 2, system) = \sum_{i=0}^{2} \binom{N+2}{i} P_{av,\ unit,\ Genset}^{N+2-i}(1-P_{av})^i$$

4. Case study, Tier III datacenter

As an example is reviewed a fictional, but realistic, Tier III datacenter case. The requirement for the critical load of our datacenter is a 15.000 kVA, which would make a reasonable size datacenter. Required is a Tier III rating, the Static UPS configuration being a 2N battery and N+1 diesel generator sets and the DRUPS configuration a N+2. The next assumptions and input parameter are used:

Assumptions	SUPS	Genset	DRUPS
Unit capacity (kVA)	600	3.000	1.670
Total units needed (N)	25	5	9
Unit MBTF (hours)	38.000	14.000	292.890
MTTR (hours)	6	8	8

The formulas explained in chapter 3, lead to the following outcome.

The availability in the number of nines for the SUPS system is limited to 4 (99.99%). The diesel generator sets bring the availability number down, but as they are a small amount and have sufficient redundancy, their influence on the total system availability is neglected.

Availability SUPS	N	2N	2(N+1)	N+1	N+2
Amount of units	25	50	52	**26**	**27**
Availability # of nines	2	4	10	**5**	**7**

The main factor is that 25 parallel battery units are needed to cope with the capacity requirement. All units need to work in order to have enough capacity. The parallel lines of the 2N bring the result up in a better range. One can improve this by adding more redundant units in the each of the parallel input lines. Adding 1 unit in each line 2(N+1), will bring the availability to 5 nines. This will increase the availability of the battery system to 10 nines.

The DRUPS system with its N+2 configuration reaches a 10 nines availability.

Availability DRUPS	N	2N	2(N+1)	N+1	N+2
Amount of units	9	18	20	**10**	**11**
Availability # of nines	3	7	14	**7**	**11**

Only 9 parallel units are needed to cope with the capacity requirement. The parallel lines of the 2N also bring the result up in a better range and this can be improved by adding more redundant units in each of the parallel input lines. SUPS configuration Tier III offers 4-nines availability, whereas Diesel Rotary UPS Tier III offers a far better availability of 11-nines.

5. Conclusions

The physical characteristics of a DRUPS system are advantageous for the reliability and availability. In itself a DRUPS system is a simple concept using a few components. This results in a higher unit MTBF figure than the more complex Static UPS systems. The Achilles heel of the Static UPS system is the diesel generator set configuration, which according to many standards needs to be available as they are considered to be the prime power supply. With low unit availability figures diesel generator sets make the SUPS systems have a low availability compared to DRUPS technology.

One can argue that the diesel generator sets are only necessary when the power fails for a longer time and take the utility into account. Even taking this to the extreme and just comparing the battery part of the SUPS with the DRUPS system, result in a higher availability of DRUPS. This is caused by the unit MTBF of the single Static UPS system being lower than of the single DRUPS system.

Even when the MTFB figures of the battery systems would improve, the lower output capacity will require many battery backed SUPS systems to be paralleled, which decreases the total system availability.

Overall this white paper shows that the prime function of a UPS system (availability) is best secured by simple technology and a high unit output capacity of Diesel Rotary UPS modules.

Other white papers available at hitec-ups.com

How green is green?
The environmental benefits of using Diesel Rotary UPS systems to support critical loads in the datacenter.

For contact details please visit www.hitec-ups.com