

Customer Case Study

A system for fault tolerant parallel power sharing: I_S-limiter in Teleticity Data Center Introduction

Chad McCarthy, Ralph Voss, Volker Schmidt

Worldwide the amount of IT data is booming which is used by private persons, all kind of industrial companies, design institutes, universities, the financial sector, insurances or governments. All kind of data is stored in data centers. The utmost importance for any data center is to ensure highest availability of data. To achieve this target, data centers are designed based on reliable technical solutions aiming at a cost efficient design.

This paper describes requirements in data center applications and outlines the improvement-process, which leads at the end to an optimized design of a data center concept by Teleticity from a technical and commercial perspective.

Improvement process in designing Data Center

A data center is a facility housing computer systems and associated components. Average sizes of data centers are between 2 – 50MW. Typical examples are telecommunications and storage systems. Redundant and back-up power supply are key features to ensure un-interrupted power supply.

Power supply to the data centers is guaranteed via complex technologies of grid-transformers, generators and uninterruptible power supplies (UPS).

It is of critical importance that there is zero downtime in data center operations.

Based on this fact, the IT equipment requires highest availability of the electrical infrastructure, specifically of the redundant uninterruptible data center power supply.

Conventionally, smaller data center leads in a n + n redundant power supply shown in Figure 1.

The reliability is realized by implementing a "system plus system" configuration .

In that case, two separate power supply systems with UPS, Genset and Distribution Board will be installed redundantly to the two grids.

The parallel connections, consisting of incoming grid-transformers, generators and uninterruptible power supplies, provide an A and B path to the customer's server.

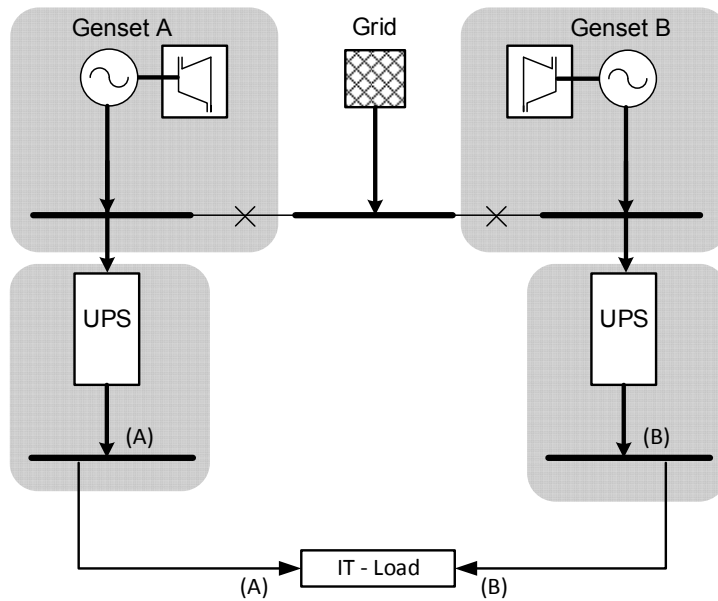


Figure 1: Parallel power supply n+n for one customer IT – Load

To ensure the effectiveness of the production and operation of large - data center supply systems and to make data center supply economically, in practice the distributed redundancy with the provision of n - 1 redundant UPS load will be used. Details can be found in figure 2. The associated savings in infrastructure over the n + n solution at the expense of system reliability, because the provided redundancy occurs of more than two UPS - supply networks. In each case a group of consumers shares redundancy with other consumer groups (distributed redundancy) .

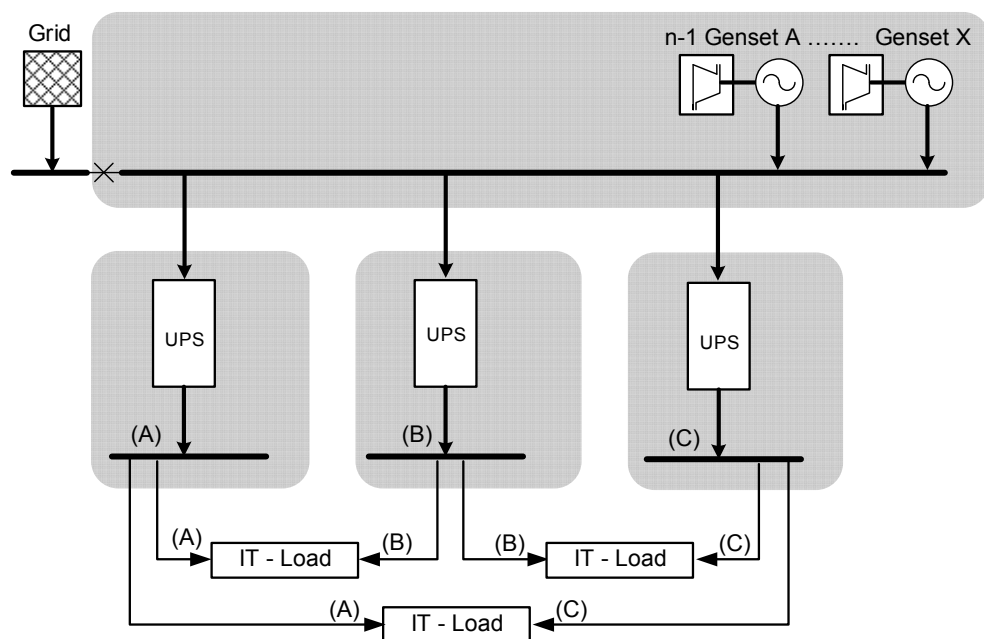


Figure 2: n-1 distributed redundant power supply for customer IT - Load

Beside the positive effects, distributed redundancy in accordance to Figure 2 provides disadvantages for data center applications such as :

- load balance between power systems is not possible
- system scaling dependent on actual load is not possible

Due to this reason a step-by-step expansion of the data center is not possible. All system components for distributed redundancy in the data center have to be installed immediately. Furthermore in the maintenance case of an UPS system or in case of problems with one power supply the redundancy is lost (unsafe service mode).

There is always a conflict between optimized total cost of ownership, system reliability and other aspects such as scalability and ease of maintenance of components of the power supply without affecting the IT-load. This results in advantages with each other for the use of distributed redundancy with an additional bus-connecting the consumption networks. This is shown in figure 3.

Key advantages of these parallel power infeed to one customer are

- Local overloads are compensated
- Local unit outages have no effects
- Load sharing improves efficiency

Based on these positive effects, availability, reliability and efficiency are increased.

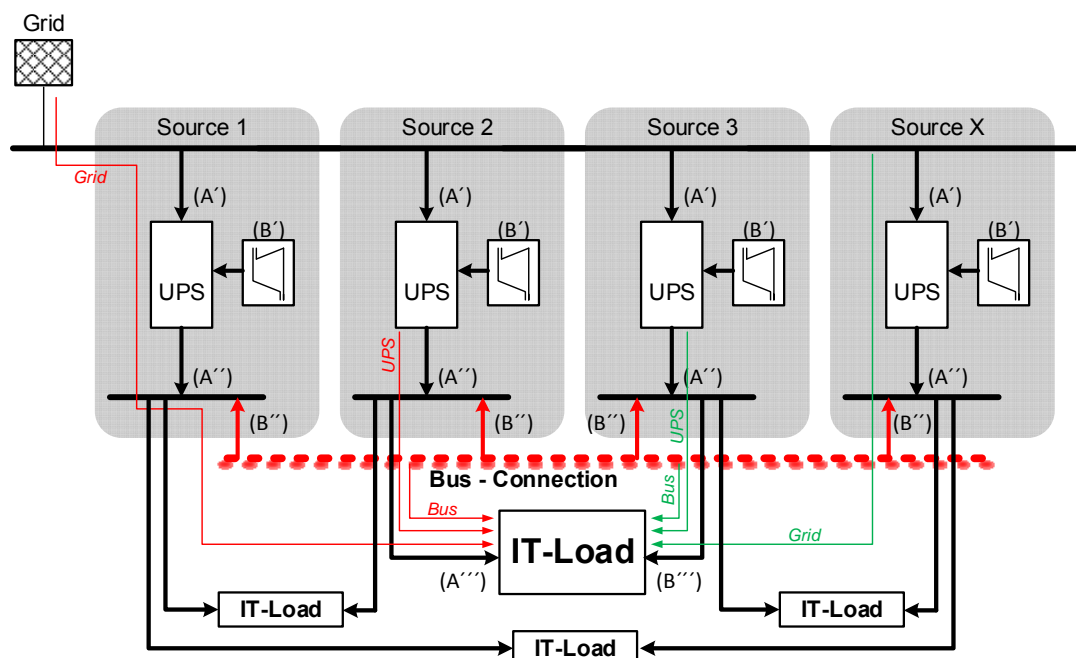


Figure 3: n-1 distributed redundant power supply with additional Bus - Connection for customer IT – Load

The additional bus-connection for each distribution for the supply of IT-load leads to a significant improvement in the overall reliability of the power system. Figure 4 shows the distribution over any two branches, the own supply UPS (A'') or via the bus - compound by the adjacent UPS supplies (B'').

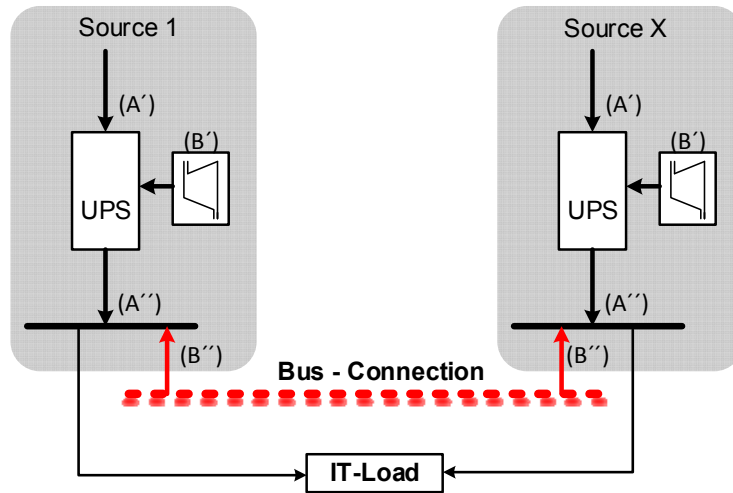


Figure 4: Distribution Board with additional Bus - Connection for customer IT-Load

The reliability of the comparison of the two systems with n - 1 distributed redundancy with and without bus connection can be derived from the following reliability block diagram. Figure 5 shows the reliability block diagram of the n - 1 redundancy conventionally used here with three supply networks in which each the reliability of the power supply in series with the reliability of energy distribution.

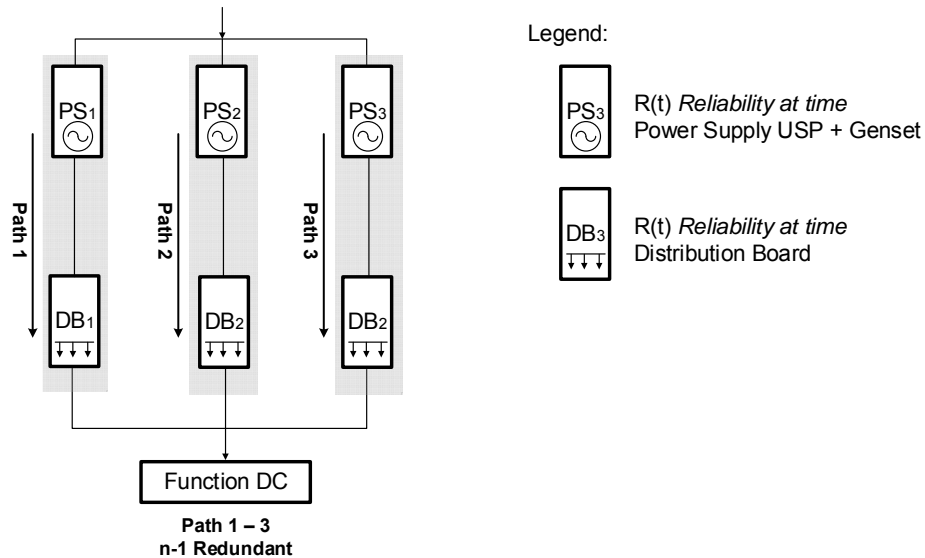


Figure 5: Applicable reliability block diagram
Distributed redundancy - Central Plant is n-1 redundant

Figure 6 shows the reliability block diagram of the n-1 redundancy used with additional bus - connection with three grids. The reliability of the power supply in n - 1 redundancy is in series with the reliability of energy distribution, each having a branch of the supply source and a branch of the bus - connection in parallel.

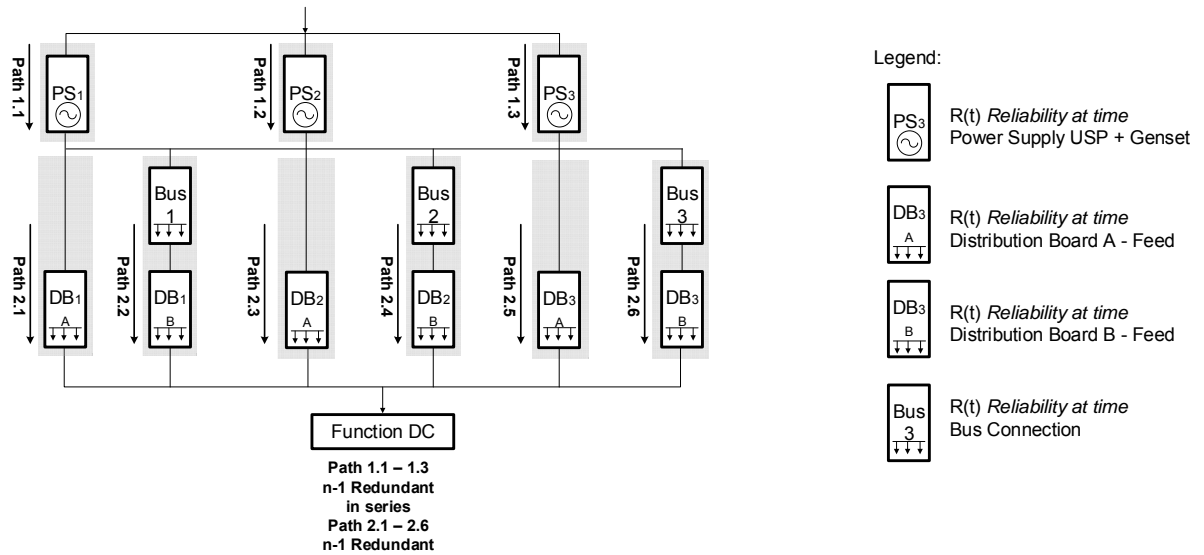


Figure 6: Applicable reliability block diagram
Distributed redundancy with additional Bus – Connection at Central Plant in n-1 redundancy

With a constant annual error rate per unit (source , distribution and bus connection) $\lambda = 0.017$ follows a system overall reliability of the two systems with bus and without bus. Comparison is shown in diagram 1.

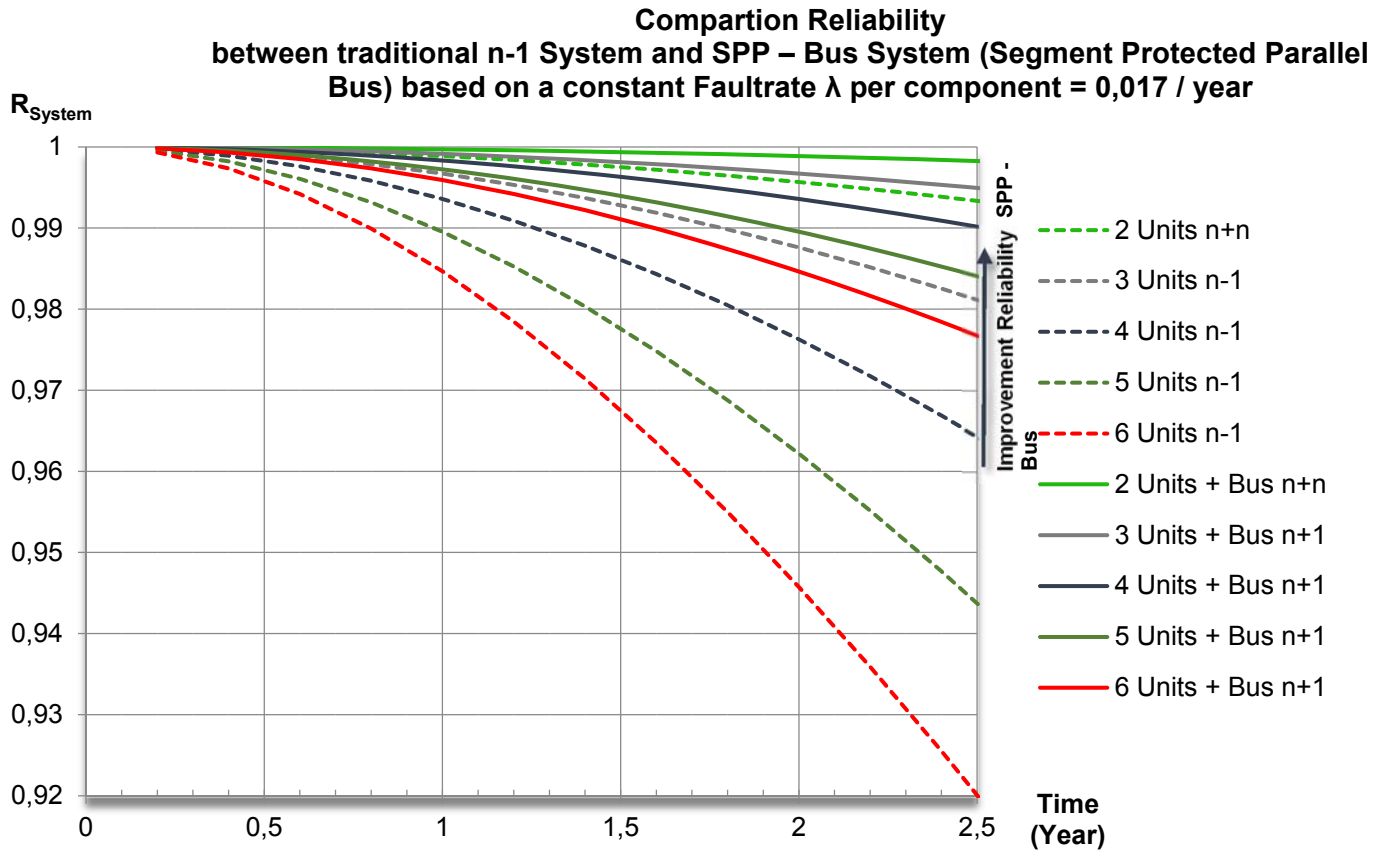


Diagram 1: Comparison Reliability n-1 System with and without Bus - Connection

The disadvantages of the n - 1 redundant power supply without bus - connection can be solved with a fault-tolerant ring. This leads to the development of the SPP - bus (segment Protected Parallel Bus), shown in Figure 7. A three stage safety concept on the parallel connection creates the prerequisite for fault tolerance in accordance with the requirements of ITIC - curve for voltage change to the distribution of IT.

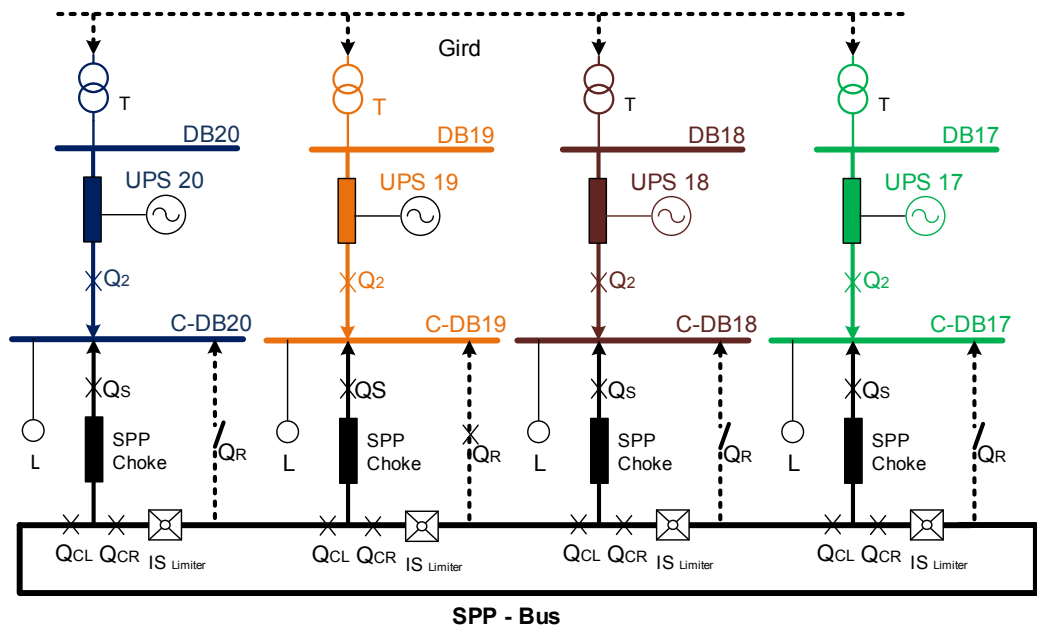


Figure 7: SLD of the SPP-Bus

Each customer has one power supply to be provided by its own source, i.e. power grid plus UPS supply. Furthermore, each customer has a second power supply via the fault tolerant parallel bus.

The system consists of equal segments, which can be added to the data center step-by-step.

In order to limit the impact of a short-circuit fault to a small area inside the data center system, additional to an impedance protection level and an ACB protection zone level one Is-limiter is installed in between each section of the SPP-Bus.

The Is-limiter detects and limits the short-circuit current during the first current rise so that the maximum short-circuit current is never reached.

Figure 8 shows the installation of Is-limiters on the SPP-Bus.

Additionally, the SPP bus with I_S -limiters provides the following advantages.

- Tier 4 levels of availability from installed costs comparable with a Tier 3 installation.
- Higher efficiency results in lower power losses and reduced electricity costs
- No reduced redundancy during service and maintenance activities
- Power outages due to human errors reduced almost to nil
- Flexibility through modular expansions. Just as much as the operation demands
- Suitable for green and brown field data centers.
- Investment protection

One additional major improvement is the reduction of voltage dips in the system.

Each short-circuit fault in the system creates a voltage dip. Especially for data centers the voltage dip causes service problems for the computer systems to be connected.

In general the faster the short-circuit fault can be cleared, the smaller the voltage dip to the system will be.

Related to the data centers it is extremely important to clear the short-circuit fault as fast as even possible.

Information Technology Industry Council (ITIC) provides the basis for the definition of the required voltage quality. The ITIC curves (shown in figure 8 and figure 9) illustrates the voltage range of transient over- and under voltages, when components of IT systems have to operate without interference.

Field tests of Telecity Data Center / Frankfurt a.M in Germany

The SPP-bus for data centers shown above was installed in the Telecity data center Frankfurt a.M. / Germany in 2012.

During commissioning of this data center system several tests have demonstrated the correct function as well as the benefits of this SPP-Bus including the I_S -limiter solution.

Figure 9 shows the configuration of the Telecity data center Frankfurt / Germany during the tests.

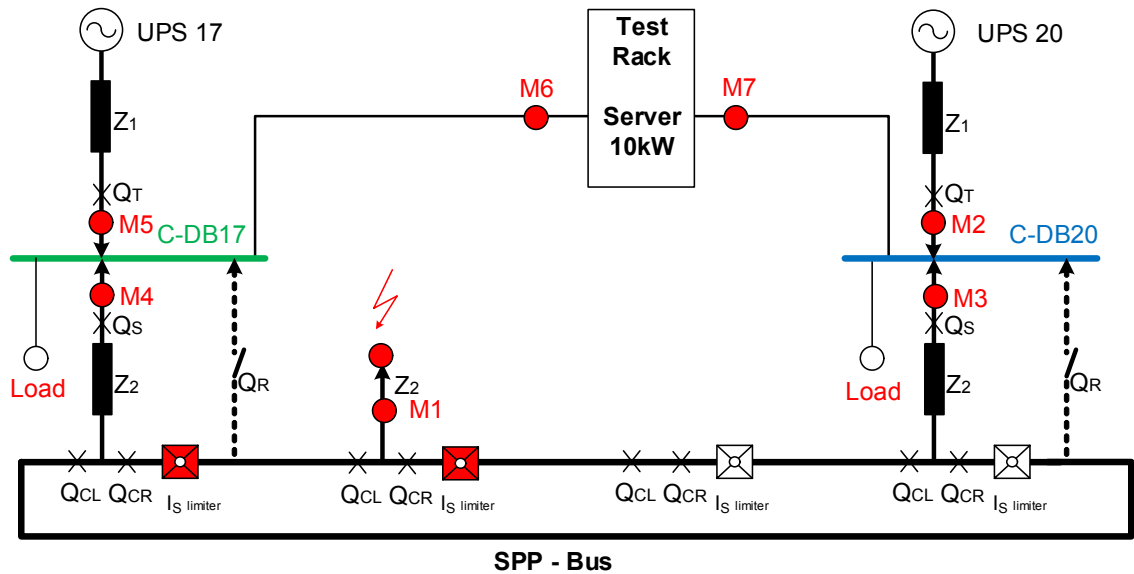


Figure 9: Configuration of the Telecty data center in Frankfurt
System test

In the first part of the system-test, the control unit of all I_S -limiters has been switched-off. This test is used as the reference point.

The conventional protection devices have detected the short-circuit fault locations and have tripped the corresponding circuit breakers.

The voltage dip ($MP4$ – figure 9) versus time of this first test is shown in diagram 2 below.

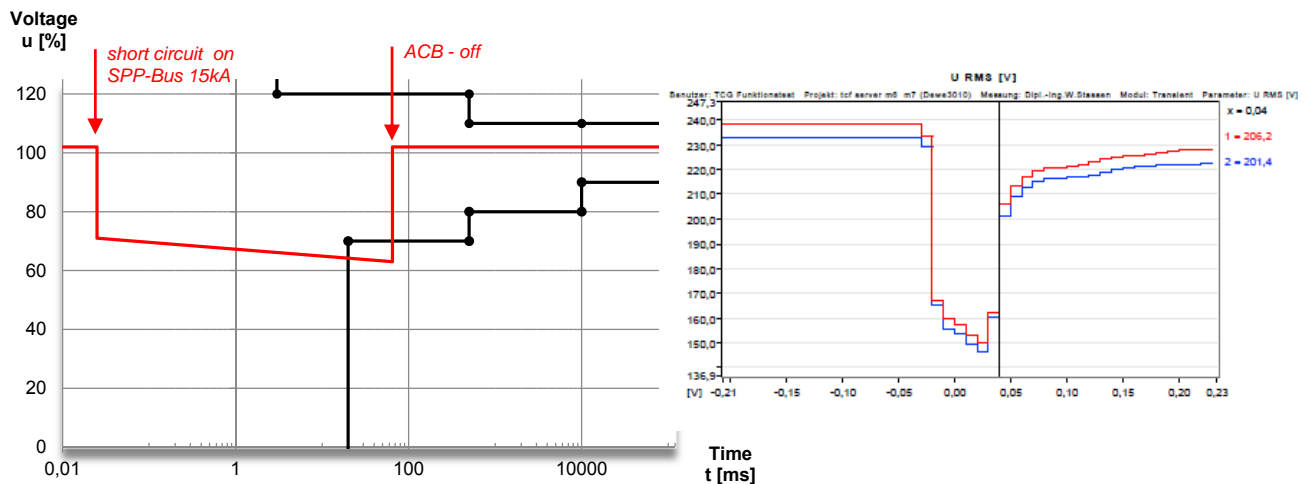


Diagram 2: Voltage dip versus time shown in ITIC - Curve
First test: control unit of I_S -limiters switched-off

As shown the measured voltage dip is outside of the acceptable voltage range, defined by ITIC curve

For the second test, the control units of all I_S -limiters are activated.

Based on the SPP-Bus the voltage dip of the system is dramatically reduced. The result (MP4 – figure 9) is listed in diagram 3 below.

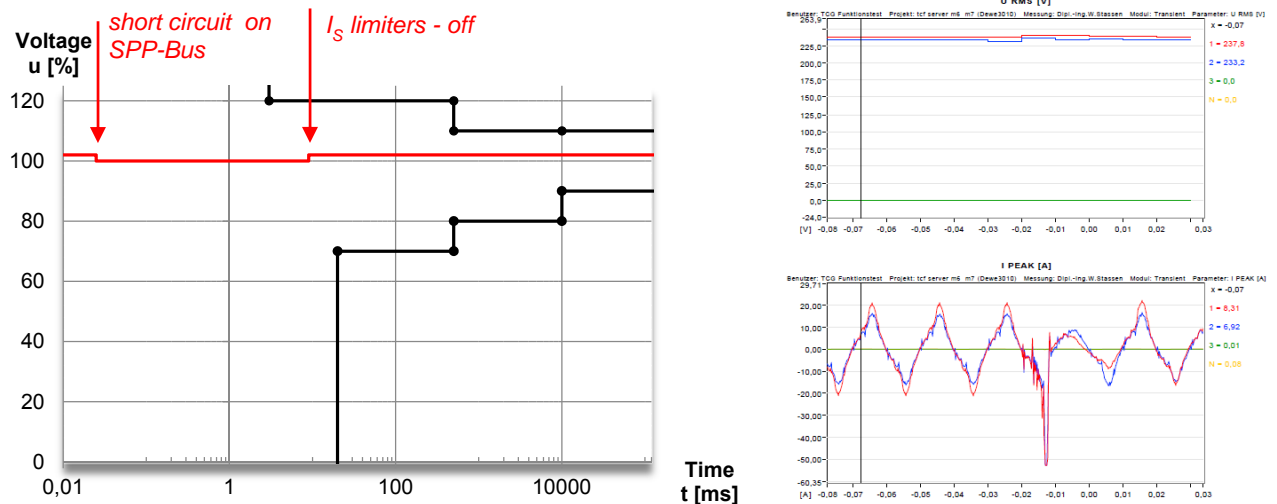


Diagram 3: Voltage dip versus time shown in ITIC - Curve
Second test: electronic of I_S -limiters switched-on

The measured voltage dip is within the acceptable voltage range, defined in the ITIC curve.

Summary

In order to increase the reliability / availability of data centers and in order to reduce the voltage drop in case of a short-circuit fault, Telectricy has designed a dedicated SPP bus for data centers. This SPP bus is a data center ring configuration including I_S -limiter short circuit protection. Compared to traditional data center designs, reliability and availability have been improved by the integration of three n-1 systems including an SPP-Bus compared to a traditional n+n System. The reliability $R_{(5years)}$ improvement for a four unit system on SPP - Bus is nearly 10% compared to traditional n-1 systems.

The main advantage of the SPP-bus solution is to provide two independent supplies to the distributors of IT while maintaining the n-1 redundancy in the generation system. This allows an efficient scaling and system expandability, in addition to an uninterrupted maintenance of all elements in the power system.

Several field tests have been applied in the Telectricy data center in Frankfurt a.M./Germany and Dublin / Ireland. In these tests, a significant reduction of the voltage dip resp. disturbance impacting the data center load has been proven in case of short-circuit faults.

Beside increased reliability and availability, also a reduction of CAPEX by 5-20 % per MW and OPEX by 20 % per MW was realized by installing I_S -limiters in the SSP bus.

Furthermore the SPP-Bus provides the possibility of modular design of data centers allowing simple expansion of data centers at a later stage. This prepares the data center for possible future extensions and protects the investment.

Main characteristics of the distributed redundancy with and without SPP - Bus

Number of Units	System Capacity incl. Redundancy	Redundancy	Load on Normal Operation	Minimum Number of Load Groups	Traditionally without SPP - Bus			SPP - Bus Solution		
					Indicative costs per kW IT Load	System Reliability $R_{(2\text{years})}$ Failure Rate $\lambda=0,017$ for Each Component	System Reliability $R_{(2\text{years})}$ Failure Rate $\lambda=0,04$ for Each Component	Indicative costs per kW IT Load	System Reliability $R_{(2\text{years})}$ Failure Rate $\lambda=0,017$ for Each Component	System Reliability $R_{(2\text{years})}$ Failure Rate $\lambda=0,04$ for Each Component
2	200%	100%	50%	1	5.00 k€	0.996	0.978	5.13 k€	0.999	0.994
3	150%	50%	67%	3	3.75 k€	0.988	0.941	4.00 k€	0.997	0.983
4	133%	33%	75%	6	3.33 k€	0.976	0.893	3.71 k€	0.994	0.968
5	125%	25%	80%	10	3.13 k€	0.962	0.839	3.63 k€	0.990	0.949
6	120%	20%	83%	15	3.00 k€	0.946	0.782	3.63 k€	0.985	0.927

Diagram 4: Main characteristics of the distributed redundancy with and without SPP - Bus

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1250 Eye Street NW Suite 200 Washington DC 20005
202-737-8888 <http://www.itic.org>

Authors

- Chad McCarthy
TelecityGroup
e-mail: chad.mccarthy@telecity.com
- Ralph Voss
Voss On Technische Planung GmbH & Co. KG
Justus-Perthes-Strasse 11
DE-99867 Gotha
e-mail: interested@voss-on.de
- Volker Schmidt
ABB AG
Oberhausener Strasse 33
DE-40472 Ratingen
e-mail: volker.schmidt@de.abb.com