WHITE PAPER

System reliability analysis

Reliability computation of modular uninterruptible power supply (UPS) with decentralized parallel architecture (DPA™)

ABB Power Protection

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1 Introduction

ABB's modular uninterruptible power supply (UPS) is based on ABB's decentralized parallel architecture. With this architecture, each power module is equipped with its own rectifier, battery charger, inverter, static bypass and control logic for autonomous operation. Please refer to figure 1.

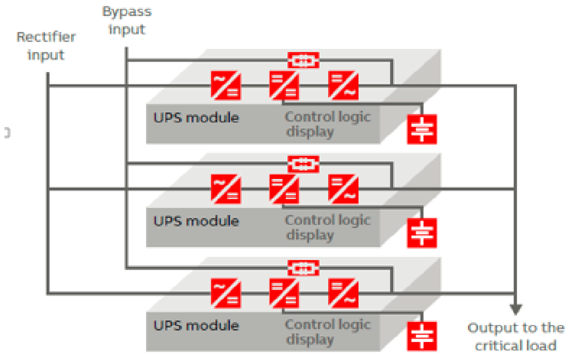

Figure 1. Patented decentralized parallel architecture

The patented DPA architecture maximizes power availability due to redundancy for critical components and fault tolerance. The autonomous operation of the power modules allows on-line, hot-swap ability for continuous uptime and automatic isolation in case of failure.

A modular UPS system consists of parallel power modules with common or separate batteries and, potentially, internal redundant power capabilities. The reliability of the modular UPS system depends on the specific configuration selected as well as on the reliability of its components.

In order to compute the system availability and reliability of an ABB modular DPA UPS, the mean time before failure (MTBF) of the system is determined, considering many sub-systems: rectifier, battery, battery converter inverter, power supplies, contactors, static switch module, redundant internal communication, control boards and fans. The MTBFs of the individual sub-systems is determined from field data related to 15 years of experience from an installed base of around 100,000 manufactured UPSs with similar design topologies and concepts. For brand-new designs, theoretical calculations are made to evaluate the reliability of the upgraded sub-system, starting from field data of similar consolidated designs and considering the changes. In fact, the Telcordia/Bellcore methodology (*), based on the component counts, does not reflect the internal circuit topology or the firmware aspect.

(*) The Telcordia document "Reliability Prediction Procedure for Electronic Equipment" (document Issue 1) can be ordered directly from Telcordia Customer Service in New Jersey; Phone: (800) 521-2673 or (732) 699-5800; the cost is about $1,000. Note: the Telcordia document, Issue 1, is an update of the Bellcore document TR-332, Issue 6.

2 Principle of the analysis

For the reliability analysis, the following conditions are considered:
1. Number of power modules in parallel
2. Internal redundant capacity N+0 and N+1
3. Common and separate battery banks
4. Decentralized static bypass switch
Please refer to table 1.

Parallel module	Redundancy	Battery	Static bypass
N	N-1/N	Common	Decentralized (DPA)
N	N-1/N	Separate	Decentralized (DPA)
N	N/N	Common	Decentralized (DPA)
N	N/N	Separate	Decentralized (DPA)

Table 1. Modular UPS configurations

Figure 1 shows the corresponding block diagrams. N represents the number of DPA power modules installed in the UPS system. The notation "N-1/N" means that a redundant module is used and, therefore, only (N-1) modules out of N are required to supply the critical load. On the other hand, "N/N" means no redundant module and, therefore, all the N modules used need to operate.

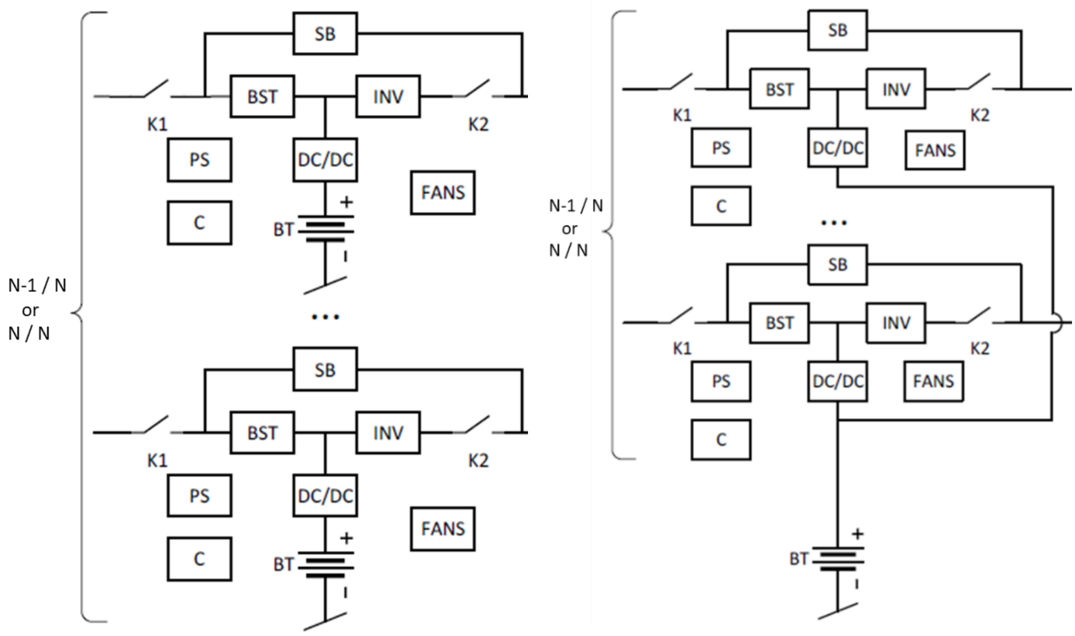

Figure 1 Block diagrams for the two topologies considered for the modular UPS system: (a) separate batteries for each module, (b) common battery for all the modules. N represents the number of modules installed in the UPS system.

For each of the block diagrams shown in Figure 1, the reliability block diagram (RBD) is established. An exhaustive analysis of the complete system has been done, considering all the failure paths as well as the interactions between hardware, software and protection. The basic principle of the RBD is that every sub-system that is not redundant and that cannot be isolated in case of failure has to be considered as a sub-system in series. Then MTBF and mean time to repair (MTTR) values should be assigned to every sub-system. Finally, the MTBF of the configuration is calculated by applying specific equations to solve the reliability diagram.

The following MTBF and MTTR for components are considered:

Element or function name	symbol
rectifier	$MTBF_{BST} = 1/\ \lambda_{BST}$
battery	$MTBF_{BT} = 1/\ \lambda_{BT}$
battery converter	$MTBF_{DCDC} = 1/\ \lambda_{DCDC}$
inverter	$MTBF_{INV} = 1/\ \lambda_{INV}$
communication bus	$MTBF_{BUS} = 1/\ \lambda_{BUS}$
contactor K1	$MTBF_{K1} = 1/\ \lambda_{K1}$
contactor K2	$MTBF_{K2} = 1/\ \lambda_{K2}$
static bypass module	$MTBF_{SB} = 1/\ \lambda_{SB}$
power supply	$MTBF_{PS} = 1/\ \lambda_{PS}$
control board	$MTBF_{C} = 1/\ \lambda_{C}$
fans	$MTBF_{FANS} = 1/\ \lambda_{FANS}$
mains	$MTBF_{Mains} = 1/\ \lambda_{Mains}$
all repairable parts inside UPS	$MTTR_{REP} = 1/\ \mu_{REP}$
mains	$MTTR_{Mains} = 1/\ \mu_{Mains}$

3 Results and discussion

The following MTBF values are calculated for the UPS configurations mentioned:

Parallel module	Redundancy	Battery	Static bypass	MTBF [h]
4	N-1/N	Separate	Decentralized (DPA)	1,248,000
4	N-1/N	Common	Decentralized (DPA)	746,000
4	N/N	Separate	Decentralized (DPA)	111,111
4	N/N	Common	Decentralized (DPA)	111,111

Table 2. Modular UPS configurations

Parallel module	Redundancy	Battery	Static bypass	MTBF [h]
5	N-1/N	Separate	Decentralized (DPA)	998,000
5	N-1/N	Common	Decentralized (DPA)	597,000
5	N/N	Separate	Decentralized (DPA)	88,000
5	N/N	Common	Decentralized (DPA)	88,000

Table 3. Modular UPS configurations

Parallel module	Redundancy	Battery	Static bypass	MTBF [h]
6	N-1/N	Separate	Decentralized (DPA)	831,000
6	N-1/N	Common	Decentralized (DPA)	497,000
6	N/N	Separate	Decentralized (DPA)	74,000
6	N/N	Common	Decentralized (DPA)	74,000

Table 4. Modular UPS configurations

Figure 2 shows the UPS system reliability as a function of the number of modules for four different configurations.

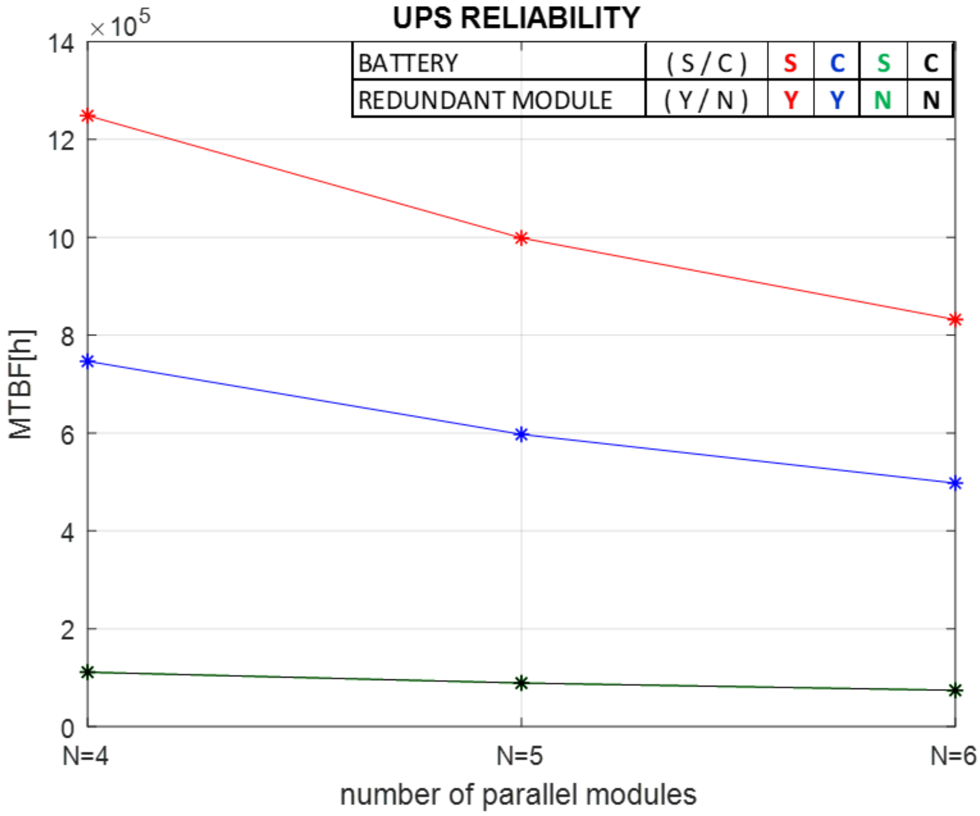

Figure 2 UPS system reliability as a function of the number of modules for four different configurations

Based on the results for all UPS configurations, the system MTBF decreases as the number of modules increases. This is normal as the failure opportunities increase with the number of components.

Clearly, the best reliability is obtained when a redundant module is used, particularly with separate batteries. When no redundancy is used, the effect of the battery configuration (separate or common) is not visible as, in our considerations, we paralleled all the originally separate battery strings into one bigger common battery.

References

A. Birolini, "Quality and Reliability of Technical Systems, Theory – Practice – Management," Springer-Verlag, 1994.