WHITE PAPER

RELIABILITY & AVAILABILITY IN LEGRAND UPS

#LegrandImprovingLives

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LEGRAND SUPPORTS YOU ON ALL YOUR PROJECTS

LEGAL INFORMATION

Presentation pictures do not always include Personal Protective Equipment (PPE), but this is a legal and regulatory obligation that must be scrupulously respected.

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summary

UPS SYSTEM

SAFETY INSTRUCTIONS

Any failure to strictly apply the procedures and to respect these recommendations, could lead to serious risk of accident, endangering people and property (in particular, without limitation, risk of burns, electric shocks, etc.).

General information

- Use only the products and accessories recommended by the Legrand Group in the catalogue, instructions, technical data sheets and all other documents provided by Legrand (hereinafter referred to as “the Documentation”) in compliance with the installation rules.

Improper installation and/or use may result in the risk of arcing in the enclosure, overheating or fire. The enclosures must be used under normal conditions, they must not be subjected to Voltage / Current / Temperature values other than those specified in the Documentation.

- Legrand declines all responsibility for any modification or repair of the equipment making up the enclosure that is not authorized by the Legrand Group, as well as any failure to comply with the rules and recommendations specified by Legrand in the Documentation. In addition, in the cases mentioned above, the warranty granted by Legrand will not be applicable.
- It is necessary to check that the characteristics of the products are appropriate for their environment and use during maintenance operations, and to refer to the Documentation.
- If you have any questions or require clarification, please contact Legrand Group.

Protection/security

- The installation, use and maintenance of the enclosures and their components must be carried out by qualified, trained and authorized personnel, in accordance with the regulations in force in each country..
- People working on the installation must have the appropriate electrical authorizations for the work to be carried out.
- Wear the PPE (Personal Protective Equipment) necessary to work on live products.

- Respect the safety rules related to electrical work.
- Improper electrical and mechanical use of equipment can be dangerous and may result in personal injury or damage to property.

Maintenance

- Depending on the maintenance operations to be carried out, partial or total power cuts of the enclosure concerned should be planned before any work.
- When performing operations that involve access to the inside of the enclosure, be aware of the risk of burns before touching any.
- Before turning the power back on, make sure that there are no foreign bodies and that all physical protections have been put back in place (e.g.: screens, covers, faceplates).

Risk of electric shock, burns and explosion.

The rules and recommendations in this document are based on our knowledge of the typical conditions of use of our products in the fields of application usually encountered. However, it is always the customer’s responsibility to verify and validate that Legrand products are suitable for its installation and use.

The customer must ensure proper installation, maintenance and operation of the equipment to avoid any risk of injury to personnel or damage to property in the event of product failure, especially for applications that require a very high level of safety (e.g., those in which the failure of a component may endanger human life or health).

The rules for storage, handling, installation and maintenance and the appropriate precautions and warnings must be strictly observed and applied.

UPS SYSTEM

DEFINITIONS & PARAMETERS

FAILURE

- The termination of the ability of an item to perform a required function. For an UPS the failure is defined as the termination to supply the load.

RELIABILITY

- The ability of an item to perform a required function under given conditions for a given time interval. For an UPS the reliability is the capacity to supply the load without any interruption and without any voltage and frequency variation.

FAILURE RATE (λ)

- Is the number of failures per million of hours.
- The failure rate is time dependent. It is related to the overall quality of the product (material, design, production) but also to the useability and maintainability.

MEAN TIME BETWEEN FAILURE (MTBF)

- The MTBF is the expectation of the time between failures. For an UPS is the average time between two failures.

$$MTBF = \frac{1}{\lambda}$$

MEAN TIME TO REPAIR (MTTR)

- The MTTR is the average time needed to complete a system repair, strongly related to the system architecture and design for easy and fast and service.

REPAIR RATE

$$\mu = \frac{1}{MTTR}$$

AVAILABILITY (A)

- The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.

$$A = \frac{MTBF}{MTBF + MTTR}$$

- A is always less than one (it is one in ideal case of MTTR = 0). It is expressed as percentage of running time during the system life and it is commonly indicated with number of “nines”, for instance:

  A = 99.9952 %.... is “four nines”

  A = 99.99973 %.... is “five nines”

  A = 99.9999845 %.... is “six nines”

- For critical application when the “Never Stop” is the main target. Availability is very useful (more than just failure rate and MTTR considered separated) to figure and compare the reliability of systems.
- In a system with a low failure rate could have less availability respect to a system with higher failure rate, because it needs more time to be repaired. For considering 3 systems:

MTBF	MTTR	Availability	“Nines”	Average downtime in a year
1,000,000 h	15 h	99.9985 %	4 Nines	8 minutes
800,000 h	2 h	99.9998 %	5 Nines	1.3 minutes
400,000 h	0.5 h	99.9999 %	6 Nines	39 seconds

UPS SYSTEM

RELIABILITY BLOCK DIAGRAM (RBD)

RBD Method

With the RBD Method the System is divided in smaller blocks or sub-systems with λ and μ (MTBF and MTTR).
The reliability of the entire system is the combination of the reliability of the single blocks. In particular, from the reliability point of view, the blocks can be connected in series or in parallel:

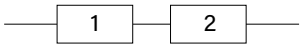
- In a system of Blocks in Series, if only one block fails all the system fails.
- In a system of Blocks in Parallel, the system fails when all the blocks fail.

In the simple case of only two blocks with:

- $MTBF_1 = m_1$
- $MTTR_1 = r_1$
- $MTBF_2 = m_2$
- $MTTR_1 = r_2$

The combination formulas to calculate the MTBF (m_s) and MTTR (r_s)of the systems are the following:

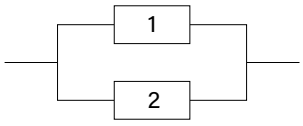
RELIABILITY SERIES CONNECTION:



$$m_s = \frac{m_1 \times m_2}{m_1 + m_2}$$

$$r_s = \frac{m_1 \times r_2 + m_2 \times r_1}{m_1 + m_2}$$

RELIABILITY PARALLEL CONNECTION:



$$m_s = \frac{m_1 \times m_2 + (m_1 \times r_2 + m_2 \times r_1)}{r_1 + r_2}$$

$$r_s = \frac{r_1 \times r_2}{r_1 + r_2}$$

UPS SYSTEM

FAILURE RATE

The failure rate in the life cycle of a product is not constant and typically the trend is the one in below figures called “Barh Curve”:

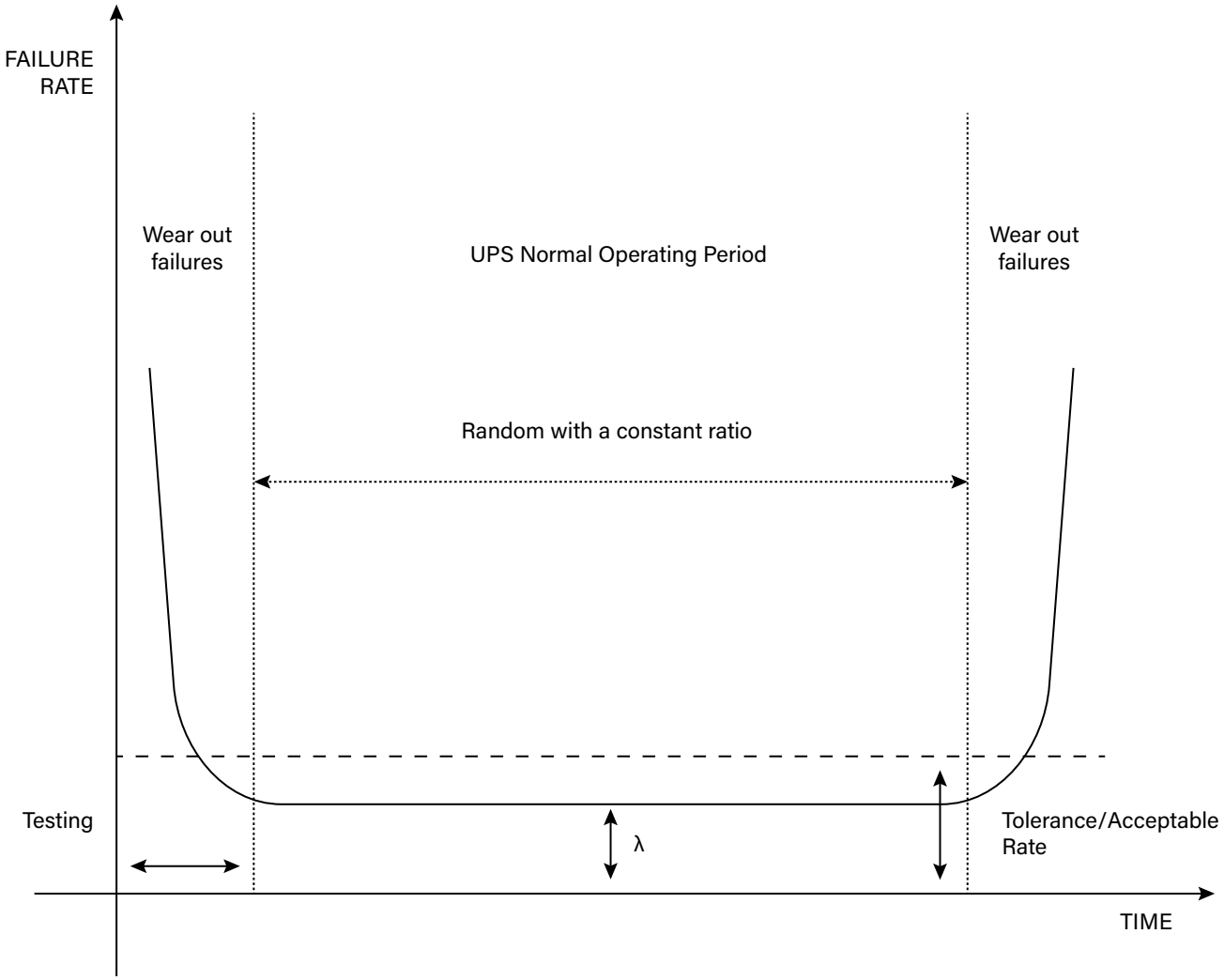


Figure 1: Failure rate (λ) as function of the time.

The curve is dived in 3 three periods: the wear-in failure period, the normal operating period and the wear- out failures period. During the wear-in failure period the failure rate is relatively high (it is called also infant mortality period). This period usually happens during the factory test and burn-in. The wear-out failure period happens when the UPS is near to the end of its useful life.

The UPS normal operating life is the useful life of the system. During this period the failure rate is constant. There is no direct correlation between the service life of a product and its failure rate.
The MTBF value is based on the rate of failure of the UPS while still in its normal operating life and it is assumed that it will continue to fail at this rate indefinitely. MTTR is the expected time to recover the UPS from a failure.

UPS SYSTEM

RELIABILITY WITH STATIC BYPASS SWITCH

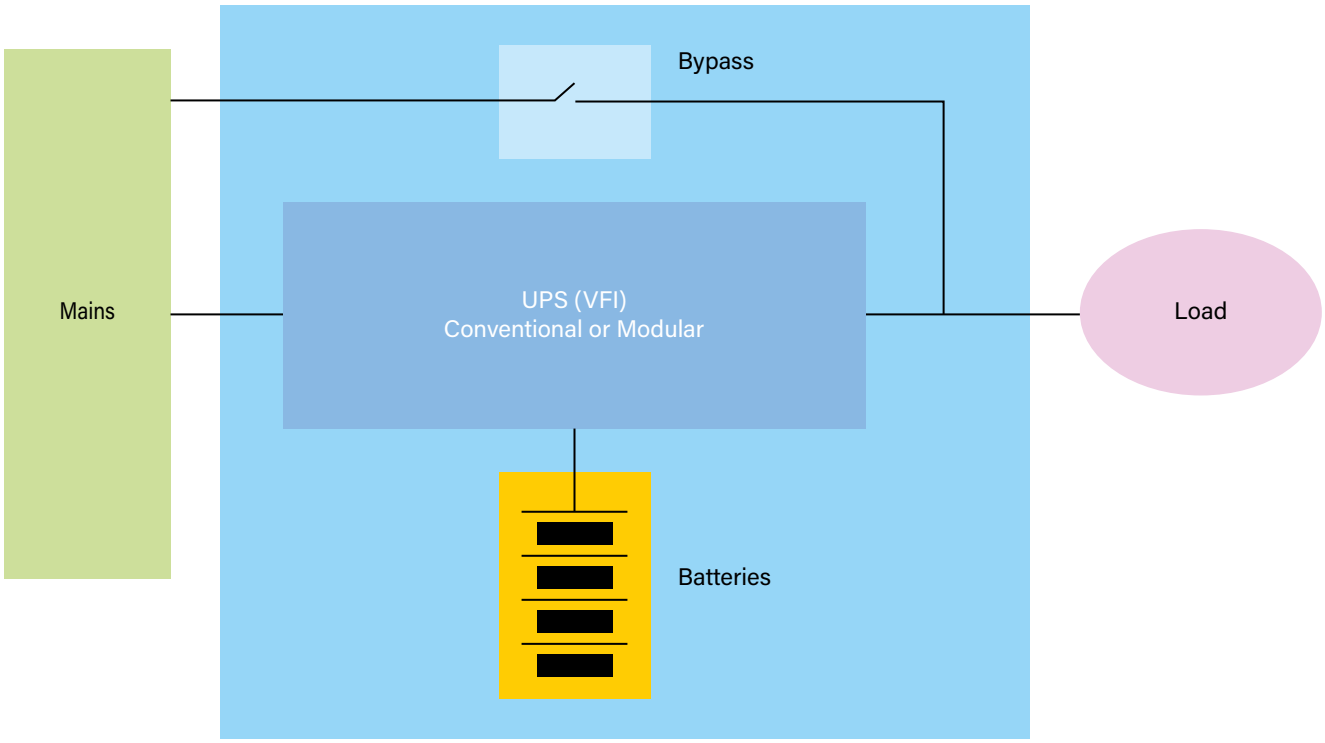


Figure 2: Schematic Block Diagram of UPS System.

Using the configuration given in the figure 2 the reliability of the System depends on the MTBF and MTTR of the UPS, but also on the MTBF and MTTR of the “utility mains”. In case of UPS failure but Mains available the load continues to run with energy flowing the bypass.

A possible assumption for Utility Mains is:

- Mains Utility MTBF = 100 h.
- Mains Utility MTTR = 12 h.

UPS SYSTEM

RELIABILITY OF CONVENTIONAL IN PARALLEL SYSTEM (REDUNDANCY AND POWER)

The reliability of a single UPS can be increased significantly by introducing a redundant parallel configuration.
The (n + 1) parallel active redundant system stands for the number of UPS modules that are required to handle an adequate supply of power for essential connected systems, plus one more.

The following diagrams show the Parallel Redundant Configuration (n + 1) with internal and external manual maintenance bypass.

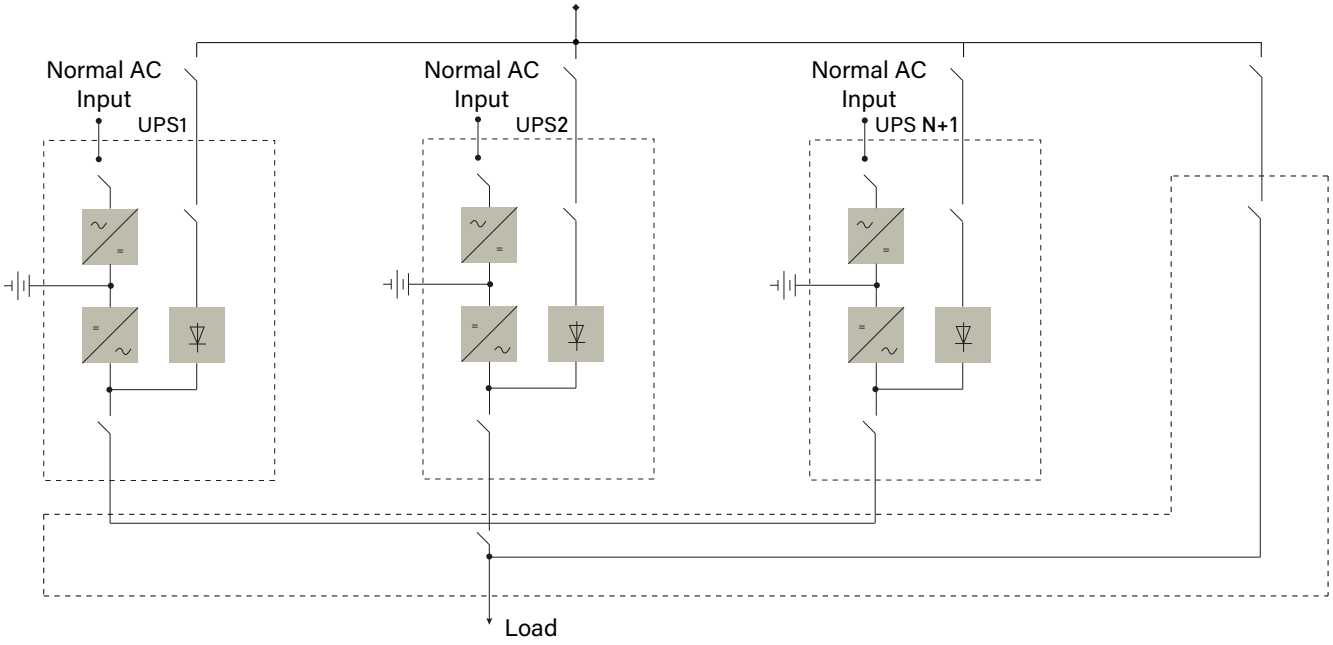


Figure 3: Redundant Parallel Configuration with external maintenance bypass.

The reliability of the redundant system depends principally on any commonality in the system.
On the other Conventional UPS connected in parallel for power, and not for redundancy, result with lower MTBF compared to a single UPS. This because any failure in each of the two UPS will cause the shutdown of the load.

RELIABILITY MODULAR WITH N + X REDUNDANCY

Independently of the failure rate, Modular UPS system have the big advantage versus Conventional UPS to have very short MTTR. In fact, in most of the cases, the repair is just the replacement of a faulty module, and smaller is the module (high granularity) shorter is the MTTR.
In reliability calculation, in case of redundancy N + X, modular UPS can be considered similar to conventional UPS in parallel, but with the big differences that they have common blocks, in particular in full modular architecture where all components are distributed (included logic, static bypass, batteries, etc.). This compensate the higher number of blocks which can fails with the high redundancy level and independency of them.

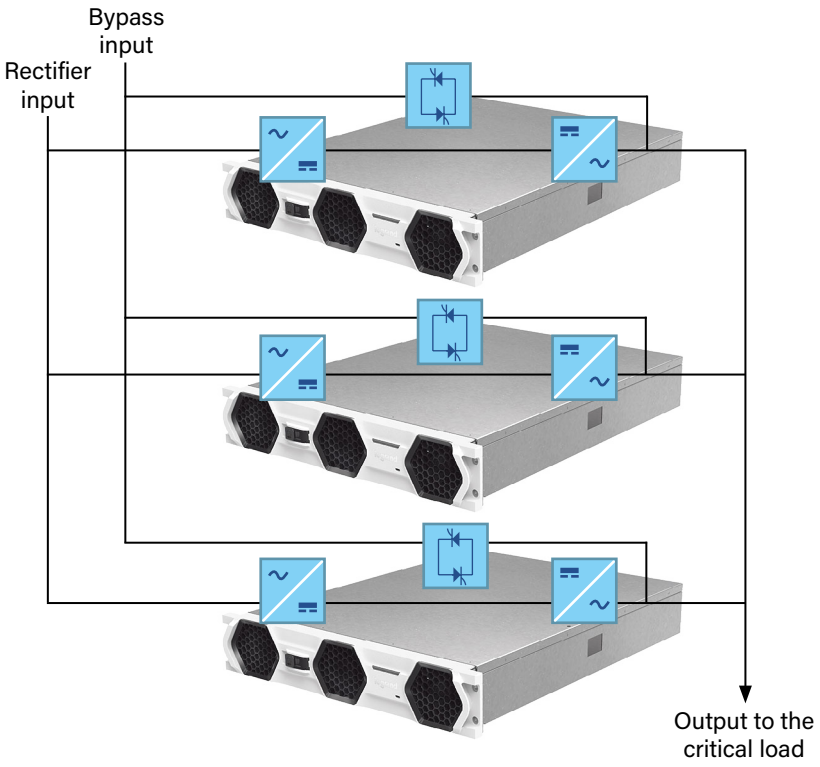


Figure 4: Modular UPS with N + X.

CONCLUSION

The MTBF of a stand-alone UPS with a static bypass line depends to some extent on the MTBF mains and the MTTRUPS.

Paralleling UPS units for redundancy increases system reliability significantly because the MTTR UPS is very small compared to the MTBF UPS of each individual module.
Paralleling UPS just for power decrease the system reliability introducing additional single point of failures compared to the case of only one unit.

Modular UPS are more complex respect Conventional UPS because composed by more blocks. In “Not Redundant” configurations increasing number of modules could have negative effects on the MTBF but this is balancing by the big advantage of very short MTTR, which brings high level of Availability.
Modular UPS in “N + 1 Redundant” configurations can reach even higher Availability thanks to the very high level of decentralization and redundancy with many independent modules in parallel.

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS

Conventional UPS transformer free

KEOR T EVO 10-60 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9995 %	2.4	437000	5 Nines
N + 1	99.9996 %	2.0	487000	5 Nines
2N	99.9987 %	2.8	219000	4 Nines

KEOR HPE 60-80 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9997 %	1.5	490000	5 Nines
N + 1	99.9998 %	1.0	490552	5 Nines
2N	99.9993 %	1.6	245000	5 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Conventional UPS transformer free (continued)

KEOR HPE 100-160 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9994 %	2.9	463000	5 Nines
N + 1	99.9994 %	3.0	487000	5 Nines
2N	99.9986 %	3.5	250000	4 Nines

KEOR HPE 200-300 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9993 %	3.3	460000	5 Nines
N + 1	99.9994 %	3.0	487000	5 Nines
2N	99.9982 %	4.1	230000	4 Nines

KEOR HPE 400-500-600 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9993 %	3.3	480000	5 Nines
N + 1	99.9994 %	3.0	487000	5 Nines
2N	99.9983 %	4.1	240000	4 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Conventional UPS transformer based

KEOR HP 100-160 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9990 %	4.0	437000	5 Nines
N + 1	99.9993 %	3.0	487000	5 Nines
2N	99.9971 %	5.7	219000	4 Nines

KEOR HP 200-300 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9990 %	3.9	490000	5 Nines
N + 1	99.9993 %	3.0	490552	5 Nines
2N	99.9971 %	5.6	245000	5 Nines

KEOR HP 400-500 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9990 %	4.4	463000	5 Nines
N + 1	99.9992 %	4.0	487000	5 Nines
2N	99.9971 %	6.0	250000	4 Nines

KEOR HP 600-800 kVA

Result	Availability	MTTR (h)	MTBF (h)	Nines
Single UPS	99.9991 %	4.4	437000	5 Nines
N + 1	99.9993 %	4.0	487000	5 Nines
2N	99.9974 %	6.2	219000	4 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Modular UPS

KEOR MOD		Non-Redundant Configuration		
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
25	99.9997 %	1.7	665000	5 Nines
50	99.9997 %	1.5	549000	5 Nines
75	99.9997 %	1.3	467000	5 Nines
100	99.9997 %	1.2	407000	5 Nines
125	99.9997 %	1.1	360000	5 Nines
150	99.9997 %	1.1	323000	5 Nines
175	99.9997 %	1.0	293000	5 Nines
200	99.9994 %	1.3	234000	5 Nines
225	99.9994 %	1.2	204000	5 Nines
250	99.9994 %	1.1	180000	5 Nines

KEOR MOD		N + 1 Redundant Configuration		
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
25	99.9999 %	0.40	670000	6 Nines
50	99.9999 %	0.41	580000	6 Nines
75	99.9999 %	0.43	500000	6 Nines
100	99.9999 %	0.44	450000	6 Nines
125	99.9999 %	0.45	390000	5 Nines
150	99.9999 %	0.47	330000	5 Nines
175	99.9998 %	0.48	300000	5 Nines
200	99.9998 %	0.50	275000	5 Nines
225	99.9998 %	0.51	260000	5 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Modular UPS (continued)

TRIMOD HE	Non-Redundant Configuration (for both 1-phase and 3-phase)			
Power kW	Availability	MTTR (h)	MTBF (h)	Nines
10	99.9996 %	1.6	430000	5 Nines
15	99.9996 %	1.6	430000	5 Nines
20	99.9996 %	1.6	430000	5 Nines
30	99.9996 %	1.3	370000	5 Nines
40	99.9996 %	1.3	370000	5 Nines
60	99.9996 %	1.2	310000	5 Nines
80	99.9997 %	1.1	310000	5 Nines

TRIMOD HE	3-phase N + 1 Redundant Configuration			
Power kW	Availability	MTTR (h)	MTBF (h)	Nines
10	99.99989 %	0.50	465000	5 Nines
15	99.99989 %	0.50	465000	5 Nines
20	99.99989 %	0.50	465000	5 Nines
30	99.99988 %	0.50	420000	5 Nines
40	99.99988 %	0.50	420000	5 Nines
60	99.99987 %	0.50	390000	5 Nines

TRIMOD HE	1-phase N + 1 Redundant Configuration			
Power kW	Availability	MTTR (h)	MTBF (h)	Nines
5	99.99990 %	0.50	485000	6 Nines
6.7	99.99990 %	0.50	485000	6 Nines
10	99.99988 %	0.50	420000	5 Nines
13.3	99.99988 %	0.50	420000	5 Nines
15	99.99987 %	0.50	371400	5 Nines
20	99.99985 %	0.50	332800	5 Nines
25	99.99983 %	0.50	301500	5 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Modular UPS (continued)

TRIMOD MCS	3-phase Non-Redundant Configuration			
Power kW	Availability	MTTR (h)	MTBF (h)	Nines
10	99.9996 %	1.6	430000	5 Nines
15	99.9996 %	1.6	430000	5 Nines
20	99.9996 %	1.6	430000	5 Nines
30	99.9996 %	1.3	370000	5 Nines
40	99.9996 %	1.3	370000	5 Nines
60	99.9996 %	1.2	310000	5 Nines
80	99.9997 %	1.1	310000	5 Nines

TRIMOD MCS	3-phase N + 1 Redundant Configuration			
Power kW	Availability	MTTR (h)	MTBF (h)	Nines
10	99.99989 %	0.50	465000	5 Nines
15	99.99989 %	0.50	465000	5 Nines
20	99.99989 %	0.50	465000	5 Nines
30	99.99988 %	0.50	420000	5 Nines
40	99.99988 %	0.50	420000	5 Nines
60	99.99987 %	0.50	390000	5 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Modular UPS (continued)

TRIMOD MCS	1-phase Non-Redundant Configuration			
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
3	99.99908 %	0.80	86200	5 Nines
5	99.99908 %	0.80	86200	5 Nines
6.7	99.99908 %	0.80	86200	5 Nines

TRIMOD MCS	1-phase N + 1 Redundant Configuration			
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
3	99.99990 %	0.50	485000	6 Nines
5	99.99990 %	0.50	485000	6 Nines
6.7	99.99990 %	0.50	485000	6 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

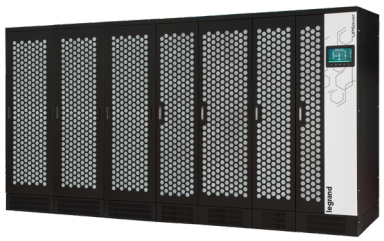
Modular UPS (continued)

KEOR XPE	Non-Redundant Configuration			
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
600	99.9995 %	4	792000	5 Nines
750	99.9993 %	4	590000	5 Nines
900	99.9993 %	4	590000	5 Nines
1000	99.9992 %	4	470000	5 Nines
1200	99.9992 %	4	470000	5 Nines
1500	99.9990 %	4	390000	5 Nines
1800	99.9990 %	4	390000	5 Nines
2100	99.9987 %	4	300000	5 Nines

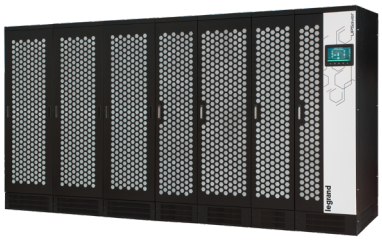
KEOR XPE	N + 1 Redundant Configuration			
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
600	99.9997 %	3	880000	5 Nines
750	99.9995 %	3	665200	5 Nines
900	99.9995 %	3	665200	5 Nines
1000	99.9994 %	3	534000	5 Nines
1200	99.9994 %	3	534000	5 Nines
1500	99.9993 %	3	446000	5 Nines
1800	99.9992 %	3	383000	5 Nines

RELIABILITY VALUES FOR LEGRAND SYSTEM 3-PHASE FAMILIES AND MODELS (continued)

Modular UPS (continued)



UPSaver	Non-Redundant Configuration			
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
670	99.999907 %	2.27	2449186	6 Nines
1000	99.999901 %	1.84	1866674	6 Nines
1340	99.999895 %	1.58	1508011	5 Nines
1670	99.999889 %	1.40	1264961	5 Nines
2000	99.999883 %	1.27	1089383	5 Nines
2340	99.999876 %	1.18	956605	5 Nines
2670	99.999870 %	1.10	852678	5 Nines



UPSaver	N + 1 Redundant Configuration			
Power kW	**Availability**	**MTTR (h)**	**MTBF (h)**	**Nines**
670 + 1	99.999913 %	2.14	2480149	6 Nines
1000 + 1	99.999910 %	1.69	1893702	6 Nines
1340 + 1	99.999907 %	1.42	1531557	6 Nines
1670 + 1	99.999904 %	1.23	1285687	6 Nines
2000 + 1	99.999901 %	1.09	1107839	6 Nines
2340 + 1	99.999898 %	0.99	973215	5 Nines

NOTES



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