TECHNICAL NOTE

Understanding Static Transfer Systems and their impact on the Power Availability and Continuity

When **energy** matters

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Innovative Power Solutions

Introduction

SITE 1038 A

What is Power Availability?

"A perfect power supply would be one that is always available, always within voltage and frequency tolerances, and has a pure noise free sinusoidal wave shape. Just how much deviation from perfection can be tolerated depends on the user's application, the type of equipment installed and his view of his requirements."
(Chapman, 2001)

As practical consequence the Power Availability is directly related to the quality of the power supply and the tolerance of the load. For critical application the power supply coming from utility grid will not be able to reach the requirements to ensure the service continuity.
The usage of Uninterruptible Power Supplies (UPS) can be a way to improve the power quality and availability. Static Transfer Systems (STS) is another/complementary mean to improve the power availability and installation flexibility.

In this paper we will focus on the impact of the usage of STS and more especially Statys on the power supply Availability and how it can improve installation flexibility and maintainability.

Contents

Load tolerance

The power utility characteristics are defined in the standard EN 50160 - Voltage characteristics of electricity supplied by public electricity networks.

The standard takes into consideration all the voltage related perturbations, among the others:

- **Frequency** for systems with synchronous connection to an interconnected system
  - 50 Hz ± 1 % (i.e. 49.5 Hz... 50.5 Hz) during 99,5% of a year,
  - 50 Hz + 4 % / - 6 % (i.e. 47 Hz... 52 Hz) during 100 % of the time.
- **Voltage**
  - Under normal operating conditions excluding the periods with interruptions, supply voltage variations should not exceed ± 10 % of the nominal voltage Un.
- **Harmonics**
  The THD of the supply voltage (including all harmonics up to the order 40) shall be less than or equal to 8 %.
- **Short interruptions** are considered to have durations not exceeding 1 minute.

It is very clear how some accepted performances of the mains are totally incompatible with loads that must assure service continuity. Here bellow the different types of critical loads.

ICT Loads

The Computer and Business Equipment Manufacturers' Association (CBEMA), based on the experience on the field, agreed on a best practice to build the IT equipment. Such best practice defines the ability of ICT equipment to withstand voltage perturbations and it is under form of a curve. It has been modified several times, chiefly in response to technological developments in electronic equipment, and is now known as the Information Technology Industry Council (ITIC) curve. The latest and most realistic version of the curve for contemporary computer equipment is shown in Figure 1.
The duration of an event is shown as a function of voltage, with reference to the rated load voltage and the curves which define the envelope within which the equipment should continue to operate, without interruptions or loss of data. With regard to dips, it is necessary to refer to the lower limit line.
This line represents the dividing line between dips which have no effect and those with problematic consequences.

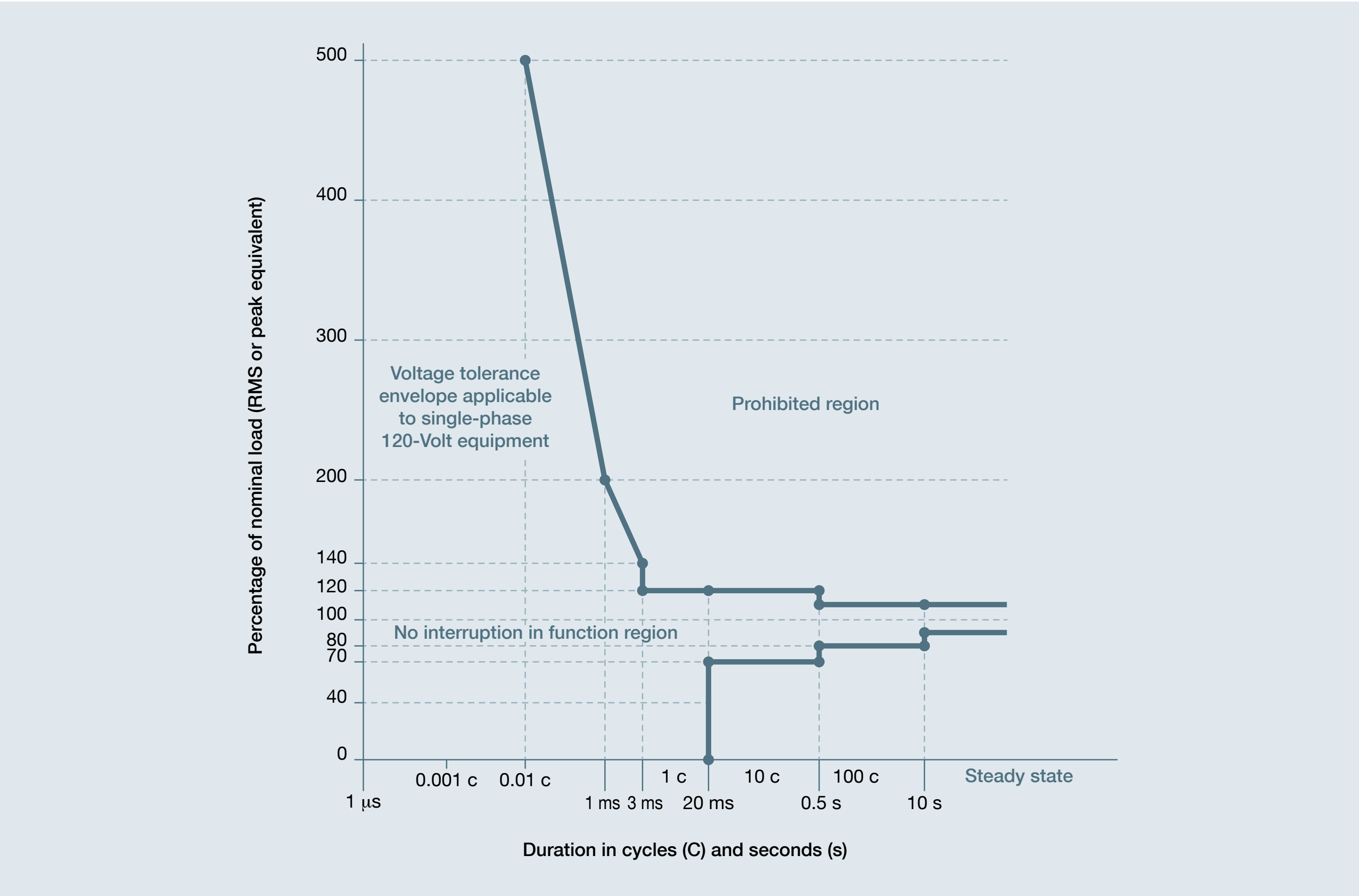

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Fig. 1 - ITIC Curve Revision 2000 (Information Technology Industry Council - www.itic.org).

Lights

Lights are typical able to sustain voltage variations of ±10% their nominal voltage but technical sensitive to many power quality problems. Limiting the dissertation to over or under voltage and outages, as done for ICT loads, the most critical application must be considered: emergency lighting systems. In such case EN 50171 states:
In general two different modes of power supply are defined, i.e. the changeover mode and the mode without interruption. The main difference is the response (changeover) time. In the changeover mode, the response time shall be no more than 0,5 s whilst in the mode without interruption, the supply is permanent so, by its nature, there is no response time.

Motors

Like lights, motors are normally able to operate with slow voltage variations within the range of ±5% the rated one but only ±2% their nominal frequency at nominal power without over temperatures (Zone A of Figure 2). They can, anyway, operate temporary with wider variations, but anyway limited to Zone B of Figure 2, at a cost of higher losses.

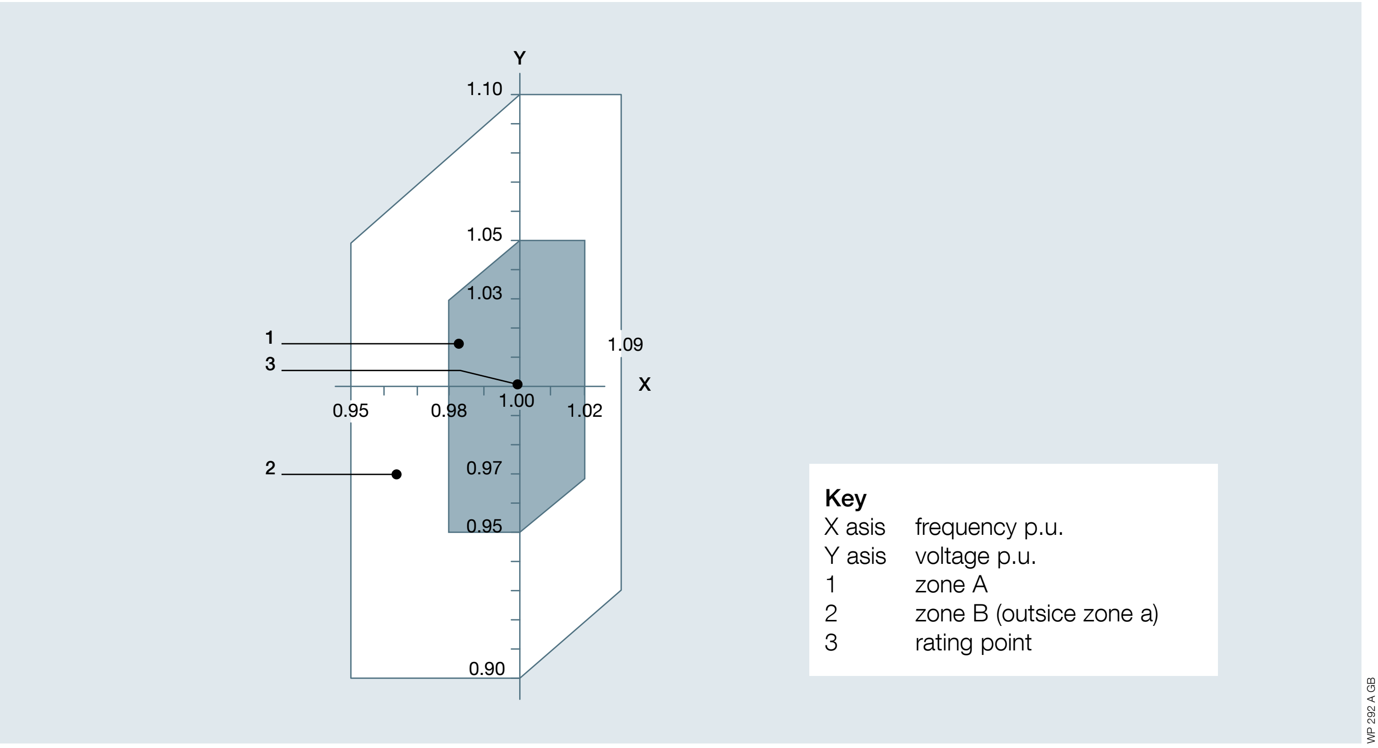

Fig. 2 - Voltage and frequency deviation in zones A and B.

How the motor behaves to fast variations is quite complex and depending from both aspects electromagnetically (impedances and magnetic energy in the iron) and mechanical (speed and inertia).
If such behaviors are almost neglectable when a motor is used for ventilation, it may be critical when it is part of an industrial process where fine control of speed and torque is crucial.

As VSD is also a load, the designer has also to do a cross check between its tolerances and the main power quality: UPS or STS may be necessary.

What is an STS ?

The STS are intelligent units with two inputs and one output. The intelligence is given by one or more microcontrollers and the switch between the sources is given by the coordination of two SCR.

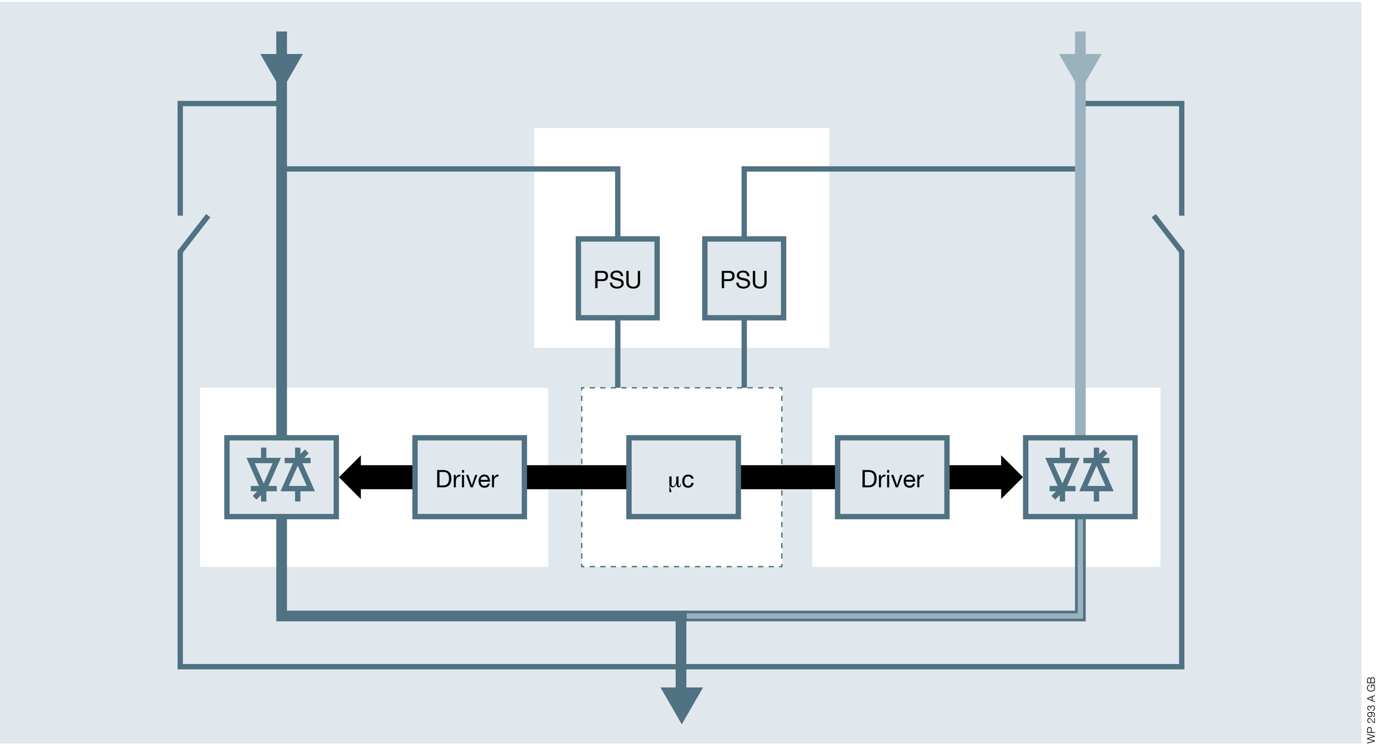

Fig. 3 - Principle scheme of an STS.

In the event that the power source supplying the load gets out of its tolerances, the STS transfers it to an alternative source with better power quality. This ensures «high availability» of the power supply for sensitive or critical installations.

Typical time for the transfer is around 4-6 ms (less than a cycle) which is within tolerances indicated in ITIC curves.
The STS provides also an extra layer of protection during maintenance actives or during abnormal event like human error, catastrophic failures or downstream perturbation.

In case of a downstream perturbation on a single source, all the loads connected to it are affected by the electrical default (Figure 4). It can take several milliseconds for the protections to clear the fault and, if this time gets longer than 20 ms, the healthy ICT loads in parallel with the faulty one may power-off (Figure 1). STS can protect the different loads by avoiding them to be supplied by a perturbed source by means of fast transfer to the alternate healthy source (Figure 5). This increases the energy available to tripping the protection with a consequent faster clearance.

Fig. 4 - Downstream failure.

Fig. 5 - STS transfers healthy loads to alternate source keeping the faulty one on the original.

Fig. 6 - Once the fault has been cleared, the STS get back to the main source.

The STS gives its maximum advantage being installed close to the load since it makes the upstream distribution cable as redundant. This, together with a wise layout of the facility (UPS in different electrical rooms and different cable pathways), increases the resilience of the power supply of the loads.

Summing-up, the purpose of STS devices is to:
- **ensure the continuity of the power supply by bringing redundancy closer to critical installations,**
- **increase power supply reliability for sensitive installations,**
- **facilitate the installation maintainability by not having to do specific manipulation on the power distribution (bypass etc.),**
- **prevent fault propagation by isolating it and transferring the remaining loads,**
- **simplfy the design and expansion of installations that guarantee a high-availability power supply.**

How does an STS switch

The preset and suggested transfer mode of Statys is Break-Before-Make (BBM). Make-Before-Break (MBB) transfer while being technically possible is rarely used due to the risk involved in overlapping two independent sources. Indeed, overlapping two independent sources would lead to uncontrolled current between them. Therefore, BBM is the preferred and most used transfer type as it avoids overlapping the phases of each sources.

Once the STS detects an anomaly in the conducting source, it takes the decision to transfer and has to wait until the current crosses zero only if there is no downstream short-circuit. Before closing the SCR of the alternate source it is necessary to introduce a little delay to avoid the Reverse-recovery effect typical of semiconductors.

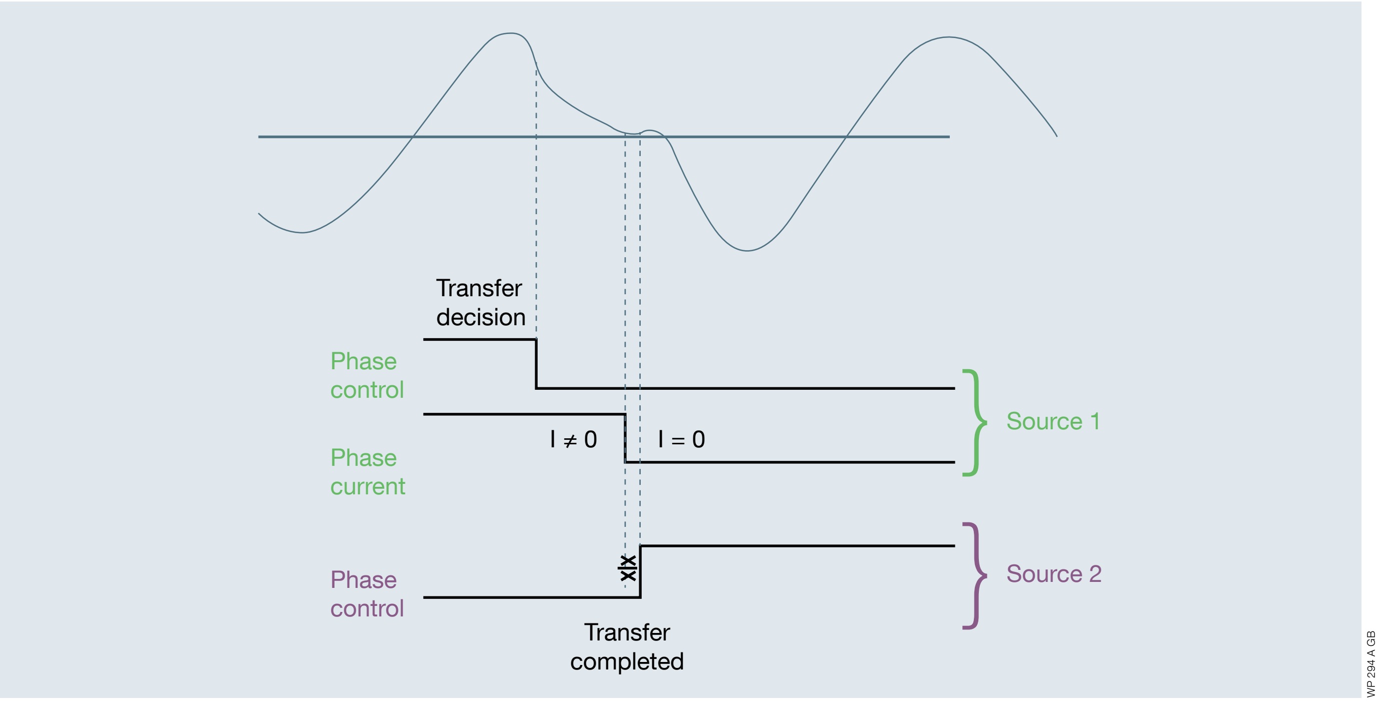

Fig. 7 - Transfer process of a BBM - Focus on one phase only.

Figure 8 extends to all the phases what introduced with Figure 7. To optimize each phase transfer time, the BBM transfer process is applied phase per phase. Particular attention deserves the neutral that is overlapped to ensure reference and path the first current of the alternate source and last phase of the original source. This overlap does not exceed 10 ms.

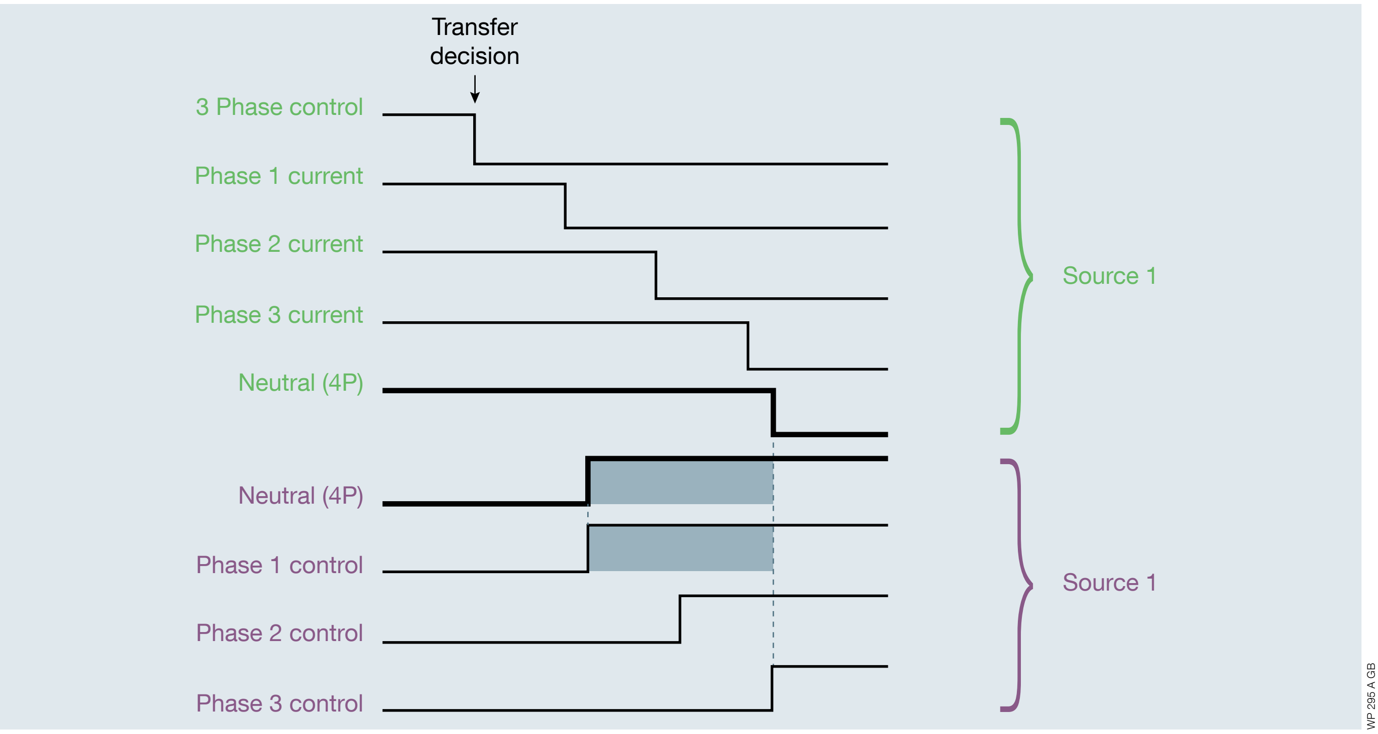

Fig. 8 - Transfer process of a BBM three phase STS.

STS performance definition

Standard IEC 62310-3 establishes a code that clearly defines the performance of a STS.

XX	YY	B	TS

Fig. 8 - Transfer process of a BBM three phase STS.

Where:

• XX characterizes the management of the fault current
- CB, STS: with integrated breakers or fuses capable of bearing and of breaking specified short-circuit currents, or,
- PC, STS: without integrated breakers or fuses capable of withstanding specified short-circuit currents but not intended for breaking short-circuit currents.

• YY refers to the neutral management characteristics
- 00: no neutral management,
- NC: both input neutrals are combined,
- NS: separation of the two input neutrals by switching,
- NI: neutral separation by isolation transformer (typically external to the machine).

• B are the transfer characteristics
- B: break-before-make (open transition transfer), there is no conduction path between the two sources during switching,
- M: make-before-break (closed transition transfer), conduction possible between the two sources during switching.

• TS characteristics of the voltage limits permitted by the critical load
- T: total transient time to the terminals of the load, including switching time,
- S: voltage tolerance before the transfer process is activated.

Differences between an STS and an electro-mechanical changeover

(Transfer Switching Equipment – TSE IEC 60947-6-1)

The TSE has two inputs and one output like the STS but the main difference the switches are made by mean of mechanical switch that can be controlled manually or automated. As consequence the speed of the transfer is in the range 200 ms – 3 seconds.

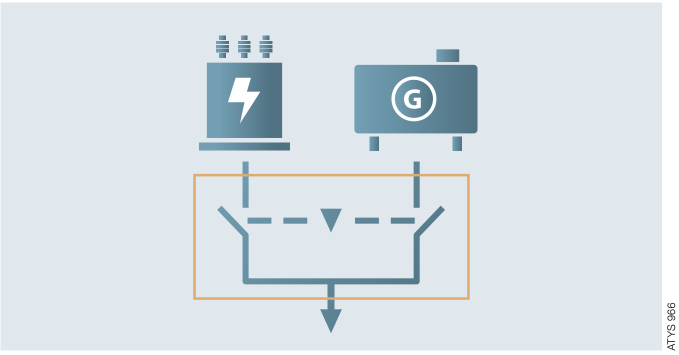

Fig. 9 - Changeover switch.

Due to its operating time, the TSE may cause outages not compatible with the loads therefore it is often used upstream the UPS, that assure no interruption, or directly with the load that do not need absolute continuity. TSE and STS just have different fields of application.

What are the critical components inside an STS and what are the strategies to increase their resiliency

Going to the essentials the STS is made by the following components that are critical for its proper workings.

- **SCRs**
  Semiconductors that operate as static switches. Two of them per phase in antiparallel are necessary since they conduct current in one direction only. To conduct, each of them needs to be switched-on every period (Fig. 10).

- **Drivers**
  PCB necessary to switch on the SCR when they are supposed to conduct.

- **Microcontroller**
  "Brain" of the STS necessary to take the decisions (e.g. when to switch from one source to the other) and notifying alarms but not necessary to keep the STS in the "as-is" status.

- **Power Supply (PSU)**
  PCB with that supplies the STS itself.

- **Fans**
  Devices necessary to generate the airflow to dissipate the losses of the STS avoiding over temperatures.

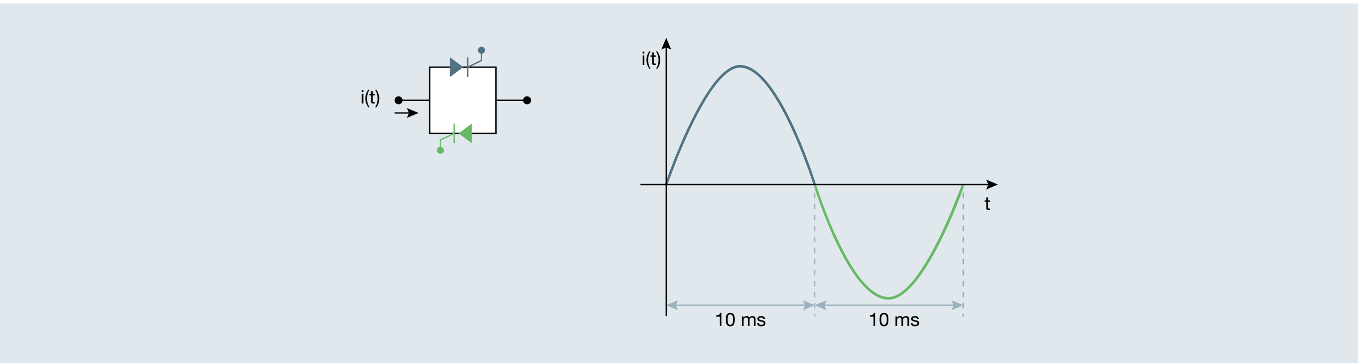

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Fig. 10 - Example of single-phase conduction of SCR at 50 Hz.

SCR

The SCR is one of the most robust and reliable semiconductor for its relative simplicity and the long presence on the field (the first thyristor devices were released commercially in 1956). They are used as static bypass for the UPS and typical MTBF magnitude is between 10 to the power of 6 and 10 to the power of 7 hours, depending on the size and the quality of the component.

However, any default has to be taken into account. Therefore, in case the SCR is faulty, Statys will automatically react to ensure the load remains powered. An alarm will be displayed to inform the user the presence of a default.

In the first case the STS automatically switches to the healthy path with a concurrent alarm to the BMS.
In the second case, Statys is able to detect the failure even if the SCR is not conducting and, in case of anomalies the transfer gets inhibited and an alarm is sent to the BMS.

Driver

In case of driver failure, its SCR cannot be switched on and consequently conduct. In normal conditions the logic to manage the situation is similar to the SCR failure even if Statys family has an "high available" version (Fig. 1) with independent redundant drivers boards getting the unit robust to a first failure.

Power Supply (PSU)

The STS on the market have by standard two independent power supplies connecting, each of them connected to one of the two sources.
The concurrent failure of a PSU and the outage of the other source causes the unit power-off.
The most common strategy is to notify the failure by BMS but, also in this case, the "high available" version of Statys has dual redundant power supply to be robust to a first failure of a PSU (Fig. 11).

Microcontroller

The failure of the microcontroller inhibits the capability of the STS to discriminate the Power Quality levels of the sources and the capability to choose the most indicated one for the load. Any anomaly to the microcontroller is not propagated to the other components of the STS since they continue to perform their own tasks.
The typical behaviors of the STS are to keep going the status they are with a concurrent alarm via BMS. The "high available" version of Statys has two independent redundant microcontrollers able to take over all the decision process in real time.

Stays "Maximum Fault Tolerance" version

STS needs to be reliable and fault tolerant. Statys comes in two versions to meet different customers' requirements.
The two versions are based on the same internal architecture that is fault tolerant to the first default.
Fig. 11 shows the architecture of the "Maximum Fault Tolerance" version of Statys.

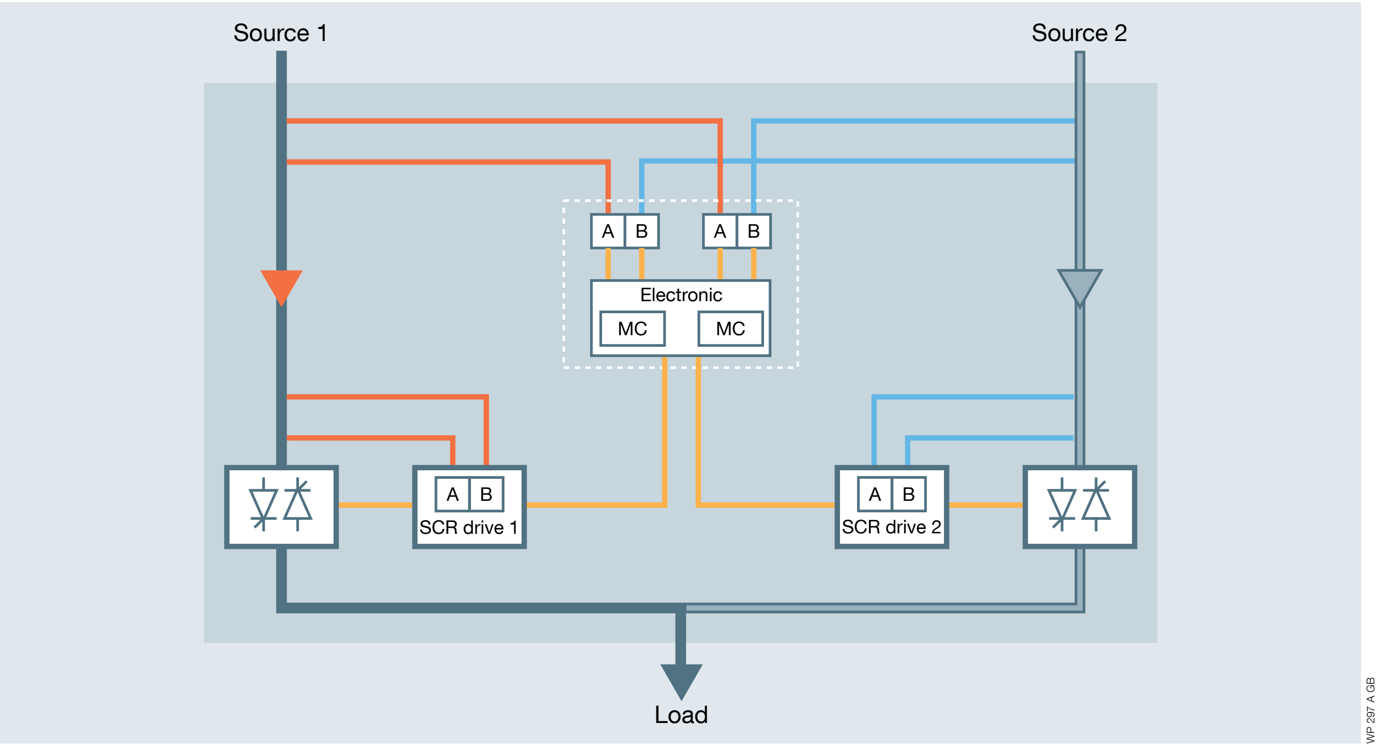


Fig. 11 - Principle scheme of an STS.

Fans

Fans failures may drive to over temperatures and consequent self-disconnection for its own protection.
Statys range by standard has fan failure detection and redundant cooling.

Auto-hold

Redundancy is key to ensure load protection in case of internal default. To protect the load form consecutive failure of the electronics, Statys integrates a function "Auto-hold" that ensures that Statys will continue to conduct even if all the internal control boards are dead.

How to select the right STS

The size of the STS is done in accordance to the current that flows through it in conjunction with other main electrical characteristics. Summing-up:

- current RMS,
- Transient Current:
  - inrush or transient current of transformer (See ATSM in “Special case of transformer”),
  - motor/pumps (transient and start up),
- voltages and Phases,
- grounding system (TN-C, TN-S, TT or IT).

How to define rated current based on load behavior.

- $S_{load\ i}$ is the apparent power of the single load downstream the STS,
- V_n is the phase voltage,
- U_n is the line voltage.

Single-Phase	Three-Phase
$I_{1ph} = \frac{\Sigma_i^n S_{load\ i}}{V_n}$	$I_{3ph} = \frac{\Sigma_i^n S_{load\ i}}{U_n \sqrt{3}}$

In case of non-balanced three-phase systems the STS has to be sized considered the most loaded phase. It is also possible to feed single phase dispatch on the 3 phases of a 3 phase STS IT application is commonly using this. Here the STS need to the sized to the most loaded phase.

In case of loads with inrush currents (e.g. induction motors), they have to be kept into considerations with their contemporaneity factor and, due to their limited duration, the option of using the overload capability of the STS can be done (otherwise we just have to oversize the STS and choose a bigger one).

The right Statys for the grounding

Table 2 sums up the Statys to use according to the plant grounding. It is built considering two independent sources with grounded secondary at MV/LV transformer, in case of TN and TT or IMD* in case of IT system.

As a quick reminder Statys exist in 3 versions:

- With no distributed neutral 3W3P
- With switched neutral 4W4P
- With non-switched neutral 4W3P

For 3 wires network there is only 1 solution available, but for a 4 wire network we need to take grounding into account.
The detailed explanation of the choices is given for the three-phase case but it is valid also for the single-phase.

** IMD: Insulation Monitoring Device.*

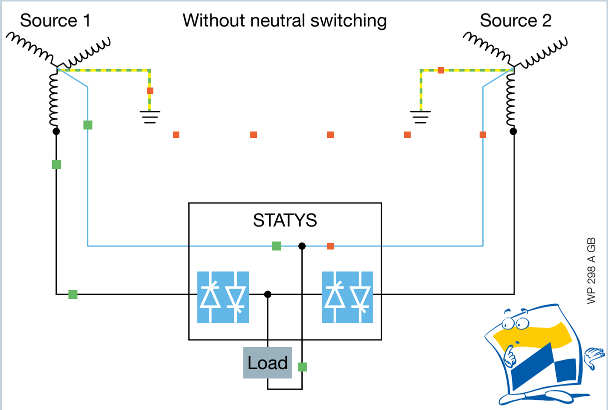
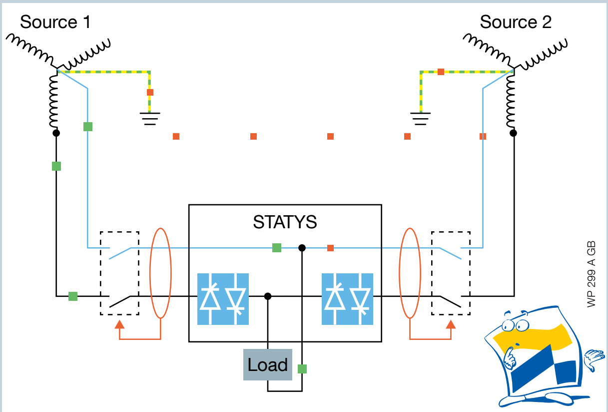
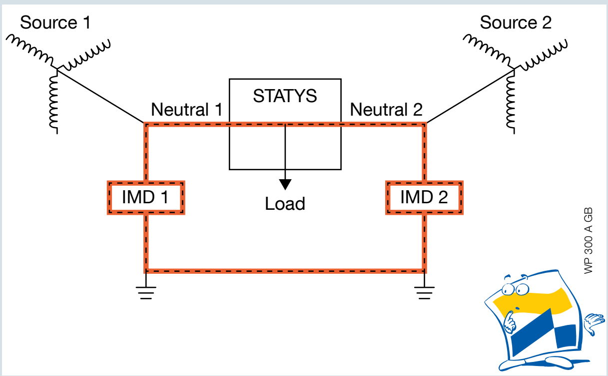
	Single-Phase	Three-Phase
TN-C	2-wires/1-pole switching (Rare case cable must be 10mm^2 min)	4-wires/3-poles Electrical installation standard forbid the switching of the PEN in TN-C network
TN-S	w/o RCD: 2-wires/2-poles switching is suggested	Electrical installation standard forbid to connect two TN-S networks together. Therefor for TN-S network : 4-wires/4-poles is mandatory. w/o RCD* : Current circulation can occur due to unbalanced loads or different ground impedances. A 4W4P prevent this current circulation Here what happens if neutral is not switched. 
	w/ RCD: 2-wires/2-poles switching	w/ RCD: 4-wires/4-poles will prevent spurious tripping due to the current circulation between the two sources that can occur 
IT with Neutral	2-wires/2-poles switching	w/ distributed Neutral: 4-wires/4-poles switching Is required otherwise the two IMD are in parallel and they measure a impedance reduction w/ consequent alarm  w/o distributed Neutral: 3 wires/3-poles switching
TT	2-wires/2-poles switching	4-wires/4-poles switching because normally RCD are present and the situation get similar to TN-S with RCD

Table 2 - Type of STS according to the grounding system.

** RCD: Residual Current Device.*

The short circuit capability of the STS

In case of short circuit downstream the STS, SCR cannot interrupt a current until it crosses the 0 value. During a downstream short-circuit this means there is no limitation and a limitation must be provided externally via an appropriate protective device. If there is no limitation and the peak current is higher than I_{TSM}* the SCR fails due to the short circuit or overcurrent.

The failure due to short circuit normally results in a permanent short circuit of the SCR itself; the semiconductor is no longer able to interrupt the current therefore it is permanently in conduction (basically it fails “closed”).

In extreme conditions, in case of wrong installation design, when the short circuit current is very high, an explosion can occur.

The tripping current for the protections, breakers or fuses is always referred to in RMS values, while the maximum surge current of the semiconductor, I_{TSM}, and components are peak values of sinusoidal waves.

The easiest and safest way to select the protection for the STS is to refer to those suggested in the manufacturer’s user manual. In it, the manufacturer evaluates the characteristics of the protections to be effective in safeguarding the SCR (considering the installation short-circuit currents) and, at the same time, to be sized as big as possible so as not to jeopardise downstream selectivity. Referring to the STS manufacturer’s indications also has the advantage that the unit’s operation may be tested, as a minimum at the development stage.

As anticipated, STS are divided into two categories:
- CB, STS: with integrated breakers or fuses capable of bearing and of breaking specified short-circuit currents, or
- PC, STS: without integrated breakers or fuses capable of withstanding specified short-circuit currents but not intended for breaking short-circuit currents.

Table 3 shows typical withstand capability of the STS according to their class and size.

	Mono.		**Tri.**										
Statys Rating (A)	32	63	63	100	200	300	400	600	800	1000	1200	1600	1800
Fuse (uR)	/	/	315 A	315 A	400 A	630 A		1000 A	1800 A		2x1400 A		
Statys withstanding (I2t)	No CB	No CB	12 000	12 000	19 000	54 000	54 000	240 000	880 000	880 000	932 400	932 400	932 400

Table 3 - CB Classe i²t.

Statys behavior in case of overload

In case of overload there are two cases:
1. both sources are available,
2. only the conducting source is available.

In the first case, Statys can takes advantage of both available source to optimize the maximum overload up to 1,5 times the overload time. To reach this value, Statys transfers to the alternate source at half the overload time. Statys can now stay the full overload time on the alternate source and therefore reach 1,5 times the overload capability of the single SCR.
In the second case only the conducting source is available it is totally exploited for 100 % of its capability.

** I_{TSM}: Peak value for a surge current in the form of a single sinusoidal half wave which lasts for 10 ms.*

Statys behavior in case of non-synchronized source

Statys has no problem in switching between non-synchronized sources even up to 180° degree phase-shift. On the other side not all the loads has the same tolerances in differences between the phase-shifts. For this reason it is always advisable using synchronized sources (e.g. UPS with synchronization cards). If the load is sensitive to phase shift and we are not able to synchroniz the sources (due to restrication in the instalation) For that particular cas, it is possible to set Statys to inhibit the transfer in case non-synchronization. This protects the load from potential damages (motors, etc.).

As an exmple IT loads are not sensitive to phase shift but other loads like motors and pumps can be :
in this case it is preferable to sychronize the sources or to adapte the Statys Configuration (See bollow the different type of transfer)

Special case of transformer or induction motor downstream

Transformers and induction motors are characterized by inrush current at start-up due to the magnetization of their core but, such behavior happens also when there is a sudden/step change in the voltage phase due to magnetic flux phase itself. In the worst case the value of the current could be much higher than the start-up inrush current therefore it may trip the upstream protections even if well selected (consider the upstream protection has the role to protect the cables and the STS itself).

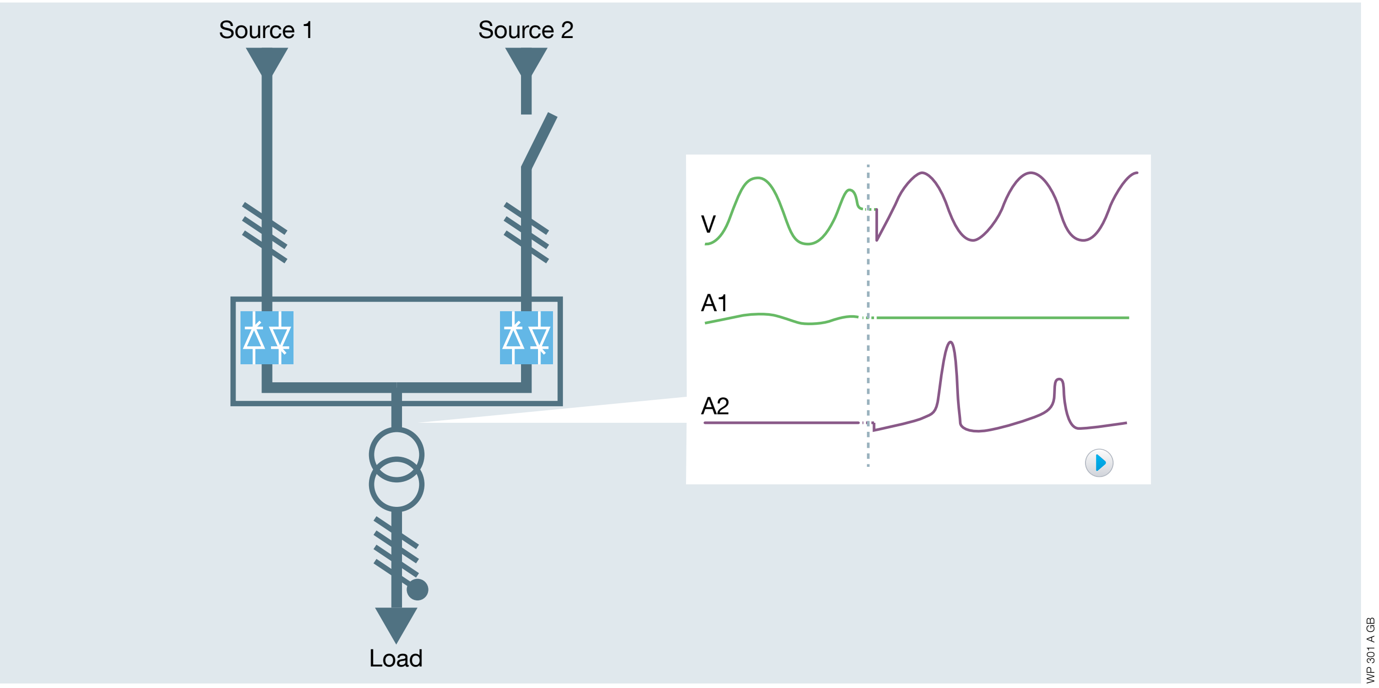


Fig. 12 - Special case of transformer or induction motor downstream.

In case of an outage of the conducting Source with a secondary source non synchronized, the switching may cause a spurious protection tripping with consequent load power-off.

Statys, to avoid this problem, has a function named “Advanced Transformer Switching Mode” (ATSM) that prevents this phenomenon.
- No more transient current after a transfer and no voltage perturbation.
- No risk to trip the upstream protection.
- No stress on the upstream UPS.

Customized transfer managment: Statys can also be customized for specific application like airport landing lights that need specific timing: Statys can manange gen set start up by adding longer energy reserve to the Std solution. Statys has also been selected to be instaled in isolated airport as it was able to be customized to match the specific transfer needs required for this application.

What is the difference between automatic and manual transfer?

Statys has some pre-set threshold that act as reference for deciding the level of quality of the sources. Once the conducting source is outside the tolerance, at the first opportunity (zero crossing of the current of the conducting source) it starts the process of changing the source.

When the operator decides to command a manual transfer, Statys may introduce a little delay, limited to one or two cycles, to choose the best moment to switch In case the sources are sliding, Statys can delay the transfer up to a few soconde in order to perform a synchrone transfer. Normally, this does not happen in “emergency” reason but for maintenance or load balancing for the sources.

The contribution of an STS on the system reliability

$$A = 1 - \frac{MTTR}{MTBF}$$

MTBF

- MTBF (Mean Operating Time Between Failures) the average time between two events that cause the exit of power supply from the loads tolerances.
- MTTR (Mean Time To Restoration) the time for the power supply to get back to acceptable conditions for the loads.

The mean availability can be defined using the simplified formula:

$$A = 1 - \frac{MTTR}{MTBF}$$

Equation 1 - Simplified formula for Mean Availability.

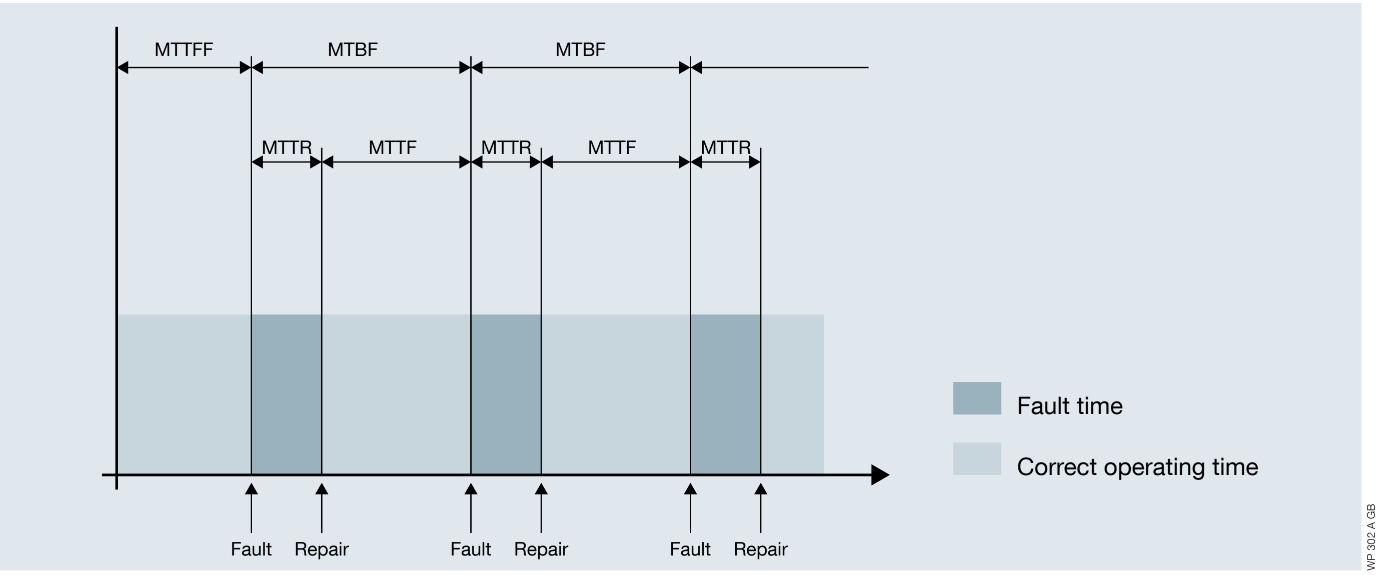


Fig. 13 - Time visualisation of relation between MTBF and MTTR where MTTFF is the Mean Time to First Failure.

While MTBF depends on the components of the system, the plant in our case, and the architecture (fault redundant), the MTTR depends on the ease to repair and aftersales coverage (e.g. time-on-site of the aftersales engineers, spare parts availability, contracts).
More orthodox definitions can be found at **Electropedia: The World's Online Electrotechnical Vocabulary (IEC 60050).**
At a first glance the STS is often dismissed quickly because considered as a Single Point of Failure (SPoF). Indeed it is, if the analysis is limited only to it, but it changes drastically the distribution architecture allowing redundant not mutual influencing paths. It is easier to understand the concept thinking to the opposite: a common distribution bus bar with two redundant cableways directly connected to it going directly to the load. In case of abnormal event, until the protection trips, both the paths have a voltage perturbation. The STS segregate the two paths avoid mutual influence at a price of a SPoF with very low failure rate (λSTS).

Here bellow the failure rate and MTBF comparison:
- $\lambda_{UPS} \approx$ 2 860 FIT (350 000 h MTBF)
- $\lambda_{cable/m} \approx$ 1 FIT* (10^9 h MTBF)
- $\lambda_{parallel}$** $\approx$ 100 FIT (10^7 h MTBF)
- $\lambda_{STS} \approx$ 150 FIT (6.67 • 10^6 h MTBF)

The above numbers are from high quality products available on the market, both UPS and STS. It is clear how STS, and Statys in particular, are much more reliable than UPS.

** Failure In Time (FIT) is another way of reporting MTBF. FIT reports the number of expected failures per one billion hours of operation for a device ($\lambda=10^{-9}$).*
*** $\lambda_{parallel}$ is the failure rate of all the subsystems that grant the proper parallel working (e.g. parallel cards, firmware part related to load sharing, etc.).*

Why an STS could be useful also with dual corded servers

Today, most of the servers are dual corded. It is natural to wonder what are the advantages of using an STS with loads that have already native dual input.

There reasons are different:

- **Power availability**
  - not all the servers have a monitoring system of the of the proper functioning of their PSU (Power Supply Units),
  - PSU of the units are not always sizes for the full power of the server, the outage of a source may drive to an overload of the only working PSU,
  - the complication of the installations and their constant modification over the years is continuously increase and the human error of connecting both PSU to one source is not so remote,
  - the number of the loads affects their availability, the failure to one of them may be propagates to the others therefore the higher is the number of the loads, the lower is their availability.
- **Infrastructure optimization**
  - when maintenance operations are planned on a UPS branch and we need to switch off this branch, servers will still have power from the other path. Servers' PSU would see no power and with consequent alarm to their owners. With an STS, maintenance is transparent to the load avoiding potential claims,
  - the use of STS may help in reaching high levels of power availability controlling the costs.
- **Site flexibility**

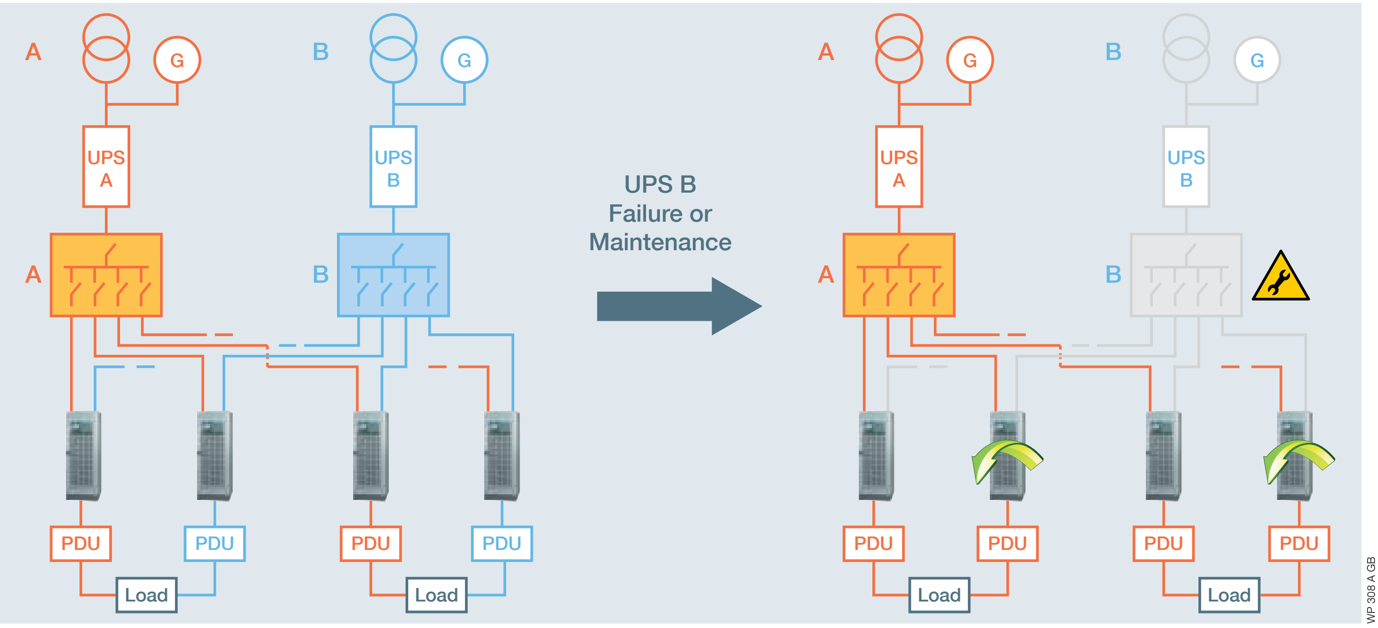


Fig. 14 - Example of usage of STS with dual corded servers.

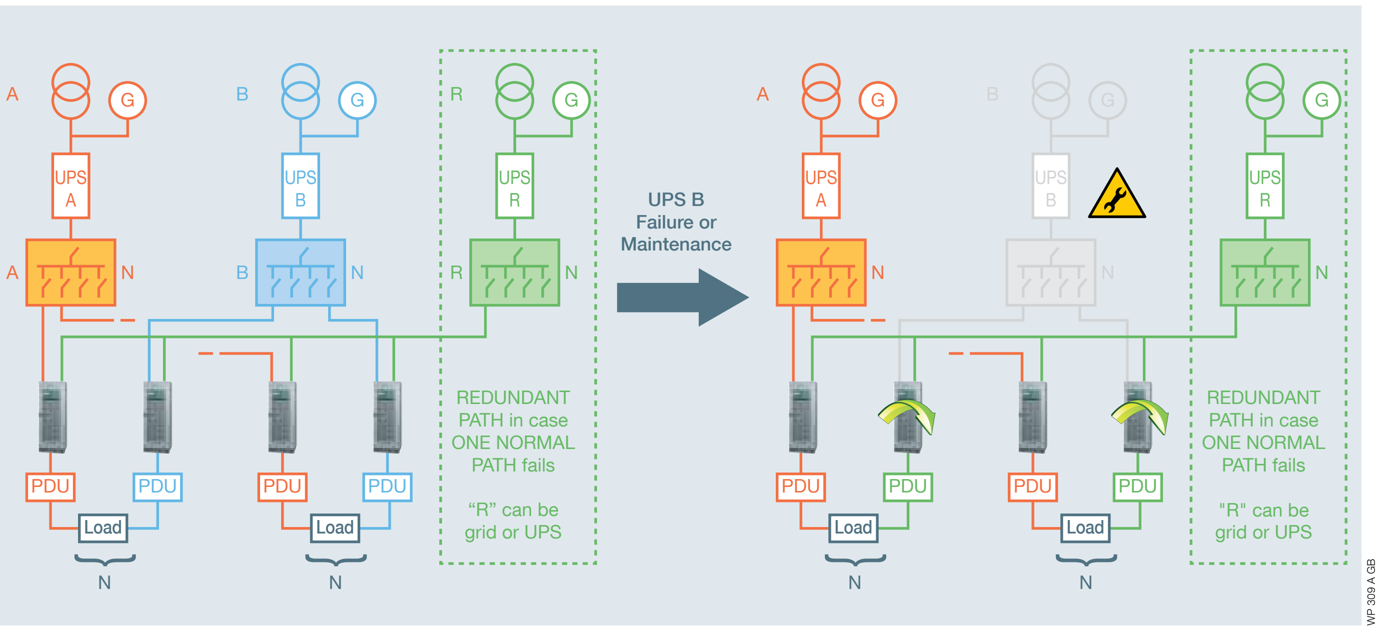


Fig. 15 - Example of the "catcher" architechture (redundant path in green). It is not necessary having a UPS, an alternate grid may be used.

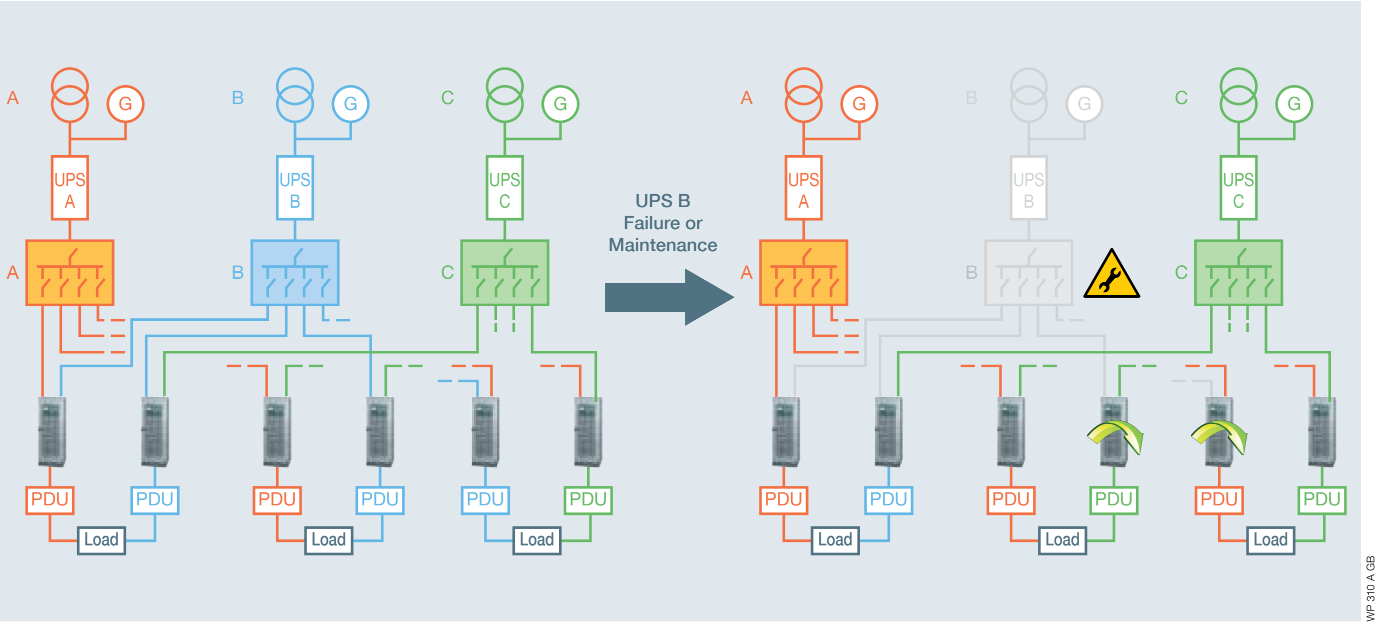


Fig. 16 - Multi-source architecture 2N/3 & 3N/4: similar to 2N in term of availabily and "1.5N" in term of costs.

How to calculate the TCO of an STS?

Whereas it is quite simple to estimate the Total Cost of Ownership of an STS itself as CAPEX and OPEX, it is very complicate to calculate the real Total Cost of Ownership of the complete distribution because it depends on:
- architecture (e.g. number of power branches, redundancy and active or passive paths),
- physical layout (e.g. location of the STS, civil works and cable length),
- CAPEX (e.g. STS, cables, protections and installation labor),
- OPEX (e.g. efficiency, service contracts and consumables).

And, the most important,
- cost of downtime.

The latter can be estimated only by the end user considering:
- the cost per minute of downtime,
- the cost per event of downtime, such
  - loss of production
  - loss of raw materials, loss of production capacity,
  - reparations,
  - damages to equipment or penalties.

Figure 17 shows example of typical hourly costs for downtime for industrial companies whereas Table 5 show the global losses in Datacenter industry based on a survey counting 241 respondents worldwide.

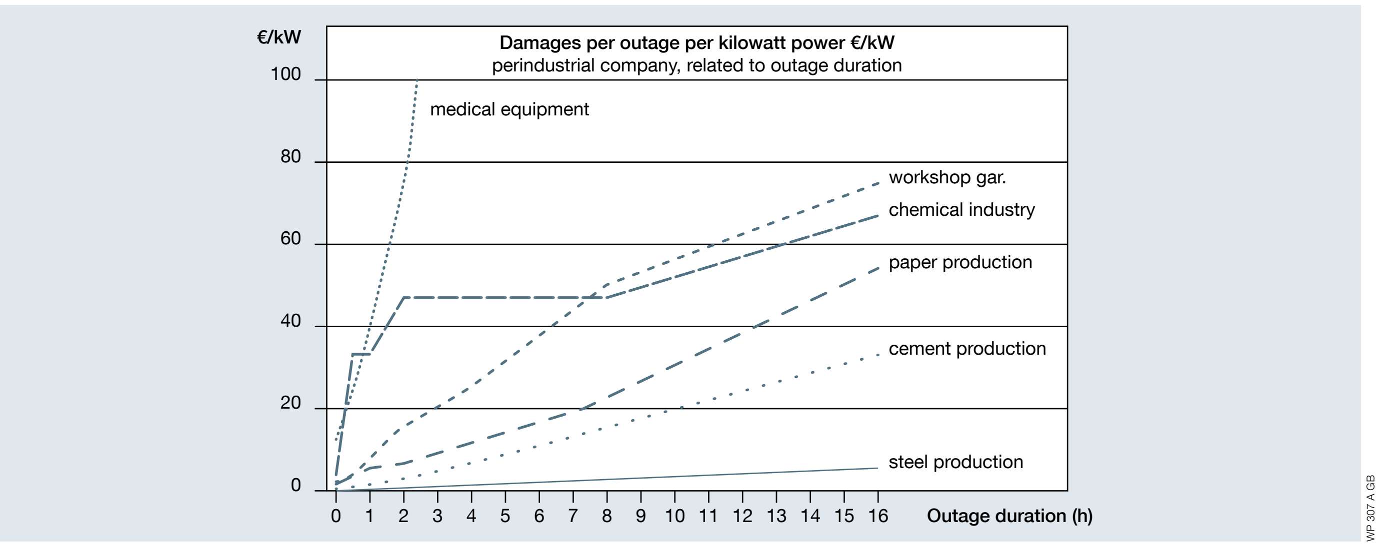


Fig. 16 - Interruption costs as a function of outage duration, KEMA 2005.

Cost ($ million)	%	Number of incidents
< 1	50.55	137
1 - 2	6.27	17
2 - 5	4.43	12
5 - 10	0.74	2
10 - 20	1.85	5
20 - 50	0.74	2
> 50 million	0.37	1
Did not calculate	35.05	95

Table 4 - Cost per incident in Datacenter industry. Uptime Institute, 2018.

Evidence the advantages in the use of an STS for reducing the probability of a Critical Failure (λ_{CF} reduction) has already provided. A way to estimate the annual cost of downtime could be

$$Annual\_Cost\_of\_Downtime = \lambda_{CF} \cdot Average\_Cost\_per\_event\_of\_Downtime$$

Considering both scenarios, with and without the STS architecture and comparing them.

CAPEX and OPEX: STS vs UPS

Most of the people are already familiar with UPS its comparison with the STS can help to understand the magnitude of the costs.

	UPS	STS
Cost	100 %	50-60 %
Efficiency	96.5 % (VFI)	99 %
Consumables	Fans, Capacitors, Batteries	Fans
Footprint	100 % (w/o batteries)	85-90 %

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