Automatic Transfer System
Generic book
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1. Preface

This documentation is an overview of the Automatic Transfer Systems with the associated benefit is to improve supply availability by automatically switching from main supply to an alternative source in case of main supply failure.

Most Industrial and Building installations like XL Datacenters, Oil & Gas and Mining projects include ATS function in MV and LV networks.

ATS is also a key element in other segments like Healthcare, Water & Waste Water and Marine.

This document is for general use and can be distributed internally and externally.
2. Introduction

Fault and outages on the electrical power are many and of various origins with immediate impacts on the industrial business and the life of people. It is true that no 100% secure power may be proposed, different specific and efficient concepts are available in line with the international and local standards and regulation to increase significantly the site reliability.

The resilience to electric power supply fault is done by providing adapted grid design, mapping the loads in secure paths and implementing stand-by redundant power sources.

In this global picture, the Transfer Switch (TS) is the most common solution applicable in most of the electrical Industrial and Building networks from Low Voltage (400 V) to Medium Voltage (66 kV). The present document gives a picture of the actual Automatic Transfer System (ATS) market in Industry & Building applications, a list of the competitors, the detailed functions and applicable standards to choose the most adapted solution.

2.1. Version management

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<th>Date</th>
<th>Authors</th>
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<td>B. ANDRE/</td>
<td>Final document</td>
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2.2. Drawings and Colour codes

In the different SLDs and drawings used in this document, the following colour conventions are applied:

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<tr>
<th>Ref</th>
<th>Description</th>
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<tbody>
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<td>🐊</td>
<td>Use to represent Line or Generator powered elements (&gt;80%Un)</td>
</tr>
<tr>
<td>🐋</td>
<td>Use to represent the Generator starting (20% &lt;Un &lt; 80%)</td>
</tr>
<tr>
<td>🐐</td>
<td>Use to represent Line or Generator non-powered element (&lt;20%Un)</td>
</tr>
<tr>
<td>Action</td>
<td>Description</td>
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<tr>
<td>------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Close Switchgear</td>
<td>Use to represent powered load (&gt; 80% Un)</td>
</tr>
<tr>
<td>Open Switchgear</td>
<td>Use to represent non-powered load (&gt;20% Un)</td>
</tr>
<tr>
<td>Electric fault</td>
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3. Electrical outages in Industry & Building sites

3.1. Power availability for Industrial plants and Building sites

Power availability is a key criterion for Industrial plant or Building site capability. Any interruption of the Electrical Distribution at MV or LV level has a direct impact on the Plant production, the Building availability and more important may create Human impact.

Power availability is measured through the time the Industrial plant or Building site electrical installation is operational and able to deliver the nominal electrical power needed. This global availability is directly derived from the individual element availability and their interconnection (or electrical topology).

Each equipment failure and time to repair this failure directly impacts the availability of the plant. It is measured in % based on the following formula:

\[
\text{Availability (\%)} = (1 – \frac{\text{MTTR}}{\text{MTBF}}) \times 100
\]

- MTBF (Mean Time Between Failure) is the mean time between to failure for a given equipment
- MTTR (Mean Time to Repair/restore) is the mean service time needed to repair/restore the installation after a failure

Having a 100% availability rate means that MTTR of the Industrial plant or Building site grid (MV & LV) is turn to zero or the MTBF is infinite.

This is unfortunately unrealistic, but various solutions exist to get as close as possible to these ideal. It can be achieve by:

- Reducing the MTTR through an adapted electrical architecture with well positioned redundant elements
- Increasing the MTBF through the adapted choice of electrical components and equipments in line with the environment

![Figure 1: MV power availability comparison](image-url)
As shown in the upper figure, the most efficient solution is to build where it is needed in the Electrical Distribution network, redundancies to reduce the MTTR and increase the effective availability.

This is mainly achieved at two levels:

- **MV level**
  - Redundant MV power circuits (Main and back-up MV incomers),
  - Back-up MV power supply (Main MV incomer + MV back-up generator).
- **LV level**
  - Redundant LV power circuits (Main and back-up LV incomers),
  - Back-up LV power supply (Main LV incomer + LV back-up generator set or genset or LV UPS).

For all these architectures, it is possible to have:

- 2 actives circuits (both powered) which on case of any failure will allow the transfer of the load to the other one (typically between to lines or two generators)
- 1 active circuit with all loads connected and in case of failure transfer of all loads to the other one (typically switch between a line and a generator)

The final Industrial plant or Building site Electrical Distribution Solution will combine the different MV & LV redundant solutions to achieve the site availability level.

### 3.2. Why Transfer Switch is required?

The main requirement for the transfer switch is to maintain a high electrical distribution availability rate and to avoid long interruptions at MV and LV levels.

Two main types of failures are considered for the Electrical power supply design:

- Failures of the Utility connections,
- Failures in the industrial plant lines
  - local generation
  - transformer
  - distribution line

The convention commonly used to dimension the risk and the power supply availability for critical process is the “N-1 rule”. It considers that at any moment the loss of any power source (Utility connection or local power generation) shall not create any impact on the facility power supply. This rule may impose specific dimensioning of the Utility power sources and feeders and also may modify the type of Generator to be used for the back-up power supply (diesel to gas e.g.).
3.3. Transfer Switch definition

If it is not controlled, the disappearance of the 'main' power supply of a facility is an event with potentially serious consequences, endangering the occupants, disrupting critical activities and causing economic loss.

A standby power supply (second line or a standby generator) is the commonly adopted solution to temporarily supply power when the main source fails. An immediate and reliable service is expected, whatever happens to the electrical installation.

The TS function is to commute the 'main' power supply to the 'standby' one in case of a power outage to still supply loads. It is mainly done automatically in the shortest time (but can be initiated manually for maintenance purpose).

The TS can be implemented in different manners; it depends on the customer electrical distribution architecture complexity. It can be a dedicated equipment where all sub-functions are integrated in “one box” or it can be a system composed of sub-assemblies when the architecture is more complex or if a higher performance is required.

But in any case, the TS remains an important part of the distribution architecture with a lot of interfaces with electrical devices.
3.4. Automatic Transfer System description

The ATS as a global concept includes different items:
1. The primary switching element (Circuit Breaker, Switch or Contactor)
2. The Automatic function that could be included in a physical IED/controller (PLC or RTU) or virtualized over various IED/controller performing other functions (protection, measurement IED, process PLC, etc...)
3. The physical housing or cabinet where all equipment are integrated
4. The associated engineering including the setting and configuration

The following elements are NOT considered as part of the ATS but as separated elements even they interact with the ATS
1. The cable and other electric wiring elements including the connectors
2. The IED performing other functions (protection, measurement IED, process PLC, etc...),
3. The external sensors to collect logic and analogue data (U, I, Pos, …),
4. The communication elements (gateway, network, etc...),
5. The support & services such as FAT & SAT,
6. The associated ancillary features such as: load-shedding, generator cooling...

3.5. Transfer Switch segmentations

3.5.1. Functional segmentation
The TS market despite the voltage domains or the segment applications can be cut into three parts:
1. The Static Transfer Switch (STS), based on semiconductors and as involving no moving part allows to switch in less than half a cycle
2. The Manual Transfer Switch (MTS), requires an operator action to switch from one source to the other using traditionally a Change Over
3. The Automatic Transfer System (ATS).

We have in the document only considered the ATS part.

3.5.2. Voltage segmentation
We have only focused in this document on the ATS in LV (<1 000 V) and MV (<66 kV) and for AC electrical applications in Industry and Building applications (Utility applications are treated in a separated document).
3.5.3. The ATS type definition

The ATS market can be segmented based on the physical constitution of the supply:

- ATS package (IED/controller + Switching devices + local panel)
- ATS IED/controller (only the intelligent and logic part)

The ATS package is only available for LV applications (< 1 000 V) and referring to the IEC 60947-6-1 is spitted in 3 switching device categories:

- CB type: ATS Based on a pair of circuit breakers

- PC type: Changeover based on a pair of switches

- CC type: Changeover is made of a pair of contactors
4. The ATS functions

The main objective of the ATS system (in LV and MV) is to increase the availability level of the electrical power supply. In case of fault, the ATS automatically transfer the load to a Back-up power supply and return back to Main supply when its power is restored. Main supply is usually the utility grid while Back-up supply can be another utility line or local generator set.

The ATS function includes three main components:

1. MV or LV switchgear with integrated current and voltage sensors (usually CTs and VTs),
2. Intelligent Electronic Device that monitors the main and back up sources and is programmed to control the operation of MV or LV switchgear associated with the main and back-up source,
3. Ancillary devices (HMI/SCADA, auxiliary power supply, protection relays, communication interface, etc).

The management of the ATS switching is based on two steps:

- Transfer of the power from the Main feeder to Back-up power feeder upon switching condition
- Return from back-up power feeder to Normal power feeder after clearance of the switching conditions

The ATS is the result of 5 different functional modules:

- Transition type defining how is manage the return phase : Close or Open,
- Involved power sources on Main and Back-up Line or Generator,
- Grid load with the various types of elements connected,
- Grid architecture with 2 or 3 feeders and bustie (real or virtual),
- Applicable ATS standards mainly from IEC, IEEE, NFPA or other committees.

The combination of all functions coupled with external ATS modules such as Protection and Measurement IED, Circuit Breaker or Operation modes define the ATS solution and associated performances.
Figure 3: ATS influencing factors

WARNING: Care must be taken with vocabulary to avoid confusion:

- ATS acronym is derived from Automatic Transfer System. However this definition is inaccurate because the MV/LV switchgear is often a Circuit Breaker (not a Switch) and the ATS includes the IED/Controller and other ancillary devices. For this reason, the ATS acronym definition proposed in this document is Automatic Transfer System.
- ACO is used to describe the Automatic Change-Over product. Many manufacturers in LV applications do not differentiate ACO from ATS
- AMF stands for Automatic Main Failure. This is a basic ATS which involves LV single phase or 3 phase emergency stand-by low power LV generator (< 50 kW) used in buildings and residential markets.
5. The ATS transition function

The ATS transfers are done using two main concepts:

- Open transition while during a certain time the installation is not powered,
- Close transition with dual connection for a certain time of both power sources.

These transitions apply to the Transfer (Normal to Back-up) and Return (Back-up to Normal) actions.

**Note:** Various ATS performance ranges are listed in the ATS functional documents

### 5.1. Open transition

The sequence of operation is also called "Break before Make". It prevents back feeding from an emergency generator back into the utility line, for example.

![Figure 4: Open transition](image)

Depending on application, site grid, voltage level and performance requirements, the open-transition transfer principle is divided into 4 categories (see §12 ATS Grid load management):

- Normal
- Time-delay
- In phase
- Fast

#### 5.1.1. Normal Open transition

The ATS pauses before disconnecting from one power source and connecting to the other. Most transfer switches will accomplish the transfer sequence very quickly, yet a brief power interruption is noticeable to the occupants, and is most certainly noticed by sensitive electronic equipment. For a small business or residential installation, without sensitive loads, or large inductive (motor) loads, this solution is generally acceptable.
The ATS Normal Open characteristics are:
- Transfer with no voltage (no coupling with grid),
- No need for synchronization when the secondary source is a generator,
- Power cut on loads.

The ATS Normal Open sequence is:
- Temporisation: validation time to confirm the failure of the current source and the availability of the second sources
- Open the CB of current supplied line
- Close the CB of the other source

5.1.2. Time-delay Open transition
A transfer switch with “delayed-transition” control logic will still provide a break-before-make transfer sequence. However, this type of equipment will disconnect from one source, and then “pause” (or delay the transition) before it proceeds to connect to the alternate source.

The Time-delay Open ATS Characteristics are:
- Transfer with no voltage (no coupling with grid)
- No need for synchronization when the secondary source is a generator,
- Power cut on loads

The Time-delay Open ATS sequence is:
- Temporisation: validation time to confirm the failure of the current source and the availability of the second sources
- Open the CB of current supplied line
- Temporisation to delay the closing
- Close the CB of the other source

5.1.3. In-phase Open transition
With in-phase open transitions, the ATS IED/Controller closes at the exact moment both power sources are synchronized (phase angle, voltage and frequency values in a compatible bandwidth). This avoids instability of the network, excessive inrush current, generator swing or motor slip
If synchronization doesn’t occur within that time span, some transfer switches have the ability to default automatically to a delayed transition that serves as a failsafe. This sequence is only uses when the both sources are available (return or manual transfer) and can’t be used on source failure.

The In-phase Open ATS Characteristics are:

- Transfer with no voltage (no coupling with grid),
- No need for synchronization when the secondary source is a generator,
- Power cut on loads.

The In-phase Open ATS sequence is:

- Quick detection of the current source failure and the availability of the second source,
- Open the CB of current supplied line,
- Close in phase of the CB of the other source.

### 5.1.4. Fast Open transition

Residual-voltage and delayed bus-transfer operations often result in severe process upsets or complete loss of plant production.

The Fast Open ATS is performed to limit the time while the motor is disconnected from the Power source. The Fast Open ATS is executed in less than 3 to 5 cycles in order to ensure that the motor has not slow down more than 15 to 20% of it reference speed.

The Fast Open ATS characteristics are:

- Transfer with no voltage (no coupling with grid),
- No need for synchronization when the secondary source is a generator,
- Not visible Power cut on loads.

The Fast Open ATS sequence is:

- Quick detection of the current source failure and the availability of the second source,
- Open the CB of current supplied line,
- Close of the CB of the other source in a limited delay.
5.2. Close transition

A Close-transition ATS is often also named « Make-before-Break » sequence. During the ATS Close transition, the current source remains connected (SW close), until the alternate source is also connected (SW close). After both have been connected (SW close), the current source is disconnected (SW open). The key to this Close transition ATS sequence is that provides a continuity of power to the load during transfer (i.e.: no power interruption).

Two conditions are mandatory to achieve a Close transition ATS closed-transition.

1. If the site is connected on the Utility grid (MV or HV), the close connection concept must be allowed by the Utility grid code. It often imposes Open transition, sometime accepts short duration close transition and seldom accepts smooth transition. A Close transition for a very short duration could be accepted as long as this does not impact the Utility grid stability and if an agreement has been preliminary done with the Utility.

2. Both sources must be synchronised before any closing action. In case of a generator, this imposes to have a synchro-coupling IED acting on the generator frequency, voltage value and phase angle. For two lines a synchro-check relay is needed to ensure that the two lines are synchronised before CB closing.

These two conditions require special accessories and depending on the configuration, closed-transition transfer switches can be further divided into three sub-categories:

- Passive,
- Active,
- Soft loading.

In addition of Utility approval, some protective relaying may also be required by the Utility. Close transition is used for a return to normal condition case when the power is back on the main source, or for an intentional switching to a secondary source for maintenance purposes.

Figure 5: Close transition
The device used to check the synchronization of two sources is called ‘synchronisation check relay’ or a ‘source differential sensor’. The relay enables transfer between live sources only when the two sources have a maximum voltage differential of 5%, frequency differential of 0.3 Hz and are within 10 electrical degrees. In case of a generator, a synchro-coupling relay is required to control voltage, frequency and phase angle of the generator before coupling.

**WARNING**: Closed transitions can produce higher fault currents, due to the period when both power sources are paralleled. As a result, the consulting engineer may specify a higher Withstand Close-on Rating (WCR), which could require oversizing the electrical distribution equipment short circuit withstanding characteristics.

### 5.2.1. Passive Close transition

It is the simplest form, whereby the synchronization is left to the slip frequency of the generator. The two sources are connected to the load only when the synchro-check relay allows it. Once the alternate source is connected (SW close), the primary source is immediately disconnected (SW open in less than 100ms). It is important to note that when two sources are left to synchronize on their own, the time needed to achieve synchronization varies from one occurrence to the next. If the timing is important, the ATS control logic can be programmed to revert to an Open-transition ATS if a Close-transition ATS cannot be completed within a predetermined time frame. Likewise, it is standard practice for these ATS to revert to an Open transition, should either source completely fail while waiting to synchronize.

### 5.2.2. Active Close transition

For the Active Close-transition, the synchronization is actively controlled by an automatic synchronizer, and the generator is “driven” to synchronize with the utility. Similarly to the Passive Close mode, once the alternate source is connected (SW close) the primary source is immediately disconnected (SW open). This mode of operation is not difficult to achieve, but it requires that the engine’s governor control be accessible to the ATS.

### 5.2.3. Soft loading Close transition

This mode can be described as a brief paralleling mode, whereby the synchronization is controlled by an automatic synchronizer. As before, the generator is brought into synchronism with the utility; but it is now connected (SW close) to the bus without load.

A load-sharing module will then ramp the load from the existing source to the oncoming source over a short period of time (typically 2 to 10 seconds). Once the load has been fully transferred, the primary source is disconnected (SW open).
**Note:** This transfer sequence can be performed in both directions, from normal to back-up, or from back-up to normal sources.

The main benefit of this configuration is the gradual transfer of the load, which provides smoother transitions and less wear and tear to the engine, generator and transfer switch components. This application is commonly seen at larger airports where the air traffic control and other navigational aids are often transferred from a “good” normal source to the emergency source in anticipation of bad weather.

Once the threat of bad weather has passed, the load is transferred back gradually, all without a power interruption to the facility.

When considering this option, be sure to consult with the local utility company as this application involves paralleling with the utility, and strict controls will be needed to maintain the safety of the utility's service personnel.
6. The ATS grid architectures

The main role of the ATS is to recover power supply to the load after a failure of the utility supply connection or of a local generator supply. It is the common point of coupling between a failed and a safe source, thus it is critical to have a system reliable and responsive to any orders (manual or automatic) whatever the situations.

But the ATS behaviour can be different between two critical applications; the reason is the value the customer wants to prioritise:

- Safety: Prevent unexpected energisation
- Service continuity: Ensure the load are always supplied

The transfer switch architecture is depending on the distribution network topology thus has got several configurations:

- 1/2 Transfer scheme
- 2/3 Transfer scheme
- Multiple Transfer scheme

6.1. 1/2 Transfer Scheme

This is the standard case to transfer load from a main source to a back up source without bus coupling CB (BusTie).

The electrical scheme of a transfer 1/2 is defined by the following figure:

![1/2 Single Line Diagram](image-url)

*Figure 6: ½ Single Line Diagram*
In normal operation, only one source is connected to the busbar and supplies the loads.

When there is a loss of the ‘main’ source powering the busbar, the second source is connected which in turn supplies back the busbar.

6.2. 2/3 Transfer Scheme

This is the most common electric scheme used for ATS case with a very efficient redundancy management as power source could be operated in parallel.

The electrical scheme of a transfer 2/3 is defined by the following figure:

In normal operation, the coupling circuit breaker (also called bus-tie) is in open position. Each source is powering half of the busbar.
When there is a loss of one source powering an half busbar, the coupling circuit breaker is closed which in turn energizes the busbar with the remaining source, thus all the loads.

![Figure 9: 2/3 Transfer scheme](image)

### 6.3. Multiple feeder transfer scheme

Other schemes exist for more complex topologies such as:

- One busbar supplied with 3 sources (with or without coupling circuit breaker)

![Figure 10: Multiple SLD with single BB](image)

The transfer switch is closely linked with the sources management (generators)

- A double busbar, each source and each feeder are associated with switches and a circuit breaker to enable a connection on the first or the second busbar.
In such a case there is no need for Automatic Transfer System between a main and a backup but it is a source management of the feeders giving the ability to reconfigure upon a source loss or a busbar failure.

- Load with double incomer connection case

Some critical loads are supplied with two incomers, in such case the Automatic Transfer System is implemented directly in the load control panel.
7. The ATS power source management

The ATS is per definition switching the power supply from one source to another. The type of Power source influences directly the performances of the ATS.

The type of power source influence directly the characteristics of the ATS, the linked performances and the associated elements

The traditional power source schemes are:

- Line to Line,
- Line to Generator,
- Generator to Generator.

Some specificity affects directly the different type of power source

- Utility incomer connection,
- Generator characteristics,
- Generator back-up connection.

7.1. Utility line connection

The most standard secured electric connection of an industrial site or building is to have

- Two MV or HV incoming feeder connections (two independent MV or HV lines) with an ATS in case of any failure affecting the grid (Line to Line scheme). This solution of redundant power lines with separated physical routes is considered as the most economical approach maximising the site or building power supply reliability. This avoid or minimise the lost of electrical power and impact on the Utility grid while using a single connection. The two lines must be if possible connected to separated Utility Distribution substations, ideally coming from separate parts of the National Grid (HV or EHV), with independent cable trenches to the plant.

- One incoming MV or HV Utility line and on site dedicated back-up generators able to supply all or part of the site or building electrical loads (Line to Generator scheme). In some segments like Hospital, Railways or Water treatment, the national or international standards or laws impose such architecture (NFPA, Hospital white book, …).

**Note:** To increase application availability and reduce fault dependability a double feeder + local back-up generation architecture is used (Line to Generator to Line).

The Utility Grid codes (specific to each Utility, voltage level and supply contract) define the applicable conditions for the transfer and the return mode of the ATS. It may impose to have only Open connection (never dual connection to the grid) or accept to have Close connection.
7.2. Generator power sources characteristics

When the transfer is carried out by a generator, special attention has to be paid to its characteristics which can determine the way the transfer shall be achieved.

The rated power, short-circuit power, connection impedances and earthing system of the replacement source may vary considerably from the main source. For example, the main source may be an 800 kVA, 380 V, 50 Hz, Isc = 20 kA transformer, whereas the replacement source is a 200 kVA generator, having a transient short circuit current of 1 kA.

Two specificities have to be considered:

- When the replacement source is a low power one, after the main source has switched to the replacement source, the inrush current and the permanent working current must be limited by partially shedding loads, staggering restarting of priority motors in the event of an interruption. If these measures are not taken, in view of the low power replacement source, voltage drops would be extremely serious and motor reacceleration impossible (driving torque lower than mechanical load torque).
- The resumption of supply of several loaded step-down transformers: When switching takes place in MV or HV, allowance must be made for the inrush currents of MV/LV or HV/LV transformers which are sometimes 10 to 15 times their rated current. In actual fact, if the replacement source is an LV generator, its generator cannot supply currents that high at rated voltage and acts as though it were supplying a short-circuit. It thus delivers a very low voltage for the first few moments after switching which does not simplify motor restarting for instance. Consequently, it is preferable to trip all the step-down transformers on the MV or HV side before switching, and then to re-energise them one after the other.

In addition, special care must be consider regarding the risk of harmonic level when generators are used due mainly to their higher impedance compare to the Utility grid towards harmonic currents. Also, it is recommended to switch off the capacitor banks when used to avoid resonance issue with the generators.

Taking into account these elements and upon the generator characteristics three transfer modes are possible:

1. Transfer with a smooth load ramp up after a blackout i.e. gradual load resumption
2. Transfer with a smooth load ramp up while being connected in parallel with the grid before cutting the main power supply
3. Transfer at full load pick up without the grid support
The connection of the generators in parallel with the utility (if allowed by the Utility grid code) imposes the use of a synchro-coupler device and an anti-islanding protection to isolate the industrial network.

### 7.2.1. Single Generator connection case

The single generator can be connected using two variants. Both are valid however according to the rating power of the generator the preference is to have the ATS running in the electrical switchgear.

In any cases a study shall be carried out to ensure the ATS is well coordinated with the upstream protection and selectivity is achieved and the operating mode is consistent with the Utility grids.

**Note**: Since October 10th 2015, the IEEE/IEC 62271-37-013:2015(E) standard is applicable for MV 3 phase AC Generator Circuit Breaker (GCB) designed for Generator >10MVA and for operation at frequencies of 50 Hz and 60 Hz on systems having voltages above 1 000 V and up to 38 kV. IEC/IEEE 62271-37-013:2015(E) standard is applicable to the operating mechanisms of GCB and to the auxiliary equipments.

### 7.2.2. Multi-Generator/Powerplant connection case

Complex architectures are using a generator powerplant with multiple feeders able to supply some switchboards. They are generally connected on a separate busbar. Each generator is connected to the busbar with a CB or SW for coupling with the others. Parallel coupling of generator is used to increase the standby power and also to compensate for any unavailability of a generator (maintenance, malfunction…)
An ATS is then located on each substation main switchgear. If close transition is intended, there is no interlocked between both ATS preventing the supply by the generators at the same time.

However a specific attention has to be paid on the operating mode of the transfer switch especially for the return to normal operation. Coordination between both ATS has to be implemented to prevent an automatic return to normal operation at the same time which could allows the connexion of all the production suppliers and exceeds the busbar limit (PCC constraints).

In addition, if a soft transition is chosen, the generator group will operate in parallel with the sources S1 and S2, which will be stringent for the switchgear ratings in term of short circuit withstanding.

**Figure 14: Multiple generator connection**
8. ATS Grid load management

A Loss of generation or Utility grid fault creates an immediate instability condition on the Industrial or Building MV & LV grid which directly impact to process rotating equipment (such as turbines/generators, pumps, fans, compressors and motors, etc.).

After the ATS sequence, the brutal reconnection of all loads may create instability over the grid and brutal inrush currents when all rotating machines try to reaccelerate at the same moment or when the power transformer is reenergized creating an inrush current that could reach 10 times the nominal current creating mechanical stress and harmonic injections.

The various MV or LV motors or MV /LV power transformers may also generate on the MV busbar voltage variations which crossed the voltage based protection threshold blocking the ATS or generating grid instabilities.

This figure shows 3 specifics opportunities for an ATS to act accordingly with the motor voltage. To avoid such constraint and risk over the Industrial or Building grid, four mains schemes are possible:

1. Fast ATS scheme (area 1)
2. In-phase ATS scheme (area 2)
3. Time delay ATS scheme (area 3)
4. Load shedding with sequenced Load restore

8.1. Fast ATS

The Fast ATS is performed to limit the time while the motor is disconnected from the Power source; During this time, the motor produce its own voltage which will slowly shift from the reference (phase and magnitude) as the motor slow down. When repowering the motor, the reacceleration requires a brutal current that may damage the machine if it exceeds a certain level (typically 1.3 Nominal current).
The Fast ATS is executed in less than 3 to 5 cycles in order to ensure that the motor has not slow down more than 15 to 20% of it referenced speed.

**Note**: It is strongly recommended before choosing Fast ATS to have a preliminary study of the MV & LV grid with the real motor characteristics.

### 8.2. In-phase ATS

The In-phase ATS is performed to avoid phase shift and mechanical impact on the motor; the ATS IED/Controller closes at the exact moment both power sources are synchronized (phase angle, voltage and frequency values in a compatible bandwidth). In addition this avoids instability of the network, excessive inrush current, generator swing or motor slip.

### 8.3. Time delay ATS

If a Fast ATS could not be performed, the alternative is to let all motors slow down and stop before restarting them. In this case the ATS time is much longer and depends of the motor; typically the Transfer time is between 5 to 30 seconds and can be check before repower to ensure that no brutal inrush current will append.

The time computation is done by a predefined value (Time delay ATS) or by the result of a residual Voltage threshold.

This method is usually a complement of the Fast ATS in case of non-success.

### 8.4. Load Shedding with sequenced Load restore

When more than one motor or power transformer are connected on the same MV or LV busbar, it is important to minimize the impact of cumulative reconnection when possible;

One solution is to create a link with the MV & LV Energy Management System (EMS or EMCS or EMIS) which will memorized the position of the various MV & LV CBs and automatically open all CBs to force the MV busbar value to zero, before initiating the ATS.

After the ATS execution, the Load shedding module will automatically reclose the various CBs based on their position before the Transfer. This reconnection is done as soon as the Power source value is available and stable. The repower order is based on the priority table defined by the Operator.
9. ATS applicable standards

International standards and local regulations, such as IEC 60 947-6-1, UL 1008, NFPA110 & 111, etc... define ATS construction and performance requirements. These standards are complemented by the IEC, UL and IEEE ones applicable to the environment (Voltage level LV or MV, temperature, EMC, seismic, etc…) where the ATS is running.

9.1. IEC60947-6

The IEC60947-6 standard applies to ATS equipments to be used in power systems for transferring a load supply between a normal and an alternate source with a supply interruption during transfer, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

Devices necessary for the control (e.g. control switches, etc.) and the protection (e.g. circuit breakers, etc.) of a TSE are covered by the relevant IEC standards.

The object of this part of IEC 60947-6-1 is to state:

1. The characteristics of the equipment:
2. The conditions of the equipment with respect to:
   a) Operation for which the equipment is intended,
   b) Operation and behaviour in case of specified abnormal conditions,
   c) Dielectric properties.
3. The tests intended to confirm that these conditions have been met and the methods for performing these tests.
4. The data to be marked on the equipment and provided by the manufacturer.

The IEC 60947-6-1 defines 3 types of LV source change-over system:
- CB type : Source changeover is made of a pair of circuit breakers
- PC type : Source changeover is made of a pair of switches
- CC type : Source changeover is made of a pair of contactors

9.2. UL 1008

The UL 1008-8 and UL 1008A-1 are US standards addressing the ATS applications and associated control devices and relays with operation higher than 750 V and up to 46 kV and are the most commonly applied and used standard for ATS construction and testing. The construction requirements within the UL 1008 standard include, but are not limited to, the enclosure equipment, field and internal wiring of the components, and installation of the equipment.
The performance and testing requirements include withstand and closing rating, overvoltage/undervoltage, overload, temperature, and endurance tests.

9.3. NFPA 110 & 111

NFPA 110 & NFPA 111 documents are US standards describing the characteristics and way to use the ATS to secure the power supply in sensitive installations. NFPA also include requirements for the primary equipments and all operator information and controls.

They also present the requirements for source monitoring, such as undervoltage sensing devices, to monitor all ungrounded lines of the primary source, voltage- and frequency-sensing equipment to monitor one ungrounded line, and to ensure that transfer to the secondary source is inhibited until voltage and frequency are within specified limits.
10. ATS activation conditions

The ATS is activated based on different conditions mostly configurable at the ATS level. Two batches of conditions have to be considered:

- The Transfer activation conditions
- The Return activation conditions

A dedicated chapter lists the operation and control modes (Local, Remote & Normal, Test, Maintenance).

10.1. Transfer activation

The transfer sequence is managed by three kinds of conditions:

- The Start: condition to start automatically a sequence
- The Lock: condition to inhibit a sequence
- The Stop: condition to stop an on-going sequence

This is shown in the below diagram:

![Diagram of ATS module conditions](image)

An ATS transfer sequence is launched when:

- The Start condition is detected
- NO lock condition is detected

10.1.1. The Transfer Start

The Transfer Start is typically activated by the detection of an outage on the main source, a logic information issued from an involved equipment (CB position e.g.) or a request from another system.
This includes:

- **Protection thresholds:**
  - Under or Over Voltage (27, 59)
  - Under or Over Frequency (81)
  - Over Current or Directional Over Current phase or earth (50, 51, 50N, 51N, 67)
  - Line or cable differential (87L) or Differential Transformer (87T)
  - Distance protection – MV or HV incomer typically (21) ….

- **Logic information**
  - Circuit Breaker or Switching equipment position (Open)
  - External trip

- **External control**
  - Operator request (local or remote)
  - Utility request

Any of these information or control could be received using traditional hardwiring or communication network. Some of these information are double (e.g. CB position) to secure the information and avoid unplanned transfer

### 10.1.2. The Transfer Lock

The Transfer lock condition is the based on information that will restraint the ATS to start its sequence. These are mainly logic data such as:

- System information (ATS block, communication failure, auxiliary power supply, etc...)
- Non compliance starting condition (SW failure, CB withdrawn, earthing non compliant,
- An external input (Upstream ATS, Motor start, load failure, …)
- Electrical fault present on back-up source

As long as a lock condition is activated the Power transfer could no executed and no acknowledgment is issued by the ATS

### 10.1.3. The Transfer Stop

The Transfer stop condition is a condition that appears during the Transfer cycle (execution on-going) and that will block the Transfer termination.

Stop conditions are typically

- Lack of nominal condition on the back-up line (low voltage, out of range frequency, protection function running)
- Generator is not started after predefined time delay(settable)
● Generator not reaching nominal power, voltage or frequency in the pre-defined time delay (settable)
● Interlock CB block
● External command or input

The stop condition is due to abnormal causes unknown by the ATS system, ATS shall be unlocked manually by the operator (reset control).

10.2. Return activation

The return sequence management is similar to the transfer one and refers to three types of conditions:

● The Start: condition to start the return sequence
● The Lock: condition to inhibit the start of a return sequence
● The Stop: condition to stop an ongoing return sequence

The normal condition before any activation is that the ATS has made a Transfer sequence before in a pre-defined time frame (settable)

An ATS return sequence is launched when

● The Transfer sequence has been fully and correctly executed
● The Start condition occurs
● NO lock condition is detected

10.2.1. The Return Start

The Start is typically activated by the solving of the reason which has initiated the Transfer: Logic information, a measurement data or a request from another system.
This includes:

- Logic information
  - Protection clearance
  - Main generator availability
- Measurement data
  - Voltage on the main line
  - Voltage and frequency from the main generator
- External controls
  - Operator request (local or remote)
  - Utility request

Any of these information or control could be received using traditional hardwiring or communication network.

### 10.2.2. The Return Lock

The Return lock condition is based on information that will restraint the ATS to start its return sequence. These are mainly logic data such as:

- System information (ATS block, communication failure, auxiliary power supply, etc...)
- Non compliance starting condition (SW failure, CB withdrawn, earthing non compliant,
- An external input (Downstream ATS, Motor start,)
- Electrical fault present on source

As long as a lock condition is activated the Power return could no executed, the back-up power source is maintain active and no acknowledgment is issued by the ATS.

### 10.2.3. The Return Stop

The stop condition is a condition that appears during the Return cycle (execution on-going) and that will block the Return sequence termination. Stop conditions are typically

- Lack of nominal condition on the Main line (Low voltage, out of range frequency, protection function running)
- Generator is not started after predefined time delay (Applicable to Generator to Generator scheme)
- Generator not reaching nominal power, voltage or frequency in the pre-defined time (Applicable to Generator to Generator scheme)
- External command or input
- Interlock CB failure

The stop condition is due to abnormal causes unknown by the ATS system, ATS shall be unlocked manually by the operator (reset control).

10.3. ATS management modes
The management modes applied to all equipments LV & MV of the electrical grid including the ATS are:
- The Control mode (Local or Remote)
- The Operational mode (Normal, Test, Maintenance, Off)

10.3.1. The Local & Remote management
It is possible using this key mode to declare the management (control) of the ATS to be performed locally or remotely. This is to avoid discrepancy controls on the ATS and avoid unplanned transfer actions.

The following table describes the associated actions and reports.

<table>
<thead>
<tr>
<th>Control mode</th>
<th>ATS transfer or Return action</th>
<th>ATS status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>All Start conditions accepted out of the logic external control (remote HMI)</td>
<td>All Status reported locally and remotely with associated time stamping Additional Local marking added</td>
</tr>
<tr>
<td>Remote</td>
<td>All Start conditions accepted out of the logic local control (local HMI or switching command)</td>
<td>All Status reported locally and remotely with associated time stamping No additional marking added</td>
</tr>
</tbody>
</table>

10.3.2. The Operation management
The electric IED/Controller Operation modes define the applicable actions on the ATS based on the Operation status. 4 main status are considered
- Normal mode
- Test mode
- Maintenance mode
- Off mode
The **Normal** mode is applicable when the equipment is fully operational and allows having all planned actions on the system (Transfer and Return sequences). The Normal mode is traditionally decline in:

- **Auto**: Automatic Transfer to back-up source upon failure of main source and re-transfer to main source upon restoration of power. This is the by default Normal mode,

- **Manual**: no Automatic Transfer operation is possible but SW can be operated manually. It is only possible if in Local management

The **Test** mode function allows the local or remote operator to check at any time any function of the system using process signals also but avoiding any impact on the process (blocking of process outputs).

The **Maintenance** mode switch off all relations between the equipment and the surrounding associated devices. No control is accepted and no action is issued by the equipment; in some case the Maintenance mode is equivalent to the Power off mode.

The **Off** mode is the Power Off status of the ATS equipment.

The below table states the controls and reports based on the Operation management status:

<table>
<thead>
<tr>
<th>Operation mode</th>
<th>ATS control</th>
<th>ATS status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>All control functions are activated as specified and configured.</td>
<td>All reports are generated, time stamped and achieved as specified and configured. No specific flag is positioned</td>
</tr>
<tr>
<td>Test</td>
<td>All control functions are activated in line with the requirements but no impact on the application is generated (no closing contact or control message send). Specific test messages are substituted.</td>
<td>All reports are generated, time stamped and achieved as specified and configured. A specific flag is positioned to indicate the Test mode. Simulation status is fully accepted</td>
</tr>
<tr>
<td>Maintenance</td>
<td>All control function are blocked and no application control is generated whatever is the control support</td>
<td>No report is created; nothing is archive out of the Maintenance status.</td>
</tr>
<tr>
<td>Off</td>
<td>No control activated, only the Watchdog output is closed (when available)</td>
<td>No report or archiving function.</td>
</tr>
</tbody>
</table>
11. ATS Sequence modes

11.1. Introduction

Following the ATS uses, the ATS sequence takes into account several power transfer needs:

- **Operational topology needs:** several network topologies are used and the ATS system allows the network to switch between these available topologies
  - Source failure: automatically switches the network in a topology which supplies the loads
  - Return to operational normal network topology (what is called: Return)
  - Main and Back-up source
  - Manual transfer to a predefine network topology (Manual sequence)
  - External request as Grid supplier request
  - Generator test to be carried out

- **Constraints due to specific equipment in the electrical network or global network topology**
  - Coordination between other ATS
  - Presence of motors or other equipment (transformer, capacitor bank, generator)
  - Grid code (I.E. allowed time connexion)

- **Process constraints and system requirements**
  - No load supply interruption
  - Allowed time disconnection
  - Reliability
  - Cost and area constraints

11.2. Operational topology transfer

The transfer from a source to another one is initiated by three different actions, a source failure, a return to normal condition or a manual action:

- A source failure: This is the automatic cause of switching from one source to the second one when there is a power outage on the current one. The sequence is always an OPEN Transition.
- A return to normal condition: This is the automatic setting on when the transfer switch shall return back to the main source.
- A manual action: This is the decision of an operator or of another system to launch a transfer sequence. This is done by the operator when there is a need for maintenance or to return to a normal topology. Another system can send a request to the ATS for financial optimization or Grid requirements.
11.3. ATS on source failure

11.3.1. 2 lines on a busbar

Both lines are in order, but only one is connected. In case of loss of the source, a transfer is done on the second one. The transfer is done by a transient dead network.

11.3.2. 1 line and a generator plant on a busbar

The line is in order, but the generator is in warming and not connected. In case of loss of the source, a transfer is done on the generator with a start of generator plant. The transfer is done by a transient dead network.
11.3.3. 2 lines via a bus tie on a busbar

Both lines are connected and the bus tie is open. In case of loss of one source, a transfer is done by closing the bus tie. The transfer is done by a transient dead half network.

11.4. Transfer to change the Operational topology

After a transfer on source failure or when a transfer must be done for others reasons, a transfer is done when both supplies sources are in order. This transfer may be done by a dead network or by coupling both sources if allowed.

11.4.1. 2 lines on a busbar

Both lines are in order, but only one is connected. A transfer is done on the second one. The transfer is done by a transient dead network or by a transient coupling if allowed.

Note: Transient means that the transfer action is a non-permanent state (less than 500ms).
11.4.2. 1 line and a generator plant on a busbar

The line and the generator plant are in order. A transfer is done on the second one. The transfer is done by a transient dead network or by a transient coupling if allowed.

11.4.3. 2 lines via a bus tie on a busbar

Both lines are powered and connected to their specific loads, the BusTie is open. The transfer is done on one line by closing of the BusTie and disconnecting of the other line.

11.5. Kind of Return in normal Operational topology

Once the Automatic Transfer System has detected a power outage on the current source and has transferred the loads to the secondary source, there are several options for coming back to normal conditions. This section is going to introduce them. It depends on the operating mode of the network topology and if the return is done automatically or by an operator request or acknowledge.

Both conditions define the return choice:

- Main/back-up source: if a source is a preferred one and the second is a back-up one or both sources are similar
- Automatic/Manual transfer: the return transfer is done automatically if
conditions happens or manually by operator request or acknowledge.

11.5.1. Self return
Self return is the only one “true” return. In case of main and back-up sources, the return is automatic.

![Diagram of self return](image)

Figure 24: Line to Line and Line to Generator transfer and return schemes

11.5.2. No Return
In this case, the ATS is locked and ATS stopped. If needed, the operator may manually change the SW position to return to normal topology or if available bypass the ATS locked condition. These actions are out of the scope of the ATS.

![Diagram of no return](image)

Figure 25: Line to Line and Line to Generator transfer scheme without return

11.6. Return to Normal condition options criteria

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>No return</td>
<td>The action execution is managed by the operator based on the site constraints</td>
<td>Impose action of maintenance people to return to main source</td>
</tr>
<tr>
<td>Self return with open transition</td>
<td>The return is automatic</td>
<td>Despite the availability of both sources, a power outage is applied to the</td>
</tr>
<tr>
<td><strong>Self return with close transition</strong></td>
<td>The return is automatic &amp; No power outage on loads.</td>
<td>It is stringent for generators. The return execution is based on operator decision.</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>----------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Self return with soft transition</strong></td>
<td>The return is automatic &amp; No power outage on loads. It improves generator life duration due to less stress</td>
<td>It is more stringent for switchgears as in case of a fault, short circuit current is higher (supplied by two sources). The return execution is based on operator decision.</td>
</tr>
</tbody>
</table>

### 11.7. Generator test sequence

In the case of main and back-up topology, generator is of little use during the life time of the plant electrical network. But it is mandatory to ensure that the generator is always able to supply the loads.

The generator test major issues are:

- Not starting of the engine of the generator,
- Modification on loads and generator capabilities lower than the full load,
- Issue during the power transfer.

To solve these issues, systematic tests are run on the generator including ATS functional tests.

3 functions have to be tested:

- The generator start (generator test)
- The permanent running of the generator (generator plant)
- The open transition (test of the whole site to be sure that the generator has always the step-up and supply the total load)

In order to check these functions, several kinds of tests are performed:

- Start the generator without load or with a load bank,
- Test the generator with the load,
- Test of the transfer,
- Partial test of the generator (use of close transition rather than open transition) in order to test generator and to take into account operational rules or limits of use.
The choice depends on

- The Utility acceptance (Grid code),
- The process limitations and constraints,
- The operating rules,
- The criticity.

All these tests are part of the monthly and/or annual Maintenance program.
12. **ATS specifics elements**

The following chapter describes briefly some key elements part of the Automatic Transfer System and to be integrated in the ATS solution.

**12.1. 3 or 4 poles LV ATS**

The choice between a 3-pole and 4-pole LV ATS depends on whether the emergency power system will be a separately-derived source. Simultaneous switching of phases and neutral is simple and reliable without impacting the Ground Fault Locator setting coordination.

On a 3-pole LV ATS, the neutral is continuous through the entire Industrial or Building LV grid and typically it is connected to the ground in a single point usually at the Utility connection. If there is a ground fault when the loads are connected on the back-up power source, the fault current runs through the ground to the single earthing connection point and then return using the neutral wire to the back-up power source.

On a 4-pole LV ATS, each source’s neutral is earthed to ground at its source, so each source has a separated and independent management. Depending of the use or not of the back-up generator; the associated grounding is connected and when a fault occurs the fault current runs through the ground directly back to the back-up power source running and connected to the loads. This is known as a switched-neutral system, and the neutral switching can be open or overlapping (closed).

**12.2. Multiple ATS scheme**

Using over a single Industrial or Building site multiple ATS impose to choose over the grid a single neutral management switch and therefore all ATS must be of the same type 3-pole or all 4-pole. This is the only way to warranty the grounding integrity and ensure people and device safety.

When multiple generators are integrated on the industrial or building site the same rules are applicable to define the choice between 3-pole and 4-pole ATS.

**12.3. ATS Selective scheme**

When electrical architectures have ATS located at several levels, a specific attention shall be paid on the coordination between them. The selectivity between the different ATS levels may be managed using:

- The fault selectivity detection
- A time-delay applied at protection tripping
- A logic selectivity between the different relays activating the ATS
A power failure on S1 is detected by the ATS 1, 2 and 3 but only one have to switch while the other ones have to wait more or being locked by the one closest to the failure.

In case of manual close transition ATS shall be coordinated to prevent a too high level of Isc.

*Figure 26: Multiple ATS with selectivity scheme*
13. **ATS associated equipments and solutions**

Different equipments are surrounding the ATS function block in order to have it working in an efficient way. Depending of the Voltage level, the customer requirements and the applicable standards, some of the below listed elements will be part of the ATS supply or considered as an independent equipment. In any case, when designing an ATS these Hardware or Software must be considered to define the final global result.

### 13.1. Protection relays

In LV, MV or HV, the protection relays are implemented at SW/CB level to protect them and the associated network from the fault affecting the electrical grid. The information generated by the protection relay may be used

- Directly by the ATS (instantaneous or time-delay threshold crossing) to start the Transfer process,
- Indirectly, through the CB position with start the Transfer sequence.

The logic information from the protection relay may be transferred to the ATS using hard wired cable or communication path.

In complement, most of the modern protection relay IEDs present measurement values and these can be also transmitted to the ATS to initiate the Transfer sequence and also the Return sequence.

The choice of protection and the associated setting must be defined by the use of the application and also consider the impact of the Automatic Transfer function (earthing evolution, Icc change, protection plan coordination modification.

In most of the cases, the choice of an IED with a least 2 or 4 setting groups is a simple answer to this constraint.

### 13.2. Switching devices

The natural complement of the ATS is the Switching equipment which will be open or close, modifies the power source connection. These Switchgears refer depending of the voltage level to precise and detailed standards regarding, the environment, the current and voltage, the security, etc...

A special attention must be put on the Generator CBs as these equipments have to support much higher constraints and especially must be able to carry high DC levels for extended periods of time. For Voltage higher than 1 000 V, the Generator CB (GenCB) characteristics and performances are defined by the IEC62271-37-03 and IEE C37-013.
13.3. Communication network

Communication based on legacy or Ethernet allows improving the capability of ATS by the simple and efficient external function integration and also through using the recent protocols (IEC61850, OPC UA, …) of modelised function ensuring the optimised inter-operability between suppliers.

In addition, Ethernet based protocols have now standardised the physical layer redundancy management promising very low switching time (IEC 62439-3 Clause 4 with PRP – Parallel Redundancy Protocol and HSR – High availability Seamless Redundancy) without comparison with the previous generation with RSTP (Rapid Spanning Tree Protocol).

Associated to the communication connection capability of the ATS IED/Controller, some functions are mostly required like: Time stamping, Event recording, Disturbance or Quality recording, etc. All these functions have their specific detailed characteristics described in the IEC, UL and IEEE standards.

13.4. Interfaces with Automation functions

In complement of the ATS, different Automation functions may be available, the most important directly interfacing the ATS function are:

- CB interlock
- Generator synchro-coupling
- Grid Synchro-check

13.4.1. Interlocks

The interlocks may be classified in two categories:

- Functional interlocks incorporated in the CB cubicles/cabinets,
- Interlocks between the CBs or between a CB and another power equipment such as a MV/LV transformer or CB at the lower or upper grid.

Note: These categories apply to LV and MV voltages.

Some interlocks are mandatory in MV according IEC 62271-200, to prevent from:

- closing a switch or circuit breaker on a closed earthing switch;
- closing an earthing switch while the associated switching function is closed
- closing together two MV networks

The interlock acknowledgement is used to lock the ATS function directly.
13.4.2. Generator Synchro-coupling

The generator synchro-coupling is a dedicated IED which adapts in a predefined bandwidth the speed and frequency of a generator to a running network. The non-respect of this coupling characteristics may directly impact the generator by out stepping (up to the generator physical destruction) or create electrical grid short circuit or instability with automatic decoupling of all loads.

The synchro-coupling considers 5 items before allowing the CB closing:

- Voltage
- Frequency,
- Phase angle
- Phase sequence
- AC wave form

Generator Voltage, frequency and phase angle can be adjusted dynamically, AC waveform and phase sequence are linked to the generator characteristics.

The closing of the CB is only executed while the Synchro-coupling IED allows it. It may delay the closing order by some 100 ms to some Seconds.

13.4.3. Feeder Synchro-Check

The synchro-check relay is an IED that measures the voltage, frequency and phase angle differences on both side of the CB. The synchro-check IED checks the compliance when two energized networks are to be connected together.

The adjustment of both side magnitude, frequency and phase angle is managed independently and the CB closing action may be delayed until synchro-check criteria compliance (from 300ms to 5 s).
14. **ATS possible architecture**

The mapping of the previous described ATS function on a real physical architecture is a key element.

Two main Architectures are possible to perform the ATS whatever will be the voltage level (LV or MV):

- Centralised physical ATS IED/Controller,
- Distributed virtualised ATS

14.1. **Centralised ATS IED/Controller**

This is the most traditional architecture for the ATS in LV and MV. It is based on a PLC/RTU type IED/Controller (dedicated or not) with the appropriate hardware (in line with the LV or MV voltage environment IEC or IEEE standards (Temperature, EMC, voltage withstand,))

The ATS data acquisition is done via hard-wired inputs (logic or analogue) and/or communication network (legacy or Ethernet). The ATS controls are mapped on physical contacts and/or communication networks. A local HMI could be available for setting and parameters visualisation of the ATS functions, alarm and event display or graphical control.

In addition, the ATS IED/Controller can be with partial or complete module redundancy (board or component) to ensure perfect availability.

14.2. **Distributed ATS architecture**

The distributed ATS Architecture concept takes benefit from the availability of existing IEDs (mostly protection relays or measurement units) able to support advanced embedded logic capabilities. The ATS functions are split between the involved IEDs and the data exchanges are performed via hard-wired and/or efficient communication network (Ethernet typically).

This solution imposes to have clear and efficient conceptual analyse and a performances study based on the imposed constraints (protection module in the IED will always run before any PLC scheme) to achieve the ATS function. It has also a constraint regarding the maintenance of the equipment as any operation or failure on the IED suspends the ATS feature as well.

A distributed ATS architecture is a way to reduce the number of box (IED) and improves the ATS global performance by taking directly benefit of existing equipments and sensors instead of adding new ones.
15. Conclusion

ATS is today the most efficient solution in LV and MV to secure the Electrical power delivery in any Industrial and Building site. Various standards exist today mainly in the IEC and IEEE catalogues which ensure the user of efficient results.

The correct understanding of the ATS construction and performance requirements, in addition to application of the proper standards will ensure that critical systems and equipment are supplied with efficient electrical power at any time.
## 16. Appendix

### 16.1. Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>AC</td>
<td>Alternative Current</td>
</tr>
<tr>
<td>AIS</td>
<td>Air Insulated Switchgear</td>
</tr>
<tr>
<td>Alarm</td>
<td>An alarm is any event tagged as an alarm during configuration phase</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interfaces</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>ATS</td>
<td>Automatic Transfer System also use for Automatic Transfer Switch.</td>
</tr>
<tr>
<td>CAGR</td>
<td>Compound Annual Growth Rate : Mean annual growth rate of an investment or a business over a specified period of time greater than one year</td>
</tr>
<tr>
<td>CB</td>
<td>Circuit Breaker: Specific dipole switches with capability to power on and break on fault current. Some has not isolation capability (nominal-earth at each side)</td>
</tr>
<tr>
<td>CB Type</td>
<td>Circuit Breaker Type of ATS : ATS based on a pair of CBS (See IEC 60947-6-1)</td>
</tr>
<tr>
<td>CC Type</td>
<td>Change Over Contactor Type of ATS : ATS based on a pair of Contactors (See IEC 60947-6-1). Only used in LV (&lt;1 000 V)</td>
</tr>
<tr>
<td>Controller</td>
<td>It is a Hardware component that runs some dedicated program. This is the equivalent of IED for LV.</td>
</tr>
<tr>
<td>CT/VT (Conventional)</td>
<td>Current and Voltage transformers</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DCS</td>
<td>Digital Control System: Generic name of industrial process system based on numeric communication and devices, to be opposed to traditional electrically wired control.</td>
</tr>
<tr>
<td>Device</td>
<td>Term used for one of the following unit: Protective relays, metering units, IED, Controller, switchgear (switching device such as CB, disconnector or earthing switch), disturbance or quality recorders.</td>
</tr>
<tr>
<td>ED</td>
<td>Electrical Distribution : the Electrical grid within the Industrial or Building plant.</td>
</tr>
<tr>
<td>Acronym</td>
<td>Meaning</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>EHV</td>
<td>Extremely High Voltage (Traditionally above 220 kV)</td>
</tr>
<tr>
<td>Event</td>
<td>An event is a time tagged change of state/value acquired or transmitted.</td>
</tr>
<tr>
<td>EMC</td>
<td>Electromagnetic Compatibility: Ability of an IED to operate near of an electromagnetic field without performance limitations</td>
</tr>
<tr>
<td>FAT</td>
<td>Factory Acceptance Test Validation procedures execution with the customer at factory.</td>
</tr>
<tr>
<td>Gateway</td>
<td>Level 6 session of OSI, the gateway is any device transferring data between different networks and/or protocol.</td>
</tr>
<tr>
<td>GCB</td>
<td>Generator Circuit-Breaker</td>
</tr>
<tr>
<td>Generator</td>
<td>Generator set is the combination of an electrical generator and an engine (prime mover) mounted together to form a single piece of self-contained equipment.</td>
</tr>
<tr>
<td>GIS</td>
<td>Gas Insulated Switchgear</td>
</tr>
<tr>
<td>GMT</td>
<td>Greenwich Meridian Time Absolute time reference</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System Based on triangulation from satellite signal, that transmit also absolute GMT time used to synchronize a master clock</td>
</tr>
<tr>
<td>GTW</td>
<td>Gateway</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
<tr>
<td>HV</td>
<td>High Voltage (Traditionally between 66 kV to 220 kV)</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>IS</td>
<td>Interrupter Switch</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission (IEC, Geneva, Switzerland)</td>
</tr>
<tr>
<td>IED</td>
<td>Intelligent Electronic Device General expression for a whole range of microprocessor based products for data collection and information processing</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers (IEEE, New York, USA)</td>
</tr>
<tr>
<td>Acronym</td>
<td>Meaning</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>Legacy</td>
<td>Apply to communication referring to serial (RS485, RS432, ..) or parallel (RS422, Centronics, …) communication path.</td>
</tr>
<tr>
<td>Local / Remote Control Mode</td>
<td>When set to Local for a given control point it means that the commands can be issued from this point, else in Remote control are issue for upper devices.</td>
</tr>
<tr>
<td>LV</td>
<td>Low Voltage (typically below 1 000 V)</td>
</tr>
<tr>
<td>Measurements</td>
<td>Values issued from digital inputs or analogue inputs (with value, state and time tag).</td>
</tr>
<tr>
<td>Metering (non-tariff)</td>
<td>Values computed depending on the values of digital or analogue inputs during variable periods of time (time integration).</td>
</tr>
<tr>
<td>Metering (tariff)</td>
<td>Values computed depending on the values of digital or analogue inputs during variable periods and dedicated to the energy tariff.</td>
</tr>
<tr>
<td>MTS</td>
<td>Manual Transfer Switch</td>
</tr>
<tr>
<td>MV</td>
<td>Medium Voltage (Typically from 1 000 V up to 66 kV)</td>
</tr>
<tr>
<td>NC</td>
<td>Normally Closed (for a relay or a CB)</td>
</tr>
<tr>
<td>NEC</td>
<td>National Electrical Code,</td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NO</td>
<td>Normally Open (for a relay or a CB)</td>
</tr>
<tr>
<td>OSI</td>
<td>Open System Interconnection Split and define communication in 7 layers : physical, link, network, transport, session, presentation, application</td>
</tr>
<tr>
<td>PC Type</td>
<td>Pair of Switch type of ATS: ATS based on a pair of switches (See IEC 60947-6-1).</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Control Within the PLC-programs are defined the configurable control sequences or automations taken into account by the application Systems.</td>
</tr>
<tr>
<td>RTU</td>
<td>Remote Terminal Unit function that correspond to the data acquisition and transmitting to a remote HMI/SCADA.</td>
</tr>
<tr>
<td>SAT</td>
<td>Site Acceptance Test Validation procedures executed with the customer on the site.</td>
</tr>
<tr>
<td>Acronym</td>
<td>Meaning</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control And Data Acquisition&lt;br&gt;Equivalent to local HMI application in Industry &amp; Building applications</td>
</tr>
<tr>
<td>Setpoint</td>
<td>Analogue setpoints are analogue outputs delivered as current loops. Used to send instruction values to the process or to auxiliary devices.&lt;br&gt;Digital values sent on multiple parallel wired outputs. Each wired output represents a bit of the value. Digital setpoints are used to send instruction values to the electrical process or to auxiliary devices</td>
</tr>
<tr>
<td>SOE</td>
<td>Sequence Of Events&lt;br&gt;Other term for the event list.</td>
</tr>
<tr>
<td>STS</td>
<td>Static Transfer Switch (power semiconductors based )</td>
</tr>
<tr>
<td>SW</td>
<td>Switch, generic wording</td>
</tr>
<tr>
<td>TBC</td>
<td>To Be Completed</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Defined</td>
</tr>
<tr>
<td>TS</td>
<td>Transfer Solution : Generic name of the different Transfer solution ATS and MTS</td>
</tr>
<tr>
<td>UL</td>
<td>Underwriters Laboratories, now formally UL LLC is a American safety consulting and certification company</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply or Source</td>
</tr>
<tr>
<td>UTC</td>
<td>Universal Time Coordinates (or Universal Time Code) &lt;br&gt;Naming that replace GMT (but it is the same)</td>
</tr>
<tr>
<td>WCR</td>
<td>Withstand Close-on Rating :&lt;br&gt;Capability of a SW</td>
</tr>
<tr>
<td>WCR</td>
<td>Watchdog output: The watchdog output is a change over relay that is used to protect a device or a system from specific software or hardware failures that may cause the device or system to maloperate or stop working.</td>
</tr>
</tbody>
</table>
16.2. **ATS Schneider Electric offers**

The Schneider Electric ATS offers is split between different organisations (BU Energy, BU Partner, BU Global Solution) for the catalogue products and product/solutions designed and manufactured by the Schneider Electric Countries. Schneider Electric today proposed ATS package (only in LV), ATS IED/Controller (from MV & LV) and various local assembled products (LV mainly)

16.2.1. **ATS package**

UA/BA product, based on Compact or Masterpact transfers from Main LV Utility line to Back-up LV Utility line or LV Generator. It is based on a simple operator interface with LED indicator.

![Figure 27: UA/BA ATS package](image)

ATMT products are design and build in China for the Chinese market by Schneider Wingoal (Tianjin) Electric Equipment Co. They are based on the ATMT Controller and Schneider Electric switches (Masterpact or Easypact ACB e.g.). These packages support for LV application the transfer the power from a Line to a Line or from a Line to a Generator. ATMT packages are leading the Chinese LV market.

![Figure 28: Wingoal ATMT ATS package](image)
16.2.1. ATS/IED Controllers

The ATS IED/Controller range is mainly build around 3 products:

1° ATMT Controller from Schneider Wingoal Electric Equipment Co (China) is the product supporting LV Automatic Transfer between 2 sources (Line to Line or Line to Generator). The ATMT controller performs Open transition (Automatic and Manual command) and Short closed transition (Manual command only). This product is for the Chinese LV market only.

![Figure 29: Wingoal ATMT Controller](image)

2° The ATS 100 is an IED develop and supply as part of the PREMSET offer (MV CB). Derived from the Easergy R200 Distribution RTU, it supports the Open transition transfer from MV Line to MV Line with optional MV Bus-Tie control. The ATS 100 is not usable for Line to Generator or Generator to Generator switch. The ATS 100 could be used at Utility MV substation or inside the MV Industrial grid for Line to Line transfer. The ATS100 is IEC compliant (not UL or IEEE).

![Figure 30: ATS100 IED](image)

3° The distributed ATS IED based on Sepam 80 protection IEDs with embedded pre-programmed ATS functions. In complement to their MV & LV protection function (Feeder, Generator, Transformer), the Sepam based solution support the MV & LV transfer from Line to Line and Line to Generator with advanced feature such as transfer inhibition in case of downstream Fault, Synchro-check, Breaker failure, etc.. The exchange between the Sepam are done using communication modules.
(MODBUS TCP/IP or IEC61850) and hardwired IOs (logic and measurements). The Sepam ATS solution supports only the Open Transition transfer. The Sepam is IEC & UL compliant.

16.2.1. ATS specific construction
For customer projects, Schneider Electric local units use to design their own LV or MV ATS solution based on Schneider Electric LV and MV CB, PLC, Protection relays or RTU or on third party equipments.
## 17. Documentations

The following documents are associated to this ATS Generic Book and must be used for more detailed elements of their relative subjects.

<table>
<thead>
<tr>
<th>Document title</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61850 ed1 &amp; 2</td>
<td>2012</td>
<td>Communication standard for electrical automation systems</td>
</tr>
<tr>
<td>IEC 60947</td>
<td>2005</td>
<td>Low Voltage switchgear and control gear</td>
</tr>
<tr>
<td>IEC 6100</td>
<td>2004</td>
<td>Electromagnetic Compatibility (EMC)</td>
</tr>
<tr>
<td>NFPA 110 A</td>
<td>2016</td>
<td>Standard for Emergency and Standby Power Systems</td>
</tr>
<tr>
<td>NFPA 111</td>
<td>2016</td>
<td>Standard on Stored Electrical Energy Emergency and Standby Power Systems</td>
</tr>
<tr>
<td>UL 1008</td>
<td>2014</td>
<td>Withstand and Closing Rating Requirements</td>
</tr>
<tr>
<td>J3 program RELIANCE</td>
<td>2011</td>
<td>Standard specifications for Fast Bus transfer System 10080-1-SS-EL-047</td>
</tr>
<tr>
<td>APP N 19 Beckwith</td>
<td>2009</td>
<td>Optimizing performance of Fast Transfer Schemes</td>
</tr>
<tr>
<td>CT 161 Schneider Electric</td>
<td>1992</td>
<td>Permutation automatique des alimentations dans les réseaux HT et BT</td>
</tr>
<tr>
<td>University of Southern Queensland</td>
<td>2013</td>
<td>Effect of transformer inrush current</td>
</tr>
<tr>
<td>EGSA 100S</td>
<td>1996</td>
<td>Performance standard for transfer switches for use with Engine./Generator sets</td>
</tr>
<tr>
<td>IEEE PCIC 89 08</td>
<td>1992</td>
<td>Fast bus transfer techniques for maintaining full plant production</td>
</tr>
<tr>
<td>Connecticut LPC et United Illuminating comp.</td>
<td>2010</td>
<td>Exhibit B- Generator Interconnection Technical Requirements</td>
</tr>
<tr>
<td>Thomson Technology INC – EB003 Rev1</td>
<td>1995</td>
<td>ATS Neutral position delay &amp; in-phase monitor</td>
</tr>
</tbody>
</table>