**1) General construction:**

A high speed transfer device should consist of two units: the central unit (the core unit itself) and a separate human machine interface (HMI) as the local control interface.

**The design of the central unit should satisfy the following requirements:**

* It can be installed in the low-voltage compartment of a medium voltage switchboard or mounted onto an electronic frame or suitable mounting plates inside a cubicle.
* The housing of the core unit must be made of metal.
* All I/O boards, the main processor unit, communication and analog boards must be inside of the core unit and shielded against all EMC disturbances.
* It must have a digital phase comparator unit and a programmable-logic control system (PLC).
* The device must be maintenance free.

**The design of the HMI should satisfy the following requirements:**

* It can be installed (flush mounted) either in the low-voltage compartment door of a medium voltage switchboard or in a dedicated compartment close to the central unit.
* It should have a back-illuminated LC graphical display.
* It should contain status (operational, communication and alarm) indication LEDs.
* A minimum of 8 freely programmable LEDs are required for alarms, messages, indications, etc.
* At least three LED bars are needed to display the measurement values.
* It should contain control push buttons to operate the high speed transfer device during local control.
* Two electronic keys - one for parameterization and the other for control mode selection – are needed.
* The interface for the keys must be on the front of the HMI.
* The HMI must be maintenance free.

The high speed transfer device shall have a power supply rating of between 48V DC and 220V DC, and the power consumed by the core unit and the HMI together should not exceed 40W.

**2) Functional requirements of a high speed transfer device**

**The central unit:**

* The unit must be capable of handling up to three circuit breakers (e.g. incoming, standby, busbar tie) with one central unit. Transfers must be possible between each circuit breaker in all directions.
* It must have a minimum of 42 binary inputs and 27 static outputs whose response times should be less than 2ms.
* A minimum of 8 analog inputs are needed for voltage and current measurements.
* Additionally, a minimum of 4 analog outputs or 6 analog inputs should also be provided as an option.
* The unit must be capable of continuous trip coil supervision (circuit breaker/open and close).
* It must have a self-supervision function displayed by the HMI control unit.
* It should contain an integrated fault and event recorder with the following capabilities:
  + The sampling rate must be at least 1.2 kHz.
  + The total recording time of the fault recorder should be comprised of the time before and after the fault has occurred. The number of records and the recording time for each event must be freely configurable within 5 seconds of the total recording time.
  + The recorder should be capable of recording up to 32 digital signals and 8 analog signals simultaneously.
  + The data exported from the fault recorder should follow the COMTRADE format.
* Optical IRIG-B interface for real time synchronization shall be available as an option.
* The unit must have several communication protocols options, such as:
* SPABUS
* MODBUS RTU
* LON
* Profibus DP
* IEC 61850
* IEC 60870-5-103
* Ethernet
* Communication between the central unit and the DCS will be carried out using either a hardwired or an optical/electrical link.
* The device shall provide a parameterization and configuration option which enables the system to be optimally adapted to satisfy customer-specific requirements.
* The programming of the core unit shall be project-specific and will be carried out by means of FUPLA (**FU**nctional block **P**rogramming **LA**nguage).
* The unit should have fast processing logic as well as high-precision analog signal processing.
* It should be capable of carrying out automatic and manually initiated transfers. The initiation of manual transfers via a communication interface must be possible.
* It must be able to issue a simultaneous switching command to the circuit breakers (for fast transfer).
* It should feature the following functionality:
* Internal undervoltage initiation
* Load shedding
* Decoupling
* It should be able to continuously:
* Calculate suitable transfer modes online. These calculations must be realized using only two phase voltage measurements from the feeders and busbars concerned. While current measurements are not necessary for the transfer mode calculations, they can be used for analysis after the transfers have occurred.
  + Measure and monitor voltages, frequency and phase angles.
  + Supervise the synchronization of the connected incoming power networks.
* The unit should be able to monitor the breaker status (i.e. position, ready for operate, operating times of the breakers).
* The device should provide, at the very least, the following functional information/alarm outputs:
* Device status (local or remote)
* Circuit breaker status (trip coil supervision)
* Device is on/off
* Device is ready or blocked
* Manual transfer is not possible
* Fast transfer is possible
* Information about the last performed transfer:
  + Fast transfer mode
  + Slow transfer mode
  + Transfer in phase
  + Residual transfer mode
  + Delayed transfer mode
  + Manual transfer operated
* Binary output signal for each transfer transaction.
* Load shedding signals, depending on the transfer mode.

**The HMI:**

Via the HMI, a wide range of functions shall be controlled and operated.

* The HMI should feature:
  + On/Off switching
  + An optical interface to upload/download data to/from the high speed transfer device to a PC
  + Integrated alarm indications and annunciator
* External equipment such as push buttons, selector switches etc. shall not be required.
* Certain operations, such as switching from local to remote (or vice-versa) or the changing of functional parameters, shall only be enabled by means of electronic keys to prevent inadvertent operations by unauthorized or untrained personnel.
* The HMI should be capable of displaying:
  + A graphical single-line diagram (SLD) showing the positions of all circuit breakers
  + The important voltages, currents and phase angles related to the configuration
  + Device status (i.e. ready, sync)
* Access to the parameterization and the control mode selection by two different electronic keys:
  + Off-local-remote selection
  + Setting mode for changing all functional parameters
* Graphical single line diagram displaying position indication of all involved circuit breakers.
* Displaying all necessary involved voltages, currents and phase angles.
* Showing status of device (ready / sync).
* Integrated alarm indications and annunciator.
* All operations must be available via the HMI.
* External equipment such as push buttons, selector switches etc. shall not be required.

**3) Functional features of the operation:**

**General operation:**

The primary function of the high speed transfer device shall be the execution of fast transfers. To complete such transfers, commands need to be issued simultaneously to the respective circuit breaker, which is then opened or closed only when the feeders are synchronous (within adjustable limits of amplitude, frequency and phase angle difference) - but independent - with one another.

The high speed transfer device shall ensure that the shortest possible transfer time is achieved when there is an initiation. The transient effect caused by a transfer must not, in any way, harm the connected loads.

It should be possible to change the parameters via the HMI and these should be stored in non-volatile memory. The SLD, showing the circuit breaker position, feeder and busbar voltages, the operating current of the feeders, the phase angle between the feeders and the status of the high speed transfer device, shall be displayed on the HMI.

The respective transfer mode of the high speed transfer device and its resultant behaviour when an initiation has occurred shall be dependent on the installation-specific environmental parameters.

**Automatic Transfer Mode**

The high speed transfer device must provide four (4) transfer modes: Fast transfer; transfer at the 1st phase coincidence; residual voltage and time depending transfer. The decisive criterion when selecting the most optimum transfer mode is the network condition at the moment of transfer initiation. To make sure it has all the information necessary to select the most optimum transfer mode, the high speed transfer device must monitor, individually and continuously, the following criteria which are then evaluated by the fast processing logic and high precision analog signal processing systems to generate the required transfer criteria:

* Phase angle
* Frequency difference
* Stand-by feeder voltage
* Busbar voltage

In addition to the position indication of the circuit breakers, another factor which is important in the determination of transfer readiness - as well as any interlocks which may be present - is the results of the analogue signal processing (phase monitoring).

One extremely important feature of a high speed transfer device is that the criteria listed above are permanently calculated and therefore always available.

The four transfer modes that must be provided by the high speed transfer device are explained in greater detail below.

***Fast transfer***

The high speed transfer device shall carry out a fast and uninterrupted transfer on condition that the busbar and stand-by feeder are synchronous and in phase at the moment of transfer initiation. For this to succeed, OPEN and CLOSE commands must be issued **simultaneously** to the circuit breakers to be switched. If the network conditions are not suitable for a fast transfer at the moment of initiation the next transfer mode must be selected.

***Transfer at 1st phase coincidence***

A transfer at 1st phase coincidence should take place when the networks are not synchronized at the moment of initiation even though certain other conditions are fulfilled. For this type of transfer, the OPEN command is given to the circuit breaker without delay. The standby circuit breaker should receive the CLOSE command at the moment the difference between the stand-by and busbar voltages reaches a minimum.

In order to compensate for the installation-specific processing time (i.e. the operating time of the high speed transfer device and the circuit breaker operating times), the CLOSE command must be issued accordingly, within a previously defined time frame, before the actual minimum differential voltage occurs.

***Residual voltage-dependent transfer***

In cases where the criteria for a fast transfer and transfer at 1st phase coincidence are not fulfilled, the high speed transfer device has to carry out a residual voltage transfer. For this type of transfer, the feeder circuit breaker is first opened after initiation by protection and the residual voltage value of the busbar is then monitored to determine the moment the stand-by circuit breaker should be closed.

***Time depending transfer***

When no other transfer mode has been selected before a preset time has elapsed after a transfer was initiated, a time-operated transfer must be carried-out. Even when a malfunction in the low-voltage circuit (caused, for example, by a tripped MCB or damaged secondary wiring) prevents the busbar voltage from being monitored, the high speed transfer device should execute a time-depending (configurable) transfer. With this transfer type, the stand-by feeder is connected after a fixed and parameterized duration.

***Load shedding***

If it is necessary to shed loads for whatever technical reasons (e.g. stand-by feeder is not suitable for a connection of all loads), different corresponding signals must be provided for this purpose.

***Decoupling***

The **simultaneous** switching command issued to the circuit breakers (which is the basis for the a.m. fast transfer mode) also includes the possibility of allowing short-term coupling between both feeders in case of a mechanical failure in a circuit breaker that should be opened. Coupling between feeders occurs when both circuit breakers are closed for longer than TDecoup = 50-200 ms (this value must be capable of being parameterized). The high speed transfer device must then be able to detect this coupling and act accordingly to re-open the circuit breaker which has been closed.

***Trip coil supervision (open and close)***

The high speed transfer device must provide a trip coil supervision of the circuit breaker to ensure maximum security. If the trip circuit is damaged in any way (e.g. wiring, circuit breaker coil,… ), the high speed transfer device must block itself.

**Manual Transfer Mode**

Manual initiation must be possible for a controlled transfer when required. The high speed transfer device allows four (4) various transfer modes to be selectively activated or deactivated, depending on the on-site installation.

The manual mode shall apply a simultaneous closing/tripping of the respective circuit breakers, thereby delaying the close or trip command depending on the selected function. The transfer shall only be performed when the voltage of the main and standby feeders are synchronous within adjustable limits of amplitude, frequency and phase angle difference.

In fast transfer mode, the commands to the breaker must be given **simultaneously**.

Once the disturbed feeder is available again (after an automatic transfer), a manually initiated re-transfer shall be executed to restore normal status. This retransfer should ensure uninterrupted continuous operation of the connected load/processes.

**4) Necessary type tests:**

A high speed transfer device should be designed, assembled and tested in accordance with the applicable requirements outlined in the latest edition of the following standards and codes.

All tests must be performed according to:

* IEC 60255
* EN 61000 respective acc. to new standard EN 50263 series.

The device also has to fulfil all important national and international EMC regulations:

**EMC**

* Interference suppression acc. to EN 55022 respectively IEC CISPR 11, Group 1
* Immunity to electrostatic discharge acc. to IEC 61000-4-2, level 3
* Immunity to radiated electromagnetic energy acc. to IEC 61000-4-3, level 3
* Electrical fast transient or burst acc. to IEC 61000-4-4, level 3
* Surge immunity tests acc. to IEC 61000-4-5, level 3
* Immunity to conducted disturbances induced by radio frequency fields acc. to IEC 61000‑4‑6, level 3
* Power frequency magnetic field immunity acc. to IEC 61000-4-8, level 5
* Pulse magnetic field immunity acc. to IEC 61000-4-9, level 5
* Damped oscillatory magnetic field immunity acc. to IEC 61000-4-10, level 5
* Oscillatory waves immunity acc. to IEC 61000-4-12, level 3
* Oscillatory waves immunity in the range from 0 to 150 kHz acc. to IEC 61000-4-16, level 3
* Ripple on DC input power port immunity acc. to IEC 61000-4-17, level 3
* Voltage dips, short interruptions and voltage variations on DC input power ports per IEC 61000-4-29, 50 ms.

**Isolation**

* Voltage test acc. to IEC 60255-5 with 2 kV RMS, 50 Hz during 1min
* Impulse voltage withstand test acc. to IEC 60255-5 with 5 kV 1,2/50 μs

**Mechanical properties**

* Seismic test acc. to IEEE 693

**Environmental conditions**

* Cold test acc. to IEC 60068-2-1
* Dry heat test acc. to IEC 60068-2-2

**5) Communication features:**

The device shall provide one of the following communication interfaces so that it can be connected to a station automation system. The selectable communication protocols shall be:

* SPABUS, optical plastic fiber interface with snap-in type connector or glass fiber (multi mode) with

F- SMA or ST connectors

* LON (according to ABB LAG 1.4), glass fiber (multi mode) optical interface with ST connectors
* MODBUS RTU/SPA-Bus, electrical interface with two galvanically insulated RS 485 ports or two optical interfaces with standard ST connector for glass fiber (multi mode)
* Ethernet interface Standard RJ45 connector on the main module
* IEC 60870-5-103 with extension according to VDN guidelines for control, glass fiber (multi-mode) optical interface with ST connectors
* IEC 61850 electrical interface with two RJ45 connectors or optical interface with two pair LC connectors for glass fiber (multi-mode)
* Profibus DP, electrical RS 485 interface (with converter)