MICROENER

High speed bus transfer function block description Operation Manual

PROTECTA HUNGARY

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CONTENTS

1 High speed bus transfer function

1.1 Application

In a simple switchgear configuration, shown in Figure *1-1*, normally the busbar is operating in two sections, the busbar sectionalizer circuit breaker is open. Both sections are supplied by separated feeders. In the bays of the substation there can be different types of consumers, among other also large motors.

If the power supply is interrupted in any of the bus sections (in Figure *1-1* the missing voltage is pointed by encircled “X”), or simply the voltage drops below the permitted level then this event can cause critical problems for the consumers. To minimize the duration of the voltage interruption, the high speed bus transfer function automatically interrupts the circuit breaker of the supplying feeder of the unsupplied section (CB1 or CB2), and closes the busbar sectionalizer circuit breaker (Sect.CB).

The high power induction motors can keep the voltage of the unsupplied busbar section for a relatively long period of time (especially if compensating shunt capacitors are also applied). The frequency of this voltage however drops as the speed of the rotating motors decreases. For rotating motors the uncontrolled bus transfer could cause additional critical problems, as the energizing moment by the reserve feeder can coincide even with voltage opposition between the decreasing voltage of the motors and that of the reserve feeder. The high speed bus transfer function controls the moment of switching, avoiding the high current surges and the mechanical stress for the rotating machines.

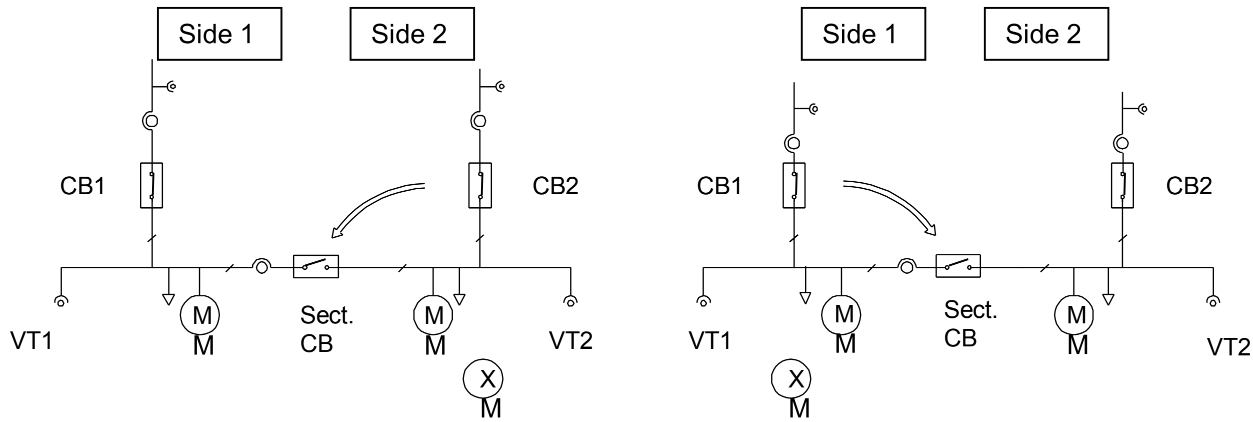

Figure 1-1 *Simple switchgear configuration*

NOTE:

This description explains the bus transfer function for the starting bus configuration shown in Figure *1-1*. For other starting configurations, e.g. if initially the bus sectionalizer (Sect.CB) is closed and only one feeder supplies the busbar then additionally similar function blocks are applied in the device.

The HSBT function block has two sets of voltage inputs. These are denoted as “Side 1” and “Side 2”. Accordingly, this also defines the identification of the primary system sides, as it is shown in Figure *1-1*.

In most substations, the busbar configuration is more complex than that shown in Figure *1-1*. Parallel busbars, separated busbar sections and/or more than two feeders can also be configured. For these applications the device performing the bus transfer can include several high speed bus transfer function instances. The coordinated operation of these individual functions is organized by the configuration of the device. One example for the possible configurations, two busbar sections and two feeders with complete device configuration, is shown in the Appendix of this document.

Mode of operation

The function block measures two sets of three-phase voltages: supplied by two voltage transformer sets at both sides of the open circuit breaker. In the HSBT function block, the VT-s are identified as measuring at "Side 1" and "Side 2". In this description, considering Figure *1-1*, these voltage transformer sets are the sets of the bus sections (VT1 and VT2, where "1" refers to "Side 1" and "2" refers to "Side 2"). The status signals of the participating circuit breakers identified by the "Sides", the open and the closed state, are also received by the function block. In case of voltage problems, a trip command is generated for the closed circuit breaker of the section with voltage problems, and receiving the changed status signal of this circuit breaker, a close command is generated for the bus sectionalizer circuit breaker.

The directions of the possible bus transfers have individual parameters for permitting the operation. There are dedicated trip command relays for both sides and the starting command form both bus sections are received by dedicated binary inputs. The mastering of these signals between the inputs of the device and the function block and also between the function block and the outputs of the device is performed by graphic logic editor in the factory. Additionally the user can fit these assignments to the special requirements, using the graphic logic editor.

The bus transfer is performed always with voltage interruption: during the transfer time the bus section is not supplied. The close command to the circuit breaker of the reserve feeder is generated only if the open state of the circuit breaker supplying the busbar before the event is received. During this time, the large motors – if they are connected to the busbar – keep the voltage.

1.1.1 Bus transfer operating modes

For minimizing the duration of the unsupplied time period and to perform safe transfer, there are three transfer operating modes:

- instantaneous mode,
- fast mode,
- slow mode.

The applied modes can be selected by a dedicated parameter, according to Table 1-1. Using this parameter, the function can also be disabled (default setting: Off).

Parameter name	Title	Selection range	Default
Selection of the operating modes for the high speed bus transfer function			
HSBT_Oper_EPar_	Operation	Off, Slow, Fast+Slow, Inst+Fast+Slow	Off

Table 1-1 Enumerated parameter of the high speed bus transfer function for operating mode selection

The priority sequence is: instantaneous mode -> fast mode -> slow mode. If any of them started but the conditions are not fulfilled then the function automatically tries the subsequent one in the priority sequence (if the parameter selection enables).

This paragraph describes the operating modes.

1. Instantaneous bus transfer mode

This mode is applied only if the parameter selection is "*Operation= Inst+Fast+Slow*". See Table 1-1.

The instantaneous bus transfer mode is started by dedicated input start signals assigned to "Side 1" or "Side 2". These signals are: "*InstStart1*" and "*InstStart2*" input signals of the function block. This information indicates that the power supply from the pointed side is going to be interrupted. The assignment is performed in the graphic logic editor, considering the available binary signals. NOTE: a trip signal from a protection function indicating a busbar fault in the substation is applied however to block the bus transfer function.

At receiving the dedicated start signal, the supplying circuit breaker is immediately tripped (the pulse duration is defined by the general timer parameter "*Pulse length*", see Table 1-3), and the function waits for the status signal, indicating the open state of the circuit breaker. These signals are: "*CB1Open*" and "*CB2Open*" input signals of the function block. The assignment is performed in the graphic logic editor.

If the status signal indicating the open state is received then the following is checked:

- The phase angle difference between the two voltage systems is below the setting level, defined by the parameter "*Inst Angle limit*". The recommended setting value is about 15 degrees. With this setting, at the moment of closing the CB poles, the angle difference is expected to remain below 60 degrees. Accordingly, the inrush current of the still rotating motors remains below the normal starting current level.
- The difference of the frequency between the two voltage systems is below the setting level, (according to factory setting it is about 1.2 Hz). This checking is needed to assure that during the transfer time the phase angle difference between the two asynchronous voltage systems could not reach to high value.
- Also the negative sequent voltage component is checked. The phase angle calculation, consequently the frequency calculation and the rate of change of frequency calculation is based on the positive sequence component of the voltages. With this method the calculation result is stabile even in case of changing frequency. The negative sequent component however causes disturbances. To avoid the problems, in case of negative sequence component above 10% related to the rated voltage of the voltage input, the instantaneous and the fast modes are not performed at all, the transfer is made in slow mode only.
- In case of fast voltage collapse the phase angle calculation, consequently the frequency calculation and the rate of change of frequency calculation cannot be performed. Accordingly, the instantaneous and the fast modes are not performed at all, the transfer is made in slow mode only (see below). The voltage collapse is detected by supervising the line-to-line voltages. If the difference between the last sampled voltages and the samples one network period before is more than 40% then the operating mode changes directly to slow mode.

In case of positive results of all checking above, the CLOSE command is generated (the pulse duration is defined by the general timer parameter "*Pulse length*", see Table 1-3). If the result of checking is negative then this instantaneous mode of operation is terminated and the function attempts to perform fast transfer mode.

The parameters related to the instantaneous bus transfer mode are summarized in Table 1-2 and Table 1-3 below.

Parameter name	Title	Dimension	Min	Max	Default
Angle difference limit for the instantaneous mode of operation					
HSBT_AngLim_FPar_	Inst Angle limit	deg	5	30	10

Table 1-2 Floating point parameters of the high speed bus transfer function, related to instantaneous bus transfer mode

Common timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
TRIP and Close pulse duration						
HSBT_Pulse_TPar_	Pulse length	msec	1000	60000	1	500

Table 1-3 Common timer parameters of the high speed bus transfer function

2 Fast bus transfer mode

This mode is applied if the parameter selection is "*Operation= Inst+Fast+Slow*" or "*Operation= Fast+Slow*". See also Table 1-1.

This mode of operation can be started by two methods:

- if the transfer was started as instantaneous transfer, but the conditions were not fulfilled, or
- it is started automatically if the rate of change of frequency (df/dt) of one of the voltage sets is above the setting value defined by the parameter "*df Start limit*", the other one is not. The related parameter is shown in Table 1-4. This parameter neglects the sign of the rate of change of frequency, it checks the magnitude only. If voltage sources (e.g. distributed generation) are connected to the busbar, then the frequency can also increase. If both transfer directions are permitted by parameter "*Negative df*" (i.e. "*Negative df =False*") then the transfer direction is selected automatically by the larger df/dt value. (Side 1 is generating the TRIP command if df/dt at side 1 is above "*df Start limit*" and df/dt at side 2 is below "*df Start limit*". Additionally, if "*Negative df =True*" then df/dt at side 1 should be negative. The "*Negative df =True*" is advised to be selected if no generators are connected to the busbar. The related Boolean parameter is shown in Table 1-5.
- Also the negative sequent voltage component is checked. The phase angle calculation, consequently the frequency calculation and the rate of change of frequency calculation is based on the positive sequence component of the voltages. With this method the calculation result is stabile even in case of changing frequency. The negative sequent component however causes disturbances. To avoid the problems, in case of negative sequence component above 10% related to the rated voltage of the voltage input, the instantaneous and the fast modes are not performed at all, the transfer is made in slow mode only.
- In case of fast voltage collapse the phase angle calculation, consequently the frequency calculation and the rate of change of frequency calculation cannot be performed. Accordingly the instantaneous and the fast modes are not performed at all, the transfer is made in slow mode only (see below). The voltage collapse is detected by supervising the line-to-line voltages. If within one period the vector change of the voltage is more than 40% then the operating mode changes directly to slow mode.

To over-bridge the transient period (time for calculation of the Fourier components, frequency measurement based on the change of the Fourier angle and the time needed for reliable df/dt calculation, at least 80 msec) the starting is delayed by 90 msec. Accordingly the evaluation is based on steady state of df/dt.

An additional condition for starting the fast transfer mode is that the additional phase shift between the voltage systems should be at least 45 deg, related to the phase shift at the moment of df/dt detection.

At the moment when this mode is started, a TRIP command is generated for the related circuit breaker (the pulse duration is defined by the general timer parameter "*Pulse length*", see Table 1-3).

If the status signal indicating the open state of the circuit breaker is received (These signals are: "*CB1Open*" and "*CB2Open*" input signals of the function block, the assignment is performed in the graphic logic editor), the following calculation is performed: Based on the frequency difference and additionally on the operating time of the circuit breaker, the optimal angle before the subsequent synchronous state for the close command generation is calculated. The operation time of the circuit breaker is given by a parameter "*CB travelling time*", defined for each circuit breaker individually (see

Maximum waiting time to reach synchronous state in fast operating mode						
HSBT_MaxFast_TPar_	Max Fast Time	msec	200	2000	1	800

Table 1-8). The command is started at the moment of the calculated angle position, and the poles of the circuit breaker will close at the moment of synchron position of the voltages.
This method is also working, if the vector position or even the frequency of the two voltage systems are different at the moment of starting.

The fast bus transfer mode of operation may not generate a close command if the calculated starting angle position is above 160 deg (too fast relative rotation, factory setting), or the voltage at the busbar is below the lower voltage level (the angle calculation is not reliable any more). The related parameter is "*U Low*". Similarly to instantaneous mode, the negative sequence voltage component must be below 10% related to the rated voltage of the voltage input. If the conditions are not fulfilled then the fast bus transfer mode is terminated and the function enters to slow bus transfer mode. The mode is transferred to slow bus transfer mode also if the elapsed time is longer than the "*Max Operating time*" timer parameter value.

The tables below show the summary of the parameters related to the fast transfer mode (Table 1-4, Table 1-5, Table 1-6, Table 1-7 and

Maximum waiting time to reach synchronous state in fast operating mode						
HSBT_MaxFast_TPar_	Max Fast Time	msec	200	2000	1	800

Table 1-8).

Parameter name	**Title**	**Dimension**	**Min**	**Max**	**Default**
Frequency changing difference limit for starting the fast mode of operation					
HSBT_dfStart_FPar_	df Start limit	Hz/sec	1.000	50.000	10.000

Table 1-4 Floating point parameters of the high speed bus transfer function, related to fast bus transfer mode

Parameter name	Title	Default
Permission for operation at negative rate of change of frequency only		
HSBT_Negdf_BPar_	Negative df	False

Table 1-5 Boolean parameter of the high speed bus transfer function, related to fast transfer mode

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage level lower limit for angle calculation and for slow operation						
HSBT_ULow_IPar_	U Low	%	10	50	1	15
Voltage level for detecting helathy state of the voltage at the reserve side						
HSBT_UHigh_IPar_	U High	%	45	100	1	70

Table 1-6 Integer parameter of the high speed bus transfer function, related to fast transfer mode

Parameter name	Title	Unit	Min	Max	Step	Default
Maximum operating time for fast bus transfer mode						
HSBT_MaxOper_TPar_	Max Operating time	msec	1000	60000	1	5000
TRIP and Close pulse duration						
HSBT_Pulse_TPar_	Pulse length	msec	1000	60000	1	500

Table 1-7 Common timer parameters of the high speed bus transfer function, related to fast transfer mode

Timer parameter individually for each instant of the function

Parameter name	Title	Unit	Min	Max	Step	Default
Expected travelling time of the circuit breaker						
HSBT_CBTrav_TPar__Bus1_Bus2	CB travelling time	msec	30	150	1	50
Maximum waiting time to reach synchronous state in fast operating mode						
HSBT_MaxFast_TPar_	Max Fast Time	msec	200	2000	1	800

Table 1-8 Individual timer parameter of each instant of the function

3 Slow bus transfer:

This mode is applied if the parameter selection is "*Operation= Inst+Fast+Slow*" or "*Operation= Fast+Slow*" or "*Operation= Slow*". See also Table 1-1.

This mode of operation can be started by two methods:

- if the transfer was tried in fast transfer mode, but the conditions were not fulfilled, or
- it is started automatically if
    - the voltage drops below the level defined by the parameter "*U High*" and
    - two out of the three line-to-line voltages is also below the level defined by the parameter "*U High*". This condition is needed if the feeder is a Yd transformer and there is a single phase to neutral fault at the Y side. This state does not start the function.

The function in this mode of operation generates the TRIP command for the circuit breaker if the waiting time after fulfilling the conditions above expires. The waiting time defined by the parameter "*Slow Delay*".

The Close command is generated if:

- The voltage gets below the low voltage level, defined by parameter "*U Low*".
- The CB supplying formerly must be already in open state, and

- The parameter "*Permissive Slow*" declares if the healthy state of the reserve power supply is the condition for the close command or not. If "*Permissive Slow=True*" then the voltages are not checked for the Close command generation (The bus transfer is performed even if the voltage is missing.)

The parameters related to slow transfer mode are summarized in Table 1-9, Table 1-10 and Table 1-11 below.

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage level for starting the slow transfer mode						
HSBT_UHigh_IPar_	U High	%	45	100	1	70
Voltage level lower limit for slow operation						
HSBT_ULow_IPar_	U Low	%	10	50	1	15

Table 1-9 Integer parameters of the high speed bus transfer function, related to slow transfer mode

Common timer parameters

Parameter name	**Title**	**Unit**	**Min**	**Max**	**Step**	**Default**
TRIP and Close pulse duration						
HSBT_Pulse_TPar_	Pulse length	msec	1000	60000	1	500
Time delay for slow operating mode						
HSBT_SlowDelay_TPar_	Slow Delay	msec	1000	60000	1	500

Table 1-10 Common timer parameters of the high speed bus transfer function, related to slow transfer mode

Boolean parameters

Parameter name	Title	Default
Definition if the healthy state of the reserve feeder is the condition of the close command. If this parameter is set to "True" then the reserve voltage state is not checked.		
HSBT_PermSlow_BPar_	Permissive Slow	False

Table 1-11 Boolean parameter of the high speed bus transfer function, related to slow transfer mode

1.1.2 Blocking of the function

If the "*Operation*" parameter is "*Operation=Off*" then the high speed bus transfer function is not operable.

The function can also be blocked when connecting active binary signals to the "Blk" input of the function block. The signals can be assigned using the graphic logic editor. If the blocking signal resets then a timer is started. The function gets active only if this timer expires (and the "*Operation*" parameter is NOT "*Off*". The related time delay parameter is "*Blocking delay*". This is shown in Table 1-12 below.

Parameter name	**Title**	**Unit**	**Min**	**Max**	**Step**	**Default**
Blocking delay after resetting the Blk input signal						
HSBT_BlkDelay_TPar_	Blocking delay	msec	1000	60000	1	5000

Table 1-12 Common timer parameters of the function

The “DynBlk” binary input of the function block serves dynamic blocking. (When this status signal resets, the function is immediately operable.) This input is applied in more complex busbar configurations, when several HSBT function blocks are applied. In this case the activating one of them blocks the operation of all other blocks. The applicable output signal is “*InPrg*” which is active if any of the operating mode is performed. When finishing the operation, this signal resets and all other HSBT instance get active again. To perform this, the blocking logic is to be composed using the graphic logic editor. An example for this application is shown is the Appendix of this document.

In any of the blocked states the “Ready” output signal is not active. This signal gets active only if the function is not blocked AND both measured voltages are healthy (above the level defined by the parameter “*U High*”).

1.2 Structure of the high speed bus transfer function

Figure 1-2 shows the structure of the high speed bus transfer function (HSBT).

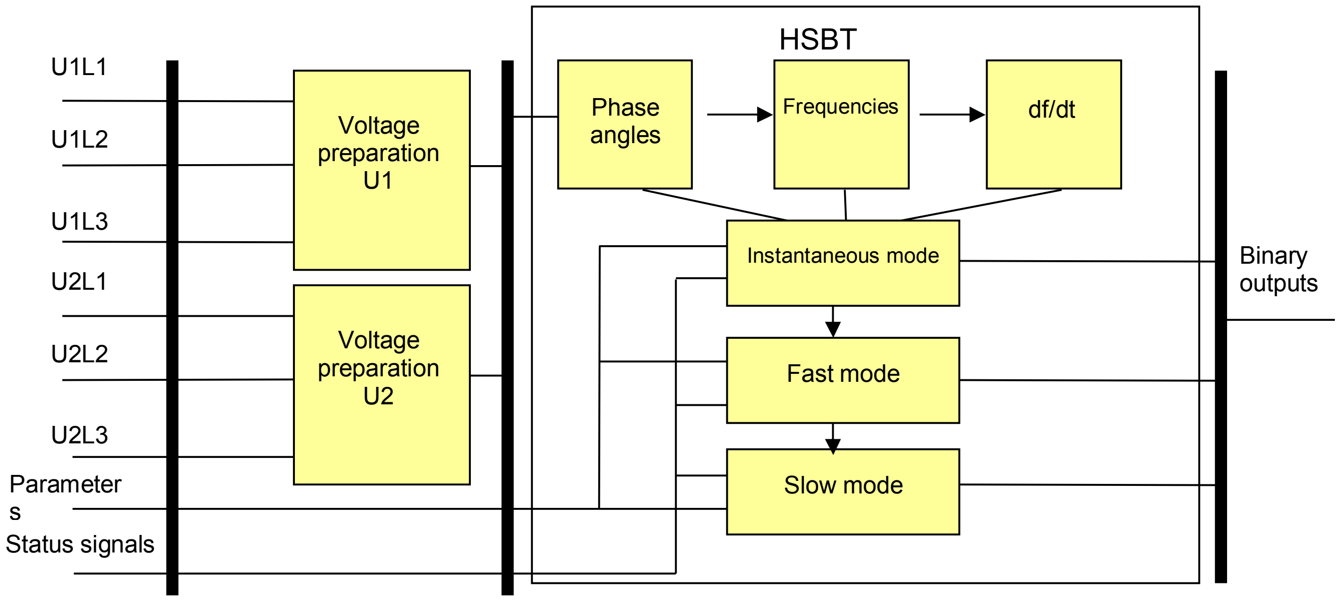

Figure 1-2 Structure of the high speed bus transfer function

The **inputs** are

- two three-phase sets of sampled voltages
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** related to the HSBT function:

Voltage preparation

These modules calculate the voltage-related information, needed for the bus transfer function. These modules are not part of the HSBT function, they belong to the preparatory phase. The results may be applied by any other protection functions, configured in the device.

HSBT function block
These module calculates additional information, needed for the bus transfer function, than it performs the procedures for high speed bus transfer.

1.2.1 Voltage preparation

Figure 1-3 shows the modules involved in voltage preparation. These modules are not part of the HSBT function, they belong to the preparatory phase. The results may be applied by any other protection functions, configured in the device.

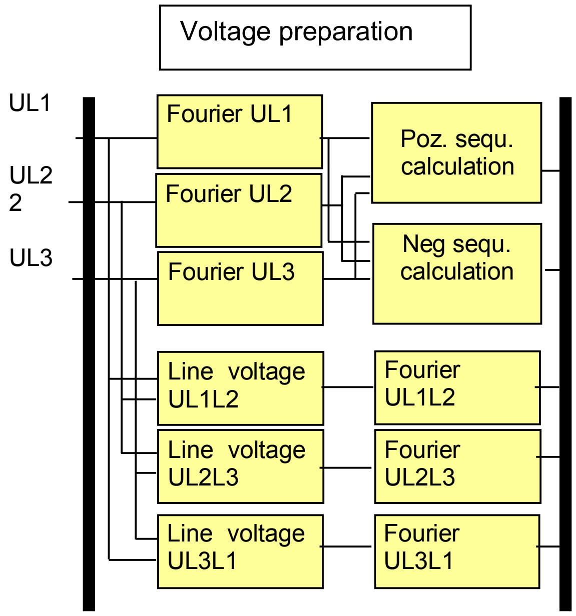

Figure 1-3 Structure of the voltage preparation algorithm

The voltage preparation is performed for both three-phase voltage sets.

The **inputs** are
- three-phase sets of sampled voltages.

The **outputs** are
- internal calculated voltage information
  - Fourier components of the line-to-ground voltages,
  - Fourier components of the line-to-line voltages,
  - Fourier components of the positive sequence component voltages,
  - Fourier components of the negative sequence component voltages.

The **software modules** of the definite time overvoltage protection function:

Fourier calculations
These modules calculate the basic Fourier components of the phase voltages individually (not part of the HSBT function).

Line-to-line voltage calculation
These modules calculate the line-to line values, based on the line-to-ground measured voltages (not part of the HSBT function).

Pos sequ. calculation
These module calculates the positive sequence basic Fourier component (not part of the HSBT function).

Neg sequ. calculation
These module calculates the negative sequence basic Fourier component (not part of the HSBT function).

1.2.2 The HSBT high speed bus transfer function

Figure 1-4 shows the principal structure of the high speed bus transfer algorithm (HSBT).

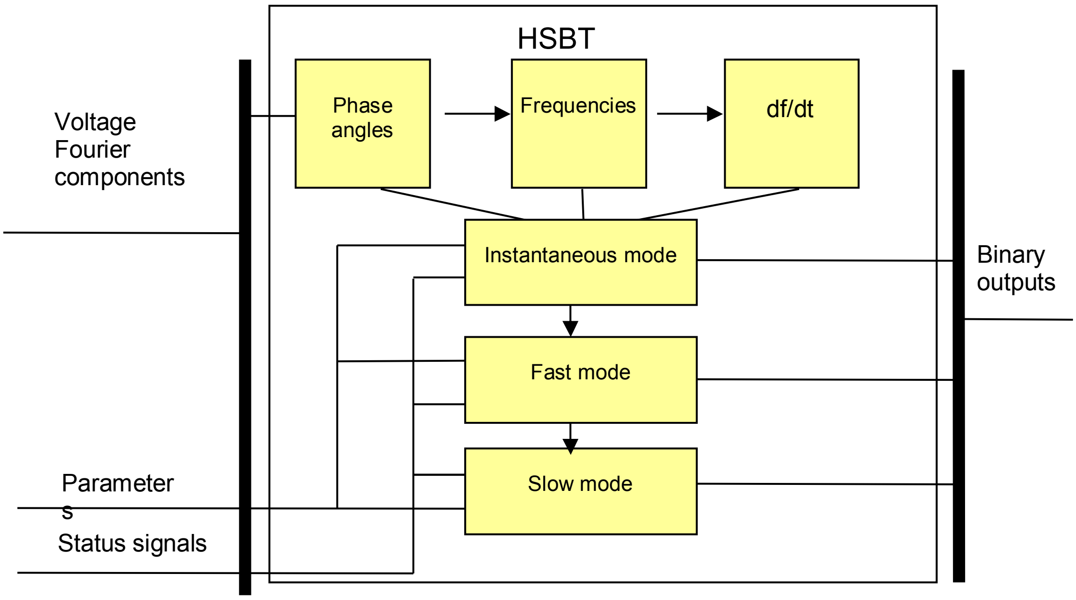

Figure 1-4 Principal structure of the HSBT algorithm

The **inputs** are

- internal calculated voltage information
    - Fourier components of the line-to-line voltages, applied for level checking
    - Fourier components of the positive sequence component voltages, applied for phase angle, frequency and df/dt calculation,
    - Fourier components of the negative sequence component voltages, applied for level checking.

The **outputs** are

- binary output signals

The **software modules** of the definite time overvoltage protection function:

Phase angles

This module calculates phase angles, based on Fourier components of the voltages. The phase angles serve for frequency calculation and for checking the voltage phase relationships.

Frequencies

This module calculates frequencies, based on the changing phase angle of the measured positive sequence component voltages. The frequency cannot be measure if the deviation related to the rated frequency is above 9.26 Hz, defined as angle rotation in a defined time span. In this case no frequency-related decision within the function are possible: the instantaneous and the fast modes are not performed at all, the transfer is made in slow mode only (see below). The frequencies serve for df/dt calculation and for checking the voltage frequency relationships.

df/dt

This module calculates the frequency changes of the positive sequence voltage components.

Instantaneous mode, fast mode, slow mode

The bus transfer mode depends on
- the parameter values,
- the received status signals,
- the measured phase angles,
- the measured frequencies and
- the measured df/dt values.

Based on this information, transfer mode changes dynamically. The algorithm has internal states, the details are described below.

1. **Blocked state**. This is the default state when starting the device. The algorithm gets to the subsequent unblocked state only, if
   - other than „*Off*" value was selected for the parameter „*Operation*",
   - there is no active signal on the „DynBlk" input of the function block,
   - there is no active signal on the „Blk" input of the function block and the delay time after resetting the „Blk" input signal expired, according to parameter value "*Blocking delay*" and
   - both voltages are symmetrical, (no negative sequent component above 10% of the rated voltage value) and the positive sequent components are above the level defined by parameter "*U High*".

2. **Unblocked state**. When entering in this state, the output "Ready" of the function block gets active. After that, the conditions for starting are supervised. The active state of the "DynBlk" input of the function block disables any starting at reset however the starting is immediately possible. (This input is usually applied for cooperation several configured HSBT function blocks: in case of starting any of them, the other ones are dynamically blocked.) In this state the transfer modes can be initiated as follows:

   Instantaneous starting is initiated if
   - a starting signal is received in any of the inputs "InstStart1" or "InstStart2"
   - both positive sequent voltage components are above the level defined by parameter "*U High*"
   - both calculated frequencies are valid (the validity is delayed by 30 ms, after the voltage increased above the voltage level defined by parameter "*U Low*").

   Fast starting is initiated if
   - the voltage at the reserve infeed is healthy,
   - the calculated df/dt on one side is above the setting level (this side defines the direction of the transfer), and the df/dt on the other side is below the setting level,
   - the angle position is at least 45 degrees, related to the position measured at the moment of high df/dt detection
   - and the frequency difference is at least 72 deg/sec (0,2 Hz). This condition filters out the transient swings.

   Slow starting is initiated if
   - neither instantaneous nor fast transfer is active,
   - the target voltage at the busbar is not healthy (it is below the level defined by parameter "*U High*"),
   - at least two of the line-to-line voltages are also below the level defined by parameter "*U High*",

- the reserve voltage is healthy (it is above the level defined by parameter "*U Low*"),
- the time measurement in this state expired, according to the parameter setting "*SlowDelay*".

If any of the starting modes get active, a timer is started. The parameter value "MaxOper" defines the maximum waiting time.

If in the unblocked state the algorithm detects a jump, then the status is changed to the appropriate state (see below).
At the moment of entering instantaneous or fast transfer mode, the "Ready" output signal of the function block resets, and the output signal "InPrg" gets active, indicating the progress of bus transfer.
The slow transfer mode is started after the time delay, and 30 ms before starting, the output signal "InPrg" gets active to dynamically block all other function blocks. At the same time the "Ready" output signal of the function block resets.

If the voltages both of the supplying side and the reserve side are not healthy at the same time (e.g. they are connected to the same point of the electric power system) then no slow transfer mode is initiated. To deliver information about the fact of not attempting the transfer, the function block generates a pulse of 30 ms duration on the output „SlowInPrg" without the active state of the output „InPrg". Using the graphic logic editor, this signal combination can be applied to start another bus transfer procedure with participation of further infeeds in a more complicated bus system arrangement.

As it was described related to state „1" above, the transfer from „Blocked state" to „Unblocked state" is possible only if both voltages are above the level defined by parameter "*U High*". To ensure a second starting (to start another bus transfer procedure with participation of further infeeds in a more complicated bus system arrangement) a timer is applied. This timer is started at the moment when the voltage of the faulty side gets below the level "*U High*". The time limit is defined by the timer parameter "*MaxOper*". If the permission for this transfer is received during the running state of the timer then the slow transfer is stated.

3. **State for Trip1**. The function generates the trip command for the circuit breaker of side 1, the duration is defined by the parameter „*Pulse length*". The assignment of the output of the function block to a relay contact of the device is made using the graphic logic editor. The algorith waits max 200 ms to receive the signal indicating the open state of the circuit breaker. According to the success, the algoritm step to the subsequent state for closing a circuit breaker or the transfer is unsuccessful.

4. **State for Trip2**. This state is analogous to State for Trip1 above.

5. **Instantaneaous transfer from Side 1 to Side 2**. The Close command is generated if the angle difference is below the limit, defined by parameter, and and also the frequency difference is less than 1,2 Hz. If these conditions are not fulfilled then the next state is Fast transfer

6. **Instantaneaous transfer from Side 2 to Side 1**. This state is analogous to the direction from 1 to 2.

7. **Fast transfer from Side 1 to Side 2.** This transfer is performed if the voltage at the reserve side (2) is above the "*U High*" level and also the disappearing voltage is above the "*U Low*" level. The angle difference should decrease, indicating that the

vectors are approaching the synchronous state. When the angle difference gets below the calculated value and it is still not more than 5 degrees, then the Close command is generated for the "*Pulse length*" time. The algorithm than waits for the signal indicating the closed state of the circuit breaker for the "*MaxFast*" time. If the signal is not received then the subsequent state is the slow transfer state.

8. **Fast transfer from Side 2 to Side 1**. This state is analogous to the direction from 1 to 2.

9. **Slow transfer from Side 1 to Side 2**. This transfer mode is performed if the disappearing voltage gets below the level defined by the parameter "*U Low*". If the Boolean parameter "*PermSlow=False*" then the reserve voltage should be above the level defined by the parameter "*U High*". If this Boolean parameter "*PermSlow=True*" then the reserve voltage is not checked. In this state the maximum waiting time is defined by the parameter "*Max Operating time*".

10. **Slow transfer from Side 2 to Side 1**. This state is analogous to the direction from 1 to 2.

11. **Close command in progress** state. In this state the algorithm waits for maximum 100 ms additionally to the circuit breaker time ("*CB travelling time"*) to receive the signal indicating the closed state of the circuit breaker.

12. **Successful transfer**. When the signal indicating the closed state of the circuit breaker is received, this is the state for 2 sec. Then the subsequent state is the Blocked state.

13. **Failed transfer**. The algorithm gets to this state when the circuit breaker getting the TRIP command did not open or the own circuit breaker, receiving the Close command did not get closed. This is also the state if the maximum transfer time, defined by the parameter „Max Operating time" expired. This is the case if the disappearing voltage does not get below the „*U Low*" level. After 2 sec additional waiting time the algorithm gets in Blocked state

14. **Jump at side 1**. In case of voltage jump, the algorithm waits for the time defined for the slow transfer. Then, if both voltage get healthy again, then the subsequent state is the Unblocked state. If only voltage 2 is healthy without jump in this system and two out of the three line-to-line voltages are below the „*U High*" level then a slow transfer from 1 to 2 is started. If not then the subsequent state is the Blocked state. If however a jump was detected in both voltage systems then the subsequent state is the Blocked state.

15. **Jump at side 2**. This state is analogous to the Jump state of side 1.

1.3 Technical summary

1.3.1 Technical data

Function	Range related to the rated voltage	Accuracy
Voltage measurement	30% … 120%	< 0,5 %

Table 1-13 Technical data of the high speed bus transfer protection function

1.4 The function block in the graphic logic editor

1.4.1 Binary input signals

The **binary inputs** are signals influencing the operation of the function. These signals are the results of logic equations graphically edited by the user.

Binary input signals	Signal title	Explanation
HSBT_Blk_GrO__Bus1_Bus2	Blk	Blocking of function
HSBT_DynBlk_GrO__Bus1_Bus2	DynBlk	Dynamic blocking of function
HSBT_Ena12_GrO__Bus1_Bus2	Ena12	Enabling transfer from CB1 to CB 2
HSBT_Ena21_GrO__Bus1_Bus2	Ena21	Enabling transfer from CB2 to CB 1
HSBT_CB1Open_GrO__Bus1_Bus2	CB1Open	CB1 is in Open state
HSBT_CB2Open_GrO__Bus1_Bus2	CB2Open	CB2 is in Open state
HSBT_OwnCBClosed_GrO__Bus1_Bus2	OwnCBClosed	Own CB is in closed state
HSBT_InstStart1_GrO__Bus1_Bus2	InstStart1	Staring the instantaneous transfer by source 1
HSBT_InstStart2_GrO__Bus1_Bus2	InstStart2	Staring the instantaneous transfer by source 2

Table 1.4-1 Binary input signals influencing the operation of the high speed bus transfer protection function

1.4.2 Binary output signals

The **binary output** status signals are summarized in Table below. These signals can be used in the graphic logic, edited by the user.

Binary output signals	Signal title	Explanation
HSBT_Ready_GrI__Bus1_Bus2	Ready	Ready for operation
HSBT_InPrg_GrI__Bus1_Bus2	InPrg	Transfer procedure in progress
HSBT_FastInPrg_GrI__Bus1_Bus2	FastInPrg	Fast operation in progress
HSBT_SlowInPrg_GrI__Bus1_Bus2	SlowInPrg	Slow operation in progress
HSBT_Trip1_GrI__Bus1_Bus2	Trip1	Trip command for CB 1
HSBT_Trip2_GrI__Bus1_Bus2	Trip2	Trip command for CB 2
HSBT_Close_GrI__Bus1_Bus2	Close	Close command
HSBT_InstOper_GrI__Bus1_Bus2	InstOper	Instantaneous operation is performed
HSBT_FastOper_GrI__Bus1_Bus2	FastOper	Fast operation is performed
HSBT_UnSuc_GrI__Bus1_Bus2	UnSuc	Unsuccessful transfer
HSBT_SyncOK_GrI__Bus1_Bus2	SyncOK	Synchron state detected*

** This output signal can be used by additional transfer functions (e.g. manual bus transfer without voltage interruption)*

Table 1.4-2 Binary output signals of the high speed bus transfer protection function

1.4.3 The function block

The function block of the function is shown in Figure *1.4-1*. This block shows all binary input and output status signals that are applicable in the graphic logic editor.

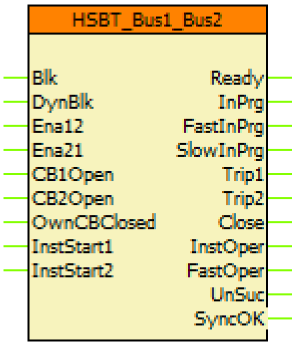

Figure 1.4-1 *The function block of the high speed bus transfer protection function*

NOTE: The Close command has also a factory connection to the dedicated output relay.

1.5 Summary of the parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Selection of the operating modes for the function			
HSBT_Oper_EPar_	Operation	Off,Slow,Fast+Slow,Inst+Fast+Slow	Off

Table 1.4-3 Enumerated parameter of the high speed bus transfer protection function

Boolean parameters

Parameter name	Title	Default
Definition if the healthy state of the reserve feeder is the condition of the close command. If this parameter is set to "True" then the reserve voltage state is not checked.		
HSBT_PermSlow_BPar_	Permissive Slow	False
Permission for operation at negative rate of change of frequency only. If this parameter is set to "True" then the function starts for negative df/dt value only.		
HSBT_Negdf_BPar_	Negative df	False

Table 1.4-4 Boolean parameter of the high speed bus transfer protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage level lower limit for angle calculation and for slow operation						
HSBT_ULow_IPar_	U Low	%	10	50	1	15
Voltage level for starting the slow transfer mode and to check the healthy state of the voltages						
HSBT_UHigh_IPar_	U High	%	45	100	1	70

Table 1.4-5 Integer parameters of the high speed bus transfer protection function

Floating point parameters

Parameter name	Title	Dimension	Min	Max	Default
Frequency changing difference limit for the instantaneous mode of operation					
HSBT_dfStart_FPar_	df Start limit	Hz/sec	1.000	50.000	10.000
Angle difference limit for the instantaneous mode of operation					
HSBT_AngLim_FPar_	Inst Angle limit	deg	5	30	10

Table 1.4-6 Floating point parameters of the high speed bus transfer protection function

Common timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Blocking delay after resetting the Blk input signal						
HSBT_BlkDelay_TPar_	Blocking delay	msec	1000	60000	1	5000
Maximum operating time for fast bus transfer mode						
HSBT_MaxOper_TPar_	Max Operating time	msec	1000	60000	1	5000
TRIP and Close pulse duration						
HSBT_Pulse_TPar_	Pulse length	msec	1000	60000	1	500
Time delay for slow operating mode						
HSBT_SlowDelay_TPar_	Slow Delay	msec	1000	60000	1	500
Maximum waiting time to reach synchronous state in fast operating mode						
HSBT_MaxFast_TPar_	Max Fast Time	msec	200	2000	1	800

Table 1.4-7 Common timer parameters of the high speed bus transfer protection function

Timer parameter individually for each instant of the function

Parameter name	Title	Unit	Min	Max	Step	Default
Expected travelling time of the circuit breaker						
HSBT_CBTrav_TPar__Bus1_Bus2	CB travelling time	msec	30	150	1	50

Table 1.4-8 Individual timer parameter of each instant of the high speed bus transfer protection function

2 Appendix: Application of the high speed bus transfer function

2.1 Example switchgear configuration: two busbar sections and two feeders

In a simple switchgear configuration, shown in Figure 2-1, the busbar has two sections, divided by a busbar sectionalizer circuit. The substation is supplied by two feeders. In the bays of the substation there can be different types of consumers, among other also large motors. This substation can have different normal modes of operation, accordingly different busbar transfer procedures may be required.

To serve all busbar transfer procedures, the HSBT function block is applied in three instances, shown also in Figure 2-1.

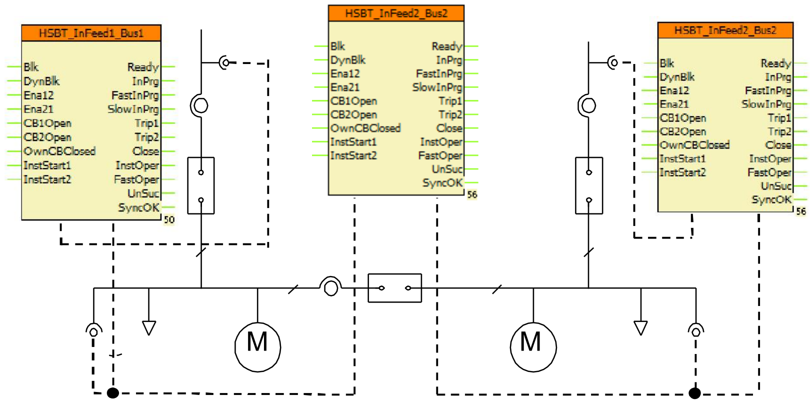

Figure 2-1 Example configuration

For correct co-operation of three applied HSBT function blocks, the “InPrg” outputs of both others (HSBT_Bus1_Bus1 and HSBT_Infeed1_Bus1) should be connected graphically in OR relationship to the binary input “DynBlk” of this HSBT_Infeed2_Bus2 function block.

All three HSBT function blocks have an “own” circuit breaker. This is the circuit breaker, which has voltage transformers on both sides, connected to the function block.

There is only one HSBT function block active at a time. This is the one, which has the “own” circuit breaker open, and the other two circuit breakers in closed state.

All these assignments are performed in the configuration procedure at the factory, using the graphic logic editor.

2.2 Application of the HSBT_Bus1_Bus2 instance of the function

The Figure below explain the role and application of the HSBT instances.

In Figure 2-2 normally the busbar is operating in two sections, the busbar sectionalizer circuit breaker is open. Both sections are supplied by separated feeders. In the bays of the substation there can be different types of consumers, among other also large motors.

In this configuration the HSBT_Bus1_Bus2 high speed bus transfer function is active if the busbar sectionalizer circuit breaker is open. The left side is considered to be the side 1 and the right side is side 2. If the power supply is interrupted in the left side bus section (in Figure 2-2 the missing voltage is pointed by encircled “X”), or simply the voltage drops below the permitted level then this event can cause critical problems for the consumers. To minimize the duration of the voltage interruption, the HSBT_Bus1_Bus2 high speed bus transfer function automatically interrupts the circuit breaker of the supplying feeder of the unsupplied section (CB of Feeder 1), and closes the busbar sectionalizer circuit breaker.

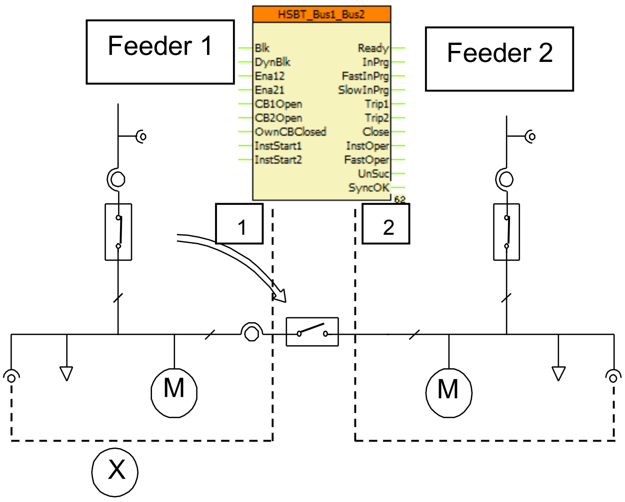

Figure 2-2 Application of the HSBT Bus1-Bus2 instance /1

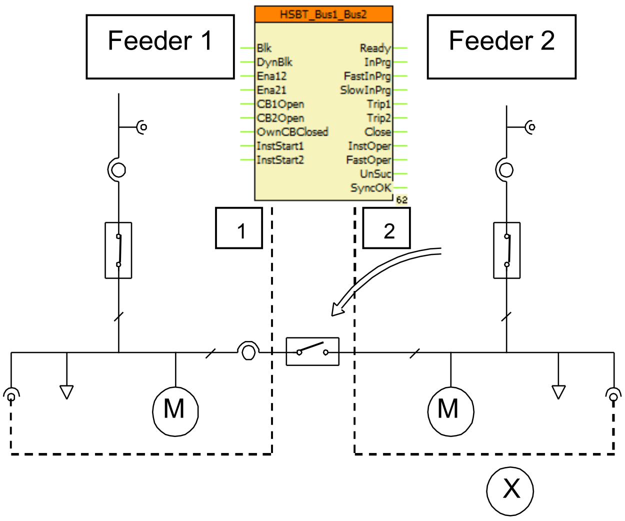

Figure 2-3 Application of the HSBT Bus1-Bus2 instance /2

In Figure 2-3 also, in normal operating mode, the busbar is operating in two sections, the busbar sectionalizer circuit breaker is open. Both sections are supplied by separated feeders. In the bays of the substation there can be different types of consumers, among other also large motors.

If the power supply is interrupted in the right side bus section (in Figure 2-3 the missing voltage is pointed by encircled “X”), or simply the voltage drops below the permitted level then this event can cause critical problems for the consumers. To minimize the duration of the voltage interruption, the HSBT_Bus1_Bus2 high speed bus transfer function automatically interrupts the circuit breaker of the supplying feeder of the unsupplied section (CB of Feeder 2), and closes the busbar sectionalizer circuit breaker.

These Figures show that the instance HSBT_Bus1_Bus2 is applied in bi-directional mode. For this mode the binary inputs of the function block “Ena12” and “Ena21” should be set to logic TRUE state.

For this application:

- The voltage transformers at both bus sections are assigned to the function.
- The status signals of the circuit breakers of both feeders are received on binary inputs "CB1Open" and "CB2Open" of the function block.
- The status signal of the bus sectionalizer circuit breaker is received on the dedicated binary input "Own CB Closed" of the function block. NOTE: as a thumbs rule, the "own" means the originally open circuit breaker in all HSBT instances.
- The "TRIP1" command should be directed to the circuit breaker in Feeder 1.
- The "TRIP2" command should be directed to the circuit breaker in Feeder 2.
- The "Close" command should be directed to the bus sectionalizer circuit breaker. NOTE: The Close command is a critical command to point to the synchronous state of the voltage vectors. To aim this, the close command does not go through the relatively slow graphic logic. By factory assignment it is directly connected to the appropriate binary output relay of the device at configuration.

All these assignments are performed in the configuration procedure at the factory, using the graphic logic editor.

For correct co-operation of three applied HSBT function blocks, the "InPrg" outputs of both others (HSBT_Infeed1_Bus1 and HSBT_Infeed21_Bus2) should be connected graphically in OR relationship to the binary input "DynBlk" of this HSBT_Bus1_Bus2 function block.

All these assignments are performed in the configuration procedure at the factory, using the graphic logic editor.

2.3 Application of the HSBT_Infeed1_Bus1 instance of the function

In this mode of operation Feeder 2 supplies the busbar alone, the bus sectionalizer circuit breaker is in closed position. In the bays of the substation there can be different types of consumers, among other also large motors.

In this configuration the HSBT_Infeed1_Bus1 high speed bus transfer function is active if the circuit breaker at the left side is open. The voltage transformer of the Feeder 1 is connected to side 1 and the voltage transformer of the left side busbar section to side 2. If the power supply is interrupted in Feeder 2 (in Figure 2-4 the missing voltage of the whole busbar is pointed by encircled "X"), or simply the voltage drops below the permitted level then this event can cause critical problems for the consumers. To minimize the duration of the voltage interruption, the HSBT_Infeed1_Bus1 high speed bus transfer function automatically interrupts the circuit breaker of the supplying feeder of the unsupplied section (CB of Feeder 2), and closes the circuit breaker of Feeder1.

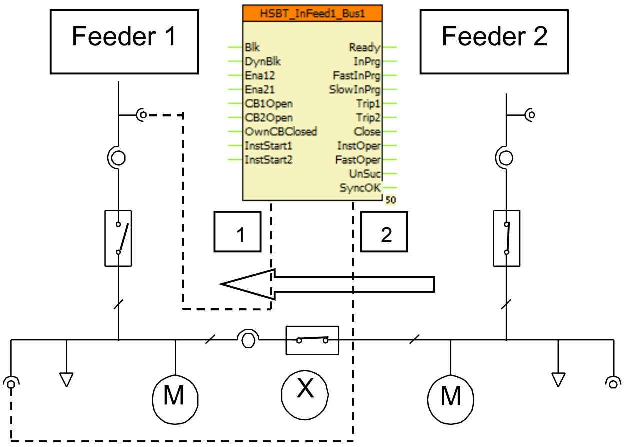

Figure 2-4 Application of the HSBT Infeed1-Bus1 instance

These Figure shows that the instance HSBT_Infeed1_Bus1 is applied in uni-directional mode, it operates if the bus voltage gets unhealthy. For this mode only the binary input of the function block “Ena12” should be set to logic FALSE state and “Ena21” input gets an active signal if the “own” circuit breaker in Feeder 1 is open, the other two ones are in closed state.

For this application:

- The voltage transformers at Feeder1 and the voltage transformers of the left side of the busbar are assigned to the function.
- The status signal of the circuit breaker of Feeder2 is received as “CB2Open”, “CB1Open” input is not assigned. NOTE: In this Paragraph 2.3 the “1” and “2” bay be consequently interchanged.
- The closed status signal of the circuit breaker of Feeder1 is received as “Own CB Closed”. NOTE: as a thumbs rule, the “own” means the originally open circuit breaker in all HSBT instances.
- The TRIP2 command should be directed to the circuit breaker in Feeder 2.
- The TRIP1 command is not applied.
- The Close command should be directed to the circuit breaker in Feeder 1. NOTE: The Close command is a critical command to point to the synchronous state of the voltage vectors. To aim this, the close command does not go through the relatively slow graphic logic. By factory assignment it is directly connected to the appropriate binary output relay of the device at configuration.

For correct co-operation of three applied HSBT function blocks, the “InPrg” outputs of both others (HSBT_Bus1_Bus1 and HSBT_Infeed2_Bus2) should be connected graphically in OR relationship to the binary input “DynBlk” of this HSBT_Infeed1_Bus1 function block.

All these assignments are performed in the configuration procedure at the factory, using the graphic logic editor.

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2.4 Application of the HSBT_Infeed2_Bus2 instance of the function

Figure 2-5 is the mirror of Figure 2-4. In this mode of operation Feeder 1 supplies the busbar alone, the bus sectionalizer circuit breaker is in closed position. In the bays of the substation there can be different types of consumers, among other also large motors.

In this configuration the HSBT_Infeed2_Bus22 high speed bus transfer function is active if the circuit breaker at the right side is open. The left side is considered to be the side 1 and the right side is side 2. The voltage transformer of the Feeder 2 is connected to side 1 and the voltage transformer of the right side busbar section to side 2. If the power supply is interrupted in Feeder 1 (in Figure 2-5 the missing voltage of the whole busbar is pointed by encircled “X”), or simply the voltage drops below the permitted level then this event can cause critical problems for the consumers. To minimize the duration of the voltage interruption, the HSBT_Infeed2_Bus2 high speed bus transfer function automatically interrupts the circuit breaker of the supplying feeder of the unsupplied section (CB of Feeder 1), and closes the circuit breaker of Feeder2.

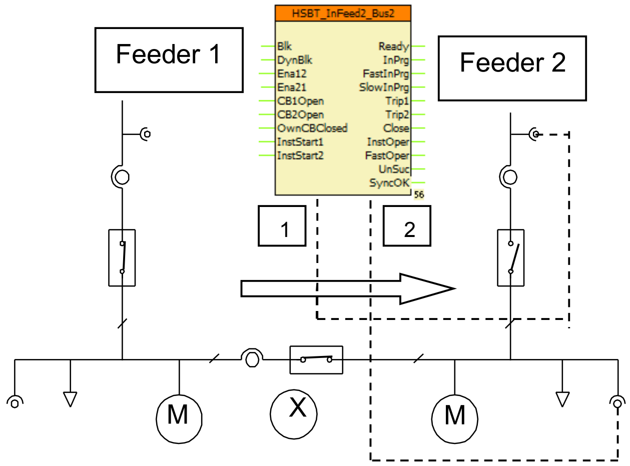

Figure 2-5 Application of the HSBT Infeed2-Bus2 instance

These Figure shows that the instance HSBT_Infeed2_Bus2 is applied in uni-directional mode, it operates if the bus voltage gets unhealthy. For this mode only the binary input of the function block “Ena12” should be set to logic FALSE state and “Ena21” input gets an active signal if the “own” circuit breaker in Feeder 2 is open, the other two ones are in closed state.

For this application:

- The voltage transformers at Feeder2 and the voltage transformers of the right side of the busbar are assigned to the function.
- The status signal of the circuit breaker of Feeder1 is received as “CB2Open”, “CB1Open” input is not assigned.
- The closed status signal of the circuit breaker of Feeder2 is received as “Own CB Closed”. NOTE: as a thumbs rule, the “own” means the originally open circuit breaker in all HSBT instances.
- The TRIP2 command should be directed to the circuit breaker in Feeder 1.
- The TRIP1 command is not applied.
- The Close command should be directed to the circuit breaker in Feeder 2. NOTE: The Close command is a critical command to point to the synchronous state of the voltage vectors. To aim this, the close command does not go through the relatively slow

graphic logic. By factory assignment it is directly connected to the appropriate binary output relay of the device at configuration.

For correct co-operation of three applied HSBT function blocks, the “InPrg” outputs of both others (HSBT_Bus1_Bus1 and HSBT_Infeed1_Bus1) should be connected graphically in OR relationship to the binary input “DynBlk” of this HSBT_Infeed2_Bus2 function block.

All these assignments are performed in the configuration procedure at the factory, using the graphic logic editor.