EUROPROT+

Automatic tap changer controller function block description

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User’s manual version information

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Preliminary	24.11.2010	Preliminary version, without technical information	Petri
V1.0	13.12.2010	First edition	Petri
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1 Automatic tap changer controller

1.1 Application

One criterion for power quality is to keep the voltage of selected points of the networks within the prescribed limits. The most common mode of voltage regulation is the application of transformers with on-load tap changers. When the transformer is connected to different taps, its turns ratio changes and supposing constant primary voltage, the secondary voltage can be increased or decreased as required.

Voltage control can take the actual load state of the transformer and the network into consideration. As a result, the voltage of a defined remote point of the network is controlled assuring that neither consumers near the busbar nor consumers at the far ends of the network get voltages out of the required range.

The voltage control function can be performed automatically or, in manual mode of operation, the personnel of the substation can set the network voltage according to special requirements.

The automatic tap changer controller function can be applied to perform this task.

1.2 Mode of operation

1.2.1 The scheme of the function block

Figure 1-1 shows the scheme of the function block.

1.2.2 Analog inputs of the controller function

The automatic tap changer controller function receives the following analog inputs:

UL1L2	Line-to-line voltage of the controlled secondary side of the transformer
IL1L2	Difference of the selected line currents of the secondary side of the transformer for voltage drop compensation
IHV	Maximum of the phase currents of the primary side of the transformer for limitation purposes

The parameter “U Correction” permits fine tuning of the measured voltage.

1.2.3 Internal checks before control operation

In Figure 1-1 the block “U-I BLOCK” performs the following checks before control operation:

- If the voltage of the controlled side UL1L2 is above the value set by the parameter “U High Limit”, then control to increase the voltage is disabled.
- If the voltage of the controlled side UL1L2 is below the value set by the parameter “U Low Limit”, then control to decrease the voltage is disabled.
- If the voltage of the controlled side UL1L2 is below the value set by the parameter “U Low Block”, then the transformer is considered to be de-energized and automatic control is completely disabled.
- If the current of the supply side IHV is above the limit set by the parameter “I Overload”, then both automatic and manual controls are completely disabled. This is to protect the switches inside the tap changer.

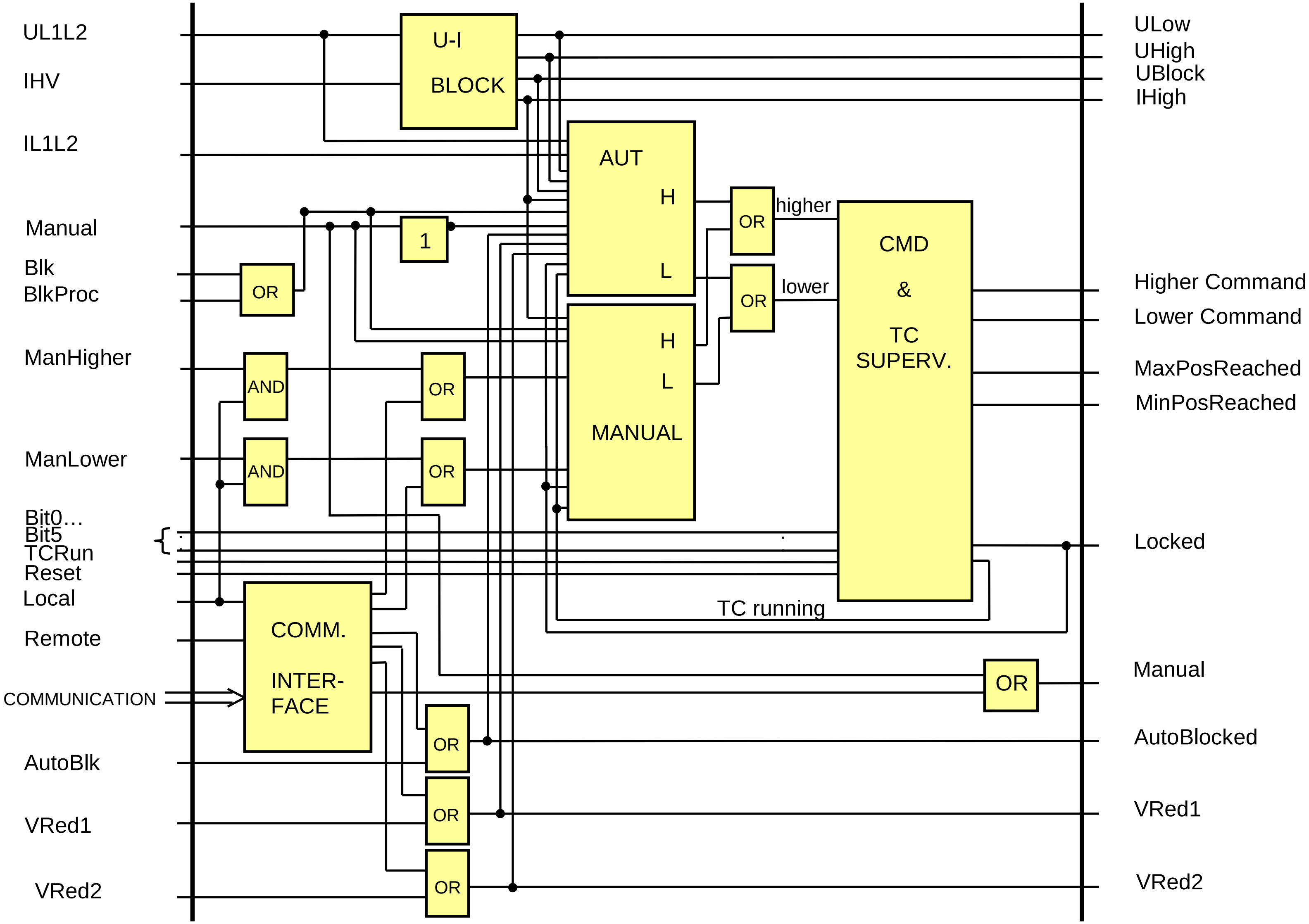


Figure 1-1 The logic schema of the automatic tap changer controller

1.2.4 Automatic control mode

Voltage compensation in automatic control mode

The module “AUTO” in Figure 1-1 gets the Fourier components of the busbar voltage and those of the current:

- $UL1L2_{Re}$ and $UL1L2_{Im}$
- $IL1L2_{Re}$ and $IL1L2_{Im}$

In automatic control mode the voltage of the controlled side *UL1L2* is compensated by the current of the controlled side *IL1L2*. This means that the voltage of the “load center” of the network is controlled to be constant, in fact within a narrow range. This assures that neither the voltage near to the busbar is too high, nor the voltage at far-away points of the network is too low. The voltage of the “load center”, i.e. the controlled voltage is calculated as:

$$|Ucontrol| = |Ubus - Udrop|$$

There are two compensation modes to be selected: “AbsoluteComp” and “ComplexComp”.

- If the parameter “Compensation” is set to **“AbsoluteComp”,** the calculation method is as follows:

In this simplified method the vector positions are not considered correctly, the formula above is approximated with the magnitudes only:

$$|Ucontrol| = |Ubus - Udrop| \approx |Ubus| - |Udrop| \approx |Ubus| - |I| * (R)CompoundFactor$$

Where

(R) Compound Factor is a parameter value.

If the current is above the value defined by the parameter “I Comp Limit”, then in the formulas above this preset value is considered instead of the higher values measured.

The method is based on the experiences of the network operator. Information is needed: how much is the voltage drop between the busbar and the “load center” if the load of the network is the rated load. The parameter “(R) Compound Factor” means in this case the voltage drop in percent.

- If the parameter “Compensation” is set to **“ComplexComp”,** the calculation method is as follows:

In this simplified method the vector positions are partly considered. In the formula above the voltage drop is approximated with the component of the voltage drop, the direction of which is the same as the direction of the bus voltage vector. (This is “length component” of the voltage drop; the “perpendicular component” of the voltage drop is neglected.)

$$|Ucontrol| = |Ubus - [(IL1L2_{Re} + jIL1L2_{Im}) * ((R)CompoundFactor + jXCompoundFactor)]|$$

Where

(R) Compound Factor is a parameter value
X Compound Factor is a parameter value

The voltage of the “load center” of the network is controlled to be within a narrow range. This assures that neither the voltage near to the busbar is too high, nor the voltage at far-away points of the network is too low.

The method is based on the estimated complex impedance between the busbar and the “load center”. The parameter *“(R) Compound Factor*” means in this case the voltage drop in percent, caused by the real component of the rated current.

The parameter *“X Compound Factor”* means in this case the voltage drop in percent, caused by the imaginary component of the rated current.

NOTE: if the active power flows from the network to be controlled to the busbar then in “AbsoluteComp” mode no compounding is performed.

Voltage checking in automatic control mode

In automatic control mode the calculated **|** *Ucontrol* **|** voltage is checked to see if it is outside the limits. The limits are defined by parameter values:

U Set	is the setting value defining the centre of the permitted range
U Deadband	is the width of the permitted range in both + and – directions
Deadband Hysteresis	is the hysteresis decreasing the permitted range of the “U Deadband” after the generation of the control command.

If the calculated **|** *Ucontrol* **|** voltage is outside the limits, then timers are started.

In an emergency state of the network, when the network elements are overloaded, the Uset value can be driven to two lower values defined by the parameters “Voltage Reduction 1” and “Voltage Reduction 2”. “U Set” is decreased by the parameter values if the binary inputs “Voltage Reduction 1” or “Voltage Reduction 2” enter into active state. These inputs must be programmed graphically by the user.

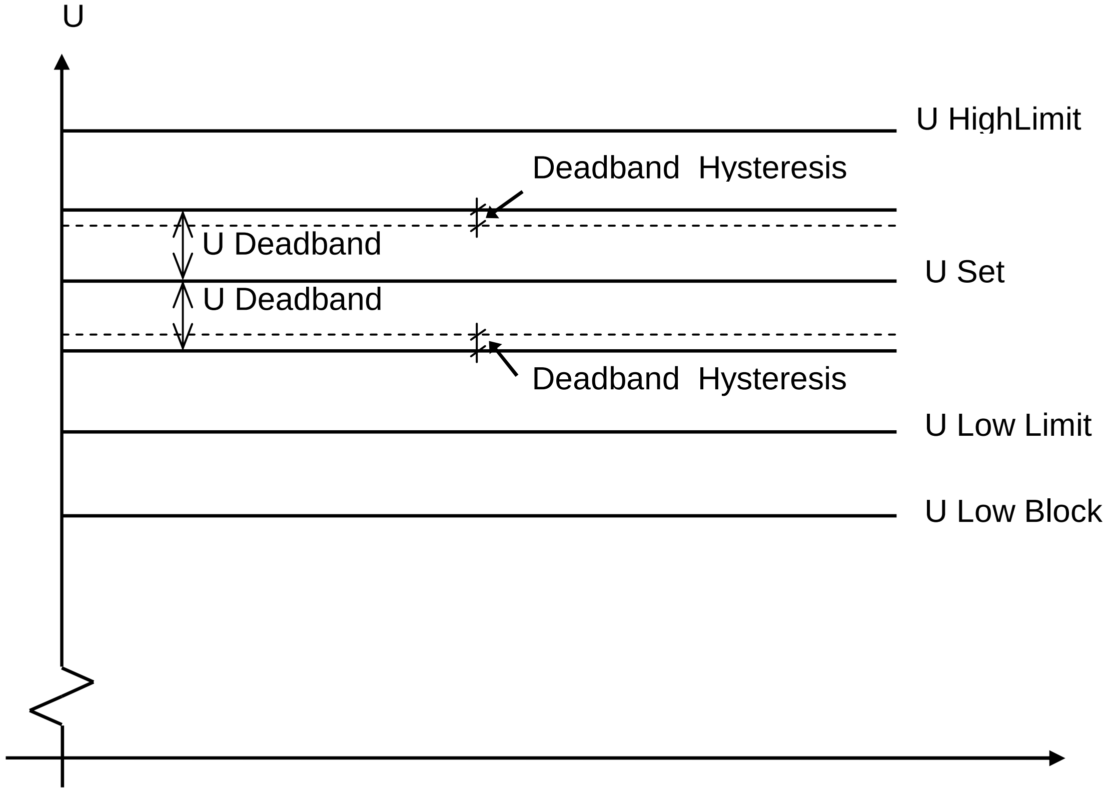


Figure 1-2 Voltage level settings

Time delay in automatic control mode

In automatic control mode the first and every subsequent control command is processed separately.

For the first control command:

The voltage difference is calculated:

Udiff= |Ucontrol- Uset|

If this difference is above the “U Deadband” value, then depending on the setting of parameter “T1 Delay Type”, three different timing modes can be selected:

- “Definite” this definite time delay is defined by parameter T1
- “Inverse” standard IDMT characteristic defined by the parameters:
  - T1 maximum delay defined by the parameter
  - U Deadband is the width of the permitted range in both + and – directions
  - Min Delay minimum time delay

$$Tdelay = \frac{T1}{\left(\frac{Udiff}{Udeadband}\right)}, but\ minimum\ Min\ Delay$$

- “2powerN”

$$Tdelay = T1 * 2^{\left(1-\frac{Udiff}{Udeadband}\right)}$$

The binary parameters “Fast Lower Enable” and/or “Fast Higher Enable” enable fast command generation if the voltage is above the parameter value “U High Limit” or below the “U Low Limit”. In this case, the time delay is a definite time delay defined by parameter “T2”.

For subsequent control commands:

In this case, the time delay is always a definite time delay defined by parameter “T2” if the subsequent command is generated within the “Reclaim time” defined by parameter.

The automatic control mode can be blocked by a binary signal received via binary input “AutoBlk” and generates a binary output signal “AutoBlocked (ext)”

1.2.5 Manual control mode

In manual mode, the automatic control is blocked. The manual mode can be “Local” or “Remote”. For this mode, the input “Manual” needs to be in active state (as programmed by the user).

In the local mode, the input “Local” needs to be in active state. The binary inputs “ManHigher” or “ManLower” must be programmed graphically by the user.

In the remote mode, the input “Remote” needs to be in active state as programmed by the user. In this case manual commands are received via the communication interface.

1.2.6 Command generation and tap changer supervision

The software module “CMD&TC SUPERV” is responsible for the generation of the “HigherCmd” and “LowerCmd” command pulses, the duration of which is defined by the parameter “Pulse Duration”. This is valid both for manual and automatic operation.

The tap changer supervision function receives the information about the tap changer position in six bits of the binary inputs “Bit0 to Bit5”. The value is decoded according to the enumerated parameter “CodeType”, the values of which can be: Binary, BCD or Gray. During switchover, for the transient time defined by the parameter “Position Filter”, the position is not evaluated.

The parameters “Min Position” and “Max Position” define the upper and lower limits. In the upper position, no further increasing command is generated and the output “Max Pos Reached” becomes active. Similarly, in the lower position, no further decreasing command is generated and the output “Min Pos Reached” becomes active.

The function also supervises the operation of the tap changer. Depending on the setting of parameter “TC Supervision”, three different modes can be selected:

- TCDrive the supervision is based on the input “TCRun”. In this case, after command generation the drive is expected to start operation within one quarter of the value defined by the parameter “Max Operating Time” and it is expected to perform the command within “Max Operating Time”
- Position the supervision is based on the tap changer position in six bits of the binary inputs “Bit0 to Bit5”. It is checked if the tap position is incremented in case of a voltage increase, or the tap position is decremented in case of a voltage decrease, within the “Max Operating Time”.
- Both in this mode the previous two modes are combined.

In case of an error detected in the operation of the tap changer, the “Locked” input becomes active and no further commands are performed. To enable further operation, the input “Reset” must be programmed for an active state by the user.

1.2.7 Error codes

The On-line information includes a variable "ErrorCode" (ATCC_ErrCode_ISt_), indicating different error states. These states are binary coded; any of them causes “Locked” state of the controller function. The explanation of the individual bits in the code value is explained in the Table below.

Bit	Value	Explanation
0	1	Drive started without control command
1	2	Drive did not start after control command
2	4	Drive did not stop in due time
3	8	Invalid position signal
4	16	Position signal did not change value

In case of multiple error states the values are added in the "ErrorCode".

1.3 Technical summary

1.3.1 Technical data

Function	Range	Accuracy
Voltage measurement	50 % < U < 130 %	<1%
Definite time delay		<2% or ±20 ms, whichever is greater
Inverse and “2powerN” time delay	12 % < ΔU < 25%	<5%
	25 % < ΔU < 50%	<2% or ±20 ms, whichever is greater

Table 1-1 Technical data of the automatic tap changer controller function

1.3.2 Summary of the parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Control model, according to IEC 61850			
ATCC_ctlMod_EPar_	ControlModel	Direct normal, Direct enhanced, SBO enhanced	Direct normal
Select before operate class, according to IEC 61850			
ATCC_sboClass_EPar_	sboClass	Operate-once, Operate-many	Operate-once
Parameter for general blocking of the function			
ATCC_Oper_EPar_	Operation	Off,On	Off
Parameter for time delay mode selection			
ATCC_T1Type_EPar_	T1 Delay Type	Definite, Inverse, 2powerN	Definite
Selection for compensation mode			
ATCC_Comp_EPar_	Compensation	Off, AbsoluteComp, ComplexComp	Off
Tap changed supervision mode selection			
ATCC_TCSuper_EPar_	TC Supervision	Off, TCDrive, Position, Both	Off
Decoding of the position indicator bits			
ATCC_CodeType_EPar	CodeType	Binary, BCD, Gray	Binary

Table 1-2 Enumerated parameters of the automatic tap changer controller function

Boolean parameters

Parameter name	Title	Default	Explanation
ATCC_FastHigh_BPar_	Fast Higher Enable	0	Enabling fast higher control command
ATCC_FastLow_BPar_	Fast Lower Enable	0	Enabling fast lower control command

Table 1-3 The Boolean parameters of the automatic tap changer controller function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Code value of the minimum position						
ATCC_MinPos_IPar_	Min Position		1	32	1	1
Code value of the maximum position						
ATCC_MaxPos_IPar_	Max Position		1	32	1	32

Table 1-4 Integer parameters of the automatic tap changer controller function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Time limit for tap-change operation						
ATCC_TimOut_TPar_	Max Operating Time	msec	1000	30000	1	5000
Command impulse duration						
ATCC_Pulse_TPar_	Pulse Duration	msec	100	10000	1	1000
Time overbridging the transient state of the tap changer status signals						
ATCC_MidPos_TPar_	Position Filter	msec	1000	30000	1	3000
Select before operate timeout, according to IEC 61850						
ATCC_SBOTimeout_TPar_	SBO Timeout	msec	1000	20000	1	5000

Table 1-5 Timer parameters of the automatic tap changer controller function

Float parameters

Parameter name	Title	Unit	Min	Max	Digits	Default
Factor for fine tuning the measured voltage						
ATCC_Ubias_FPar_	U Correction	-	0.950	1.050	3	1.000
Set-point for voltage regulation, related to the rated voltage (Valid at I=0)						
ATCC_USet_FPar_	U Set	%	80.0	115.0	1	100.0
Dead band for voltage regulation, related to the rated voltage						
ATCC_UDead_FPar_	U Deadband	%	0.5	9.0	1	3.0
Hysteresis value for the dead band, related to the dead band						
ATCC_DeadHyst_FPar_	Deadband Hysteresis	%	60	90	0	85
Parameter for the current compensation. See Chapter 1.2.4						
ATCC_URinc_FPar_	(R) Compound Factor	%	0.0	15.0	1	5.0
Parameter for the current compensation. See Chapter 1.2.4						
ATCC_UXinc_FPar_	X Compound Factor	%	0.0	15.0	1	5.0
Reduced set-point 1 for voltage regulation (priority), related to the rated voltage. See Chapter 1.2.4						
ATCC_VRed1_FPar_	Voltage Reduction 1	%	0.0	10.0	1	5.0
Reduced set-point 2 for voltage regulation, related to the rated voltage. See Chapter 1.2.4						
ATCC_VRed2_FPar_	Voltage Reduction 2	%	0.0	10.0	1	5.0
Maximum current value to be considered in current compensation formulas. See Chapter 1.2.4						
ATCC_ICompLim_FPar_	I Comp Limit	%	0.00	150	0	1
Current upper limit to disable all operation. See Chapter 1.2.3.						
ATCC_IHVOC_FPar_	I Overload	%	50	150	0	100
Voltage upper limit to disable step up. See Chapter 1.2.3.						
ATCC_UHigh_FPar_	U High Limit	%	90.0	120.0	1	110.0
Voltage lower limit to disable step down. See Chapter 1.2.3						
ATCC_ULow_FPar_	U Low Limit	%	70.0	110.0	1	90.0
Voltage lower limit to disable all operation. See Chapter 1.2.3.						
ATCC_UBlock_FPar_	U Low Block	%	50.0	100.0	1	70.0
Time delay for the first control command generation						
ATCC_T1_FPar_	T1	sec	1.0	600.0	1	10.0
Definite time delay for subsequent control command generation or fast operation (if it is enabled)						
ATCC_T2_FPar_	T2	sec	1.0	100.0	1	10.0
In case of dependent time characteristics, this is the minimum time delay						
ATCC_MinDel_FPar_	Min Delay	sec	1.0	100.0	1	10.0
After a control command, if the voltage is out of the range within the reclaim time, then the command is generated after T2 time delay						
ATCC_Recl_FPar_	Reclaim Time	sec	1.0	100.0	1	10.0

Table 1-6 Float parameters of the automatic tap changer controller function

1.3.3 Summary of the generated output signals

The **binary output status signals** of the breaker failure protection function are listed in the table below.

Binary status signal	Title	Explanation
ATCC_AutoBlocked_GrI_	Auto Blocked (ext)	Automatic control blocked
ATCC_Manual_GrI_	Manual	Signaling the manual mode of operation
ATCC_HigherCmd_GrI_	Higher Command	Command for increasing the voltage
ATCC_LowerCmd_GrI_	Lower Command	Command for decreasing the voltage
ATCC_MaxReached_GrI_	Max Pos Reached	Signaling the maximal position
ATCC_MinReached_GrI_	Min Pos Reached	Signaling the minimal position
ATCC_UHigh_GrI_	U High	Voltage is high
ATCC_ULow_GrI_	U Low	Voltage is low
ATCC_UBlock_GrI_	U Block	Blocked state for too low voltage
ATCC_IHigh_GrI_	I High	Blocked because of current limit
ATCC_Locked_GrI_	Locked	The supervision detected tap changer error, the blocking can be released exclusively by the Reset impulse
ATCC_VRed1_GrI_	Voltage Reduction 1	Controlling to reduced voltage 1
ATCC_VRed2_GrI_	Voltage Reduction 2	Controlling to reduced voltage 2

Table 1-7 Binary output status signals of the breaker failure protection function

1.3.4 Summary of the input signals

Binary status signals

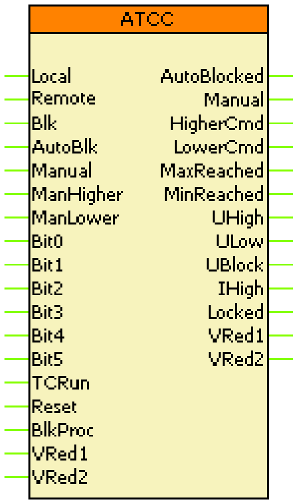
The automatic tap changer controller function has binary input status signals**. The conditions are defined by the user applying the graphic equation editor.**

The **binary input status signals** of the automatic tap changer controller function are listed in the table below.

Binary status signal	Title	Explanation
ATCC_Local_GrO_	Local	Local state of the manual operation
ATCC_Remote_GrO_	Remote	Remote state of the manual operation
ATCC_Blk_GrO_	Blk	Blocking of the function
ATCC_AutoBlk_GrO_	AutoBlk	Blocking of the automatic function
ATCC_Manual_GrO_	Manual	Manual mode of operation
ATCC_ManHigher_GrO_	ManHigher	Manual command for increasing the voltage
ATCC_ManLower_GrO_	ManLower	Manual command for decreasing the voltage
ATCC_Bit0_GrO_	Bit0	Bit 0 of the position indicator
ATCC_Bit1_GrO_	Bit1	Bit 1 of the position indicator
ATCC_Bit2_GrO_	Bit2	Bit 2 of the position indicator
ATCC_Bit3_GrO_	Bit3	Bit 3 of the position indicator
ATCC_Bit4_GrO_	Bit4	Bit 4 of the position indicator
ATCC_Bit5_GrO_	Bit5	Bit 5 of the position indicator
ATCC_TCRun_GrO_	TCRun	Running state of the tap changer
ATCC_Reset_GrO_	Reset	Reset to release from blocked state
ATCC_BlkProc_GrO_	BlkProc	Blocking signal from the tap changer
ATCC_VRed1_GrO_	VRed1	Reduced voltage 1 is required
ATCC_VRed2_GrO_	VRed2	Reduced voltage 2 is required

Table 1-8 Binary input signals of the breaker failure protection function

1.3.5 The symbol of the function block in the graphic editor



The names of the input and output signals are parts of the "Binary status signal" names listed in the previous paragraph.