FUNCTION BLOCK DESCRIPTION

Automatic tap changer controller

ANSI 90V

PROTECTA HUNGARY

DOCUMENT ID: PP-13-21171
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2022-01-13, BUDAPEST

PROTECTION, AUTOMATION AND CONTROL FOR POWER INDUSTRY

VERSION INFORMATION

VERSION	DATE	MODIFICATION	COMPILED BY
Preliminary	2010-11-24	Preliminary version, without technical information	Petri
1.0	2010-12-13	First edition	Petri
1.1	2012-12-20	Corrected formula for complex compensation	Petri
1.2	2013-01-29	Error code added	Petri
1.3	2016-01-14	The default value and the titles of some parameters are changed.	Seida
2.0	2020-02-06	Operation behavior modification: Tap changer control; New documentation design, on-line data added, event listing added; Application for parallel transformers included	Tóth
2.1	2022-01-27	Information added to the description about tap changer supervision with mA signals	Seida
2.2	2022-03-29	New subchapters defined for better overview Contents of the new chapter 1.4.1.1 updated Deadband hysteresis explanation corrected Figures 1-2, 3-1, 3-2 updated Overload parameter max. setting and default value raised U low block parameter explanation updated Parameters table updated Optional “Time scheduler (for ATCC)” function added in Chapter 1.4.1.3	Erdős, Tóth
2.3	2023-01-13	Figure 1-3 introduced to better illustrate *Deadband Hysteresis* parameter	Saina

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USED SYMBOLS

Additional information

Useful information for settings.

Important part for proper usage.

Information relating transformer parallel operation

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.

With the growing customer demand for the higher security and reliability of supply, it is common practice two or more transformers are operating in parallel on one site or across the network. In this situation, the main goal of the tap changer controllers is to maintain the voltage within the prescribed limits, at the same time, to minimize circulating current between parallel transformers.

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

1.1 Operation principles

Figure 1-1 shows the structure of the automatic tap changer controller function block.

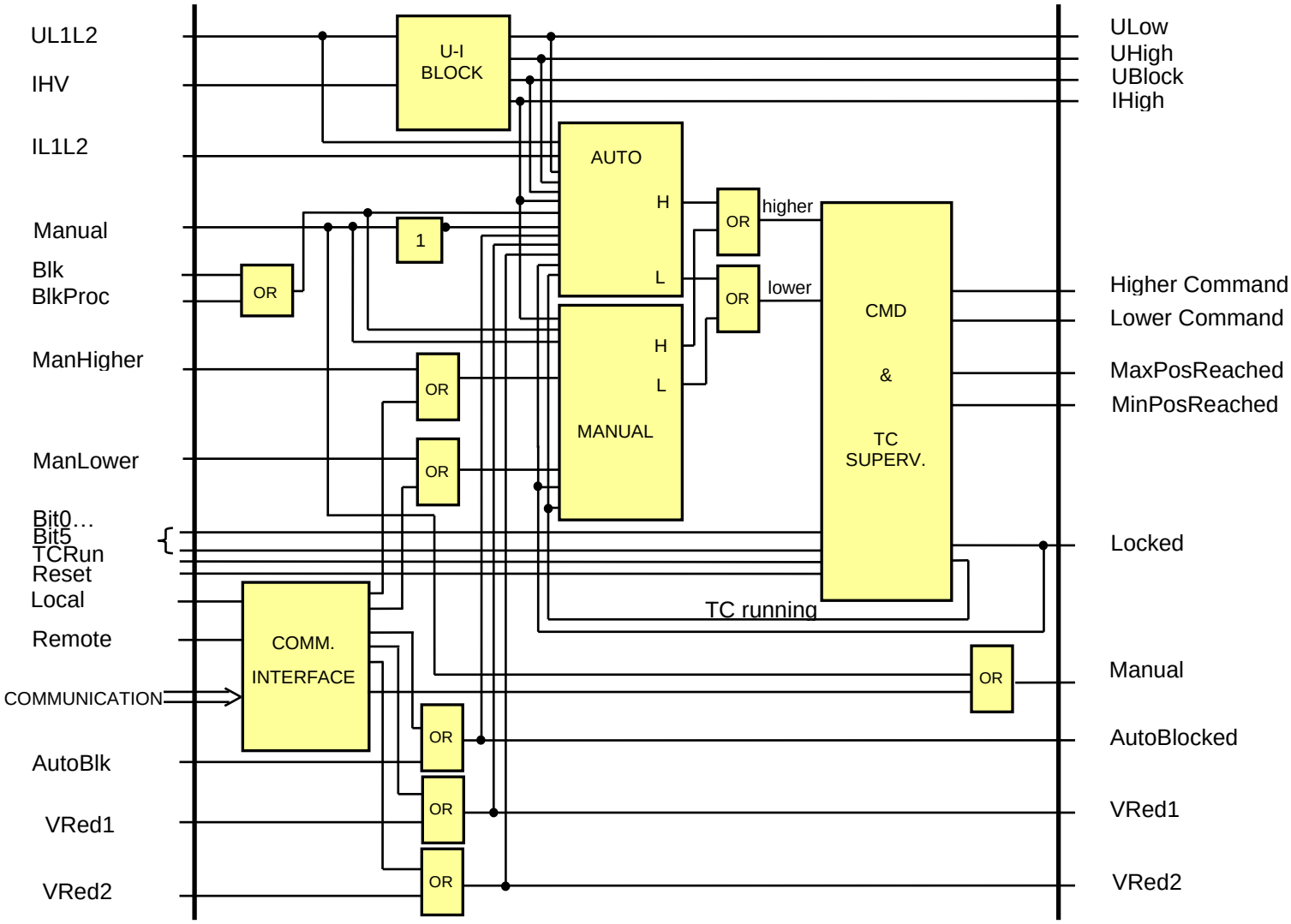

Figure 1-1 The logic schema of the automatic tap changer controller

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** (optional): 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.

The **software modules** of the automatic tap changer controller function:

U-I BLOCK

This module performs an internal check before control operation. If the

AUTO

This module provides the automatic control mode of the function.

MANUAL

This module provides the manual control mode of the function.

CMD & TC SUPERV.

The software module “CMD&TC SUPERV.” is responsible for the generation of the tap changer commands. This module also supervises the operation of the tap changer.

COMM. INTERFACE

This module receives all control commands from remote control. Additionally, in case of parallel mode it is responsible for the inter-communication among the co-operating automatic tap changer controller devices.

1.2 Operation of the automatic tap changer control

The automatic tap changer control function has the “Operation” parameter which can be set to one of the following:

- *Off*, tap changer control function is switched off;
- *Single*/*On*, for selecting the controller in single mode or in negative reactance circulating current mode with special setting. (See Paragraph 3.1.2 for more details about negative reactance circulating current mode.);
- *Min Circulating Current*, for operating the controllers of the parallel connected transformers to minimize the circulating current. (See Paragraph 3.1.1.);
- *Master*, for selecting one of the controllers of the parallel connected transformers to be the master, to transmit commands to the slave controllers. (See Paragraph 3.1.3);
- *Slave-Cmd*, for selecting the controller to operate in slave mode, and follow the UP and DOWN commands (See Paragraph 3.1.3);
- *Slave-Tap* for selecting the controller to operate in slave mode, and drive the tap changer to the same position as the transformer assigned to the master controller. (See Paragraph 3.1.3)

1.3 Internal checks before control operation - “U-I BLOCK”

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 automatic 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 automatic 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.
    - Current overload limitation on primary side IHV is not default limitation parameter. It is an ordering option. (Additional CT module has to be integrated into the tap changer controller device so that the current of the primary side can be measured.)
- If the voltage of the controlled side UL1L2 is below the value set by the parameter “U Low Block”, then parallel cooperation is disabled in Auto mode. Nevertheless, the parallel cooperation is still enabled in Manual mode.

1.4 Control mode of tap changer controller

1.4.1 Automatic control mode – “AUTO” module

The automatic control mode can be selected with the “Auto/Man” control channel (ATCC_**Man**_Con_) if the “Manual” binary input (ATCC_**Manual**_GrO_) of the function block is FALSE.
The automatic control mode can be blocked by a binary signal received via binary input “AutoBlk” and generates a binary output signal “AutoBlocked (ext)”

Follower mode

Follower mode is submode of the auto mode. It is only relevant in the parallel automatic tap changer controller function. The actual mode of the device is changed to “Follower” if the auto mode is selected and the “Operation” parameter is set to either SlaveCmd or SlaveTap”.

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: “Absolute” and “Complex”.

- If the parameter “Compensation” is set to **“Absolute”,** 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 ***"Complex"*,** 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 *"Absolute"* mode no compounding is performed.

1.4.1.1 Voltage checking in automatic control mode

In automatic control mode the calculated |*Ucontrol*| voltage is checked to see if it is outside the limits. If so, is outside the limits, then timers are started.

The limits are defined by parameter values:

*U Set**	is the setting value defining the center of the permitted range

* "U Set" value can be updated during the calendar day when "Time scheduler (for ATCC)" function is set to enabled. More details can be found in Chapter 1.4.1.3.

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" during the running of the timer (see Chapter 1.4.1.2) before the generation of the control command. Also see Figure 1-3.

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.

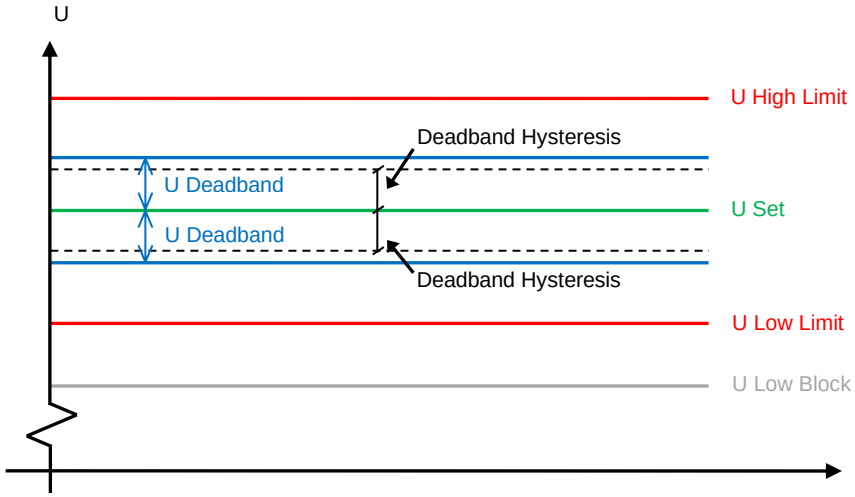

Figure 1-2 Voltage level settings

1.4.1.2 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 "Time delay 1 type", three different timing modes can be selected:

- "Definite" this definite time delay is defined by parameter "*Time delay 1*", but minimum "Min Delay" time
- "Inverse" standard IDMT characteristic defined by the parameters:
  - "Time delay 1" maximum delay defined by the parameter
  - U Deadband" is the width of the permitted range in both + and – directions
  - Min Delay minimum time delay

$$T_{delay} = \frac{Time\ delay\ 1}{\frac{Udiff}{U\ Deadband}}$$, but minimum "Min Delay" time

- "2powerN"

$$T_{delay} = (Time\ delay\ 1) * 2^{\left(1-\frac{Udiff}{UDeadband}\right)}$$, but minimum "Min Delay" time

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 "Time delay 2", but minimum "Min Delay" time.

For subsequent control commands:

If the subsequent command is generated within the "Reclaim time" defined by parameter the time delay is always a definite time delay defined by parameter "Time delay 2", but minimum "Min Delay" time.

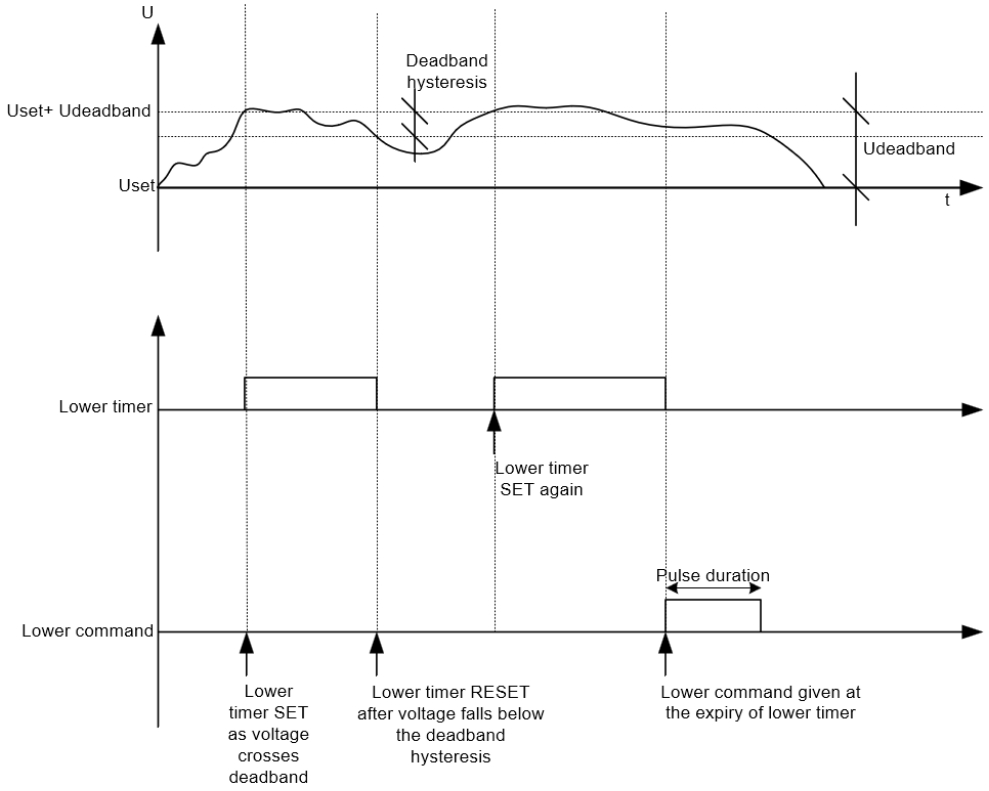

Figure 1-3 Example of command generation sequence to illustrate deadband hysteresis

1.4.1.3 Time scheduler (for ATCC)

This optional function can be used to provide daylong update of the “U set” value.

Its “Operation” parameter is set to enable to activate the scheduler function.

Each calendar day are divided into seven time intervals where user-defined “U set” value can be applied. Each interval related “U set” value overwrites the “U set” value of the ATCC function when time schedular function is enabled.

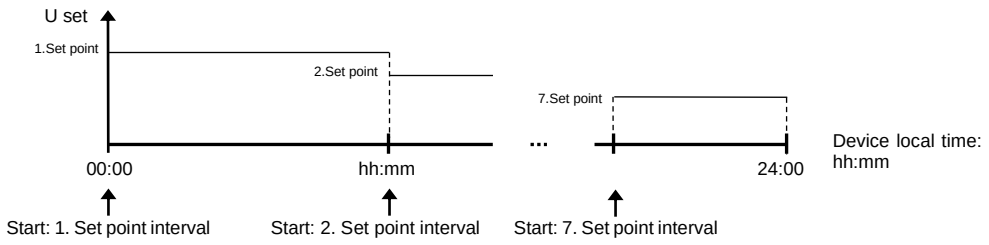

Figure 1-4 Time scheduler function set points and intervals

NOTE: time is based on the device local time (UTC/GMT + GMT offset)

Parameter description of the “Time scheduler (for ATCC)” function can be found in Table 3-3.

1.4.2 Manual control mode – “MANUAL” module

The tap changer controller receives remote commands from the SCADA system and local commands from the local LCD of the device when Manual mode is selected.

The Manual mode can be selected either the “Auto/Man” control channel (ATCC_Man_Con_) via command or the “Manual” binary input (ATCC_**Manual**_GrO_) of the function block is TRUE (as configured in the User Logic of the EuroCAP configuration software tool by the user). In manual mode, the automatic control is blocked.

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

In local mode, the “Local” binary input needs to be in active state as programmed by the user. In this case the manual commands are generated with same controlled channel as mentioned above with the local LCD of the device.

Other manual control option can be performed with the dedicated binary inputs “ManHigher” or “ManLower” which must be configured graphically by the user. It can be used in both Local and Remote modes.

1.4.3 Command generation and tap changer supervision – “CMD & TC SUPERV.” module

The software module “CMD&TC SUPERV.”, which can be seen in Figure 1-1 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.

1.4.3.1 Tap changer position

The tap changer supervision function receives the information about the tap changer position either in six bits of the binary inputs “Bit0 to Bit5” or via mA input (mA input decoding is ordering option with an additional AIC+/0202 module).

The six bits of the binary inputs value is decoded according to the enumerated parameter “CodeType”, the values of which can be: Binary, BCD, Gray or mA.

If mA decoding is applied the “CodeType” parameter has to be set to “mA” and additional function block “TCPos Transducer Input” (StepmA) needs to be integrated into the configuration. “TCPos Transducer Input” function block provides the mA input decoding pre-process to the automatic tap changer controller function. Note, that during the decoding process the stepmA function supervises the magnitude of the received mA signal. The magnitude of the received mA signal must be within the ±45% range of the nominal mA value of the related tap position to avoid fluctuation between neighboring positions. This ±45% range is related to the exact mA value range between two neighboring positions. If the received magnitude is between two valid range, the tap position is not defined and the tap position shows 0 value. (The range is ±40% instead of ±45% with earlier RDSP firmware versions than rev. 2.8.13.2080-H2.)

During switchover, for the transient time defined by the parameter “Position Filter”, the position is not evaluated.

Table 1-1 Parameters of the “TCPos Transducer Input” function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Input Low	mA	-20 – -5	1	4	Minimum value for the current
Input High	mA	5 – 20	1	20	Maximum value for the current
MinStep	-	1 – 32	1	1	Minimum value for scaling
MaxStep	-	1 – 32	1	27	Maximum value for scaling

The parameters “Min Position” and “Max Position” define the upper and lower limits. In the upper position the output “Max Pos Reached” becomes active and if the “TC Supervision” parameter is set to either “Position” or “Both”, no further increasing command is generated. Similarly, in the lower position, no further decreasing command is generated if the “TC Supervision” parameter is set as written above and the output “Min Pos Reached” becomes active.

1.4.3.2 Supervision of the tap changer operation

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” output becomes active and no further commands are performed. To enable further operation, the input “Reset” must be programmed for an active state trigger by the user.

1.4.3.3 Error codes of the operation of the tap changer

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

Table 1-2 “ErrorCode” Table

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

2 Automatic tap changer controller function overview

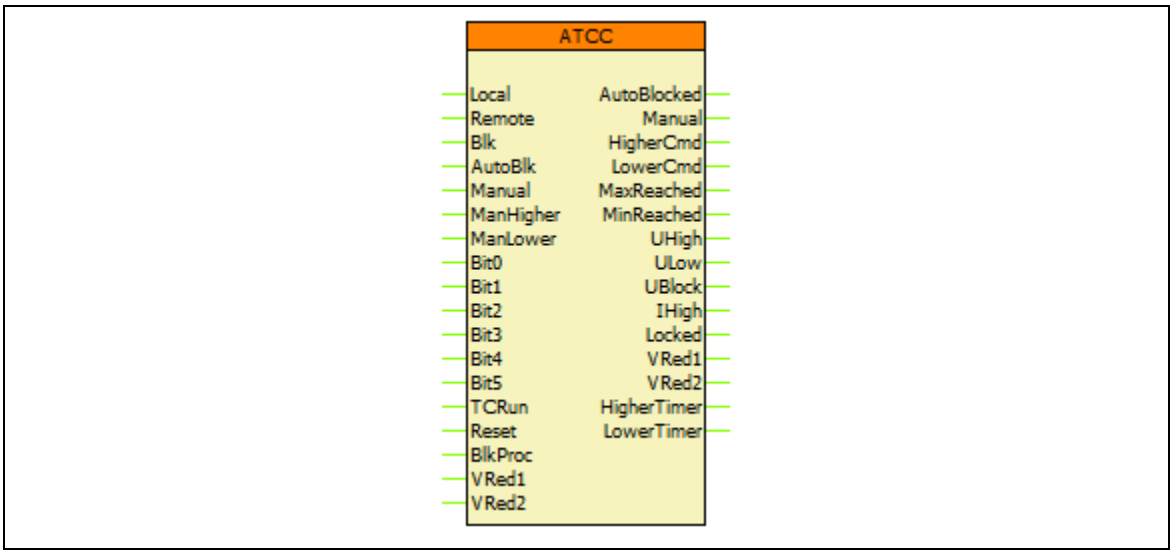

Figure 2-1 Graphic appearance of the function block of automatic tap changer controller

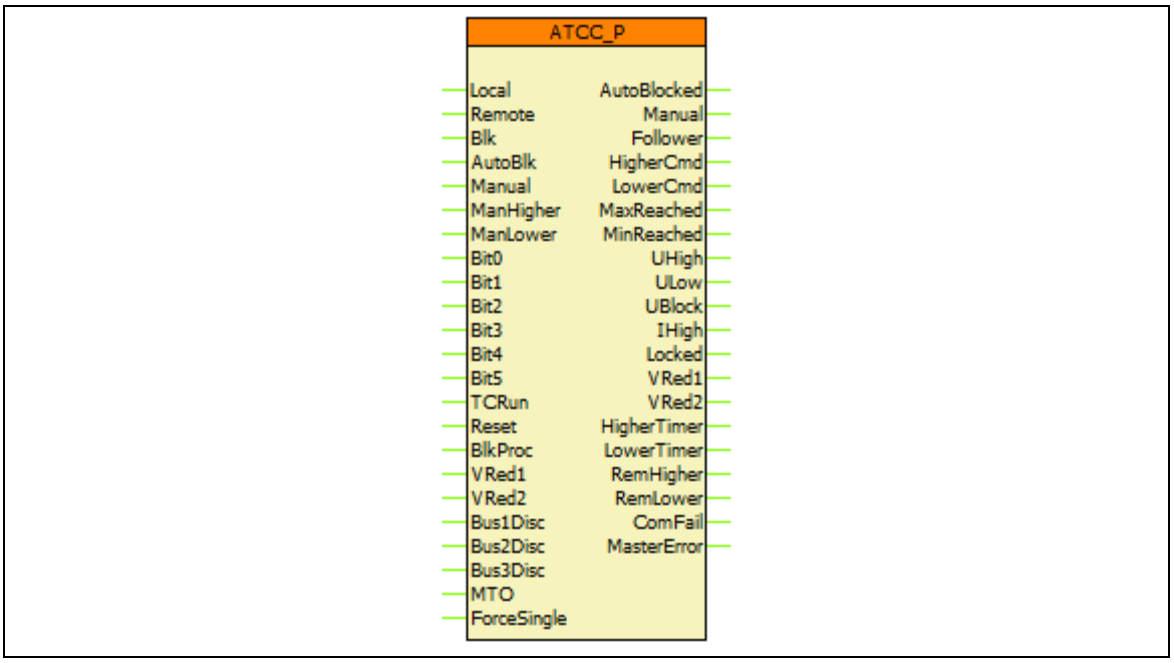

Figure 2-2 Graphic appearance of the function block of automatic tap changer controller for parallel transformers

3 Mode of operation to control parallel transformers

This mode of operation is selected if the "Operation" parameter is set to one of the following values:

- *Single* mode with special setting of the voltage compensation can be performed **negative reactance circulating current control**
- *Min Circulating Current*, for selecting the controllers of the parallel connected transformers to **minimize circulating current control**;
- *Master*, for selecting one of the controllers of the parallel connected transformers to be the master, to transmit commands to the slave controllers in **master slave control**;
- *Slave-Cmd*, for selecting the controller to operate in slave mode, and follow the UP and DOWN commands;
- *Slave-Tap*, for selecting the controller to operate in slave mode, and drive the tap changer to the same position as the transformer assigned to the master controller.

Up to 4 transformers may be involved. Individual EuroProt+ controllers are assigned to each of them, and these devices co-operate with each other. The method of co-operation depends on the selected mode, as set by the "Operation" parameter.

Usually the devices must be connected to the same Ethernet communication network, characterized with the same "GroupID". This must be selected by parameter setting, identical for the co-operating devices. The "Device Address" must be set unique for the devices within the group, for two transformers "0" and "1", etc. The "GroupID" can be applied also for VLAN identifier. To do this, the parameter "UseVLAN" must be set to logic "1".

EuroProt+ CPU+xxxx module SB (station bus) ports can be used to establish the communication network among the cooperating tap changer controller devices.

The messages sent via Ethernet network are similar multicast messages to the GOOSE messages according to the IEC 61850 communication standard, but they are device specific commands. The MAC address of these multicast messages is 01-0C-CD-07-"GroupID".

3.1.1 Minimizing circulating currents control mode

This mode of operation is selected if the "Operation" parameter is set to "Min Circulating Current".

To perform the related algorithm, communication is needed among the controllers. The co-operating controllers must be identified by each device, by checking the parameters "Address 0 InUse", "Address 1 InUse", "Address 2 InUse", "Address 3 InUse". For minimizing the circulating current, the following information is needed from each co-operating devices:

- Calculated voltage drop (U_{di} see below),
- Current real and imaginary components (relative to the common bus voltage),
- Sn/{Short circuit impedance}, calculated internally from parameters "Transformer Sn" and "Transformer short circuit impedance".
- Connected or disconnected state of the transformer to the busbar of the regulated voltage level.

Based on this information the current vectors are transformed into a common coordinate system defined by the common voltage vector. The sum of these currents is the total load current:

$$I_L = \sum_i I_{Ti}$$

The transformers disconnected from the busbar of the regulated voltage level are not involved in this calculation.

The current, according to the impedance relationship is calculated by:

$$I_{Li} = \frac{\frac{S_{ni}}{\varepsilon_i}}{\sum_j \frac{S_{nj}}{\varepsilon_j}} I_L$$

The difference of the measured I_{Ti} current and the current I_{Li} due to the current division is the circulating current:

$$I_{CCi} = I_{Ti} - I_{Li}$$

This circulating current causes a voltage drop, which is equivalent to the voltage difference caused by the tap changer position:

$$U_{di} = Im(I_{CCi}) * \frac{\varepsilon_{iContr}}{100} \frac{U_{ni}^2}{S_{ni}}$$

In this formula a special short circuit impedance value is applied: ε_{iContr} called “control short circuit impedance”, and can be set as parameter “Control short circuit impedance”. If this value is set different as compared with the setting value of the parameter “Transformer short circuit impedance” then the calculated effect of the circulating current can be influenced.

With this U_{di} voltage drop, the measured busbar voltage U_B to be controlled is modified:

$$U'_B = U_B - U_{di}$$

Based on the calculated U_{di} voltage drops, the controller with the highest U_{di} calculated value starts generating the required control command, the operation of all other controllers are delayed. This method prevents the possibility to regulate quickly up and down subsequently, due to the mutual influence of tap-changer operations.

3.1.2 Negative reactance circulating current control mode

Negative reactance circulating current control mode can be provide effective solution to control power transformers in any configuration, in parallel at a site, even across a network, because no communication is requested among the tap changer controllers.

The negative value of reactance with voltage compensation mode (see Paragraph 1.4.1) settings is used to control the tap positions of parallel transformers to be similar to minimize the circulating current.

The following equations show the connection between the voltage drop compensation and the negative reactance circulating current setting:

$$Z_{voltage\ drop\ compensation} = (R)CompoundFactor + jXCompoundFactor)$$

$$Z_{\text{negative reactance circulating current}} = (R)CompoundFactor - jXCompoundFactor)$$

In the negative reactance method the circulating current is minimized by changing the control voltage according to:

$$U'_B = Ubus - [(IL1L2_{Re} + jIL1L2_{Im}) * ((R)CompoundFactor - jXCompoundFactor)]$$

So the negative reactance method uses the line drop compensation method (LDC) with a negative reactance value, being the resistance value equal to zero.

This modified busbar voltage is applied as the $U_{control}$ voltage in Paragraph 1.4.1, and using this value, the controller perform the task as if the transformer would be alone. The result of this mode of operation is that additionally to the required control of the load center voltage, the circulating current is minimized.

Negative reactance circulating current control mode can be set with the following parameters easily:

- "Operation" parameter of the tap changer controller function is set to "**Single"**.,
- "Compensation" parameter is set to ***"Complex"***,
- *"(R) Compound Factor"* and *"X Compound Factor"* are set according to the equations above.

3.1.3 Master slave control mode

This mode of operation is selected if the "Operation" parameter of one of the co-operating devices is set to "Master" and for all other devices it is set either to "SlaveCmd" or to "SlaveTap". (The not consistent setting is signaled as setting error.)

By selecting Master slave mode, the "Device Address" parameter of the "Master" tap changer controller device must be set to lower value than the "Slave" controller.

In this mode of operation, the master is controlling the assigned transformer, as if it would be alone, and transmits the HIGHER and LOWER commands and the tap changer position to the slaves.

The slave devices react according to the parameter setting.

In master slave mode of operation both auto and manual control commands of master device are forwarded to the slave devices and the slave devices control their own tap changers according to the received commands if the slave devices are set to auto mode.

Operation in "SlaveCmd" mode

If all slave's "Operation" parameter is set to "SlaveCmd" mode then the master device transmits the HIGHER or LOWER commands, received via Ethernet connection from the master, without comparing the tap changer position. If the initial state of all tap-changers assures the operation of the system without any circulating currents, and the appropriate tap steps generate the same voltage regulation then this mode can be applied. If there is a single failure in the operation of any of the tap-changers then the error is not corrected automatically.

Operation in "SlaveTap" mode

If all slave's "Operation" parameter is set to "SlaveTap" mode, then the master device transmits the own tap position as the required tap position for all co-operating controllers. The slave devices generate the appropriate commands until this required position is reached. If the tap position of a slave is identical with that of the master then the subsequent operation is performed according to the rule of the "SlaveCmd" mode.

There is a correction possibility for tap position adjustment, if the tap-changers are not of the same type: the parameter setting "Tap Offset" can match the parallel running of the individual tap-changers

3.1.4 Forced modes of operation

In case of intentional user action or certain errors the algorithm can override the mode of operation defined by parameter setting as follows:

- **Forced "Single" mode**

  Intentional user action:
  The mode of operation is changed to "Single mode" when the ATCC_**ForceSingle**_GrO_ binary inputs of the parallel tap changer controller function block is active.

  Errors**:**
  The mode of operation is changed to "Single mode" and at the same time the operation is disabled in case of any of the following errors:

  - Contradiction in addresses
  - Topology error:
    - It may arise if the controlled transformer is not connected to any of bus sections or connected to more than one bus section (any of the ATCC_**Bus1-3Disc**_GrO_ (Bus1-3Disc) binary inputs of the tap changer controller function block is not active or more than one is active).
  - If the device set to "Master" mode finds another master with higher priority connected to the same bus section
  - In "Min Circulating Current" mode the voltage measurement is missing
- **Forced "Master" mode**
  The slave with the highest priority can enter to this mode of operation, if the "MTO" input is active and the former Master is not available.

The device displays the actual mode of operation in the "On-line" menu of the LCD and in the WEB interface as well.

3.1.5 Operation in case of errors

For proper operation the following conditions must be fulfilled:

- The devices to control parallel transformers must be connected to the same Ethernet network,
- The status signals indicating the busbar configuration must be correct (the automatic tap changer controllers which are operating in parallel must be connected to same bus section (must be connected to the same ATCC_**Bus1-3Disc**_GrO_ (Bus1-3Disc) binary input of the tap changer controller function block).
- Also the parameter setting of the co-operating controllers must be correct.

In case of any errors the “On-line” window of the controller function shows an error code. The configured code vales of the “Parallel error” field are summarized in the Table below:

Table 3-1 “Parallel error” code values

ERROR CODE (DECIMAL)	ERROR CODE (HEXA)	EXPLANATION
0	Ox0	No error
1	Ox1	There is no interconnection with the device on address 0
2	Ox2	There is no interconnection with the device on address 1
4	Ox4	There is no interconnection with the device on address 2
8	Ox8	There is no interconnection with the device on address 3
256	Ox100	Invalid address
512	Ox200	Master error (indicated by the slave device): No master controller can be found by the slave device.
1024	Ox400	Error in the topology (e.g. a transformer seems to be connected to more than one bus section)
2048	Ox800	There is another master with higher priority in the system (indicated by the master device)
4096	Ox1000	Address error (more then one device with the same address)

In case of multiple errors, the assigned code values are added.

The devices are blocked in “Min Circulating Current” mode if the communication fails with any of the co-operating devices, or any of them is blocked.

3.2 Settings

3.2.1 Parameters

Table 3-2 The measured analogue values of the automatic tap changer controller function

TITLE	DIM.	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, Single (On), Min. Circulating Current, Master, Slave-Cmd, Slave-Tap	-	Off	Parameter for general operation of the function: Single, Min. Circulating Current, Master, Slave-Cmd, Slave-Tap are valid only in automatic tap changer controller for parallel transformers function.
TC Supervision	-	Off, TCDrive, Position, Both	-	Off	Tap changer supervision mode selection
Code Type	-	Binary, BCD, Gray, *mA	-	Binary	Decoding of the position indicator bits *mA: this option is only available if mA decoding has been ordered for tap changer position decoding
Min Position	-	1-32	1	1	Code value of the minimum position
Max Position	-	1-32	1	32	Code value of the maximum position
I Overload	%	50 – 150	1	150	Current upper limit to disable all operation.
Max Operating Time	msec	1000 – 30000	1	5000	Time limit for tap-change operation
Pulse Duration	msec	100 – 10000	1	1000	Command impulse duration
Position Filter	msec	1000 – 10000	1	3000	Time of overbridging the transient state of the tap changer status signals which the status is not evaluated
Time delay 1 type	-	Definite, Inverse, 2powerN	-	Definite	Parameter for time delay mode selection
Compensation	-	Off, Absolute, Complex	-	Off	Selection for compensation mode
Fast Higher Enable	-	FALSE,TRUE	-	FALSE	Enabling fast higher control command
Fast Lower Enable	-	FALSE,TRUE	-	FALSE	Enabling fast lower control command
U Correction		0.950 – 1.050	0.001	1.000	Factor for fine tuning the measured voltage
U Set	%	80.0 – 115.0	0.1	100.0	Set-point for voltage regulation, related to the rated voltage (Valid at I=0)

U Deadband	%	0.5 – 9.0	0.1	3.0	Dead band for voltage regulation, related to the rated voltage
Deadband Hysteresis	%	60 – 90	1	85	Hysteresis value for the dead band, related to the dead band
(R) Compound Factor	%	0.0 – 15.0	0.1	5.0	Parameter for the current compensation.
X Compound Factor	%	-15.0 – 15.0	0.1	5.0	Parameter for the current compensation (negative value needs to be set when Negative reactance circulating current mode is used)
Voltage Reduction 1	%	0.0 – 10.0	0.1	5.0	Reduced set-point 1 for voltage regulation (priority), related to the rated voltage.
Voltage Reduction 2	%	0.0 – 10.0	0.1	5.0	Reduced set-point 2 for voltage regulation, related to the rated voltage
I Comp Limit	%	0 – 150	1	100	Maximum current value to be considered in current compensation form
U High Limit	%	90.0 – 120.0	0.1	110.0	Voltage upper limit to disable step up
U Low Limit	%	70.0 – 110.0	0.1	90.0	Voltage lower limit to disable step down
U Low Block	%	50.0 – 100.0	0.1	70.0	Voltage lower limit to disable all automatic operation
Time Delay 1	sec	1.0 – 600.0	0.1	10.0	Time delay for the first control command generation
Time Delay 2	sec	1.0 – 100.0	0.1	10.0	Definite time delay for subsequent control command generation or fast operation (if it is enabled)
Min Delay	sec	1.0 – 100.0	0.1	10.0	Minimum time delay in all operation cases
Reclaim Time	sec	1.0 – 100.0	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
Extension for automatic tap changer controller of parallel transformers					
Address0 InUse	-	FALSE,TRUE	-	FALSE	0 priority level is used in the system
Address1 InUse	-	FALSE,TRUE	-	FALSE	1 priority level is used in the system
Address2 InUse	-	FALSE,TRUE	-	FALSE	2 priority level is used in the system
Address3 InUse	-	FALSE,TRUE	-	FALSE	3 priority level is used in the system
UseVLAN	-	FALSE,TRUE	-	TRUE	VLAN identifier is used for the communication
GroupID	-	0 – 4095	-	0	VLAN Identifier for the group of cooperating controllers

Device Address	-	0 – 3	-	3	Device address within the group of cooperating controllers
Tap Offset	-	-5 – 5	-	0	Setting the tap offset position in master-slave “SlaveTap” mode
Transformer Drop	%	1.0 – 30.0	0.1	5	Transformer short circuit impedance for the circulating current mode of operation
Transformer Sn	MVA	1.0 – 500.0	0.1	40	Transformer rated power for the circulating current mode of operation
Control Drop	%	1.0 – 50.0	0.1	10	Short circuit impedance for weighting the influence of the circulating current for the circulating current mode of operation
ControlModel	-	Direct normal, Direct enhanced, SBO enhanced	-	Direct normal	Control model, according to IEC 61850 standard
sboClass	-	Operate-once, Operate-many	-	Operate-once	Select before operate class, according to IEC 61850 standard
SBO Timeout	msec	1000 – 20000	1	5000	Duration of the waiting time between object selection and command selection. At timeout no command is performed

Table 3-3 The parameters of the time scheduler (for ATCC) function

TITLE	DIM.	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Disable,Enable	-	Disable	Activation of the time scheduler function
1.Set point (from 0:00)	%	80.0 - 115.0	0.1	100	“U set” value during 1. Set point interval
2.Interval Start	Hour	0 - 23	1	7	2.Interval Start hour
2.Interval Start	Minute	0 - 59	1	1	2.Interval Start minute
2.Set point	%	80.0 - 115.0	0.1	100	“U set” value during 2. Set point interval
…	…	…	…	…	…
7.Interval Start		0 - 23		22	7.Interval Start hour
7.Interval Start		0 - 59		1	7.Interval Start minute
7.Set point		80.0 - 115.0		100	“U set” value during 7. Set point interval

3.3 Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.3.1 Analogue inputs

The function uses the sampled values of the three phase currents of each side.

3.3.2 Analogue outputs (measurements)

The measured values of the automatic tap changer controller function are listed in the table below.

Table 3-4 The measured analogue values of the automatic tap changer controller function

MEASURED VALUE	DIMENSION	EXPLANATION
U Bus	Un %	*UL1L2 voltage*
U Controlled	Un %	*UL1L2* compensated by the current of the controlled side *IL1L2*
I Circulating reactive	In %	Circulating reactive current in parallel transformer operation

3.3.3 Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in **bold** is seen on the function block in the logic editor.

Table 3-5 The binary input signal of the automatic tap changer controller function

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
Extension for automatic tap changer controller of parallel transformers		
ATCC_**Bus1Disc**_GrO_	Bus1Disc	Disconnector closed for Bus1

ATCC_**Bus2Disc**_GrO_	Bus2Disc	Disconnector closed for Bus2
ATCC_**Bus3Disc**_GrO_	Bus3Disc	Disconnector closed for Bus3
ATCC_**MTO**_GrO_	MTO	Slave is enabled to take over the master role
ATCC_**ForceSingle**_GrO_	ForceSingle	Forced single operation

3.3.4 Binary output signals (graphed input statuses)

The binary output status signals of the automatic tap changer controller function. **Parts** written in **bold** are seen on the function block in the logic editor.

Table 3-6 The binary output signal of the automatic tap changer controller function

Binary status signal	Title	Explanation
ATCC_**AutoBlocked**_GrI_	Auto Blocked (ext)	Automatic control blocked externally (by AutoBlk input).
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
ATCC_**HigherTimer**_GrI_	HigherTimer	Timer before generation “Higher” command is running
ATCC_**LowerTimer**_GrI_	LowerTimer	Timer before generation “Lower” command is running
Extension for automatic tap changer controller of parallel transformers		
ATCC_**RemHigher**_GrI_	Remote Higher	Signal of the slave, indicating execution of the master command
ATCC_**RemLower**_GrI_	Remote Lower	Signal of the slave, indicating execution of the master command
ATCC_**ComFail**_GrI_	Communication Error	No connection with at least one of the configured devices
ATCC_**MasterError**_GrI_	Master Error	The slave device can not follow the master

3.3.5 On-line data

Visible values on the on-line data page:

Table 3-7 On-line data of the automatic tap changer controller function

SIGNAL TITLE	DIMENSION	EXPLANATION
U Bus	%	*UL1L2 voltage*
U Controlled	%	*UL1L2* compensated by the current of the controlled side *IL1L2*
Position	-	Tap changer position
Error Code	-	Error codes of the operation of the tap changer based on the Table 1-2 “ErrorCode” Table
Remote Tap Position	-	In Master-Slave mode receiving the Master tap position
Min Pos Reached	-	Signaling the minimal position
Max Pos Reached	-	Signaling the maximal position
Higher Command	-	Command feedback for increasing the voltage
Lower Command	-	Command feedback for decreasing the voltage
U High	-	Controlled side UL1L2 exceeds the “U High Limit” parameter value, more details in Chapter 1.3
U Low	-	Controlled side UL1L2 goes under the “U Low Limit” parameter value, more details in Chapter 1.3
U Block	-	Controlled side UL1L2 goes under the “U Low Block” parameter value, more details in Chapter 1.3
I High	-	IHV (load side) is above the limit set by the parameter “I Overload”, more details in Chapter 1.3
Locked	-	In case of an error detected in the operation of the tap changer and no further commands are performed. See Chapter 1.4.3
Higher Timer	-	Timer running to indicate higher command
Lower Timer	-	Timer running to indicate lower command
Auto Blocked (ext)	-	Automatic control blocked
Voltage Reduction 1	-	Voltage Reduction 1 is active
Voltage Reduction 2	-	Voltage Reduction 2 is active
Manual	-	Manual mode of operation is active
Extension for automatic tap changer controller of parallel transformers		
I Circulating reactive	%	Circulating reactive current in parallel transformer operation (% based on IL1L2 nominal current)
Follower	-	Follower control mode is active. See Chapter 1.4.1
Parallel error	-	Indicated the error code of parallel operation. See Chapter 3.1.5
Actual mode	-	Actual mode of operation
Remote Higher	-	Received command from the remote master tap changer controller device

Remote Lower	-	Received command from the remote master tap changer controller device
Communication Error	-	Communication error in parallel operation. See Chapter 3.1.5
Master Error	-	The slave device can not follow the master

3.3.6 Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

Table 3-8 Events of the automatic tap changer controller function

EVENT	VALUE	EXPLANATION
Min Pos Reached	off,on	Minimum position reached
Max Pos Reached	off,on	Maximum position reached
ATCC local mode	off,on	Local mode of tap changer controller is active
AutoMode	off,on	Auto mode of operation
Blocked	off,on	Tap changer control is blocked
Voltage Reduction 1	off,on	Controlling to reduced voltage 1
Voltage Reduction 2	off,on	Controlling to reduced voltage 2
Higher Command	off,on	Higher command generated
Lower Command	off,on	Lower command generated
U Block	off,on	U Block condition is active. See Chapter 1.3
U High	off,on	U High condition is active. See Chapter 1.3
U Low	off,on	U Low condition is active. See Chapter 1.3
I High	off,on	I High condition is active. See Chapter 1.3
Locked	off,on	Locked state is active. See Chapter 1.4.3
Extension for automatic tap changer controller of parallel transformers		
Actual Mode	Off,Single,Min Circulating, Master,Slave-Cmd,Slave-Tap.	Actual mode of tap changer controller
Communication Error	off,on	Communication error in parallel operation. See Chapter 3.1.5

Commands

The following table contains the issuable commands of the function block. The name of the command channel is used while working in the EuroCAP configuration tool, whereas the title is seen by the user on the device web page.

Table 3-9 The command of the automatic tap changer controller function

COMMAND CHANNEL	TITLE	RANGE	EXPLANATION
ATCC_Oper_Con_	Operation	Lower,Higher	Manual higher/lower command of automatic tap changer controller
ATCC_Blk_Con_	Blocking	Enabled,Blocked	Blocking command of automatic tap changer controller
ATCC_VRed1_Con_	Voltage Reduction 1	Back,Reduction	Command to reduced set-point 1 for voltage regulation (priority), related to the rated voltage
ATCC_VRed2_Con_	Voltage Reduction 2	Back,Reduction	Command to reduced set-point 2 for voltage regulation, related to the rated voltage
ATCC_Man_Con_	Auto/Man	Auto,Manual	Command to change the mode of operation of tap changer

3.4 Technical data

Table 3-10 Technical data of the automatic tap changer controller function

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 % < △U < 25%	<5%
	25 % < △U < 50%	<2% or ±20 ms, whichever is greater