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SIPROTEC 5 Application

Voltage Control of Transformers in Parallel Operation

SIP5-APN-034, Edition 2

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SIPROTEC 5 – Application
Voltage control of transformers in parallel operation using SIPROTEC 7UT8x and the master-follower method
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Content

1 Voltage control of transformers in parallel operation using SIPROTEC 7UT8x and the master-follower method

1.1 Introduction

The voltage control functionality in SIPROTEC 5 is tailored to the control of two- and three-winding transformers or grid coupling transformers. The present application enables this voltage controller scheme to be expanded to two or more parallel transformers using IEC 61850 GOOSE communication and CFC in master-follower mode.

Remark: Alternatively, the signals between the function groups can be interconnecting using CFC. As a result, the connection is directly in the devices and features multiple 3-phase voltage connections and additional instancing of the voltage controller function group.

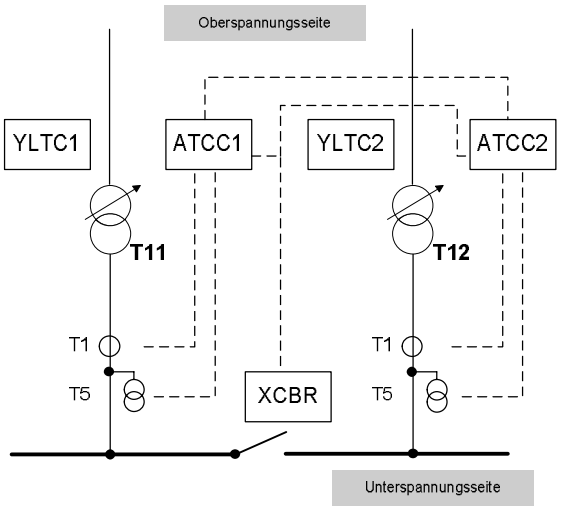


Figure 1: Overview of the system configuration and the IEC 61850 nodes for parallel controllers

1.2 Master-follower principle

In the master-follower principle, one voltage controller is defined as the master. This controller takes the lead while the other controller regulates to the same tap position as the master. The master automatically controls the busbar voltage following the same principles of the available voltage controller functionality for a two-winding transformer.

In the master-follower scheme, the master tap is compared with the follower tap and the follower autonomously follows the master's tap changing commands. Compared to master-slave operation, this method has the advantage that a loss of higher/lower command (e.g. loss of communication, auxiliary voltage failure of the follower) will not result in non-synchronous transformer tap positions.

This procedure is best suited for transformers identical in construction. When transformers with different capacities are controlled according to the master-follower principle, identical tap positions must result in identical transmission ratios (= same no-load voltages) and the relative short-circuit voltages of the transformers must not differ too much (max. 10%).

1.3 Operating modes

The following operating modes are possible due to the image of the switching devices and transformers involved as well as the power system operation requirements.

1.3.1 Automatic mode

- The circuit breaker of the busbar section is open.

The transformers work independently. The two devices T11 and T12 work independently in automatic mode.

- The circuit breaker is closed.
  The transformers work in parallel: T11 = master, T12 = follower
  Follower device T12 uses the CFC follower logic to send higher/lower commands until the positions of both tap changers are identical. The master checks the maximum tap changer difference (>2).
  Manual control in the follower device from "local" or "remote" is blocked.
  Moreover, switching to automatic mode from "local" or "remote" is prevented for the follower.

- Communication failure between devices or failure of one device
  Parallel operation cannot be recognized due to a communication failure in both devices. Manual control is activated in the follower and master device.
  The interlocking to manually switch the tap changer from "local" or "remote" is released.
  The follower mode in device T12 is cancelled or higher/lower commands are suppressed by the follower logic. So in this condition the operator must manually assure that there is no tap changer difference between the tap changers.

1.3.2 Manual operating mode

The control object *TapChg* ("command with feedback") in LN ATCC of devices T11 and T12 is adjusted using the control panel or the function keys (local) or via the control system (remote).

- The circuit breaker of the busbar section is open.
  Manually updating the tap changer is separately possible for T11 and T12.

- The circuit breaker is closed.
  Consequently, the tap changers can only be switched manually in the master device T11.
  Follower device T12 uses the CFC follower logic to send higher/lower commands until the positions of both devices are identical, also across multiple taps.
  The tap changer difference is not verified in the master. The operator has to check whether a tap changer difference exists after the tap change time of the follower.
  Manual control in the follower device is interlocked.

- Communication failure between devices or failure of the master device
  Manual control in the follower device and in the master device must be possible in the event of a fault. Switching to automatic mode is blocked, see 1.3.1 Automatic Mode.

1.4 Follower device

1.4.1 Switching to parallel operation

In the present CFC extension of the existing voltage controller, a user-defined signal of the type SPS "ParallelMode" is created in the master device and is generated by means of a CFC logic from the circuit breaker position (binary input). This signal is transmitted to the follower device with IEC 61850 GOOSE.

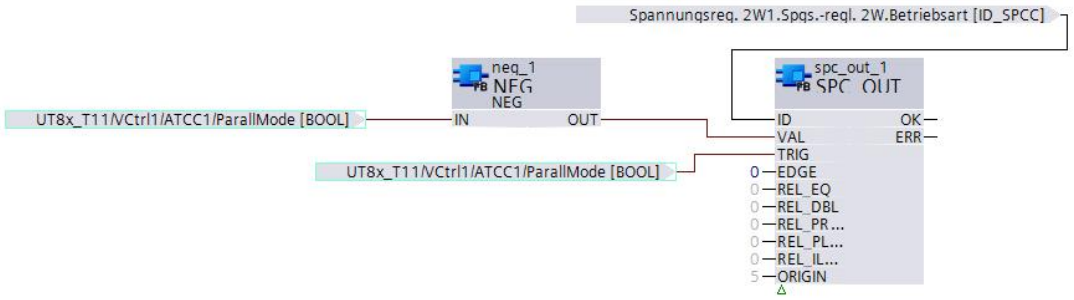


Figure 2: Follower CFC chart for switching to follower mode

The follower device UT8x_12 creates the states from chapter 1 as follows:

	1 automatic control			2 manual mode (from remote/local)		
	1.1 Transformers operate independently	1.2 Parallel operation	1.3 GOOSE failure	2.1 Transformers operate independently	2.2 Parallel operation	2.3 GOOSE failure
		Follower mode - manual	Auto block		Follower mode - manual	Auto block
CFC inputs						
UT8x_T11/CTRL/ATCC1/ParallelMode *User-defined signal SPS*	*Off*	*On*	-	*Off*	*On*	-
UT8x_T11/CTRL/ATCC1/ParallelMode *Quality* User-def. signal SPS	VALID	VALID	VALID	VALID	VALID	INVALID
Input messages tap changer (YLTC) output CFC						
UT8x_T11/CTRL/STON_YLTC1/Enable 13981.501 “<Enable” SPS	On	Off	On	On	Off	On
Input messages voltage controller 2W (ATCC) output CFC						
UT8x_T11/CTRL/ATCC1/Auto 14011.311 “operating mode” SPC	Auto	Manual	Auto	Manual	Manual	Manual
14011.81 “<Block” SPS	Off	Off	On	-	-	On
Output messages voltage controller 2W (ATCC)						
UT8x_T12/VCtrl1/ATCC1/AutoBlk 14011.317 “Automatic blocked“ SPS	Off	Off	On	Off	Off	On

If the transformers are operated in parallel, the voltage controller's operating mode in the follower device T12 is switched by means of a CFC chart "master/follower operation" with the IEC 61850 control object "operating mode".

1.4.2 Interlocking of manual operation "local" / "remote" in follower mode

In follower mode, manual control ("local") and control system ("remote") has to be blocked. The blocking functionality is enabled through the possibility to check the interlocking conditions at the tap changer. If there is a communication error, manual updating of the tap changer from a local or remote source should also be possible in follower mode (manual control). In this case, interlocking in the follower mode has to be released.

If the input message at tap changer .13981.501 "> Enable" is configured, the value "1" has to apply there for the tap changer to be actuated. Only the CFC chart is capable of bypassing this by setting the input of the BSC_EXE "REL_ILOC" in the follower CFC logic (see Figure 5) to 1 (release interlocking).

The message "> Enable" is set if no parallel mode is activated or if it cannot be determined during a communication error. "> Enable" allows the tap changer to be switched manually.

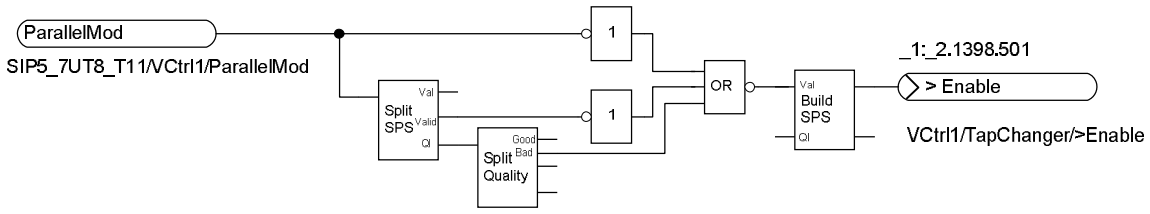


Figure 3: Principle of the CFC logic: Interlocking of manual operation "local" / "remote" SIP5_7UT8_T12

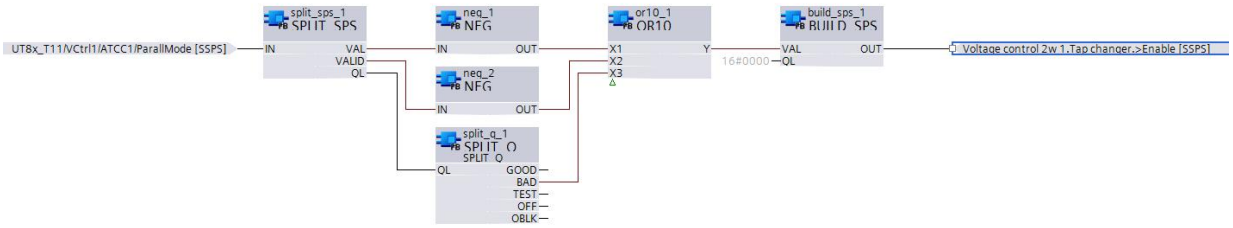


Figure 4: CFC logic: Interlocking of manual operation "local" / "remote" SIP5_7UT8_T12

1.4.3 Blocking in the follower device

1. If there is a communication error, the parallel mode in the follower cannot be determined. In that case, automatic mode in the follower has to be blocked for safety reasons even if the transformers are working independently.

2. It should be impossible to switch the "Auto" controllable for switching the operating mode of the voltage controller from "local" or "remote" to "automatic mode" in the follower mode during parallel operation. The following CFC chart causes the "automatic mode" in the follower device to be blocked during parallel operation.

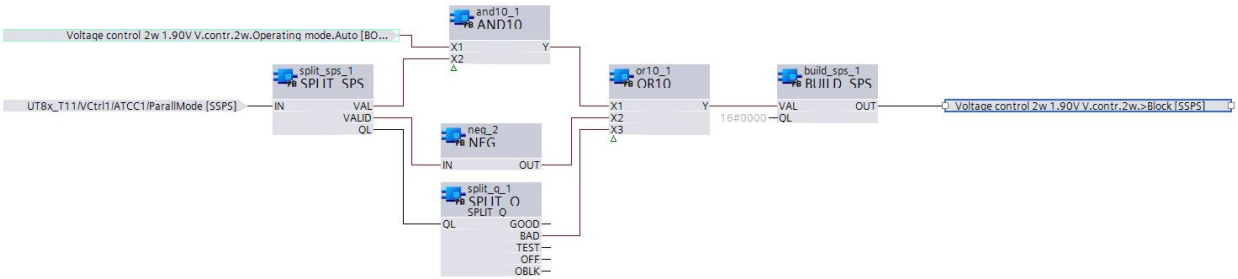


Figure 5: CFC logic: Blocking "Automatic Mode" SIP5_7UT8_T12

3. Follower mode is blocked if

- the tap changer position in the master or follower device is invalid,
- communication is interrupted,
- the motor moving contact is active.

To report these statuses in due time, a user-defined message "follower blocked" is created.

Follower logic

The further configuration includes connecting the tap changer information of the SIP5_7UT8_T11 (master) which is transmitted to the SIP5_7UT8_T12 (follower) via IEC 61850 GOOSE. The SIP5_7UT8_T12 device receives the tap changer information and compares the received tap changer position with its own tap position by means of a CFC chart. If it detects a deviation, corresponding higher/lower commands are sent to the tap changer of transformer T12. The following CFC logic of the follower device compares the tap changer positions.

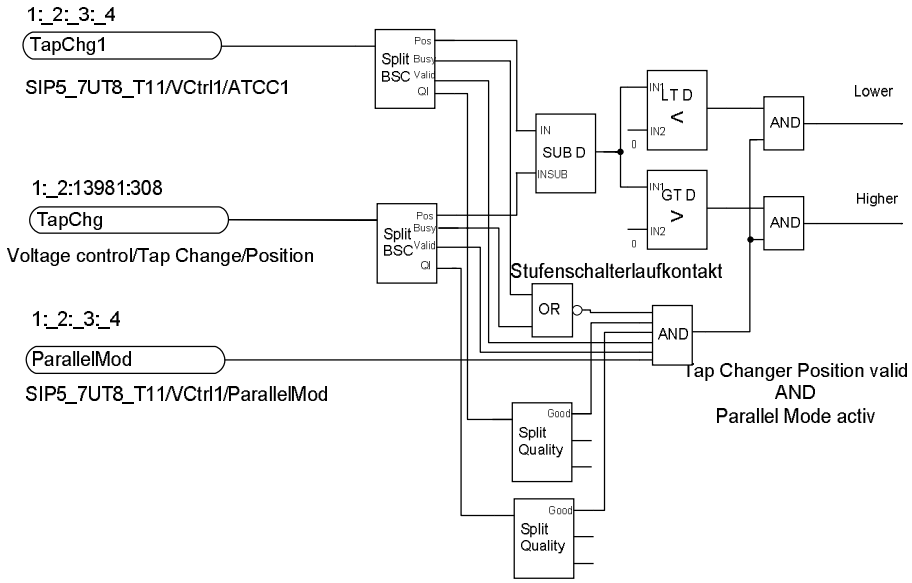


Figure 6: Principle of the CFC logic in the SIP5_7UT8_T12 follower device

The purpose of the "Split BSC" CFC block is to obtain an integer value . Additionally, the signals "busy" (moving contact) and the quality have to be evaluated. To evaluate the quality, the "Split Quality" block is additionally required. A higher/lower command is only issued if the tap changer position is valid or if the tap changing process is finished ("busy" = false) and command execution is not active ("active" = false).

If the transformers run in parallel mode ("ParMod" = on), the logic is active. To activate execution of the tap changer, the input "Rel_ILoc" of BSC_EXE has to be set to 1 despite blocked interlocking condition ("> Enable" = off).

The input "Select" of block BSC-DEF has to be set to the value 2 according to parameter "control model" = SBO with command state monitoring.

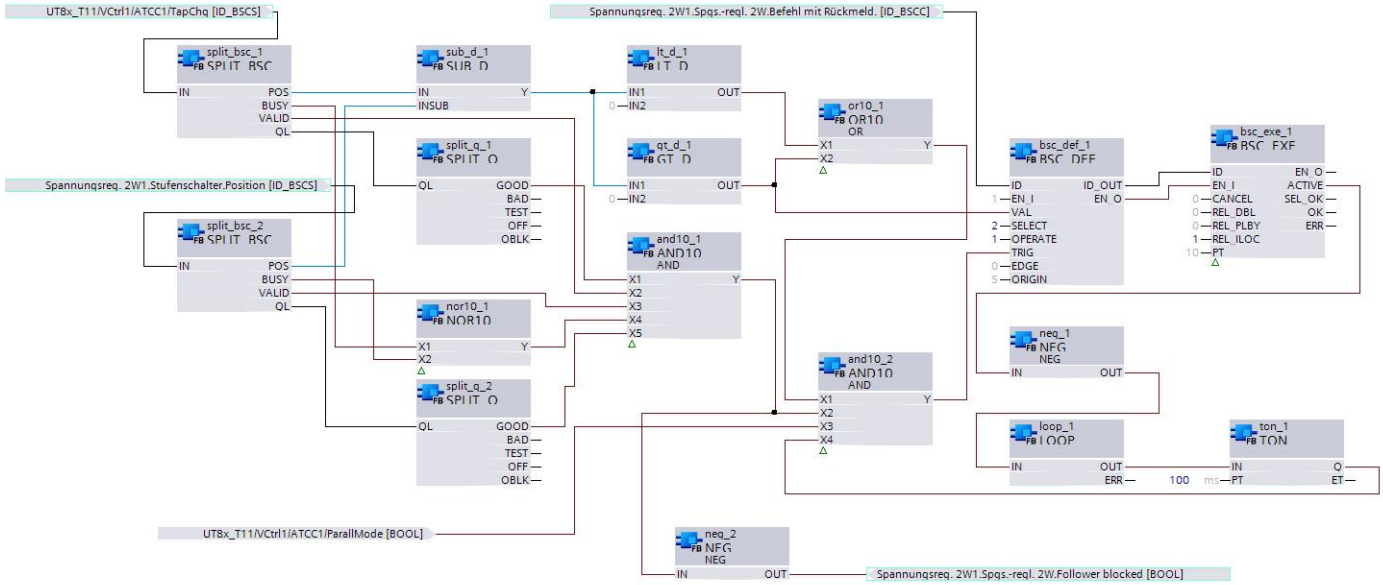
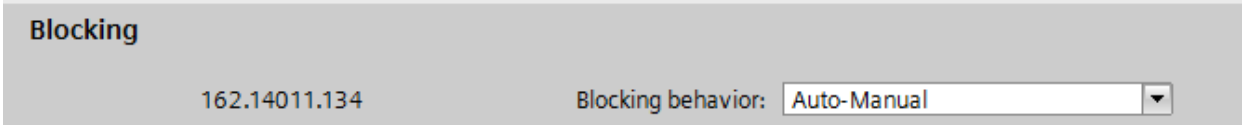


Figure 7: CFC follower logic SIP5_7UT8_T12

1.4.4 Blocking the tap changer during a fault in follower mode

To assure that the monitoring functions (I>, V<, I<) or transformer differential protection pickup when used with transformer differential protection are also activated in the follower mode, the parameter "blocking" 162.14011.134 in the voltage controller has to be set to "auto-manual mode".



1.5 Monitoring the follower in the master device

The master's CFC logic monitors the valid tap positions of the follower device and blocks automatic voltage control.

If the follower voltage controller is faulted and the master continues to control automatically, the tap changer difference could become too large resulting undesired circulating reactive currents. The maximum tap changer difference is set to 2 for safety considerations. This chart may be active in parallel mode only and the signal "ParallelMod" releases this blocking.

Since the creation of the user-defined message "ParallMod" in the master device also depends on GOOSE messages (e.g. disconnector positions of other devices), the "Automatic Mode" also has to be blocked during communication failures.

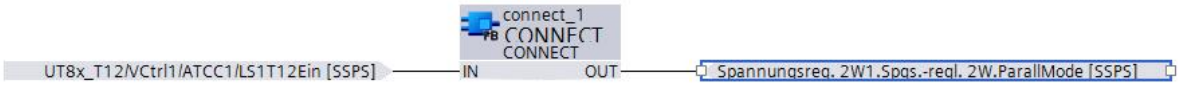


Figure 8: Master CFC chart logic, example of ParallelMod creation

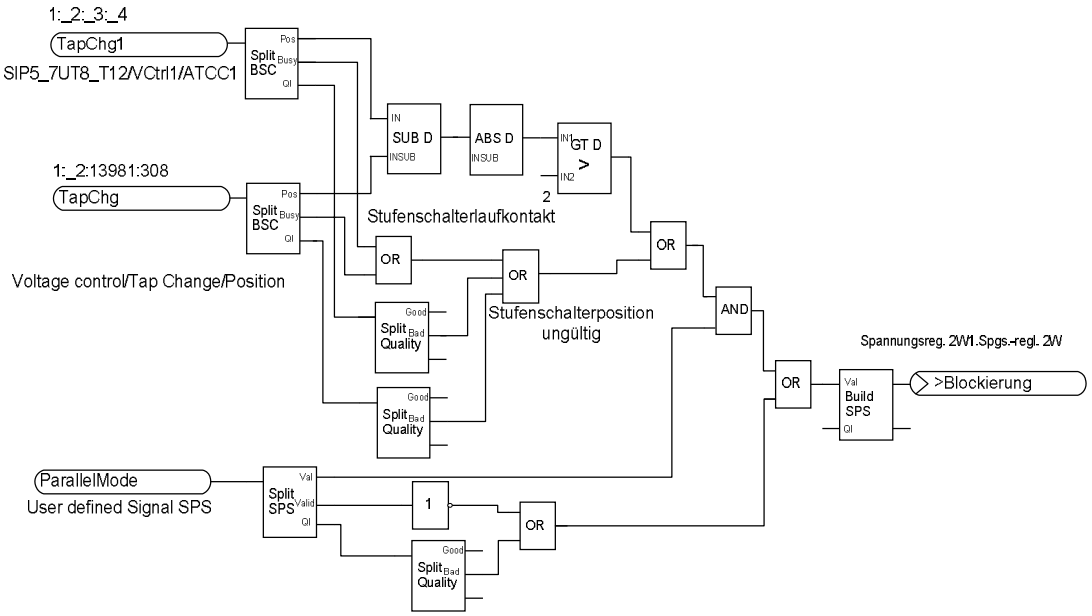


Figure 9: Principle of the CFC logic in the master device SIP5_7UT8_T11

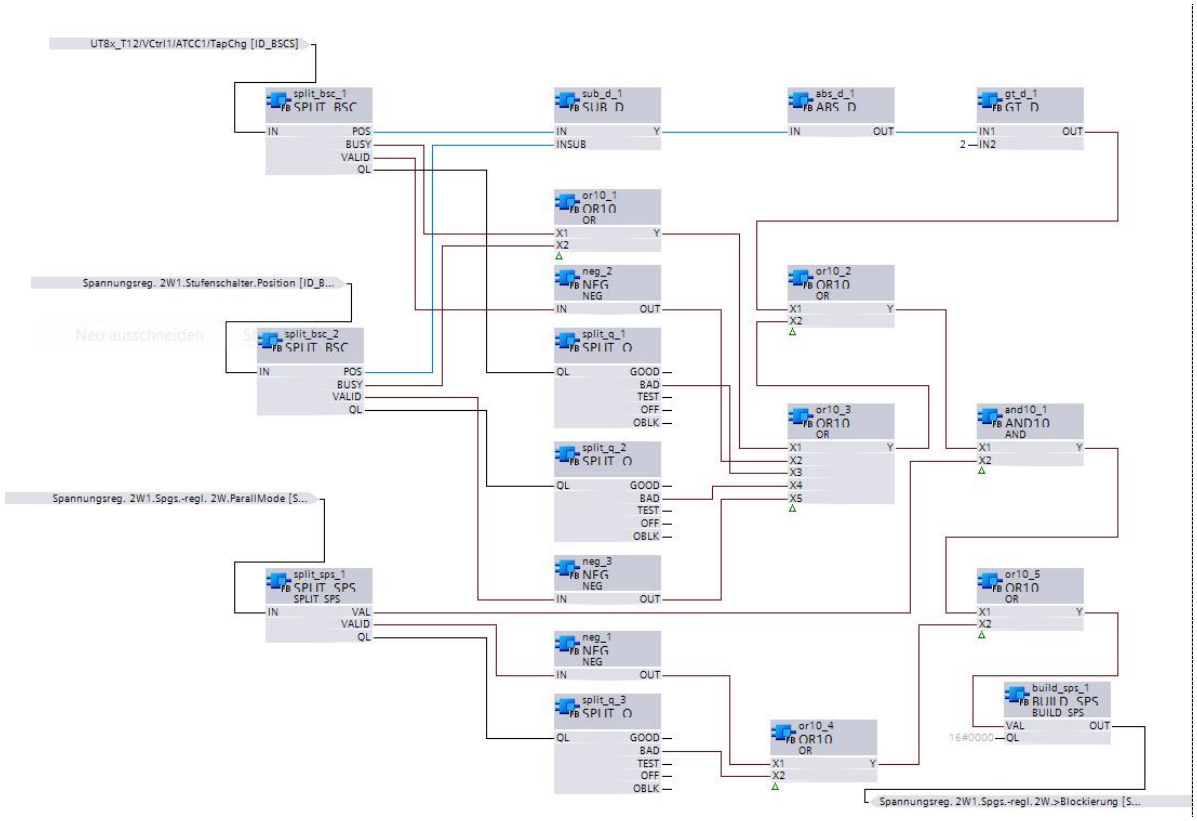
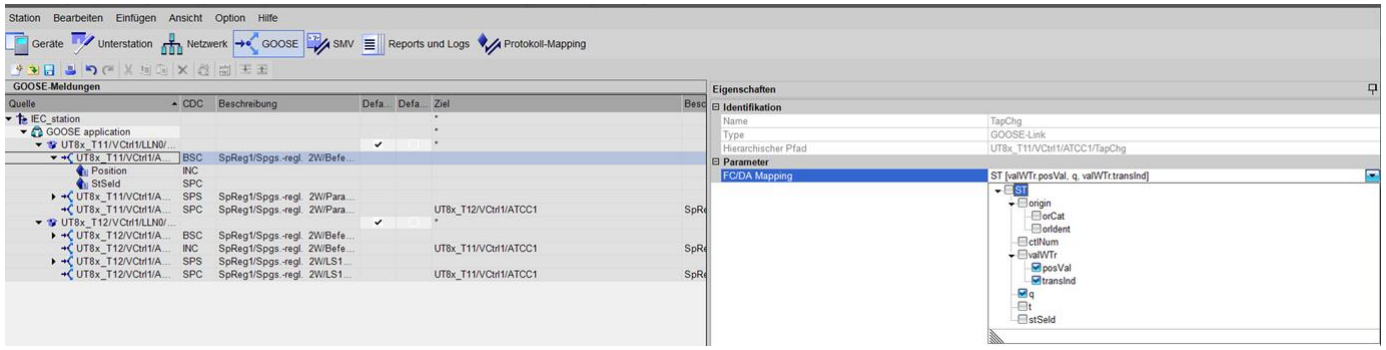


Figure 10: CFC logic in the master device SIP5_7UT8_T12

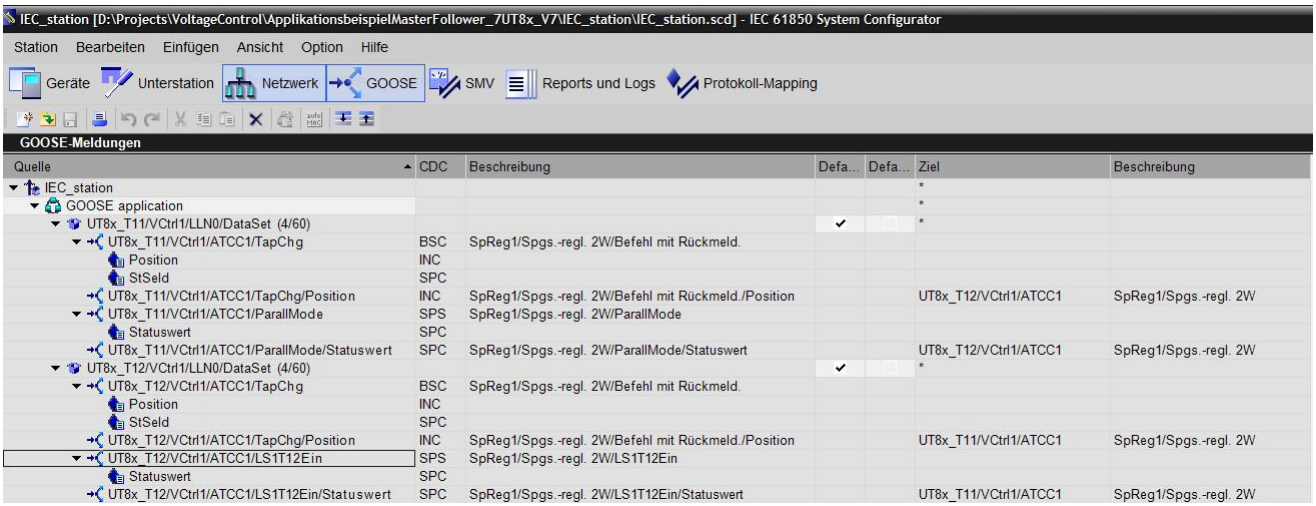
In the CFC example above, the IEC 61850 object "ParOP" in ATCC is not set by the master operation. Instead, the user-defined message "ParallMod" has to be used or transmitted to the control system.

1.6 IEC 61850 GOOSE communication

The GOOSE messages between the two devices are set in the IEC 61850 System Configurator:



First, the FC/DA mapping has to be adjusted for the BSC control objects "TapChg" in the source objects and the valWTr.transInd has to be added.
Properties -> Parameters -> Open drop-down box.



In the example, the ATCCs of the target device are used as target logical node (LN). Alternatively, a user-defined function block (FB) can be used. The user-defined FB represents an IEC 61850 LN (LN = Logical Node).

In the logical node ATCC of the follower device SIP5_7UT8_T12, the tap changer position of CDC type BSC is created in the path SIP5_7UT8_T12/VCtrl1/ATCC1/TapChg1. The tap changer position of the follower device SIP5_7UT8_T12 is sent to the master. This tap changer position or its quality attributes serve to recognize errors and the automatic mode in the master is blocked (see CFC logic in the master device).

1.7 Summary

The voltage controller function ANSI 90 V in SIPROTEC 5 is tailored to two- and three-winding transformers and grid coupling transformers. Using IEC 61850 GOOSE for secure inter-device communication as well as arithmetic, tested CFC blocks (+40 function points) allows the application to be expanded flexibly for two or more parallel transformers in master-follower mode.

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