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SCE Training Curriculum

Siemens Automation Cooperates with Education (SCE) | 09/2015

PA Module P01-08
SIMATIC PCS 7 –
Sequential Control Systems

Cooperates with Education
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SEQUENTIAL CONTROL SYSTEMS

TRAINING OBJECTIVE

The students will be able to successfully implement sequential control systems by using sequential function charts. They will understand the structure and the operating principle of sequential function charts and will be introduced to the corresponding design methods. Their knowledge regarding operating modes and protective measures will be expanded for sequential control systems. The students understand the interaction between the programs of basic automation and sequential control systems. They know how to generate sequential control systems in ***PCS 7***.

THEORY IN BRIEF

Sequential control systems allow for time-discrete or event-discrete execution of sequential or parallel processes. They are used to coordinate different continuous functions as well as to control complex process sequences. Depending on defined states and events, operating and state changes are generated in the existing logic control systems and thus the desired sequential behavior is realized. They are implemented with one or several ***sequential function charts***.

A sequential function chart is the alternating concatenation of ***steps*** that trigger certain actions, and ***transitions*** that initiate the change from one step to another as soon as the corresponding ***step enabling condition*** is met. Each sequential function chart has exactly one ***start step*** and one ***end step*** and in addition to any number of intermediate steps that are connected through oriented edges and interposed transitions. The diagrams may also generate feedback through loops within the SFC. Likewise, they can include parallel or alternate branches. However, in this case it has to be ensured during the design that the sequence does not contain unsafe or inaccessible parts.

For designing a sequential control system, particularly the formal design methods using ***state diagrams*** or ***Petri nets*** can be applied. State diagrams are easily learned, allow for automatic error diagnostics and can be implemented without a problem in many existing program languages for sequential control systems. However, designing parallel structures is not possible because state diagrams only have exactly one active state.

Petri nets are considerably more complicated. However, all structures that are permitted in sequential control systems can be modeled and extensively analyzed. Thus necessary properties of the control system can be verified formally. Petri nets can also be implemented in sequential control systems without any problem.

Sequential control systems parameterize and activate lower level logic control systems by setting corresponding global control signals. The effect of these control signals can be of short duration or permanent, direct or delayed. Just like logic control systems, sequential control systems have to support different operating modes; particularly manual control of transitions and temporary or permanent interruption of the process sequences has to be possible. In addition, process specific protective functions are implemented with sequential control systems.

In ***PCS 7***, sequential control systems are implements with ***sequential function charts (SFC)***. SFCs offer an efficient operating mode management, high controllability through several switching modes as well as extensive parameter assignment through different sequence options. In ***PCS 7***, SFCs and CFCs interact and are linked by means of process values and control values. The interaction behavior can also be controlled in detail.

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THEORY

CONTINUOUS AND SEQUENTIAL CONTROL SYSTEMS

Within the scope of basic automation, different logic control systems are developed; each implements a limited, clearly defined function. The functions are continuously processing input signals and generate corresponding output signals. By means of different control signals, the functions can also be activated and parameterized. To implement complicated process sequences, for example, manufacturing specifications for products (***recipes***), it is necessary to coordinate the different functions and to activate them at the right time with the correct parameters. This task can be implemented by using sequential control systems.

Sequential control systems enable step by step, event-discrete processing of sequential and parallel processes using ***sequential function charts*** (also called ***sequencers***). Depending on defined states or events they generate operating and state changes in the existing logic control systems and thus implement the desired sequential behavior.

STRUCTURE OF SEQUENTIAL FUNCTION CHARTS

A sequential function chart is the alternating sequence of ***steps*** and ***transitions***. The individual steps activate certain actions; transitions control the change from one step to another.

The first step of a sequential function chart is called the ***start step***. It is the unique entry point into the sequence and is always performed for that reason. The last step of a step sequence is correspondingly called ***end step***. It is the only step in the sequence that does not have a sequential transition. After the end step is processed, the step sequence is terminated or processing starts anew. The latter case is also referred to as sequence loop.

Steps and transitions are connected to each other through directed graphs. A step can be connected with several sequential transitions; the reverse is also possible. A transition is enabled when all series-connected steps are active and the step enabling condition is met. In this case, first the immediately preceding steps are deactivated and then the direct sequential steps are activated.

The simplest form of a sequential function chart is the unbranched sequence. Each step is followed by exactly one transition which in turn is followed by exactly one step. Thus, a purely sequential process sequence is realized. Figure 1 shows the corresponding graphic basic elements.

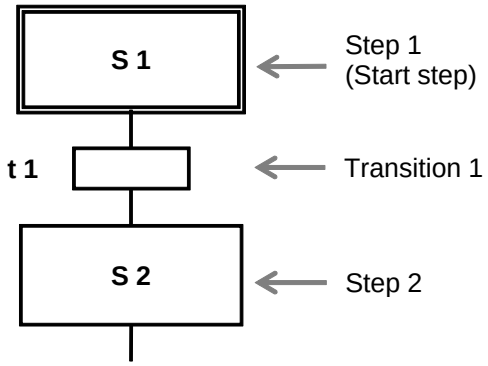

Figure 1: Basic elements of a sequential function charts

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Loops within the sequential function chart occur when a cyclical execution within the sequence is possible through concatenating several steps. The sequence loop is a special case of a loop in which all steps are executed cyclically.

Sequential function charts can also be structured using jumps. When a jump label is reached, processing is continued with the step to which the jump label points. Jumps within the sequential function chart can also cause loops. Because this structuring can only be followed with difficulty, it should be dispensed with if possible.

From the process view it is necessary in many cases to react differently to different events at program execution time. If this is the case, a step has several alternative follower steps. This structure is called ***alternative branch***. The step is connected with each possible follower step over a separate transition. To ensure that no more than one of these transitions is enabled at any time (and the branches are truly alternative), the transitions should be mutually locked out or prioritized. Otherwise, transitions are evaluated from left to right in most control systems, and the first transition whose step enabling condition is met is enabled.

Figure 2 shows the general structure of an alternative branch with two branches. It is represented by bordering horizontal single lines with protruding ends. As you can see, alternative branches always start and end with transitions.

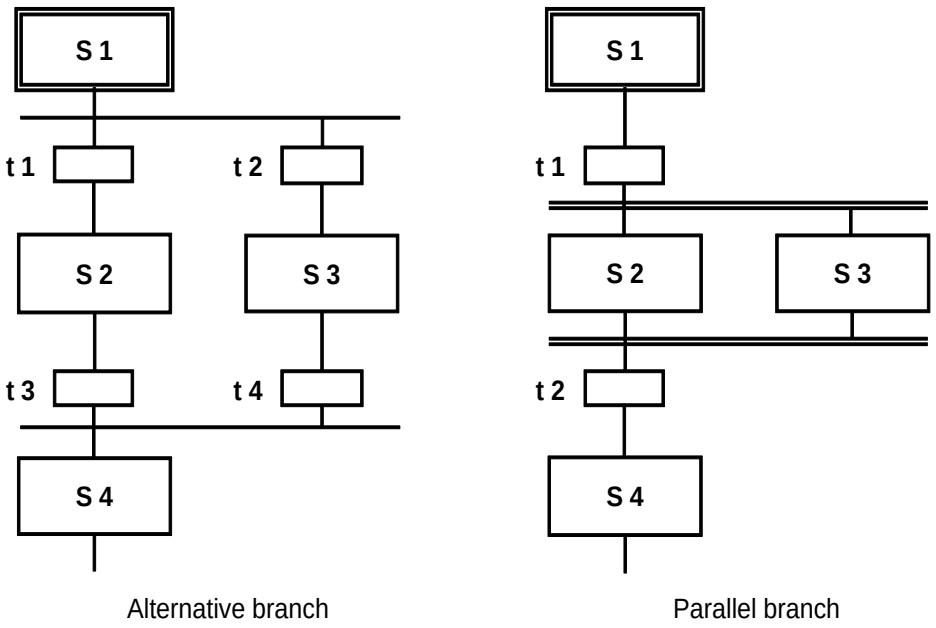

Figure 2: Alternative and parallel branches in sequential function charts

Another frequent requirement consists of this: After a step, several follower steps are to be processed simultaneously. In this case, the output step has exactly one transition that activates several follower steps at the same time. This structure is called ***parallel branch***. The follower steps of the individual branches are then processed independent of one another and then merged again. All branches end in a joint transition. Only after all branches are processed completely and the step enabling condition of the subsequent transition is met can the joint follower step be activated.

The sequence of a parallel branch with two branches is also shown in Figure 2. The branches are represented by bordering horizontal double lines with protruding ends. As you can see, parallel branches begin and end with actions.

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A special control problem is the possibility of generating faulty step sequences through the unfavorable use of jumps and branches. Three possible cases have to be distinguished.

– ***Uncertain sequence***: A sequential function chart contains a structure whose accessibility is not certain through the defined sequence behavior.

– ***Partial jamming***: A sequential function chart contains an inner loop that is not exited. Although the steps within this loop can be executed, the steps outside the loop cannot. This makes parts of the sequential function chart inaccessible.

– ***Total jamming***: A sequential function chart contains a structure for which there is no permissible step enabling condition. In this case the sequential function chart remains permanently in one state and all other steps remain inaccessible.

Such structures are not permitted in sequential function charts and have to be ruled out with corresponding formal design methods. Figure 3 shows an example of two sequential function charts with illegal structures.

In the left sequence it cannot be ensured that step S6 is accessible because the alternative branch after step S3–if transition t3 is enabled–prevents that the parallel branch in transition t4 is merged again. For this reason, the sequence is uncertain. The right sequence, on the other hand, is executed exactly once and then remains in step S4. Because step S2 is not active in this state, the parallel branch in transition t3 can no longer be merged. Total jamming is the result; step S5 is not accessible.

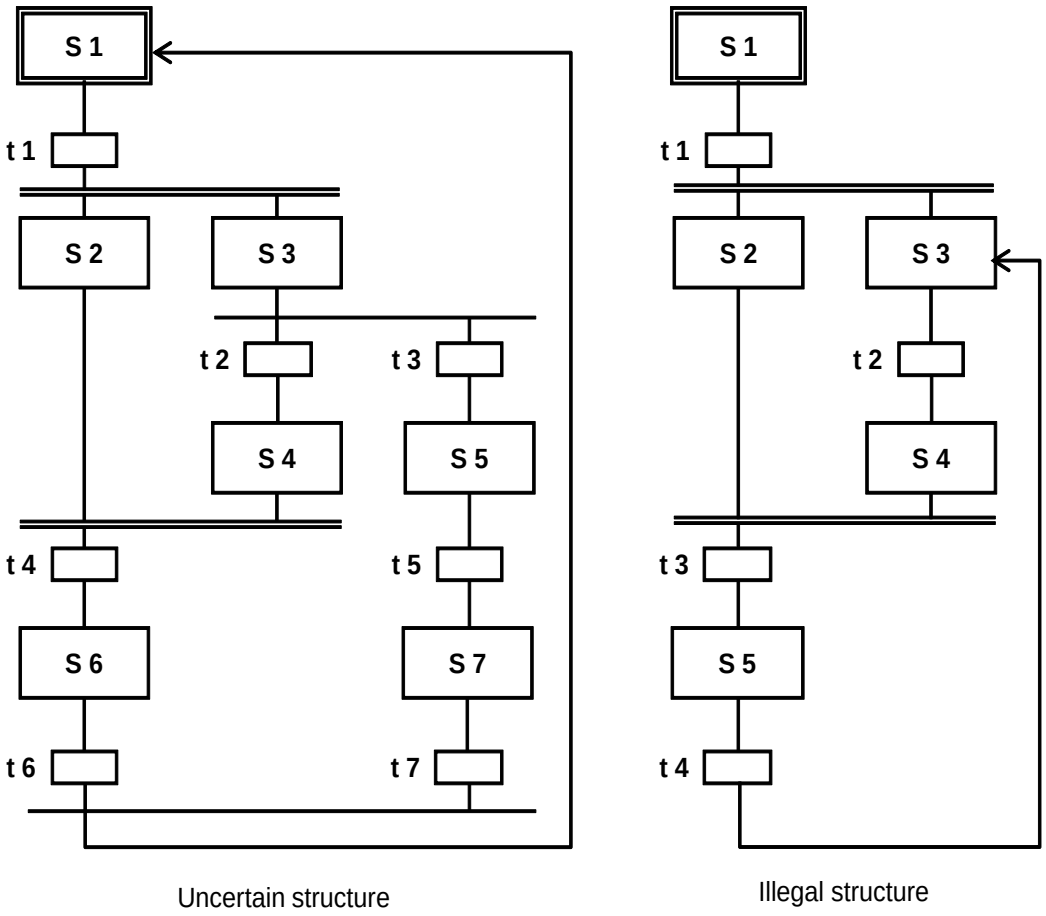

Figure 3: Uncertain and illegal structures in sequential function charts

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DESIGNING SEQUENTIAL CONTROL SYSTEMS

A variety of formal design methods exists for sequential control systems. In practice, however, particularly the models of the ***state diagram*** and the ***Petri nets*** have proven themselves.

A ***state diagram*** is a connected, directed graph. States are shown as circles and state transitions as arrows that connect exactly two states with each other. In a state diagram, exactly one state is always active at a time. The states can be linked to certain actions. To these actions, a certain execution behavior can be assigned. They can be executed once when entering the state or when exiting the state, or cyclically as long as the state is active. State transitions can be subject to transition conditions.

State diagrams can be arranged hierarchically and linked to each other. State diagrams are considered easy to learn, and enable automatic error diagnostics, for example, through pair, time or state monitoring. They can be easily implemented into many existing programming languages for sequential control systems.

Petri nets are particularly suitable for modeling asynchronous processes. A Petri net consists of locations and transitions that are connected to each other through directed edges. This also results in a directed graph. A location is represented with a circle and a transition with a rectangle (often reduced to a cross bar). Active locations are indicated with labels; they are represented with a dot within the circle for the corresponding location.

The state in a Petri network differs from that of a function diagram in that the state is determined by the number of active locations in the entire network. The dynamics of the system is modeled through the motion of the labels within the network. The meaning of the locations and transitions for the modeled process (i.e., the ***semantics*** of the Petri net) is not defined and has to be specified depending on the application. Petri nets whose semantics were specified are called ***interpreted Petri nets (IPN)***. For the control design, ***signal interpreted Petri nets (SIPN)*** are used.

Petri nets can be analyzed extensively. They also permit the implementation into existing programming languages for sequential control systems without any problem. There are numerous expansions for Petri nets that are optimized for specific applications, or provide for more exact process modeling. For this reason, Petri nets can get rather complex which makes them more demanding as a design method. Based on their structural similarity to sequential function charts and the capability of modeling parallel processes, Petri nets do also offer clear advantage.

The design method that is used depends ultimately on the requirements of the design task as well on the preference of the developer. Additional information is provided in the pertinent technical literature.

INTERACTION OF SEQUENTIAL CONTROL AND LOGIC CONTROL SYSTEMS

As described above, each step in the sequential function chart can be assigned certain actions. In general, these actions consist of parameter assignment and activating logic control systems. To this end, corresponding control signals are set.

Process and control signals that are used by sequential function charts have to be declared globally to be available to the programs of the sequential control and the logic control systems. The signals are usually listed in a symbol table,

The control signals have an effect as long as the corresponding step is active. For implementing more complicated function sequences it is possible, however, to vary the processing of the control signals themselves (latching or non-latching, time delayed or limited).

Usually, process specific functions are implemented with sequential control systems while logic control systems implement all device specific functions.

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PROTECTIVE FUNCTIONS AND OPERATING MODES IN SEQUENTIAL CONTROL SYSTEMS

As in the case of single control functions, adequate protective functions and operating modes have to be implemented for sequential control systems. Even if there is a fault, sequential control systems have to be operable. To this end, corresponding operating modes have to be provided in the control system.

– ***Automatic mode***: The action of the sequential function chart is performed when the series-connected transition is enabled.

– ***Manual mode***: The operator activates the action of the sequential function chart even if the series-connected transition is not enabled.

– ***Mixed mode***: The action of the sequential function chart is carried out when the series-connected transition is enabled or when the operator has triggered it. Alternatively, activation by the operator as well as the enable of the series-connected transition may be required.

Using the manual mode prevents permanent blocking of the sequential control system when there is a fault. The mixed mode allows for manual interruption of the process for testing or commissioning purposes. The step enabling conditions of all transitions of the sequential control system have to be expanded accordingly.

Sequential function charts have to be able to react to faults in the controlled devices. This requires continuous fault monitoring. It detects and indicates faults in the controlled devices. It enables automated safeguarding of the plant by automatically stopping the sequential function chart when there is a fault. In addition, it has to be possible for the operator to stop and abort a sequential function chart when there is a fault.

In both cases, corresponding protective functions have to be activated to take the plant to a safe state. If the sequence is stopped, it has to be ensured that the sequence can be continued safely and in a permitted mode even after a prolonged interruption. In the sequential control systems, process specific protective functions such as sequential interlocking of several devices is realized if there is a fault in the process.

SEQUENTIAL CONTROL SYSTEMS IN PCS 7

Sequential control systems in ***PCS 7*** are implemented with ***Sequential Function Charts (SFC)***. They include the sequencers and define their sequence topology, the conditions for the transitions, and the actions of the steps. The start conditions and the sequence characteristics can be defined and prioritized separately for each sequencer. In addition, pre-processing and post-processing steps can be defined that are performed once prior to or after the sequential function chart is performed.

Operating Modes and Switching Modes

The performance of a sequential control system in ***PCS 7*** depends on the selected operating mode, the specified switching mode, its current operating state and the sequence options. For sequential control systems, two different operating modes can be selected.

– ***Auto***: The program controls the sequence.

– ***Manual***: The operator controls the sequence with commands or by changing the sequence options.

In the manual mode, the commands *Start*, *Stop*, *Hold*, *Terminate*, *Cancel*, *Continue*, *Restart*, *Reset* and *Fault* are available to the operator for operating the sequential control system manually. The behavior of a sequential function chart when enabling active steps to follower steps can be controlled through different switching modes, depending on the selected operating mode.

– ***Switching mode T***: The sequential control system is executed process controlled, which means automatically. When the transition is enabled, the predecessor steps are deactivated and follower steps are activated. (T = transactions)

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- ***Switching mode O***: The sequential control system is executed operator controlled, which means manually. The transition is enabled with an operator command. Each follower transition of an active step sets an operator prompt automatically. (O = operator)
- ***Switching mode T or O***: The sequential control system is executed process controlled or operator controlled. The transition can be enabled either through an operator command or through a step enabling condition that was met.
- ***Switching mode T and O***: The sequential control system is executed process controlled and operator controlled. The transition is enabled only through an operator command and through a step enabling condition that was met.
- Switching mode ***T/T and O***: In this switching mode we can specify for each step individually whether the sequential control system is executed process controlled or operator controlled; in the test mode, hold points can be defined in the sequential control system. (T/T = test transactions)

In ***Auto*** *mode,* only the switching modes ***T*** as well as ***T/T and O*** can be selected. The operating mode of the sequential control system shows the current state in the sequence and the resulting operational performance. A corresponding operating state logic defines the possible states of the permissible transitions between the states as well as the transition conditions for a state change. ***PCS 7*** defines its own operating state logic for sequential control systems and for sequential function charts. It is possible to let sequential function charts run dependent on the state of the sequential control system.

Execution Options

By using execution options, the runtime behavior of a sequential control system can be controlled. For example, we can specify whether a sequential control system is processed once or cyclically, (***cyclical mode*** option) or whether the actions of the active step are actually executed (***command output*** option). In addition, time monitoring can be activated for the individual steps in a sequential function chart that indicates a stepping error if the time is exceeded (***time monitoring*** option).

Interaction Behavior

In ***PCS 7***, CFCs and SFCs interact by means of process values and control values. These values are linked to each other by means of the desired signals either from the global symbol table or by specifying the absolute signal address. Controlling the processing of the control signals is possible by means of the SFC characteristics. In the ***SFC Library***, ***PCS 7*** provides pre-assembled sequential function charts for different standard scenarios. These templates can be used and adapted to current projects.

LITERATURE

[1] Seitz, M. (2008): Speicherprogrammierbare Steuerungen. Hanser Fachbuchverlag (Programmable Controllers)

[2] Wellenreuther, G. und Zastrow, D. (2002): Automatisieren mit SPS: Theorie und Praxis. Vieweg+Teubner (Automating with PLC)

[3] Uhlig, R. (2005): SPS - Modellbasierter Steuerungsentwurf für die Praxis: Modellierungsmethoden aus der Informatik in der Automatisierungstechnik. Oldenbourg Industrieverlag (Model based control design in practice: Modeling methods from information technology in automation engineering)

[4] Siemens (2009): Process control system PCS 7: SFC for SIMATIC S7

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STEP BY STEP INSTRUCTIONS

TASK

Corresponding to the recipe in the chapter 'Process Description', we are setting up and programming an SFC.

1. First, 350ml will be drained from the educt tank =SCE.A1.T1-B003 to the reactor =SCE.A1.T2-R001, and at the same time 200ml from the educt tank =SCE.A1.T1-B002 to the reactor =SCE.A1.T2-R002.
2. When reactor =SCE.A1.T2-R001 is filled, the liquid it contains is heated to 25°C with the stirrer switched on.
3. When reactor =SCE.A1.T2-R002 is filled, 150ml of educt A from educt tank =SCE.A1.T1-B001 is dispensed to the reactor =SCE.A1.T2-R002. When this is completed, the stirrer of reactor =SCE.A1.T2-R002 is switched on for 10s.
4. When the temperature of the liquid in reactor =SCE.A1.T2-R001 has reached 25°C, the mixture from reactor =SCE.A1.T2-R002 is pumped to reactor =SCE.A1.T2-R001.
5. The mixture in reactor =SCE.A1.T2-R001 is now heated to 28°C and then drained to product tank =SCE.A1.T3-B001.

TRAINING OBJECTIVE

In this chapter, the student learns the following:

– Setting up and editing SFCs
– Establishing connections between SFCs and CFCs
– Establishing connections between SFCs and the addresses from the symbol table
– Testing SFC programs

These instructions are based on project 'PCS7_SCE_0108_Ueb_R1505_en.zip'.

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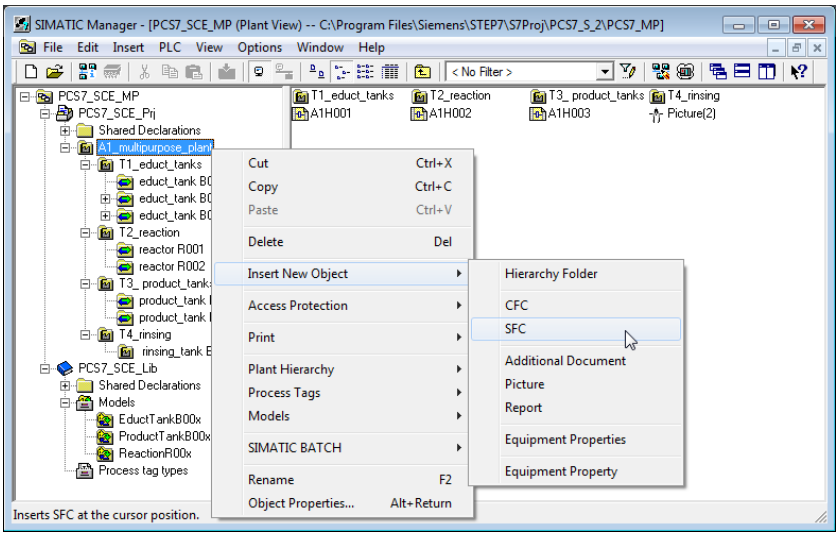
PROGRAMMING

1. To start, set up a new SFC in the folder ‘A1_multipurpose_plant’ in the Plant View.
   (→ A1_Multipurpose_plant → Insert New Object → SFC)



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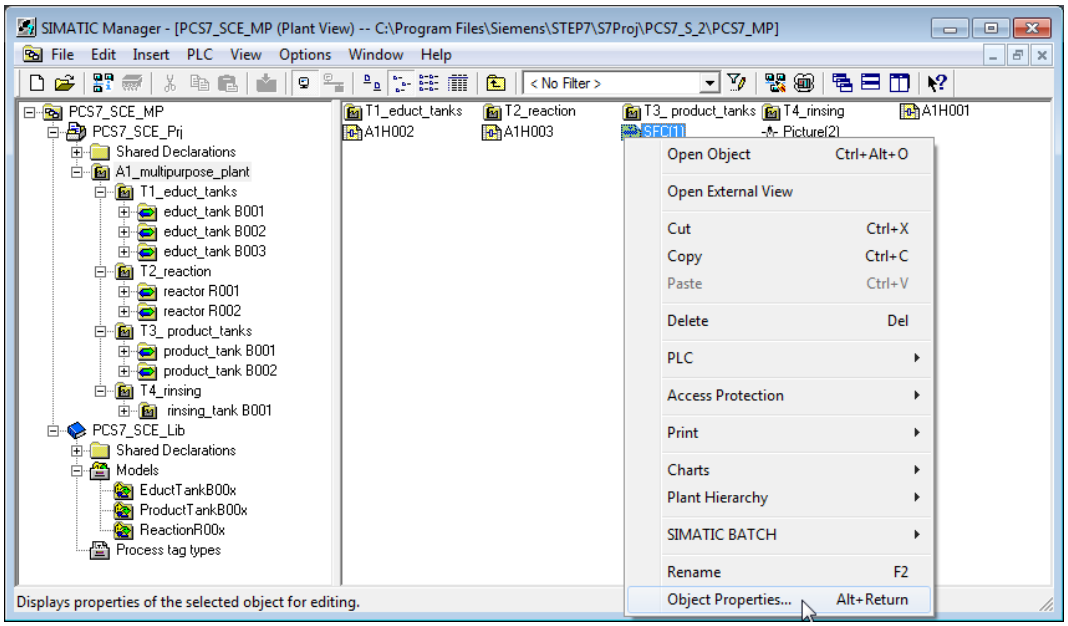
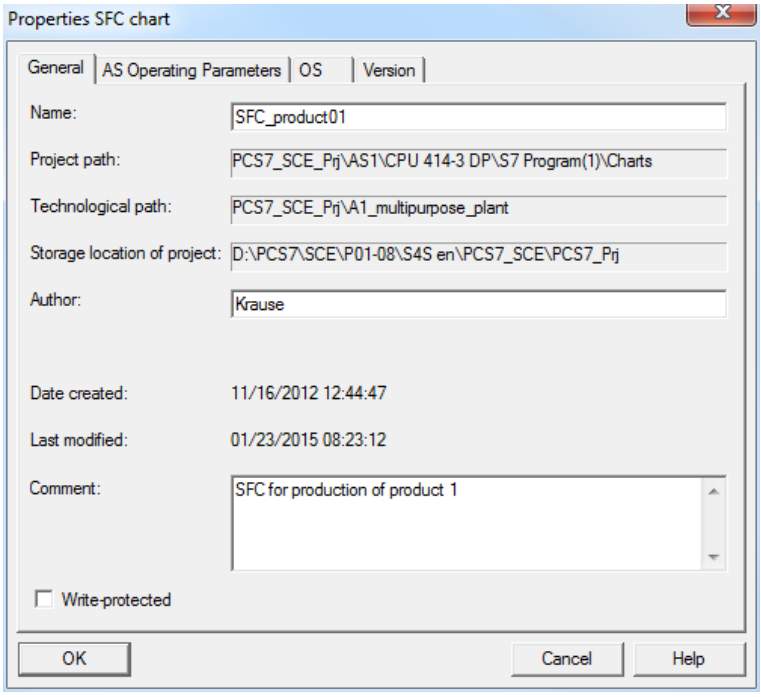
2. Then open the object properties of the SFC.

   (→ SFC(1) → Object Properties)



3. Next, under General, the name is changed to ‘SFC_product01’ and a comment as well as the author is entered.

   (→ General → SFC_product01)



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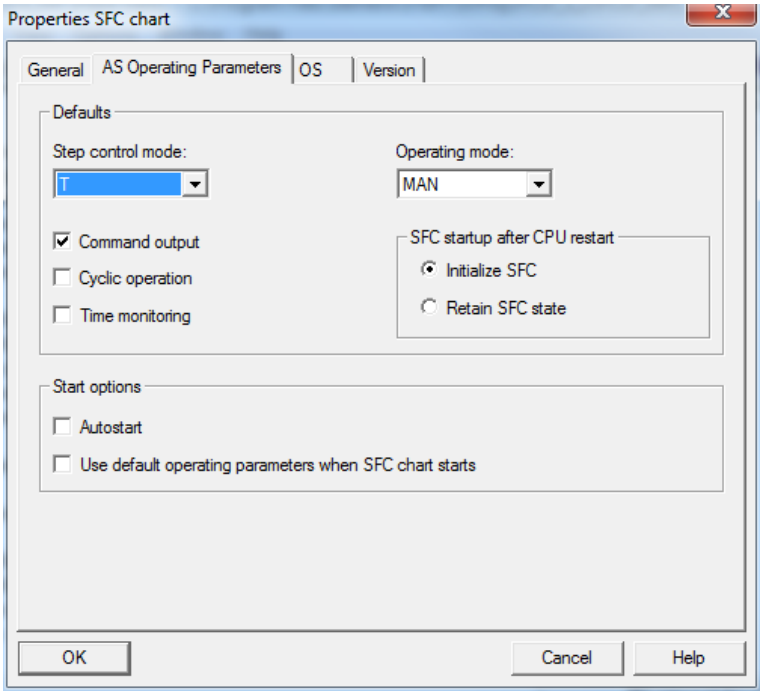
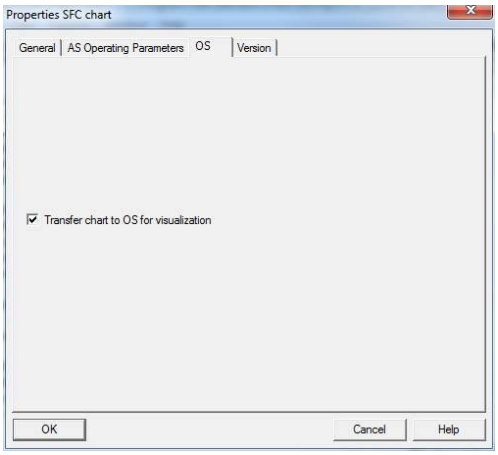
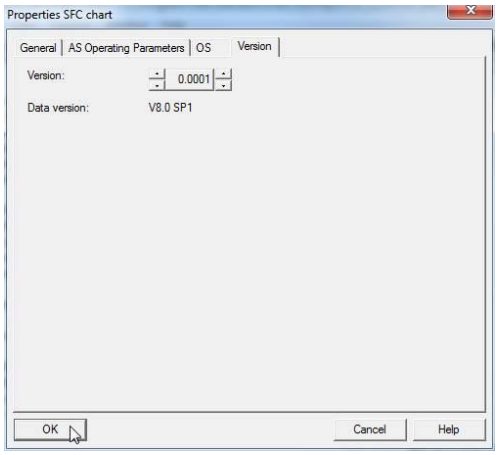
4. The operating parameters are set as follows; they can later be changed in the online mode. (→ AS Operating Parameters)



5. It is important that the checkmark is set in the OS option so that the SFC will be available later for visualization. With the display of the version, accept all parameters with OK.

   (→ OS → Transfer chart to OS for visualization → Version → OK)





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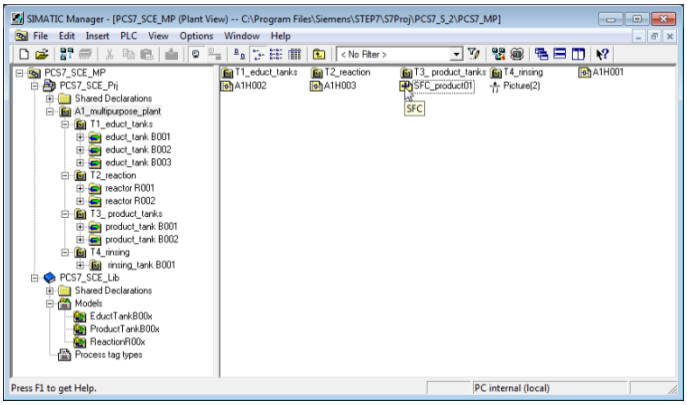
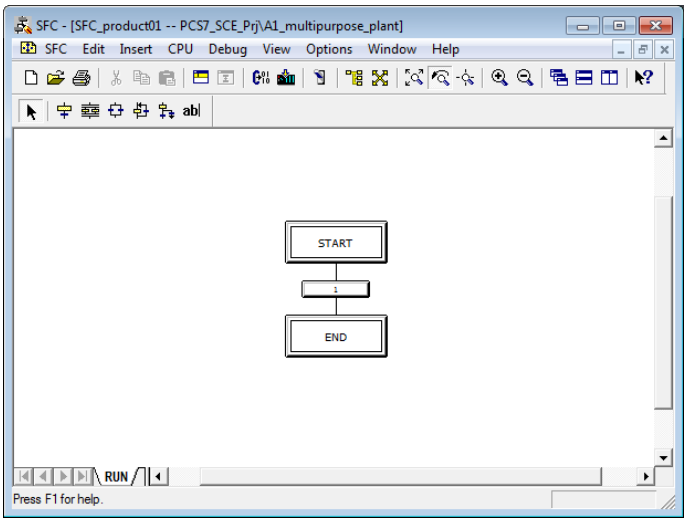
6. In the ***SIMATIC Manager*** we now open the sequential function chart ‘SFC_product01’ with a double click. (→ SFC_product01)





7. With the following symbols from the toolbar, the sequential control can now be set up in the SFC Editor.


Button ***Selection On***


Button ***Insert Step + Transition***


Button ***Insert parallel branch***


Button ***Insert alternative branch***


Button ***Insert loop***


Button ***Insert jump***

Button ***Insert text field***

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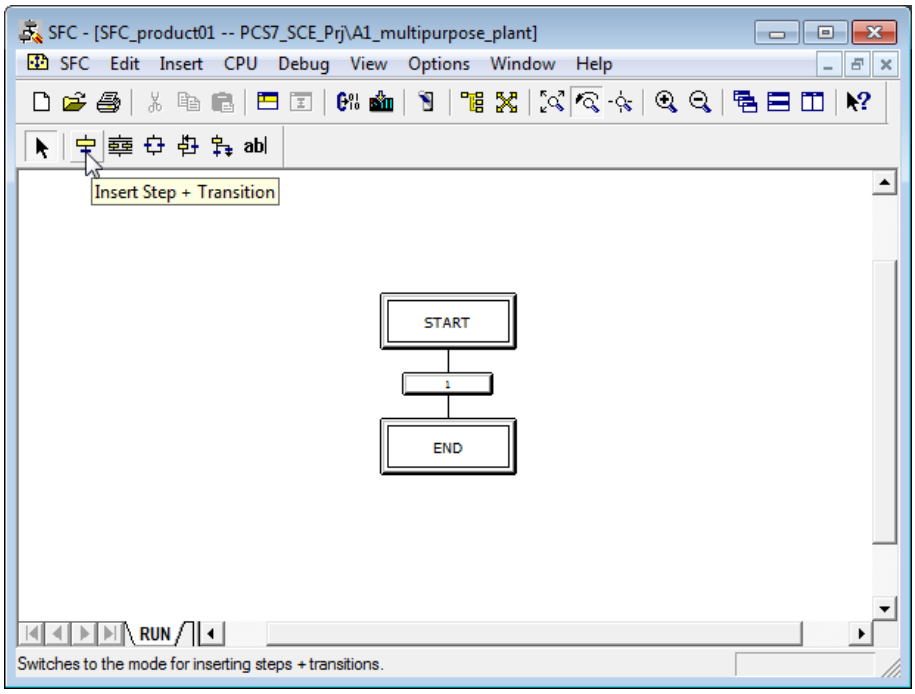
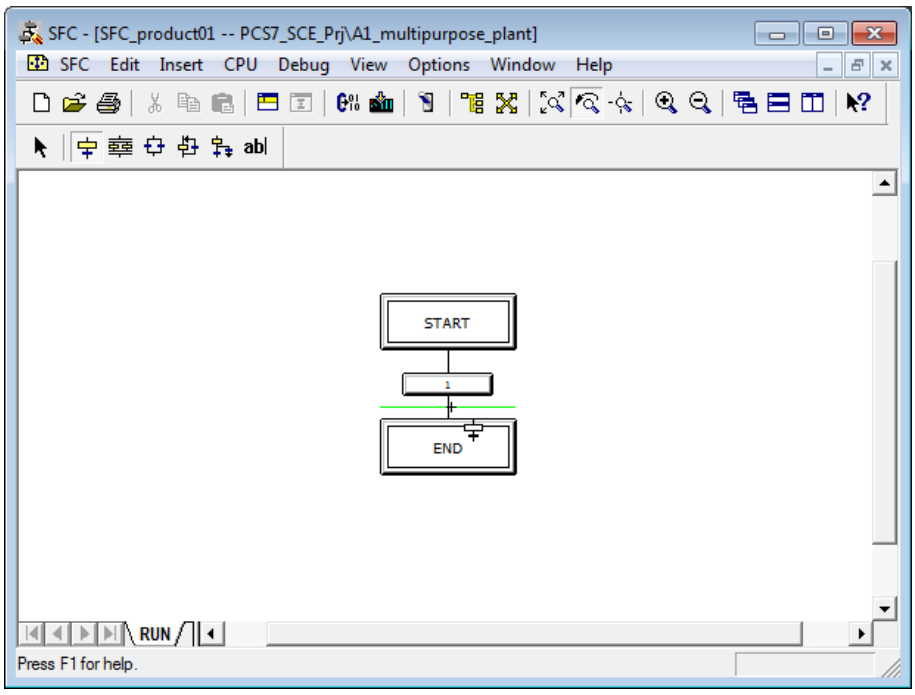
8. For this task, you will need additional steps and transitions. To insert both, select the button  and check the location where you want to insert them. (→ )





Note: Step and transition numbering is of no significance to the sequence in which the sequential function chart is processed.

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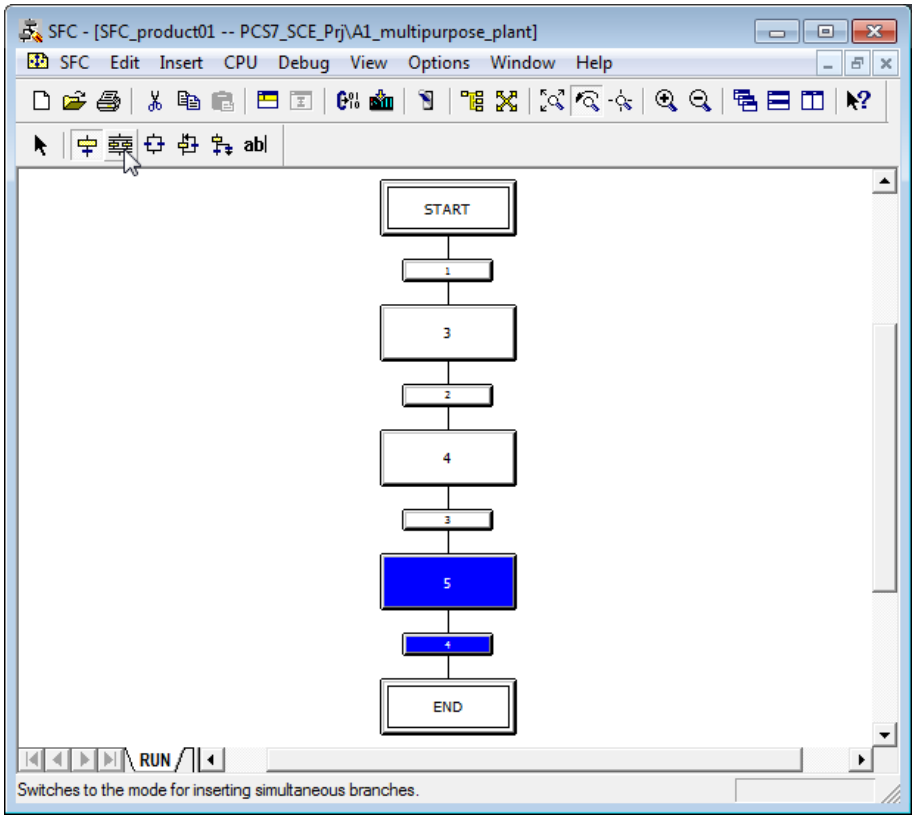
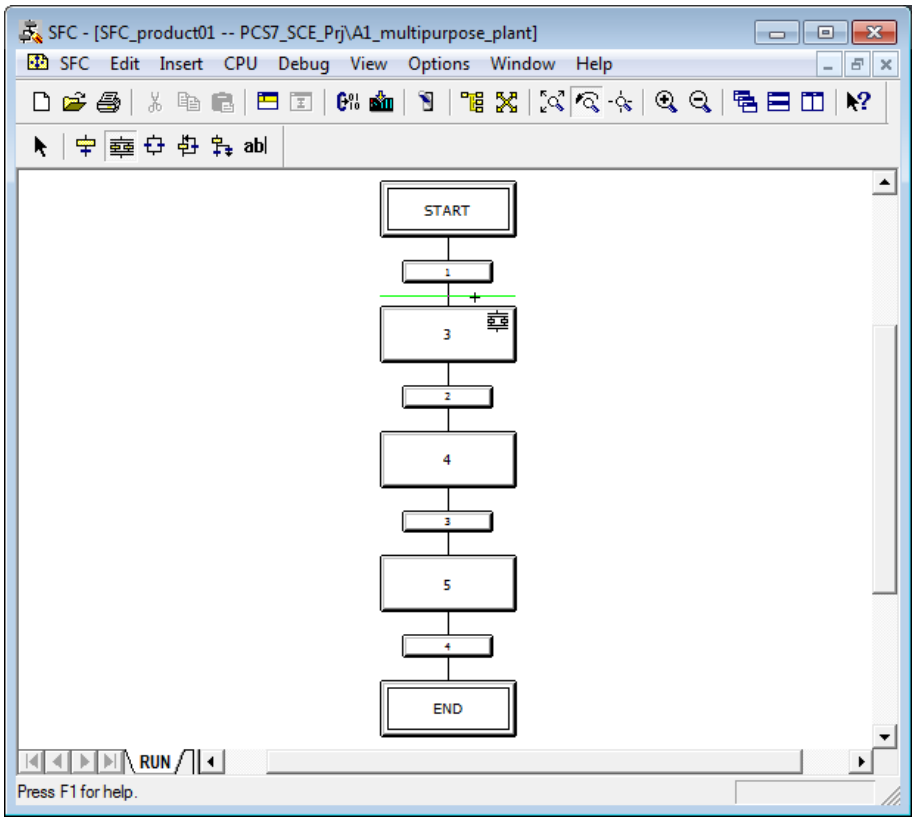
9. After the steps and transitions were inserted in this way, click on the symbol  to add a parallel branch. Again indicate the location where you want to enter it. (→ )





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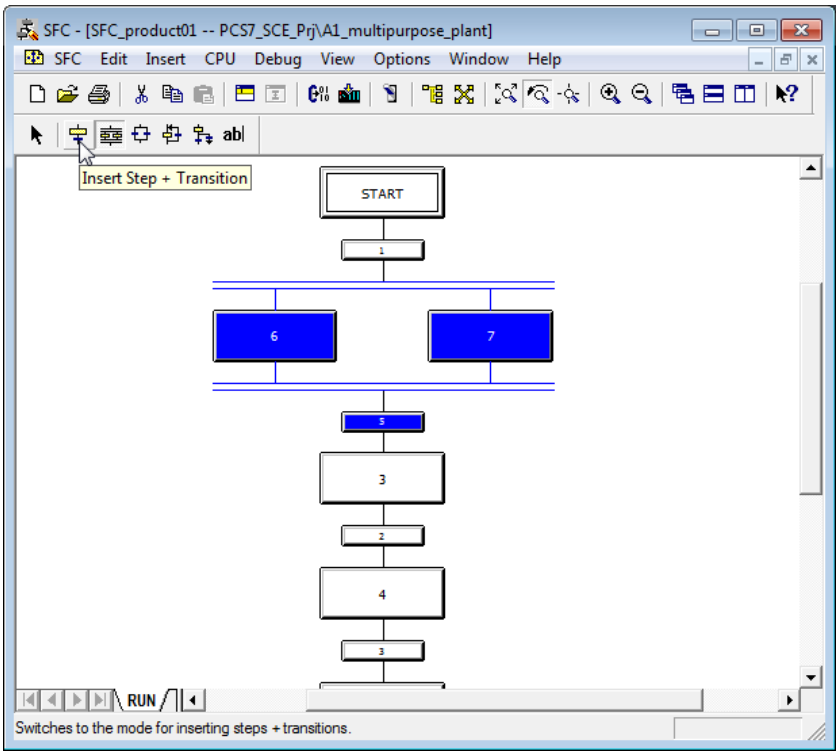
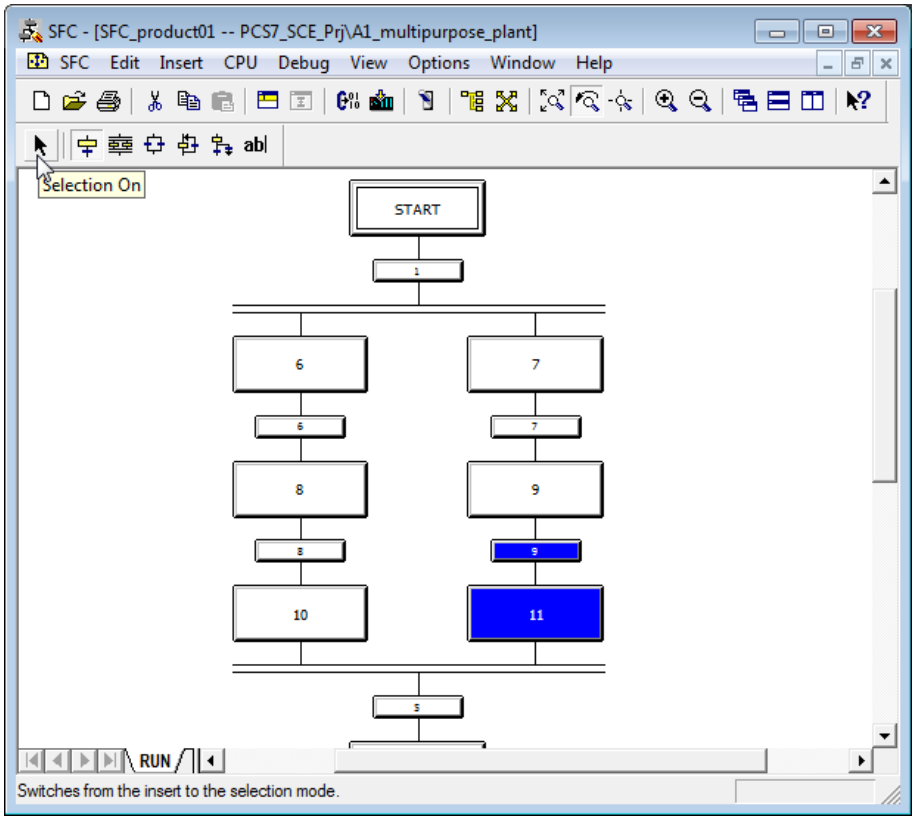
10. We are now entering additional steps and transitions in the parallel branch. Switch again to the symbol  and insert the other steps and transitions. (→ )



11. Click on the symbol  to edit normally. (→ )



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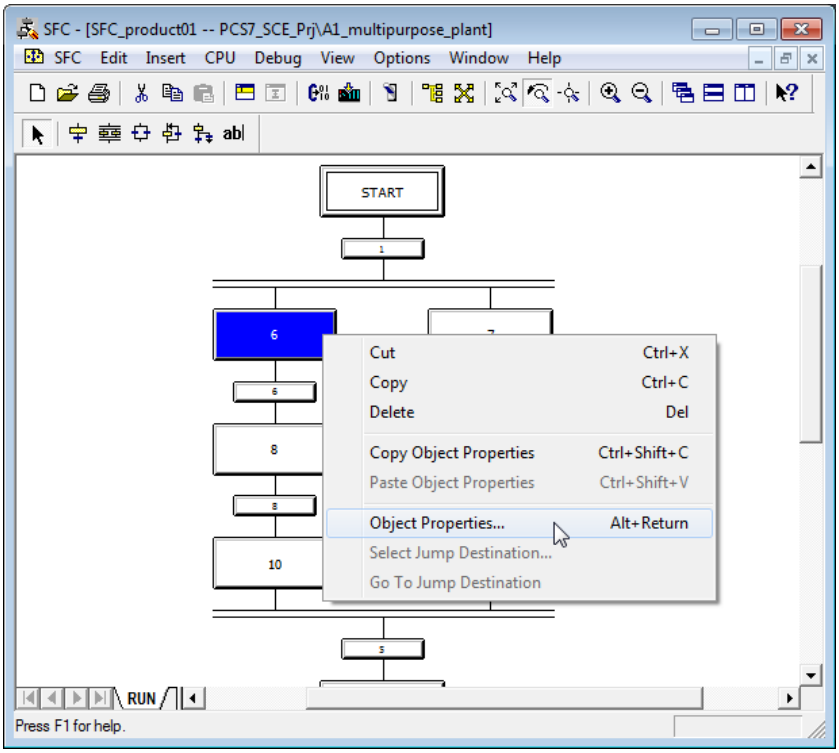
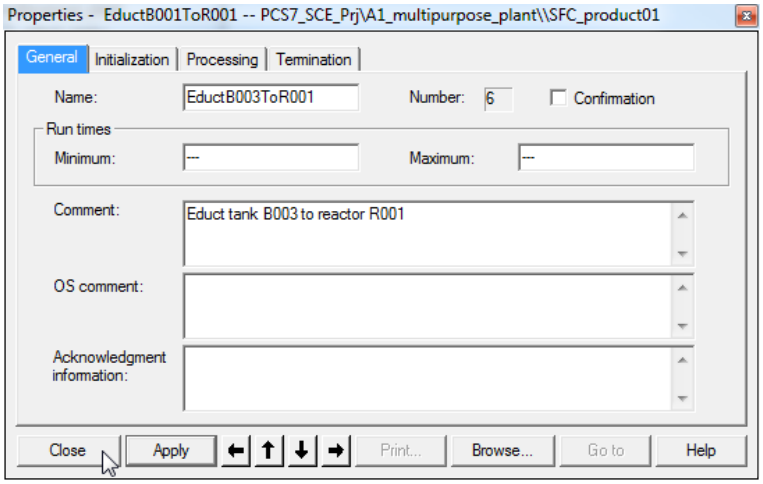
12. The screenshot shows how the properties of a step can be changed, To this end, right-click on the step and then select Object Properties. (→ 6 → Object Properties)

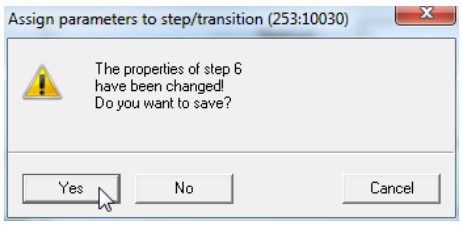


13. In the object properties, each step is assigned a name and a comment for better transparency. (→ EductB003ToR001 → Educt tank B003 to Reactor R001 → Close)



14. Confirm the question whether the changes should be saved with "Yes“.

(→ Yes)



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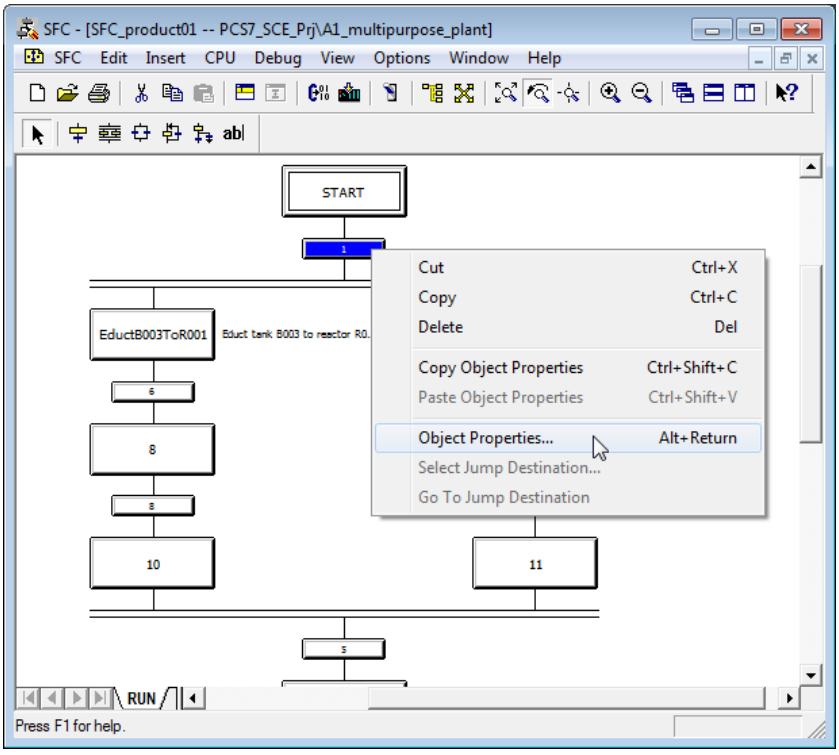
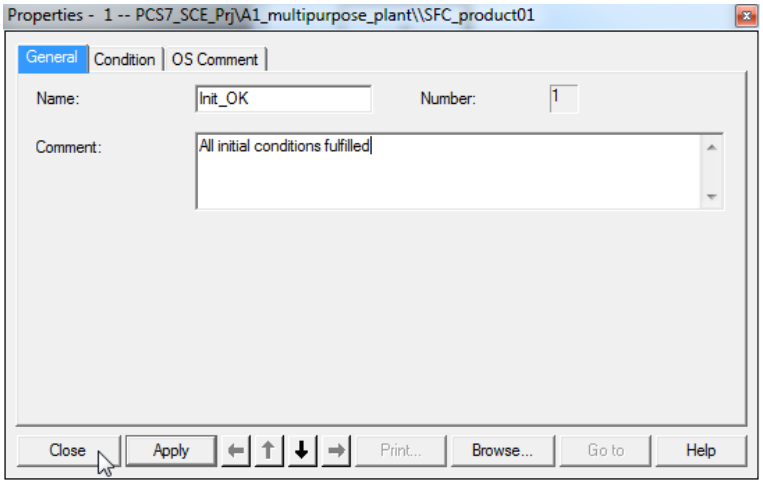
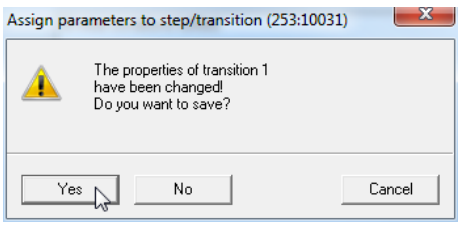
15. As for the steps, the properties for the transitions can also be changed. Right-click on the transition and then select Object Properties. (→ 1 → Object Properties)



16. Here you also change the name and the comment first. (→ Init_OK → All initial conditions fulfilled → Close)



17. This change is saved, too. (→ Yes)



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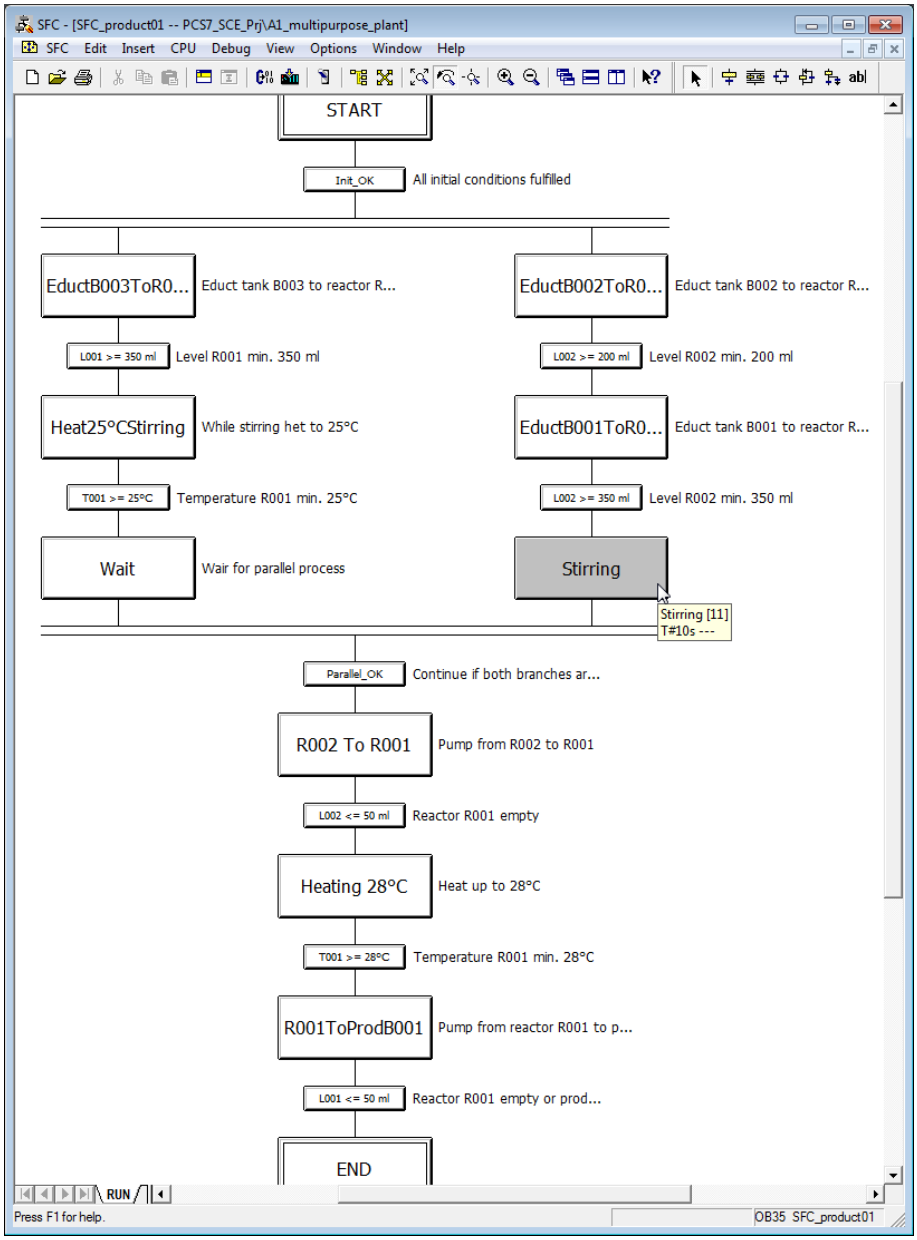
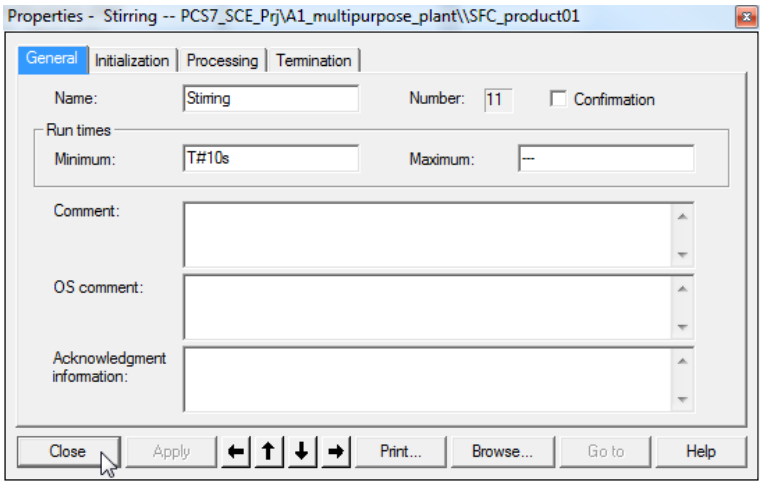
18. Repeat the previous steps until the SFC looks like this. It is important to also enter a minimum execution time of 10s at the step ‘Stirring’. (→ T#10s)





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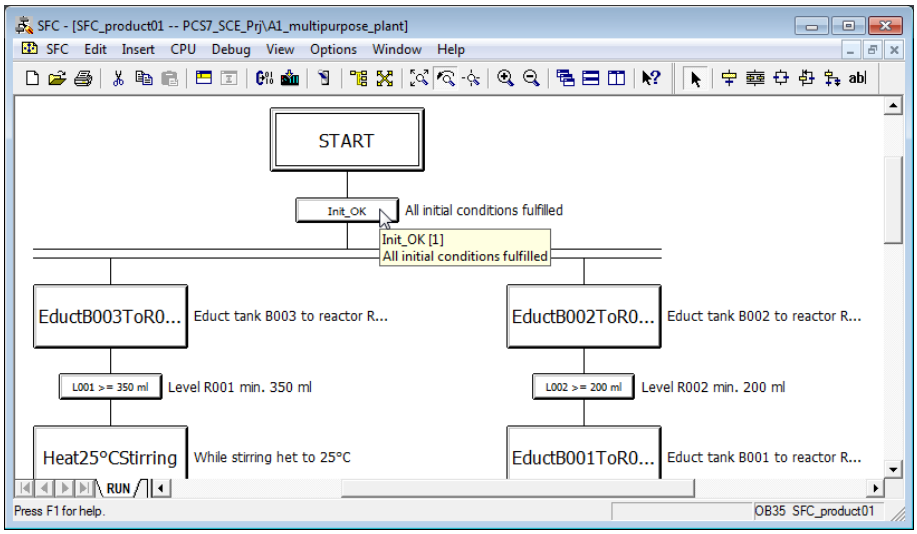
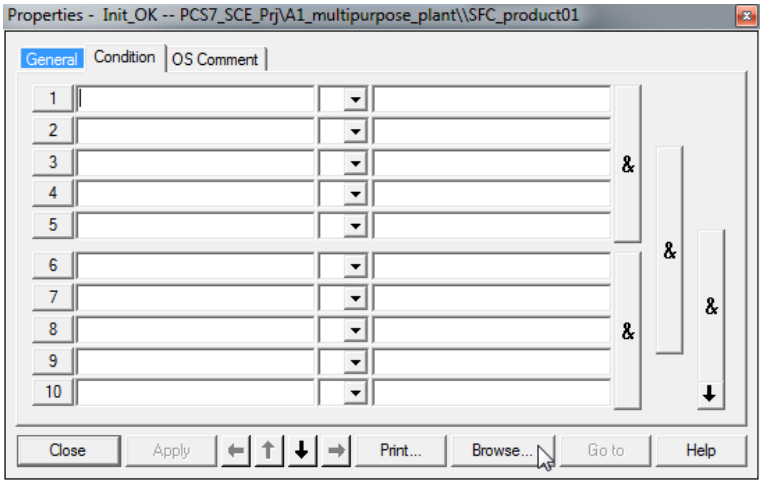
19. Now we have to implement the actual function of the sequential function chart. No instructions are entered in the step ‘START‘. Therefore, start by double clicking on the transition ‘Init_OK’. (→ Init_OK)

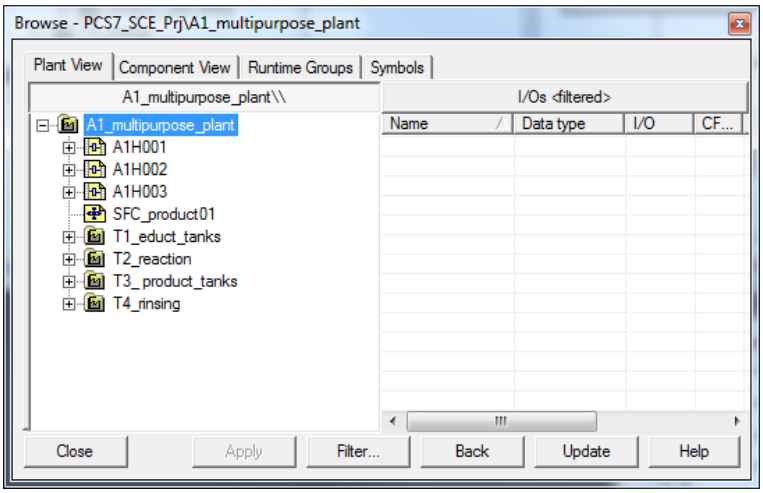


20. Select the ‘Condition’ tab and add the initialization conditions by clicking on ‘Browse‘.

    (→ Condition → Browse)



21. A window opens for adding I/Os and symbols.



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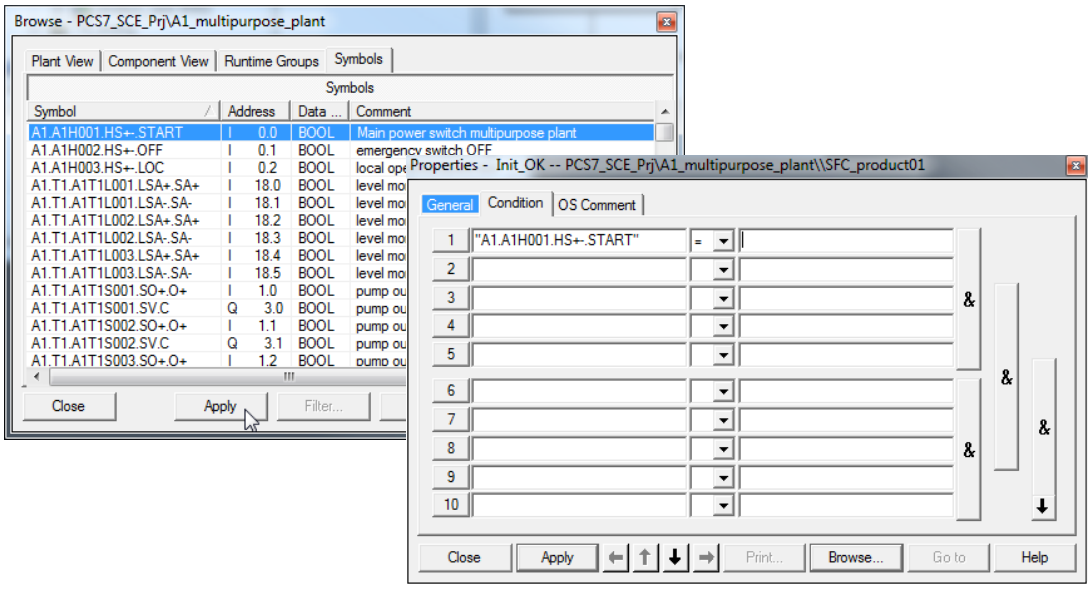
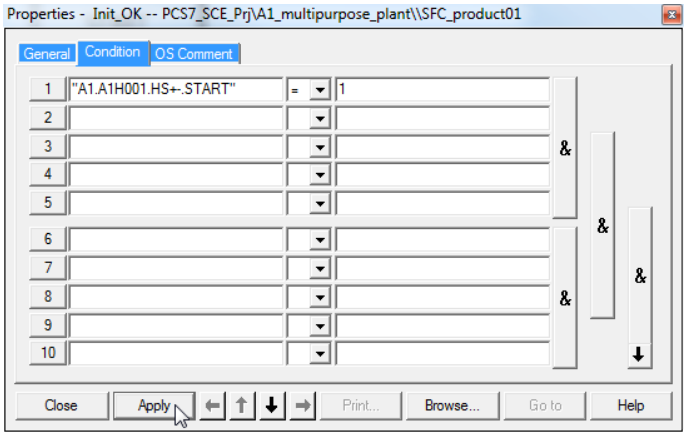
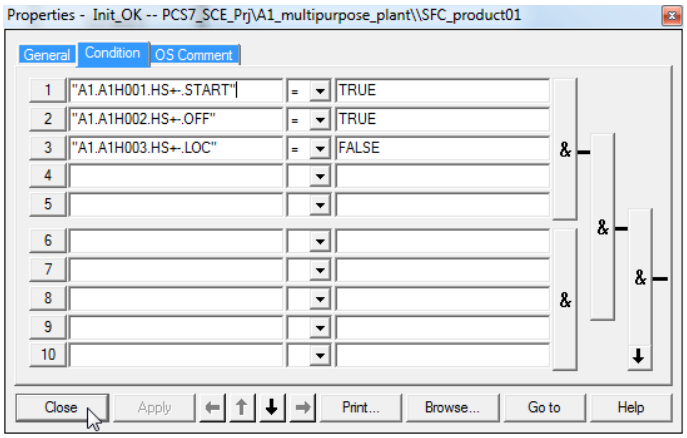
22. Now, select the ‘Symbols’ tab where you select the symbol for the main power switch ‘A1.A1H001.HS+-.START‘; then click on ‘Apply‘. The symbol is entered on the left side of the first condition. (→ Symbol → A1.A1H001.HS+-.START → Apply)



23. Next, enter ‘1’ or ‘TRUE’ on the right side of the first condition for the next steps to be processed only when the plant is switched on. Apply this value. (→ 1 → Apply)



24. Now add the conditions that EMERGENCY STOP is enabled and local operation is deactivated. Then close the dialog.
(→ A1.A1H002.HS+-.OFF → 1 → A1.A1H003.HS+-.LOC → 0 → Close)



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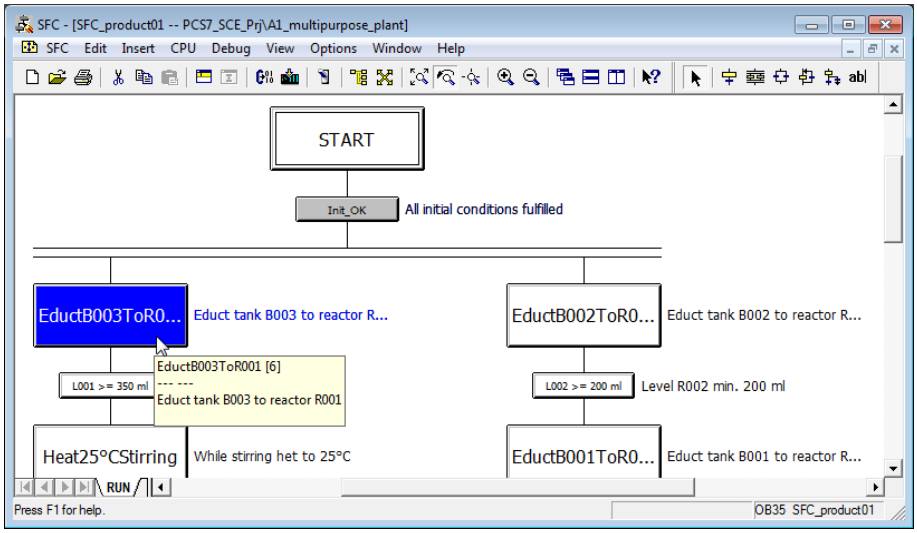
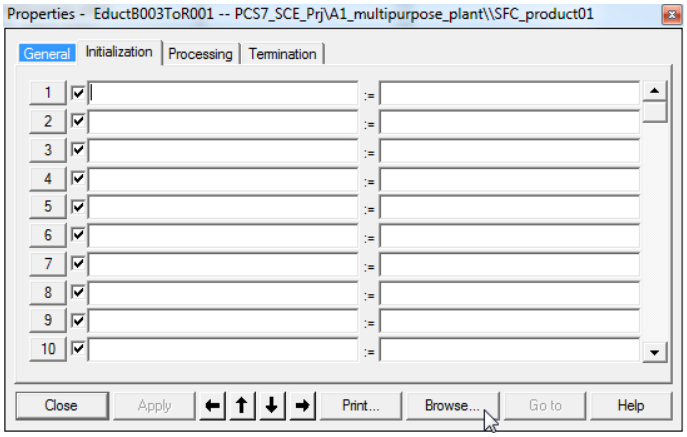
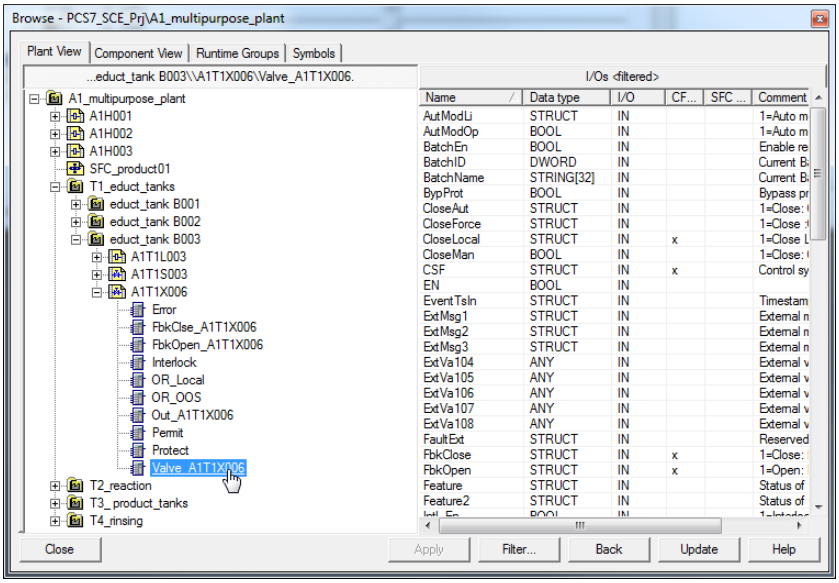
25. Next, open the step ‘EductB001ToR001‘.(→ EductB001ToR001)



26. Select the ‘Initialization’ tab and click on ‘Browse‘. (→ Initialization → Browse)



27. Next, in the ‘Plant View” tab of the selection window in CFC ‘A1T1X006‘ select the valve block ‘Valve_A1T1X006‘. (→ A1_multipurpose_plant → T1_educt_tanks → educt_tank B003 → A1T1X006 → Valve_A1T1X006)



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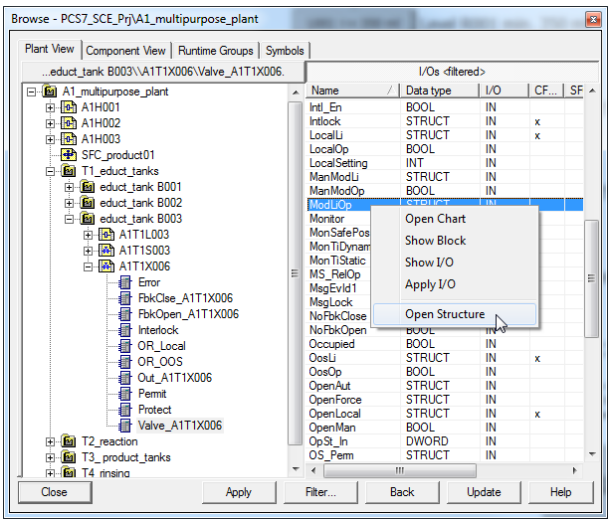
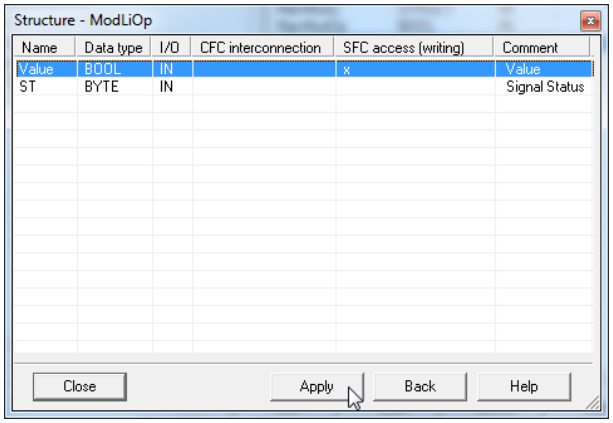
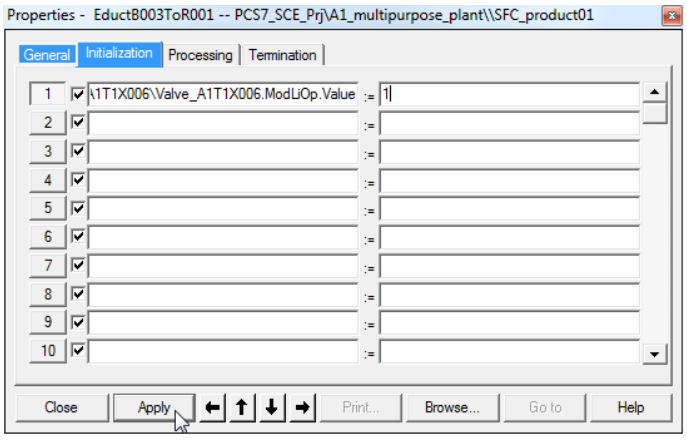
28. First, we set the ‘ModLiOp‘ I/O to ‘1‘ for the valve to be controlled only by means of interconnections or SFC. Because the ‘ModLiOp‘ I/O is of the data type ‘STRUCT‘, we have to open the shortcut menu with a right click; then click on ‘Open Structure‘. (→ ModLiOp → Open Structure)



29. The structure dialog opens; select ‘Value‘ of the data type BOOL. With Apply, the selection is included on the left side of the first instruction. (→ Value → Apply)



30. On the right side of the first instruction, enter "1". This sets the ‘ModLiOp‘ I/O to the SFC mode. With ‘Apply‘,"1" is automatically replaced with "TRUE". (→ 1 → Apply)



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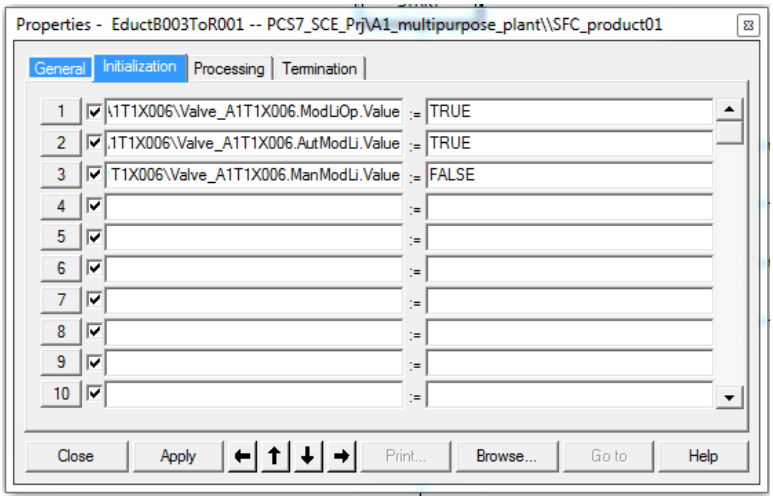
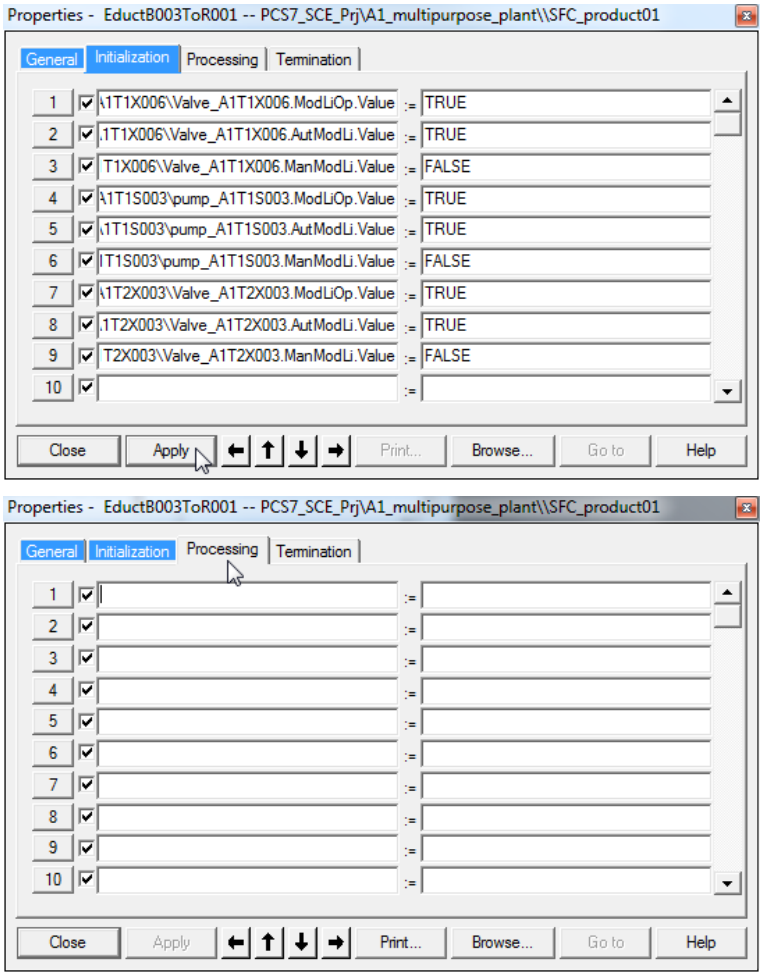
31. Now add the I/Os ‘AutModLi‘ = ‘1‘ and ‘ManModLi‘ = ‘0‘ for the valve to be set to automatic mode. (→ AutModLi → 1 → ManModLi → 0 → Apply)



32. The same has to be done for the pump A1T1S003 and the valve A1T2X003 because they also participate in filling reactor R001 from educt tank B003. Then, change to the ‘Processing‘ tab.
(A1T1S003 → ModLiOp.Value = 1 → AutModLi.Value = 1 → ManModLi.Value = 0 → Apply → A1T2X003 → … → Apply → Processing)



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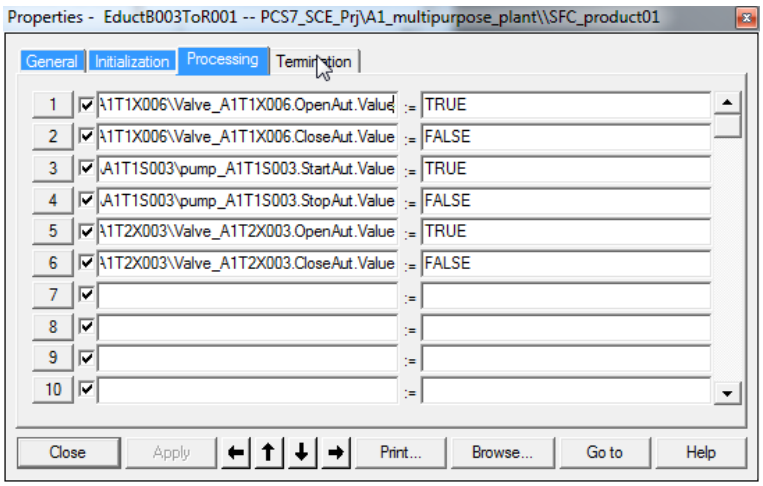
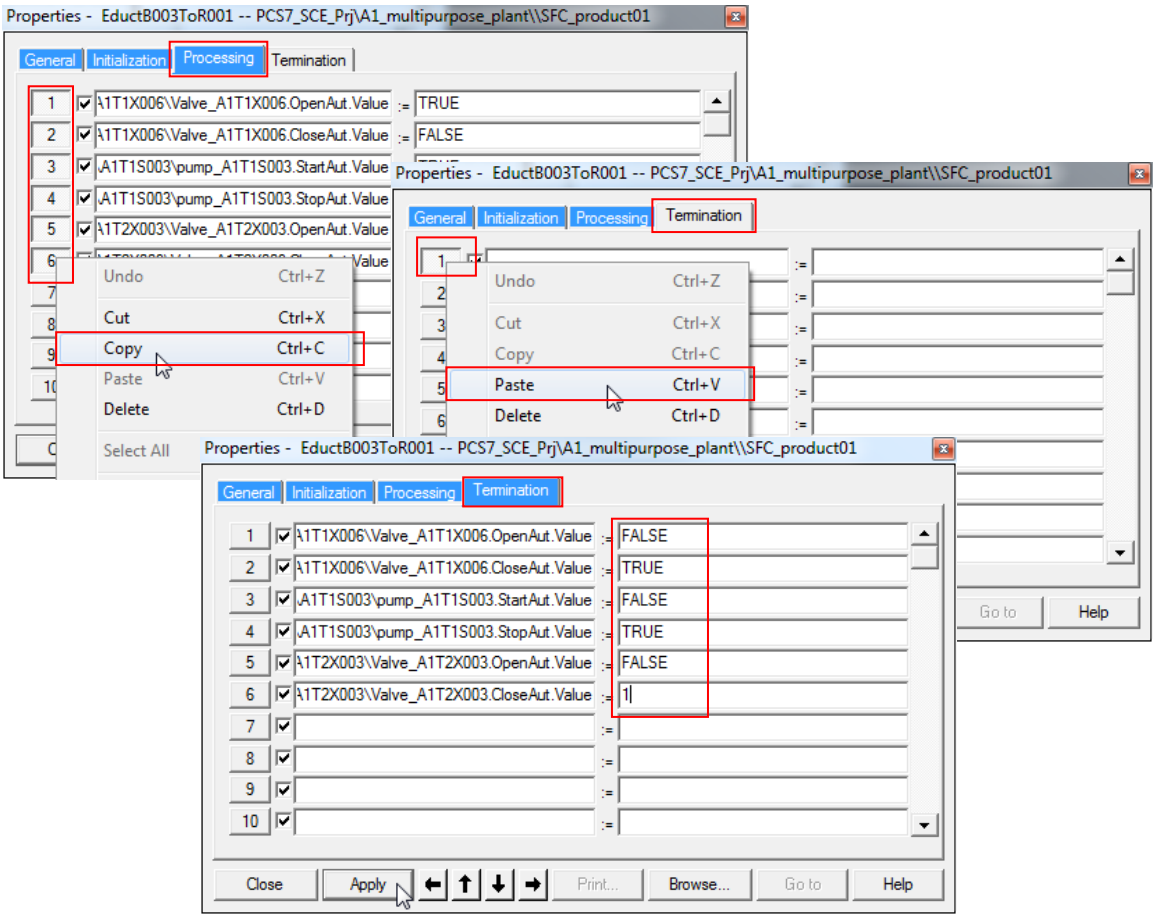
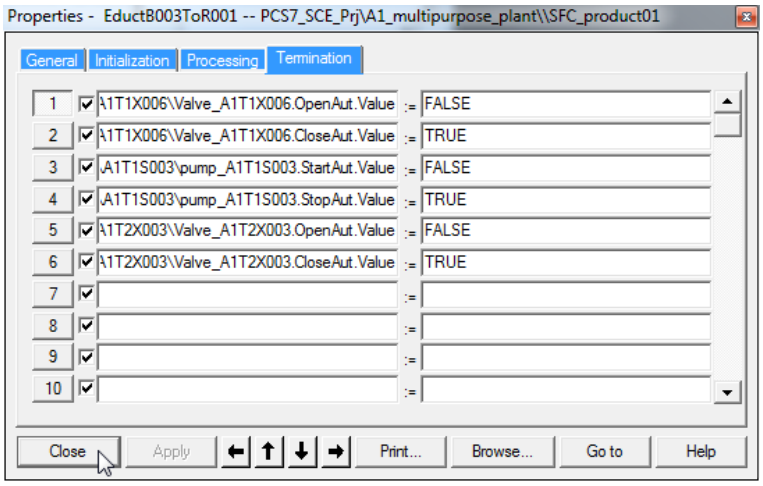
33. In ‘Processing’, we now enter the instructions for opening the valves and starting the pump. For the valves, the I/Os ‘OpenAut.Value‘ = ‘1‘ and ‘CloseAut.Value‘ are set to = ‘0‘. For the pump, use the I/Os ‘StartAut.Value‘ = ‘1‘ and ‘StopAut.Value‘ = ‘0‘. (A1T1X006 → … → A1T1S003 → … → A1T2X003 → … → Apply → Close)

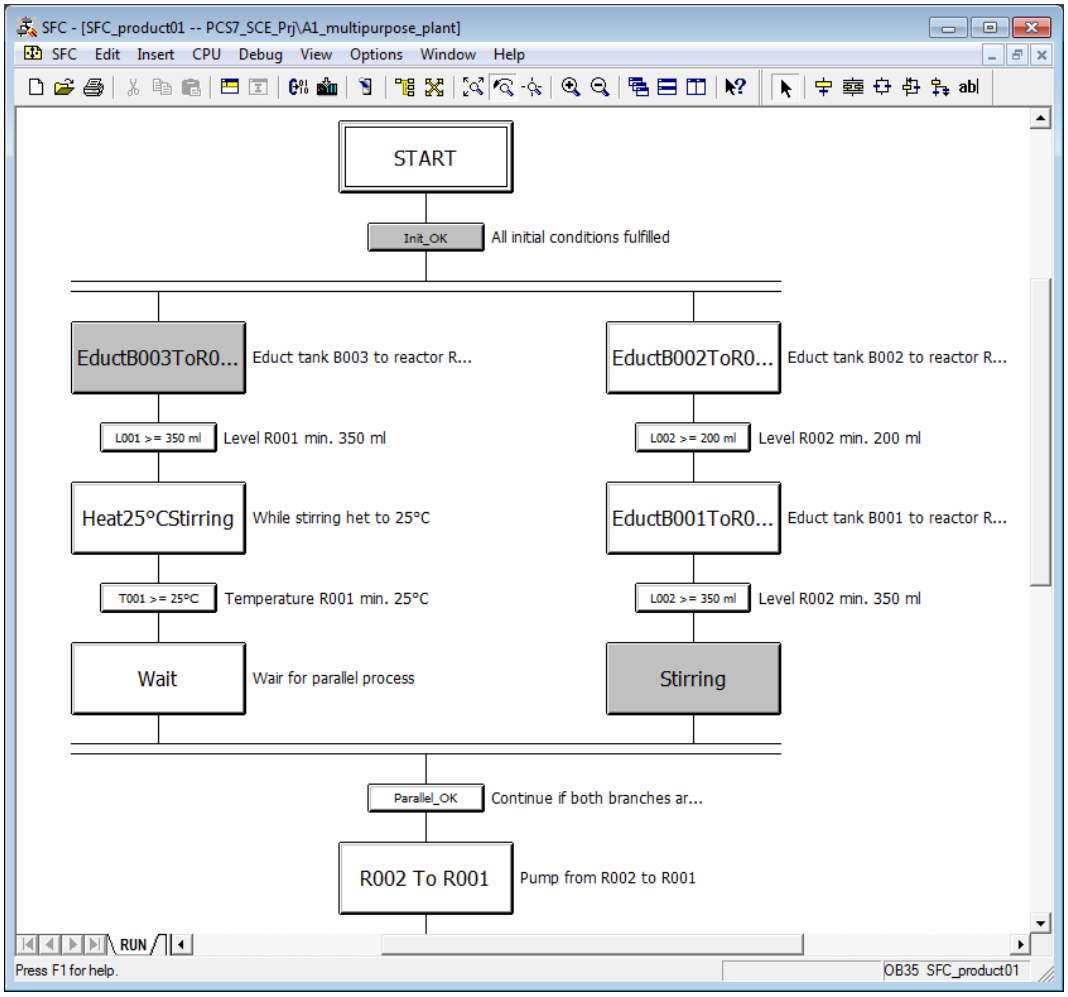


34. Now the instructions that have to be executed when terminating this step are entered in ‘Termination‘. Here, the valves and the pump have to be closed again. The valves and the pump can also be reset into the manual mode and the operator mode, but we want to wait until the step ‘END’ to do this. It is easiest to copy the instruction of ‘Processing’ to ‘Termination’ and only invert the values (‘TRUE‘ -> ‘FALSE‘ and vice versa). To copy and insert, the numbers preceding the instructions have to be checked and the shortcut menu called.



35. Next, close the properties dialog for step ‘EductB003inR001‘. The SFC Editor shows the transition ‘Init_OK‘, the steps ‘EductB003inR001‘ und ‘Stirring‘ grayed out because instructions already exist there. (→ Close)





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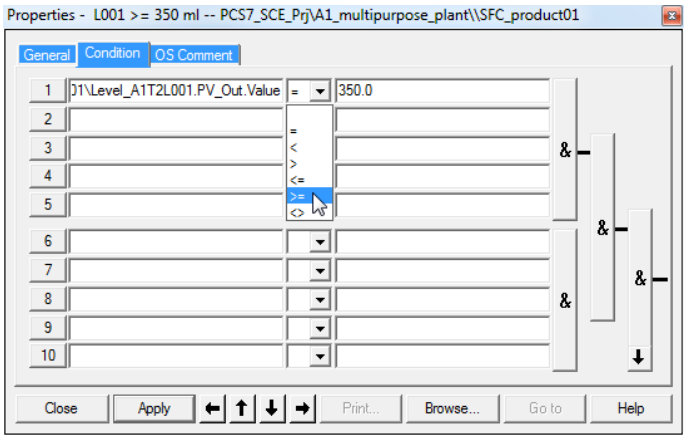
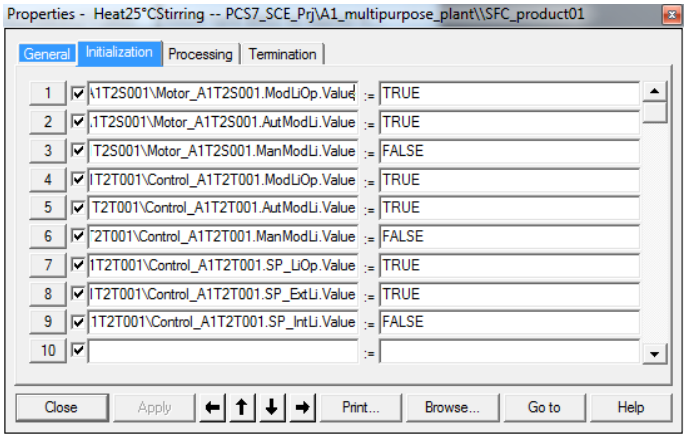
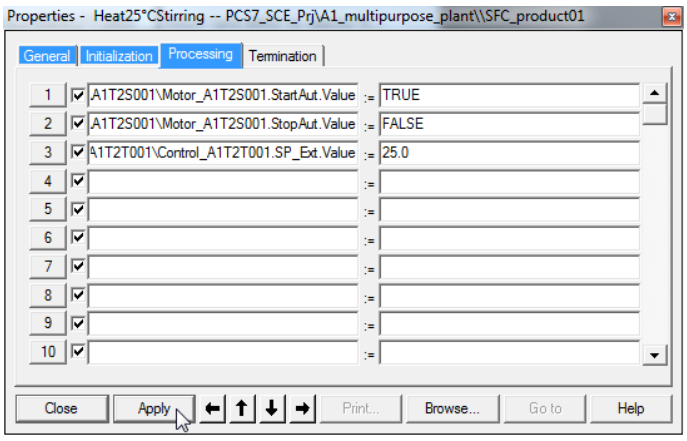
36. Now, open the transition ‘L001 >= 350ml‘. Enter the condition that the level of reactor R001 is larger or equal to 350ml. (→ L001 >= 350 ml → Condition → Browse → …Reactor R001\\A1T2L001\Stand_A1T2L001.PV_Out → Right click → Open structure → Value → >= → 350 → Apply → Close)



37. In step “Heat25°CStirring“, again add the I/Os ‘ModLiOp‘, ‘AutModLi‘ and ‘ManModLi‘in ‘Initialization‘ for ‘Stirrer_A1T2S001‘ and ‘Control_A1T2T001‘. For the control, switch the setpoint entry to SFC mode ‘SP_LiOp‘ = ‘1‘ and to external setpoint entry ‘SP_ExtLi‘ = ‘1‘ and ‘SP_IntLi‘ = ‘0‘. (→ Heat25°CStirring → ‘Initialization‘ → …)



38. Then switch to ‘Processing’ and add the displayed I/Os and values. This starts the stirrer and the control is assigned the setpoint 25°C.



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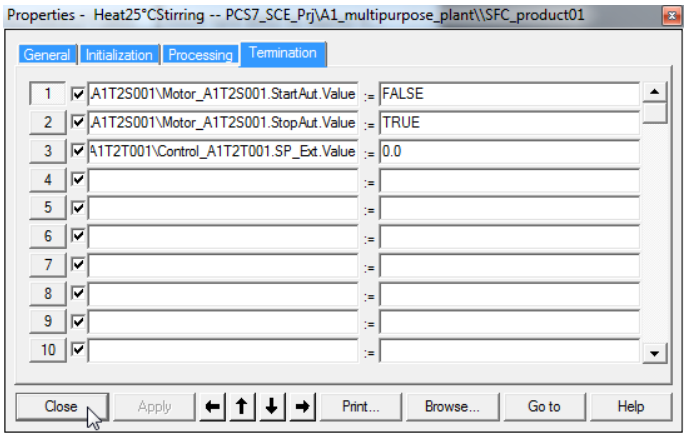
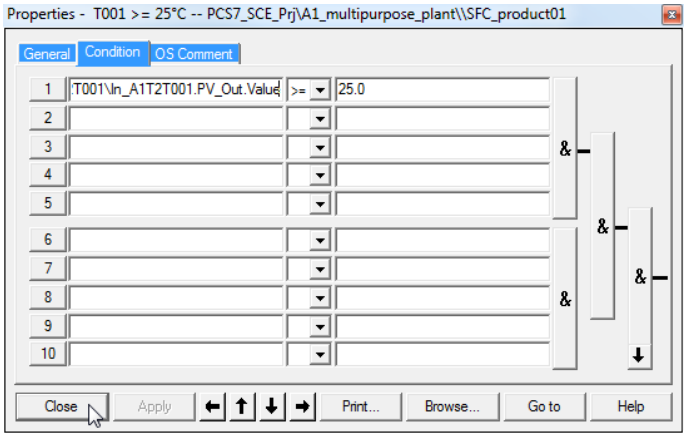
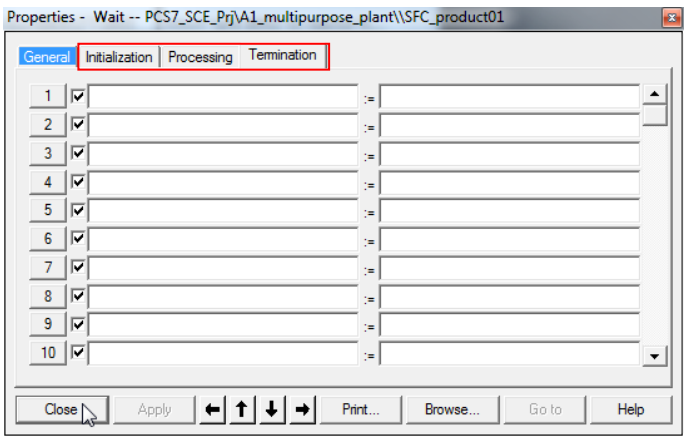
39. Under ‘Termination’ the stirrer is stopped. Set the setpoint to 0°C. Then close the dialog.



40. Now we parameterize transition ‘T001 >= 25°C‘. For this, we need the measured temperature. (→ T001 >= 25°C → Condition → …\T2_Reaction\Reactor R001\\A1T2T001\In_A1T2T001 → PV_Out → Value → Apply → >= → 25.0 → Apply → Close)



41. ‘Initialization‘, ‘Processing’ and ‘Termination‘ remain empty In the step ‘Wait‘‘. This is indicated by the tabs not being highlighted.



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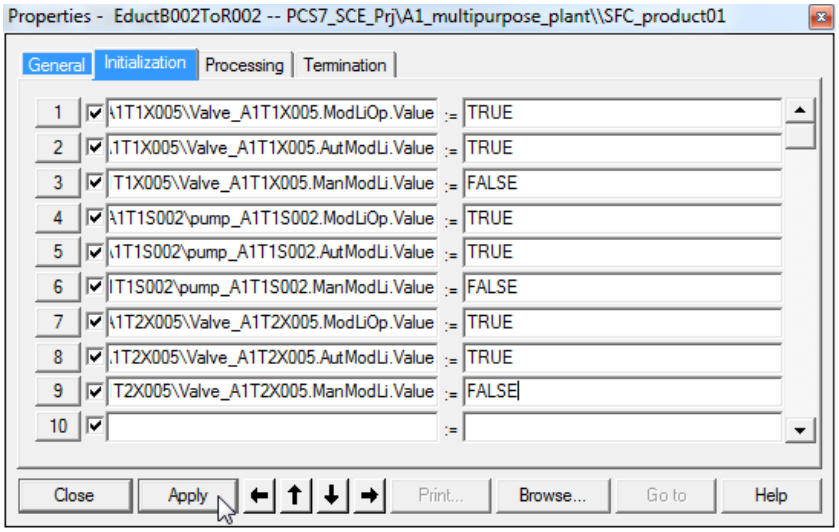
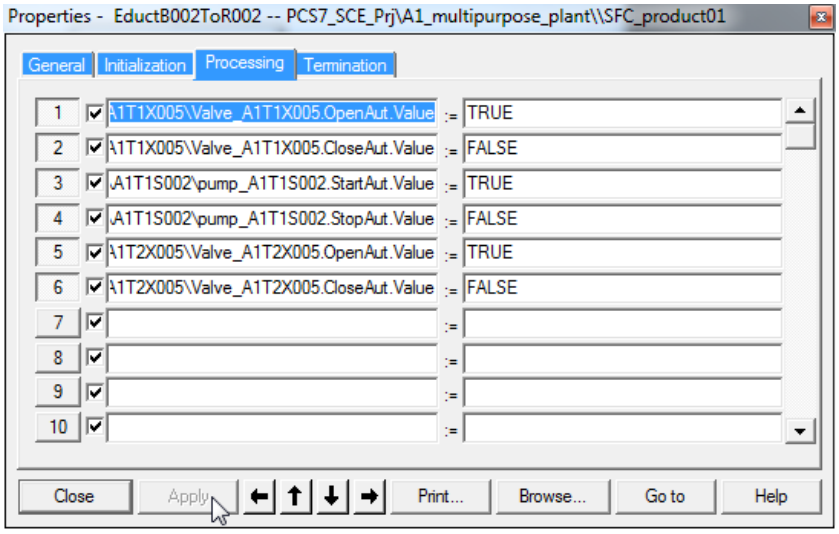
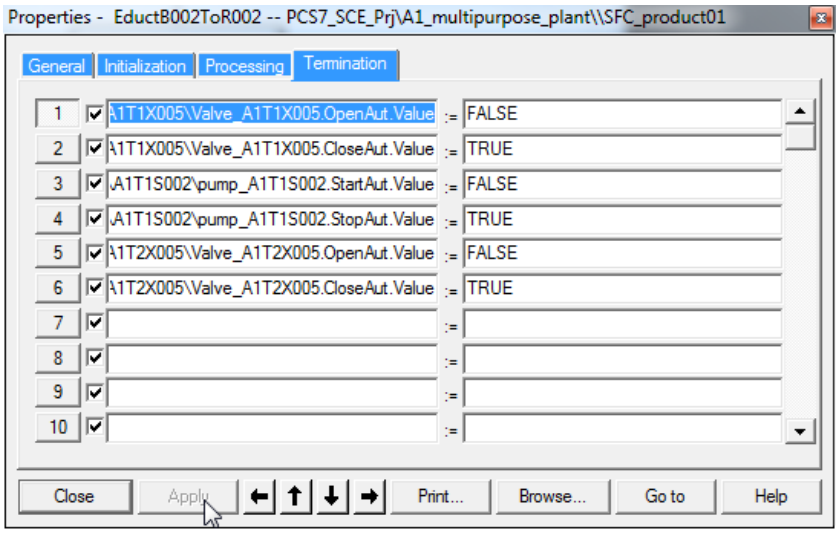
42. Now fill in the parallel branch. Start with step ‘EductB002ToR002‘ and utilize the figures below. (→ EductB002ToR002)







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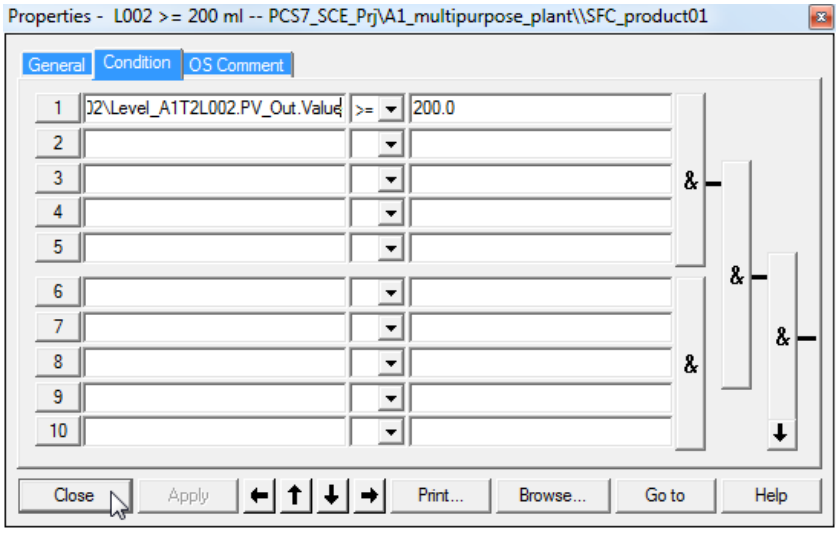
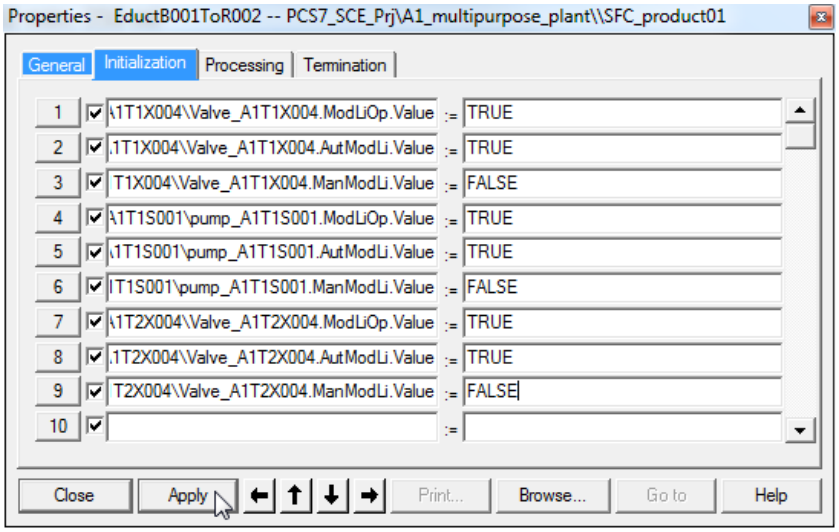
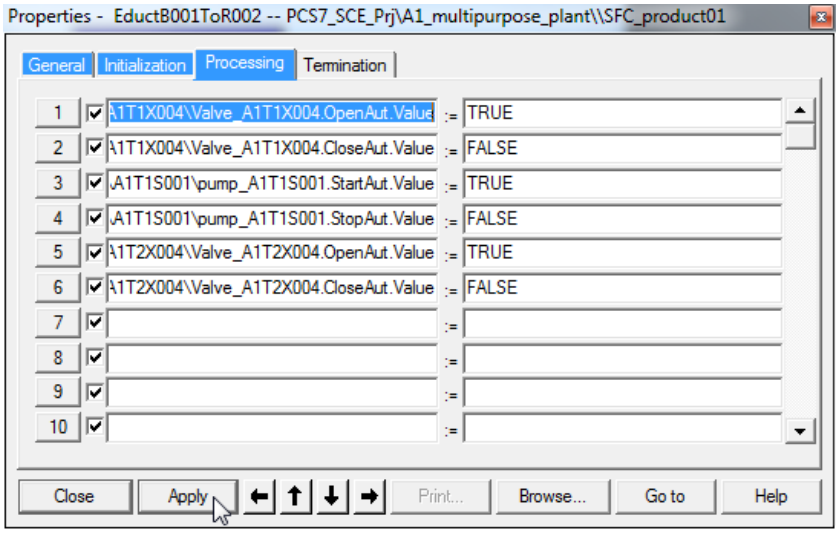
43. The transition ‘L002 >= 200ml’ then looks as follows. (→ L002 >= 200 ml)



44. The following interconnections have to be set up in step ‘EductB001ToR002‘.





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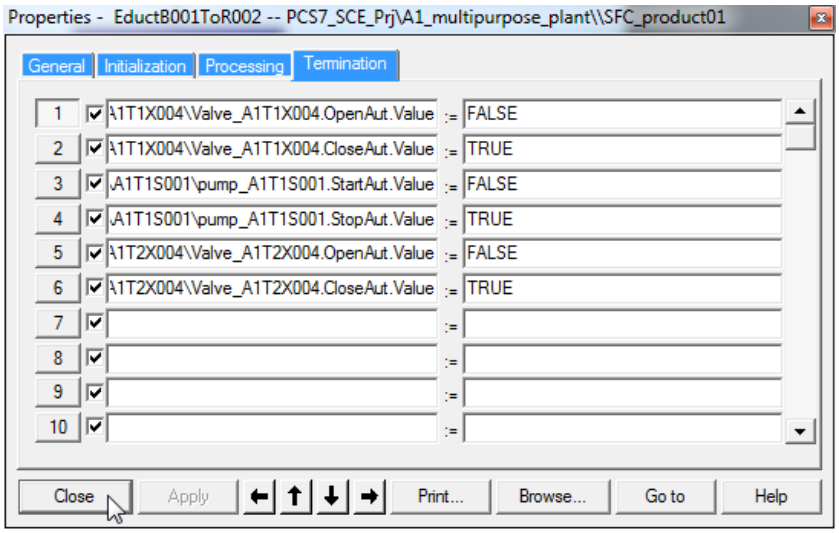
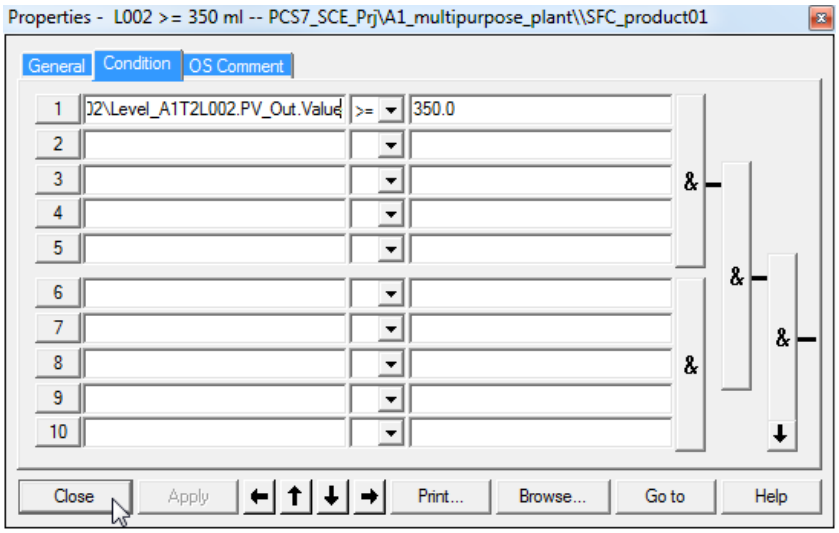
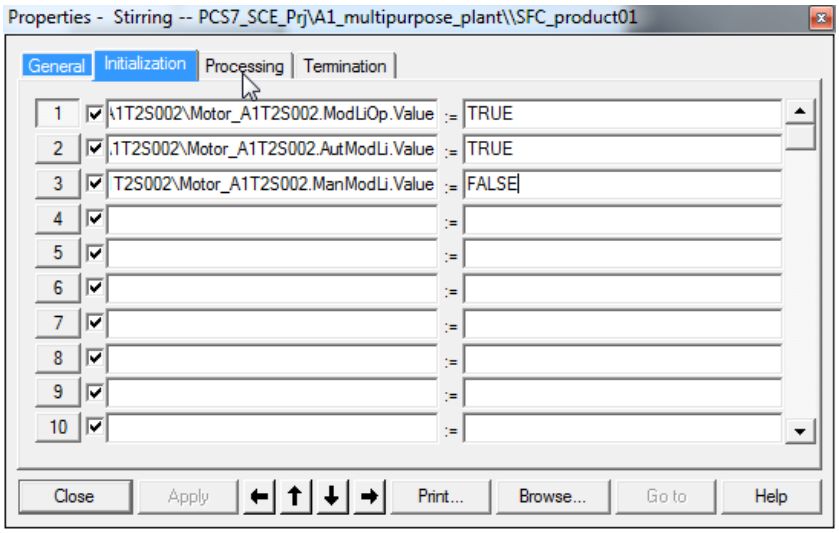


45. Transition ‘L002 >= 350ml’ then looks like this. (→ L002 >= 350ml)



46. The step ‘Stirring’ has a minimum execution time of 10 seconds. We parameterized this at the beginning. Now, Stirrer_A1T2S002 has to be initialized, started and stopped again.



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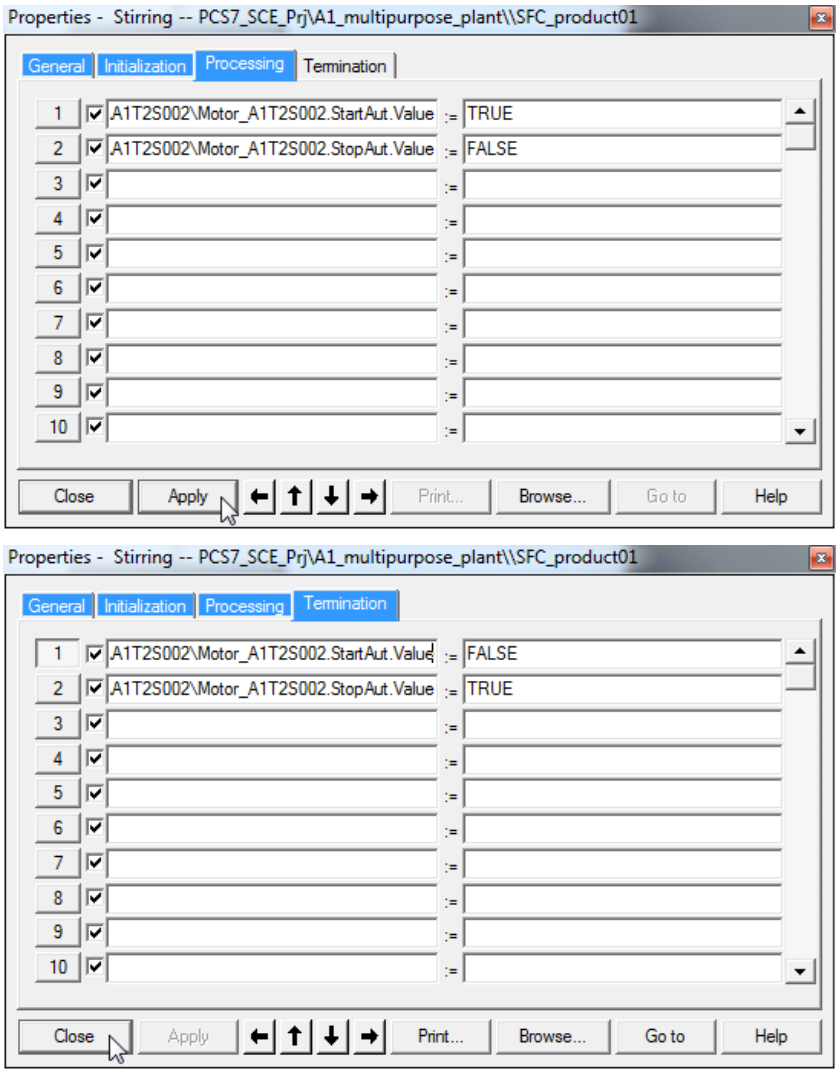
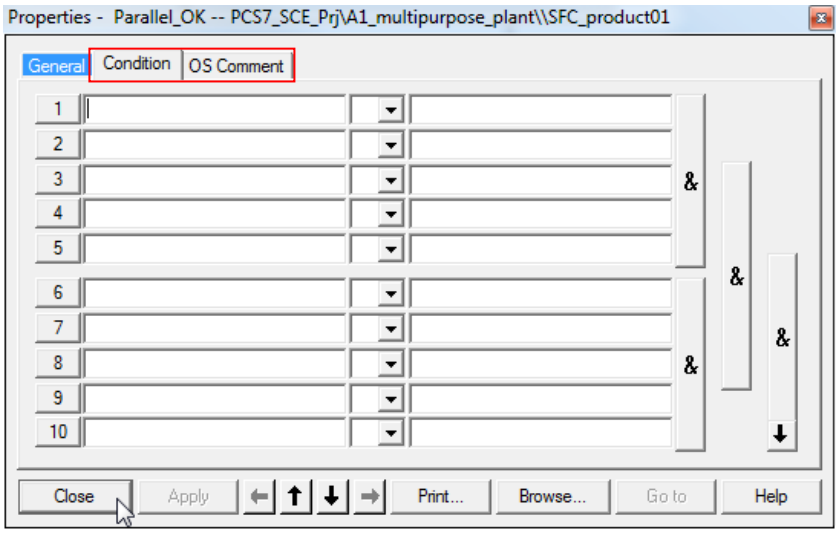


47. Now, the parallel branch is parameterized. Transition ‘Parallel_OK’ remains blank. This means that as soon as the steps ‘Wait‘ and ‘Stirring‘ are processed, step ‘R002ToR001‘ becomes active.



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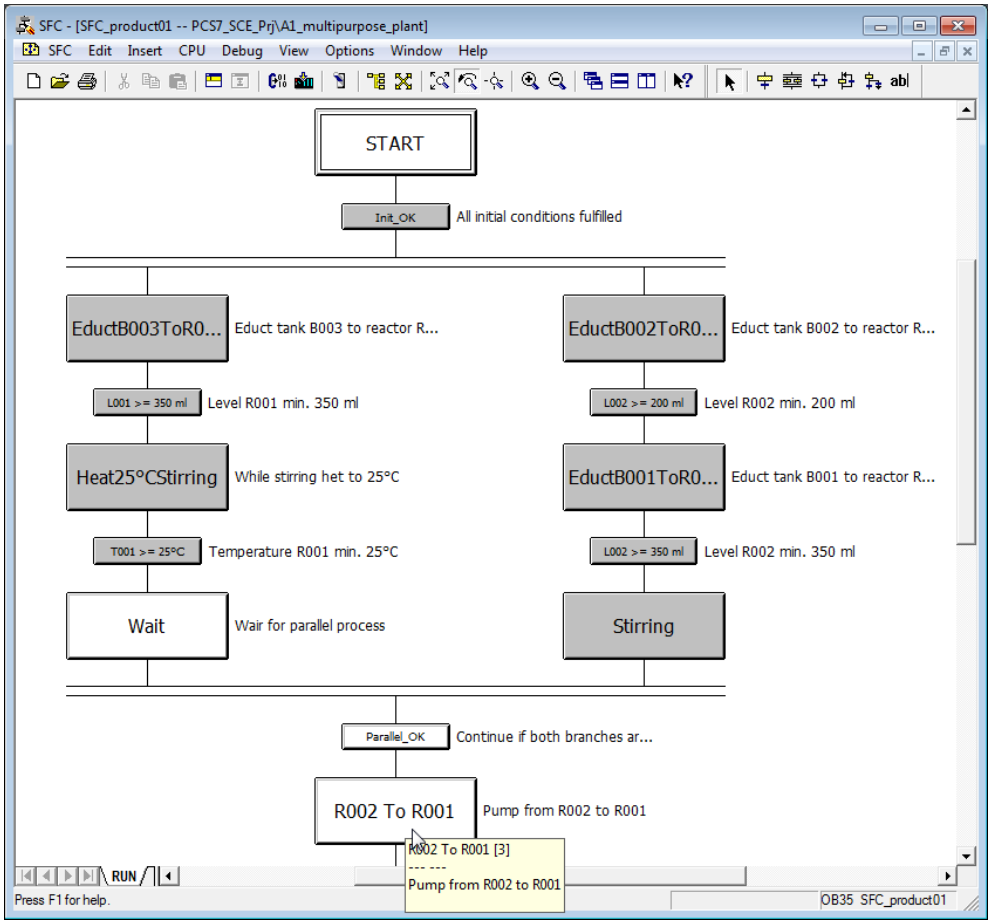
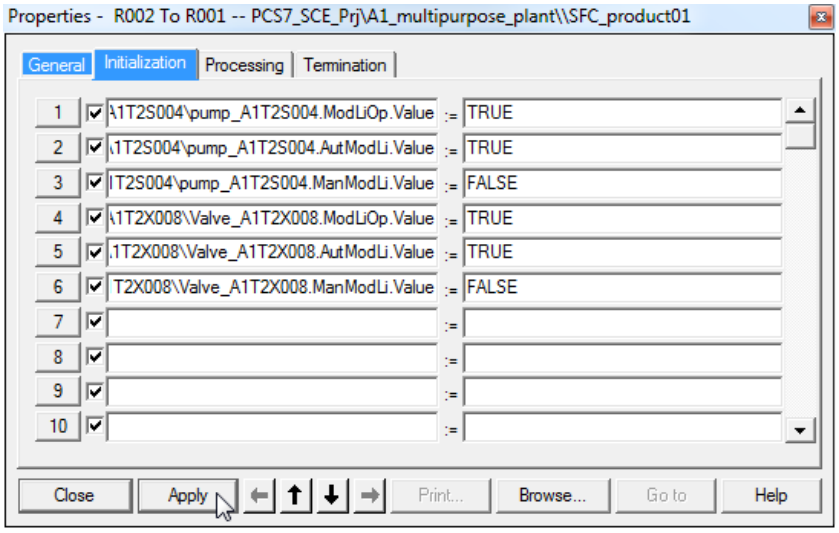
48. Now, the sequential control system looks like this.



49. Next, step ‘R002ToR001’ is interconnected.



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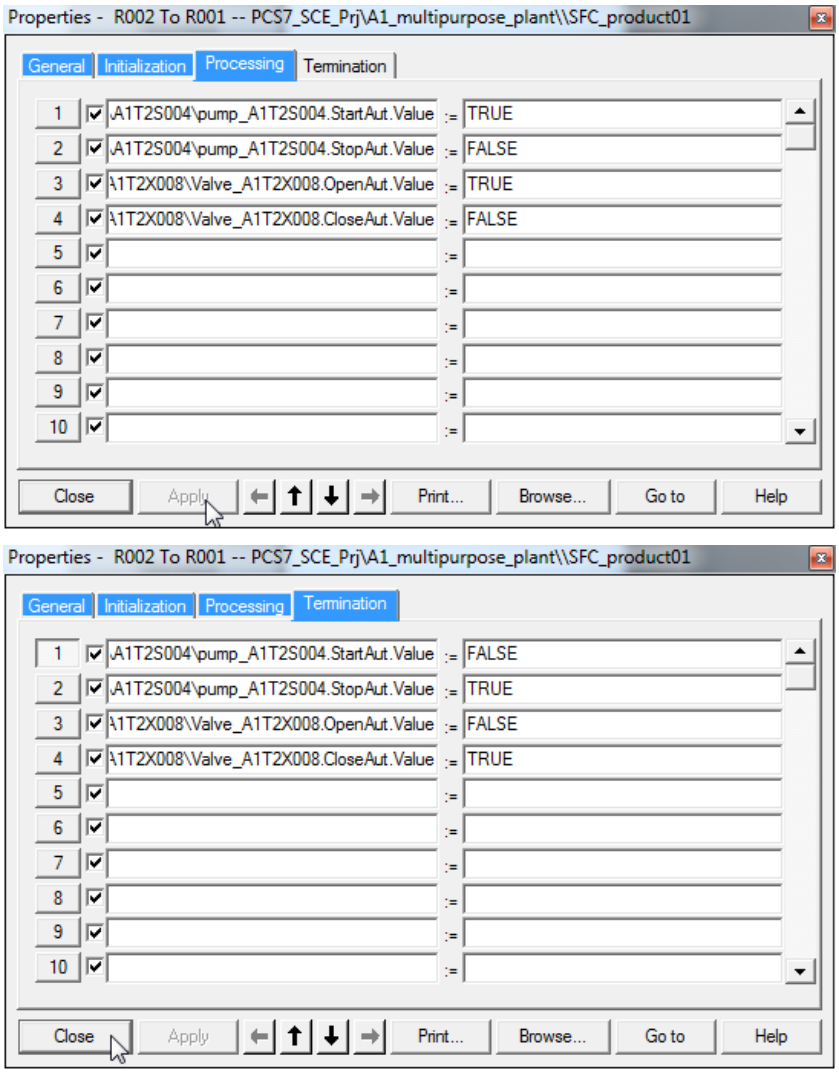
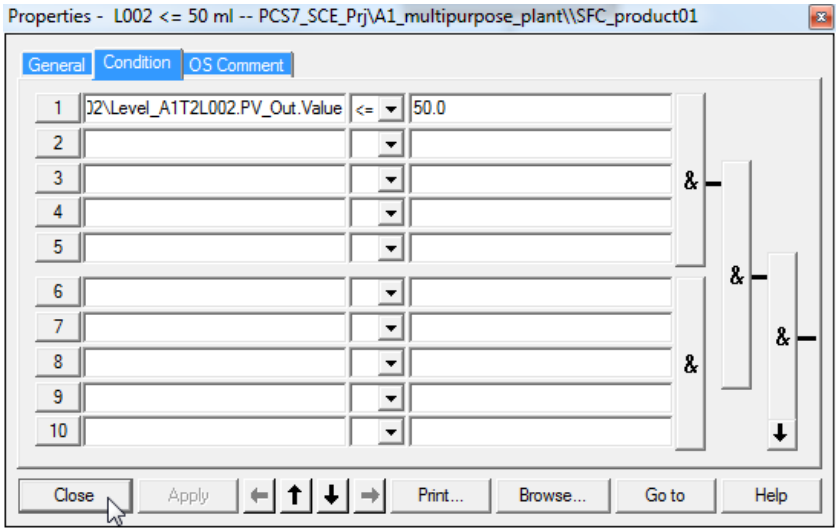


50. Transition ‘L002 <= 50ml’ must be interconnected as follows.



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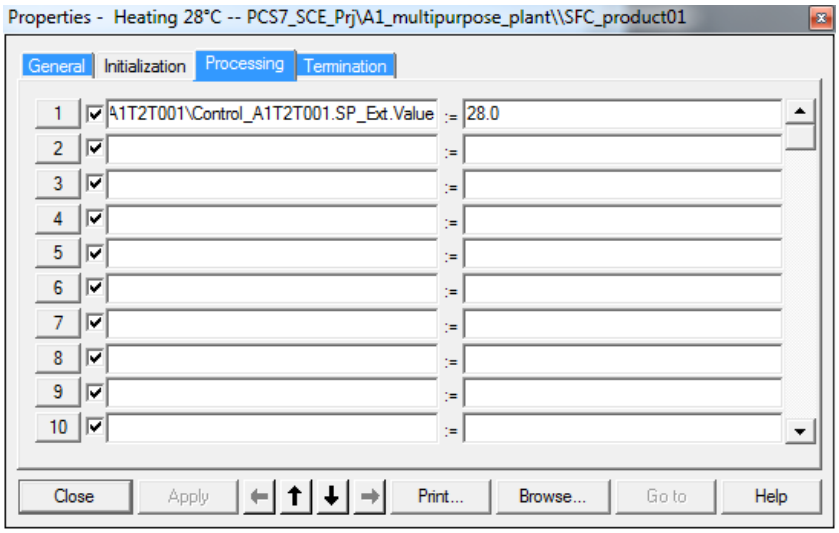
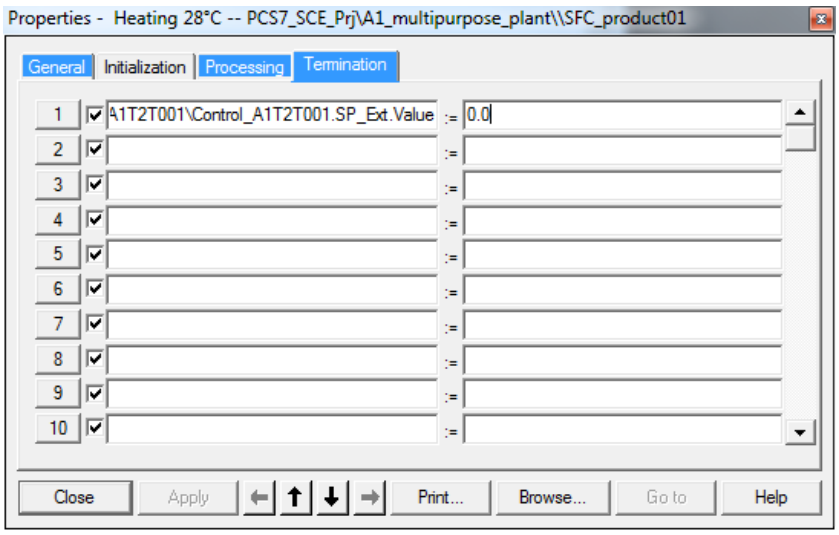
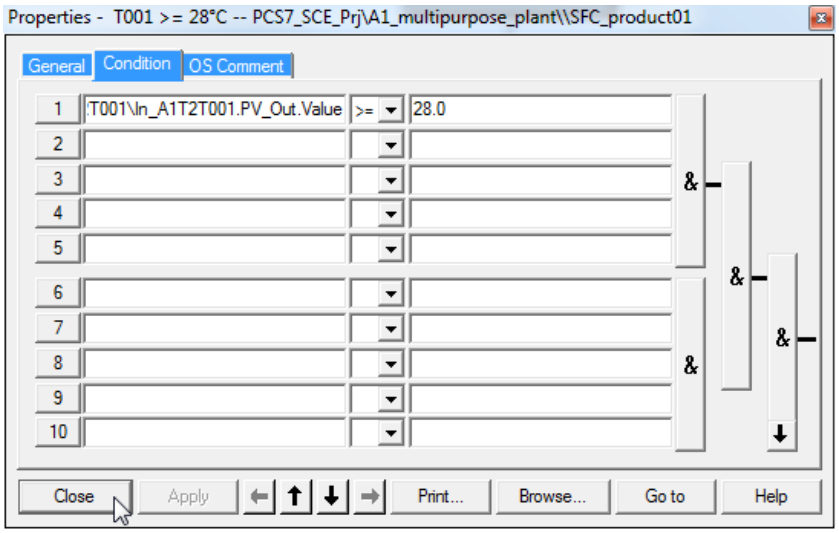
51. In step ‘Heating28°C’, the control is activated again. Because it is already set to SFC mode and automatic mode, only the setpoint has to be specified. At termination, it has to be reset to 0°C.





52. The condition in transition ‘T001 >= 28°C’ now looks like this.



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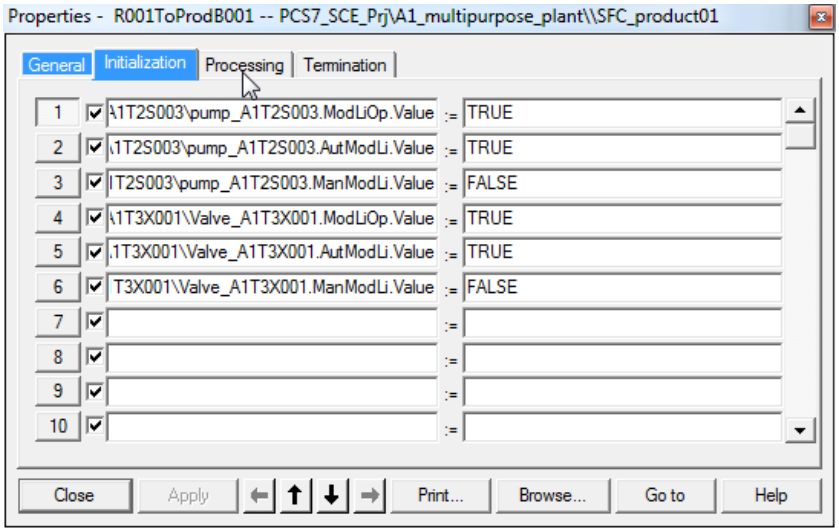
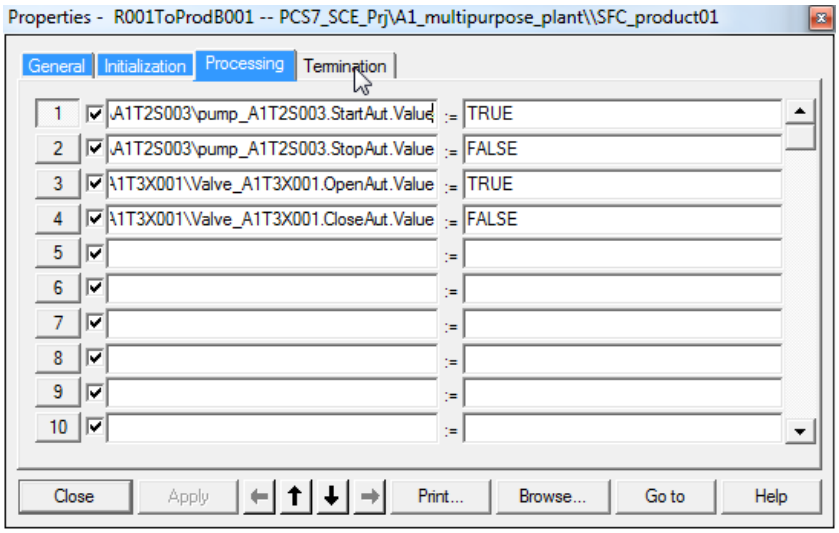
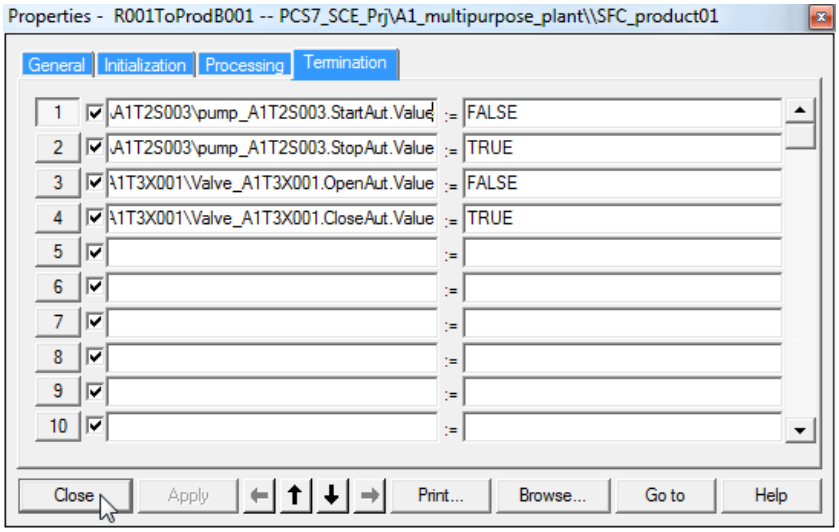
53. The last step “R001ToProdB001” of the recipe fills the content of reactor R001 into the connected product tank B001. The interconnections are shown below.







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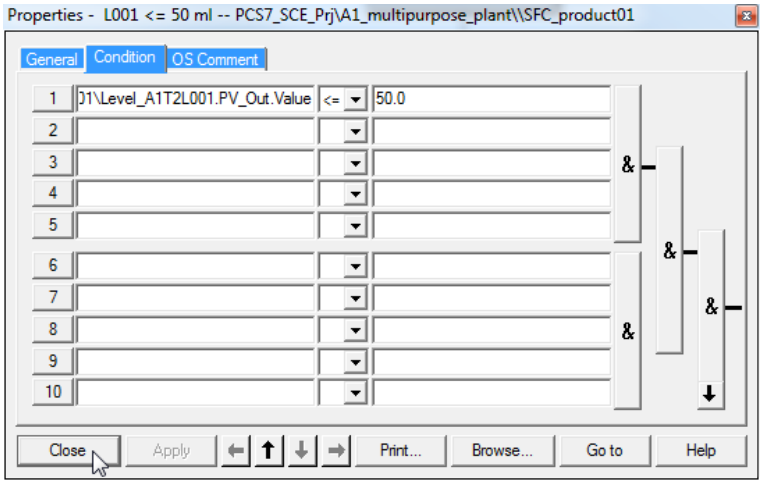
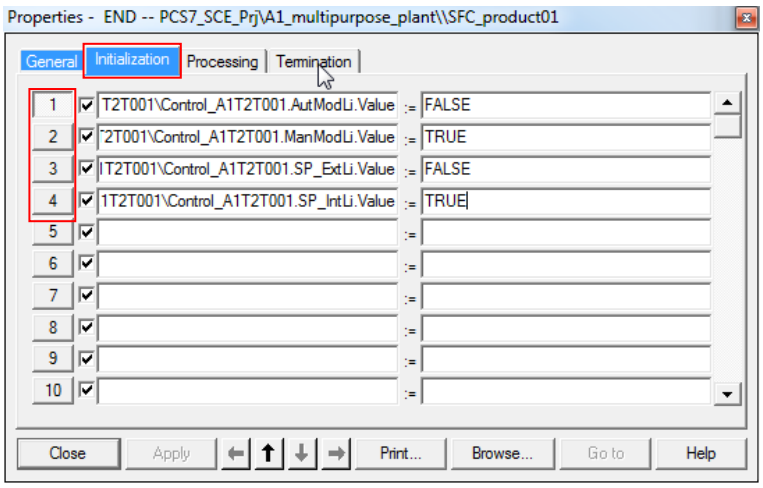
54. The transition ‘L001 <= 50ml’ is the last transition of the recipe. It can be enabled when reactor R001 is empty (<= 50ml).



55. In the step ‘END’, the automatic mode has to be switched on for all utilized valves, pumps, stirrers and control and manual mode must be switched on again. (→ step 56) Regarding the control, the internal setpoint must be set again.

‘Initialization’



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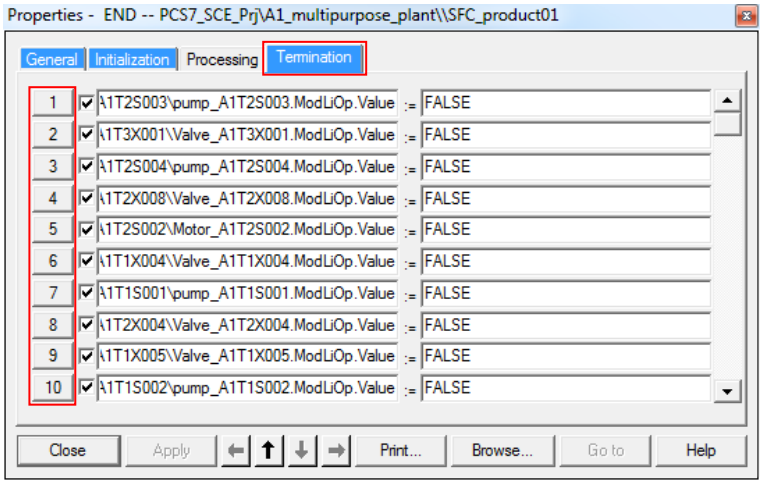
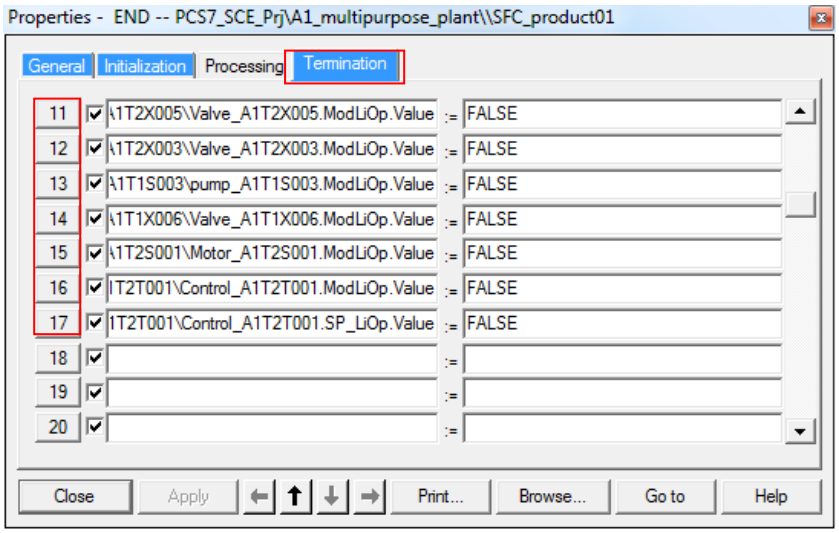
56. Then, all utilized pumps, valves, stirrers and controls are reset again to the operator mode. (‘ModLiOp‘ = ‘0‘)

’Termination’ - 1:



’Termination’- 2:



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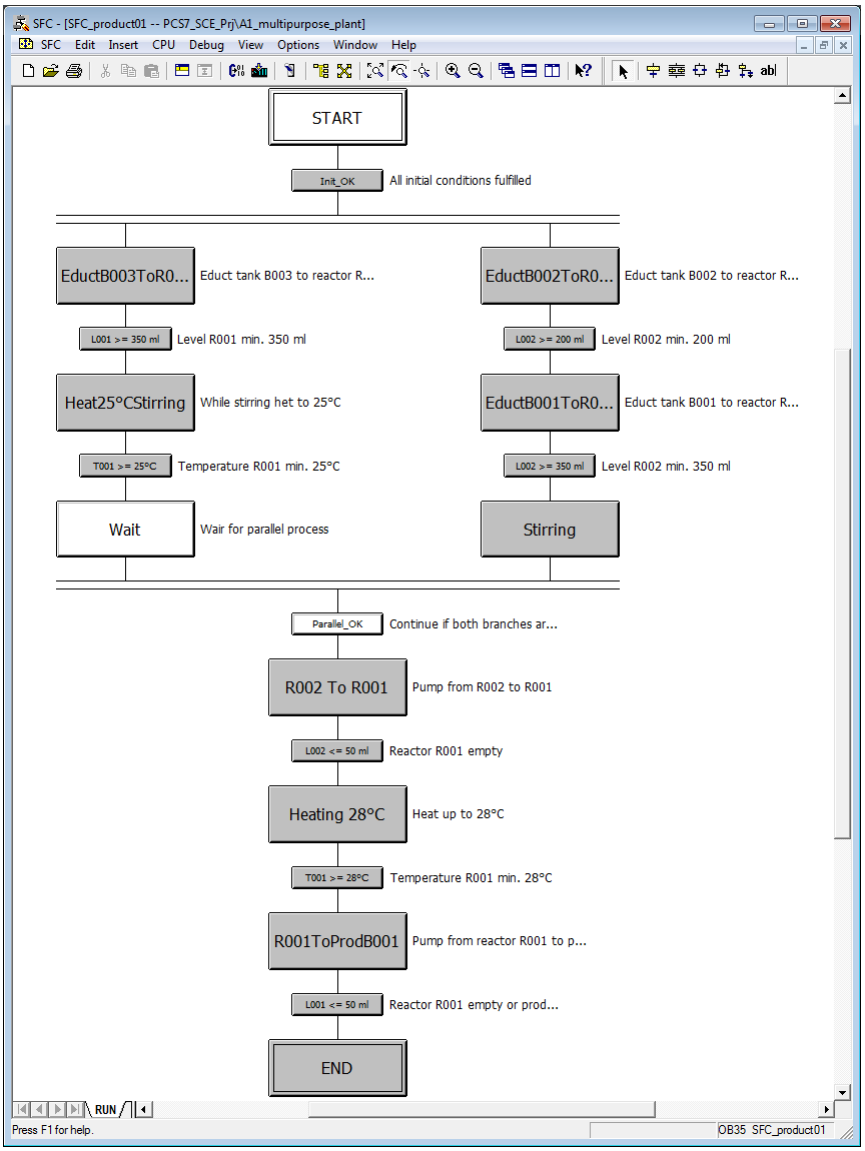
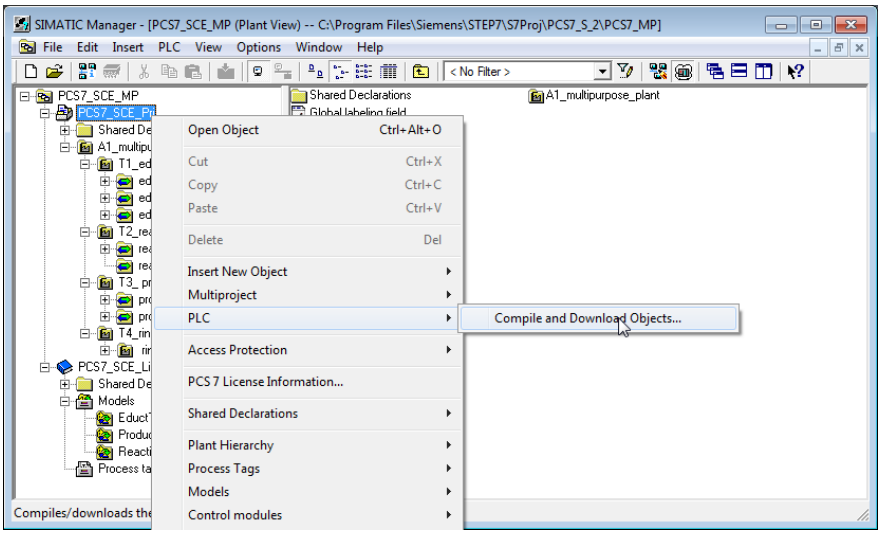
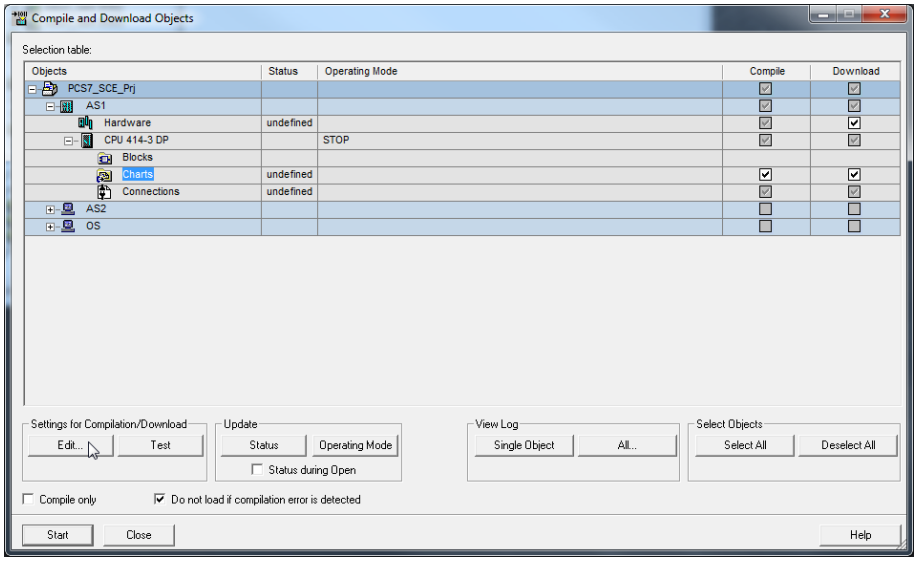


57. After all steps and transitions for the SFC are completed, you can compile and download your project in the known manner.

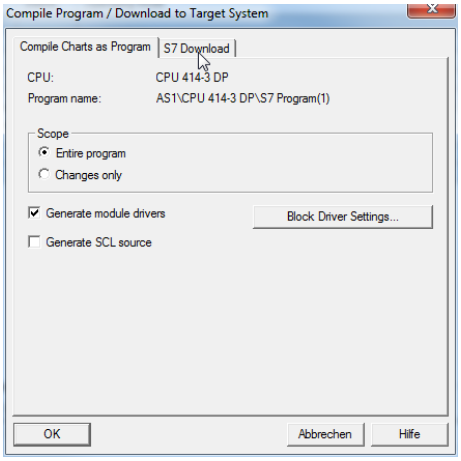
    (SCE_PCS7_Prj → PLC → Compile and download objects…)

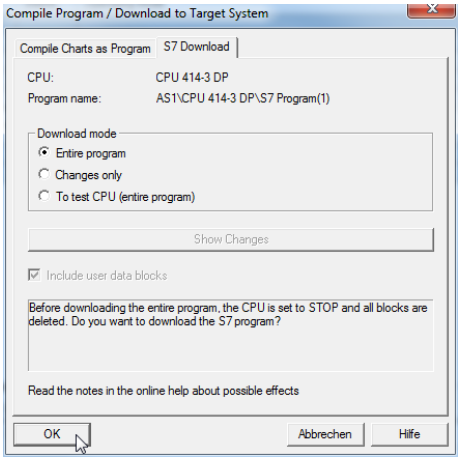


58. Prior to compiling and downloading, open the settings for compiling and downloading the charts. (→ Charts → Edit)

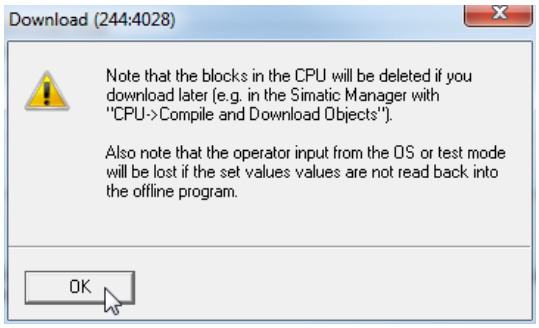


59. Here it is important to select the entire program for “Compile Charts as Program” as well as for “S7 Download” for Scope or Download mode. (→ Compile Charts as Program → Entire program → S7 Download → Entire program → OK)





60. The warning is confirmed with “OK“. (→ OK)



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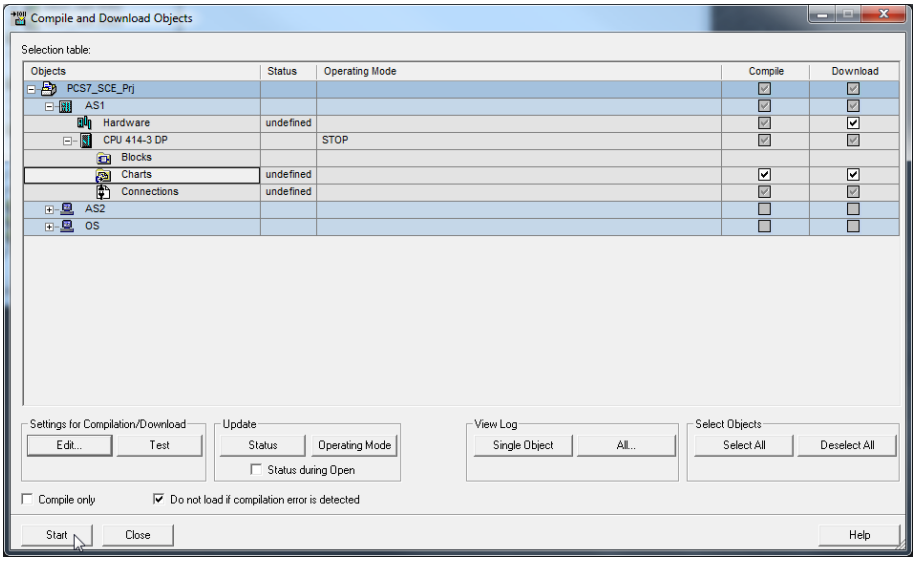
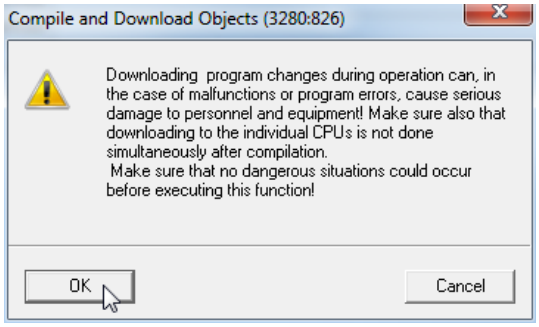
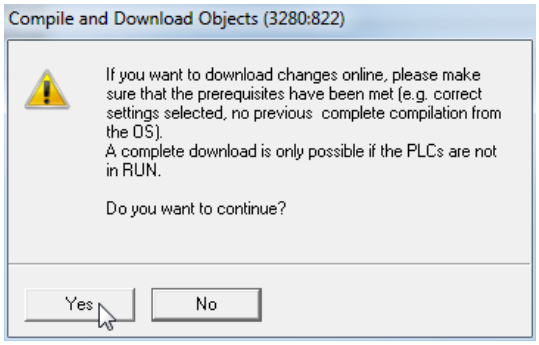
61. Now we can start compiling and downloading. (→ Start)



62. All warnings that follow are read carefully and confirmed. (→ OK → Yes)





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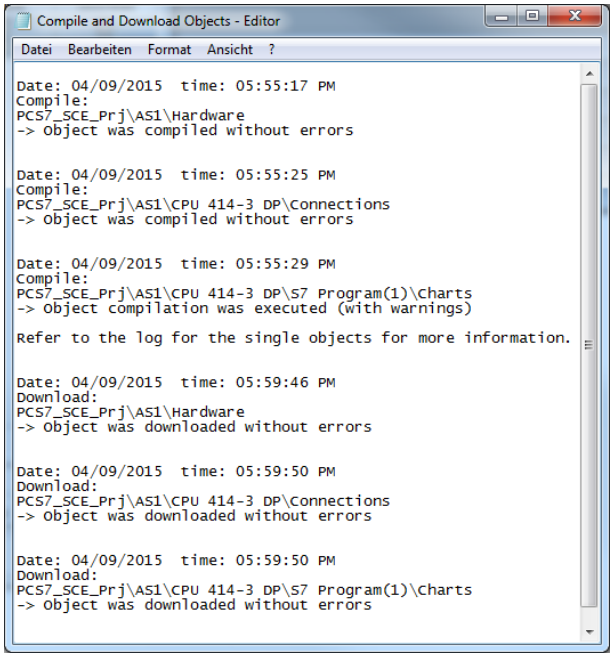
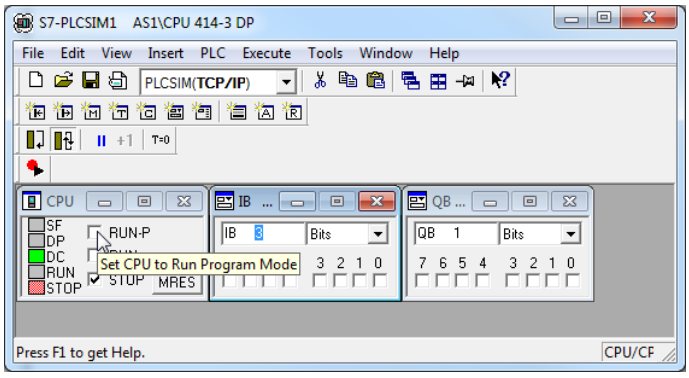
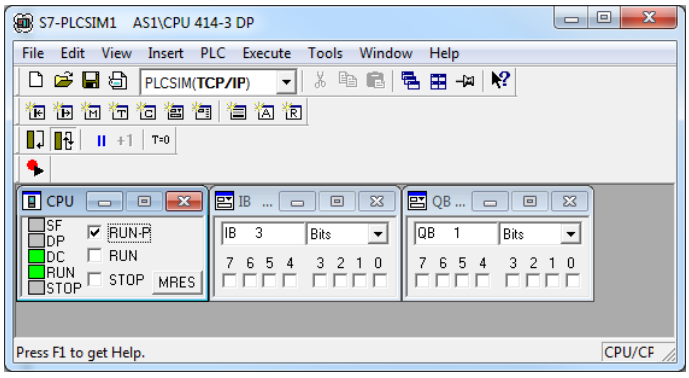
63. In the log, no errors should be shown, warnings at the most. Details for warning are provided in the log of the individual object. (→ X)

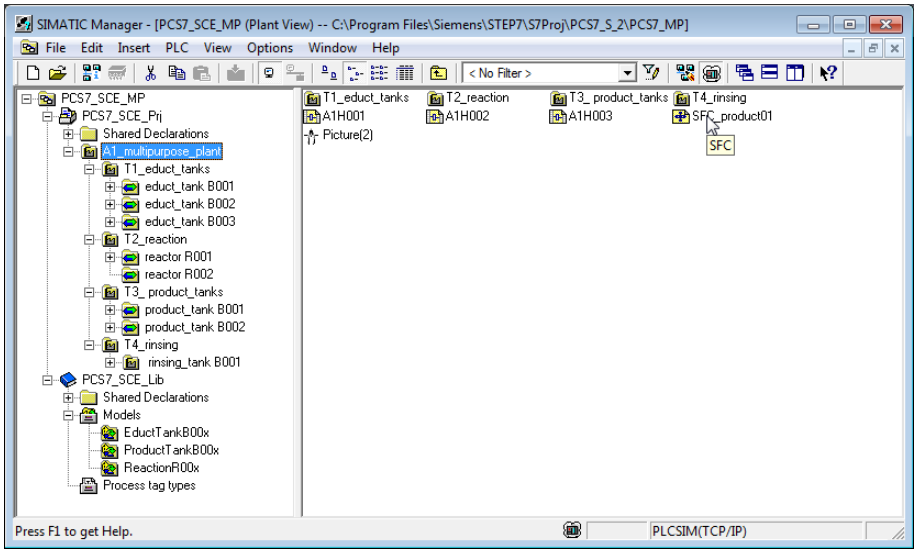


64. Now, set PLCSIM to the RUN-P mode. (→ PLCSIM → RUN-P)

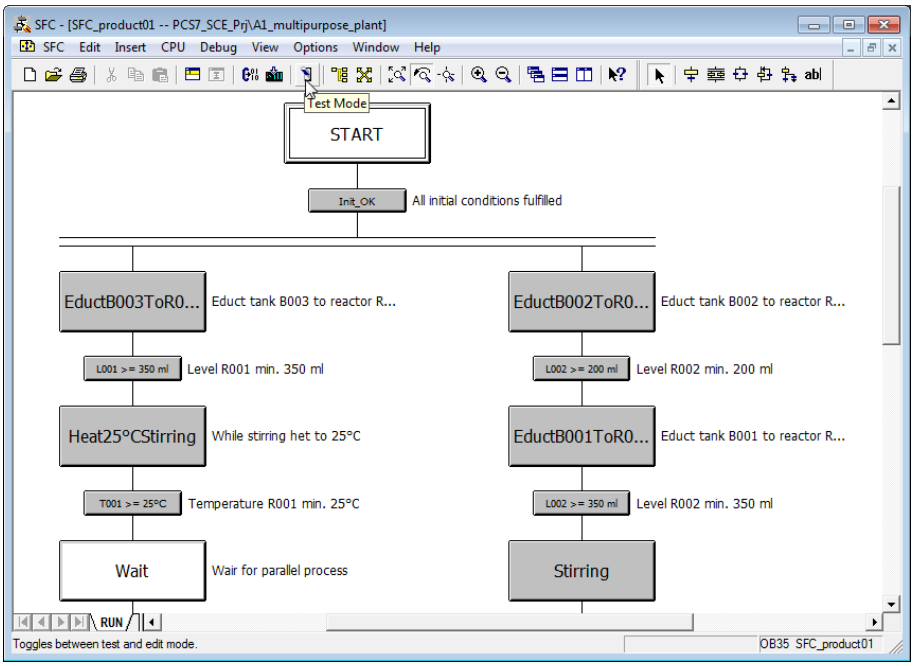




65. With a double click, open the sequential function chart from the plant hierarchy. (→ SFC_Product01)



66. To watch the sequence, switch on the test mode. (→ Test Mode on/off)



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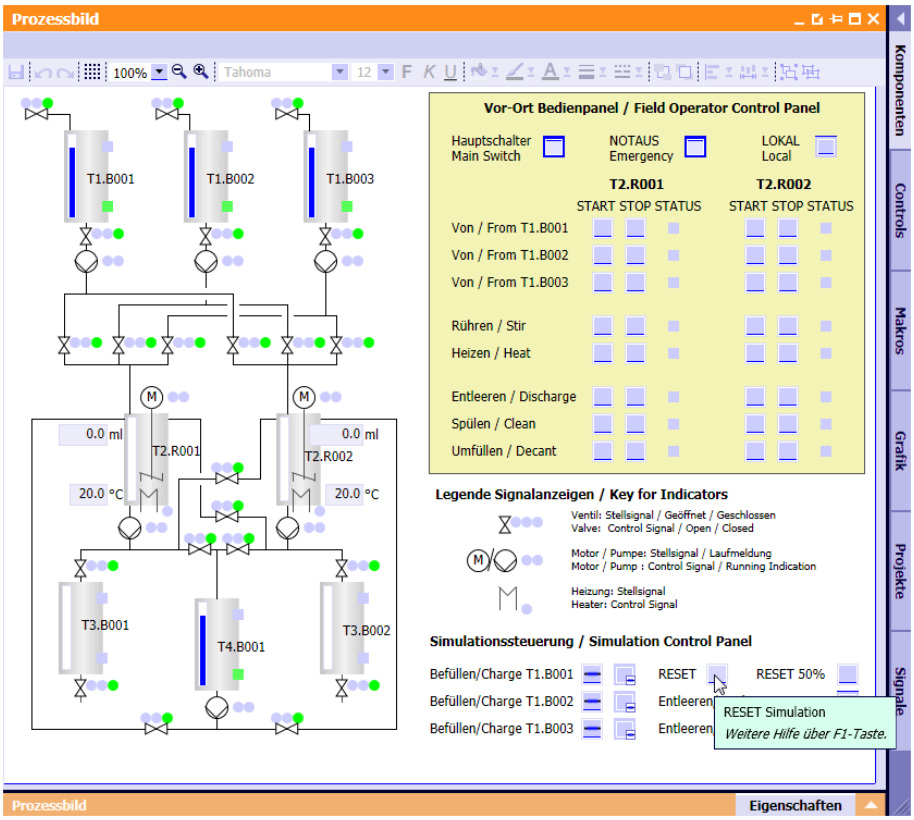
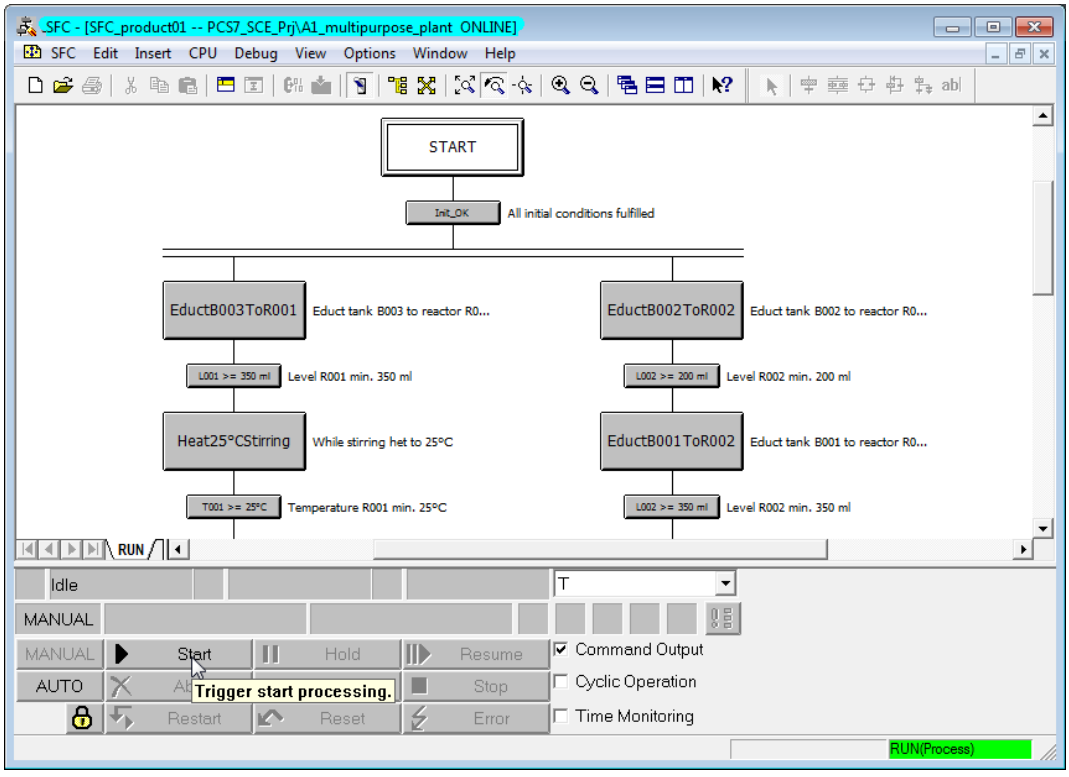
67. The simulation has to be reset and the main switch and Emergency STOP activated. Local operation has to be deactivated.



68. We can now start the SFC. (→ Start)



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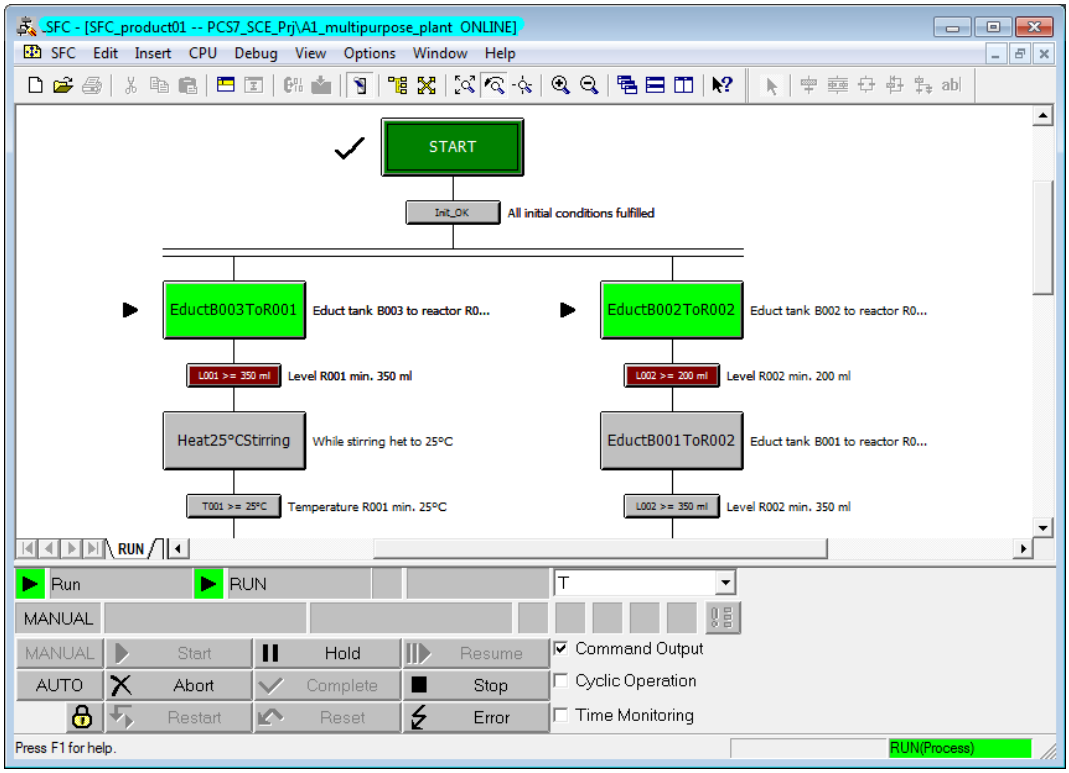
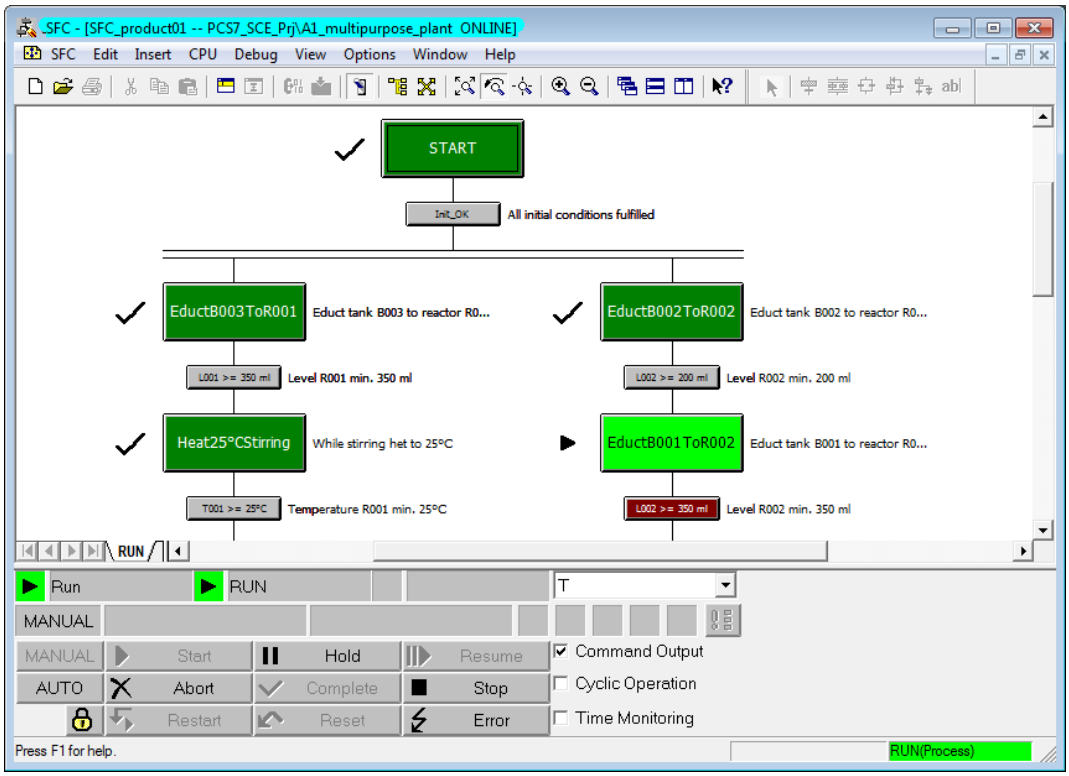
69. We can now monitor the execution of the sequential function chart. Active steps and steps that have been processed are indicated.





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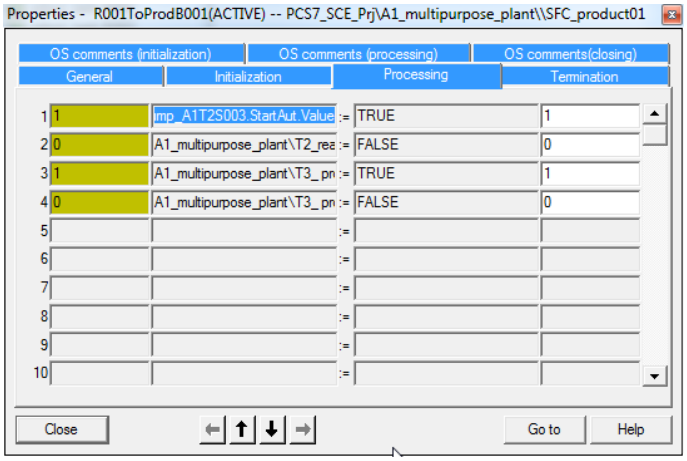
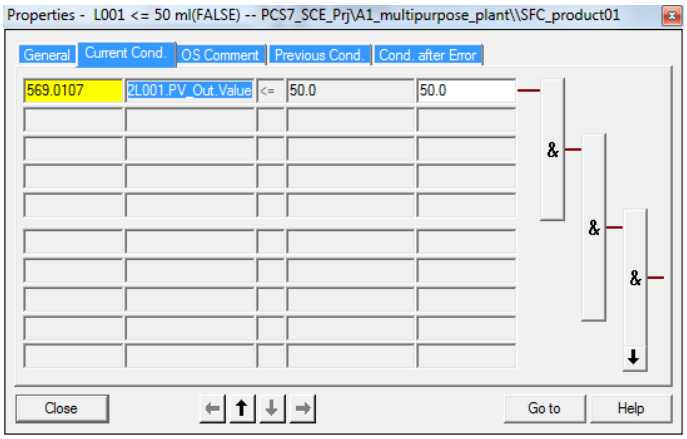
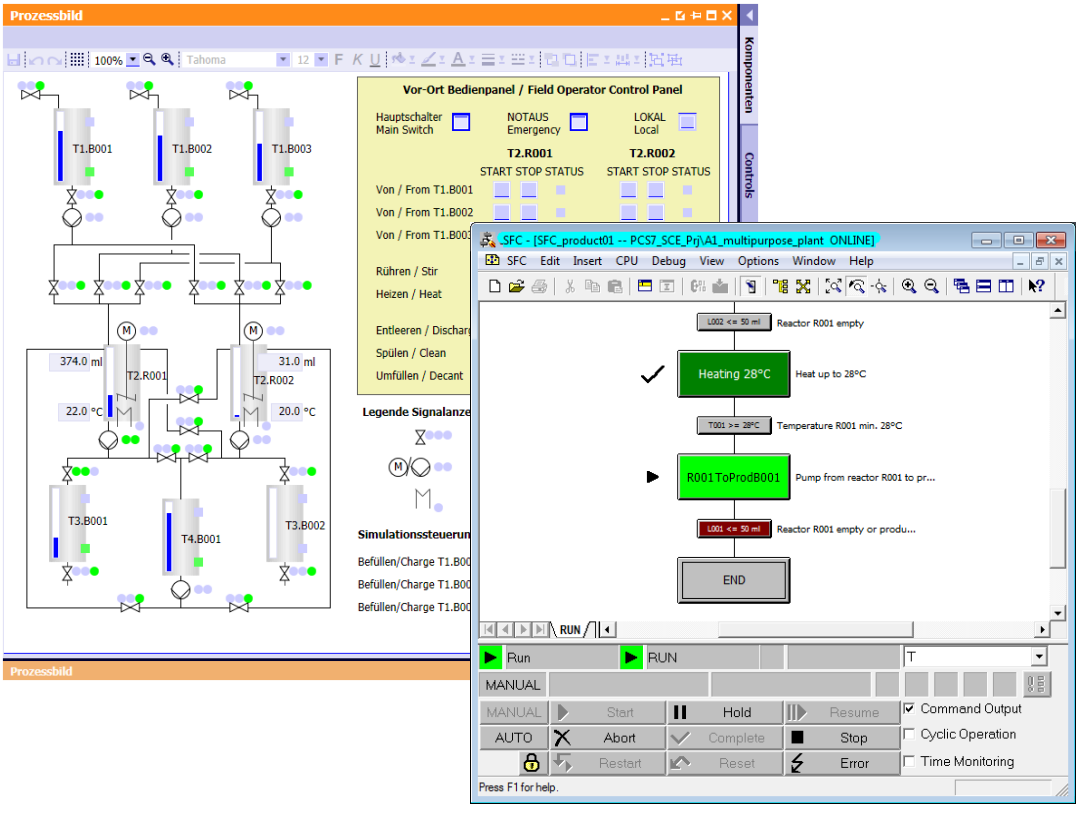
70. By double clicking on or opening individual steps or transitions, current conditions and values can be displayed.





71. In the state ‘R001ToProdB001’ the SFC and the simulation look like this.



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EXERCISES

In the exercises we apply what we learned in the Theory section and in the Step by Step Instructions. The existing multi-project from the step by step instructions (PCS7_SCE_0108_Ueb_R1505_en.zip) is used for this and expanded.

This exercise implements an additional recipe that is designed to clean the reactors. The task below suggests a possible concept.

TASKS

1. Create the SFC ‘SFC_Rinse’ in the chart folder ‘A1_multipurpose_plant‘ that rinses reactors R001 and R002 with rinse water. Cleaning consists of the following steps:

   – Filling the reactors (up to 500ml) with rinse water
   – Stirring the rinse water (for 20 seconds) in the reactors
   – Draining the rinse water into the product tank.

   Design the rinse process in a way that both reactors are cleaned at the same time.

   Check whether both reactors are empty (< 50ml) before rinsing starts.

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