Model Behaviour Generation for Multiple Simulators

Faculty of Engineering / Research Group CEA

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TECHNOLOGY, BUSINESS AND DESIGN

Prerequisite

A prerequisite for this supplementary material is the knowledge of Chapter 1.5, where basic concepts of the System Entity Structure (SES) are described.

Outline

1. Case study
2. Implementation of the SES and an MB
3. Model selection and model generation
4. Organization of a simulator-independent MB
5. Full automation of simulation experiments
6. Summary

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1. **Case study**
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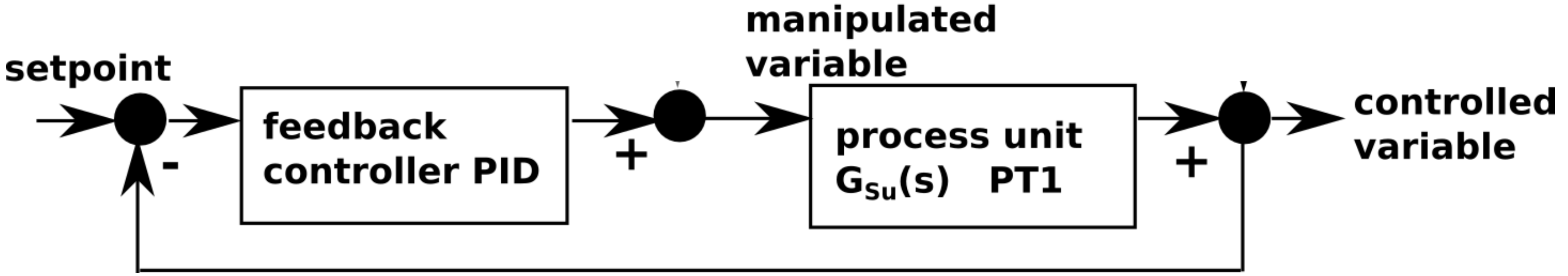
Case Study

Case Study

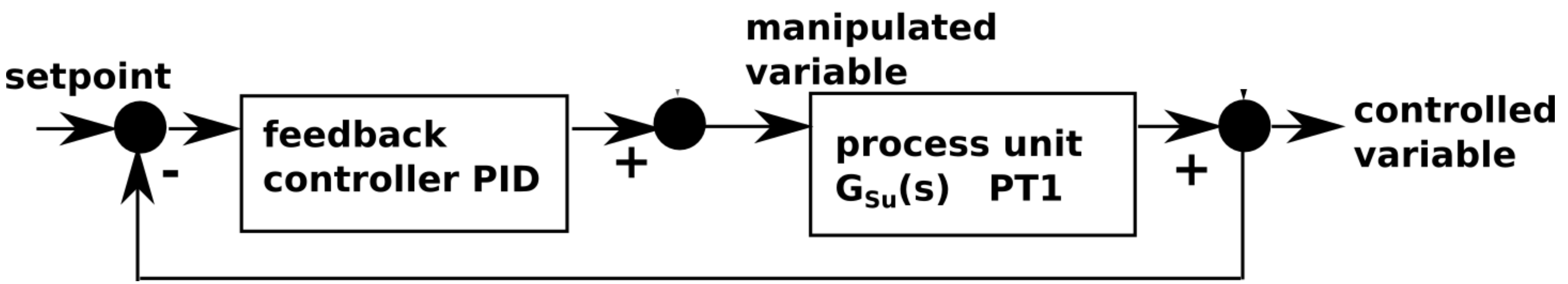
- Feedback control system



Case Study

- Feedback control system
- Described by transfer functions

$$G_{Su}(s) = \frac{1}{20 \cdot s + 1}$$

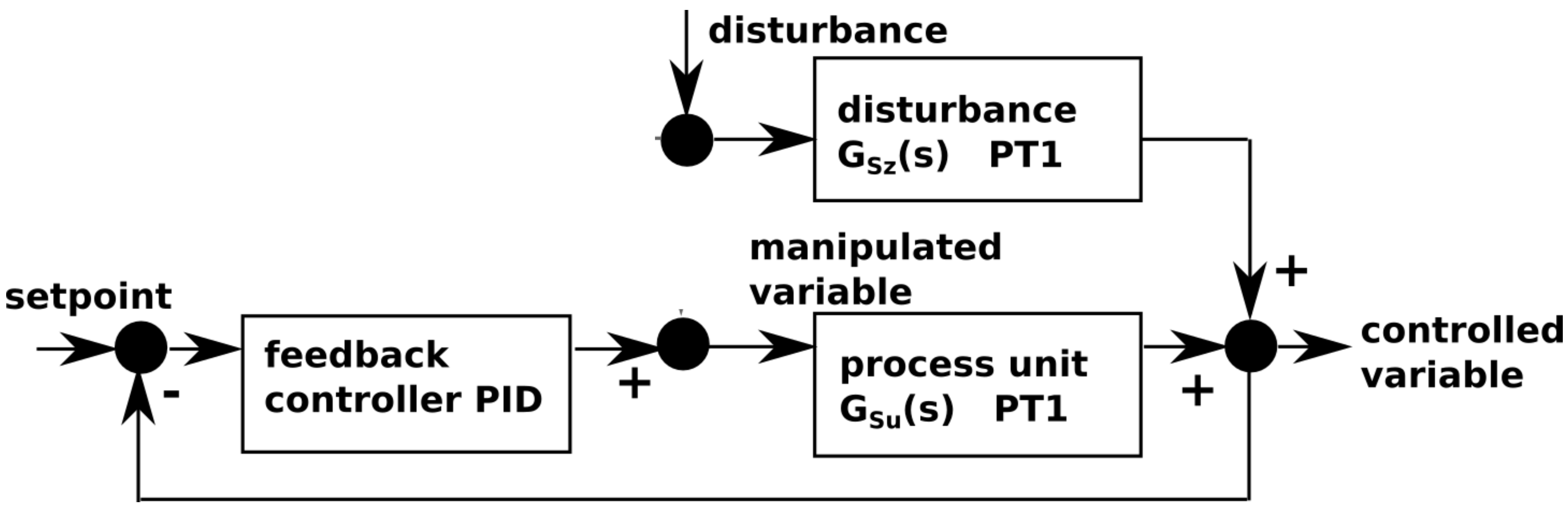


Case Study

- Feedback control system
- Described by transfer functions
- Influenced by disturbances

$$G_{Su}(s) = \frac{1}{20 \cdot s + 1}$$

$$G_{Sz}(s) = \frac{1}{10 \cdot s + 1}$$



Case Study

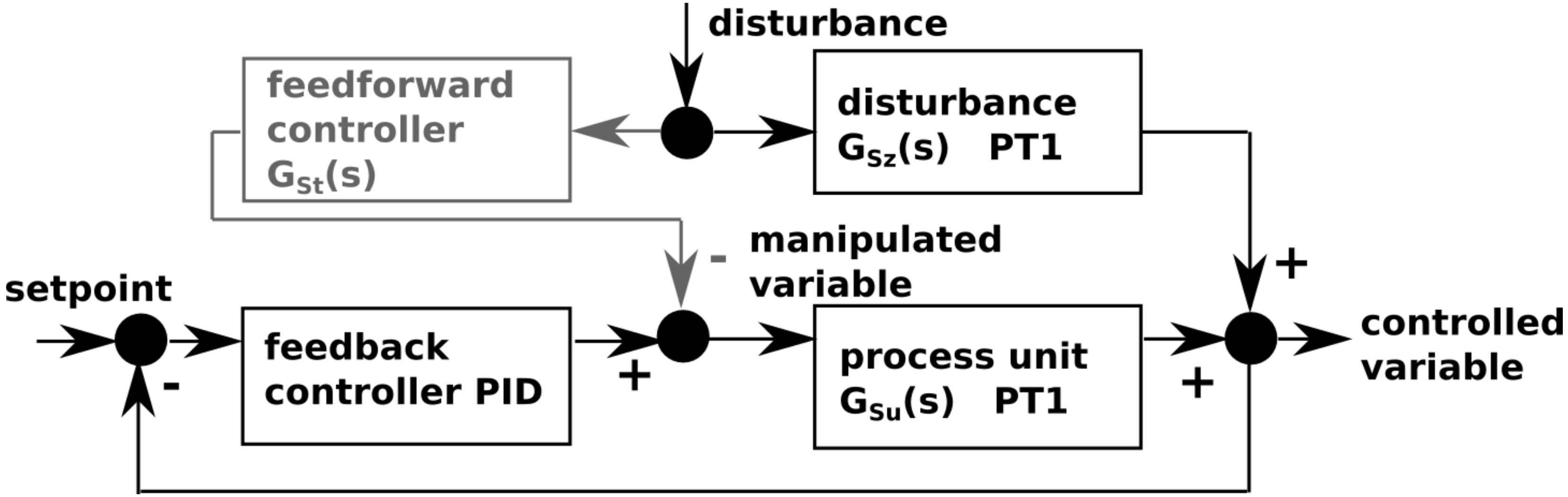
- Feedback control system
- Described by transfer functions
- Influenced by disturbances
- Measurable disturbances

  → Compensated with feedforward control

$$G_{Su}(s) = \frac{1}{20 \cdot s + 1}$$

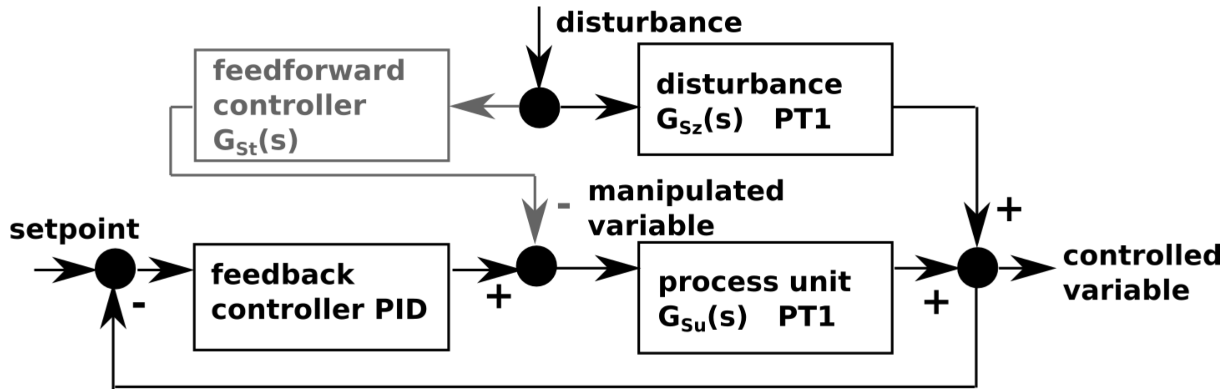
$$G_{Sz}(s) = \frac{1}{10 \cdot s + 1}$$

$$G_{St}(s) = \frac{20 \cdot s + 1}{10 \cdot s + 1}$$



Case Study (2)

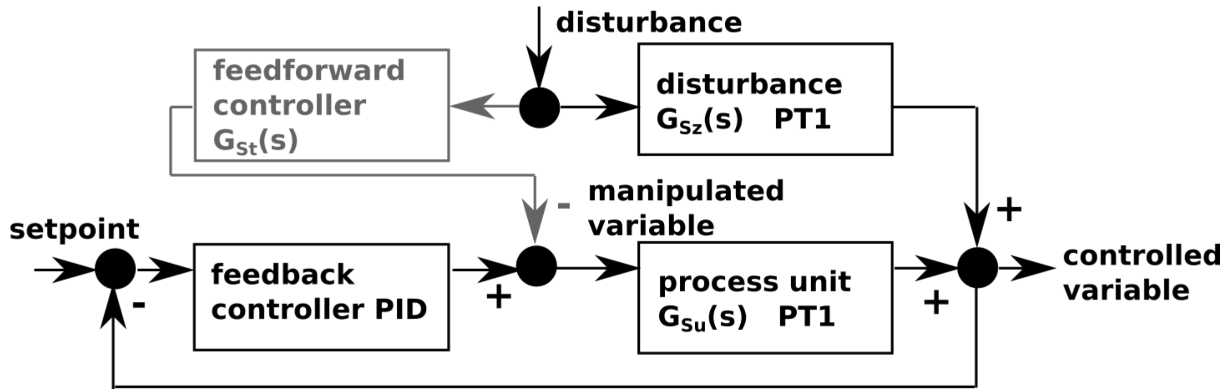
- **Two system structure variants**
  - Without feedforward control: `feedforward=0`
  - With feedforward control: `feedforward=1`



Case Study (2)

- **Two system structure variants**
  - ➢ Without feedforward control: `feedforward=0`
  - ➢ With feedforward control: `feedforward=1`
- For every structure variant

→ **Different parameter configurations of PID controller** (we consider two)



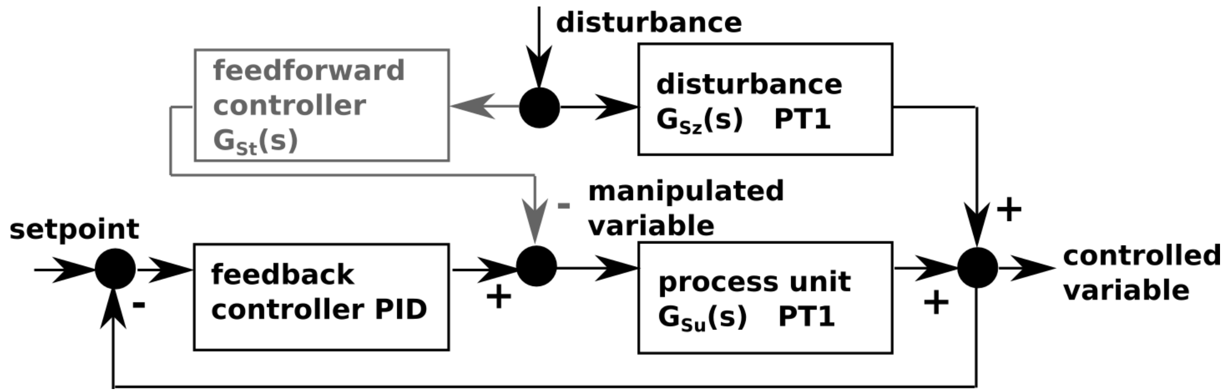
Case Study (2)

Design objective:
Find best control configuration.

- **Two system structure variants**
  - Without feedforward control: `feedforward=0`
  - With feedforward control: `feedforward=1`
- For every structure variant

  → **Different parameter configurations of PID controller**

  (we consider two)



Outline

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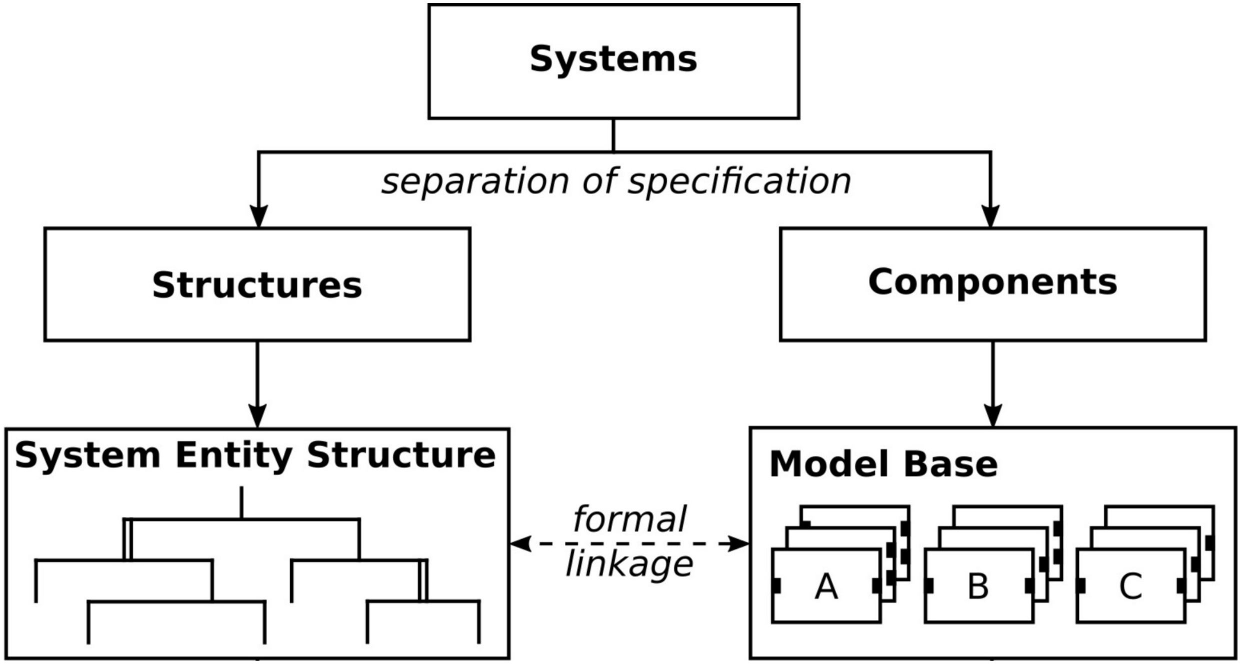
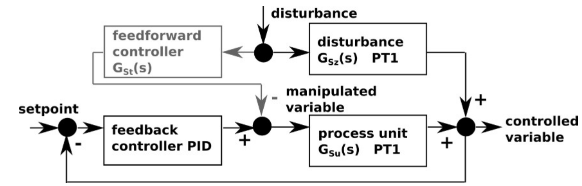
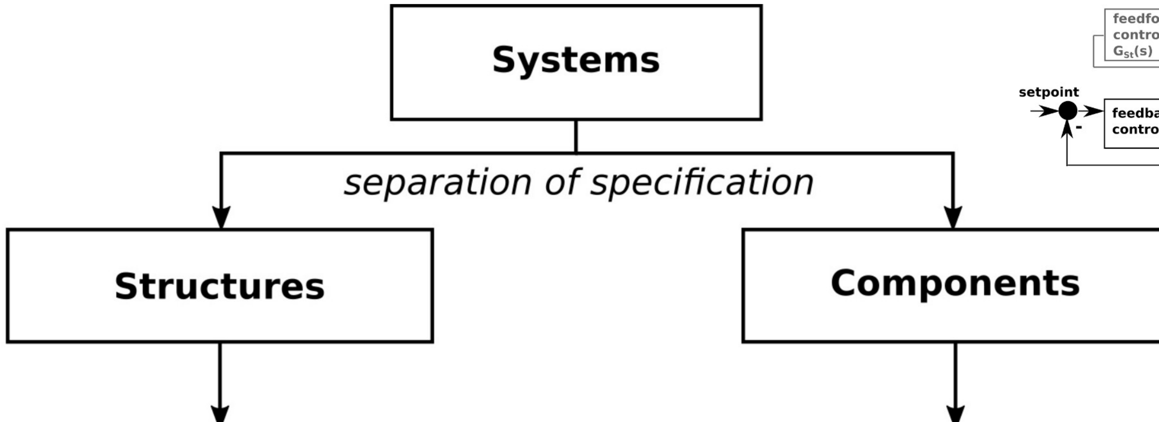
SES/MB-based Modeling

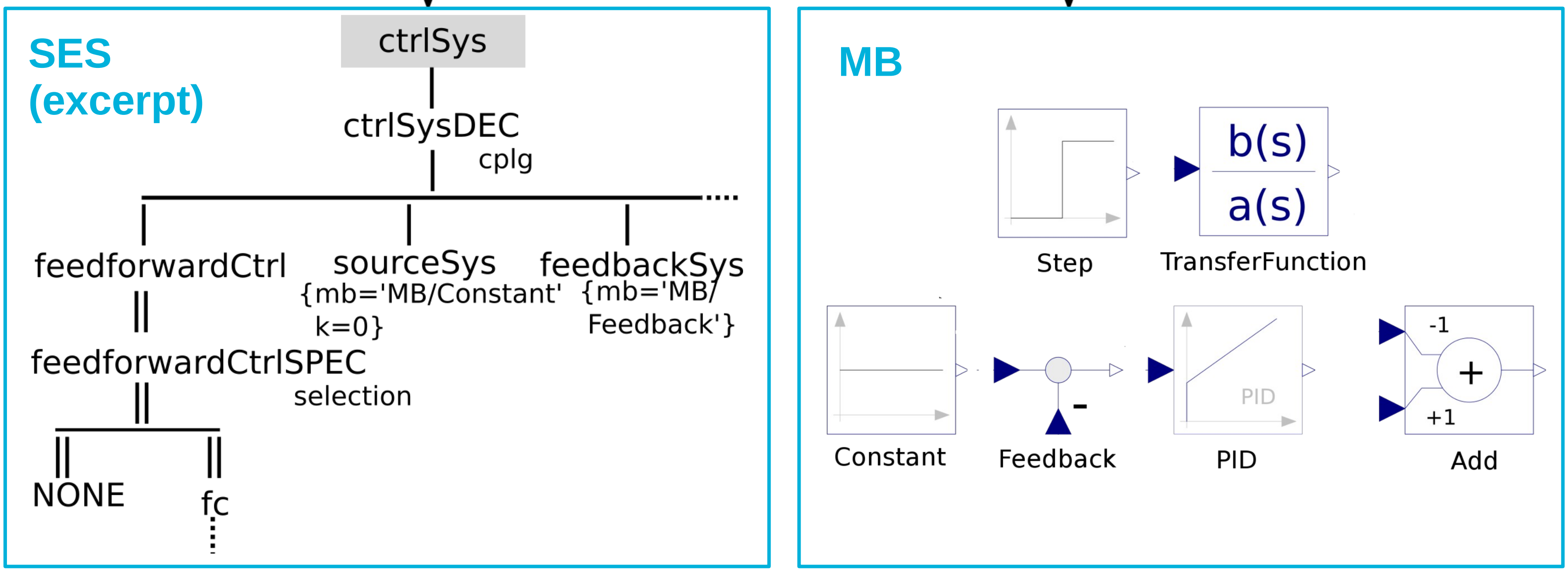


- **SES** describes permissible structure & parameter variants (simulator-independent)
- **MB** defines basic dynamic models (usually simulator dependent)

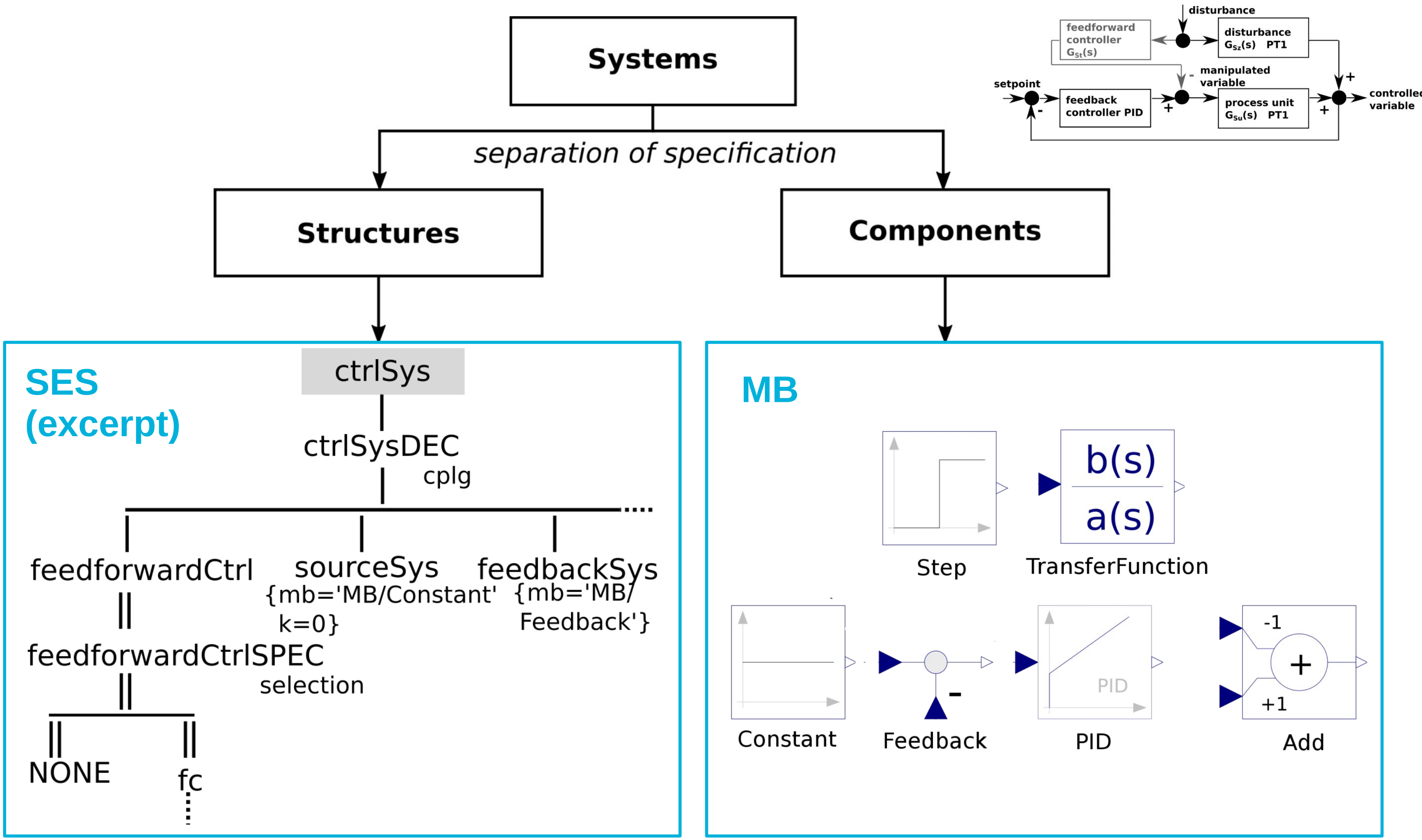
SES/MB-based Modeling of the Case Study







SES/MB-based Modeling of the Case Study



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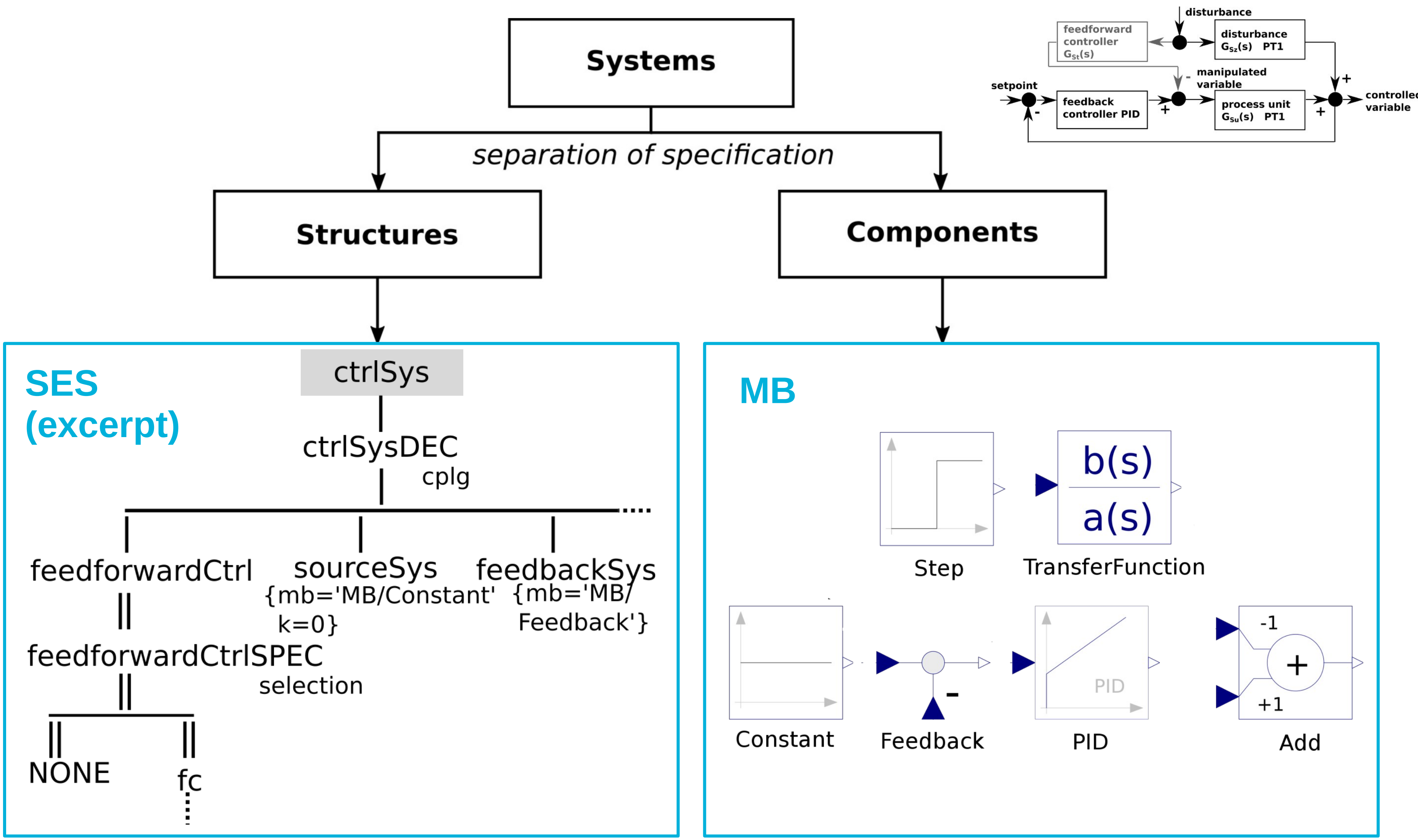
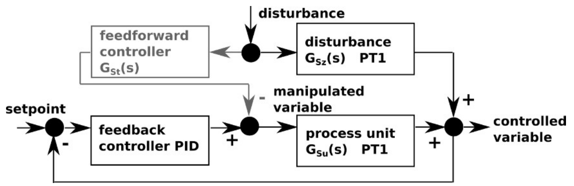
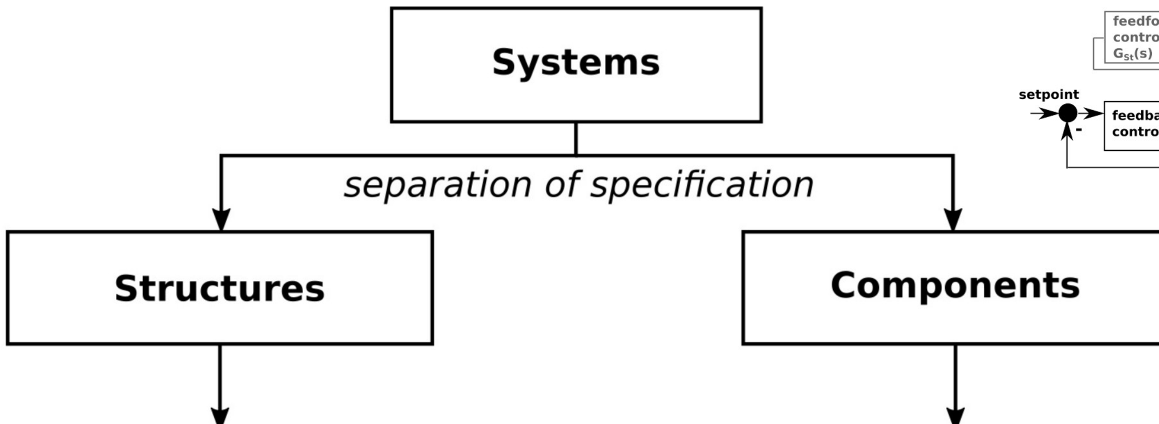
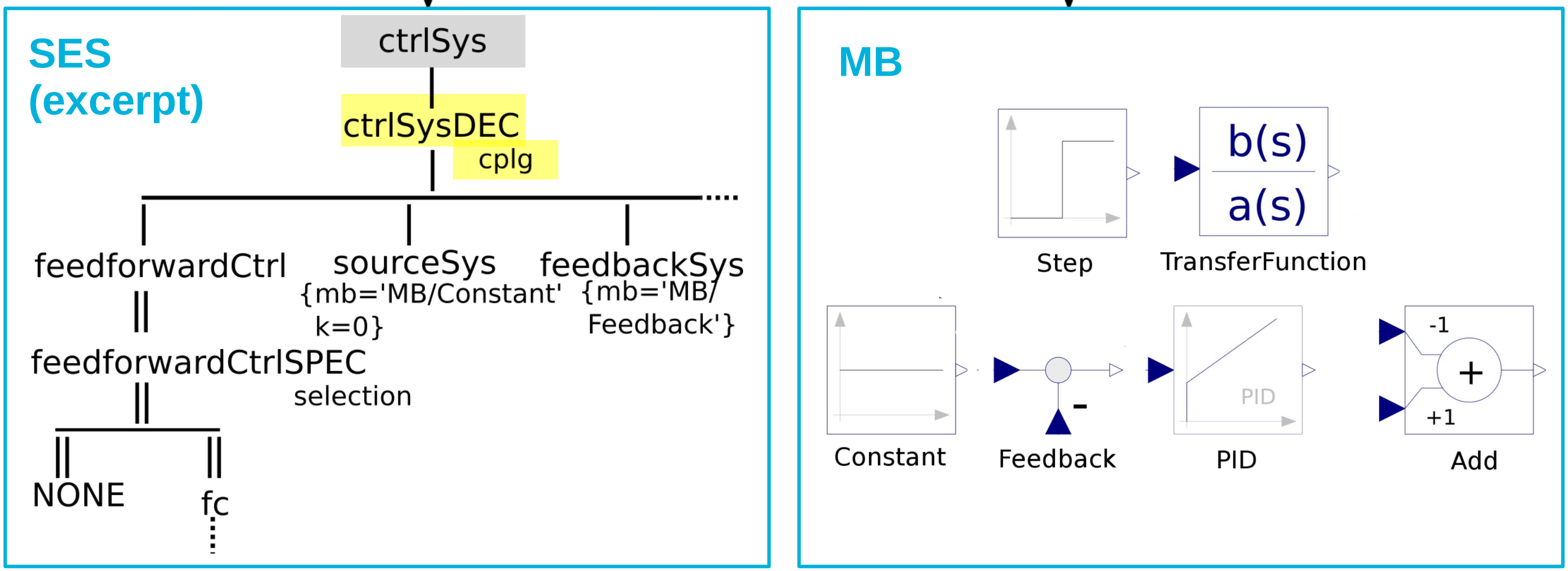


SES/MB-based Modeling of the Case Study







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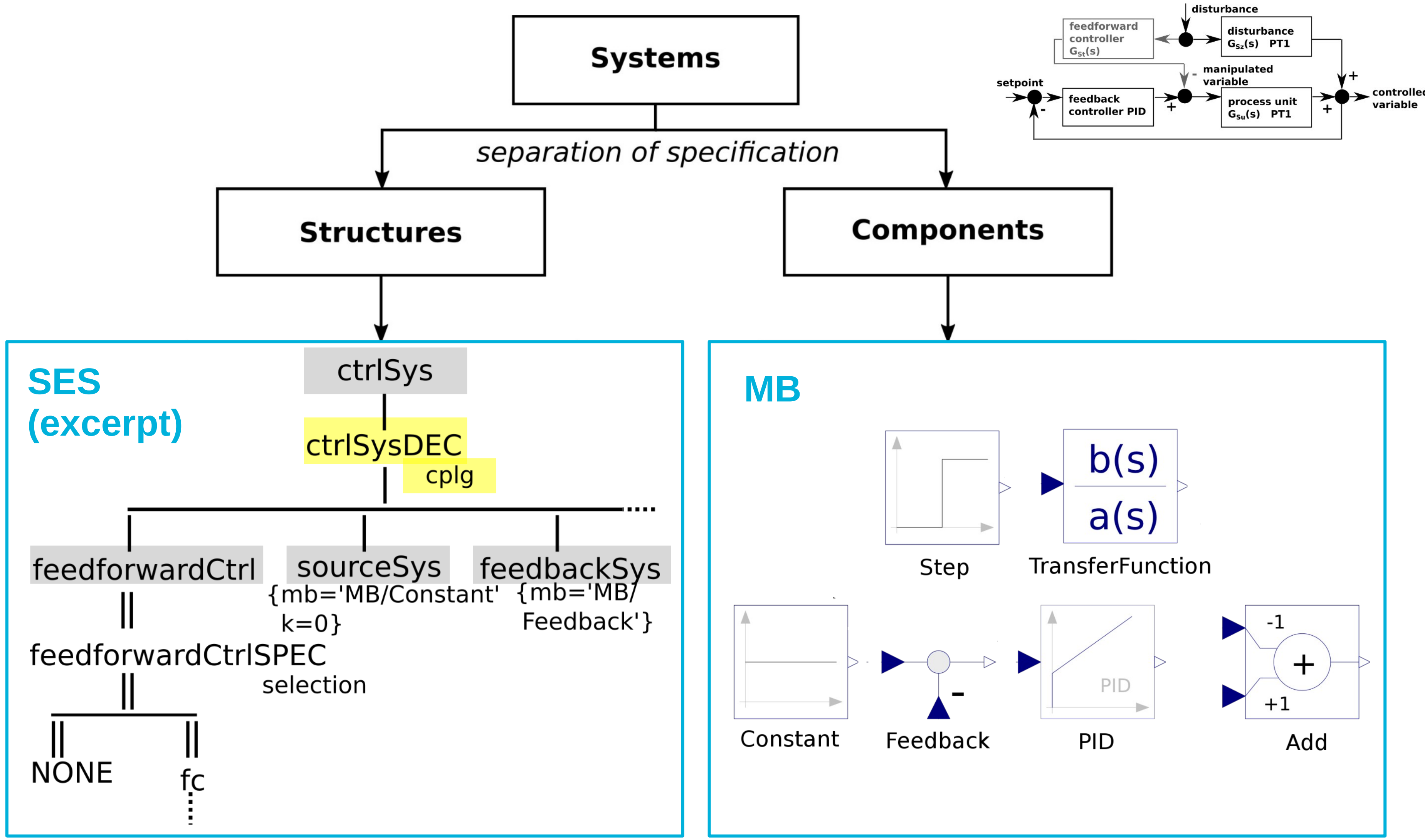

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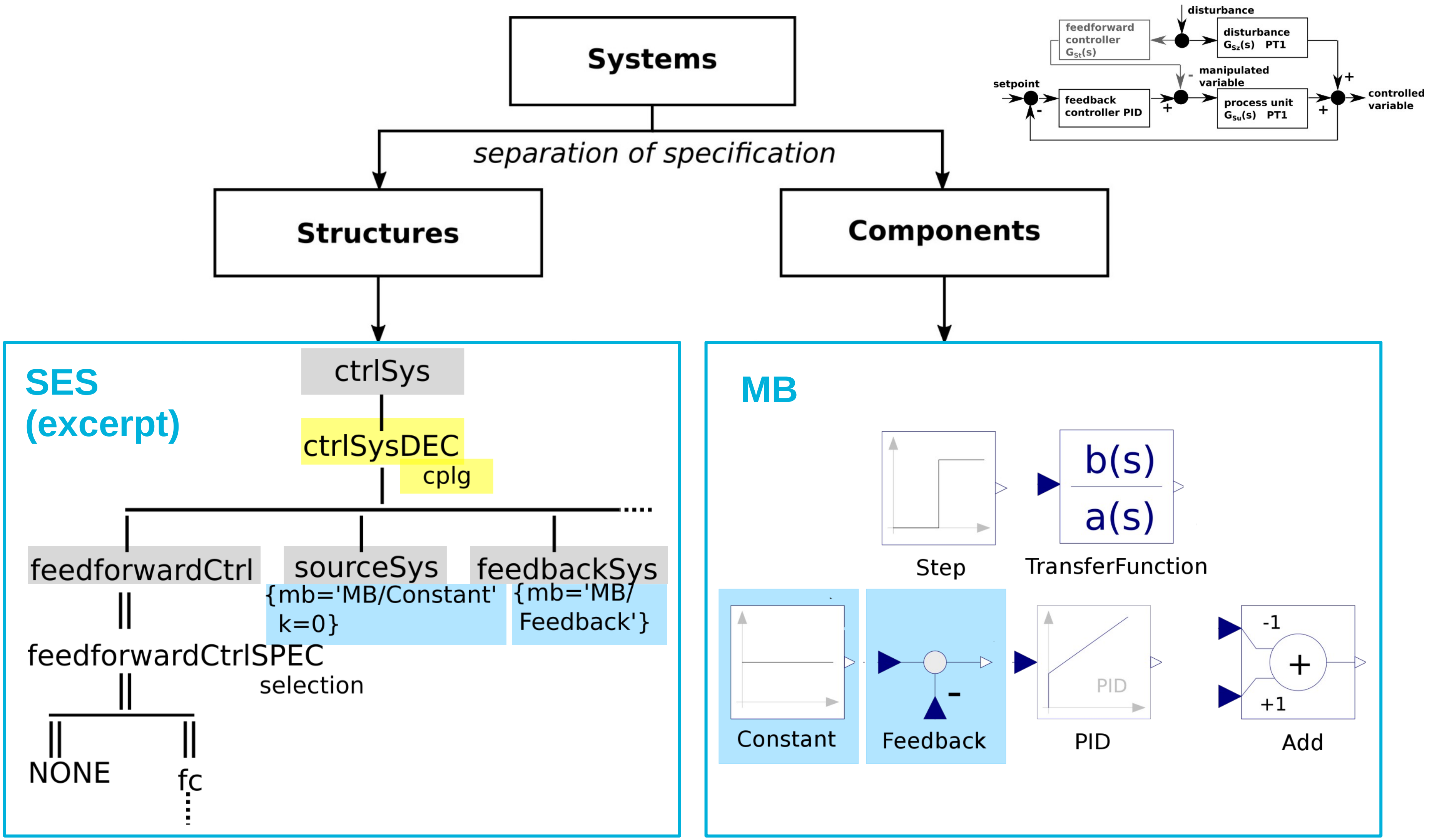

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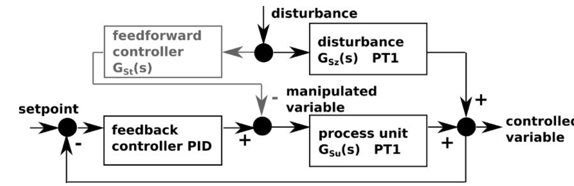

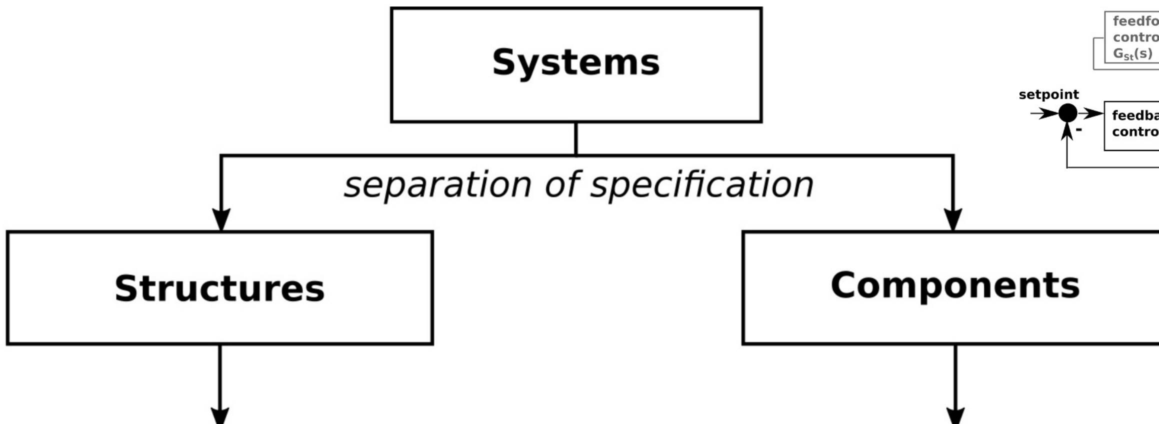

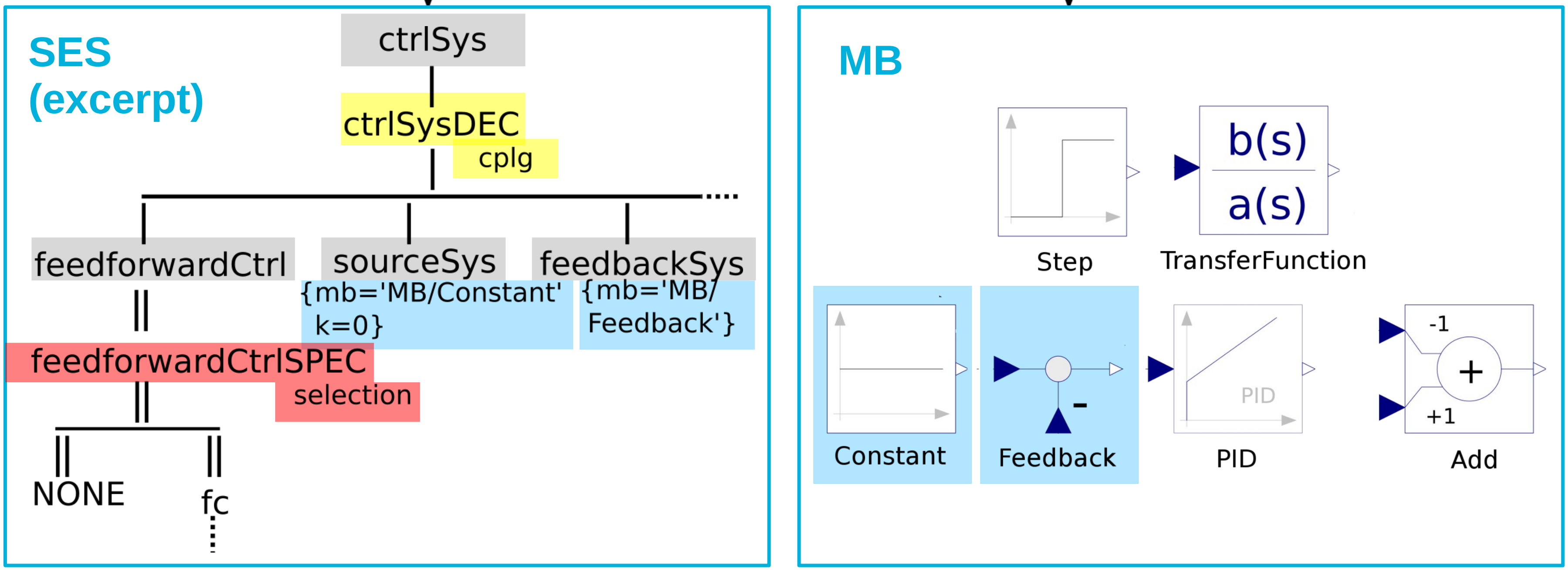

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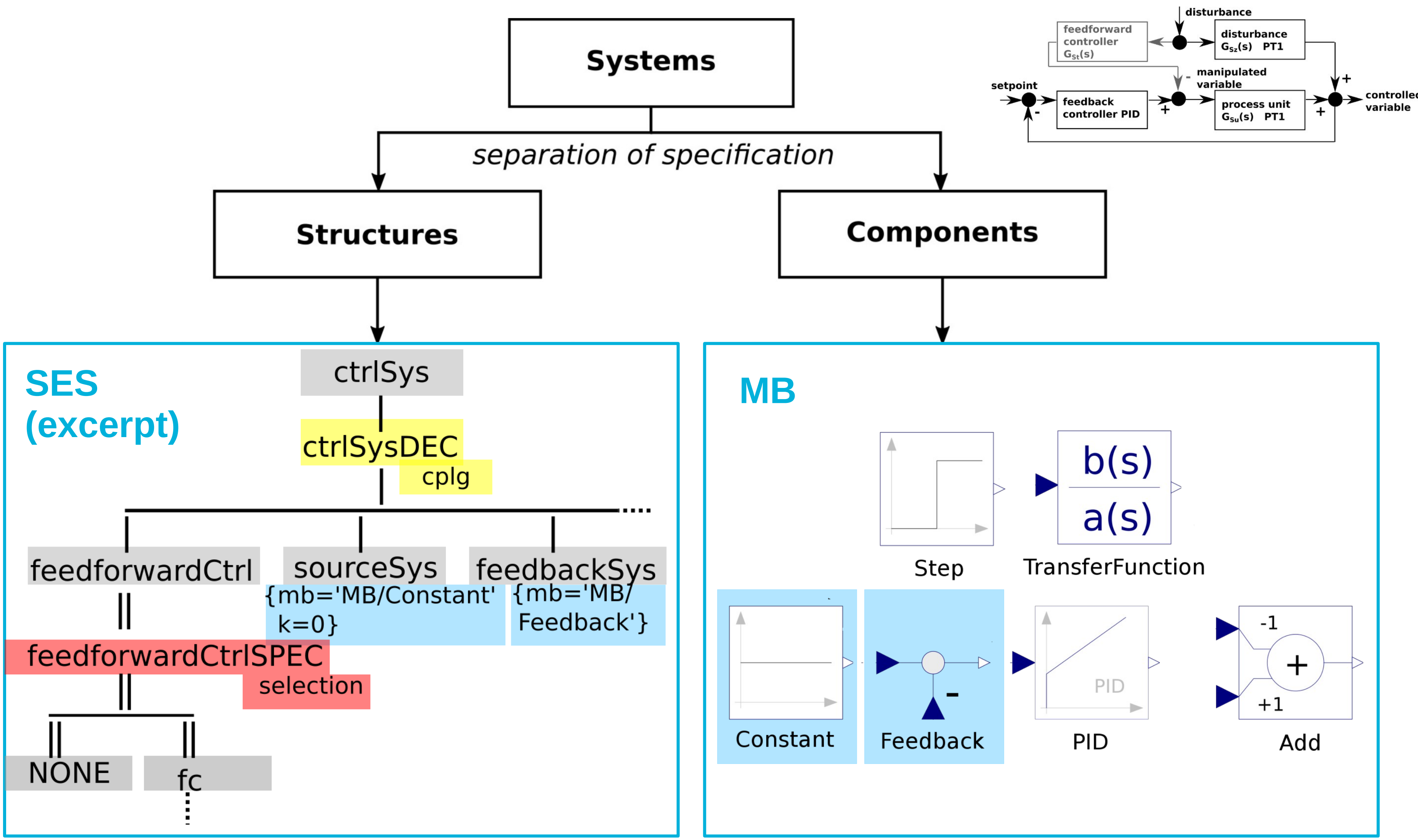
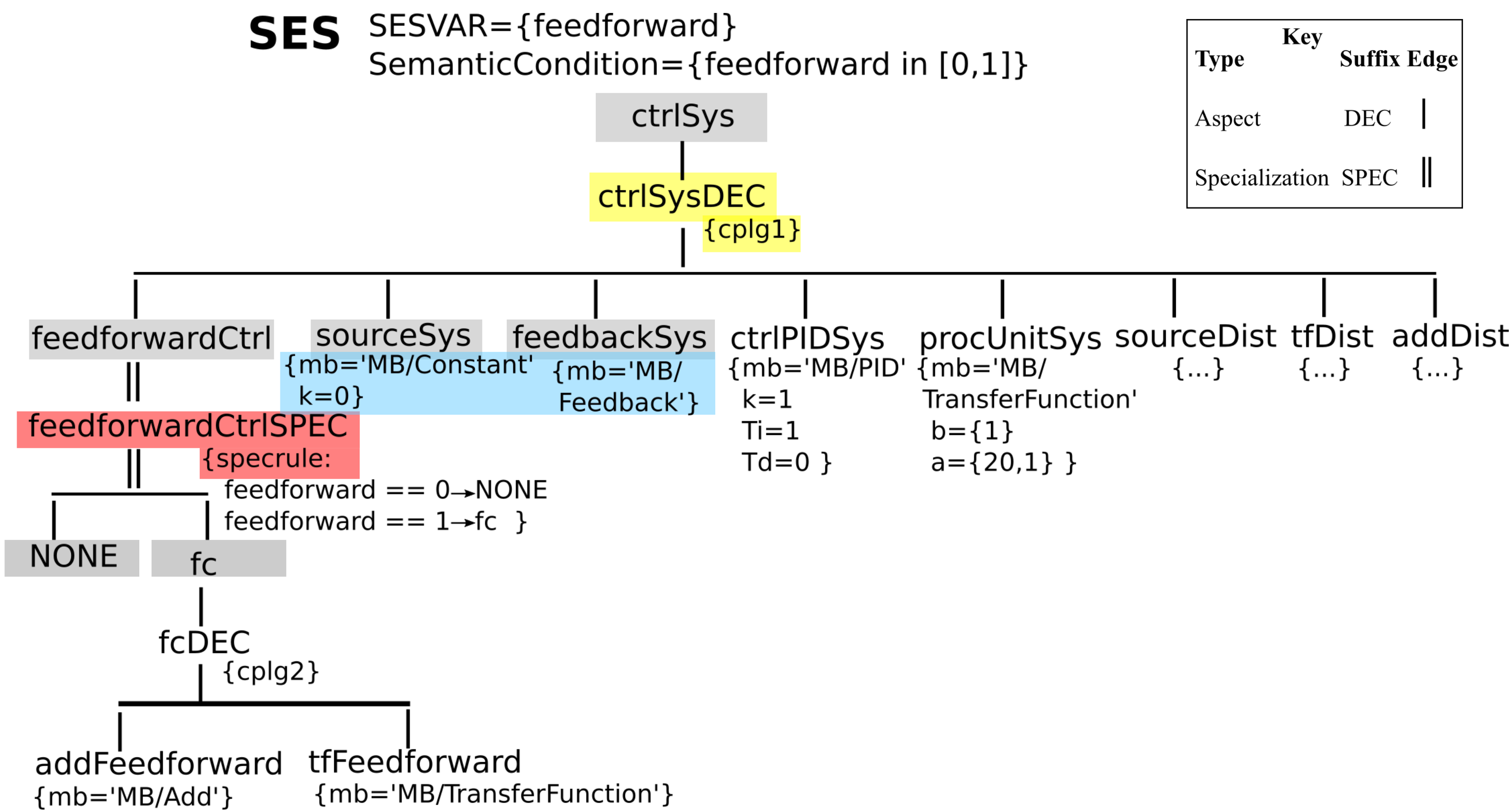


More Detailed Extract of the SES



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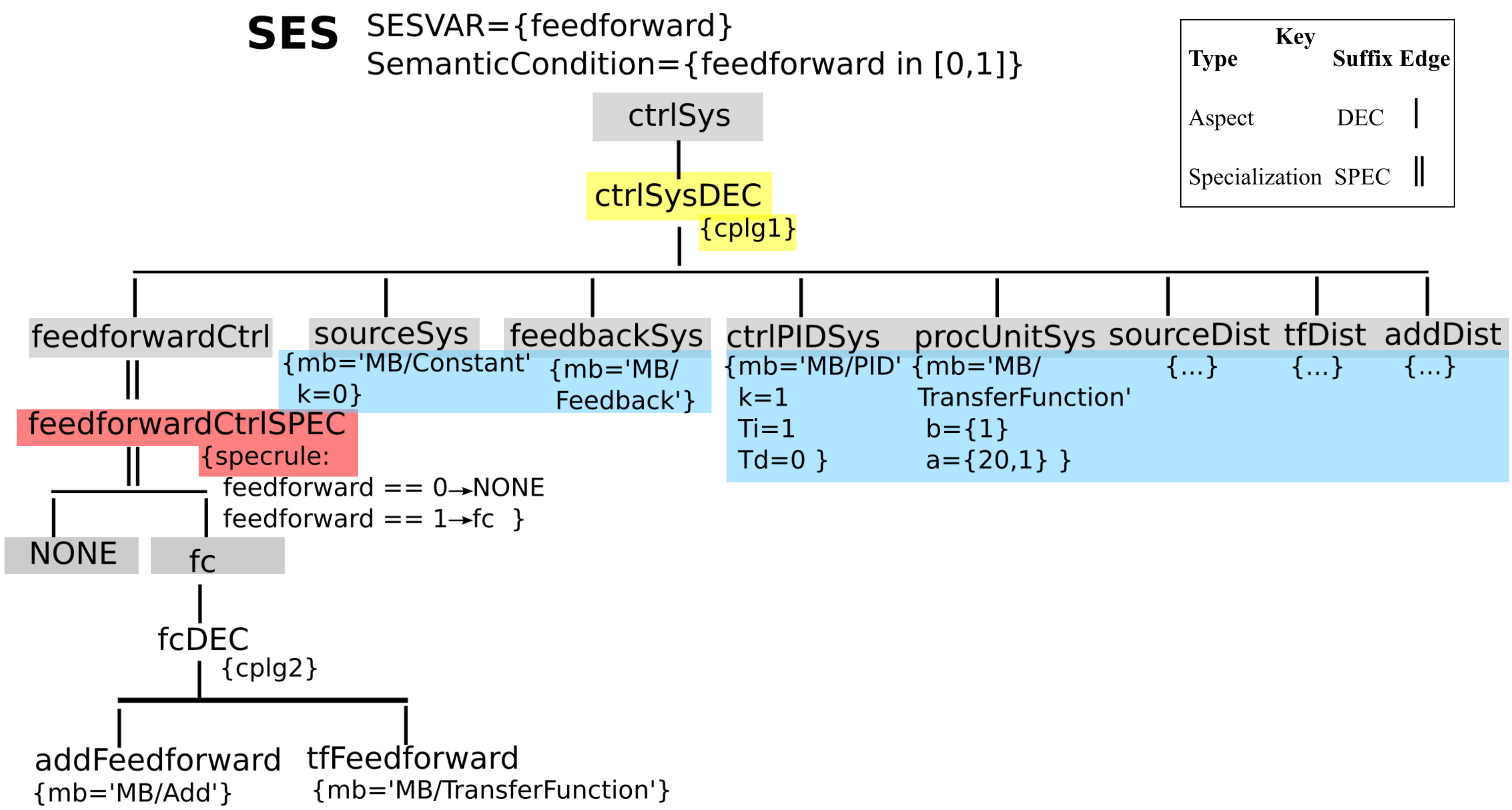

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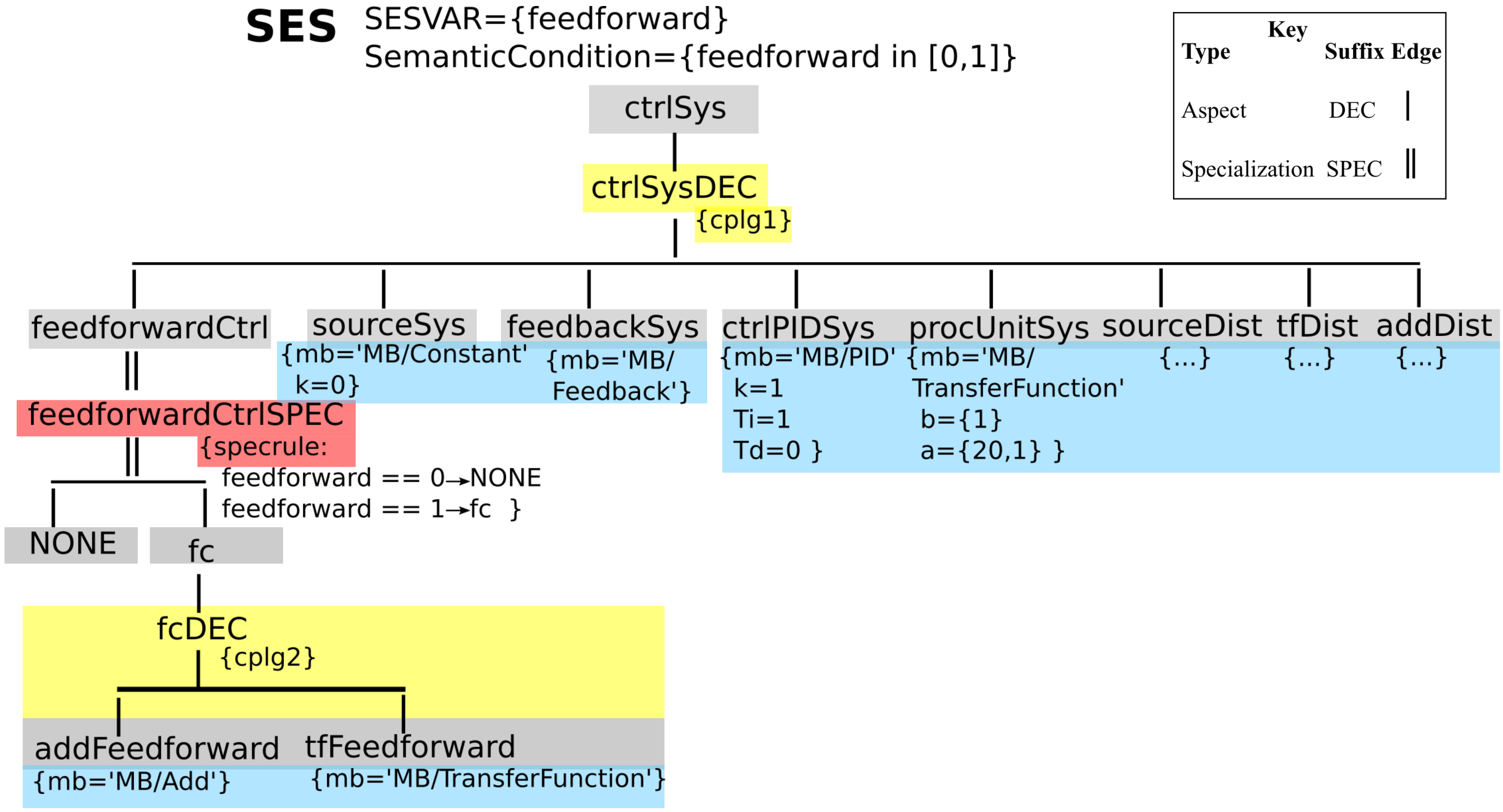

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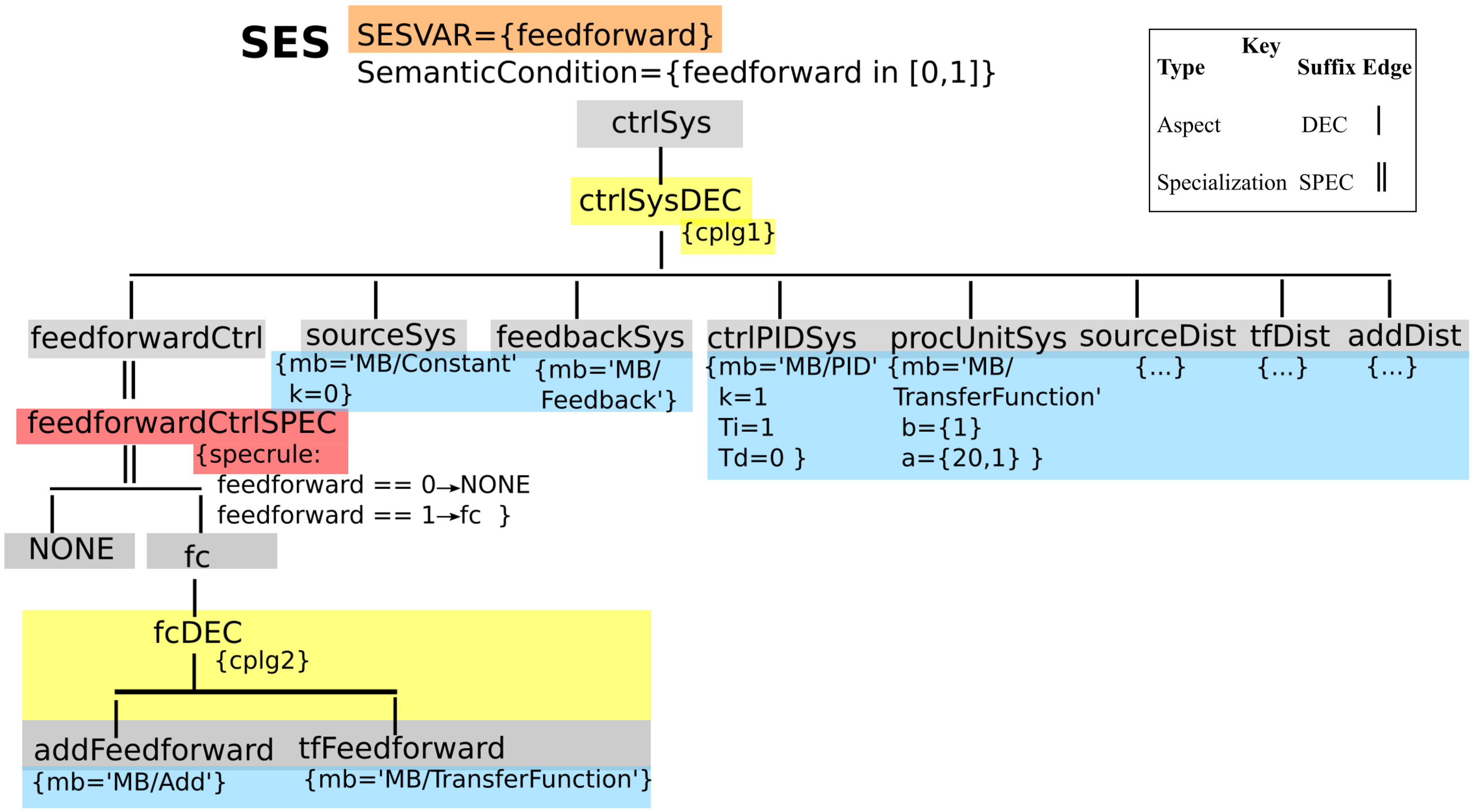

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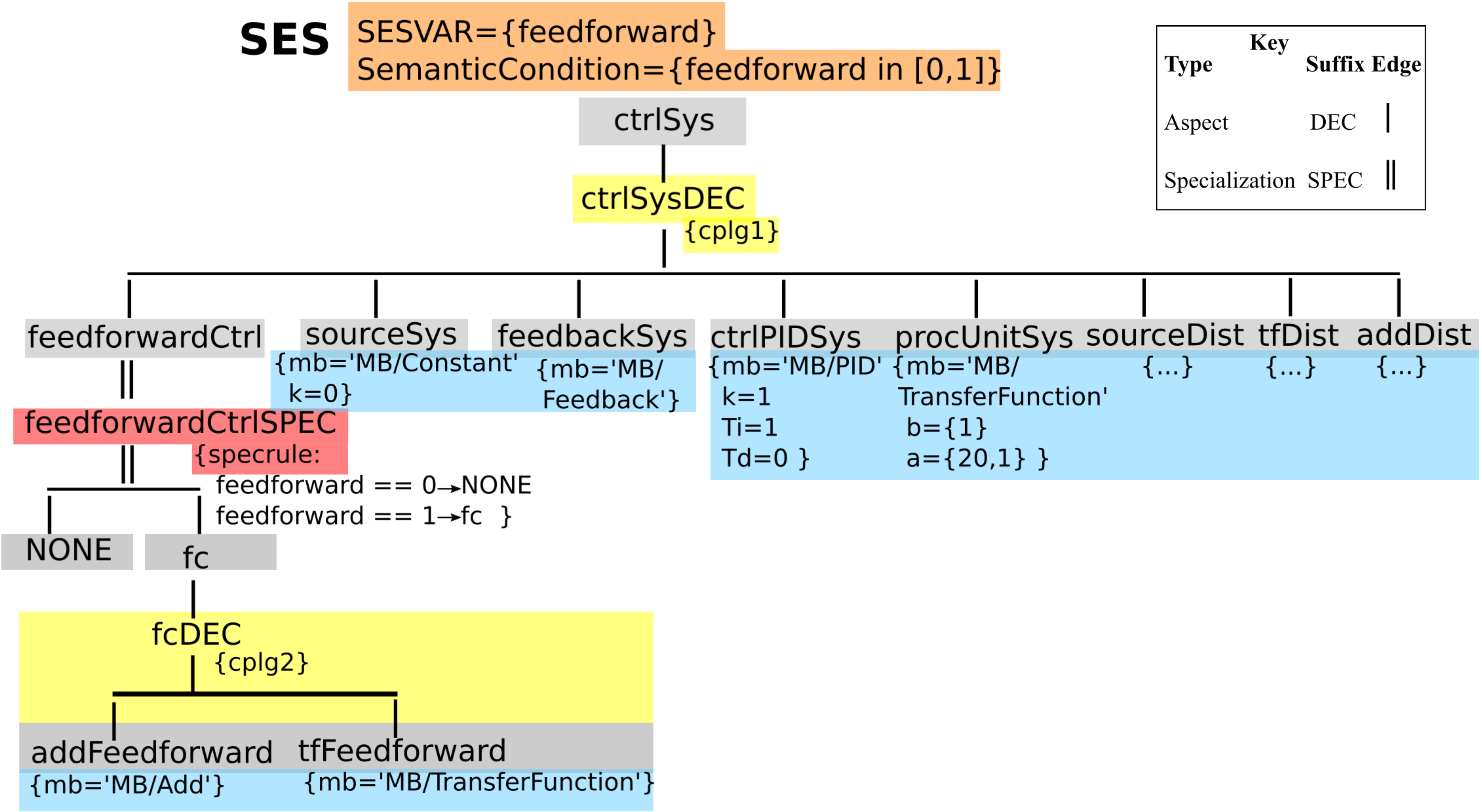
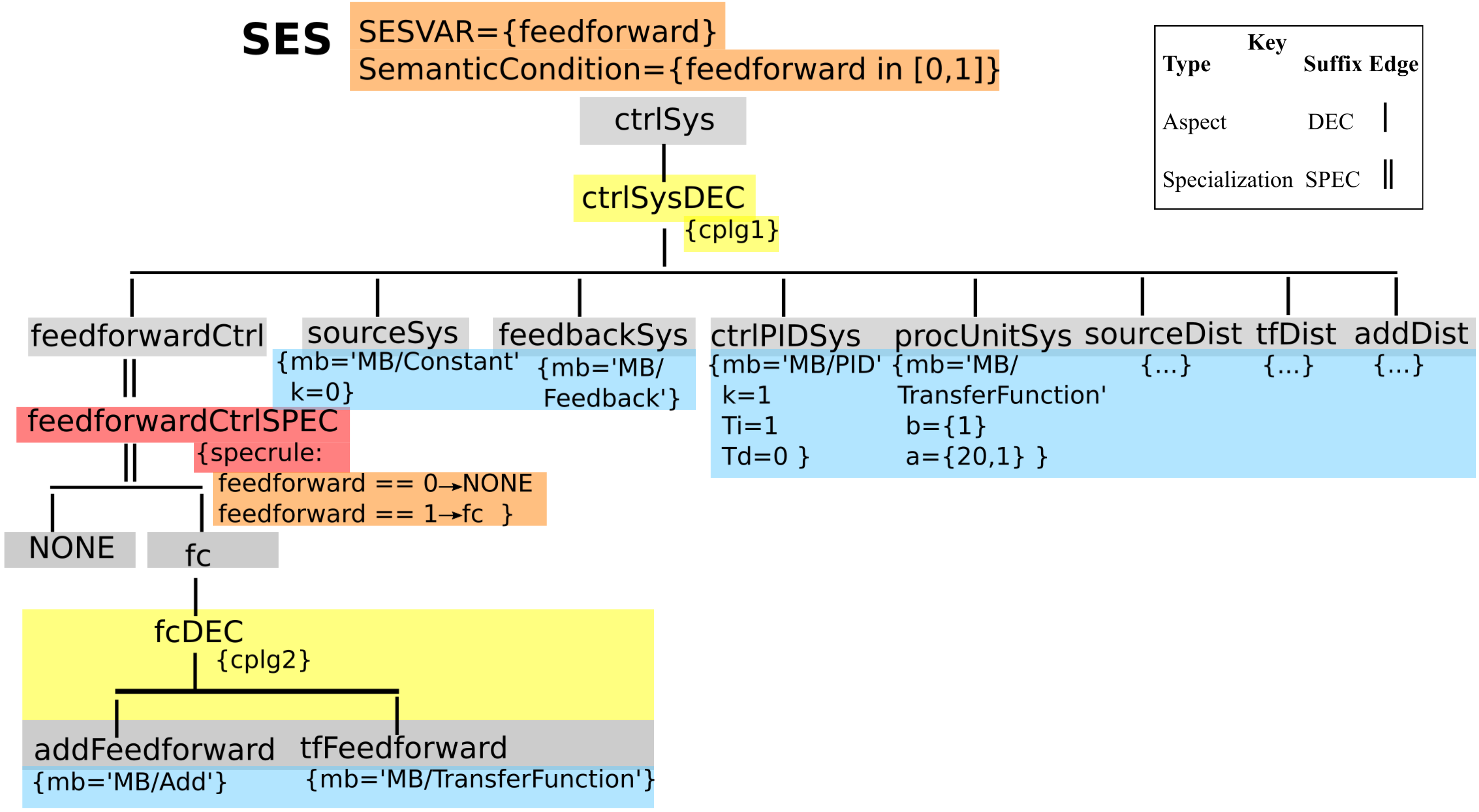
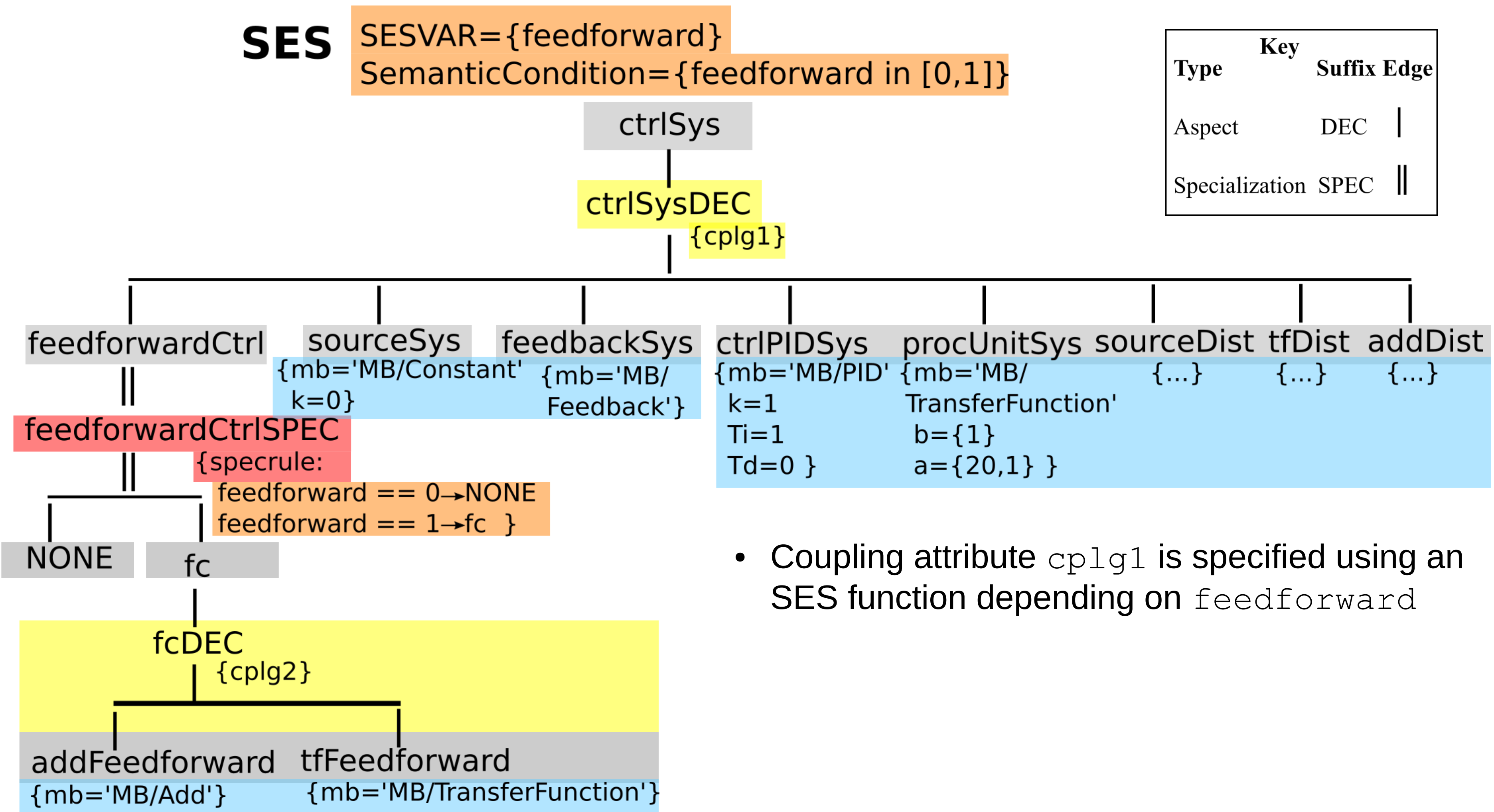


More Detailed Extract of the SES

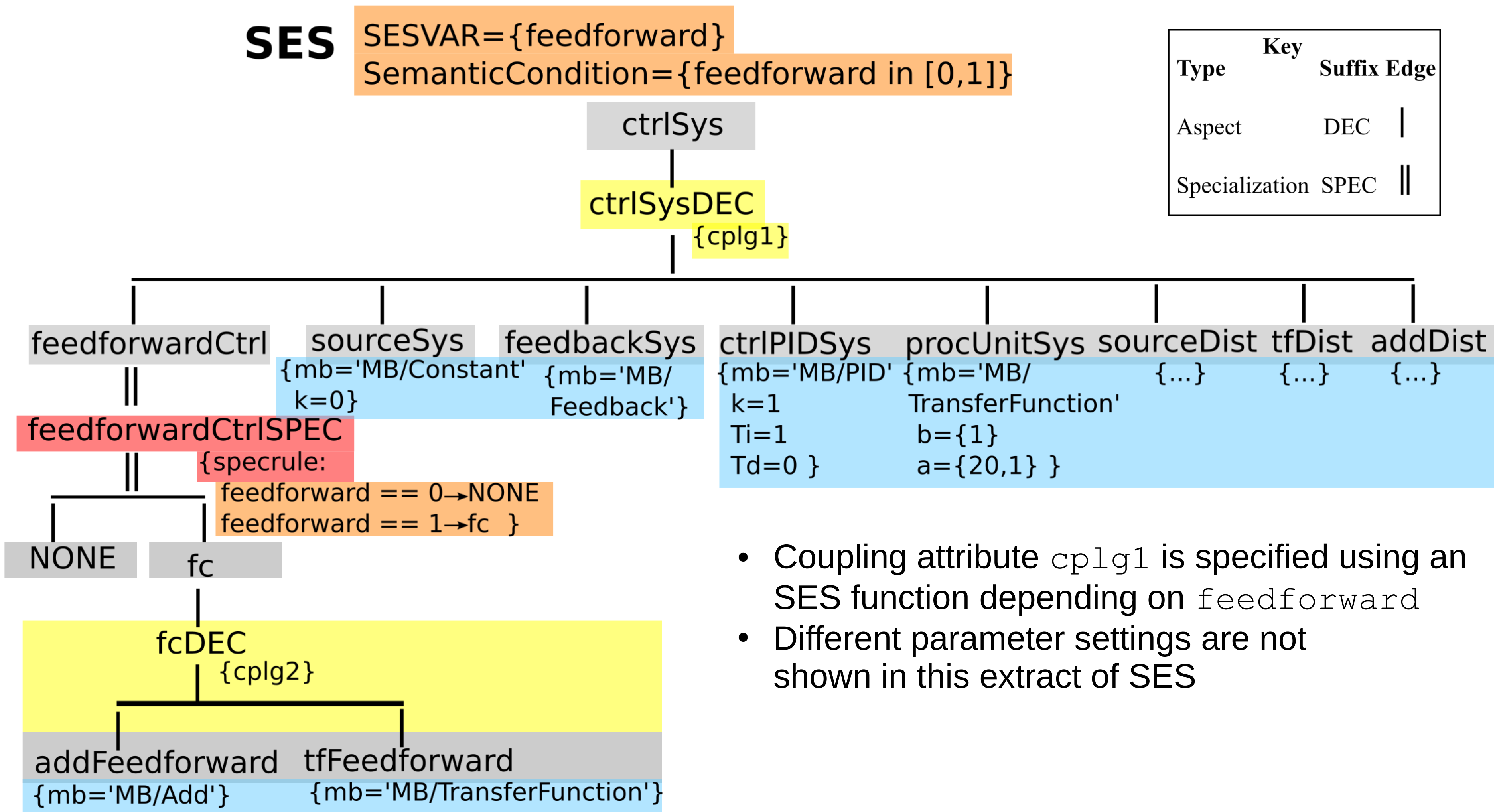


More Detailed Extract of the SES



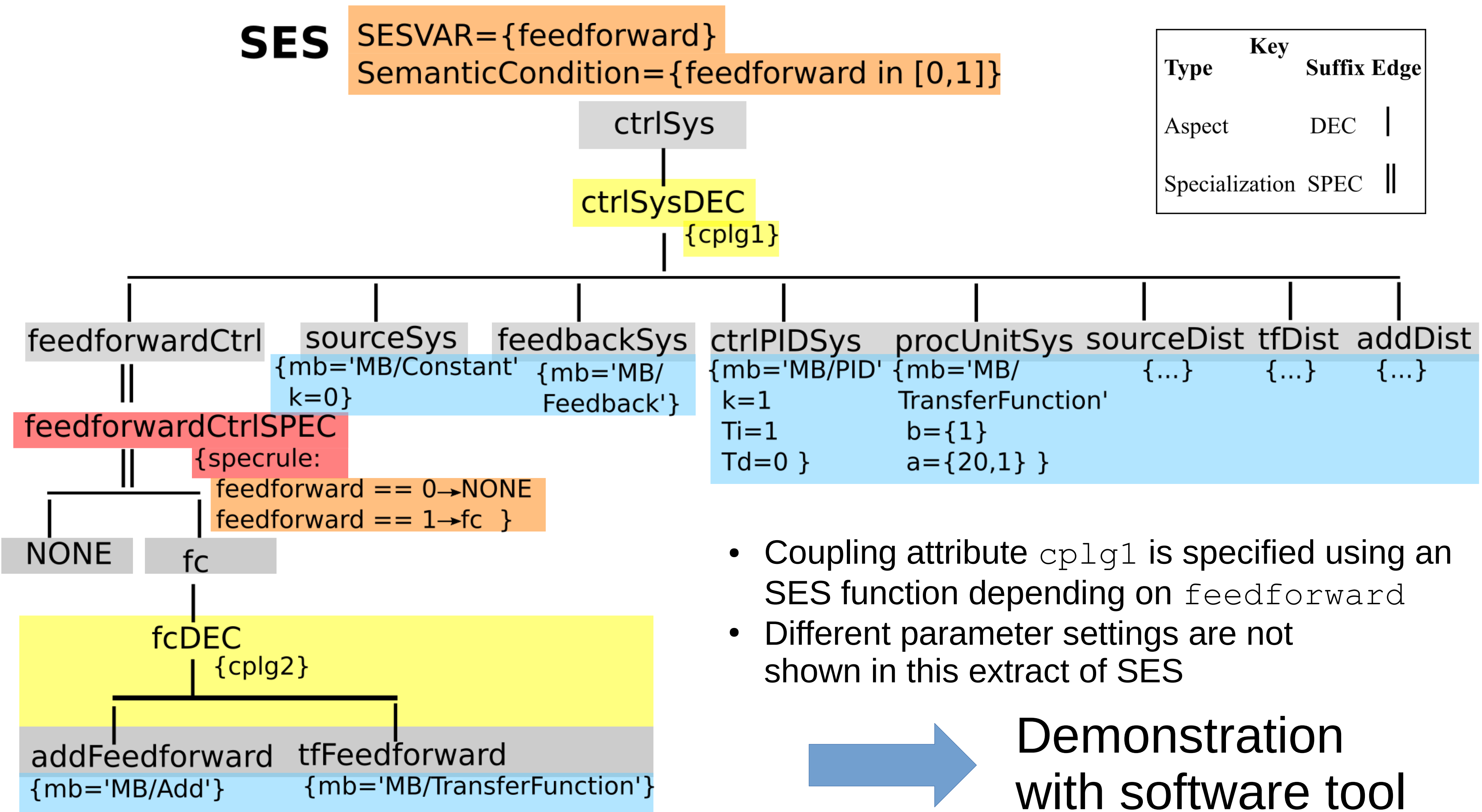
- Coupling attribute `cplg1` is specified using an SES function depending on `feedforward`

More Detailed Extract of the SES



- Coupling attribute `cplg1` is specified using an SES function depending on `feedforward`
- Different parameter settings are not shown in this extract of SES

More Detailed Extract of the SES



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- Different parameter settings are not shown in this extract of SES

Demonstration with software tool

Python Toolset

- Available:
  `https://github.com/cea-wismar/SESMB_Inf_Python/`

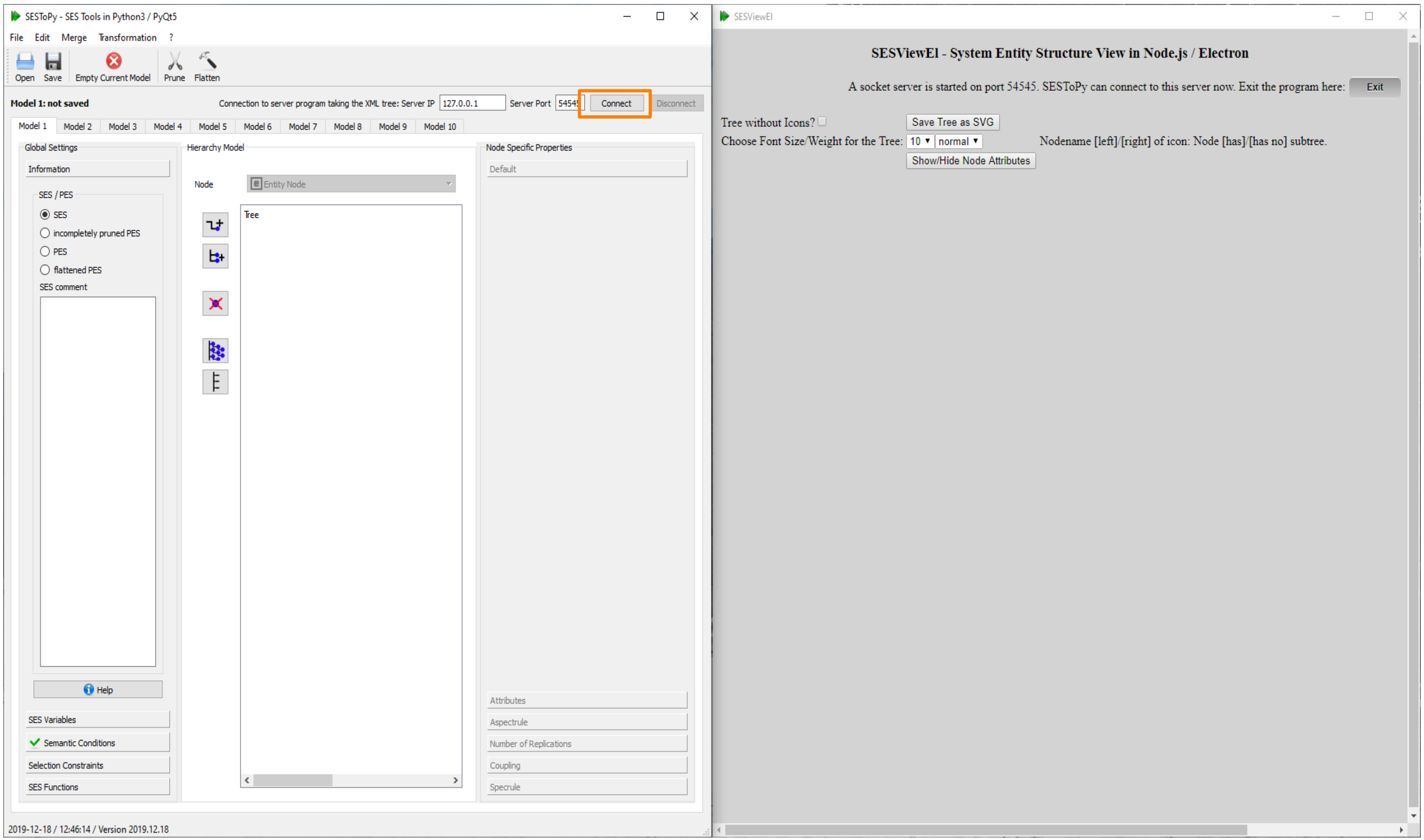
- Tools
  - **SESToPy** → SES editor and IDE
  - **SESViewEl** → SES tree viewer

  - SESMoPy
  - SESEuPy
  - SESEcPy

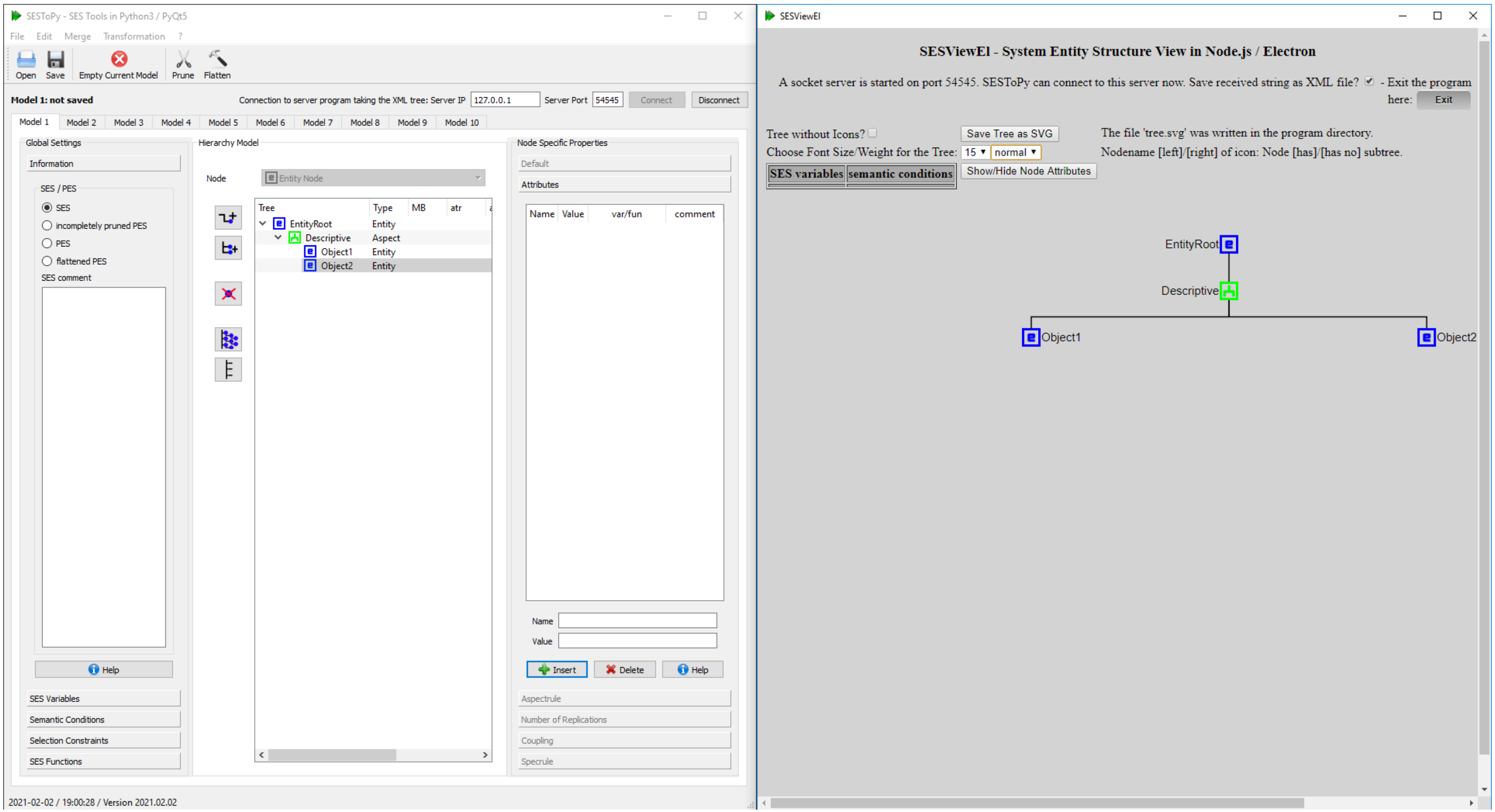
Demonstration of SESToPy with SESViewEl (case study) → Screenshots on Next Slides

- Connect SESToPy with SESViewEl (show SESToPy and SESViewEl next to each other)
- Add sub node, add sibling node, change type of node, rename node, delete node, inflate tree, deflate tree
- Edit entity node, descriptive node (aspect, specialization)
- Empty current model
- Save/Load model (JSON) → load `Feedback.jsonsestree` example
- Export/Import model (XML)
- Maximize SESToPy
- Use the feedback example to show:
  - SES Variables, Semantic Conditions
  - Selection rules → here: specrule
  - NONE node
  - Attributes, mb-attribute (decouple name of node and name of basic model)
  - Coupling list (composition of basic models)
  - SES function to set couplings (dynamic coupling) → procedural knowledge
- Merging

Connection of SESToPy and SESViewEl



Create SES Tree with SESToPy



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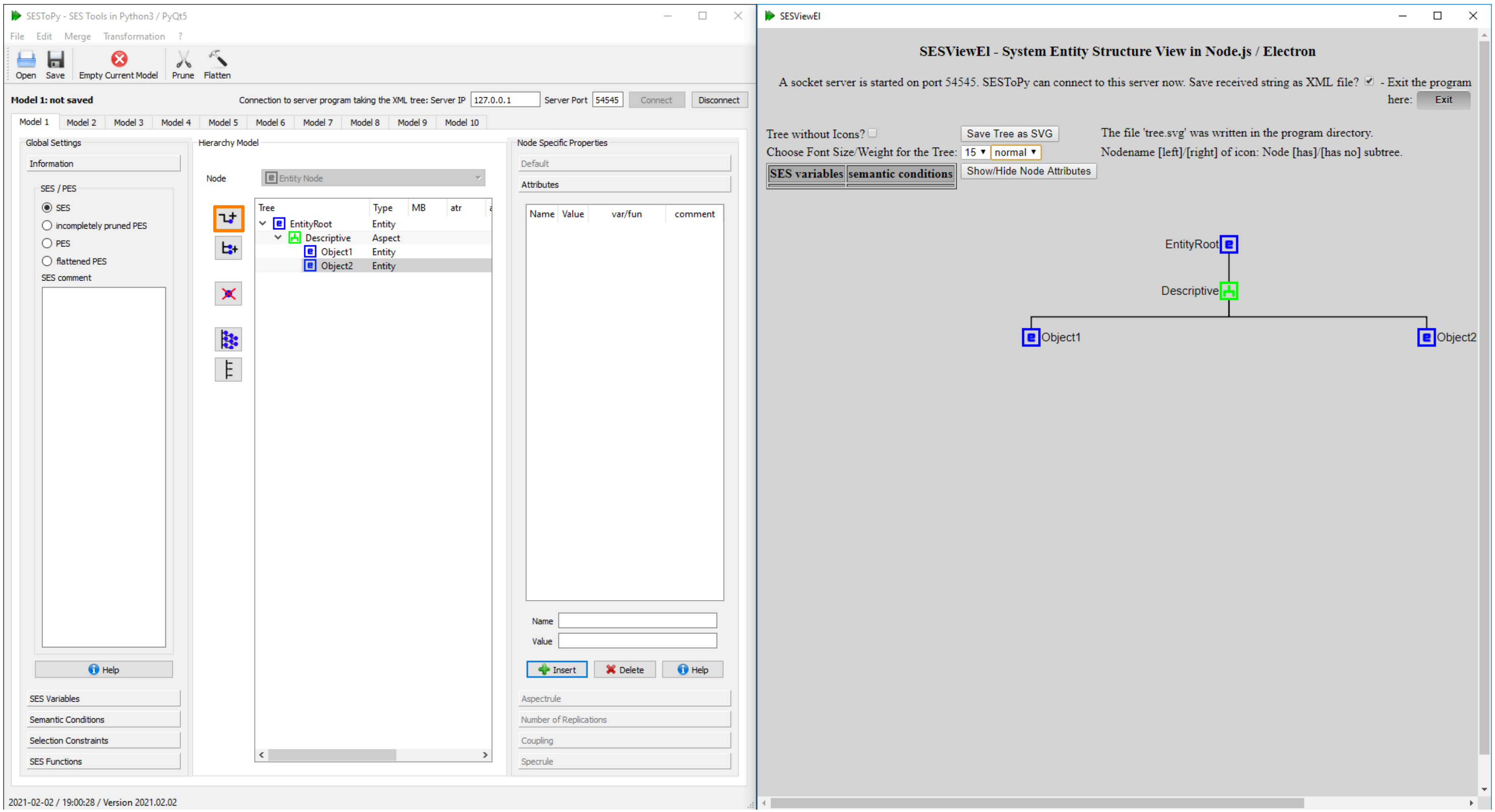

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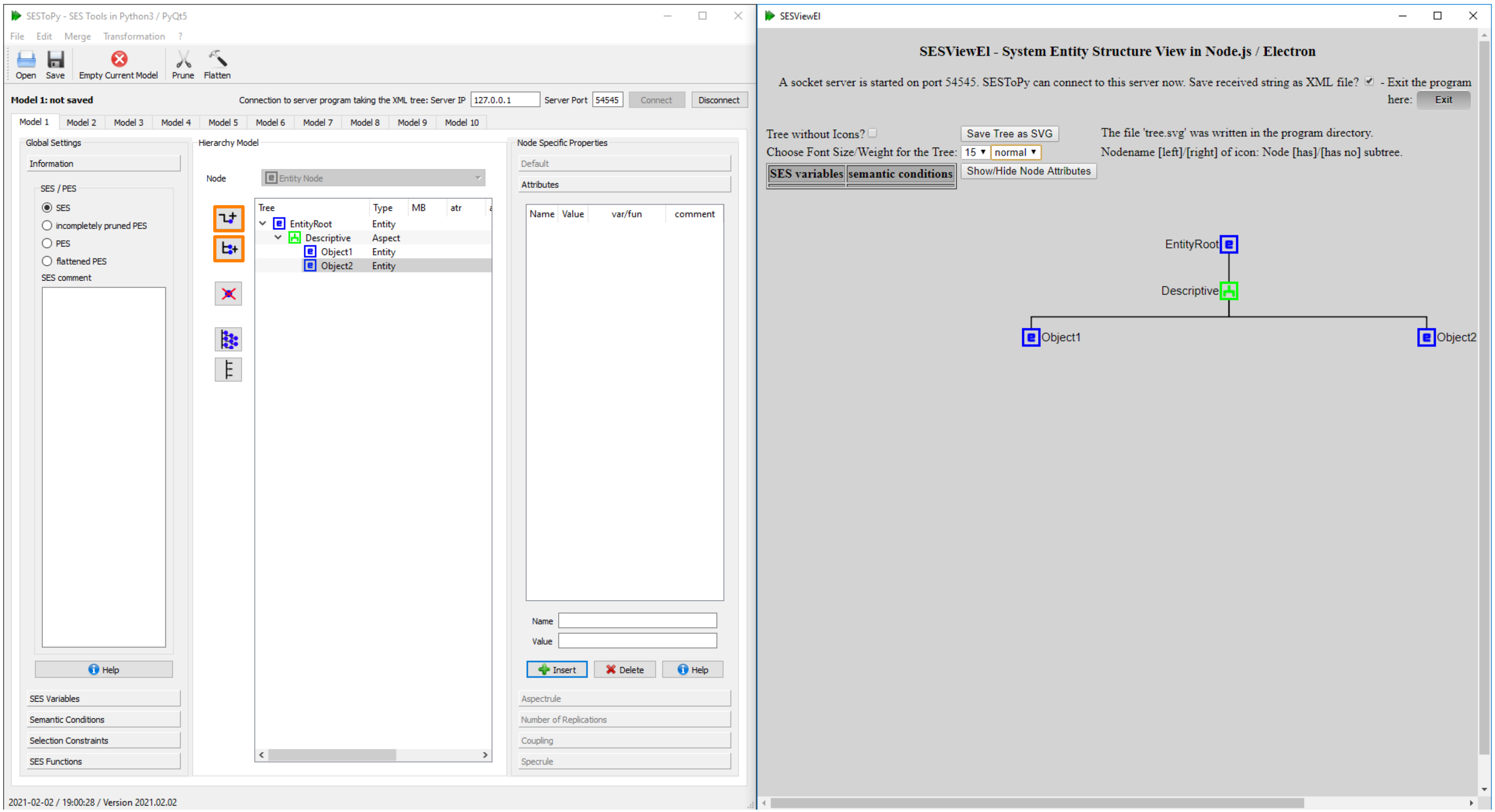

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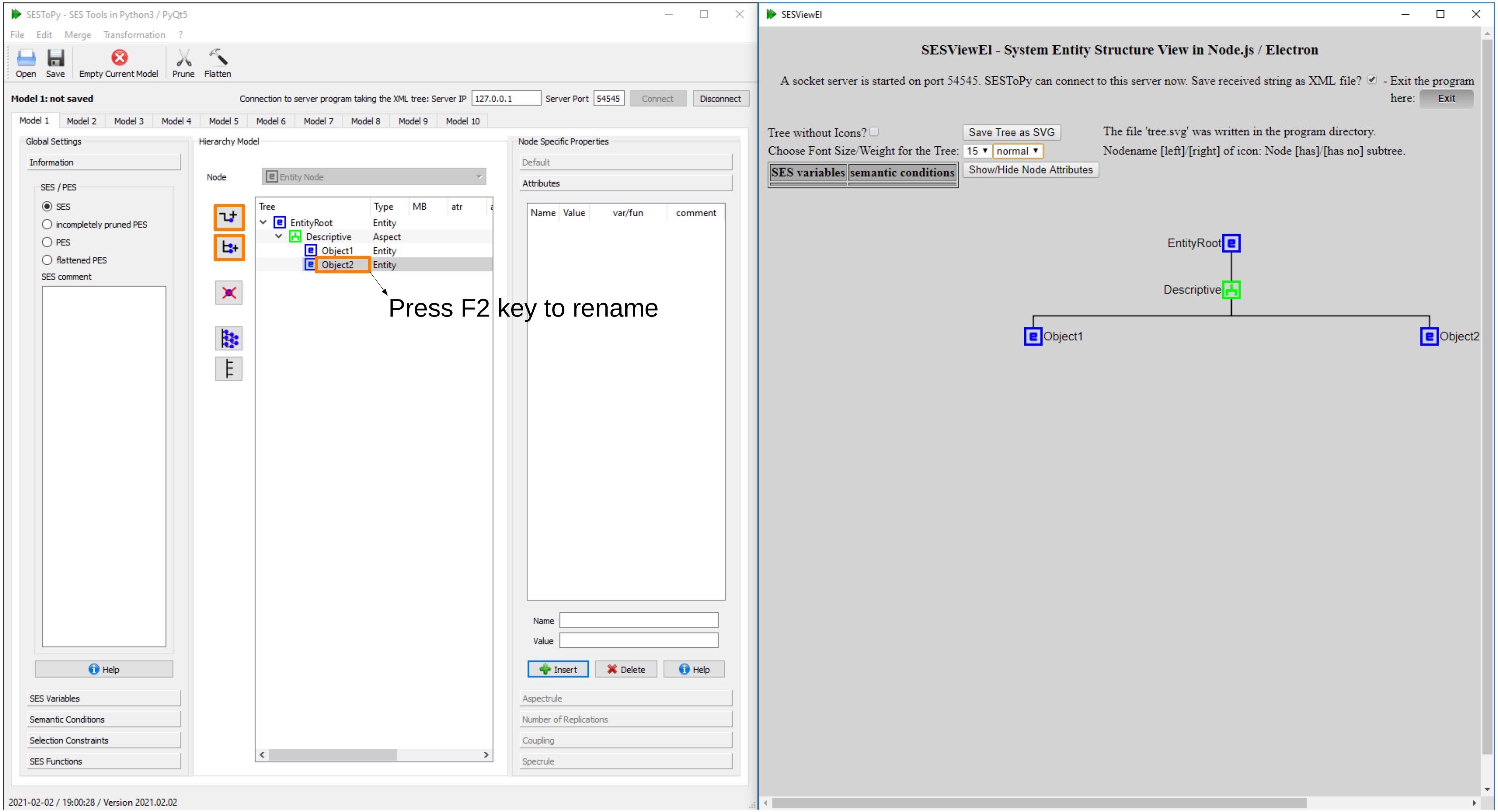

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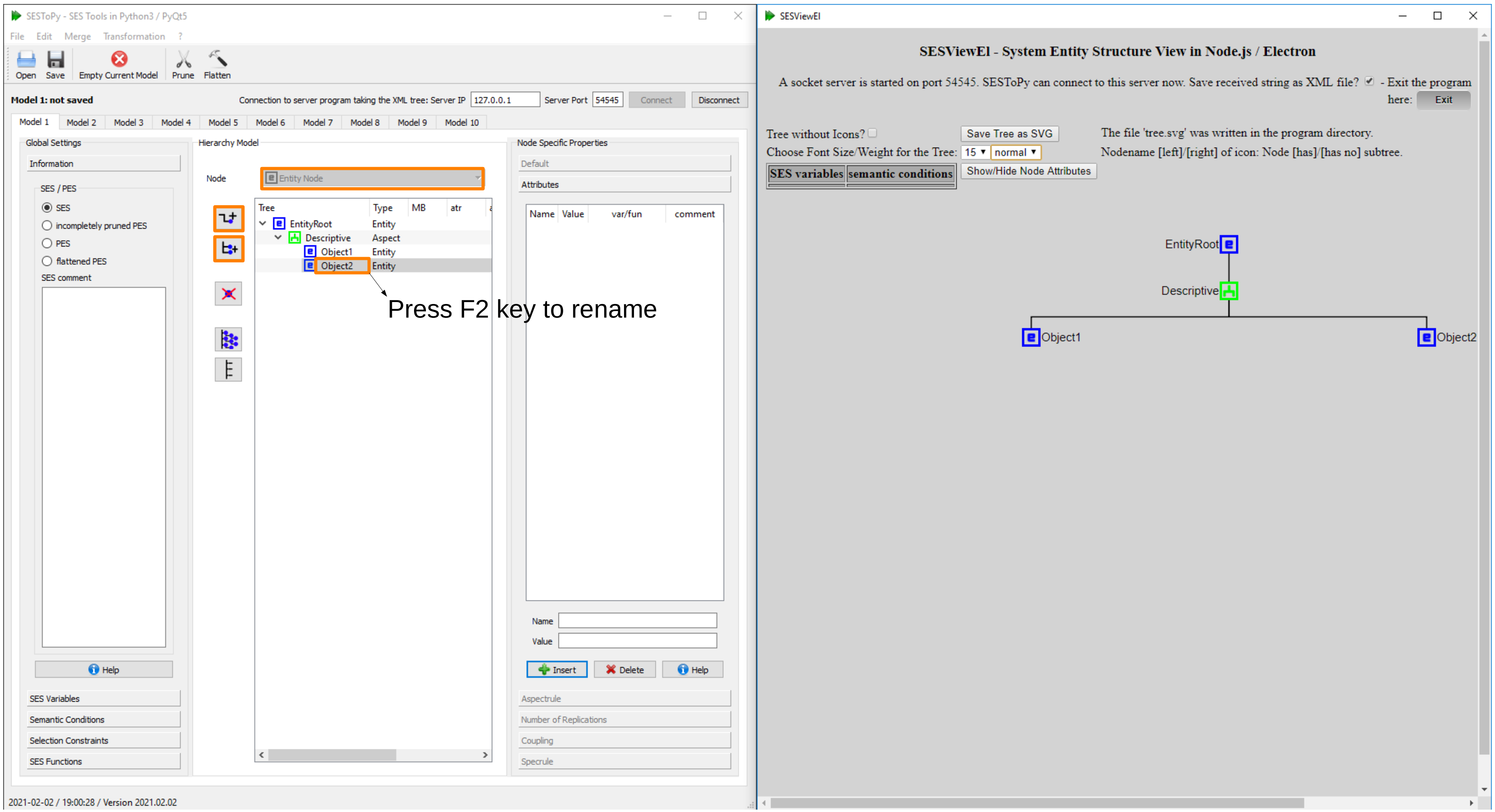

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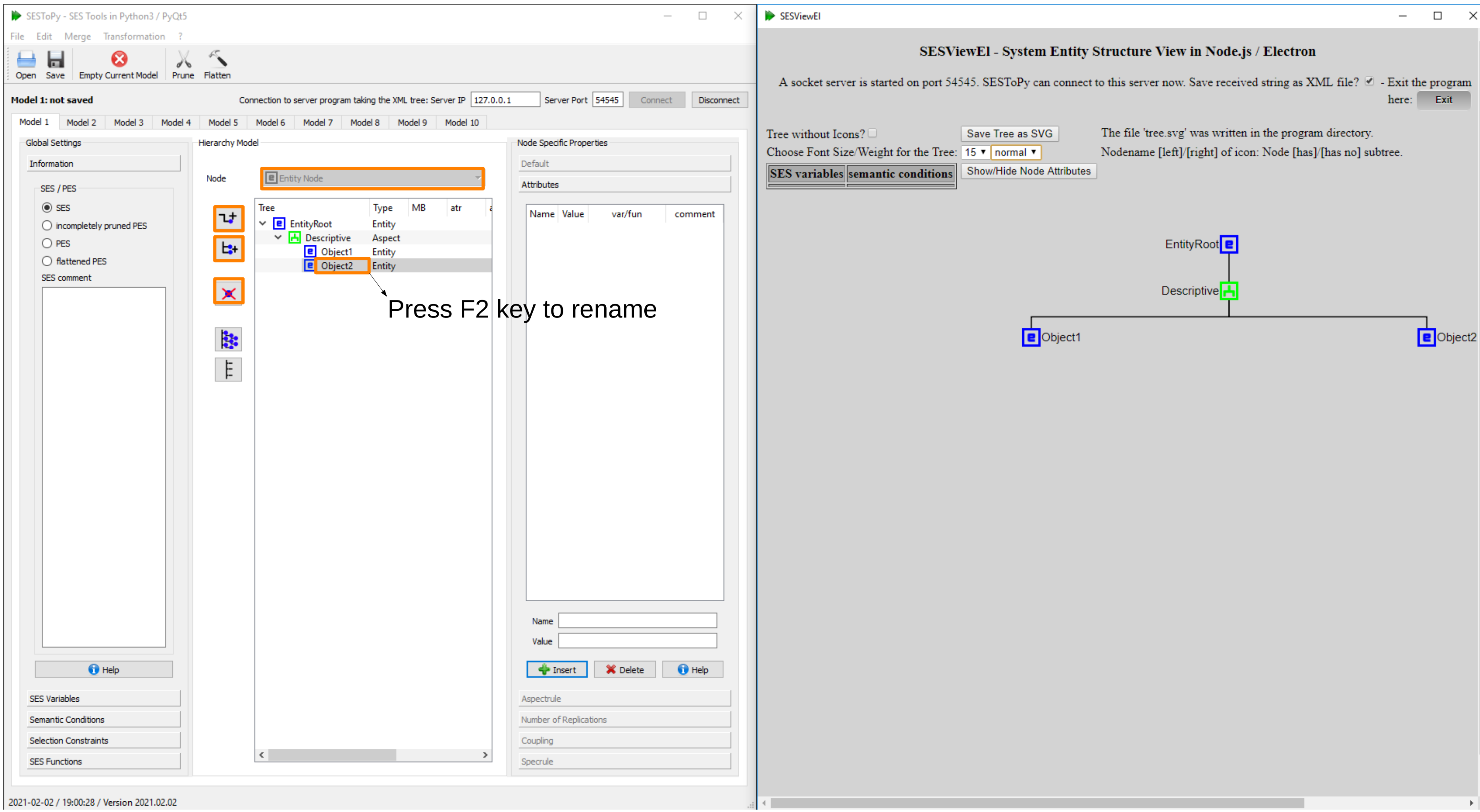

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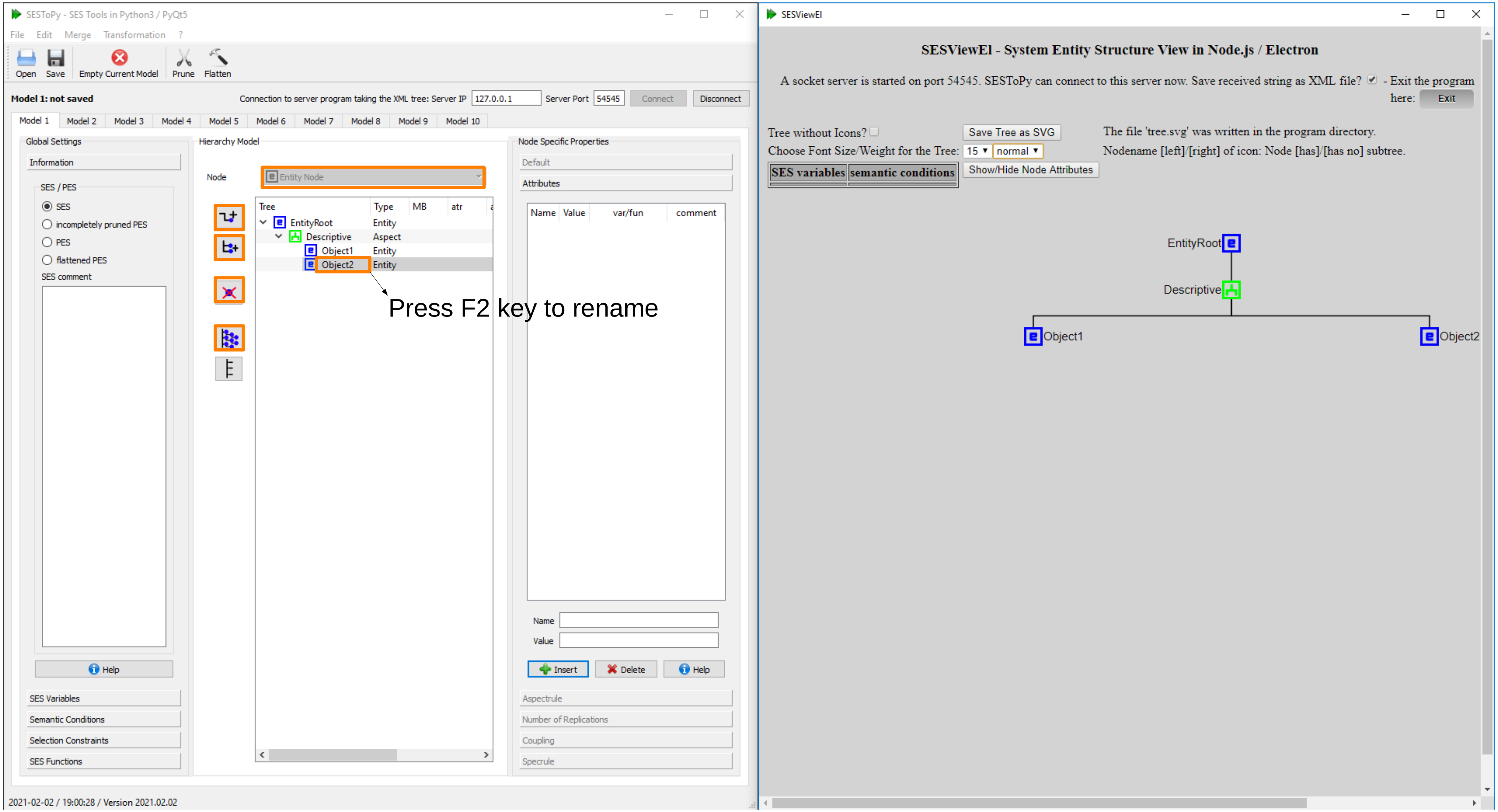

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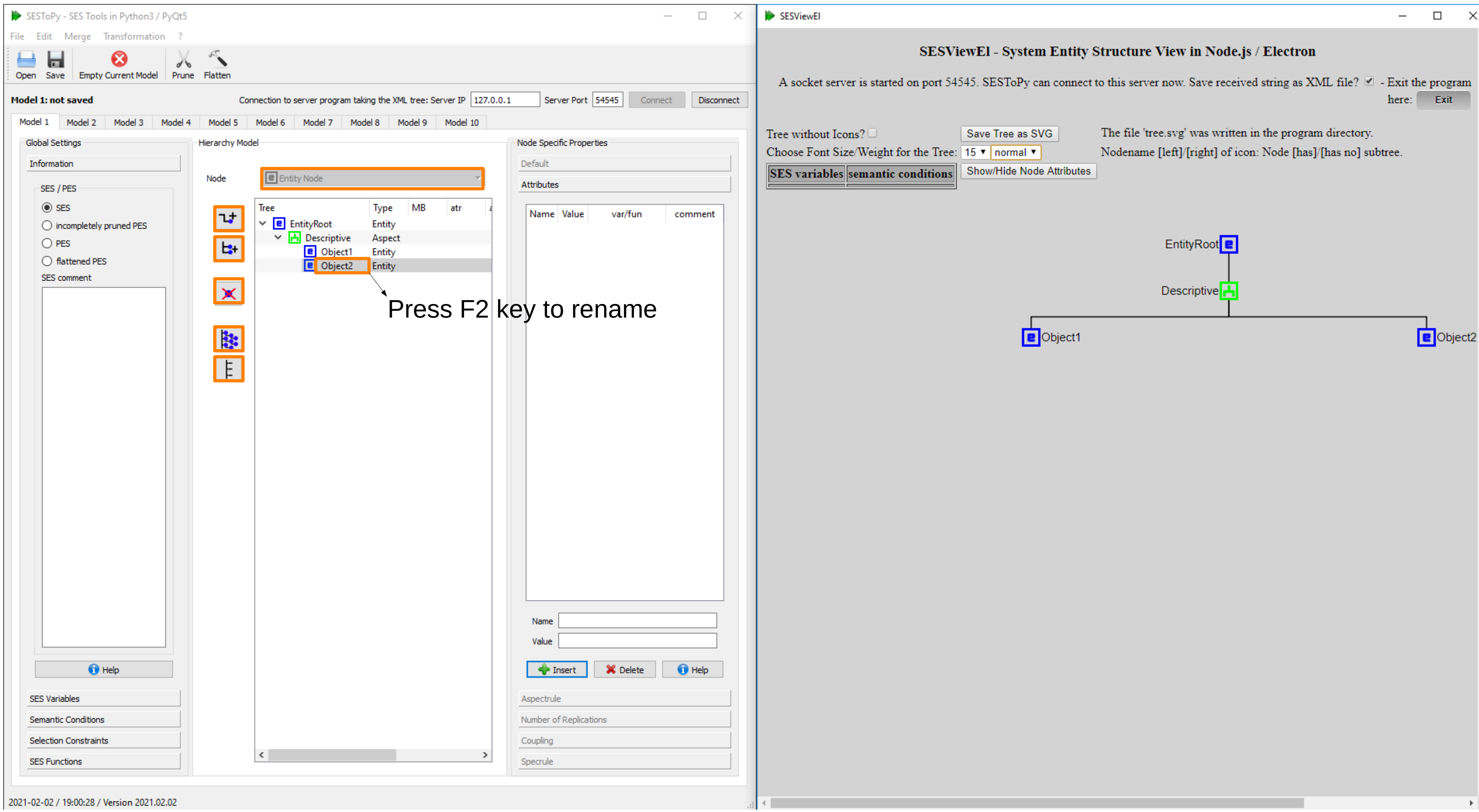

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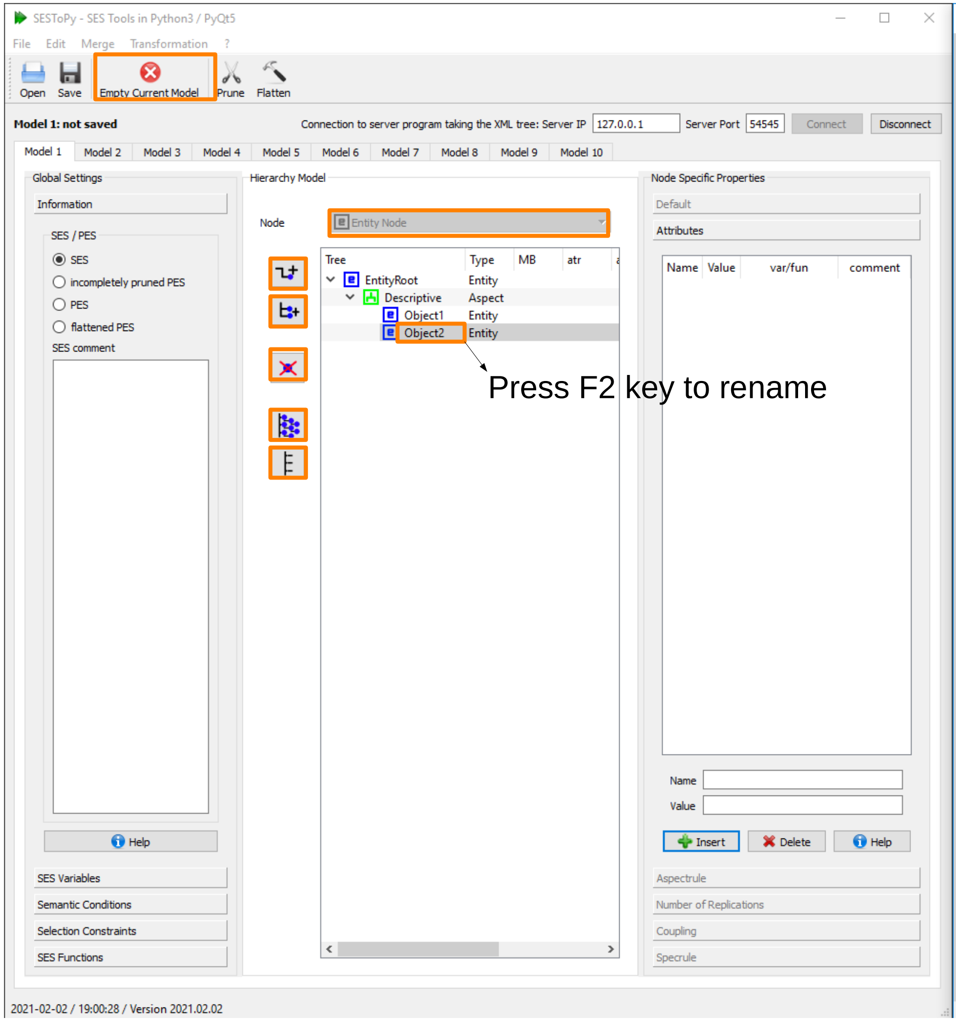
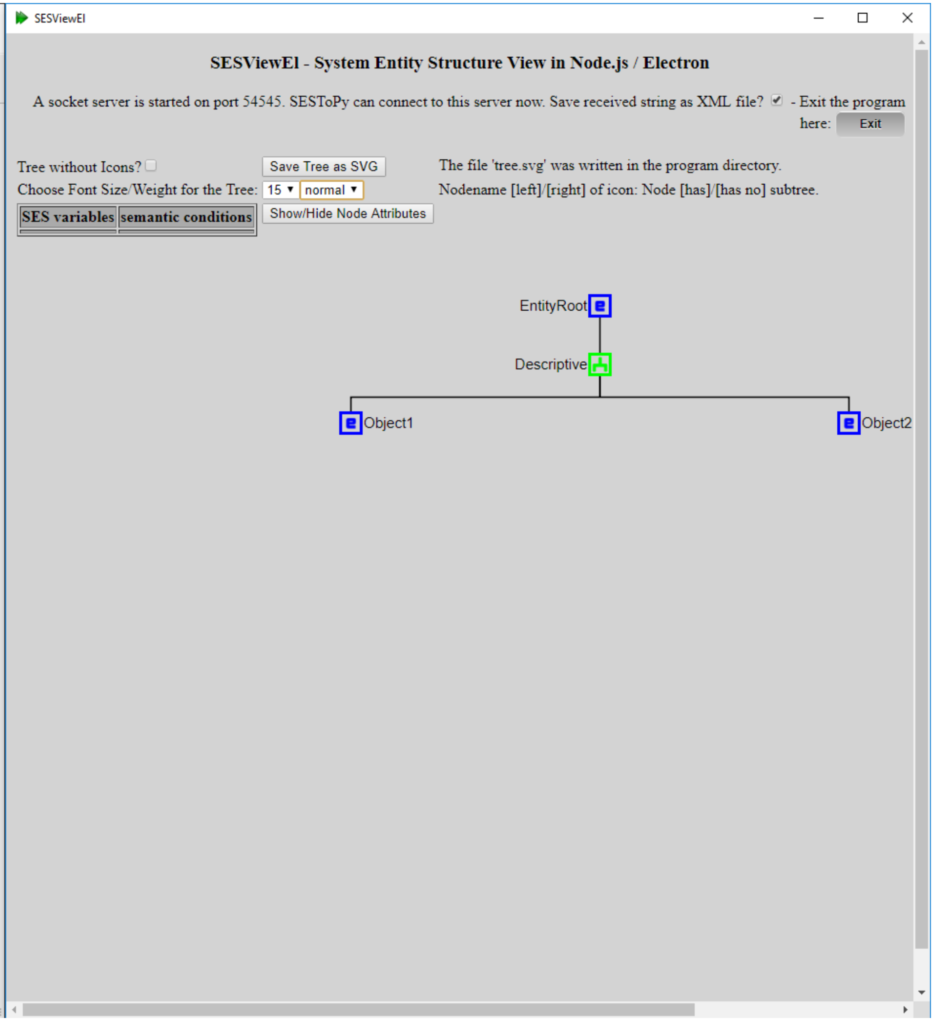
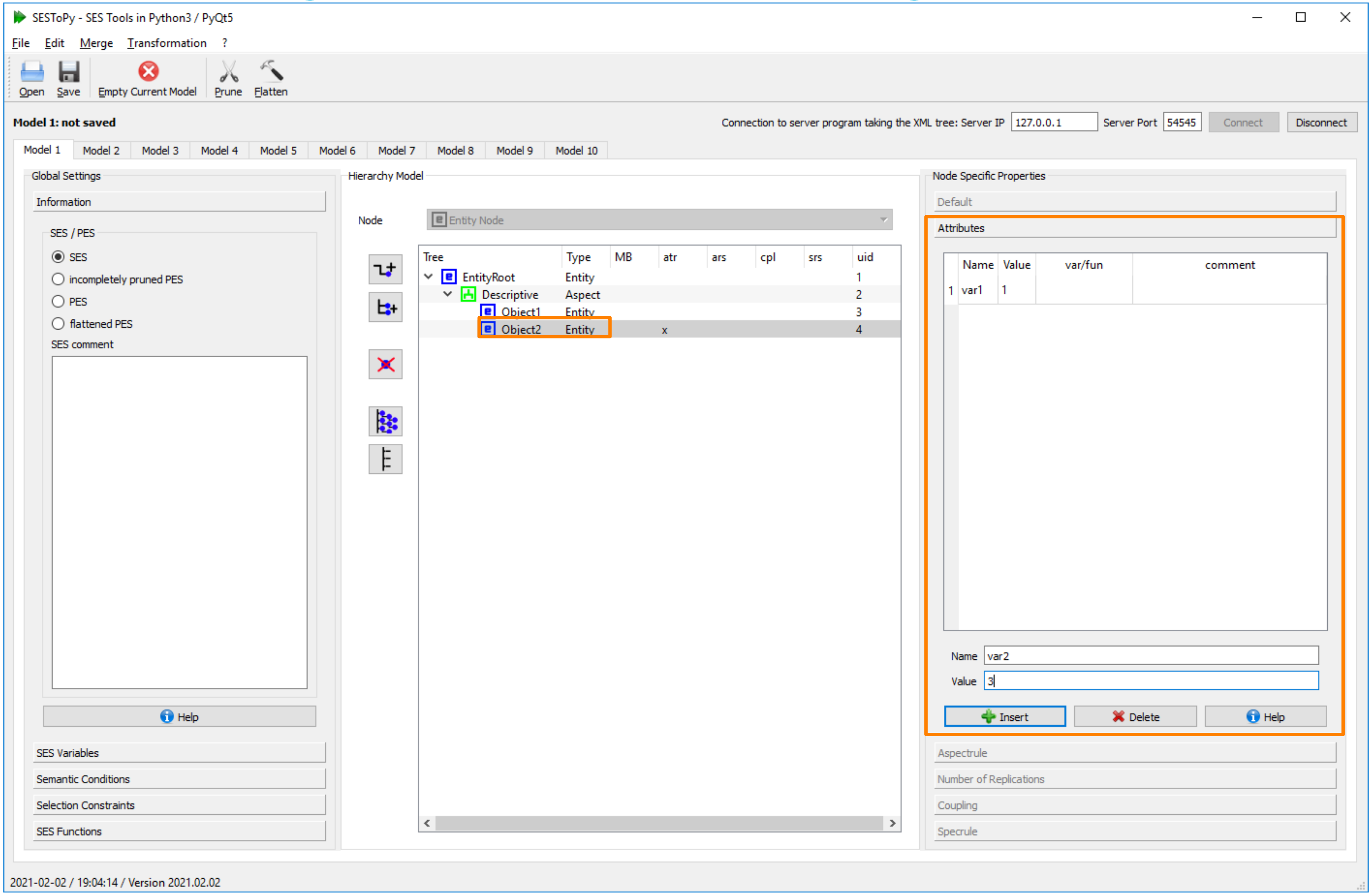
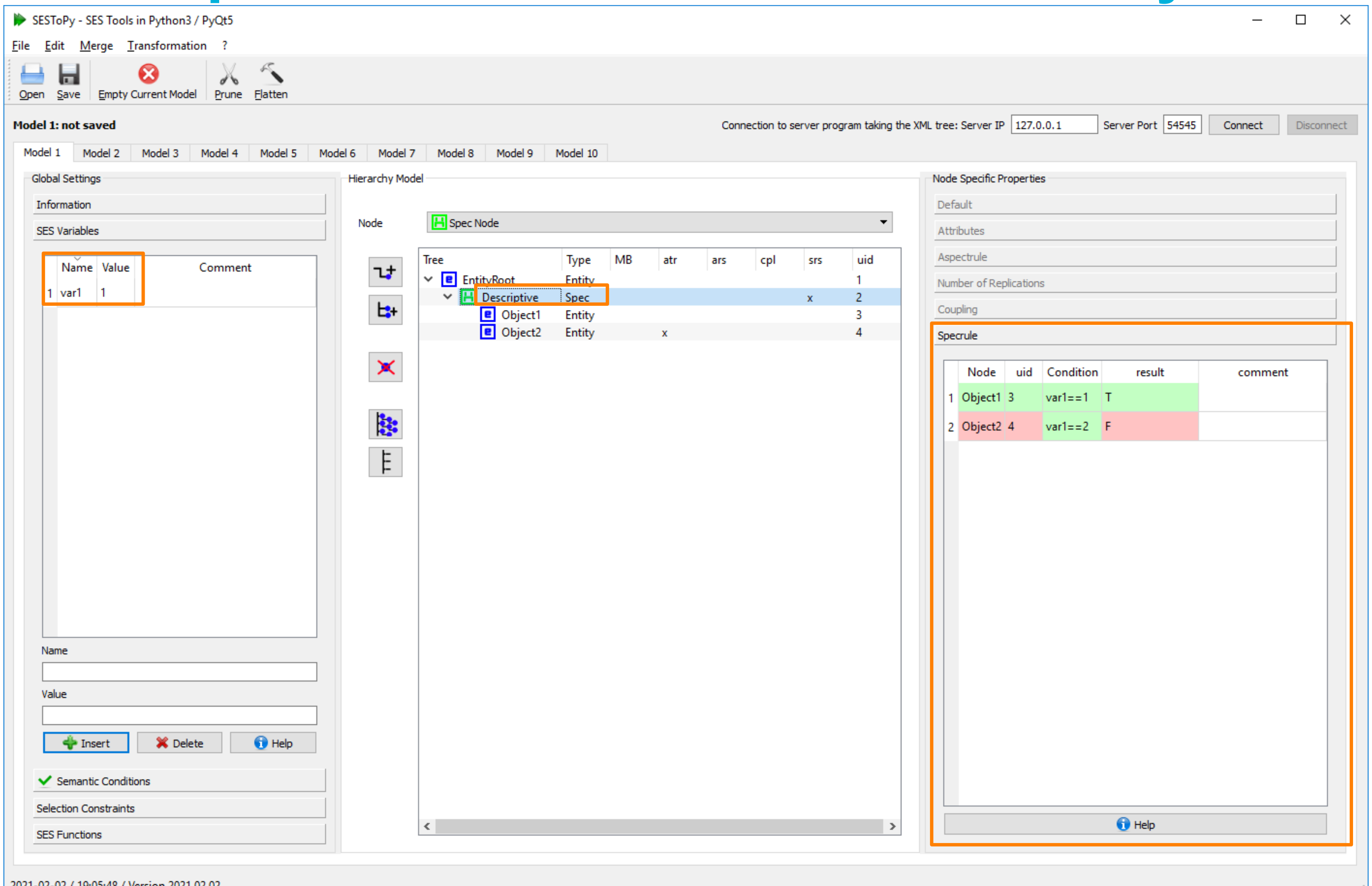




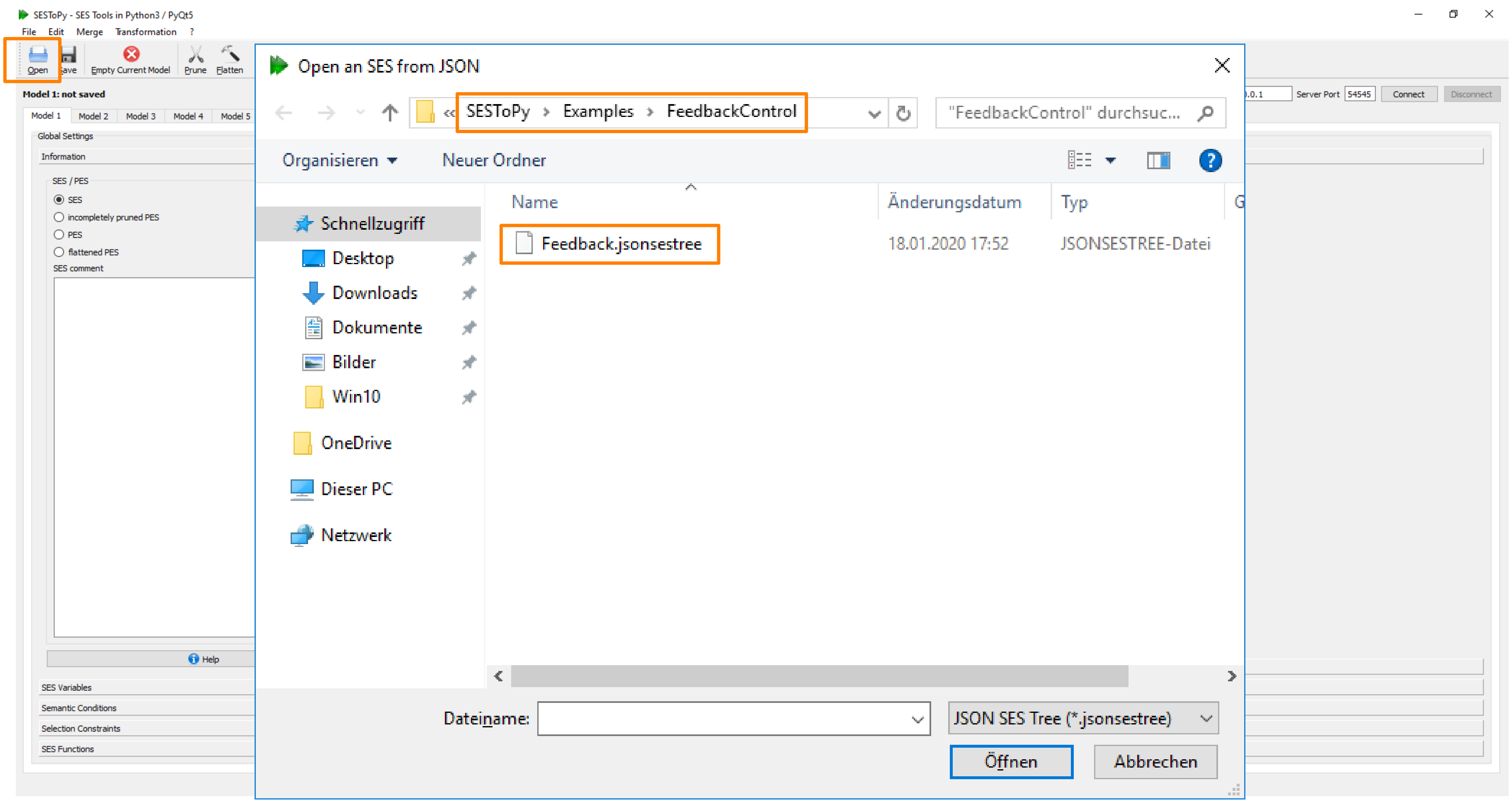
Edit Entity Node with SESToPy



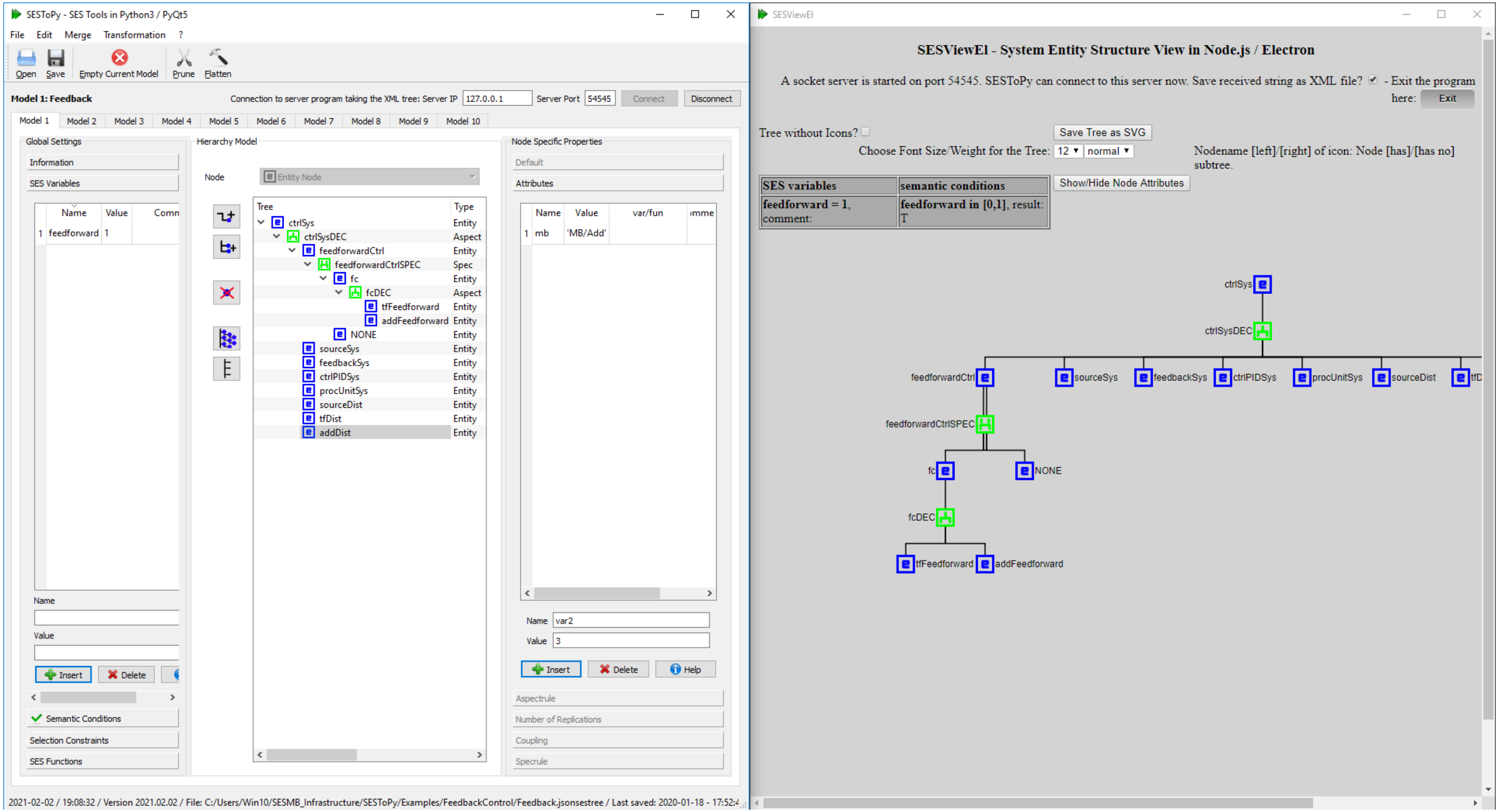
Edit Specialization Node with SESToPy



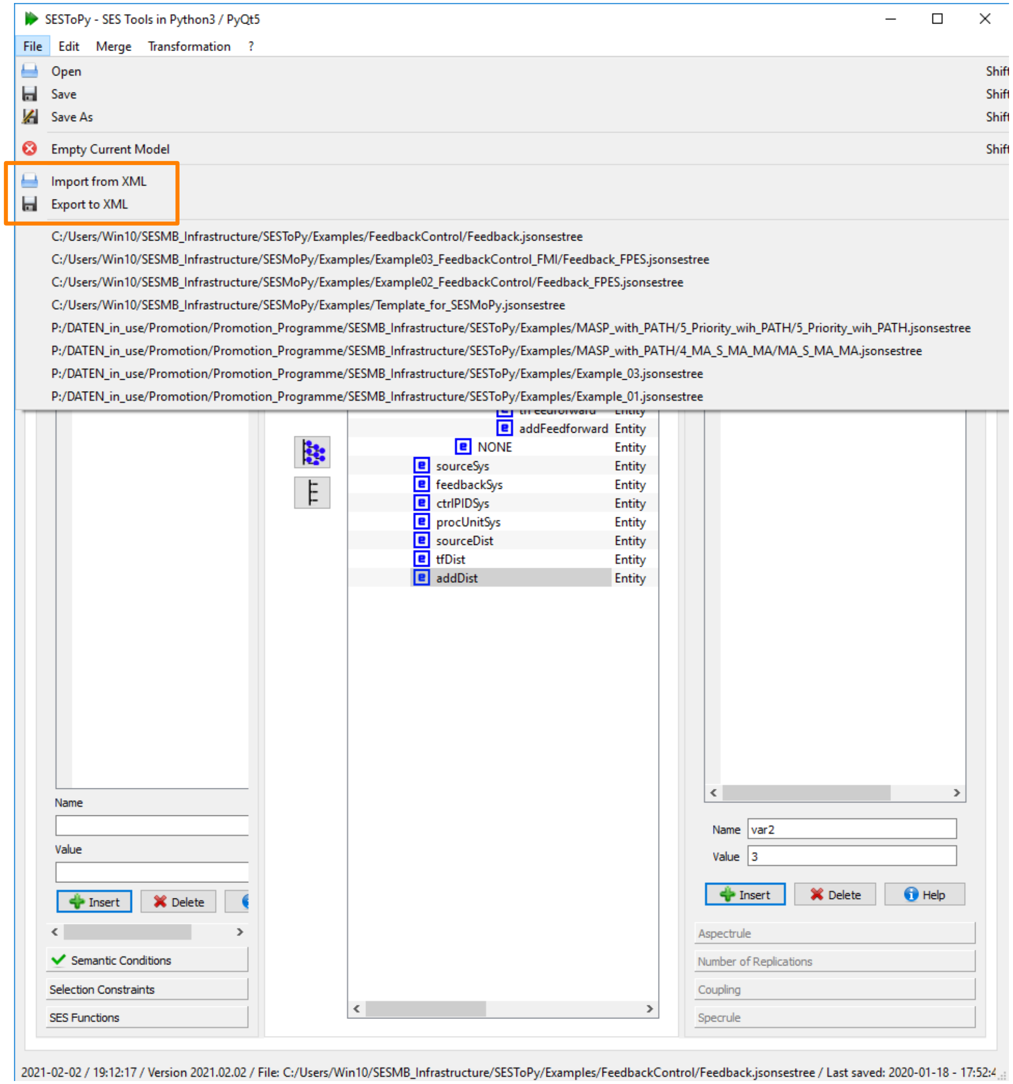
SESToPy Open the Feedback Example



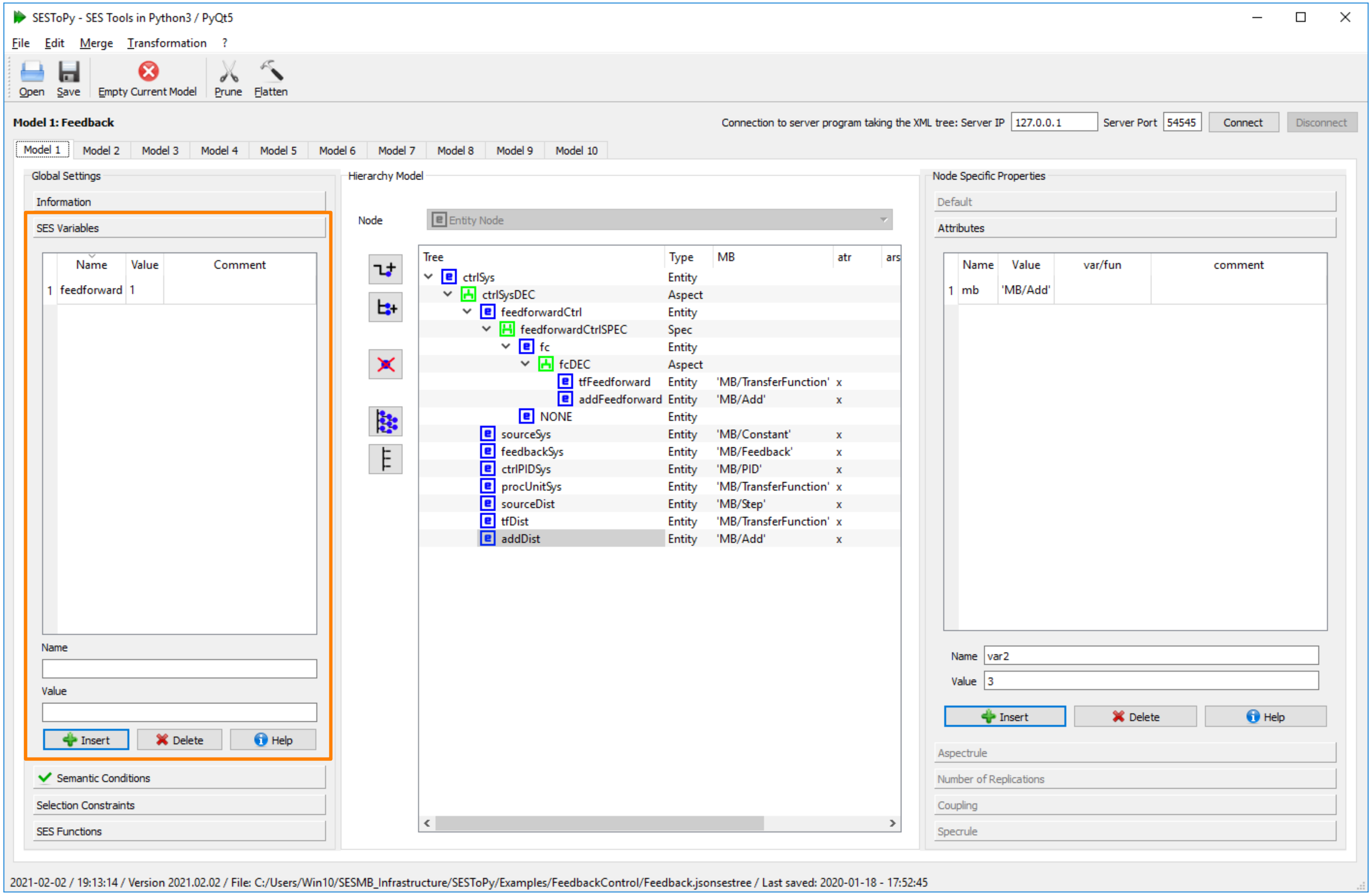
SESToPy Feedback Example



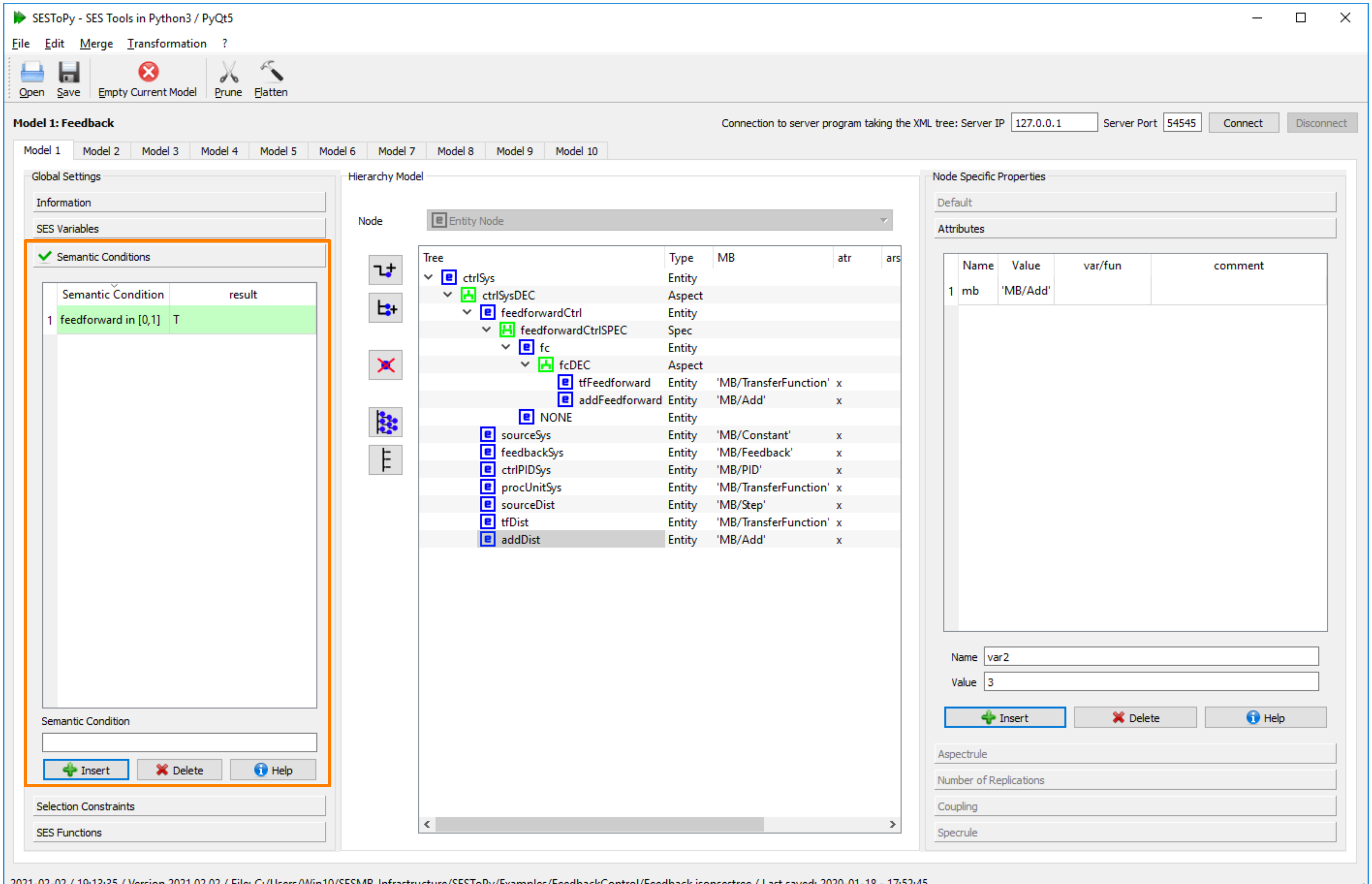
SESToPy XML Export / Import



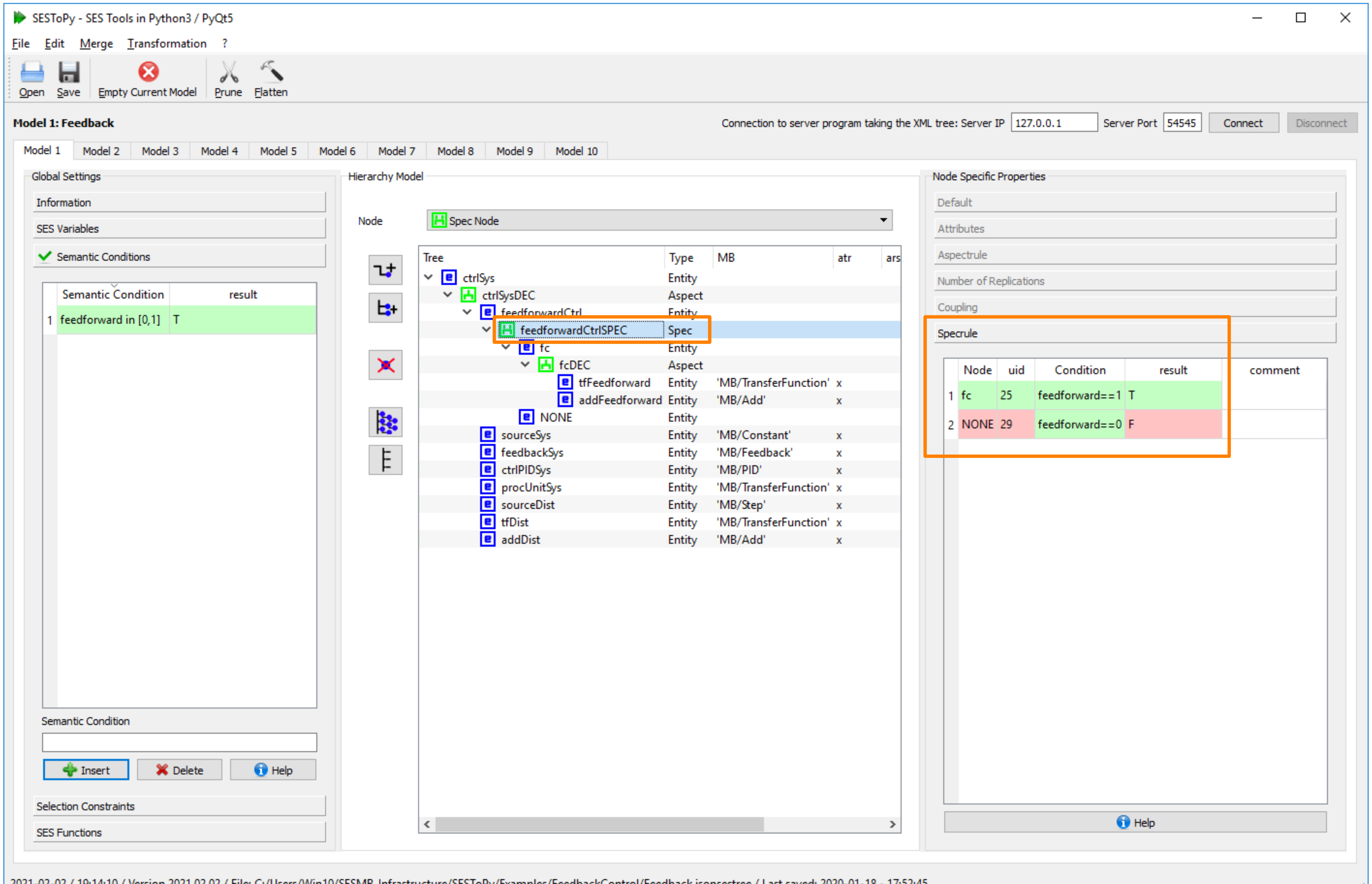
SESToPy SES Variables



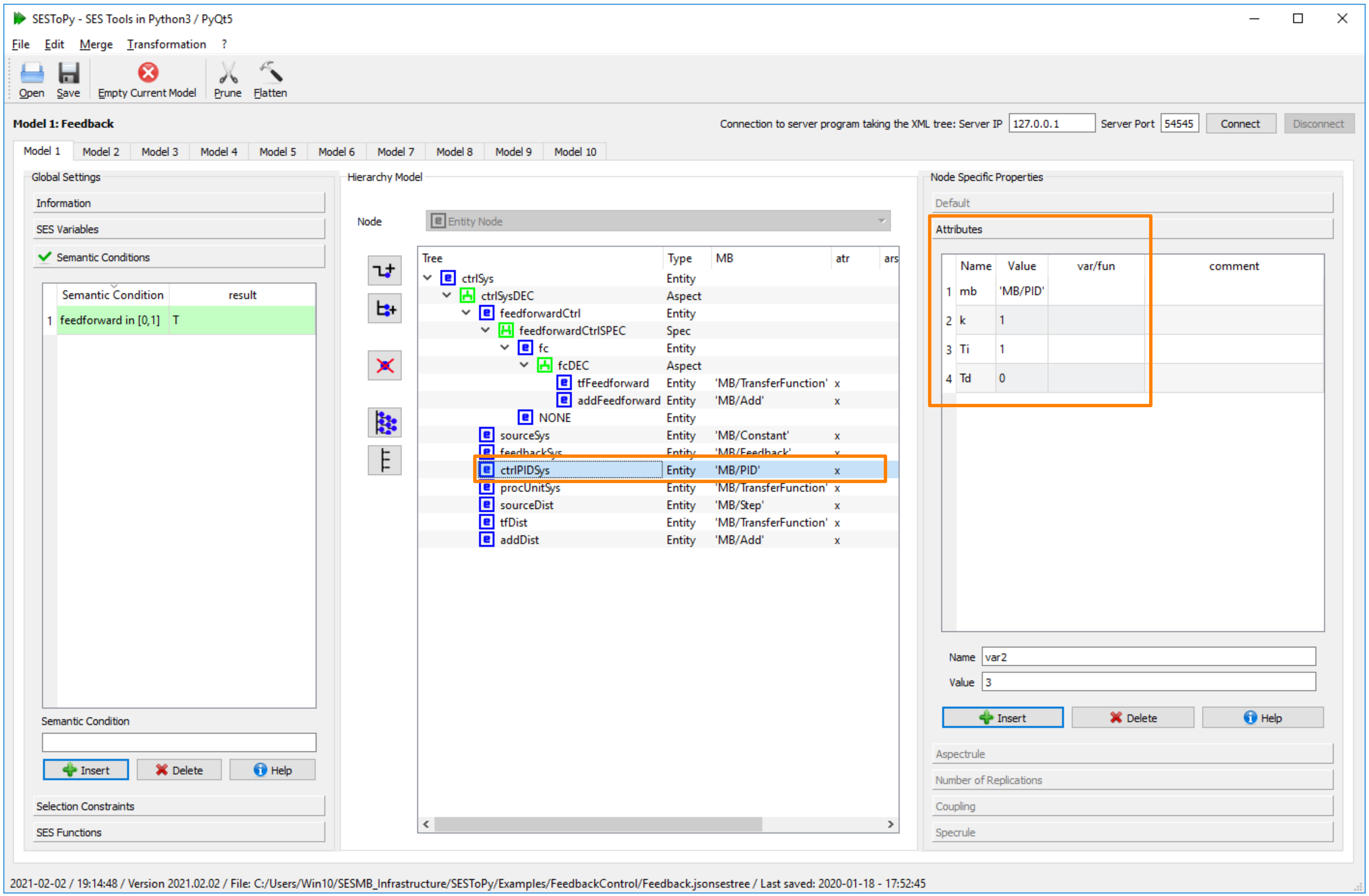
SESToPy Semantic Conditions



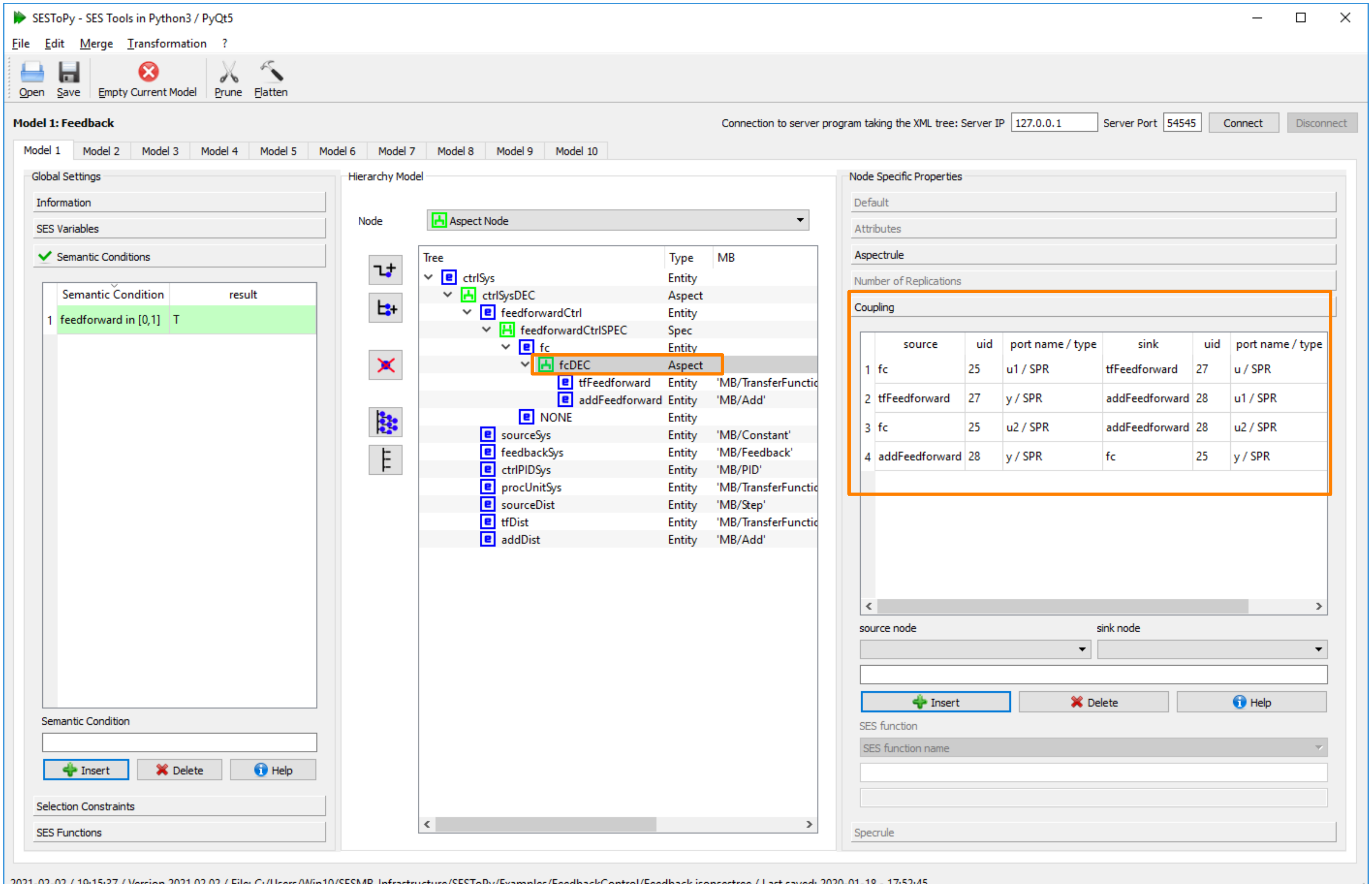
SESToPy Selection Rules (here Specrule)



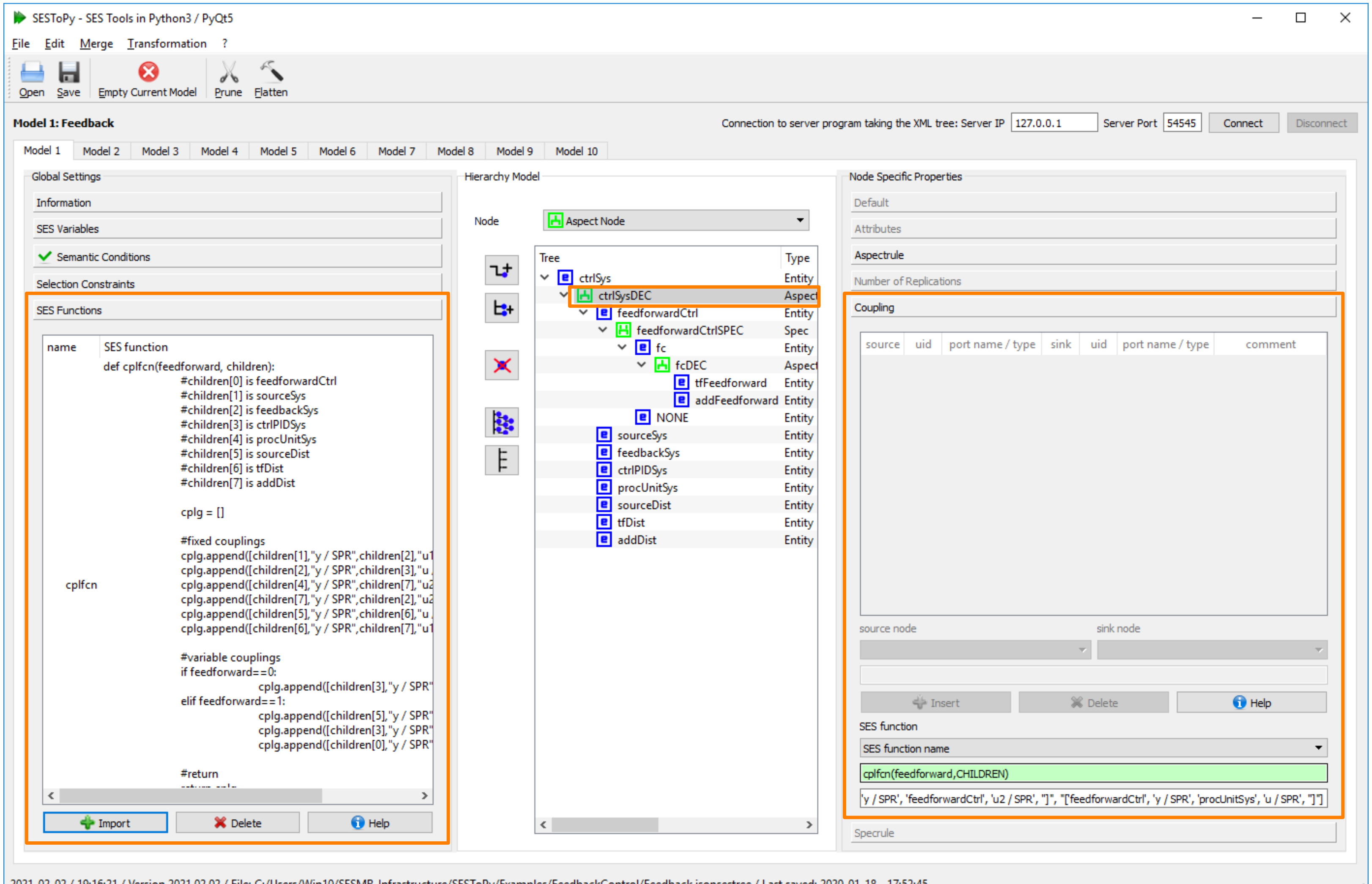
SESToPy Attributes



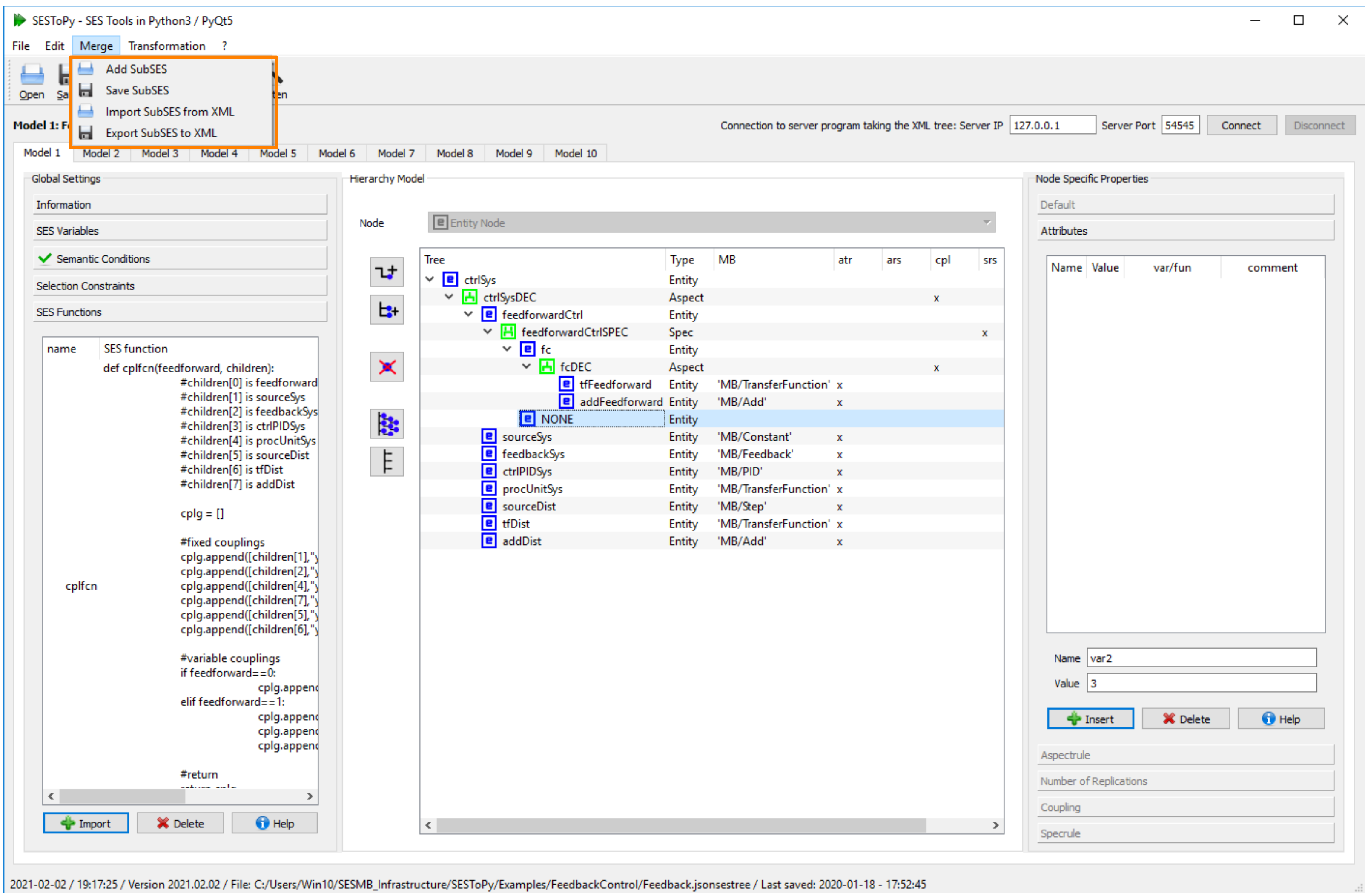
SESToPy Coupling List



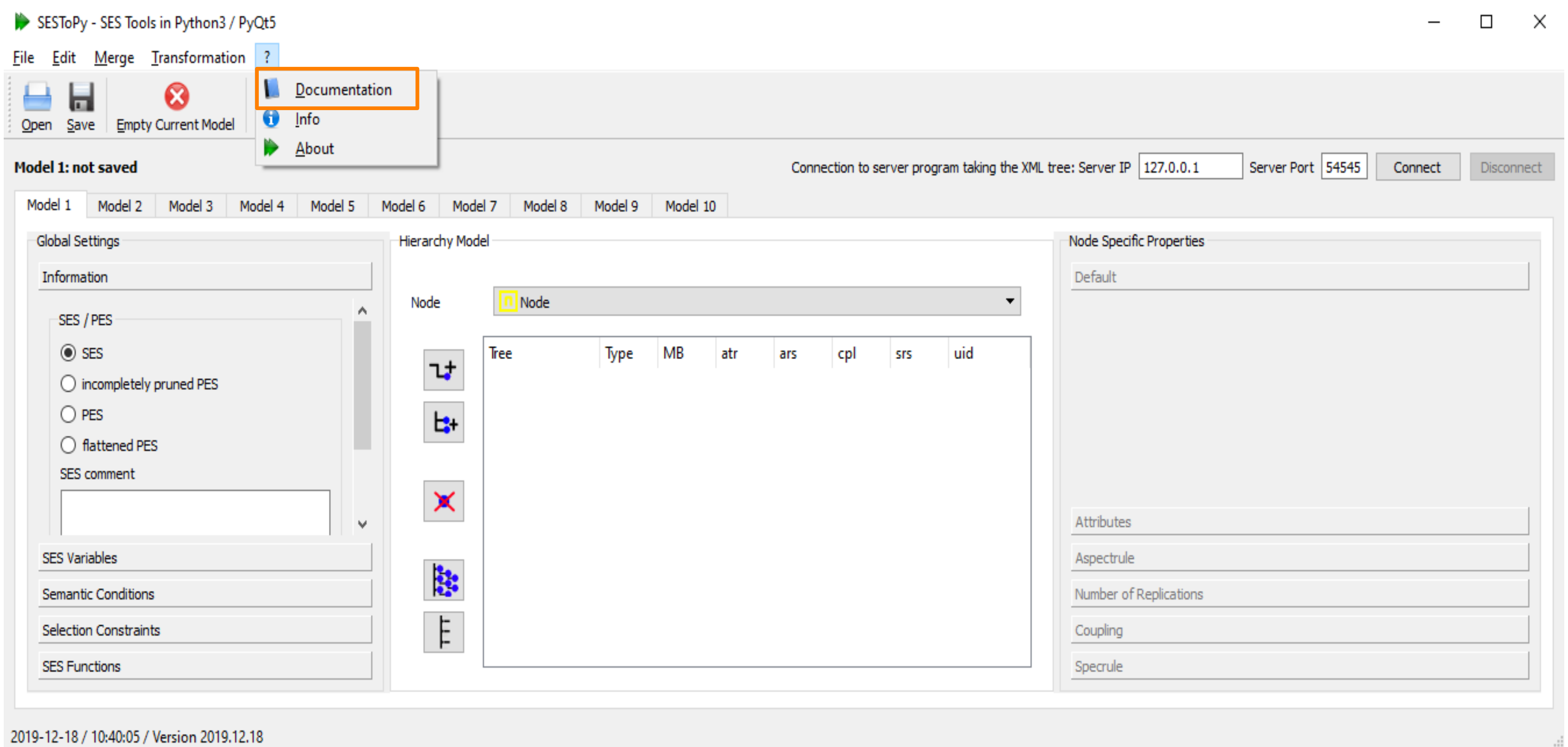
SESToPy SES Function / Coupling Function



SESToPy Merging



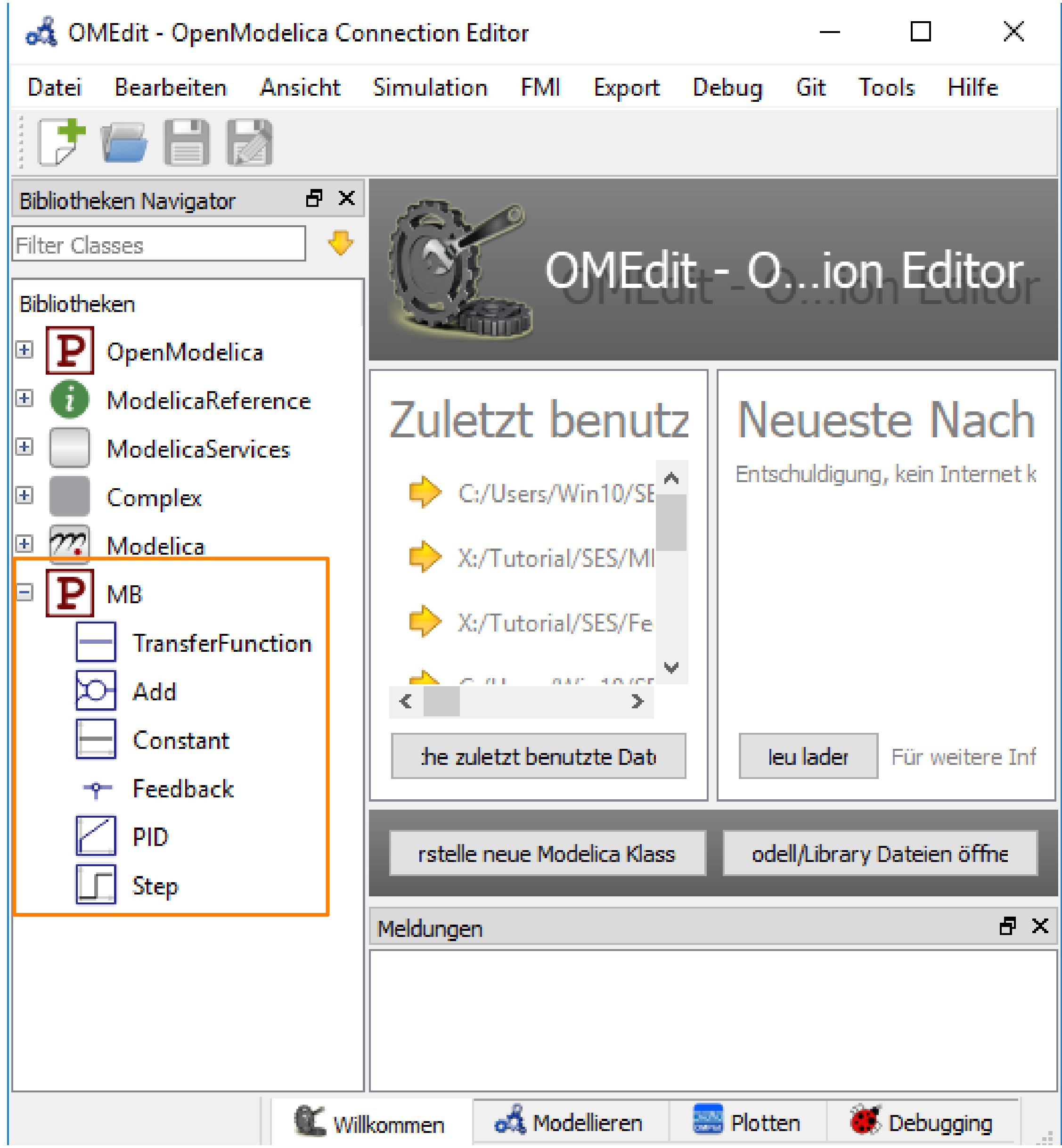
SESToPy Documentation



- See the documentation for more information

OpenModelica MB

- MB built of Modelica basic models in a **Package**
- Save package as `MB.mo` file



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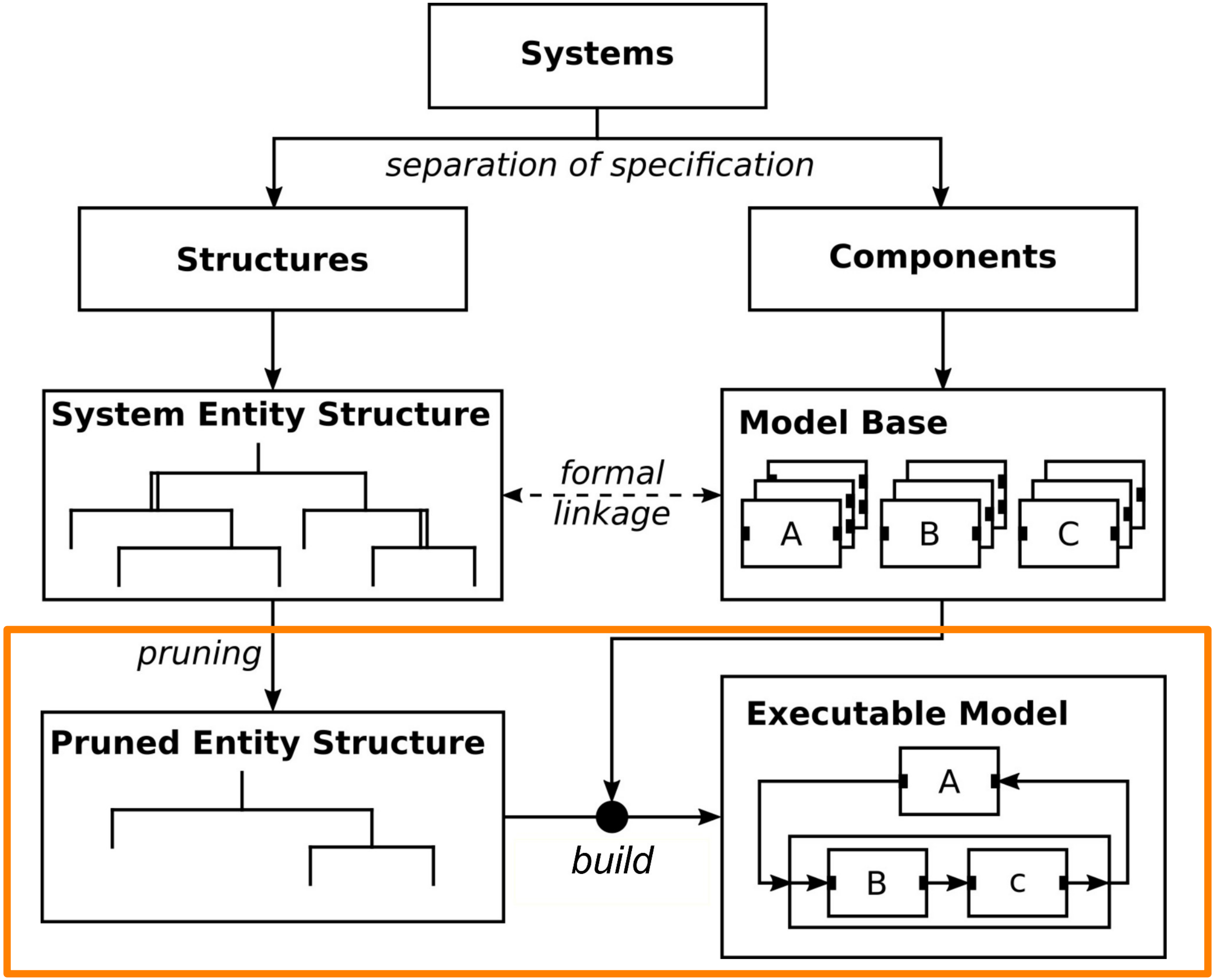
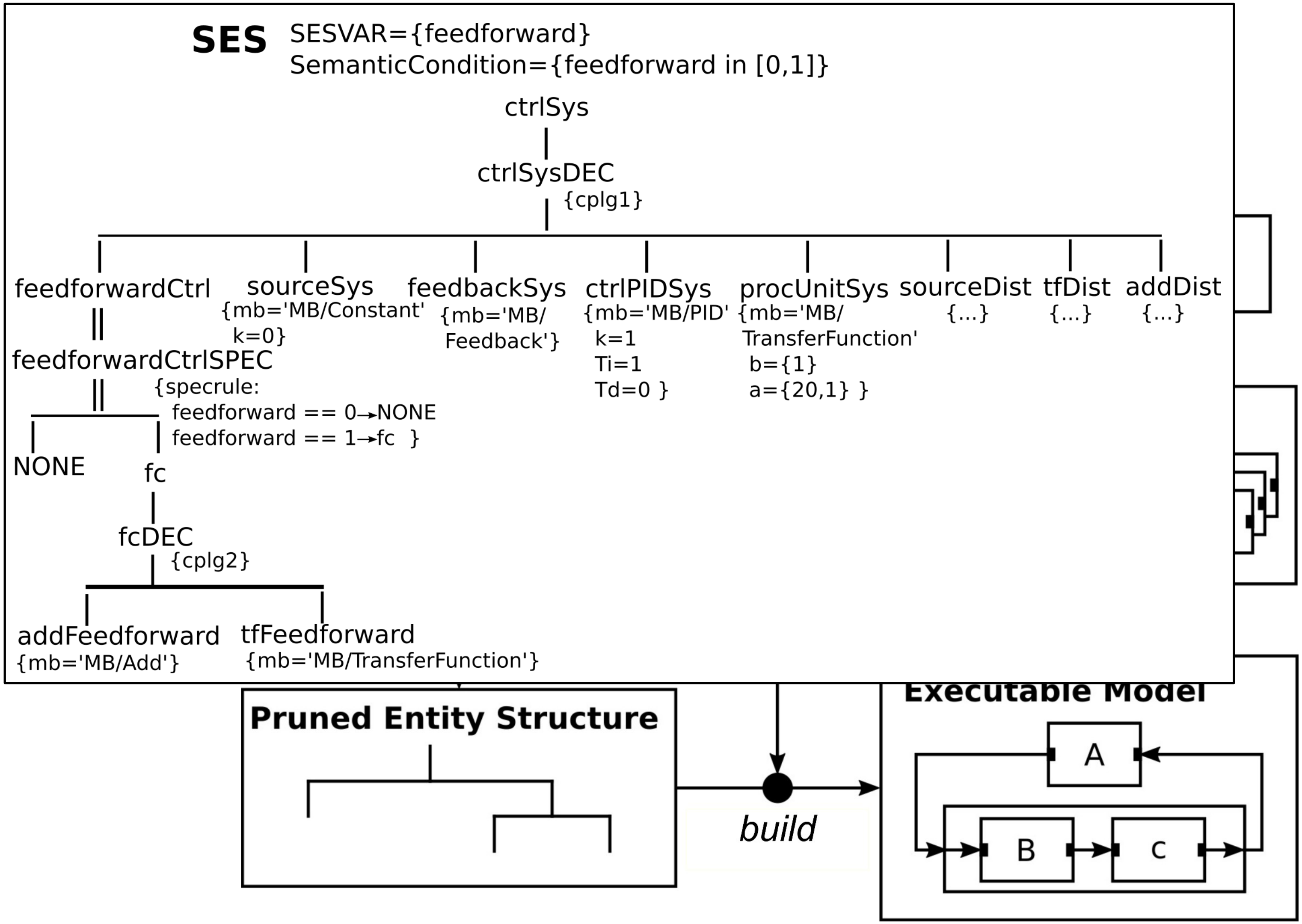
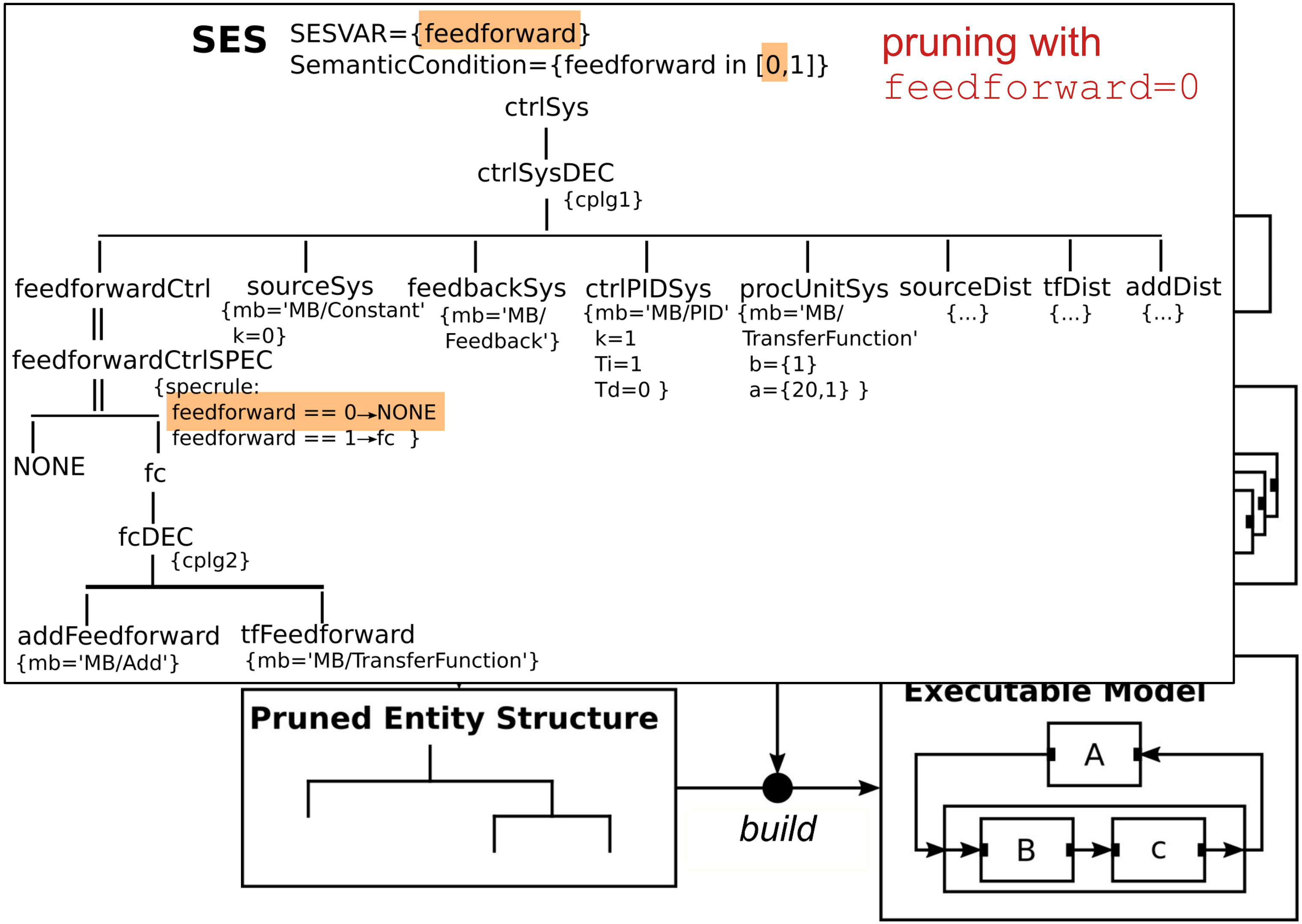
Model Selection and Generation



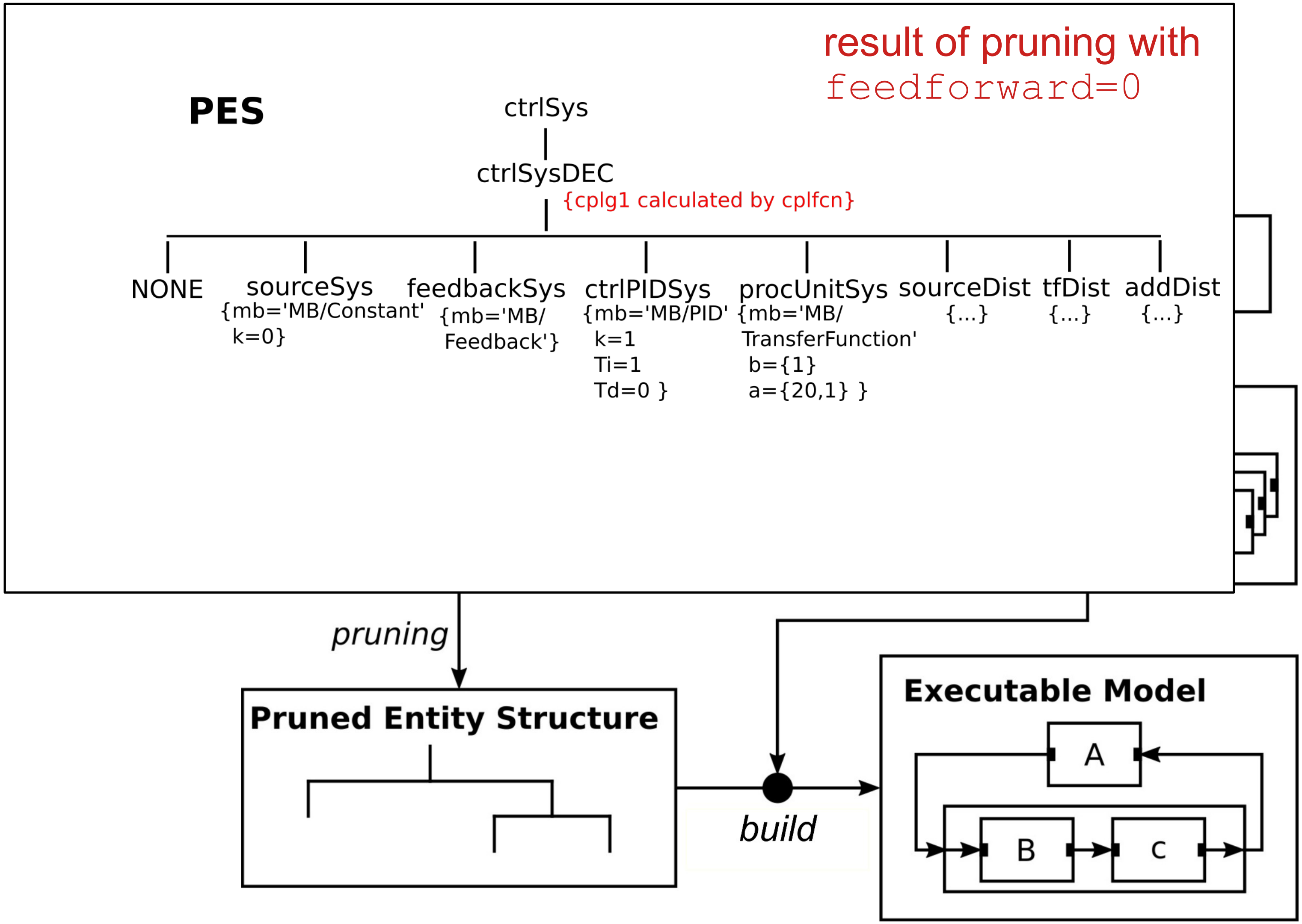
Model Selection and Generation of Variant #1



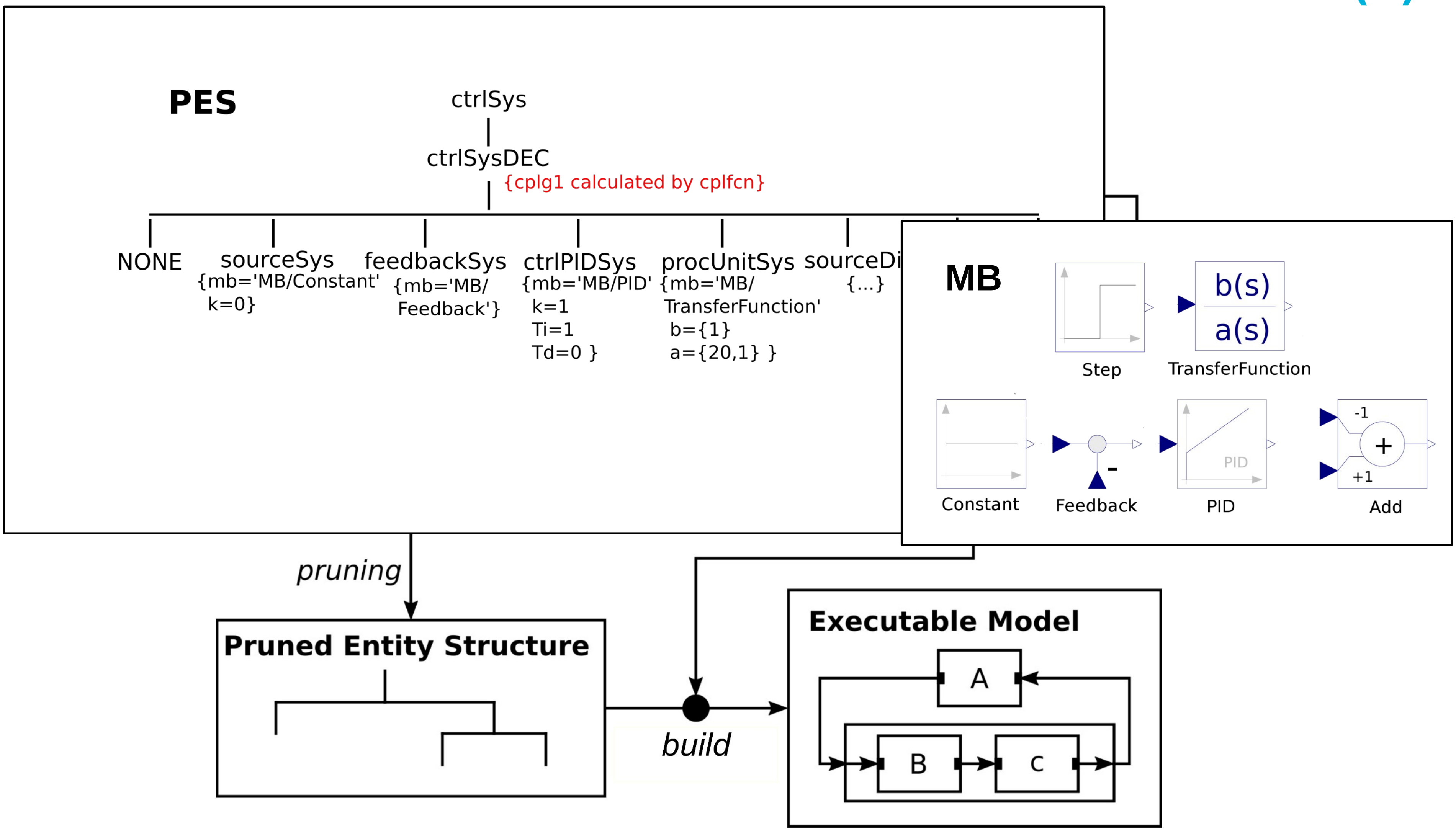
Model Selection and Generation of Variant #1



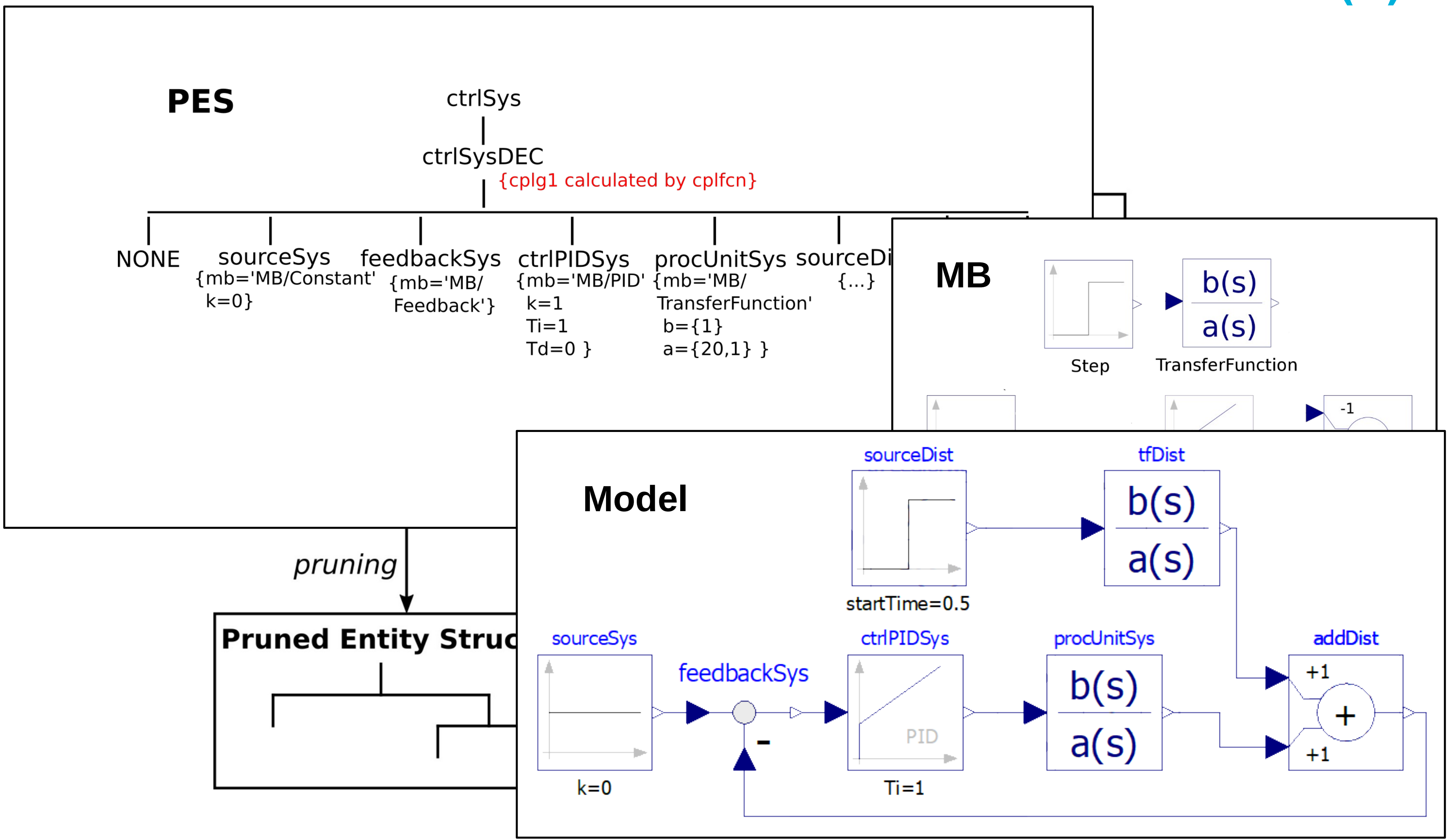
Model Selection and Generation of Variant #1 (2)



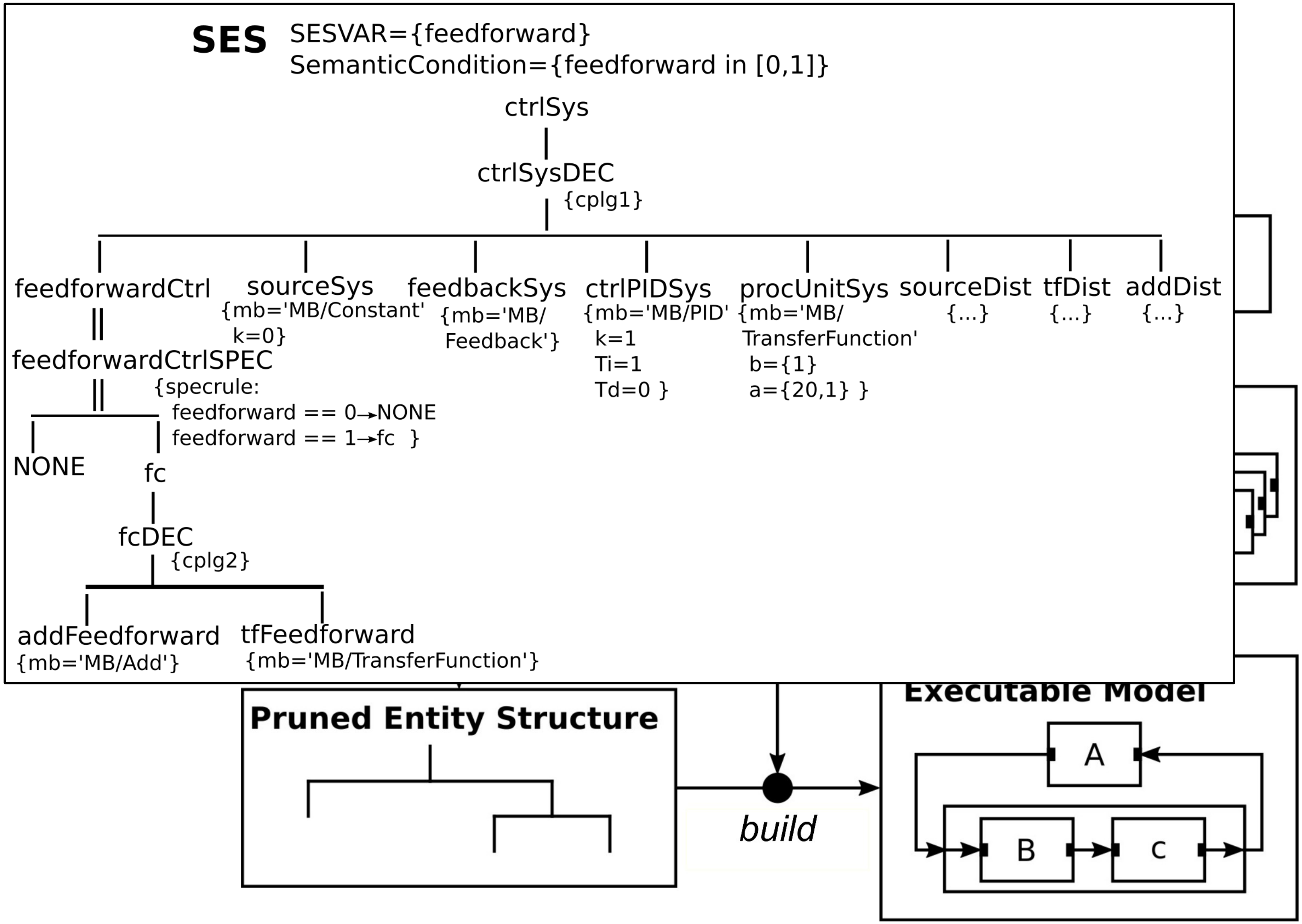
Model Selection and Generation of Variant #1 (3)



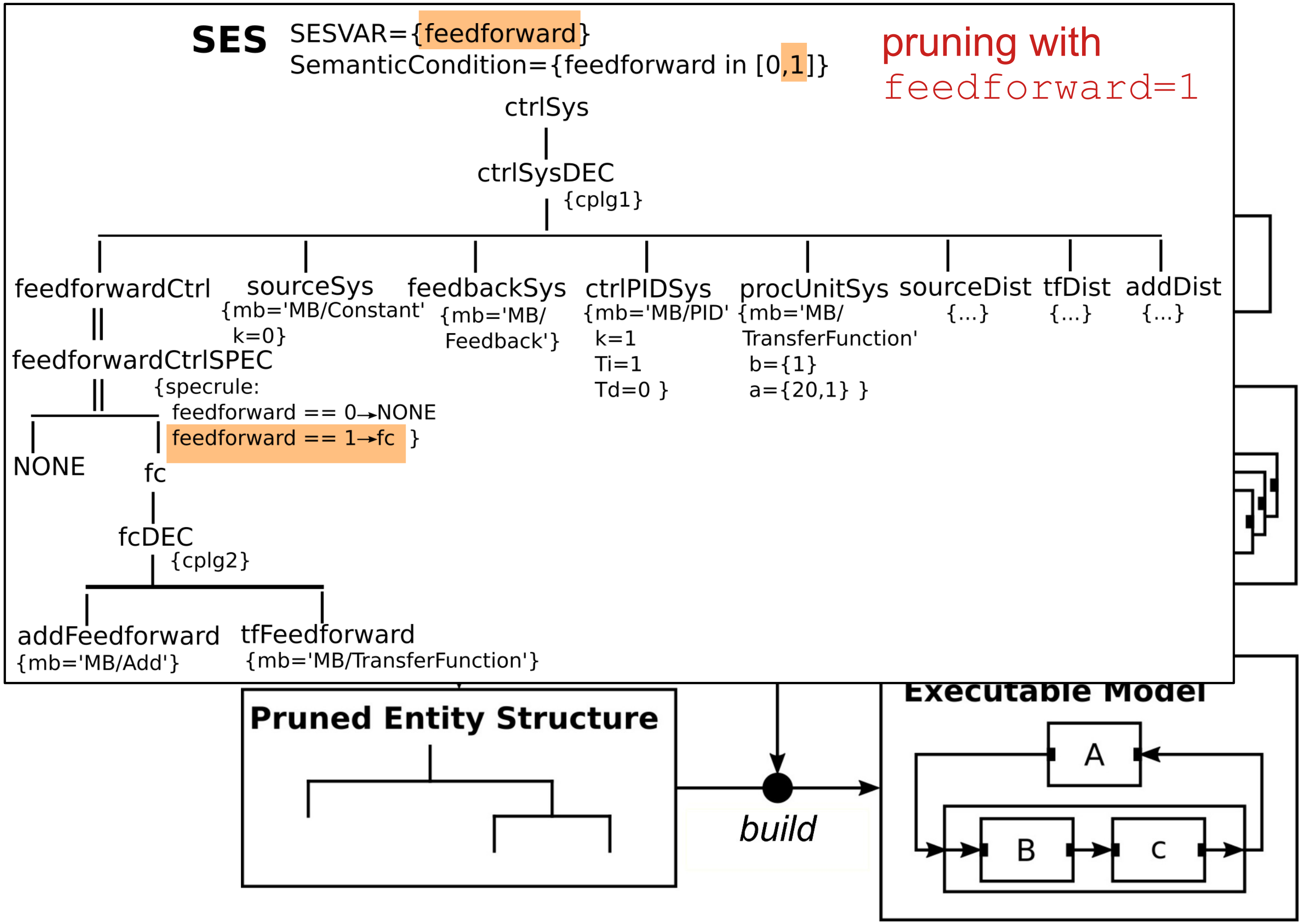
Model Selection and Generation of Variant #1 (4)



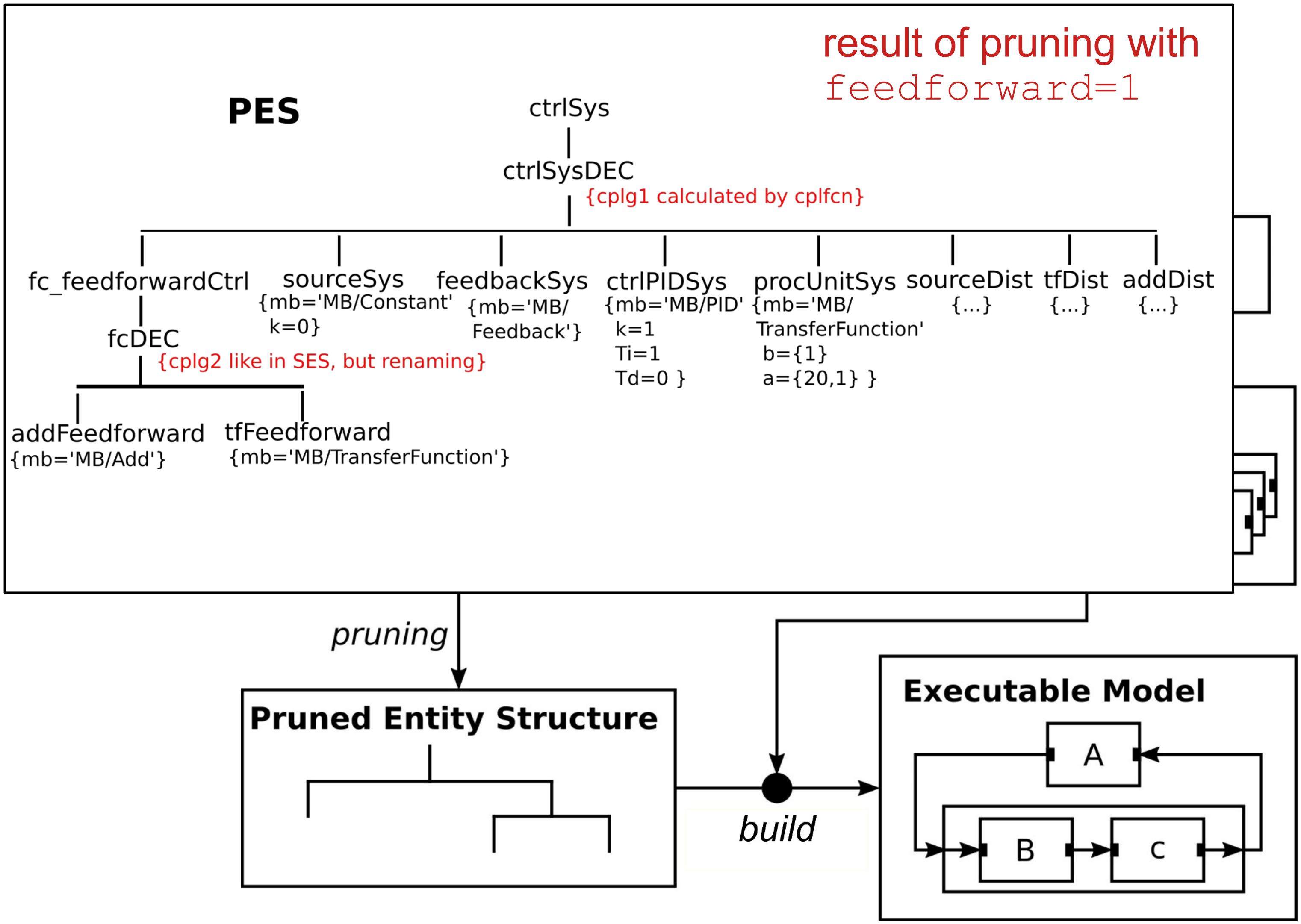
Model Selection and Generation of Variant #2



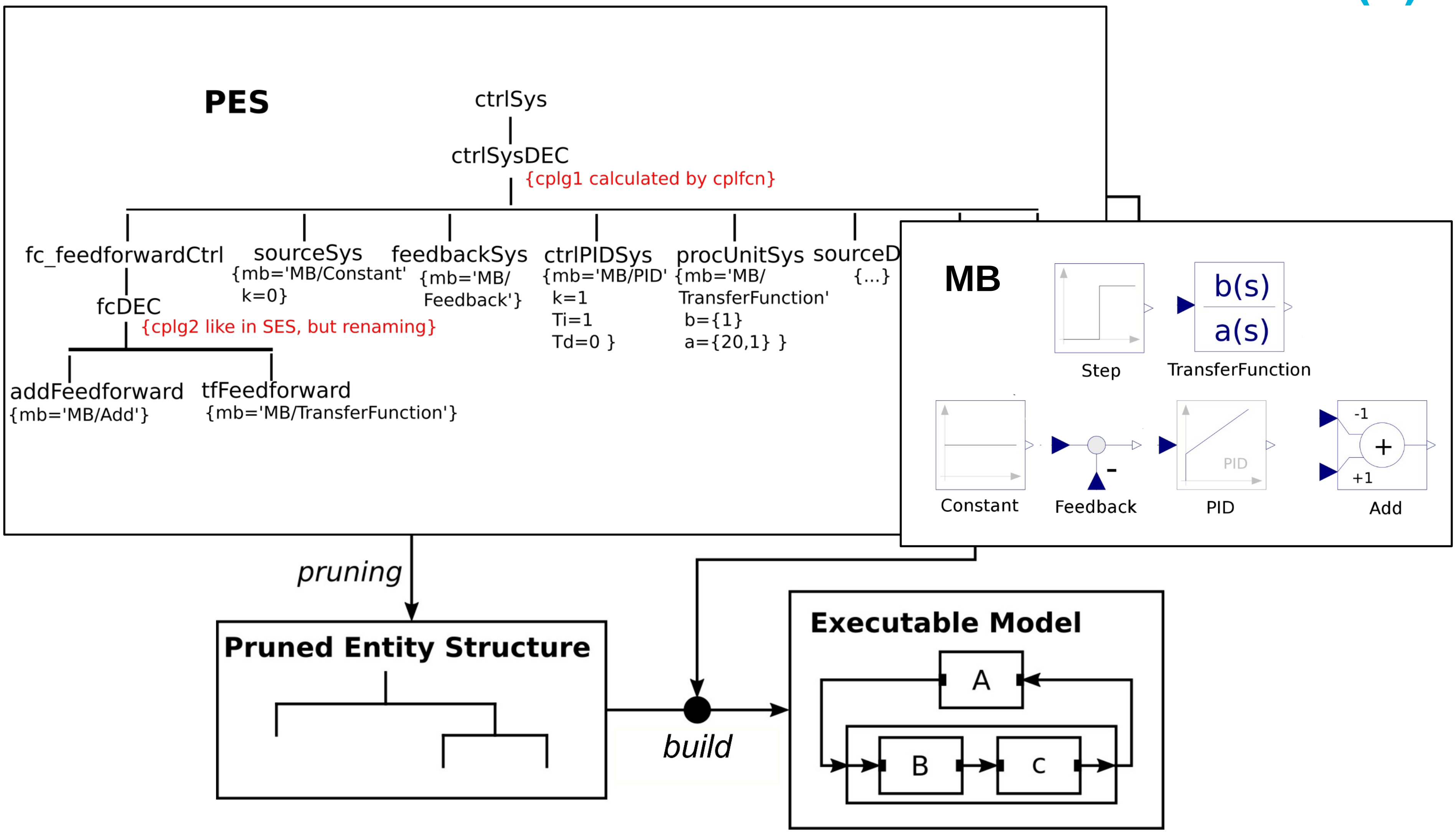
Model Selection and Generation of Variant #2



Model Selection and Generation of Variant #2 (2)



Model Selection and Generation of Variant #2 (3)



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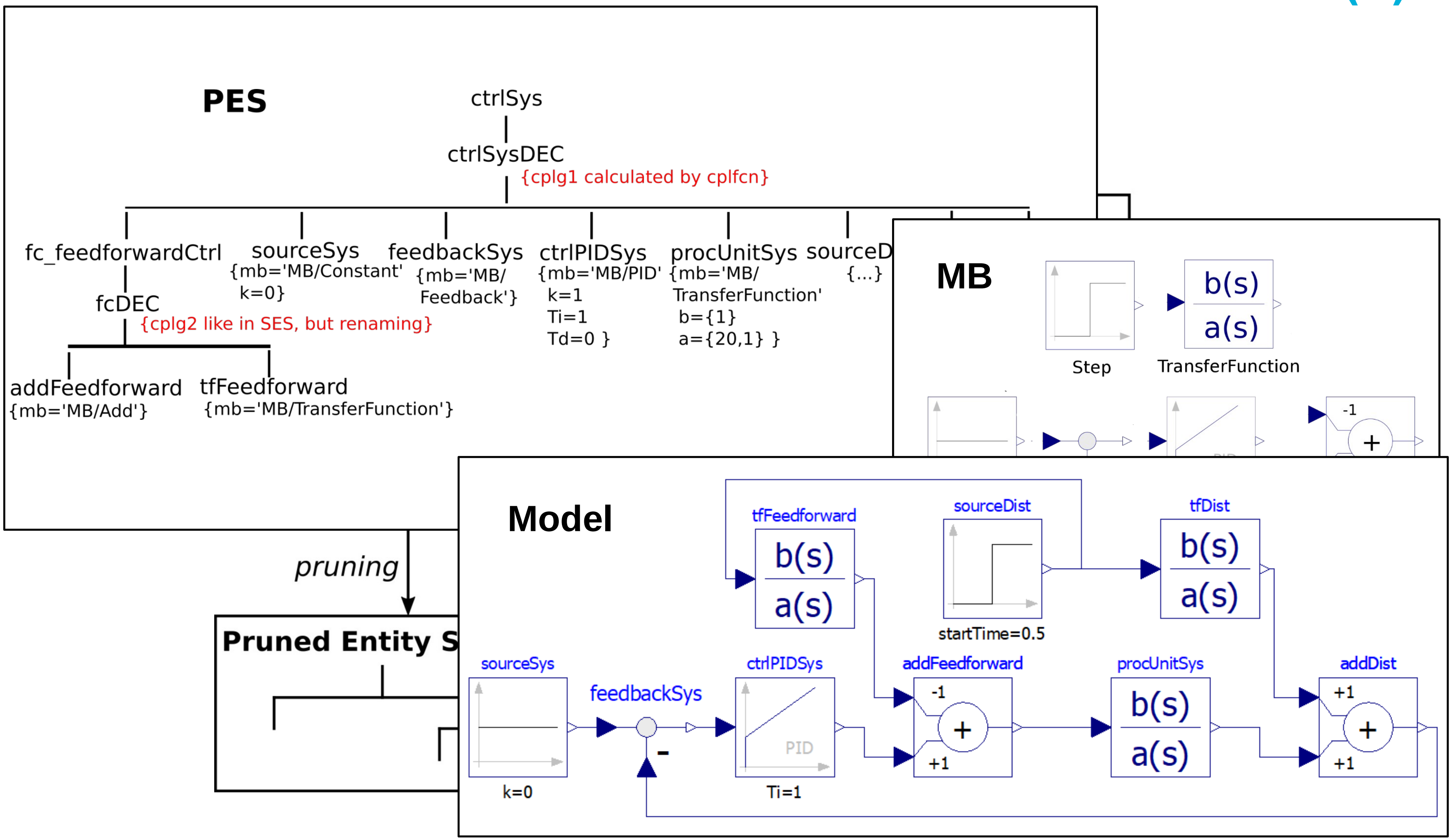

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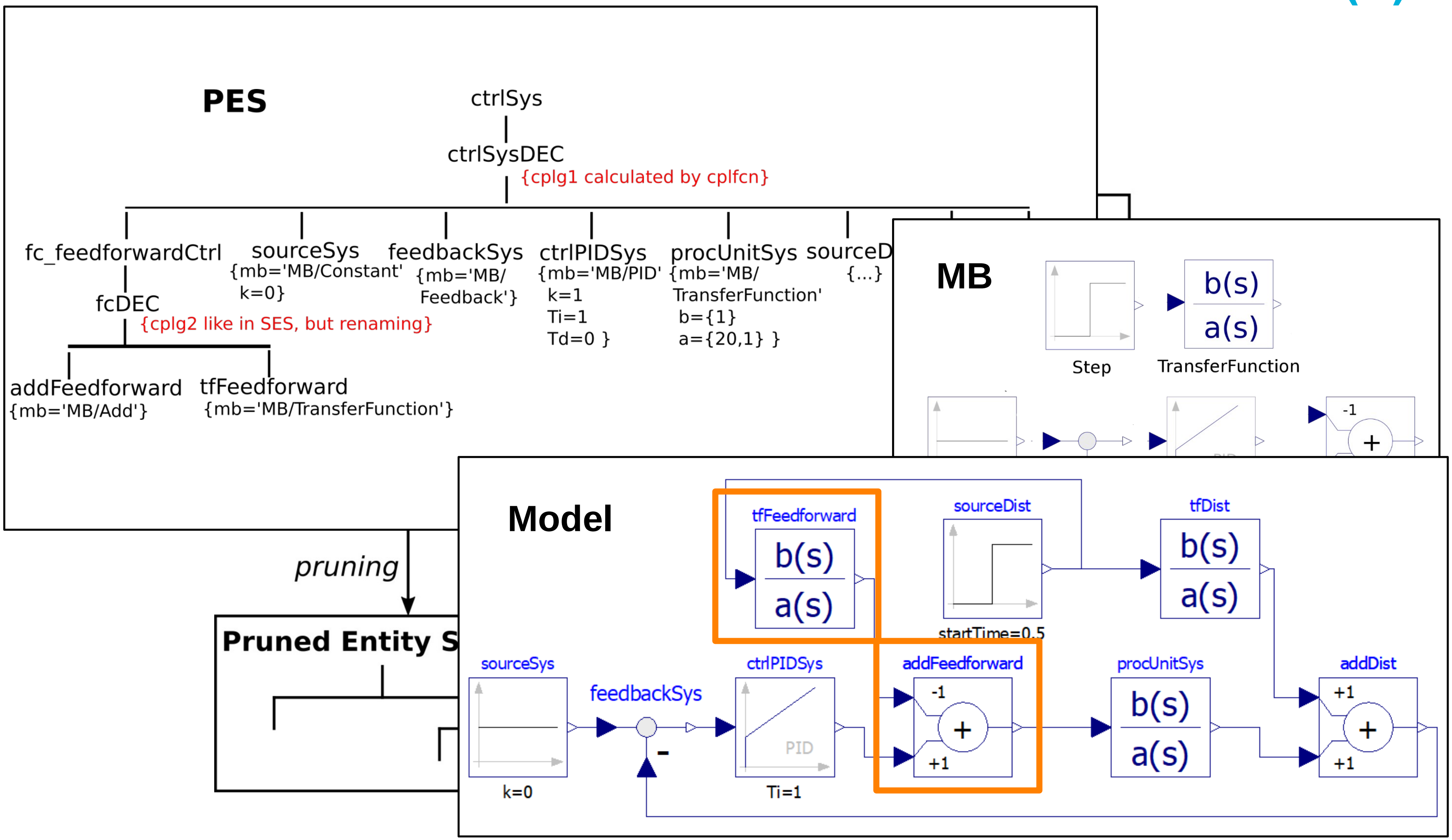


Python Toolset

- Available:
  `https://github.com/cea-wismar/SESMB_Inf_Python/`

- Tools

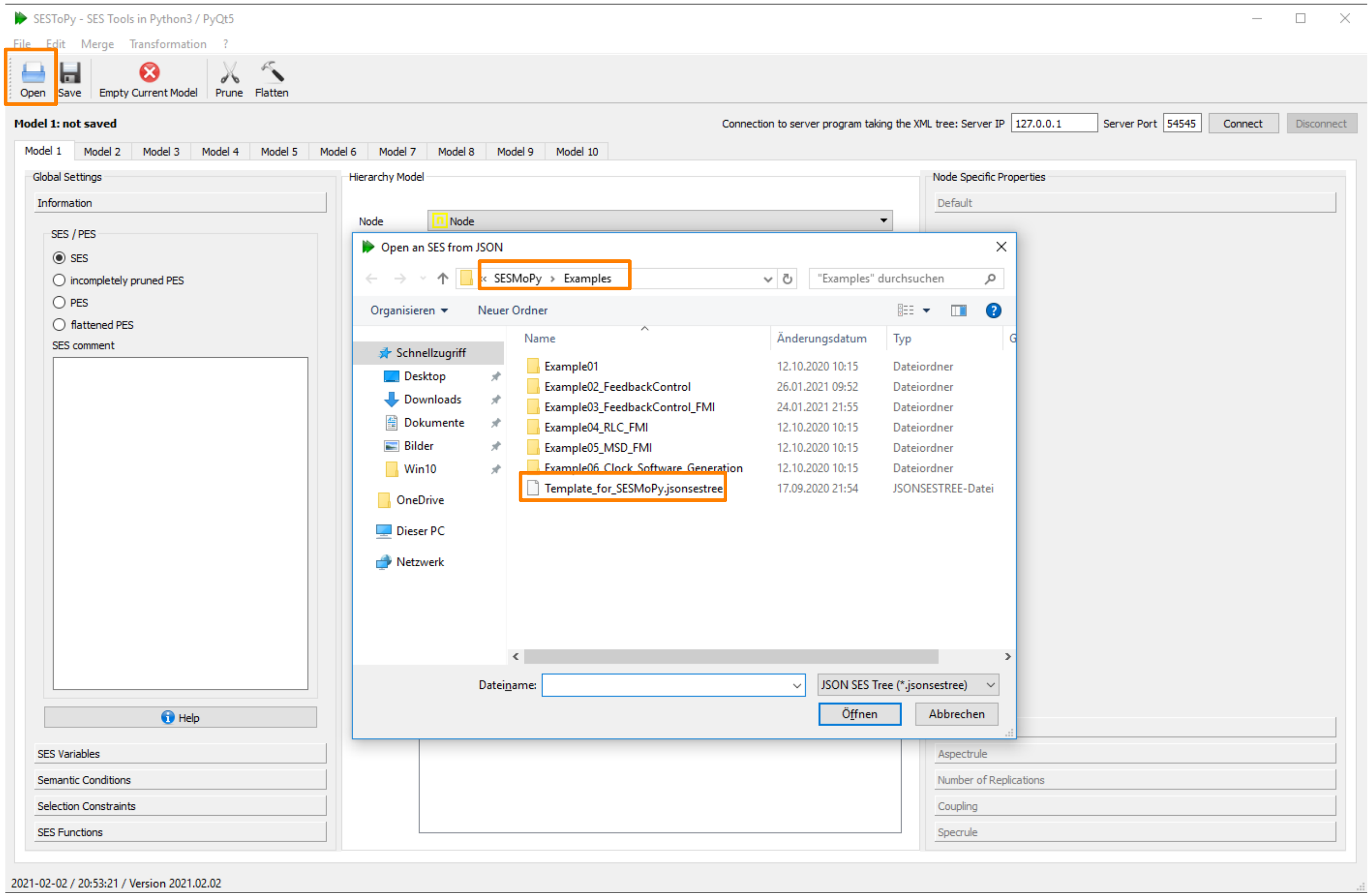
  - SESToPy → SES editor and IDE
  - SESViewEl → SES tree viewer
  - **SESMoPy** → Model builder → OpenModelica / Dymola / Simulink
  - SESEuPy
  - SESEcPy

Demonstration of SESMoPy (case study) → Screenshots on Next Slides

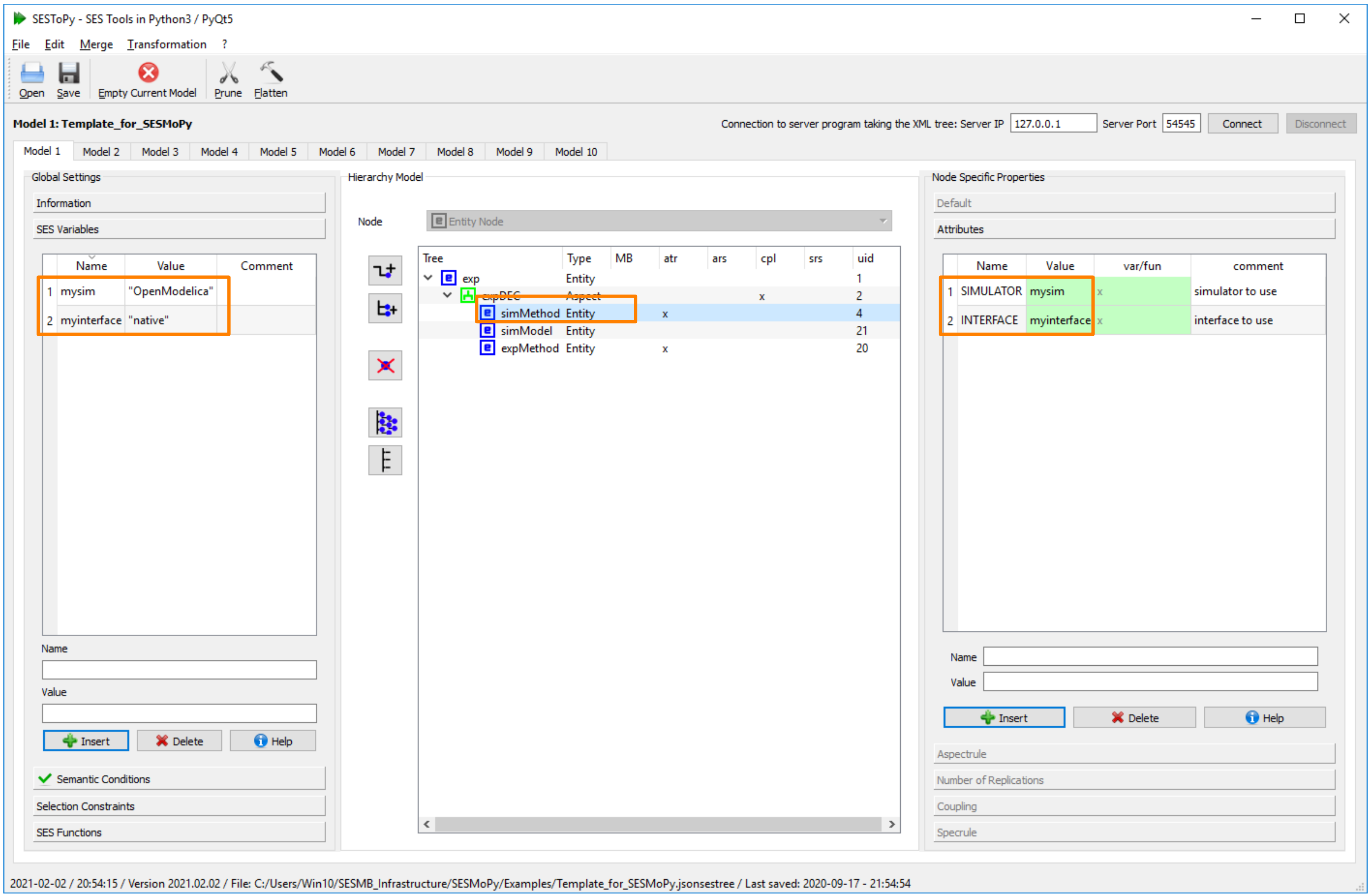
- Show provisional Experimental Frame from SESMoPy examples → `Template_for_SESMoPy`
- Show that different simulators can be set → here `OpenModelica`
- Show that two interfaces can be set → here `native`
- Merge Feedback SES from SESToPy examples to simModel → rename `simModel` to `ctrlSys` for merging.
- Show that configurations can be set in `expMethod`
- Prune for `feedforward=0` → dynamic couplings to static couplings
- Flatten for `feedforward=0` and save the FPES as file → explanation flattening: remove inner, coupled components → root node and leaves stay in tree → couplings recalculated
- (Prune for `feedforward=1` to show)
- Show the OpenModelica MB `MB.mo` and copy it in the same directory to the FPES file
- Open SESMoPy GUI → set FPES → create model → models for both configurations created
- Open one created model in OpenModelica and load MB file
- In OpenModelica open the model by double clicking → model not displayed (no annotation set) → click button `Text View`
- Execute simulation → set simulation time to 50 seconds
  → Signals of interest (setpoint, disturbance, controlled variable):
  `sourceSys.y sourceDist.y addDist.y`
  → If the signals do not show up in plot: Click `Auto Scale` and `Fit in View` in plot

- If design objectives are not met with this structure and parameterization → later how to simulate automatically to find fitting structure and parameterization

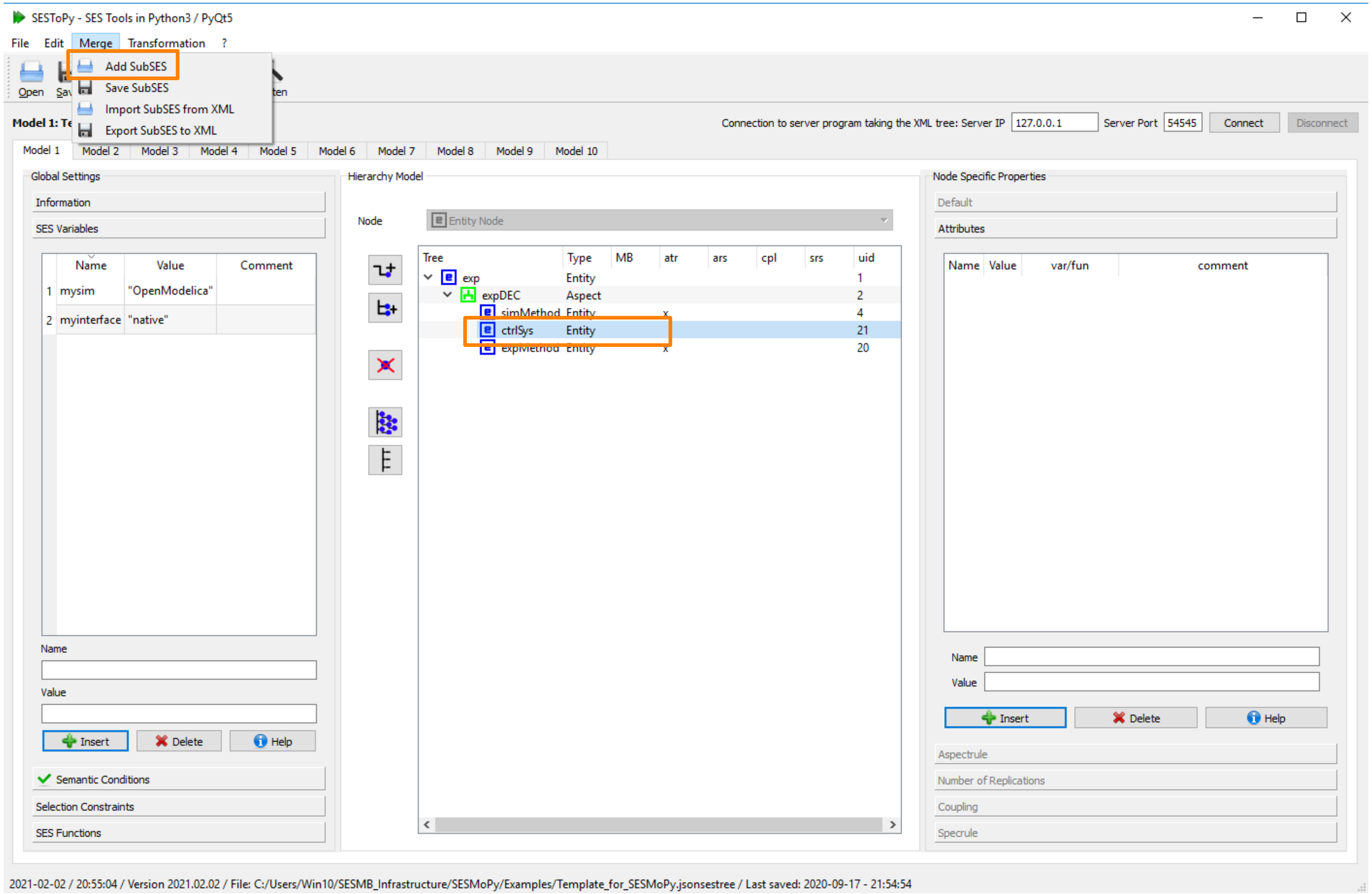
SESMoPy's Provisional Experimental Frame Show in SESToPy



Different Simulators & Interfaces can be set



Merge Feedback SES to Provisional Experimental Frame



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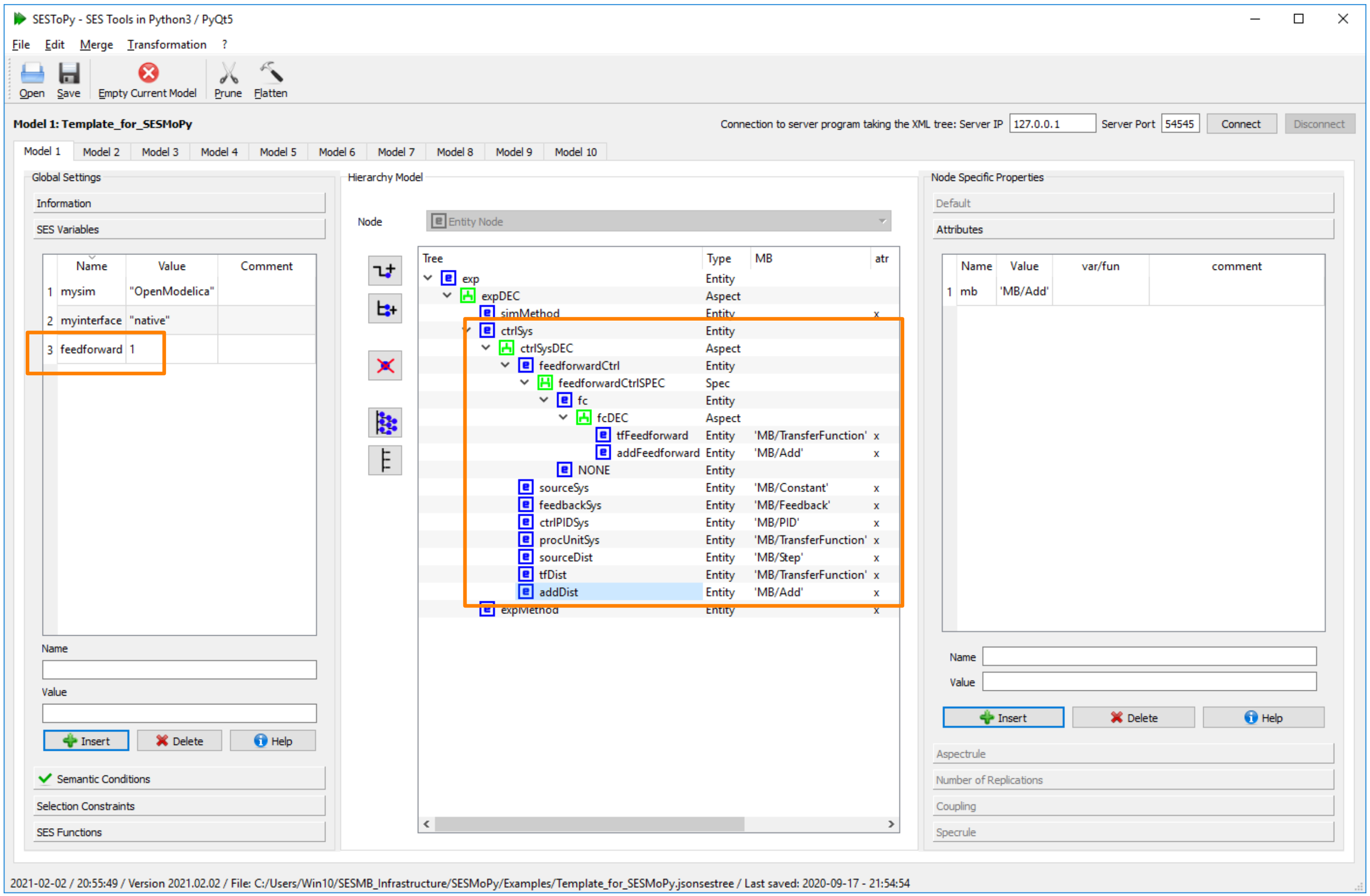
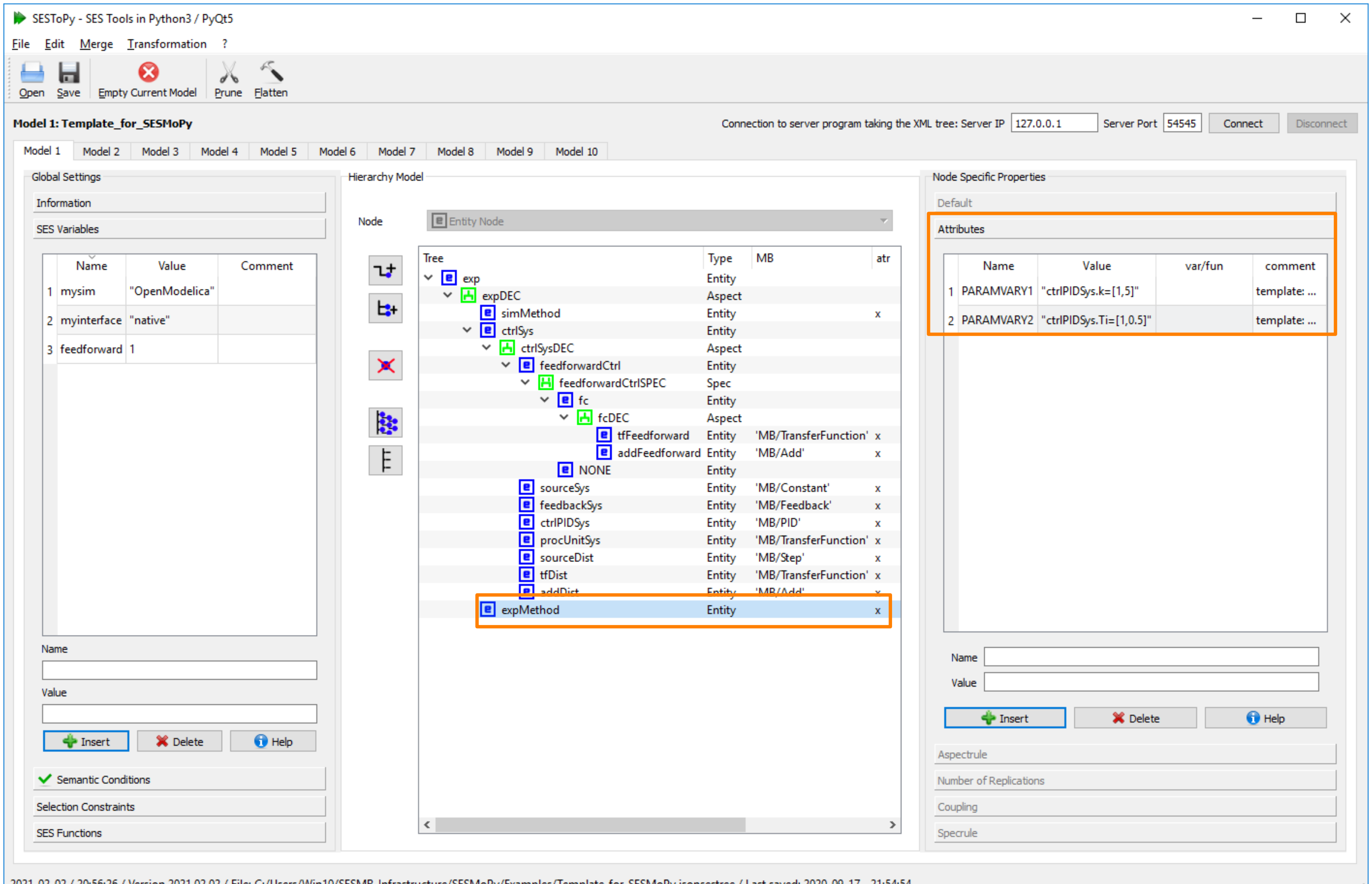
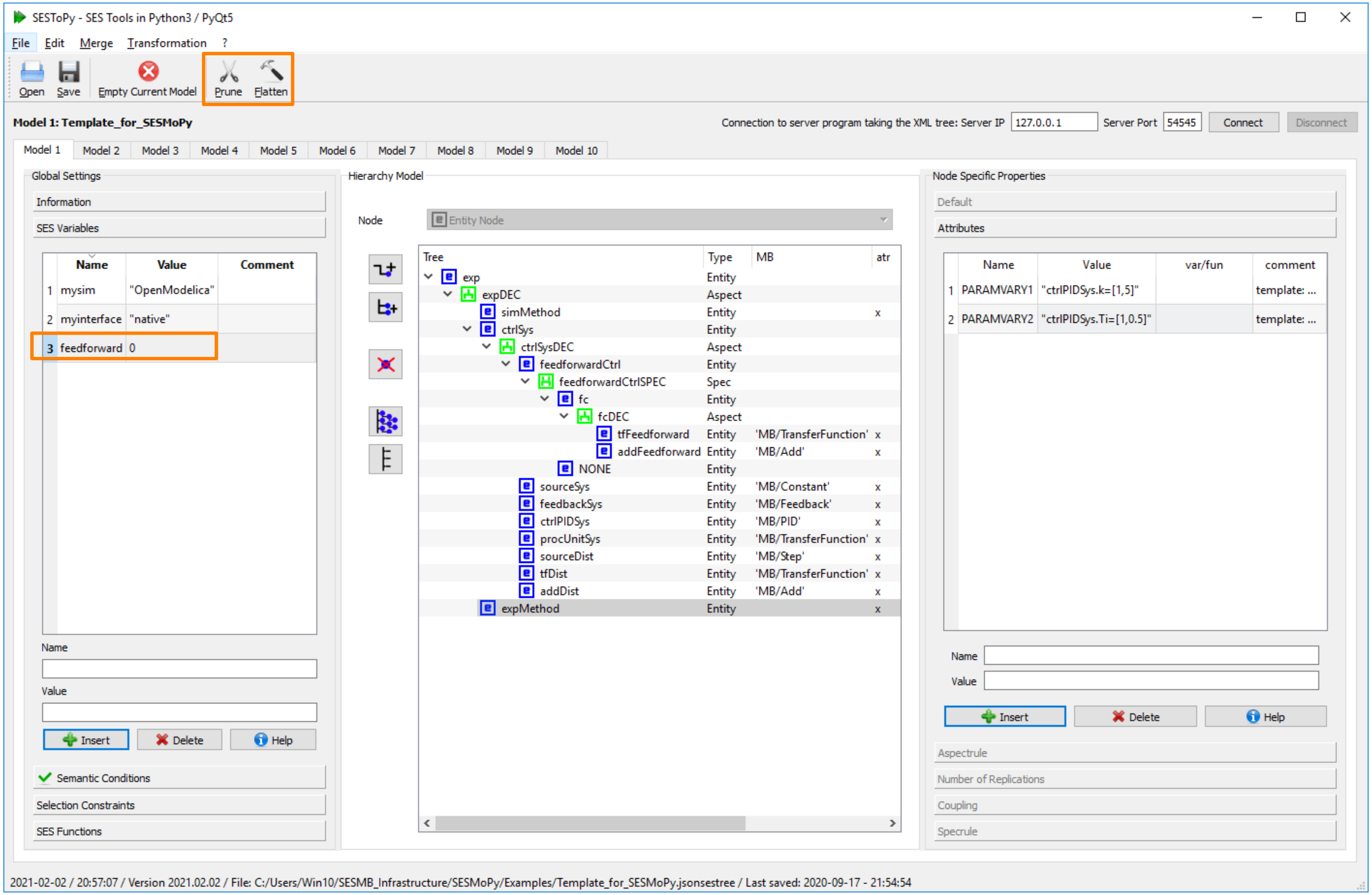


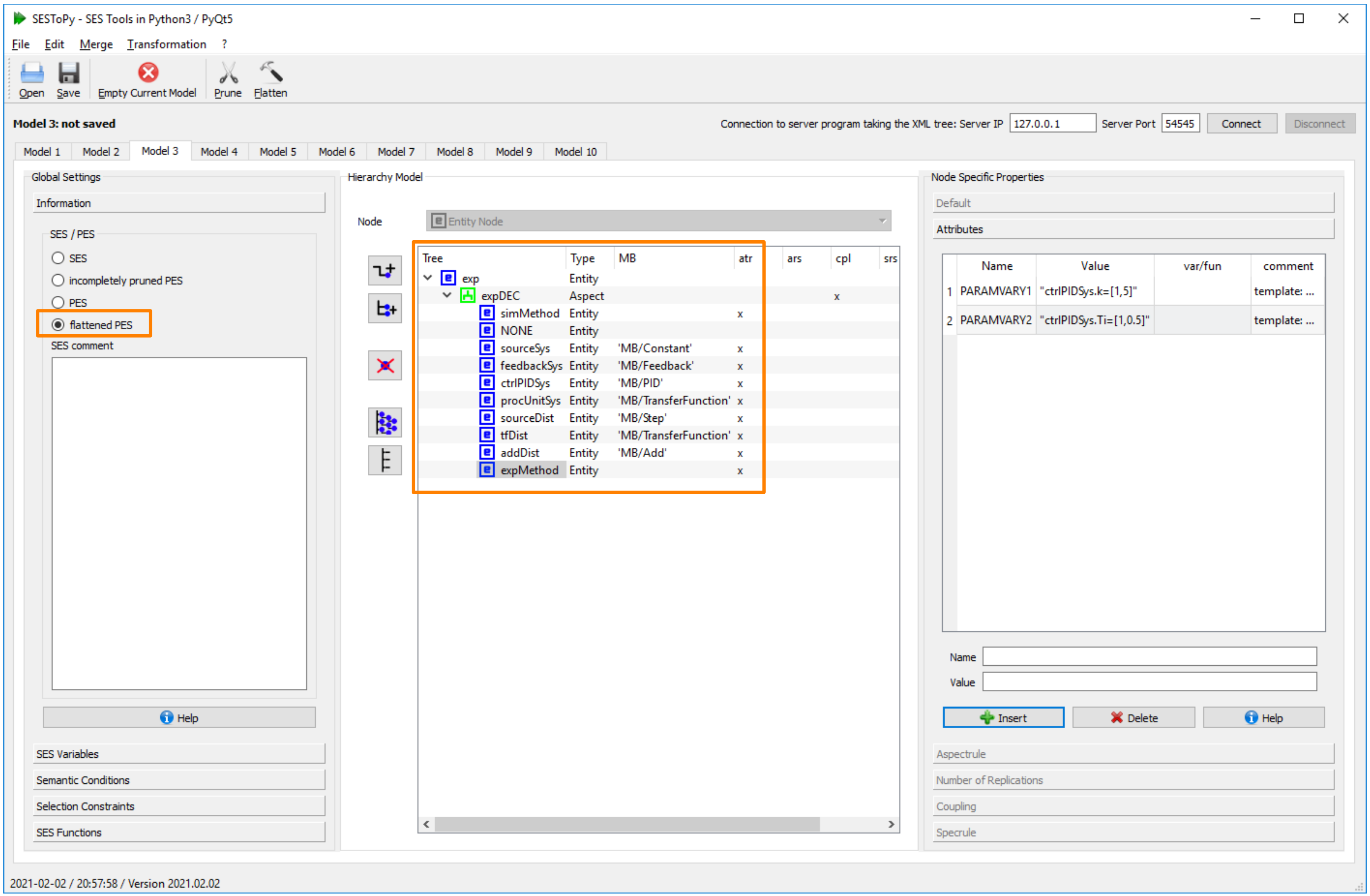
Different Parameters can be set



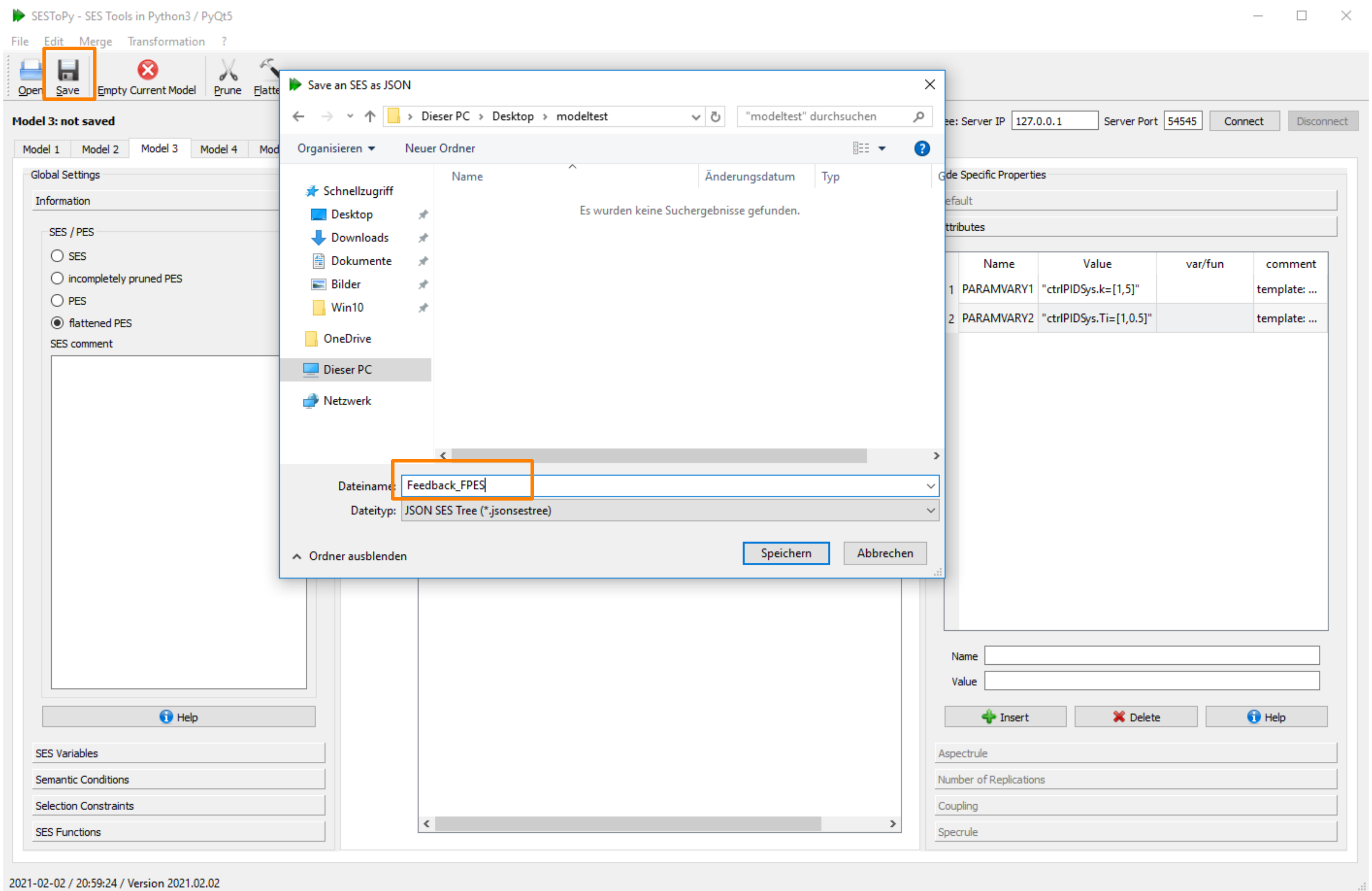
Prune & Flatten for feedforward=0



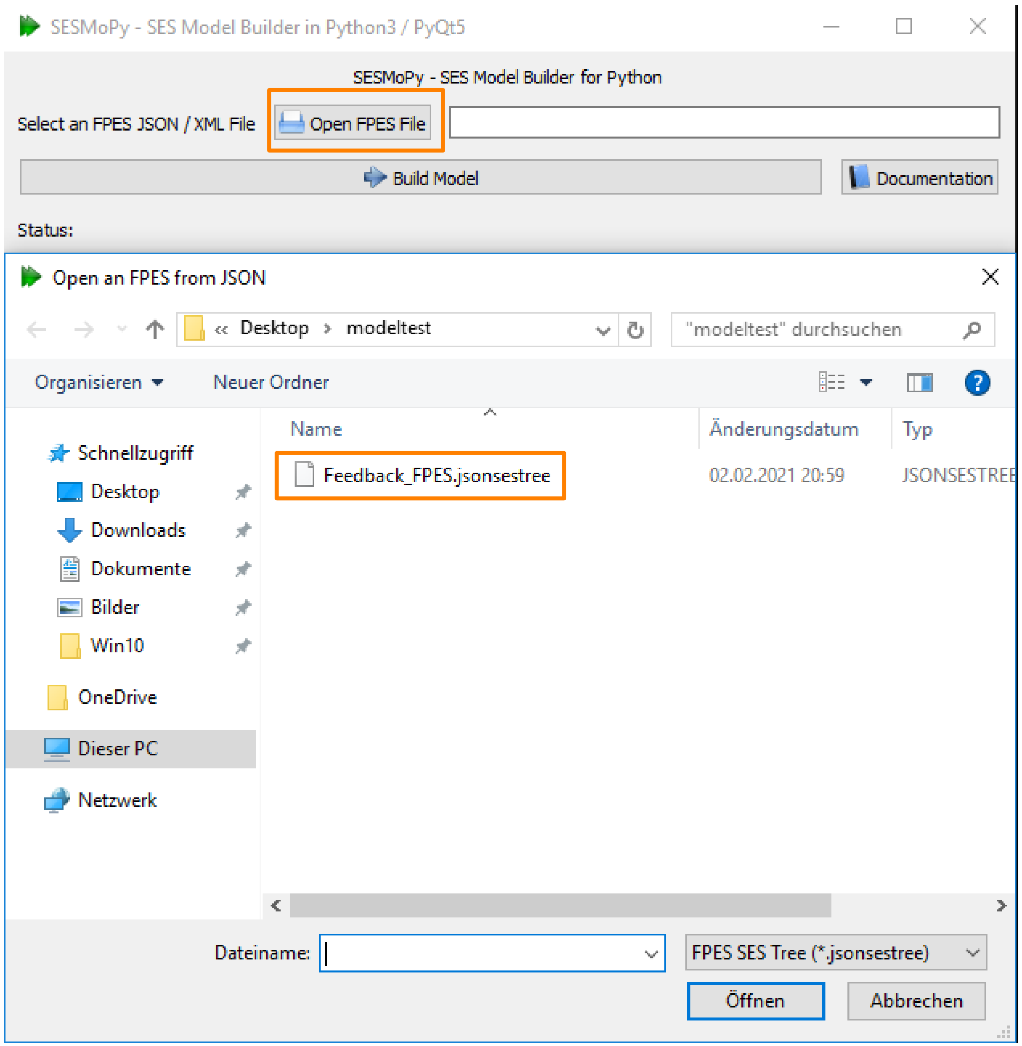
Flattened PES for feedforward=0



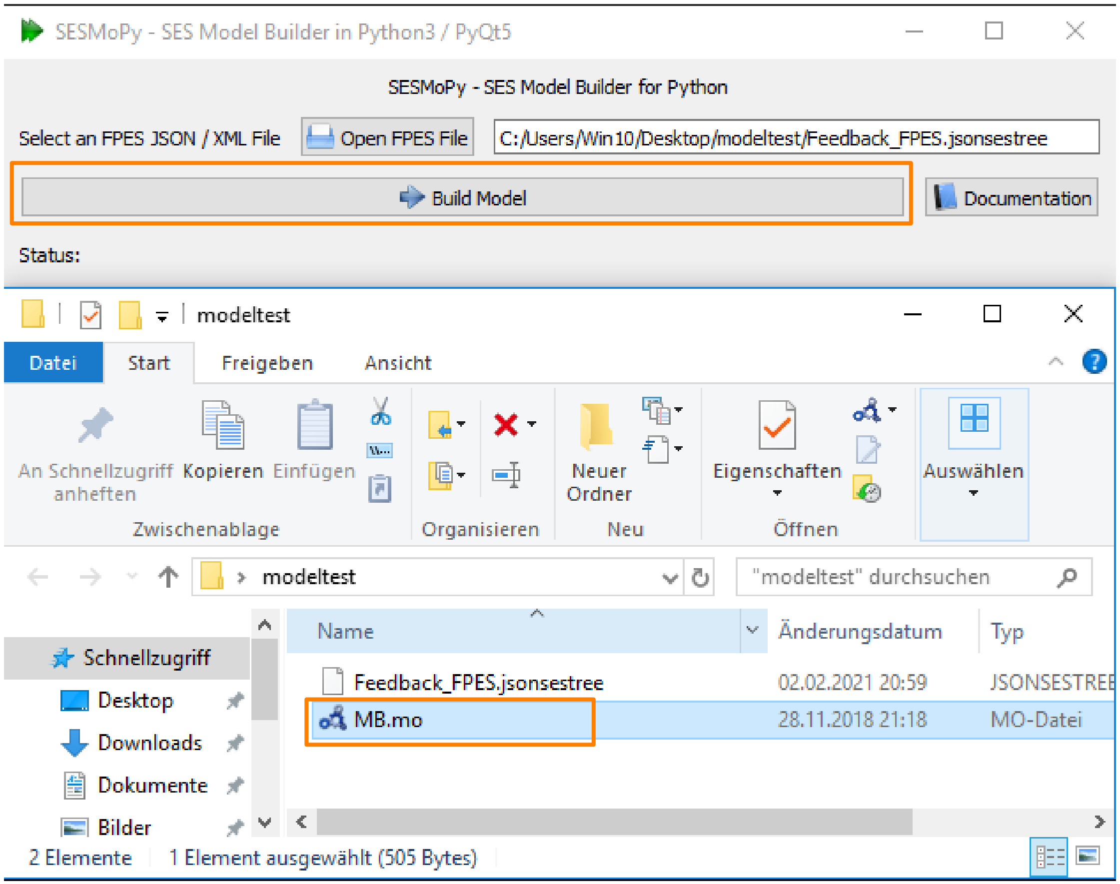
Save Flattened PES for feedforward=0



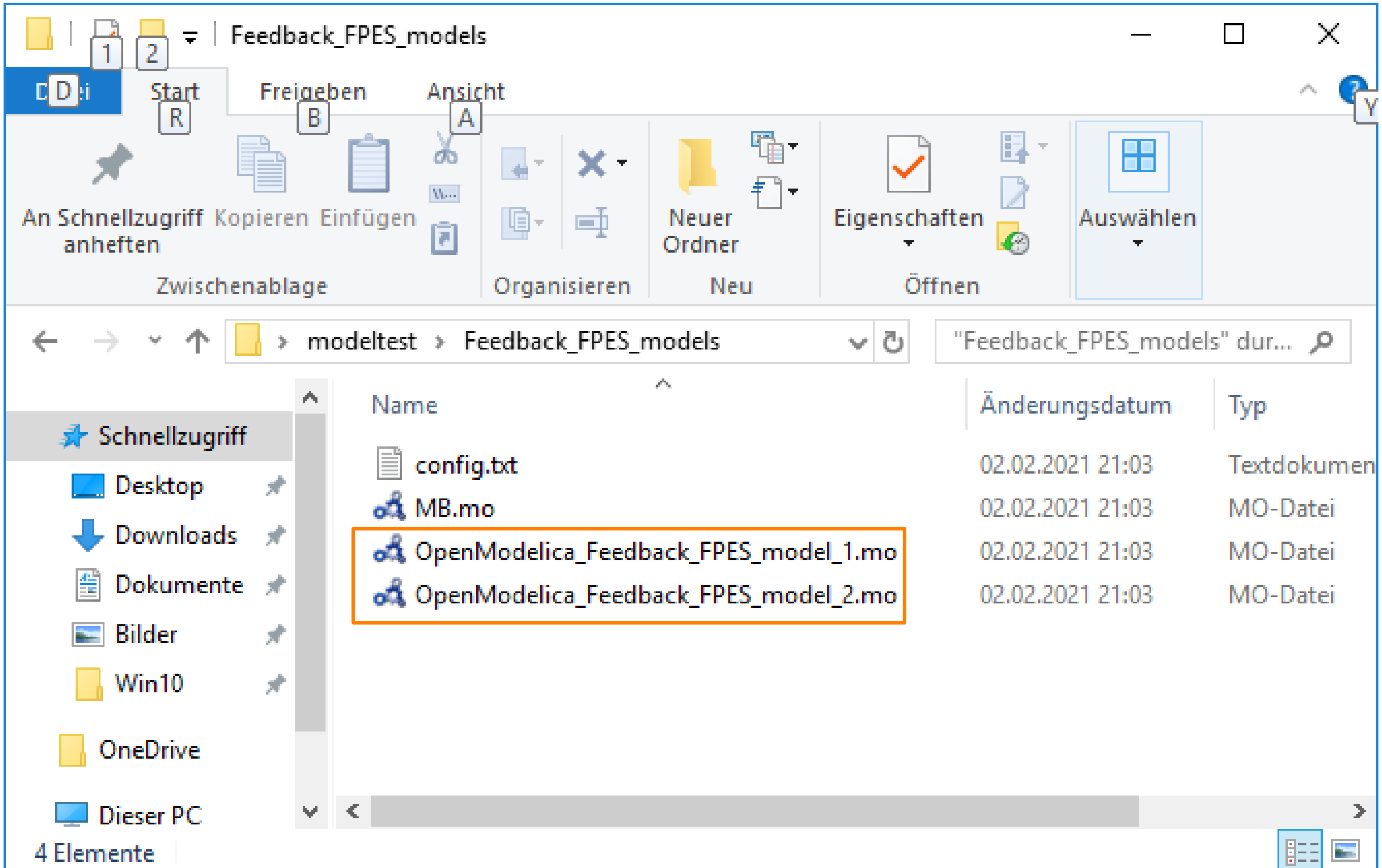
Open Flattened PES in SESMoPy



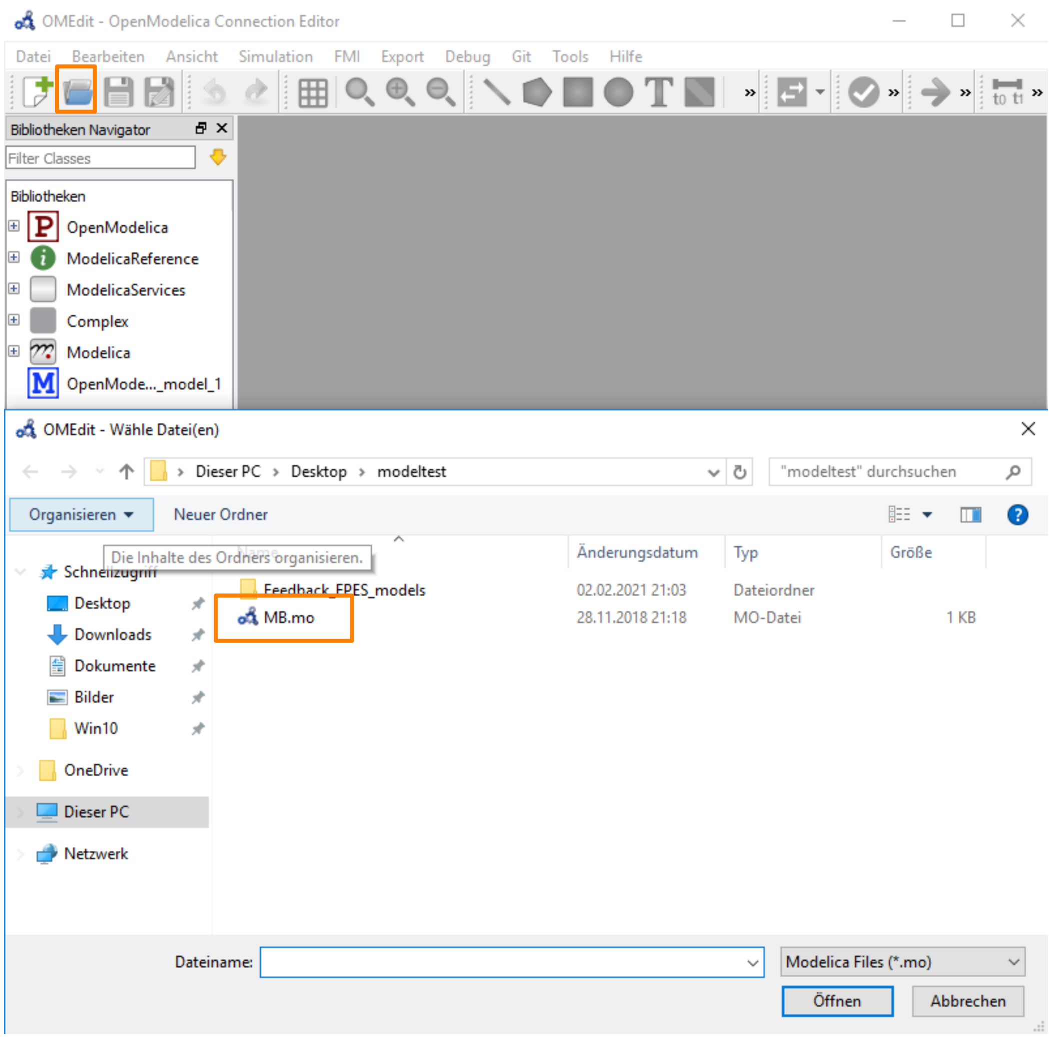
Add MB in Modelfolder & Build Model



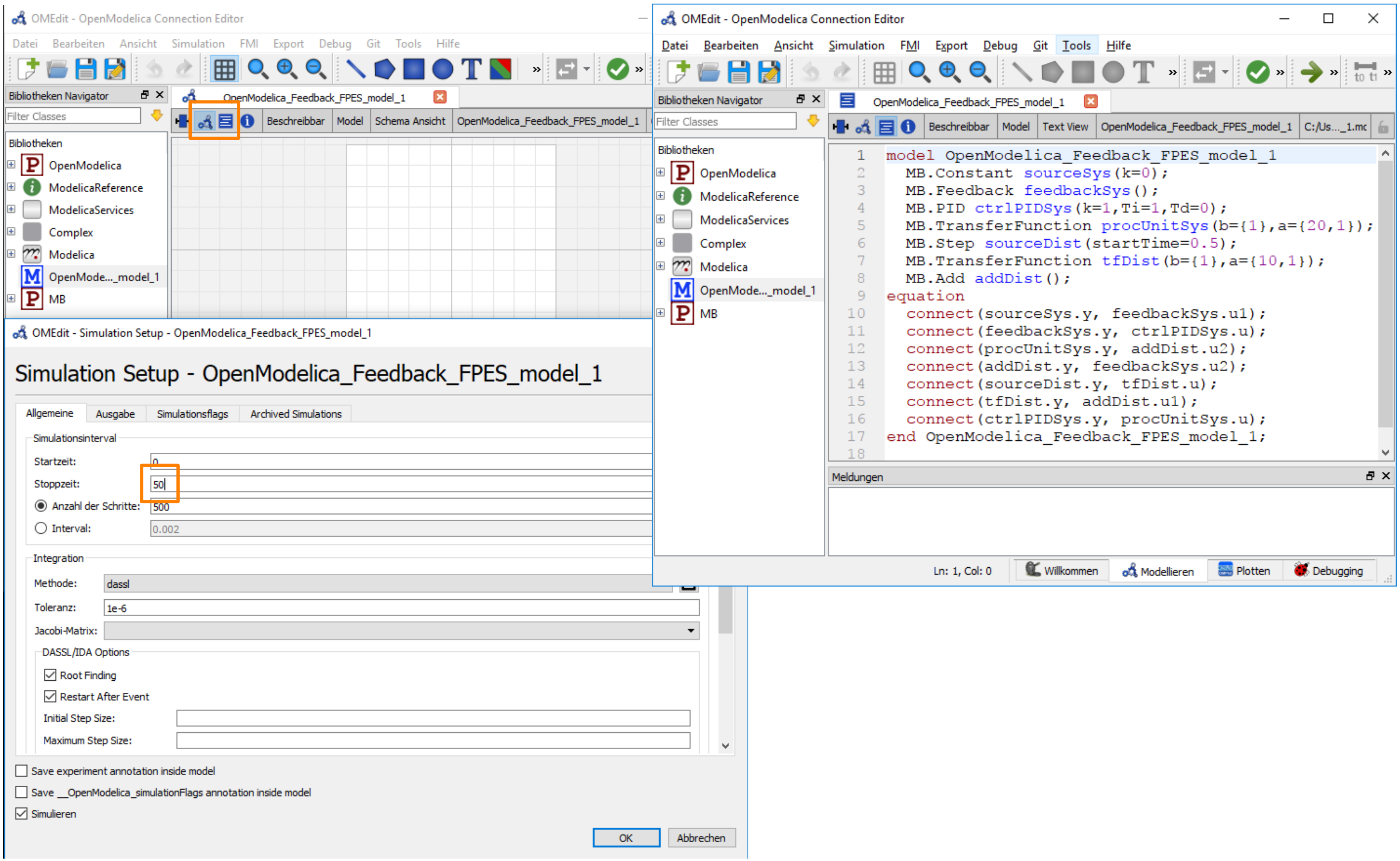
Created Models



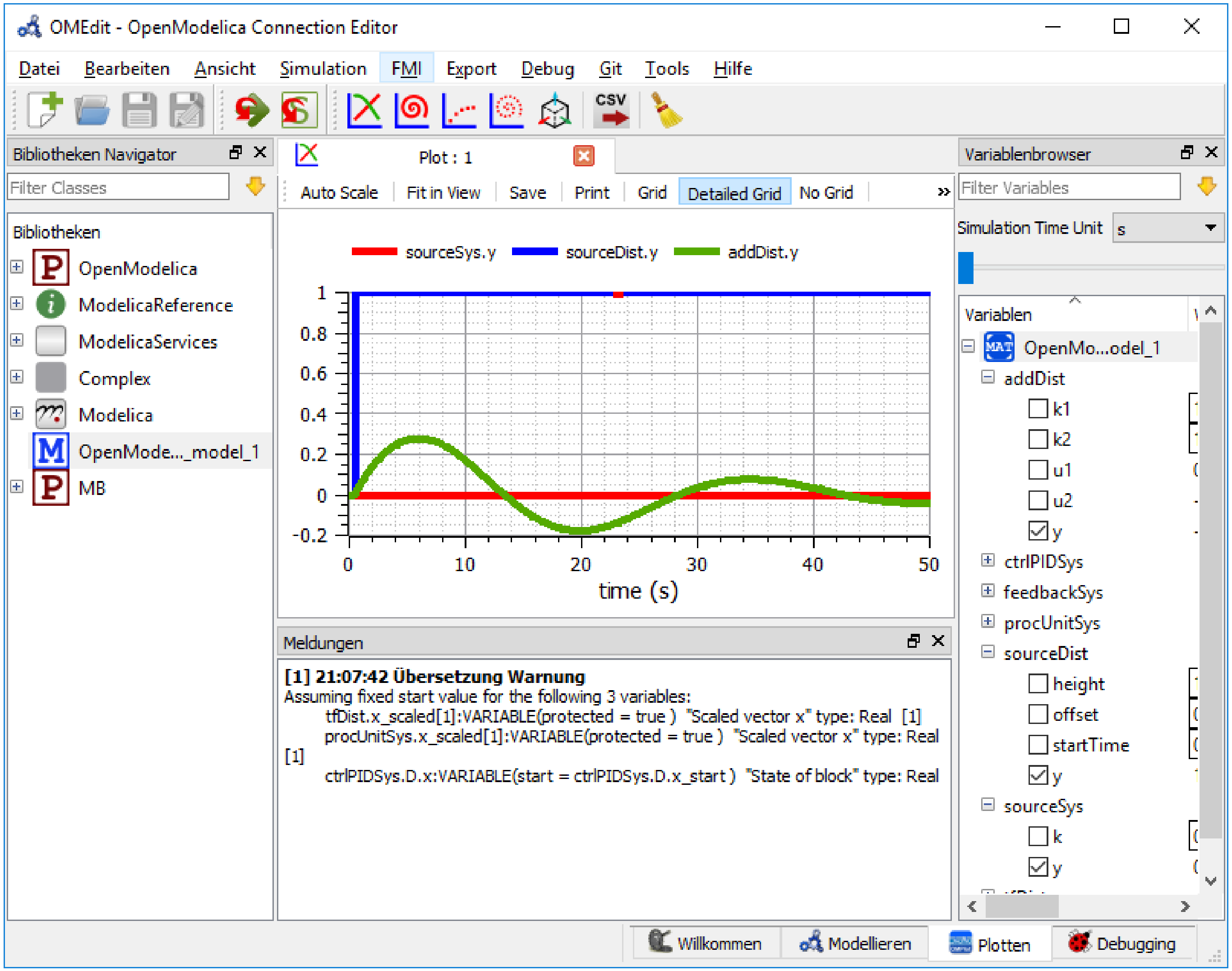
Open Created Models in OpenModelica & Load MB



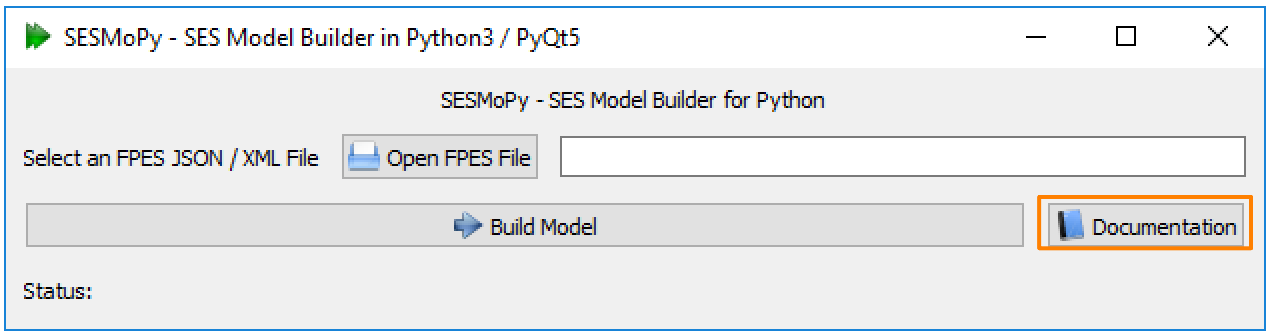
Model & Setup Simulation in OpenModelica



OpenModelica Simulation Results



SESMoPy Documentation



- See the documentation for more information

Outline

1. Case study
2. Implementation of the SES and an MB
3. Model selection and model generation
4. **Organization of a simulator-independent MB**
5. Full automation of simulation experiments
6. Summary

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- **Goal: One** (simple) MB and model builder for **all** simulators

Functional Mock-up Interface (FMI) [1,2]

[1]Blochwitz et al. (2011) „The Functional Mockup Interface for Tool independent Exchange of Simulation Models“. Proc. of the 8th Modelica Conference, Dresden.

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a zipped file with fileextension .fmu

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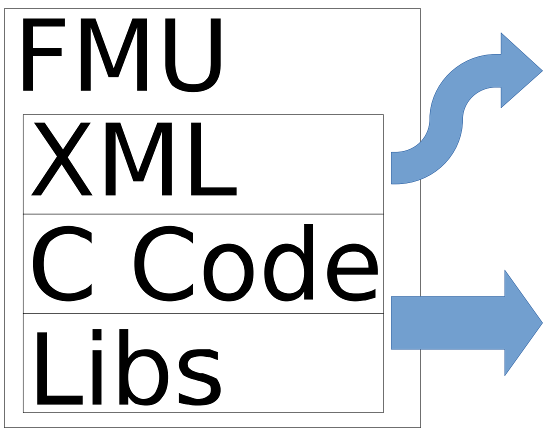

Description of interface data (variables, ...)

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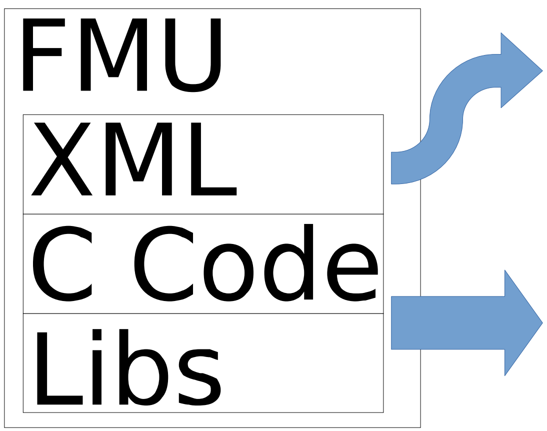

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Model Exchange

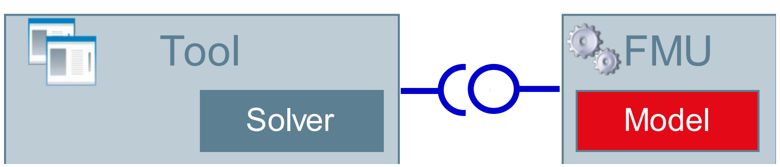

Figure taken from the FMI presentation on the website www.fmi-standard.org.

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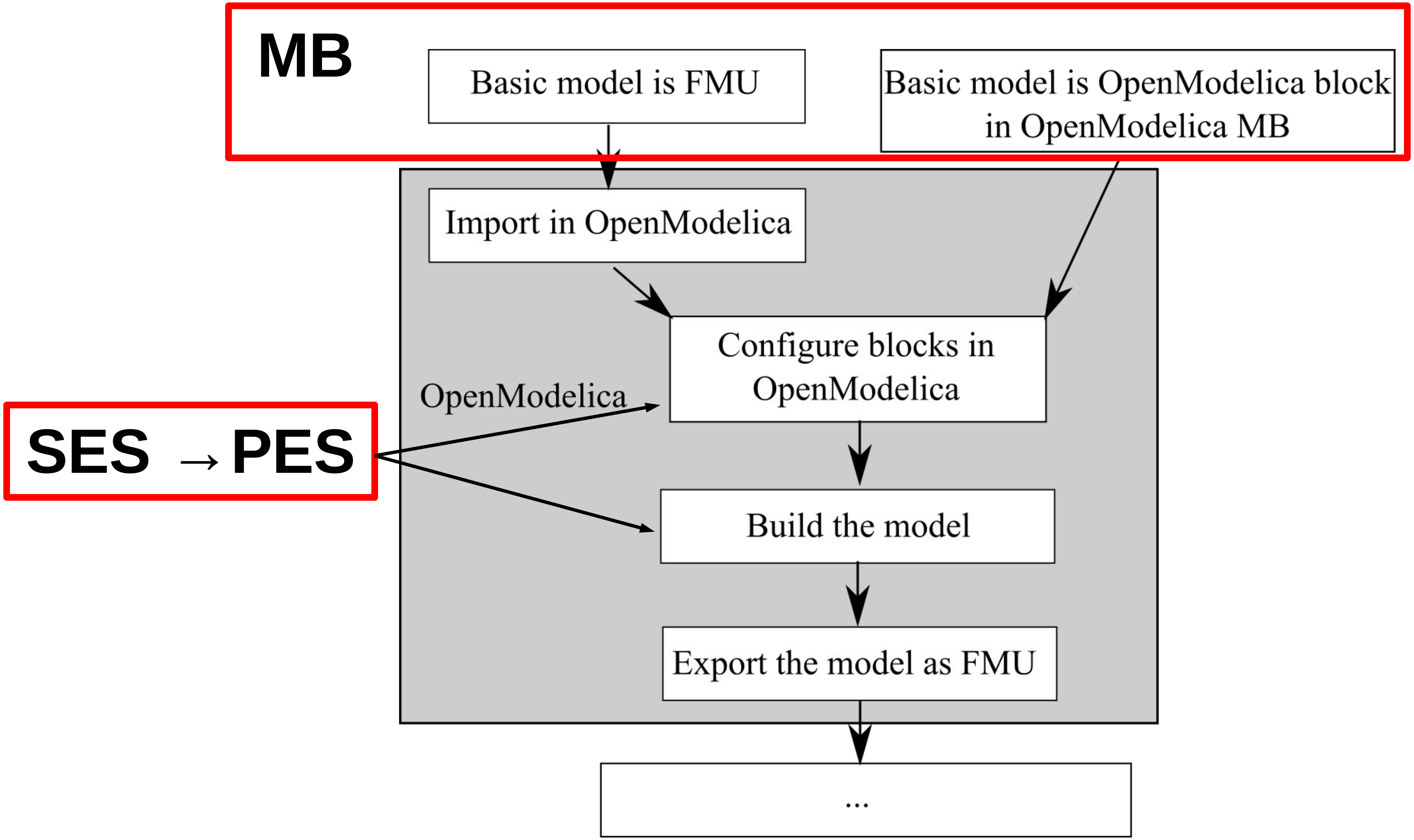

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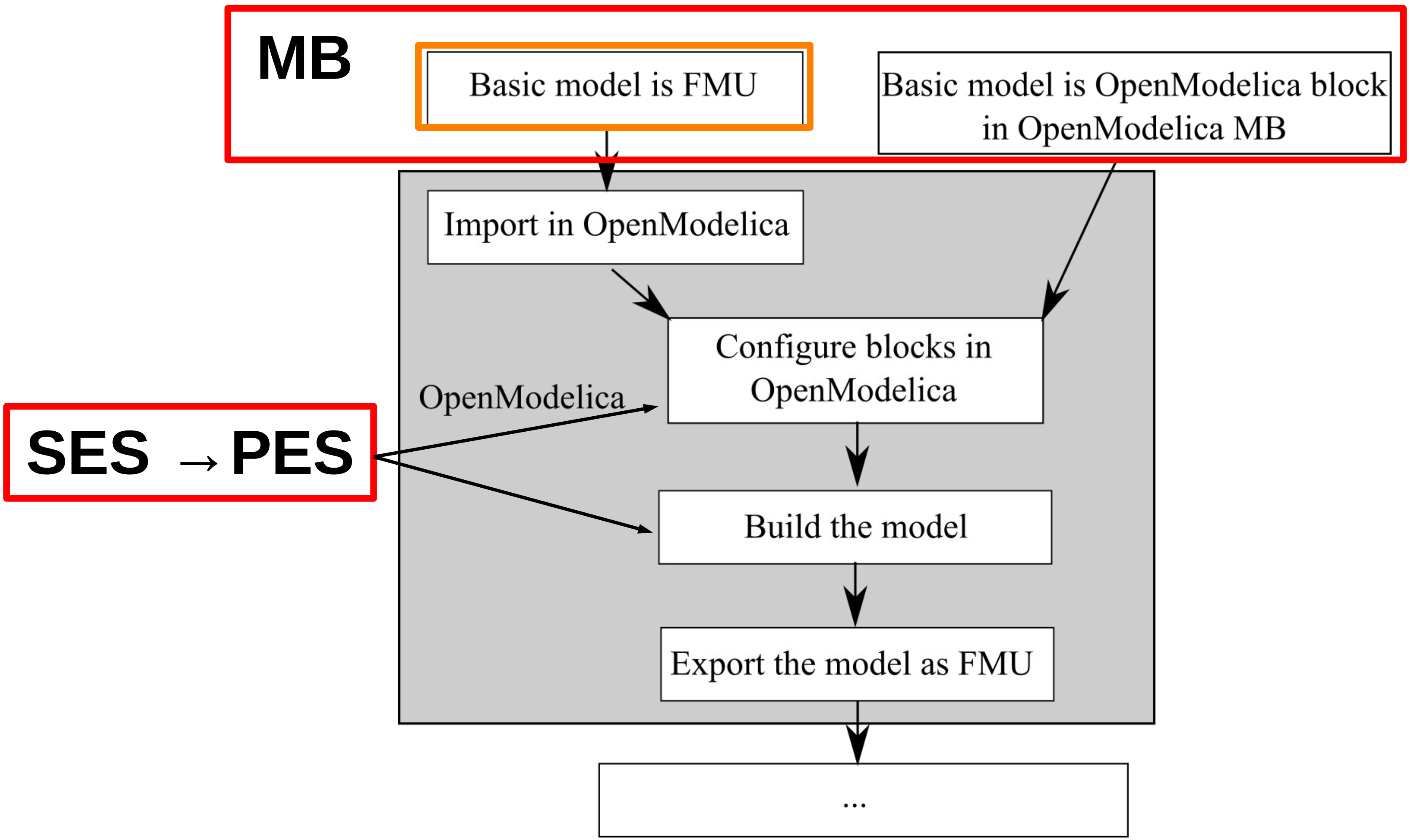

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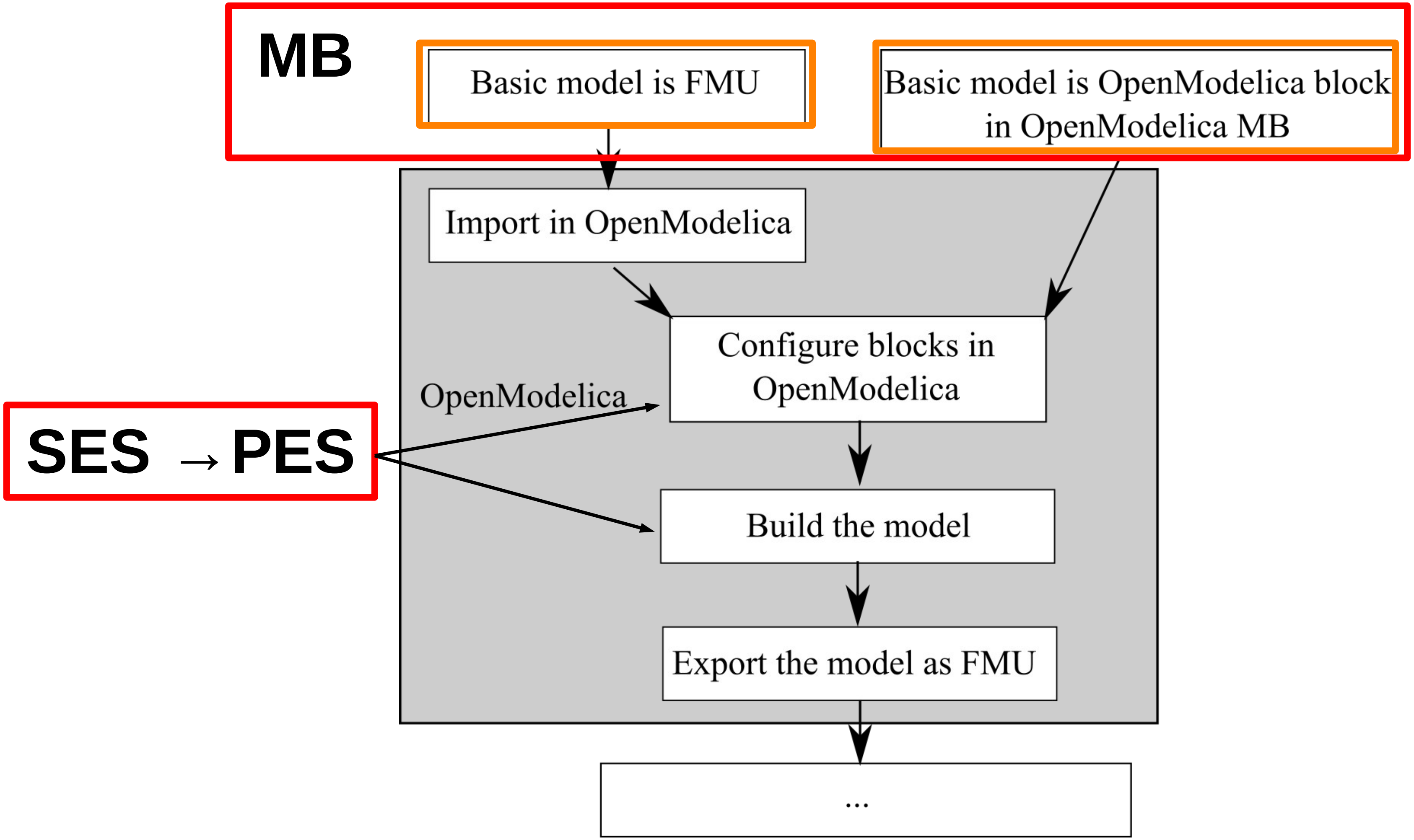

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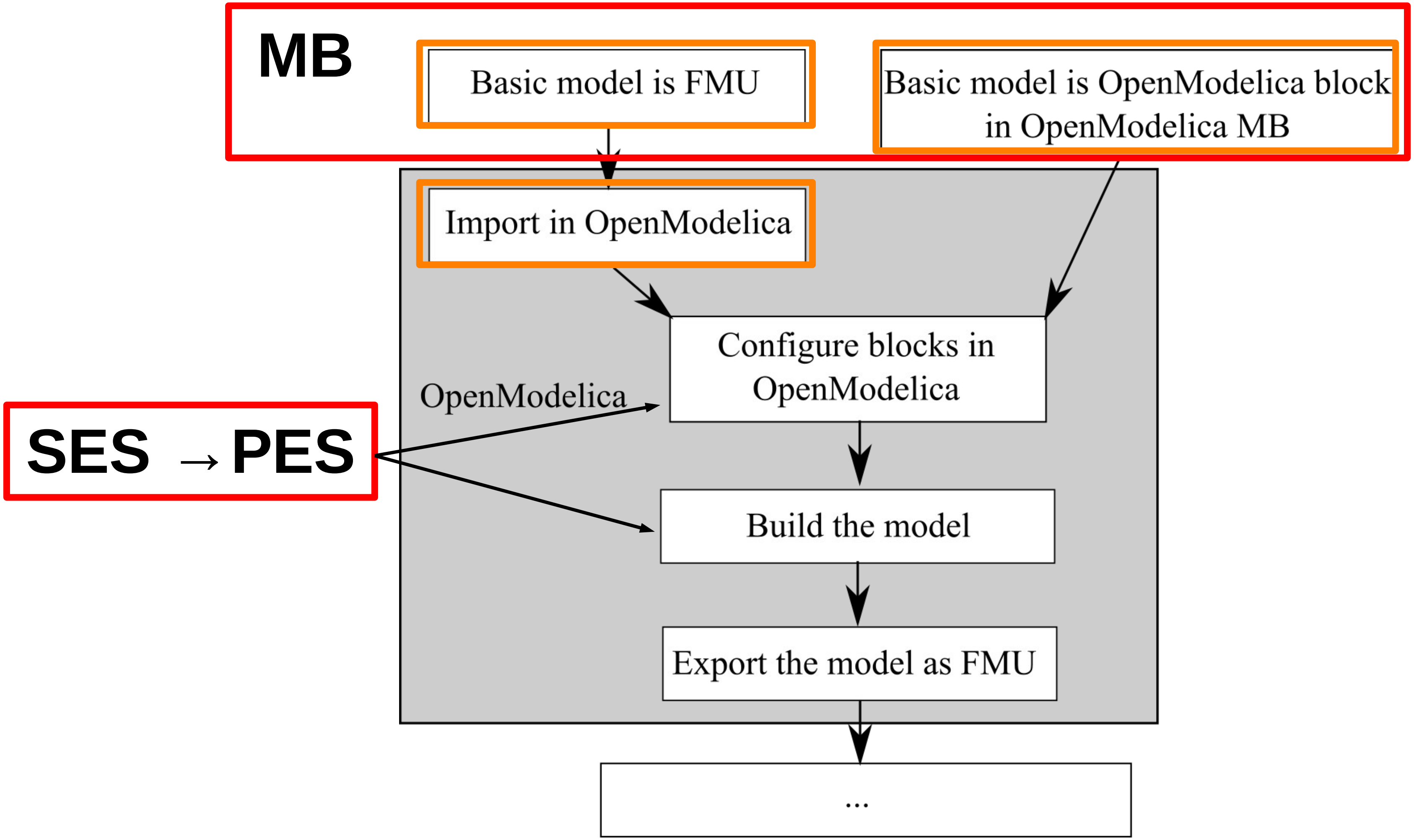

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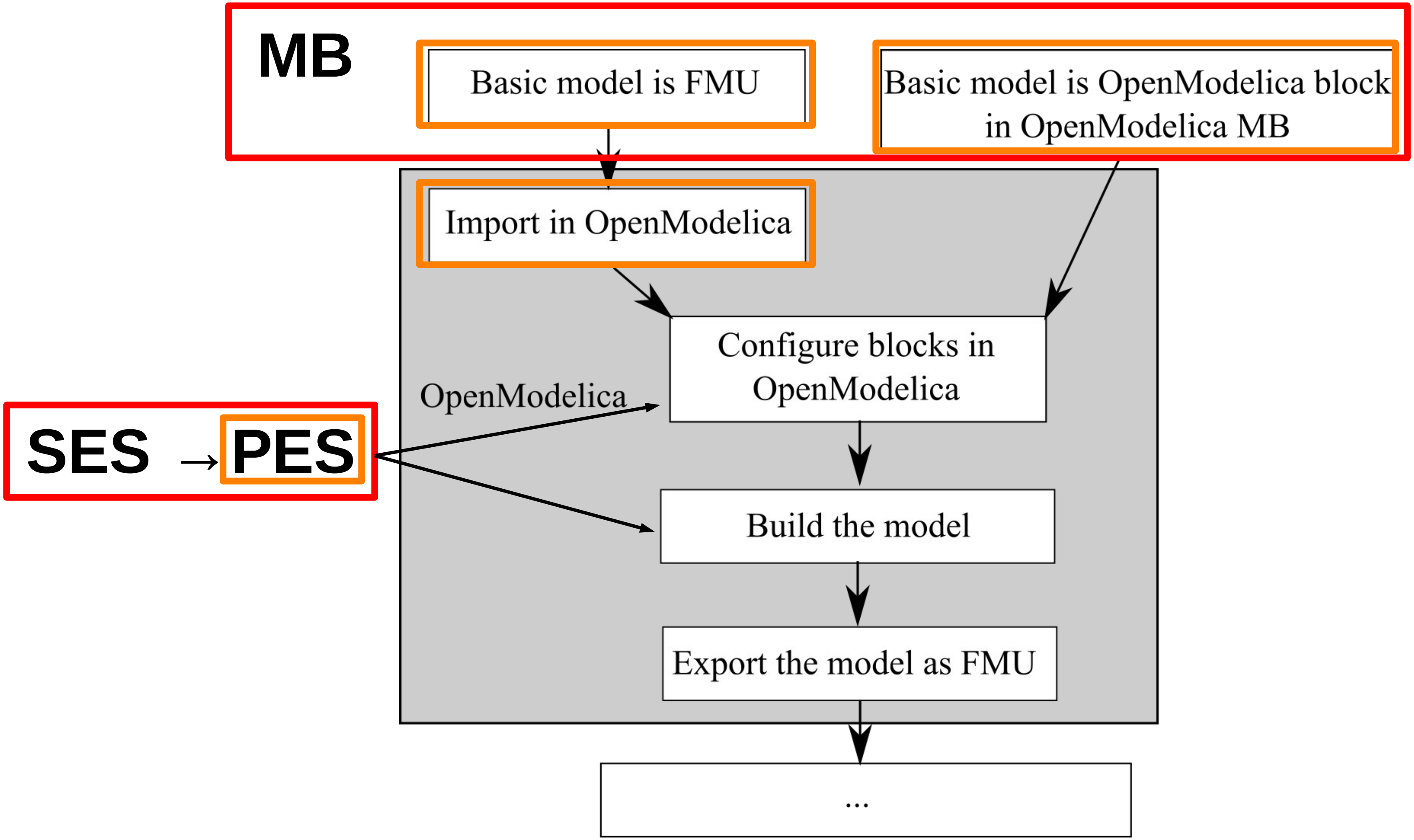

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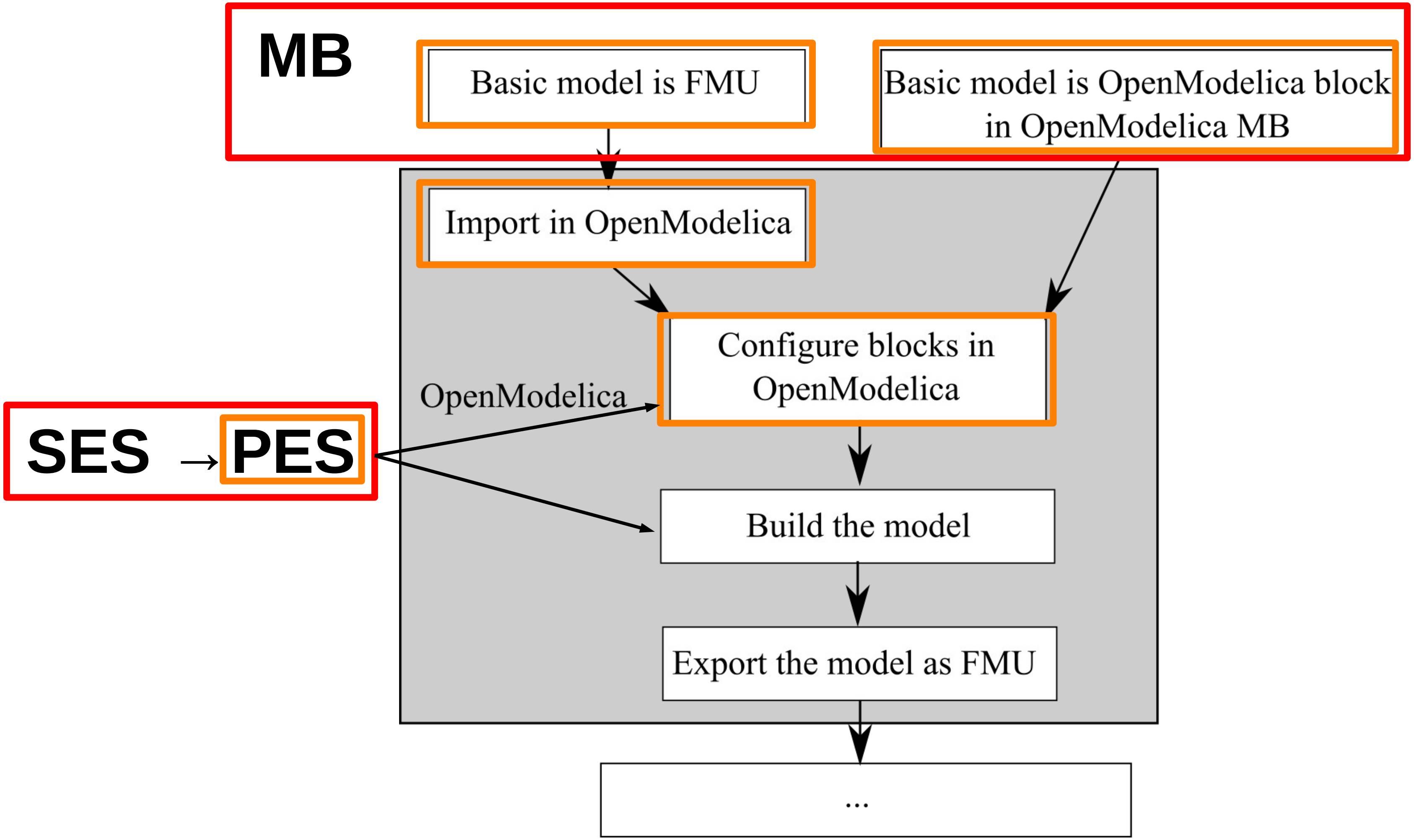

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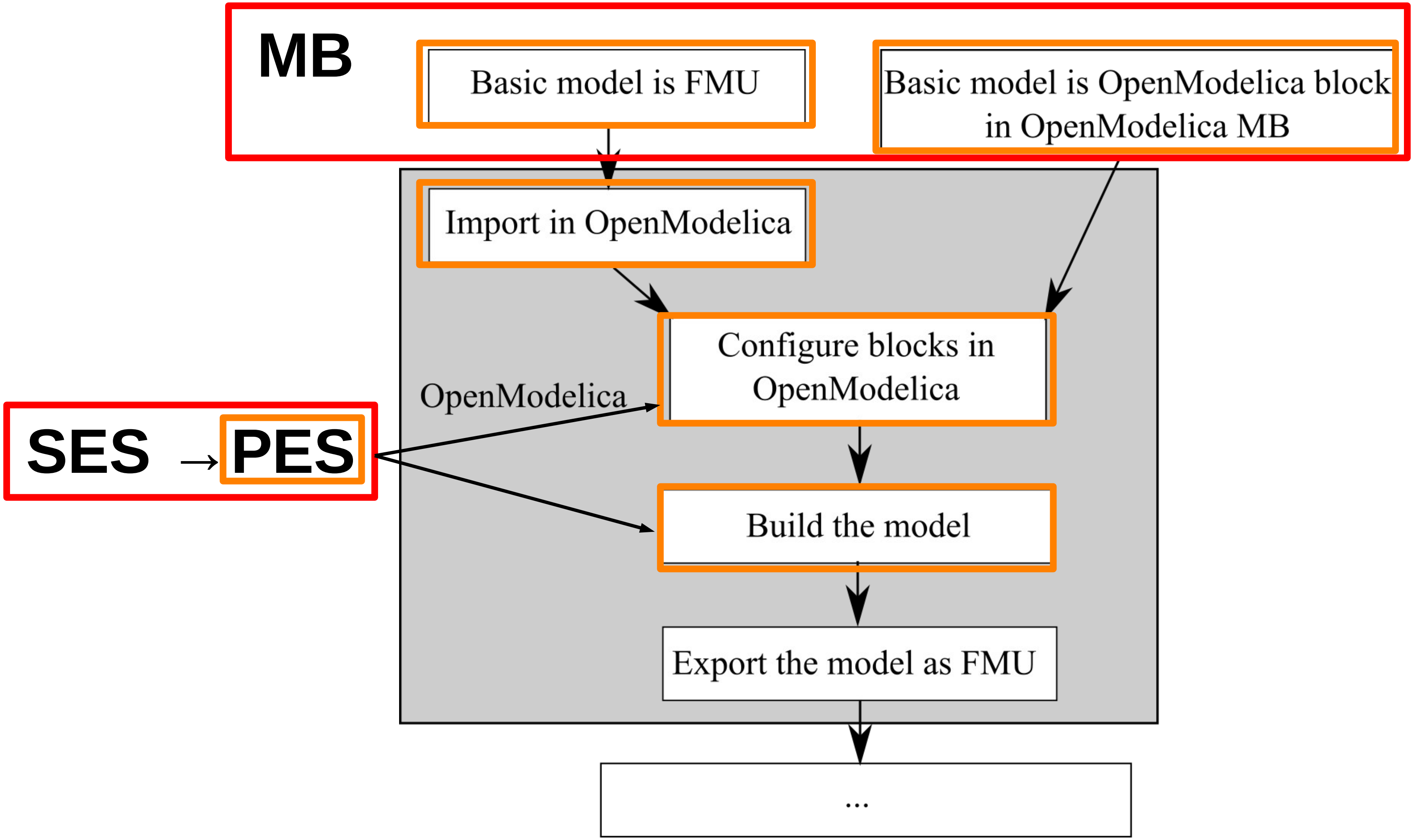

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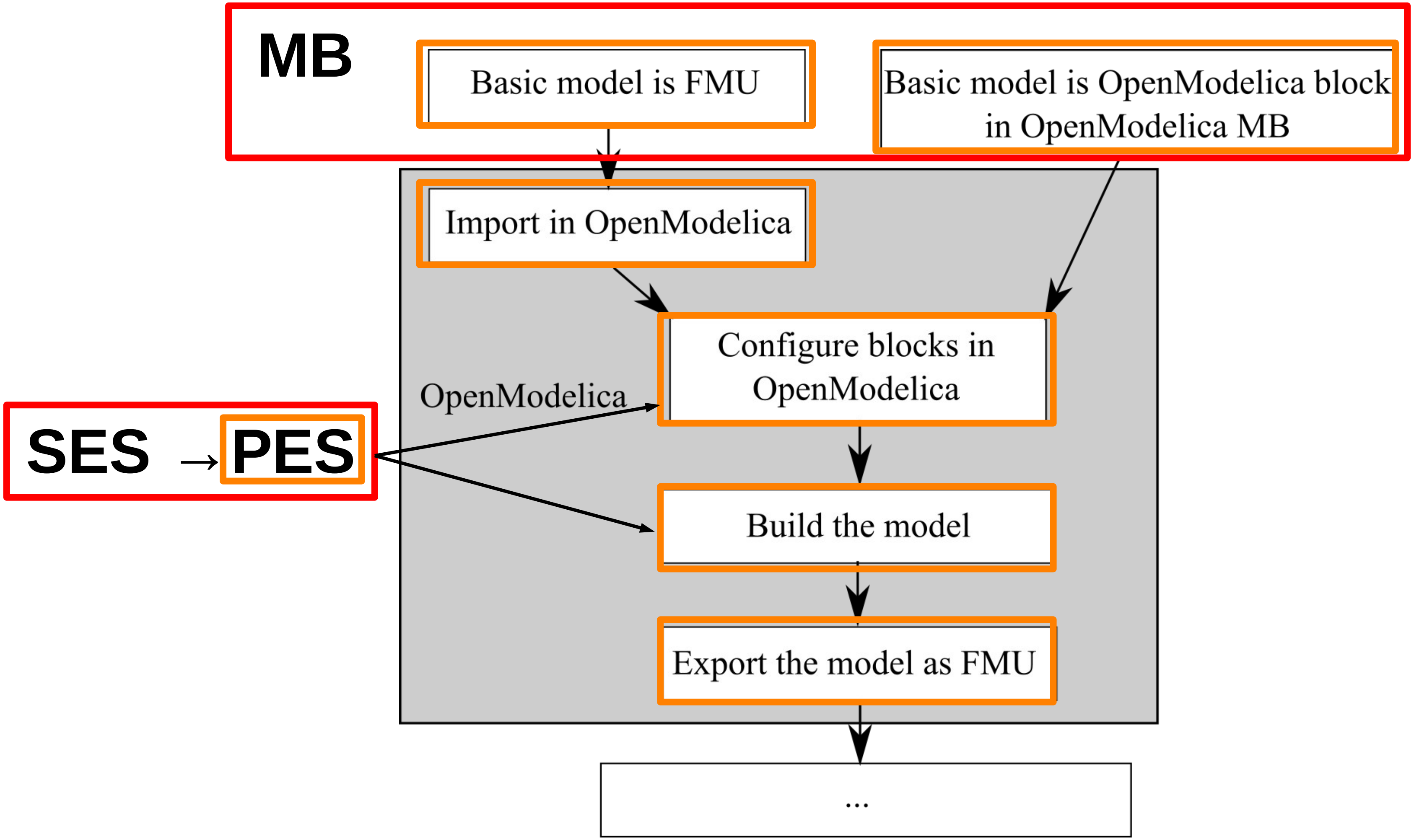
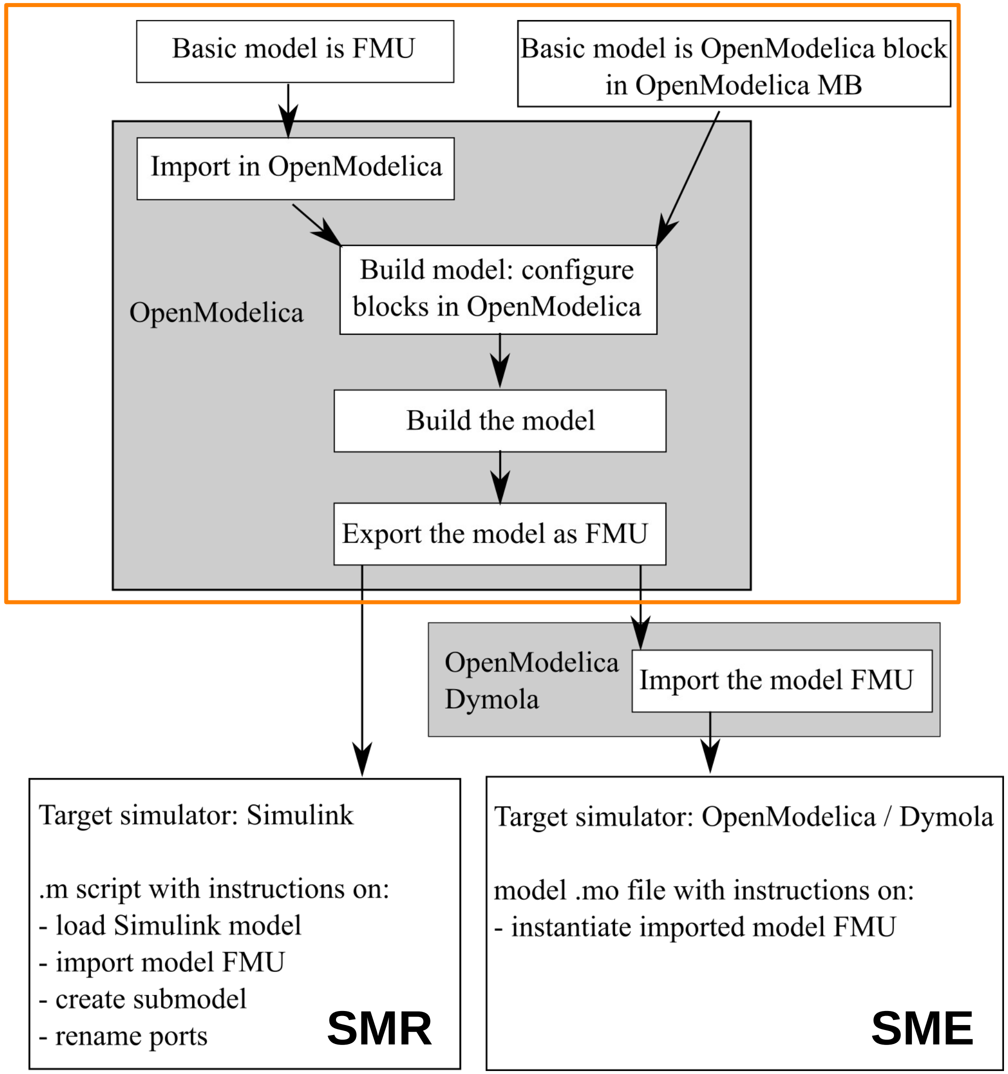


Model Building Using FMI (2)



Model Building Using FMI (2)

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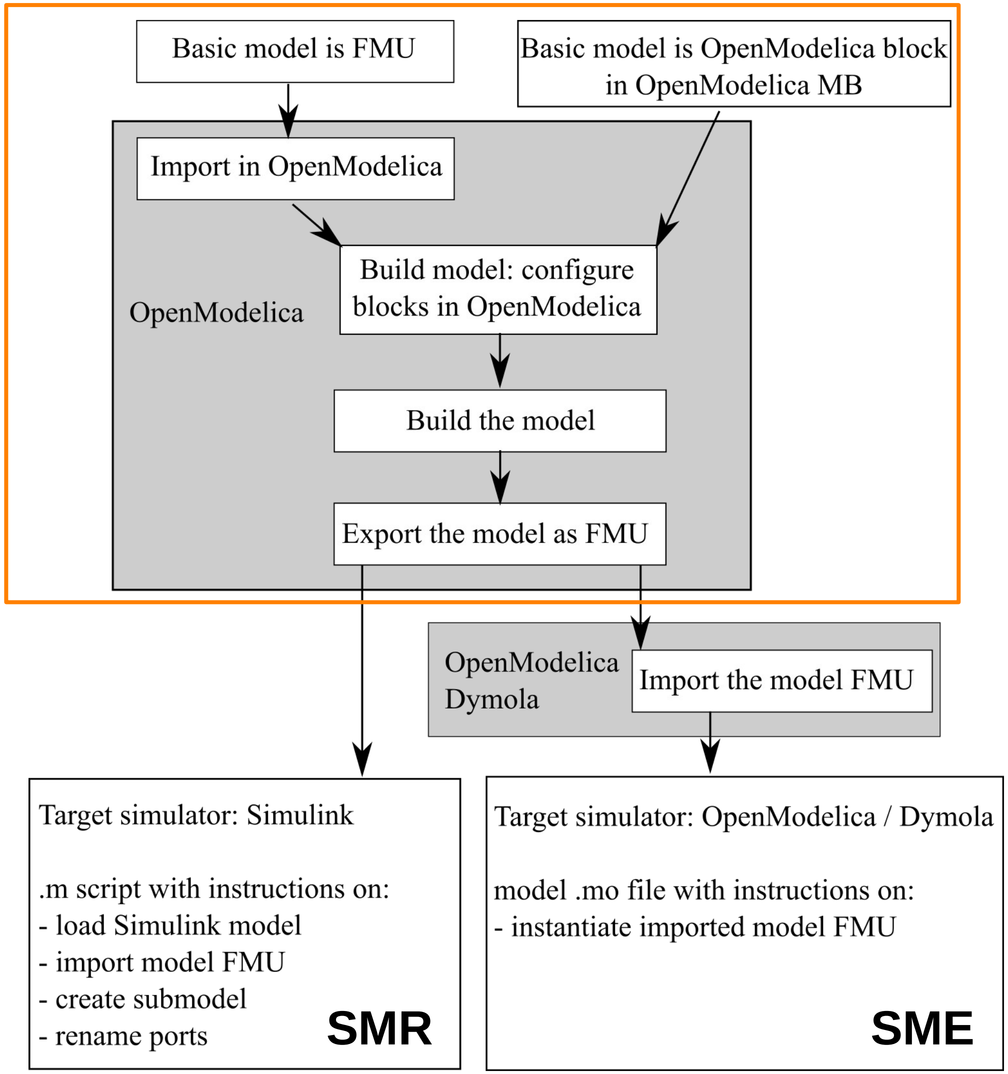

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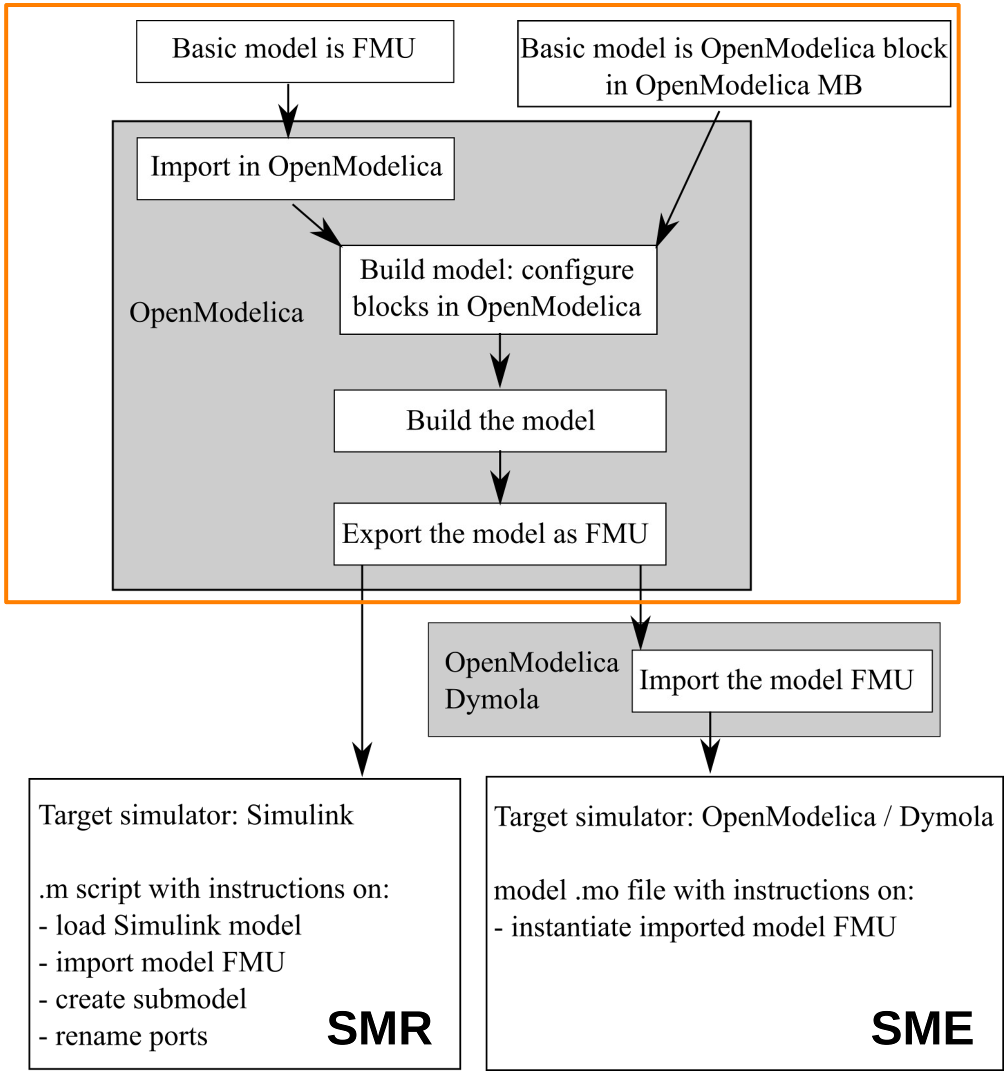

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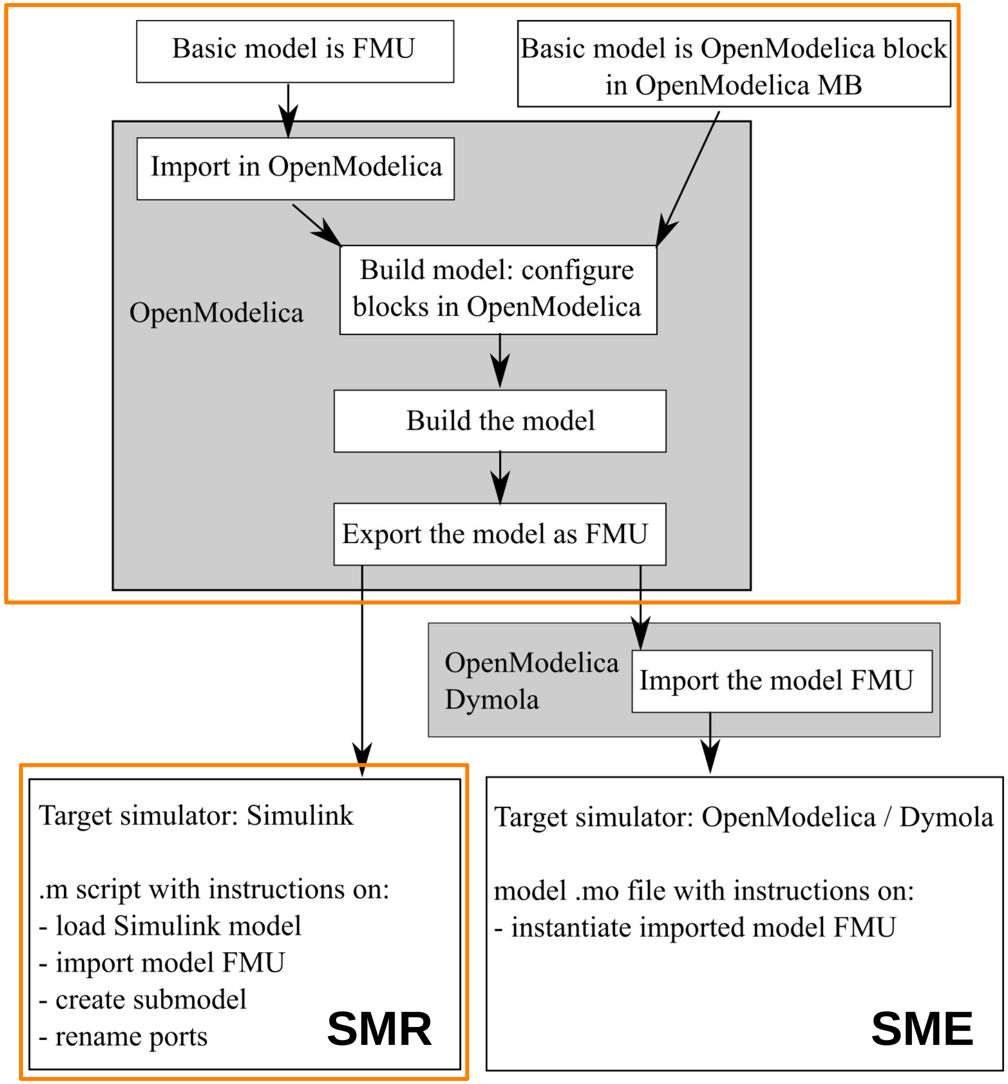

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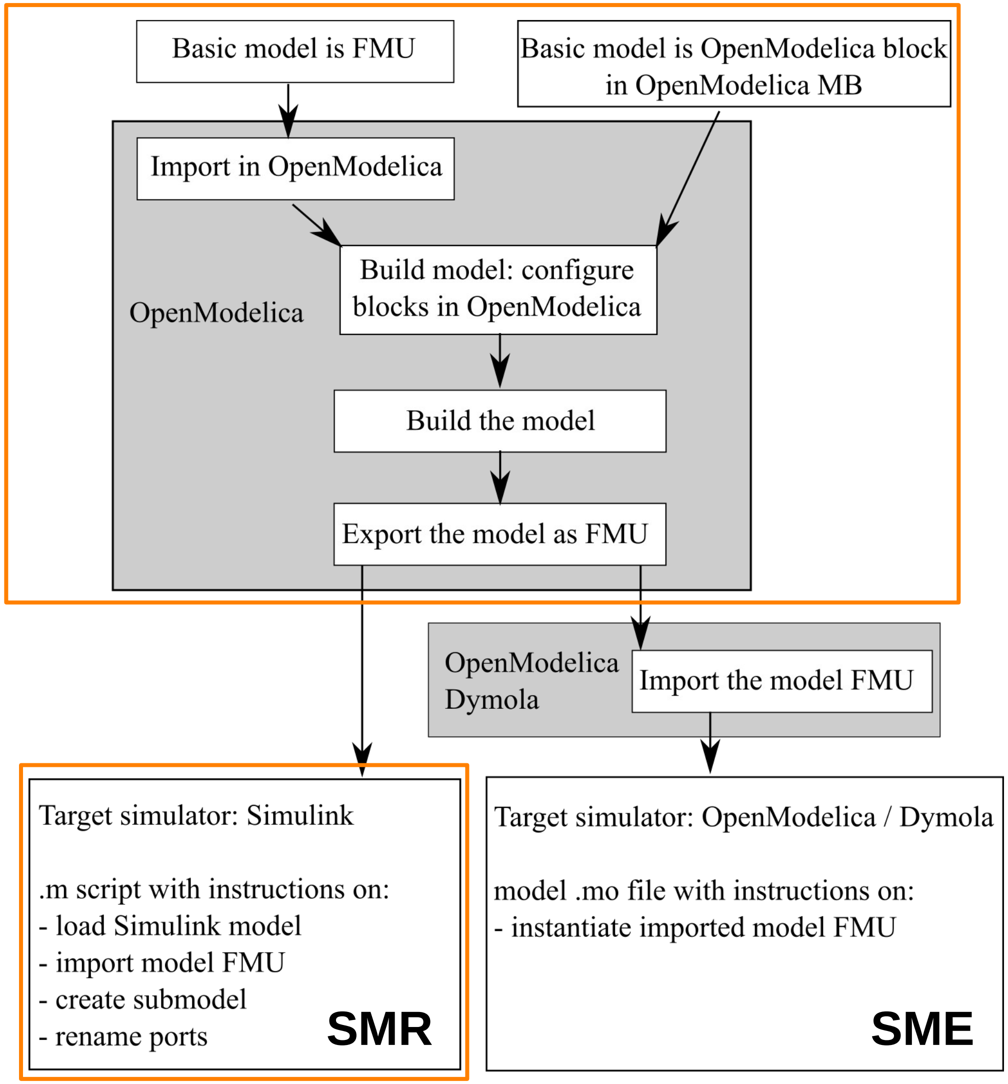

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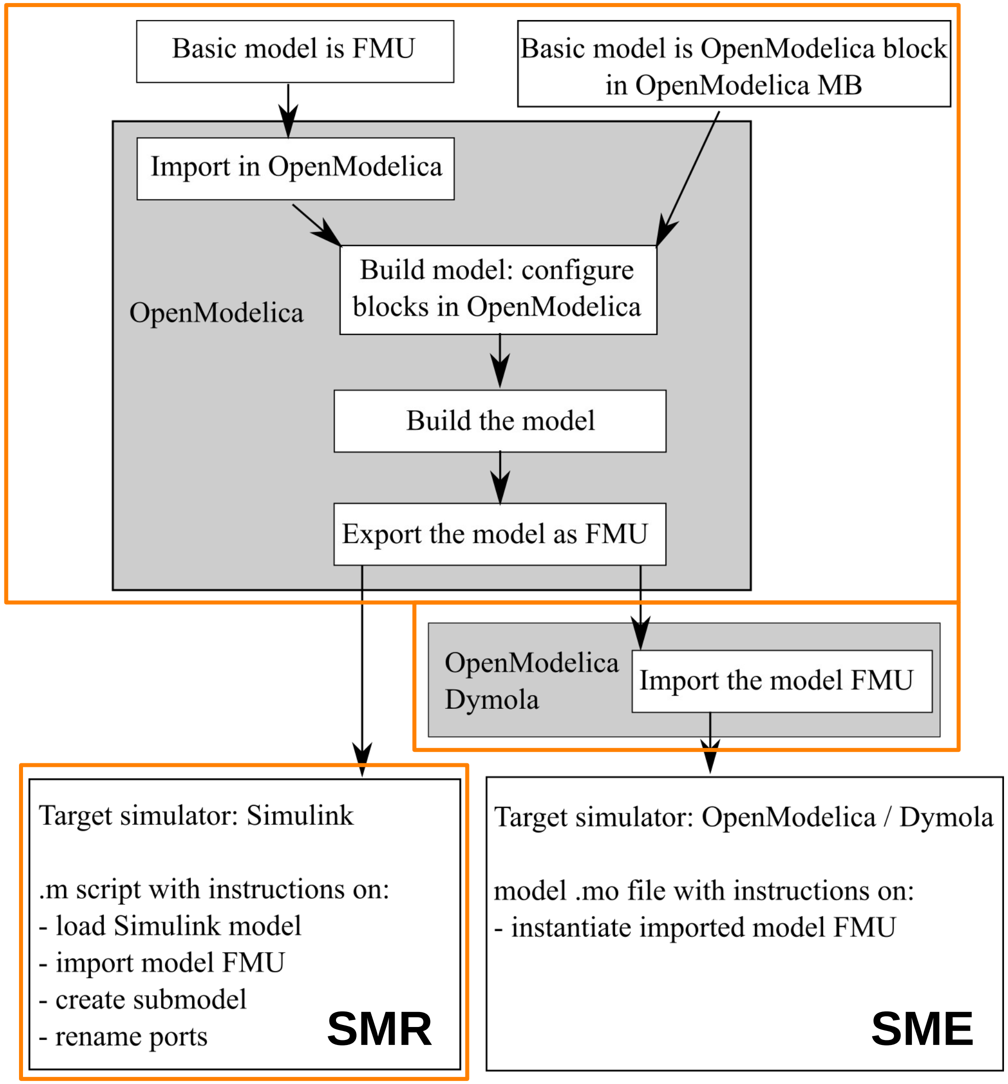

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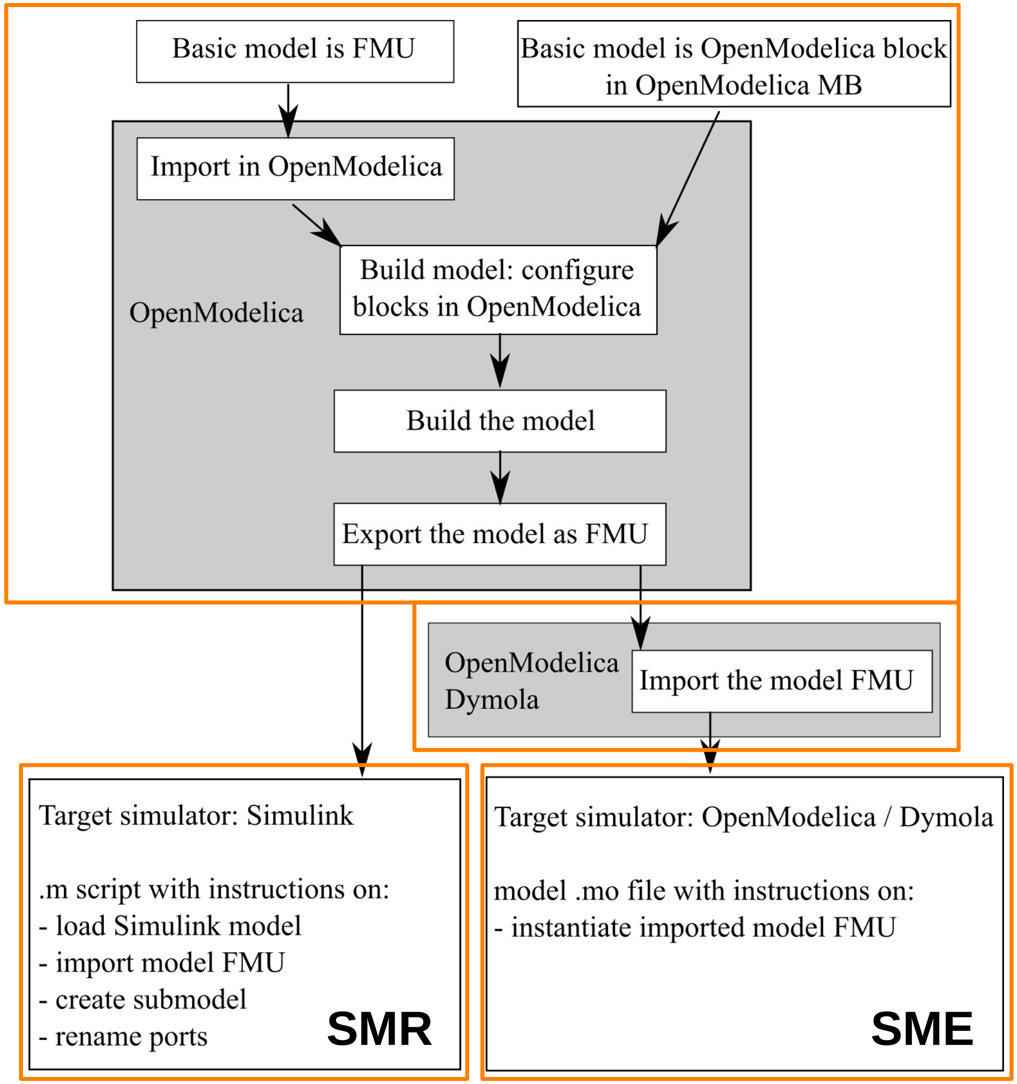
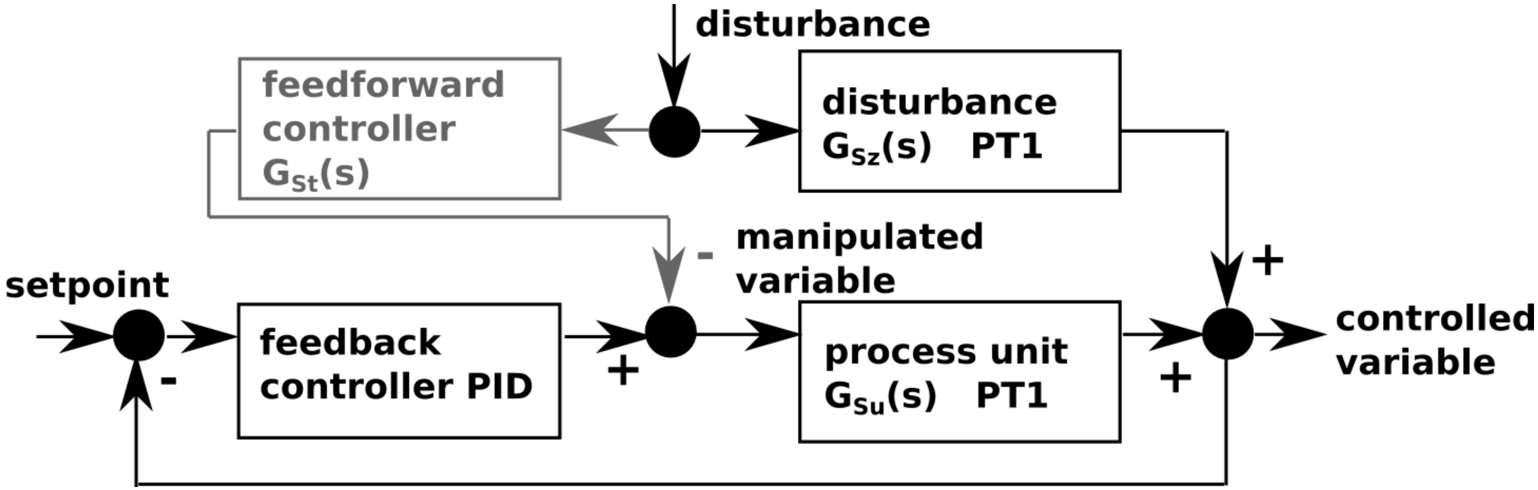
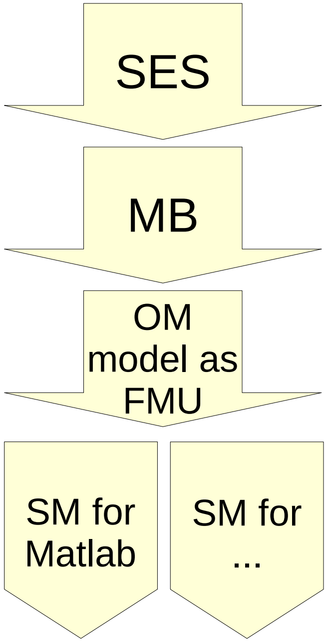


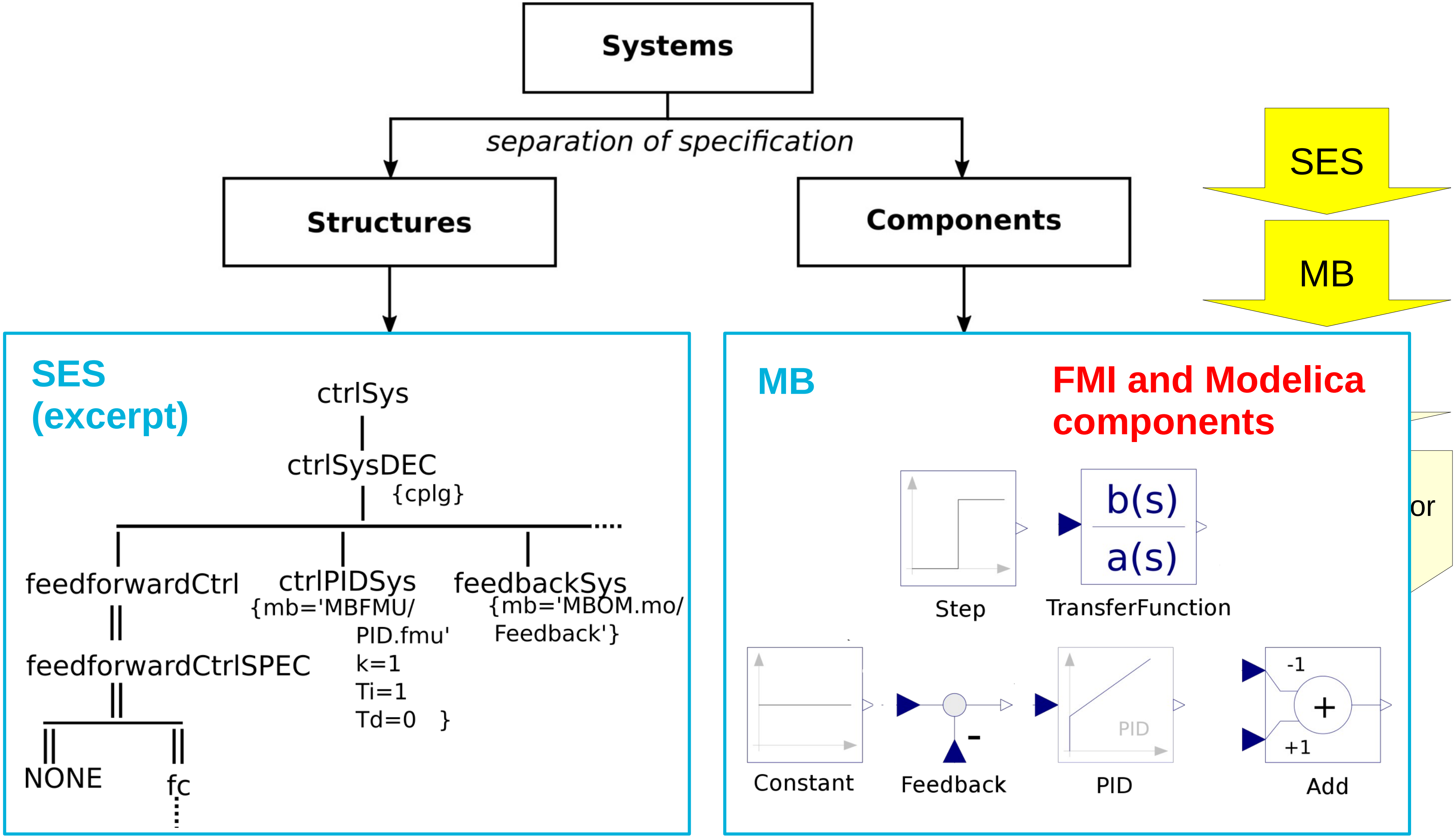
Case Study with FMI





- FMI-based approach implemented in SESMoPy
- Flattened PES for the FMI-based case study in the `examples/Example03_FeedbackControl_FMI` directory of SESMoPy: `Feedback_FPES.jsonsestree`
- Usage of SESMoPy as presented before

SES/MB Approach with FMI Components



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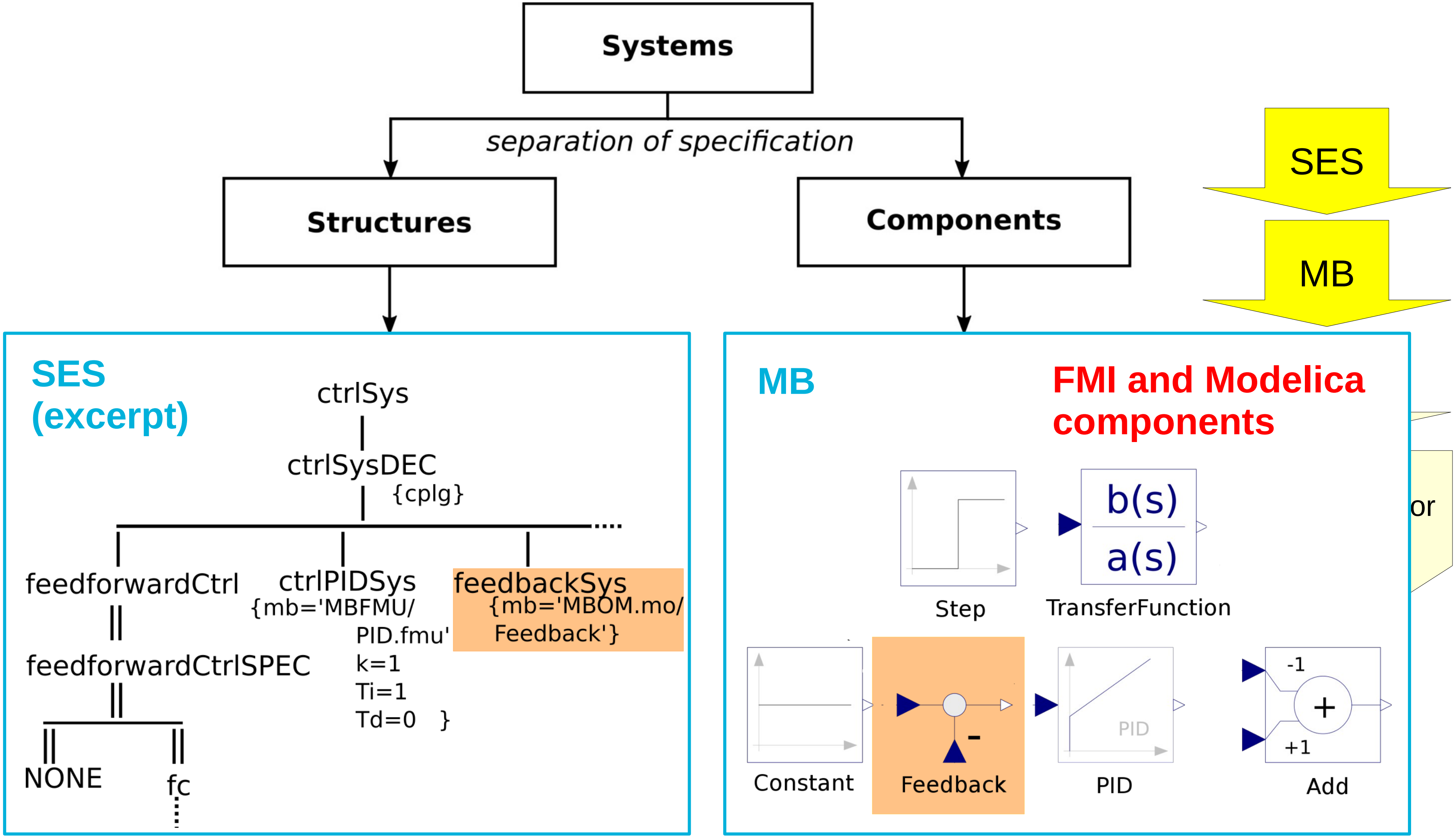

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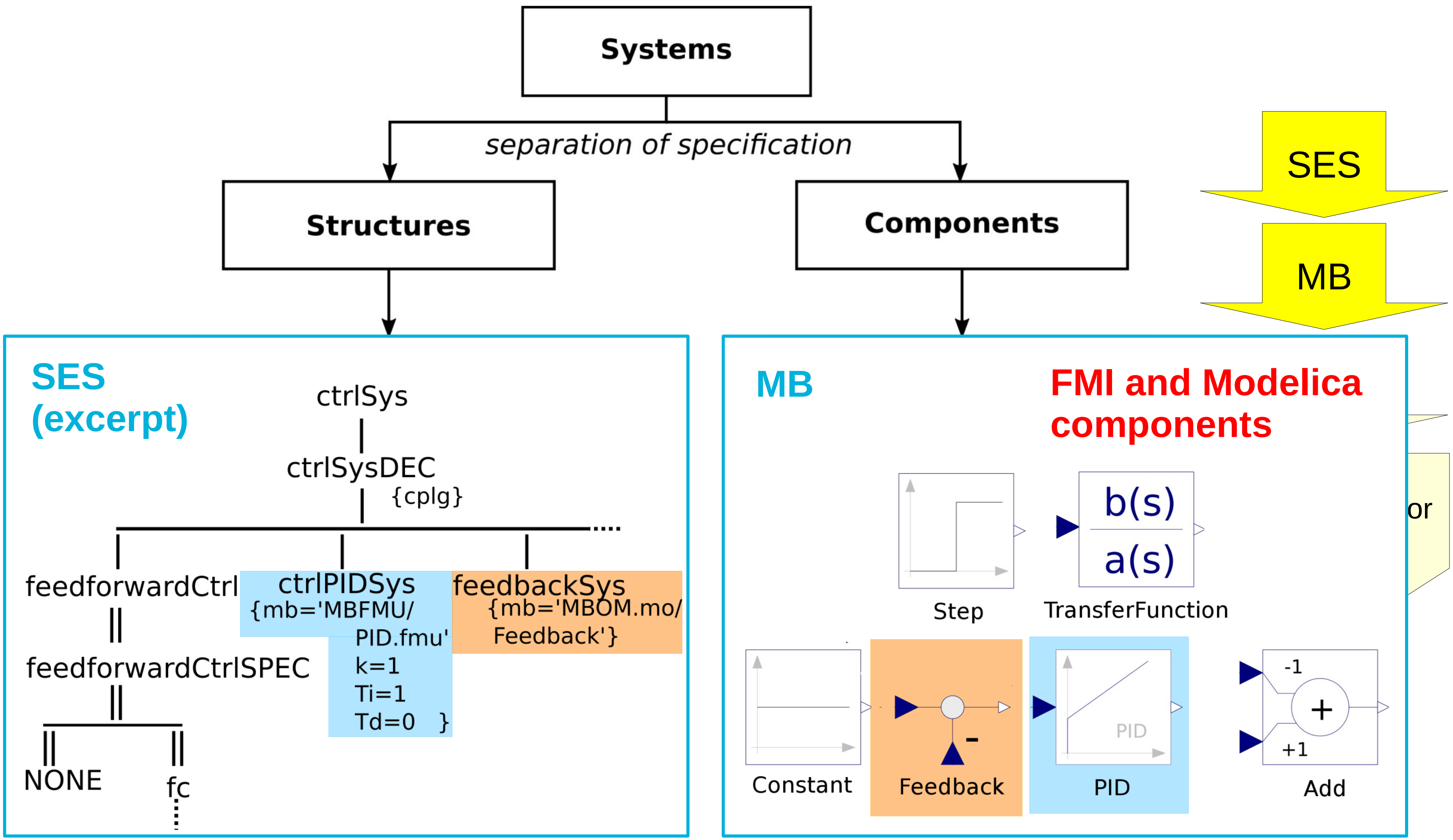

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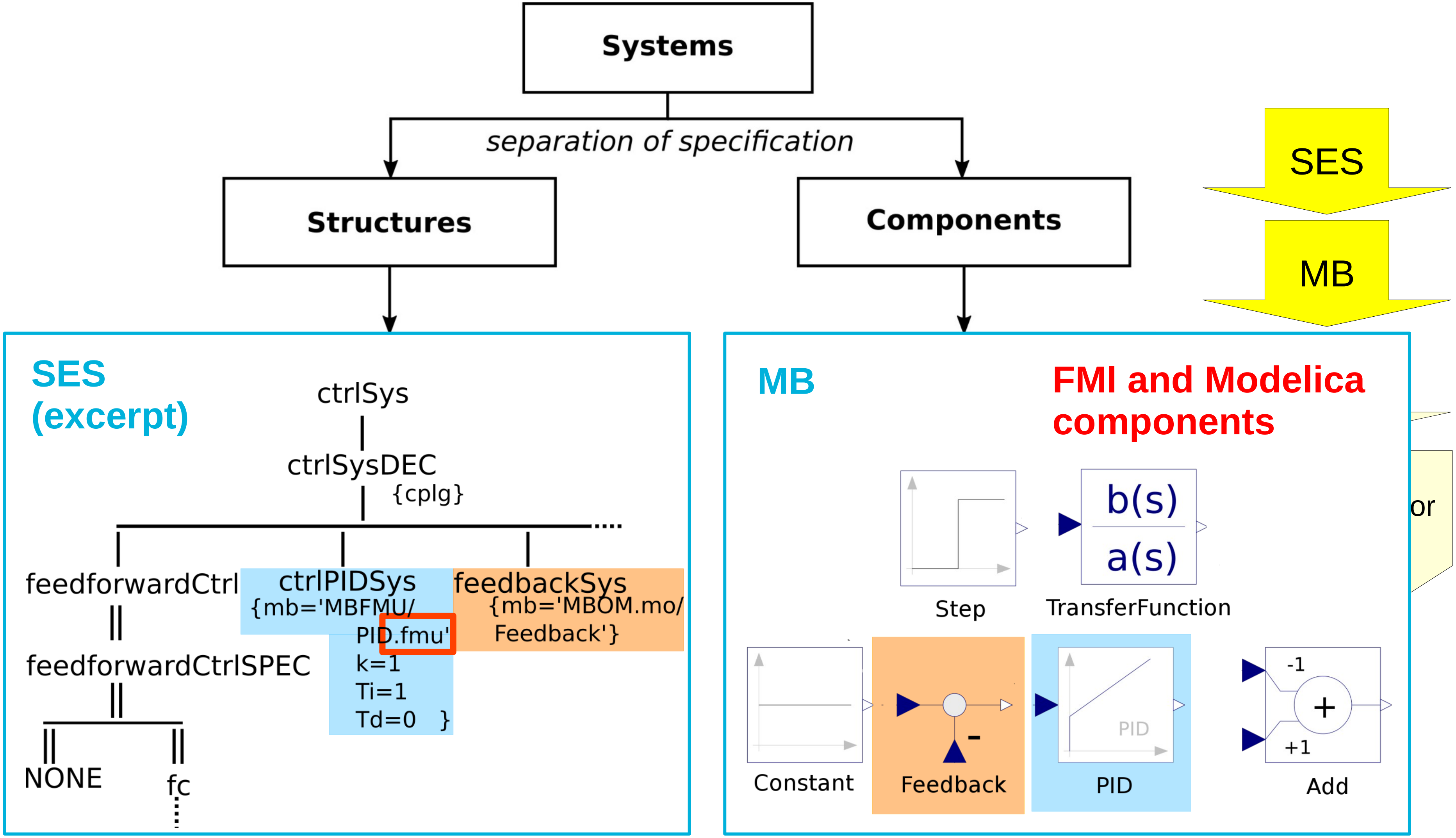
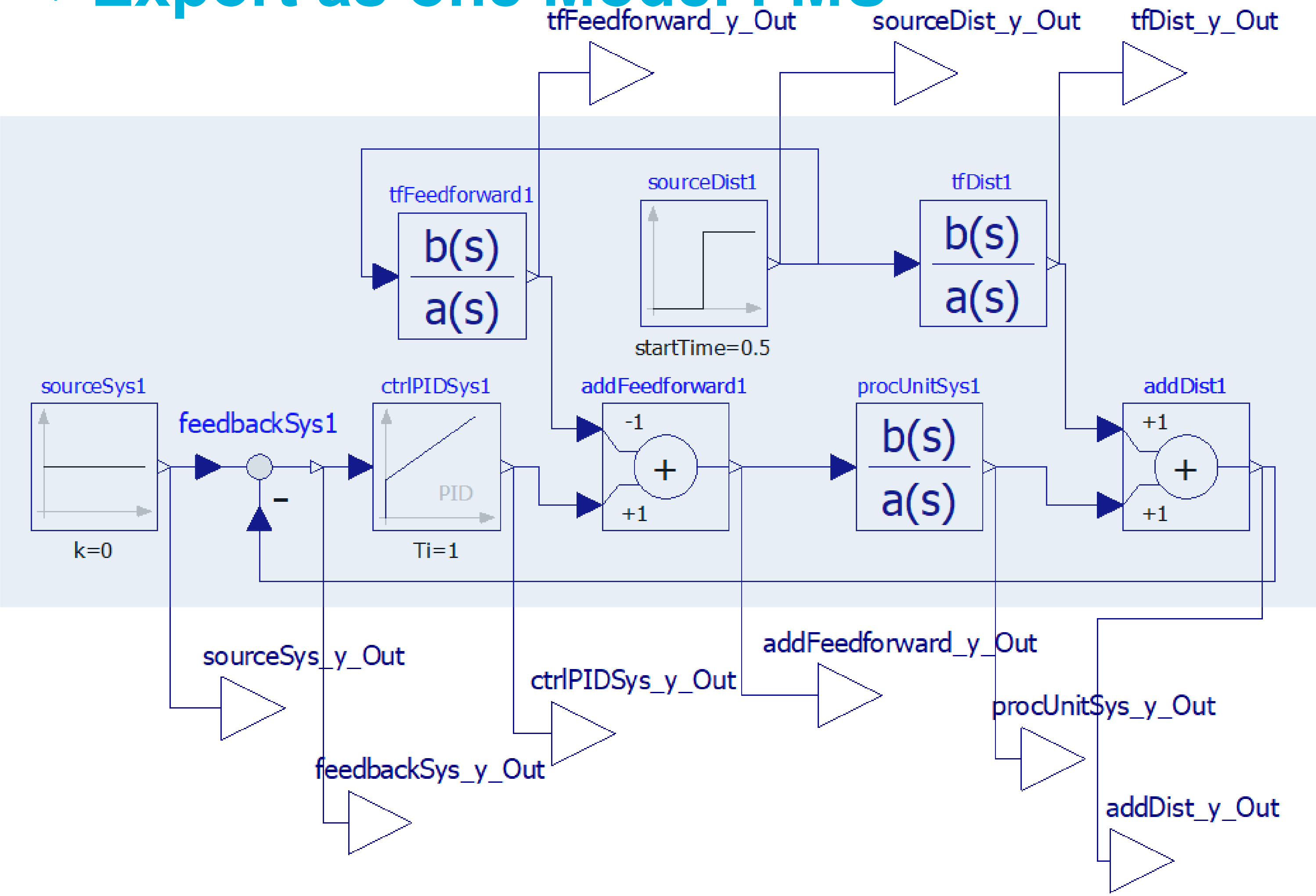
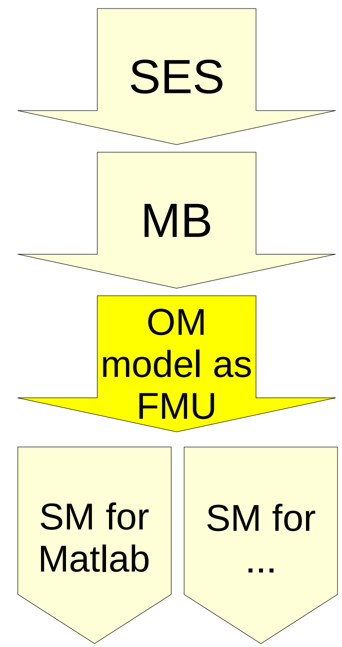
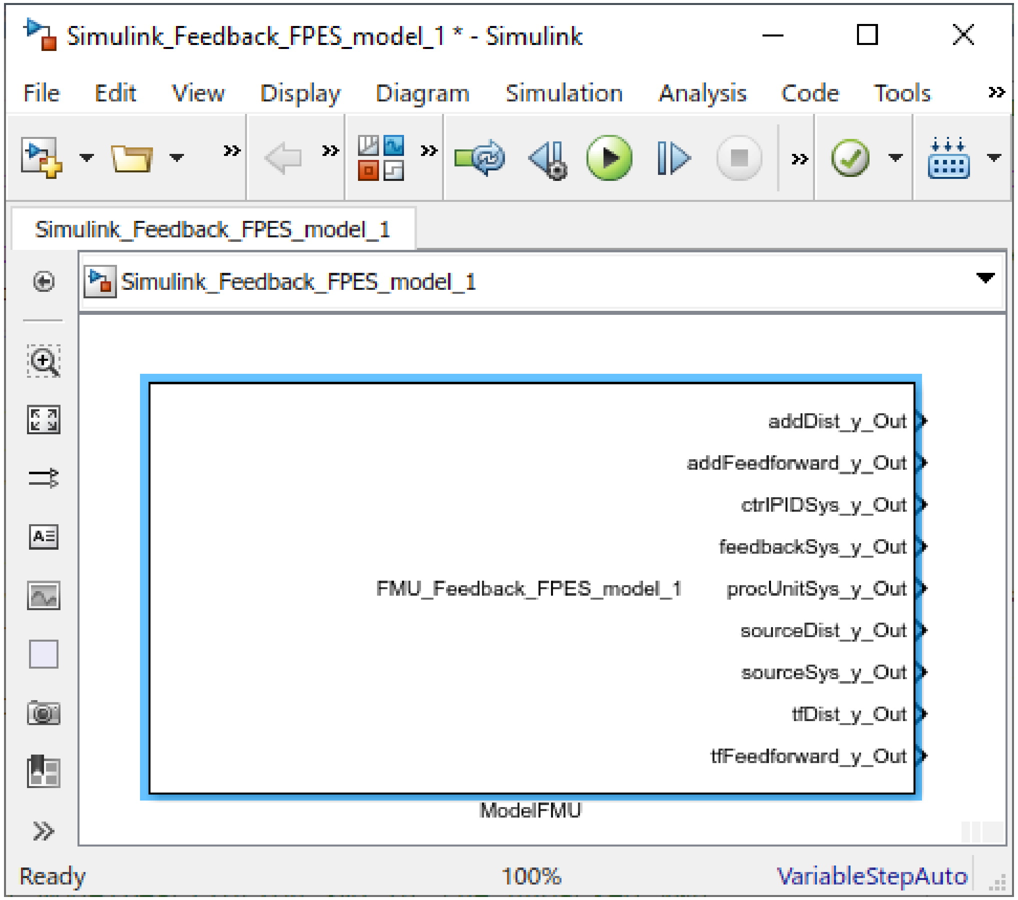


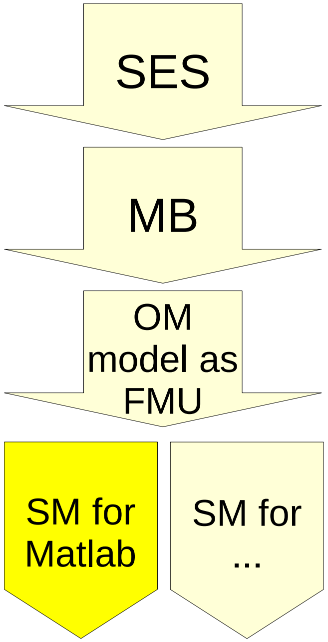
Generated Model in OpenModelica → Export as one Model FMU





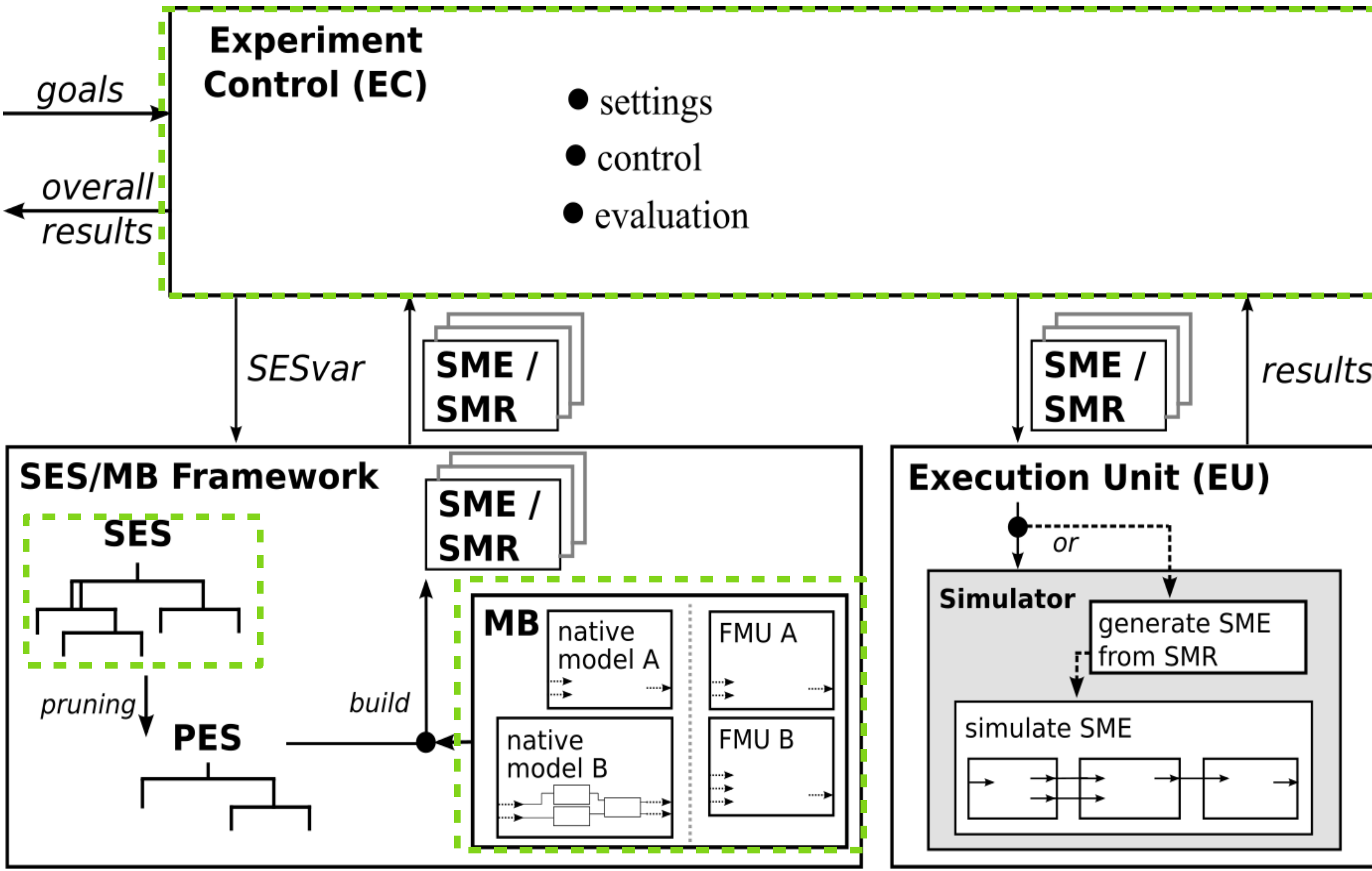
Case Study: Model FMU Imported in MATLAB/Simulink





Outline

Extended SES/MB Architecture (Native and FMI)



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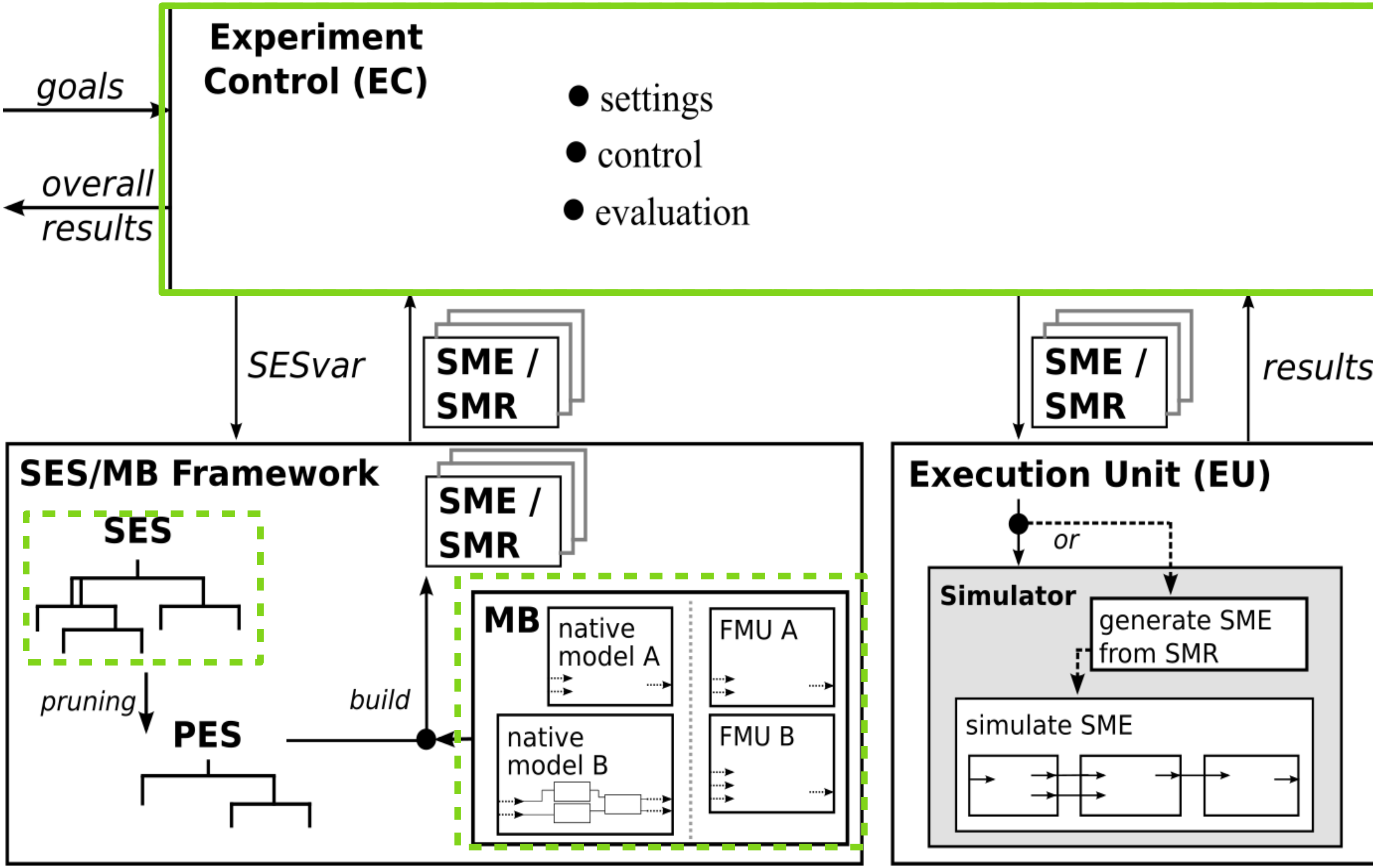

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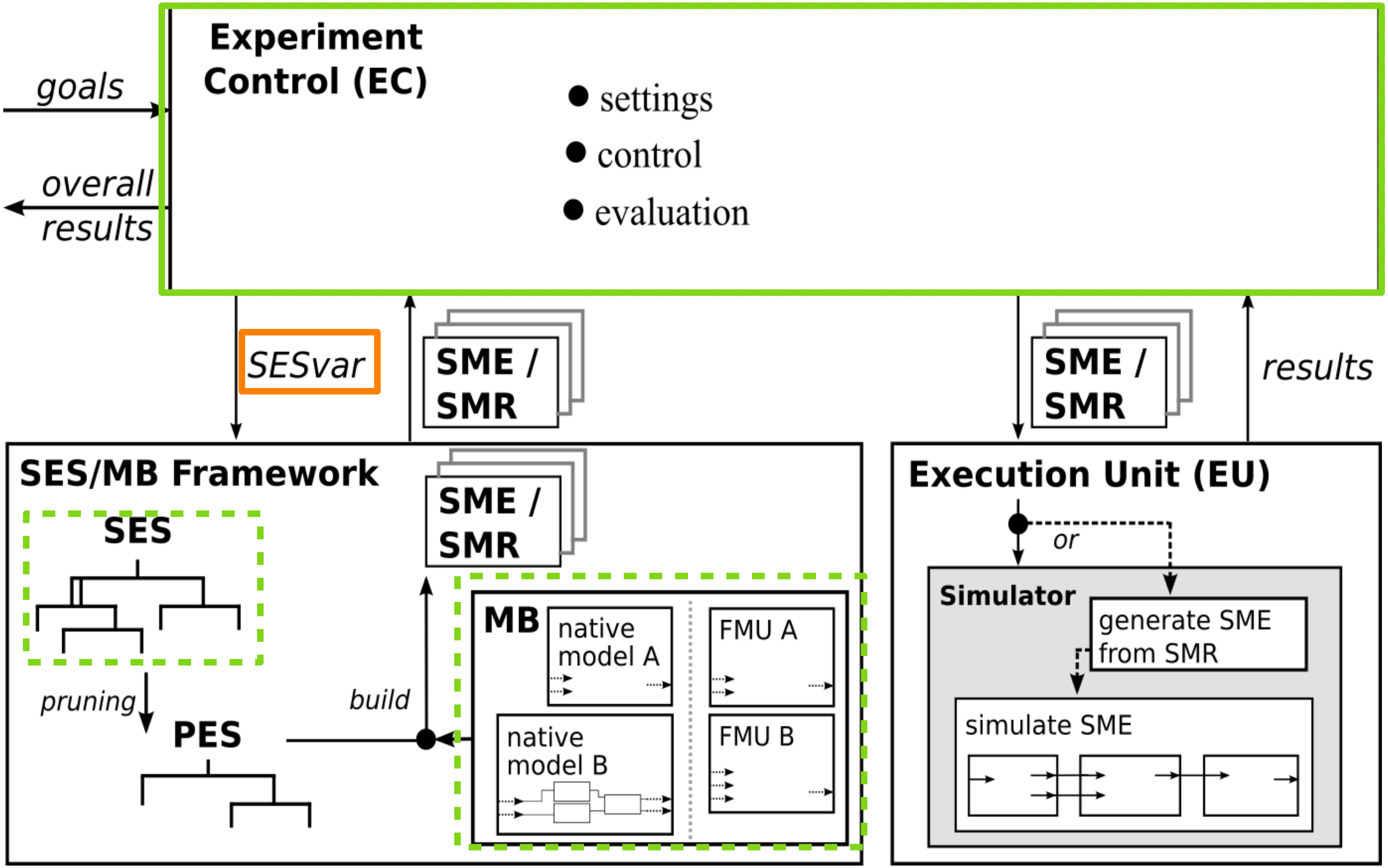

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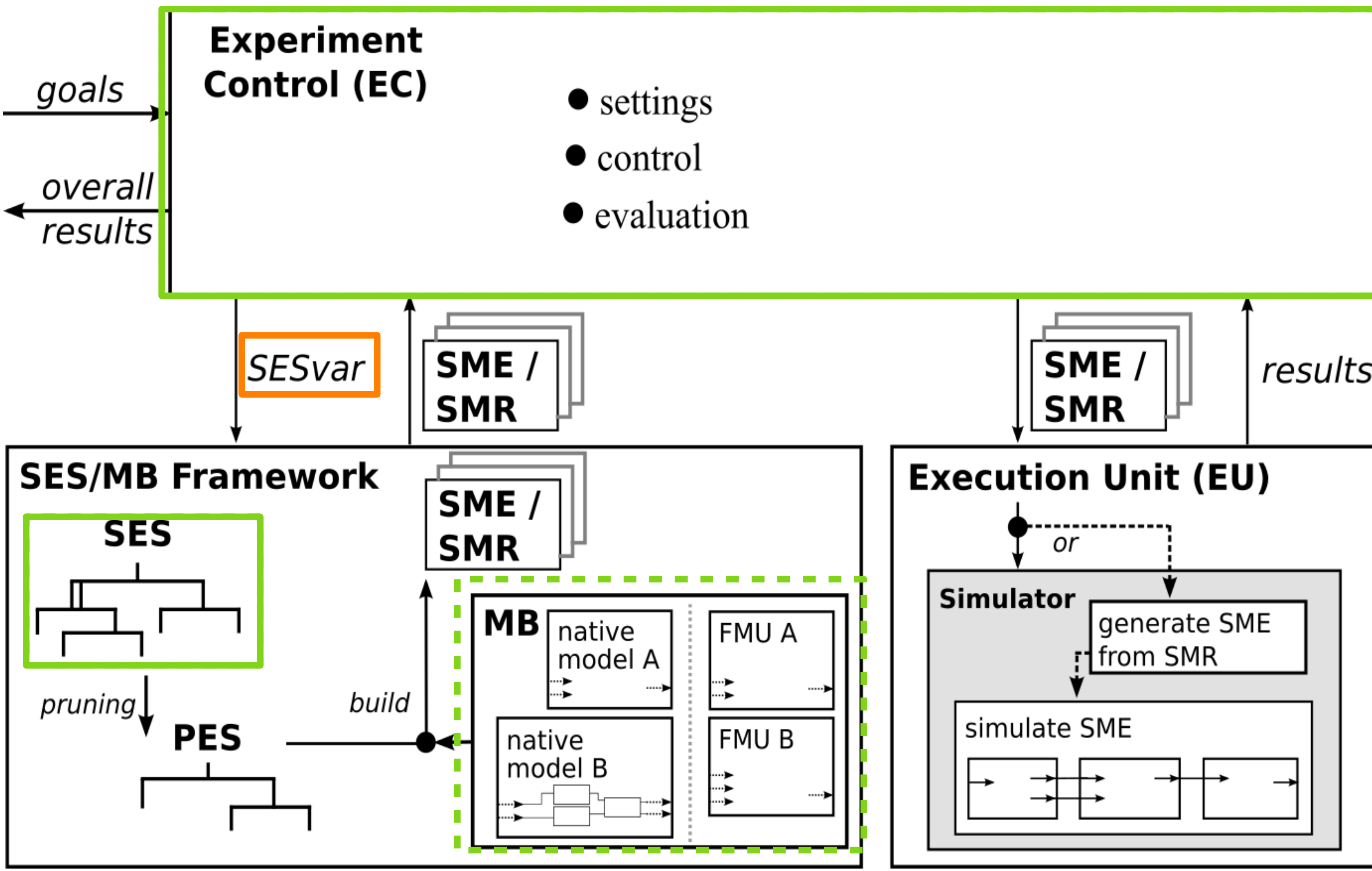

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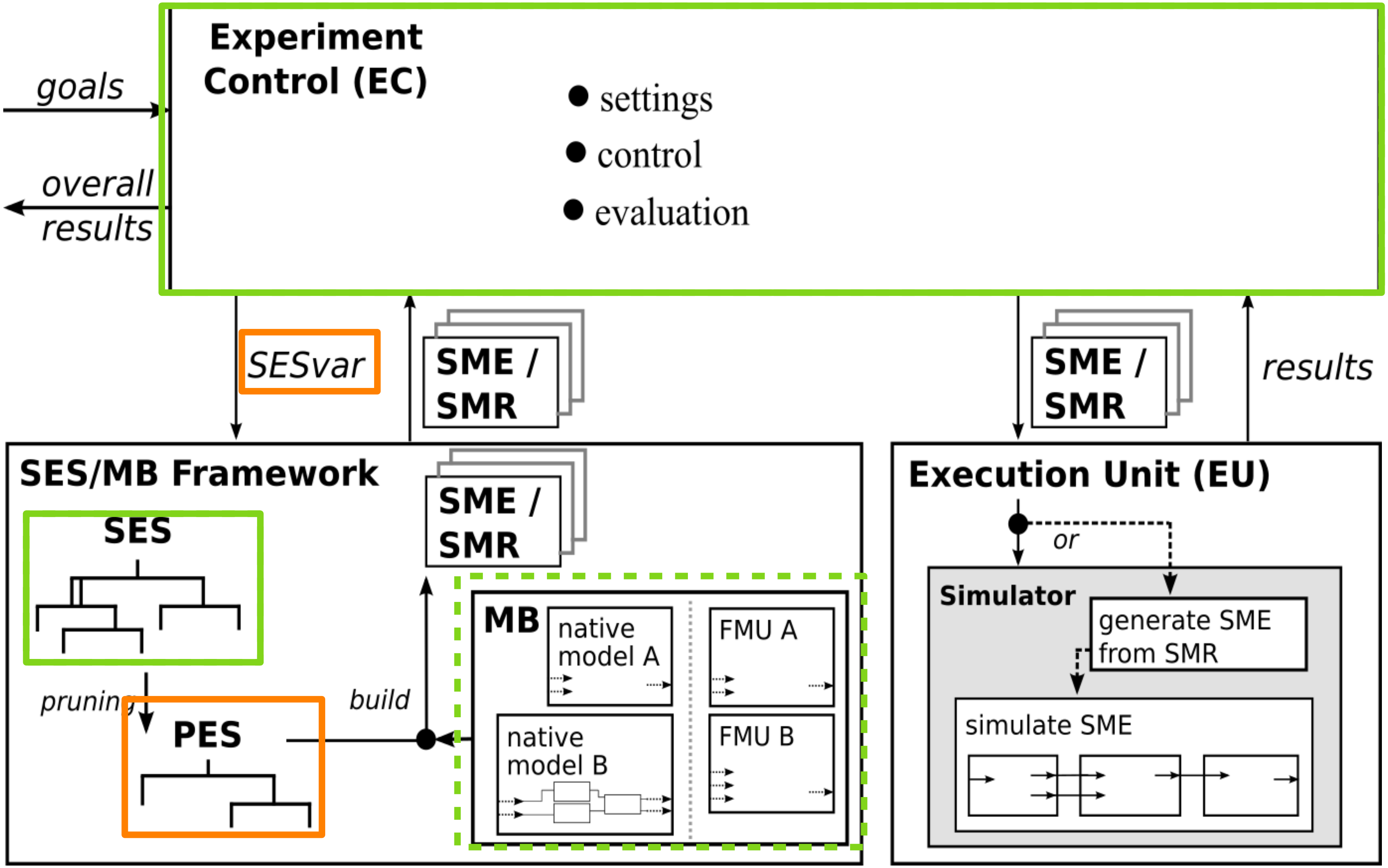

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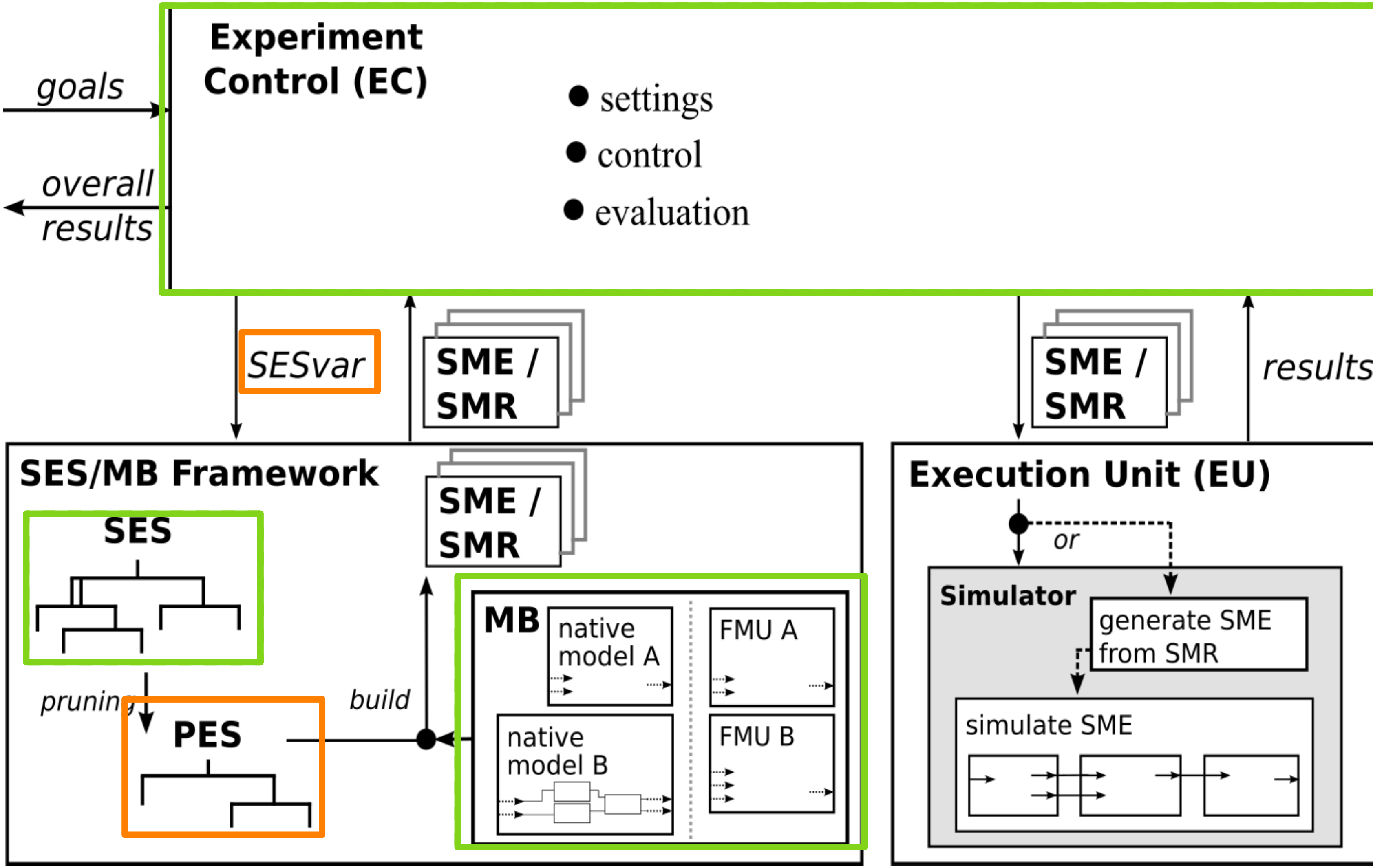

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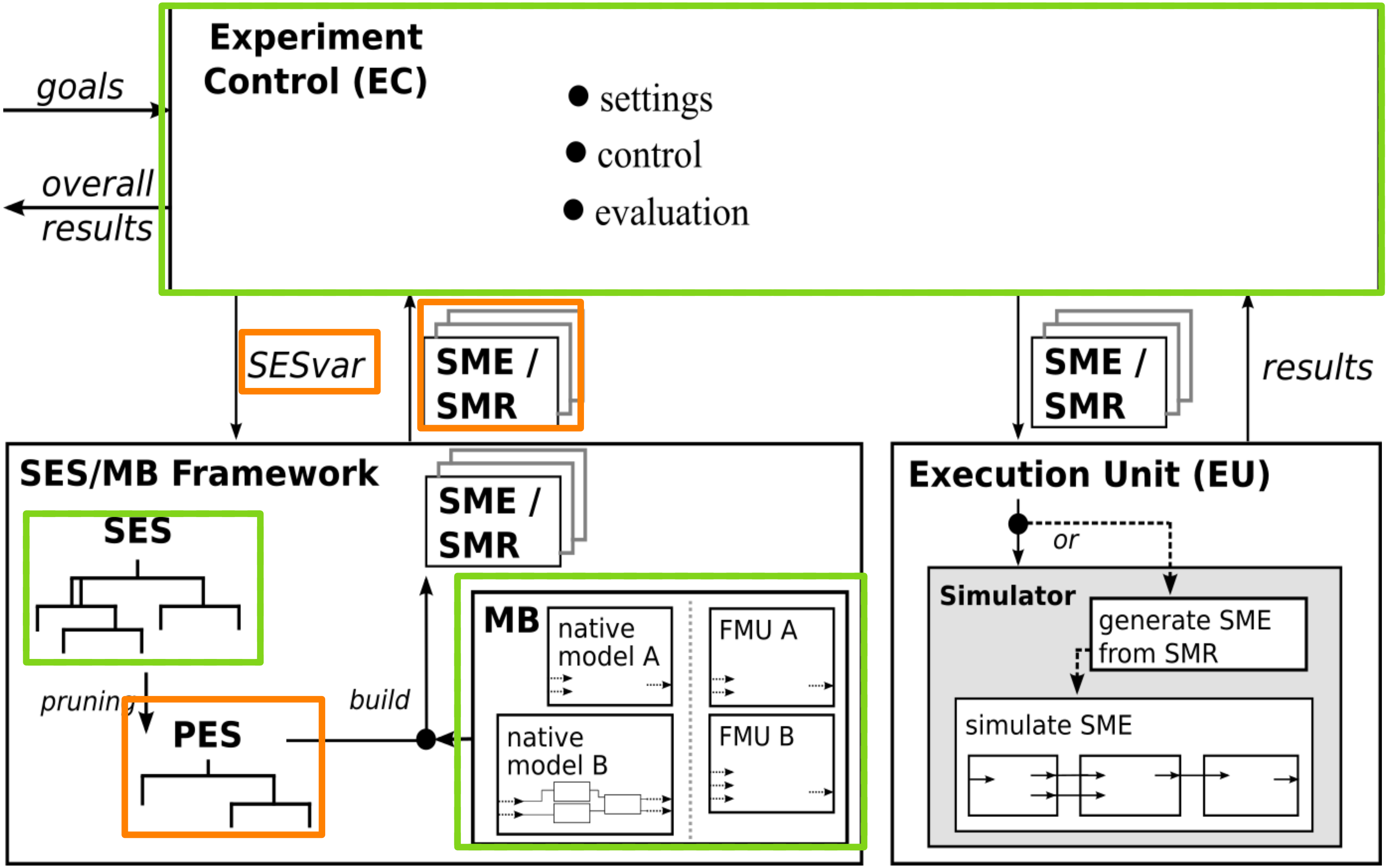

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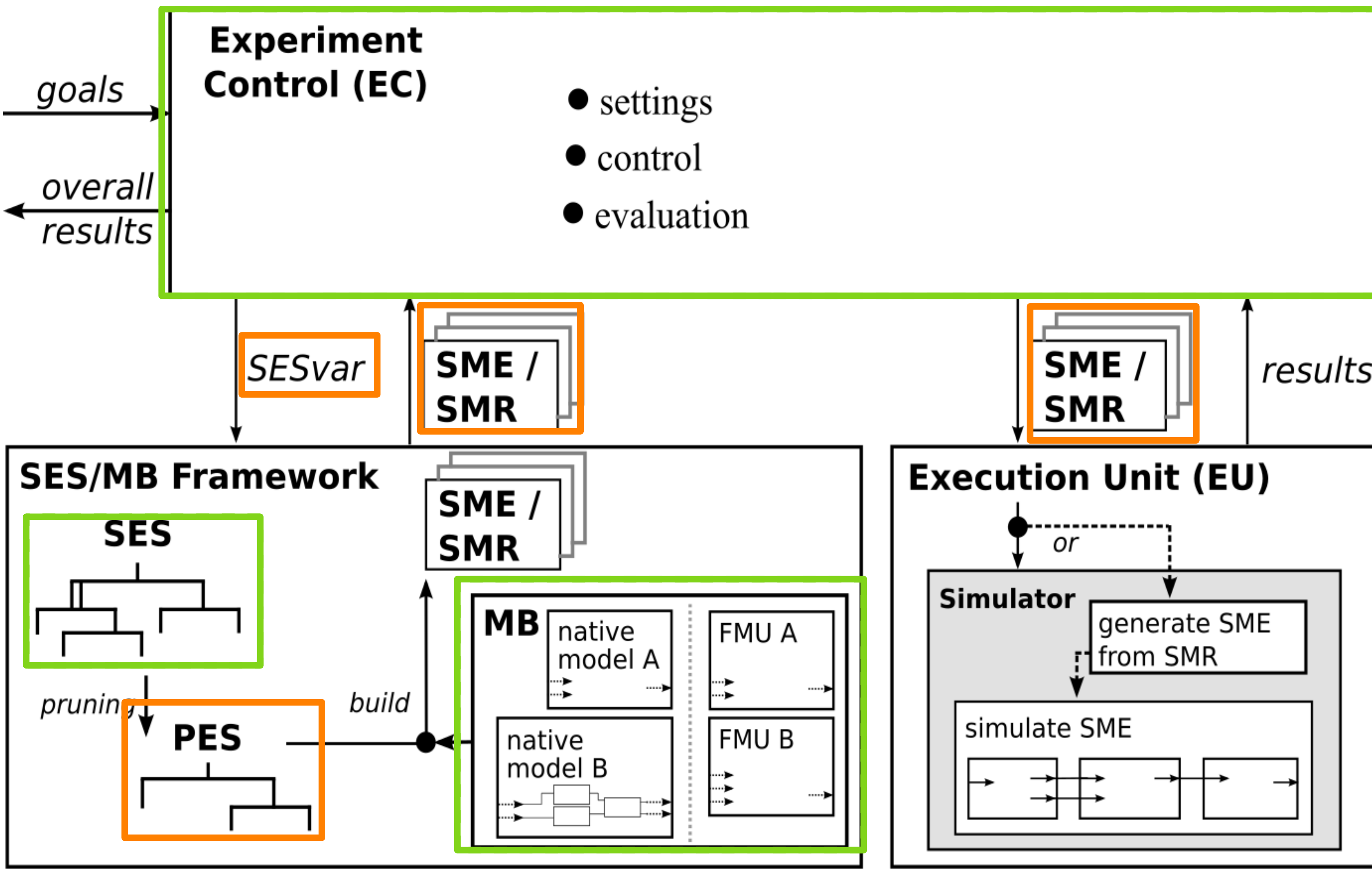

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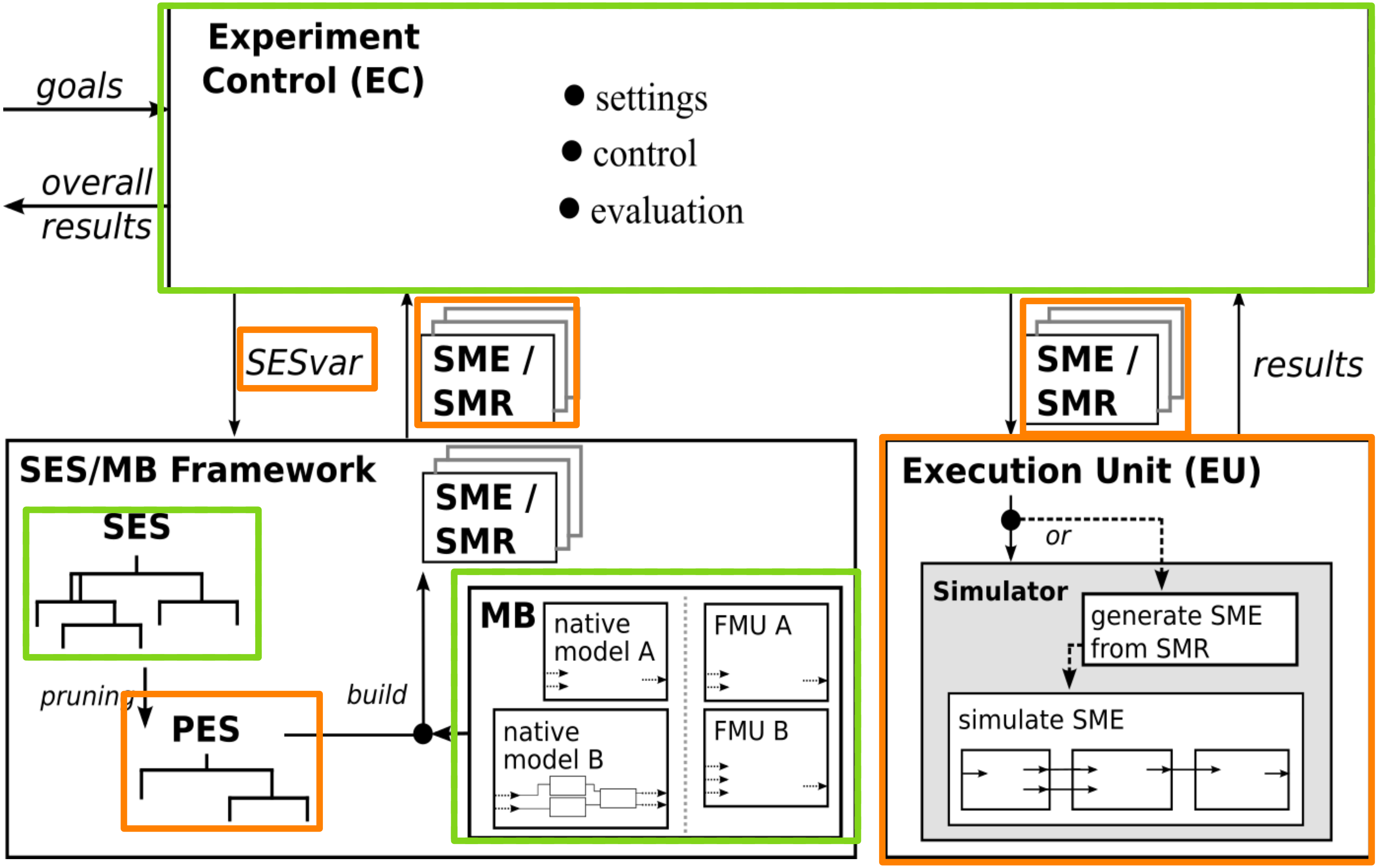

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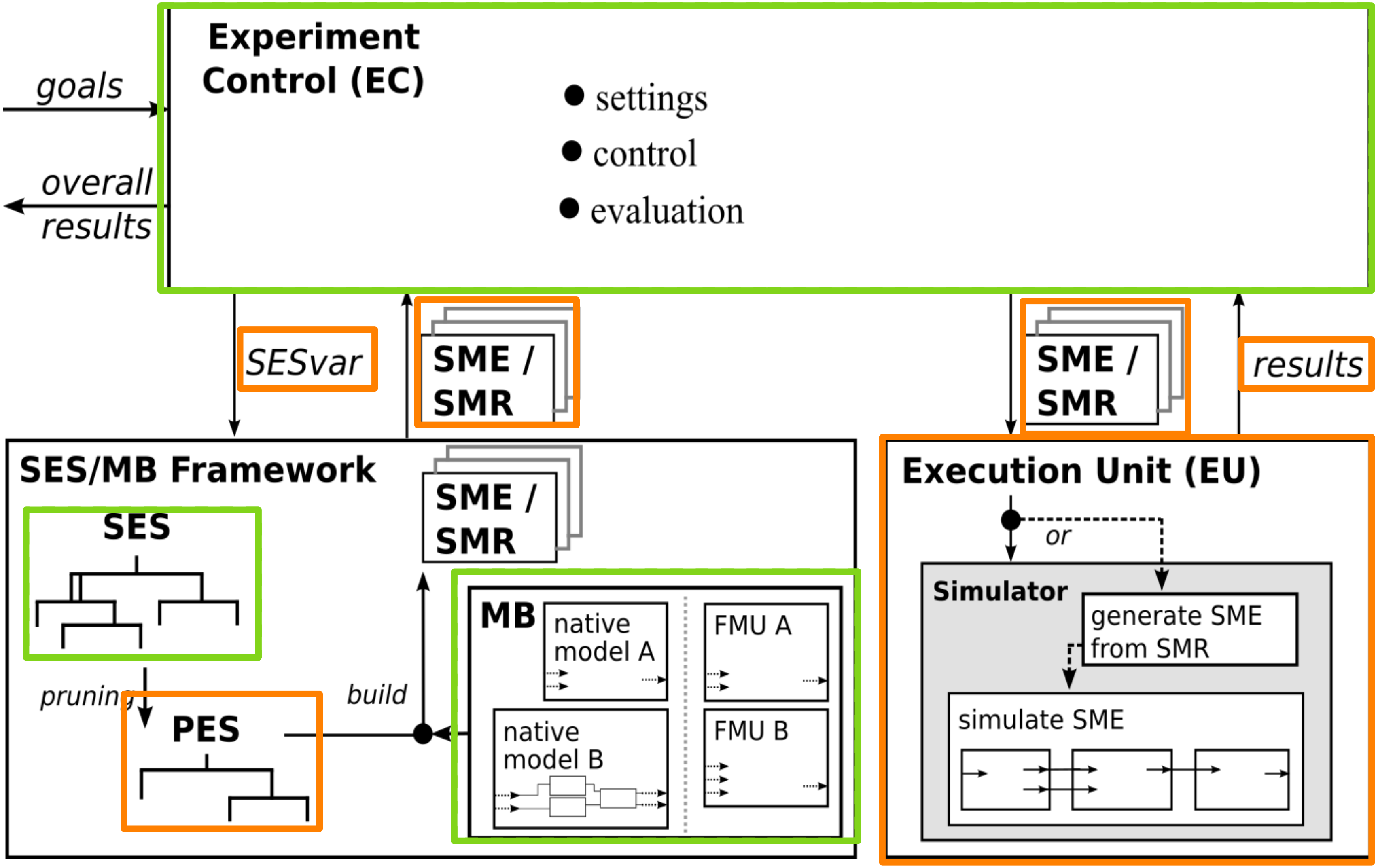

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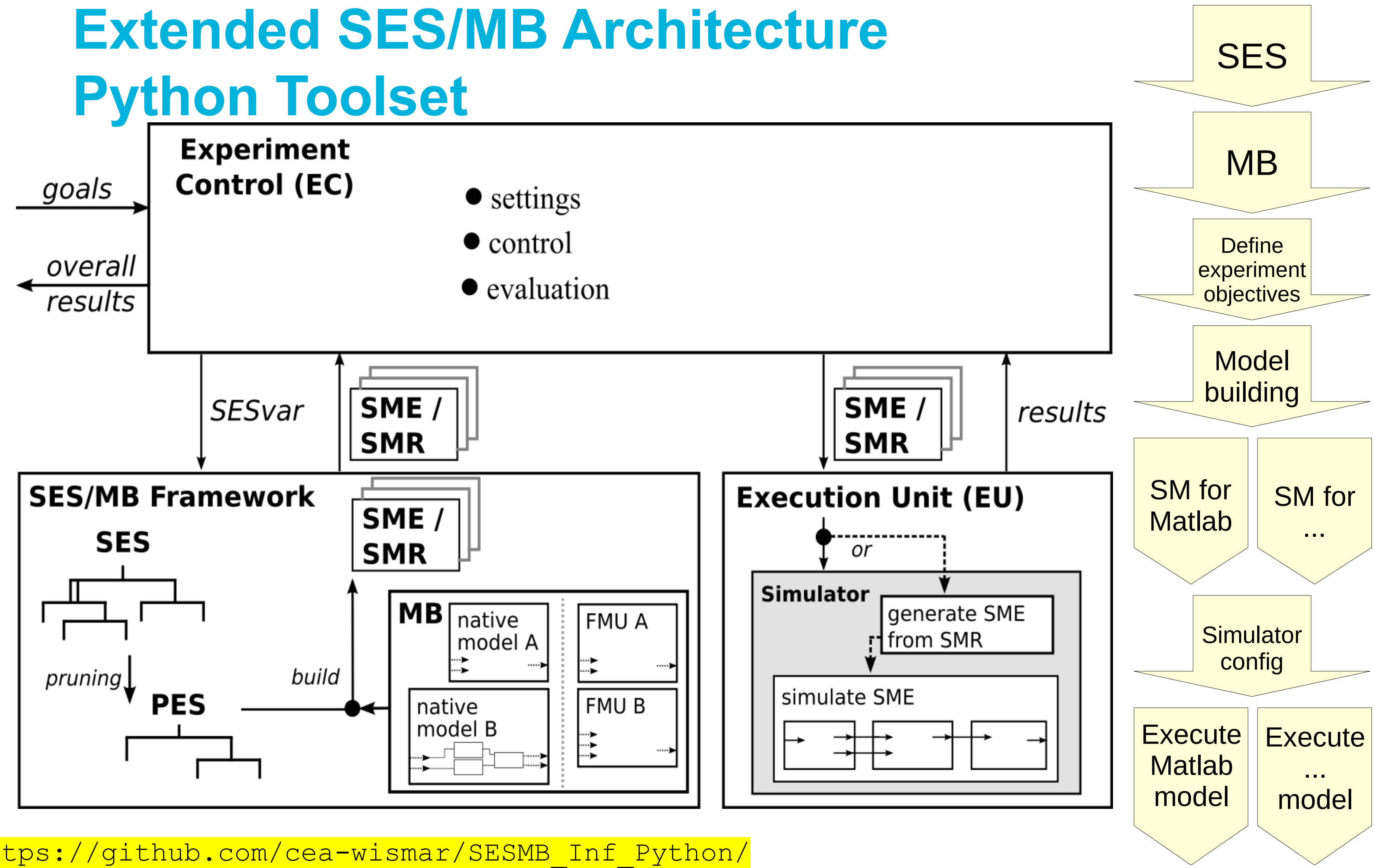
Extended SES/MB Architecture Python Toolset



https://github.com/cea-wismar/SESMB_Inf_Python/

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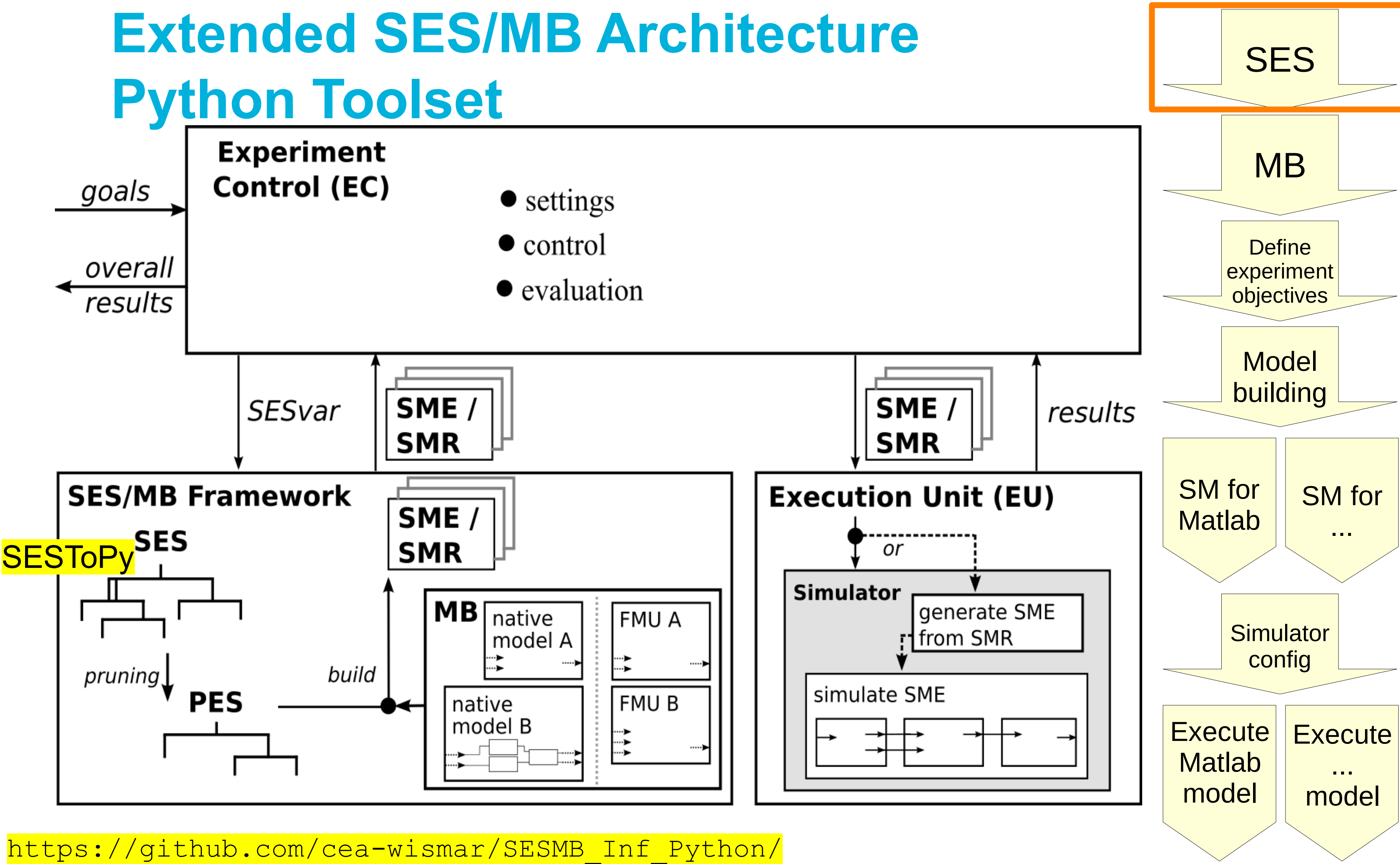

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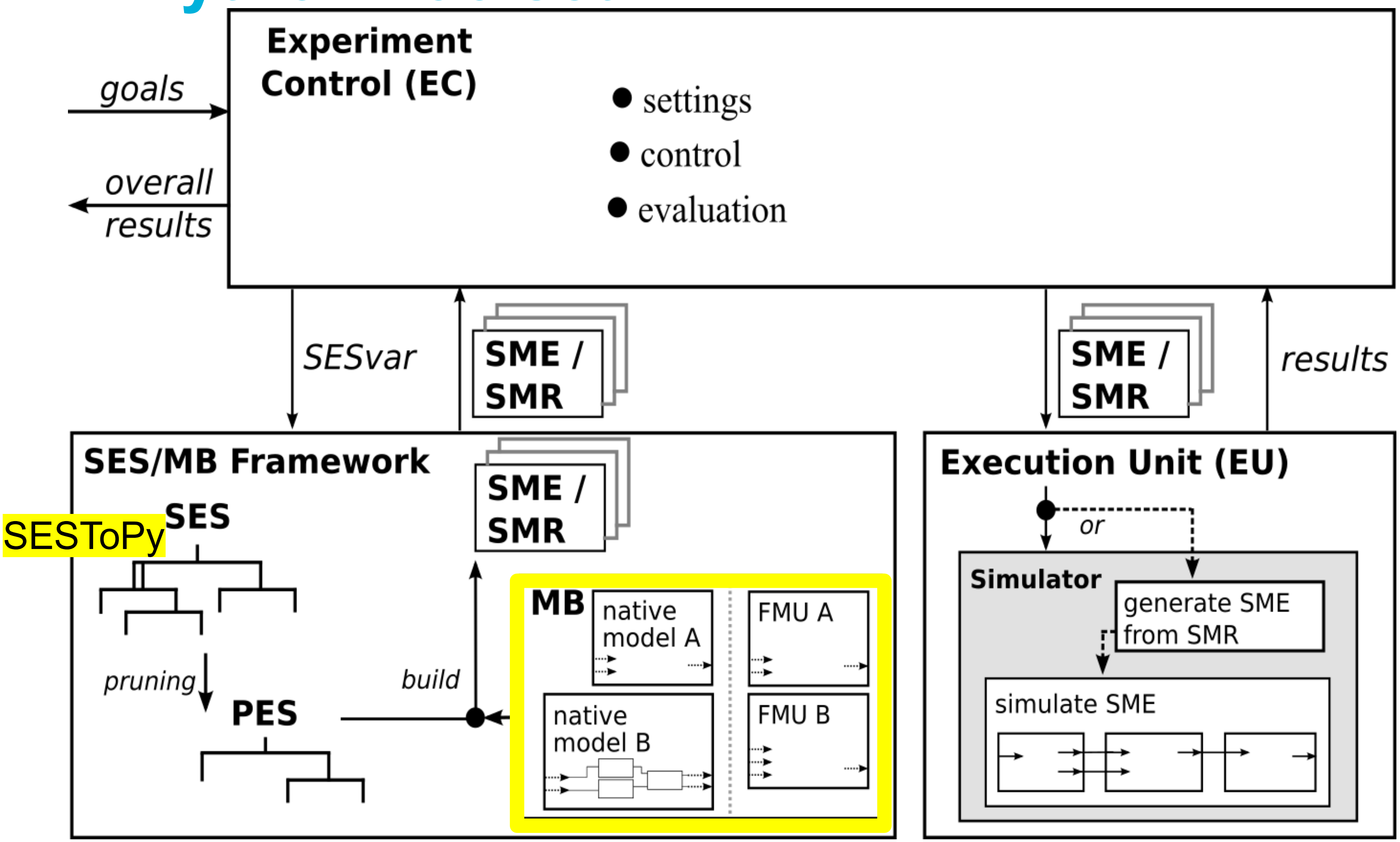

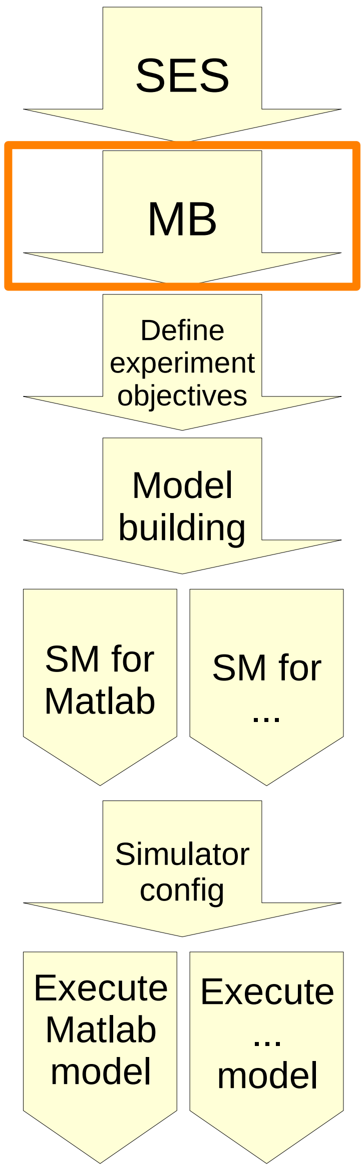

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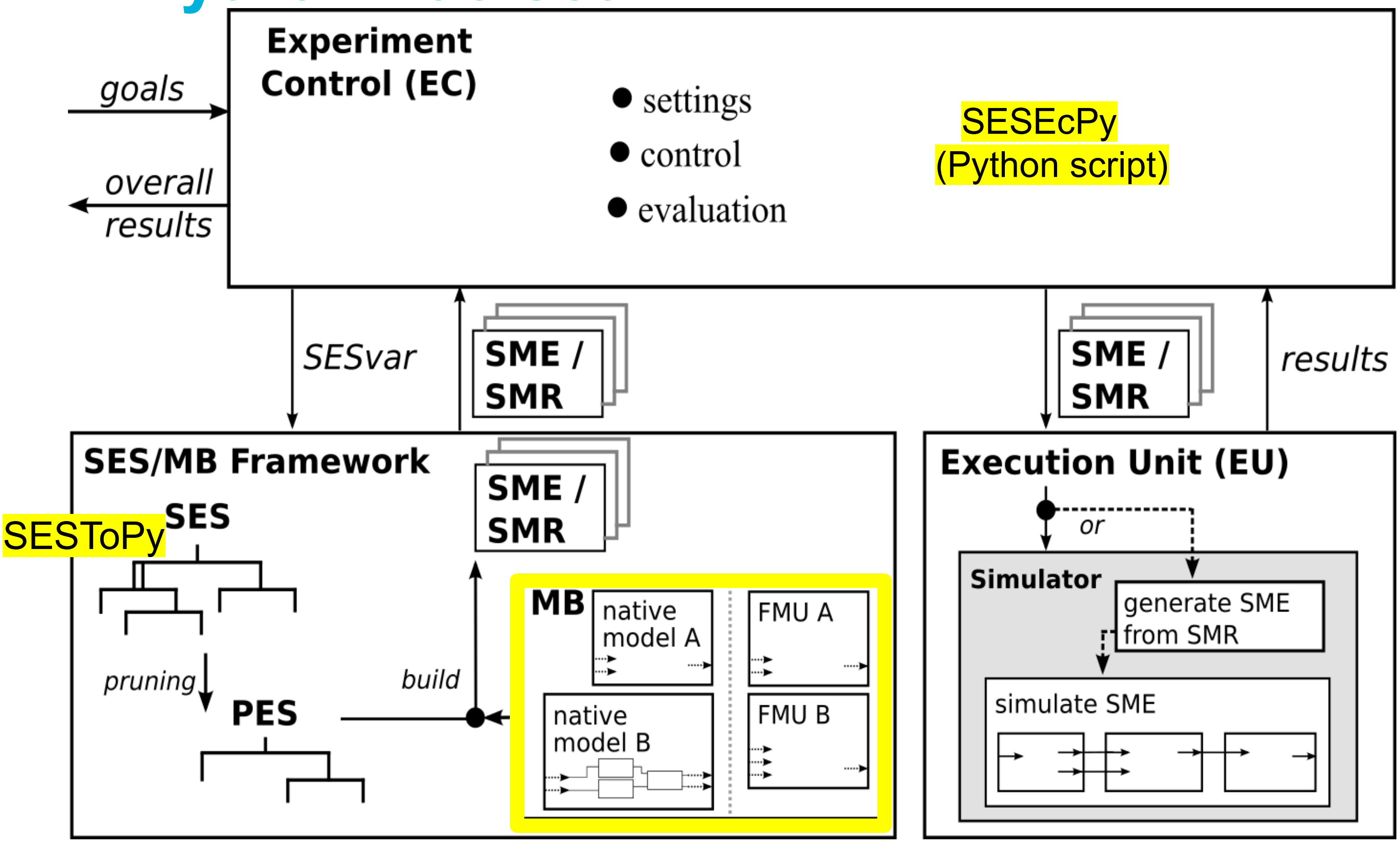

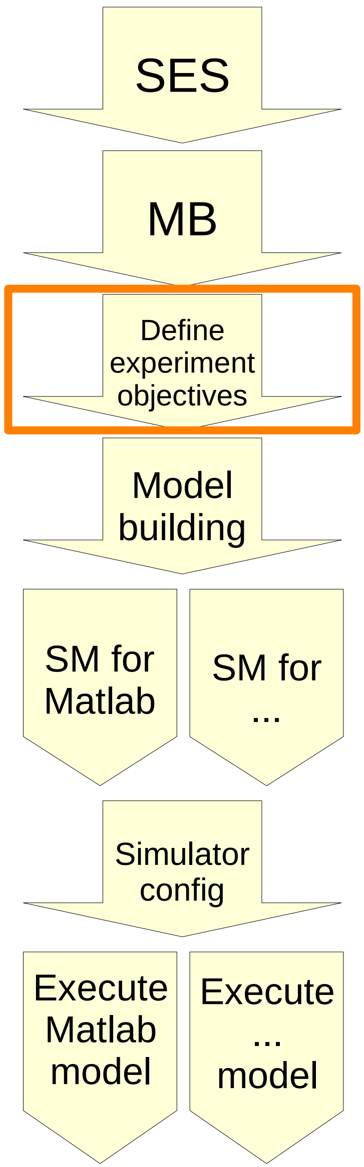

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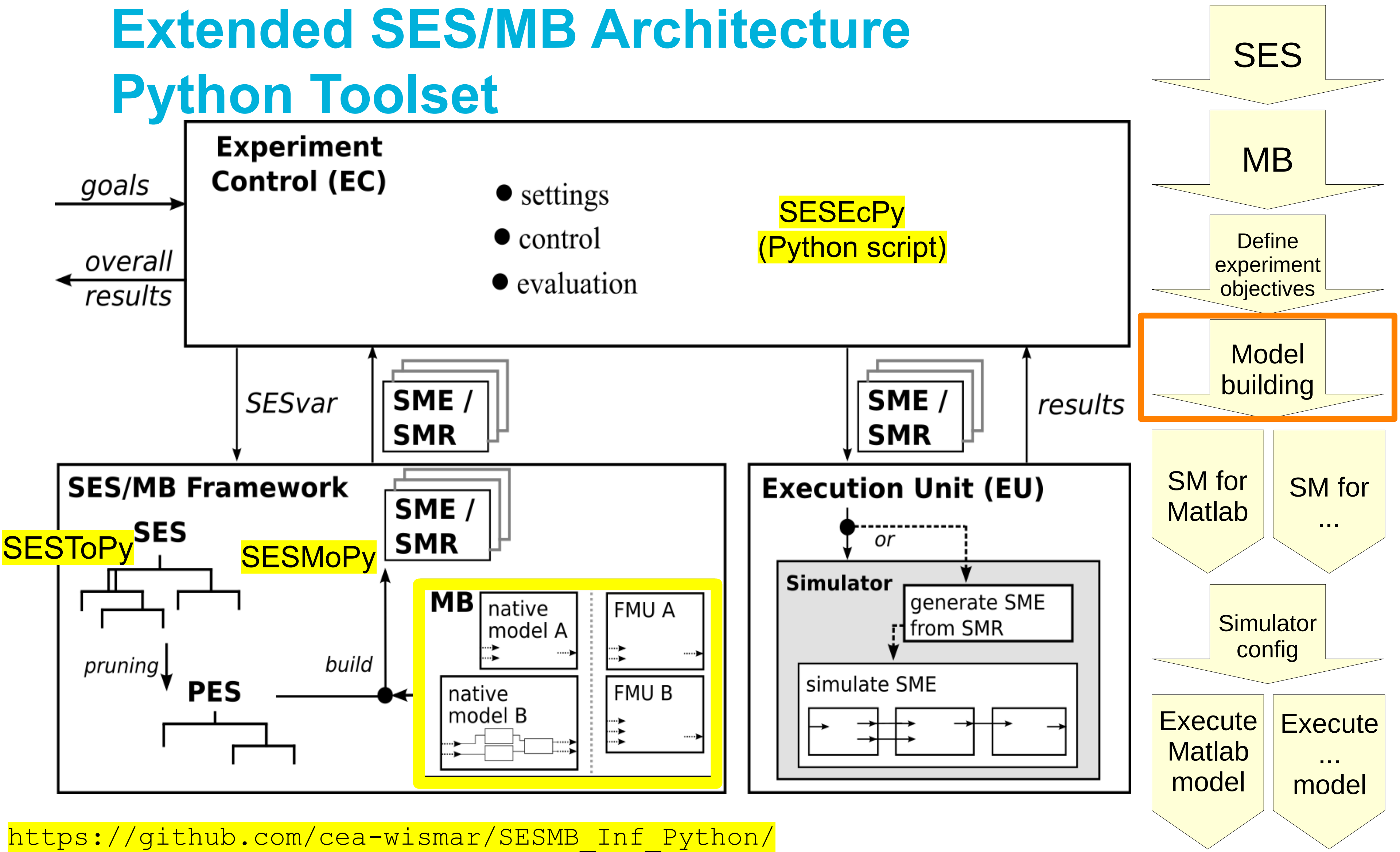

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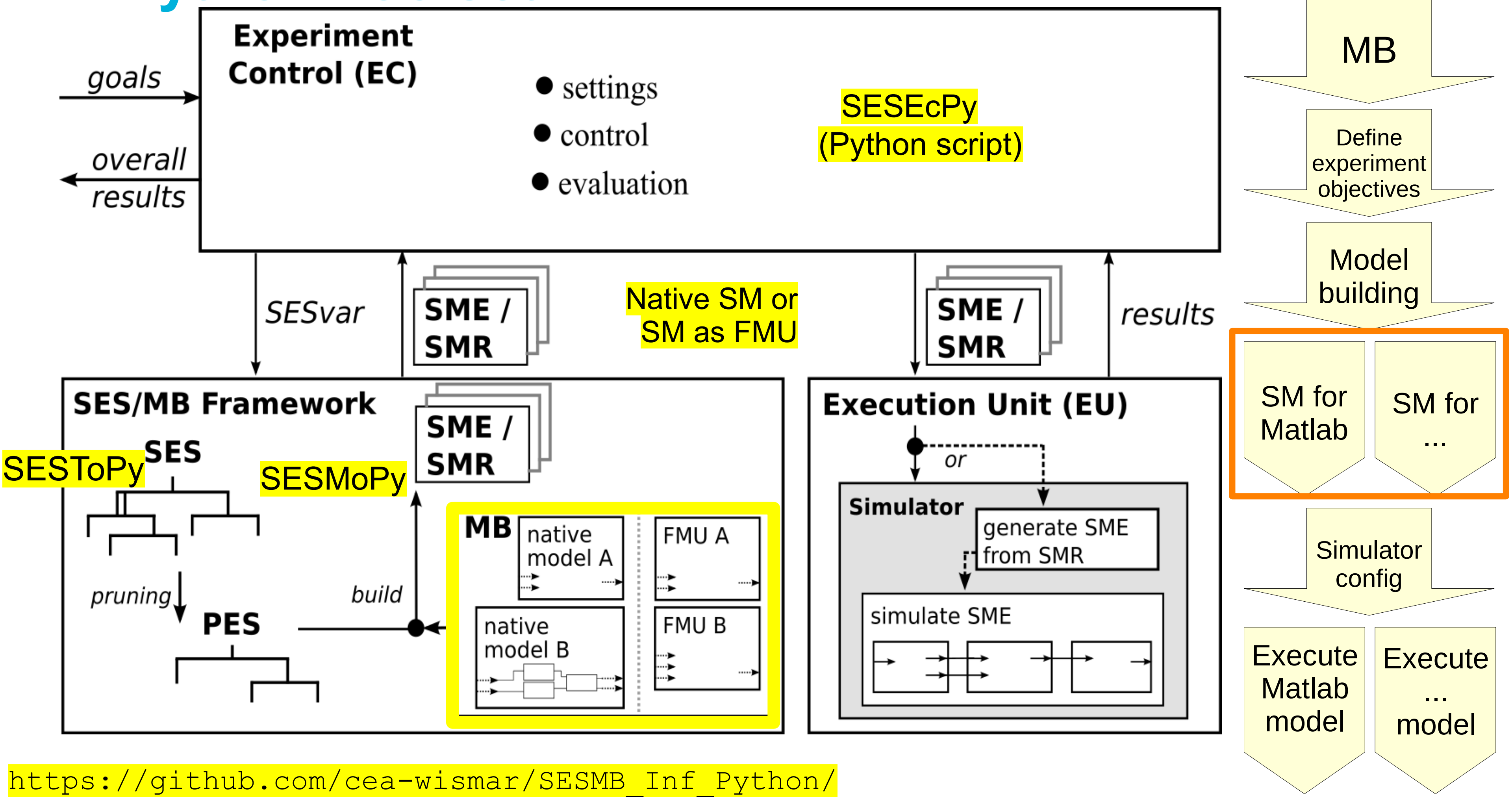

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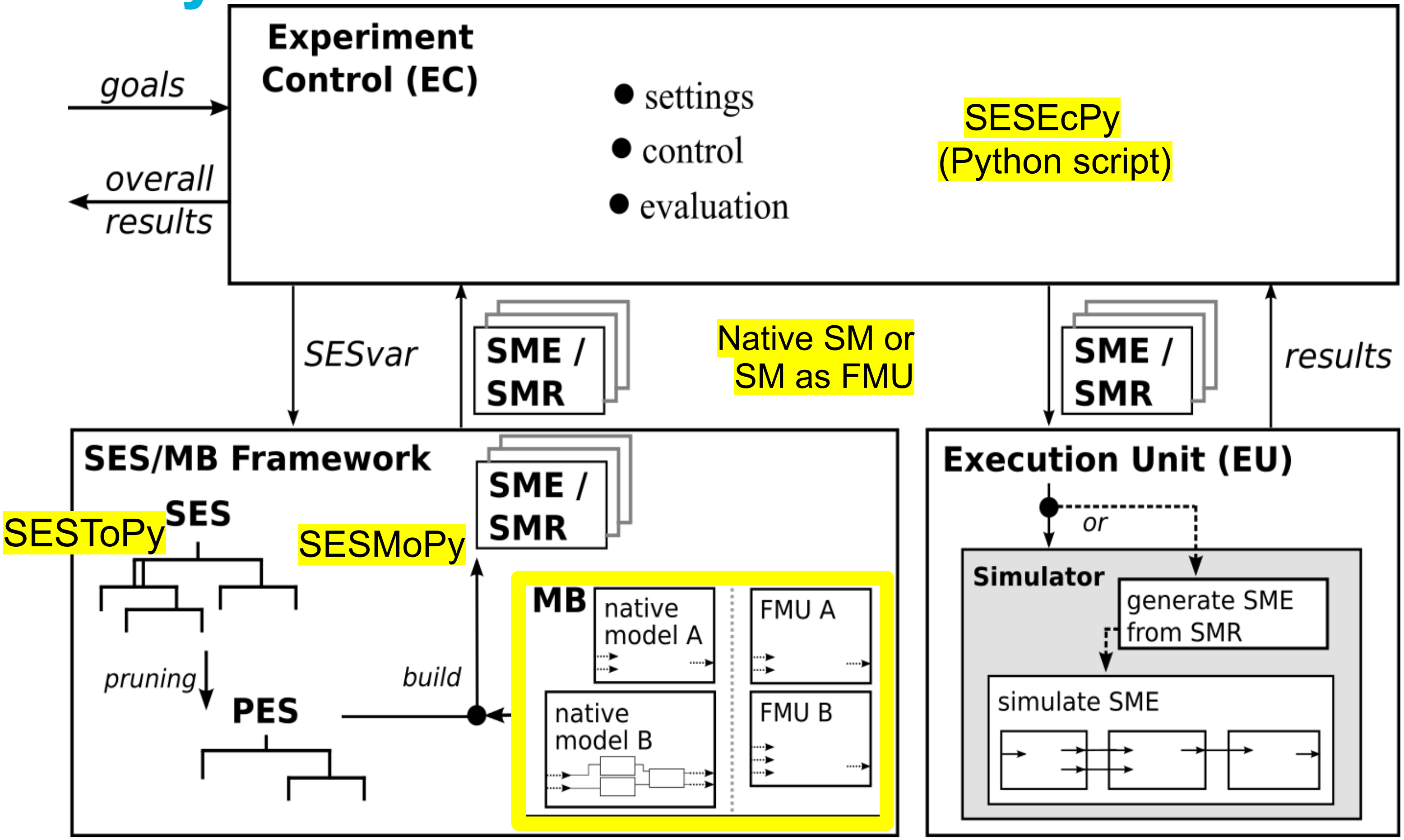

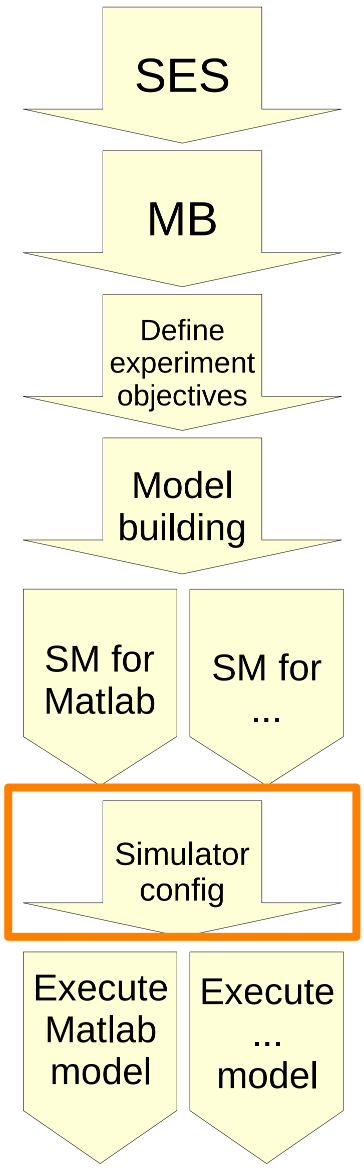

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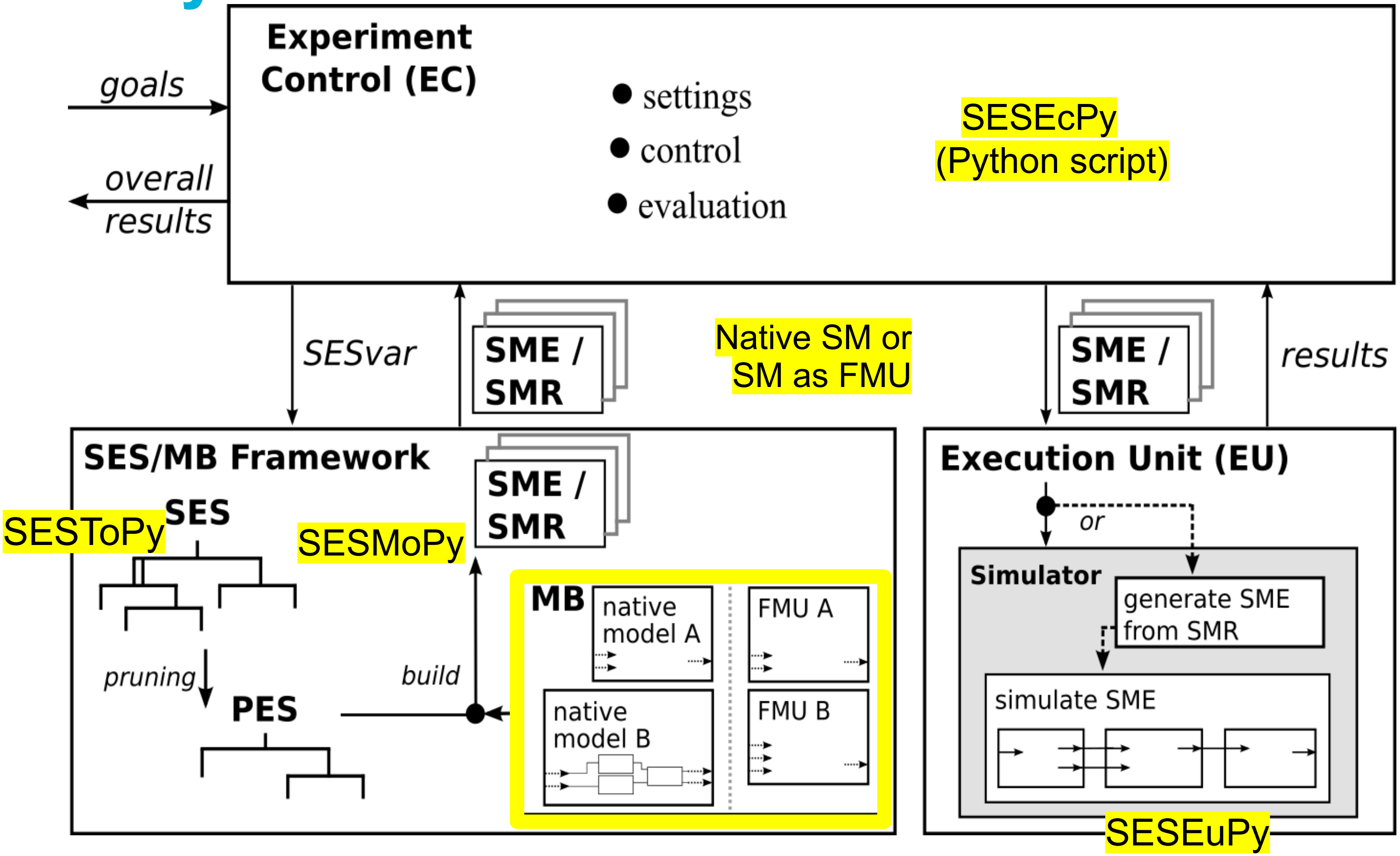

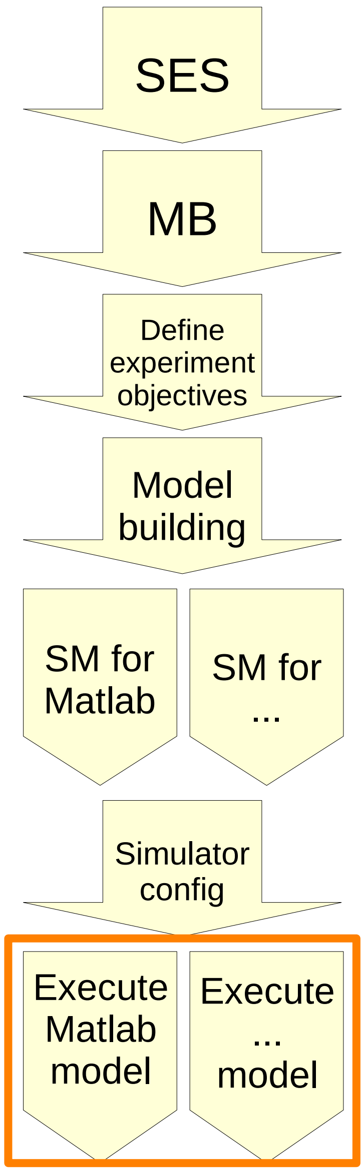

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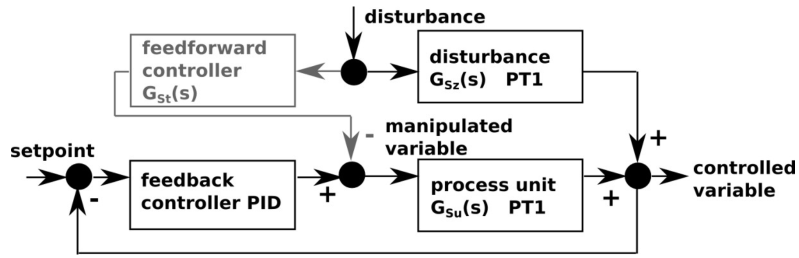
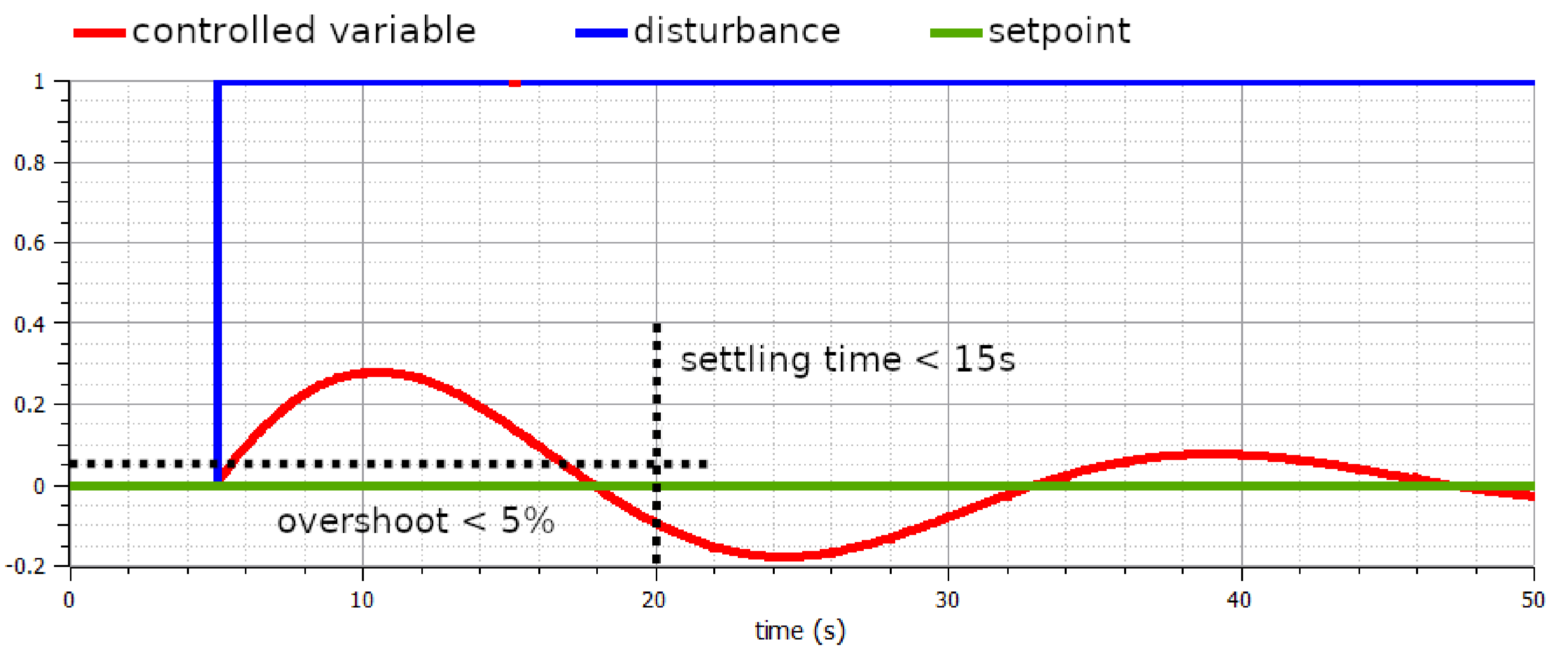
(wrapper for a simulator)

Automation of Case Study: Control Goals

- Goal for the control after a disturbance
  - Overshoot < 5%
  - Settling time < 15s





Case Study: Experimentation Steps

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- **Code in Experiment Control**

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  - **Try without a feedforward control:**
    - `feedforward=0` simulate with PID: `k=1, Ti=1, Td=0`
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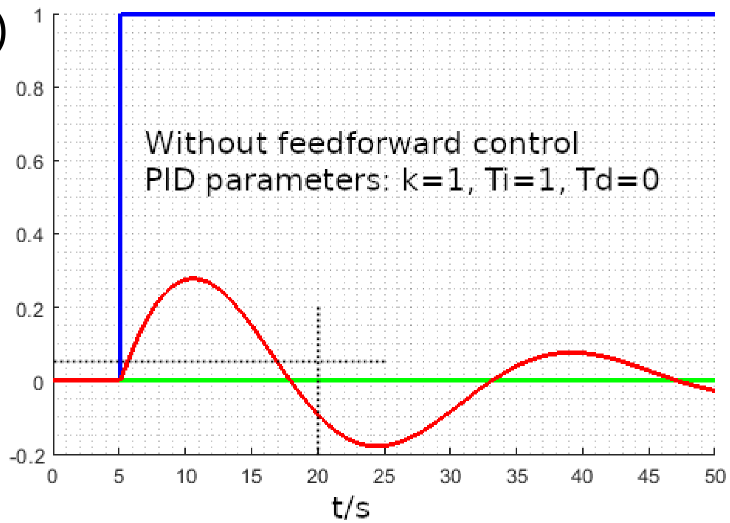
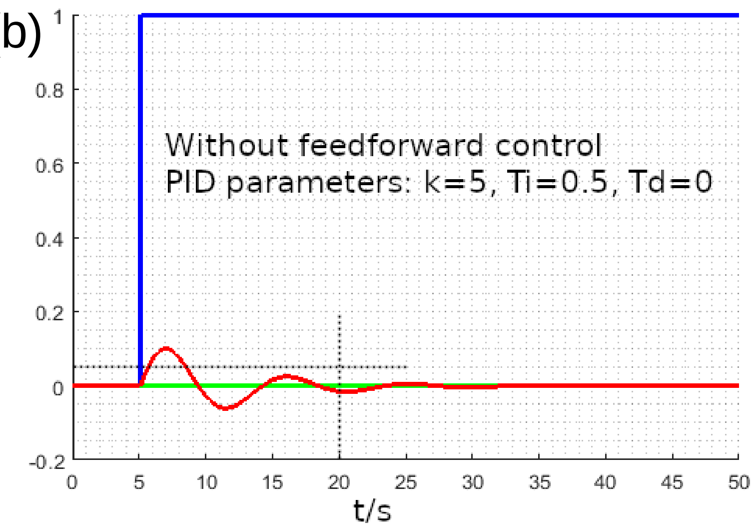
Starting over with another simulator possible (model by model validation)

Case Study: Simulation Results

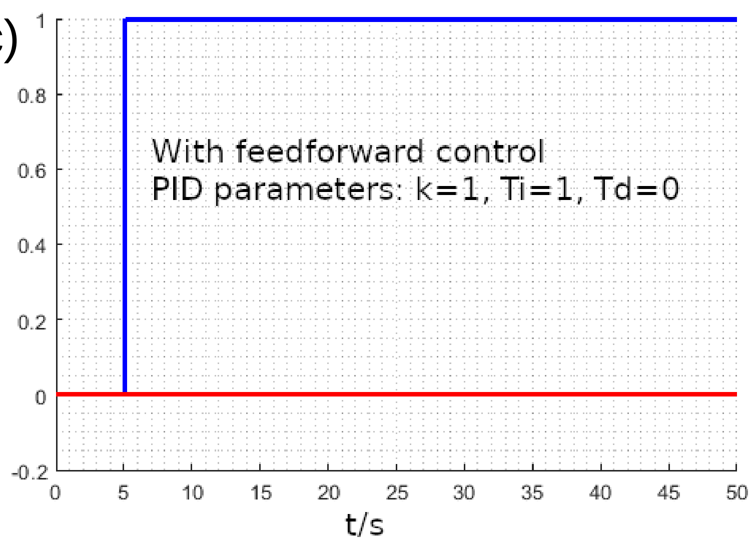
(a)



(b)



(c)



Key:
- setpoint
- disturbance
- controlled variable

Control goals:
overshoot < 5%
settling time < 15s

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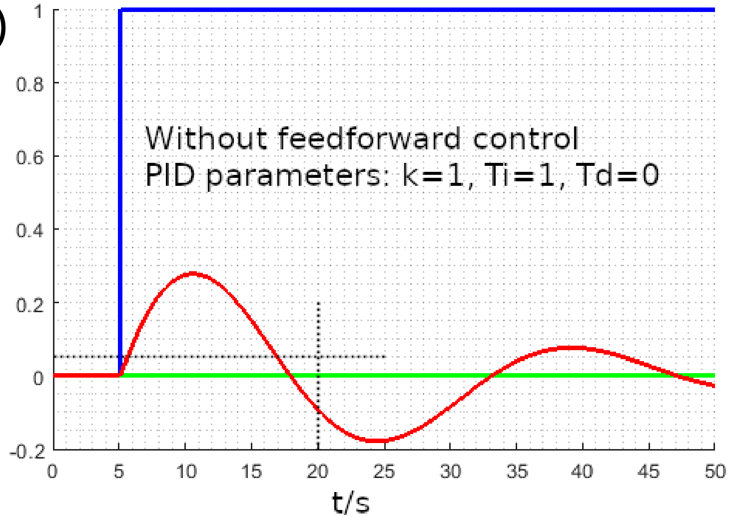

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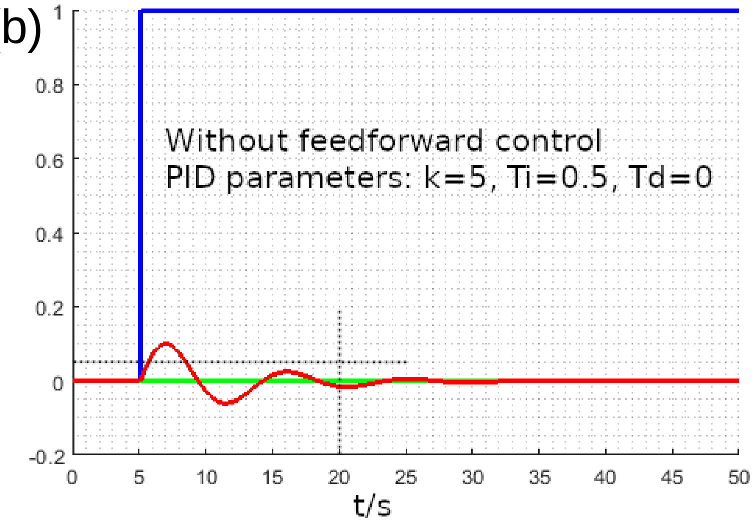

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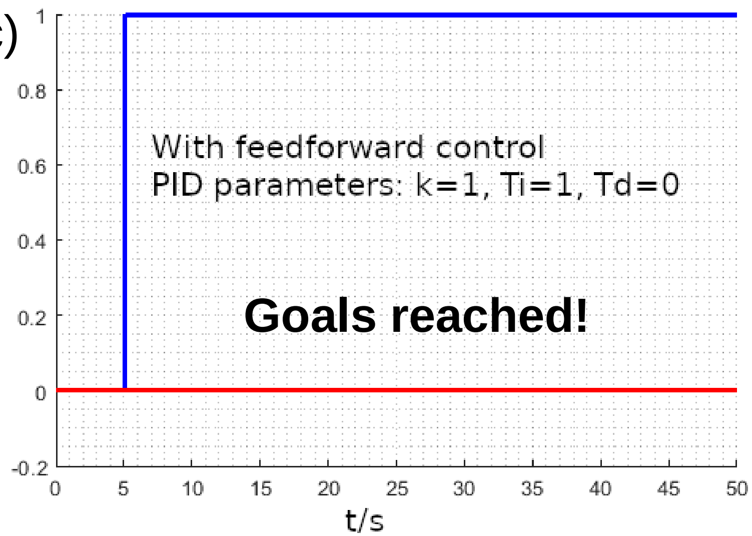

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Outline

1. Case study
2. Implementation of the SES and an MB
3. Model selection and model generation
4. Organization of a simulator-independent MB
5. Full automation of simulation experiments
6. **Summary**

Summary

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