Updates on SMS++ – PyPSA interface

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Model characterization – PyPSA-Eur energy system

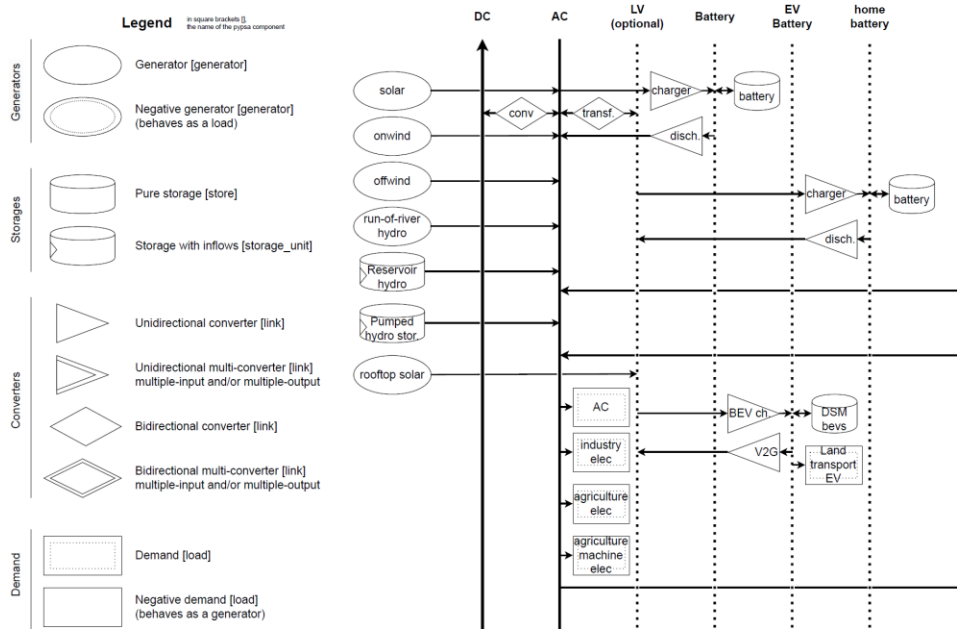
- **Mapping of PyPSA-Eur structure**
  - Carriers
  - Technologies and components
  - Types of parameters by component

	A	B	C	D	E
1	**Technology name**	**Category**	**Physical compone**	**Option**	**Carrier**
2	co2 atmosphere	co2	N		co2
3	Co2 storage	co2	Y		co2 stored
4	Sequestration link	co2	N		co2 sequestred
5	Sequestration store (e.g. underground)	co2	Y/N		co2 sequestred
6	CO2 vent co2 from storages	co2	?	co2_vent	co2 vent
7	CO2 pipelines	co2	Y	co2_network	CO2 pipeline
8	Allam (gas) cycle	electricity	Y	allam	allam
9	Direct Air Capture	co2	Y	dac	co2
10	Conventional generators	electricity	Y	conventional_generation	electricity
11	Haber-Bosch process	ammonia	Y	ammonia	Haber-Bosch
12	Ammonia cracker	ammonia	Y	ammonia	ammonia cracker
13	Ammonia storage	ammonia	Y	ammonia	ammonia store
14	Electricity distribution	electricity	Y	electricity_distribution_grid	low voltage
15	rooftop solar	electricity	Y	electricity_distribution_grid	solar rooftop

- **Graphical representation:**

  - **PyPSA-Symbols-drawio :**
    repository with drawio symbols for PyPSA objects
    https://github.com/SPSUnipi/PyPSA-symbols-drawio

  - **PyPSA-Eur-drawio:**
    repository with drawio graph for PyPSA-Eur
    https://github.com/SPSUnipi/PyPSA-Eur-drawio



Model characterization – Mathematical representation

PyPSA

Objective function	Symbol	Generator	Link	Line	Storage unit	Store
Capital cost	CAP	X	X	X	X	X
Marginal cost	MC	X	X	X	X	X
Marginal cost energy storage	MCE				X	X
Stand-By costs	SB	X	X			
Start up/ shut down cost	SC	X	X			
Splillment costs	SC				X	

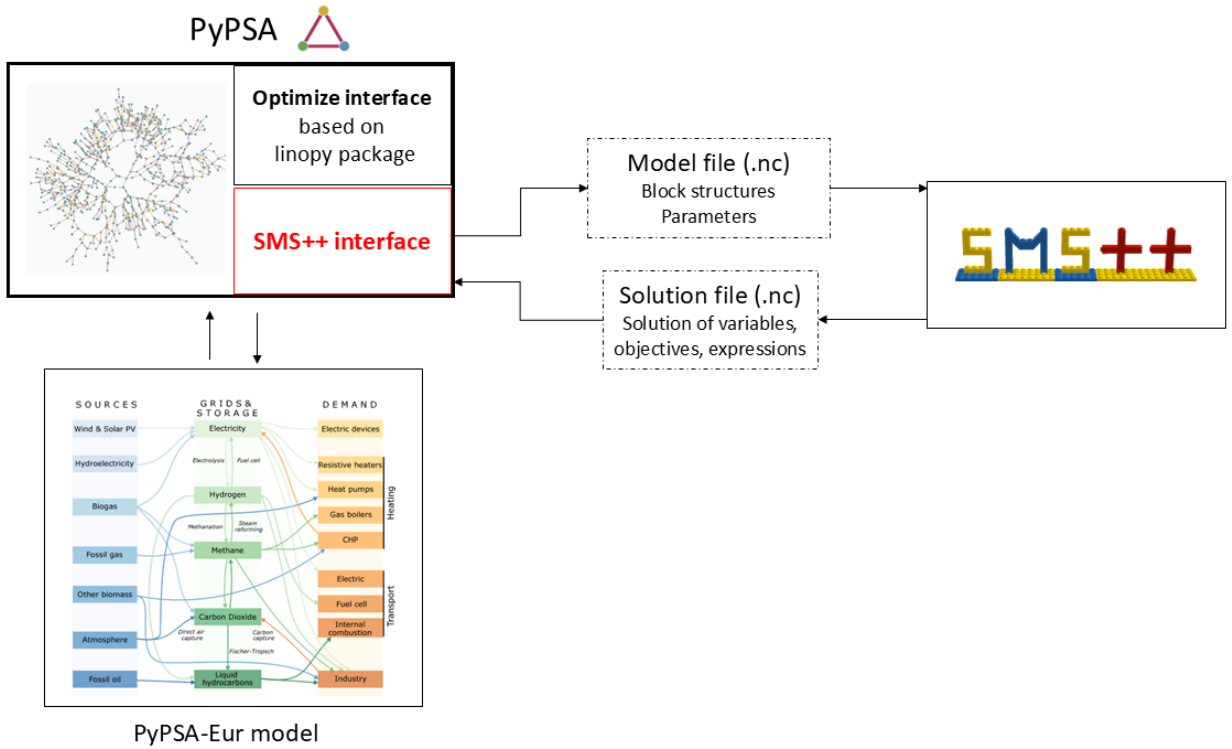
Equation	Symbol	Generator	Link	Line	Storage unit	Store	Condition	Example
Size bound	SB	X	X	X	X	X		$\underline{G}_{i,r} \leq G_{i,r} \leq \overline{G}_{i,r}$
Modularity	MD	X	X	X	X	X		$G_{i,r} = \underline{G}^{mod}_{i,r} n_{i,r}$
Power bound	PB	X	X	X	X	X		$\underline{g}_{i,r,t} G_{i,r} \leq g_{i,r,t} \leq \overline{g}_{i,r,t} G_{i,r}$
Power unit commitment	PB_{UC}	X	X				committable	$\delta_{i,r,t} \underline{g}_{i,r,t} G_{i,r} \leq g_{i,r,t} \leq \delta_{i,r,t} \overline{g}_{i,r,t} G_{i,r}$
Minimum time	MT	X	X					$\sum_{t'=t}^{t+T^{min_{up}}} \delta_{k,t'} \geq T_{min_{up}} (\delta_{k,t} - \delta_{k,t-1})$
Total energy produced	PSUM	X	X					$E^{sum}_{min} \leq \sum_{t \in T} w^G_t g_{i,r,t} \leq E^{sum}_{max}$
Start up/shut down cost	SC	X	X					$suc_{k,t} \geq suc_k (\delta_{k,t} - \delta_{k,t-1})$
Rump up/down	RUD	X	X					$(g_{i,r,t} - g_{i,r,t-1}) \leq ru_{i,r} G_{i,r}$
Kirchhof's law	KL			X				$\sum_l C_{l,c} x_l p_{l,t} = 0$
Line losses	LL			X				$P^{loss}_l = \alpha_l + \beta_l p_{l,t}$
Energy storage level	ESL				X	X		$e_{i,s,t} = e_{i,s,t-1} + w^S_t h_{i,s,t}$
Energy storage bound	ESB				X	X		$0 \leq e_{i,s,t} \leq E_{i,s} e^{max}_{i,s}$
Initial energy level	IEL_S				X	X		$e_{i,s,0} = e_{i,s,init}$
Cyclic energy level	IEL_{CS}				X	X	cyclic_state_of_charge	$e_{i,s,0} = e_{i,s,\|T\|}$

SMS++

Equation	Symbol	Intermittent	Thermal	Battery	Hydro	DC Network
Maximum reserves power	RMAX	X	X	X	X	
Minimum reserves power	RMIN	X	X	X	X	
Power bound	PB	X				
Power bound unit commitment	PB_{UC}	X				
Binary relation	BINR		X			
Binary start-up	BINU		X			
Binary shut-down	BIND		X			
Rump up/down	RUD		X	X	X	
Primary reserves	RPR		X	X		
Secondary reserves	RSC		X	X		
Power bound $\tau = 2$	$PB_{\tau=2}$		X			
Power bound $\tau = 1$	$PB_{\tau=1}$		X			
Power balance	PBAL			X		
Power bound discharge	PB^+			X		
Power bound charge	PB^-			X		
Power bound discharge unit commitment	PB^+_{UC}			X		
Power bound converter	PBC			X		
Energy storage level	ESL			X		
Energy storage level simplified	ESLS			X		
Energy storage bound	ESB			X		
Energy storage discharge	ESD			X		
Energy storage charge	ESC			X		
Volume bound	VB				X	
Primary reserves turbine	RPR_T				X	
Primary reserves pump	RPR_P				X	
Secondary reserves turbine	RSC_T				X	
Secondary reserves pump	RSC_P				X	
Power-to-flow function turbine	PTF_T				X	
Power-to-flow function pump	PTF_P				X	
Volume level	VL				X	
Power bound DC network	PB_{DC}					X
Power bound AC network	PB_{AC}					X
Power bound AC-DC network	PB_{AC-DC}					X
Network cost	NC					X
Energy balance	EBAL					X

PyPSA – SMS++ interface

The goal



PyPSA-Eur model

Possible strategies

1. Notebook implementation
   https://github.com/SPSUnipi/SMSpp_PyPSA
2. No auxiliary packages
   https://github.com/SPSUnipi/SMSpp_builder
3. Auxiliary repositories
   - Python input/output for SMS++
     https://github.com/SPSUnipi/SMSpy
   - (optionally) transformation PyPSA – SMS++
     https://github.com/SPSUnipi/PyPSA_SMS_interface

SMSpp_builder: compile and test SMS++ PyPSA interface

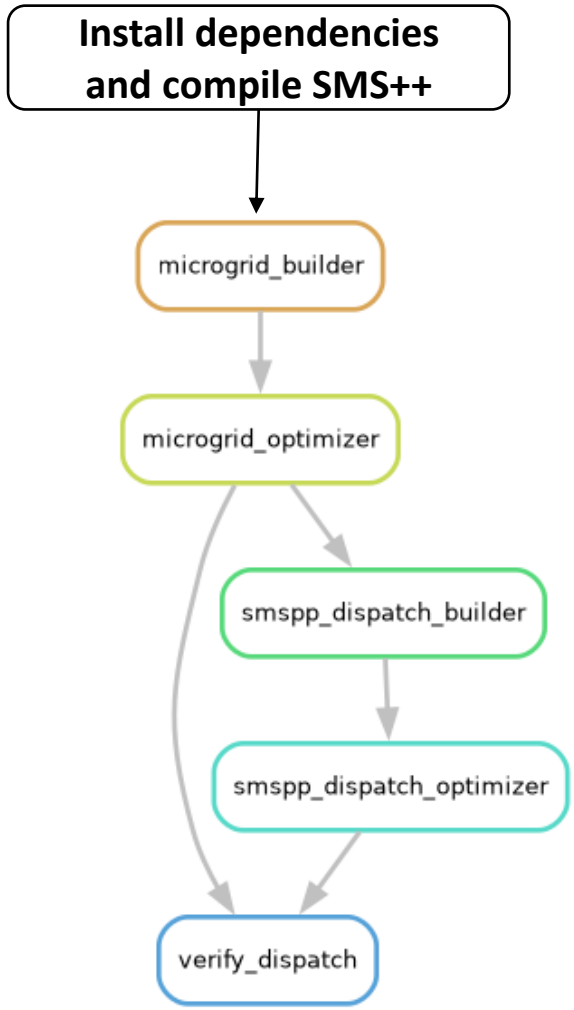
- **Goal:**
  Test compilation and execution of PyPSA - SMS++

- **Automation:**
  - Github Action
  - Snakemake (except installation and compilation)

- **Tested configurations (dispatch analysis)**

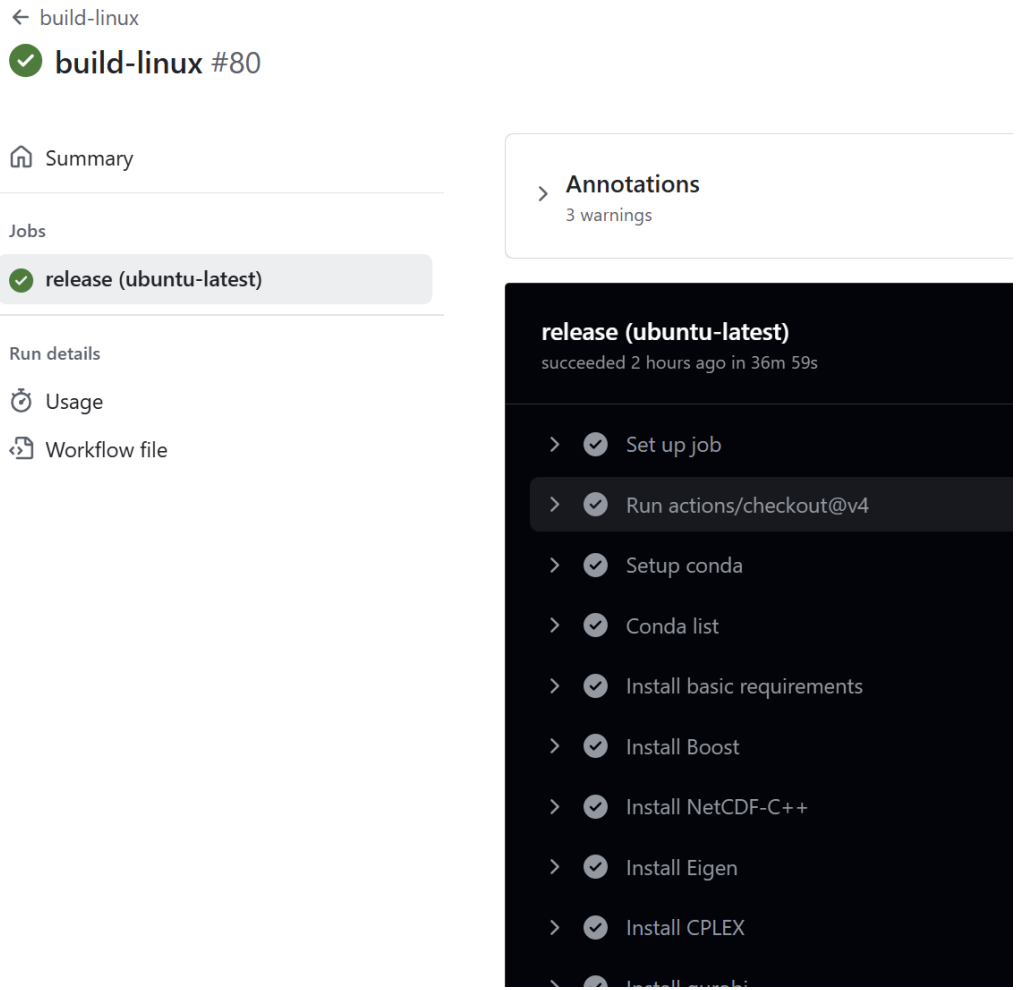
Test case	Network	Nodes	PyPSA components					
			Generator	StorageUnit	Store	Line	Link	Load
	[Yes/No]	[#]	[#]	[#]	[#]	[#]	[#]	[#]
1	No	1	1					1
2	No	1	3	2				1
3	Yes	2	1			1		2
4	Yes	5	3	2	1	3	1	4
5	No	2	1		1		1	2

Table 4.1: Test cases of *SMSpp_builder*



SMSpp_builder: compile and test SMS++ PyPSA interface

CI is successful



SMS++ results match PyPSA

```
[Tue Nov 19 18:47:51 2024]
localrule verify_dispatch:
    input: results/networks/microgrid_microgrid_ALL_4N_optimized.nc, result
    output: results/microgrid_microgrid_ALL_4N_complete.txt
    log: logs/verify_dispatch_microgrid_ALL_4N.log
    jobid: 0
    reason: Missing output files: results/microgrid_microgrid_ALL_4N_comple
    resources: tmpdir=/tmp

INFO:pypsa.io:Imported network microgrid_microgrid_ALL_4N_optimized.nc has
INFO:verify_dispatch:SMS++ obj                                : 19315.875900
INFO:verify_dispatch:PyPSA dispatch obj                       : 19315.875923
INFO:verify_dispatch:Relative difference SMS++ - PyPSA [%]: -0.00000
INFO:verify_dispatch:Absolute difference SMS++ - PyPSA [€] : -0.00002
INFO:verify_dispatch:Verification successful
Touching output file results/microgrid_microgrid_ALL_4N_complete.txt.
```

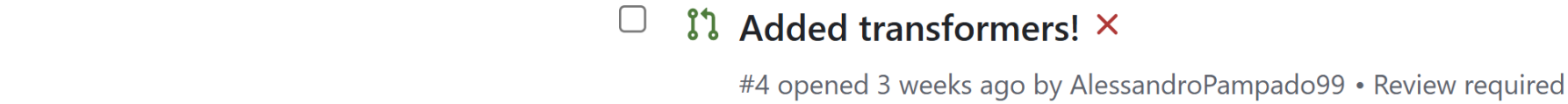
Ongoing priorities

Energy system representation

- **Finalize PyPSA and SMS++ description**
- **Define mapping of mathematical representations**
- **Define key priorities** and requirements for RESILIENT
- **Implement** in SMS++ the key missing options

Interface

- **Integrate Transformers**



- **Support capacity expansion problems**
- **Define software architecture of interface**
  - Notebook implementation (discarded)
  - No auxiliary packages (not recommended)
  - Auxiliary packages
    - comprehensive PyPSA-SMS++ conversion package
    - Python SMS++ input/output package
    - PyPSA-SMS++ conversion repository or PyPSA integration
- **Support more parameters and functionalities**

SMS++ developments

Activities done

- **Enhanced installation** file by a single bash file:
  - INSTALL.sh in Mac/Ubuntu
    https://gitlab.com/smspp/smspp-project/-/blob/develop/INSTALL.sh
  - INSTALL.ps1 for windows
    https://gitlab.com/smspp/smspp-project/-/blob/develop/INSTALL.ps1
- **Development of [MultiStage]ScenarioGenerator**
- **Initial development of TwoStageStochasticBlock**
- **Handling of quadratic constraints in MILPSolver**
- **Integration of AC load flow**
  https://gitlab.com/smspp/ucblock/-/blob/develop/src/ACNetworkBlock.cpp
- **Bug fixing**
- **Preliminary investigation of Multi-Energy design**

Planned activities

- **Define / implement OptimalTransportBlock and :OptimalTransportSolver** [scenario reduction, Q3 2025]
- **Finalise development of TwoStageStochasticBlock** [goal functional draft by Q1-Q2 2025]
- **Improve data output** [to support interface]
- **Multi-energy design** [After M18]
- **Improve BundleSolver** [decomposition]
- **Develop PrimalProximalSolver** [integer decomposition]
- **Bug fixing:**
  - InvestmentBlock solver for investment analyses
  - Hydro issue with storing capabilities
- **Feature inclusions to adapt to RESILIENT needs**