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RT22
ENERGIZING TOMORROW

Streamlined Real-Time Model Development for the OPAL-RT Platform Using SwAGSM

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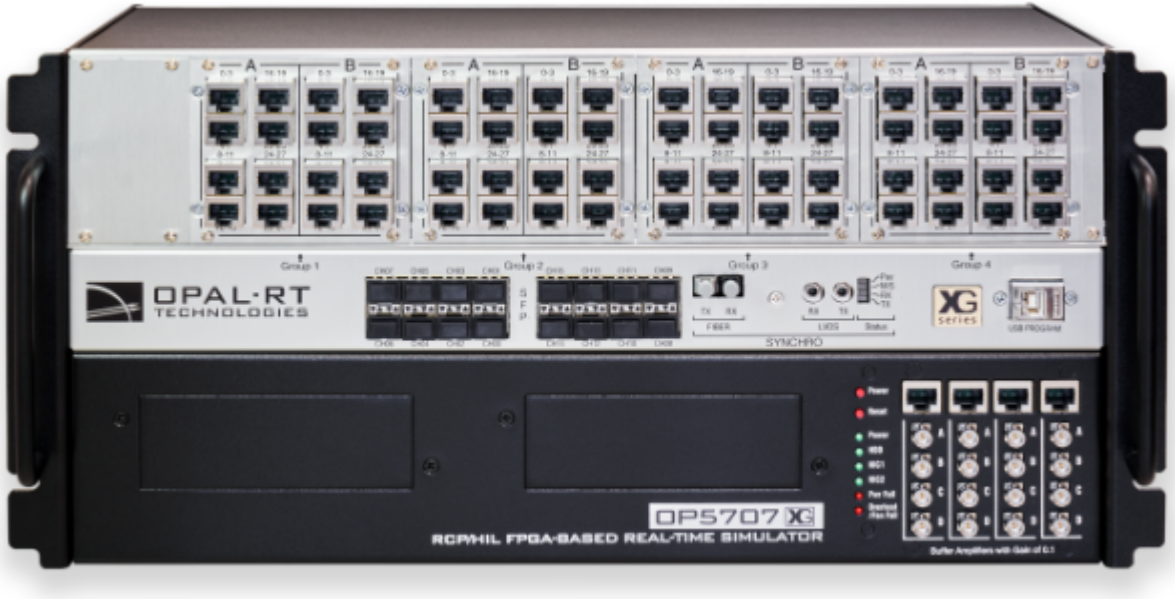
INTRODUCTION: REAL-TIME MODELING

- Real-time modeling allows for an engineer to test controllers and interact with a system as it would operate in the real world.

- Additionally, models which run rather slowly may be easily parallelized on the OPAL-RT platform to allow for faster computation time for more complex systems.



COMPLICATIONS TO REAL-TIME MODEL DEVELOPMENT

Development Time

- Developing OPAL-RT Models involves manually developing Simulink Models
  - Potential for human error during development process
- For large models, Simulink's drag-and-drop interface can be time consuming to utilize.
- Models which run offline may not be immediately compatible with the OPAL-RT platform

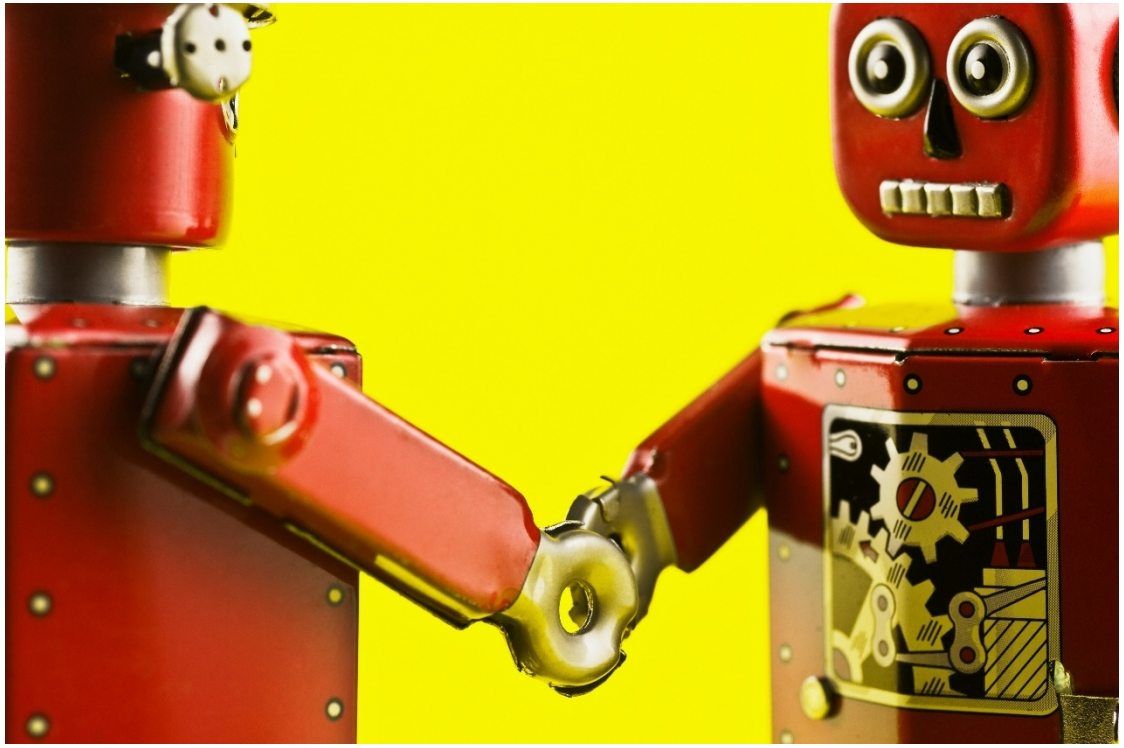
All of these can result in additional time spent manually developing and debugging models to run on the OPAL-RT platform.

COMPLICATIONS TO REAL-TIME MODEL DEVELOPMENT

Collaboration

- Partners may not have the same number of cores available.
  - Tune all models to operate for whoever has the lowest number of cores available
  - Manually create multiple version of the same model based on the number of cores available to each collaborator

Neither of these choices is optimal. The first option is a waste of resources and the second option is a waste of labor efforts.



PROPOSED SOLUTION: MODEL AUTOMATION

- Skip the drag-and-drop interface
- Skip the Debugging
- Develop models independent of core availability
- Guarantee model is OPAL-RT ready from the start

But How?

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SOFTWARE FOR AUTOMATIC GENERATION OF SIMULINK MODELS

Proposed Tool: SwAGSM (**S**oft**w**are for **A**utomatic **G**eneration of **S**imulink **M**odels)

- Requires minimal knowledge of MATLAB/Simulink
- Does not require use of drag-and-drop interface to create OPAL-RT models
- Automatically generated models from Excel Spreadsheets
- Allows for the model core count to be adjusted on-the-fly
  - Simply edit a few values in a spreadsheet.
- No debugging required
- Models automatically formatted to immediately load to OPAL-RT platform.

SOFTWARE FOR AUTOMATIC GENERATION OF SIMULINK MODELS

- SwAGSM is current being utilized at Sandia National Laboratories to aid in the development of electric ship models for NSWC
- In the remainder of this presentation, examples utilized will be those relevant to the electric ship modeling efforts currently in progress.

Image courtesy of Naval Sea System Command (NAVSEA).
https://www.navsea.navy.mil/Home/Team-Ships/PEO-Ships/DDG-51/

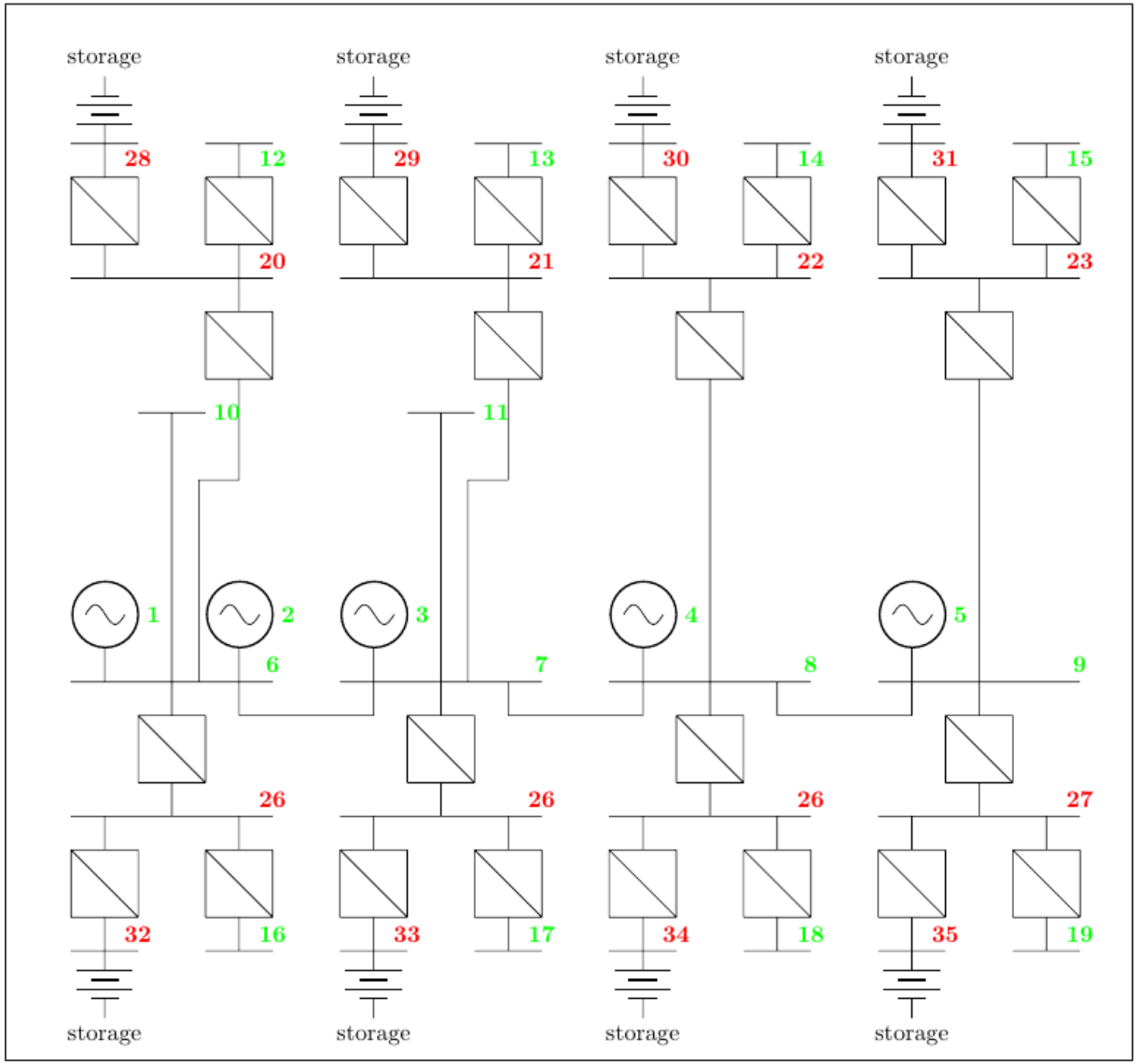
HOW DOES SWAGSM WORK?

- There is no model initially
- Library components are called by MATLAB script
  - System parameters fully defined in Excel Spreadsheet
- The steps as follows
  1. Edit and save spreadsheet
  2. Run script
     1. A new blank Simulink model is automatically opened and populated with requested components
  3. Save model and load to OPAL-RT as normal

EXAMPLE

Consider the generic shipboard network to the right

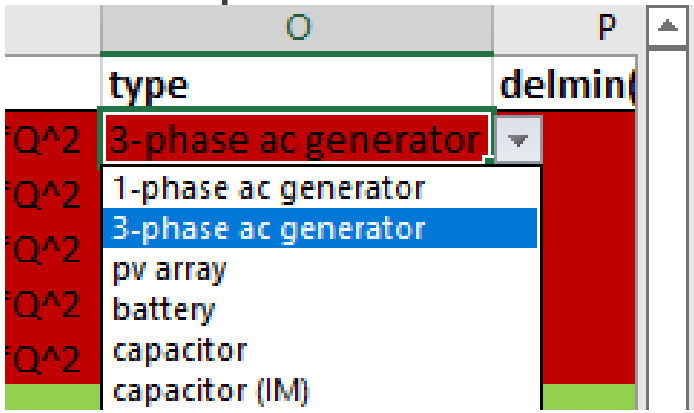
- The parameters are defined on the preceding slides as
- 3-phase AC buses are labeled in green
- DC buses are labeled in red



BUS PARAMETERS

Available Options:

- 3-phase ac generator
- PV-array
- Battery
- Capacitor



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	core	bus	ac or dc	C(uF)	active (W)	reactive (VAr)	Vbase	Vmin	Vmax	Pmin	Pmax	Qmin	Qmax	objective	type
2	1	1	ac	0	0	0	3983.717	3784.531	4182.903	0	50000000	-50000000	50000000	0.01*P^2+1.0*Q^2	3-phase ac generat
3	2	2	ac	0	0	0	3983.717	3784.531	4182.903	0	50000000	-50000000	50000000	0.01*P^2+1.0*Q^2	3-phase ac generat
4	1	3	ac	0	0	0	3983.717	3784.531	4182.903	0	10000000	-10000000	10000000	0.01*P^2+1.0*Q^2	3-phase ac generat
5	2	4	ac	0	0	0	3983.717	3784.531	4182.903	0	10000000	-10000000	10000000	0.01*P^2+1.0*Q^2	3-phase ac generat
6	1	5	ac	0	0	0	3983.717	3784.531	4182.903	0	10000000	-10000000	10000000	0.01*P^2+1.0*Q^2	3-phase ac generat
7	2	6	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
8	1	7	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
9	2	8	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
10	1	9	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
11	2	10	ac	1000	18000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
12	1	11	ac	1000	18000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
13	2	12	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
14	1	13	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
15	2	14	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
16	1	15	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
17	2	16	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
18	1	17	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
19	2	18	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
20	1	19	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
21	2	20	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
22	1	21	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
23	2	22	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
24	1	23	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
25	2	24	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
26	1	25	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
27	2	26	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
28	1	27	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
29	2	28	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
30	1	29	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
31	2	30	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
32	1	31	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
33	2	32	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
34	1	33	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
35	2	34	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
36	1	35	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery

Model Parameters | **Bus Data** | Line Connections | Diesel Generator Parameters | Gas 1 ...

Core defined in Col A

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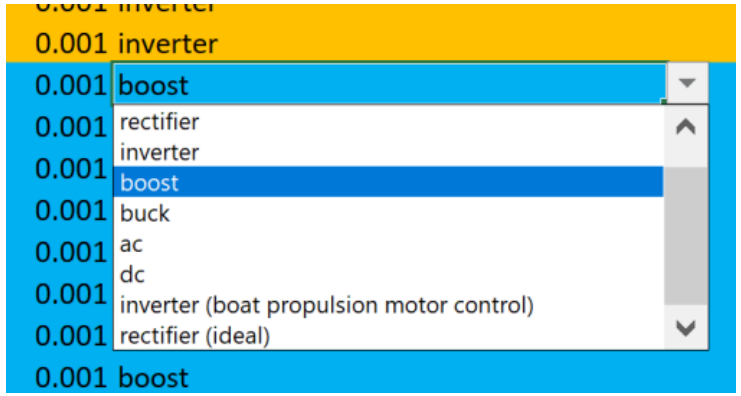
LINE PARAMETERS

Available Options:

- AC lines
- DC lines
- Buck Converters
- Boost Converters
- 3-phase inverters
- 3-phase rectifiers

	A	B	C	D	E	F	G	H	I	J
1	line no.	from	to	R(ohms)	L(H)	type	ac/dc #	dc/dc #	kp	ki
2	1	1	6	0.1	0.0001	ac			0	0
3	2	2	6	0.1	0.0001	ac			0	0
4	3	3	7	0.1	0.0001	ac			0	0
5	4	4	8	0.1	0.0001	ac			0	0
6	5	5	9	0.1	0.0001	ac			0	0
7	6	6	7	0.1	0.0001	ac			0	0
8	7	7	8	0.1	0.0001	ac			0	0
9	8	8	9	0.1	0.0001	ac			0	0
10	9	6	10	0.1	0.0001	ac			0	0
11	10	8	11	0.1	0.0001	ac			0	0
12	11	6	20	0.01	0.001	rectifier	1		0	0
13	12	7	21	0.01	0.001	rectifier	2		0	0
14	13	8	22	0.01	0.001	rectifier	3		0	0
15	14	9	23	0.01	0.001	rectifier	4		0	0
16	15	6	24	0.01	0.001	rectifier	5		0	0
17	16	7	25	0.01	0.001	rectifier	6		0	0
18	17	8	26	0.01	0.001	rectifier	7		0	0
19	18	9	27	0.01	0.001	rectifier	8		0	0
20	19	20	12	0.01	0.001	inverter	9		0	0
21	20	21	13	0.01	0.001	inverter	10		0	0
22	21	22	14	0.01	0.001	inverter	11		0	0
23	22	23	15	0.01	0.001	inverter	12		0	0
24	23	24	16	0.01	0.001	inverter	13		0	0
25	24	25	17	0.01	0.001	inverter	14		0	0
26	25	26	18	0.01	0.001	inverter	15		0	0
27	26	27	19	0.01	0.001	inverter	16		0	0
28	27	28	20	0.01	0.001	boost		1	0	0
29	28	29	21	0.01	0.001	boost		2	0	0
30	29	30	22	0.01	0.001	boost		3	0	0
31	30	31	23	0.01	0.001	boost		4	0	0
32	31	32	24	0.01	0.001	boost		5	0	0
33	32	33	25	0.01	0.001	boost		6	0	0
34	33	34	26	0.01	0.001	boost		7	0	0
35	34	35	27	0.01	0.001	boost		8	0	0

Model Parameters | Bus Data | **Line Connections** | Diesel Ge



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COMPONENT PARAMETERS

	A	B	C	D	E	F
1	bus	type	Vnom(V)	Ah rating	effic.(%)	SOC(0)
2	28	Li-Ion	3000	300000	99.5	0.8
3	29	Li-Ion	3000	300000	99.5	0.8
4	30	Li-Ion	3000	300000	99.5	0.8
5	31	Li-Ion	3000	300000	99.5	0.8
6	32	Li-Ion	3000	300000	99.5	0.8
7	33	Li-Ion	3000	300000	99.5	0.8
8	34	Li-Ion	3000	300000	99.5	0.8
9	35	Li-Ion	3000	300000	99.5	0.8
10		Lead-Acid				
11		Li-Ion				
12		NiCd				
		NiMH				

... Battery Parameter ...

- Component parameters defined by sheets of spreadsheet
- Automatically placed based on core locations defined in “Bus Parameters” sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	ac bus	P(poles)	J	Bm(Nm.s)	Rs(ohms)	K	T1	T2	T3	T4	T5	T6	Tmin	Tmax	Td	Pm0	rated kW	kDelta
2	1	4	256.38	0.1	0.087	1	0.01	0.02	0.2	0.25	0.009	0.0384	-0.1	1.1	0.024	0.25	150000	-0.1
3	2	4	256.38	0.1	0.087	1	0.01	0.02	0.2	0.25	0.009	0.0384	-0.1	1.1	0.024	0.25	150000	-0.1
4	3	4	256.38	0.1	0.087	1	0.01	0.02	0.2	0.25	0.009	0.0384	-0.1	1.1	0.024	0.25	150000	-0.1
5	4	4	256.38	0.1	0.087	1	0.01	0.02	0.2	0.25	0.009	0.0384	-0.1	1.1	0.024	0.25	150000	-0.1
6	5	4	256.38	0.1	0.087	1	0.01	0.02	0.2	0.25	0.009	0.0384	-0.1	1.1	0.024	0.25	150000	-0.1

Model Parameters | Bus Data | Line Connections | Diesel Generator Parameters | Gas Turb ...

LOAD DEFINITIONS

time(s) / bus	0	29.99	30	59.99	60	89.99	90	119.99	120
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	1000	1000	1000	1000	1000	1000	1000	1000	1000
7	1000	1000	1000	1000	1000	1000	1000	1000	1000
8	1000	1000	1000	1000	1000	1000	1000	1000	1000
9	1000	1000	1000	1000	1000	1000	1000	1000	1000
10	18000	18000	18000	18000	18000	18000	18000	18000	18000
11	18000	18000	18000	18000	18000	18000	18000	18000	18000
12	1000	1000	1000	1000	1000	1000	1000	1000	1000
13	1000	1000	1000	1000	1000	1000	1000	1000	1000
14	1000	1000	1000	1000	1000	1000	1000	1000	1000
15	1000	1000	1000	1000	1000	1000	1000	1000	1000
16	1000	1000	1000	1000	1000	1000	1000	1000	1000
17	1000	1000	1000	1000	1000	1000	1000	1000	1000
18	1000	1000	1000	1000	1000	1000	1000	1000	1000
19	1000	1000	1000	1000	1000	1000	1000	1000	1000

Active Load (kW) | Reactive Load (kVAr) | DC Lo: ...

time(s) / bus	0	29.99	30	59.99	60	89.99	90	119.99	120
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0

Active Load (kW) | Reactive Load (kVAr) | DC Lo: ...

time(s) / bus	0	60	120	180	240	285	300
20	1000	1000	1000	1000	1000	1000	1000
21	1000	1000	1000	1000	1000	1000	1000
22	1000	1000	1000	1000	1000	1000	1000
23	1000	1000	1000	1000	1000	1000	1000
24	1000	1000	1000	1000	1000	1000	1000
25	1000	1000	1000	1000	1000	1000	1000
26	1000	1000	1000	1000	1000	1000	1000
27	1000	1000	1000	1000	1000	1000	1000
28	1000	1000	1000	1000	1000	1000	1000
29	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0

DC Load (kW) | Environmental Conditions | DW ...

- Load Profiles
  - Active loads
  - Reactive loads
  - DC loads

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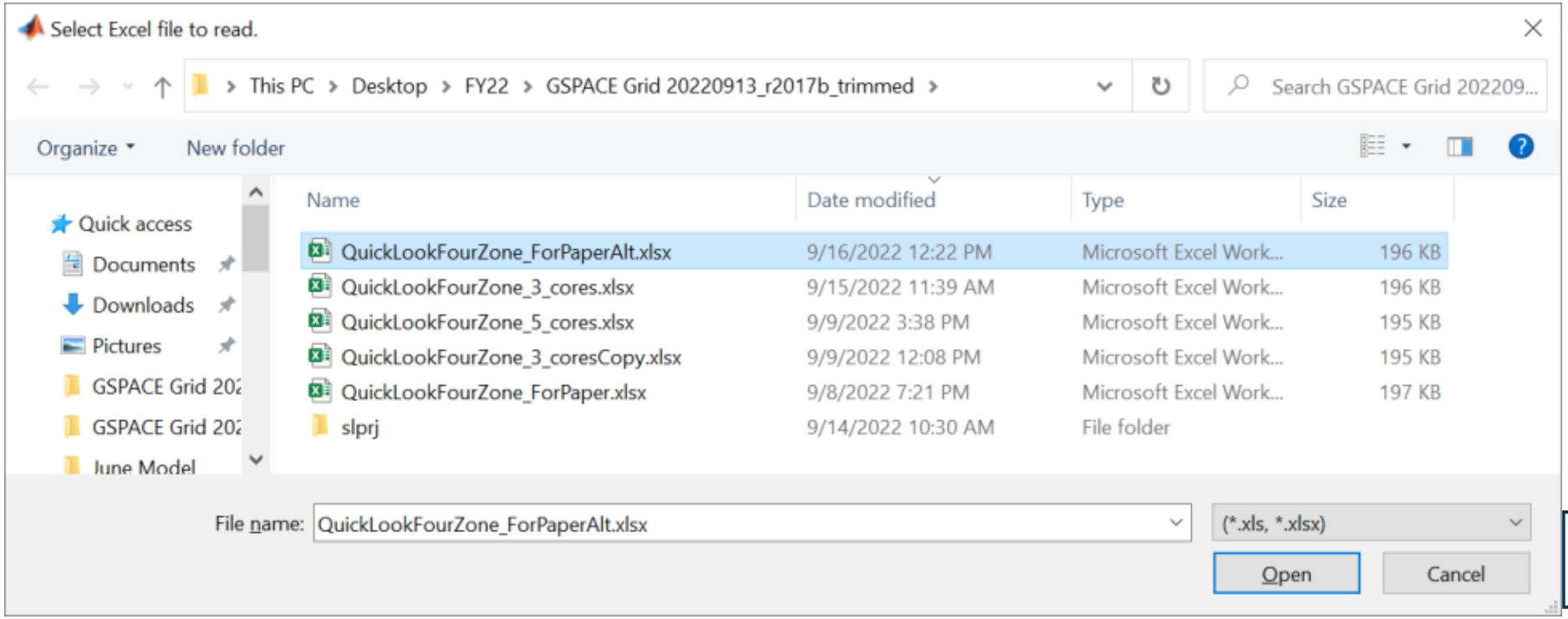
GENERATING THE MODEL

Once Spreadsheet edits are saved

- Run script currently called ‘main.m’ to generate the model
- Choose the desired excel file



OPTIMAL POWER FLOW (OPF) RESULT DISPLAYED

Once file is chosen

- File read time is tracked
- AC/DC Optimal power flow is computed
- OPF results is used to initialize model state variables
- After OPF completes, new Simulink model is automatically opened and populated

```
Reading data from Excel file ...
File read complete!
Elapsed time is 12.439287 seconds.
```

acBus	VacLN	delDeg
1	3988	0
2	3988	-1.8447e-13
3	3914.4	0.66615
4	3872.5	0.28609
5	3877.3	1.0019
6	3921.9	-0.35788
7	3871.8	0.43243
8	3829.4	0.047519
9	3834.2	0.76358
10	3896.3	-2.9287
11	3800.5	-2.5423
12	3845.1	-2.8045
13	3862.7	-2.8017
14	3859.9	-2.8007
15	3865.8	-2.7989
16	3845.1	-2.8045
17	3862.7	-2.8017
18	3859.9	-2.8007
19	3865.8	-2.7989

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OPTIMAL POWER FLOW RESULT DISPLAYED

dcBus	Vdc
20	12460
21	12603
22	12565
23	12604
24	12460
25	12603
26	12565
27	12604
28	3297
29	3297
30	3297
31	3297
32	3297
33	3297
34	3297
35	3297

acdcConvNo	dutyMag	dutyAngDeg
1	0.25789	-0.61599
2	0.25265	0.13673
3	0.24781	-0.25811
4	0.25487	0.44002
5	0.25789	-0.61599
6	0.25265	0.13673
7	0.24781	-0.25811
8	0.25487	0.44002
9	0.26478	-2.269
10	0.26298	-2.2687
11	0.26358	-2.2674
12	0.26315	-2.2664
13	0.26478	-2.269
14	0.26298	-2.2687
15	0.26358	-2.2674
16	0.26315	-2.2664

dcdcConvNo	mu
1	0.26454
2	0.26156
3	0.26235
4	0.26153
5	0.26454
6	0.26156
7	0.26235
8	0.26153

bus_no	MWgen	MVARgen	charging
1	15.793	0	false
2	15.793	0	false
3	10.009	0	false
4	10	0	false
5	10	0	false
28	0.25818	0	false
29	0.19181	0	false
30	0.17561	0	false
31	0.17631	0	false
32	0.25818	0	false
33	0.19181	0	false
34	0.17561	0	false
35	0.17631	0	false

```
0.071991 per-unit loss (Pgen - Pload)
11.3912 % loss
3.847s to solve.
41 iterations.
f=0.000835
```

AC/DC converter duty cycles are displayed as phasor quantities

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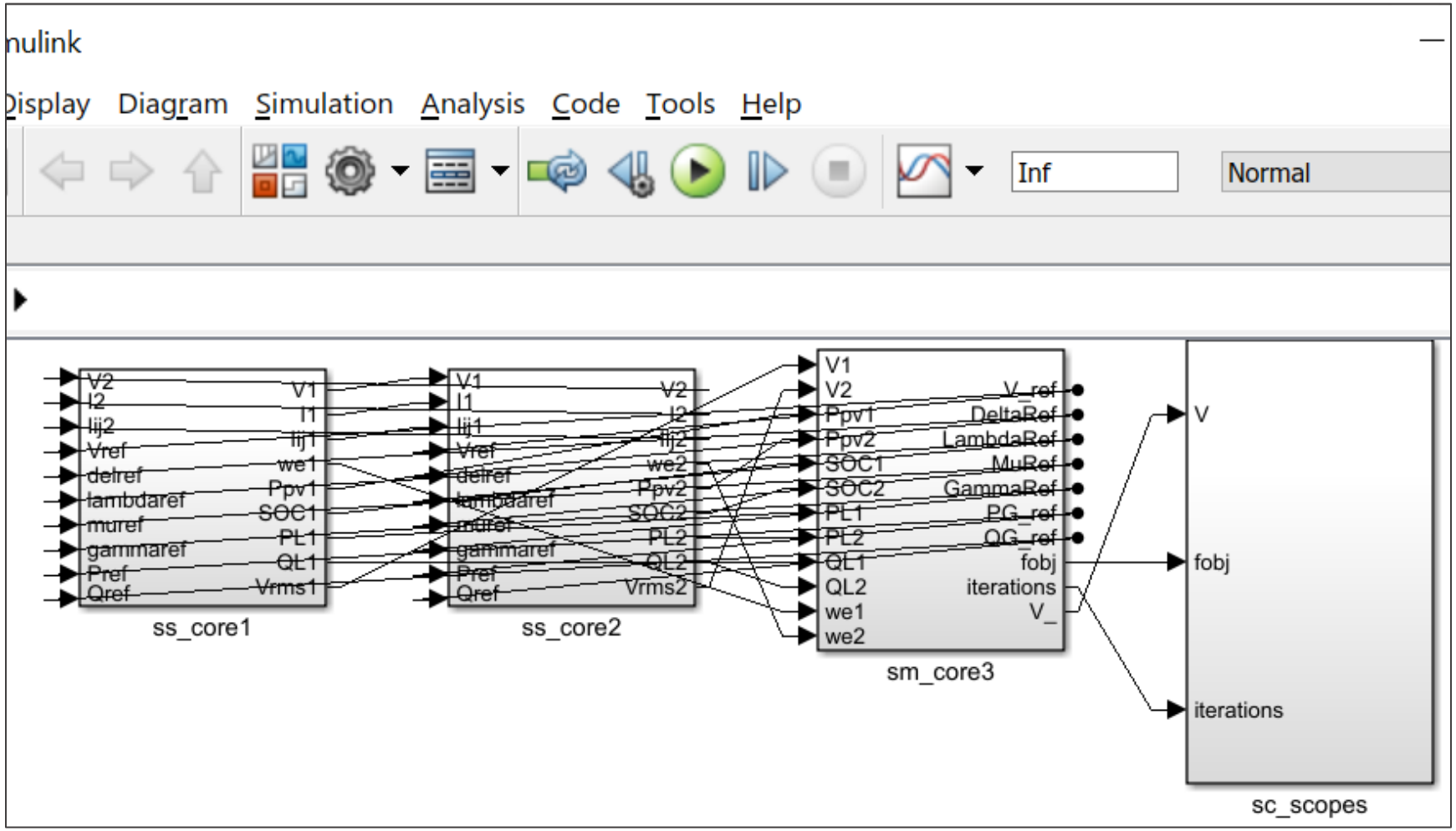
OPAL-RT MODEL AUTOMATICALLY GENERATED

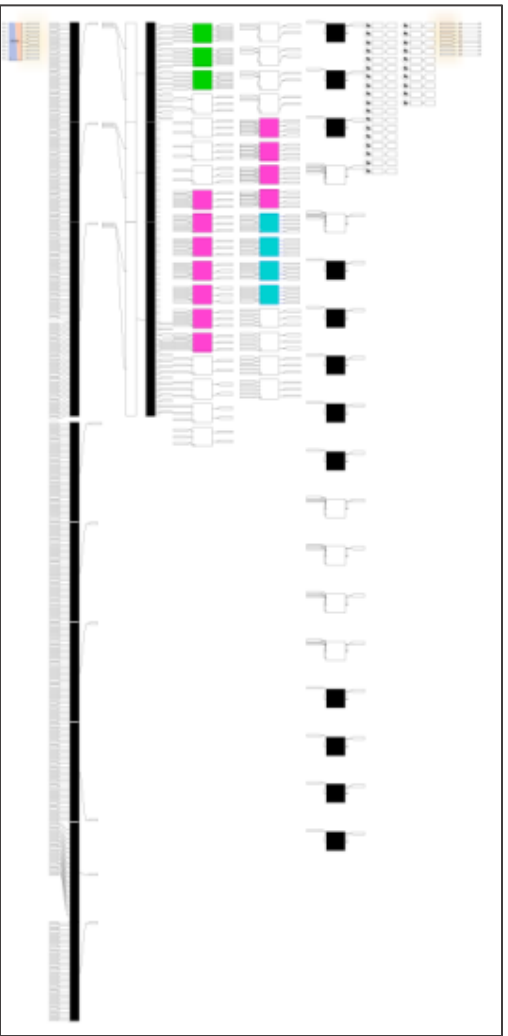
Automatically split across the specified number of cores

- 1-2 are plant cores
- 3 is the OPF core
  - Periodic OPF computation

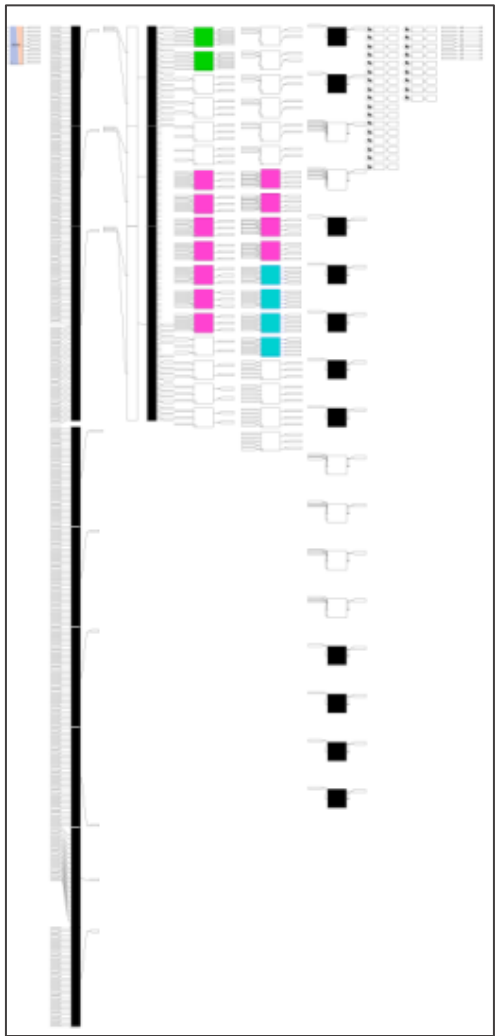


UNDER THE HOOD

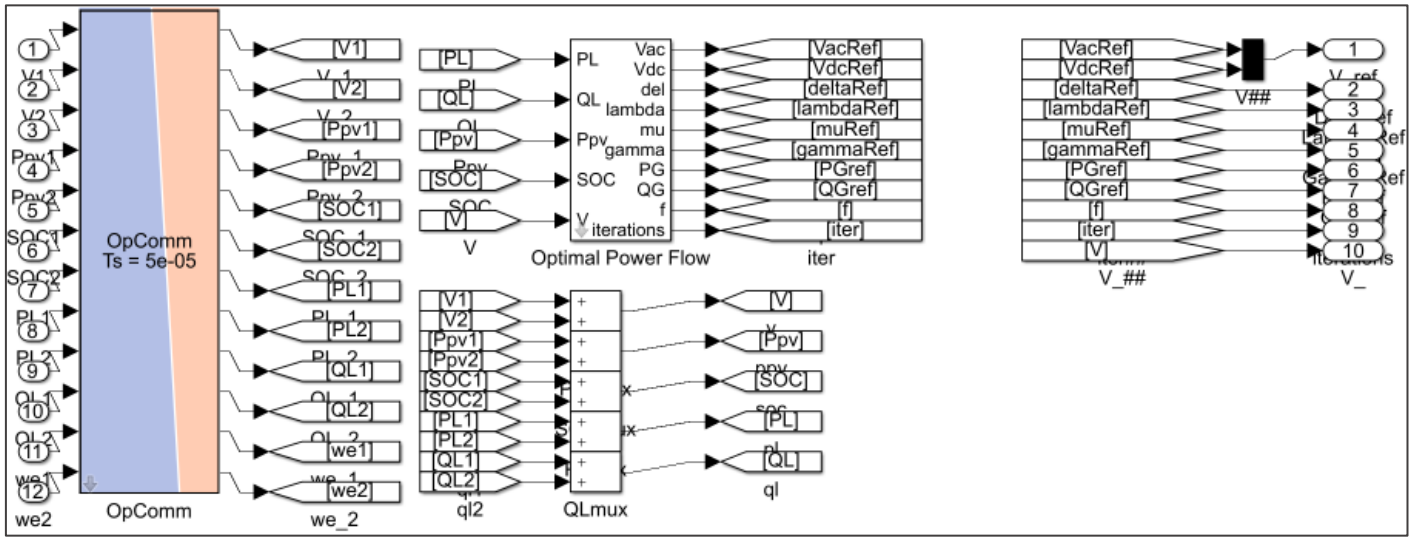
ss_core1



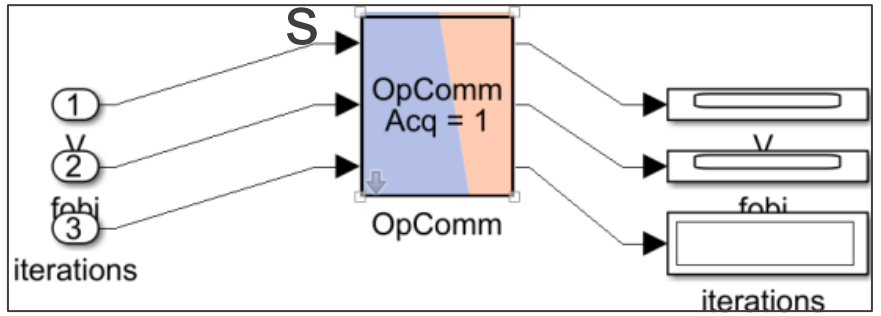
ss_core2



sm_core3



sc_scope



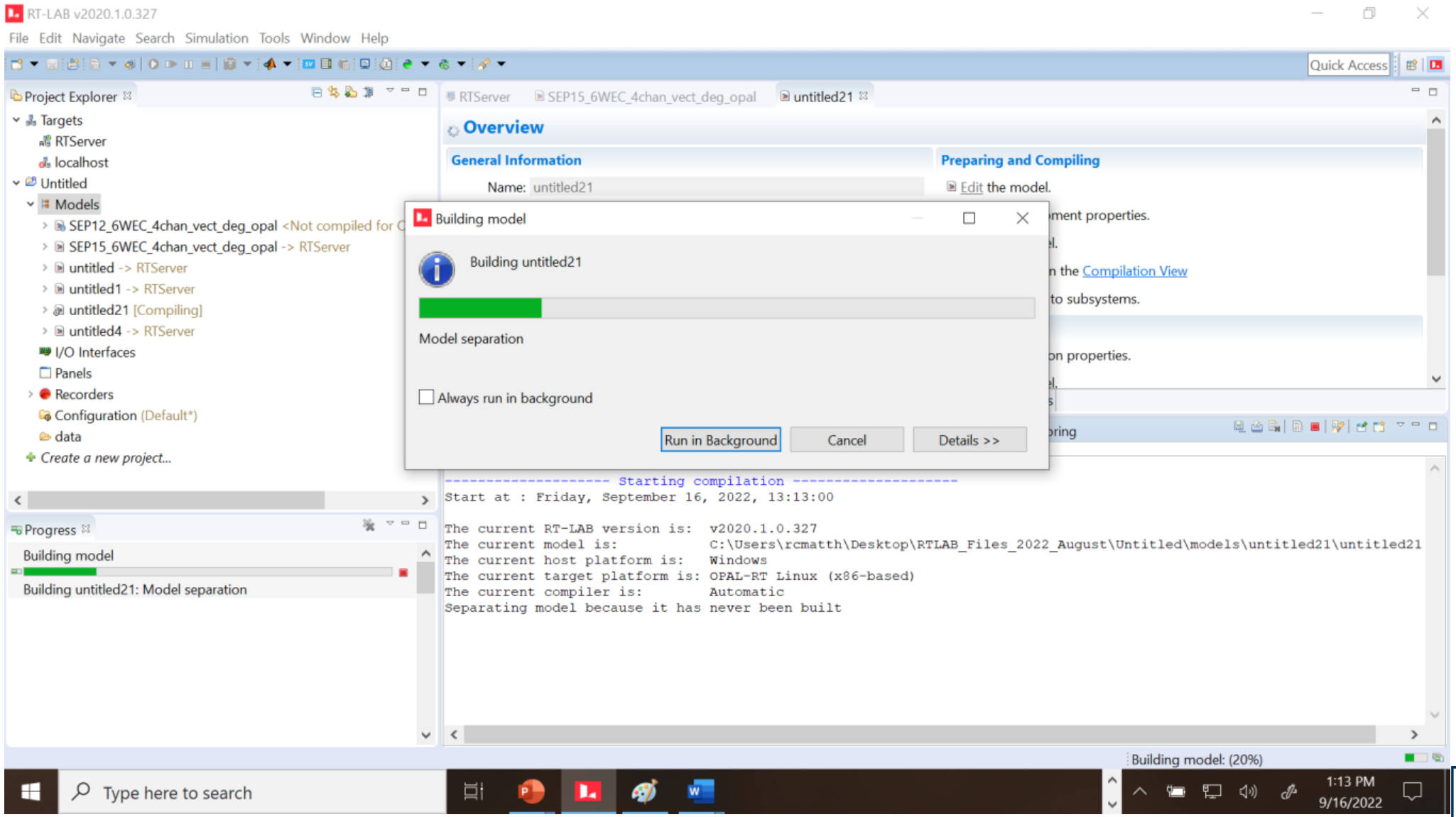
UNDER THE HOOD

- Hundreds of Simulink blocks are automatically places throughout the model
- OPAL-RT OpComm blocks are automatically placed

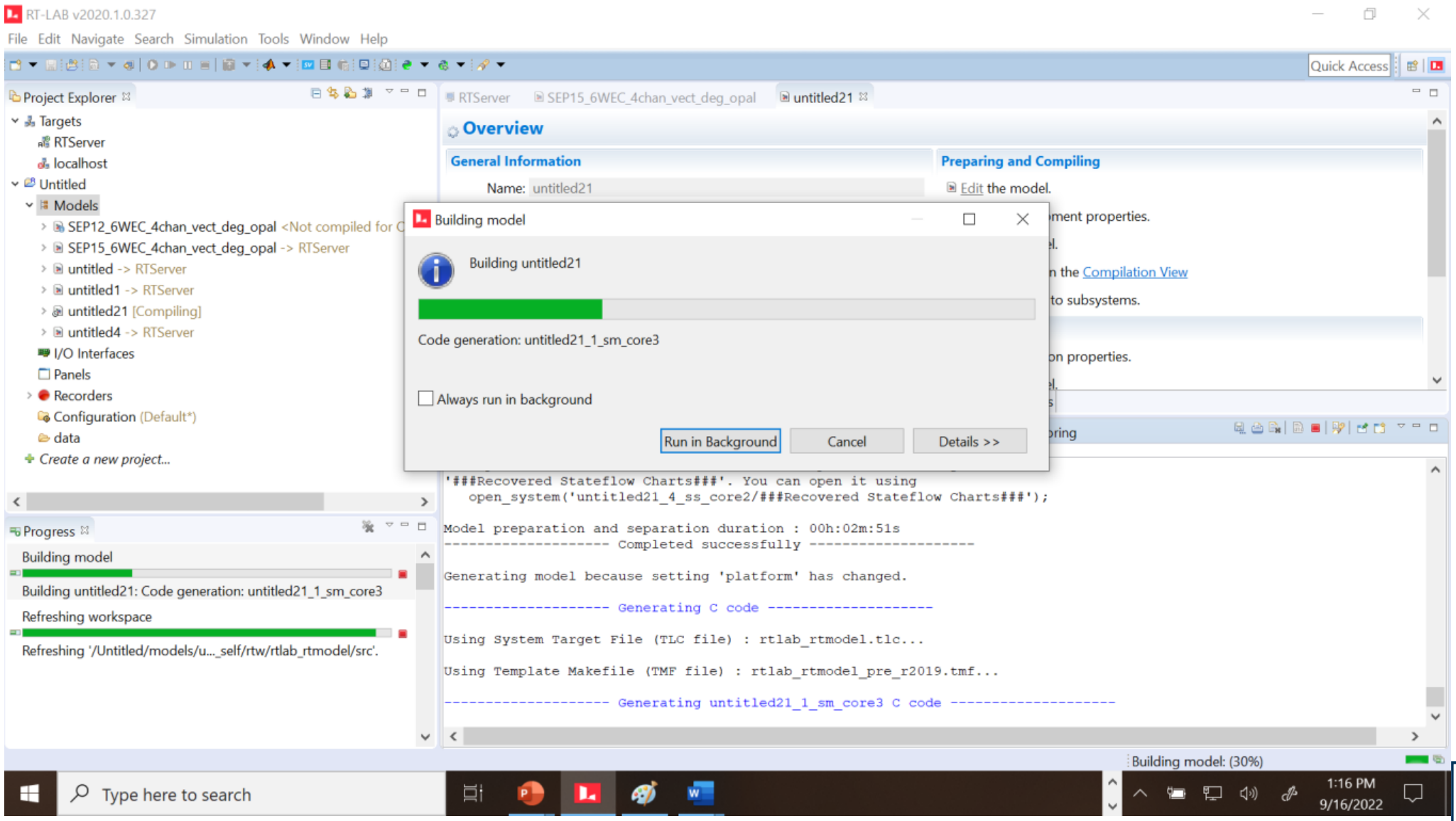
OPAL-RT SIMULATION

- Simply save model and load to OPAL-RT as normal
- ‘IGNORE CRITICAL WARNINGS’ must be chosen in the ‘Variable’ tab in OPAL-RT before loading

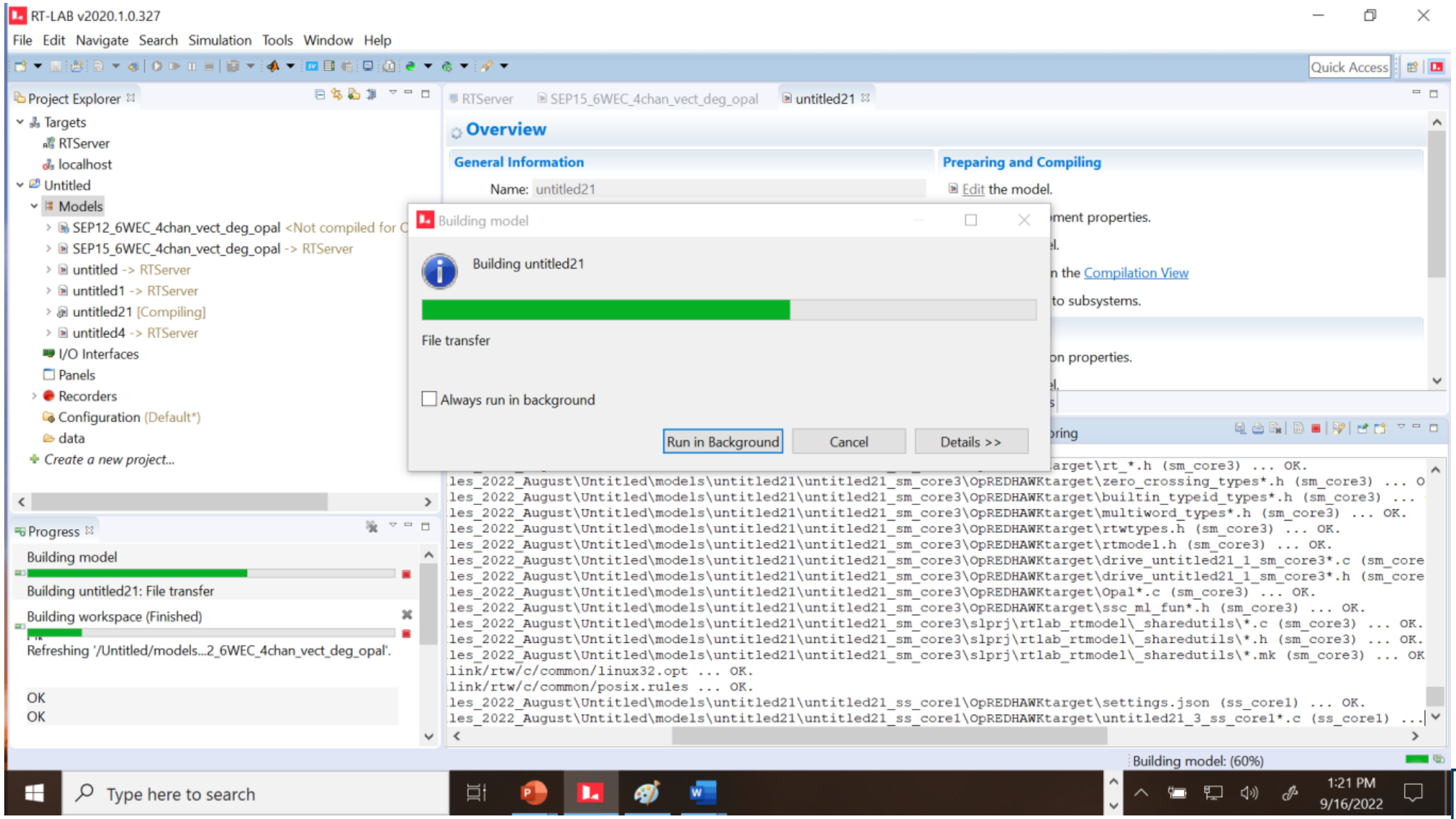
OPAL-RT SIMULATION (BUILD MODEL)



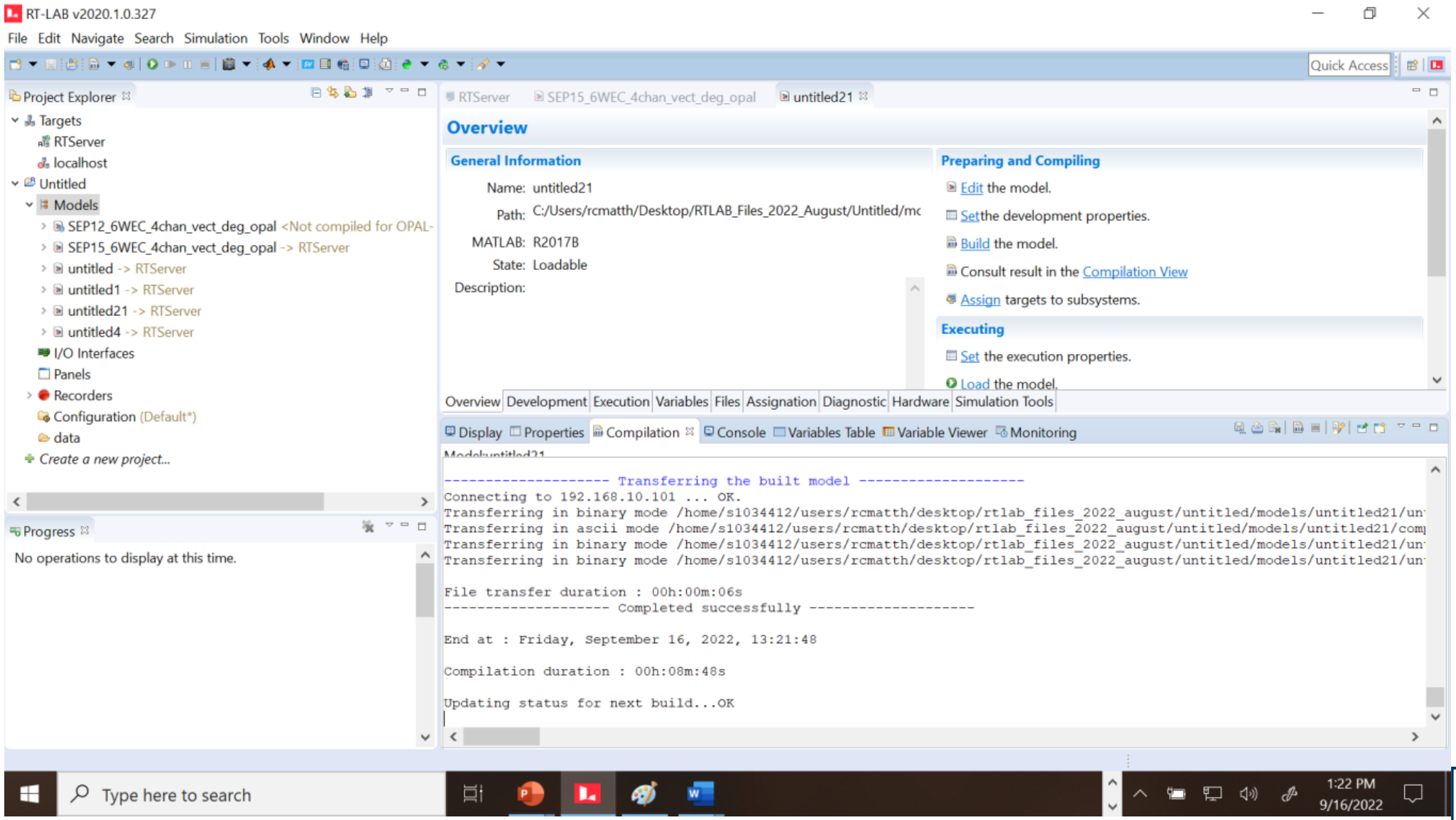
OPAL-RT SIMULATION (BUILD MODEL)



OPAL-RT SIMULATION (BUILD MODEL)

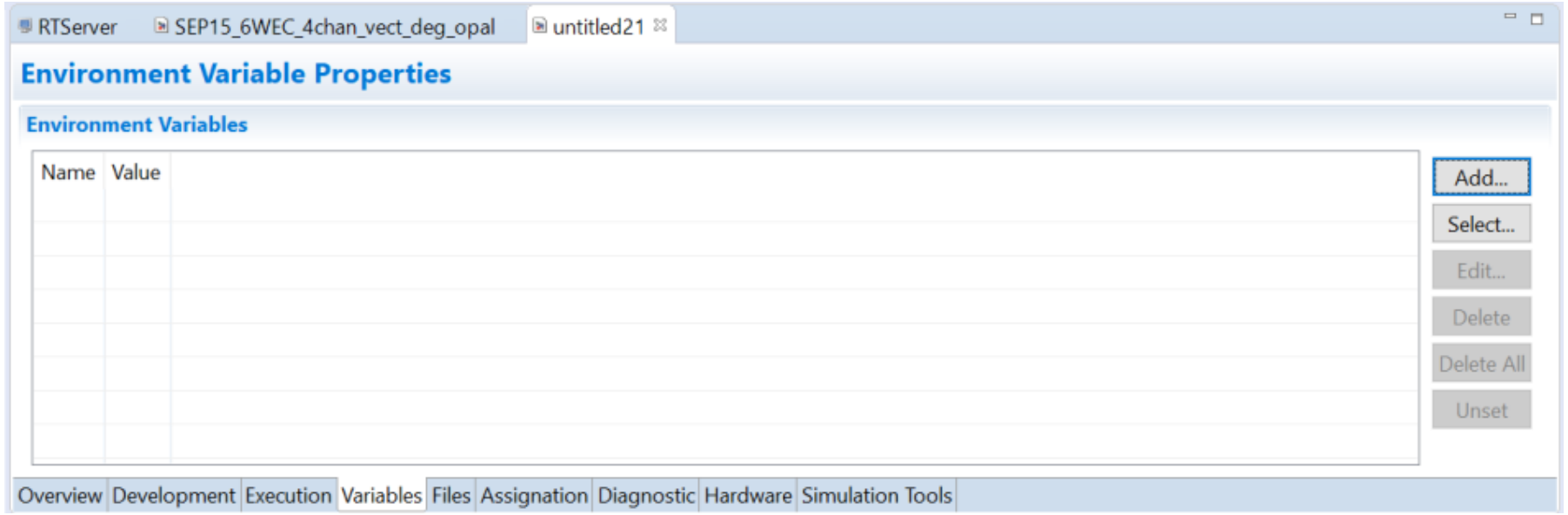


OPAL-RT SIMULATION (BUILD MODEL)



RT22 ENERGIZING TOMORROW

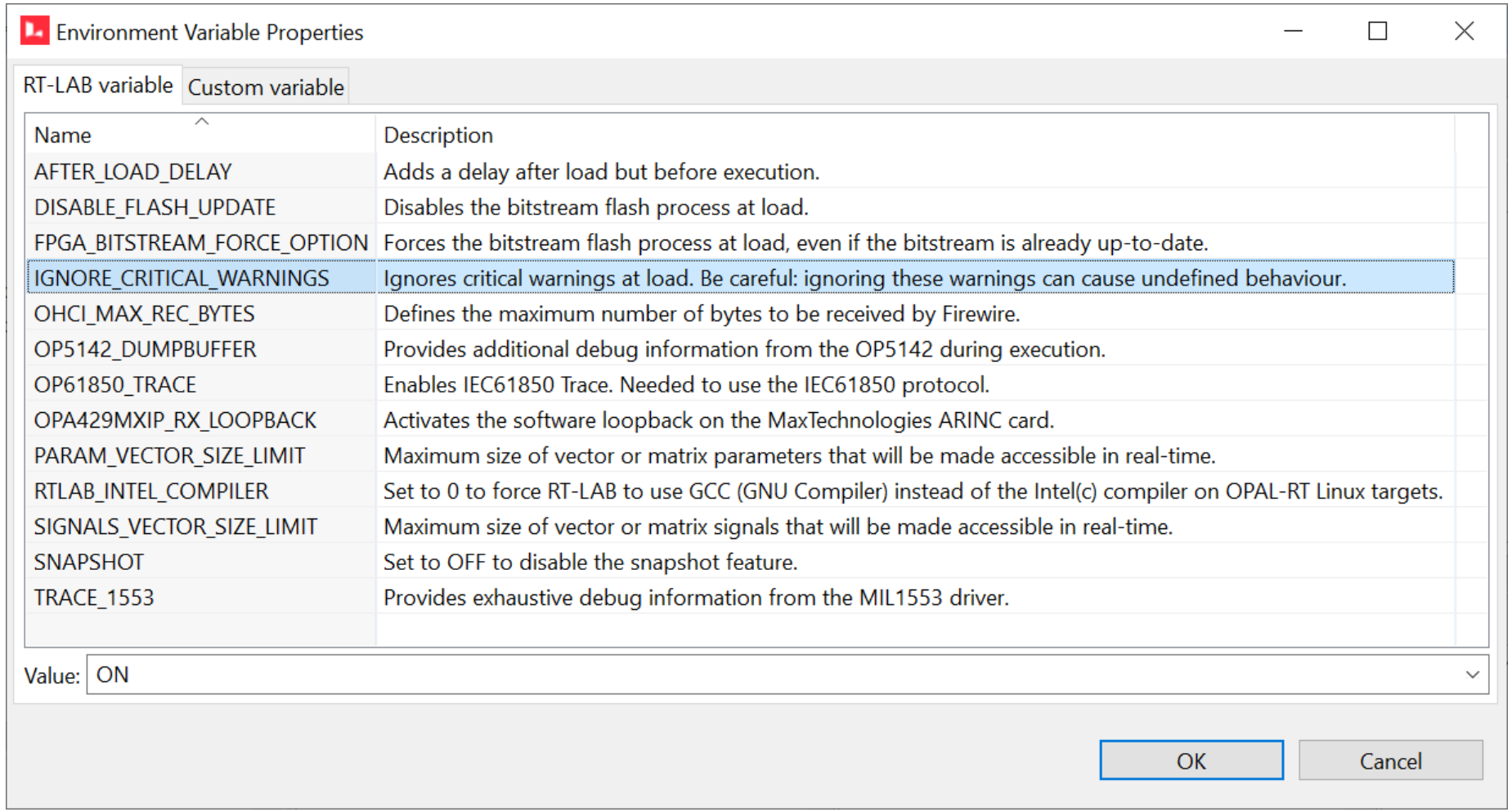
OPAL-RT SIMULATION (LOAD MODEL)



First select ‘IGNORE CRITICAL WARNINGS’ from ‘Variables’ Tab in RT-LAB

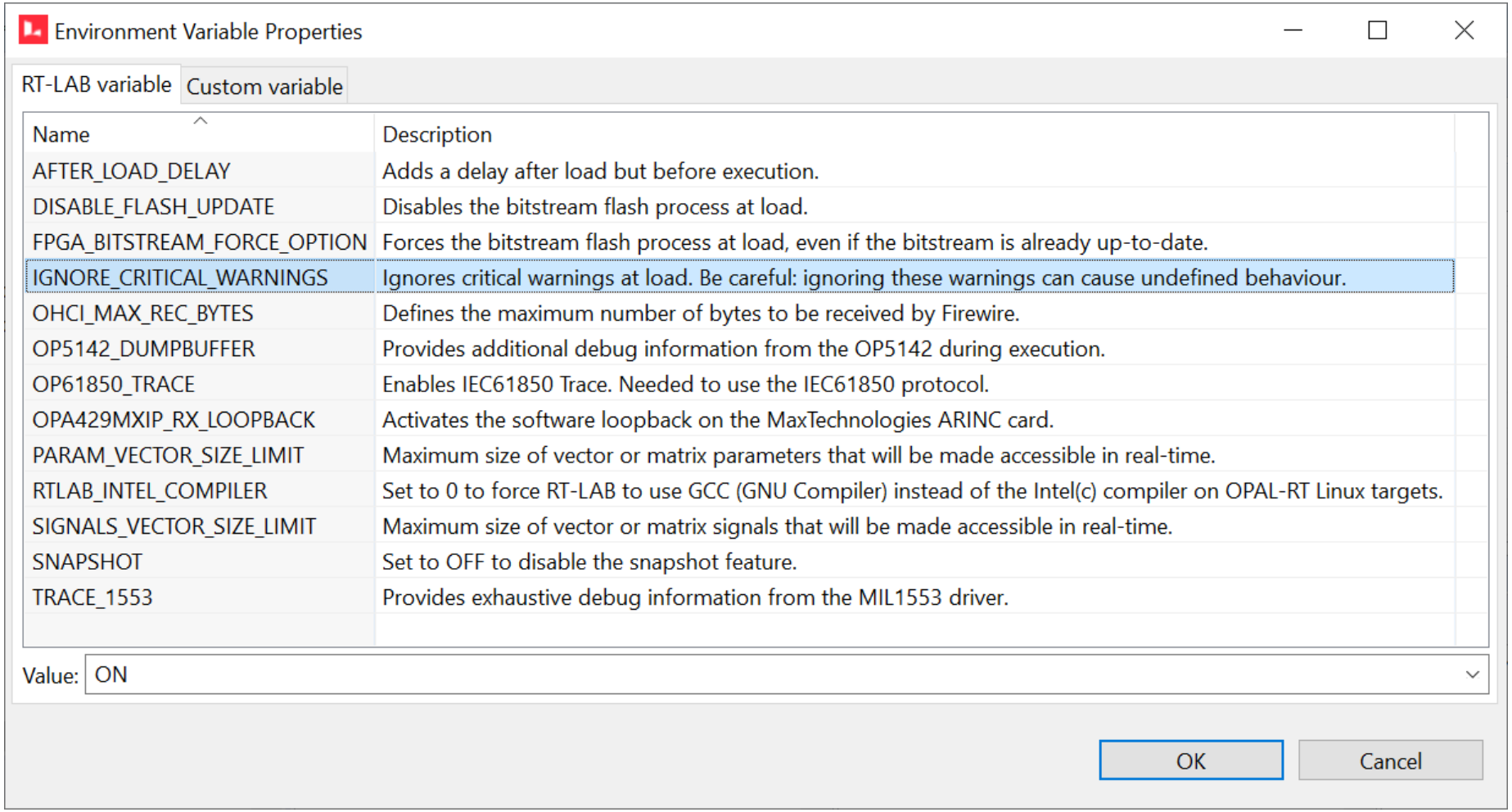
RT22 ENERGIZING TOMORROW

OPAL-RT SIMULATION (LOAD MODEL)



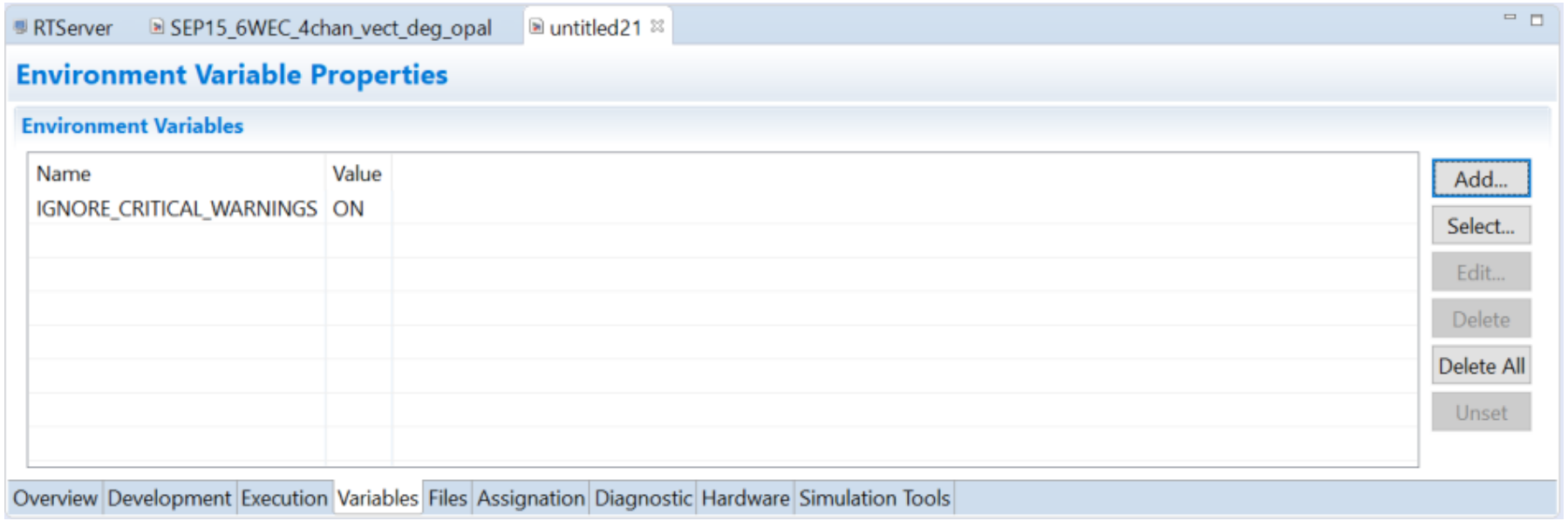
RT22
ENERGIZING TOMORROW

OPAL-RT SIMULATION (LOAD MODEL)



RT22
ENERGIZING TOMORROW

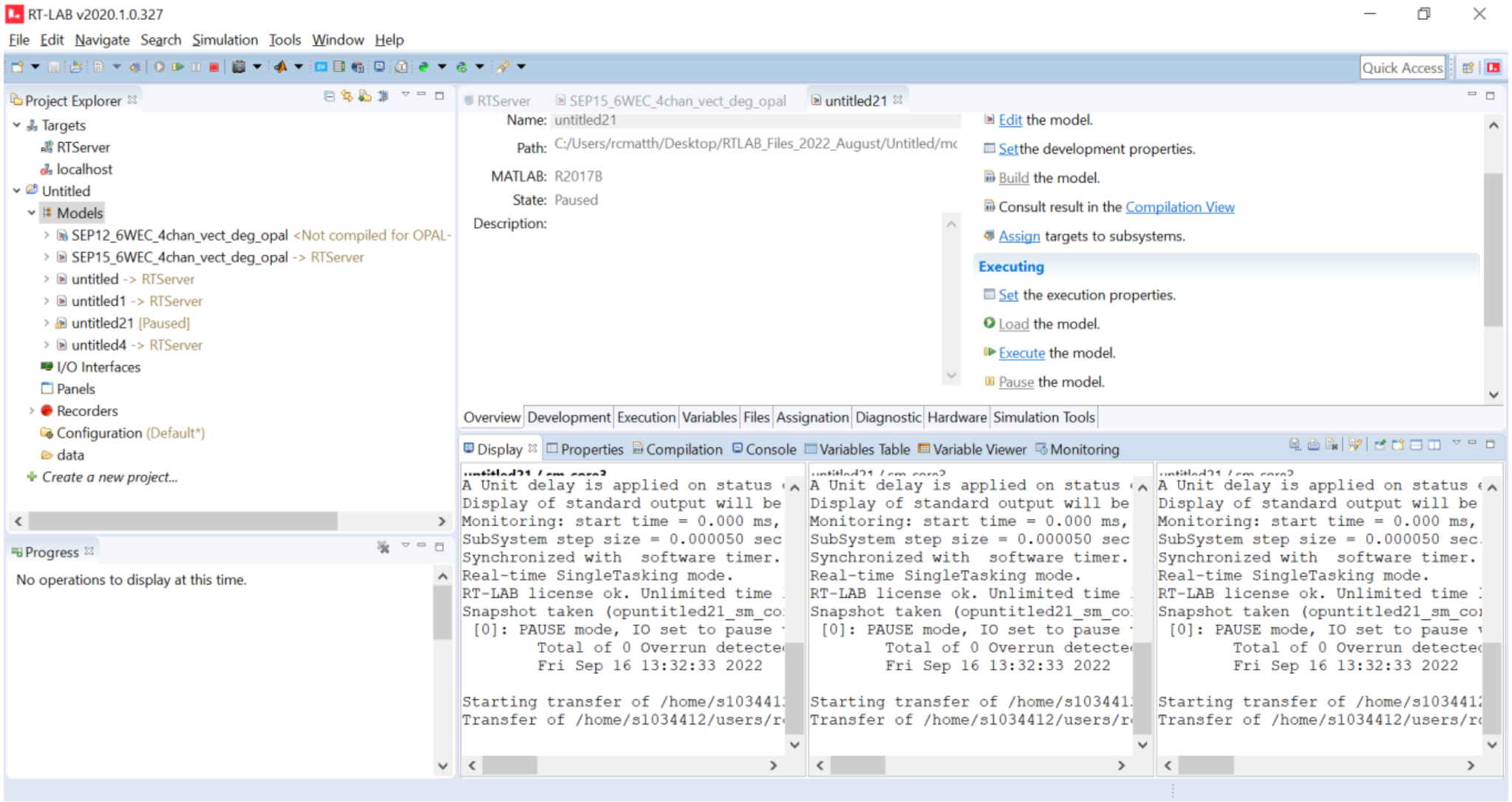
OPAL-RT SIMULATION (LOAD MODEL)



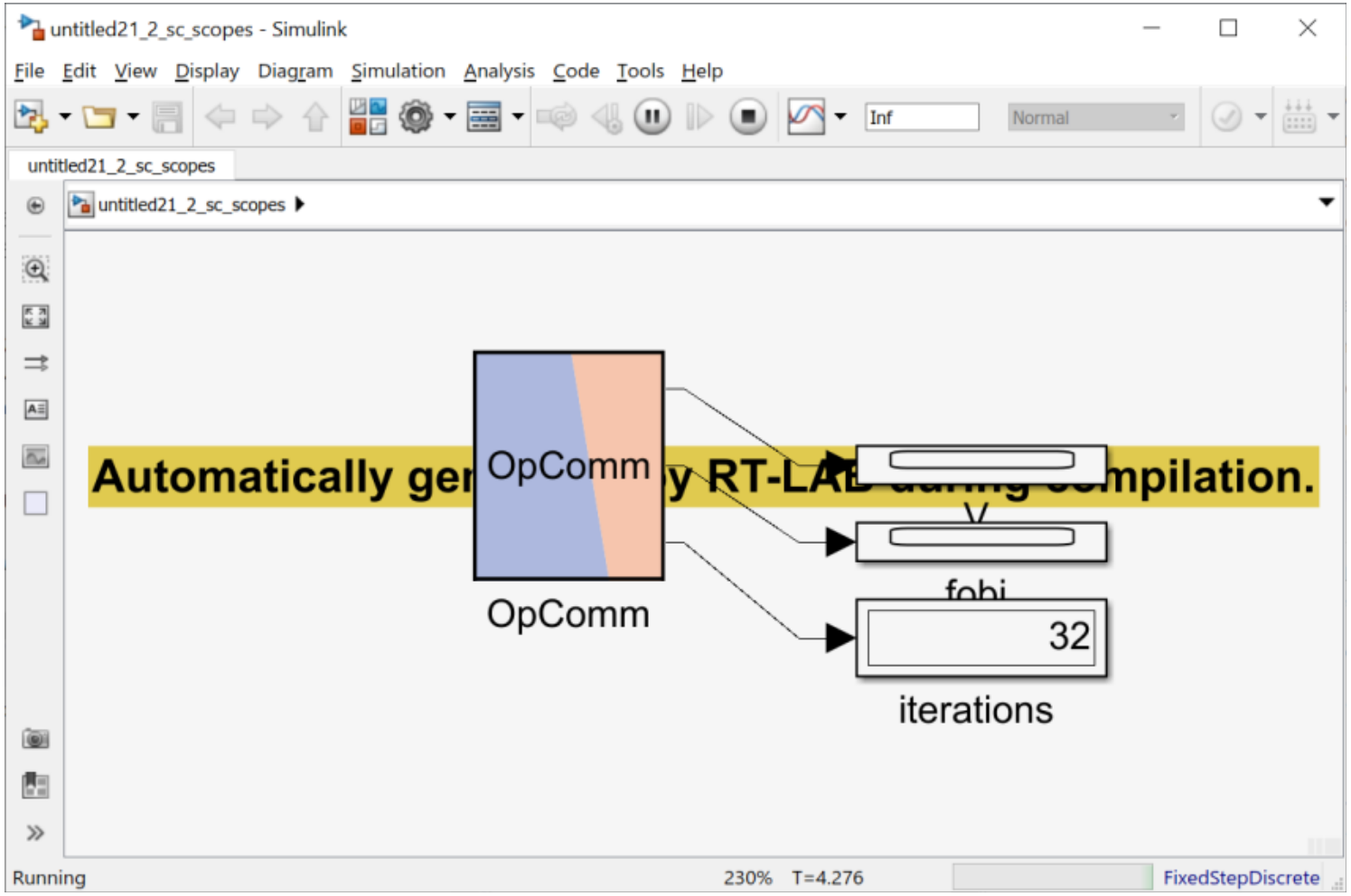
- If done correctly, the ‘Variables’ tab will be populated as shown
- Next, the model can be loaded to OPAL-RT as normal

RT22 ENERGIZING TOMORROW

OPAL-RT SIMULATION (LOAD MODEL)

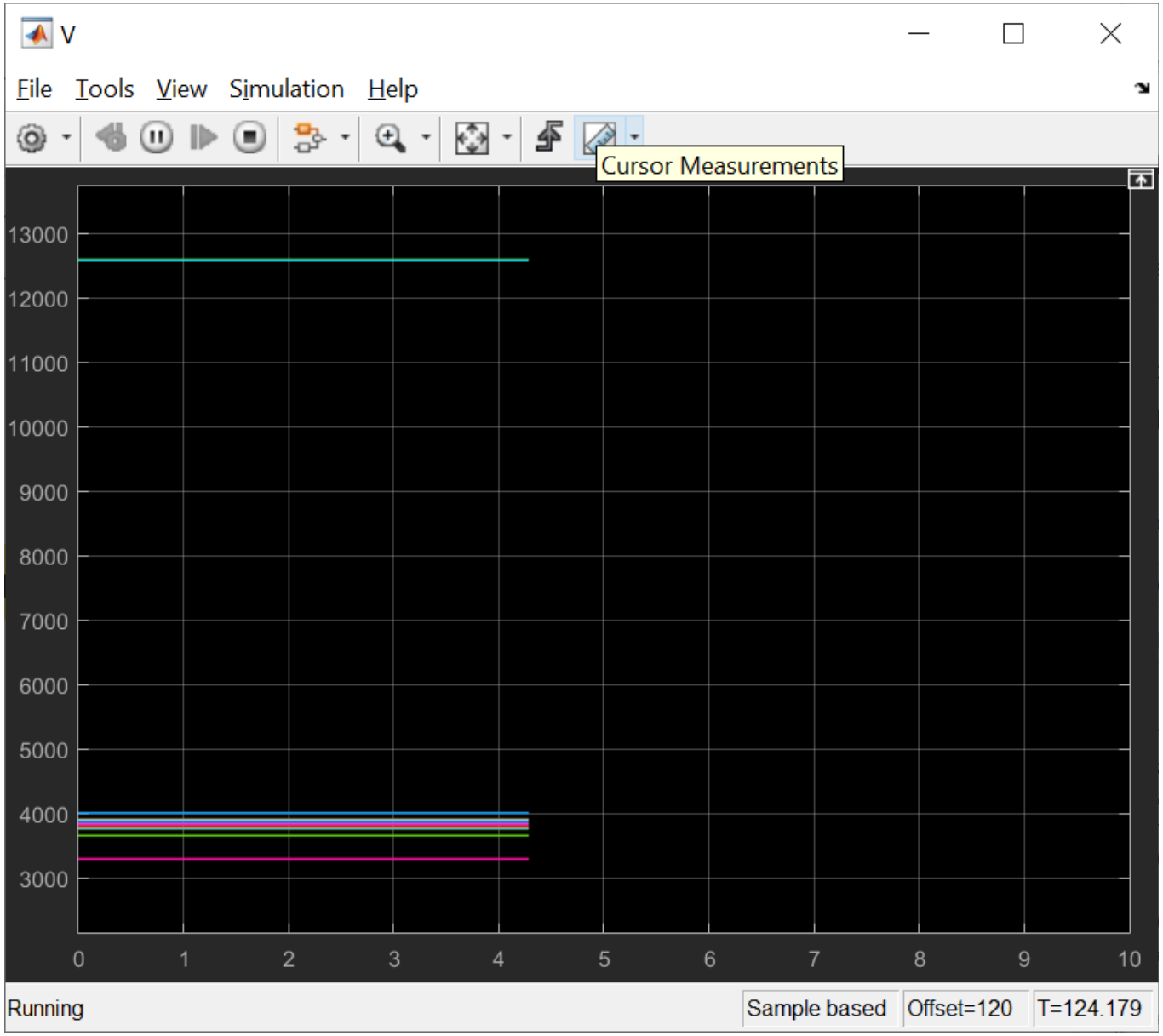


OPAL-RT SIMULATION (EXECUTE MODEL)



- RMS and dc voltages are plotted on scope
- Objective function value for OPF is displayed on scope
- Number of OPF iteration is displayed

OPAL-RT SIMULATION



- Voltages are as earlier defined by OPF

CHANGING NUMBER OF CORES

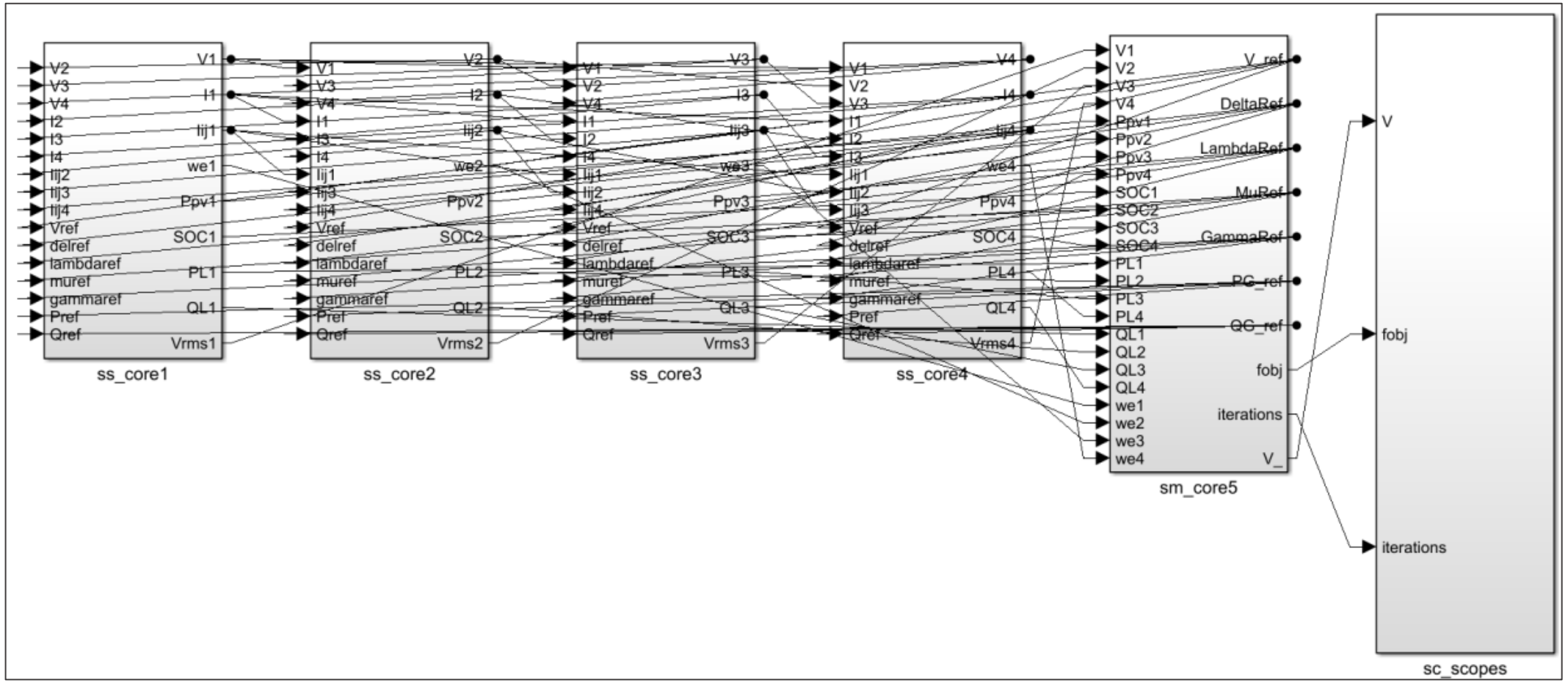
By simply modifying column A of the ‘Bus Parameters Sheet, the model can be instead divided across 5 cores on-the fly.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	core	bus	ac or dc	C(uF)	active (W)	reactive (VAr)	Vbase	Vmin	Vmax	Pmin	Pmax	Qmin	Qmax	objective	type
2	1	1	ac	0	0	0	3983.717	3784.531	4182.903	0	50000000	-50000000	50000000	0.01*P^2+1.0*Q^2	3-phase ac generatc
3	2	2	ac	0	0	0	3983.717	3784.531	4182.903	0	50000000	-50000000	50000000	0.01*P^2+1.0*Q^2	3-phase ac generatc
4	3	3	ac	0	0	0	3983.717	3784.531	4182.903	0	10000000	-10000000	10000000	0.01*P^2+1.0*Q^2	3-phase ac generatc
5	4	4	ac	0	0	0	3983.717	3784.531	4182.903	0	10000000	-10000000	10000000	0.01*P^2+1.0*Q^2	3-phase ac generatc
6	1	5	ac	0	0	0	3983.717	3784.531	4182.903	0	10000000	-10000000	10000000	0.01*P^2+1.0*Q^2	3-phase ac generatc
7	2	6	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
8	3	7	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
9	4	8	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
10	1	9	ac	2000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
11	2	10	ac	1000	18000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
12	3	11	ac	1000	18000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
13	4	12	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
14	1	13	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
15	2	14	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
16	3	15	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
17	4	16	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
18	1	17	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
19	2	18	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
20	3	19	ac	1000	1000000	0	3983.717	3784.531	4182.903	0	0	0	0		capacitor
21	4	20	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
22	1	21	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
23	2	22	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
24	3	23	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
25	4	24	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
26	1	25	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
27	2	26	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
28	3	27	dc	16000	1000000	0	12000	11400	12600	0	0	0	0		capacitor
29	4	28	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
30	1	29	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
31	2	30	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
32	3	31	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
33	4	32	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
34	1	33	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
35	2	34	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
36	3	35	dc	0	0	0	3297	3297	3297	-10000000	10000000	0	0	1*P^2	battery
37															

Model Parameters | Bus Data | Line Connections ...

OPAL-RT MODEL AUTOMATICALLY GENERATED

Exact same model split across 5 cores



LIMITATIONS

There is a limit to how many subsystems the model can be divided across

- Memory blocks/delays required for algebraic signal
  - Such additions slightly alter model dynamics
  - Adding more subsystems adds more delays
- There is no interpolation for signals passed among blocks
  - Smoothness of derivatives may suffer

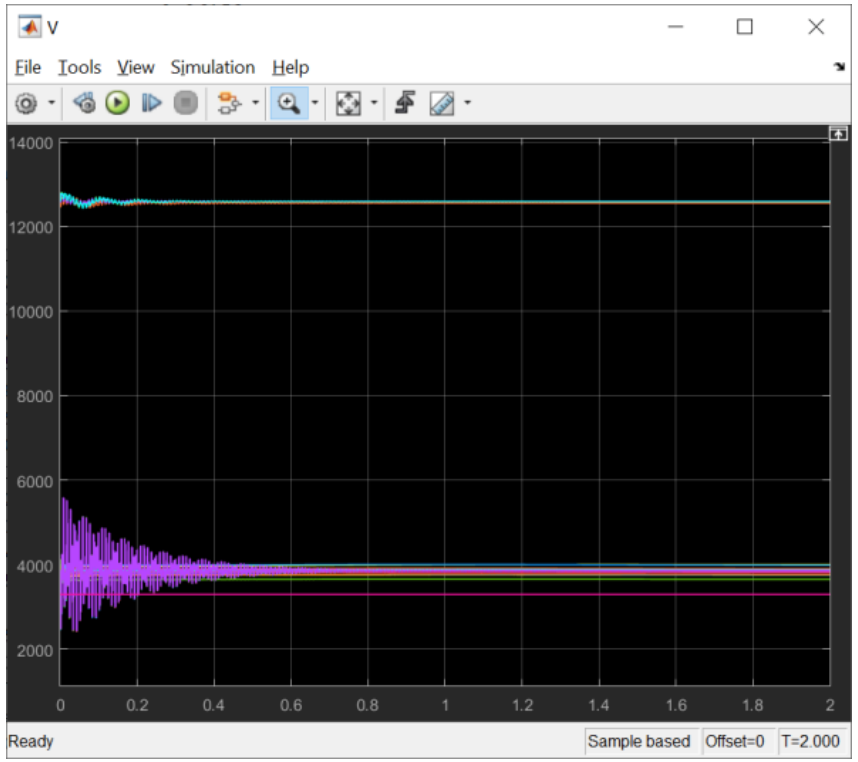
MODEL PARTITIONING

Up until now “core” and “subsystem” have been assumed to be interchangeably.

Now we make a distinction between the 2 with some more precise language.

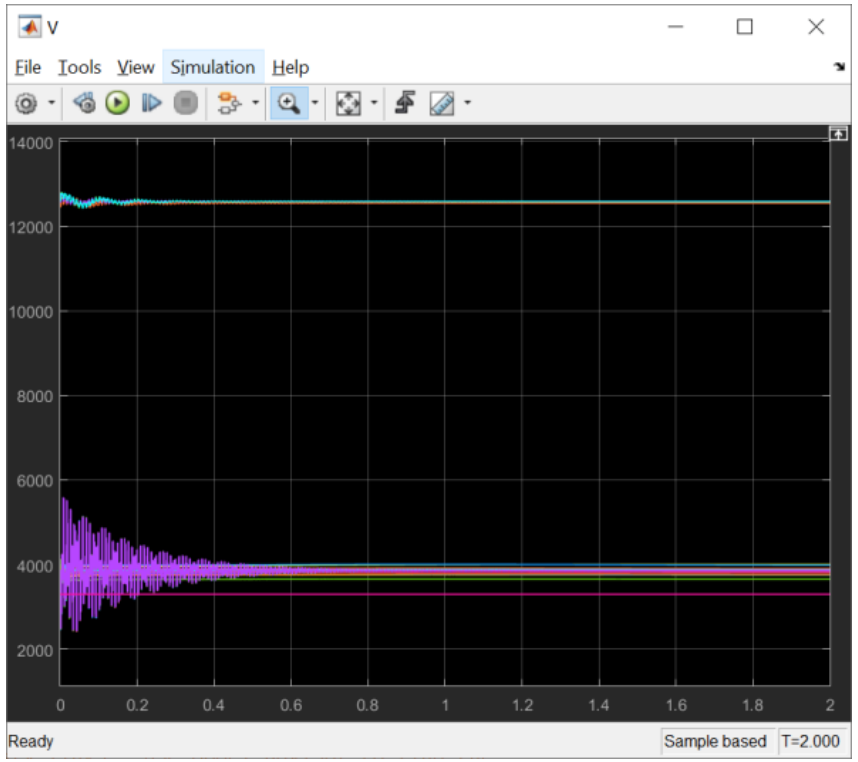
- **Logical core** = logical core on physical processor
- **Simulation core** = subsystem over which model is parallelized by OPAL-RT
- An increased number of subsystems can adversely effect model stability as will bee seen shortly
- Experimentally: Exceeding 5 subsystems seems to cause instability
- If model has overruns when spit across 5 cores, multiple logical cores may be assigned to a single simulation core

SAME MODEL ACROSS 3, 5, AND 8 SUBSYSTEMS



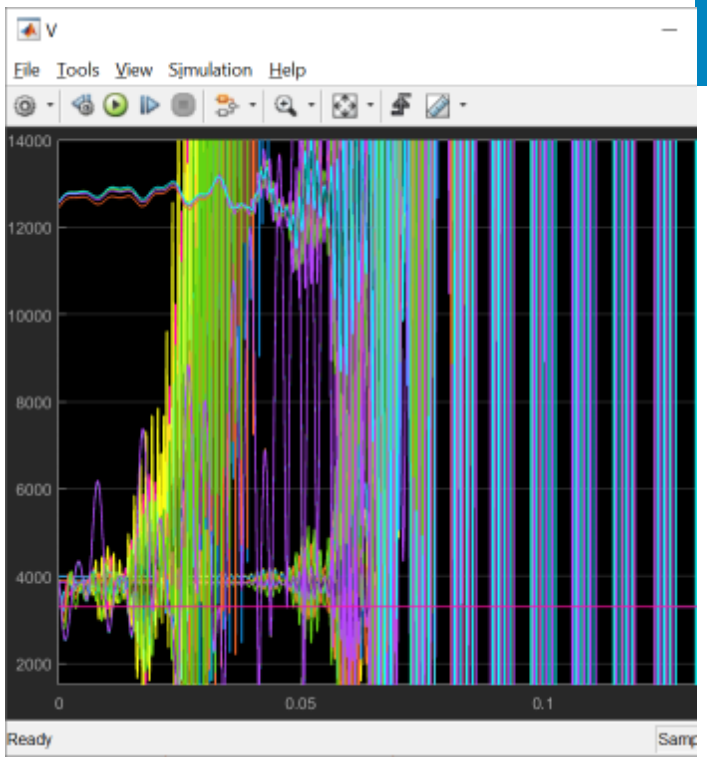
3 ”cores”

stable



5 ”cores”

stable



6 ”cores”

unstable

RT22 ENERGIZING TOMORROW

CONCLUSIONS

SwAGSM:

- Allows for rapid model development
- Eliminates the debugging process
- Allow for number of cores to be changed without manually reconstructing model
- Streamlines the process of real-time simulation on the OPAL-RT platform

Availability:

- Not yet available for public release

For further details, contact:

- Ronald Matthews
- rcamtth@sandia.gov
- Sandia National Laboratories

ACKNOWLEDEGMENT

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