Two-Zone MVDC Electric Ship

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Acknowledgement

- The models described in this presentation are based on information provided by the Electric Ship Research and Development Consortium (ESRDC) at the following link,

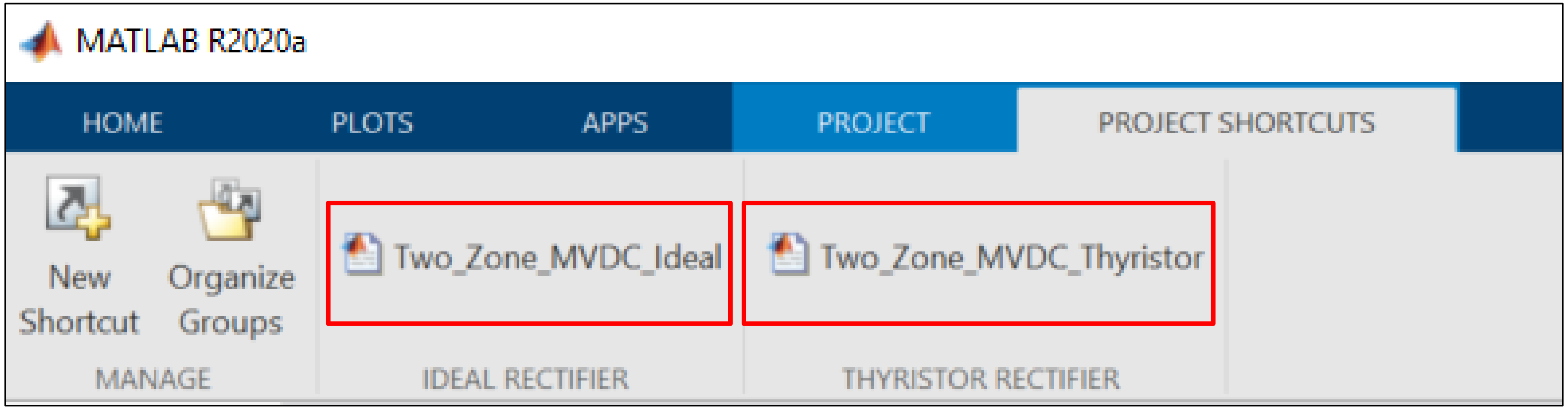
  https://www.esrdc.com/library/documentation-for-a-notional-two-zone-medium-voltage-dc-shipboard-power-system-model-implemented-on-the-rtds/

- While system architecture and physical parameters have been honored as closely as possible, differences in the implementation of certain components and control algorithms is expected.

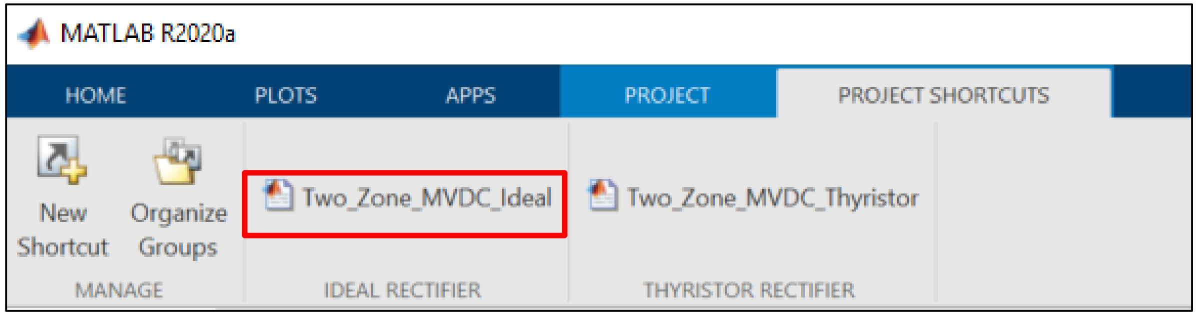
- Simulation results in this report should be regarded as being representative, rather than providing an exact engineering match.

Setting up the Simulation Environment

- After downloading and extracting the files, please run Two_Zone_MVDC.prj.
- This will open a Simulink project which will load parameter values and configure the examples, and make the models available through one-click project shortcuts as shown below.
- We'll start with the model that uses ideal rectifiers.



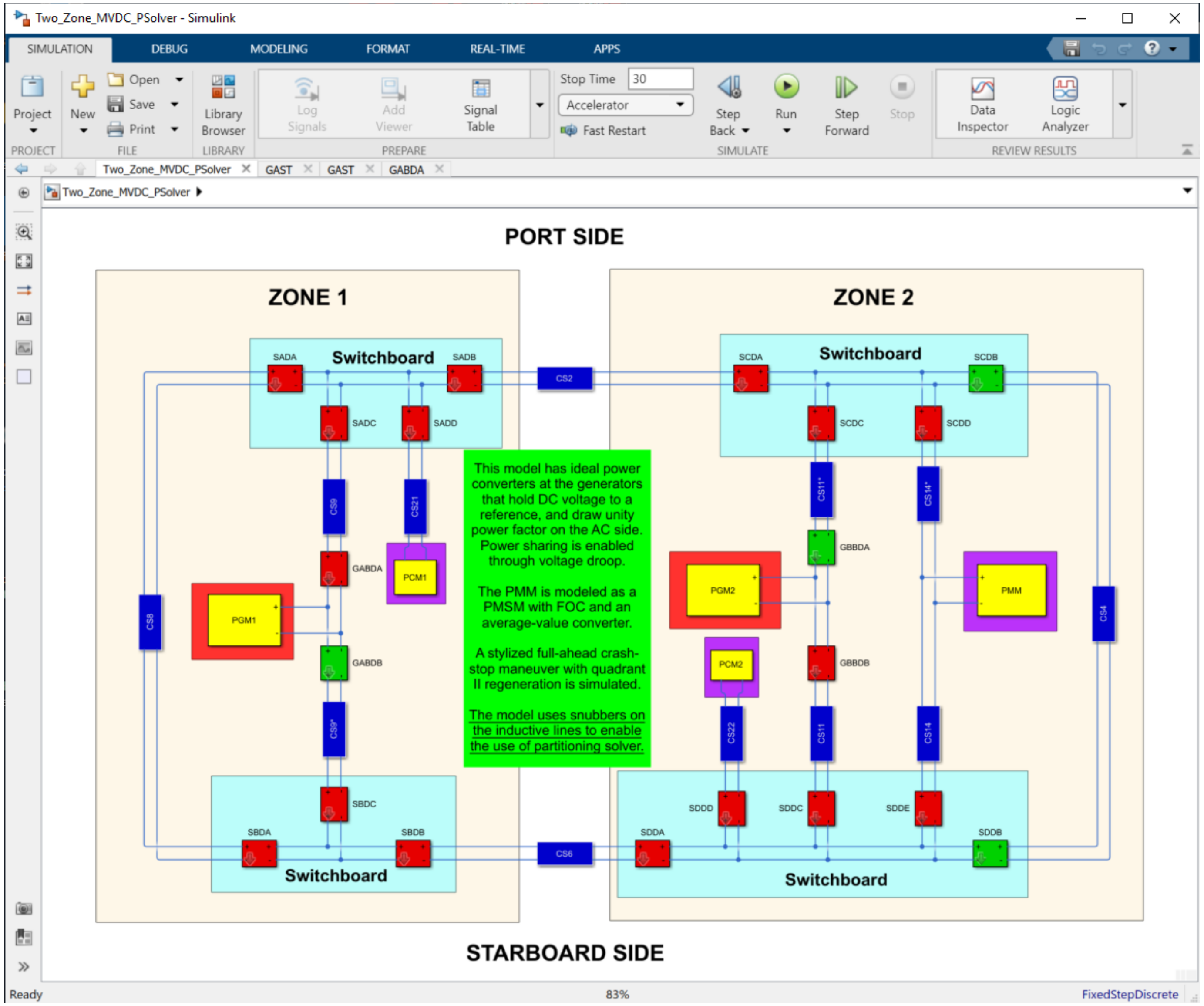
Two-Zone MVDC with Ideal Rectifiers

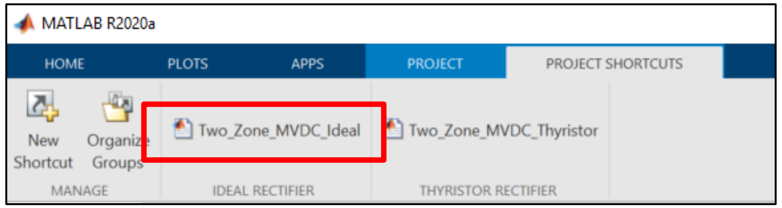


- In this example, an ideal power converter is implemented that will hold DC voltage perfectly at a reference value, and provide unity power factor at the AC input.

- While the ideal power converter honors the exchange of power across the AC/DC boundary, it should not be used for fault studies (in its current form) as it holds DC voltage perfectly to a reference value. It is, however, a good choice for running operational studies with a fast simulation time, and enabling real-time simulation.

Two-Zone MVDC with Ideal Rectifiers



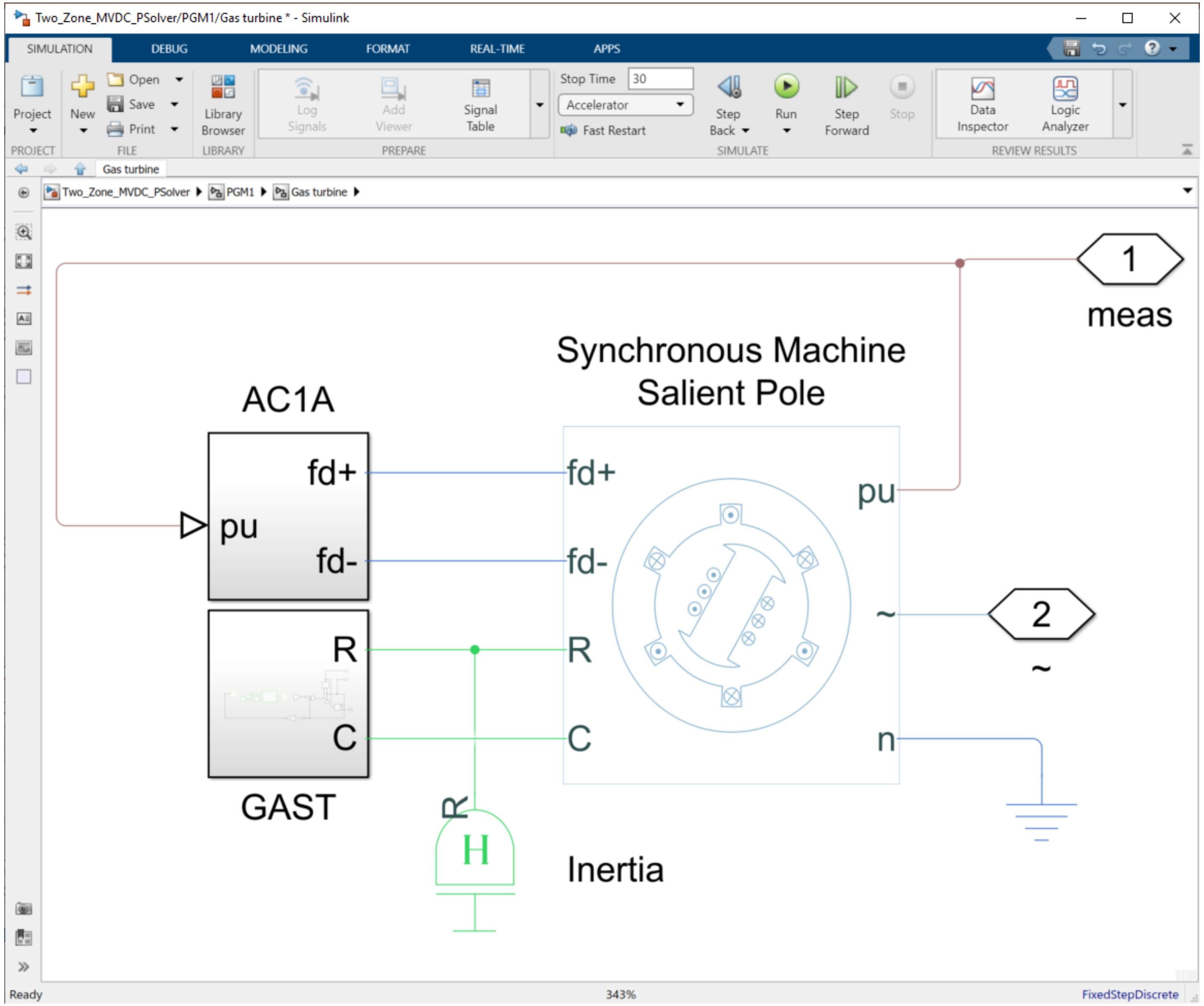


Click on the Two_Zone_MVDC_Ideal project shortcut, to load the model shown on the left.

Note that breakers are color coded depending on their initial state.

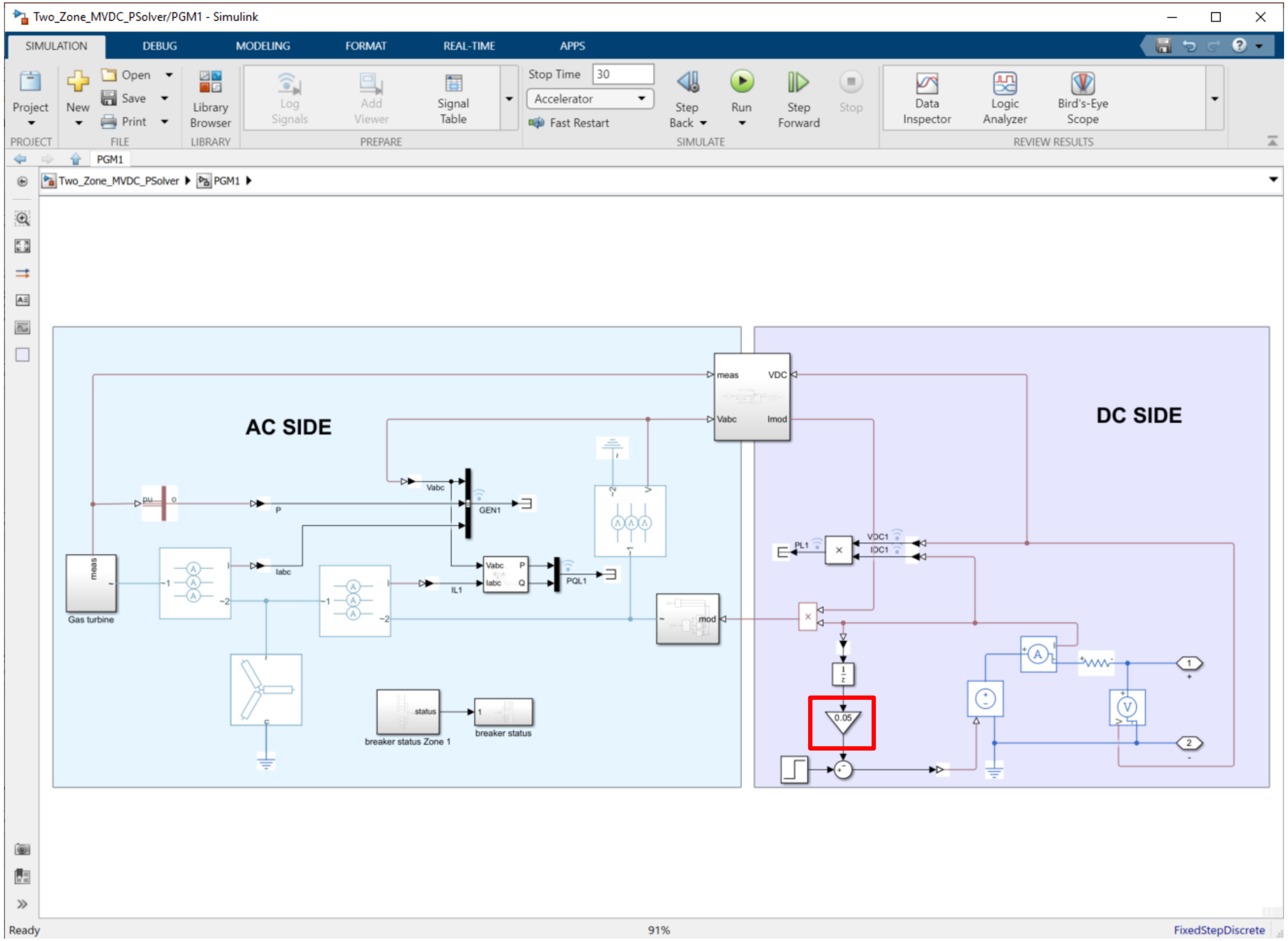
Red = closed, Green = open.

Two-Zone MVDC with Ideal Rectifiers



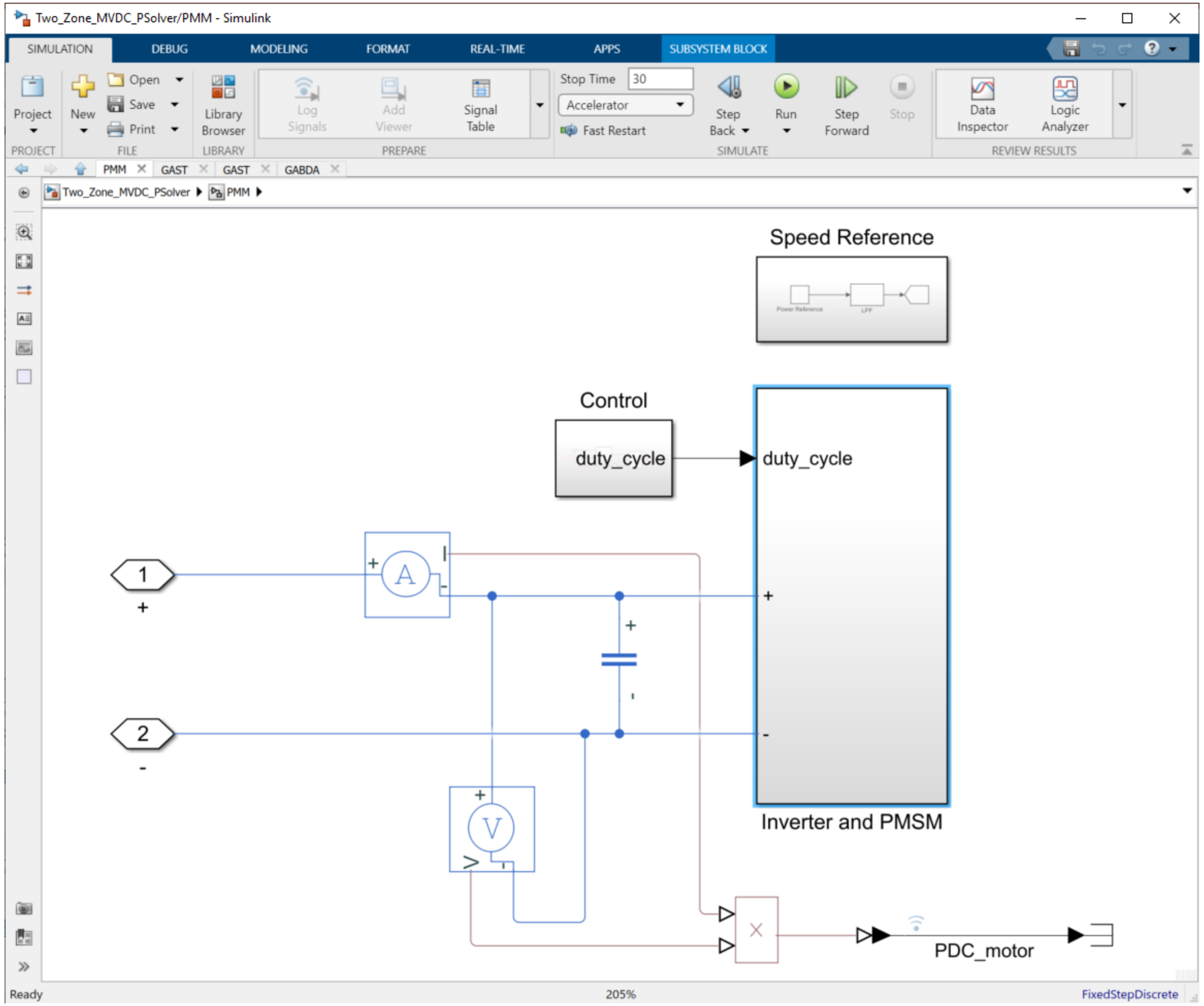
The generators are salient-pole synchronous machines, with AC1A voltage control and GAST gas turbines.

Two-Zone MVDC with Ideal Rectifiers



Power sharing of the generators is enabled through voltage droop. Change the droop value (highlighted in red) on both generators to modify the power sharing. If the droop values are equal, then power sharing will be equal. The default setting in this model is for PGM2 to provide twice as much DC power as PGM1.

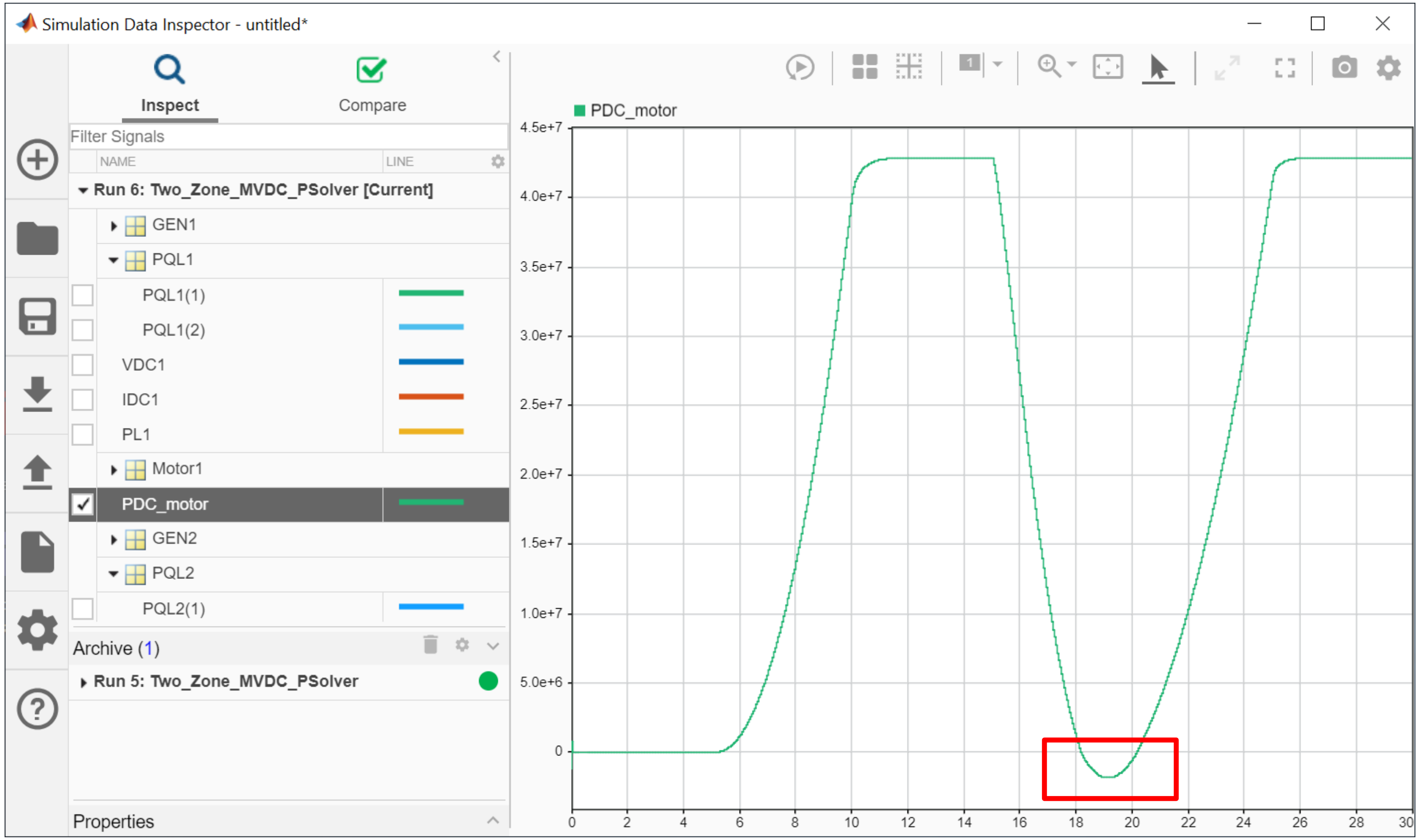
Two-Zone MVDC with Ideal Rectifiers



The Propulsion Motor Module (PMM) is implemented as a PMSM with field-oriented control (FOC), connected to the DC system through an average-value converter.

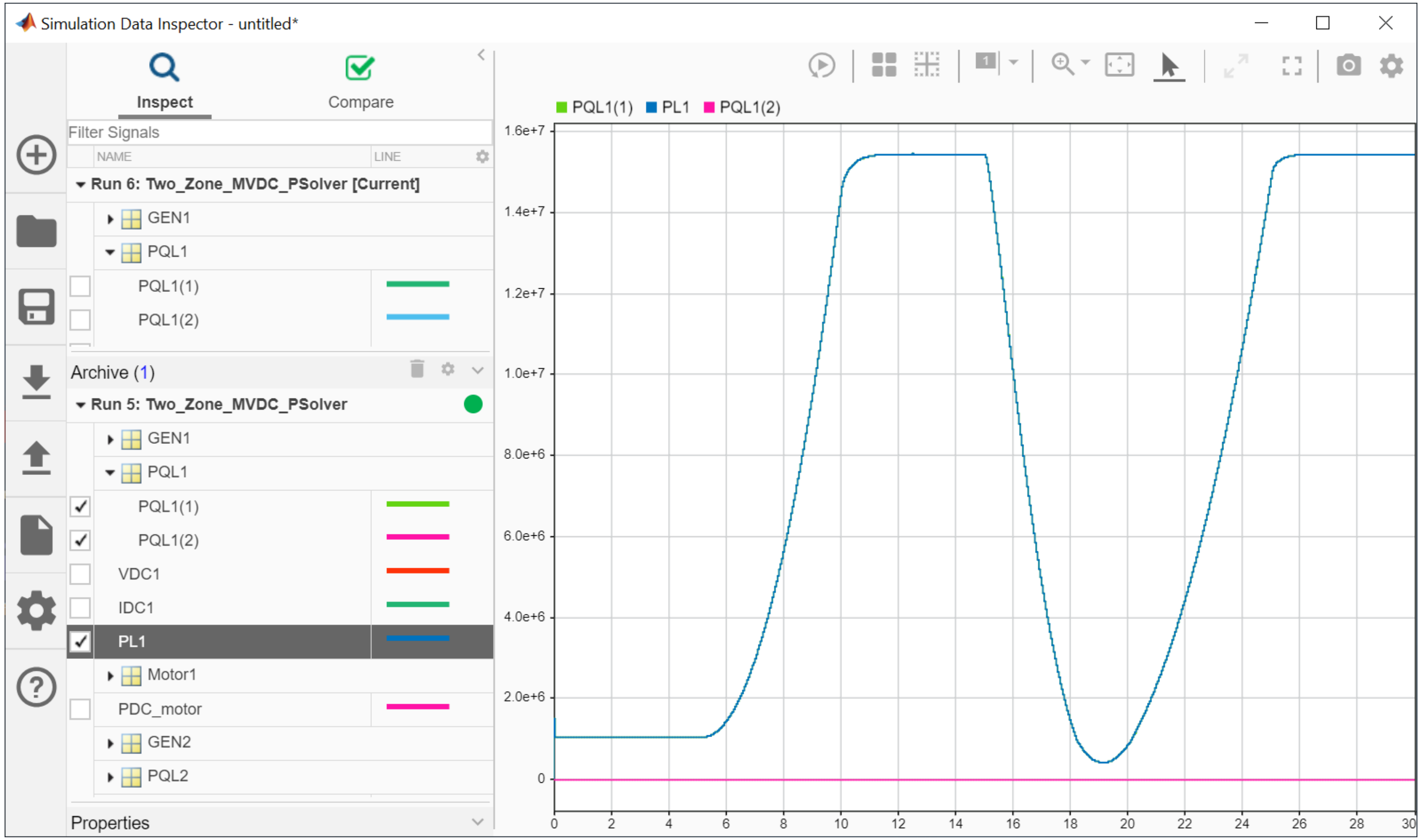
The PMM is configured to simulate a stylized full-ahead crash-stop with Quadrant 2 regeneration.

Two-Zone MVDC with Ideal Rectifiers



Run the simulation and observe PDC_motor in the Simulation Data Inspector. Note the regenerated power as shaft speed transitions from positive to negative.

Two-Zone MVDC with Ideal Rectifiers



To confirm that power transfer over the AC/DC boundary is honored, and that the AC side operates at unity power factor, select the following signals,

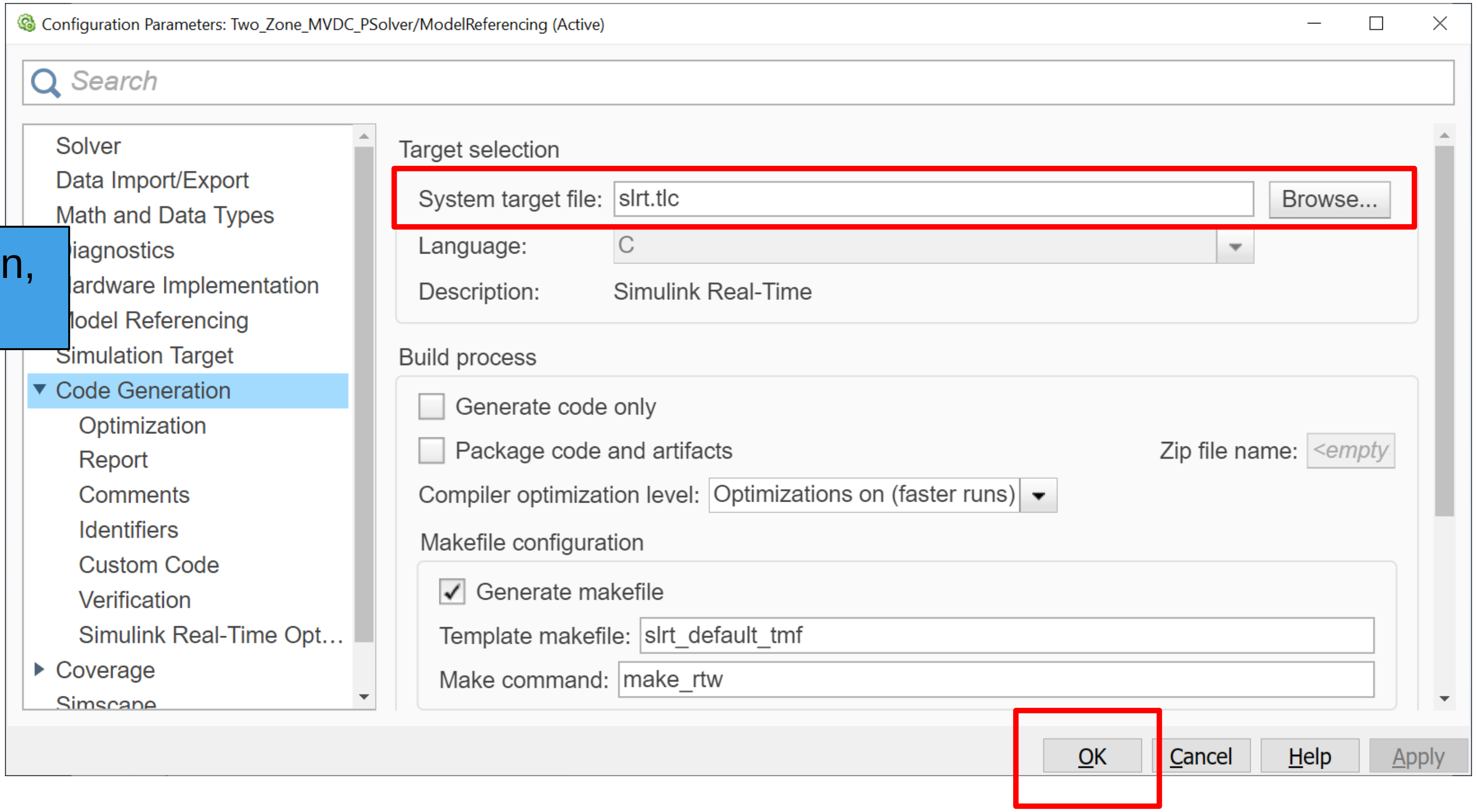
PQL1(1) – PGM1 active power.
PQL1(2) – PGM1 reactive power.
PL1 – PGM1 DC power.

Observe other signals as desired.

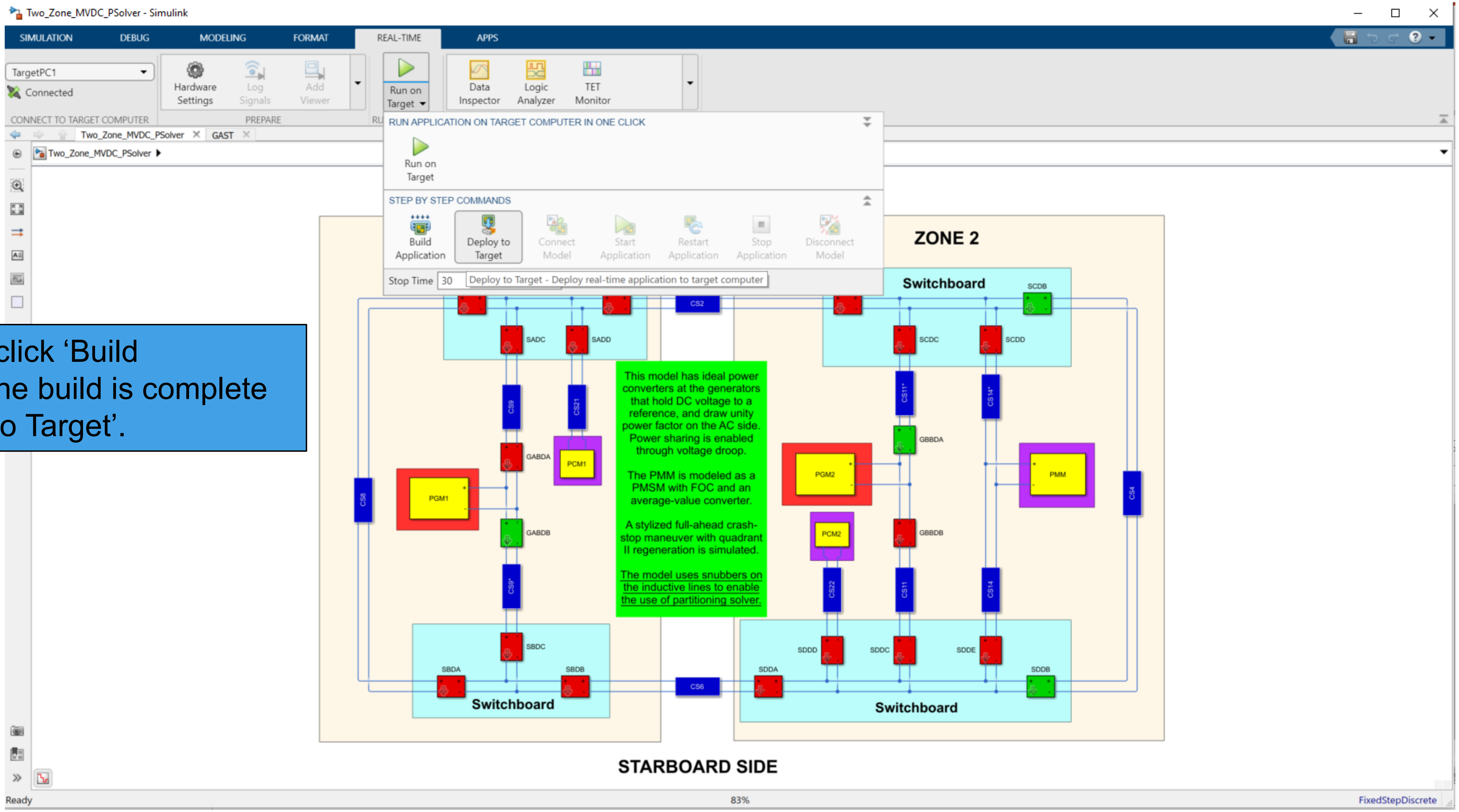
Real-Time Simulation

- To prepare the model with ideal converter for real-time simulation, ensure that you have Simulink Real-Time, and a Speedgoat system, and follow these steps.

In Configuration Parameters -> Code Generation, select slrt.tlc as the system target file. Click OK.



Real-Time Simulation

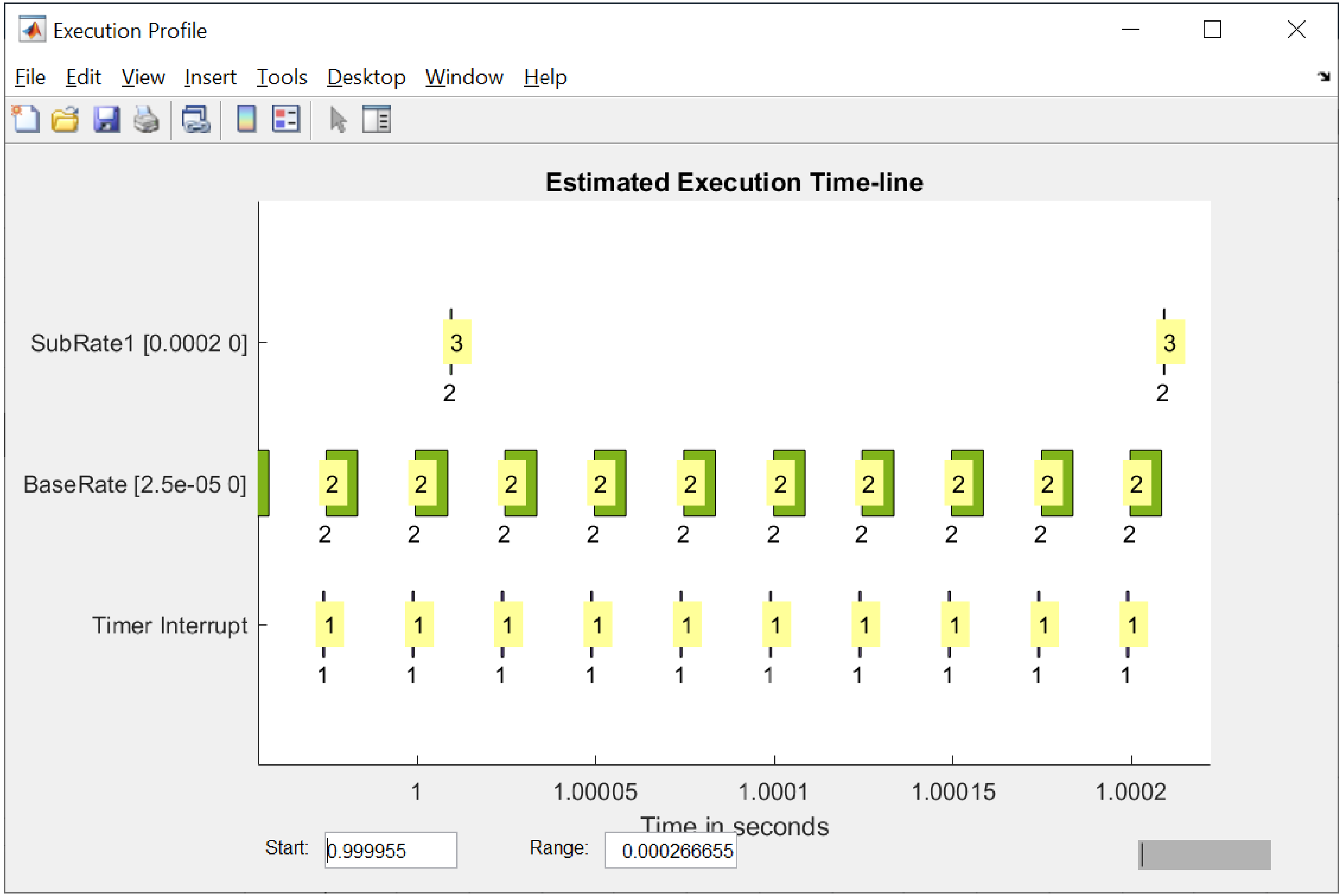


On the Real-Time tab, click ‘Build Application’, wait until the build is complete and then click ‘Deploy to Target’.

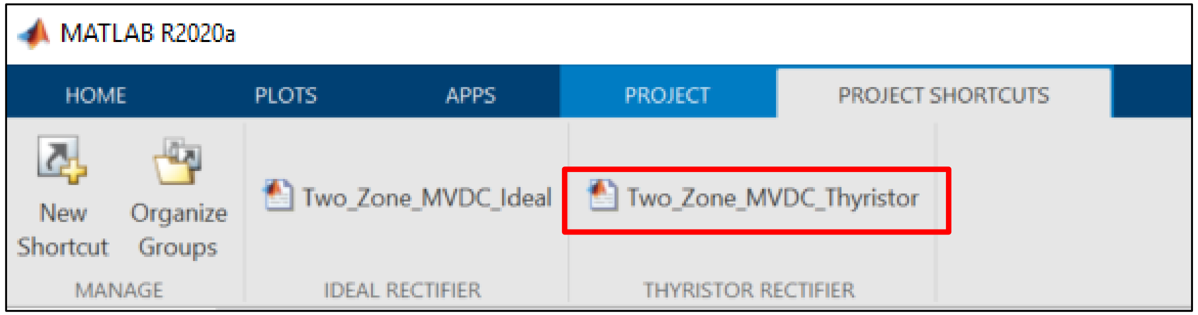
Real-Time Simulation

Task-Execution-Time (TET) for the model with ideal converter is approximately 10 microseconds, and the simulation with Ts = 25 microseconds runs comfortably.

Note that the model with Thyristor Rectifier runs with Ts = 1 microsecond and is a desktop-only simulation.



Two-Zone MVDC with Thyristor Rectifiers

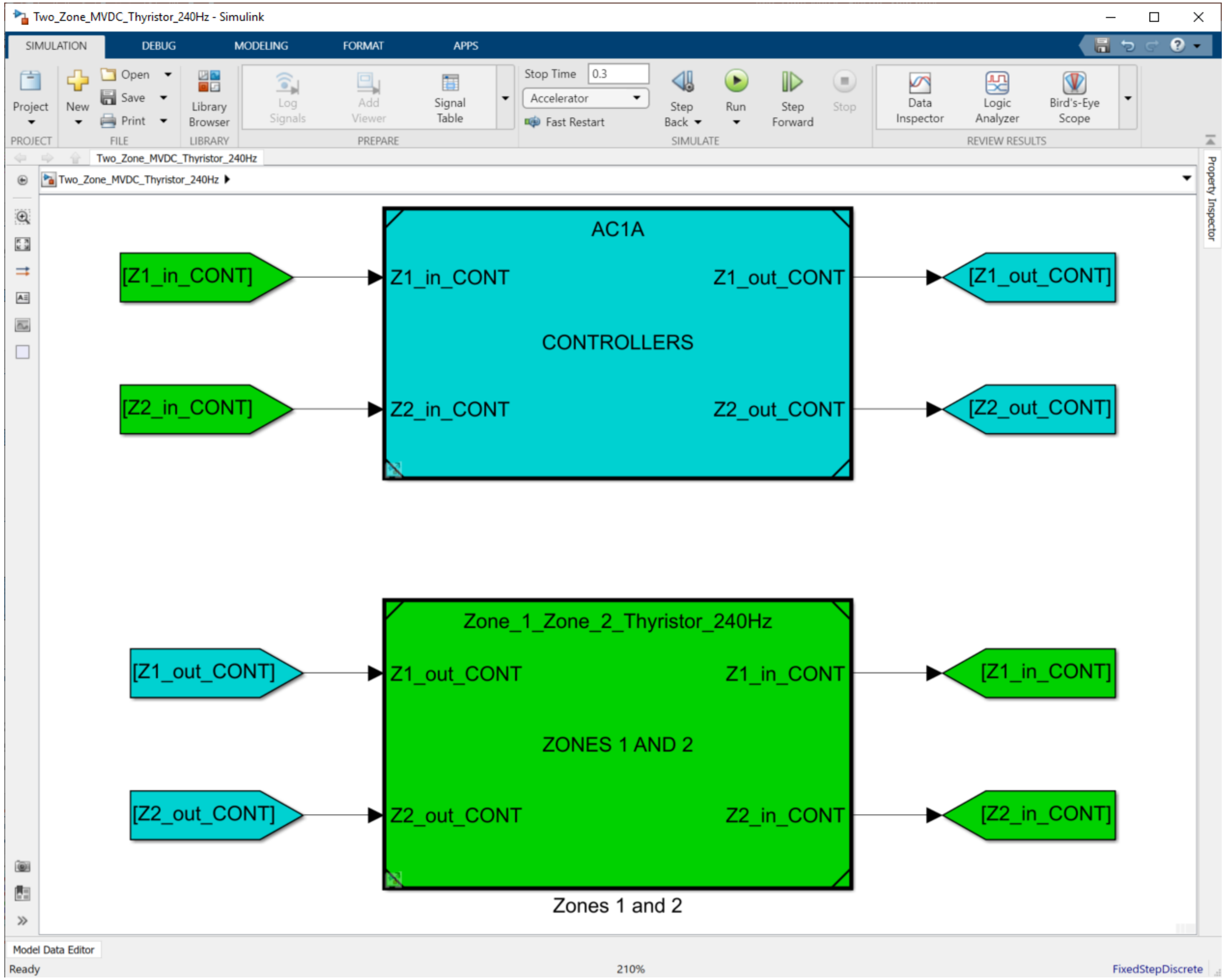


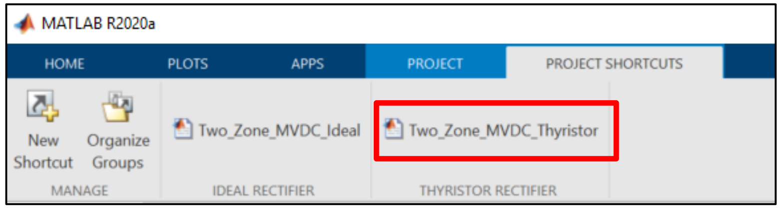
- In this example, a six-pulse thyristor rectifier is implemented with active DC voltage control.

- This model is set up to run a fault scenario. Sample-time is set to Ts = 1 microsecond.

- This model is for desktop simulation.

Two-Zone MVDC with Thyristor Rectifiers

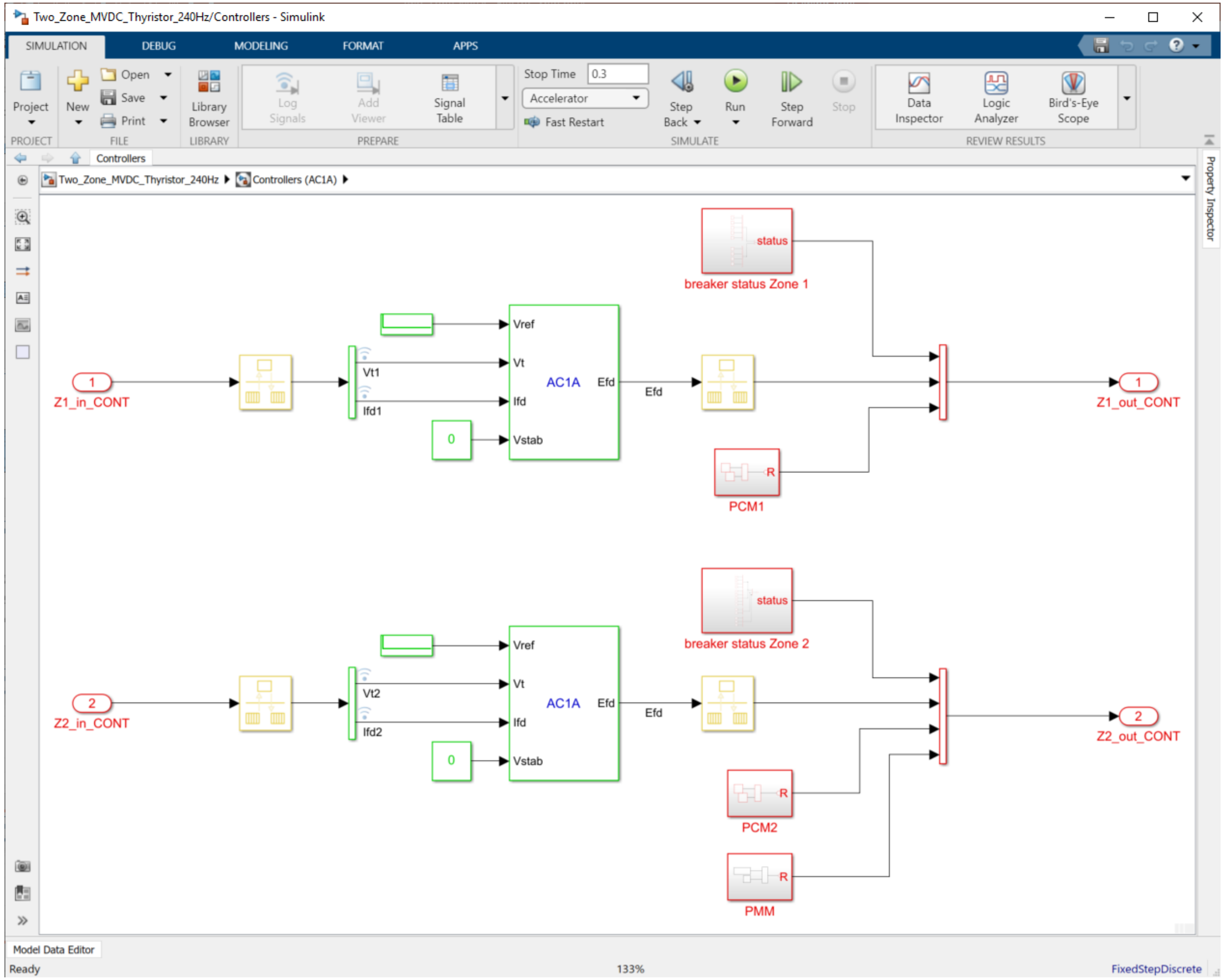




Click on the Two_Zone_MVDC_Thyristor project shortcut, to load the model shown on the left.

Note that the model is constructed as two model-references. This is simply to show how model-reference models may be used in the construction of system levels models.

Two-Zone MVDC with Thyristor Rectifiers

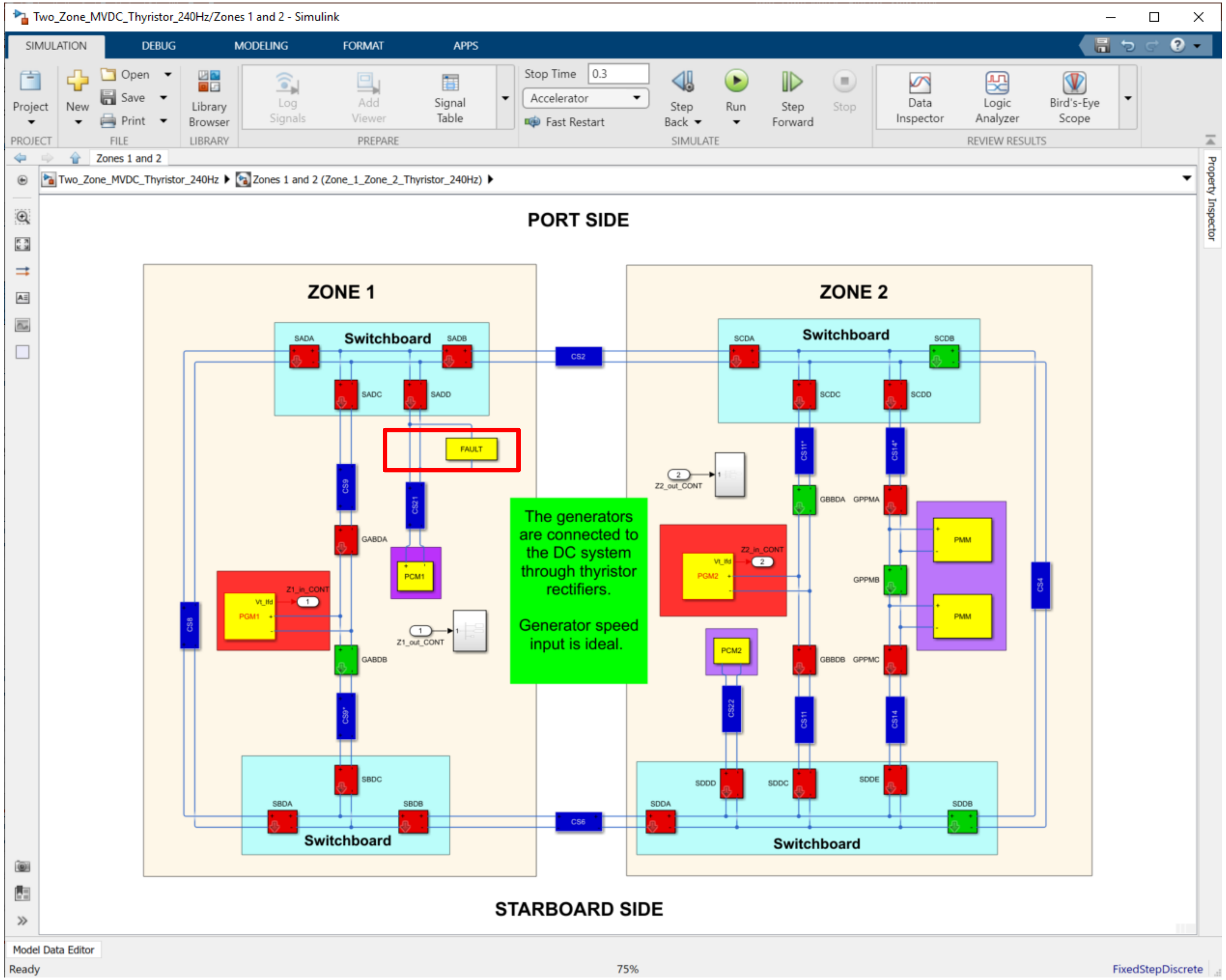


Click on the AC1A model reference.

Note that the control systems run at a slower rate than the electrical system.

Breaker status and PMM input is defined in this model reference.

Two-Zone MVDC with Thyristor Rectifiers

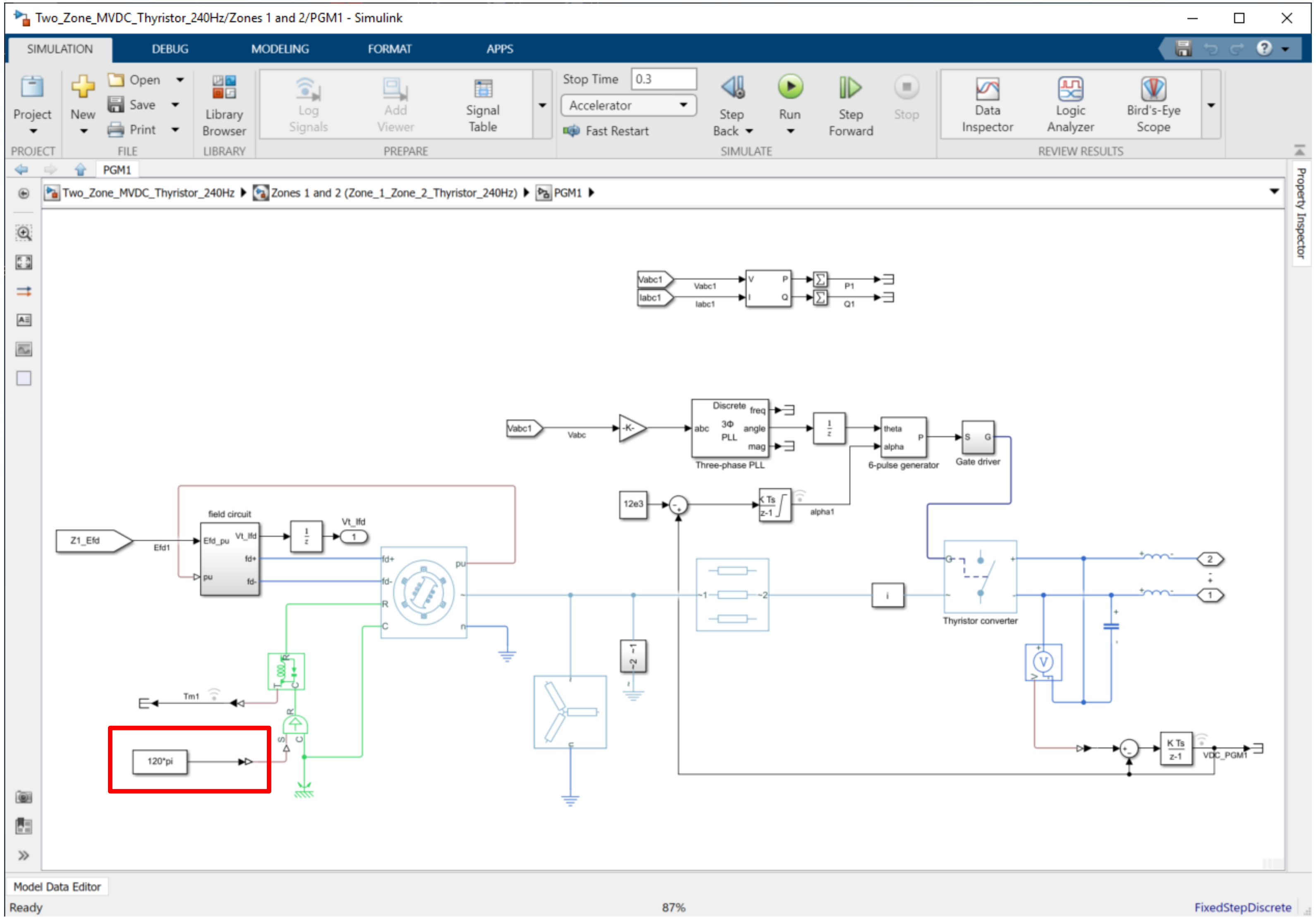


Click on the
Zone_1_Zone_2_Thyristor_240Hz
model reference.

A fault is located just below the SADD breaker. The fault is applied at 0.2s.

The PMMs are modeled as variable resistances.

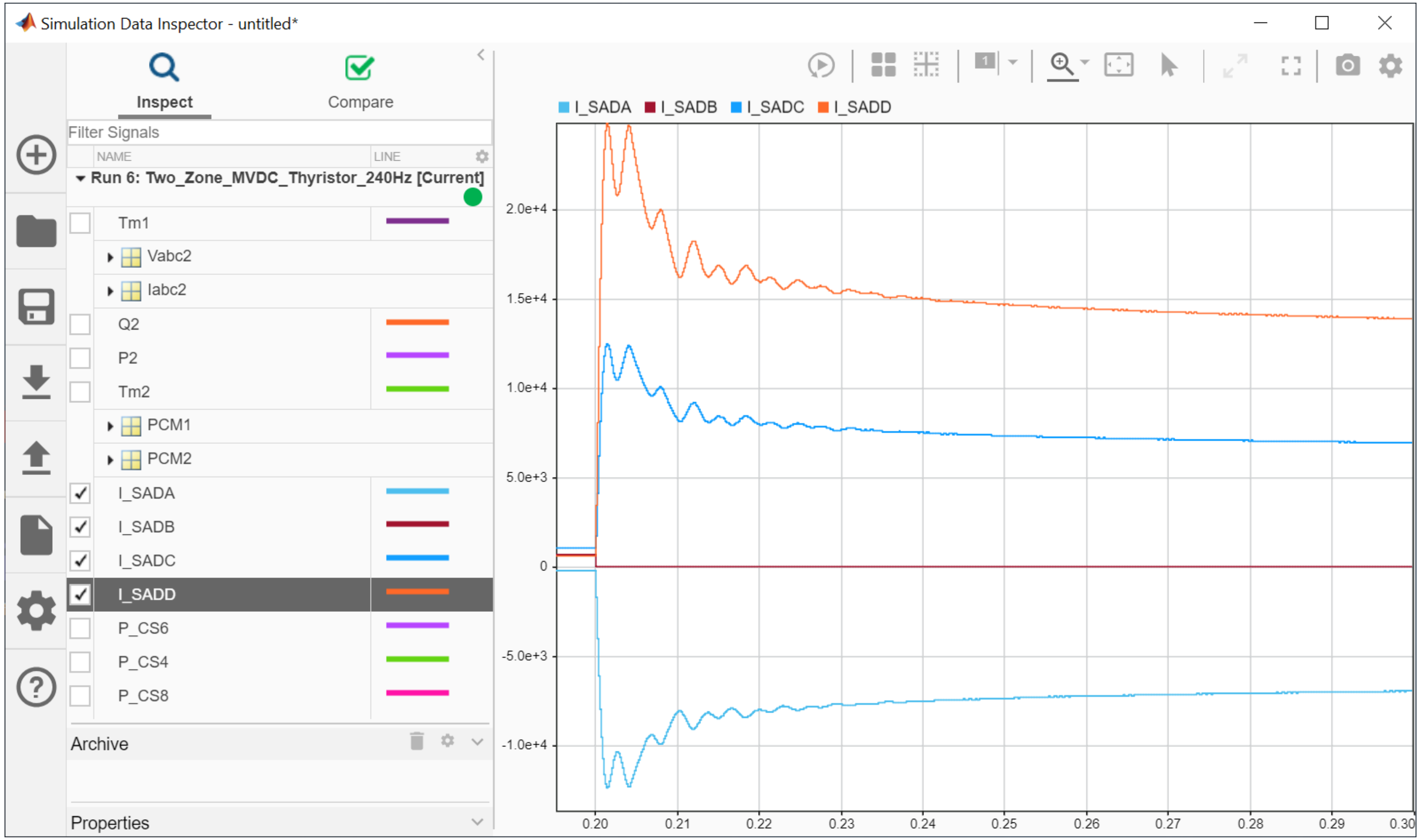
Two-Zone MVDC with Thyristor Rectifiers



This model runs only for 0.3s, and so the speed reference for the generator is an ideal input.

For longer duration simulations, the GAST models could be included.

Two-Zone MVDC with Thyristor Rectifiers



Run the simulation and observe the fault currents through the Zone 1 portside switchboard.

Observe other measurements as desired.