Circuit Breaker Unit Test

Description:
The objectives of this test are:
1) To verify the generic circuit breaker model properly handles the open/close mechanical delays
2) To verify the generic circuit breaker trips at the current zero-crossing
3) To revise the operation of dynamic/parallel/series loads during various switching conditions

Initial conditions:
- Circuit Breaker: using the generic CB model with 5 cycles open/close mechanical delay. The trip signals to the breaker are send by a signal-sequencer block. The initial status of the circuit breaker will vary depending on the case being evaluated.
- Ideal source: 13.8kV, 375MVA, 7.9 X/R ratio
- Cable modeled as PI-section
- Transformer: 2500 kVA, 13.8/0.48 kV, 5.75%, 6.6 X/R ratio
- Controlled dynamic load: using one minute data for load profile
- Constant load: parallel constant 1000 kVA @ 0.9 pf
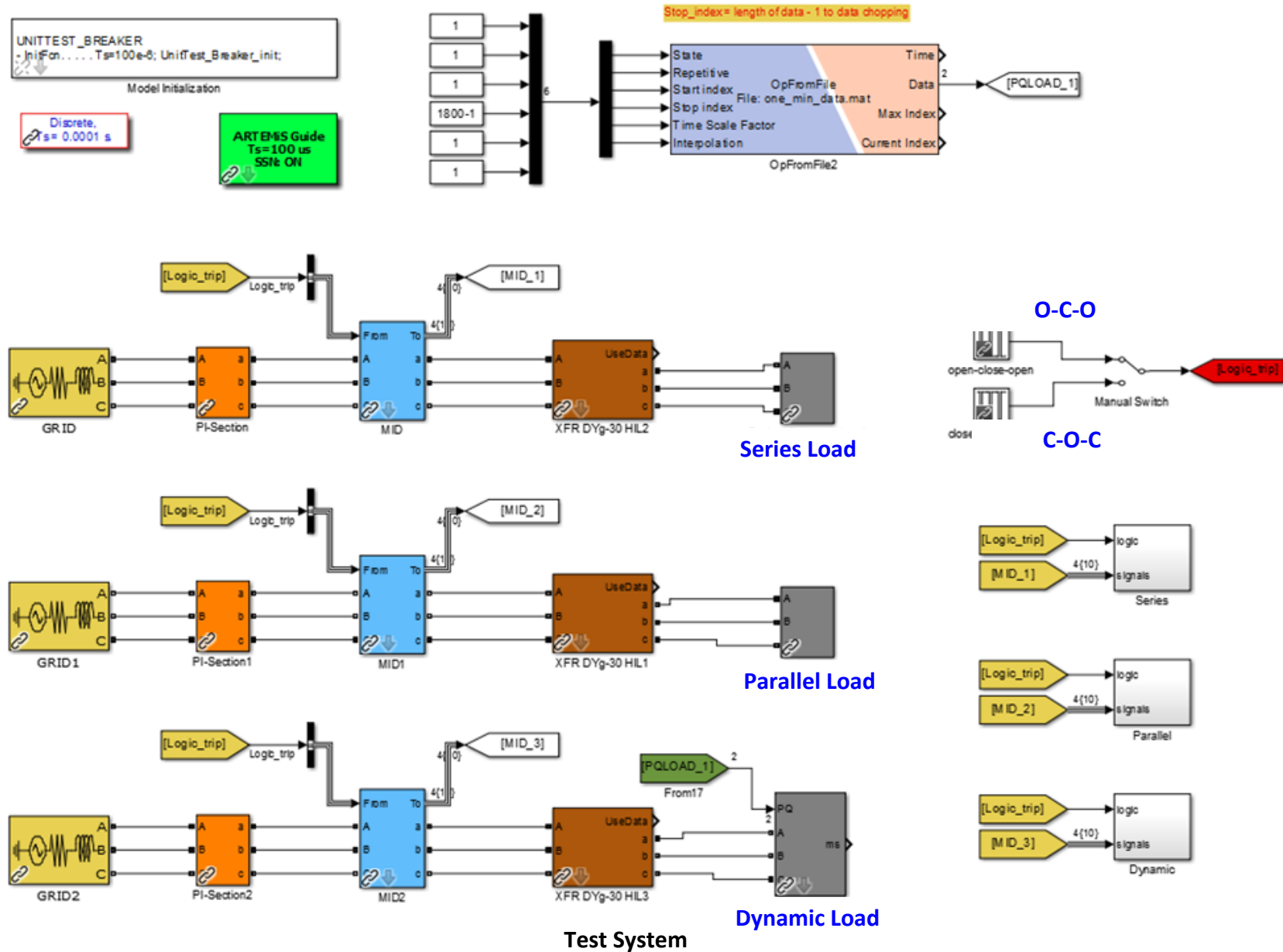- Tmax = 8secs, dT = 100us

Cases:
1) Evaluating Open/Close/Open Commands (DYNAMIC LOAD ONLY)
2) Evaluating Open/Close/Open Commands (PARALLEL LOAD ONLY)
3) Evaluating Open/Close/Open Commands (SERIES LOAD ONLY)
4) Evaluating Close/Open/Close Commands (DYNAMIC LOAD ONLY)
   ----- Cases having the circuit breaker close/open/close with a parallel and series PQ loads were also evaluated and the CB operated correctly.
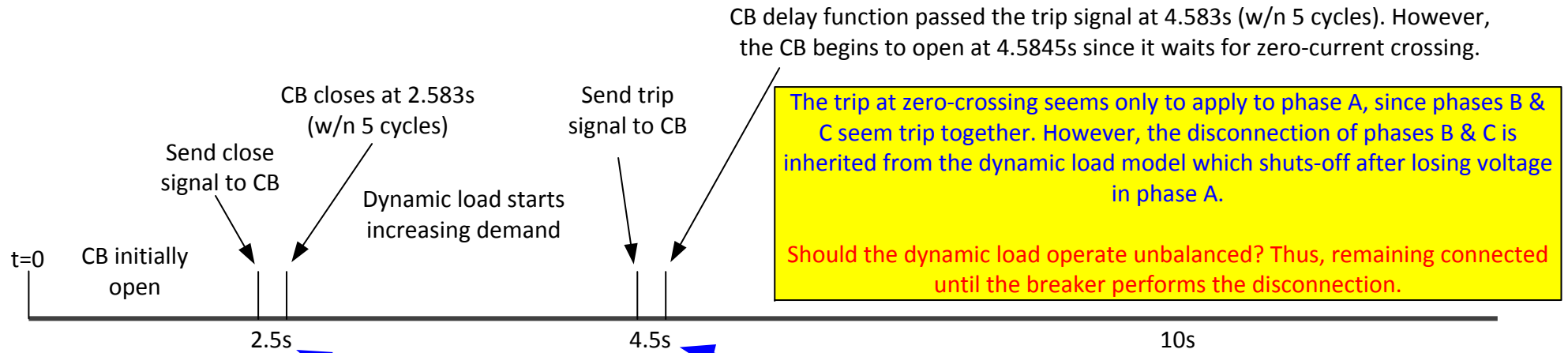
Series Load

Parallel Load

Dynamic Load

Test System

O-C-O

C-O-C

Case 1: Evaluating Open/Close/Open Commands (DYNAMIC LOAD ONLY)

CB delay function passed the trip signal at 4.583s (w/n 5 cycles). However, the CB begins to open at 4.5845s since it waits for zero-current crossing.

CB closes at 2.583s (w/n 5 cycles)
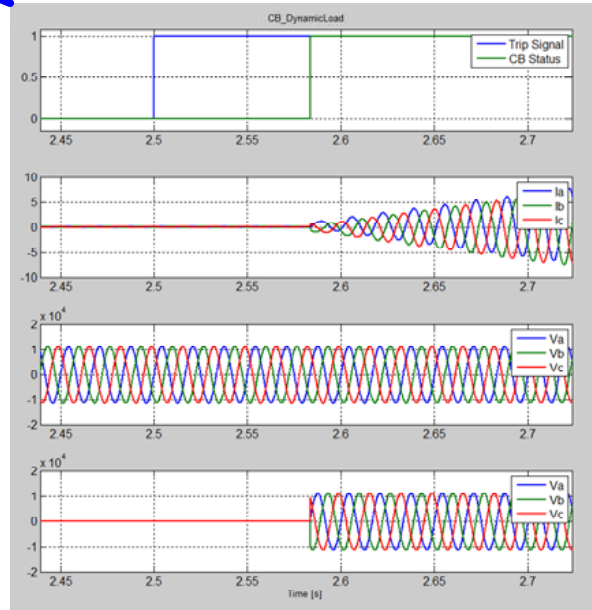
Send trip signal to CB

The trip at zero-crossing seems only to apply to phase A, since phases B & C seem trip together. However, the disconnection of phases B & C is inherited from the dynamic load model which shuts-off after losing voltage in phase A.

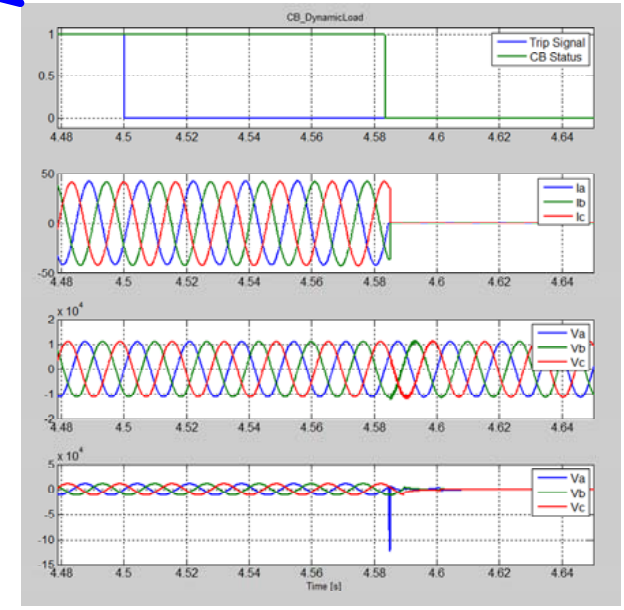Should the dynamic load operate unbalanced? Thus, remaining connected until the breaker performs the disconnection.

Send close signal to CB

Dynamic load starts increasing demand

t=0   CB initially open

2.5s   4.5s   10s

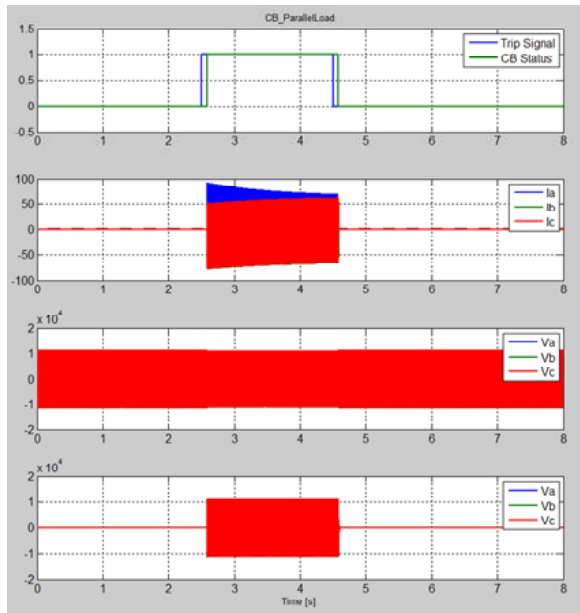

Complete simulation plots

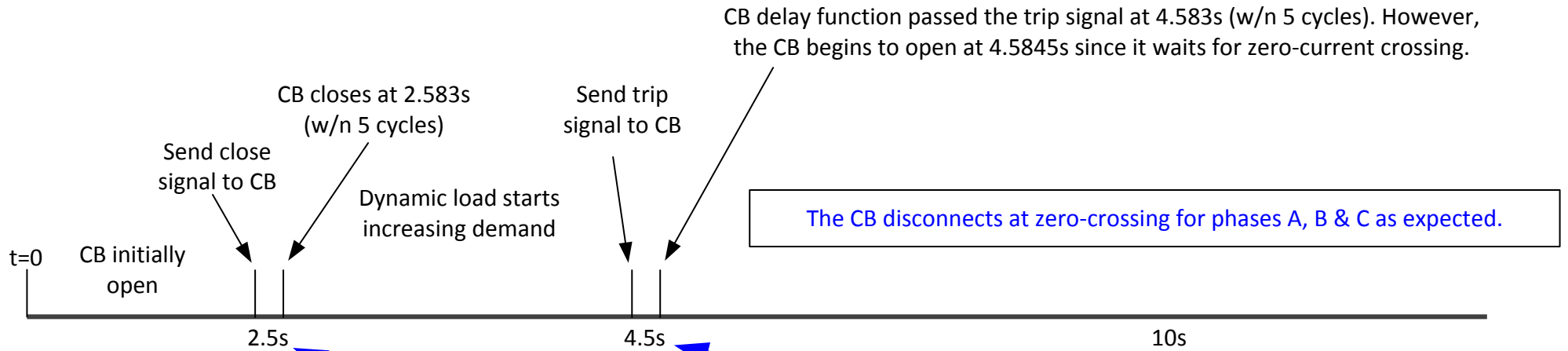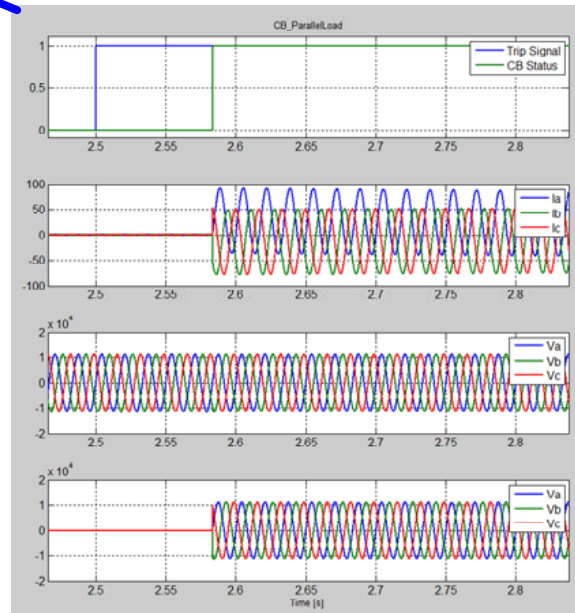Zoom-in : Closing circuit breaker

Zoom-in : Opening circuit breaker

Case 2: Evaluating Open/Close/Open Commands (PARALLEL LOAD ONLY)

CB delay function passed the trip signal at 4.583s (w/n 5 cycles). However, the CB begins to open at 4.5845s since it waits for zero-current crossing.

CB closes at 2.583s (w/n 5 cycles)

Send trip signal to CB

Send close signal to CB

Dynamic load starts increasing demand

The CB disconnects at zero-crossing for phases A, B & C as expected.

t=0   CB initially open

2.5s

4.5s

10s

Complete simulation plots
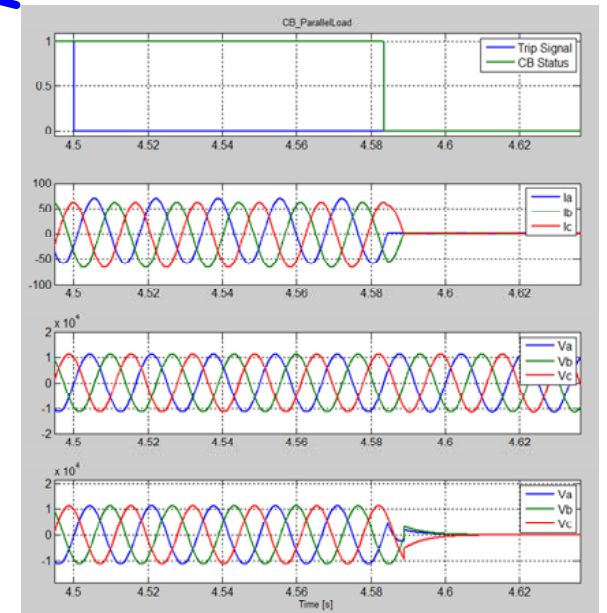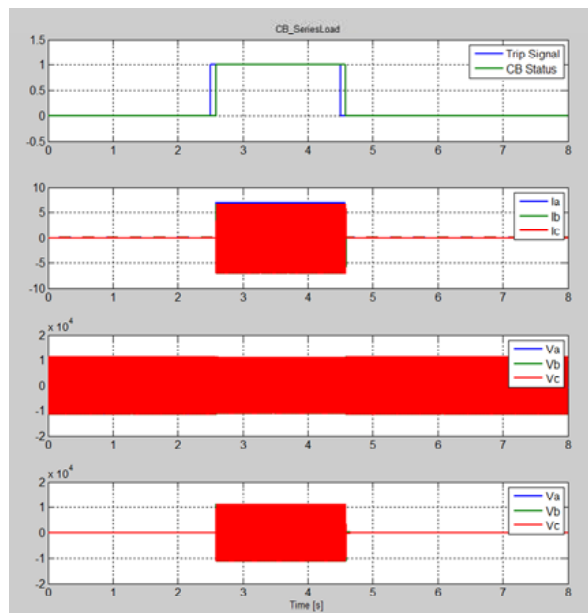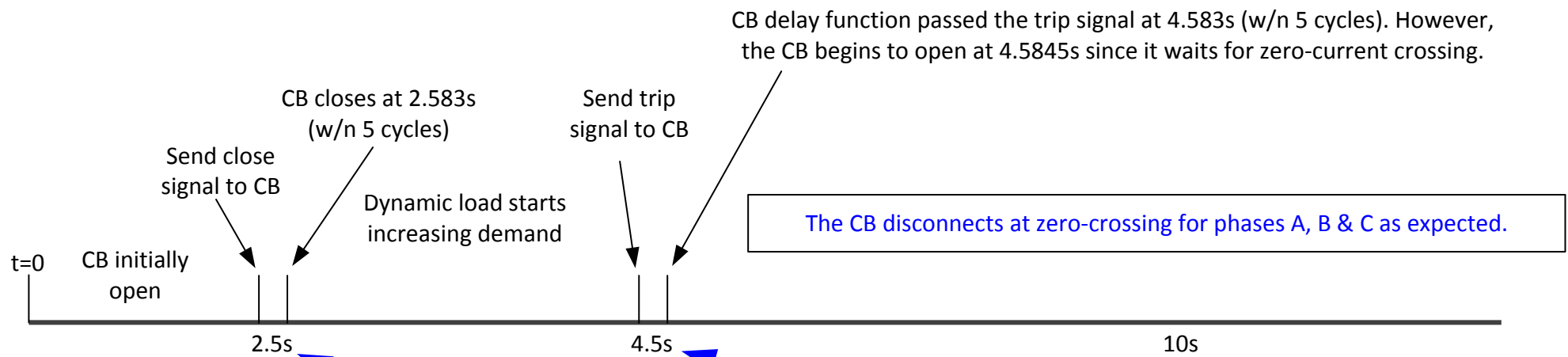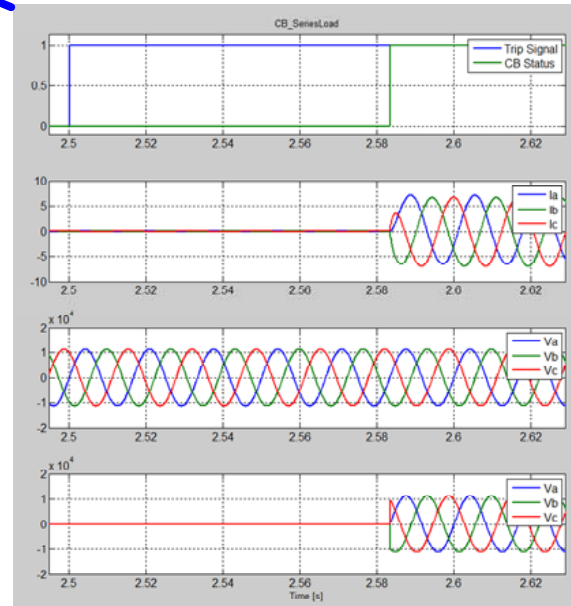
Closing circuit breaker

Opening circuit breaker

Note the start-up transient does not damp completely since the load is connected for a brief period of time.
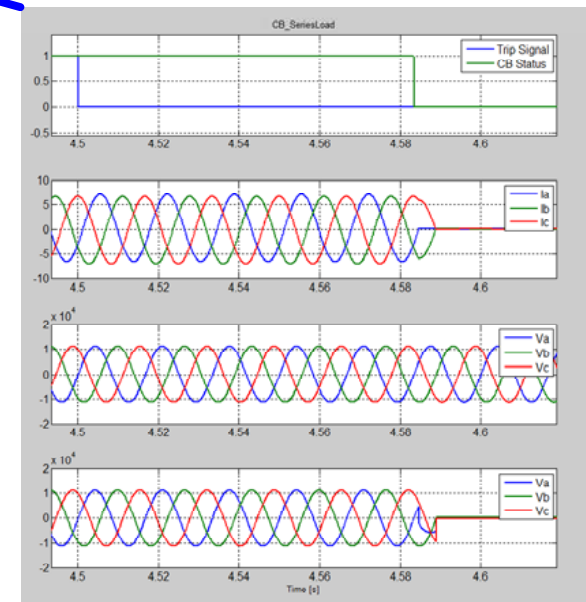
Case 3: Evaluating Open/Close/Open Commands (SERIES LOAD ONLY)

CB delay function passed the trip signal at 4.583s (w/n 5 cycles). However, the CB begins to open at 4.5845s since it waits for zero-current crossing.

CB closes at 2.583s (w/n 5 cycles)

Send trip signal to CB

Send close signal to CB

Dynamic load starts increasing demand

The CB disconnects at zero-crossing for phases A, B & C as expected.

t=0   CB initially open

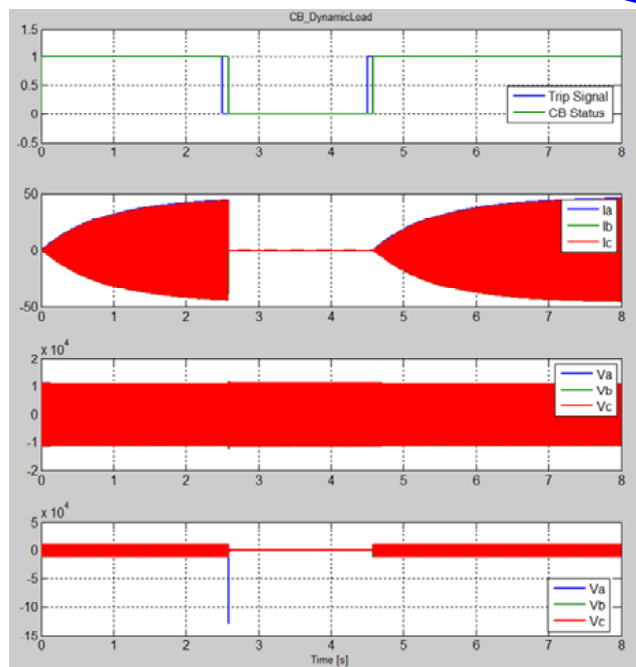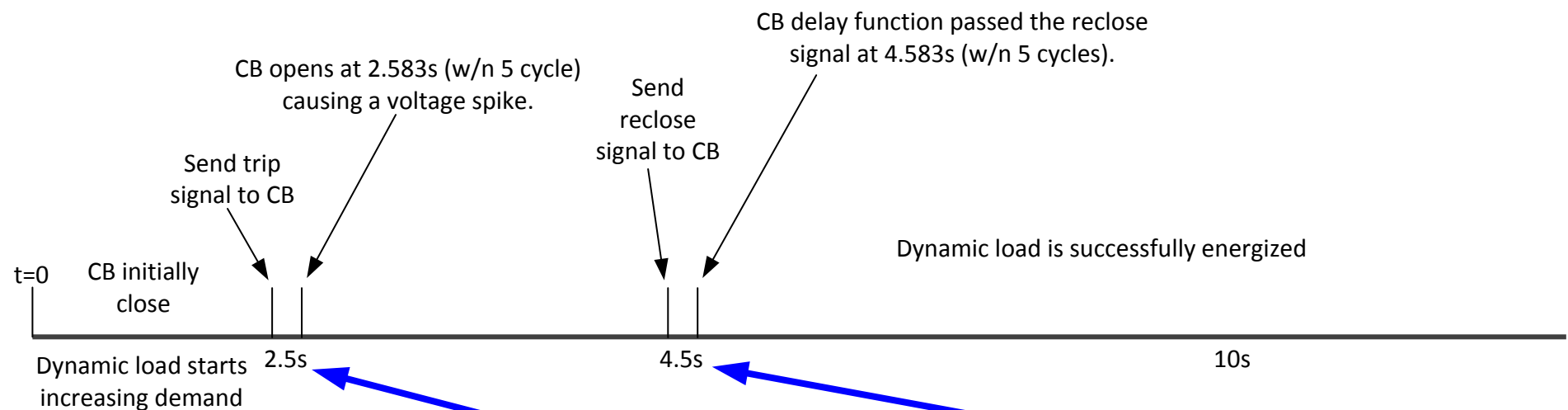2.5s

4.5s

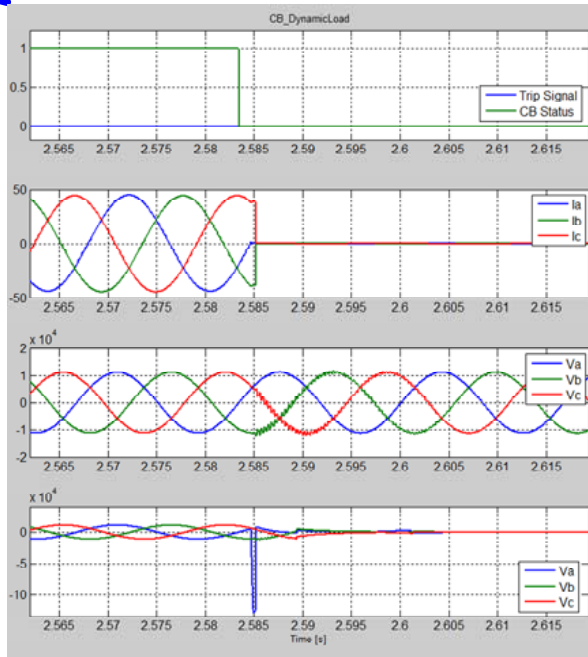10s

Complete simulation plots

Closing circuit breaker

Opening circuit breaker

Note the start-up current is nearly balanced when compared to the case of the pallalel-pq-load due to the series resistance
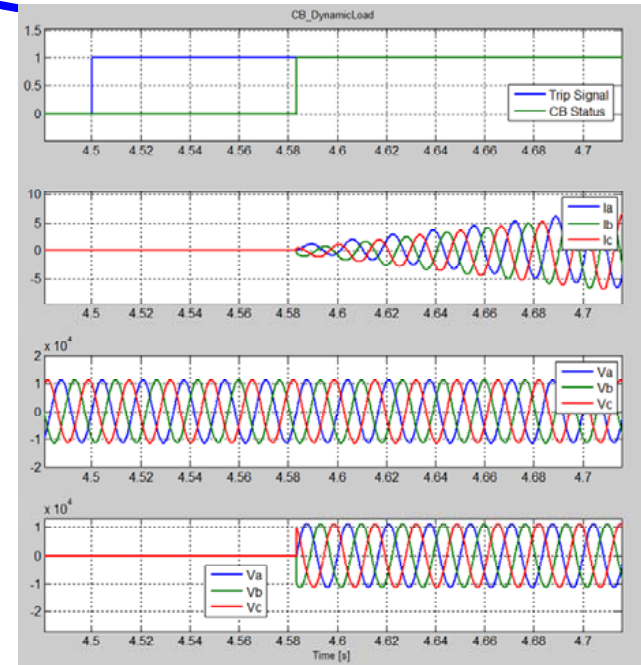
Case 4: Evaluating Close/Open/Close Commands (DYNAMIC LOAD ONLY)

CB delay function passed the reclose signal at 4.583s (w/n 5 cycles).

CB opens at 2.583s (w/n 5 cycle) causing a voltage spike.

Send reclose signal to CB

Send trip signal to CB

Dynamic load is successfully energized

t=0   CB initially close

Dynamic load starts increasing demand

2.5s

4.5s

10s

Complete simulation plots

Zoom-in : Opening circuit breaker

Zoom-in : Closing circuit breaker

The trip at zero-crossing seems only to apply to phase A, since phases B & C seem trip together. However, the disconnection of phases B & C is inherited from the dynamic load model which shuts-off after losing voltage in phase A. Should the dynamic load operate unbalanced? Thus, remaining connected until the breaker performs the disconnection.