Interfacing Electromagnetic Transient Simulation to Transient Stability Model Using a Multi-port Dynamic Phasor Buffer Zone

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Presentation Flow

1. Overview of simulation tools
2. Objective
3. Implementation
4. Results
5. Conclusions & Future Work

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Power System Simulation Tools

Electromechanical transients:

- Generator rotor dynamics

Sub-synchronous oscillations

Electromagnetic transients (EMT):

- Network dynamics

Frequency →

Transient Stability (TS) programs:

PSSE, TSAT, DigSilent

- Frequency range: Less than 5Hz
- Simplified models of machines, HVDC, FACTS components
- Time step: 1ms-10ms
- Suitable for large scale power systems

Electromagnetic Transient simulations:

RSCAD, PSCAD

- Frequency range: 0 – MHz
- Detailed modelling of components
- Time step: 50µs or less
- Computationally demanding
- Not suitable for large scale power systems

Objective

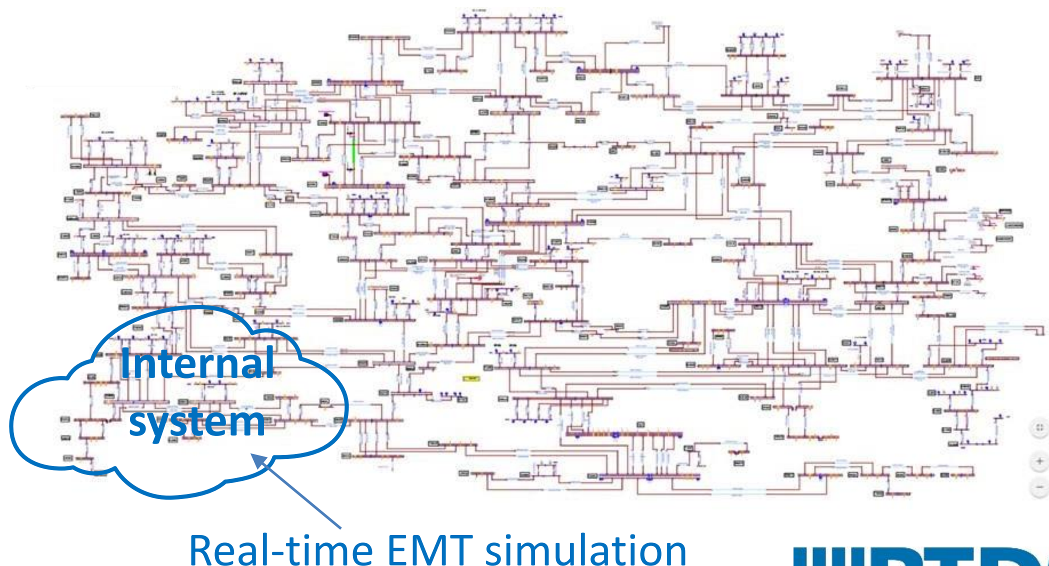
- The goal of the co-simulation model is to analyse electromagnetic transients in a large scale power system using RTDS.

- The co-simulation model include:
  - Electromagnetic Transient (EMT) model: To model the internal system in more detail
  - Transient Stability (TS) model: To model the rest of the system as a low frequency equivalent

- Conventional methods use Frequency Dependent Network Equivalents (FDNE).

- We propose Dynamic Phasors (DP) to model a multi-port buffer zone between the two models.

- This is a simple alternative to using an FDNE.



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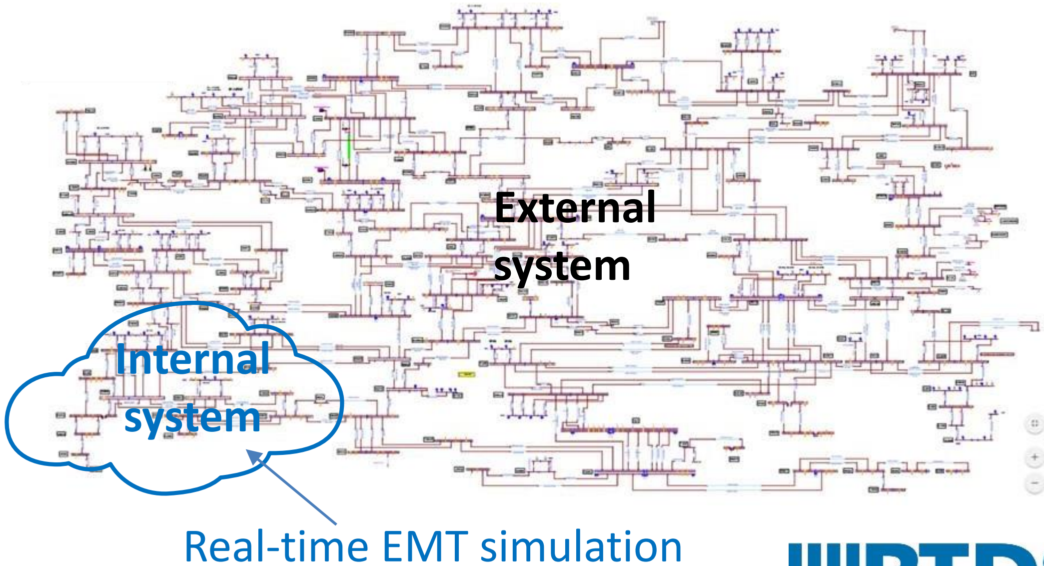

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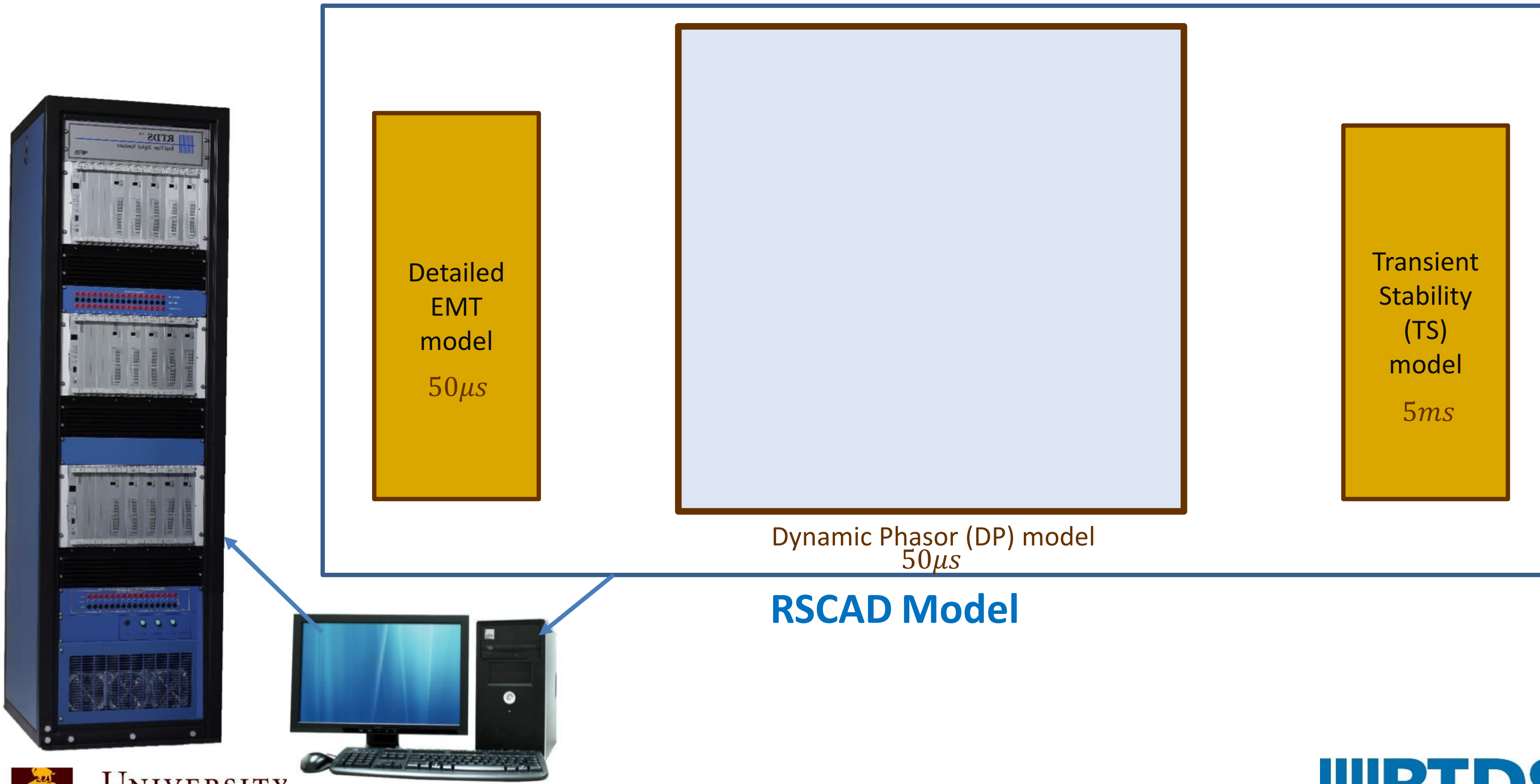
Proposed Co-Simulation Platform



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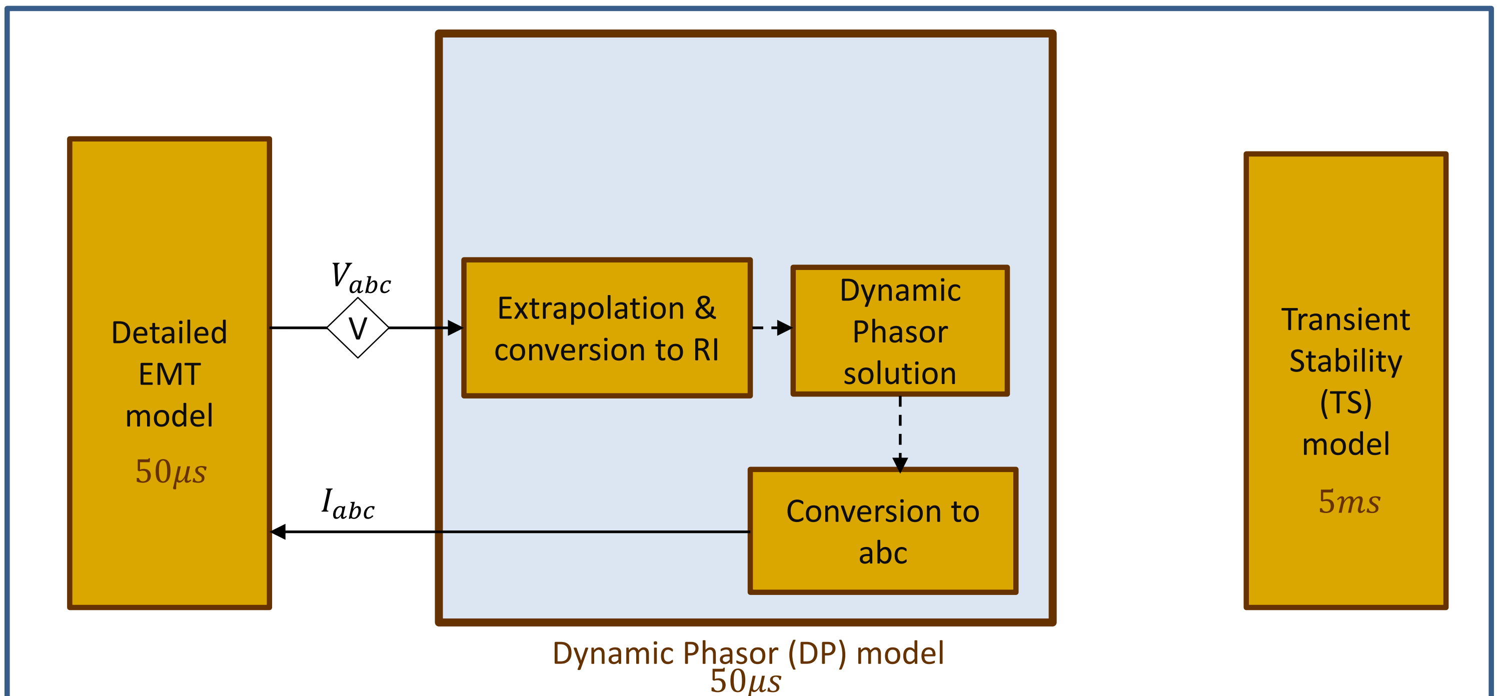

RSCAD Model

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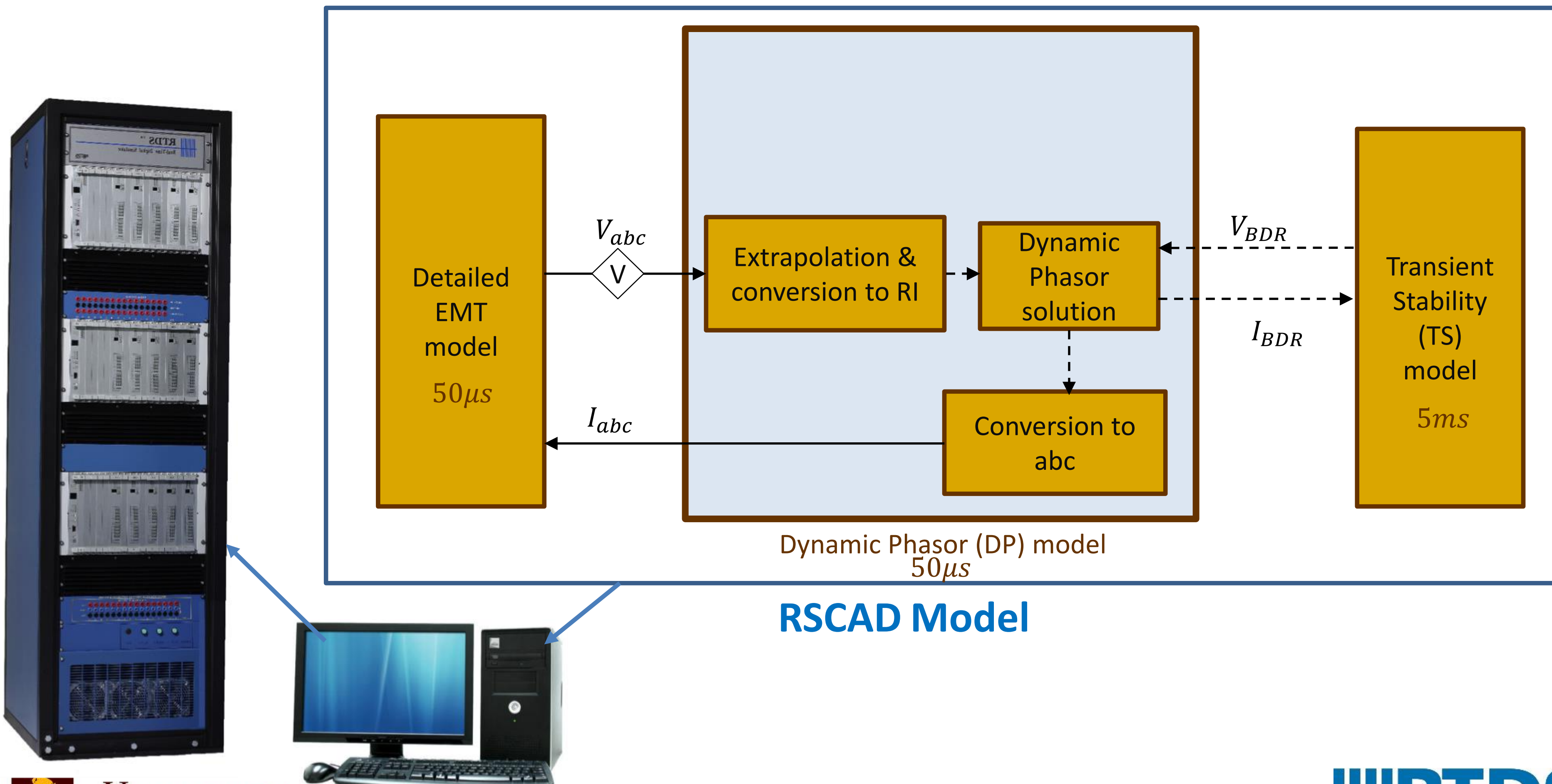

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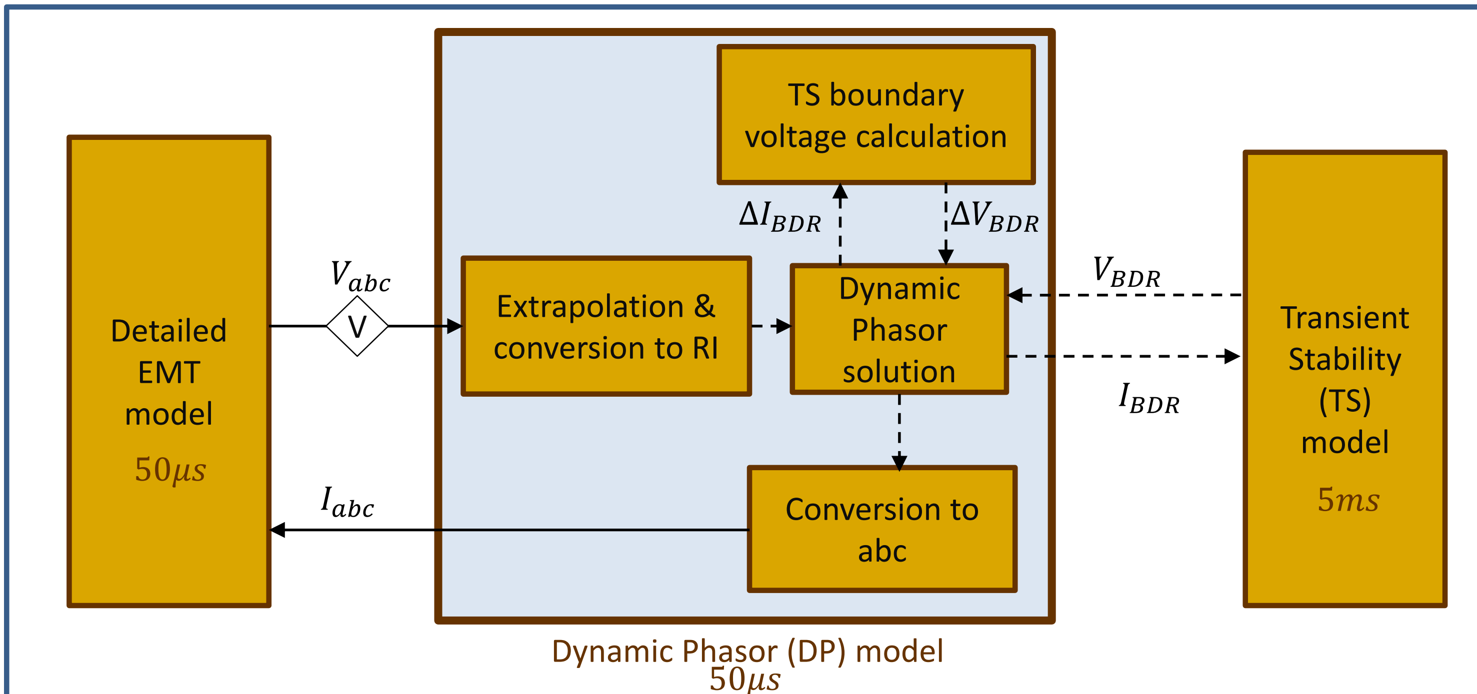

RSCAD Model

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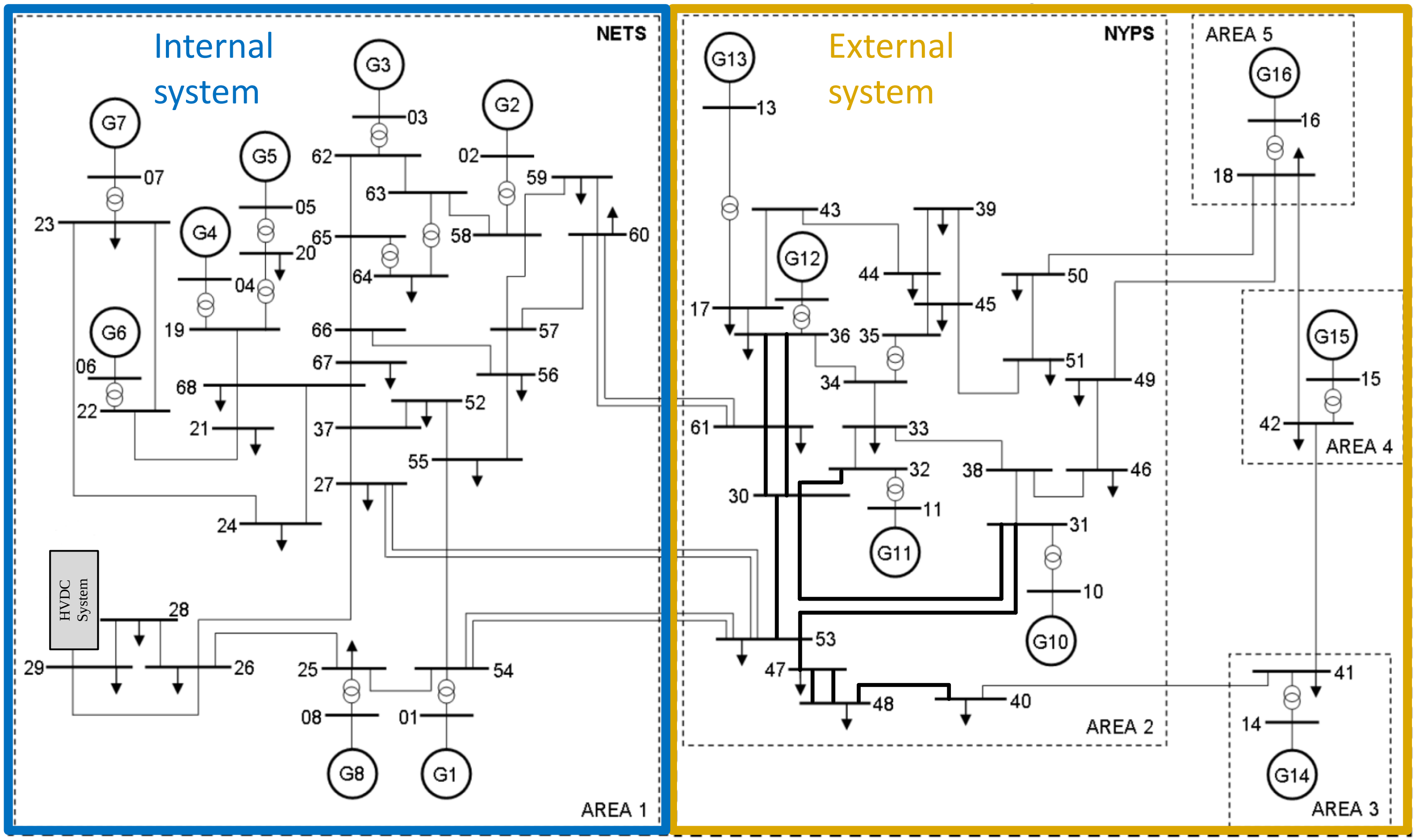
Test system: IEEE 68 Bus System



- Buses 61 and 53: EMT and DP interface buses
- Buses 61, 53, 47, 48, 40, 30, 36, 31 and 32: DP Buffer zone
- Buses 36, 32, 31 and 40: TS and DP interface buses

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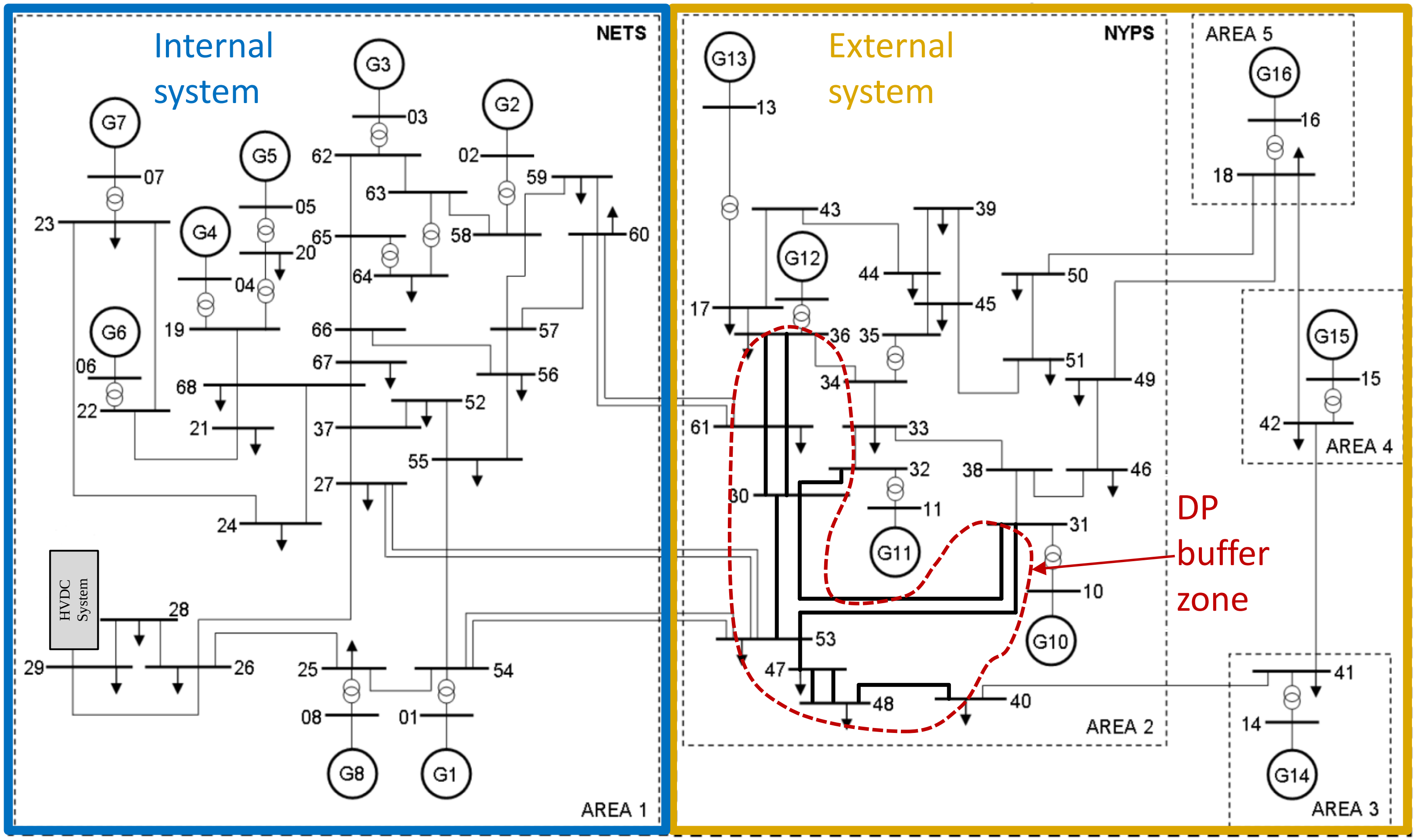
Test system: IEEE 68 Bus System



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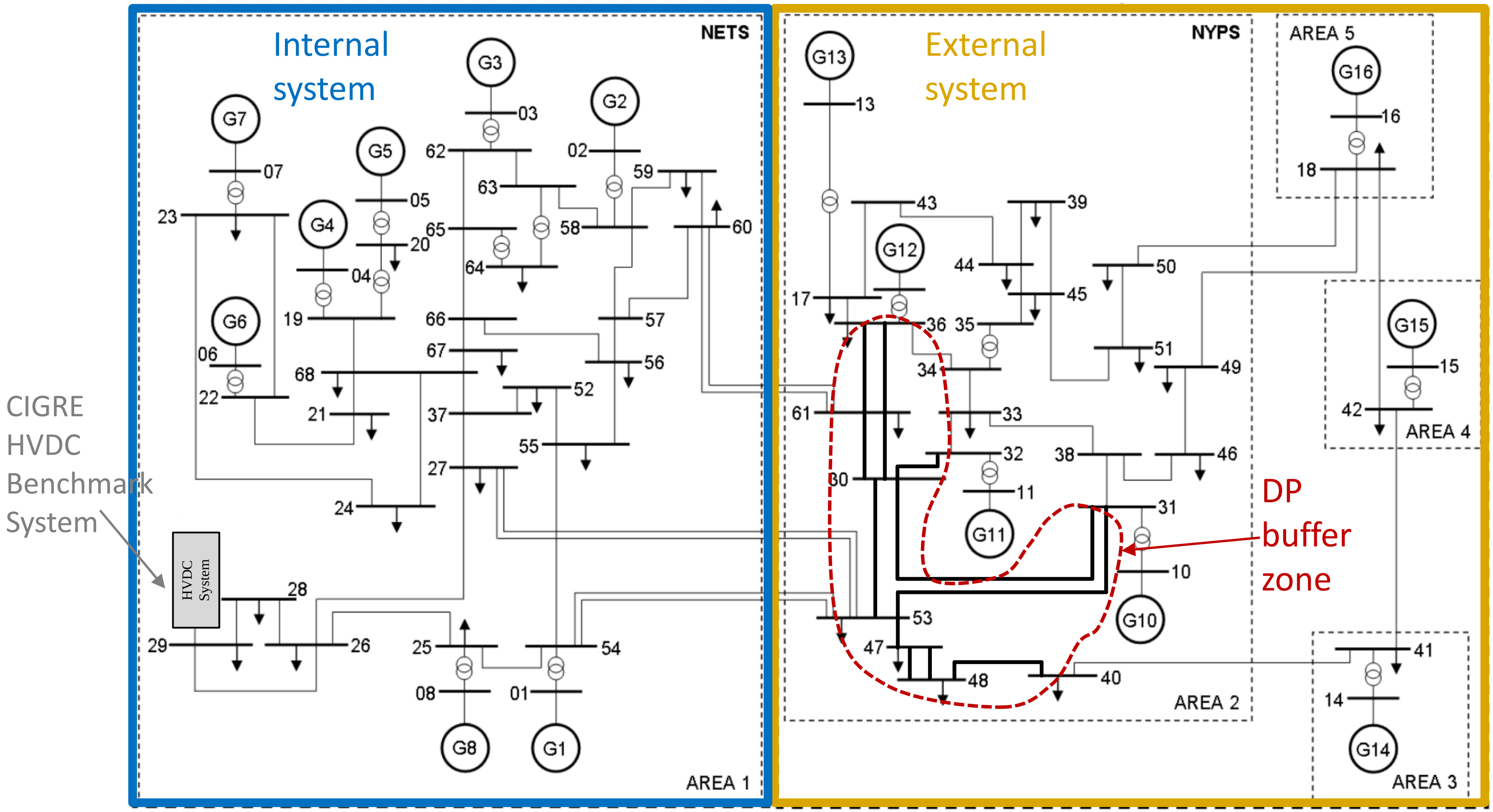

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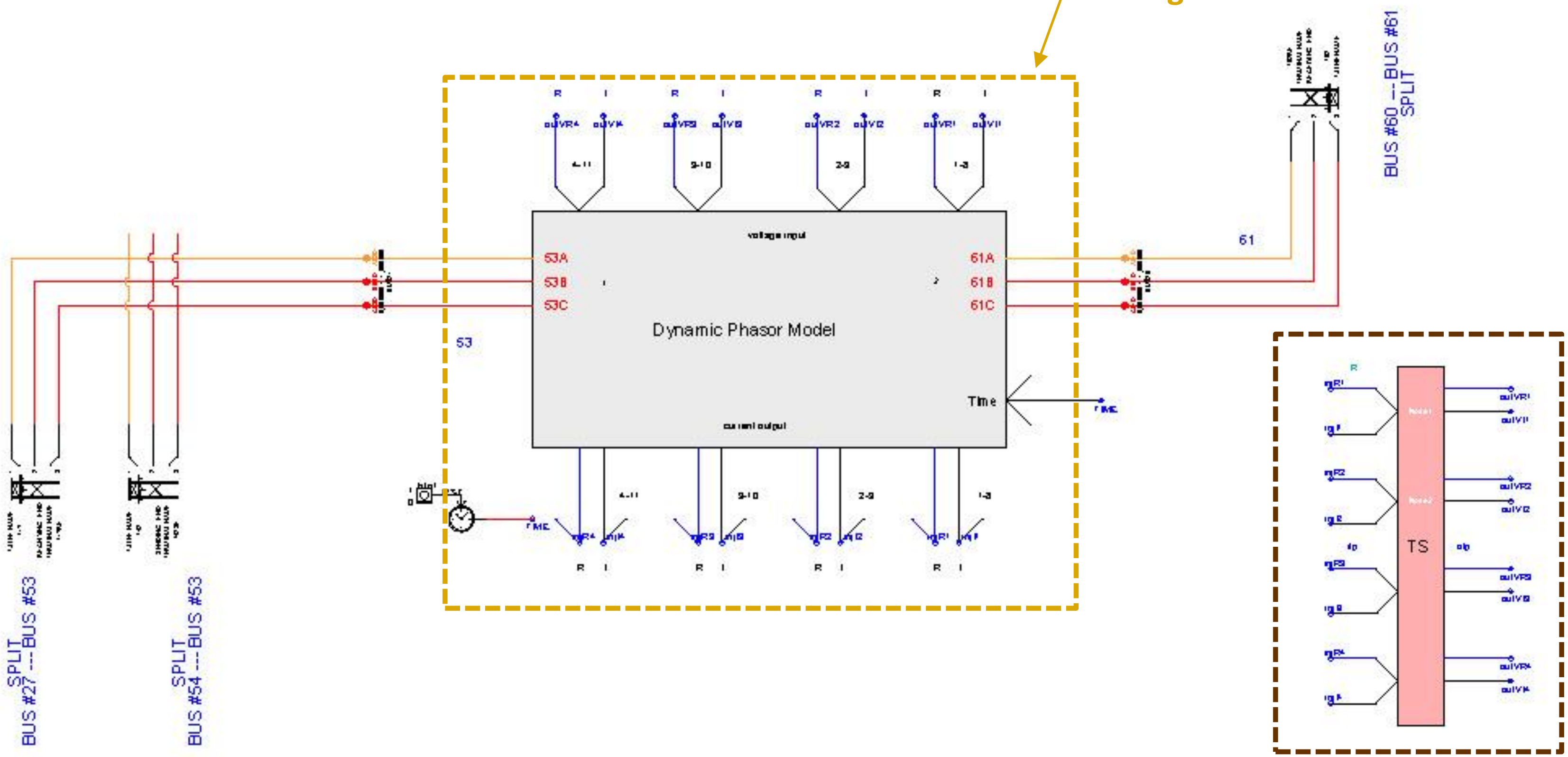
RSCAD Model

Dynamic Phasor buffer zone implemented as a power system component using C-builder



Transient stability (TS) model implemented as a control component using C-builder

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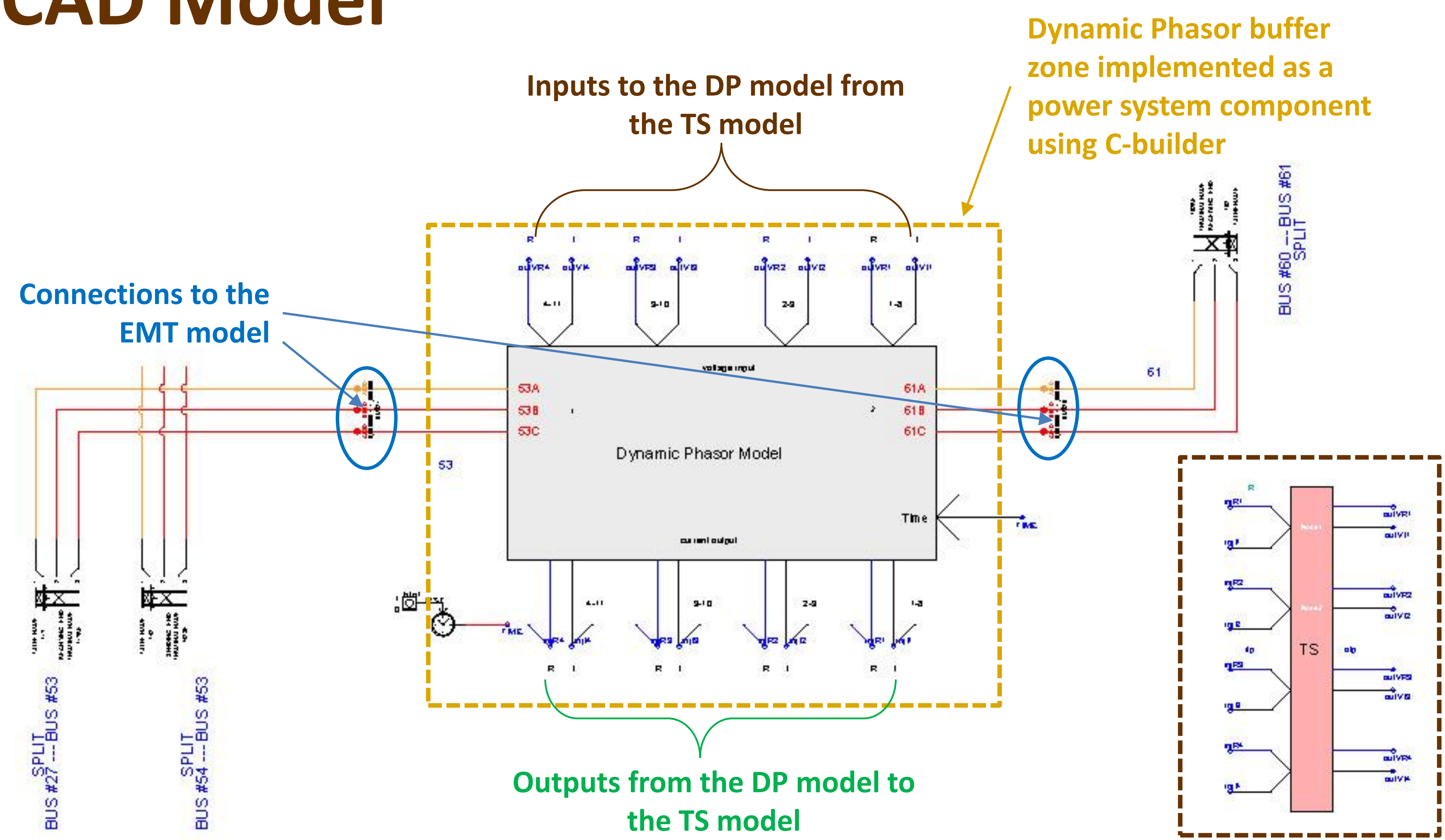
RSCAD Model



Transient stability (TS) model implemented as a control component using C-builder

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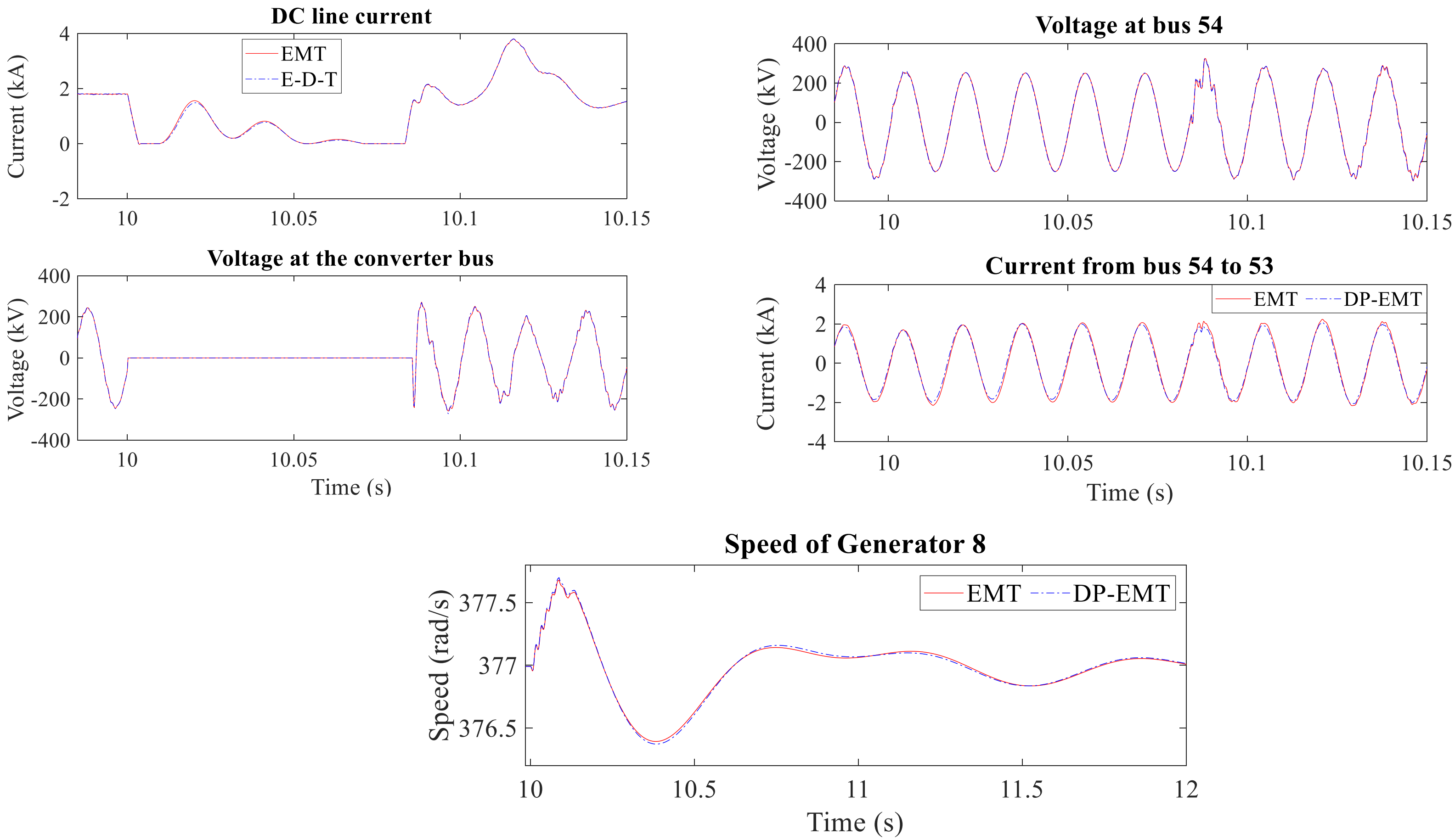
Simulation Results - Case 1

- Three Phase Fault at the Converter Bus (bus 29)



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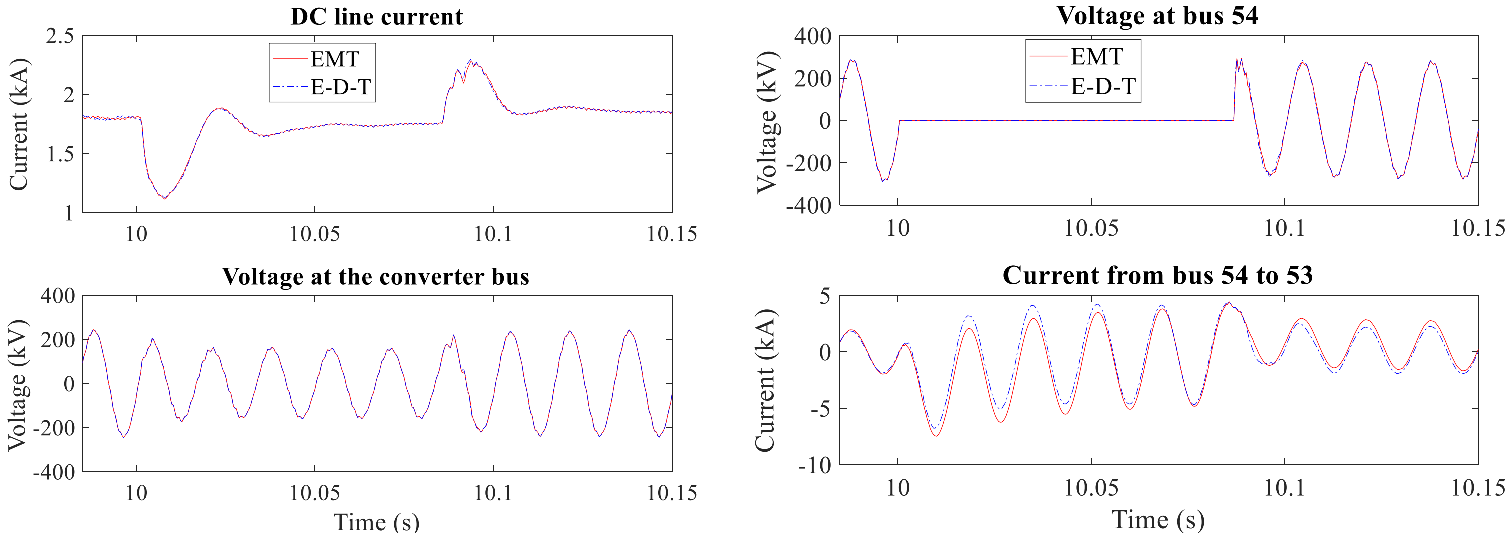
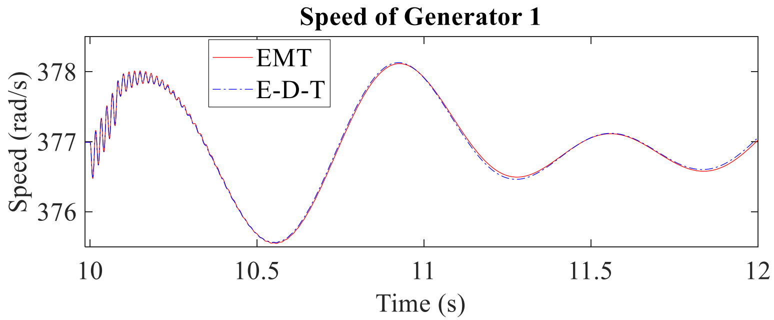
Simulation Results - Case 2

- Three-Phase Fault at a Bus (Bus 54) Next to the EMT-DP Interface Buses





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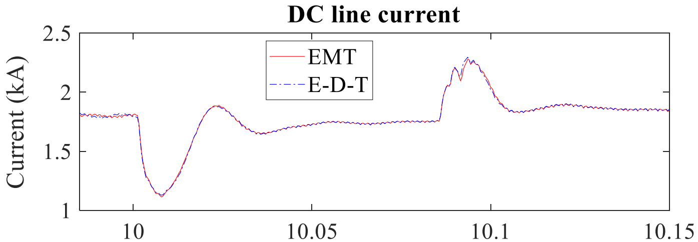

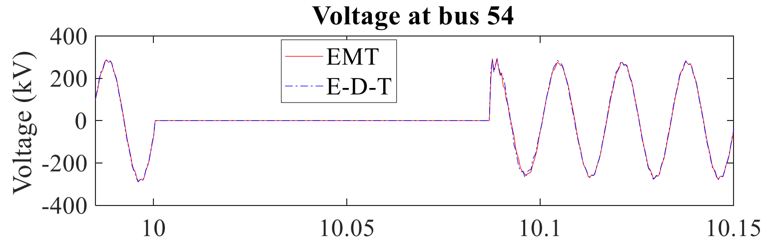

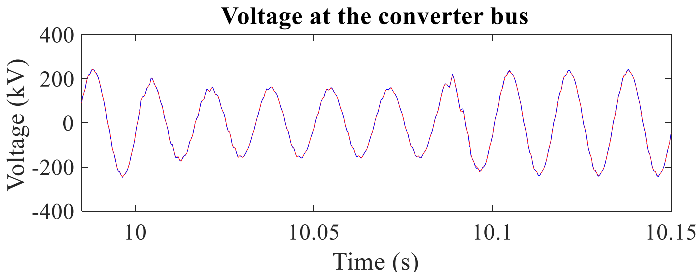

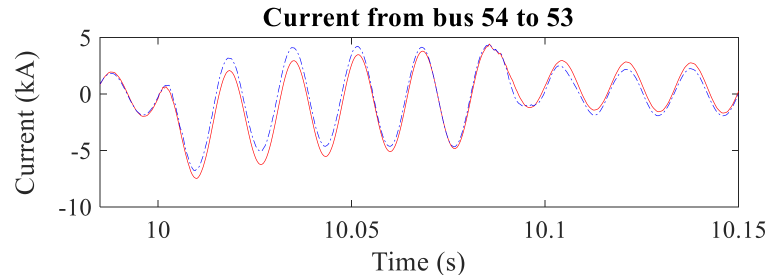

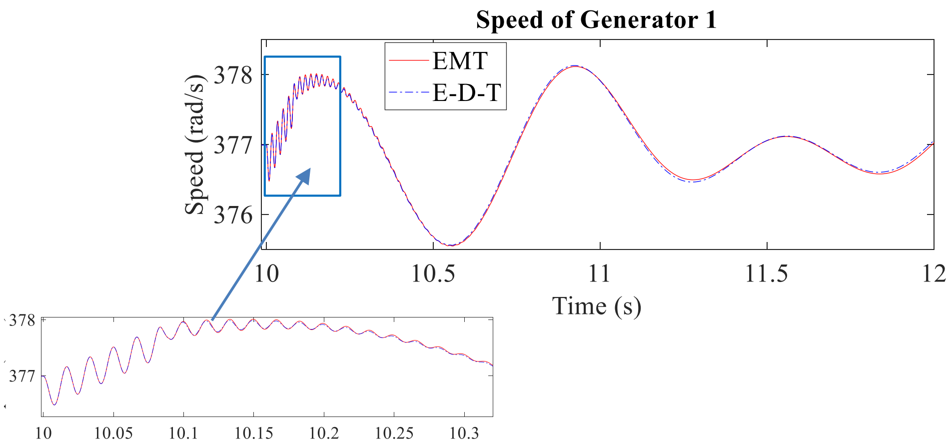

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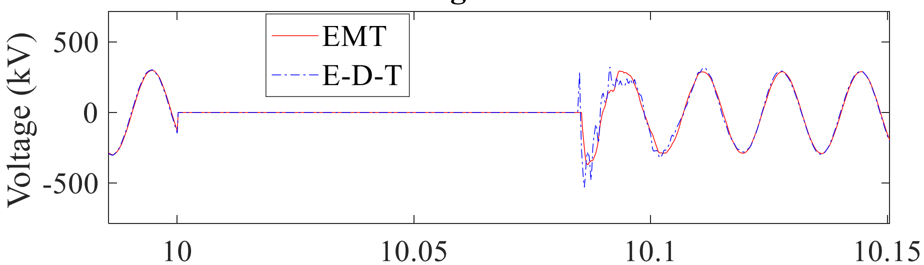
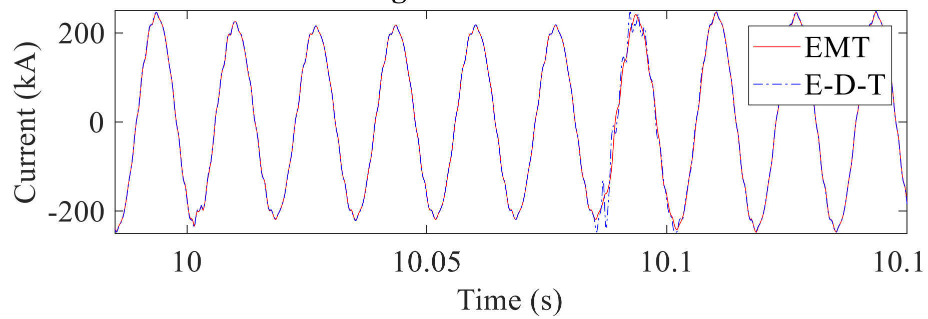
Simulation Results - Case 3

- Three-Phase Fault at Buses Right at the EMT-DP Interface ([Bus 53]())

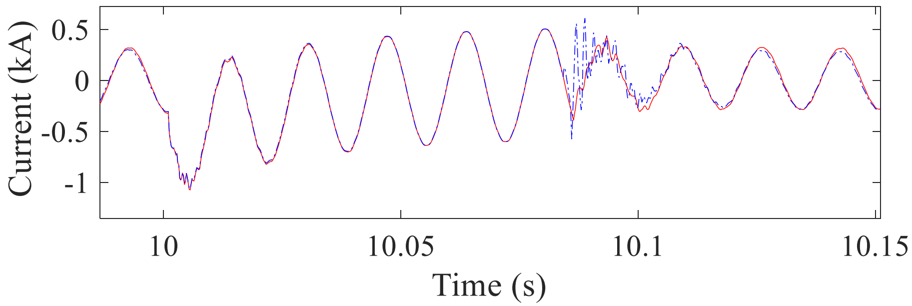
Voltage at bus 53



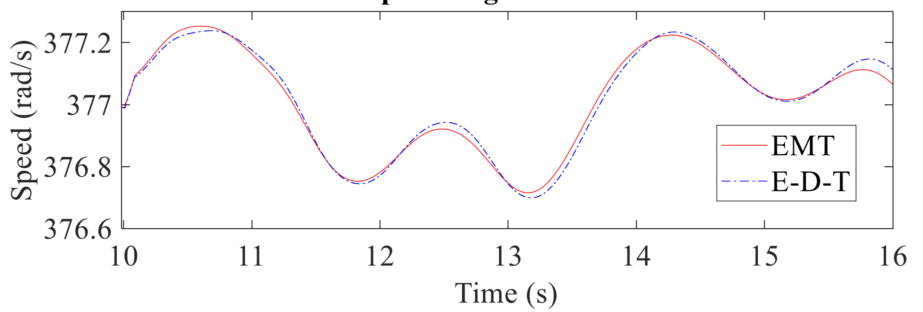
Voltage at the converter bus



Current from bus 27 to 53



Speed of generator 16



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Conclusions & Future Work

- The co-simulation model shows promising results under disturbances applied in the internal system.

- EMT model can be connected to Transient Stability model through a dynamic phasor buffer zone.

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- The co-simulation model shows promising results under disturbances applied in the internal system.

- EMT model can be connected to Transient Stability model through a dynamic phasor buffer zone.

Possible enhancements:

- Improve the co-simulation model to handle unbalances in internal network.
  - DP and TS parts will have to be modelled to incorporate the negative and zero sequence components of the currents and voltages

- Simulate faults in the external system.
  - In this work, the disturbances were applied only in the internal system.
  - The system response to a disturbances in the external system is needed in some studies.

- Further partitioning of the external system to simulate as different TS models.

Thank You !

Any questions?

Dynamic phasor based simulations

- Similar to TS simulations, DP also uses positive sequence phasor quantities.
- The phasors are modelled as state variables using differential equations in DP.

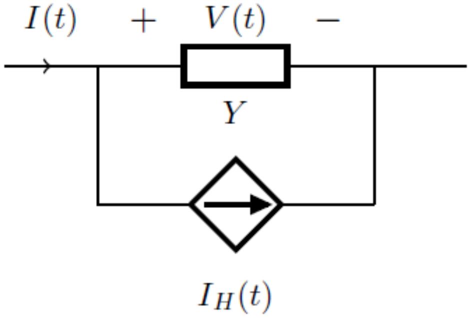
E.g.: Dynamic phasor representation of a series RL branch

$$V_{12} = L\frac{d}{dt}I + (R + j\omega_0 L)I$$

Applying Trapezoidal rule of integration,

$$\tilde{I}(t) = h_1\tilde{V}_{12}(t-1) + h_2\tilde{I}(t-1) + Y\tilde{V}_{12}(t) \qquad I_H = h_1\tilde{V}_{12}(t-1) + h_2\tilde{I}\,(t-1)$$

- $h_2 = \frac{1 - {}^{R\Delta t}/_{2L} - {}^{j\omega_0\Delta t}/_{2}}{1 + {}^{R\Delta t}/_{2L} + {}^{j\omega_0\Delta t}/_{2}}$ $\qquad h_1 = Y = \frac{{}^{\Delta t}/_{2L}}{1 + {}^{R\Delta t}/_{2L} + {}^{j\omega_0\Delta t}/_{2}}$



Stability criteria for interfacing

As a current source

- TS reads voltage from DP side

$$V = V(r - 1)$$

- Calculate the current

$$I_2 = I_1 = \frac{V_{TS} - V(r-1)}{R_1}$$

- Calculate the new interface voltage

$$V(r) = \frac{V_{TS} - V(r-1)}{R_1} R_2 + V_{DP}$$

As a voltage source

- TS reads current from DP side

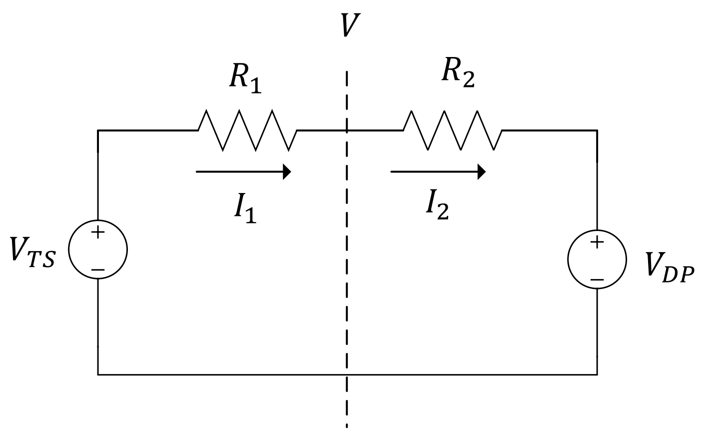
$$I_1 = I_2 = I(r - 1)$$

- Calculate the interface voltage

$$V = V_{TS} - I(r-1)R_1$$

- Update the current injection from the DP side

$$I(r) = \frac{V_{TS} - I(r-1)R_1 - V_{DP}}{R_2}$$



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Stability criteria for interfacing cont.

As a current source

- If TS part is modelled as a current injection, simulation is numerical stable only if

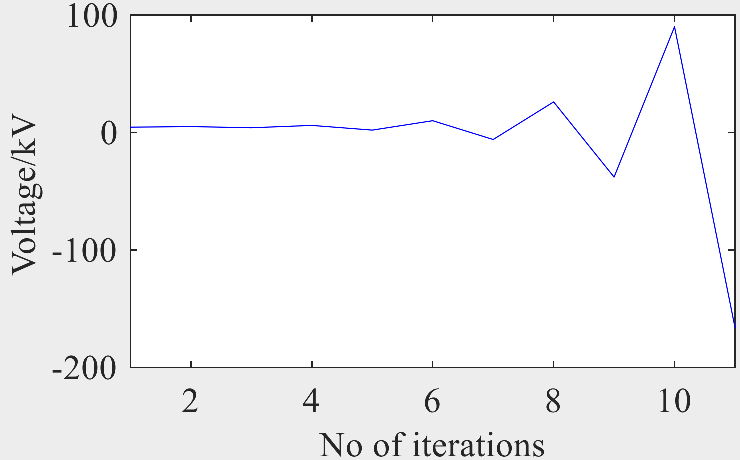
$$|\boldsymbol{R_2}| \leq |\boldsymbol{R_1}|$$

As a voltage source

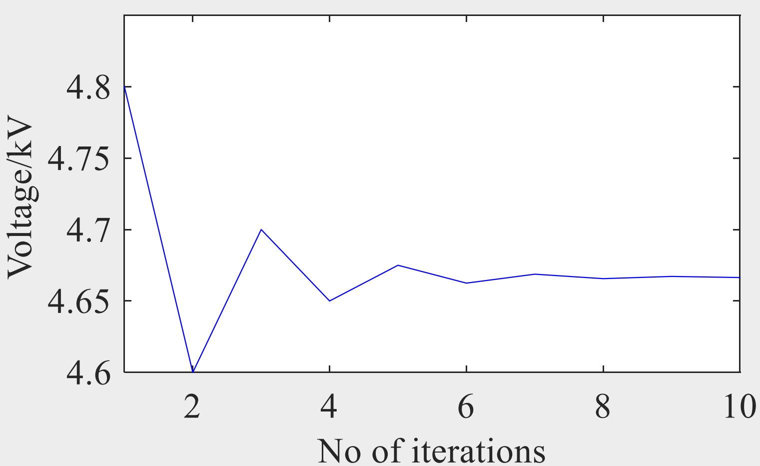
- If TS part is modelled as a voltage injection, simulation is numerical stable only if

$$|\boldsymbol{R_1}| \leq |\boldsymbol{R_2}|$$

As a current source



As a voltage source



$R_1 = 1\Omega \;\; R_2 = 2\Omega$

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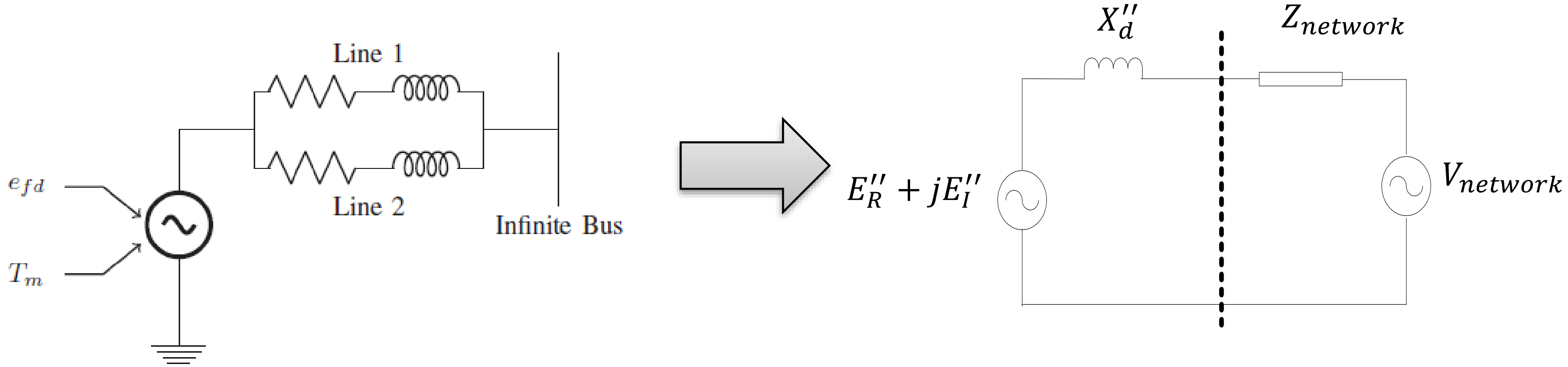
Stability criteria for interfacing cont.



As a current source	As a voltage source