Progressive Tripping and Reconnecting

August 10, 2021
Load Modeling Update
WECC MVS Meeting Online

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Progressive Tripping and Reconnecting

- CMPLDW, CLOD, MOTORW, etc…
- What are these models trying to do?
  - Use ONE set of dynamics equations
  - To represent 1000s of individual loads
- Our goal it to transform an individual load model into a model of an aggregate load

Aggregate Motor Model with Tripping (part of CMPLDW)

- What does it mean when a motor model says "50% tripped"
  - Think of it as ONE set of equations representing a huge set of identical motors.
  - When we say 50% tripped it just means that we now have 50% of the current injection as we did before (and double the Norton impedance)
  - It's essentially a scalar multiplier on those things
- What does it mean when some of these induction motors "restart"
  - We are NOT modeling the motor starting from zero speed with the large current spikes that go with that
  - We're pretending that all the motors continued to spin and operate after they tripped, they just magically were no longer seen by the transmission network
  - When they "restart", they magically return operating at full load and speed.

Tripping of Loads from Relays

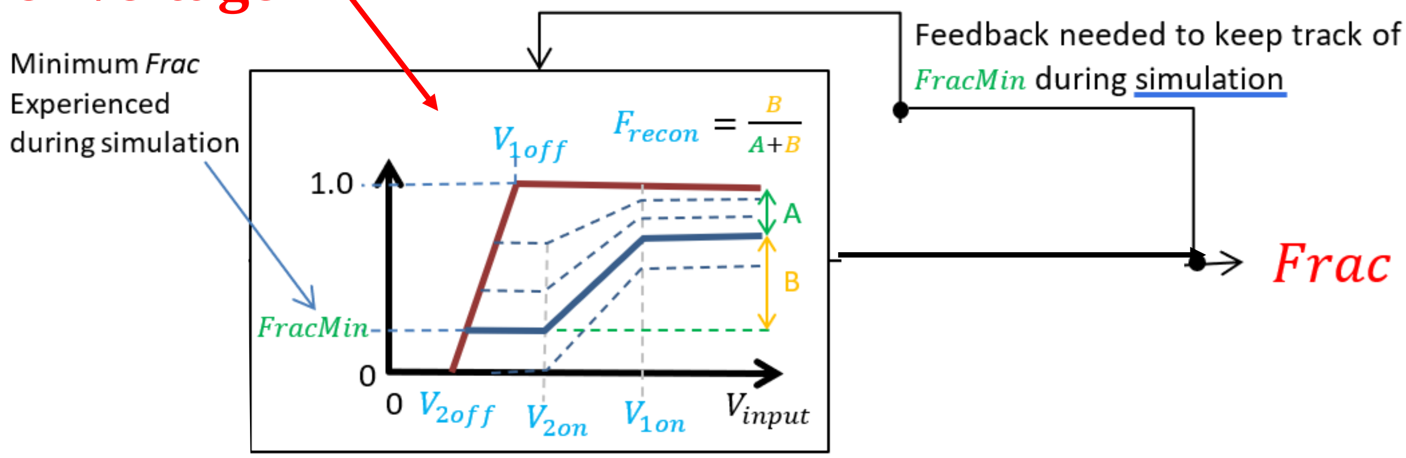
- Definite Time Under-Voltage Relays
  - Vtr1, Ttr1, Ftr1
    - Voltage falls below Vtr for Ttr1 seconds, then we trip Ftr1 of the load
    - Voltage falls below 0.5 per unit voltage for 0.20 seconds, then we trip 50% of the induction motor
- Composite load model has typically included 2 blocks of this tripping
- Trouble is parameter sensitivity
  - Vpu goes to 0.49999 and stays there for 0.20 seconds then we trip 50% of load
  - Vpu goes to 0.50001 and says there for 0.20 seconds and we do NOT trip anything
  - Some load records in WECC cases are several hundred MW, so this can give radically different results

Progressive Tripping and Reconnecting

- Describes a continuously varying fraction of load as a function of terminal voltage
- Won’t have discrete jumps as the definite time relays are doing
- User can vary how quickly the load fraction goes down (“trips”)
- Use can also vary how quickly the load fraction goes up (“reconnects”)

Progressive Tripping and Reconnecting (PTR)

Describes "Steady State" behavior as function of voltage



As voltage drops, following the maroon lines

As voltage increases, following the Navy Lines

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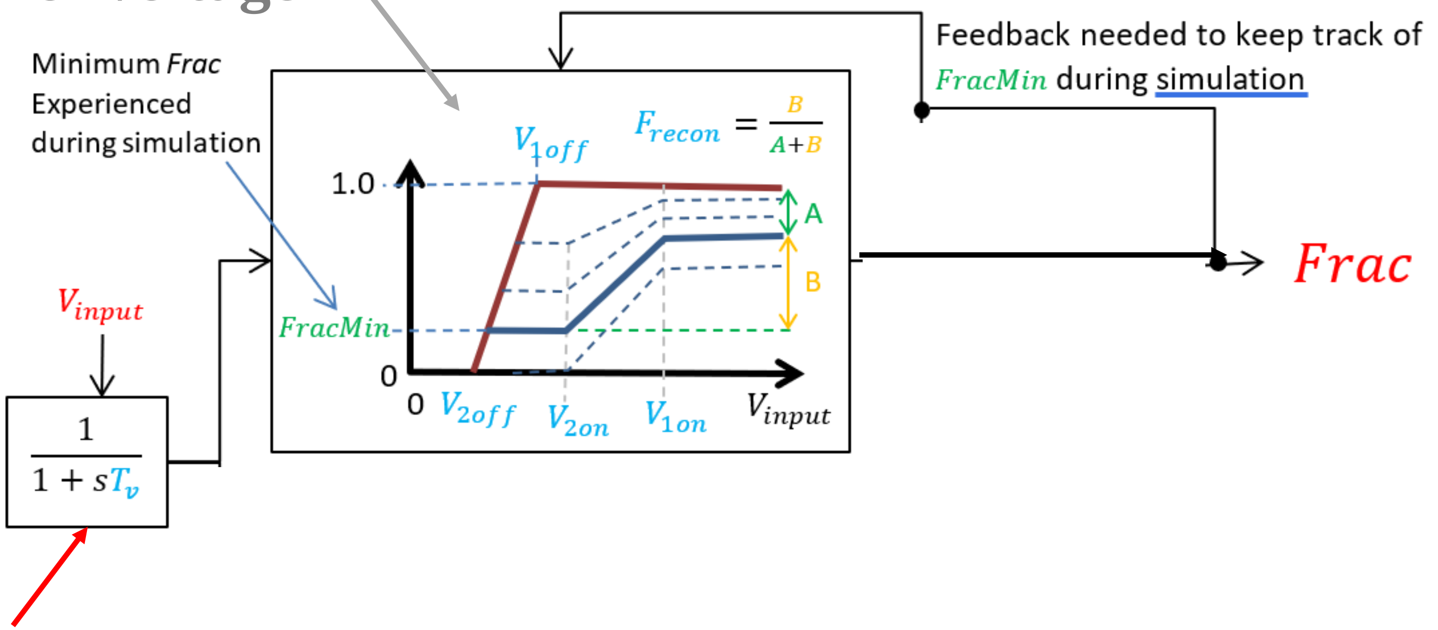

Smooth Response to Changes in Voltage to remove numerical noise in input voltages

Progressive Tripping and Reconnecting (PTR)

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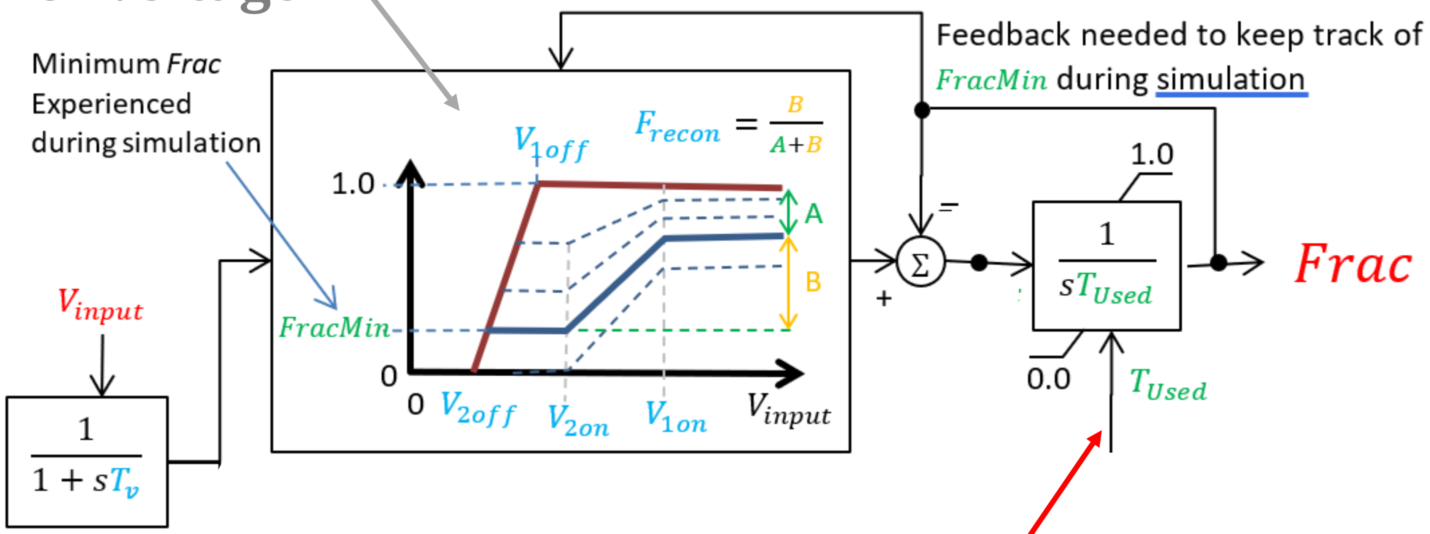
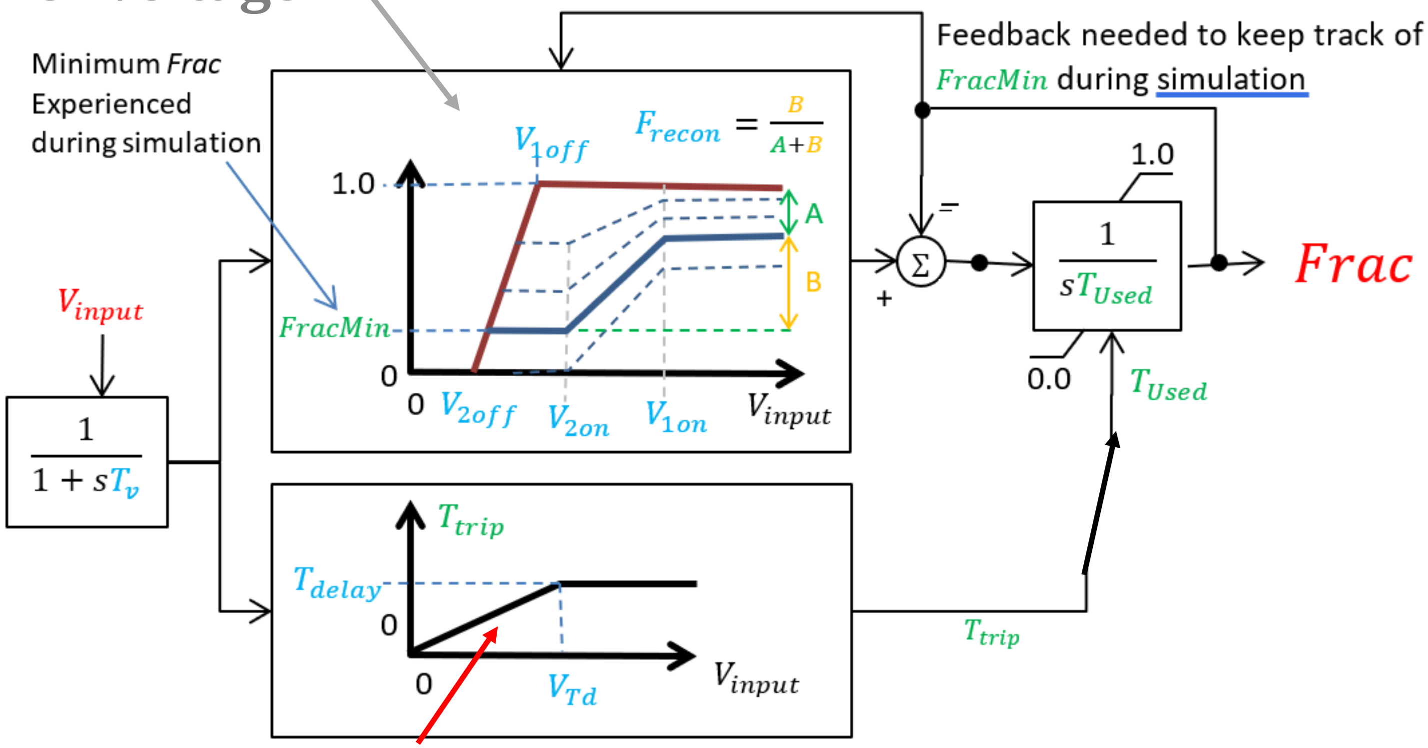


Smooth change in Fraction with a Time Delay (Removes sudden changes)

Progressive Tripping and Reconnecting (PTR)

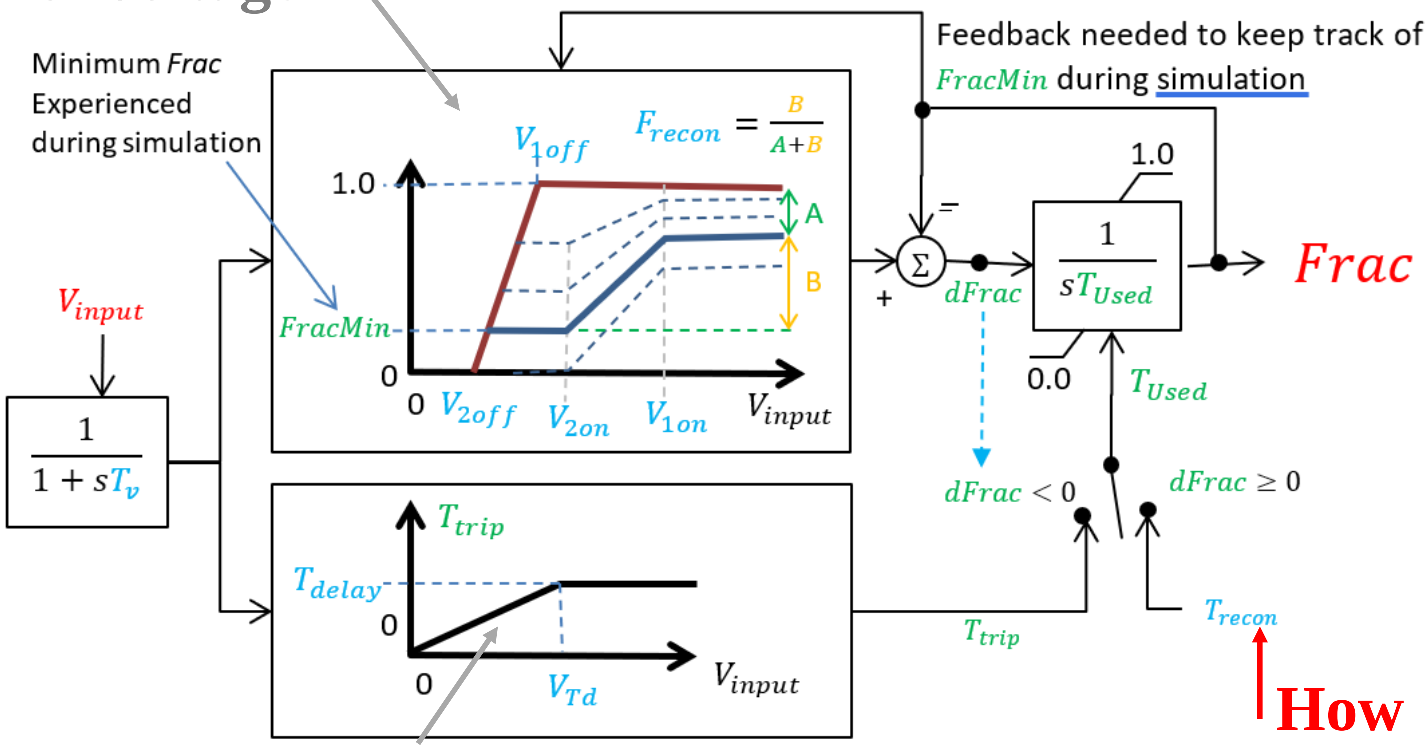
Describes "Steady State" behavior as function of voltage



How quickly does it transition to a new steady state for dropping fraction respond instantly to very low voltages

Progressive Tripping and Reconnecting (PTR)

Describes "Steady State" behavior as function of voltage

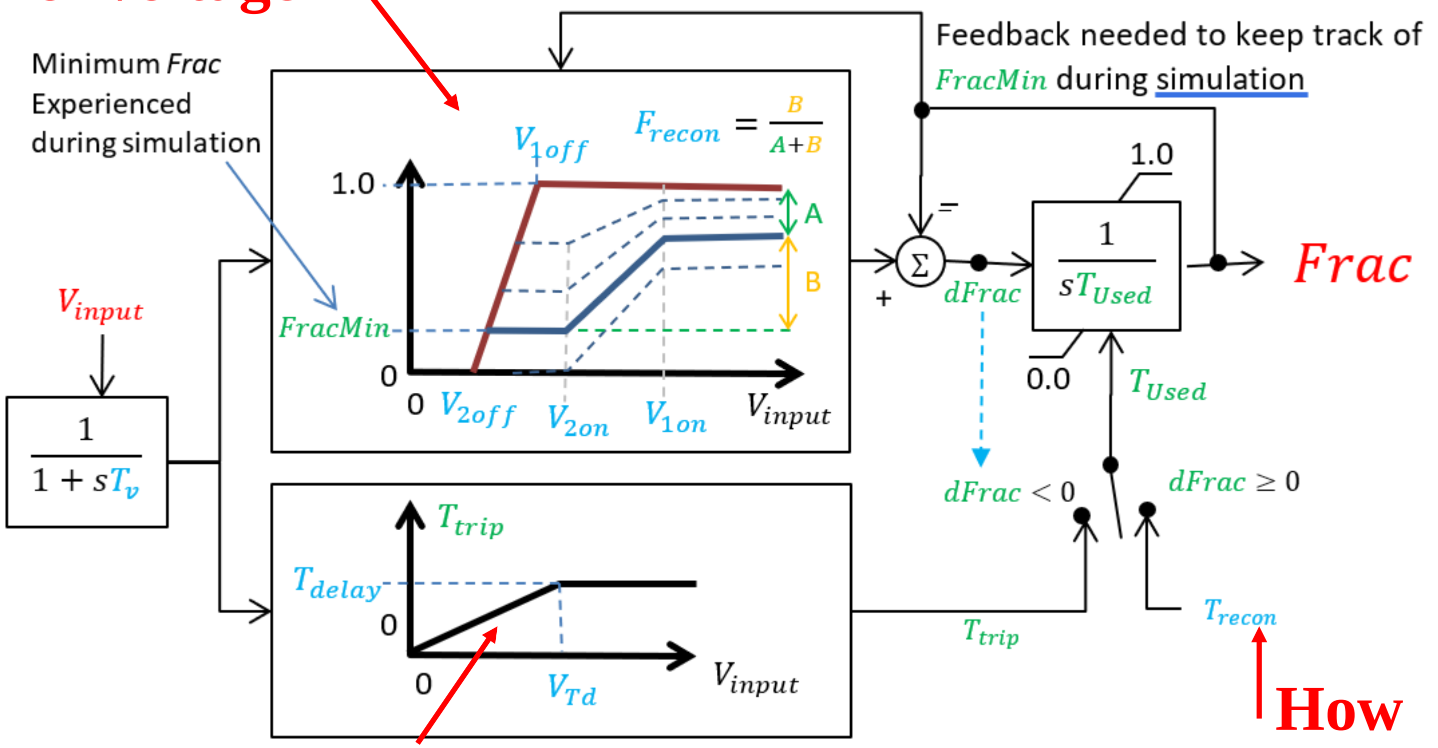


How quickly does it transition to a new steady state for dropping fraction

How quickly it reconnects

Progressive Tripping and Reconnecting (PTR)

Describes "Steady State" behavior as function of voltage

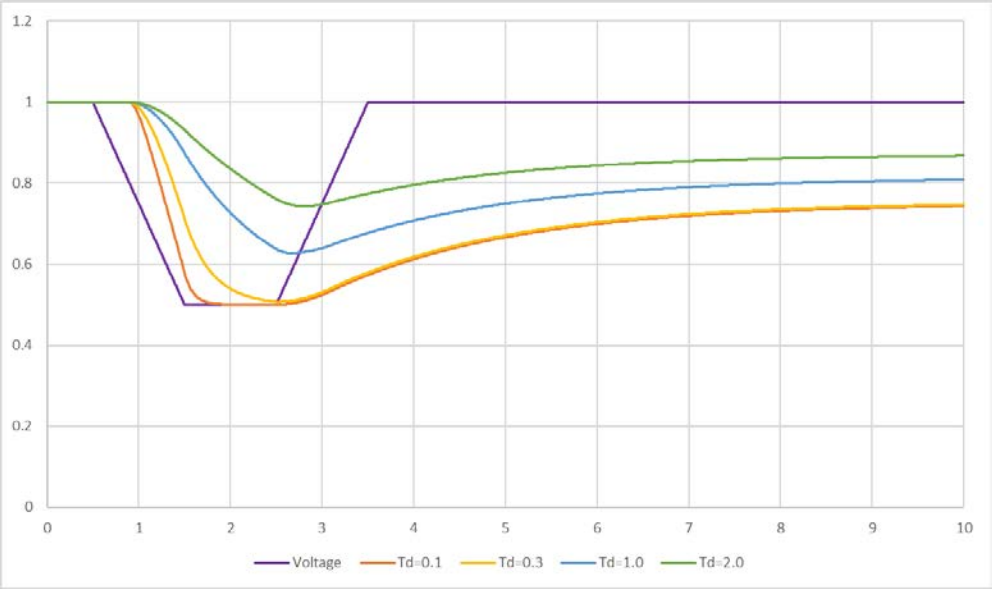


How quickly does it transition to a new steady state for dropping fraction

How quickly it reconnects

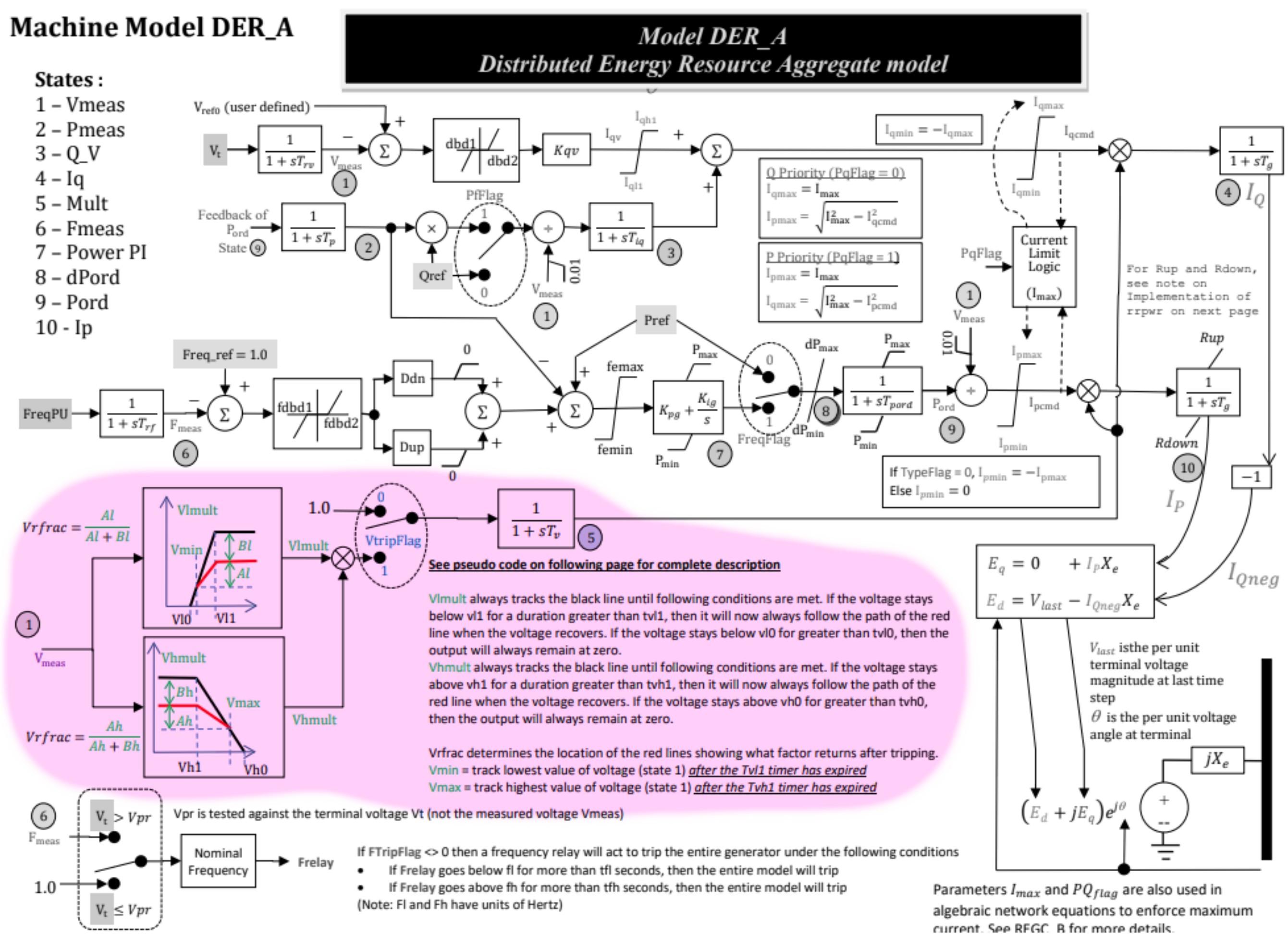
Input Parameters for PTR

T_v	Voltage measurement delay in seconds
V_{1off}	Voltage in per unit at which load fraction begins decreasing
V_{2off}	Voltage in per unit at which load fraction decreases to zero
V_{1on}	Voltage in per unit at which load fraction begins increasing
V_{2on}	Voltage in per unit at which load fraction increases back to [FracMin + Frecon*(1.0-FracMin)]
F_{recon}	Fraction of load that has been disconnected that will reconnect as voltage recovers
T_{delay}	Time delay use to approximate time vs voltage nature of load loss as the voltage is decreasing expressed in seconds
V_{td}	Voltage threhold below with the Time delay used starts decreasing toward 0 seconds at a voltage of 0
T_{recon}	Time delay use to approximate the reconnection of load as the voltage is increasing



I’m not that creative! DER_A has the same concept!

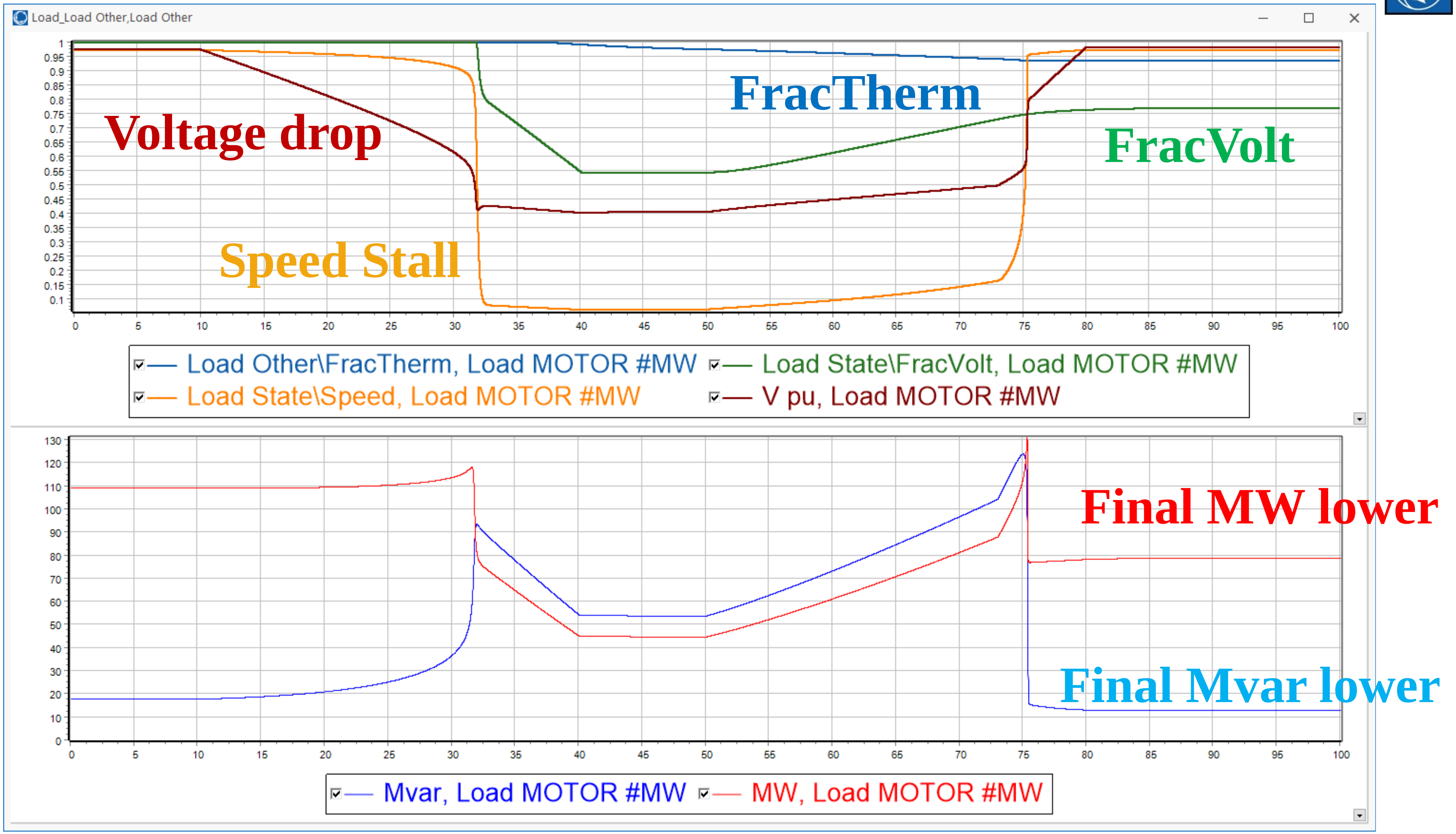
- Concept has already been used in DER_A!



INDMOT1P_PTR Model

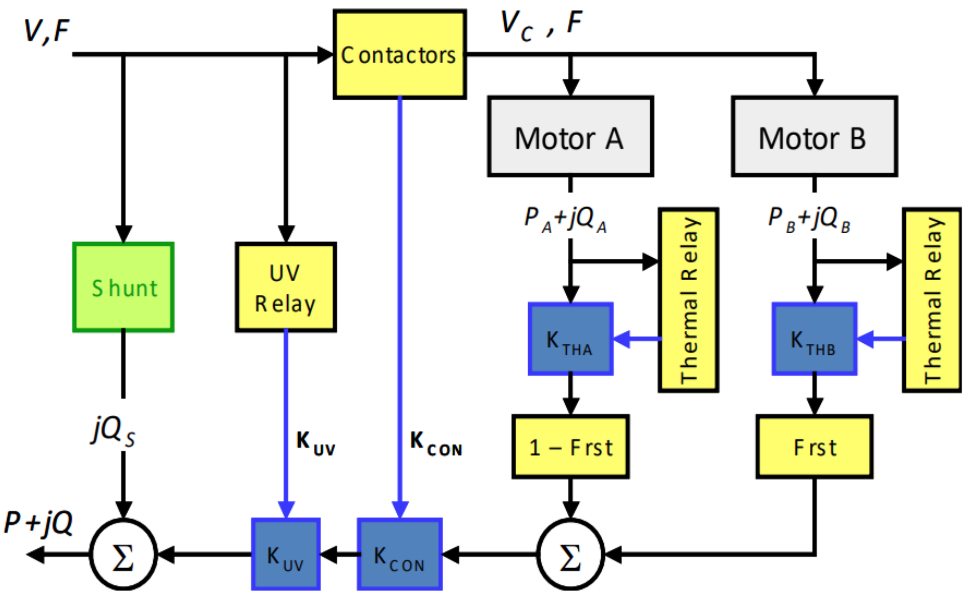
- Same as INDMOT1P, but with
  - Removes the modeling of magnetic saturation. The aSat term in the INDMOT1P model is assumed to be 1.0 for the entire simulation (no saturation)
  - Simplifies the mechanical torque equation to a single parameter Etrq: $T_{mech} = T_{nom}\left(\omega_r^{E_{trq}}\right)$
  - Models progressive tripping and reconnecting for under voltage (just described)
  - Models a thermal relay (same as LD1PAC)
- These equations are documented in great detail on PowerWorld's public help documentation on our website
  - Thanks to Joe Eto at Lawrence Berkeley National Lab for helping me make the time to write this all up
  - https://www.powerworld.com/WebHelp/Default.htm#TransientModels_HTML/Load%20Characteristic%20INDMOT1P_PTR.htm

INDMOT1P_PTR

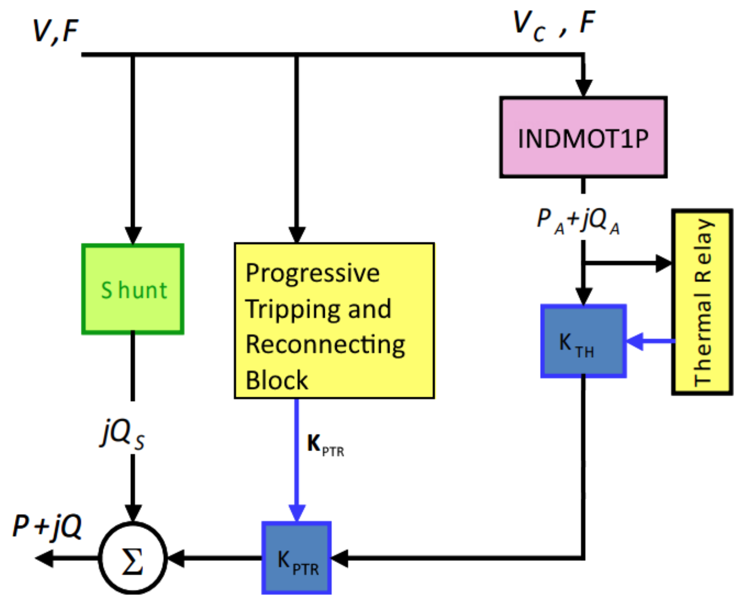


LD1PAC vs. INDMOT1P_PTR

LD1PAC



INDMOT1P_PTR



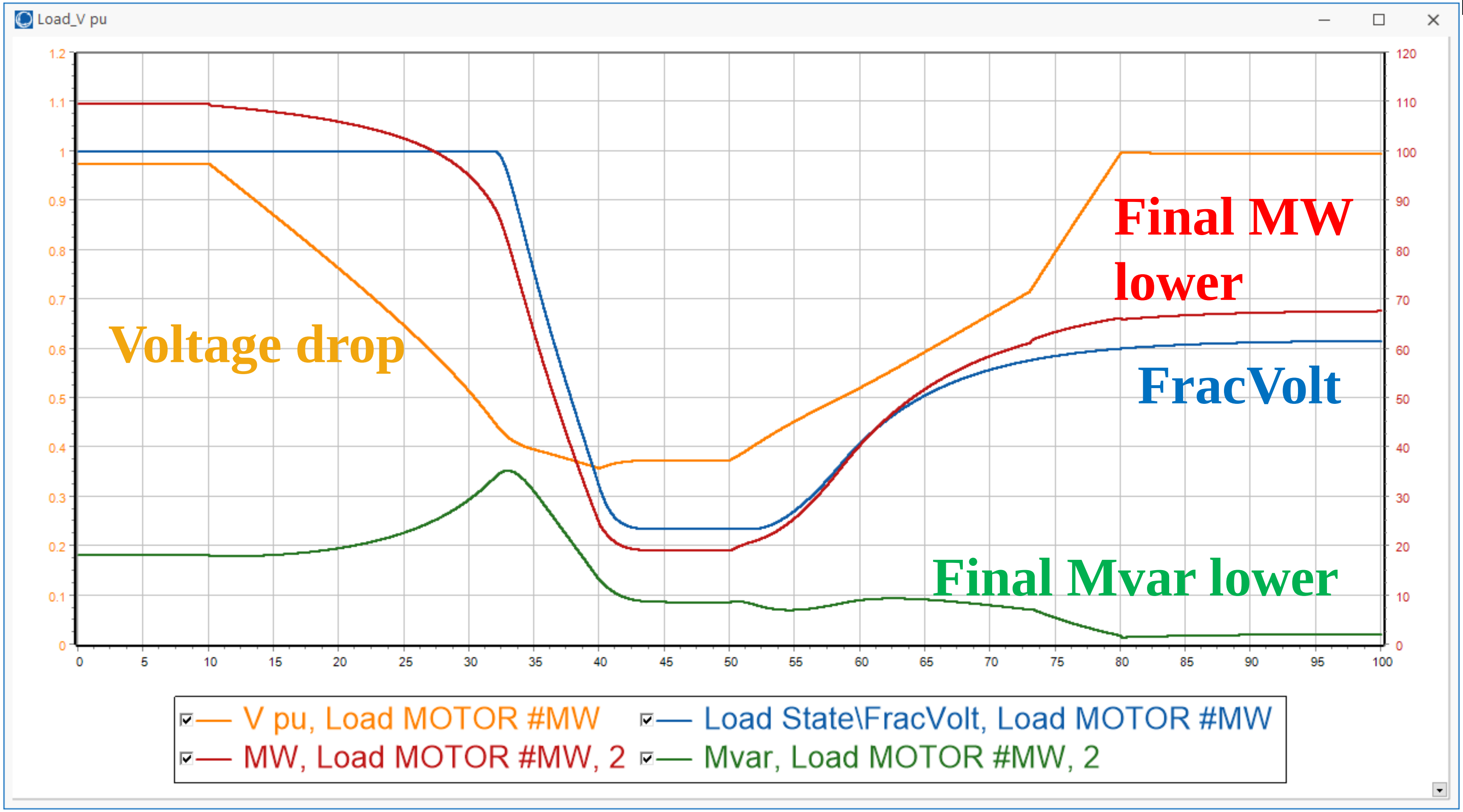
Motor may Restart or Not

- You could achieve this by adding two INDMOT1P_PTR models in the same modular load component mode
  - Big difference would be the torque exponent
    - $T_{mech} = T_{nom}\left(\omega_r^{E_{trq}}\right)$
  - Etrq = 0 (constant torque) → make restarting very difficult
    - Still a very big torque even at complete stall
  - Etrq = 2 (restart more likely)

CIM5_PTR Model

- Same as CIM5, but with
  - Removes the modeling of magnetic saturation
  - Replaces the definite time under voltage relays with progressive tripping and reconnecting for under voltage (just described)
  - Modification to network interface equation to include the impact of terminal frequency
- These equations are documented in great detail on PowerWorld's public help documentation on our website
  - https://www.powerworld.com/WebHelp/Default.htm#TransientModels_HTML/Load%20Characteristic%20CIM5_PTR.htm

CIM5_PTR



Load_V pu
Voltage drop
Final MW lower
FracVolt
Final Mvar lower
V pu, Load MOTOR #MW
Load State\FracVolt, Load MOTOR #MW
MW, Load MOTOR #MW, 2
Mvar, Load MOTOR #MW, 2

Summary: Discussion Items for Load Tripping

- Get comfortable with fractional tripping (we’ve always been doing that)
  - ONE set of equation, 1000s of loads
- Progressive Tripping and Reconnecting turns the fraction into a dynamic variable
  - Varies continuously instead of instantaneously
  - No more sudden block tripping (or reconnecting)
- INDMOT1P_PTR *merges* the concept of contactor and undervoltage tripping
  - These both are based on voltage
  - This is removing detail from the model so they can no longer be modeled separately
  - Still discussing if we should do this
- PTR concept can be applied to any load model
  - CIM5_PTR has been added as well for testing