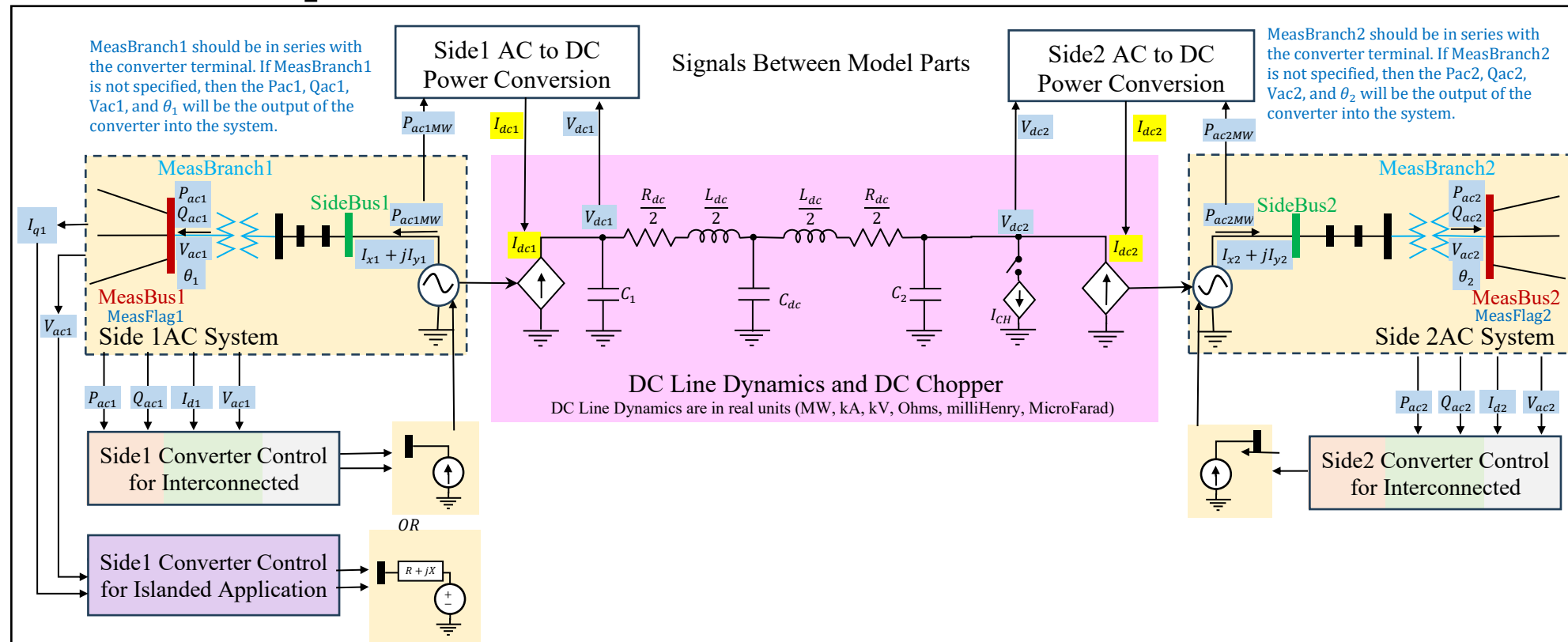
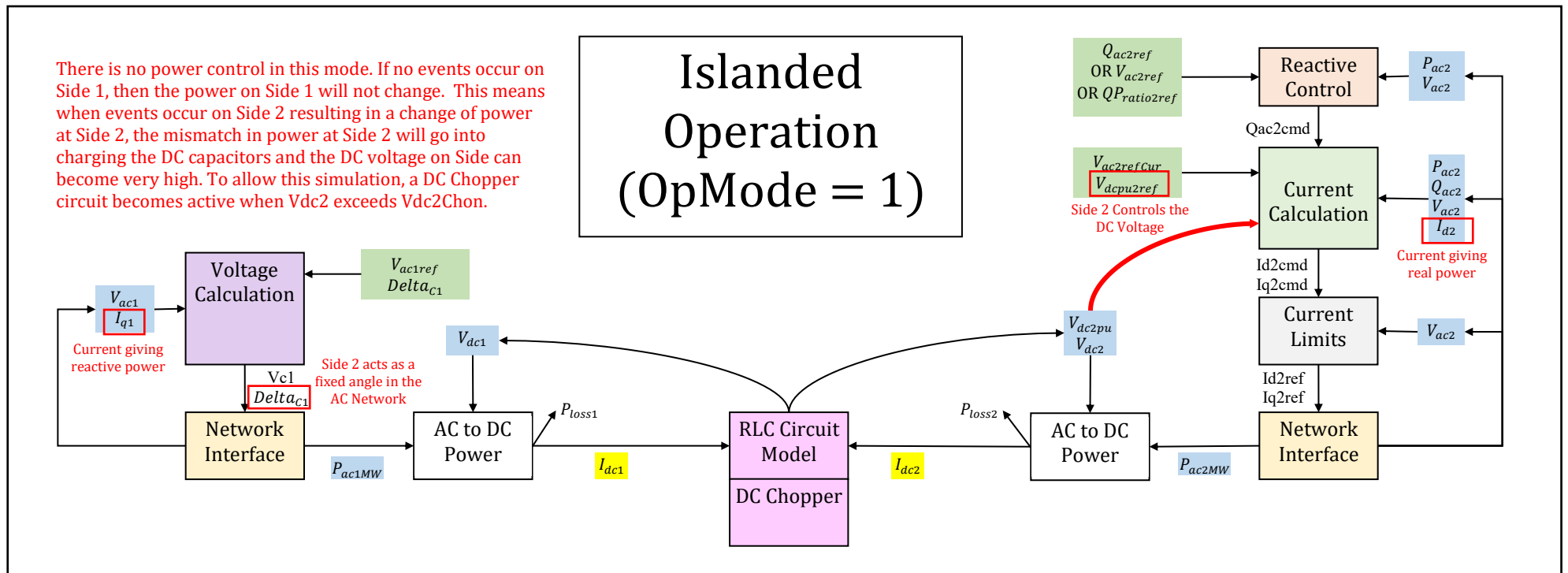
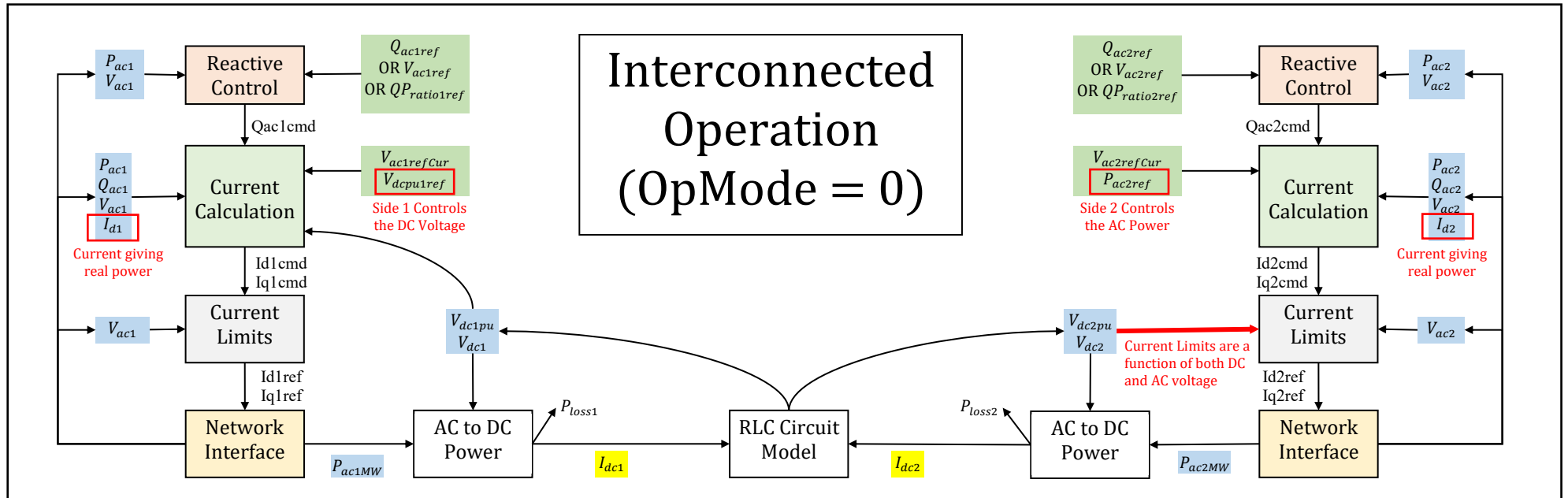


VSC DC Line VHVDC_A1

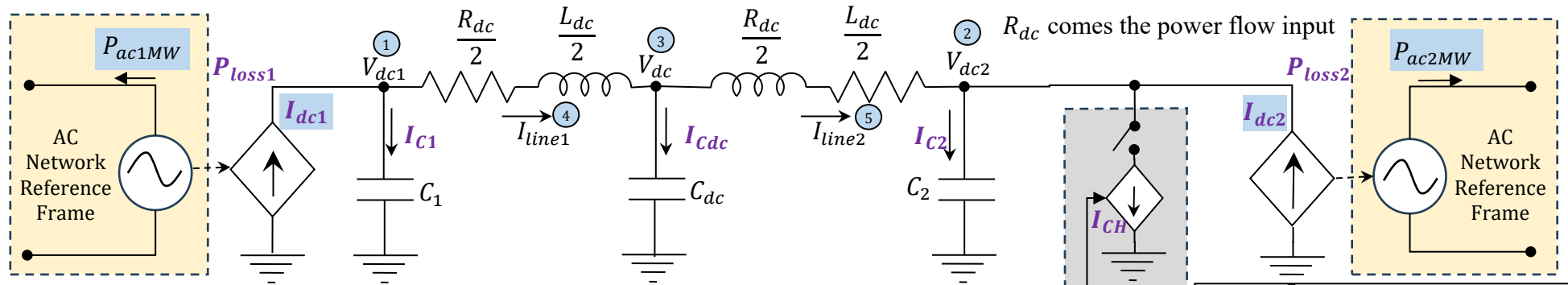


	States			
DC Dynamics and Chopper	1 – Vdc1 2 – Vdc2 3 – Vdc 4 – Iline1 5 – Iline2 6 – Ech 7 – Ichfb 8 – Ichint	09 – DeltaPLL1	Network Interface	26 – DeltaPLL2
		10 – DQac1V 11 – Qac1Q 12 – Qac1PF 13 – Vac1meas 14 – Pac1meas	Reactive Control	27 – DQac2V 28 – Qac2Q 29 – Qac2PF 30 – Vac2meas 31 – Pac2meas
		15 – Vdc1Int 16 – Id1meas 17 – Qac1Int 18 – Vac1measlong 19 – Vac1measf2	Current Calculation	32 – Vdc2Int 33 – Id2meas 34 – Qac2Int 35 – Vac2measlong 36 – Vac2measf2
		20 – Vac1measf1 21 – Id1max	Current Limits	37 – Vac2measf1 38 – Id2max 39 – Id2min
		22 – Vc1Int 23 – Tiq1fw 24 – Vac1wInt 25 – Tvac1measf3	Voltage Calculation	40 – PacInt 41 – PacrefRate

Other Fields				
DC Dynamics and Chopper	1 – Idc1	09 – Id1	Network Interface	24 – Id2
	2 – Idc2	10 – Iq1		25 – Iq2
	3 – Ploss1	11 – Frz1Q	Reactive Control	26 – Frz2Q
	4 – Ploss2	12 – Frz1QTimer		27 – Frz2QTimer
	5 – IC1	13 – Frz1QTimerAct		28 – Frz2QTimerAct
	6 – IC2	14 – Qac1cmd		29 – Qac2cmd
	7 – Icdc			
	8 – ICH			
		15 – Frz1	Current Calculation	30 – Frz2
		16 – Frz1Timer		31 – Frz2Timer
		17 – Frz1TimerAct		32 – Frz2TimerAct
		18 – Id1cmd		33 – Id2cmd
		19 – Iq1cmd		34 – Iq2cmd
		20 – Id1ref	Current Limits	35 – Id2ref
		21 – Iq1ref		36 – Iq2ref
		22 – Vc1	Voltage Calculation	
		23 – Deltac1		



DC Line Dynamics and DC Chopper



Units are: kA for DC Currents; kV for DC Voltages; MW for Power Values

The DC currents injections are calculated based on the power conservation for AC and DC side injections and the converter losses.

$$I_{dc1} = \frac{P_{dc1}}{V_{dc1}} = -\frac{P_{ac1mw} + P_{loss1}}{V_{dc1}}$$

$$P_{loss1} = \text{Max} \left(\frac{A_{loss1}}{1000} + B_{Loss1} |I_{dc1}|, \frac{P_{minloss1}}{1000} \right)$$

Where A_{loss1} , B_{loss1} , and $P_{minloss1}$ come from power flow input data for the voltage source converter on side 1. The same calculation is done for I_{dc2} and P_{loss2} where A_{loss2} , B_{loss2} , and $P_{minloss2}$ come from power flow input data for the voltage source converter on side 2. See details on computation later in this document.

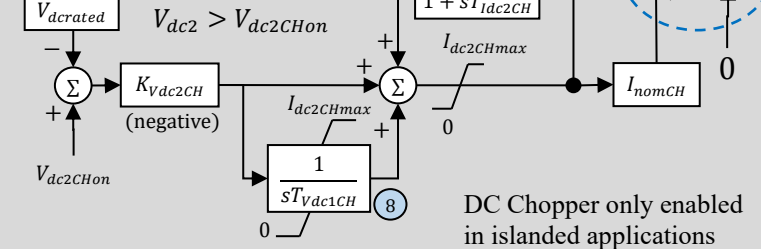
States

- 1 - Vdc1
2 - Vdc2
3 - Vdc
4 - Iline1
5 - Iline2
6 - Ech
7 - Ichfb
8 - Ichint

Other Fields

- 1 - Idc1
- 2 - Idc2
- 3 - Ploss1
- 4 - Ploss2
- 5 - IC1
- 6 - IC2
- 7 - Idc
- 8 - ICH

DC Chopper states initialize at 0 and will be activated when $H_{dc1} > H_{dc2}$



Energy Dissipated by Chopper is initialized to 0.0 and is then updated through during simulation using the equation $\frac{dE_{CH}}{dt} = V_{dc2}I_{CH}$. (6)

At each time-step if $E_{CH} > E_{CHmax}$ then HVDC line and chopper are tripped.

If ($C_{dc} > 0$) AND ($L_{dc} > 0$) use 5 equations

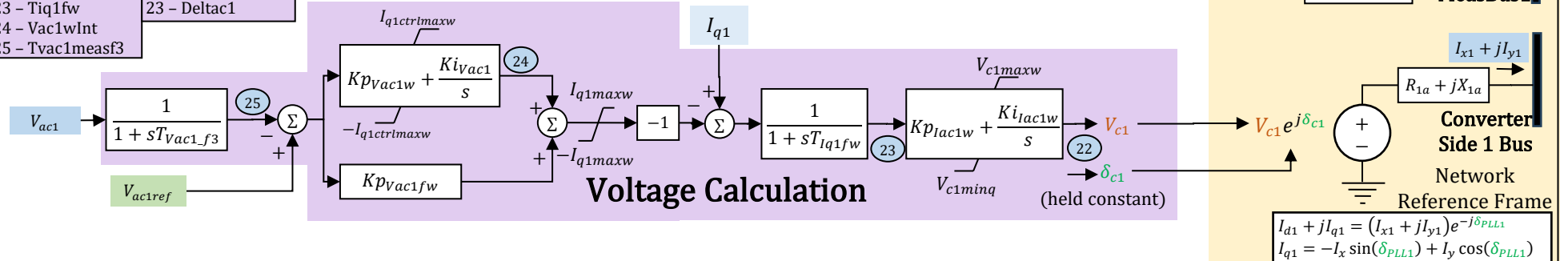
- $$\begin{aligned} (1) \quad C_1 \frac{dV_{dc1}}{dt} &= (I_{dc1} - I_{line1}) \\ (2) \quad C_2 \frac{dV_{dc2}}{dt} &= (I_{line2} - I_{CH} + I_{dc2}) \\ (3) \quad C_{dc} \frac{dV_{dc}}{dt} &= (I_{line1} - I_{line2}) \\ (4) \quad \frac{L_{dc}}{2} \frac{dI_{line1}}{dt} &= \left(V_{dc1} - V_{dc} - I_{line1} \frac{R_{dc}}{2} \right) \\ (5) \quad \frac{L_{dc}}{2} \frac{dI_{line2}}{dt} &= \left(V_{dc} - V_{dc2} - I_{line2} \frac{R_{dc}}{2} \right) \end{aligned}$$

Model requires that $C_1 > 0$ and $C_2 > 0$.
However the model supports setting $C_{dc} = 0$,
 $L_{dc} = 0$ or $R_{dc} = 0$ in any combination.

These 5 differential equations will be modified in various ways when combinations of these parameters are set to zero. See the section later in this help topic for more details.

Side 1 Converter Control for Islanded Operation

States	Other Fields
22 - Vc1Int	22 - Vc1
23 - Tiq1fw	23 - Deltac1
24 - Vac1wlnt	
25 - Tvac1measf3	

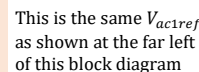


Model Parameters, Inputs and Outputs (Pac1, Qac1, Ix1, Iy1, Id1ref, Iq1ref) are in per unit on the ACMVABase of the Side2Bus' Converter from the power flow data of the VSCDCLine object.

See notes on a following page regarding the software implementation of Rate Limit States

Using contingency actions that “Change Converter Control Vref or Qref”, the value changed depends on the user parameter of **Qmode1Flag**.
 If **Qmode1Flag** = 0 Then Qac1ref changes
 If **Qmode1Flag** = 1 Then Vac1ref changes
 If **Qmode1Flag** = 2 Then QPRatio1ref changes.

Initialize
 $Q_{ac1ref} = Q_{ac1init}$



Id Limit Control

[illegible]

This is the same V_{dVref} as shown at the far left of this block diagram

Circular Current Limiting

$$I_{cmd1} = \sqrt{I_{d1in}^2 + I_{q1in}^2}$$

If $I_{cmd1} < I_{c1max}$ Then

$$I_{d1ref} = I_{d1in}$$

$$I_{q1ref} = I_{q1in}$$

Else

$$I_{d1ref} = I_{d1in} \left(\frac{I_{c1max}}{I_{cmd1}} \right)$$

$$I_{q1ref} = I_{q1in} \left(\frac{I_{c1max}}{I_{cmd1}} \right)$$

[illegible]

Side 2 Reactive Power and Main Converter Control for Interconnected and Islanded Operation

Model Parameters, Inputs and Outputs (Pac2, Qac2, Ix2, Iy2, Id2ref, Iq2ref) are in per unit on the ACMVABase of the Side2Bus' Converter from the power flow data of the VSCDCLine object.

States	Other Fields
26 - DeltaPLL2	24 - Id2
27 - DQac2V	25 - Iq2
28 - Qac2Q	26 - Frz2Q
29 - Qac2PF	27 - Frz2QTimer
30 - Vac2meas	28 - Frz2QTimerAct
31 - Pac2meas	29 - Qac2cmd
32 - Vdc2Int	30 - Frz2
33 - Id2meas	31 - Frz2Timer
34 - Qac2Int	32 - Frz2TimerAct
35 - Vac2measlong	33 - Id2cmd
36 - Vac2measf2	34 - Iq2cmd
37 - Vac2measf1	35 - Id2ref
38 - Id2max	36 - Iq2ref
39 - Id2min	
40 - PacInt	
41 - PacrefRate	

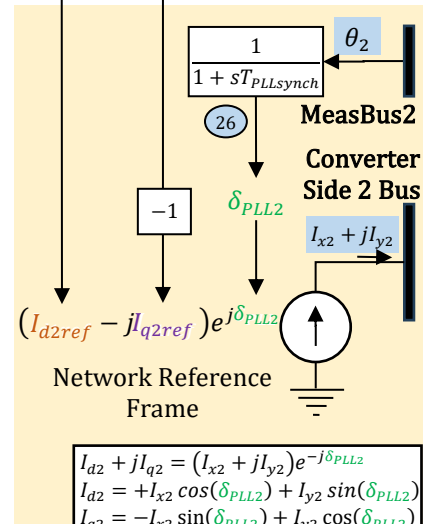
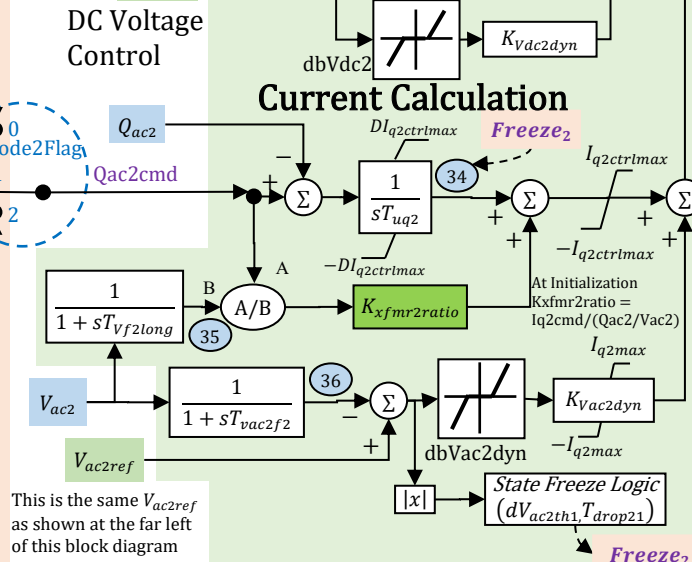
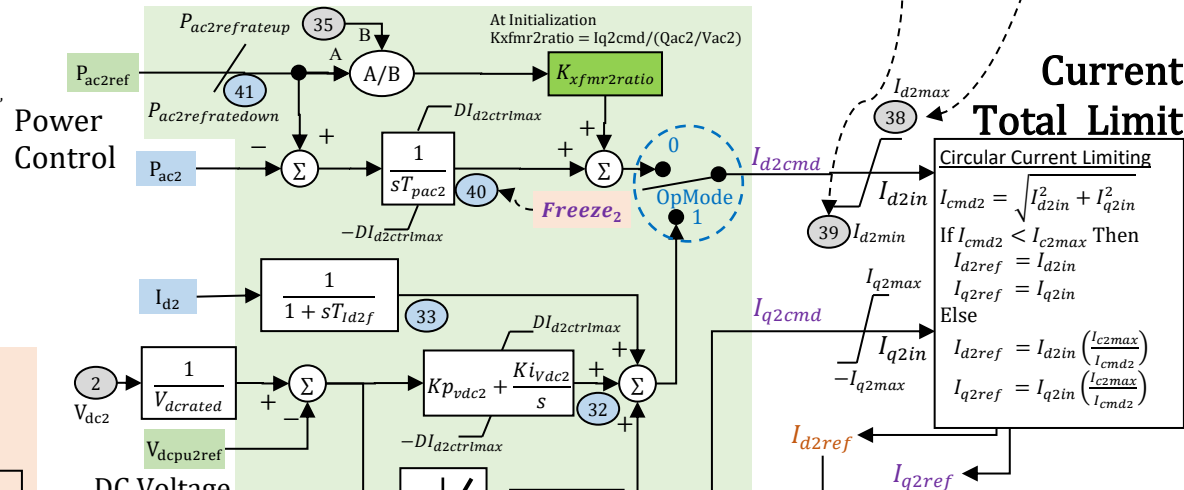
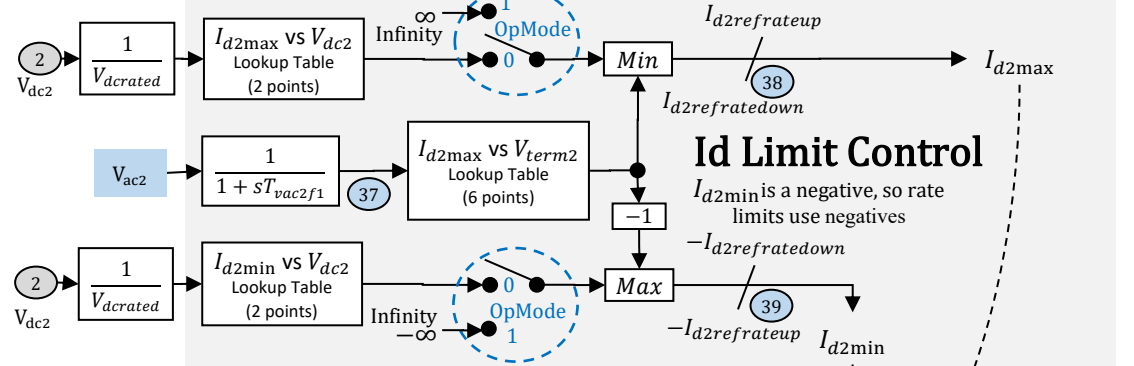
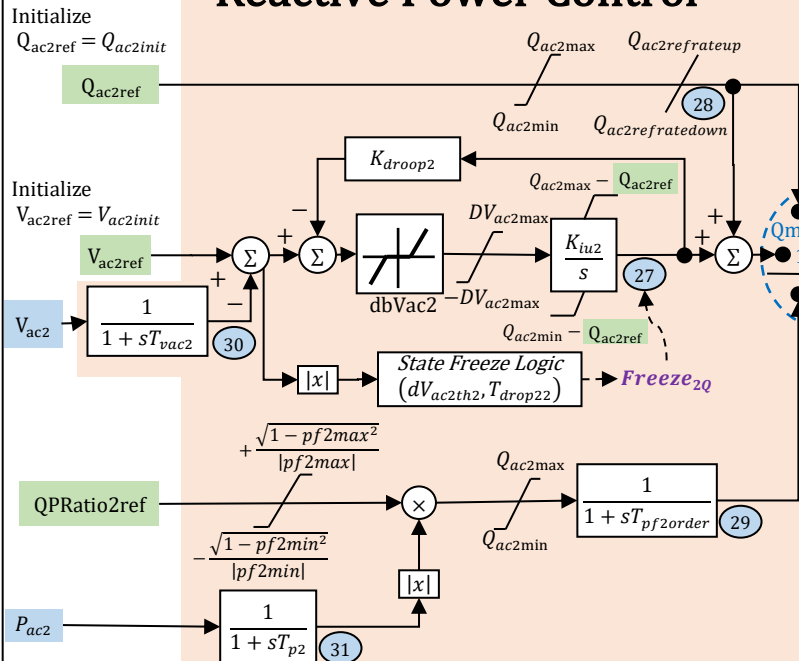
See notes on a following page regarding the software implementation of Rate Limit States

Also see notes on the PI controller state

Using contingency actions that "Change Converter Control Pref" will all change Pac2ref

Using contingency actions that "Change Converter Control Vref or Qref", the value changed depends on the user parameter of Qmode2Flag.
 If Qmode2Flag = 0 Then Qac2ref changes
 If Qmode2Flag = 1 Then Vac2ref changes
 If Qmode2Flag = 2 Then QPRatio2ref changes.

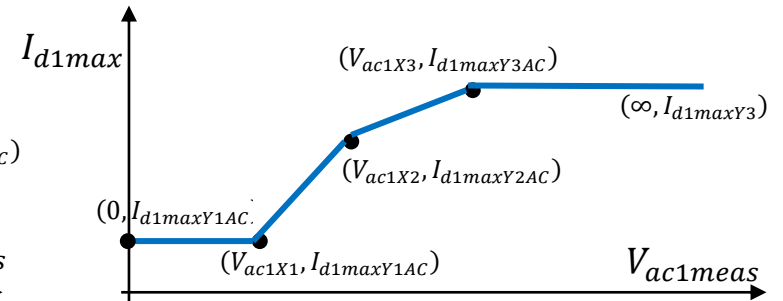
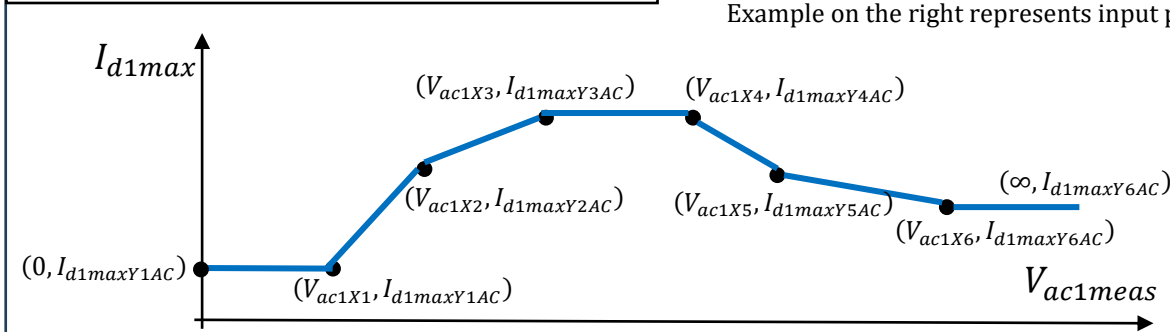
Reactive Power Control



Idmax vs Vac Lookup Tables

Both converter 1 and Converter 2 have lookup tables to get Idmax as a function of the AC voltage at MeasBus. The Lookup tables may have up to 6 x/y coordinate points. Values below the first point are treated as equal to the Y value of the first point. Values after the last specified point are treated as equal to the Y value of the last specified point. The picture represents the I_{d1max} versus V_{ac1} lookup table. An identical one exists for I_{d2max} versus V_{ac2} .

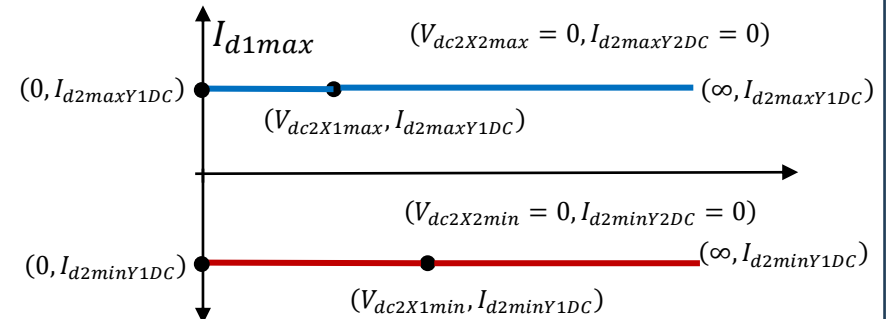
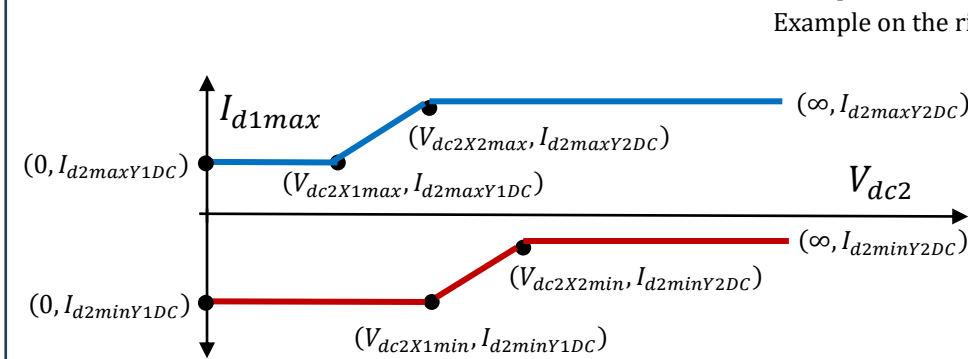
I_{d1max} versus V_{ac1} Lookup Table with up to 6 points.



Id2max vs Vdc Lookup Tables

Converter 2 has lookup tables to get both Id2max and Id2min as a function of the DC voltage. Each of these lookup tables has only 2 x/y coordinate points. Values below the first point are treated as equal to the Y value of the first point. Values after the last specified point are treated as equal to the Y value of the last specified point.

I_{d2max} and I_{d2min} versus V_{dc2} Lookup Table with 2 points.



Rate Limiters

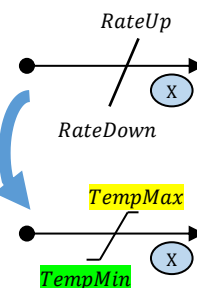
There are 6 sets of rate limits using the parameters.

(Qac2refrateup, Qac2refratedown) (Id1refrateup, Id1refratedown)
(Qac1refrateup, Qac1refratedown) (Id2refrateup, Id2refratedown)
(Pac2refrateup, Pac2refratedown)

Rate limiters are modelled algebraically by calculating a temporary minimum and maximum value at the beginning of each time step

$TempMax = StateX + TimeStep * RateUp$

$TempMin = StateX + TimeStep * RateDown$

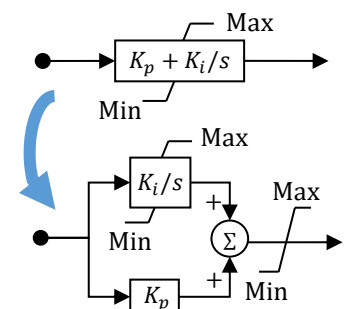


PI Controllers with Non-Windup Limits

There are 4 PI Controllers with non-windup limits. They are implemented as a K_p and K_i gains.

($K_pVdc1, KiVdc1$) ($K_pVac1w, KiVac1w$)
($K_pVdc2, KiVdc2$) ($K_pIac1w, KiIac1w$)

All PI Controllers will be implemented in software as shown in the bottom image to the right: an integrator state with non-windup limits with the same limits applied at the summation of the proportional and integral paths.



Description of a State Freeze Logic Blocks: Output is TRUE or FALSE

Inputs from block diagram

|X| : input from block diagram into freeze decision block is the absolute value of an AC voltage deviation from a reference

PresentTime : the present time of the simulation

Modal Input Parameters related to State Freeze Block

dVActh : deviation of X value at which state freezing occurs (done for both high and low deviations)

Tdrop : seconds that must elapse after voltage recovers before the state will unfreeze

Variables stored with the Model for a particular State Freeze Block

FreezeState : boolean // Initialize as FALSE - specifies whether state is frozen
UnFreezeTimerActive : boolean // Initialize as FALSE - specifies whether the UnfreezeTimer is active
UnFreezeTimerStart : single // Initialize as 0 stores the time at which voltage first recovers

Timer Logic that must be run each time-step of the numeric simulation

```
If |X| >= dVacth Then // Falling edge for low voltages because deviation from Vacref is large
    FreezeState = TRUE
    UnFreezeTimerActive = FALSE // must reset this timer to prevent accumulation for repeated
    voltage changes
Else // "Rising" edge after a low voltages deviation because we are back close to Vacref
    If FreezeState Then // Need to see if we should unfreeze
        If UnFreezeTimerActive = FALSE Then
            UnFreezeTimerActive = TRUE // activate timer
            UnFreezeTimerStart = PresentTime // start the timer by setting to present time
        Else
            If (PresentTime - UnFreezeTimerStart) >= Tdrop Then
                FreezeState = FALSE
                UnFreezeTimerActive = FALSE // must reset for next use
            EndIf
        EndIf
    EndIf
EndIf
```

AC to DC Power Conversion for Side 1 and Side2

This calculation takes the PacMW and Vdc values and calculates the Idc current injection and Ploss of the converter

$$I_{dc} = -\frac{(P_{acmw} + P_{loss})}{V_{dc}} \text{ and } P_{loss} = \max\left[\frac{A_{loss}}{1000} + B_{loss}|I_{dc}|, \frac{P_{minloss}}{1000}\right]$$

Assume for now that Idc is positive and the parameter Pminloss less than the final loss amount. That means

$$I_{dc}V_{dc} = -\left(P_{acmw} + \frac{A_{loss}}{1000} + B_{loss}I_{dc}\right) \rightarrow I_{dc}V_{dc} + B_{loss}I_{dc} = -\left(P_{acmw} + \frac{A_{loss}}{1000}\right)$$

Thus $I_{dc} = -\frac{(P_{acmw} + \frac{A_{loss}}{1000})}{V_{dc} + B_{loss}}$. Use this equation along with approximations to avoid divide by zero and you can calculate the I_{dc} and P_{loss} based only on the inputs PacMW and Vdc.

User parameters from the Power Flow object. These values must be >= 0

Pminloss : in kW
Aloss : in kW
Bloss : in MW/kA

Inputs this calculation

PacMW : in MW
Vdc : in kV

Local Variable in calculation

VdcUsed : in kV
BlossSigned : in MW/kA

Values being calculated

Idc : in kA
Ploss : in MW

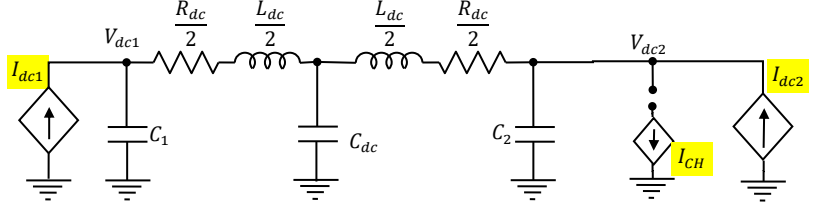
```
// prevent numeric problems for unrealistic situation when Vdc is very low
VdcUsed = Vdc
If VdcUsed < 0.1 then VdcUsed = 0.1 EndIf
If (PacMW+Aloss/1000) > 0) Then
    BlossSigned = -Bloss // Idc will be negative so flip sign of Bloss
Else
    BlossSigned = +Bloss
EndIf
If (VdcUsed + BlossSigned) < 0.1 Then
    Idc = -(PacMW+Aloss/1000) / 0.1
Else
    Idc = -(PacMW+Aloss/1000) / (VdcUsed + BlossSigned)
End
Ploss = Aloss/1000 + BlossSigned*Idc
If Ploss < Pminloss/1000 Then
    Idc = -(PacMW+PminLoss/1000) / VdcUsed
    Ploss = PminLoss/1000
EndIf
```

DC Circuit Natural Frequency Calculation to determine when to ignore Cdc

PowerWorld attempts to ensure that the maximum natural frequency does not result in a oscillation period which is smaller than 8 time-steps. If it does, PowerWorld may take the value of C_{dc} and split it between the sides of the model and internally treat $C_{1used} = C_1 + \frac{C_{dc}}{2}$; $C_{2used} = C_2 + \frac{C_{dc}}{2}$; $C_{dcused} = 0$. PowerWorld Simulator also uses the natural frequencies to inform how many internal subintervals to use for numerical integration. Details are shown below.

Natural Frequency of the DC circuit

Assuming that the control systems creating I_{dc1} and I_{dc2} have much slower oscillations than the DC circuit, then we can concentrate only on the natural frequency of oscillation for the DC circuit by itself. There are 2 two frequencies of oscillation for this.



	Mode	Natural Frequency	Natural Frequency for $C_{dc} = 0$	Natural Frequency $C_1 = C_2$ and $R_{dc} = 0$
ω_{c12}	C_1 and C_2 oscillation against L_{dc}	$\sqrt{+\frac{1}{L_{dc}}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{2}{C_{dc}}\right) - \frac{1}{L} \sqrt{\left(\frac{1}{C_1} - \frac{1}{C_2}\right)^2 + \frac{4}{C_{dc}^2}} - \left(\frac{R_{dc}}{2L_{dc}}\right)^2}$	$\sqrt{+\frac{1}{L_{dc}}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) - \left(\frac{R_{dc}}{2L_{dc}}\right)^2}$	$\sqrt{\frac{2}{L_{dc}C_1}}$
ω_{cdc}	C_1 and C_2 oscillation against C_{dc}	$\sqrt{+\frac{1}{L_{dc}}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{2}{C_{dc}}\right) + \frac{1}{L} \sqrt{\left(\frac{1}{C_1} - \frac{1}{C_2}\right)^2 + \frac{4}{C_{dc}^2}} - \left(\frac{R_{dc}}{2L_{dc}}\right)^2}$	Infinite (∞)	$\sqrt{+\frac{2}{L_{dc}}\left(\frac{1}{C_1} + \frac{2}{C_{dc}}\right)}$

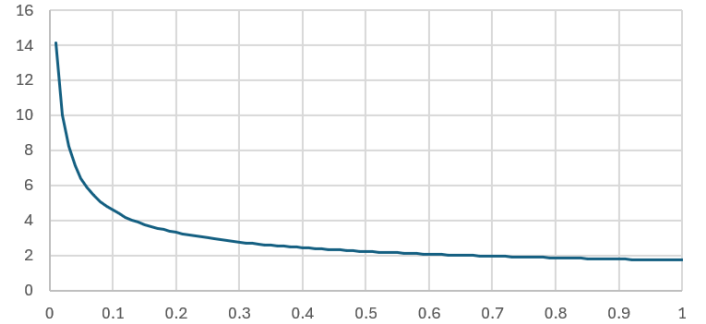
$\omega_{cdc} > \omega_{c12}$ always, and in particular if the value of $C_{dc} < C_1$, then ω_{cdc} will become very large. A common set of input parameters for a short VSC DC Line may have relative large values of C_1 while C_{dc} is very small. This can create extremely high oscillation frequencies that are not relevant for positive sequence simulation.

To better understand, assume $C_1 = C_2$, $R_{dc} = 0$, and $C_{dc} = kC_1$ (where k is a scalar multiplier). You can then show that

$$\omega_{cdc} = \omega_{c12} \sqrt{\frac{k+2}{k}}$$

which expresses one frequency as a multiple of the other.

The figure on the right shows a plot of $\sqrt{\frac{k+2}{k}}$ versus k . Small values of k will result in very high frequencies that can not be simulated in our positive sequence simulations.



PowerWorld attempts to ensure that the maximum natural frequency does not result in a oscillation period which is smaller than 8 time-steps. If it does, PowerWorld may take the value of C_{dc} and split it between the sides of the model and internally treat $C_{1used} = C_1 + \frac{C_{dc}}{2}$; $C_{2used} = C_2 + \frac{C_{dc}}{2}$; $C_{dcused} = 0$. PowerWorld Simulator also uses the natural frequencies to inform how many internal subintervals to use for numerical integration. PowerWorld always rounds up to a number of subintervals that is a power of 2. The equations used to inform the number of subintervals are as follows.

If $C_{dcused} = 0$

$$\text{Then } \omega_{natural} = \sqrt{+\frac{1}{L}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) - \left(\frac{R_{dc}}{2L_{dc}}\right)^2}$$

$$\text{Else } \omega_{natural} = \sqrt{\frac{1}{L_{dc}}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{2}{C_{dc}}\right) + \frac{1}{L} \sqrt{\left(\frac{1}{C_1} - \frac{1}{C_2}\right)^2 + \frac{4}{C_{dc}^2}} - \left(\frac{R_{dc}}{2L_{dc}}\right)^2}$$

If $\omega_{natural} > \left(\frac{2\pi}{8*TimeStep}\right)$ then treat $L_{dc} = 0$ and model only R_{dc} , C_1 , and C_2

Number of Subintervals = $256 * \left(\frac{\omega_{natural}}{\frac{2\pi}{8*TimeStep}}\right)$, then round up to a power of 2, but no larger than 128.

DC Circuit Handle Equations as Terms become zero

This model requires $C_1 > 0$ and $C_2 > 0$. These are fundamental parts of the voltage source converter and a value of zero does not make sense. In the software minimum values of 5 microFarad are enforced for both. Other parameters in the DC circuit model are allowed to be equal to zero ($C_{dc} \geq 0$, $L_{dc} \geq 0$, or $R_{dc} \geq 0$). Also if ($R_{dc} < 0.01$) and ($L_{dc} = 0$), then we assume $R_{dc} = 0$. The equations used then vary as shown below.

Color Coding for Equations Original Dynamic Equations in Blue Algebraic Equations in Red Modified Dynamic Equations in Green	Original Dynamic States in Blue V_{dc1} Algebraic States in Red V_{dc} Modified Dynamic State in Green I_{line1} Inputs to circuit I_{dc1}
If ($C_{dc} > 0$) AND ($L_{dc} > 0$) Then // ($R_{dc} \geq 0$) (1) $(C_1) \frac{dV_{dc1}}{dt} = (I_{dc1} - I_{line1})$ (2) $(C_2) \frac{dV_{dc2}}{dt} = (I_{line2} - I_{CH} + I_{dc2})$ (3) $(C_{dc}) \frac{dV_{dc}}{dt} = (I_{line1} - I_{line2})$ (4) $\left(\frac{L_{dc}}{2}\right) \frac{dI_{line1}}{dt} = \left(V_{dc1} - V_{dc} - I_{line1} \frac{R_{dc}}{2}\right)$ (5) $\left(\frac{L_{dc}}{2}\right) \frac{dI_{line2}}{dt} = \left(V_{dc} - V_{dc2} - I_{line2} \frac{R_{dc}}{2}\right)$	$[(C_{dc} > 0), (L_{dc} > 0), (R_{dc} > 0)]$ OR $[(C_{dc} > 0), (L_{dc} > 0), (R_{dc} = 0)]$
Else If ($R_{dc} = 0$) AND ($L_{dc} = 0$) Then // ($C_{dc} \geq 0$) (1) $\frac{dV_{dc1}}{dt} = \frac{1}{C_1 + C_2 + C_{dc}} (I_{dc1} + I_{dc2} - I_{CH})$ (2) $V_{dc2} = V_{dc1}$ (3) $V_{dc} = V_{dc1}$ (4) $I_{line1} = \frac{+I_{dc1}(C_2 + C_{dc}) - (I_{dc2} - I_{CH})(C_1)}{C_1 + C_2 + C_{dc}}$ (5) $I_{line2} = \frac{+I_{dc1}(C_2) - (I_{dc2} - I_{CH})(C_1 + C_{dc})}{C_1 + C_2 + C_{dc}}$	$[(C_{dc} > 0), (L_{dc} = 0), (R_{dc} = 0)]$ OR $[(C_{dc} = 0), (L_{dc} = 0), (R_{dc} = 0)]$ Current equations come from current divider to get (4) and (5) $I_{c1} = (I_{dc1} + I_{dc2} - I_{CH}) \frac{C_1}{(C_1 + C_2 + C_{dc})}$ $I_{c2} = (I_{dc1} + I_{dc2} - I_{CH}) \frac{C_2}{(C_1 + C_2 + C_{dc})}$ $I_{line1} = +I_{dc1} - I_{c1}$ $I_{line2} = -I_{dc2} + I_{CH} + I_{c2}$
Else If ($C_{dc} = 0$) AND ($L_{dc} > 0$) Then // ($R_{dc} \geq 0$) (1) $(C_1) \frac{dV_{dc1}}{dt} = (I_{dc1} - I_{line1})$ (2) $(C_2) \frac{dV_{dc2}}{dt} = (I_{line2} - I_{CH} + I_{dc2})$ (3) $V_{dc} = \frac{1}{2} (V_{dc1} + V_{dc2})$ (4) $(L_{dc}) \frac{dI_{line1}}{dt} = (V_{dc1} - V_{dc2} - I_{line1} R_{dc})$ (5) $I_{line2} = I_{line1}$	$[(C_{dc} = 0), (L_{dc} > 0), (R_{dc} > 0)]$ OR $[(C_{dc} = 0), (L_{dc} > 0), (R_{dc} = 0)]$
Else If ($C_{dc} = 0$) AND ($L_{dc} = 0$) Then // ($R_{dc} > 0$) (1) $(C_1) \frac{dV_{dc1}}{dt} = (I_{dc1} - I_{line1})$ (2) $(C_2) \frac{dV_{dc2}}{dt} = (I_{line2} - I_{CH} + I_{dc2})$ (3) $V_{dc} = \frac{1}{2} (V_{dc1} + V_{dc2})$ (4) $I_{line1} = \frac{(V_{dc1} - V_{dc2})}{R_{dc}}$ (5) $I_{line2} = I_{line1}$	$[(C_{dc} = 0), (L_{dc} = 0), (R_{dc} > 0)]$
Else If ($L_{dc} = 0$) Then // ($R_{dc} > 0$) AND ($C_{dc} > 0$) (1) $(C_1) \frac{dV_{dc1}}{dt} = (I_{dc1} - I_{line1})$ (2) $(C_2) \frac{dV_{dc2}}{dt} = (I_{line2} - I_{CH} + I_{dc2})$ (3) $(C_{dc}) \frac{dV_{dc}}{dt} = (I_{line1} - I_{line2})$ (4) $I_{line1} = \frac{2}{R_{dc}} (V_{dc1} - V_{dc})$ (5) $I_{line2} = \frac{2}{R_{dc}} (V_{dc} - V_{dc2})$	$[(C_{dc} > 0), (L_{dc} = 0), (R_{dc} > 0)]$

Object Parameters

MeasBus1	OtherObject:0	Measurement Bus 1. This is the terminal bus of the Measurement Branch 1 at which Qac1, Pac1, Vac1 and Theta1 are measured. Note that the parameter MeasFlag1 determines whether the flow is measured into or out of the branch.
MeasBranch1	OtherObject:1	Measurement Branch 1. Branch on which Qac1 and Pac1 are measured. This branch should be in series with the VSCDCLine on the SideBus1 side of the VSCDCLine, but does not have to be directly connected to the terminal SideBus1. If MeasBranch1 is not specified, then the Qac1 and Pac1 will be the output of the converter on Side 1 into the AC system, and Vac1 and Theta1 will be at the Side1Bus converter terminal.
MeasBus2	OtherObject:2	Measurement Bus 2. This is the terminal bus of the Measurement Branch 2 at which Qac2, Pac2, Vac1 and Theta1 are measured. Note that the parameter MeasFlag2 determines whether the flow is measured into or out of the branch.
MeasBranch2	OtherObject:3	Measurement Branch 2. Branch on which Qac2 and Pac2 are measured. This branch should be in series with the VSCDCLine on the SideBus2 side of the VSCDCLine, but does not have to be directly connected to the terminal SideBus2. If MeasBranch2 is not specified, then the Qac2 and Pac2 will be the output of the converter on Side 2 into the AC system, and Vac2 and Theta2 will be at the Side2Bus converter terminal.

Parameters that are taken from the Power Flow Data input for VSCDCLine

Rdc	Resistance in Ohms of the DC Line used in the DC Line Model
ACMVABase1	For converter at the Side1Bus, Maximum AC MVA which is used as the ACMVABase for the converter dynamic model
Aloss1	For converter at the Side1Bus, Constant term of the converter loss function [kW]
Bloss1	For converter at the Side1Bus, Linear term of the converter loss function [MW per kA] or [kW per Amp]
Pminloss1	For converter at the Side1Bus, Minimum loss of the converter [kW]
ACMVABase2	For converter at the Side2Bus, Maximum AC MVA which is used as the ACMVABase for the converter dynamic model
Aloss2	For converter at the Side2Bus, Constant term of the converter loss function [kW]
Bloss2	For converter at the Side2Bus, Linear term of the converter loss function [MW per kA] or [kW per Amp]
Pminloss2	For converter at the Side2Bus, Minimum loss of the converter [kW]

Integer Parameter Flags

0	OpMode	0=Interconnection; 1=Islanded operation (for example an off-shore wind farm) (default = 0)
1	Qmode1Flag	Side-1 Q control mode: 0=Q; 1=QV; 2=PF (default = 0)
2	Qmode2Flag	Side-2 Q control mode: 0=Q; 1=QV; 2=PF (default = 0)
3	MeasFlag1	0 indicate that positive flow for MeasBranch1 is leaving MeasBus1 going out to the line. 1 indicate that positive flow for MeasBranch1 is arriving at MeasBus1 coming in from the line.
4	MeasFlag2	0 indicate that positive flow for MeasBranch2 is leaving MeasBus2 going out to the line. 1 indicate that positive flow for MeasBranch2 is arriving at MeasBus2 coming in from the line.

Float Parameters

Network Interface	0	TPLLsync	If <2*ΔT use 0 If <4*ΔT use 4*ΔT	PLL synchronization time constant for both Side 1 and Side 2 [seconds]	0.05
	1	R1a		Side 1 arm resistance in per unit on Side 1 ACMVABase	0.10
	2	X1a		Side 1 arm resistance in per unit on Side 1 ACMVABase	0.10
DC Line Model	3	Vdcrated		Rated DC voltage of the converters [kV]	525.0
	4	Ldc	If <0 use 0	DC line total inductance [milli Henry]	129.3
	5	Cdc	If <0 use 0	DC line total capacitance [micro Farad]	140.5
	6	C1	If <5 use 5	Equivalence Capacitance of Side 1 converter [micro Farad]	221.7
	7	C2	If <5 use 5	Equivalence Capacitance of Side 2 converter [micro Farad]	221.7

Main Converter Control on Side 1 for Interconnection Applications	8	Tvac1f2	If <4*ΔT use 0	Side 1, Second AC voltage filter time constant [s]	0.02
	9	TId1f	If <4*ΔT use 4*ΔT	Side 1, Id filter time constant (>0) [s]	0.02
	10	Tvfllong	If <4*ΔT use 0	Side 1, AC voltage filter long time constant [s]	60.0
	11	Tuq1	If <4*ΔT use 4*ΔT	Side 1, Integral time of Iq controller (>0) [s]	10.0
	12	DIqlctrlmax	Use +(absolute value)	Side 1, Maximum Delta Iq control limit [pu]	0.3
	13	Iqlctrlmax	Use +(absolute value)	Side 1, Maximum Iq control limit [pu]	0.35
	14	Iqlmax		Side 1, Maximum Iq limit [pu]	1.1
	15	Kvacldyn		Side 1, Vac error gain during faults	1.0
	16	dbVacldyn	Use +(absolute value)	Side 1, Deadband Uac error in faults [pu]	0.1
	17	dVac1th1	Use +(absolute value)	Side 1, First high AC voltage error threshold [pu]	0.1
	18	Tdrop11		Side 1, First delay of high AC voltage error [s]	0.01
	19	dbVdc1	Use +(absolute value)	Side 1, Deadband of DC voltage error [pu]	0.01
	20	KVdcldyn		Side 1, Feedforward Vdc gain	6.0
	21	KpVdc1		Side 1, Gain of Proportional control of DC PI controller	4.0
	22	KiVdc1		Side 1, Gain of Integral control of DC PI controller (>=0. Zero allowed.) [1/s]	0.05
	23	DIIdlctrlmax	Use +(absolute value)	Side 1, Maximum Delta Id control limit [pu]	0.3
	24	Idlrefrateup	Use +(absolute value)	Side 1, Id limit ramp-up rate [pu/s]. Up is defined as away from zero, therefore this is used in negative ramp direction for Id1min.	9.0
	25	Idlrefratedown	Use -(absolute value)	Side 1, Id limit ramp-down rate [pu/s]. Down is defined as towards zero, therefore this is used in positive ramp direction for Id1min.	-9999
Reactive Power Control on Side 1 for Interconnection Applications	26	TVac1	If <4*ΔT use 0	Side 1, Q Control Vac filter time constant [s]	0.02
	27	TP1	If <4*ΔT use 0	Side 1, Q Control P filter time constant [s]	0.5
	28	Tpflorder	If <4*ΔT use 0	Side 1, Smoothing time constant of PF order [s]	1.0
	29	dbVac1	Use +(absolute value)	Side 1, Deadband QV control [pu]	0.0
	30	DVac1max		Side 1, Maximum AC voltage error in Q-V control [pu]	0.2
	31	Kiul		Side 1, Proportional gain QV control [pu]	20.0
	32	Kdroop1		Side 1, Inverse droop in deltaV/deltaQ [pu]	0.1
	33	dVac1th2	Use +(absolute value)	Side 1, Second high AC voltage error threshold [pu]	0.18
	34	Tdrop12		Side 1, Second delay of high AC voltage error [s]	0.15
	35	pflmin		Side 1, Minimum PF value	0.9
	36	pflmax		Side 1, Maximum PF value	1.0
	37	Qac1max		Side 1, Maximum reactive power [pu]	0.33
	38	Qac1min		Side 1, Minimum reactive power [pu]	-0.33
	39	Qac1refrateup	Use +(absolute value)	Side 1, Reactive power setpoint ramp-rate upper limit [pu/s]	9999
	40	Qac1refratedown	Use -(absolute value)	Side 1, Reactive power setpoint ramp-rate lower limit [pu/s]	-9999
Id1max vs Vac1 Lookup Table for Side 1 in Interconnection applications	41	Ic1max	If <=0 then ignore limit	Side 1, Maximum Total Current [pu]	1.1
	42	Tvac1f1	If <4*ΔT use 0	Side 1, First AC voltage filter time constant [s]	0.04
	43	Vac1X1		Side 1, X1 for Id1max vs Vac1 lookup table	0.0
	44	Id1maxY1AC		Side 1, Y1 for Id1max vs Vac1 lookup table	0.2
	45	Vac1X2		Side 1, X2 for Id1max vs Vac1 lookup table	0.5
	46	Id1maxY2AC		Side 1, Y2 for Id1max vs Vac1 lookup table	0.2
	47	Vac1X3		Side 1, X3 for Id1max vs Vac1 lookup table	0.85
	48	Id1maxY3AC		Side 1, Y3 for Id1max vs Vac1 lookup table	1.1
	49	Vac1X4		Side 1, X4 for Id1max vs Vac1 lookup table	2.0
	50	Id1maxY4AC		Side 1, Y4 for Id1max vs Vac1 lookup table	1.1
	51	Vac1X5		Side 1, X5 for Id1max vs Vac1 lookup table	2.1

	52	Id1maxY5AC		Side 1, Y5 for Id1max vs Vac1 lookup table	1.1
	53	Vac1X6		Side 1, X6 for Id1max vs Vac1 lookup table	2.2
	54	Id1maxY6AC		Side 1, Y6 for Id1max vs Vac1 lookup table	1.1
Main Converter Controller on Side 1 in Islanded Applications	55	TVac1f3	If <4*ΔT use 0	Side 1, Third AC voltage filter time constant [s]	0.0001
	56	KpVac1w		Side 1, Proportional gain voltage controller [pu]	4.0
	57	KiVac1w		Side 1, Integral gain of voltage controller (>= 0. Zero allowed) [1/s]	2.0
	58	Iq1ctrlmaxw		Side 1, Maximum Iq in Vac control [pu]	0.3
	59	KVac1fw		Side 1, Feed-forward gain in Vac control [pu]	3
	60	Iq1maxw		Side 1, Maximum current Iq [pu]	1.1
	61	TIq1fw	If <4*ΔT use 0	Side 1, Time constant of filter iq [s]	0.02
	62	KpIac1w		Side 1, Proportional gain of current controller [pu]	0.25
	63	KiIac1w		Side 1, Integral gain of current controller (> 0. Zero not allowed) [1/s]	2.0
	64	Vclminw		Side 1, Minimum limit of offshore converter voltage [pu]	-0.1
	65	Vclmaxw		Side 1, Maximum limit of offshore converter voltage [pu]	1.3
DC Chopper	66	Vdc2CHon		DC Chopper, activation threshold voltage [pu]	1.035
	67	KVdc2CH	Use -(absolute value)	DC Chopper, Proportional gain control (<= 0) [pu]	-20.0
	68	TVdc2CH	If <4*ΔT use 4*ΔT	DC Chopper, Integrator time constant control (>0) [s]	0.025
	69	Idc2CHmax		DC Chopper, Maximum current [pu]	1.4
	70	KIdc2CH	If >1 use 1	DC Chopper, Proportional gain of current control [pu]	0.9
	71	TIdc2CH	If <4*ΔT use 4*ΔT	DC Chopper, Integrator time constant of current control (>0) [s]	0.15
	72	InomCH		DC Chopper, nominal current [kA]	1.8
	73	ECHmax		DC Chopper, Maximum energy [MJ]	2142.2
Main Converter Control on Side 2	74	Tvac2f2	If <4*ΔT use 0	Side 2, Second AC voltage filter time constant [s]	0.02
	75	TId2f	If <4*ΔT use 4*ΔT	Side 2, Id filter time constant (> 0) [s]	0.02
	76	Tvf2long	If <4*ΔT use 0	Side 2, AC voltage filter long time constant [s]	60.0
	77	Tuq2	If <4*ΔT use 4*ΔT	Side 2, Integral time of iq controller (>0) [s]	10.0
	78	DIq2ctrlmax	Use +(absolute value)	Side 2, Maximum Delta Iq control limit [pu]	0.3
	79	Iq2ctrlmax	Use +(absolute value)	Side 2, Maximum Iq control limit [pu]	0.35
	80	Iq2max		Side 2, Maximum Iq limit [pu]	1.1
	81	Kvac2dyn		Side 2, Vac error gain during faults	1.0
	82	dbVac2dyn	Use +(absolute value)	Side 2, Deadband Uac error in faults [pu]	0.1
	83	dVac2th1	Use +(absolute value)	Side 2, First high AC voltage error threshold [pu]	0.1
	84	Tdrop21		Side 2, First delay of high AC voltage error [s]	0.01
	85	dbVdc2	Use +(absolute value)	Side 2, Deadband of DC voltage error [pu]	0.01
	86	KVdc2dyn		Side 2, Feedforward Vdc gain	6.0
	87	KpVdc2		Side 2, Gain of Proportional control of DC PI controller	4.0
	88	KiVdc2		Side 2, Gain of Integral control of DC PI controller (>=0. Zero allowed.) [1/s]	0.05
	89	DId2ctrlmax	Use +(absolute value)	Side 2, Maximum Delta Id control limit [pu]	0.3
	90	Id2refrateup	Use +(absolute value)	Side 2, Id limit ramp-up rate [pu/s]. Up is defined as away from zero, therefore this is used in negative ramp direction for Id2min.	9.0
	91	Id2refratedown	Use -(absolute value)	Side 2, Id limit ramp-down rate [pu/s]. Down is defined as towards zero, therefore this is used in positive ramp direction for Id2min.	-9999
	92	Tpac2	If <4*ΔT use 4*ΔT	Side 2, Integral time of active power controller (>0) [s]	20.0
	93	Pac2refrateup	Use +(absolute value)	Side 2, Upper limit of active power setpoint ramp-rate [pu/s]	9999
	94	Pac2refratedown	Use -(absolute value)	Side 2, Lower limit of active power setpoint ramp-rate [pu/s]	-9999

Reactive Power Control on Side 2	95	TVac2	If $<4 \cdot \Delta T$ use 0	Side 2, QControl Vac filter time constant [s]	0.02
	96	TP2	If $<4 \cdot \Delta T$ use 0	Side 2, QControl P filter time constant [s]	0.50
	97	Tpf2order	If $<4 \cdot \Delta T$ use 0	Side 2, Smoothing time constant of PF order [s]	1.00
	98	dbVac2	Use +(absolute value)	Side 2, Deadband QV control [pu]	0.00
	99	DVac2max		Side 2, Maximum AC voltage error in Q-V control [pu]	0.20
	100	Kiu2		Side 2, Proportional gain QV control [pu]	20.0
	101	Kdroop2		Side 2, Inverse droop in deltaV/deltaQ [pu]	0.10
	102	dVac2th2	Use +(absolute value)	Side 2, Second high AC voltage error threshold [pu]	0.18
	103	Tdrop22		Side 2, Second delay of high AC voltage error [s]	0.15
	104	pf2min		Side 2, Minimum PF value	0.90
	105	pf2max		Side 2, Maximum PF value	1.00
	106	Qac2max		Side 2, Maximum reactive power [pu]	0.33
	107	Qac2min		Side 2, Minimum reactive power [pu]	-0.33
	108	Qac2refrateup	Use +(absolute value)	Side 2, Reactive power setpoint ramp-rate upper limit [pu/s]	9999
	109	Qac2refratedown	Use -(absolute value)	Side 2, Reactive power setpoint ramp-rate lower limit [pu/s]	-9999
Id2max vs Vac2 Lookup Table for Side 2	110	Ic2max	If ≤ 0 then ignore limit	Side 2, Maximum Total Current [pu]	1.1
	111	Tvac2f1	If $<4 \cdot \Delta T$ use 0	Side 2, First AC voltage filter time constant [s]	0.04
	112	Vac2X1		Side 2, X1 for Id1max vs Vac1 lookup table	0.00
	113	Id2maxY1AC		Side 2, Y1 for Id2max vs Vac2 lookup table	0.20
	114	Vac2X2		Side 2, X2 for Id1max vs Vac1 lookup table	0.50
	115	Id2maxY2AC		Side 2, Y2 for Id2max vs Vac2 lookup table	0.20
	116	Vac2X3		Side 2, X3 for Id2max vs Vac2 lookup table	0.85
	117	Id2maxY3AC		Side 2, Y3 for Id2max vs Vac2 lookup table	1.05
	118	Vac2X4		Side 2, X4 for Id2max vs Vac2 lookup table	2.00
	119	Id2maxY4AC		Side 2, Y4 for Id2max vs Vac2 lookup table	1.05
	120	Vac2X5		Side 2, X5 for Id2max vs Vac2 lookup table	2.10
	121	Id2maxY5AC		Side 2, Y5 for Id2max vs Vac2 lookup table	1.05
	122	Vac2X6		Side 2, X6 for Id2max vs Vac2 lookup table	2.20
	123	Id2maxY6AC		Side 2, Y6 for Id2max vs Vac2 lookup table	1.05
Id2min vs Vdc2 Lookup Table for Side 2	124	Vdc2X1min		Side 2, X1 for Id2min vs Vdc2 lookup table	1.05
	125	Id2minY1DC		Side 2, Y1 for Id2min vs Vdc2 lookup table	-1.00
	126	Vdc2X2min		Side 2, X2 for Id2min vs Vdc2 lookup table	1.10
	127	Id2minY2DC		Side 2, Y2 for Id2min vs Vdc2 lookup table	0.00
Id2max vs Vdc2 Lookup Table for Side 2	128	Vdc2X1max		Side 2, X1 for Id2max vs Vdc2 lookup table	0.90
	129	Id2maxY1DC		Side 2, Y1 for Id2max vs Vdc2 lookup table	0.00
	130	Vdc2X2max		Side 2, X2 for Id2max vs Vdc2 lookup table	0.96
	131	Id2maxY2DC		Side 2, Y2 for Id2max vs Vdc2 lookup table	1.10