Generic vendor agnostic grid forming inverter models

For positive sequence studies

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WECC MVS (Virtual)
18th May 2022

SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

This presentation is, in part, supported by the U.S. Department of Energy, Solar Energy Technologies Office under Award Number DE-EE0009025 *A Scalable Control Architecture for 100% PV Penetration with Grid Forming Inverters* and is in part supported through EPRI's P173 Research Program

A generic grid forming (GFM) model

- Model developed through collaborative work across EPRI, Univ of Illinois (UIUC), University of Washington (UW), and University of Minnesota (UMN).

- In the context of this model, a grid forming (GFM) resource is defined as a resource that can transiently change its current injection to help control voltage and frequency.

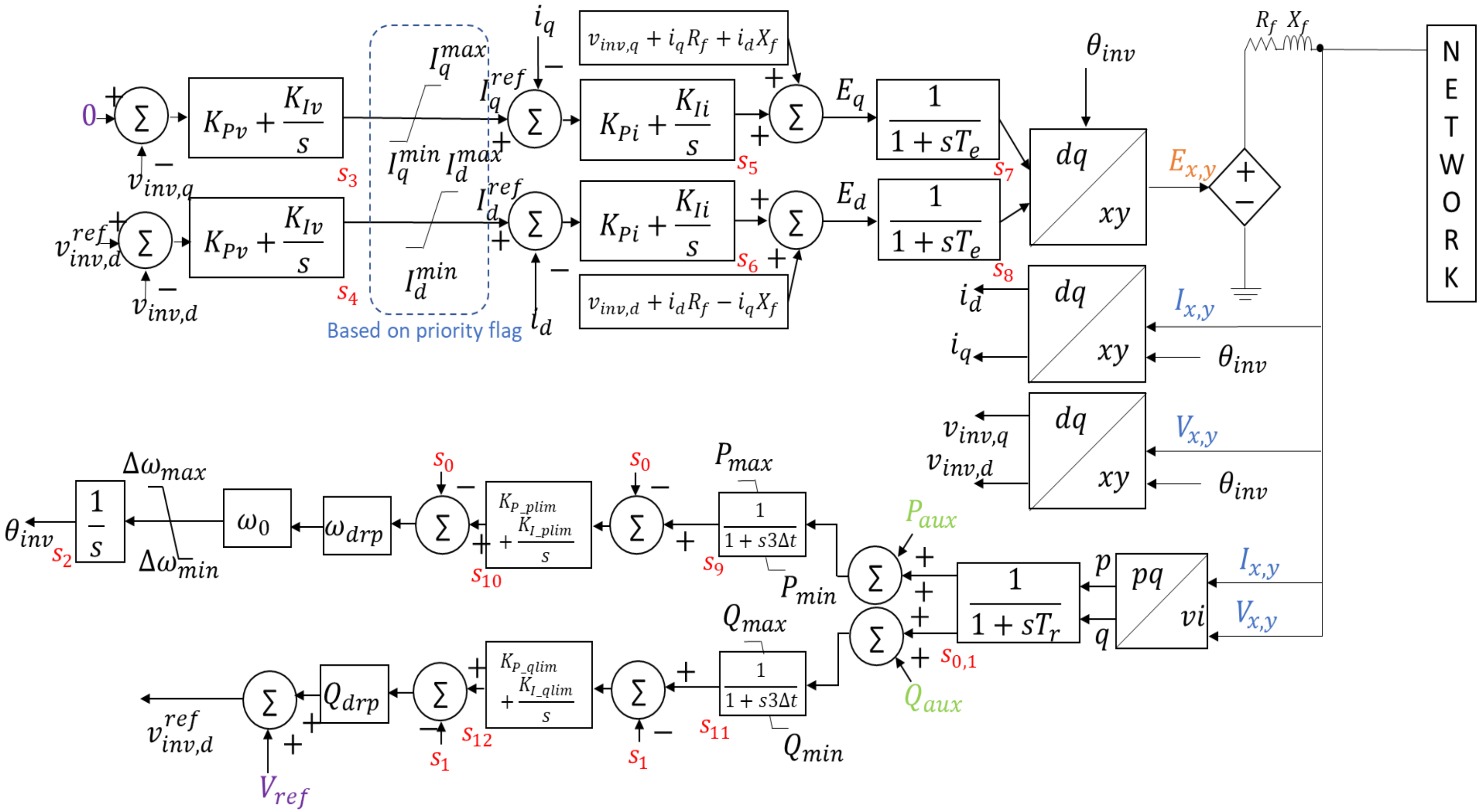
- The generic model is structured to allow representation of different GFM control methods:
  - Droop based GFM (Type – A Droop)
  - Virtual synchronous machine (VSM) based GFM
  - Dispatchable virtual oscillator (dVOC) based GFM

- Model can be interfaced with existing generic plant controller models (REPC_*)

- Model additionally also has power limits included.

- Earlier version of this type of generic GFM model developed in 2018 through a DOE – GMLC project
  - Earlier version did not have a means to limit current during fault

Structure of generic model for droop based GFM



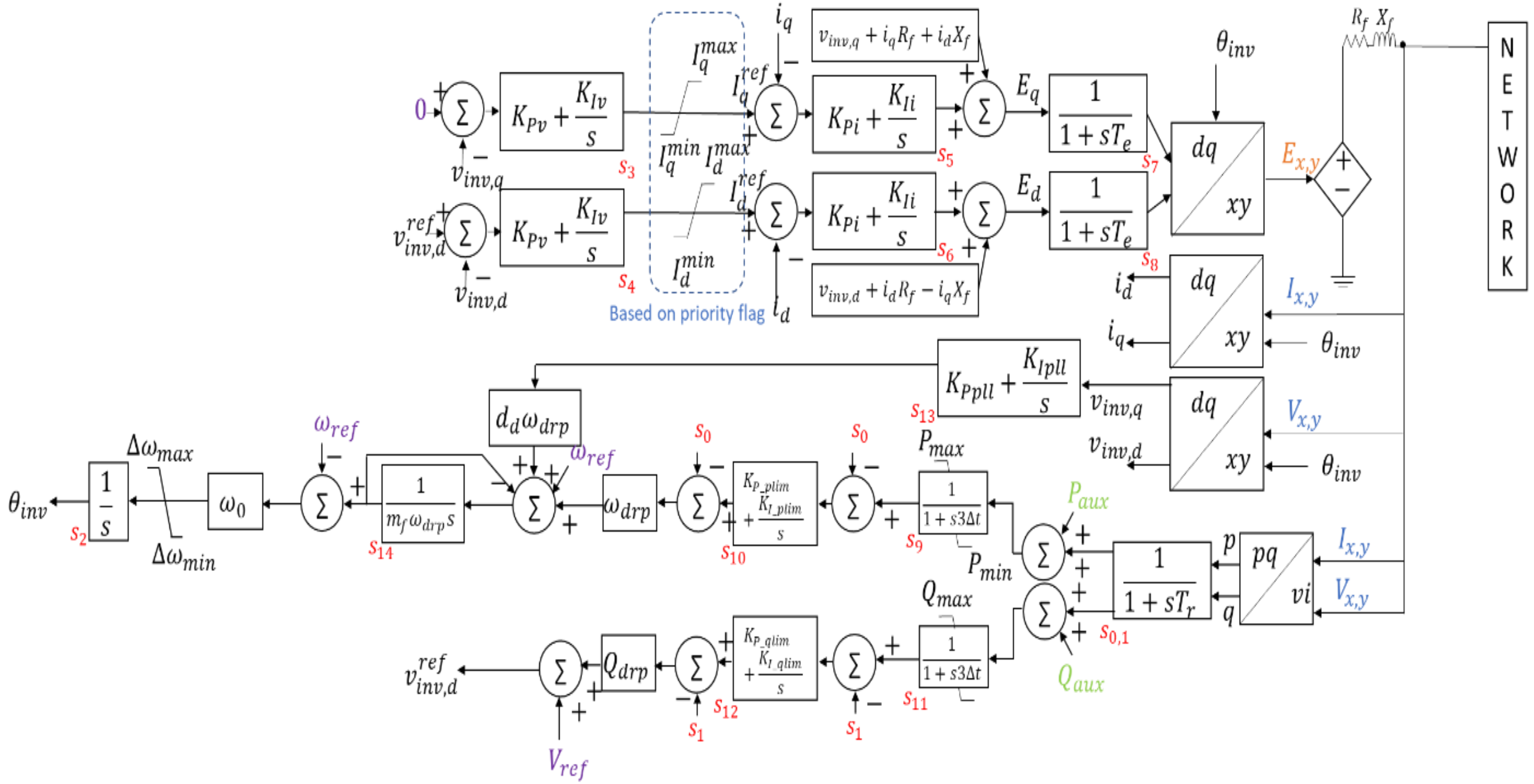
- Fault current limiting handled at network interface

B. Johnson, T. Roberts, O. Ajala, A. D. Dominguez-Garcia, S. Dhople, D. Ramasubramanian, A. Tuohy, D. Divan, and B. Kroposki, “A Generic Primary-control Model for Grid-forming Inverters: Towards Interoperable Operation & Control,” *2022 55th Hawaii International Conference on System Sciences (HICSS)*, Maui, HI, USA, 2022 [Link]

D. Ramasubramanian, “Differentiating between plant level and inverter level voltage control to bring about operation of 100% inverter-based resource grids,” *Electric Power Systems Research*, vol. 205, no. 107739, Apr 2022 [Link]

Deepak Ramasubramanian, Wes Baker, Julia Matevosyan, Siddharth Pant, and Sebastian Achilles, “Asking for Fast Terminal Voltage Control in Grid Following Plants Could Provide Benefits of Grid Forming Behavior,” *IET Generation, Transmission & Distribution,* early access [Link]

Structure of generic model for VSM based GFM



- Fault current limiting handled at network interface

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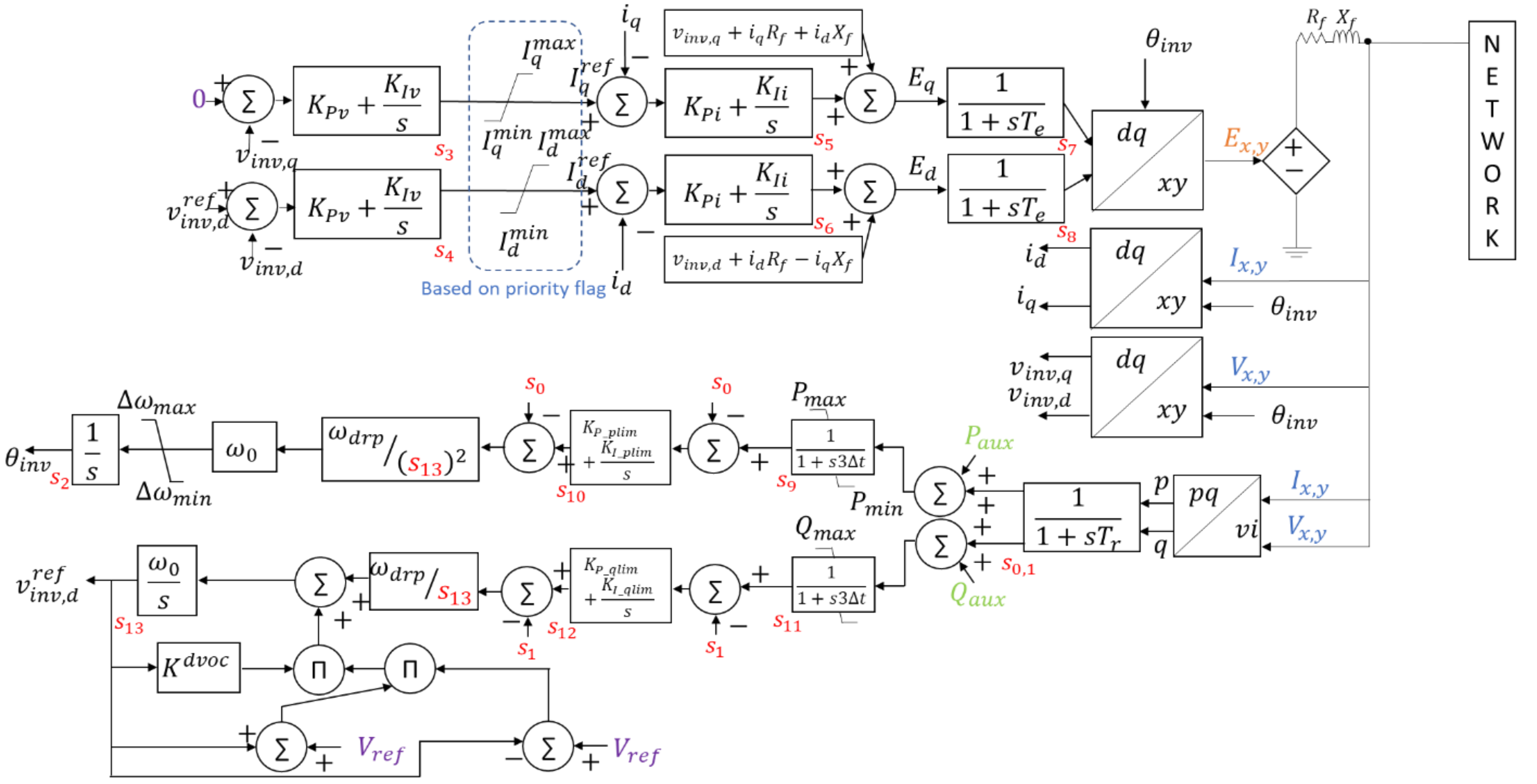
Structure of generic model for dVOC based GFM



- Fault current limiting handled at network interface

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Mathematical similarity between different GFM structures

- Three GFM structures (Type A droop, Virtual Synchronous Machine, dispatchable Virtual Oscillator) share the same equation structure as shown below:

$$\theta_{inv} = \frac{\omega_0\left(K_1(s_{15} - s_0) + K_d s_2\right)}{s\left(1 + sT_f\right)};$$

$$v_{inv,d}^{ref} = \frac{K_2(s_{17} - s_1) + K_3 V_{ref} + K_4 K_2^{dvoc} v_{inv,d}^{ref}\left(\left(V_{ref}\right)^2 - \left(v_{inv,d}^{ref}\right)^2\right)}{1 + sT_v}$$

- Parameters in red font are related to each other

Parameterization of generic GFM structure

- User only needs to enter value for:
  - Flag to choose type of GFM (ω_{flag})
  - Frequency droop percentage (ω_{drp})
  - Voltage droop percentage (Q_{drp})
- Only if virtual synchronous machine (VSM) is chosen, then two additional parameters
  - Inertia constant (m_f)
  - Damping factor (d_d)
- The parameters are then related as

	K_1	K_2	K_3	K_4	$K_\mathbf{d}$	T_f	T_v
Type A Droop	ω_{drp}	Q_{drp}	1	0	0	0	0
VSM	ω_{drp}	Q_{drp}	1	0	$\mathrm{d_d}\omega_{drp}$	$m_f\omega_{drp}$	0
dVOC	$\omega_{drp}/(s_3)^2$	ω_{drp}/s_3	0	1	0	0	$1/\omega_0$


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