TO: WECC REMWG

FROM: POUYAN POURBEIK, PEACE®

SUBJECT: PROPOSAL FOR NEW REPC_E POWER PLANT CONTROLLER MODEL

DATE: 8/15/25 (REVISDED 9/9/25; 1/23/26)

CC: D. RAMASUBRAMANIAN, EPRI

Background:

This brief memo covers the proposal for yet another updated renewable energy power plant controller model REPC_E. The presented aspects have been discussed at a WECC MVS meeting in May, 2025 (see: https://www.wecc.org/wecc-document/21086). The recommended updates, in summary, are as follows:

1. To provide a secondary frequency response (SFR) characteristic into the PPC (this is referred to as FCAS in Australasia and LFSM in Europe). This recommendation was received by WECC through an email from Energinet (from Anders Oddleif Nielsen in January, 2025)

2. To provide multiple sets of parameters for the Kp/Ki gains of the main volt/Var control-loop for the various modes, thus enabling the model to automatically pick-up the appropriate gain pairs for each control mode rather than the user having to remember to change the gains when the control mode is changed (again form Energinet in the same email of January, 2025)

3. To be able to mode P-available (again form Energinet in the same email of January, 2025).

4. To have a QV-droop control path (comment from BC Hydro Sam Li, during a WECC MVS meeting in 2024)

In addition to the above, herein several other minor modifications are recommended to allow the use of this new PPC model with all the new REGFM_A1 and REGFM_B1 (GFM inverter) models, as well as the existing REEC_*/REGC_* models.

Proposed Additions Received in December 2025:

During the last MVS meeting in September, 2025 the then 9/9/25 version of this memo/specification was formally approved, which is the version of the REPC_E model shown in Figure 1 herein, with the accompanying descriptions that follow.

In December 2025, some additional comments were received from Tesla (Sai Gopal Vennelaganti and Fatemeh Sharifi). Those proposed additions are now shown herein in Figure 2. The additions can be briefly explained as follows:

- Adding a few more time constants (to PFR and SFR) and a rate limit to the frequency measurement. These can be used or disabled by the user (i.e. set time-constants to zero and rate limit to a very large number).

- The addition of yet another fourth control path for reactive power, where a double PI strategy is employed (RefFlag = 4)

- The addition of a feedforward path for the reactive power control – it should be noted that if the feedforward path is used, then the main PI controller (*Ki*) cannot be zero. If it is set to zero by the user then it should be forced to a small default value (e.g. 0.001) and the user warned of their error.

- The addition of a loss calculation using two parameters (*Rloss* and *Xloss*) which can bet set to zero to disable their use. These paths essentially can be used to estimate collector system P and Q losses, and thus adding them into the P and Q control path to compensate for the losses. **Aside Note:** the standard PI loops in essence already do this, and so these additions are not necessary to compensate for losses. However, some vendors may use this strategy so that the PI loop outputs correspond more directly to the P/Q target values.

These additions need to be discussed at the next MVS for general agreement by the whole group. The additions certainly seem reasonable and would add value for greater generalization of the proposed model.

REPC_E (new model)

This proposed new plant-controller model is based off of the existing REPC_D model, which is able to interfaces with multiple downstream aggregated inverter models. Thus, other than the new changes described herein, all other parameters, variables and structural aspects of REPC_E should be exact the same structure as REPC_D.

The proposed new features are described below and shown in summary, in RED, in Figure 1.

The proposed changes are as follows:

1. **Gains:** adding two pairs of Kp/Ki gains for the reactive controller loop. The model will then automatically switch between the gain pairs depending on the setting of the flag *RefFlag*. See Table 1 and Figure 1.
2. **VQ-droop:** adding a new VQ-droop control option as *RefFlag* = 3. In this control option the voltage error is passed through a symmetrical deadband of ± *dbdqv* and then multiplied by a VQ-droop gain *Kdqdv* to get the Q setpoint that is compared with the measured POI branch Q and then fed into the PI control loop.
3. **SFR:** add a Secondary Frequency Response (SFR) loop, which can be enabled/disabled using the new flag *SFRflg*. The SFR control loop has its own deadband (*fdbd2*,*fdbd4*), error limits (*dfmax1*,*dfmin1*) and its own droop gains (*Ddn1*,*Dup1*).
4. **The output limits:** A new flag *QVCntrlMode* should be added so that the user can define whether the downstream aggregated inverters are all to receive a Q-command or a V-command. Then based on that choice the main reactive control loop state is initialized to a Q-command or V-command (*Vext*) and the respective limits (*xmax*/*xmin* and *xrmax*/*xrmin*) are set to either the Q limits (*Qmax*/*Qmin* and *Qrmax*/*Qrmin*) or the V limits (*Vmax*/*Vmin* and *Vrmax*/*Vrmin*). Associated with this addition, this PPC model should be able to interface with all existing generic inverter models, namely: REEC_A, REEC_C, REEC_D, REEC_E, REGFM_A1 and REGFM_B1.
5. ***Qmaxpom/Qminpom:*** Two new parameters, *Qmaxpom*/*Qminpom* have been added to the model and limit (see Figure 1) the Q setpoint calculated by each of the three (3) different Q-control paths. In this way, this limit can act to limit the max/min Q injected by the PPC at the point of measurement (POM), which is the Q measured on the defined measurement branch. To disable the limits, they may be set to 999/-999.

A final consideration, it to add the base-load flag feature to this model, which was not added to REPC_D. This can be done as follows:

- Consider any one of the downstream connected aggregated IBRs, for example the n^{th} aggregated IBR.
- Within the power flow model the base-load flag for this n^{th} IBR will be set to either:
  - 0 – meaning it can regulated both up and down (curtailed, with headroom),
  - 1 – meaning it can only regulated down (at maximum available power), or
  - 2 – meaning it cannot regulate up or down (blocked)
- Thus, depending on the value of baseload flag $Pmax_n$ and $Pmin_n$ (see Figure 1) should be set as follows upon model initialization:
  - If baseload flag = 0, then leave $Pmax_n$ and $Pmin_n$ at the values designated by the user,
  - If baseload flag = 1, then $Pmax_n$ = initial value of $Pgen_n$ and $Pmin_n$.is unchanged, or
  - If baseload flag = 2, then $Pmax_n$ = $Pmin_n$ =initial value of $Pgen_n$.

All aspects not explicitly mentioned here (e.g. MSS switching logic, etc.) remain identical with REPC_D, on which this model is based.

Initialization in V-output Control: When the model is initialized such that the output of the main reactive path is a voltage reference (i.e. using Vext instead of Qext) then the following should be done:

- All the downstream Kw_i factors are forced to '1',
- The $qref_i$ values are initialized to the initial voltage reference (setpoint) of the i^{th} inverter, and
- The $Qref_o$ valaue is set to $Vref\_average_o = \frac{\sum_{i=1}^{n} Vt_i}{n}$, where n is the number of downstream inverter models connected to the PPC model and Vt_i is the initial voltage (in pu) of the terminal bus to which the inverter is connected (i.e. its initial terminal voltage) from the power flow solution.

Table 1: Additional Parameters REPC_E – only new additional parameters are listed here; all other parameters are identical to REPC_D.

Parameter	Description	Typical Range/Value
SFRflag	0 – no secondary frequency response, 1 – enable secondary frequency response	0
QVCntrlMode	0 – send Qcommand to downstream inverters; 1 – send Vcommand	N/A
Kpq[1]	Proportional gain for reactive power control for RefFlg = 0, 2 and 3 [pu/pu]	N/A
Kiq	Integral gain for reactive power control for RefFlg = 0, 2 and 3 [pu/pu/s]	N/A
Kpv	Proportional gain for reactive power control for RefFlg = 1 [pu/pu]	N/A
Kiv	Integral gain for reactive power control for RefFlg = 1 [pu/pu/s]	N/A
Kdqdv	Reactive droop gain for VQ-droop control [pu/pu] on total plant MVA base[2]	7 to 20
Dbdqv	VQ-droop control loop voltage error deadband [pu] (symmetrical)	0 to 0.005
Qmaxpom	Qmax limit at the Point of Measurement (POM) [pu] (>0)	N/A (999 to disable)
Qminpom	Qmin limit at the Point of Measurement (POM) [pu] (<0)	N/A (-999 to disable)
Qmax[3]	Qmax limit of the PPC controller output when *QVCntrlMode = 0* [pu] (>0)	0.329 to 1
Qmin	Qmin limit of the PPC controller output when *QVCntrlMode = 0* [pu] (<0)	-1 to -0.329
Qrmax[4]	Max Q rate limit of the PPC controller output when *QVCntrlMode = 0* [pu] (>0)	N/A (999 to disable)
Qrmin	Min Q rate limit of the PPC controller output when *QVCntrlMode = 0* [pu] (<0)	N/A (-999 to disable)
Vmax	Vmax limit of the PPC controller output when *QVCntrlMode = 1* [pu]	1.08 to 1.1
Vmin	Vmin limit of the PPC controller output when *QVCntrlMode = 1* [pu]	0.9 to 0.92
Vrmax	Max V rate limit of the PPC controller output when *QVCntrlMode = 1* [pu]	N/A (999 to disable)
Vrmin	Min V rate limit of the PPC controller output when *QVCntrlMode = 1* [pu]	N/A (-999 to disable)
fdbd3	SFR frequency deadband for over frequency [pu] (<0)	N/A
fdbd4	SFR frequency deadband for under frequency [pu] (>0)	N/A
dfmax1	SFR frequency error max limit [pu] (<0)	N/A
dfmin1	SFR frequency error min limit [pu] (>0)	N/A
Ddn1	SFR over frequency droop gain [pu/pu]	N/A

[1] **Note:** Kpq and Kiq replace parameter Kp and Ki in REPC_D.
[2] **Note:** in REPC_D if the user enters a value for *MVAplt* then this is a fixed value for the entire simulation. Otherwise, if the user enters a value of '0' for *MVAplt*, then *MVAplt* is calculated dynamically and equal to the sum of the MVA of all downstream inverters. The base of *Kdqdv* is *MVAplt* per this approach (i.e., fixed when entered by the user, and dynamically calculated by the model when entered as '0')
[3] *Qmax/Qmin* are existing parameters of REPC_D
[4] *Qrmax/Qrmin* are existing parameters of REPC_D

Dup1	SFR under frequency droop gain [pu/pu]	N/A

Optional Addition:

In the past a pure delay (e^{-sT}) has not been modeled to represent the communication delay between the PPC and downstream inverters. Instead the time constants *Tfv* and *Tlag* are used to emulate this. The group did discuss this again with the software vendors, and the possibility of introducing a pure delay block at the output of both active and reactive power command (i.e., just after the *Tfv* and *Tlag* blocks) to allow for emulating a pure delay of up to 100 ms. The software vendors felt that the complication is not worth it, and more evidence is needed to support the importance of such an addition.

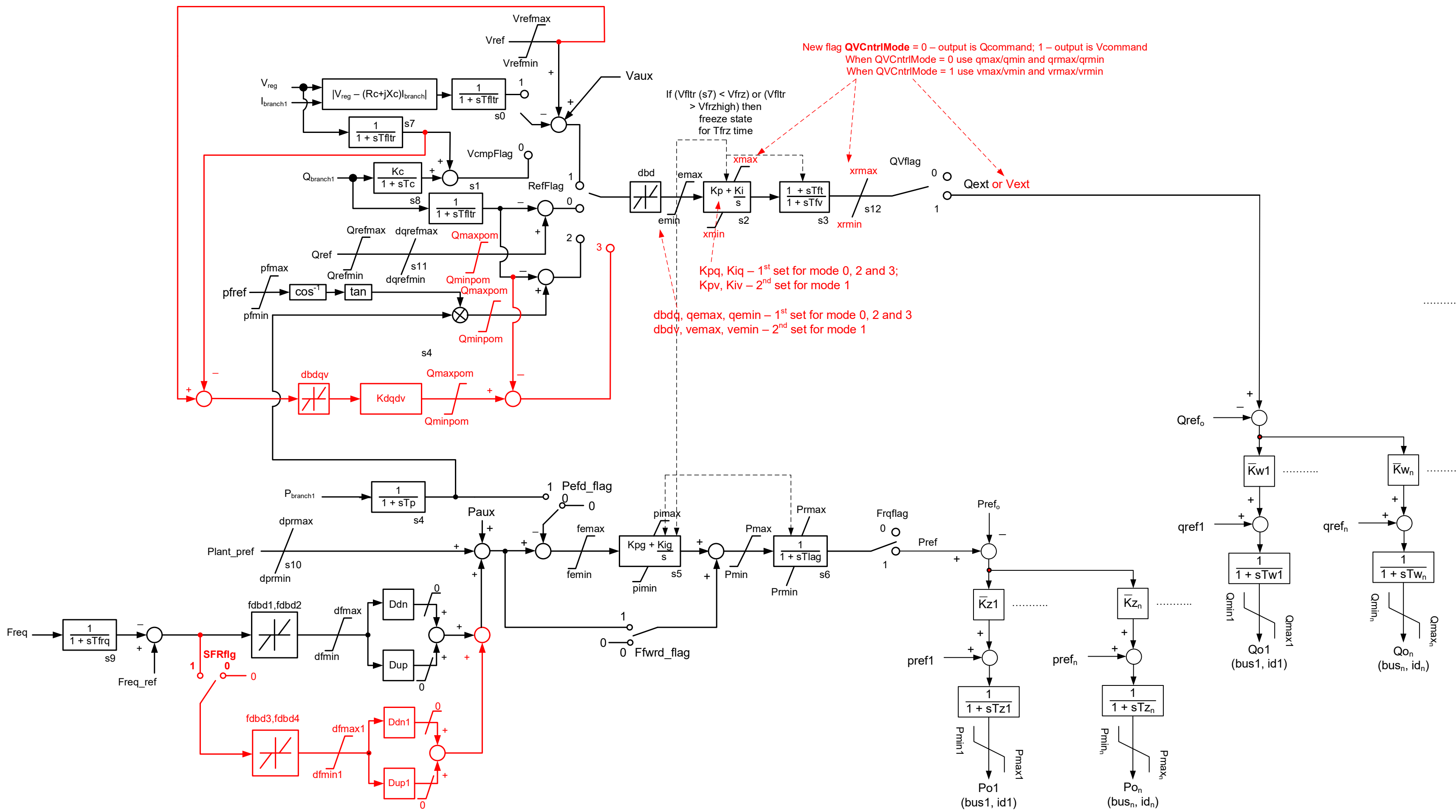

Figure 1: REPC_E model (approved specification from September 2025)

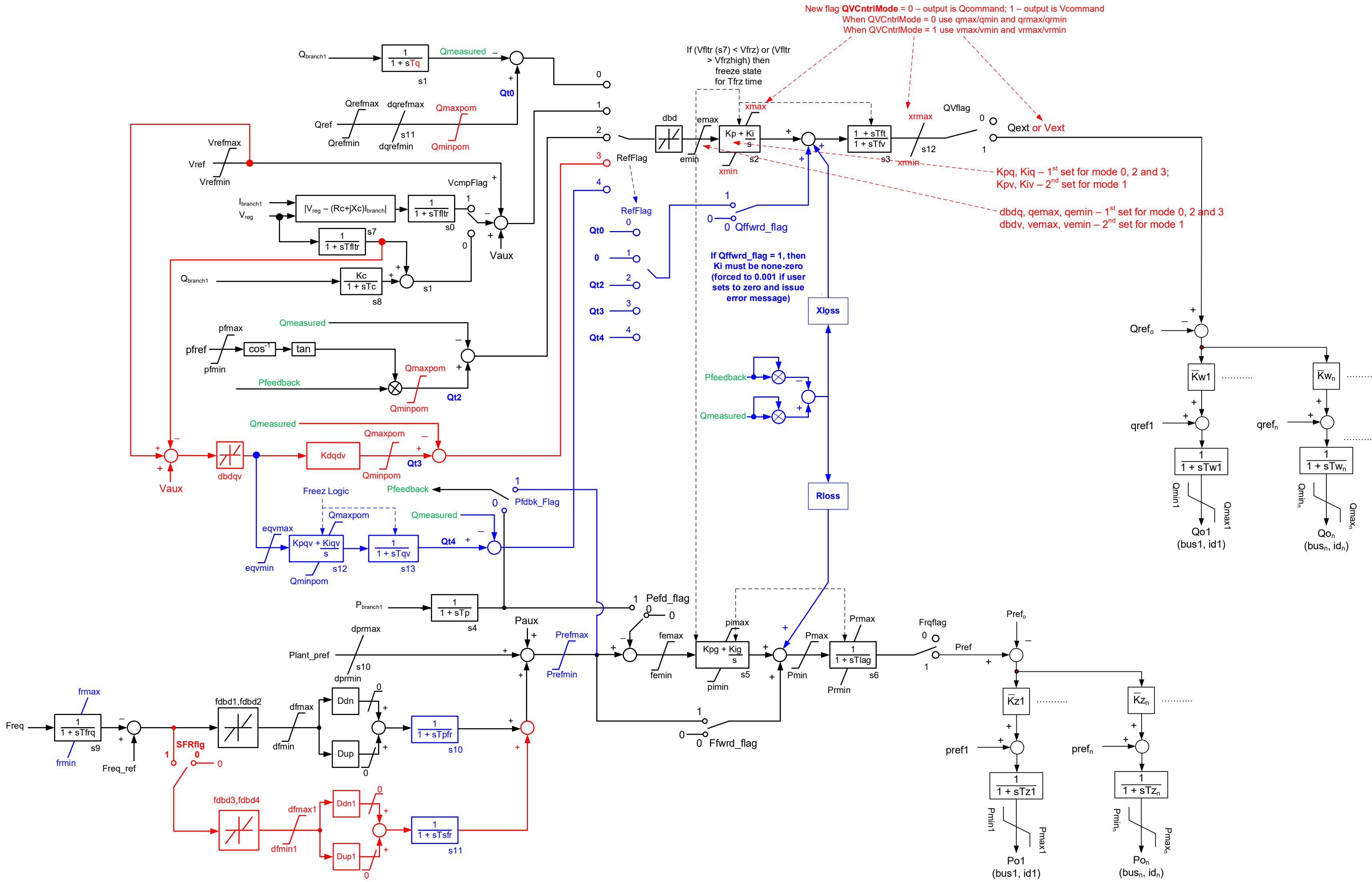

Figure 2: REPC_E model with proposed new additions as of December 2025 (proposed additions shown in **BLUE** and provided by Tesla)

Acknowledgements:

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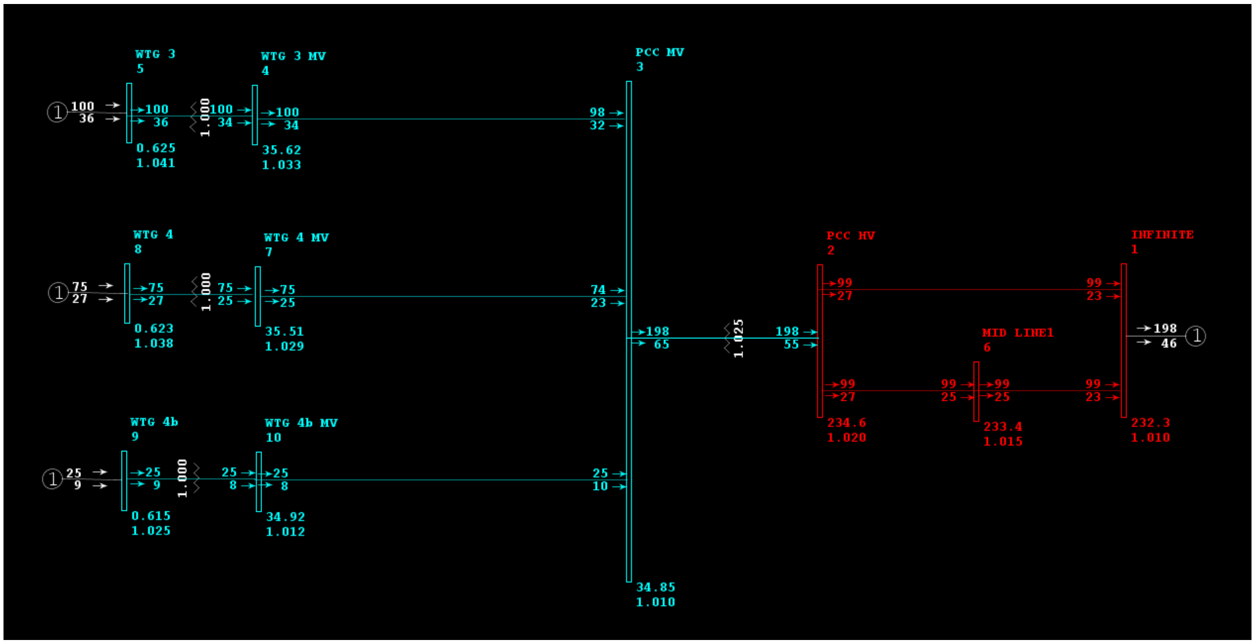
Pouyan Pourbeik (PEACE®), Sam Li (BC Hydro), Jamie Weber (PowerWorld), Jay Senthil (Siemens PTI), Mengxi Chen (GE Vernova), Deepak Ramasubramanian (EPRI), Jeff Bloemink (PowerTech Labs), Wei Du (PNNL), Sai Gopal Vennelaganti and Fatemeh Sharifi (Tesla), Song Wang (PGE), Songzhe Zhu (Qualus) and Doug Tucker (WECC), as well as many others within WECC MVS who provided comments and feedback.

PEACE® wishes to gratefully acknowledge EPRI research funding for time spent by PEACE® to prepare this memo.

We apologize for any inadvertent omissions.

Appendix A – Simple Test Case for REPC_E Model

The REPC_D model has been previously benchmarked across all the major software tools and approved in 2024. The REPC_E is identical in its core control structure to the REPC_D model, with only the additional of the QV-droop loop, and the Secondary Frequency Response loop. Thus, a complete retest of the model is not necessary. The following benchmark case that was used in testing REPC_D can be reused with only a few tests to ensure the new control loops are working properly.



The case consists of three (3) aggregated RES models:

A 200 MVA WTG type 3 plant

A 100 MVA WTG type 4 plant, and

A 50 MVA PV plant

All of these are "fictitious" and do not represent any specific plant or equipment. This is all simply for the purpose of software testing.

The REPC_E model is set up to control all three (3) plants with all *Ks* = 1.

Then two (2) test simulations are to be run and compared across the software tools:

- Test 1 – playback a 200 mHz droop in system frequency at bus 1, starting at T = 1 second and running for 20 seconds. Do this with the SFR loop enabled and set as:
  - *fdbd3* = -0.0017, *fbdb4* = 0.0017
  - *Ddn1* = 40, *Dup1* = 40
- Test 2 – place a 0.25% (0.0025 pu) *Vaux* reference step on the plant at T = 1 second and run to 20 seconds. Do this with the VQ-droop enabled (*RefFlag* = 3), *dbdqv* =0 and *Kqvdroop* = 20.

The simple test case has been setup and shared amongst the group and can be obtained upon request.