**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)

**CC:** D. RAMASUBRAMANIAN, EPRI

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## 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.

**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.

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

<u>Optional Addition:</u>

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.

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[1] **<u>Note:</u>** Kpq and Kiq replace parameter Kp and Ki in REPC_D.

[2] **<u>Note:</u>** 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

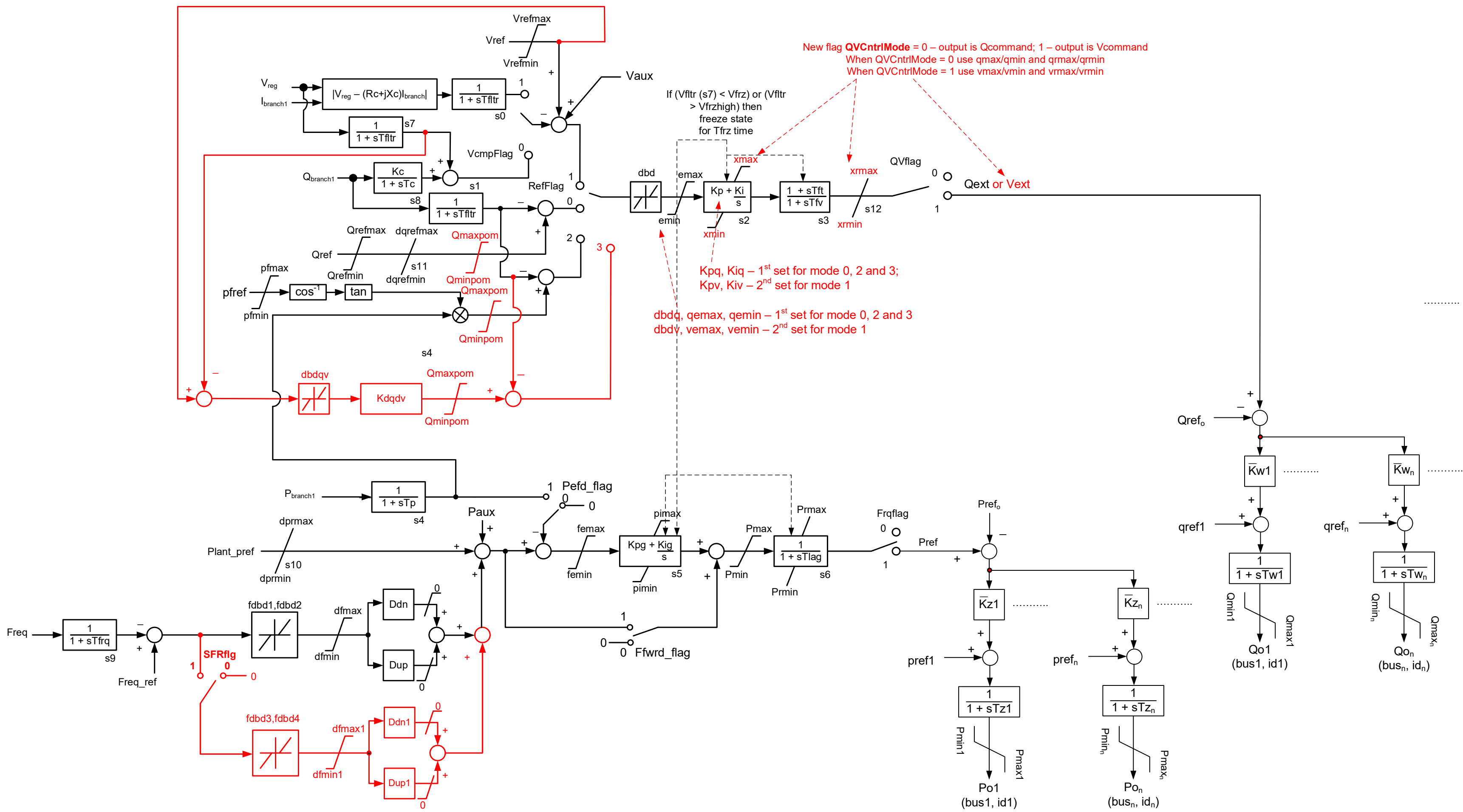

**Figure 1:** REPC_E model – note:

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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), Song Wang (PGE), Songzhe Zhu (Qualus) and Doug Tucker (WECC), as well as many others within WECC MVS who provided comments and feedback.

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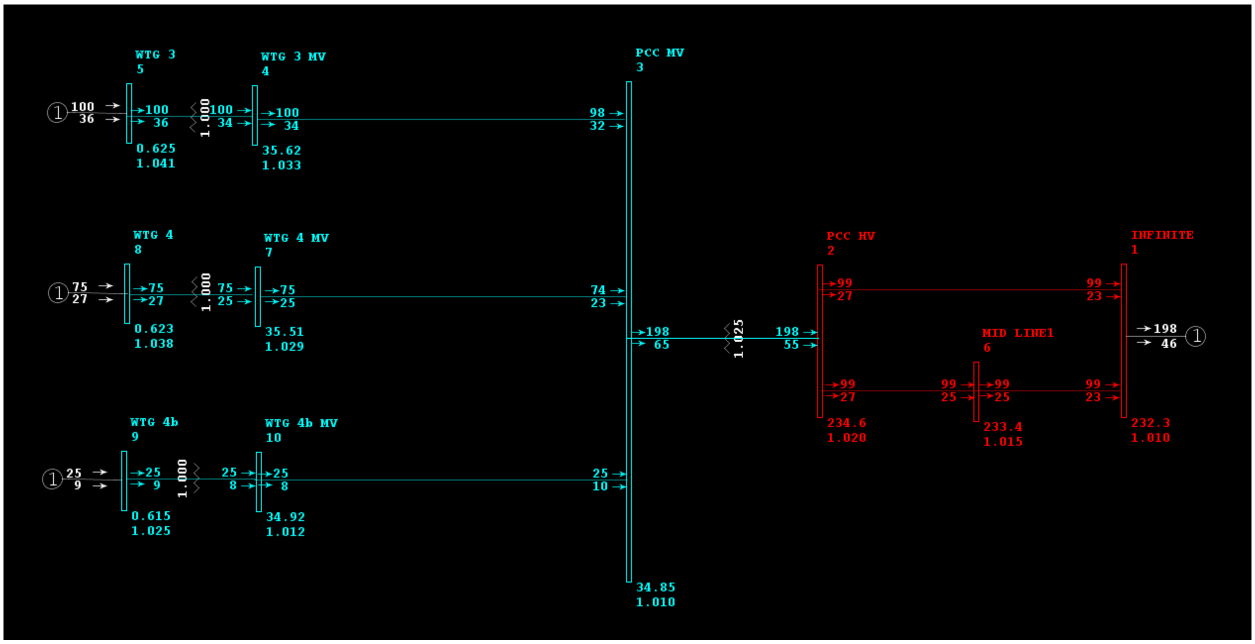
We apologize for any inadvertent omissions.

**<u>Appendix A</u>** – 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.