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POWER SYSTEMS · AI · RESEARCH

Technical Note 005: WECC Generator and Controller (REEC_C & REGC_C) Modelling in PSCAD using FORTRAN

N-005

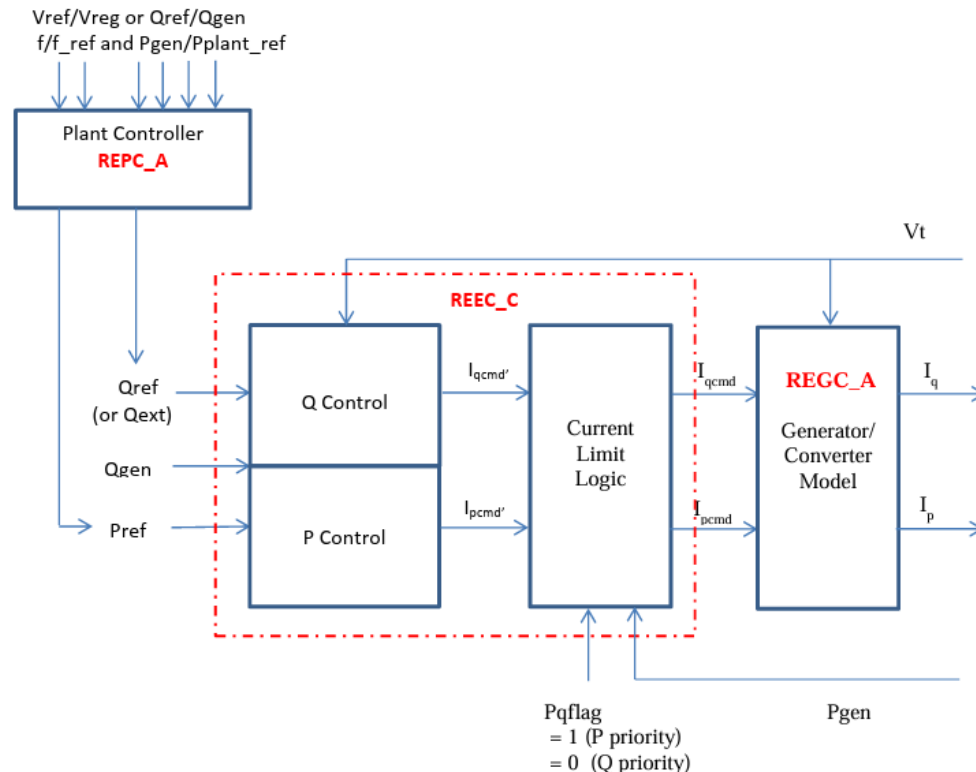
This is preliminary research and has not been validated or peer-reviewed. It could therefore be totally wrong.

Key Concepts

- This is a follow-on exercise to the previous Technical Note (TN-004), which looked at building a WECC REPC_C Plant Controller in PSCAD Using FORTRAN.
- In this use case I take things to the next level and use the AI to build a model of an electrical storage systems based on the WECC REEC_C and REGC_C models. These are both substantially more complex than the previous REPC_C model.
- WECC REEC_C is the control system directly associated with a typical generic IBR systems such as Solar PV, Wind or BESS.
- WECC REGC_C is a model of the generation associated with a typical generic IBR systems such as Solar PV, Wind or BESS and is based on a simple dq reference frame. (Not a dq0 – as its positive sequence only)
- Each module was built directly by the AI in PSCAD using a FORTRAN only code and then connected back-to-back to give a full inverter model.
- I left out the protection and weak grid options, but the same principles apply – although for protection I think I would still prefer to hand build and test!

WECC Generic Models – Pulling Them All Together

- The WECC model names are similar sounding and can be confusing if you are not used to them. The diagram below shows how the three conceptual blocks discussed in this and the previous technical note all fit together.
- The plant controller (REPC) gives setpoints to the Inverter controller (REEC) which then gives the generation signals to the hardware model (REGC)



Electrical Control System – WECC REEC_C

- The WECC Electrical Control System model REEC_C has been around for a while and represents the control system of the inverter, that will directly interface with the physical hardware
- Most OEM models follow a similar approach with additional functions and hardware implementation levels. Key differences tend to be in the Fault Ride Through (FRT) performance and the Current Limit control loops.
- The REEC_C contains all the core functions for an inverter controller that can work with Solar, Wind and Storage:
 - Active Power and Reactive Power Setpoints.
 - Current Limit Logic.
 - Fault Ride Through Logic.
 - Freeze mode during Fault Ride Through / Voltage Dips.
 - Localized Voltage Control.
 - Battery State of Charge.

Electrical Control System – WECC REEC_C

- The version below is from the WECC document library and shows the REEC_C model, which take input signal set-points for MW and MVar and measurements and then send the ***lq*** and ***lp*** values for the inverter hardware implementation (the REGC_C model).

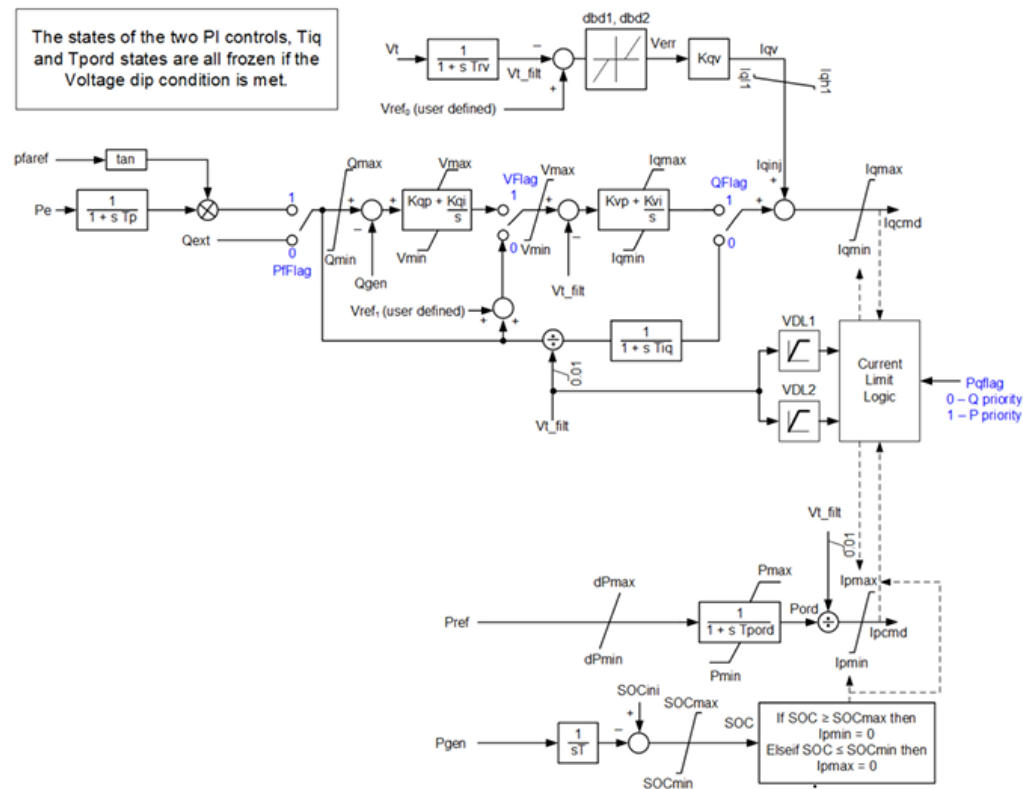
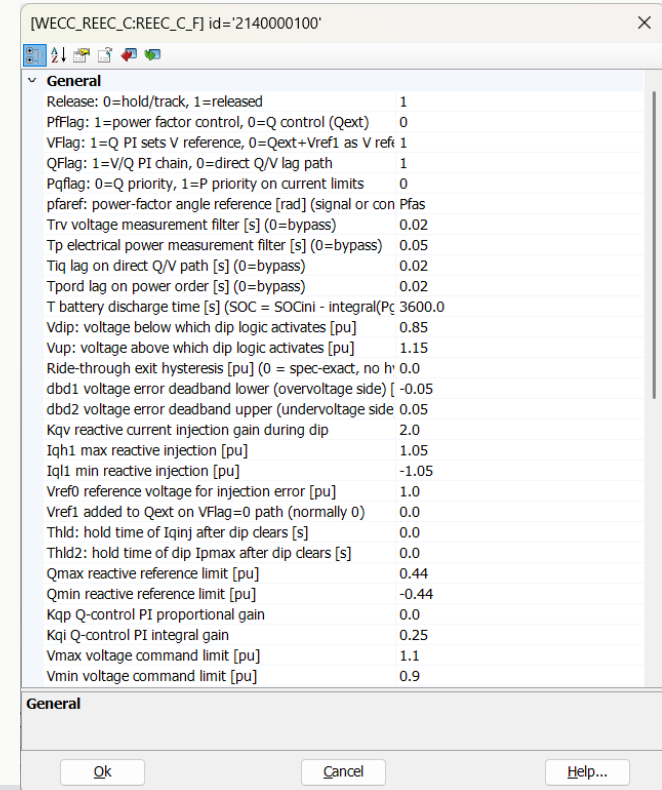
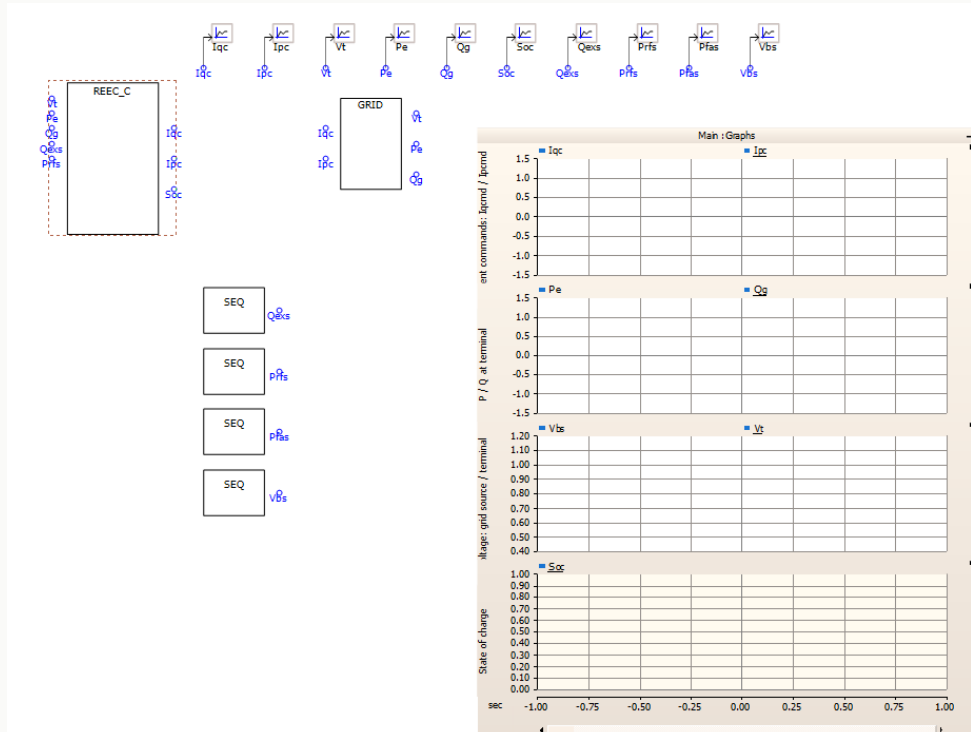


Figure 6: Block Diagram of Renewable Energy Control Module (REEC_C).

Inverter Controller – WECC REEC_C

- The implementation was done by uploading the WECC REEC_C model and associated transfer functions and WECC guidance note into Claude.
- As with the REPC implementation approach the submodule and ports were created directly by Claude and the control system and parameters implemented through direct FORTRAN coding.



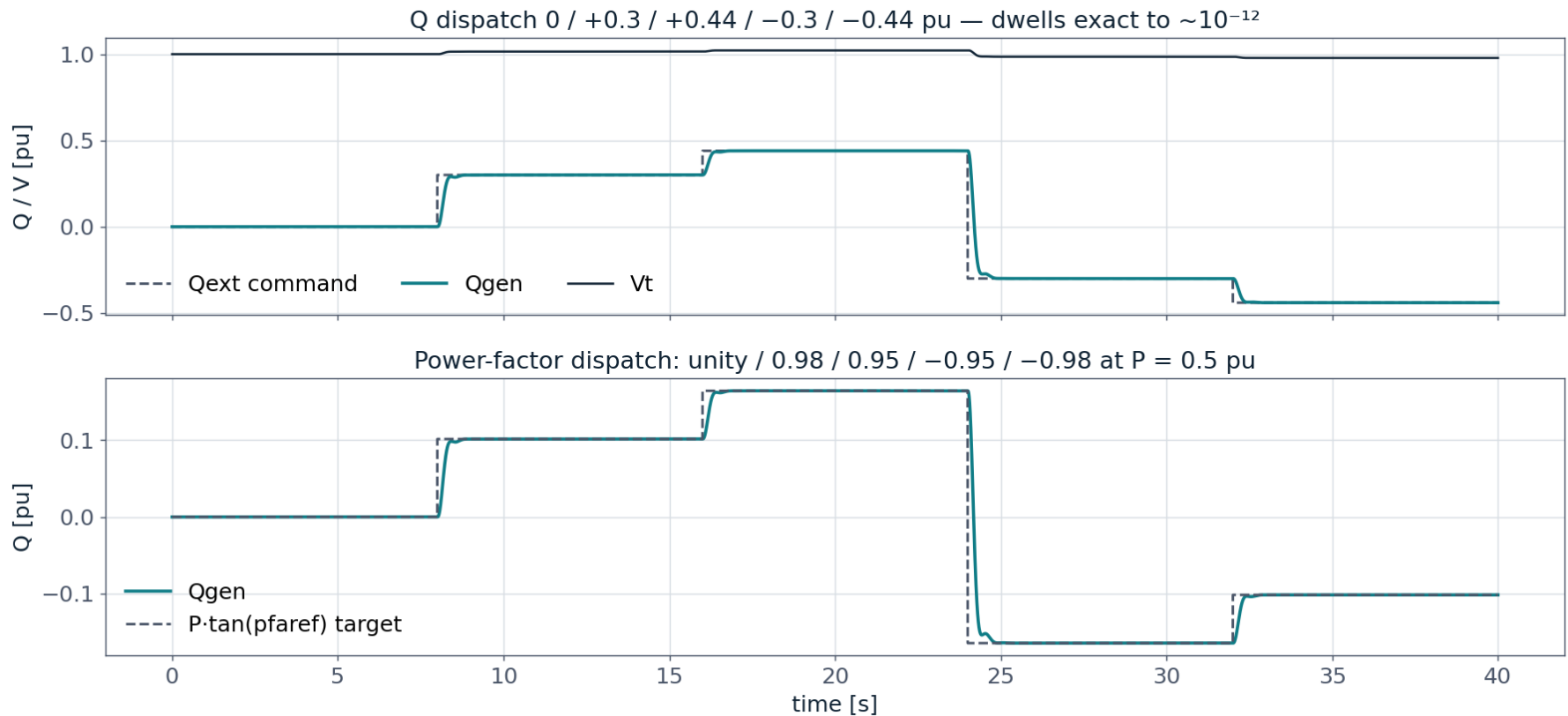
REEC_C Testing

- As with the REPC approach Claude developed the test plan to prove the implementation was correct and worked as expected.

Series	Results
Q dispatch $0 \rightarrow \pm 0.44$ pu	dwells exact ($\sim 10^{-12}$); $V_t = 1 + 0.05 \cdot Q$ cross-check holds
pf dispatch unity $\rightarrow \pm 0.98$ / ± 0.95	$Q = P \cdot \tan \phi$ exact both signs
Local V dispatch (VFlag = 0)	V_t lands on command to 10^{-14} ; $Q = 20 \cdot \Delta V$ exact
BESS SOC (40 s battery)	discharge blocked at SOCmin, charge blocked at SOCmax, clean release
GB FRT 140 ms $\times$ 4 fault types	injection at I_{qh1} ceiling; $I_p = \sqrt{I_{max}^2 - I_q^2}$ exact; clean recovery
GB LVRT 30%/384 ms, 50%/710 ms, 80%/2.5 s	every settled operating point matches the closed-form solution
85% retained / 180 s	no spurious FRT — but exposed the V_{min} interaction (Part 2)

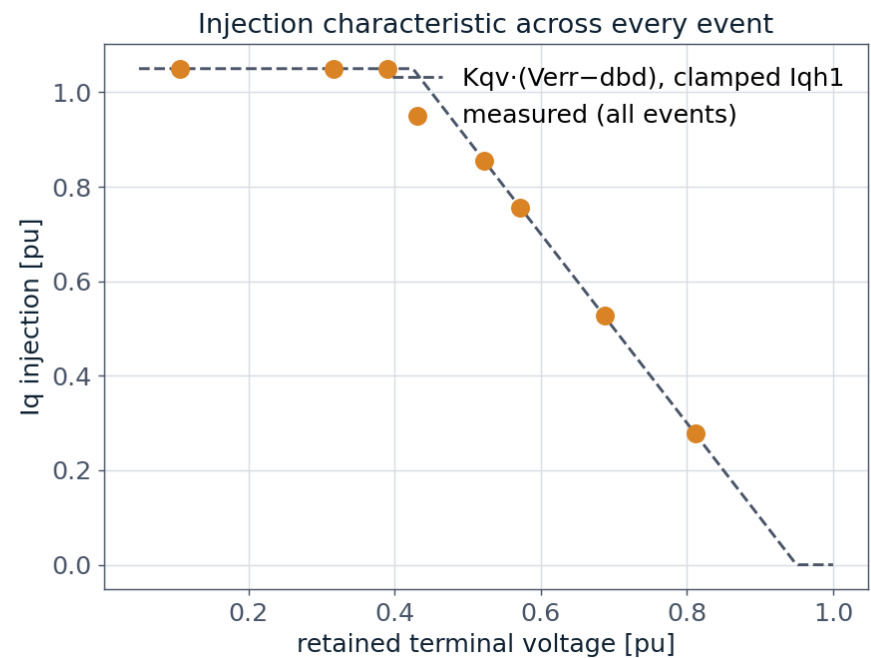
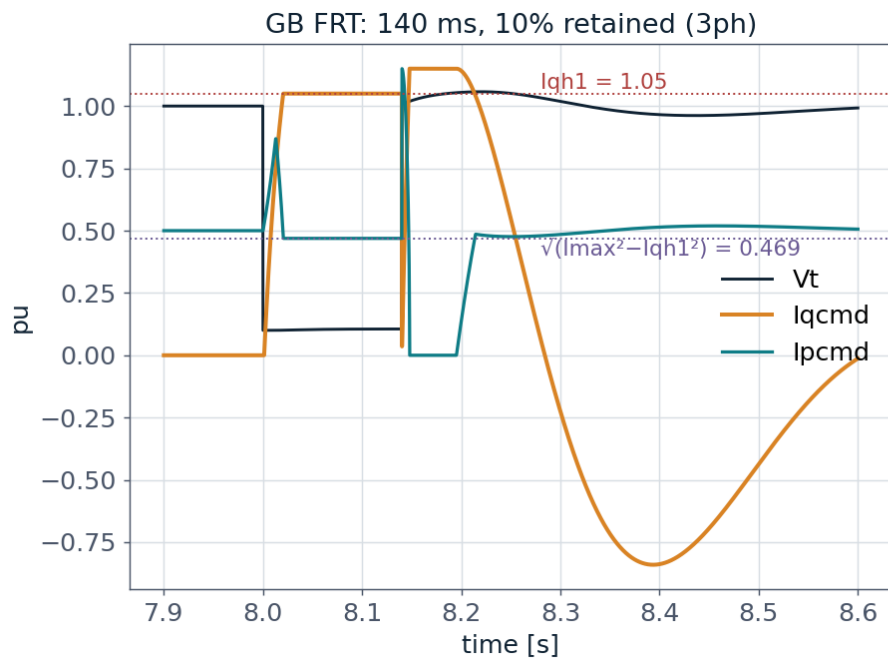
Q Setpoints and Control

- Testing of inverter output for Q MVAR and power factor dispatch commands.



FRT Simulation and Current Limit

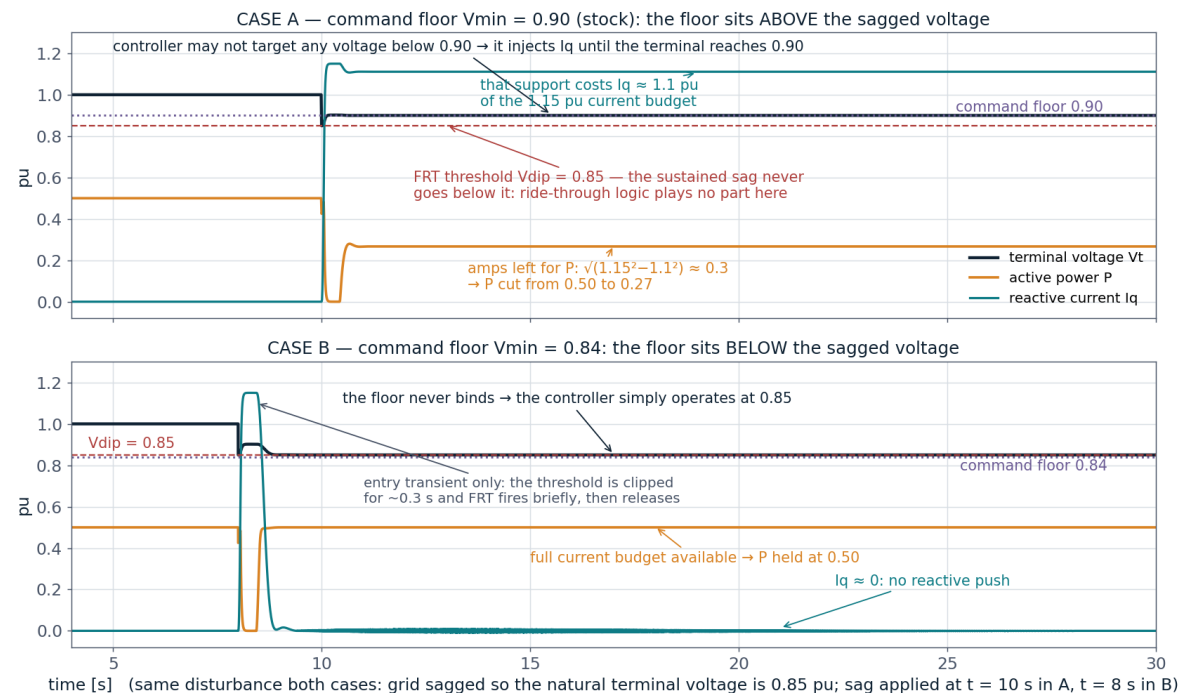
- Testing of inverter response for Fault Ride Through (FRT) – for a 10% retained voltage and a fault duration of 140ms
- All Fault types tested, but focus on the 3ph as it is the most onerous.
- Cross checking of current limiting logic by increased retained voltage.



LVRT Behaviour

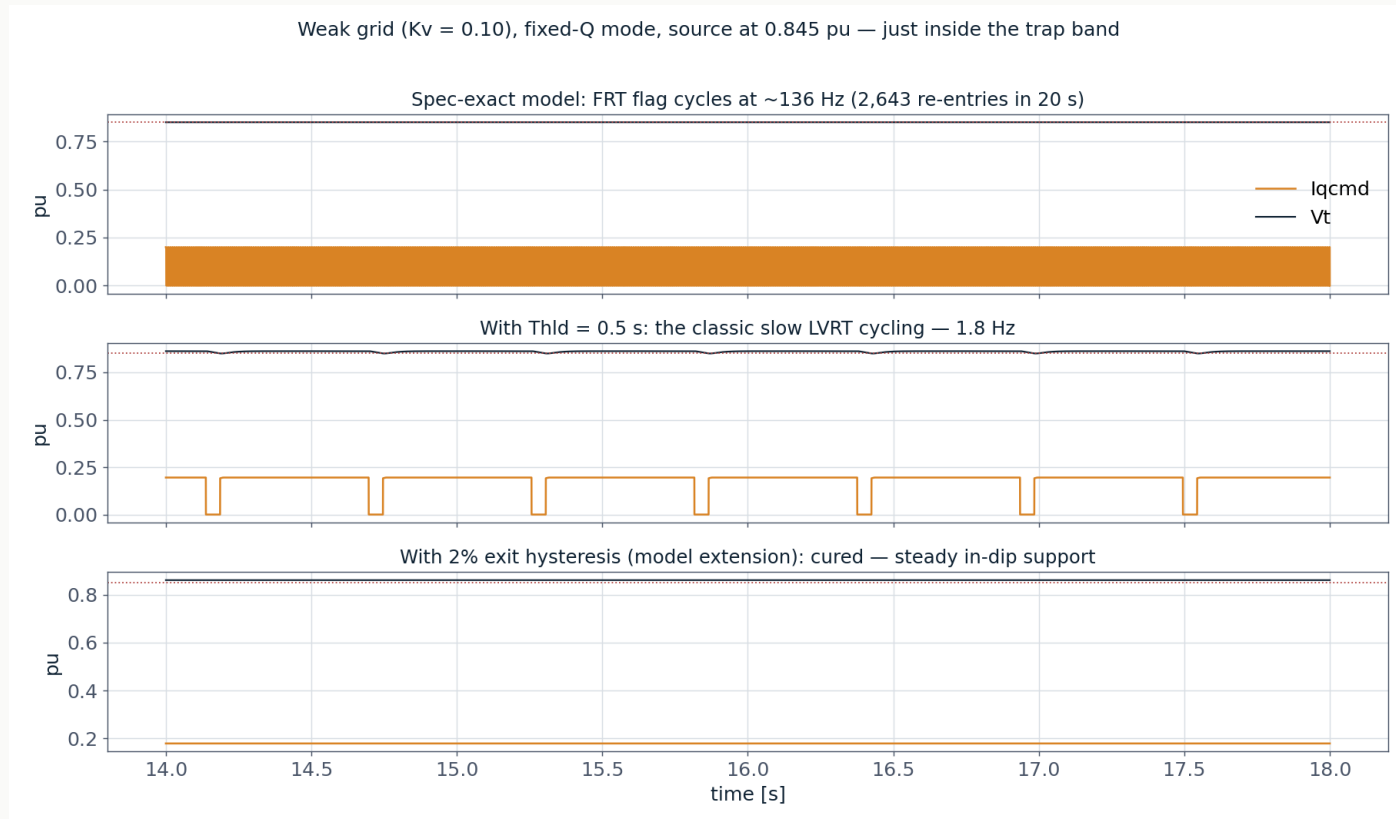
- Testing of inverter Low Voltage Ride Through, picked up some interesting behaviour.
- At a voltage sag to 85% nominal (A UK Grid Code requirement) the inverter does not respond correctly as the V_{min} (voltage floor) default is set to 0.9 – which causes the power output collapse. V_{min} needs to be set below the LVRT threshold.

The 85% sustained sag, run twice — the only difference is the controller's internal voltage-command floor (' V_{min} ', not an FRT setting)



LVRT Oscillation

- Claude picked up a known (but uncommon) problem in a weak grid – during LVRT.
- The output of the reactive current injection is sufficient to drive the terminal voltage back to a healthy state. The inverter drops out of LVRT mode, the voltage falls again and the inverter re-enters FRT and starts injecting reactive current.
- LVRT Hysteresis function is needed to overcome this type of problem.

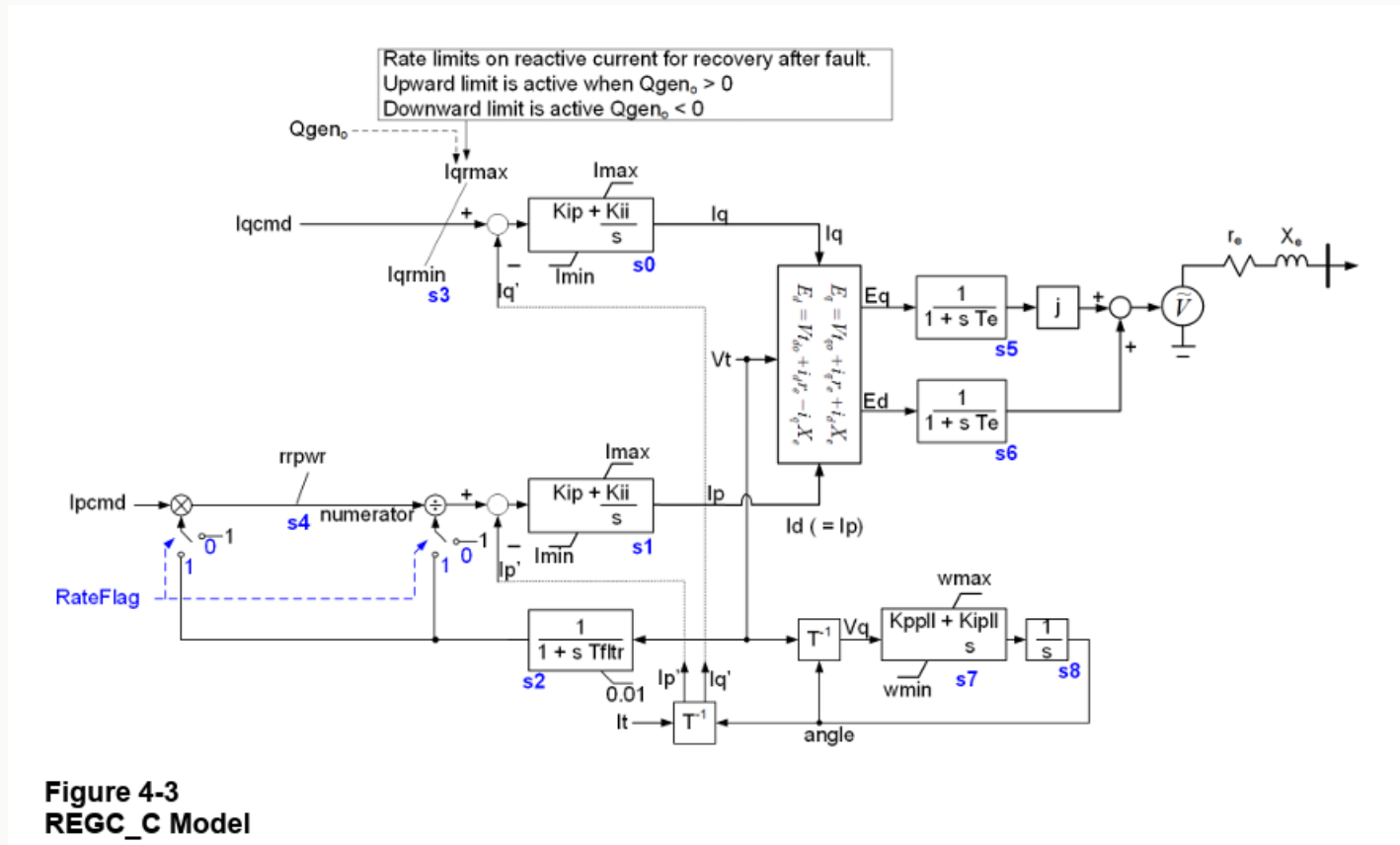


Electrical Generator System – WECC REGC_C

- The WECC Electrical Generation System model REGC_C is a step forward from the earlier models and uses a controlled voltage source, rather than a simple controlled current source, to represent the behaviour more accurately.
- OEM models start to diverge at this point, as it is a physical implementation layer and representations tend to be vendor specific. The WECC model is a deliberately simple positive sequence model rather than a full equivalent model.
- The REGC_C contains all the core functions for a generation controller; it receives the ***I_q*** and ***I_p*** current setpoints from the REEC system and tries to implement that at a physical level. It specifically includes additional functions for approximating the PLL behaviour and inner current control loops.
 - Controlled Voltage source.
 - Inner current control loop.
 - Simple Phase Locked Loop (PLL) Representation.

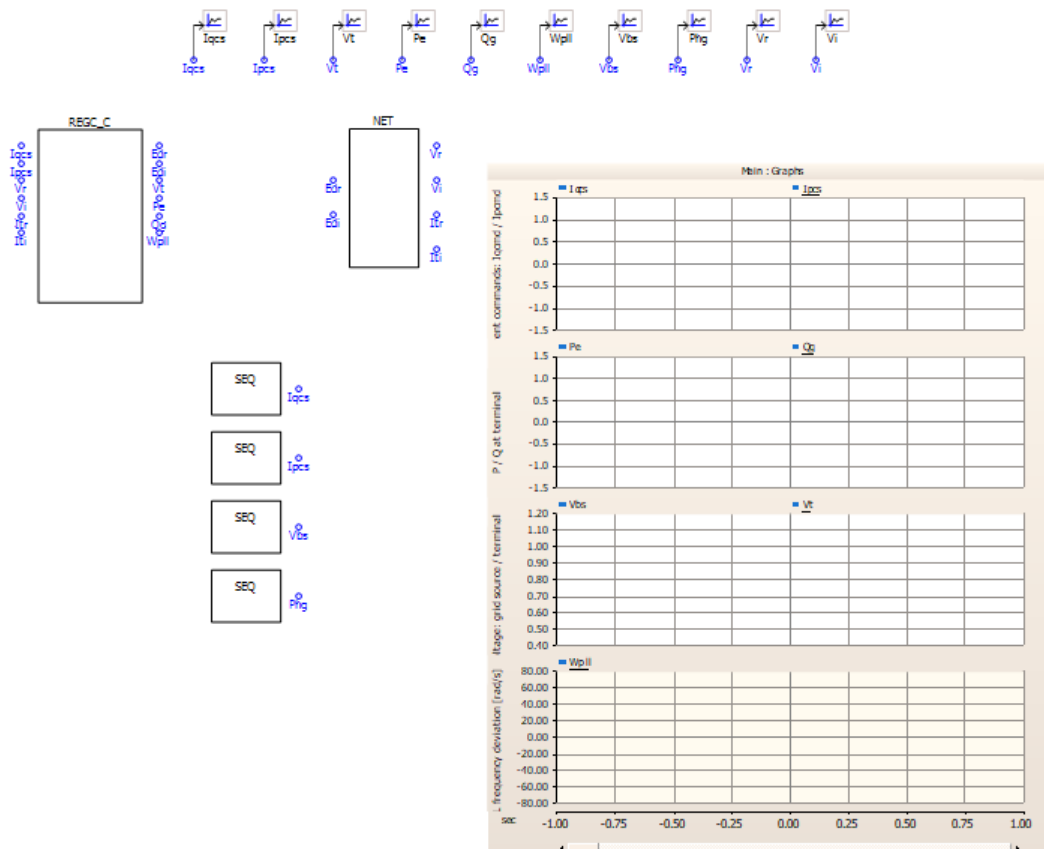
Electrical Control System – WECC REGC_C

- The version below is from the WECC / EPRI document library and shows the REGC_C model, which takes the input I_q and I_d values and passes them through the inner current control loop and PLL to realise them as a controlled voltage source.



Generator Controller – WECC REGC_C

- The implementation of the REGC_C model was carried out in the same way as the REEC_C model



[WECC_REGC_C:REGC_C_F] id='2145000100'

General

Release: 0=hold/track, 1=released 1

RateFlag: 0=current ramp, 1=power ramp on Ipcmd

Tftr voltage sensor time constant [s] (0=byp: 0.02

Te network interface (EMF) lag [s] (0=bypass: 0.01

Re generator effective resistance [pu] 0.0

Xe generator effective reactance [pu] 0.15

rrpwr active current/power ramp rate (signed 10.0

Iqrmax reactive current recovery rate up [pu/ 99.0

Iqrmin reactive current recovery rate down [p -99.0

Imax converter current rating [pu] (match RE 1.15

Kip inner current PI proportional gain 0.5

Kil inner current PI integral gain 20.0

Kppll PLL proportional gain 60.0

Kipll PLL integral gain 1400.0

wmax PLL frequency deviation upper limit [rad 75.0

wmin PLL frequency deviation lower limit [rad -75.0

Vpllfz: PLL integrator frozen below this Vmea 0.4

General

Ok Cancel Help...

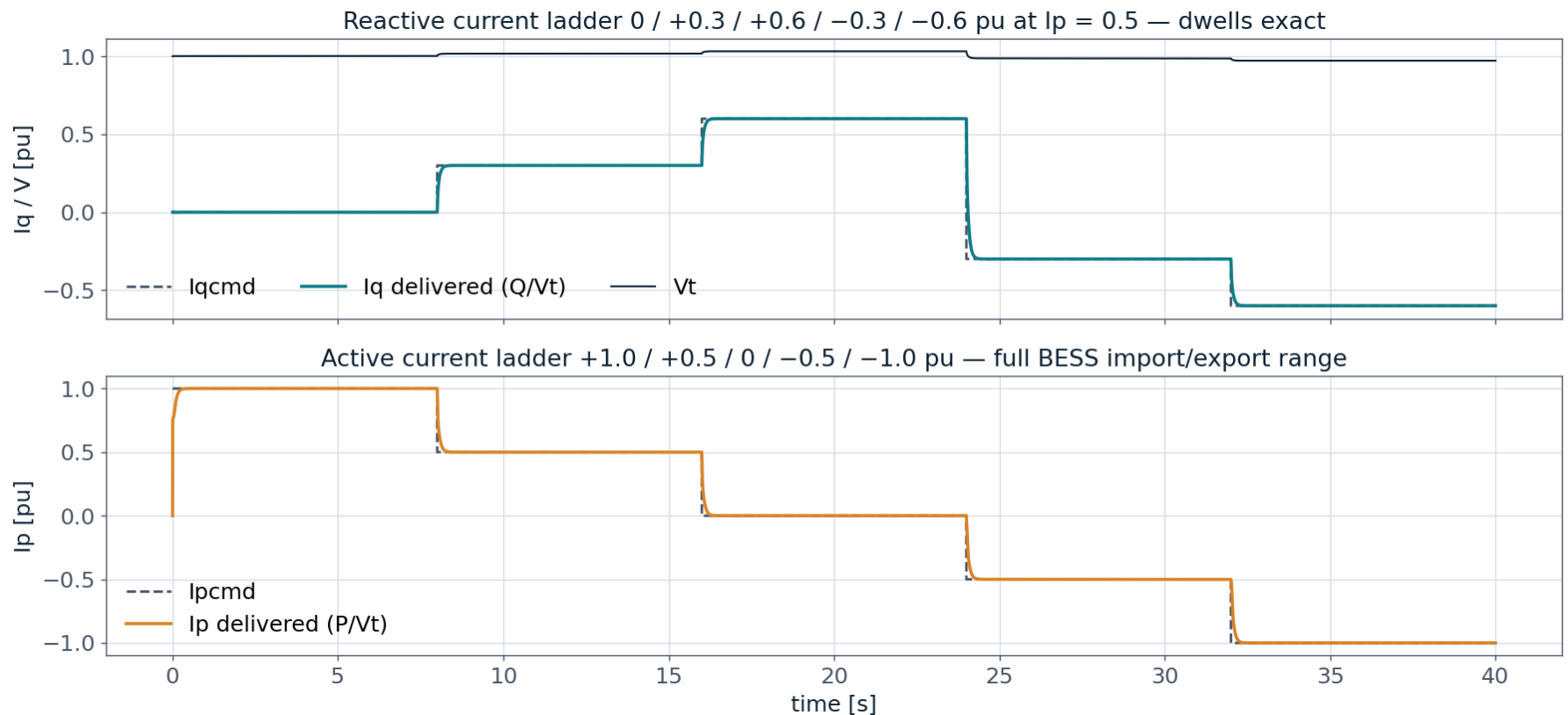
REGC_C Testing

- As with the REPC and REEC approach Claude developed the test plan to prove the implementation was correct and worked as expected.

Series	Results
Smoke, $I_p = 0.5$ into $0.005 + j0.05$	settles on the closed-form network fixed point: V_t 1.00219, P_e 0.50109, $Q = 0$
I_q ladder $0 / \pm 0.3 / \pm 0.6$ · I_p ladder $\pm 1.0 / \pm 0.5$	every dwell exact: $Q = V_t \cdot I_q$ and $P = V_t \cdot I_p$ to 5 decimal places
$rrpwr = 0.25$ pu/s, command ± 1.0	all four signed-ramp behaviours correct (limited up while +ve, free shed, limited descent below zero, free recovery)
RateFlag = 1 at $V_t = 0.70$	ramp measured at exactly 0.25 pu/s of POWER — not current
Dip to 0.30 pu (below V_{pllfrz})	PLL integrator freezes, proportional path re-tracks, clean recovery
$\pm 30^\circ$ phase jumps · $w_{max} = 10$ retest	resync ~ 0.25 s, peak 21.8 rad/s; clamp pins W_{pll} at exactly +10.0
I_q command $1.5 \times$ both signs	held at exactly $\pm I_{max} = \pm 1.15$

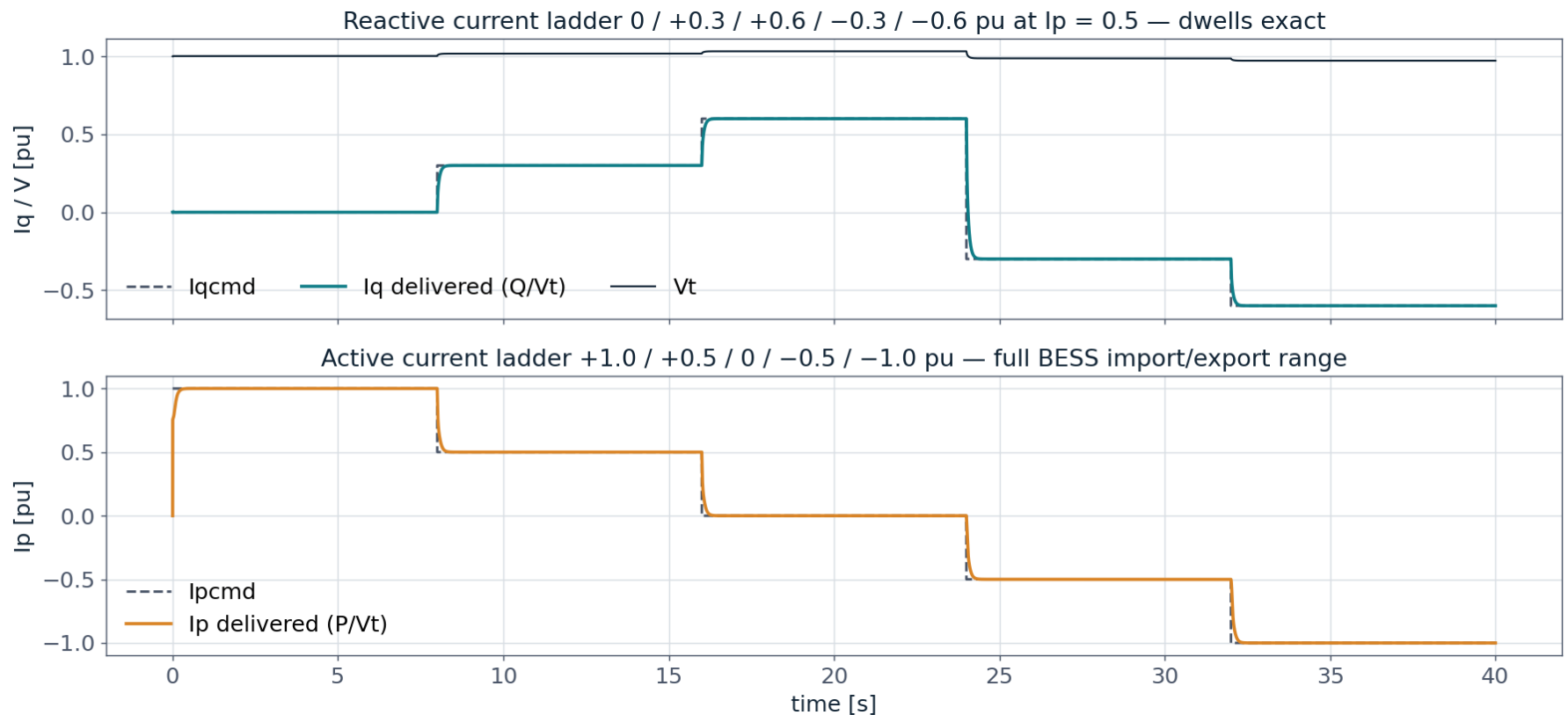
REGC – Current Commands

- Simple testing of I_p and I_q current control commands to check response from the voltage source.



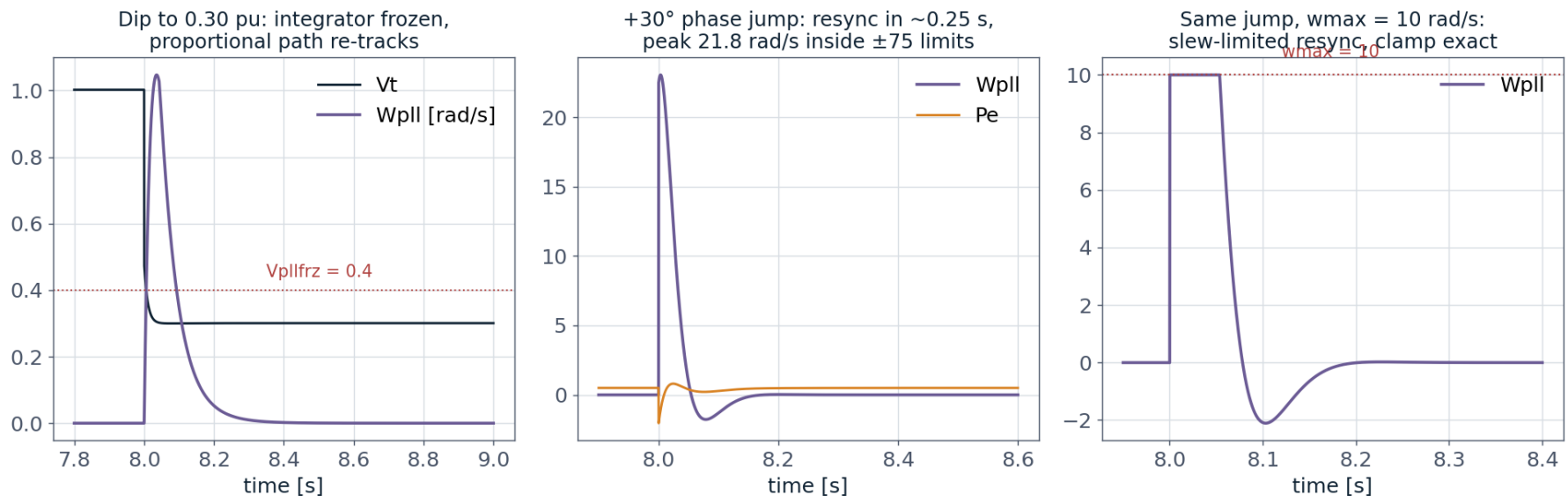
REGC – Current Commands

- Simple testing of I_p and I_q current control commands to check response from the voltage source.



REGC – PLL Response

- The PLL is represented as a simple equivalent positive sequence model, and is tested for voltage dips and phase jumps
- Deep voltage dip: the integrator freezes below V_{pllfrz} while the proportional path keeps tracking — leaving a small, genuine Q offset from the frozen state.
- Phase jump: 30° resynchronised in a quarter second.
- Clamp: tighten W_{max} to 10 and the PLL slews at exactly the limit.



Summary

- The use of AI was a huge help in this and is very much playing to the AI strengths, of mathematical modelling and a direct MCP plug-in to PSCAD.
- As with the earlier REPC case. Claude ran through and built and tested the REEC and REGC modules and then joined them together with ease. It picked up a few interesting bugs and oddities on the way – specifically:
 - Sustained shallow voltage dips – setting parameter conflicts
 - LVRT oscillation behaviour in weak grids.
- The sustained 85% voltage dip is a problem I have encountered frequently in the day job, and has often been the cause of some head scratching, as many OEM models are not always clear as to what all their parameters actually do.
- LVRT oscillation is a known issue on weak grids – although it is uncommon, and a trap for the unwary.
- Claude picked up and identified the behaviour and the root cause of both responses and correctly identified the problem and the solution. Next steps is to integrate with the REPC and a whole plant model.