**IBRWG Meeting Minutes**

**August 2025**

**Chair: Julia Matevosyan, Vice-Chair: Miguel Cova Acosta**

**IBRWG met on August 15th (Webex, Open Meeting).**

The agenda and the presentation slides are available [here](https://www.ercot.com/calendar/08152025-IBRWG-Meeting-_-Webex)

~100 people attended the meeting (at peak)

**IBRWG Main Meeting**

**Reactive Capability at Low MW Output**

Freddy Garcia, ERCOT

* Recapped the discussion from previous meetings.
* NOGRR 245 introduced wholesale reference to IEEE2800 Clause 5 (Reactive capability, incl. down to 0 MW, during normal operation) in ERCOT’s Nodal Operating Guide Voltage Rider-Through (VRT) section (Section 2.9.1).
* This created ambiguity with existing ERCOT Protocols (Sec. 3.15), which require reactive support at output ≥10%.
* Sect. 3.15 also requires utilization of reactive capability at lower output levels, if available, when an IRR is online.
* Combined with wholesale adoption of IEEE2800 Clause 5 through NOGRR245, this seems to have introduced a requirement for all future IBRs (SGIA signed after 08/01/24) to have and utilize reactive capability down to 0 MW output.
* However, with Clause 5 (relates to normal operation) being referenced in VRT Section of ERCOT NOG there is lack of clarity.
* Miguel Cova Acosta (Vestas) brought this issue at June IBRWG meeting.
* IBRWG leadership, the OEM and some interested REs met offline in July to discuss.
* Currently, ERCOT legal is reviewing protocol language on this topic, to take note of any language related to this topic before deciding on how to address, more updates to follow.
* Julia adds that on top of addressing the issues itself, it would be good to bring back to IBRWG, how the requirement for reactive capability (and/or performance) at 0 MW output will be assessed/verified during interconnection process.
* Freddy: yes will do.

**VRT / PFR Controls Coordination - GE Vernova Perspective**

Dustin Howard, GE Vernova

* Part of consulting services at GE Vernova, so not representing any specific product line. So will be sharing a broader GE Vernova’s perspective today.
* The topic of interest here is how does PFR response relate to VRT of the plants and how the trade off between VRT and normal operation happens; how do we measure frequency to provide frequency response.
* Start with the basics of the objectives of the plant control (outlined on slide 3), regulating active power, voltage and frequency response. It’s a middleman between the grid and the inverters in the plant.
* In wind and solar PPC it’s only regulating power only if it has to do so, e.g. curtailment or ramping limitation.
* PPC control is slow and not intended to impact the in-fault behavior and immediately after the fault is over (cycles – up to a second), during this time the behavior is driven largely by inverters.
* How do we measure frequency to do PFR (slide 4), the way the plant knows about frequency is through POI voltage measurement (e.g. zero crossing in the voltage, or PLL algorithms)
* The voltage at the particular node gives you a good indication of frequency only during steady state conditions, but during events it’s challenging and can result in frequency spikes due to noise in voltage waveform itself (non-fundamental components in the voltage can distort where the zero crossing occur), transients like phase jumps (e.g. due to line opening) can result in perceived frequency spikes (illustrated on the slide)
* Various tools to address these challenges (on slide 5), e.g. simple filtering (heavier filtering reduces the risk of misdetection but slows down the response time), freezing of response if determined that the data is not, wider deadband to be less susceptible to noise in frequency (again slows down the response) – generally a combination of these is used in equipment design.
* Speaking about VRT and IBR unit level (slide 6), the IBR units are themselves measure voltage at MV or LV of its terminals and decide if it does or doesn’t need to respond
* Some IBR units have an explicit VRT mode (or switch) that measures voltage level and once it falls below certain level they respond.
* Other is non-explicit VRT (no mode switching) and control structure is retained during faults, but IBR units change limits on this control in order to support the grid.
* The severity of the fault can be detected from positive sequency voltage magnitude and then the type of fault can be detected from negative sequency voltage – all in the matter of cycles, not seconds
* What happens during faults – e.g. during low voltage faults IBR units increase reactive current, reduces active current and temporarily override or ignore PPC commands. After disturbance depending on controls IBR unit in terms of active and reactive current either tries to return to pre-disturbance voltage or reactive power (depending on controls), restore active power and then return to following PPC control dispatch
* During fault and fault clearing, voltage is very unsteady (not only magnitude is falling but also IBR unit reactive current injection is affecting voltage and phase angle) – difficult to get reliable frequency or RoCoF measurement
* So, transition between VRT and normal operation: for smooth transition 1) the reactive current at the IBR unit level needs to be adjusted based on it’s local voltage conditions (don’t want to continue injecting high reactive current once the fault been cleared) 2) ramp active power relatively slowly to avoid subsequent voltage collapses, especially in weak grid 3) smoothly transition to the resumption of the PPC control and you want to avoid aggressive control response to perceived frequency at the IBR plant level.
* If there are issues with this transition they can be avoided by relatively easy changes of parameters, changes in transition time and/or filtering of frequency but care needs to be taken to avoid any adverse impacts on other responses
* Patrick (ERCOT): question on slide 5. Curious about temporary freezing control to avoid undesired response. How do you know what active power output to freeze at, i.e. how do you freeze at pre-disturbance output, rather than at lower output that may happen during VRT?
* Dustin: few ways to do that. If you use freezing logic, you can monitor the signal of the PFR function and filter that signal as desired. If something happened in the grid and you realize you are getting unreliable signal you can go back to last reliable signal – this is conceptual implementation not applied in any particular product necessarily.
* Patrick: Slide 4, when you are monitoring frequency at PPC, is it seeing this frequency spikes from this one cycle of the phase jump or is it averaged over a number of cycles (referring to the figure on the slide).
* Dustin: unlikely to make a control decision based on 1-2 cycle measurement, some filtering or averaging is very likely implemented because this issue is understood, and you don’t want to respond to this sudden change
* Patrick: is there a standard or a best practice on what that averaging timing should be?
* Dustin: yes FNN standard <https://www.vde-verlag.de/buecher/636339/ermittlung-und-bewertung-der-frequenz-in-energieversorgungsnetzen.html>
* Rishi: How you test and validate the behavior of actual controls and interaction between unit level and PPC (in reality vs simulation models). Larger discrepances are observed with third party PPC vendor.
* Dustin: From the product teams there are layers of validation. The engineers responsible for development of the products have their own tools for testing and debugging of the control software, often there are CHIL test beds where the control hardware is tested, the third category is where the customer models, used in interconnection studies are used to test what’s happening. For the first two validation methods there would be a large set of generic test cases based on observed issues historically.
* Rishi: are the simulation models that product engineers are using internally, ar they the same black box EMT models that are then given to the developers, or are these open models that they use.
* Dustin: It can be either, these cannot be answered generically.
* Julia: I understood your answer to Patrick that you can freeze to what you chose to but do you have any recommendation, what would make more sense to freeze to?
* Dustin: I would expect that the best you could do, is you want the plant to return to the pre-disturbance value, before you start responding to any kind of frequency event. Not allowing PFR to be taking over very quickly because it would be hard to even determine the frequency during the recovery phase
* Julia: To that end what kind of signal PPC would use to understand that it now fully recovered from VRT? You mentioned voltage but is active power recovery PPC is looking at to understand that now you are fully recovered.
* Dustin: you want to see if voltage and frequency active power are back to pre-disturbance values (last reliable measurement).
* Julia: Where you have IBR unit from one manufacturer and PPC model from another, is there a recommendation of how this control handover is set and tested?
* Dustin: Not involved in such coordination but suspect it’s common practice for PPCs not aggressively react during VRT and there should be multiple handles within PPC to adjust when to stop and when to start these controls. At the connection stage you should have models of both and find any issues and mitigate them accordingly.
* Julia: where you were talking about the two VRT hand over modes (explicit vs non-explicit), would you recommend one over the other or is this something that cannot be changed in the product once it’s decided?
* Dustin: In some places in the world, it’s a requirement, and for some vendors there may be a way to choose it. GE Vernova equipment is using non-expicit more to avoid the risk of toggling between the modes (in weaker parts of the system specifically)
* Comment in the chat from Rishi: One of the issues we are aware of as owner/developer is that PPC simulation models aren't required to be validated, so you have a PSCAD model developer developing a model to pass MQT / meet model requirements which bears little relation to what the real PPC does. Also, the real PPC developer (who is a 3rd party) has no simulation environment available to test alongside unit controls or in a large disturbance case. In this case, you cannot really test or tune the PPC-unit controls coordination in simulation. Whatever happens in the field during large disturbances is basically going to be a surprise. For example, we recently found one PPC developer had a 5-minute hardcoded freeze timer, despite this value being adjustable down to 0.01s in PSCAD. Accurate PPC models are rarely used in interconnection stage as the eventual PPC vendor is probably not known.
* Jimmy Zhang (ERCOT): control freezing delay (on slide 5), what are default times that we are talking about here.
* Dustin: Control freezing only happening for a few seconds during and immediately after the fault, filtering is on the 100s millisecond timeframe but may vary widely between different equipment.
* Jimmy: (slide 6) for the zero-crossing calculation and PLL tracks frequency they have their own pros and cons do you use different methods in different equipment or just use only one of these?
* Dustin: at the inverter level you are required to have a PLL (unless it’s GFM) to track not only frequency but also phase angle of the voltage, the zero crossing can be used that the PPC level, slower method and doesn’t need to track the angel.
* Farhad: PASCAD model often doesn’t include PPC, does not exactly replicate the plant. Coordination between different PPC manufacturers and different inverter OEM is difficult. A lot of issues are uncovered during the commissioning and later stages of it. – any thoughts or best practices?
* Dustin: a lot of movement in the right direction with various requirements e.g. IEEE P2800.2 on post-commissioning monitoring and model validation, some work at CIGRE in that direction. As vendors we are constantly improving our models to increase fidelity. Ideally the models that are used for development and debugging should be the same as the ones used for studies but often development engineers are even using different software and are not aware of PSCAD. Increased model validation and benchmarking should help going forward.
* Farhad: There are different models in different software PSCAD, PSS/E etc. CIGRE has a unified dll modeling approach for all of these programs. Not all the software packages support this yet, but certainly this can be helpful in the future and for moving models between different software and versions.
* Thair: Question about functionality of the ride through capability at the PPC and enabling it against the inverter level, do you recommend enabling this functionality or do you recommend inverters do it.
* Dustin: it can depend on system where a plant is interconnecting, also studying both and seeing if there’s a meaningful performance difference, this then can be decided – general recommendations cannot be made here.
* Thair: In Australia it’s disabled and VRT is at inverter level to prevent that confusion that ERCOT is seeing.
* Sun Wook: comment on Rishi’s note in the chat. It is a valid point about PPC models and interconnection processes. There are requirements in the planning guide to ensure that the model represents what’s in the field, it’s the responsibility of the plant owner /developer to ensure it. If any changes are made, then pieces of the interconnection process/studies may need to be repeated. So, there’s an incentive for the developer/owner to make sure that the models are accurate as soon as possible in reality.
* Julia: After the July presentation from Patrick, I’ve reached out to EirGrid, AEMO and NESO to see if they see similar issues as ERCOT for VRT/PFR coordination and they all said No. Based on your experience can you think of grid code requirements that they have that may be helping not having this issue? Frequency measurement standards, priority of controls requirements etc.?
* Dustin: Don’t know off hand, could be differences in PFR requirements, ride through requirements. May be other aspects on the grid that may be unique, e.g. not having series compensation… this probably wouldn’t matter.
* Julia: you are raising the right point may be ERCOT’s more stringent PFR requirement is actually something to look into and that’s leading to this issue
* Rishi: Responding to Sun Wook. Agree that every entity to do their best to get accurate models, but the requirements today are so vague that it doesn’t amount to anything. For example, to have an accurate PPC model, it should be required at the QSA (with rigor similar to unit model) and then the developers would actually have to do this. Otherwise, everyone will be just saying they have an accurate model
* Sun Wook: You can set up multiple check points for model review at every single stage of the interconnection process, but we have to be practical. But any time you understand you have PPC model that changed from what was studied during FIS, it needs to be resubmitted to ERCOT and restudied.
* Rishi: That’s correct but all this back and forth has timeline and cost implications to the developers and people making these decisions are not engineers and will not accept doing it until ERCOT says you cannot commission the project without.
* Julia: I can confirm that we are here across the industry including [DOE i2x FIRST forum](https://www.esig.energy/i2x-first-forum/) that the developer with submit and comply to only what’s clearly set in the requirements.

**VRT / PFR Controls Coordination – Power Electronics’ (PE) Perspective**

Stephen Giruere, PE

* Will talk about inverter response to the VRT during a frequency event.
* Inverter VRT responses are configurable and depending on how they are configured they’ll do different things. The most common in ERCOT is reactive response based on voltage threshold and K value (Slide2).
* Can be set up on Q priority or P priority
* During VRT the PPC setpoints are ignored
* And exit response is based on VRT recovery ramp rates (some utilities want it slow others want it fast). There’s also hysteresis built in to avoid toggling between VRT and non-VRT modes.
* Slide 3, different types of PPC exist and each one will have a different approach and focus
* The inverter has a number of tools, voltage and frequency protection setting, inverter active power output limit and stings, P and Q ramp rate limits, various VRT algorithms, frequency and voltage droop curves
* It’s easier to have specific discussion on specific project – hard to talk about these issues in general.
* Slide 6 typical frequency event (including hysteresis)
* Slide 7, it is important to understand where the frequency droop curve is physically located within the system. If it is in the PPC it is reading the frequency from the revenue grade meter, and because its mod bus communication is not looking at the waveform it’s looking at the RMS voltage. SEL would be a good resource to look at how this is done. There are other OEMs for the revenue grade meters as well. They all have some kind of averaging method to filter out spikes. But the point is if it’s PPC measuring and responding to frequency it will take about 2 seconds to respond including measuring, calculating frequency and with all the delays (the response time also depends on number of inverters in the plant.
* If you break this response out and have a dedicated PLC in the plant controller you can do a little faster
* But if you want to go even faster you have to get these functions into the inverter (e.g. this is needed for FFR, because the response time is so short)
* The disadvantage of it is that all of these inverters are acting on their individual frequency measurement, which may result in difference in response.
* Slide 10 shows what is happening at the LVRT response when the plant is not operating at the maximum. You’ll see the voltage deep, the inverter will respond by providing reactive power until the voltage returns back to normal (e.g. 1pu), the way the inverter knows that it’s in LVRT mode is that we set a voltage threshold, typically 0.9 pu. There are configurable parameters on how fast to respond and how fast to exit and also how much to respond in terms of Q.
* If you are at maximum power (slide 11) and you set a Q priority and you are at LVRT, the inverter will reduce active power in order to provide reactive power until you get to nominal voltage
* What does the PPC do? In LVRT, slide 12, (purple line indicates the setpoint power), in LVRT response this P setpoints will not change, the inverter ignores P and Q setpoints until it exits LVRT
* Slide 13, if in the middle of LVRT event there is also a frequency event. The PPC will change the set point that it gave to the inverter, to respond to the frequency event. And what will happen is that when you get out of the LVRT you are at the setpoint where you do not necessarily want to be and that would continue until the frequency event went away.
* There are several techniques to address this. E.g. freeze the setpoint at PPC, to ignore the frequency event during LVRT. So how does PPC knows to freeze the set point. The inverter has a status register, normal operation or VRT, and have to coordinate with PPC controller designer to know to freeze the PPC settings when the inverters see the VRT mode.
* When you exist LVRT there’s a number of configurable parameters (listed on slide 14), these parameters give you flexibility of how you get out of VRT mode.
* There was a lot of discussion about modeling, we had a number of our customers bringing their PPC controller to us and we did coordination testing to ensure that as the system is installed in the field it has expected performance
* Julia: There was a slide about coming out LVRT mode, how does inverter understand? You said you are using the voltage threshold, but are you also tracking active power recovery to know that now VRT mode is over?
* Stephesn: it’s different in solar and storage, because in storage you can come to the same setpoint, while in solar you may not be able to because irradiance might have changed, so you are trying to get to the pre-disturbance level with solar, but you might not be able to. So, it’s voltage that’s telling you that the VRT mode is over.
* Julia: So, you are basically not looking at active power recovery?
* Stephen: Correct
* Julia: You said speed of response varies depending on how many inverters you have, does distance of inverters also play a role
* Stehpen: if you have microfiber the difference may be in microseconds between 50 feet and 500 feet distance. What matters more is how busy the network is at the time. If e.g. network cameras or data historian are on the same network that will take over some bandwidth this may affect how fast PPC interacts with the inverters.
* Julia: Do you have a specific method or standard that you use to measure frequency e.g. for FFR type of response. Is it same for all products or varies?
* Stephen: We use synchro phasors line by line, but it’s not something that’s reported to the revenue grade meter, because it’s too much information. But we can measure frequency very granularly.
* Julia: What frequency measurement PPC will respond to?
* Stephen: if we are using the inverter, it’s mod-bus registry with frequency, for FFR we wouldn’t be using revenue grid meter. It is slower but on the other hand also be more accurate
* Patrick: On slide 13, question about the frequency event that you are seeing during LVRT, how do you know if it’s an actual frequency event or just some mis-measured frequency spike? Or do you know?
* Stephen: If we are trusting the revenue grade meter, we’d assume it’s measuring it’s accurately and it won’t catch those spikes if it’s averaging appropriately. But if we are talking about FFR type response at the inverter you can potentially see more nuisance events.
* Patrick: walks through the issues that ERCOT is seeing with response to perceived frequency events during VRT events and asking how to eliminate these improper responses?
* Stephen: couple of things you could do, slow down the ramp rates for the inverter, to take longer to get to a new set point. Another one is freezing PPC delta setpoint so that it doesn’t start changing until you start recovering from VRT, then chances are higher that this response is to actual event.
* Patrick: ERCOT is trying to give some kind of direction about how it needs to be handled, leaning towards prioritizing VRT, don’t respond to frequency until you exit VRT mode and recover.
* Stephen: Dustin’s comment about freezing commands is probably the right approach
* Patrick: Yes, as long as you are freezing to the right set point. IF you are freezing to the set point / active power during VRT, then it’s not the right setpoint, you got to freeze to the pre-disturbance set point. Is this something that PE is doing to operate in that fashion or is this something that we need to verify.
* Stephen: If we are getting a setpoint from the PPC you’ll tend to jump to that set point right after VRT, the tools you’d have to prevent this is slower ramp rates. We also have a way to prioritize volt-var response or frequency droop response, so those are couple of tools…
* Patrick: we’ve seen both when inverters are on the way back to their pre-disturbance setpoint, but then erroneous PFR response setpoint makes it drop the output where it shouldn’t be. And we also seen where inverters during the VRT that the PPC kind of grabs the control and the inverter never fully come out of VRT and start responding to the perceived frequency event. So picking this erroneous setpoint during VRTis the problem.
* Rishi: On the same slide this is demonstrating a PPC that does not freeze during VRT mode at the PPC level, because PPC is changing its P setpoint in response to the frequency event that occurs during VRT. The inverters are not responding to the PPC since they are in VRT mode, but as soon they come out of VRT they’ll follow the new PPC setpoint that was not frozen during the VRT event and has changed from the pre-disturbance level due to a frequency event.

Stephen: Yes. This is one possible ideal response and kind of the way I was thinking about the problem

Rishi: and then maybe one of the ways to mitigate the issue is also freezing the PPC to the pre-disturbance value in theory it helps to mitigate that shift in setpoint. So, the question is, for you as OEM that works with 3rd party PPC vendors and also have your own PPC. In your latter function what’s you approach to measure frequency at PPC, how that external revenue meter is configured, how is the frequency filtered.

Stephen: It depends on the grid; in some grids the frequency is steady and zero crossing is easy to measure in other areas and more averaging is needed.

Rishi: Wonder if this could be a good opportunity to integrating the meter model in the IBR model testing. At minimum there is a synchro phasor class that defines what filters will be applied to that measurement and maybe as an industry we can investigate this further and address the issues.

Rishi: We are talking about this primarily in the context of event analysis and erroneous response to perceived frequency during a VRT event, but what happens if there’s an actual event following a VRT event (e.g. because a lot of gen tripped), how ERCOT would want to prioritize there>

Patrick: Great question, this is something we are actively working on in collaboration with IBRWG and figuring out best practices and with event analysis team. Maybe we still want to prioritize VRT and then PFR once the recovery is complete. For PFR units across the system will be responding to this an event, each relatively small amount, and only a smaller portion of these units will be in VRT mode, so may be that’s ok if the latter units are recovering first while others are responding to the PFR event from the onset. But still if the unit that entered VRT are doing some kind of freezing we need to define what do they freeze their setpoint to.

Rishi: Agree, maybe when you get that you have a more detailed guideline of what you would like us to do. Starting a HIL testing for a hybrid plant and would like to have some test around this VRT/PFR coordination and would like to know what behavior is expected.

Patrick: This sounds great, and we would like to work with IBRWG to figure this out and also from modeling side.

**NERC Updates**

Eric Newnam, TRE

* FERC Order 901 and Milestone 2 update, FERC has approved PRC-024 on July 24, 2025, with effective data of October 2026 (links on slide 2),
* This also triggers the implementation plan for PRC-028 and PRC-030 approved earlier in the year
* Project 2020-06 Verification of Models and Data for Generators:
	+ Model validation and verification definitions adopted by NERC Board on August 14, 2025
	+ MOD-026 Verification of Dynamic Models and Data, comment period open through September 10, 2025, 8 pm ET.
* Project 2021-01- System model validation with IBRs – Posted for comments and ballot through September 10
* Project 2022-02 – Uniform Modeling Framework for IBRs – Posted for comments and ballot through September 10
* Milestone 4 – Posting SARs and drafting team nomination solicitation the week of August 25th
	+ Project 2025-03 Operational Studies
	+ Project 2025-04 901 Planning Studies
* NERC other activity on slides 3:
	+ NERC issued essential actions to industry: IBR Performance and modeling on May 20, Questions responses are due midnight August 18, 2025
	+ Standard Project 2022-004 EMT Modeling, Formal comment period and initial ballot, target posting mid-August for FAC-002-5 Facility Interconnection Studies.

**Other Industry Updates**

Julia Matevosyan, ESIG

* G-PST/ESIG Webinar: [Requirements and Verification Procedures for Grid-Forming Units – The German Approach to Ensuring Power System Stability](https://www.esig.energy/event/german-approach-stability/) (see slide 2 for details)
* DOE Forum for the Implementation of Reliability Standards for Transmission (i2X FIRST) – Season 2. The July meeting on IBR Plant Design Evaluation with Applicable Requirements. Presented the developer and IPC perspective on challenges with design evaluation, especially in multi-vendor projects and many consultant/contractors involved. More details on slide 4.
* Follow ESIG i2X FIRST website <https://www.esig.energy/i2x-first-forum/> for meeting materials & recordings and for future meeting details & agendas
* August i2x FIRST meeting will continue the discussion on the same topic of IBR Plant Design Evaluation. We’ll hear ISO/utility perspective as well as how to use available documentation and type tests for design evaluation to complement purely simulation-based assessment.
* NASPI Webinar: Julia will present on [Post-Commissioning Monitoring Aspects of IEEE P2800.2](https://www.naspi.org/node/1017) – August 20, 2025
* ESIG Offers two training opportunities [Interconnection Studies Short course](https://www.esig.energy/event/esig-interconnection-studies-short-course/) Nobember 17-19 in Manatee Lagoon, FL and [EMT Training](ESIG%20Electromagnetic%20Transient%20Training) December 16-19 2025, at Texas RE’s offices in Austin. Click on links for more information (also slide 7 of the deck has more info)