Update on Inverter Based Resource (IBR) Modeling and Simulation in ASPEN OneLiner

ERCOT SPWG Meeting
July 17th, 2024

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History of IBR Models in OneLiner

2010

Current Limited Generator

Ability to constrain generator output to a specific value

2016

VCCS
(Voltage Controlled Current Source)

Tabular Voltage-Current curve for positive sequence

2021

CIR (Converter Interfaced Resource)
K-Factor control for positive and negative sequence

Type-3 Wind Plant

Future

Vendor Specific DLL Models

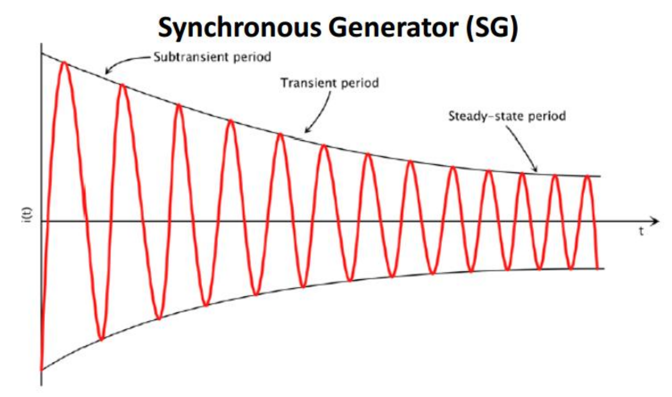
Comparison of Conventional and IBR Fault Response

- **Conventional fault current:**
  - Uncontrolled
  - All 3 sequences: +, -, 0
  - Magnitude typically 5 pu or higher
  - Angle lags the voltage by approximately 90 deg
- **IBR fault current:**
  - Computer-controlled
  - Magnitude typically 1.1-1.5 pu
  - Angle can lag or lead the voltage (control dependent)
  - No zero sequence
  - No or artificially low negative sequence

Comparison of Conventional and IBR Fault Response

Conventional Generator

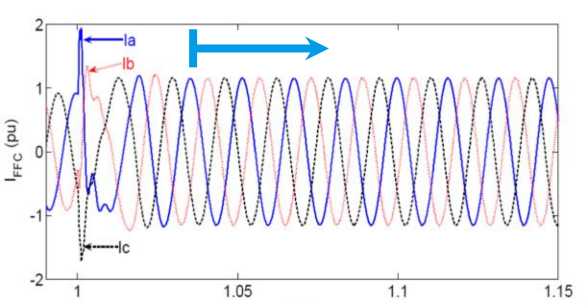
Phasor-domain Solution based on specific time periods



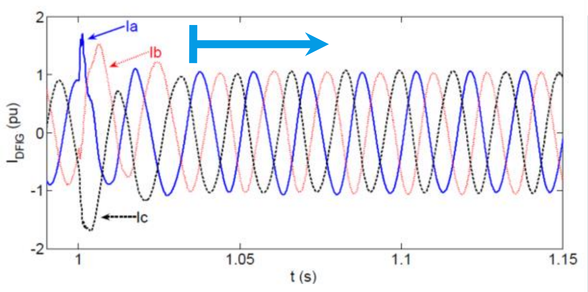
IBR Generator

Phasor-domain Solution based on post-transient period

Type-4



Type-3



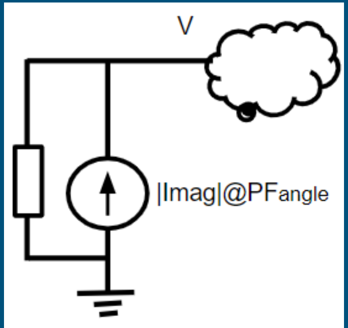
Type-3 and Type-4 Diagram Reference: EPRI

Comparison of Conventional and IBR Fault Response

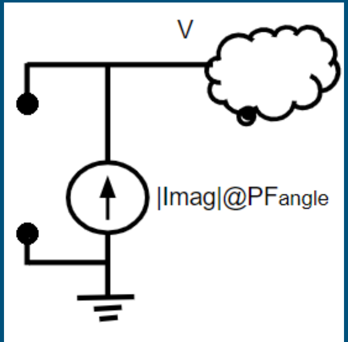
- Ideal voltage-dependent current source
  - Impedance (current-limited generator only)
- Iterative solution

(more details later)

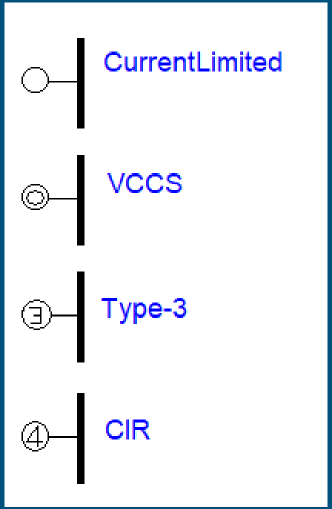
Current Limited Generator



CIR Type-3 VCCS



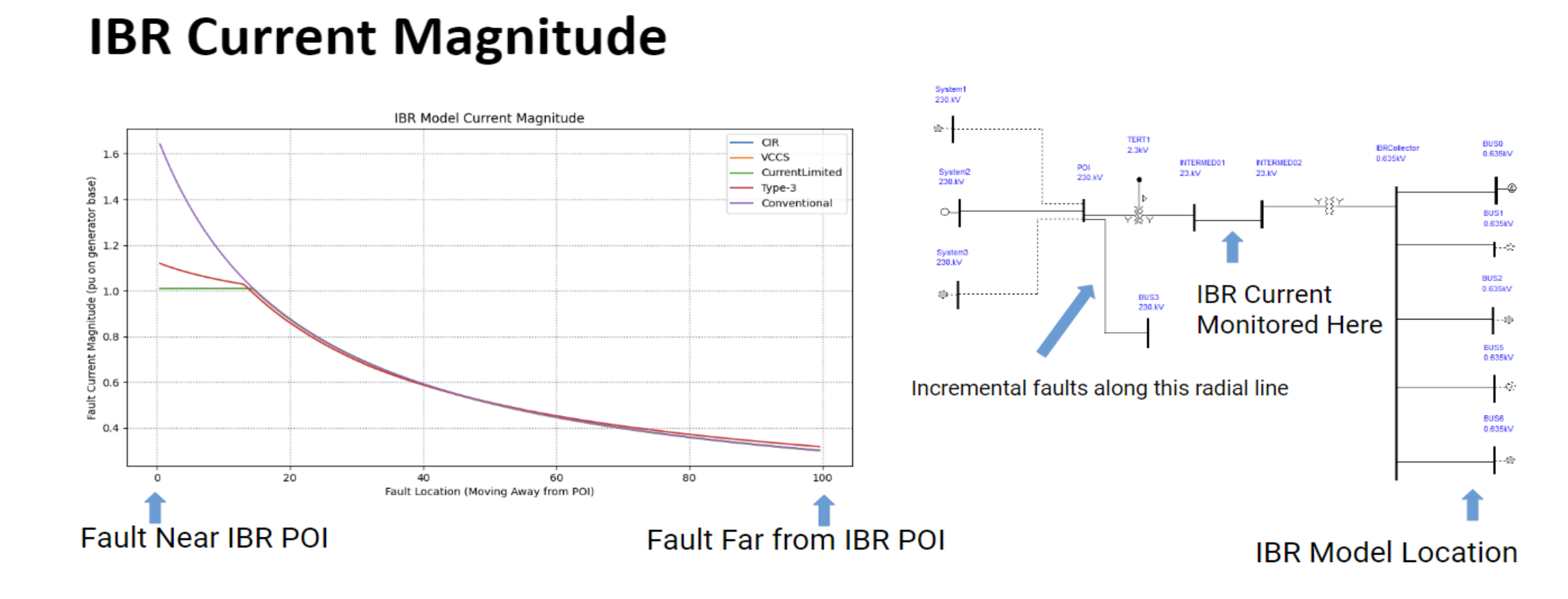
OneLiner Models Currently Available



Reference: Modification of Commercial Fault Calculation Programs for Wind Turbine Generators (PES-TR78)

Comparison of Conventional and IBR Fault Response

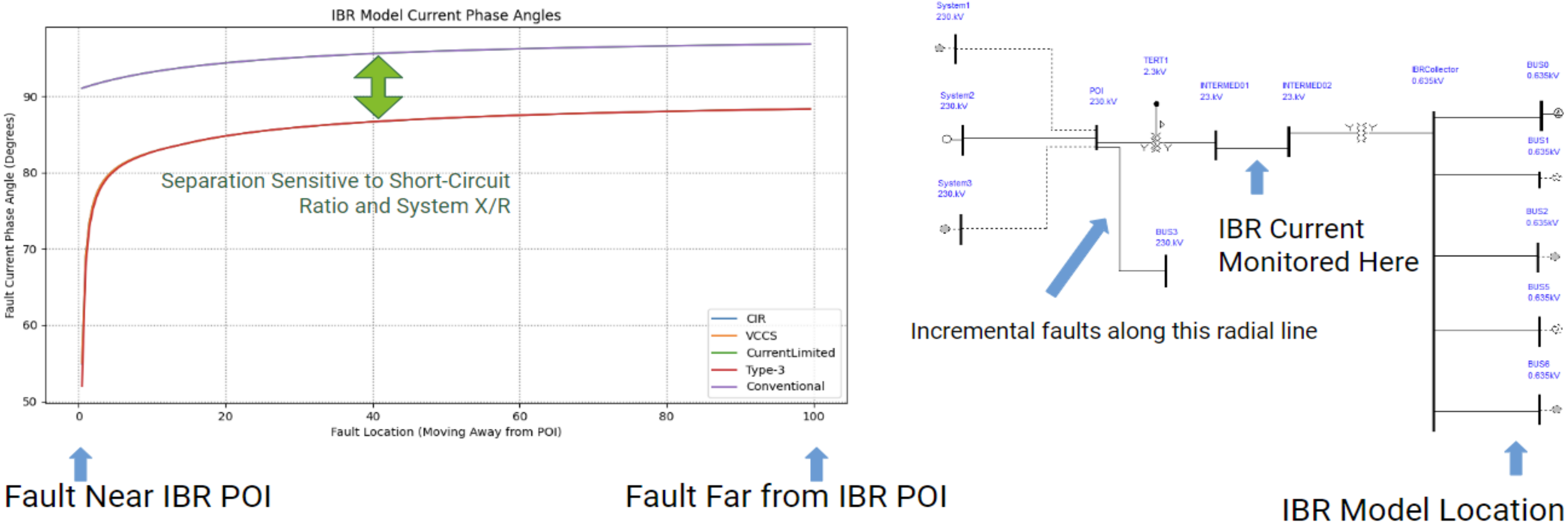
OneLiner Model Response Comparison Example



Comparison of Conventional and IBR Fault Response

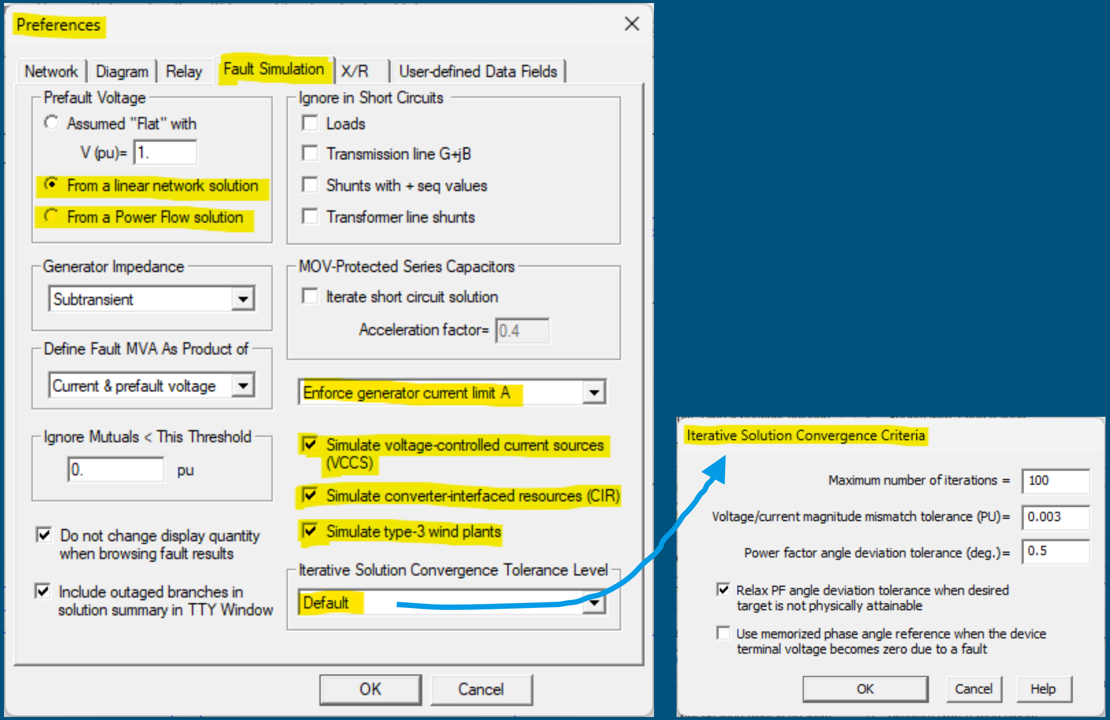
OneLiner Model Response Comparison Example

Fault Current Phase Angle



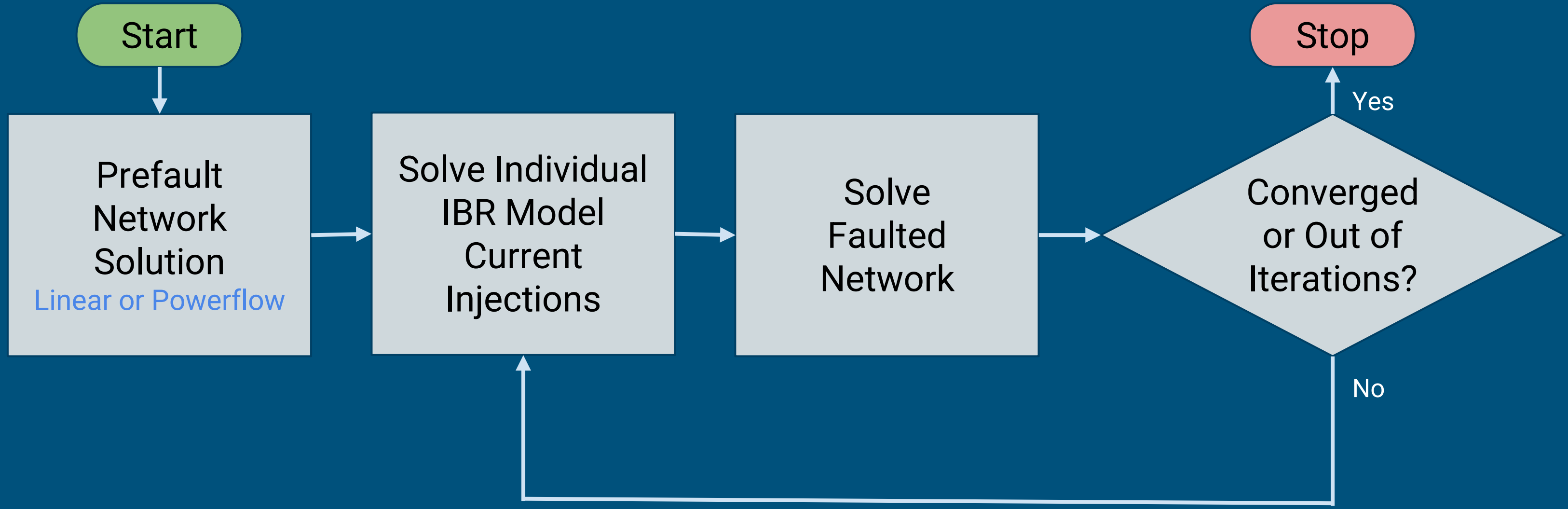
IBR Phasor Domain Simulation Primer

Key OneLiner options related to IBR simulation (OneLiner V15.8)



IBR Phasor Domain Simulation Primer

Basic Solution Framework



IBR Phasor Domain Simulation Primer

Prefault Solution with IBR

Prefault solution must be from:

- a linear network solution, or
- a power flow solution

VCCS, CIR, and Type-3 Wind Plant objects will not be simulated if you choose the "Assumed flat" option.

Recent research indicates that in the long term, full power flow solution may become a requirement for systems with significant amounts of IBR

IBR Phasor Domain Simulation Primer

Prefault Solution Tuning with IBR

An important first step is tuning the network prefault condition, which can help resolve non-convergence in fault simulations

Significant factors that can affect the prefault network condition

- Phase shift anomalies - Generators and Transformers
- Off-nominal transformer taps
- Generator REFV settings
- Generation/Load balance
- Nonlinear participation in linear prefault solution

IBR Phasor Domain Simulation Primer

Tools that May Help with Tuning the Network Prefault Condition

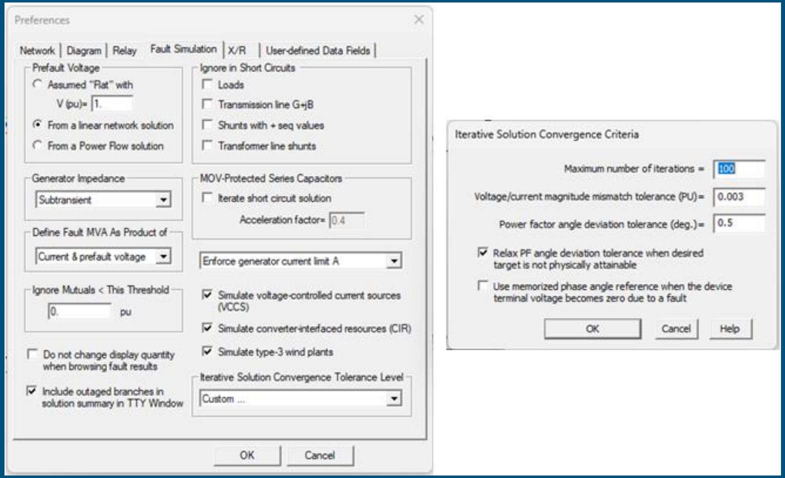
OneLiner Built-in Tools

- Transformer phase-shift anomalies
- Generator reference angle anomalies
- Transformer tap anomalies
- IBR Modeling and Simulation FAQ

Coming soon:

Python OlxAPI Applications

- Transformer Phase Shift Anomaly Tool
- Network Review Tool



IBR Phasor Domain Simulation Primer

Fault solution with IBR

IBR models are nonlinear

Analytic or exact solutions of nonlinear equations is often not possible

Iterative methods can be used to solve nonlinear models

- Continue iterating until each quantity is within a specified tolerance
- Non-convergence means that, for at least one nonlinear model, at least one of the specified tolerances was not met
- Convergence of iterative methods depends on the initial conditions

IBR Phasor Domain Simulation Primer

Fault Ride Through Model Limitations

CIR, Type-3, and VCCS are Functional Models

- The internal device topology and circuit physics are not simulated directly in OneLiner
- Simulation represents the post-transient period of IBR fault ride through based on functional requirements
- The model is grid-following - it needs a reference from the grid
- Low Short Circuit Ratio can result in unstable solution because of hunting
- POI path impedance errors can have a significant impact

Large number of IBR models will slow down the network solution

- We are actively enhancing the solution algorithm to improve network solution time

IBR Phasor Domain Simulation Primer

Important considerations when including IBR models in your network

The Thevenin equivalent theorems apply to linear circuits

- The OneLiner Thevenin calculation only account for the linear circuit elements
- TTY and other Thevenin reports in OneLiner are linear only
- As IBR models increase within your network, you must take into account that the nonlinear elements are ignored in the Thevenin values

*We have developed a demo Python API script to calculate the nonlinear Thevenin based on the Voc/Isc definition and the nonlinear OneLiner simulation results, if needed

IBR Phasor Domain Simulation Primer

All models are wrong, therefore: *

- a “correct” model cannot be obtained with excessive detail
- we must be aware of where a model is “importantly wrong”

Key point: Modeling and simulation has always required judgment, the same is true of these new models

Example where the phasor-domain model of grid-following IBRs can be importantly wrong:

- 3LG POI fault - because the grid-following IBR loses its reference angle
  - This is an area of active research
  - OneLiner V15.8 includes an optional feature to emulate one kind of 3LG POI fault ride through for IBR

*George E. P. Box, “Science and Statistics”, 1976 (Paraphrased)

Active Research and Development

PLL Phase Angle Memorization or Freeze

- When voltage is too small to measure reference angle, emulate PLL freeze during 3LG POI Fault - (Feature available in OneLiner V15.8)

DLL Approach to Detailed IBR Modeling

- DLL - allow protected representation of detailed short circuit models from vendors
- Nonlinear network calculations still done by OneLiner
- OneLiner quantities passed to DLL for use in internal calculations
- Let us know if your OEM provider would like to discuss

Questions?

Recommendation:

Update to the latest version of OneLiner regularly, since the VCCS, Type-3, and CIR models are relatively new and we continue to make improvements and fix bugs