Session Session 8a: System Oscillations

A Guide to Oscillations

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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2024 ESIG SPRING WORKSHOP

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System Oscillations

- **Why are we here?**
  - A growing litany of (scary) oscillations, many of which are (or seem to be) correlated to the rise of IBRs
- **What is new and different?**
  - Less physics (in the sense of behavior linked to material reality of equipments)
  - More control (in that the brains, or lack thereof, of fast acting devices is at the core of the observed behaviors)
  - Not everything! (We aren't 100% IBR; the "old" dynamics are still critically important)

A call from the industry for HELP!

Diagnosis and Mitigation of Observed Oscillations in IBR-Dominant Power Systems

A Practical Guide

ESIG Stability Task Force

Beta Version:

Spring WS 2024

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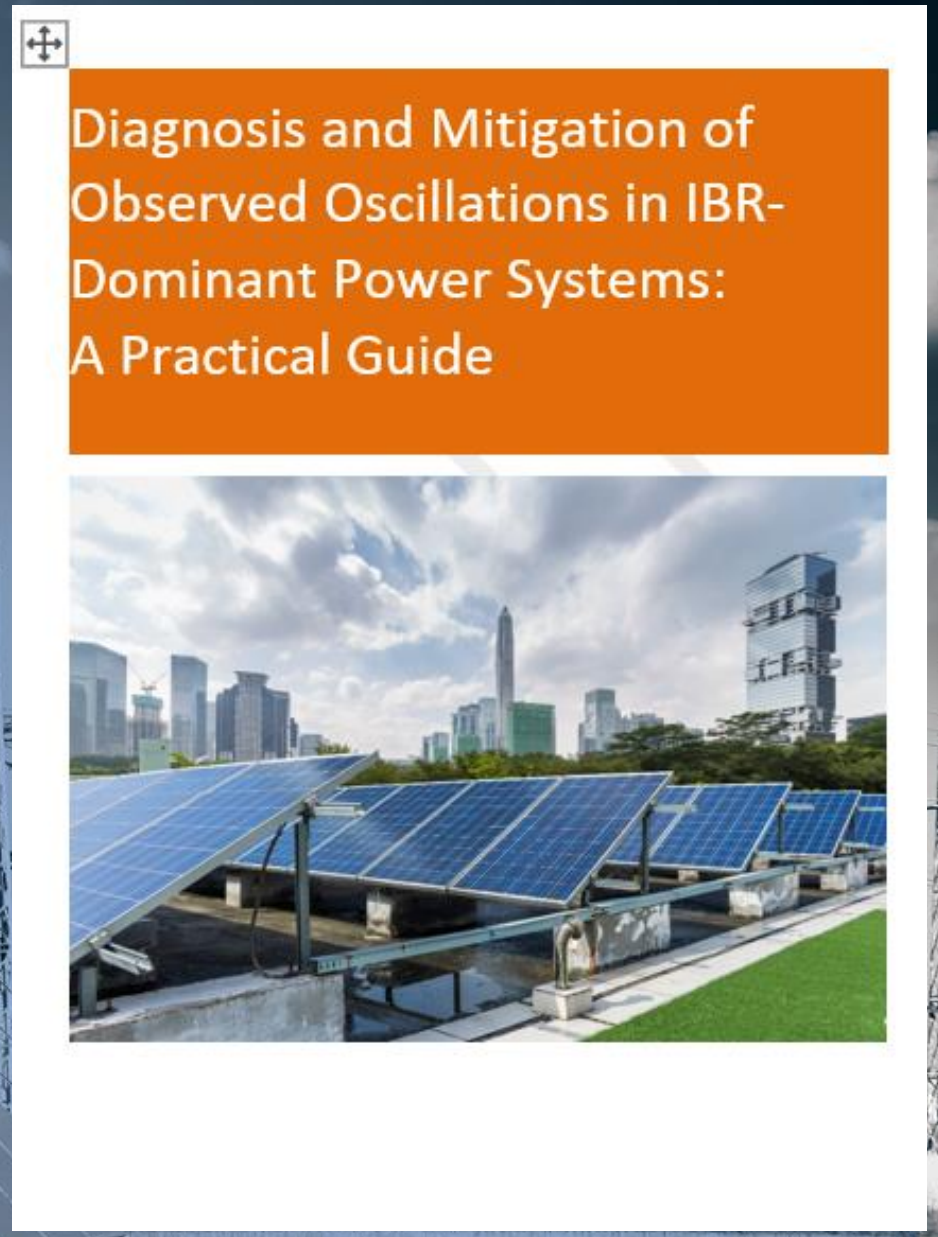


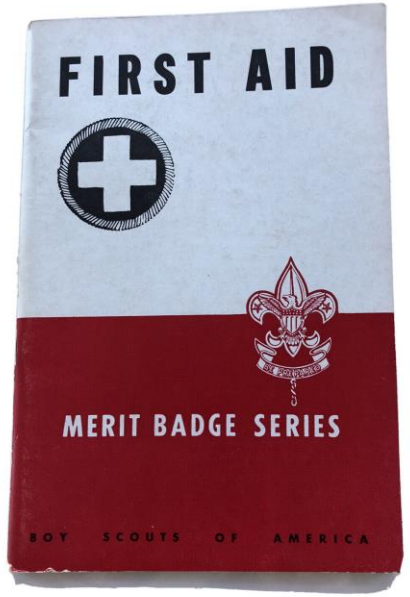
Intended Audience

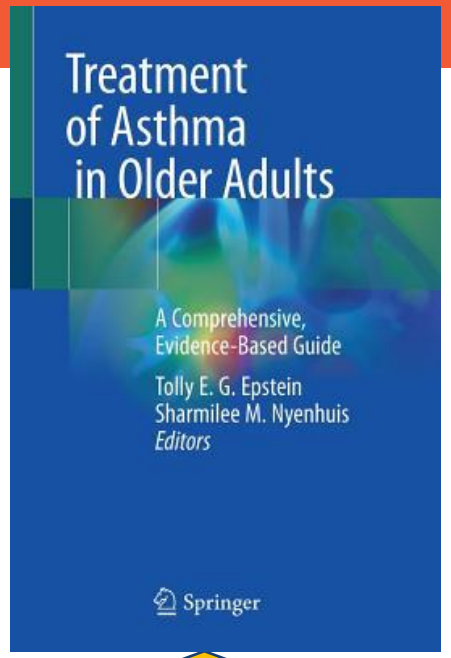
Who will use this guide? Moderately experienced system planners.

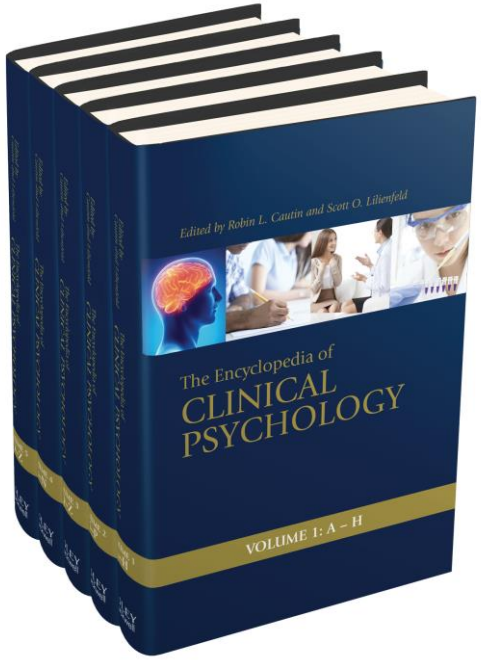
- i.e. people who regularly perform dynamic analysis (e.g. phasor stability work, EMT work) for ISOs, RTOs, TOs, Asset owners, developers.
- But who may not have extensive experience with integration of IBRs

- Experienced system operator engineering staffs.
  - i.e. people who will be in the line of fire when reports/measurements of oscillations (grid, otherwise) come in (after something whacky happens in the field).
  - Engineering support thereof. People who will be charged with **"what the heck is this, and what do we do about it?"**

This is what we aimed for:







This

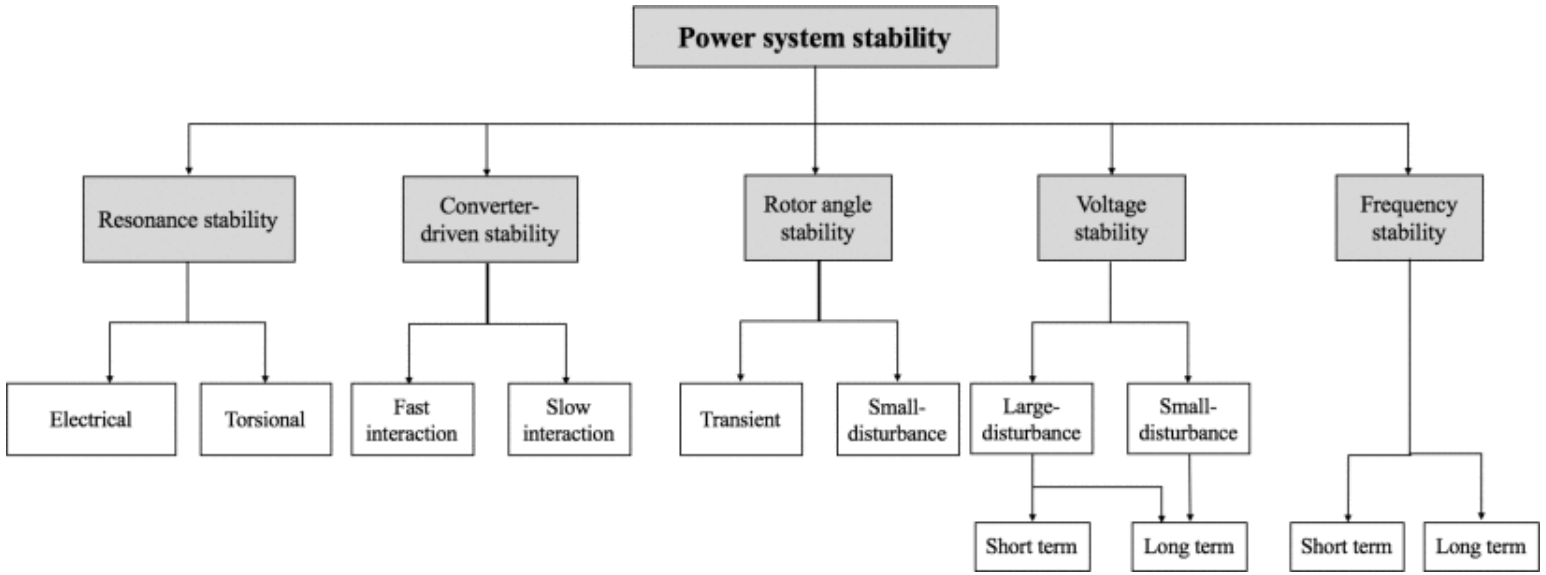
Maybe a bit of this

Definitely not this

We engage the user as “diagnostician” in the guide

Taxonomy isn't as obvious as you might think

IEEE Stability hierarchy is not ideal for diagnosis focused on oscillations



We adopted a somewhat different hierarchy:

- SSO
- Voltage
- Angle/ Transient Stability
- Frequency
- Harmonics

source

N. Hatziargyriou *et al.*, "Definition and Classification of Power System Stability – Revisited & Extended," in *IEEE Transactions on Power Systems*, vol. 36, no. 4, pp. 3271-3281, July 2021, doi: 10.1109/TPWRS.2020.3041774.

Elements of a Practical Guide

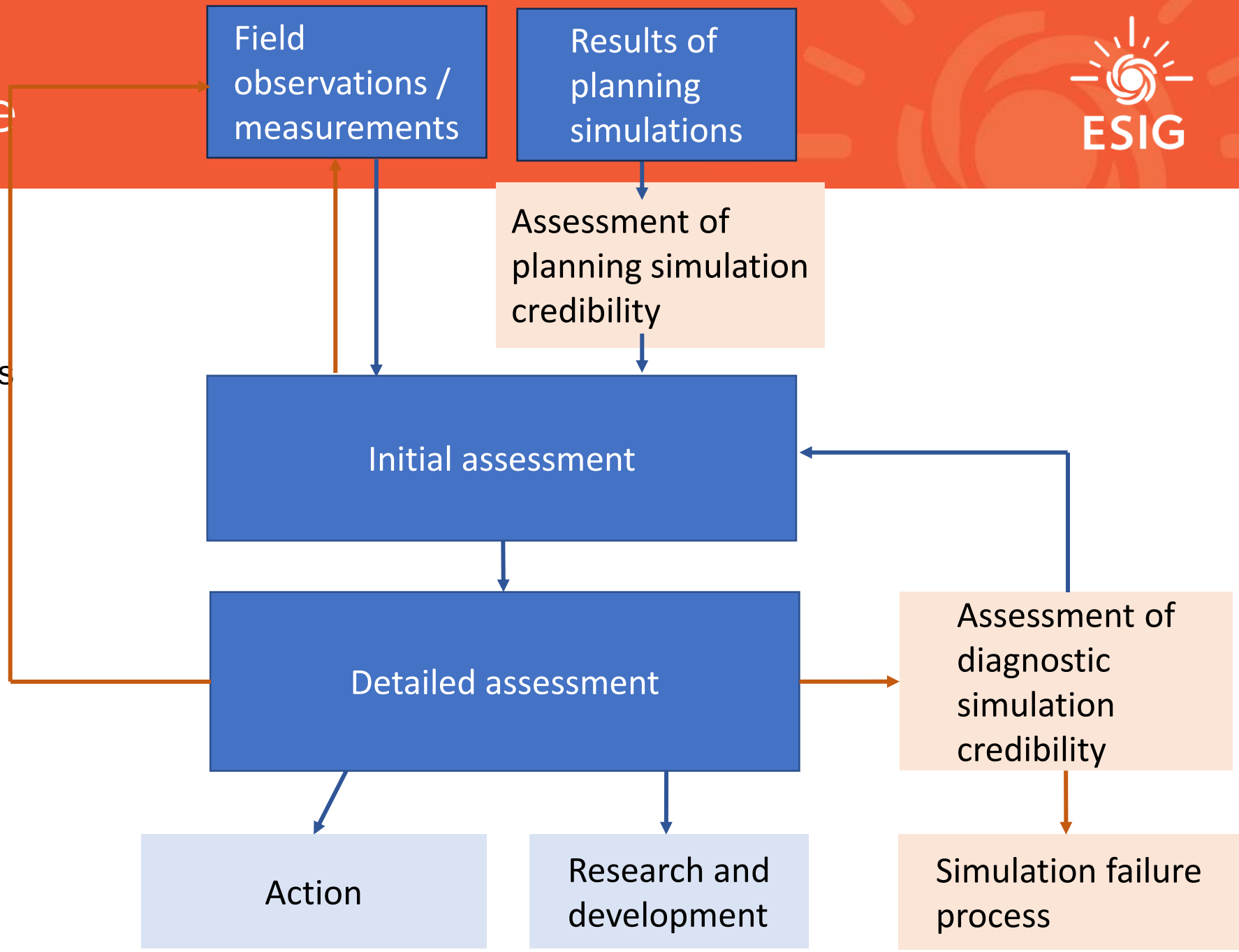
Observations
- Field measurements vs. simulations?

Simulation credibility
- Do you trust the simulations?

Initial Assessment (what might this be?)
- Do you have the right information/measurements?
- What do you look for initially?
- Initial Assessment
  - ID suspected causality for detailed assessment (or get more data)

Detailed Assessment
- Discussion of phenomenon;
- Explanation of the screening matrix
- Techniques for performing analysis
- What we don't know/gaps: R&D needed)

Countermeasures
- Is mitigation needed?
- Various techniques mitigation (what specifically is needed?)



Elements in the Guide

Introduction
Oscillations and System Stability
- IEEE Stability Definitions
- Forced Oscillations and Systemic Poor Damping

Basics of Identification Diagnostics
- Field Measurements and Observations
- Measurement Quality
- Signal Processing

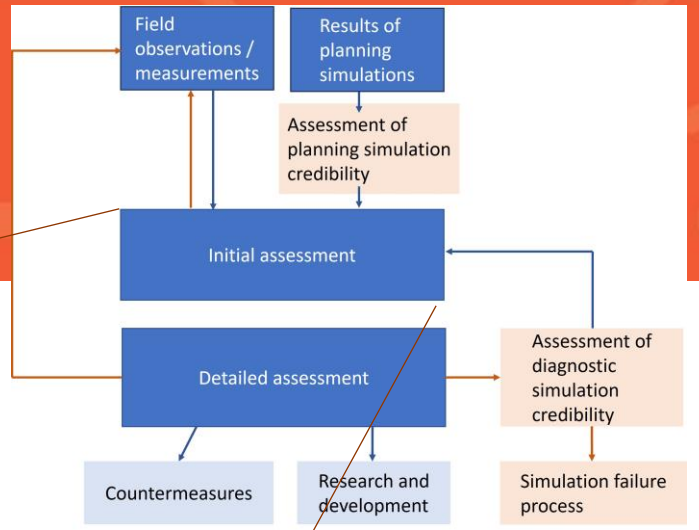
Initial Assessment
- General Discussion of Analytical Tools and Approaches
- Tools Overview
- Simulation Credibility

Detailed Assessment and Countermeasures
- Latency
- Subsynchronous and Supersynchronous Oscillations (SSO)
- Voltage Control Induced Oscillations
- Transient/synchronization Stability Induced Oscillations
- Frequency or Active Power Control Induced Oscillations
- Harmonic Oscillations

Simulation Failures
Closure
References

Initial Assessment

Field observations / measurements



Simulation ?

No

Yes

Screening questions

Simulation check questions

Simulation is not credible

Selection of likely cause(s)

Simulation failure process

Detailed assessment

What seems to be happening, and what appears to be participating?

Screening Matrix: An aid for "Likely Causes"

Strong Positive Indicator
Weak Positive Indicator
Neutral Indicator
Weak Contraindicator
Contraindicator

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Causality/Failure Mode

Characteristics (Question Answers)

	Causality / Failure Mode	Sub/super Synchronous Oscillations				Voltage Control Induced Oscillations			Angle (Transient) Stability Induced Oscillations			Frequency or Active Power Control Induced Oscillations			Harmonic Oscillations	
Characteristics		Traditional SSR	Control Interaction with network (SSCI)	Torsional interaction with IBRs (SSTI)	Ferro-resonance with non-linear elements	Voltage control mistuning	Voltage control malperformance	PSS and torque related mistuning	Incipient voltage collapse	Large signal transfer limit	FIDVR or other load/DER failure	PFC/ governor mistuning	Inter-regional Power Oscillations	Market services miscoordination	Within plant	Between plants and/or network elements
Frequency	Very Low <0.1Hz											0.2<ω<2	0.01<w<.2	0.01>w		
	Low 0.1< F < 3															
	Subsynch 3 < F < 60(F0)															
	Supersynch F0 < F < ~500Hz															
	> 3rd harmonic or >2kHz															
Participation	IBRs											18				
	Synchronous															
	Loads and DER											17				
	AGC															
	Markets															
Phase/Coherency	Single Device															
	Small Group							15								
	Between Large Groups		4					16								
Signals	Voltage dominant															
	Active Power dominant		5													
	Limit Cycles/Square Sawtooth signals															
Grid	Radial and/or Radial															
	Low Resonance															
	Series Capacitors near			3	11											
	Shunt Capacitors near															
	HVDC near															
	Large IBRs near															
Operating conditions	Generation power high	1	6													
	High power transfer		7			14										
	Poor Pre-event voltage health															
Stimulous	Spontaneous															
	Topology change				12											
	Fault		9		13											
	Self-extinguished															

Detailed Assessment

Candidate failure mode(s) from initial assessment

Signal diagnostics

Diagnostic simulations and field tests

Causality conclusion

Countermeasure need

Countermeasure design

Insufficient information

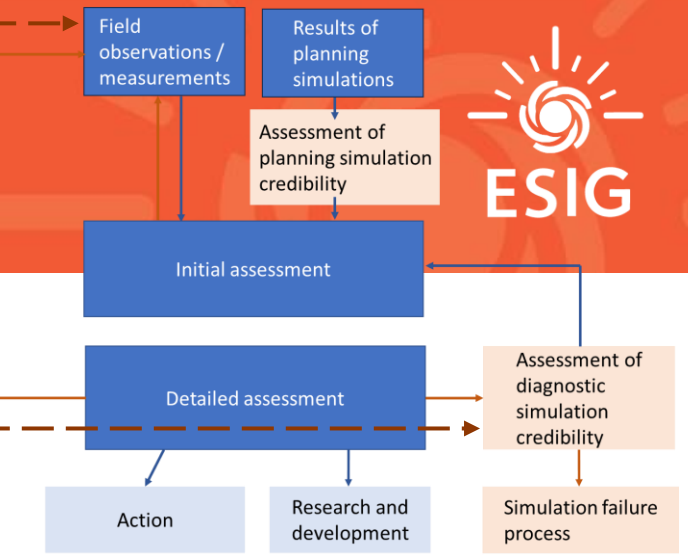
Test simulation for credibility

Causality inconclusive

Available countermeasures inadequate

Action

Research and development



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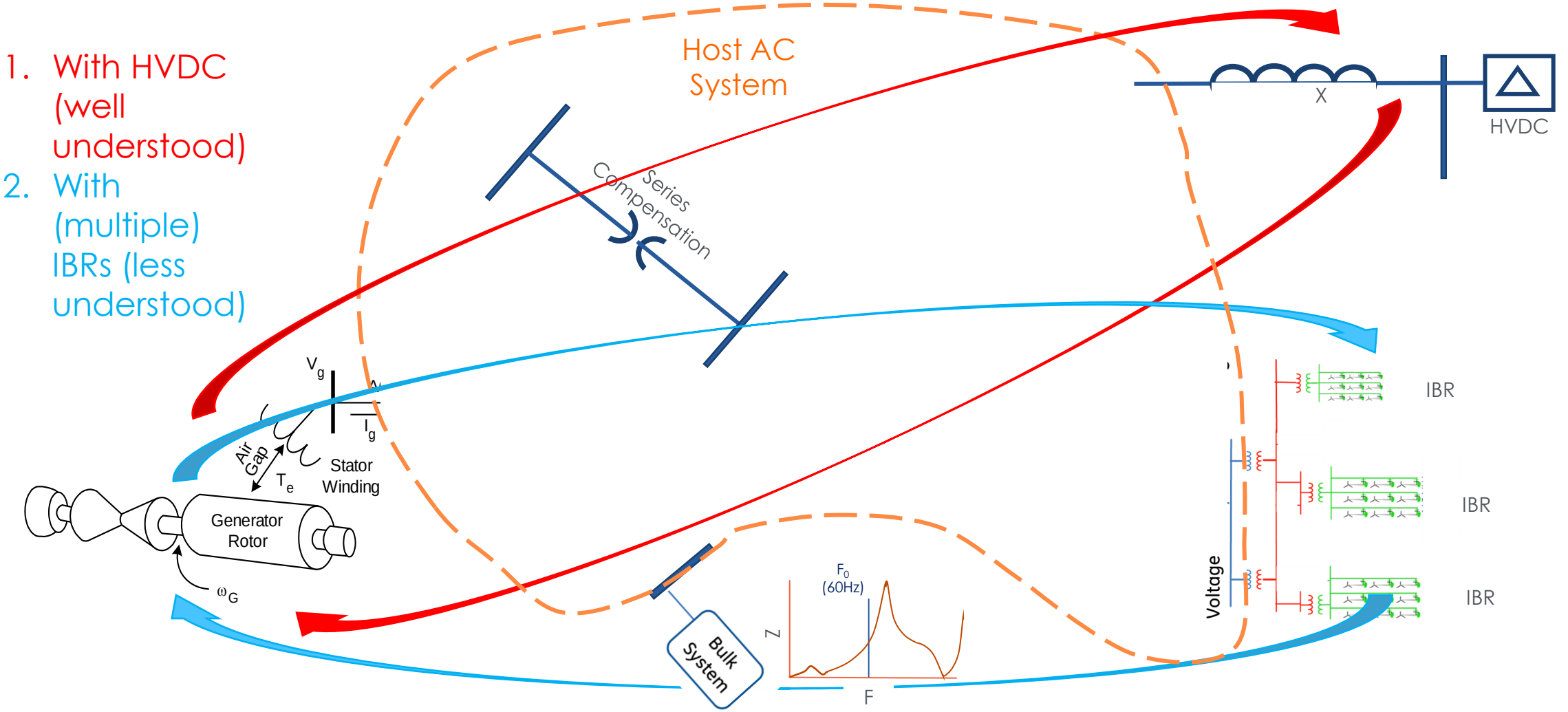
Types of SSO:
SSTI – subsynchronous torsional interaction

1. With HVDC (well understood)
2. With (multiple) IBRs (less understood)



Tools

- State Space Methods
- Static Frequency Scan Methods
- Dynamic Model Network Frequency Scans
- Static Power Frequency Tools
- Methods for Locating the Source of Oscillations
- Time Domain Simulation with Sequence/Phasor-based Tools
- Time Domain Simulation with 3 phase, Point-on-wave Tools
- Hybrid Tools
- Tools Applicability

What's Next

A final draft is available for review.

We will be taking notes during the special workshop tomorrow

We are accepting comments for about 3 more weeks. (see feedback in draft guide)

We will finalize, i.e.

- Incorporate final inputs
- Edit for clarity, syntax
- Finalize attributions, permissions, figure quality

Release to public

- Rollout details TBD.

Thanks

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