SERIES | SSR & OSCILLATIONS | PART 2 OF 12

SSR, SSCI, SSTI, IGE: a field guide to the sub-synchronous alphabet

Part 2 of GridAxon's technical series on sub-synchronous oscillations

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Original: gridaxon.io/insights/sso-terminology-field-guide.html

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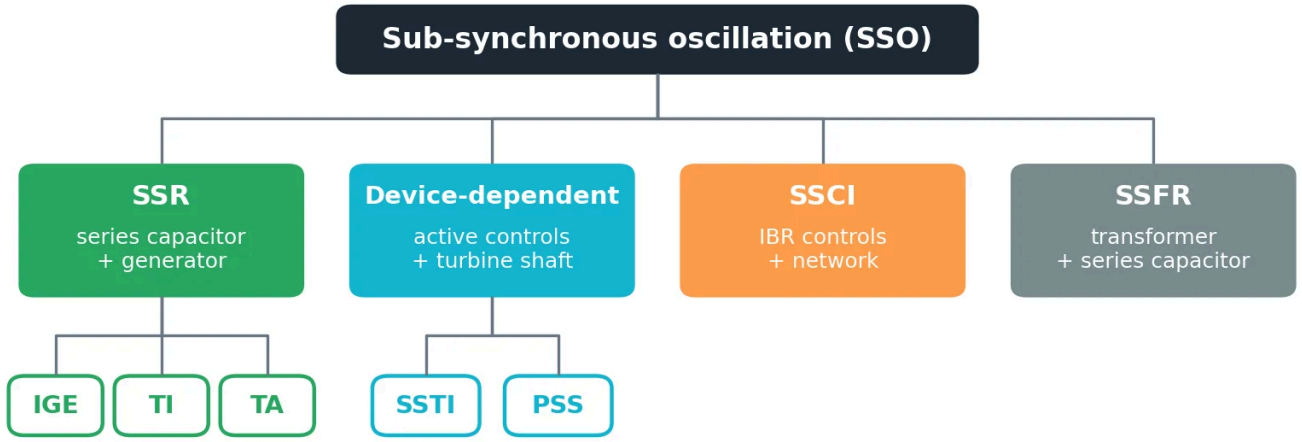
Sub-synchronous oscillation (SSO) is the umbrella term for any oscillatory exchange of energy between the grid and a machine, converter, or other device below the system's rated frequency. Everything else in this field (SSR, IGE, TI, TA, SSTI, SSCI) is a specific mechanism underneath that umbrella. The mechanisms differ in what is interacting, whether a series capacitor is required, and how you screen for them.

Getting the names right is not pedantry. A study scope that says "SSR study" can mean three different pieces of work, and the one that gets skipped is usually the one that matters.

Where the vocabulary came from

Most of the terms were standardized by the IEEE SSR Working Group in 1985, building on a set it first proposed in 1980, after a decade of investigation following Mohave and Square Butte. That paper is still the reference. The two later additions, SSCI and sub-synchronous ferroresonance, came from wind plant experience and from ERCOT's work on series-compensated corridors.

The sub-synchronous family



IGE: electrical only TI: shaft mode + resonance TA: fault energy into the shaft

SSTI: HVDC, SVC, STATCOM or IBR controls + shaft PSS: stabilizer acting on a shaft mode

Sub-synchronous oscillation is the umbrella. SSR, device-dependent SSO, SSCI and SSFR sit underneath, and SSR divides into induction generator effect, torsional interaction and torque amplification.

The terms, side by side

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Term	What interacts	Series capacitor needed?	Typical first screen	Classic example
SSR, Sub-synchronous resonance	A generator and a series-compensated network. Umbrella for IGE, TI and TA	Yes	Depends on the mechanism below	Mohave, 1970–71
IGE, Induction generator effect	The electrical resonance and the machine's rotor circuit. Purely electrical, no shaft	Yes	Impedance scan; check the sign of total resistance at the resonance	Type 3 wind on a compensated line
TI, Torsional interaction	A turbine-generator shaft mode and the electrical resonance	Yes	Electrical damping from scans, compared with mechanical damping per mode	Mohave investigations
TA, Torque amplification	Energy stored in the series capacitor during a fault, released into a shaft mode after clearing	Yes	Scans to pick cases, then EMT fault simulations	Mohave investigations
SSTI, Sub-synchronous	A shaft mode and the controls of an active device:	No	Unit Interaction Factor; 0.1 is	Square Butte HVDC, 1977

Term	What interacts	Series capacitor needed?	Typical first screen	Classic example
torsional interaction	HVDC, SVC, STATCOM, IBR		the usual threshold for conventional HVDC	
SSCI, Sub-synchronous control interaction	IBR controls and the network. ERCOT ties it to series compensation; wider usage includes weak-grid interactions	Per ERCOT, yes	Terminal transfer-function scans plus system scans, then EMT	South Texas wind, 2009
SSFR, Sub-synchronous ferroresonance	A saturating transformer and a series capacitor	Yes	EMT with full saturation curves	Flagged by ERCOT as a distinct SSO type

One related case sits outside the table: power system stabilizer interaction. A PSS tuned well for network swings below about 3 Hz can respond with the wrong phase to a disturbance that starts on the shaft. That is also device-dependent SSO.

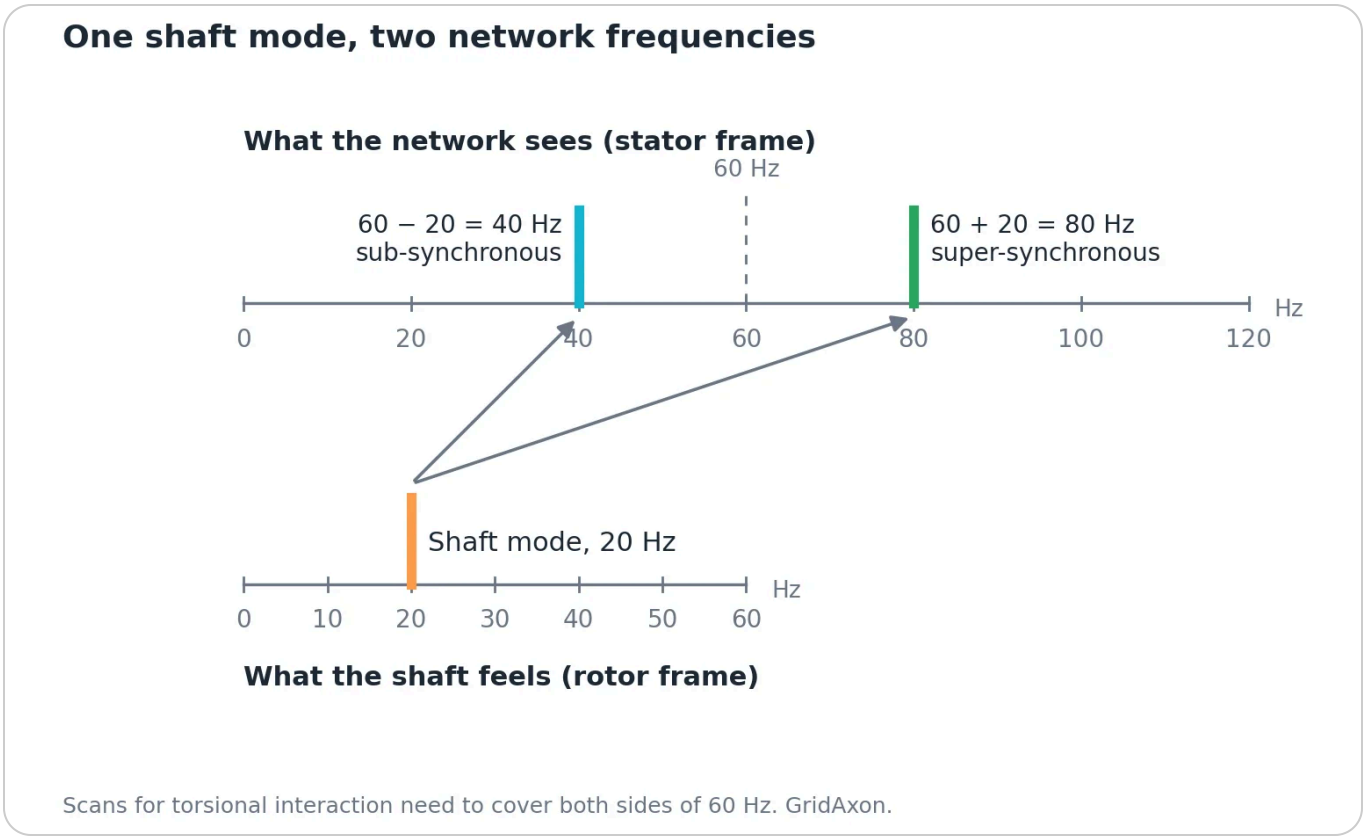
Two of those screens deserve a caution. The Unit Interaction Factor came out of the research that followed Square Butte, where a turbine-generator sat electrically close to the HVDC rectifier, and its usual 0.1 threshold is an empirical value for conventional line-commutated HVDC. Most systems studied today look nothing like that. Our view is that it is often applied well outside the conditions it was built for, even though it usually lands close. Treat UIF as a coarse filter, and confirm anything near the threshold with damping calculations. The idea is also getting a second life: ERCOT's proposed limits for data center power variation compute an interaction-factor-based limit for each load location, so the most exposed nearby generator sets the cap.

Ferroresonance is the other. Frequency scans assume the network is linear, and a saturating transformer is not. On this we are deliberately old school: if you're looking for ferroresonance, do it in EMT, with saturation curves that run all the way out to the air-core region.

The concept that ties them together: two frames of reference

Shaft modes live in the rotor's frame of reference. The network sees the stator frame. A shaft oscillating at a mode frequency fm modulates the generator's output and produces currents at two frequencies on the network: 60 − fm and 60 + fm.

So a 20 Hz torsional mode shows up on the grid at 40 Hz and 80 Hz. This is why torsional interaction scans have to run from 0 to 120 Hz, not just up to 60. A scan that stops at 60 Hz throws away the super-synchronous half of the damping picture.

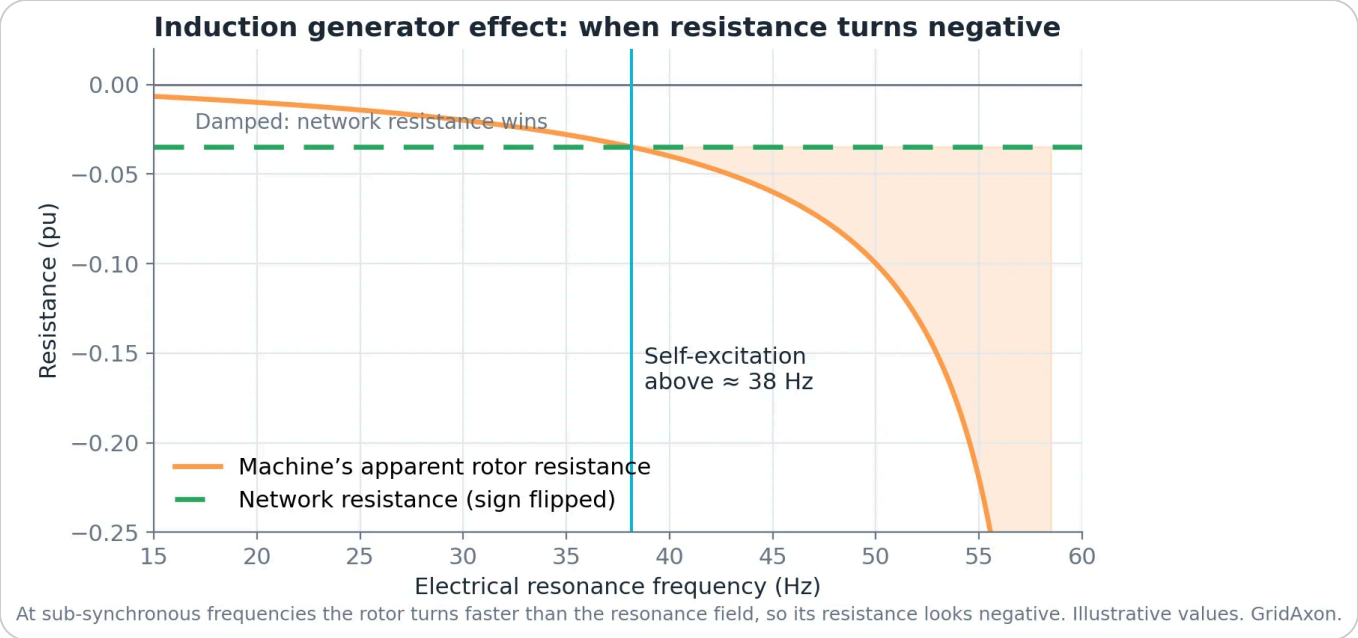


A 20 Hz shaft mode appears on the network at 40 Hz and 80 Hz, which is why torsional interaction scans cover both sides of 60 Hz.

Even the sign of damping is not universal. Write the shaft torque equation one way and positive electrical damping means the network is undamping the shaft. Write it the other way and negative means undamping. We prefer the second: positive damping should mean the system is damping better. Check which convention a report uses before you compare its numbers with yours.

Our view on ”SSCI”

The name SSCI was coined after the 2009 Texas event, because the problem could be fixed by changing converter controls. That made it sound like a controls problem. Even the last letter is unsettled: early papers on the event, and some ERCOT study material, spell it sub-synchronous control instability, while ERCOT's protocols and most of the industry now say interaction. We think the label hides something useful. In a Type 3 turbine, the converter sets the effective rotor resistance the network sees, and the instability looks a great deal like classic induction generator effect. The controls made it worse or better. The machine was still part of the mechanism.



At sub-synchronous frequencies the rotor turns faster than the resonance field, so its resistance looks negative. Once that outweighs the network's resistance, the oscillation sustains itself.

That distinction matters in practice. A Type 4 full-converter turbine isolates the machine from the grid, so induction generator effect is not expected. Its controls can still interact with a network resonance or with other devices. Same acronym, different physics, different study.

Definitions depend on who wrote them

ERCOT's protocols define SSCI specifically as an interaction between a series-compensated system and the control systems of generators, and, since its large-load revisions, of loads as well. Much of the wider industry uses the term, or "IBR oscillations," for control interactions in weak grids with no series capacitor anywhere nearby. ERCOT has also argued for SSO as the overarching term precisely because it covers ferroresonance, which SSR does not.

None of these usages is wrong. They come from different rulebooks, and the rulebooks are still moving: IEC has published a technical report that revisits the whole classification for converter-heavy grids. A study done to satisfy one rulebook may not answer the question another one asks.

Four questions to ask when someone hands you an ”SSR study” scope

- **Which mechanisms?** IGE, TI, TA, SSTI, SSCI and ferroresonance need different methods. Name the ones in scope.
- **Which machines?** Synchronous units need shaft data: inertias, stiffnesses, modal damping. IBRs need EMT models valid at sub-synchronous frequencies. Each is a separate data request.
- **Which method for each?** Frequency scans for screening, UIF for SSTI, EMT for confirmation. A scan alone is not a final answer for torque amplification.
- **How deep in outages?** Most SSO risk appears only after a specific combination of line outages. The contingency depth is set by the system operator or transmission owner. Confirm it in writing before the work starts.

Next in this series

Part 3 looks at ERCOT's proposed 10 MW / 5-second limit on data center power variation, and what it means for developers.

GridAxon builds study automation for power system engineers, including our own tools for sub-synchronous screening across thousands of system conditions.

Sources

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Educational content, not engineering advice for a specific project.

About GridAxon

GridAxon is a power systems engineering firm based in Lewisville, Texas. Our engineers deliver interconnection studies, transmission planning and NERC compliance work for developers, IPPs, utilities and large loads such as data centers across North America. We build our own AI-enabled automation and software, which compresses weeks of study work into hours.

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