< BACK

IN DEPTH

Grid Resonance: A novel early warning system for transmission networks

04/29/2016 - 11.34 am

NETWORK MANAGEMENT PMU WAMS

A new sub-synchronous oscillation monitoring system provides warning of the early stages of resonance—which could otherwise lead to protection tripping or system damage—across a far wider range of frequencies than previously existing systems.

Post a comment

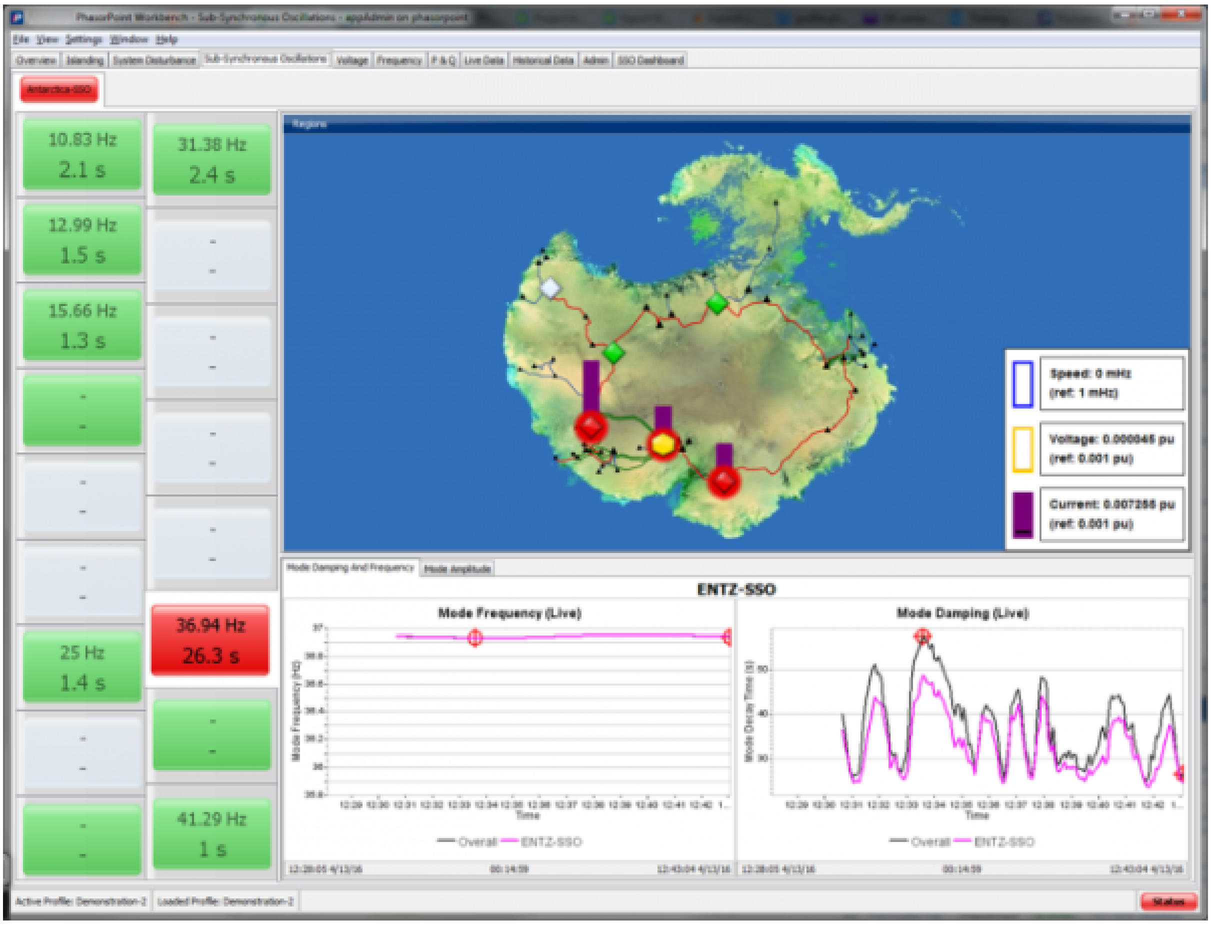
The electric grid that is powering the transition to a low-carbon economy will rely increasingly on generation from renewable sources, on HVDC links and on Flexible AC Transmission System (FACTS) plant[1] to provide extra capacity and flexibility. However, increased deployment of these technologies to the grid, including series compensation and power electronic converters, has implications on system dynamic performance. It presents new challenges for stability and reliability, in particular, to avoid instability in the frequency range up to the nominal frequency of the grid, termed Sub-Synchronous Oscillation (SSO). Instability can result in large oscillations that can trip or damage plants, and an early warning system helps utilities to mitigate the risks.

SSO can take three main forms. The first of these, Sub-Synchronous Resonance (SSR), has been widely studied since the 1970s when it was identified as the cause of turbine shaft failures at the Mohave generating station in Nevada, USA. This involved interaction of shaft torsional modes with an electrical "LC" natural frequency[2] created by capacitors in series with inductive transmission lines. The second, Sub-Synchronous Control Interaction (SSCI), is due to the interaction of power electronic converters, such as those contained in wind turbines and HVDC links, with the LC natural frequency of series compensated lines. Third, Sub-Synchronous Torsional Interaction (SSTI) arises from the interaction of power electronic converters with generator shaft torsional modes.

In energy management systems for transmissions networks, wide area monitoring systems (WAMS) utilize synchronized phasor measurements transmitted via the well-known IEEE C37.118 protocol at up to 50/60 frames per second (fps) for a practical observable range of up to about 10 Hz. But as Stuart Clark, WAMS Power Systems Engineer with GE Grid Solutions explains, “with SSO we’re dealing with much higher frequencies, 4-46 Hz, that typical WAMS measurements will not record.”

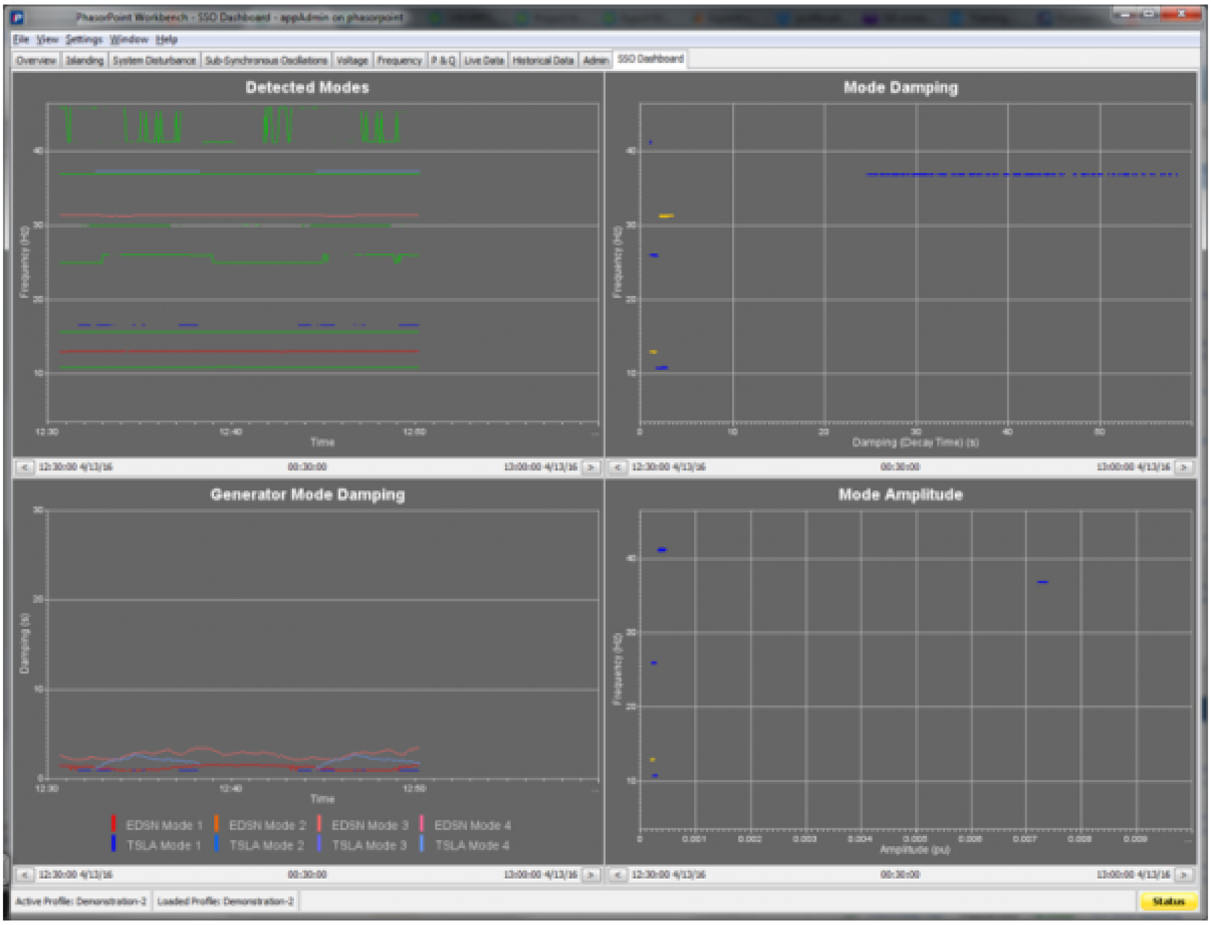
A new Waveform Measurement Unit (WMU) was therefore developed to provide synchronized voltage and current point-on-wave measurements at 200 samples per second, streamed in real time via the C37.118 protocol as “analog” type values. Additionally, speed measurements from turbine shaft transducers can also be sent. This approach accurately represents oscillatory components in the 4-46 Hz range, and also gives visibility of the 54-96 Hz range so as to differentiate modulations such as torsional modes from added components such as LC grid modes. Note that, although not a typical implementation of the C37.118 standard, this approach is fully compliant and rates such as 200 fps are encouraged by the standard.
The WMU is implemented on a multifunction recorder that already incorporates Phasor Measurement Unit (PMU) capability. The 200 fps voltage and current waveforms from each WMU stream are then collated, processed and stored by a central or regional WAMS server, where real-time analysis, monitoring and presentation of SSO information is performed.
[1] FACTS plant describes a range of devices, often power-electronic based, that provide flexible control of the AC transmission system. Examples include Series Capacitors, the STATCOM (Static Synchronous Compensator) and the SVC (Static Var Compensator).
[2] LC: Inductance (L) – Capacitance (C)

Douglas Wilson, WAMS Chief Scientist at GE Grid Solutions, explains the different ways the results can be analyzed and used. “The most immediate use is to provide real-time SSO situational awareness and to identify interactions, particularly when connecting new plant onto the existing transmission system. Operators have to be able to understand and use the data quickly, so the results are presented in a practical wide-area map view with live data charts.” The system-wide SSO map view presents mode amplitude and alarm state across the system. “A particular challenge consisted in rationalizing oscillation information from multiple signal types from two such different domains as electrical and mechanical systems to provide a clear, effective presentation to users,” according to Wilson.



System-Wide SSO Overview

Human factors are likewise central to the design of the alarm system. "Anticipation is always better than reaction when you're managing a transmission grid, and the new system is monitored for alarms on raised amplitude or poor damping to give early warning of growing oscillations, as well as to highlight persistent mid-level oscillations that would not trigger protection but may cause excessive plant wear." The user can configure both "alert" and "alarm" thresholds and sort the information into frequency bands of interest.



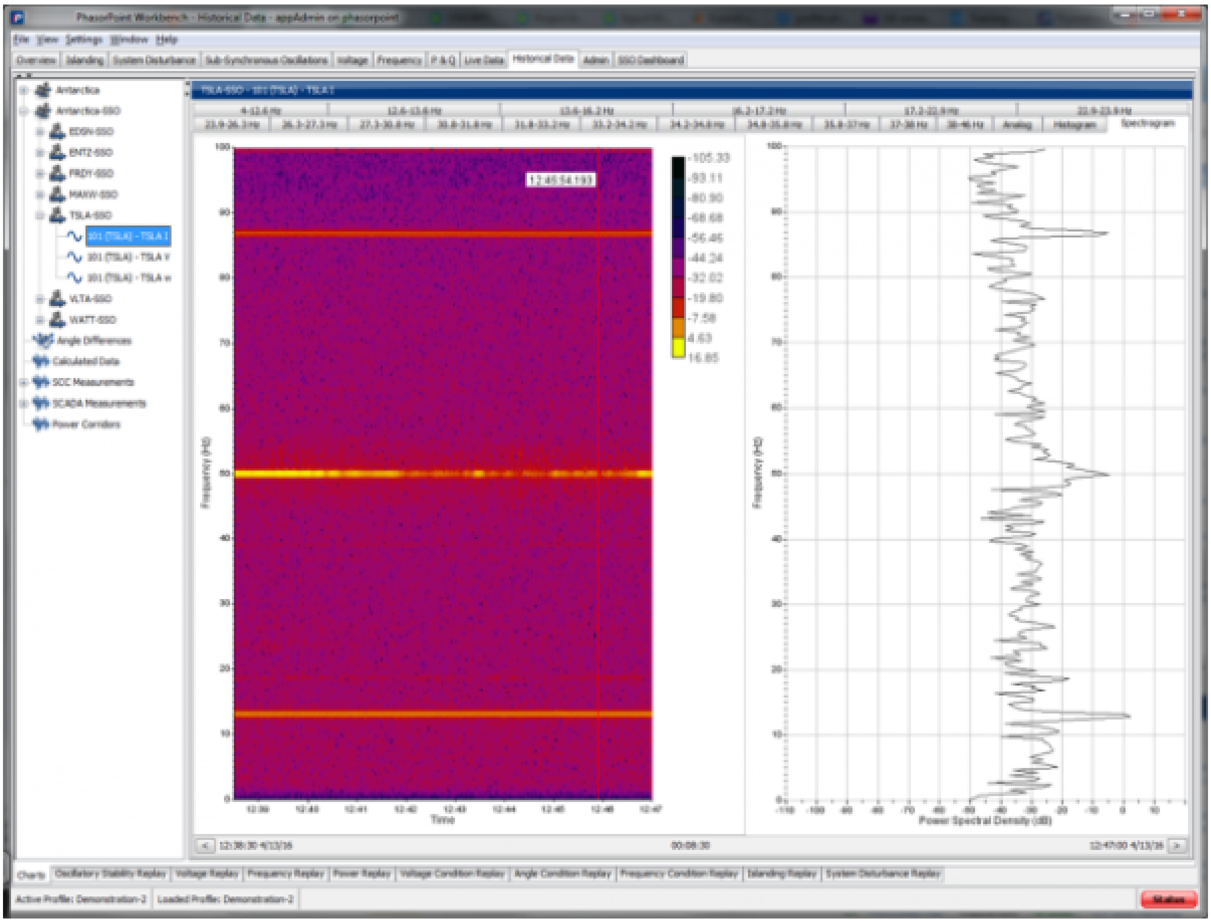
Flexible User-Defined Displays

Of equal value is the use of the stored oscillation data for further analysis and historical review. This includes:

- diagnosis of events and unusual conditions
- long-term review for system studies
- defining suitable frequency bands of interest and alarm thresholds
- validation of network and plant models.

In addition to the 4-46 Hz range, the SSO application module provides diagnostic visibility of the 54-96 Hz range through a spectrogram to enable users to differentiate between added components, such as LC modes, and modulations of the 50 Hz waveform such as torsional modes.

A key advantage of this solution compared to previous approaches is that users can gain a better understanding and experience from continuous long-term observation of low-level SSO behavior, and can identify and have the opportunity to respond early to significant oscillations before automated protection is triggered and plant is tripped or bypassed. Under traditional approaches, only severe resonance effects or those occurring following a disturbance or during dedicated study periods are captured.



Historical SSO Analysis

2 Already delivering benefits

Practical experience to date using the SSO monitoring solution on the British national transmission grid is very encouraging. Several months of data collected from a number of WMU devices are already feeding long-term reviews of observed SSO behavior, including recommendations for further investigations. So far, the expected generator torsional modes are observable in the network voltage and current signals, as well as other high frequency oscillations likely to be related to wind farms and other power electronics systems.

The monitoring system was used extensively in the commissioning of series compensation systems, in initial live system tests, and in subsequent network operations and tests. The detected oscillations are generally very small and well damped, with the majority in the region of 2 V and 0.1 A at the 400 kV level. Equally there have been some instances of non-torsional modes with higher amplitudes and poorer damping—behavior that was to be expected but that warrants further investigation. The observations have enabled alarm thresholds to be better configured around a baseline of normal behavior, so that any excursions of behavior with raised amplitude and poor damping can be flagged in real time and for post-event analysis. This perfectly highlights a tangible benefit of SSO monitoring: awareness of real system behavior that leads to investigation and mitigation before it becomes a problem.

“In a nutshell,” Clark concludes, “what we’re offering with this new system is substantial reassurance and security against the risks of SSO, complementing existing SSO mitigation practices. This comes from better visibility and understanding of normal and abnormal states, validation of models and studies, and improved configuration of protection-based defense.”

An interesting mode

The new GE Grid Solutions real-time Grid Resonance System to provide early warning of emerging SSO threats and long-term review of SSO behavior features a new substation data acquisition function, the Waveform Measurement Unit (WMU), implemented in GE's Reason RPV311 recorder, and a new central analysis, monitoring and visualization application within the **e-terra***phasorpoint* WAMS software suite.

RPV311 (Processing Unit)

The solution was developed in-house by GE and demonstrated under the VISOR project[3] , and has also been deployed by SP Energy Networks to support the commissioning of series compensation on the British transmission network. Analysis of the system's data has provided added-value from the outset. In one example, an oscillatory mode, seen across a 100-mile wide area, was observed not as a generator torsional oscillation and was present independently of the status of the series compensation. The mode varied in frequency, occasionally moving close to a generator torsional mode, and showed some occurrences of reduced damping and raised amplitude. Although the amplitudes involved were very small throughout the period of monitoring, this has provided engineers with valuable information to target further investigation as a matter of prudence.

[3] VISOR is a UK innovation demonstration project funded by the British electricity consumer through the Network Innovation Competition mechanism, awarded by Ofgem, the UK regulator.

RATE THIS ARTICLE

COMMENTS

SIGN UP FOR OUR NEWSLETTER

LEARN MORE

EXPERTS

Douglas Wilson

Grid Solutions - WAMS Chief Scientist

Stuart Clark

Grid Solutions – Power Systems Engineer (WAMS)

SEND A MESSAGE TO OUR EXPERTS