Detection of subsynchronous control interaction oscillations near renewable generation and HVDC

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Introduction

- Stability-the capability of a power system to regain a steady state, characterized by the synchronous operation of the generators after a disturbance due, for example, to variation of power or impedance
- Power system oscillations are dangerous – can lead to many undesirable effects on the power system operations, such as degraded power delivery quality, separation of the parts of the power system, blackouts and damage to the equipment.
- The concern is how multiple and different types of the renewable generation can interact with each other and with remaining synchronous generation to maintain system stable operation with and without disturbances.

Introduction

Guidelines for Subsynchronous Oscillation Studies in Power Electronics Dominated Power Systems

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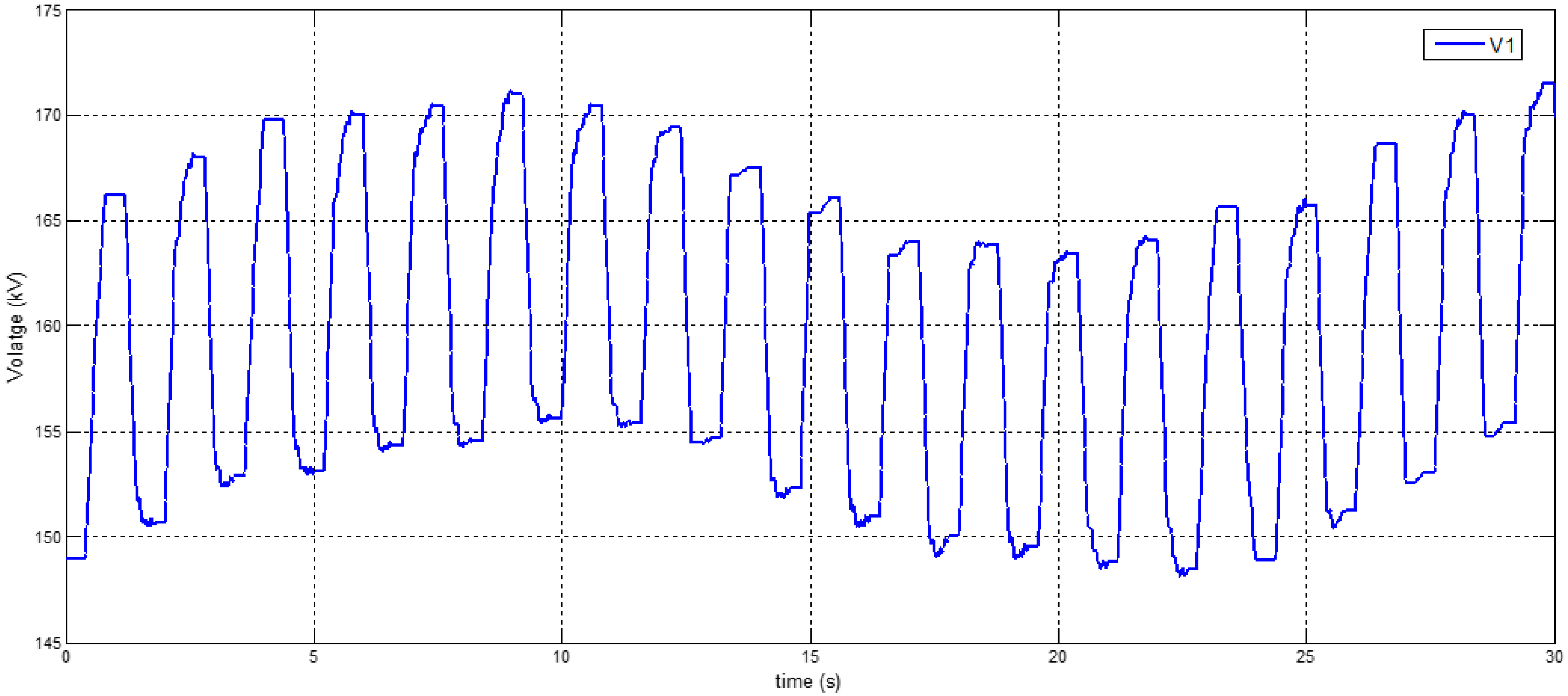
Stability definitions and characterization of dynamic behavior in systems with high penetration of power electronic interfaced technologies

Introduction

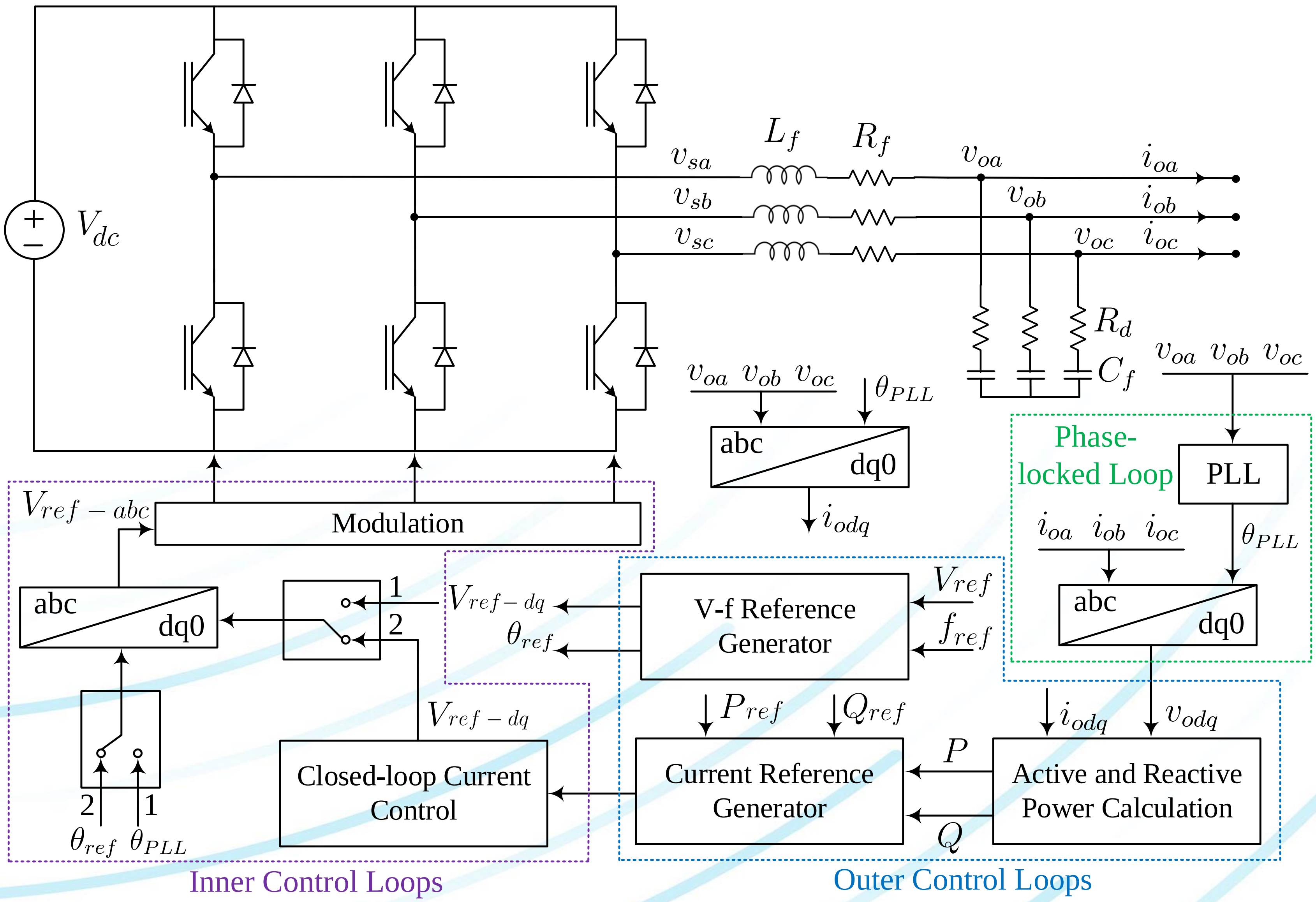
- Australia is in the midst of an energy transformation with massive REN deployment. Some areas, such as West Murray Zone (WMZ), was exposed to the oscillations in areas with low system strength.
- Two dominant oscillation frequencies with two envelopes are present in this event, one at 6.5Hz and another at 0.5Hz



Introduction

- Inter-area electromechanical oscillation: slow electromechanical phenomenon of synchronous machines between different parts of system with a characteristic frequency of 0.1-2Hz
- Forced (or control) oscillations: malfunctioning control systems, incorrect stabilizer or governor control settings, incorrect DC converter settings with a characteristic frequency range of 1-20Hz
- Subsynchronous resonance oscillations (SSR): interaction of the series capacitors with a type III wind power plant, generator torsional mode oscillations, control interactions between synchronous generators with power electronics devices (HVDC, SVC, TCSC, type IV renewable generation), with a characteristic frequency range of 10-55Hz (at 60Hz systems)

Cause of oscillations with high penetration of IBRs



Cause of oscillations with high penetration of IBRs

- Conventional generators have an inherent damping torque due to machine design parameters and generator loading. Damping torque of the synchronous generators is provided by the rotor windings, i.e., the damper windings and the field winding of the rotating masses.
- Power system stabilizers (PSS) can significantly enhance the damping of the synchronous generators
- The SSO damping mechanisms of IBRs are naturally different than those of the synchronous generators. IBRs' damping mechanisms are based on implementing a specific controller in the inverter's control system.

Cause of oscillations with high penetration of IBRs

IBR Technology	Type 3	Type 4	Solar PV	Frequency of oscillation
SSR	✓	✓	✓	10 Hz to 55 Hz
IGE	✓	X	X	10 Hz to 55 Hz
SSTI	✓	X	X	1 Hz to 4 Hz
CSI	✓	✓	✓	Two modes: <10 Hz and >20 Hz

Detection of the oscillations, damping and contributors

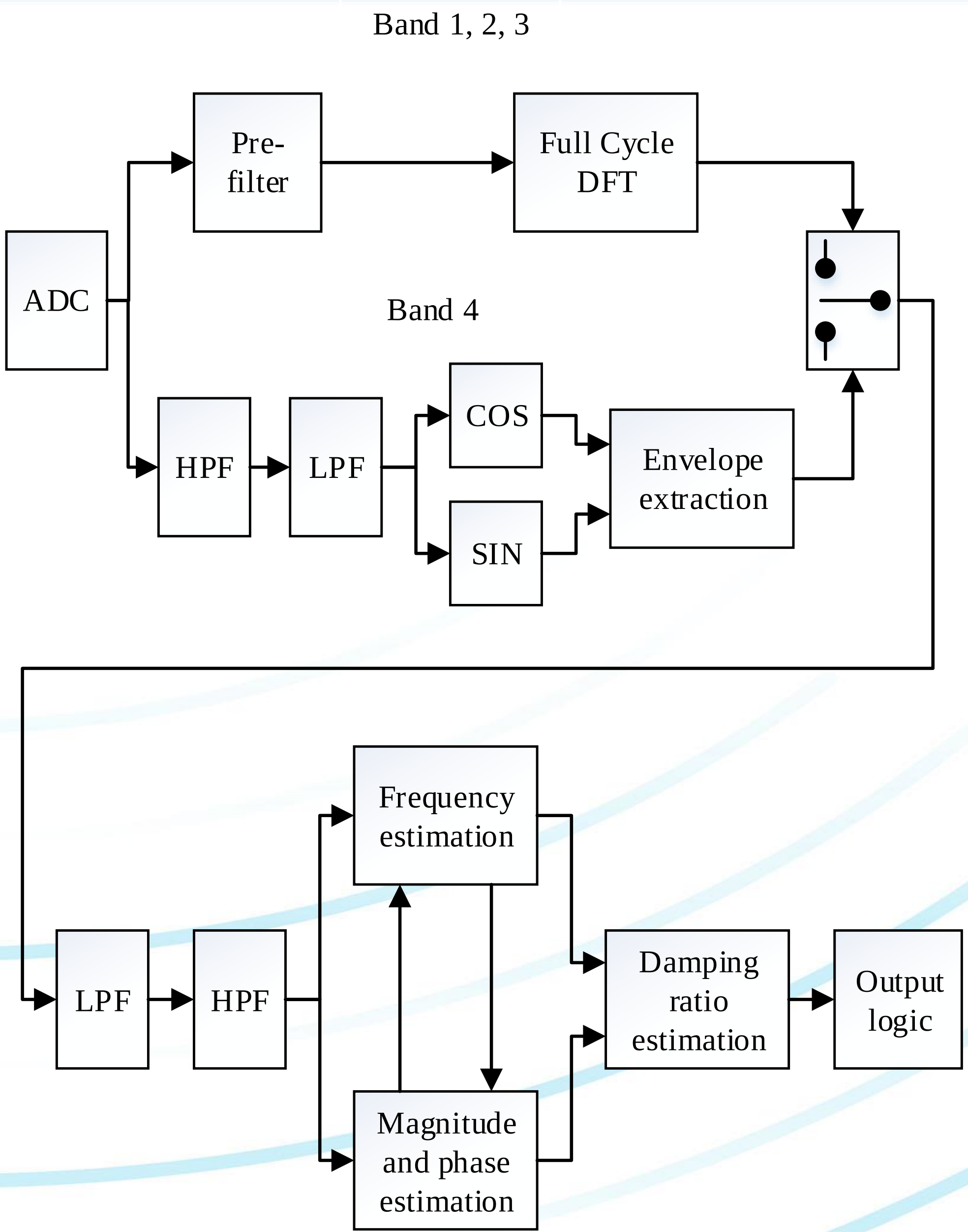
The oscillation signal can be expressed as a sinusoidal signal with a modulated magnitude

$$y(t) = \sqrt{2}A(1 + m \cdot e^{\sigma(t-t_0)} \cdot sin(\omega_m(t - t_0)) \cdot u(t_0)) \cdot sin(2\pi f_1 t)$$

The damping ratio of the signal is defined as

$$\xi = \frac{-\sigma}{\sqrt{\sigma^2 + \omega_m^2}}$$

Detection of the oscillations, damping and contributors



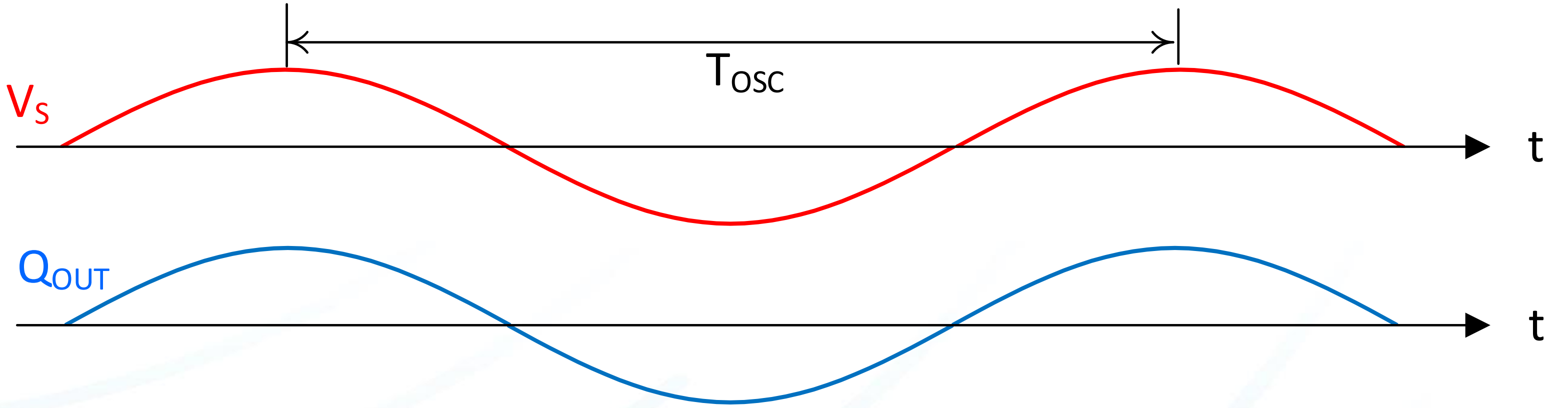
Multi-range Signal Oscillation Detector (MSOD)

Band	Frequency range (Hz)
1	0.01-0.1
2	0.1-1
3	1.0-10
4	10-55

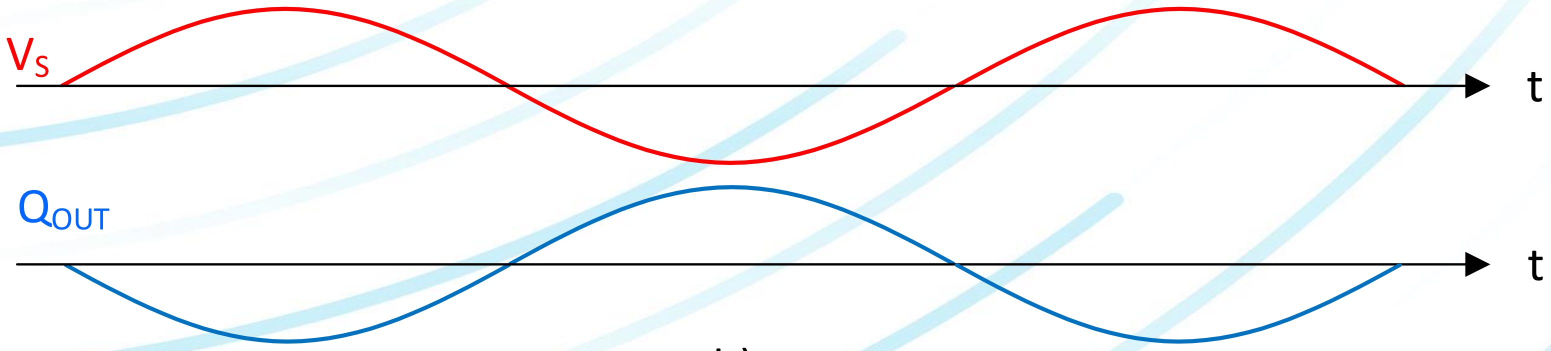
Detection of the oscillations, damping and contributors

Positive or negative contributor to oscillation

$$\Delta I_Q = k \cdot \Delta V_S$$



a)



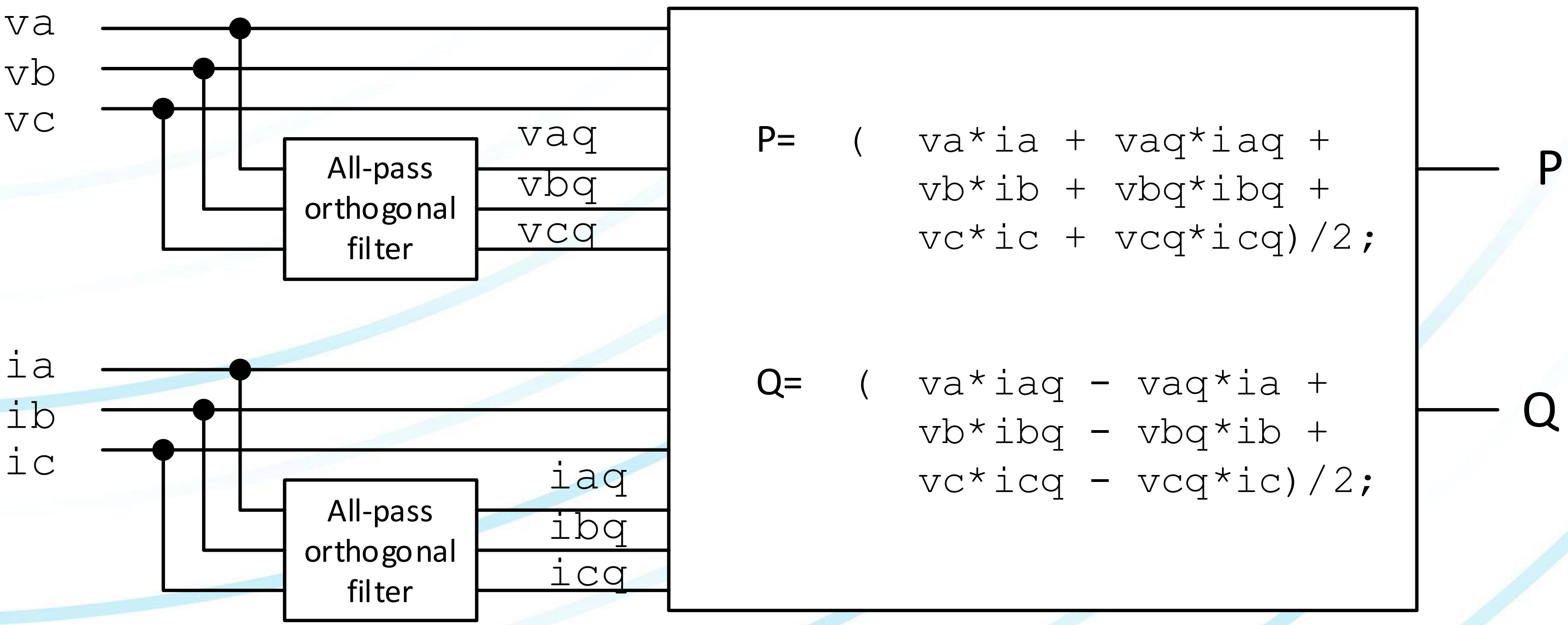
b)

Detection of the oscillations, damping and contributors

Positive or negative contributor to oscillation

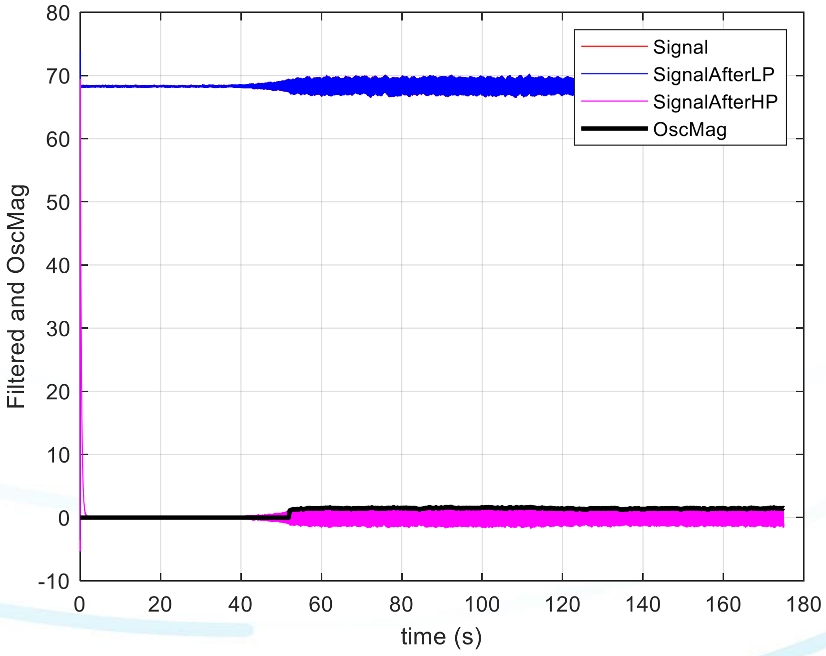
$$P = V_d I_d + V_q I_q$$

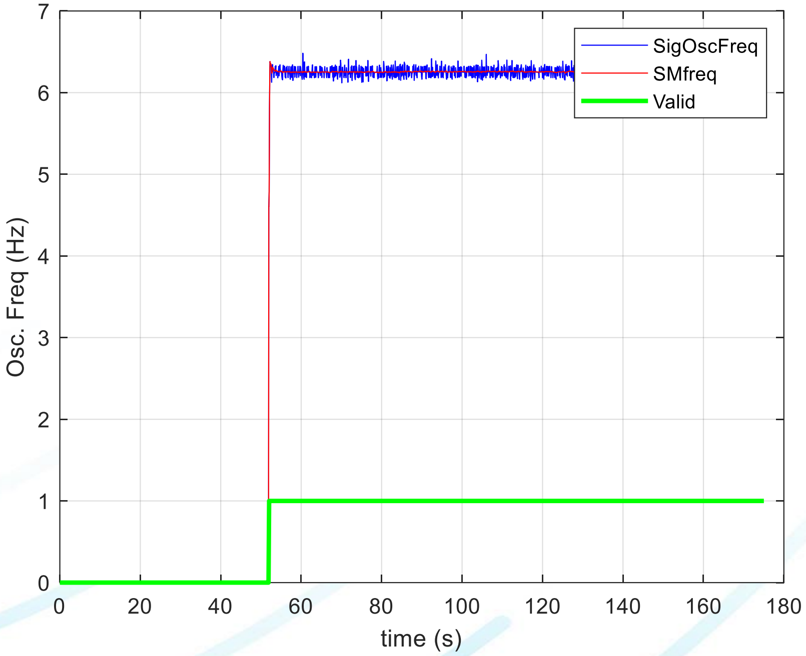
$$Q = V_d I_q - V_q I_d$$

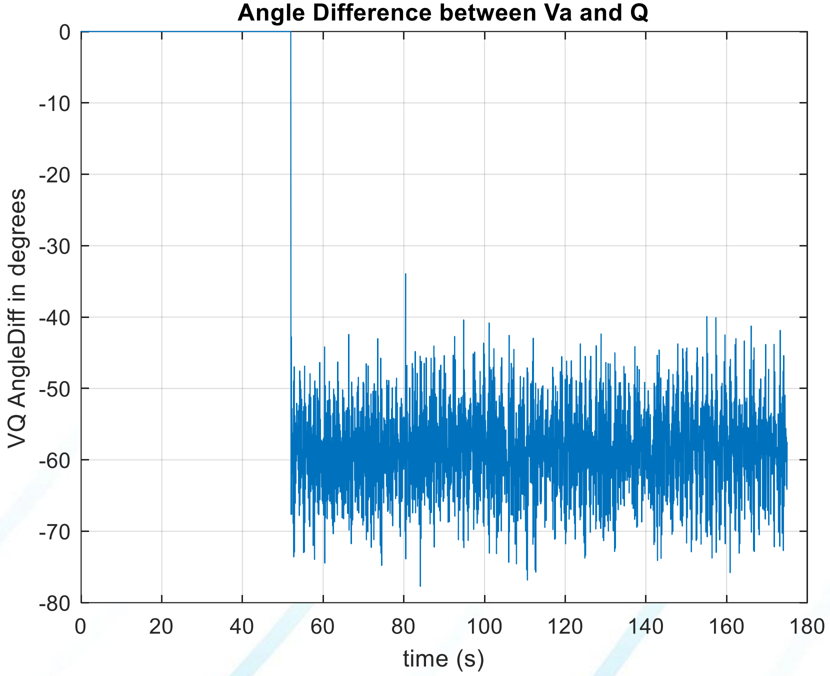


Field oscillation cases

Australia HWF site

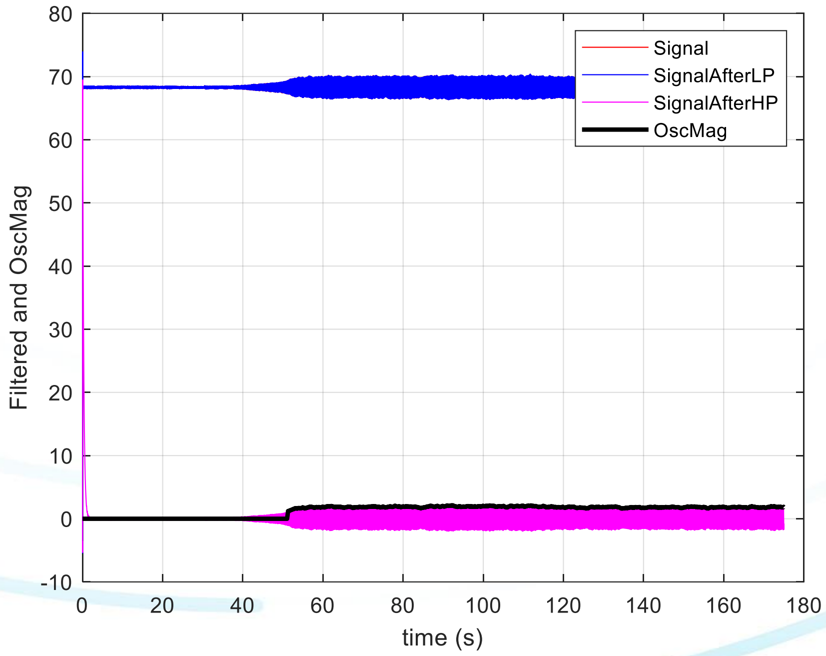


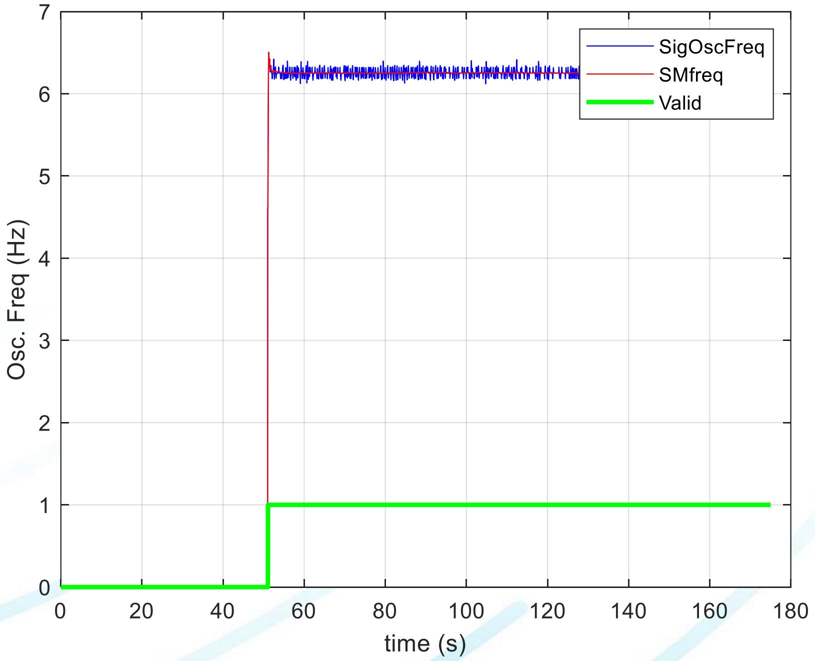


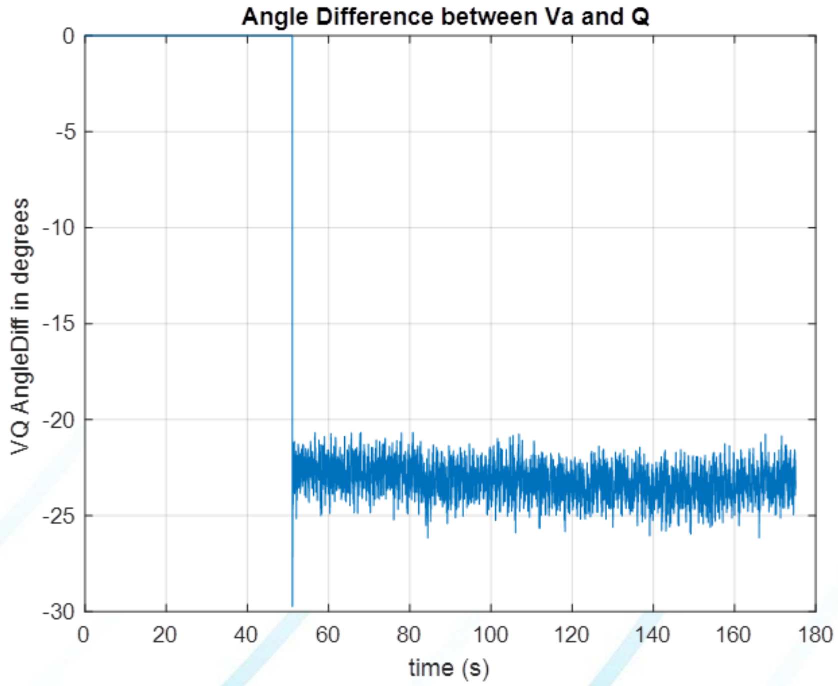


Field oscillation cases

Australia PAREP site

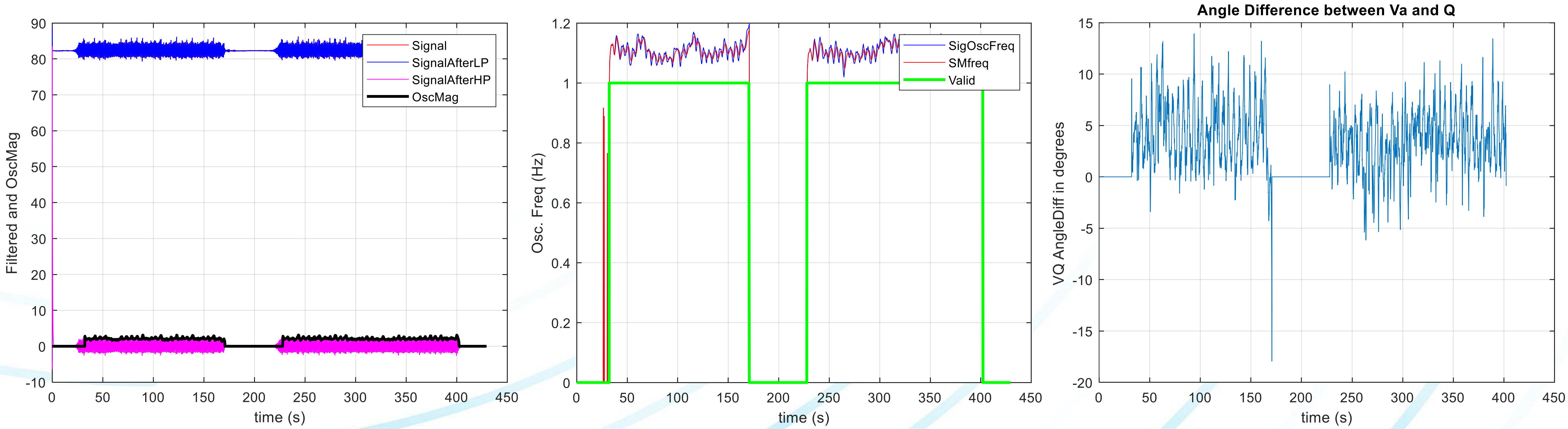






Field oscillation cases

Australia YARRANLEA solar farm site



Field oscillation cases

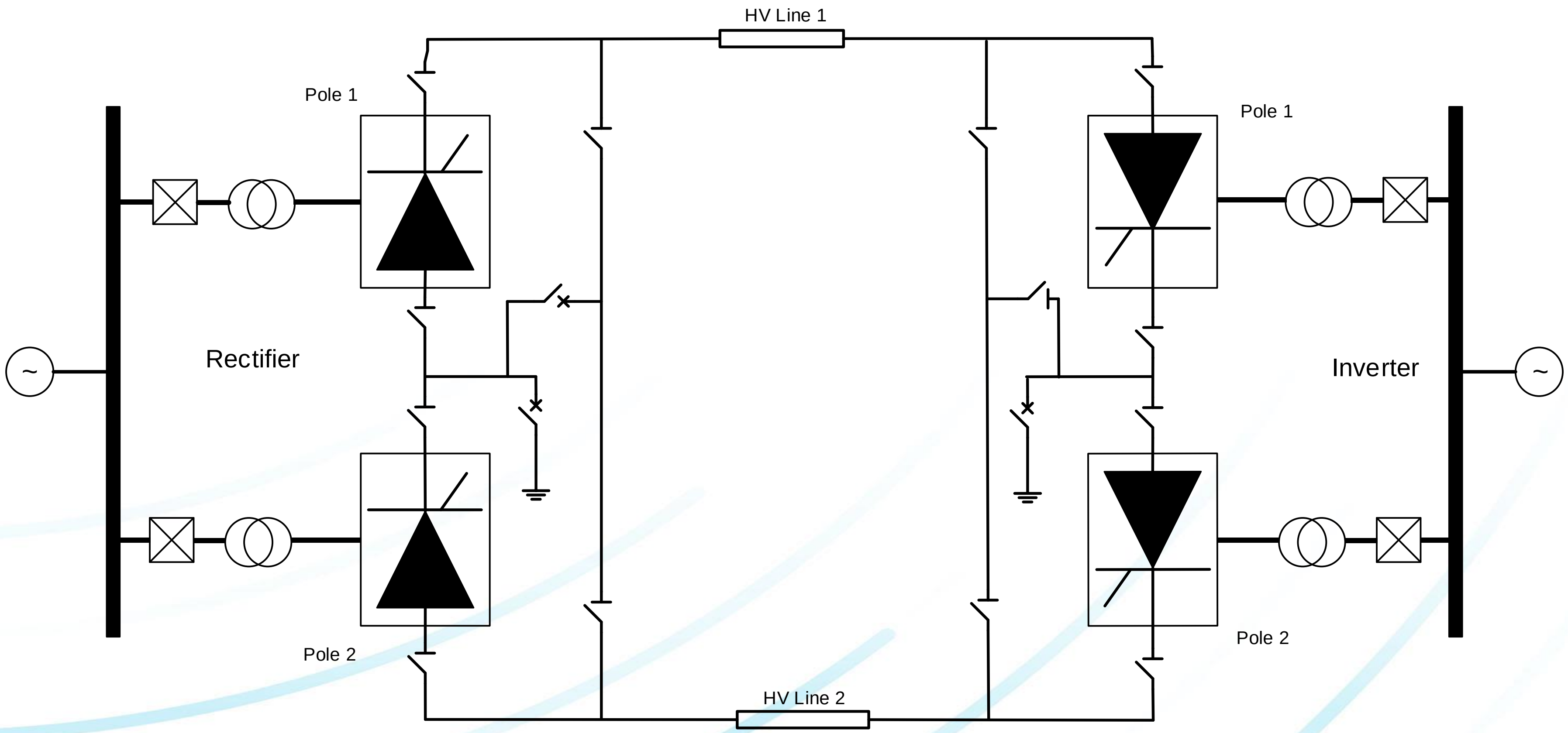
HVDC case

The biggest risk of STTI is linked with HVDC installation connected to steam turbine generators by a short, radial line. Risk of STTI it is important to assess whether the generator can be considered nearby, which is done by using the Unit Interaction Factor (UIF).

$$UIF_i = \frac{MW_{HVDC}}{MVA_i}\left(1 - \frac{SC_i}{SC_{tot}}\right)^2$$

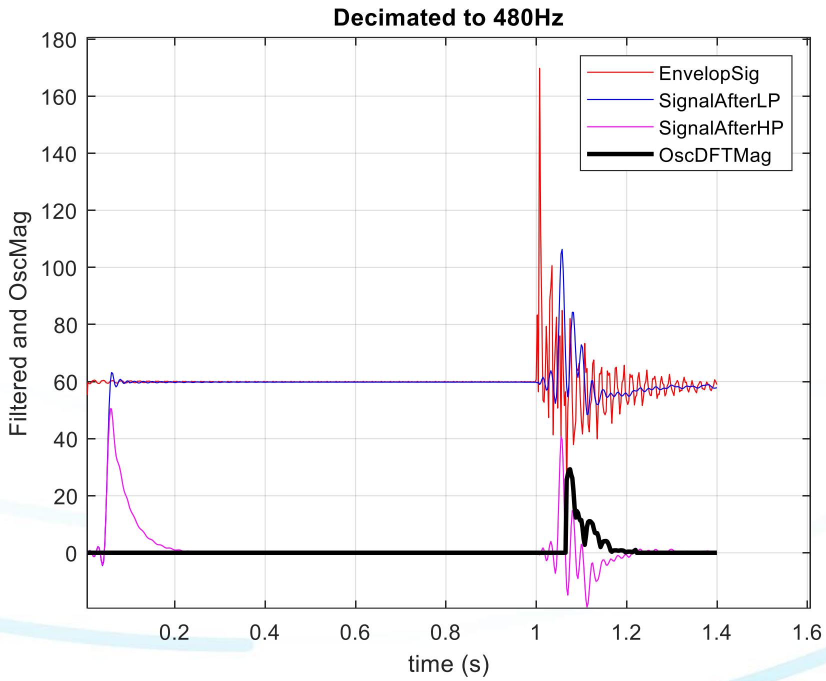
Field oscillation cases

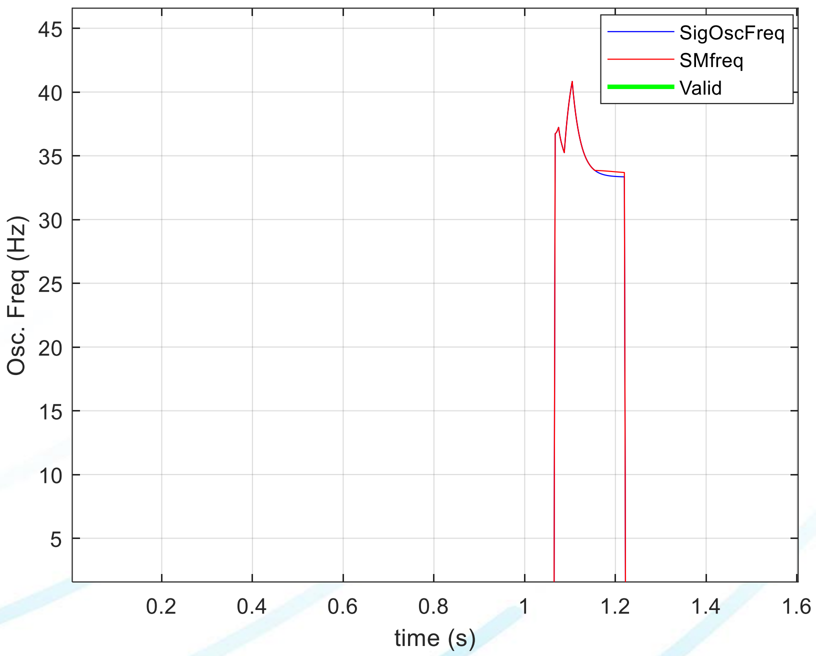
HVDC case

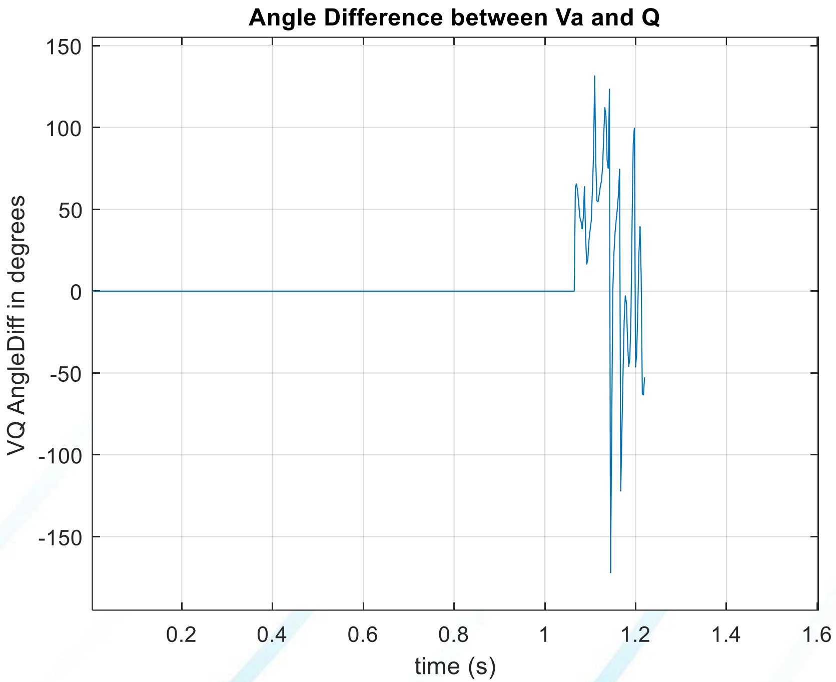


Field oscillation cases

HVDC case







Conclusions

- Subsynchronous oscillations is not a new phenomenon in the power system and were presenting challenges even with a conventional synchronous generation
- The range of oscillation frequency can be very wide, from 0.1Hz to near system nominal frequency.
- With the fast deployment of the renewable generation of the different types and with power electronics converters and their controllers, the issue of the subsynchronous oscillations and their mitigation is becoming even more important. It's complex phenomenon.
- Detection of subsynchronous oscillations and detection of the contributors to these oscillations is essential to ensure reliable operation of the power system

Thank You

Questions?