



Managing the effect of parallel HVDC systems on subsynchronous damping of nearby generators

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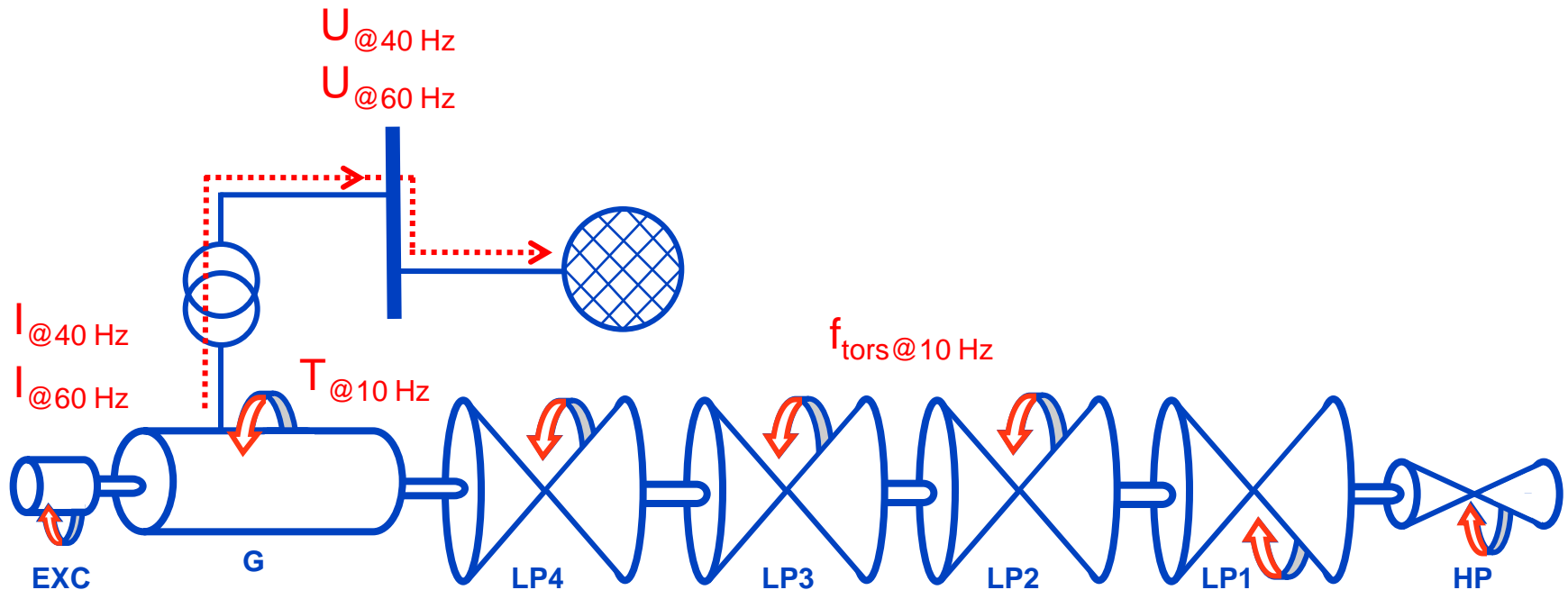
Structure of the presentation

- the paper covers both damping circuit (SSDC) and SSO protection related aspects
 - this presentation concentrates on SSO protection part of the work

Structure:

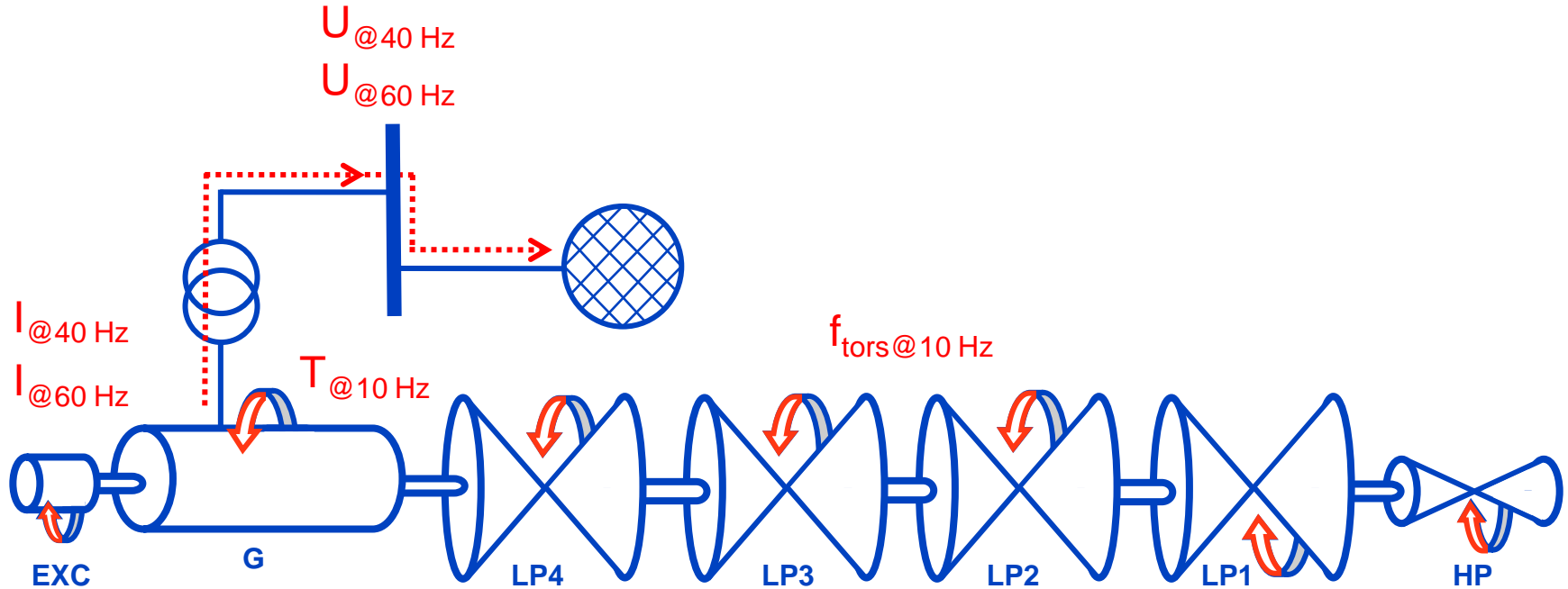
- Introduction to effect of HVDC on subsynchronous oscillations
- Approaches to SSO protection
- HVDC SSTI: Introduction to Finnish case study
- Preconditions and scope of the study
- The main results
- Summary

Subsynchronous oscillations



- subsynchronous damping can be solved based on current injections that are proportional to
 - generator and system admittance
 - amplitude of torsional oscillations
 - frequency of torsional oscillations
 - loading of the unit

Detection of subsynchronous oscillations



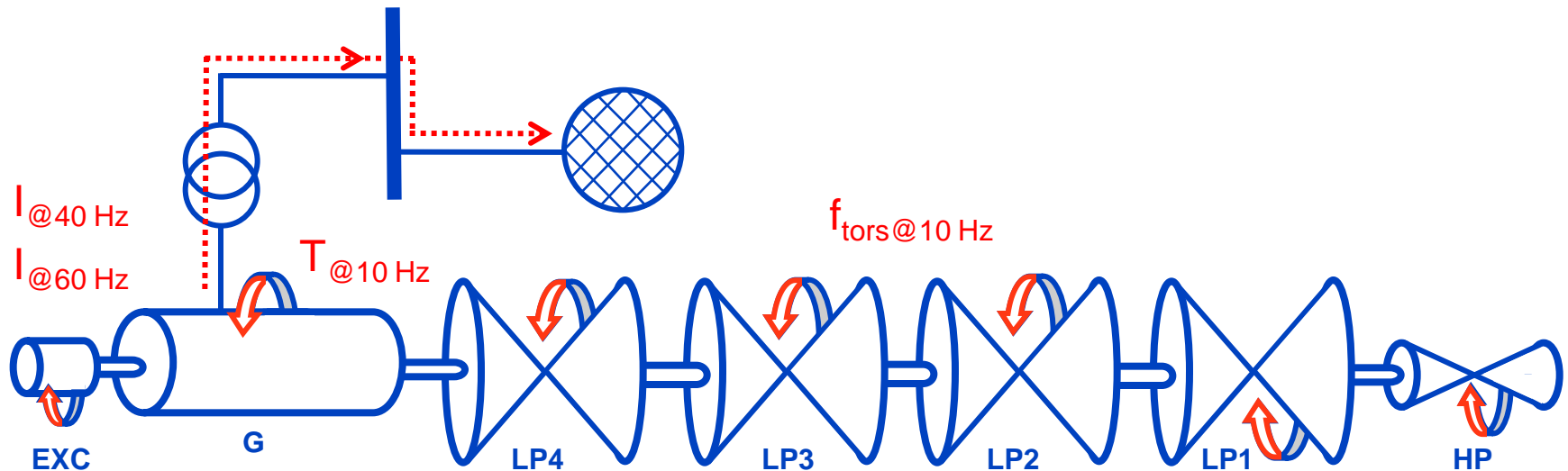
Detection of subsynchronous oscillations

$= \omega_{@10\text{ Hz}}$ measurement of shaft speed and/or displacement

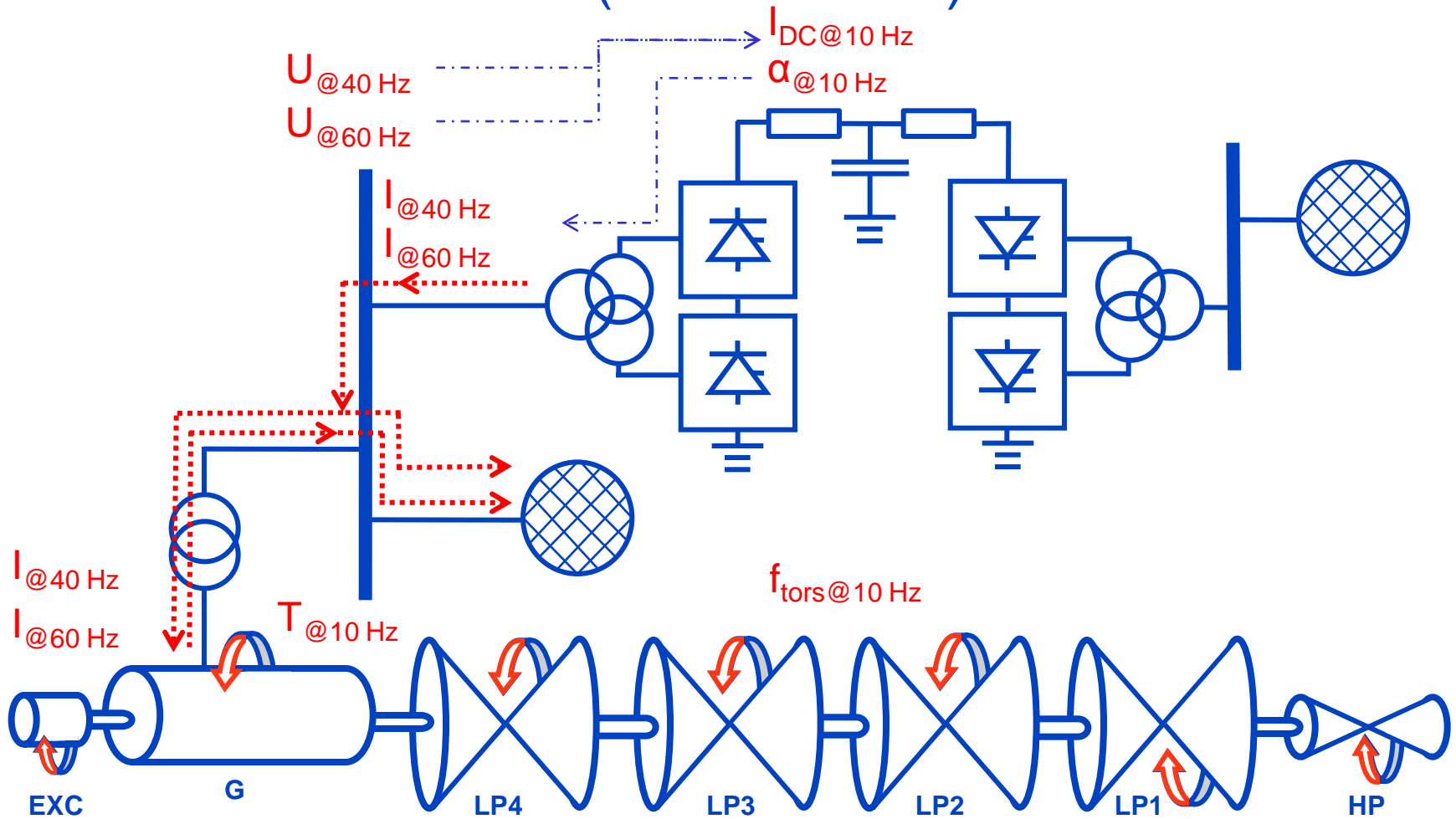
amplitude of subsynchronous current (or torque)

$U_{@40\text{ Hz}} \rightarrow f_{\text{elec}@10\text{ Hz}}$ local frequency measurement

$U_{@60\text{ Hz}}$



Effect of HVDC on subsynchronous damping of torsional oscillations (HVDC SSTI)

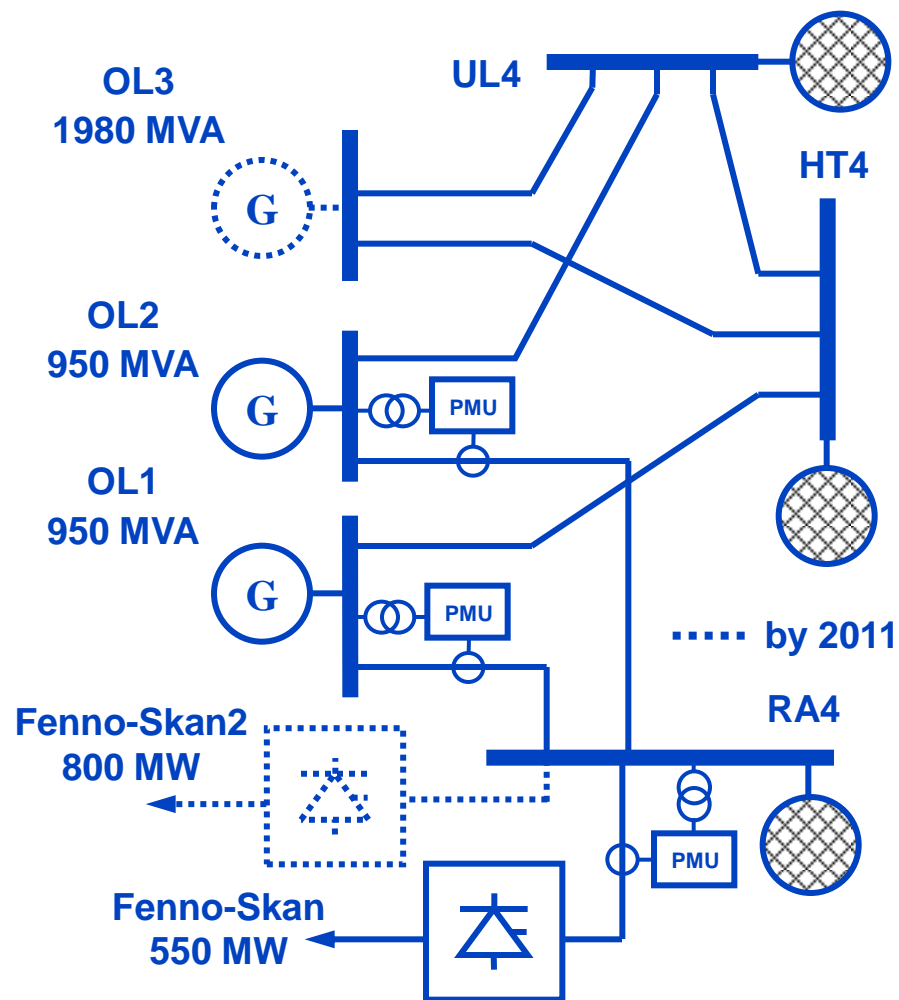


Protection against torsional oscillations with extreme amplitudes (SSR protection schemes)

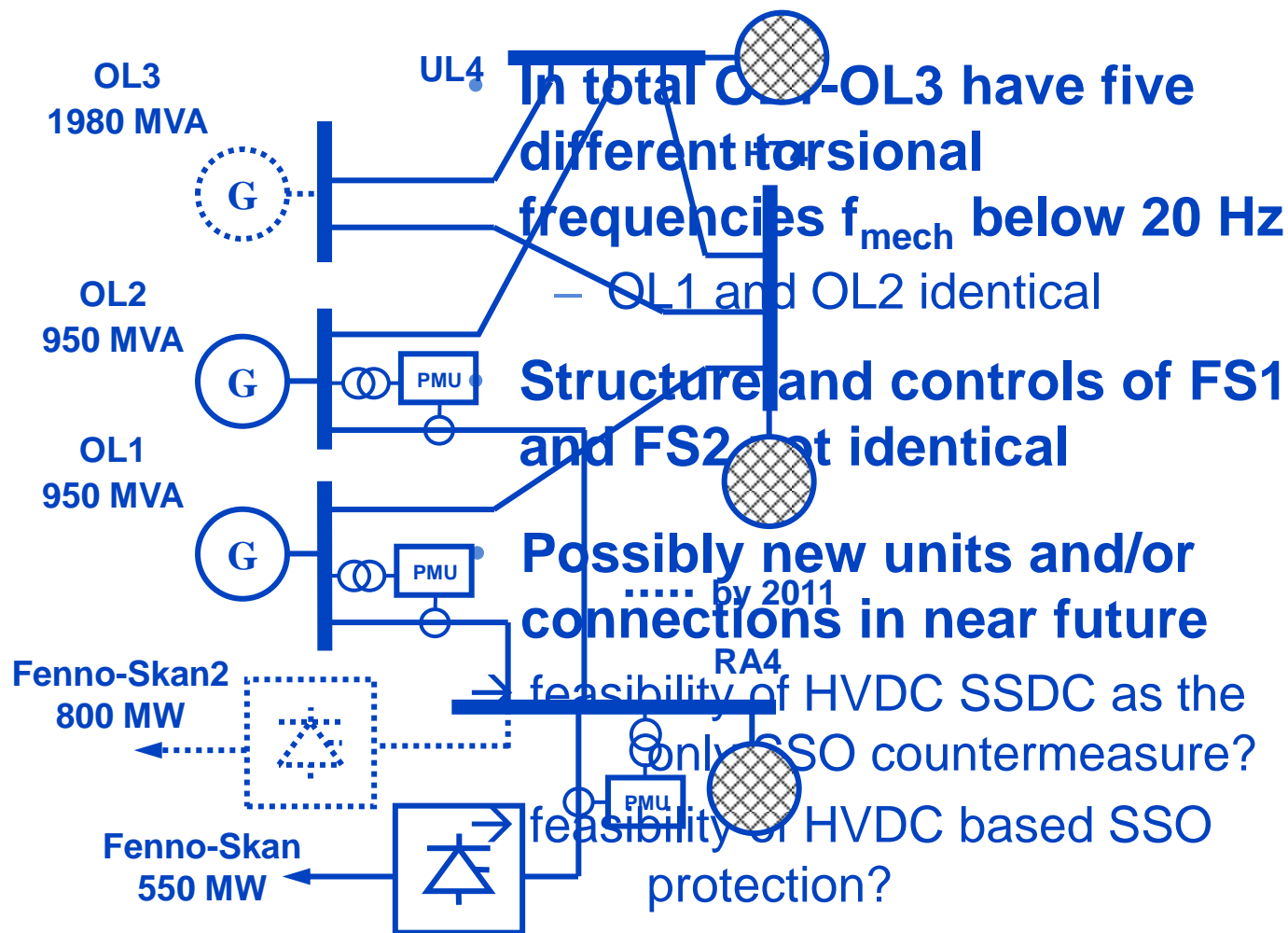
Device tripping scheme	Unit tripping scheme
<ul style="list-style-type: none"> - sudden tripping of HVDC may momentarily increase SSO significantly - selectivity guaranteed only if single component may affect damping <ul style="list-style-type: none"> - typically based on locally measured electrical signal(s) 	<ul style="list-style-type: none"> - "last line of protection" - selective - typically based on shaft speed or displacement signal(s)

- this paper concentrates on feasibility of HVDC tripping scheme based on locally measured frequency
 - measurement of subsynchronous currents valid only up to 35-40 Hz and thus, current based HVDC tripping SSO protection not feasible

HVDC SSTI: Case southwest Finland



HVDC SSTI: Case southwest Finland



The scope of the SSO protection related study: The three questions to be answered

1. Special case of two different torsional modes that are 1 Hz apart and that are modes of two different unit
2. Effect of parallel AC network on selectivity of SSO protection based on local frequency measurement
3. Effect of structure of HVDC system on selectivity of SSO protection based on local frequency measurement

The planning values for torsional modes

Planning values [Hz] for torsional frequencies below 20 Hz				
G1/G2 (950 MVA)		G3 (1900 MVA)		
9.5	19.5	6	10.5	14.5

- the high ratings of the units basically guarantee that if all units are in operation, torsional oscillations are well damped
- if G3 and either G1 or G2 is in operation, G3 guarantees that torsional modes of G1/2 are well damped
- thus, basically two sets of SSDC and SSO protection parameters could be implemented and activated depending on switching conditions
 - may not be considered feasible due to complexity of the network

Range of operating conditions under which the effect of HVDC on subsynchronous damping is significant

Approximate short circuit capacity (MVA) required to reach UIF threshold 0.1			
		G1/G2 (950 MVA)	G3 (1900 MVA)
Active HVDC pole(s)	600 MW	3000	3500
	800 MW	4000	5000
	1400 MW	5500	8000

- short circuit level above the values given in table above in all the normal operating conditions and typical contingencies
- SSDC may reduce the given values down to $\frac{1}{4}$ of the given levels
- is SSO protection really required?
 - verification of the effect of damping controls
 - nature of the phenomenon

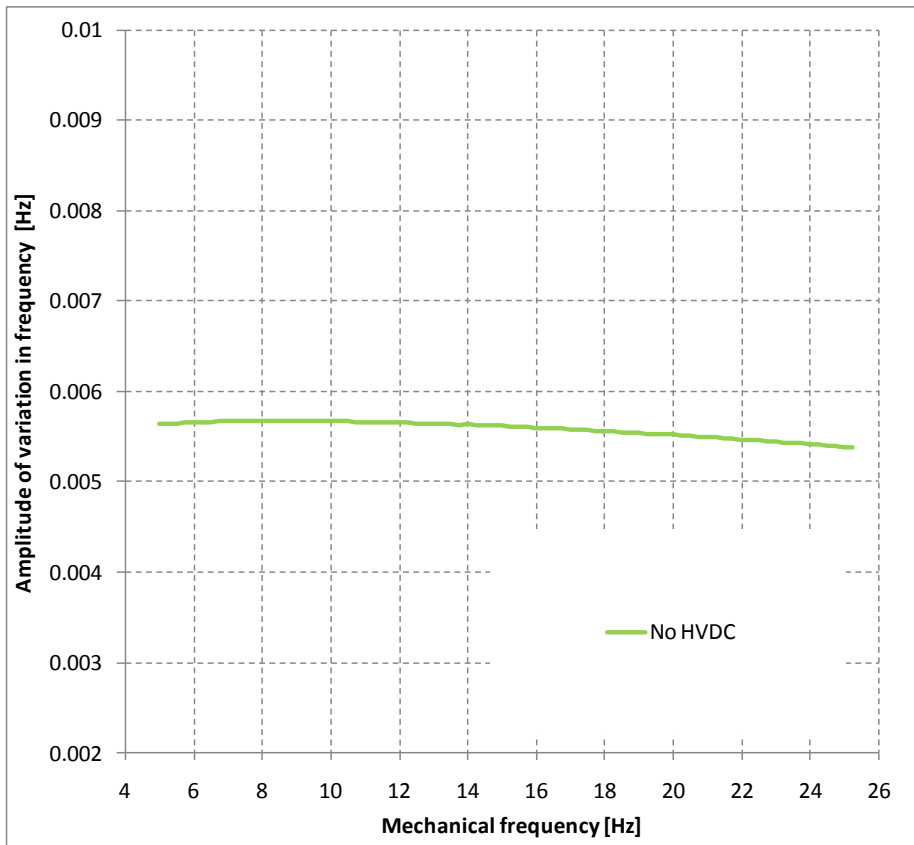
Factors contributing to the negative effect of HVDC on subsynchronous damping

Factors affecting damping basically affect the amplitude and phase of the sub- and supersynchronous currents injected by HVDC

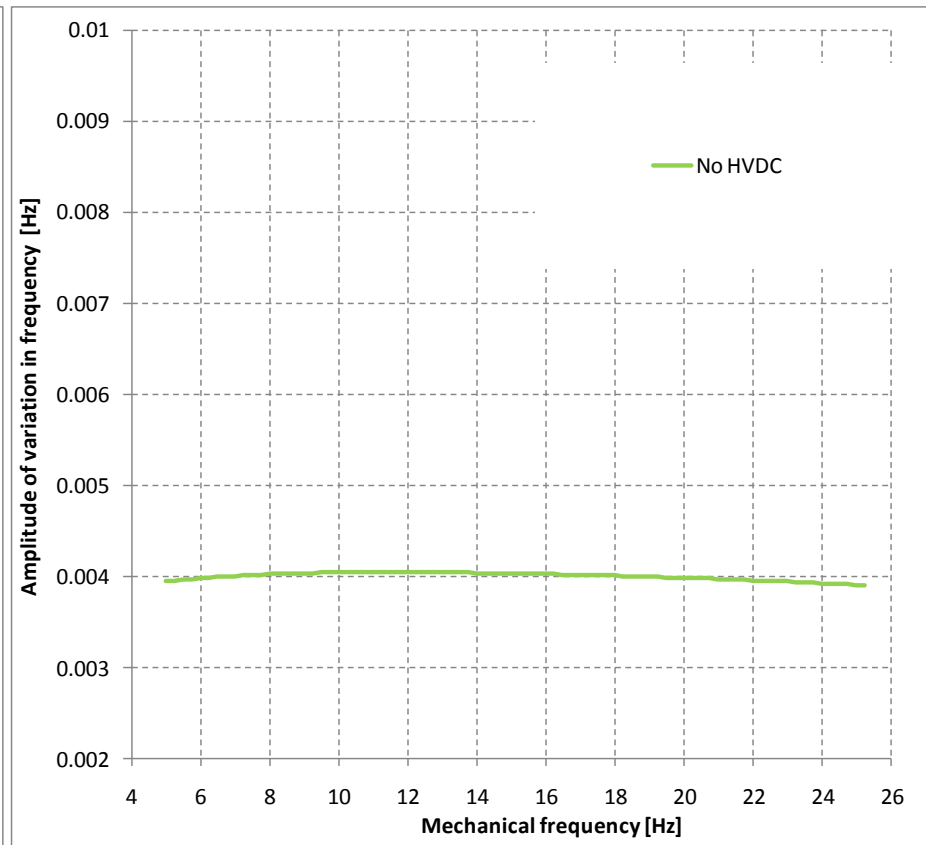
→ following factors affect thus also local frequency measurement

- 1. Constant current and/or power controller**
 - structure of the primary controls in general
- 2. Method applied for synchronization of firing pulses**
- 3. HVDC LCC vs. HVDC VSC**
- 4. Nominal rating of the HVDC system**
- 5. Operating point of the HVDC system**
- 6. Structure of the DC system**
 - length of the DC connection, cable vs. OH

Effect of HVDC on subsynchronous variation in local frequency measurement (no HVDC)

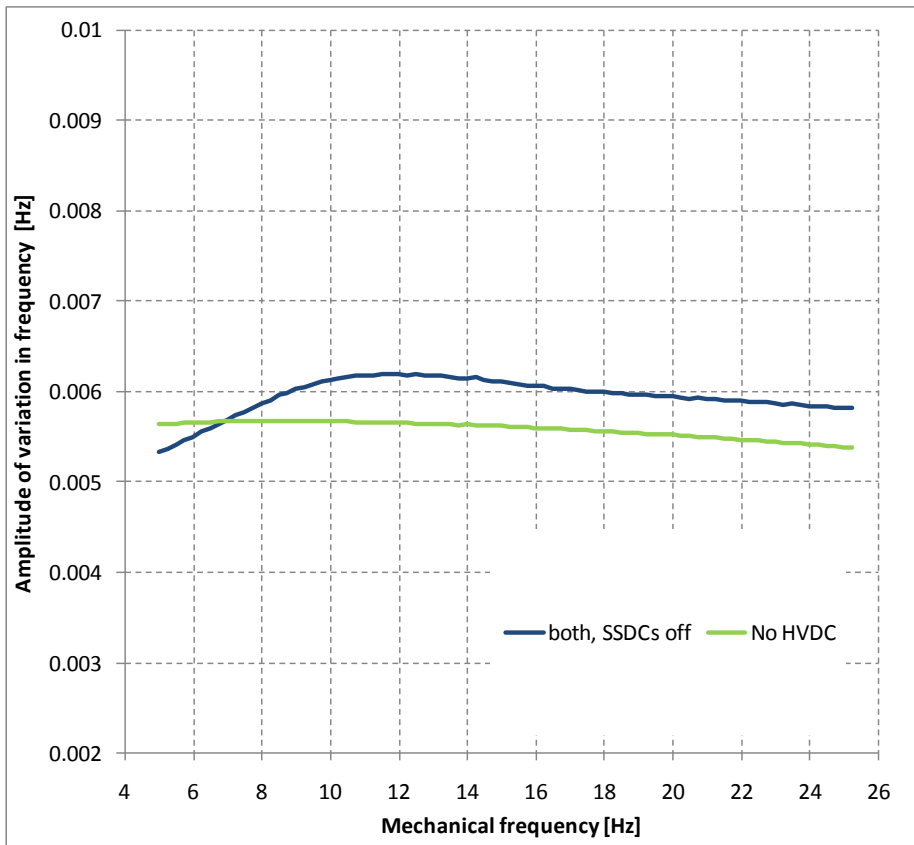


Generator G3

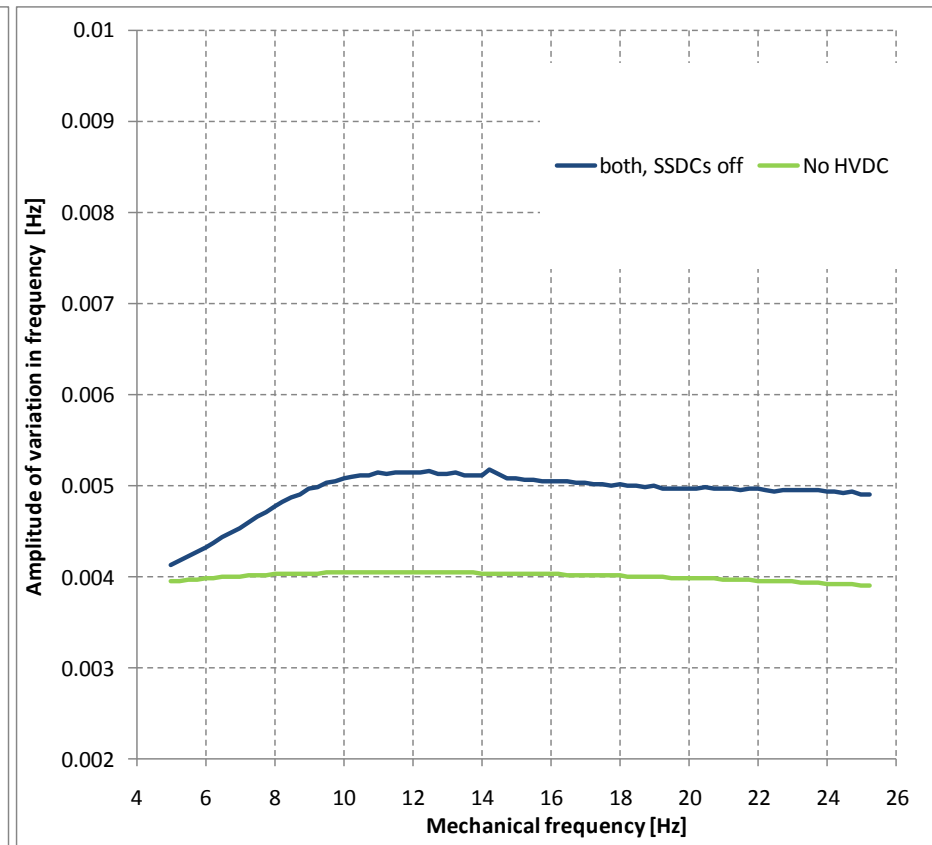


Generators G1/G2

Effect of HVDC on subsynchronous variation in local frequency measurement (both HVDCs, no SSDCs)

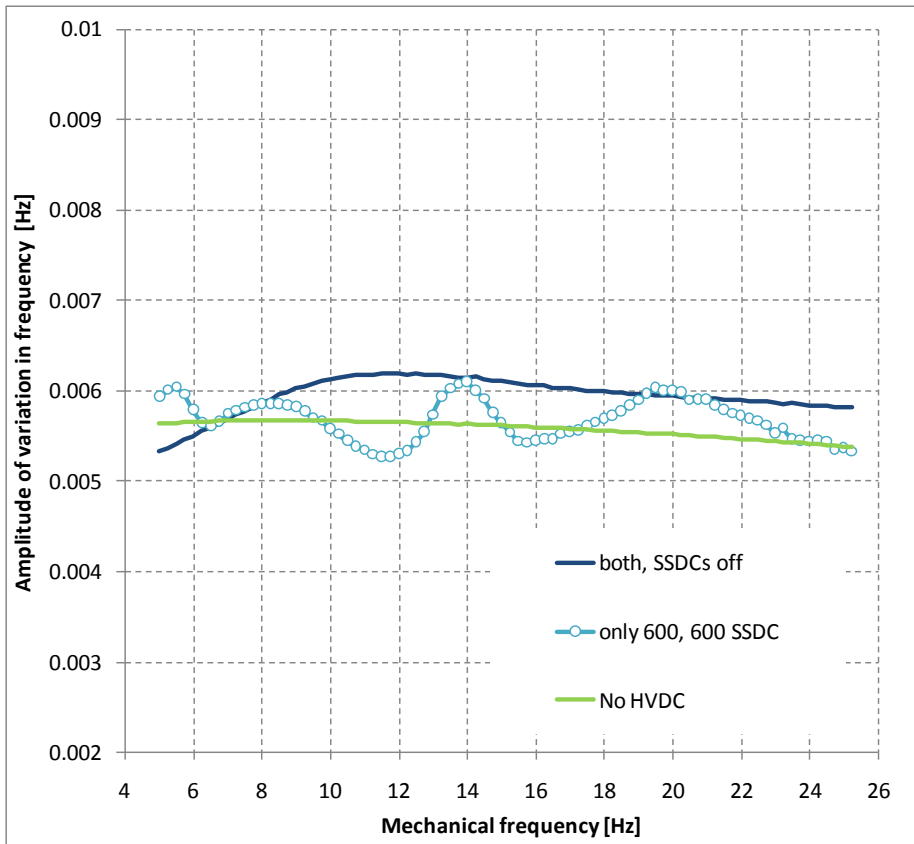


Generator G3

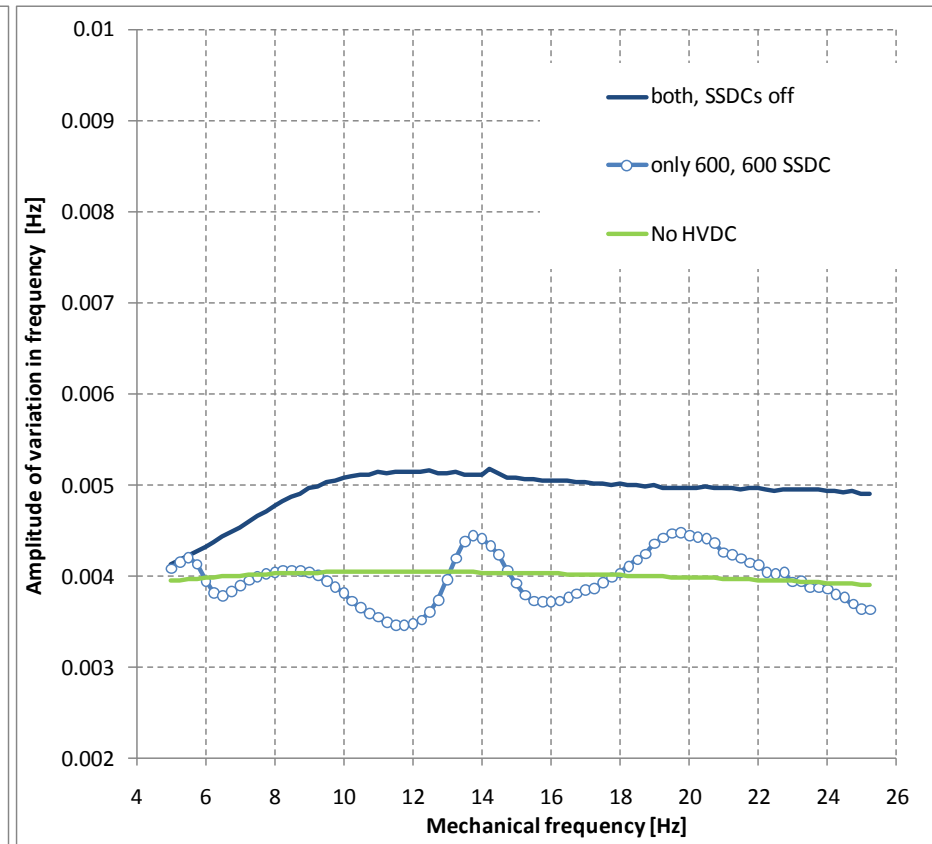


Generators G1/G2

Effect of HVDC on subsynchronous variation in local frequency measurement (600 MW pole with SSDCs)

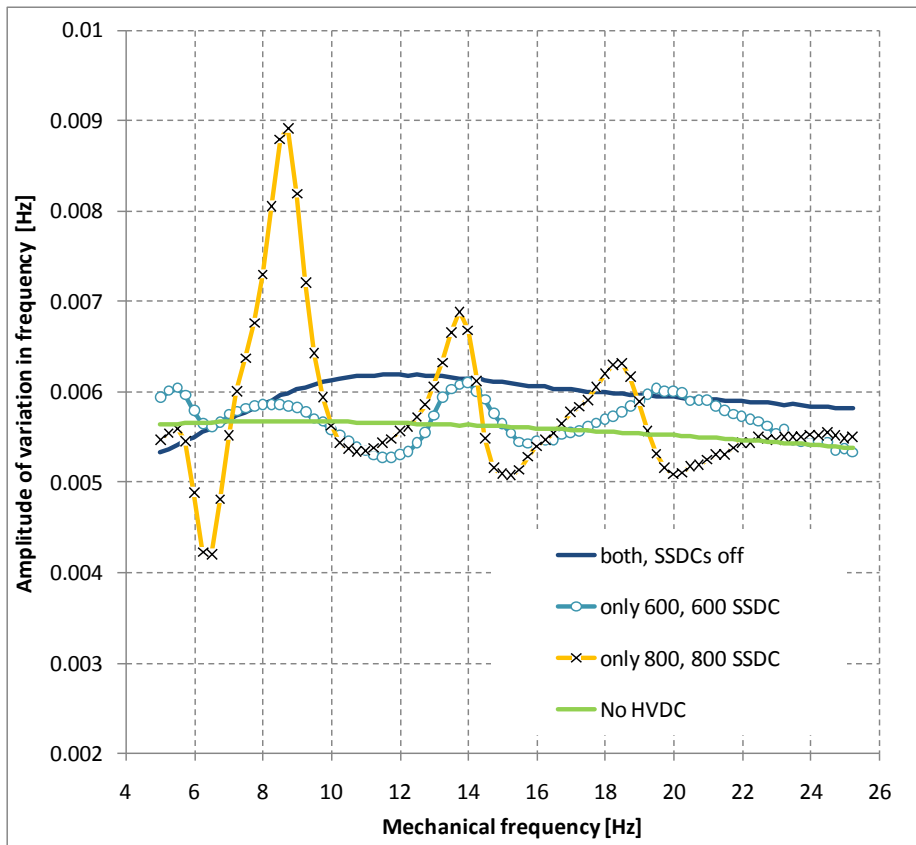


Generator G3

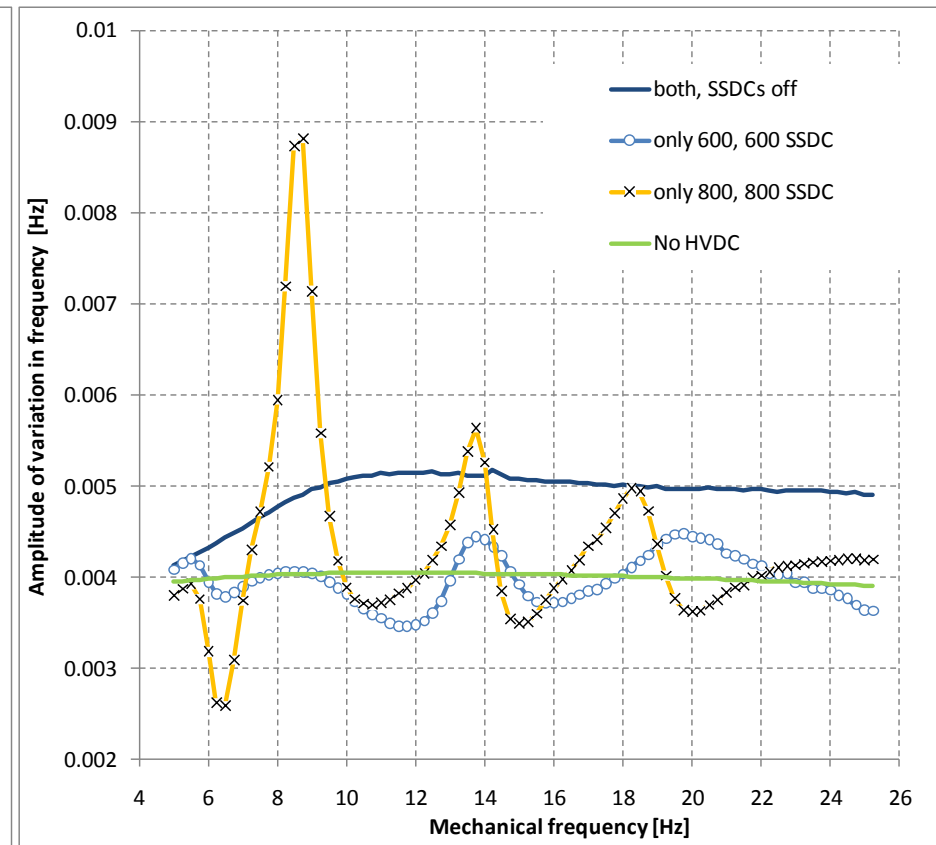


Generators G1/G2

Effect of HVDC on subsynchronous variation in local frequency measurement (800 MW pole with SSDCs)

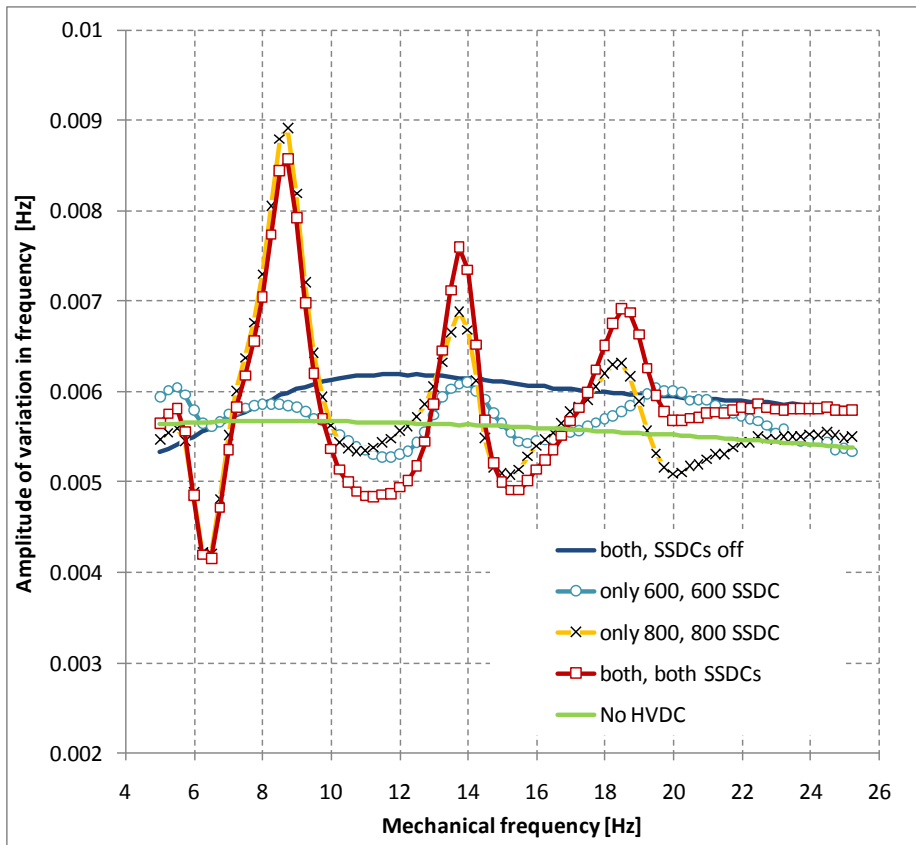


Generator G3

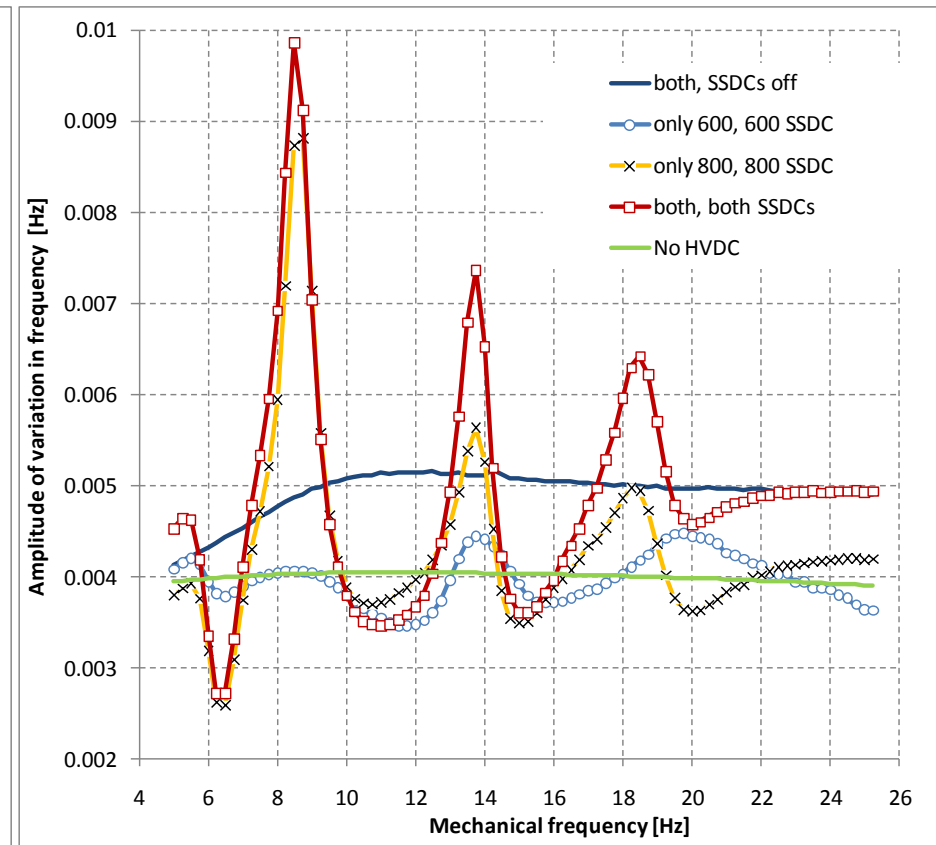


Generators G1/G2

Effect of HVDC on subsynchronous variation in local frequency measurement (both poles with SSDCs)



Generator G3



Generators G1/G2

Effect of structure of HVDC on local frequency measurement

		Range of subsynchronous variation in frequency measurement [mHz] due to subsynchronous oscillation of generator speed with amplitude of 8 mHz (peak)					
		G1/G2			G3		
		9.5	19.5	6.0	10.5	14.5	
SCC of parallel AC network	SCC2	3.9 - 4.6	3.8 - 4.8	4.8 - 5.8	5.0 - 5.5	5.5 - 5.7	
	SCC5	2.2 - 2.8	2.2 - 2.5	3.4 - 3.7	3.5 - 3.8	3.7 - 3.8	

- variation in short circuit level results in significant variation in amplitudes of subsynchronous components
 - selectivity of protection scheme cannot be guaranteed
- identical HVDC's and generators would have decreased the variations
 - nevertheless, the effect of SCL dictates the level of variation
 - the study also ignored the differences in torsional characteristics

Summary (1)

The main reasons for rejecting HVDC tripping SSO protection

1. SSO protection should have been implemented for both poles
 - risk of losing both poles as well risk of significant momentary increase in amplitude of SSO
 - also selectivity could have been an issue
 2. Relatively large range of operating conditions under which HVDC may have adverse effect on torsional damping
 3. No reasonable selectivity could have been obtained without complex telecom arrangements and control/logic systems
- unit tripping SSO protection scheme was recommended as the last line of protection

Summary (2)

- torsional protection system should also have monitoring and fault recorder capabilities
 - level of damping in connection of very high amplitude SSO cannot be tested in practice
- monitoring system shall not replace extensive testing of torsional damping in connection of unit commissioning
 - after all, total subsynchronous damping is likely at lowest the generator unit is on low load

Summary (3)

- based on the analysis applying local frequency measurement based HVDC tripping SSO protection could be feasible as last line of SSO protection **only if**
 1. only one HVDC system is located in vicinity of the generator
 2. HVDC results in negative subsynchronous damping only within narrow range of short circuit levels (or operating conditions)
 3. the frequencies and the shapes of the torsional modes to be protected are either different and well separated or nearly identical
 4. SSDC is not adequate to cancel the negative effect of HVDC
- criterias 1-3 were not fulfilled in the case presented
 - preliminary analysis indicate that SSDC should be adequate

