

# **Damping Low Frequency Oscillation by HVDC Supplementary Control**

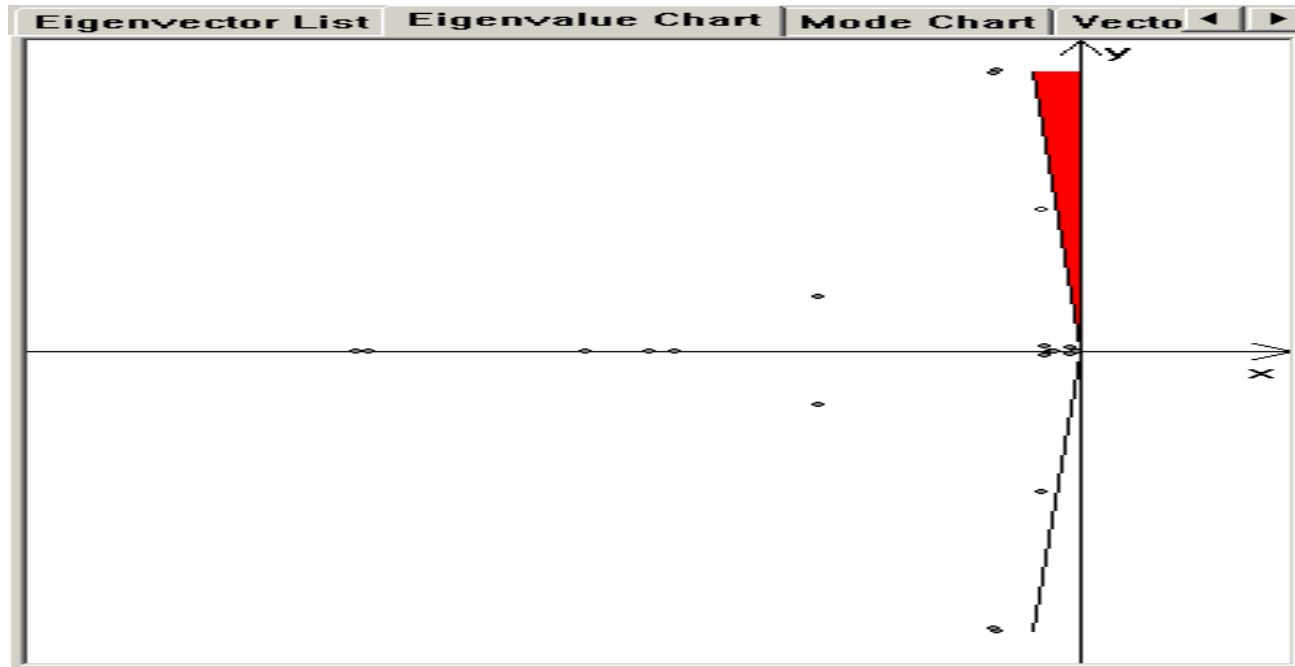
## **in an AC/DC Parallel Transmission Power System**

**China Southern Power Grid Technology Research Center  
Shanghai Jiao Tong University**

**June 2009, Norway**



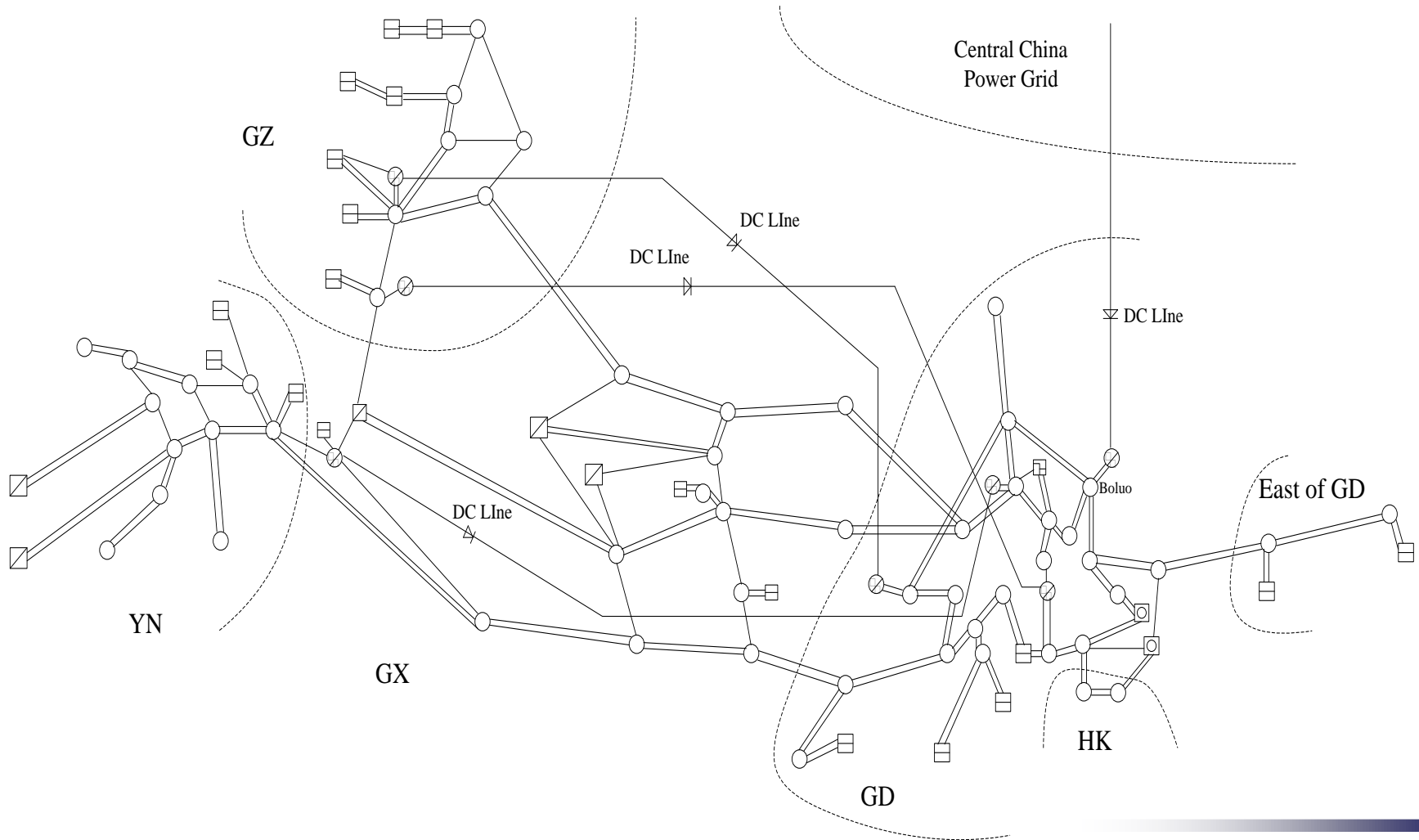
## ■ Implicit Restarted Arnoldi (IRA) Method



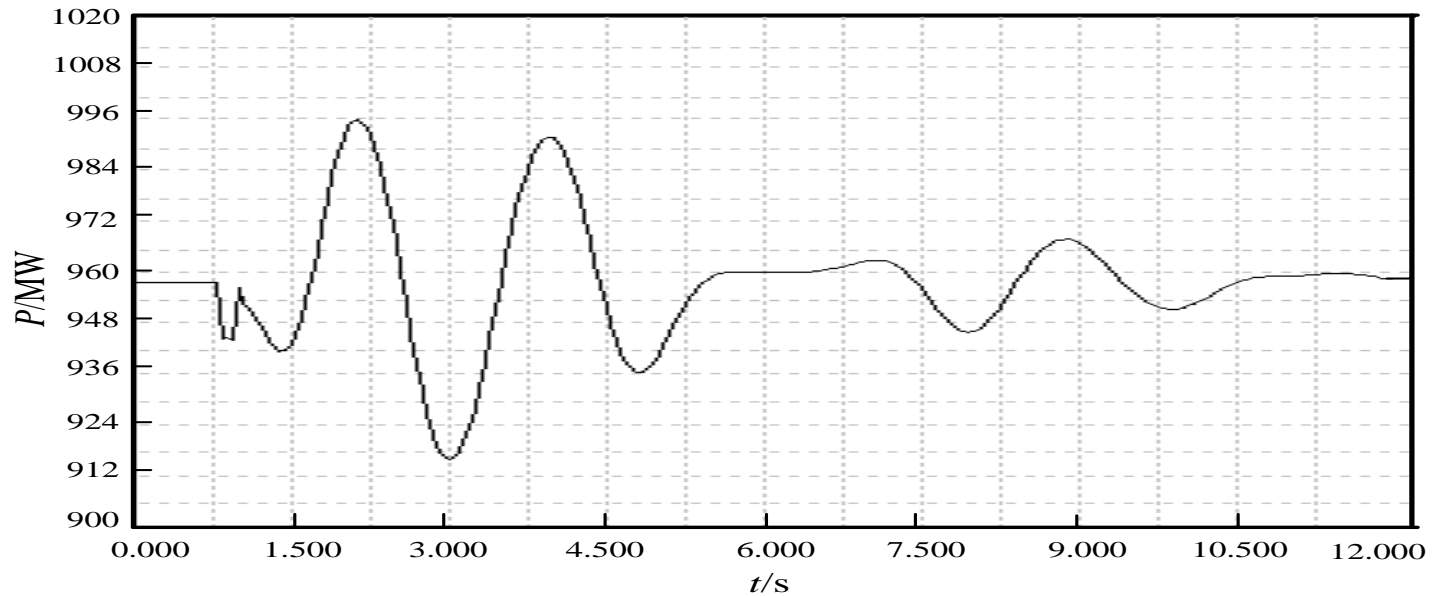
## ■ Calculating critical eigenvalues in the red area

- **247 generators**
- **35 in IEEE type excitation system models & equipped with PSS**
- **1399 nodes (500kV/220kV/10kV)**
- **2227 branches**
- **623 loads of ZIP static models**
- **4 HVDC links ( $\pm 500\text{kV}$ )**

# AC/DC Transmission System with 4 HVDC Tie Lines



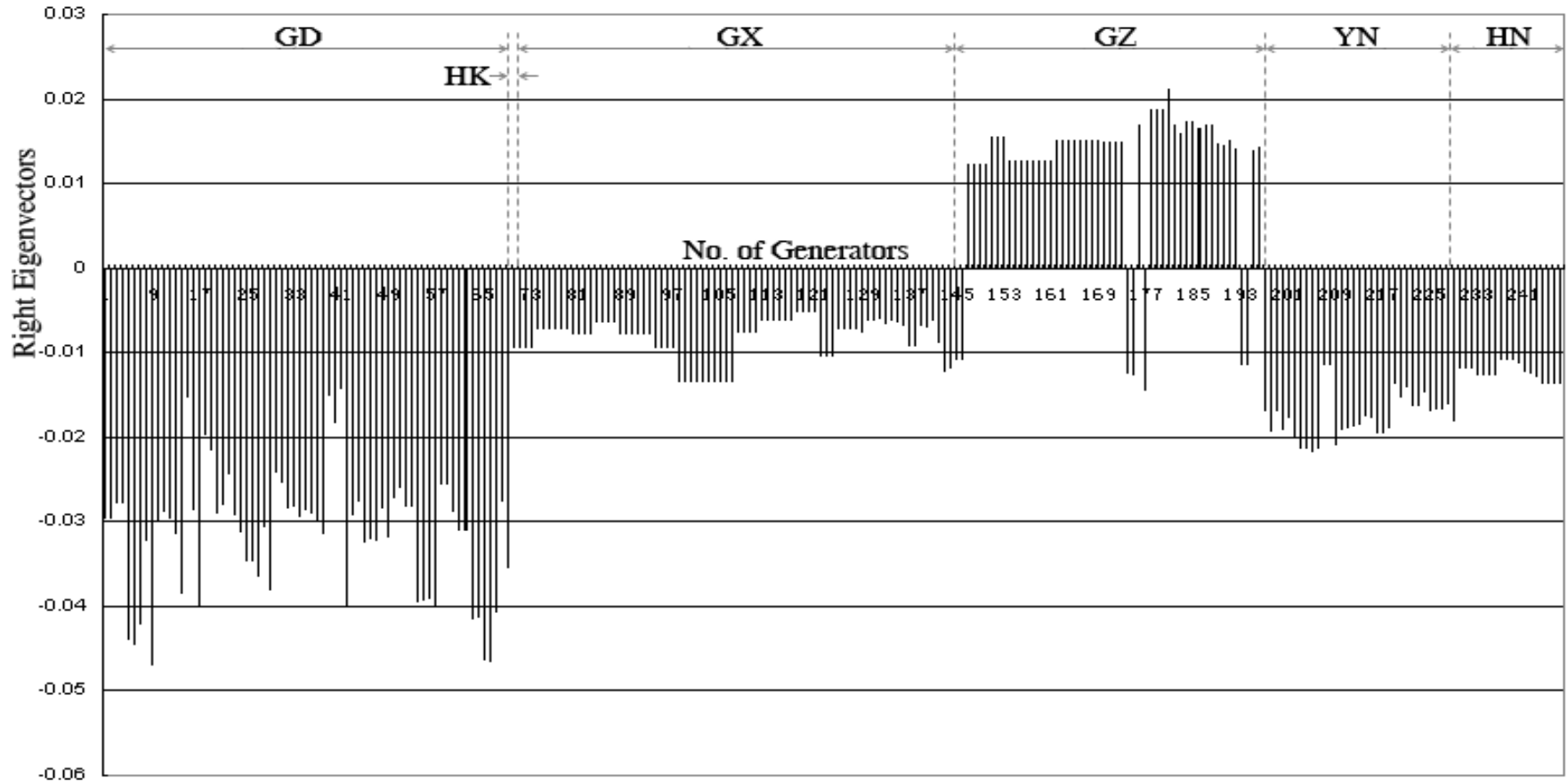
# System Oscillation after Disturbance by Transient Simulation / by SSAP



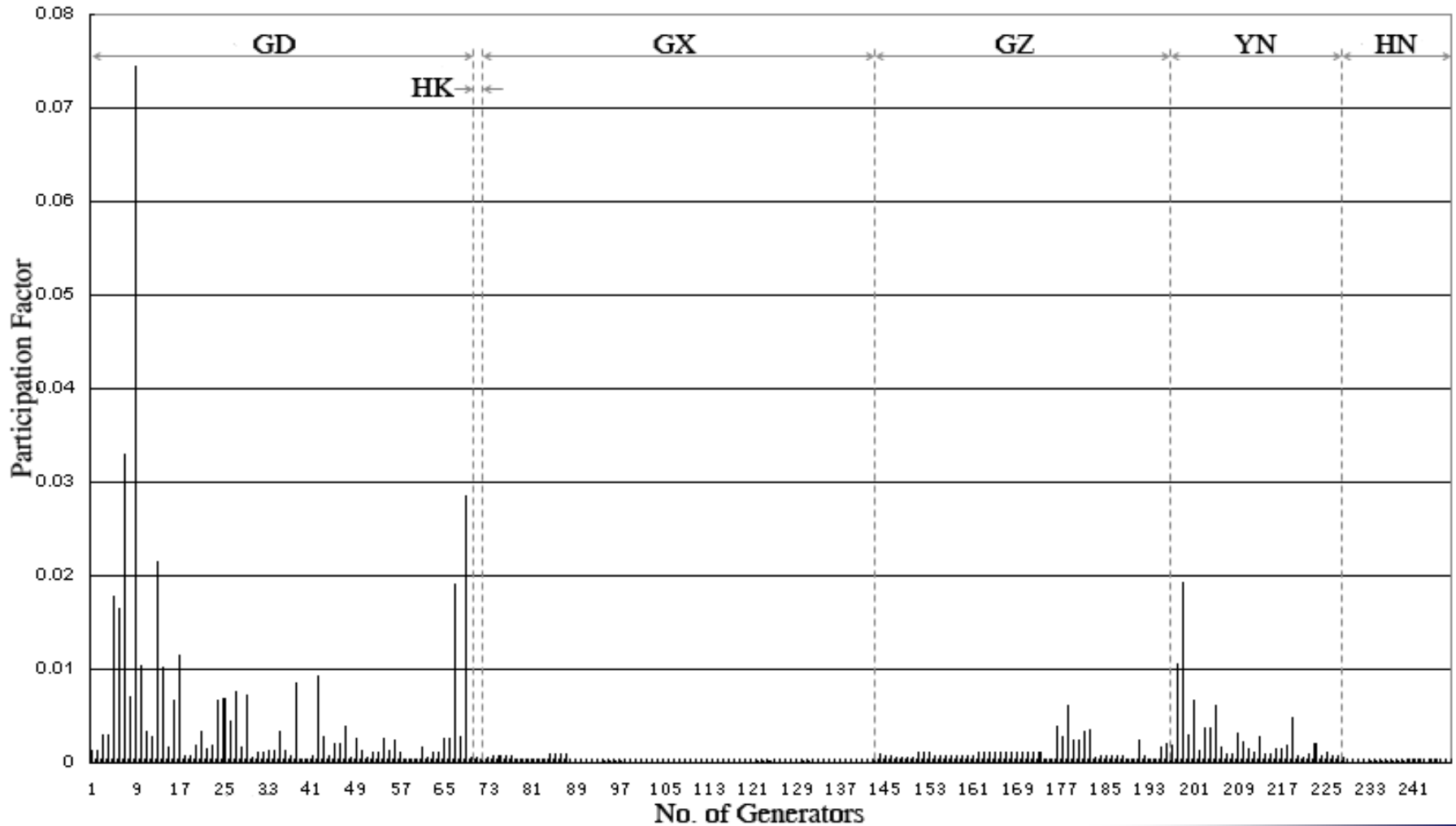
f Hz	<b>0.41/0.403</b>	<b>0.603/0.585</b>	<b>0.794/0.786</b>
Damping ratio	<b>0.066/0.055</b>	<b>0.082/0.100</b>	<b>0.046/0.028</b>

# Mode Analysis (generators in groups)

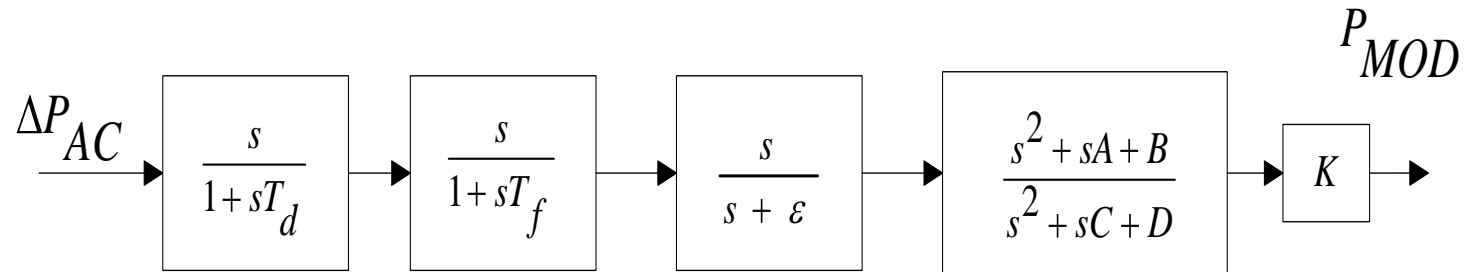
## mode 1 (0.403Hz)



# Participation Factors of Mode 1



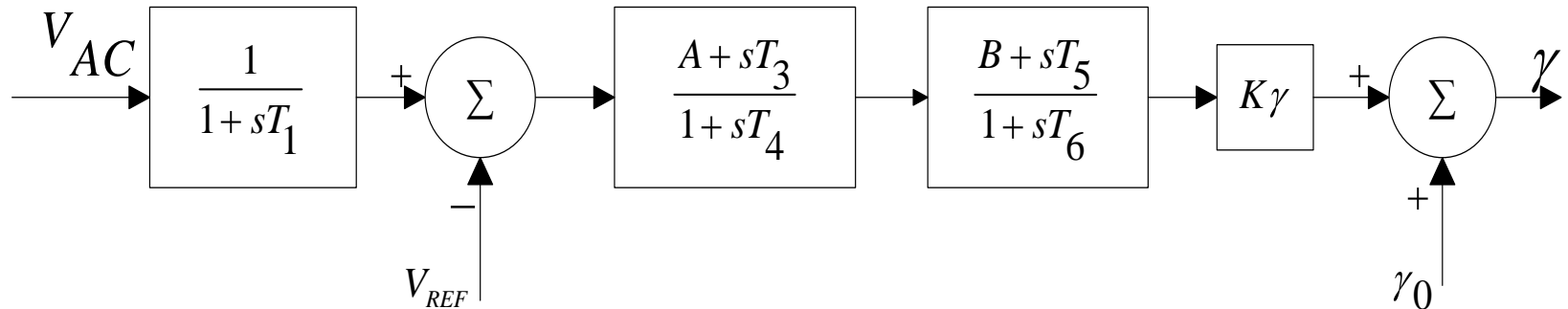
# HVDC Supplementary Power Modulation Control



GZ-GD HVDC POWER MODULATION

- **0.403Hz: Damping ratio 0.058 → 0.071**

# HVDC Supplementary Power Modulation Control

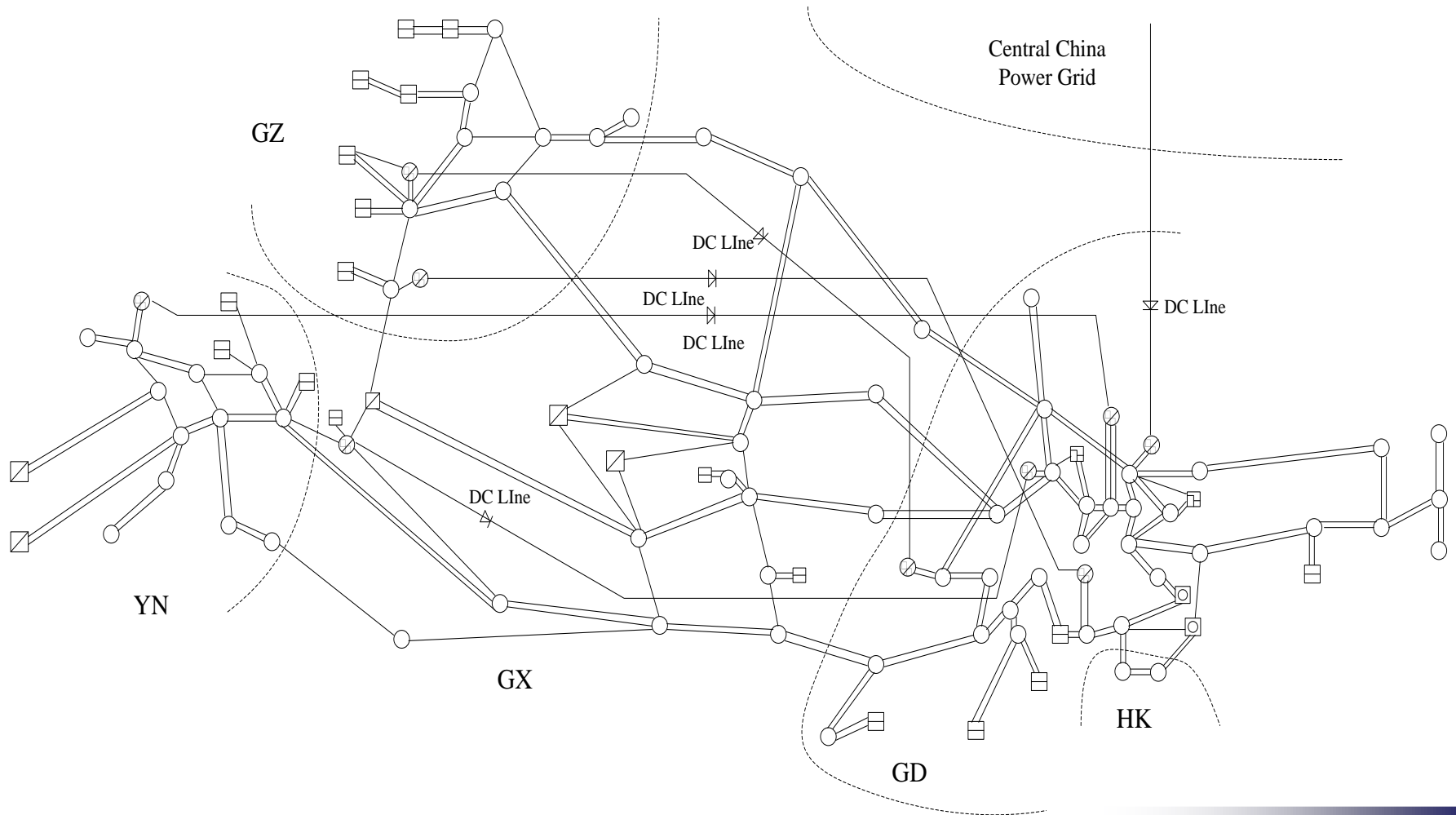


## HVDC Supplementary $\gamma$ Modulation Control

- **0.403Hz→0.426Hz, Damping ratio 0.058→0.140**
- **0.484Hz→0.604Hz, Damping ratio 0.100→0.096**

- **$\pm 800$  kV HVDC transmission line from west (YN) to east (GD)**
- **536 generators (529 modeled by Park's Equation, 7 in classical model with E' constant)**
- **494 with excitation models & 140 with PSS**
- **2657 nodes**
- **4034 lines**
- **930 loads in ZIP**

# 2012 AC/DC Transmission System with $\pm 800\text{kV}$ UHVDC



# Coordinated Control (PMU)

## 3 remote AC power flows as input

	<b>without / with</b>	<b>coordinated control</b>
	<b>f ( Hz )</b>	<b>Damping ratio</b>
<b>Mode 1</b>	<b>0.445 / 0.2879</b>	<b>0.0635 / 0.1720</b>
<b>Mode 2</b>	<b>0.6017 / 0.6419</b>	<b>0.0549 / 0.0633</b>

- **All Large Capacity Generators equipped with PSS**
- **Supplementary Control of HVDC is effective to the inter-area mode of LFO**
  - frequency difference of HVDC both-sides**
  - power deviation of AC bus**
  - extinguishing angle**
- **Coordinated Control with input by PMU measured P or I from remote AC lines has strong impact on LFO.**

**Thank You!**

