FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

STUDY FIELD: POWER ENGINEERING
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DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING

Dynamic model of two synchronous generators connected via long transmission line

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Aims of the dissertation

1) Implement the complete system model for electromechanical oscillation of connected generators including mechanical components under steady state and disturbances condition.
2) Analysis the influence of the length of line for oscillation of power system using the complete system model.

Method

A. Synchronous generator modeling

Steady State model	Transient Model
Equation of the motion of the rotor assembly and torque, expressed in per unit, are: $2H\frac{d\left(\frac{\omega_r-\omega_e}{\omega_b}\right)}{dt}=T_{mech}+T_{em}-T_{damp}$ $T_{em}=\Psi_d i_q-\Psi_q i_d$ Where: $\frac{d\delta_e}{dt}=\omega_r-\omega_e$ $T_{damp}=D\left(\frac{\omega_r-\omega_e}{\omega_b}\right)$	The stator winding equations are: $v_q=-r_s i_q-x'_d i_d+E'_q$ $v_d=-r_s i_d-x'_q i_q+E'_d$ $T'_{do}\frac{dE'_q}{dt}=-E'_q-(x_d-x'_d)i_d+E_f$ $T'_{qo}\frac{dE'_d}{dt}=-E'_d-(x_q-x'_q)i_q$ The torque and motion equation are: $T_{em}=E'_d i_d+E'_q i_q+(x'_q-x'_d)i_d i_q$ $2H\frac{d\left(\frac{\omega_r-\omega_e}{\omega_b}\right)}{dt}=T_{mech}-T_{em}-T_{damp}$

B. Excitation modeling

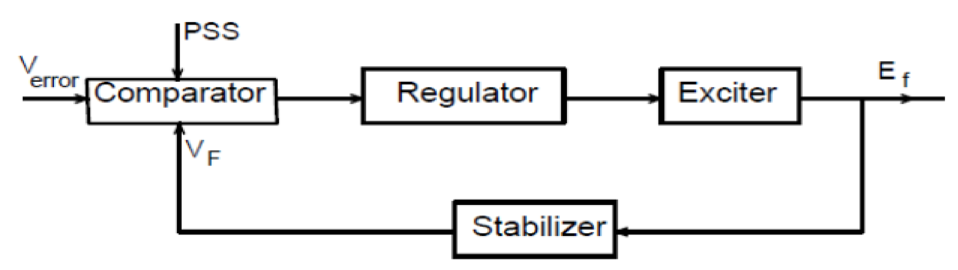

Fig 1. Block diagram of the Excitation System with AVR and PSS

Stabilizer

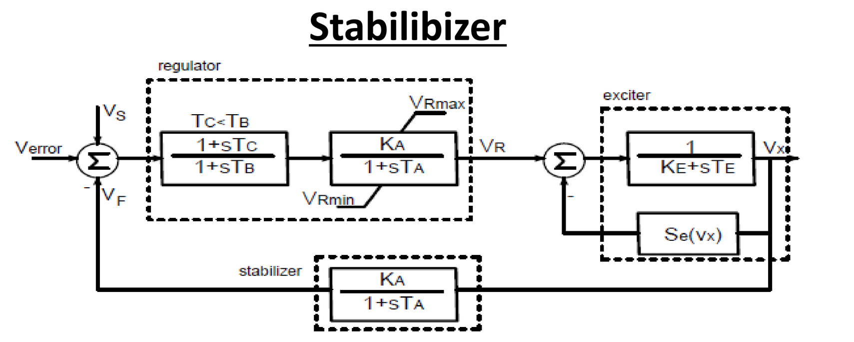

Fig 5. Stabilizer for the regulator/exciter loop

C. Network modeling

Long transmission line

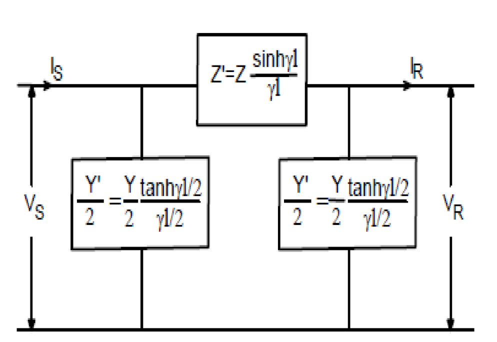

Fig 6. Equivalent π-network of a long transmission line

$$\begin{bmatrix}V_S\\ I_S\end{bmatrix}=\begin{bmatrix}(1+\frac{1}{2}Y'Z') & Z'\\ Y'(1+\frac{1}{4}Y'Z') & (1+\frac{1}{2}Y'Z')\end{bmatrix}\begin{bmatrix}V_R\\ I_R\end{bmatrix}$$

Transformer

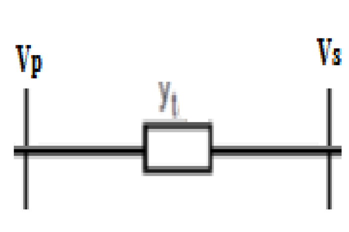

Fig 7. Transformer model

$$y_t=\frac{1}{z_t}$$

Transmission network is represented by an algebraic equation given:

$$Y_{bus}V=I$$

Load

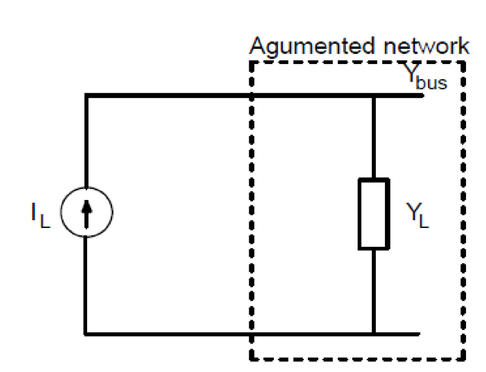

Fig 8. Equivalent circuit of load

$$Y_L=\frac{P_L-jQ_L}{V^2}$$

$$I_L=-\left(\frac{S_L}{V}\right)^*+Y_L V$$

D. Proposed system model

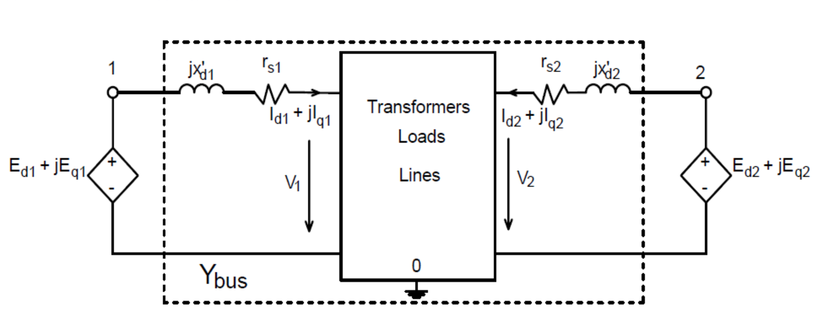

Fig 9. Equivalent circuit of system model

$$\begin{bmatrix}E_1\\ E_2\end{bmatrix}=\begin{bmatrix}E_{d1}+jE_{q1}\\ E_{d2}+jE_{q2}\end{bmatrix}=\begin{bmatrix}e_{d1}+je_{q1}\\ e_{d2}+je_{q2}\end{bmatrix}\begin{bmatrix}e^{j\delta_1}\\ e^{j\delta_2}\end{bmatrix}$$

$$\begin{bmatrix}I_1\\ I_2\end{bmatrix}=\begin{bmatrix}I_{d1}+jI_{q1}\\ I_{d2}+jI_{q2}\end{bmatrix}=\begin{bmatrix}i_{d1}+ji_{q1}\\ i_{d2}+ji_{q2}\end{bmatrix}\begin{bmatrix}e^{j\delta_1}\\ e^{j\delta_2}\end{bmatrix}$$

Further work

- That would be important for further refinement in the restructure to widen networks, in the improvement control system and in application of DC transmission system. Having a reliable, regional, uncongested transmission system will enable to ensure stability of system.
- In terms of measurement technique, extensive and powerful tools to facilitate the gathering of information on all aspects regarding system stability is possible through implementation of Phasor Measurement Unit (PMU).
- In the future work, the stability analysis is focused on the Vietnam Power System which has a longitudinal network structure with the trunk 500 kV transmission system.

Simulation and Results

A. Steady state single generator model

Changing mechanical torque

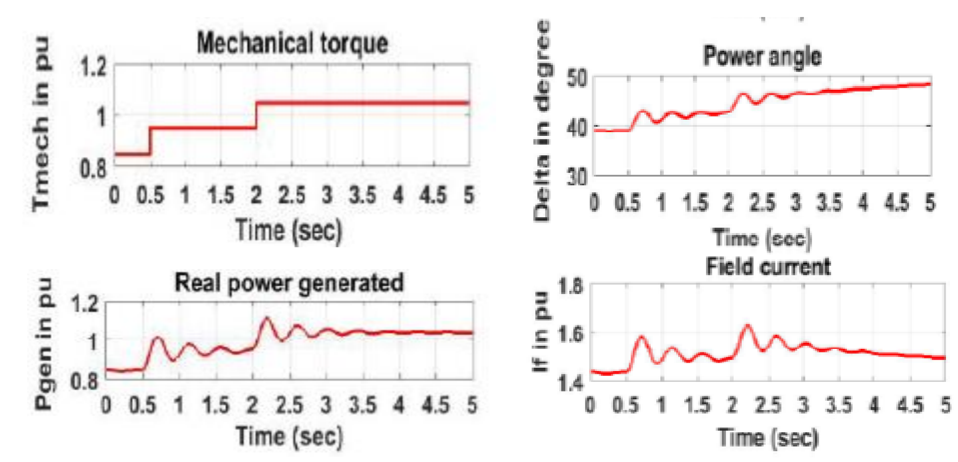

Fig 10. Torque, power, angle and field current results of simulation 1 in pu

Changing field voltage

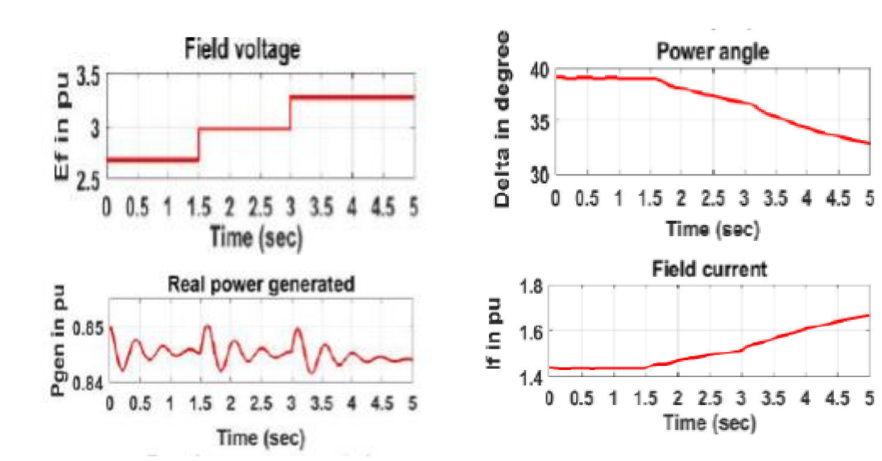

Fig 11. Torque, power, angle and field current results of simulation 2 in pu

B. Transient two generators model

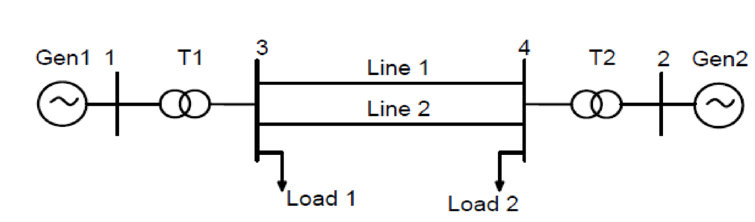

Fig 12. Simulation network

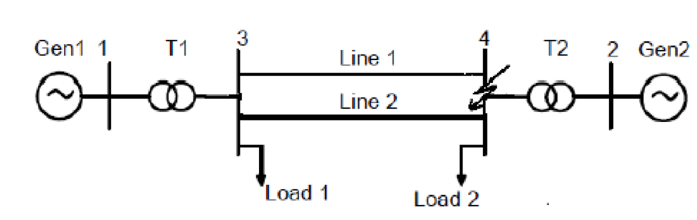

Fig 13. Simulation network with short circuit at bus 4

L=250km

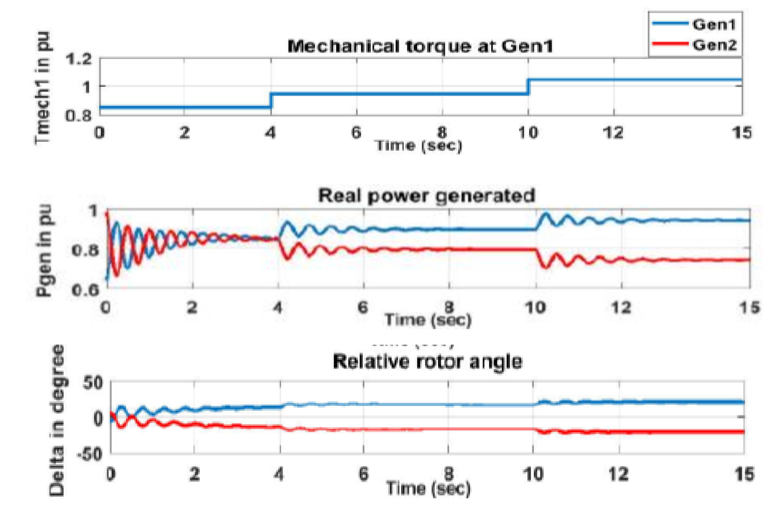

Fig 14. Torque, power and rotor angle results in pu

L=250km

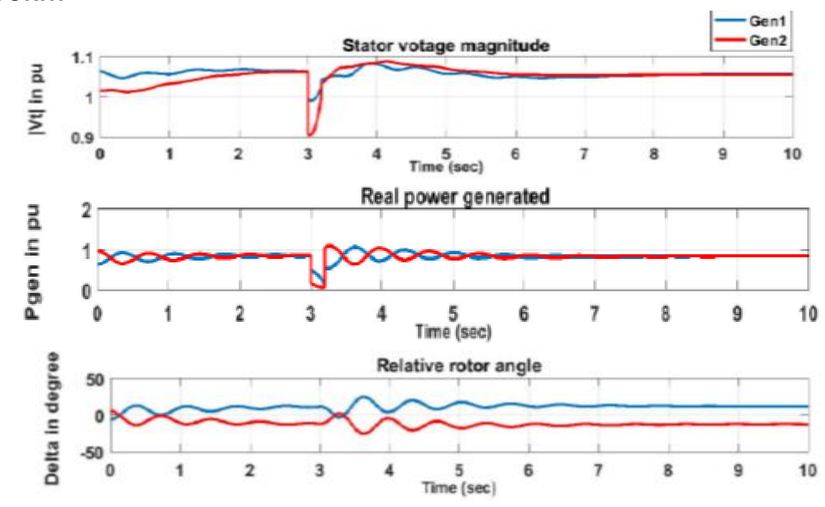

Fig 16. Torque, power and rotor angle results in pu

L=1200km

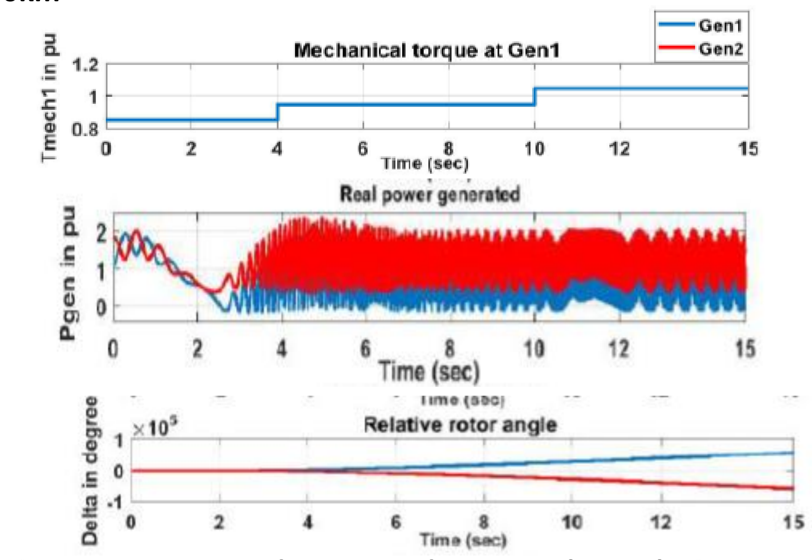

Fig 15. Torque, speed power and rotor angle results in pu

L=1210km

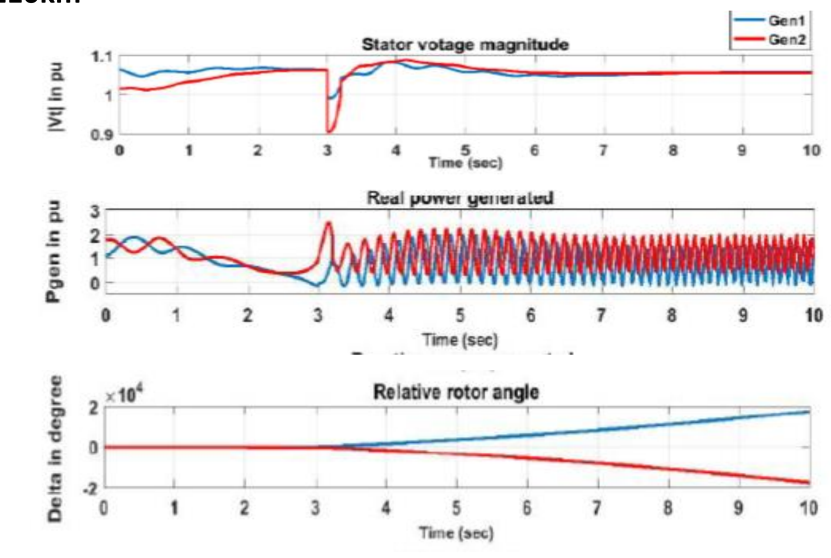

Fig 17. Torque, power and rotor angle results in pu

Obviously, the longer transmission lines are, the more oscillate the speed and power transmission capacity of generators do. When the length of lines reach to 1200 km, there will exist a loss of synchronism between two generators through power and speed index.

Conclusion

The following conclusions are made:

- The synchronous machine models have been documented and explained in detail in this technical thesis, including the steady-state operation and transient operation.
- The two synchronous machine fundamental frequency models, connected via the long transmission lines, have been analyzed in synchronization in term of transient stability.
- Influence of length of line to the system oscillation is analyzed and determined as the important index of stability.

Articles related to the dissertation

PI. Le Thi Minh. T, Uhlíř.I, Inter-area Power Oscillation and Potential Application Phasor Measurement Units for the Power System, Seminar on New Methods and Procedures in the Fields Instrumentation, Automatic Control and Informatics, Instrumentation and Control Department, CTU in Prague, Pages 47-51, 25.05.2015 - 27.05.2015.

PII. Le Thi Minh.T, Uhlíř.I, Analyzing of phasor oscillations in 500kV power system and using synchrophasors for control stability, Student Conference in Mechanical Engineering Faculty, CTU in Prague, Pages 4-8, 19.04.2016.

PIII. Le Thi Minh. T, Uhlíř. I, Inter-area Power Oscillation and Potential Application Phasor Measurement Units for the Vietnam 500kV Power System, IFAC and CIGRE/CIRED Workshop on Control of Transmission and Distribution Smart Grids, Prague, Pages 342-347, 11.10.2016 - 13.10.2016.

PIV. Le Thi Minh. T, Uhlíř. I, Dynamic phasor and frequency estimation with harmonic and DC offset infiltration by using weight least squared method, IEEE International Conference on Smart Grid and Smart Cities (ICSGSC), Pages 172-177, July 2017, Singapore.

PV. Le Thi Minh. T, Uhlíř.I, The frequency stability assessment of the transmission system using phasor measurement unit data, 2018 IEEE PES conference on innovative smart grid technologies, Pages 45-50, 19-22 February 2018, Washington DC, USA.

PVI. Le Thi Minh. T, Hassan Nouri, " Modeling Dynamic Frequency Control with Power Reserve Limitations", 53rd International Universities Power Engineering Conference (UPEC 2018), 4th – 7th September 2018.

PVII. Le Thi Minh. T, Hassan Nouri, Development of a Dynamic Load Frequency Control System Model Considering the Influence of Induction Motor Load, IEEE Transactions on Power Systems (submitted 2018).