



A Virtual Laboratory for Teaching Power System Dynamics and Control at Undergraduate Level in Developing Nations

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INTRODUCTION

Development of a virtual laboratory framework for teaching power system dynamics and control at the undergraduate level being used in developing nations.

This poster presents:

- ✓ Customized and third party computer simulation tools.
- ✓ A sample design activity

OBJECTIVES

- ✓ Facilitate simulation tools,
- ✓ enhance learning through simulations, and
- ✓ provide a reference manual in Spanish.

User experiences and adoption plans from Universities of:

- ✓ Guatemala
- ✓ Costa Rica
- ✓ El Salvador
- ✓ Honduras

NEED AND AIM FOR A VIRTUAL LABORATORY FRAMEWORK

Project developed at USCG where the needs of the undergraduate power program were

- ✓ to support the *Generation Systems* course
- ✓ introduce advanced topics to the curriculum
- ✓ pedagogic material for teaching new courses
- ✓ self learning and research

Aims to provide undergraduates with

- ✓ a supplement to their formal lecture courses
- ✓ motivation for self learning in advanced topics
- ✓ simulation tools
- ✓ reference manual

VIRTUAL LABORATORY FRAMEWORK

A Comprehensive Manual in Spanish

Language is a barrier for learning in developing nations where:

- ✓ literacy index (LI) is low, (in GT, LI is 69.1% [1])
- ✓ knowledge of English as a second language is scarce
- ✓ access instructional material is expensive (in GT, HDI is 0.663 [1])

The manual can be used for:

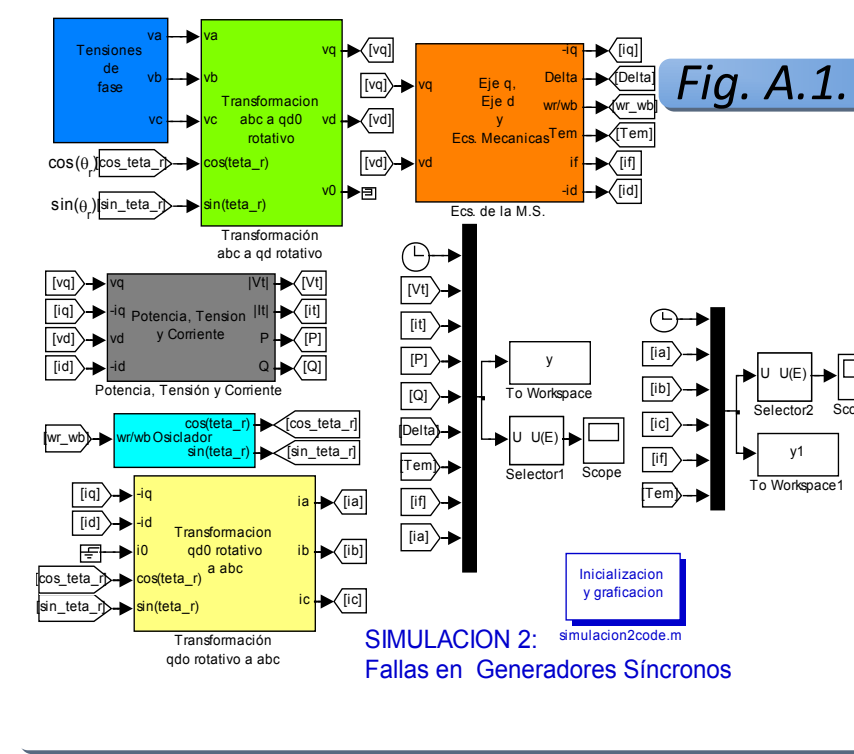
- ✓ laboratory instruction
- ✓ independent study
- ✓ support textbook

Being an inexpensive option for instruction.

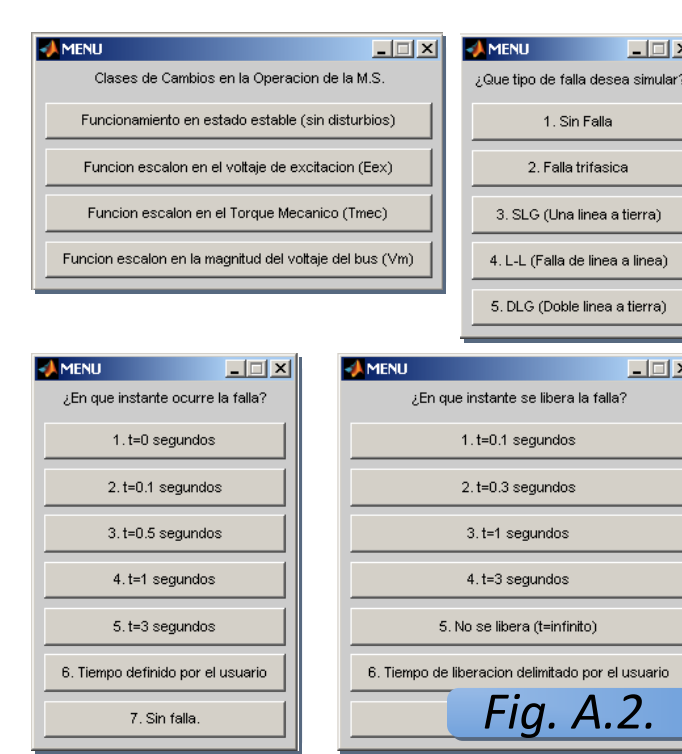
Customized MATLAB/Simulink Models:

A sample model is shown in Figure A.1. It can be used to simulate faults on generators.

- ✓ Provides several user menus (Figure A.2.)
- ✓ Figure A.3. shows a three-phase fault.
- ✓ Provides a simple protective relay where fault clearing time can be configured.
- ✓ Figure A.4. shows a generator response for various fault clearing time.



MATLAB/Simulink Customized model



Simulation menus

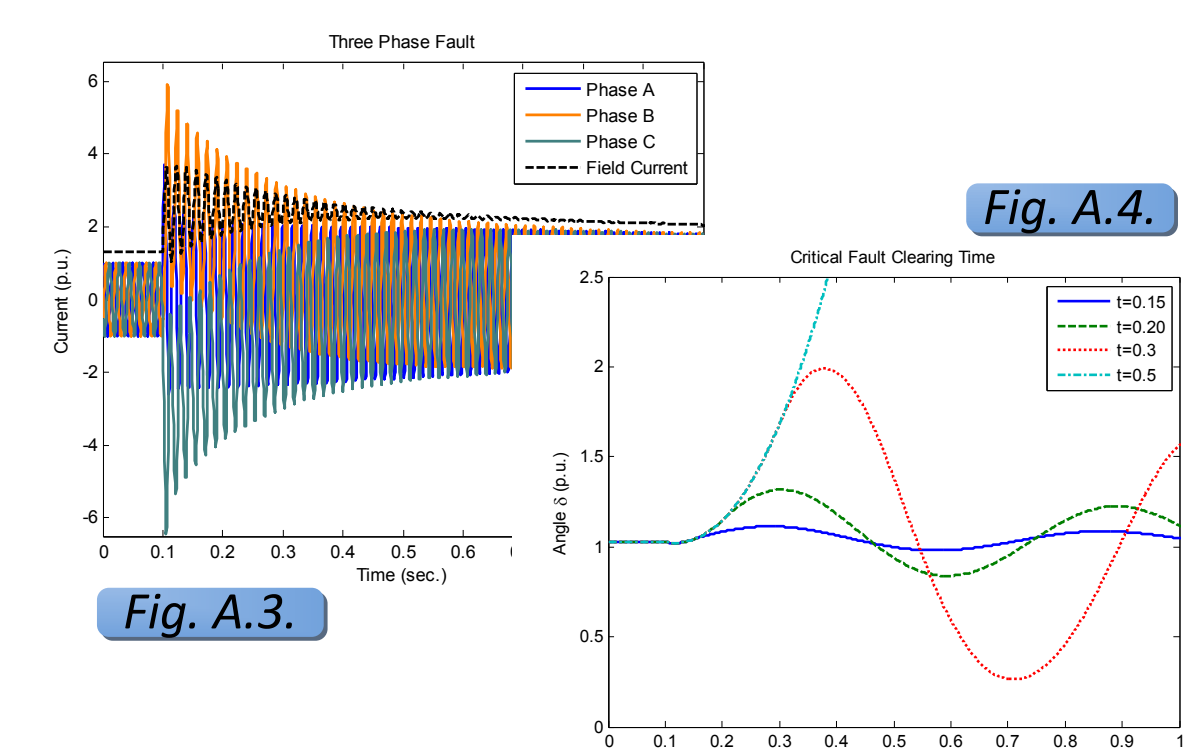


Fig. A.3.

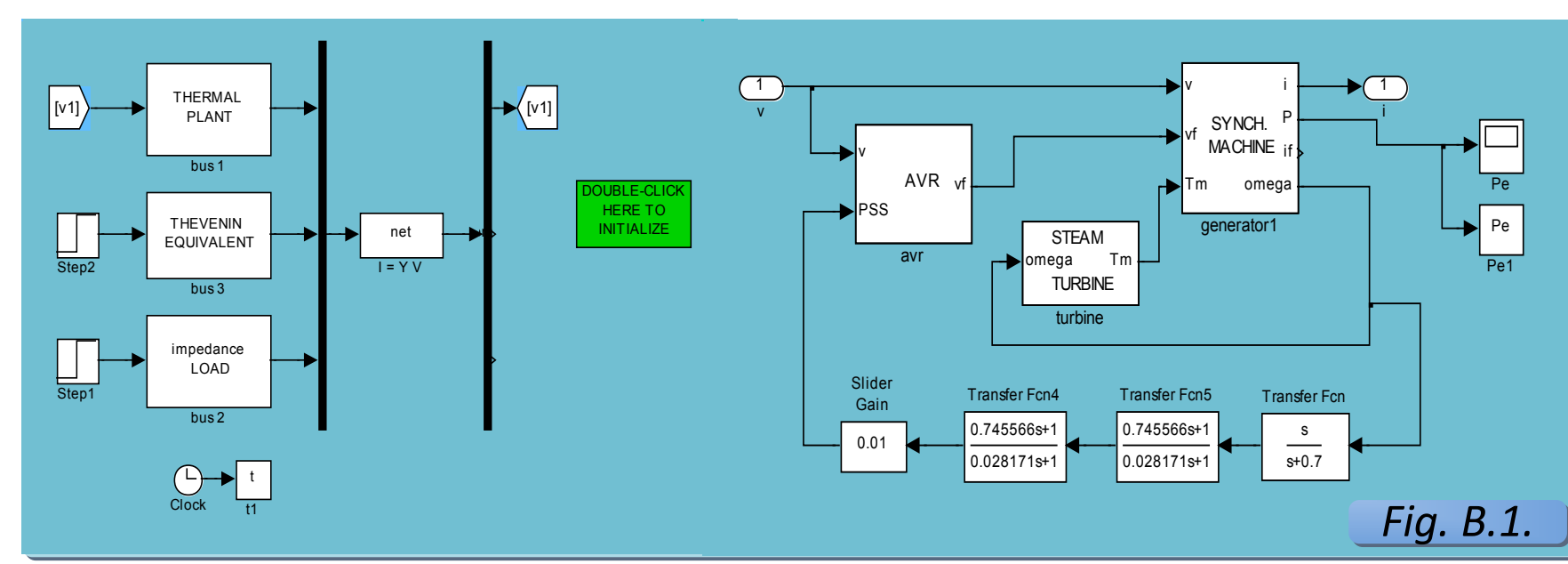
Fig. A.4.

Plotting and analysis capabilities

ULg MATLAB/Simulink Blockset:

ULg provided a Simulink model in [3].

- ✓ It consists of detailed blocks (Figure B.1.)
- ✓ They represent synchronous machines, turbine, governor, AVR, PSS, etc.
- ✓ Figure B.2. shows the response of the system under a fault on Bus 2 with different types of control systems.



MATLAB/Simulink Customized model

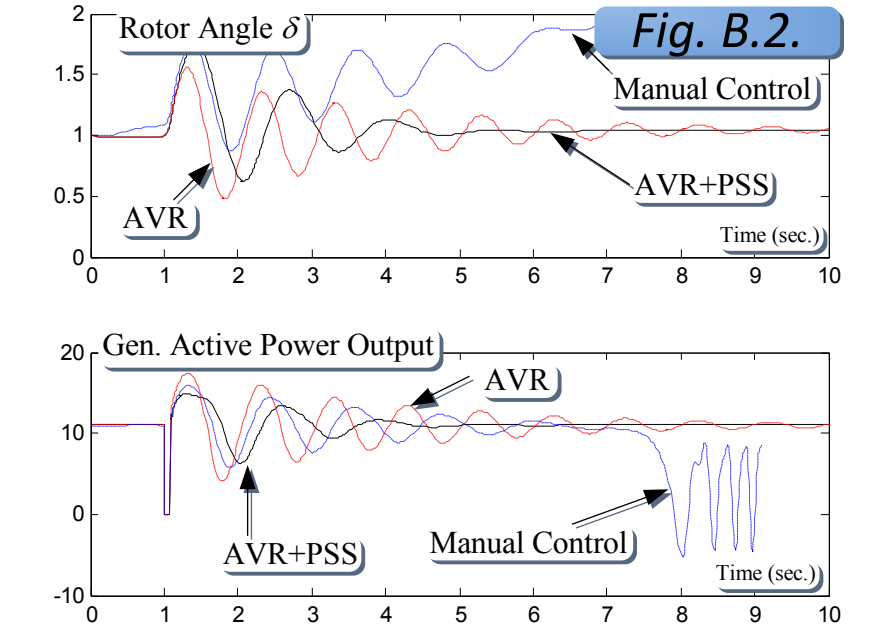


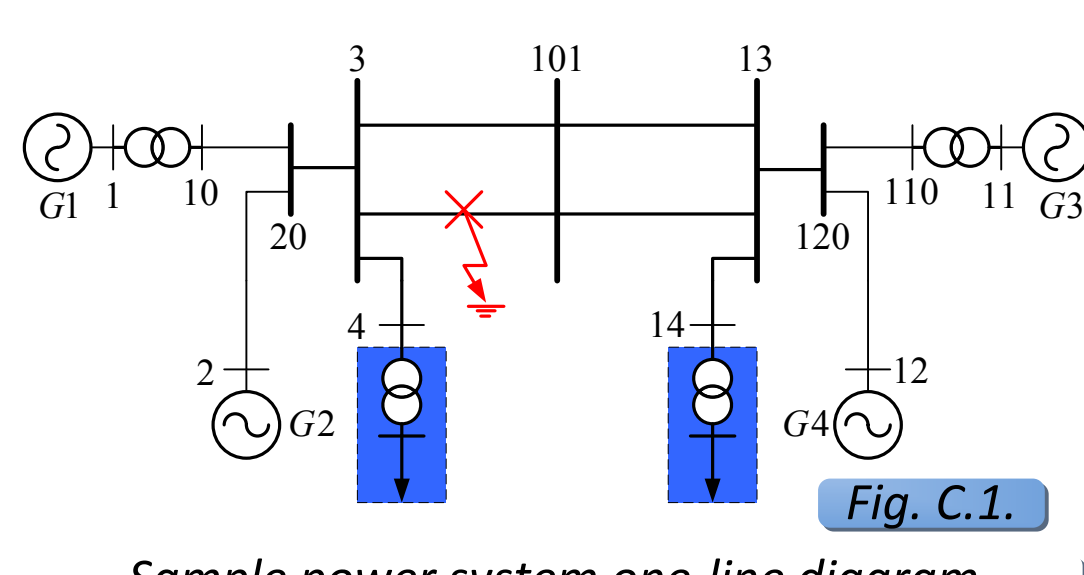
Fig. B.2.

Plotting and analysis capabilities

Power System Toolbox (PST):

PST [4] is a MATLAB tool conceived for research in power system dynamics and control [2]. It is used to:

- ✓ observe the effect of different control systems on the system of Figure C.1.
- ✓ analyze damping - Figure C.2. and C.3.



Sample power system one-line diagram

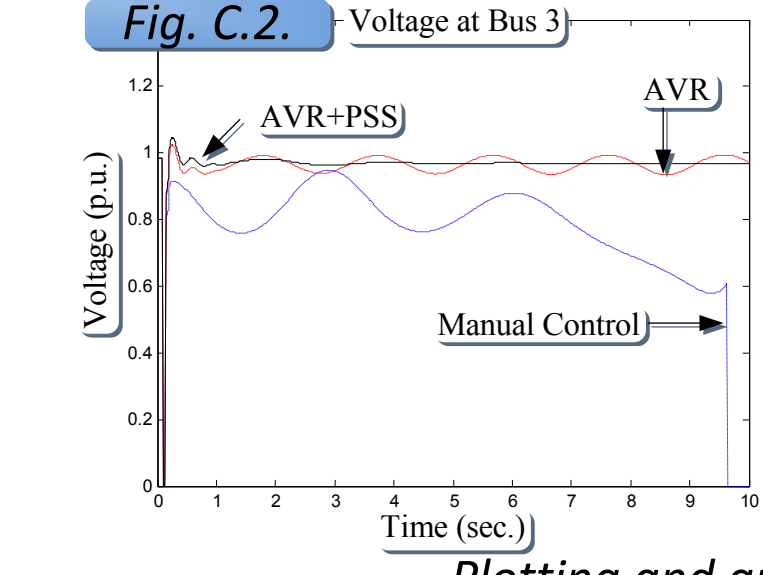


Fig. C.2.

Plotting and analysis capabilities

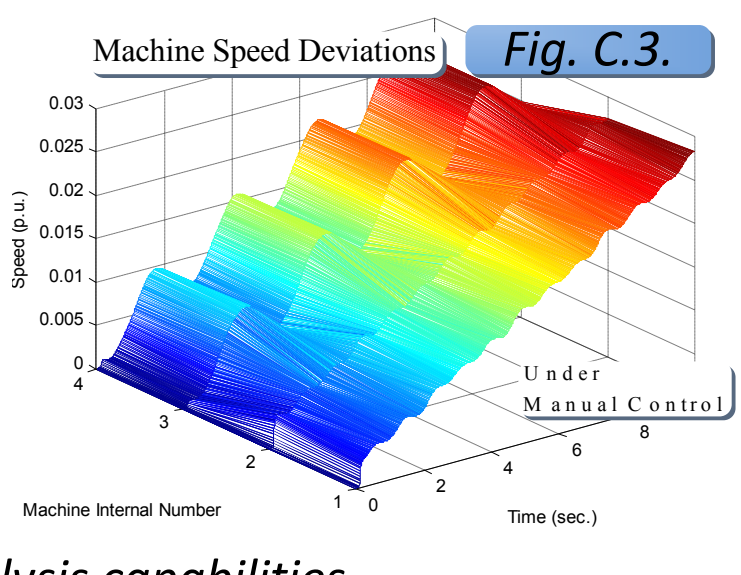


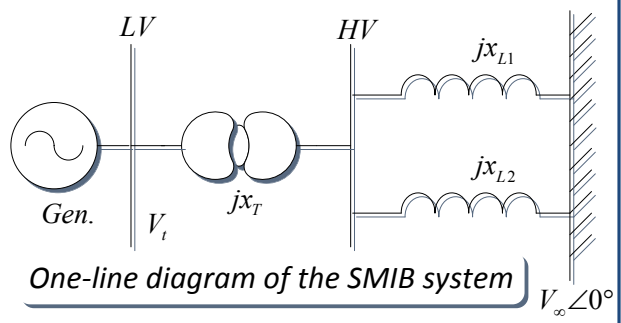
Fig. C.3.

Sample design activity:

Linearized analysis of the SMIB

Activity:

Design the AVR gain and a PSS to stabilize the swing mode of the SMIB system.



One-line diagram of the SMIB system

Mathematical model:

The state space model is given by:

$$\dot{x} = f(x, u(t)) \quad y = g(x, u(t))$$

where the states and the outputs are

$$x = [\delta \quad \omega \quad E'_q \quad \psi_{fd} \quad E'_d \quad \psi_{fd} \quad V_r]^T$$

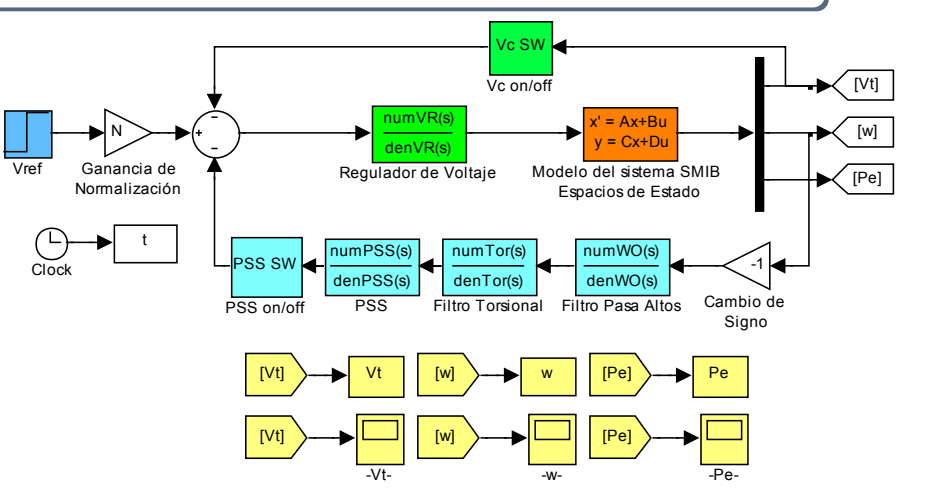
$$y = [V_r \quad \omega \quad P]^T$$

Linearized at the operating equilibrium point

$$\Delta \dot{x} = A \Delta x + B \Delta u(t) \quad y = C \Delta x + D \Delta u(t)$$

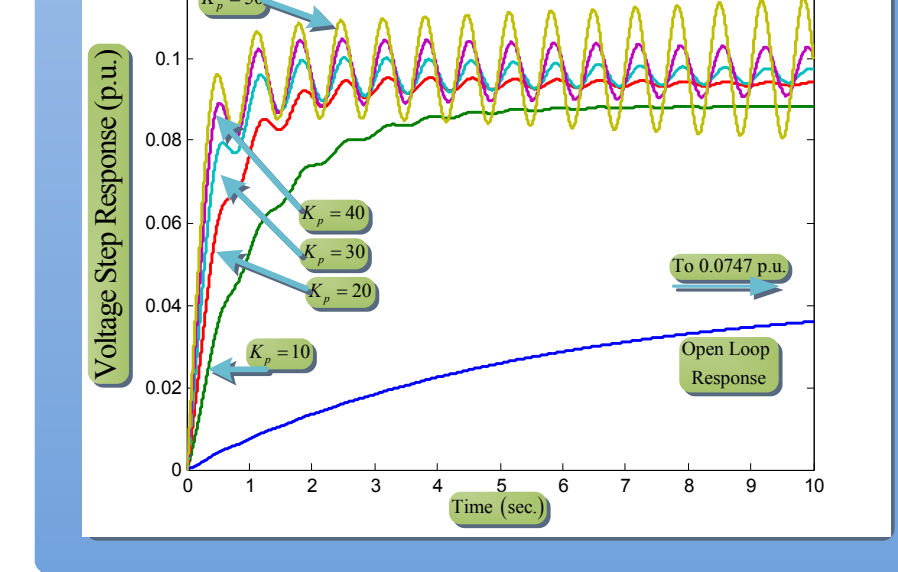
Model implemented in MATLAB/Simulink

MATLAB/Simulink simulation tool:

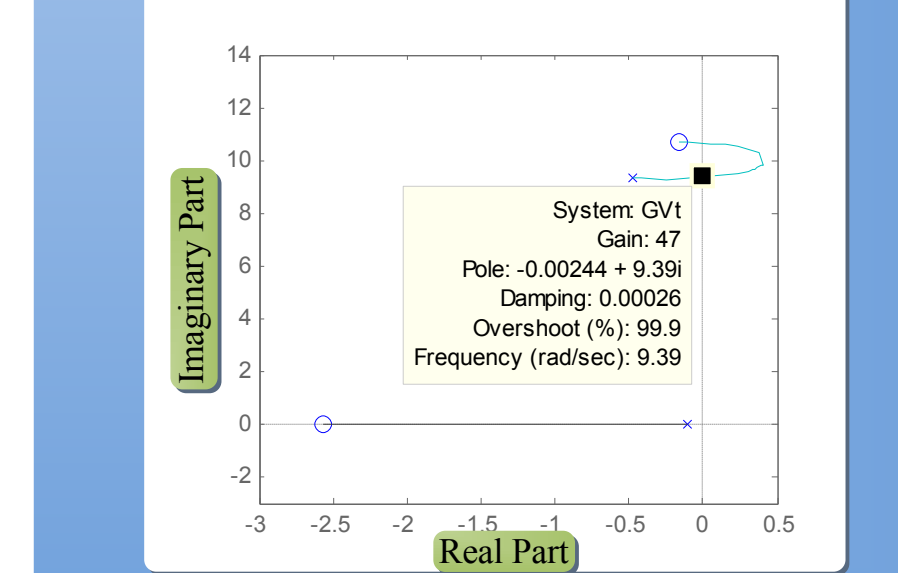


Analysis and Design:

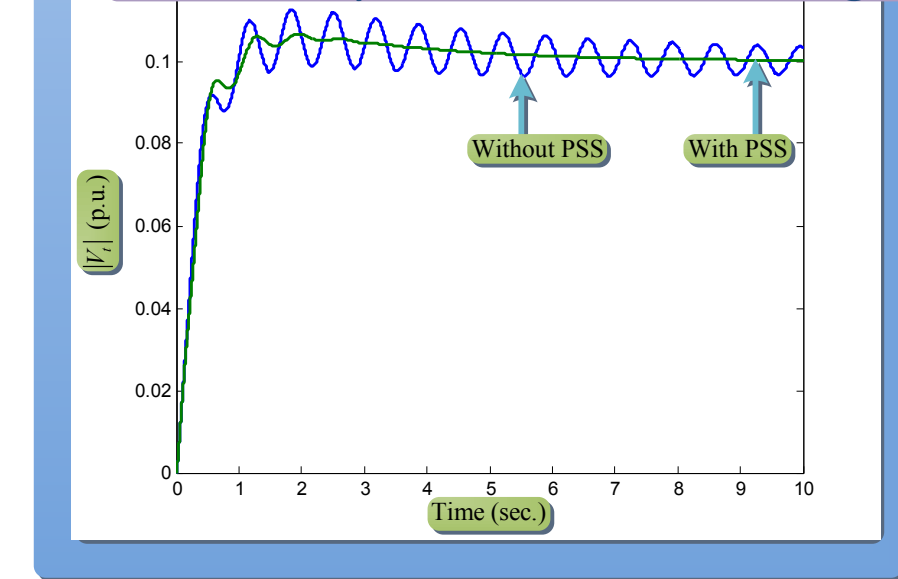
Sensitivity analysis



Root Locus Analysis



Power System Stabilizer Design



EDUCATIONAL TECHNOLOGY TRANSFER TO DEVELOPING NATIONS

Users experience:

The USCG case:

Used during Spring and Summer '06 for:

- ✓ *Generation Systems* course
- ✓ *Power System Analysis* course

Future plans: use of the synchronous machine Simulink models for the *Electric Machines* course and to teach MATLAB/Simulink to in a seminar.

The UCA case:

Collaboration started Summer '05. The lab is used in the *Power System Dynamics* course particularly for teaching LFC and AGC.

Future plans – the manual will be used for teaching

- ✓ synchronous machine modeling and simulation
- ✓ synchronous machine parameters.

The custom models for machine modeling will be used to supplement LabVIEW applications already available at UCA.

Adoption plans:

At UNAH:

The lab will support the *Electric Machines* course:

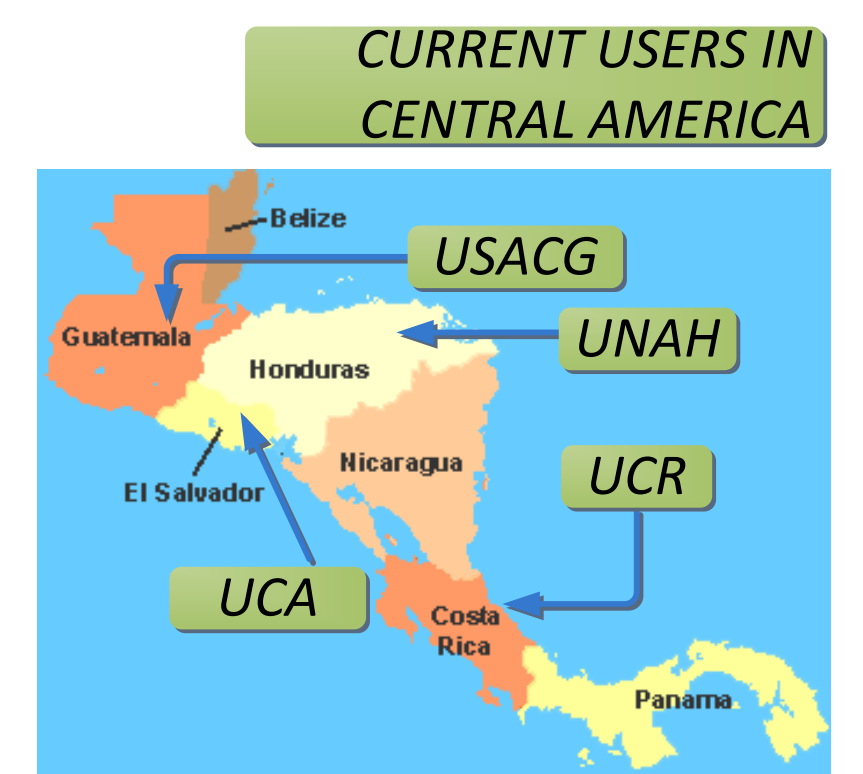
- ✓ using the different synchronous machine Simulink models
- ✓ the manual to accompany class lectures on machine modeling.

At UCR:

- ✓ Starting Fall '06, the lab be used in two courses: *Power Transmission* and *Power System Analysis*.
- ✓ The manual in MS Word format was provided to Prof. Araya. He will use it to prepare slides for his lectures.
- ✓ UCR has also been provided with the ULg Simulink tool and will obtain PST.

Prospective users:

The lab. is suitable for any institution with access to MATLAB/ Simulink and Spanish as instruction language.



CURRENT USERS IN CENTRAL AMERICA

acknowledgments

The author would like to thank Profs. Graham Rogers and Thierry Van Cutsem for providing their computer tools. The feedback of Profs. Juan Carlos Morataya (USCG), Eduardo Pérez (UCA), Rosa María Díaz (UNAH) and Eddie Araya (UCR) is appreciated. The author would also like to thank Prof. Joe Chow for his help in preparing this poster.

[1] United Nations Development Programme Report 2005. Available online: <http://hdr.undp.org/reports/global/>

[2] G. Rogers and J.H. Chow, "Hands-on teaching power system dynamics," IEEE Computer Applications in Power, vol. 8, no. 1, pp. 12-16, Jan 1995.

[3] C.D. Vournas, E.G. Potamianakis, C. Moors and T. Van Cutsem, "An educational simulation tool for power system control and stability," IEEE Transactions on Power Systems, vol. 19, no. 1, pp. 48-55, Feb. 2004.

[4] J.H. Chow and K.W. Cheung, "A Toolbox for power system dynamics and control engineering education and research," IEEE Transactions on Power Systems, vol. 7, no. 4, pp. 1559-1564, Nov. 1992.

[5] J.H. Chow, G.E. Boukarim and A. Murdoch, "Power system stabilizers as undergraduate control design projects," IEEE Transactions on Power Systems, vol. 19, no.1, pp. 144-151, Feb. 2004.

references