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MATLAB/SIMULINK Simulation Tool for Power Systems

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Abstract - This paper describes the modeling and simulation library for power systems simulation under SIMULINK environment. The different features of MATLAB Toolboxes used in the analysis of power systems are described. Software introduces SIMULINK environment of MATLAB for implementing user friendly and future expansion. To illustrate the capabilities of SIMULINK simulation tool, a case study based on a test system is presented.

Keywords - Modeling; Protective relaying; Power System Blockset.

I. INTRODUCTION

A product of The MathWorks, Inc. MATLAB started life as a program designed to perform matrix mathematics, but over the years it has grown into a flexible computing system capable of solving essentially any technical problem. MATLAB can manipulate and invert large matrices and can be used in many numerical applications. MATLAB's capabilities can be extended with addition called SIMULINK, a program which is normally used in the analysis and synthesis of modern systems.

SIMULINK, now incorporated into MATLAB, can also be used to analyze and design of power systems. During last four decade's simulation of power systems have gained more importance. Recently published IEEE paper discussing different approaches to modeling protective relays and related power system events indicates a variety of possible software tools that may be used for this purpose [1]. But rather than MATLAB/SIMILINK software it is difficult to add the modeling and simulation features to teach specific protective relaying concepts that go beyond the level of detail originally provided by the software. The MATLAB software package with SIMULINK support and Power System Blockset (PSB) [2, 3] is utilized to develop customized model libraries for teaching protective relaying concepts.

In this paper the section II describes the reasons for using MATLAB compared with EMTP/ATP; section III

describes features of MATLAB toolboxes; section IV focused on block libraries of Power System Blockset and section V describes a case study.

II. MATLAB DE-FACTO STANDARD

When we compare MATLAB/SIMULINK with EMTP/ATP, we will see which one is better for the power systems simulation. The following items summarize their most important differences in protection systems simulation [4]:

1. The EMTP/ATP is specific software to simulate power system transient problem, whereas the MATLAB/SIMULINK can be used to simulate power system faults and protective relay algorithm at the same time.
2. ATP/EMTP is designed to simulate the physical processes of transmission lines and transformers quickly and in a convenient way but MATLAB/SIMULINK offers more possibilities in power electronics, signal processing and control.
3. Users can easily create new relay model with MATLAB/SIMULINK, whereas EMTP/ ATP doesn't have such capacity.
4. MATLAB/SIMULINK encompasses better graphic function tools than EMTP/ATP of pplot, plotxy and so on.

Therefore, for automatic interactive systems MATLAB/SIMULINK is selected.

III. FEATURES OF MATLAB TOOLBOXES

The features of the MATLAB toolboxes used in the analysis of power systems are, facilitating future revision and expansion of software. This is very important for researches that are interesting in developing and testing new for various power system applications. It provides an avenue to easily prepare input data files in commonly accepted formats for networks that are created and the results produced by one application can be easily used either fully or partially by any other application supported by the package [5].

MATLAB/SIMULINK toolbox consists of:

- a. MatPower Toolbox
- b. Power System Analysis Toolbox and
- c. Voltage Stability Toolbox.

MatPower Toolbox is a package for solving power flow and optimal power flow problems. This package is designed to give the best performance possible while keeping the code simple to understand and modify.

Power System Analysis Toolbox is for electric power system analysis and control. It includes power flow, continuous power flow, optimal power flow, small signal stability analysis and time domain simulation.

Voltage Stability Toolbox analyzes voltage stability problems and provides information for power system planning, operation and control.

IV. BLOCK LIBRARIES

The PSB is a graphic tool that allows building schematics and simulation of power systems in the SIMULINK environment. The blockset uses the SIMULINK environment to represent common components and devices found in electrical power networks. It consists of a block library that includes electrical models such as RLC branches and loads, transformers, lines, surge arrester, electric machines, power electronics devices, etc. Diagrams can be assembled simply by using click and drag procedures into SIMULINK windows. The Power System Blockset uses the same drawing and interactive dialogue boxes to enter parameters as in standard SIMULINK blocks.

Simulation results can be visualized with SIMULINK scopes connected to outputs of measurement blocks available in the PSB library. These measurement blocks acts as an interface between the electrical blocks and the SIMULINK blocks. The voltage and current measurement blocks can be used at selected points in the circuit to convert electrical signals into SIMULINK signals. Nonlinear elements requiring control, such as power electronic devices, have a

SIMULINK inputs that allow control from a SIMULINK system.

Elements in the PSB block library are classified in various groups according to their nature: Application Libraries, Electrical Sources, Elements, Extra Library, Machines, Power Electronics, Connectors, Measurements and Powergui.

Application libraries consists of Distributed resources library, Electric drives library and Flexible AC transmission library.

Electrical Sources group contains A.C. current source, A.C. and D.C. voltage source, Controlled voltage and current source, Three-phase programmable voltage source, Three phase source and Battery.

The Elements group contains single-phase models RLC branches and loads, linear and saturable transformers, mutual inductances, n-section lines, MOV type surge arrester, circuit breaker and n-phase distributed-parameter line model. Using the masking facility of SIMULINK, the user can easily add more complex elements built from the basic PSB building blocks and associate a dialog box. This technique has been used to develop a three-phase library which is also provided. The Power Electronics group contains common semiconductor devices. Each element in this group (except Diode) has a SIMULINK gating control input and a SIMULINK output returning switch current and voltage.

Extra library consist of Control blocks, Discrete control blocks, Discrete measurements and Phasor Library.

The Machines group contains simplified and detailed models of synchronous machine, an asynchronous machine, a permanent magnet synchronous machine, a model of hydraulic turbine governor, and an excitation system. Each machine block has a SIMULINK output returning measurements of internal variables.

The PSB graphical interface (Powergui) includes an interactive tool to set initial conditions. This allows simulation with initial conditions, or to start the simulation with steady-state.

A load-flow computational engine allows initializing three-phase circuits containing synchronous and asynchronous machines, so that the simulation directly starts in steady-state [6].

V. CASE STUDY

The following example illustrates applications of PSB [7].

Circuit Description:

A three-phase generator rated 200 MVA, 13.8 kV, 112.5 rpm is connected to a 230 kV, 10,000 MVA network through a Delta-Wye 210 MVA transformer. At $t = 0.1$ s, a three-phase to ground fault occurs on the 230 kV bus. The fault is cleared after 6 cycles ($t = 0.2$ s).

The system will initialize in order to start in steady-state with the generator supplying 150 MW of active power and the dynamic response of the machine and of its voltage and speed regulators are observed.

It is observed that the terminal voltage V_a (Figure. 4) is 1.0 p.u. at the beginning of the simulation. It falls to about 0.4 p.u. during the fault and returns to nominal

quickly after the fault is cleared. This quick response in terminal voltage is due to the fact that the Excitation System output V_f (Figure. 5) can go as high as 11.5 p.u. which it does during the fault.

The speed (Figure.6) of the machine increases to 1.01 p.u. during the fault then it oscillates around 1 p.u. as the governor system regulates it. The speed takes much longer than the terminal voltage to stabilize mainly because the rate of valve opening/closing in the governor system is limited to 0.1 p.u./s.

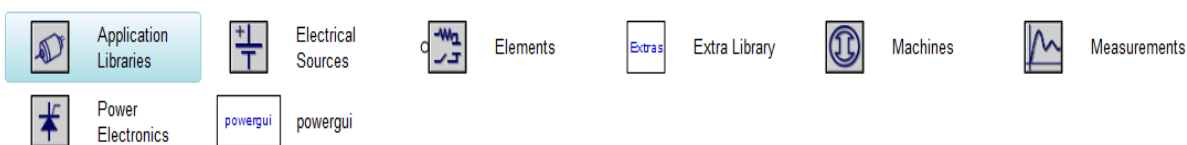


Fig. 1 : The Power System Blockset Library

Synchronous Machine

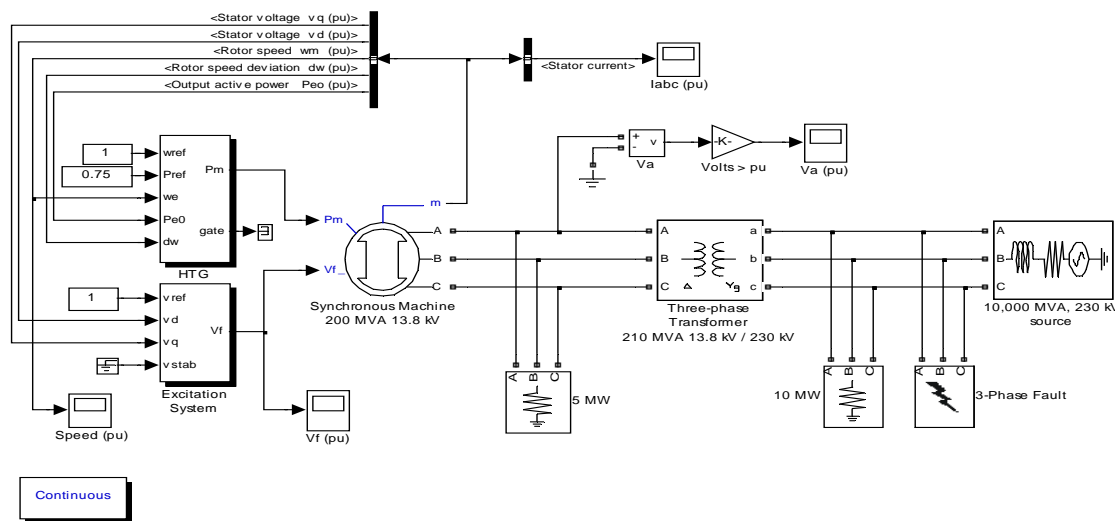


Fig. 2 : Load Flow to Initialize Synchronous Machine Currents

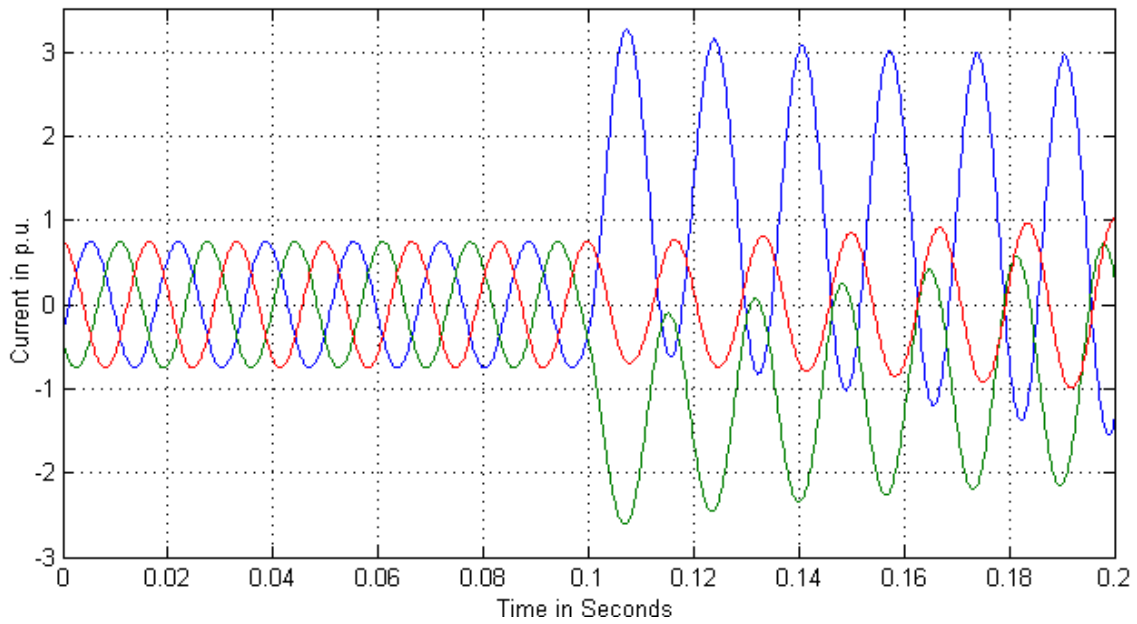


Fig. 3 : Stator Currents of Synchronous Machine

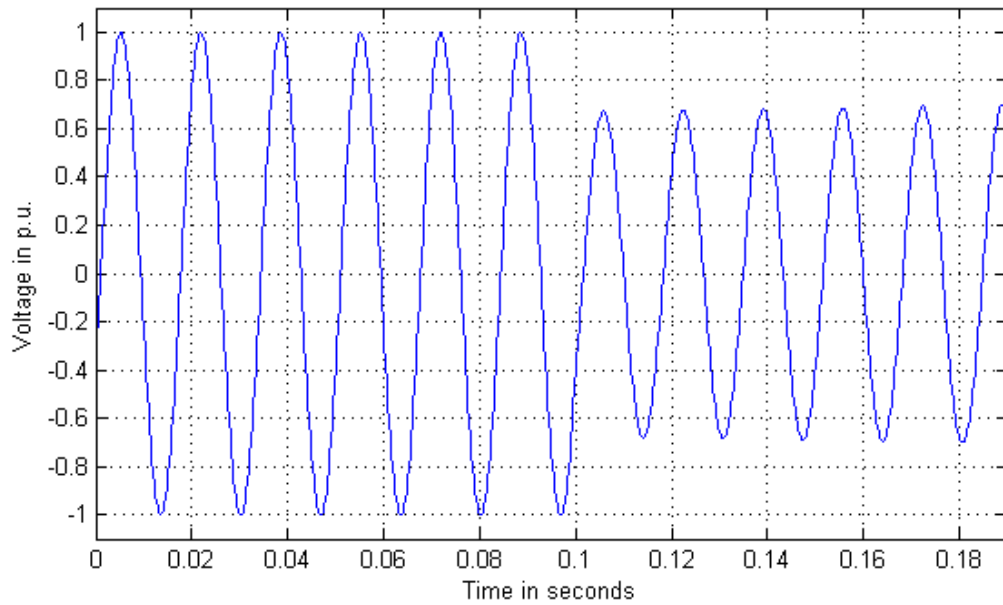


Fig. 4 : Terminal Voltage V_a (p.u.)

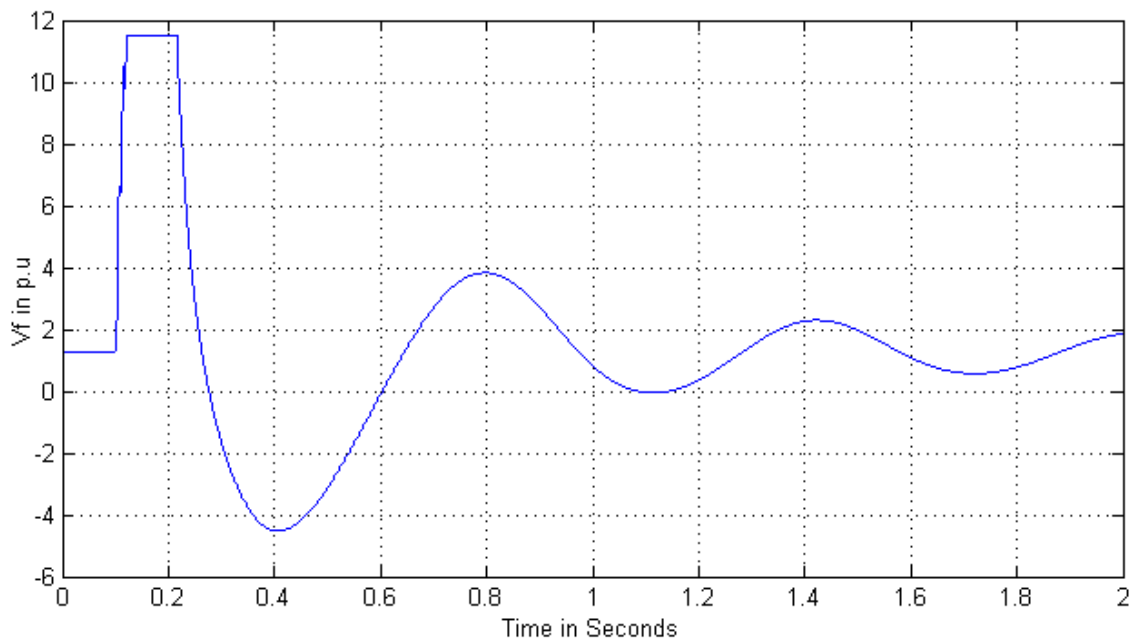


Fig. 5 : Excitation System output V_f

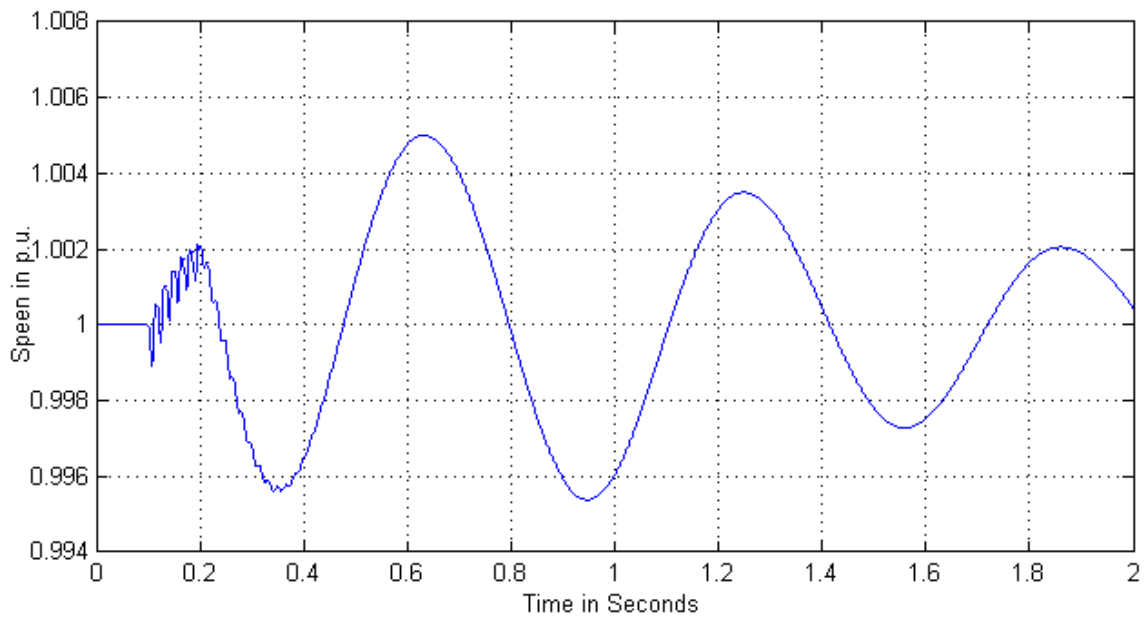


Fig. 6 : Speed of Synchronous Machine

VI. CONCLUSION

This paper presents user friendly features of simulation under SIMULINK environment and various MATLAB toolboxes which can be used in power system analysis. The user friendly features are facilitated with the use of a simple drag-and-drop and cut-and-paste approach to building the exercises with pre-defined library elements. This is very important for researchers who are interested in developing and testing new for various power system applications.

Application example for power systems with simulation results obtained with SIMULINK has been presented to illustrate the capabilities of the PSB.

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