Transient Stability Analysis of Multimachine Power System with FACT Devices using MATLAB/Simulink Environment

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Abstract

Power system stability is a term applied to alternating current electric power system denoting condition in which various synchronous machine of the system remain in synchronism or in step with each other. This paper describes the multi machine power system example to demonstrate the features and scope of graphical simulink environment of general purpose of MATLAB software. MATLAB /simulink are advanced software which is being used increasingly in many areas of research. It also holds great potential in area of power system stability used simulink.

Further, Unified Power Flow Controller (UPFC) is used to control the power flow in the transmission systems by controlling the impedance, voltage magnitude and phase angle. This controller offers advantages in terms of static and dynamic operation of the power system. It also brings in new challenges in power electronics and power system design. The basic structure of the UPFC consists of two voltage source inverter (VSI); where one converter is connected in parallel to the transmission line while the other is in series with the transmission line.

This paper also involves the designing of a single phase UPFC using Matlab and Simulink software, and constructing a lab scale model of the UPFC along with transient stability of multimachine power system. The experimental result which has been obtained from a lab scale system showed a good agreement with the simulation result.

Keywords: MATLAB, power system, transient stability, UPFC, simulation.

Introduction:

The usage of computer simulation is gaining popularity particularly for power system. It is appreciated that most of the computer simulation studies require a GUI that makes user interaction easier and more effective when compared with classical text based with approaches [1]. The stability of power system has been and continues to be of major concern in system operation. Modern electrical powers systems have grown to a large complexity due to increasing inter connection, installation of large generating units and extra high voltage tie lines etc. Transient stability is the ability of power system to maintain synchronism when subjected to a severe transient disturbance, such as a fault on transmission facilities, sudden loss of generation, or loss of a large load. The system response to such disturbances involves large excursions of generator rotor angles, power flows, bus voltages, and other system variables. It is important that, while steady-state stability is a function only of operating conditions, transient stability is a function of both the operating conditions and the disturbance(s) [2]. This complicates the analysis of transient stability considerably. Repeated analysis is required for different disturbances that are to be considered. In the transient stability studies, frequently considered disturbances are the short circuits of different types. Out of these, normally the three-phase short circuit at the generator bus is the most severe type, as it causes maximum acceleration of the connected machine [3]. Simulink is particularly useful for studying the effects of nonlinearity on the behaviour of the system, and as such, is also an ideal research tool. The key features of Simulink are: [4]

- interactive simulations with live display;
- a comprehensive block library for creating linear, nonlinear, discrete or hybrid multi-input/output systems;
- seven integration methods for fixed-step, variable-step and stiff systems;
- unlimited hierarchical model structure;
- scalar and vector connections;
- mask facility for creating custom blocks and block libraries;

The user can also derive many features and in-built components from the Power System Blockset (PSB) [5]. PSB by itself gives the detailed three-phase representation of machine models and other components. Use of Simulink is rapidly growing in many areas of research work and so also in the field of power systems.[6–8] In this paper we have demonstrated a simplified and yet an efficient approach to study the transient stability performance of a practical power system, with Simulink as a tool. We hope that this attempt will add some more practical information

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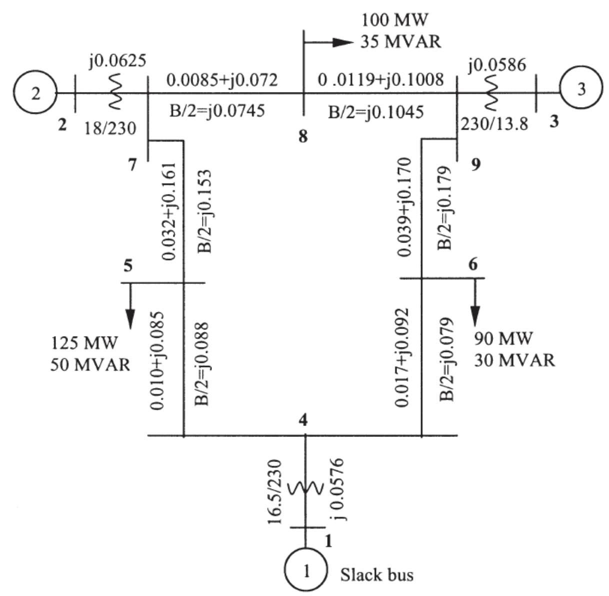

Fig. 1 *WSCC 3-machine, 9-bus system; all impedances are in pu on a 100MVA base.*

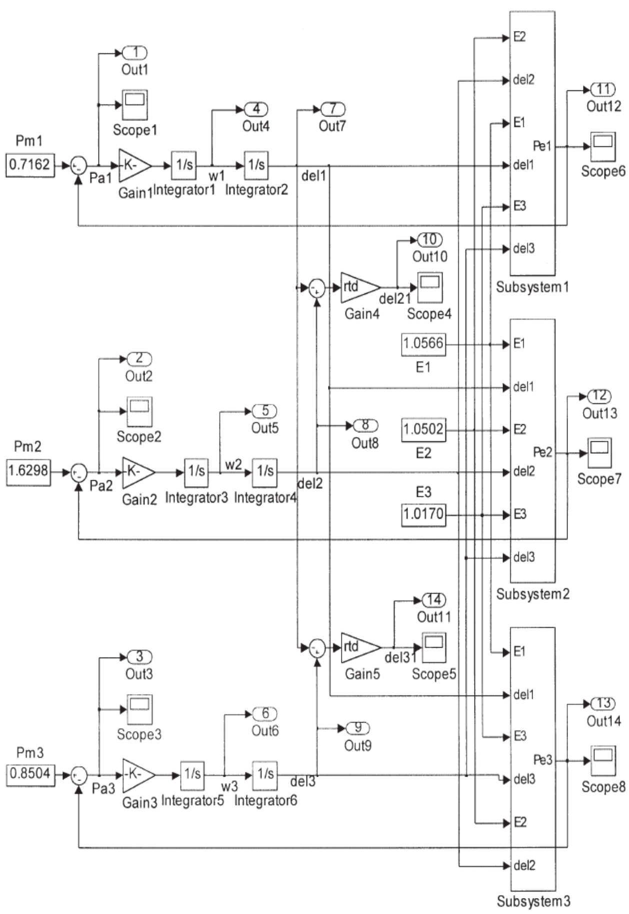

Fig. 2 *Complete classical system model for transient stability study.*

in this important and unexhausted domain. We have considered the popular Western System Coordinated Council (WSCC) 3- machine, 9-bus system shown in Fig. 1.1[9]. The base MVA is 100, and system frequency is 60 Hz. The system has been simulated with a classical model for the generators. The disturbance initiating the transient is a three-phase fault occurring near bus 7 at the end of line 5–7. The fault is cleared by opening line 5–7. The system, while small, is large enough to be nontrivial and thus permits the illustration of a number of stability concepts and results.

Mathematical modelling

Once the **Y** matrix for each network condition (pre-fault, during and after fault) is calculated, we can eliminate all the nodes except for the internal generator nodes and obtain the **Y** matrix for the reduced network. The reduction can be achieved by matrix operation with the fact in mind that all the nodes have zero injection currents except for the internal generator nodes. In a power system with *n* generators, the nodal equation can be written as:

$$\begin{matrix} I_n \\ 0 \end{matrix} = \begin{pmatrix} Y_{nn} & Y_{nr} \\ Y_{rn} & Y_{rr} \end{pmatrix} \begin{matrix} V_n \\ V_r \end{matrix} \qquad (1)$$

Where the subscript *n* used to denote generator nodes and the subscript *r* is used for the remaining nodes.

Expanding equation (1),

$$I_n = Y_{nn} V_n + Y_{nr} V_r , \quad (2)$$

$$0 = Y_{rn} V_n + Y_{rr} V_r$$

From which we eliminate V_r to find

$$I_n = (Y_{nn} - Y_{nr} Y_{rr}^{-1} Y_{rn}) V_n \qquad (2)$$

Thus the desired reduced matrix can be written as follows:

$$Y_R = (Y_{nn} - Y_{nr} Y_{rr}^{-1} Y_{rn}) \ (3) \qquad (3)$$

It has dimensions (*n* x *n*) where *n* is the number of generators. Note that the network reduction illustrated by equations (1)–(3) is a convenient analytical technique that can be used only when the loads are treated as constant impedances. For the power system under study, the reduced matrices are calculated.

The power into the network at node *i*, which is the electrical power output of machine *i*, is given by:

$$P_{ei} = E^2G_{ii} + \sum_{j=1}^{n} E_iE_jY_{ij}\cos(\theta_{ij} - \delta_i + \delta_j) \quad (4)$$

Where

i=1,2,3,…………………..n $\overline{Y_{ij}} = Y_{ij}\angle\theta_{ij} = G_{ij} + jB_{ij}$ (5)

= negative of transfer admittance between nodes *i* and *j*

$$\overline{Y_{ii}} = Y_{ii}\angle\theta_i = G_{ii} + jB_{ii}$$

= driving point admittance of node *i*

The equation of motion is then given by:

$$\frac{2H_i}{\omega_R}\frac{d\omega_i}{dt} + D_i\omega_j = P_{mi} - \left[E^2G_{ii} + \sum_{j=1}^{n} E_iE_jY_{ij}\cos(\theta_{ij} - \delta_i + \delta_j)\right]$$

(6)

It should be noted that prior to the disturbance (t = 0)

$$P_{mi_0} = P_{ei_0} \quad (7)$$

As the network changes due to switching during the fault, the corresponding values will be used in the above equations.

Classical System model

The complete 3-generator system, given in figure 1, has been simulated as a single model. The mathematical model given above gives the transfer function of different blocks. The figure 2 shows the complete block diagram of a classical system representation for transient system study. The subsystems 1, 2 and 3 are meant to calculate the values of electrical power outputs for different generators; for example Figure 3 shows the computation of power output of generator 1.

System modeling load flow analysis

The complete system has been representing in term of simulink block in a single integral model. Simulink makes the display of signal at any point readily available and one has to in add a scope block as an output port .a parameter with any block can be controlled a MATLAB command line or through m- file command. This is useful for transient stability as the power system configurations are different before, during and after fault.

UPFC Construction

The UPFC consists of two voltage source converters; series and shunt converter, which are connected to each other with a common dc link. Series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line, while shunt converter or Static Synchronous Compensator (STATCOM) is used to provide reactive power to the ac system, beside that, it will provide the dc power required for both inverter. Each of the branches

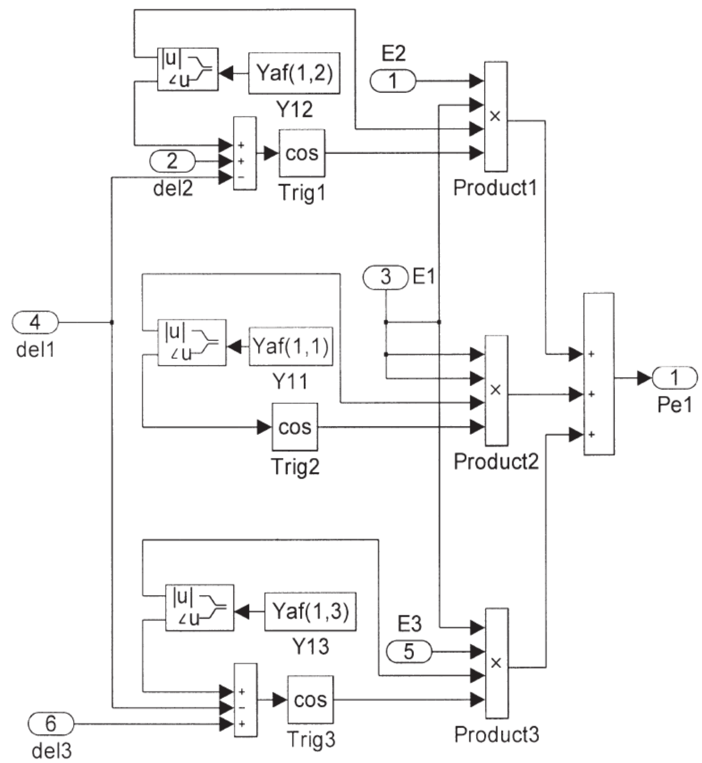

Fig. 3 *Computation of electrical power output of gen. #1 by Subsystem 1.*

consists of a transformer and power electronic converter. These two voltage source converters shared a common dc capacitor.[10]

Conclusion:

A complete model for transient stability study of multi machine power system has been developed using simulink environment. It is basically a transfer function and bock diagram representation of the system equations. A variety of component blocks are available in various Simulink libraries and also in other toolboxes such ad control system toolbox, Power System Blockset etc. Therefore, a Simulink model is not only well suited for an analytical study of a power system network, but it is also helpful in detailed study of load flow and parameter variations.

Results:

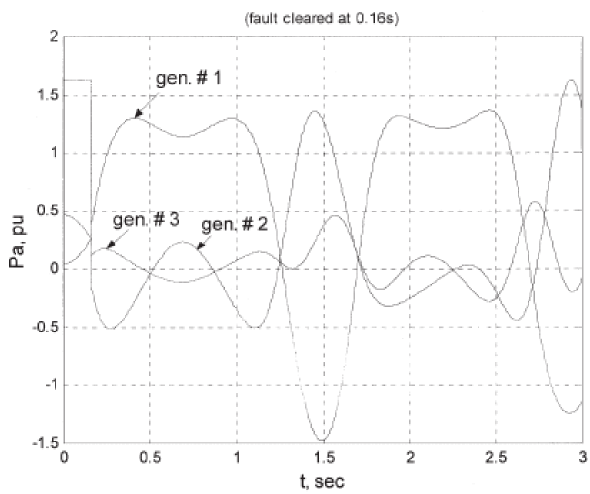

Fig. 4 UPFC Simulink model

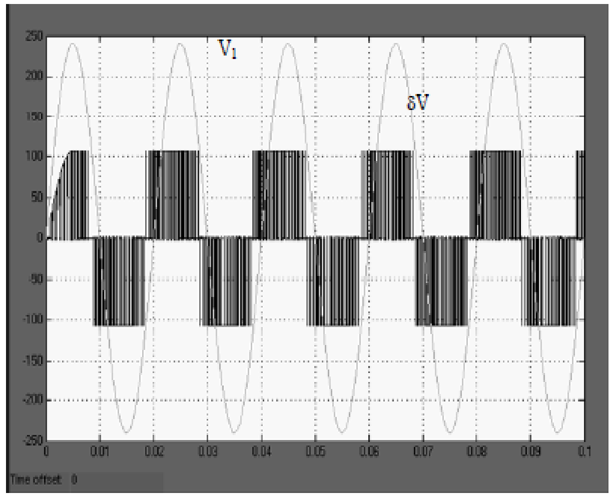

Fig. 5 Generator output voltages

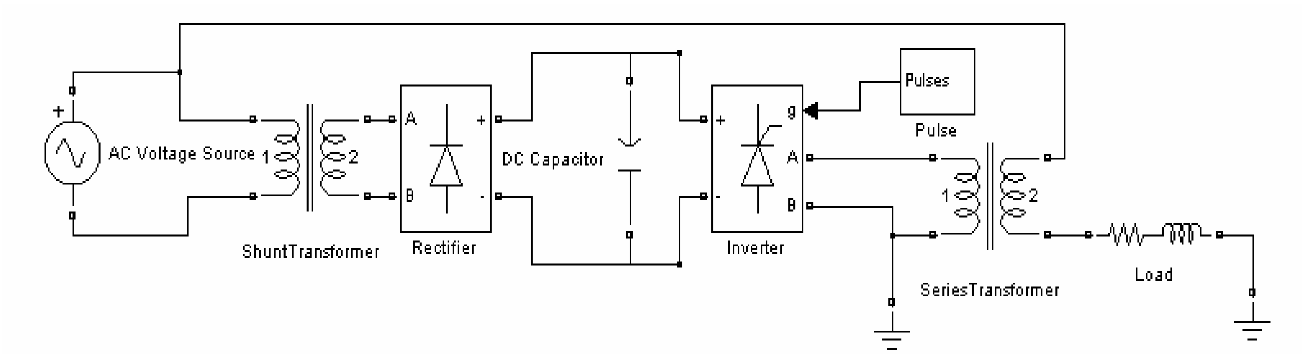

Fig. 6 Supply voltage vs output voltage

It is clear from the above study that simulink offers e wide perspective for simulation and analysis of various types of power system networks. In the present study of power system network, a simple classical model of 3-machine, 9 bus system is considered. It explains very well the principles and the scope of the various toolboxes in the MATLAB Simulink environment. Furthermore, the optimization and application of some advanced tools is also much easier such as fuzzy logic, ANN within MATLAB.

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