

TRANSIENT STABILITY ANALYSIS OF SYNCHRONOUS GENERATOR USING SINGLE MACHINE INFINITE BUS (SMIB) SYSTEM

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Abstract— This paper presents transient stability analysis using time domain method for 2.1 synchronous generator model and classical model. SMIB system is used for this analysis. Analysis is compared using Critical Clearing Time (CCT) for 2.1 model and classical model. Transient Stability Analysis and Critical Clearing Time (CCT) is evaluated for specified Terminal fault.

Index Terms— Transient stability, SMIB system, detailed models, Critical Clearing Time, synchronous generator

INTRODUCTION

Power system stability can be defined as the ability of a power system to remain in a state of operating equilibrium during normal conditions, and to regain an accepted state of operating equilibrium after a disturbance.[1][2] During normal operating conditions of the power systems (in steady state), two main conditions should be satisfied for generators: (1) Rotors should be in synchronism. (2) The generated voltages are sinusoidal waveforms with the same frequency. [4] These conditions are violated when any type of disturbances are developed on the power system. Due to these disturbances instability in power system is developed. These disturbances may be small or large. Power system must be able to withstand against these disturbances. The ability of a power system to recover and maintain synchronism is called rotor angle stability.[2] Small signal stability is the ability of the power system to maintain synchronism under small disturbances.[2] Transient stability is the ability of the power system to maintain synchronism under large disturbances.[2]

The rotor of synchronous generator is driven by prime mover. The frequency of the terminal voltage of the generator depends on the speed of rotor. Rotor mechanical speed is synchronized with the frequency of the stator electrical quantities. When two or more synchronous generators are inter connected, stator voltage and current of each generator must have the same frequency. The rotors of all interconnected generators must be in synchronism during normal operating conditions of power system. Mechanical input power (P_m) from prime mover to generator shaft and generated electrical power (P_e) should be in balanced condition

Sudden change in load, and loss of a line or generator) are developed on power system, the maintenance of rotor angle stability is known as transient stability. Due to these disturbances the synchronous machines may lose synchronism.

It is important to note that, steady-state stability is a function of only the operating condition, whereas transient stability is a function of both the operating condition and the disturbances. This complicates the analysis of transient stability considerably. Transient Stability requires analysis for different disturbances. Transient stability analysis in a power system is the ability of power system to remain in synchronism before the large disturbance as well as after the large disturbance. Now a days transient stability analysis of power system is mainly performed by simulations. Calculation of critical clearing time (CCT) for a fault is a main assessment in the transient stability analysis.

This paper presents the mathematical formulation of 2.1 and classical models of synchronous machine used in the transient stability simulation. Synchronous machines are, in general, expressed by dq-axis Park model in the simulations. There are several types of approximated models. In this paper, we have considered 2.1 model and the simple classical model of machine representation. The detailed model 2.1 having one damper circuit both in d-axis and q-axis. Stator transients are considered here in 2.1 model. The accuracy of both synchronous machine models are evaluated by performing simulations for three phase short circuit fault in a model SMIB system.

II. SYNCHRONOUS GENERATOR MODEL [3],[5]

This section presents the differential equations for the dynamic behavior of the stator and rotor winding system in generator.

A. Mathematical Model

Equations of generator model are basically in abc form but these equations are converted into dq0 form to eliminate time varying equations. Equations in dq0 form are used for modeling as shown in below,

$$v_d = \frac{1}{\omega_0} \frac{d\psi_d}{dt} - \omega_m \psi_q + R i_{ad} \quad (1)$$

$$v_q = \frac{1}{\omega_0} \frac{d\psi_q}{dt} + \psi_q + R i_{ad} \quad (2)$$

$$v_0 = \frac{1}{\omega_0} \frac{d\psi_0}{dt} + \psi_0 + R i_{a0} \quad (3)$$

$$v_f = \frac{1}{\omega_0} \frac{d\psi_f}{dt} + \psi_f + R i_{ff} \quad (4)$$

$$0 = \frac{1}{\omega_0} \frac{d\psi_h}{dt} + \psi_h + R i_{hh} \quad (5)$$

$$0 = \frac{1}{\omega_0} \frac{d\psi_g}{dt} + \psi_g + R i_{gg} \quad (6)$$

$$\psi_d = L_{ls} i_d + L_{md} (i_d + i_h) \quad (7)$$

$$\psi_q = L_{ls} i_q + L_{md} (i_q + i_g) \quad (8)$$

$$\psi_0 = L_{ls} i_0 \quad (9)$$

$$\psi_f = L_{lf} i_f + L_{md} (i_d + i_h) \quad (10)$$

$$\psi_h = L_{lh} i_h + L_{md} (i_d + i_h) \quad (11)$$

$$\psi_g = L_{lg} i_g + L_{md} (i_q + i_g) \quad (12)$$

A. Model2.1

This is the fifth order model which has two rotor circuits on d - axis (a field circuit and a damper circuit) and one damper circuit on q-axis. The differential equations for this model are represented by above equations. [6]

B. Classical Model

It is the simplest model of the synchronous machine. In this model, the synchronous generator is represented by a constant voltage behind d-axis transient reactance (X'). In this model, the voltage is assumed constant, only its phase angle changes. Here, the changes in the flux linkages and the transient saliency are neglected. This model is very useful for the first swing transient stability study, involving a short period of study say one second or less. It is a second order model governed by two dynamic state variables (δ, ω) represented by below equations.[6]

$$M \frac{d^2 \delta}{dt^2} - D \frac{d\delta}{dt} = p_m - p_e \quad (13)$$

$$\frac{d\omega}{dt} = \omega \quad (14)$$

In this paper generator is excited by constant voltage in 2.1 model and stator dynamics are also considered. Three phases to ground fault is considered at the terminal of synchronous generator for simulation. Rotor speed is considered with respect to 1 pu that is why during steady state rotor speed is 1 pu.

III. MATLAB MODELING

Using above mathematical equations (1–14), MATLAB model can be prepared which can be used in time domain for transient stability analysis.

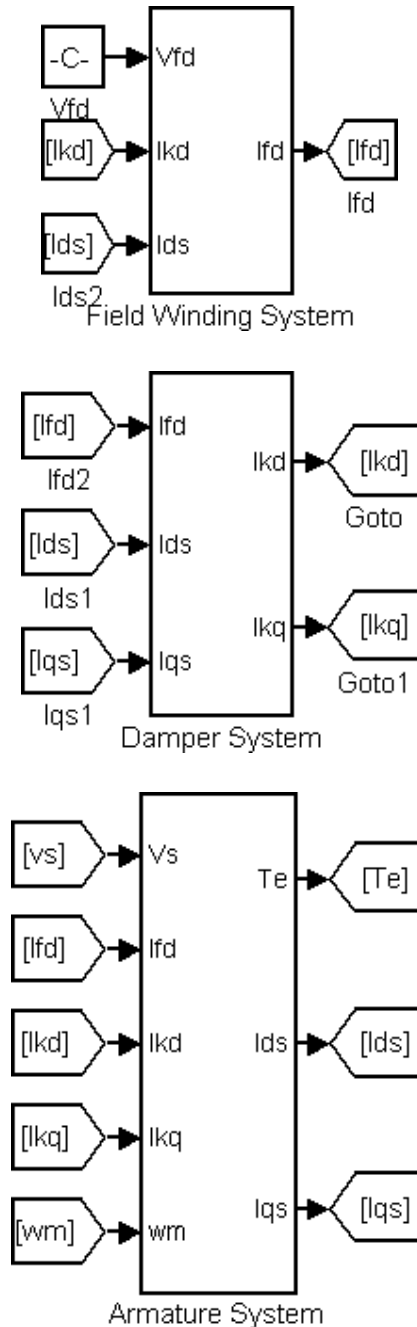


Fig.1 Field windings system, Damper system, Armature system.

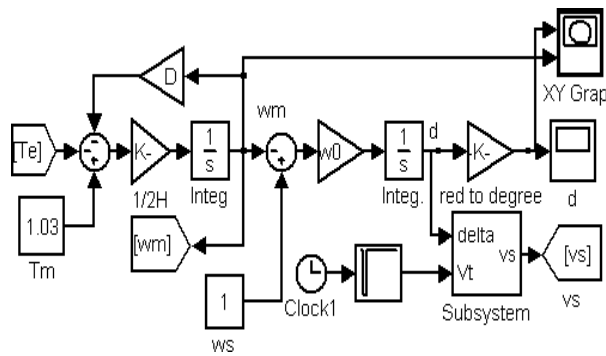


Fig.2SwingequationMATLABModel

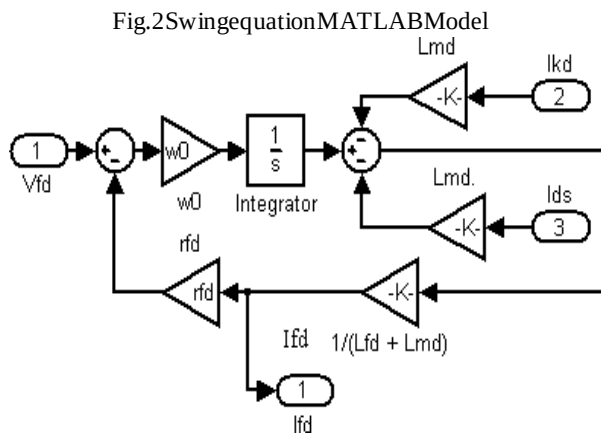


Fig.3 Field windings system MATLAB Model

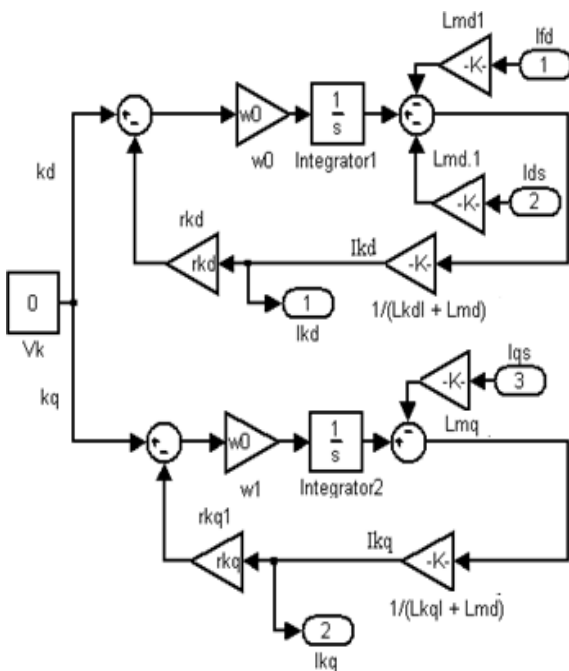


Fig.4DampersystemMATLABModel

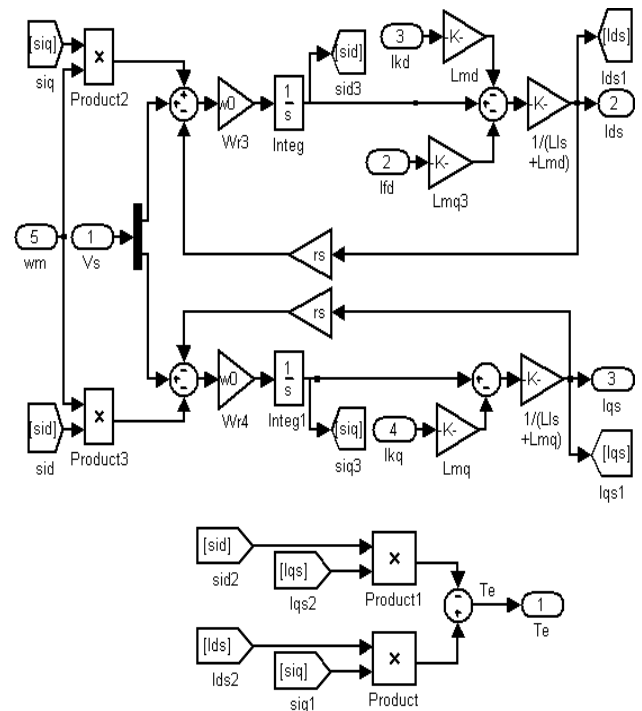


Fig.5 ArmaturesystemMATLABModel

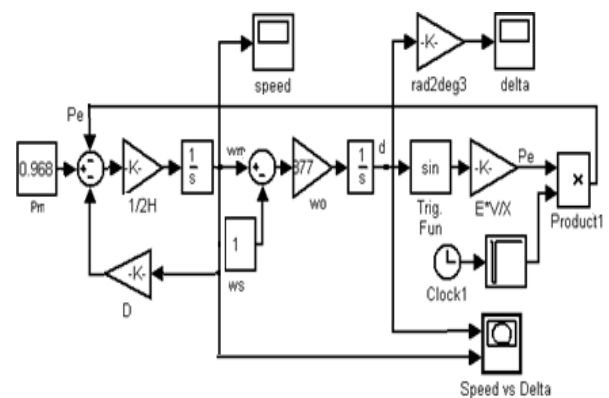


Fig.6 Classical Generator model MATLAB

IV. SIMULATION RESULTS

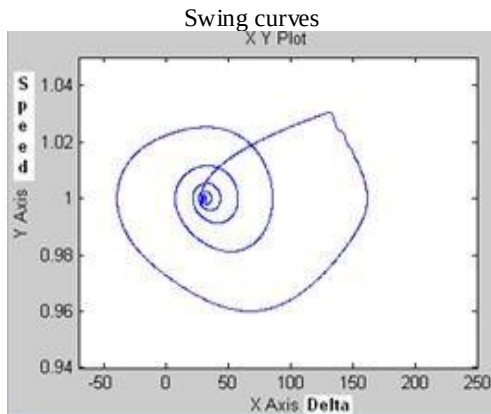
Transient stability analysis is done using 2.1 model and classical model. Aim of both models simulation is to determine Critical Clearing Time (CCT).

Comparison of Critical Clearing Time (CCT) of different models for transient stability analysis of synchronous generator in power system is done here in MATLAB simulation

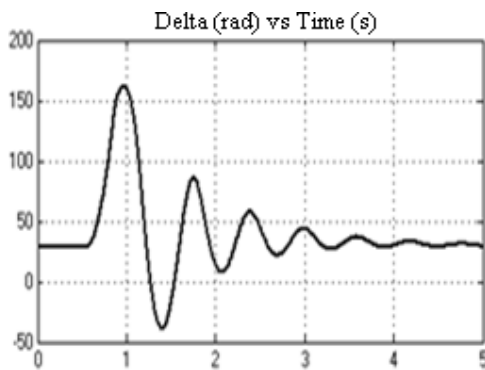
INPUTDATA[7]

Sn.	Generator Parameters	Value
1	Stator Resistance(Rs)	0.02
2	d-axis inductance(Ld)	1
3	q-axis inductance(Lq)	1
4	Stator leakage inductance(Lsl)	0.15
5	Field circuit resistance(Rf)	0.001
6	Field circuit inductance (Llf)	0.2
7	d-axis damper circuit resistance(Rh)	0.02
8	d-axis damper circuit inductance(Llh)	0.11
9	q-axis damper circuit resistance(Rg)	0.04
10	q-axis damper circuit inductance(Llg)	0.15
11	Inertia constant (H)	4sec
12	Damper coefficient(D)	1e-6
13	Frequency(f)	60Hz
14	Terminal voltage(v)	1
15	Delivering current(Ia)	1.25
16	Power factor(pf)	0.8
17	Clearing time(tc)	0.35,0.36 sec
18	Excitation voltage	0.00218

RESULTSOFF2.1MODEL

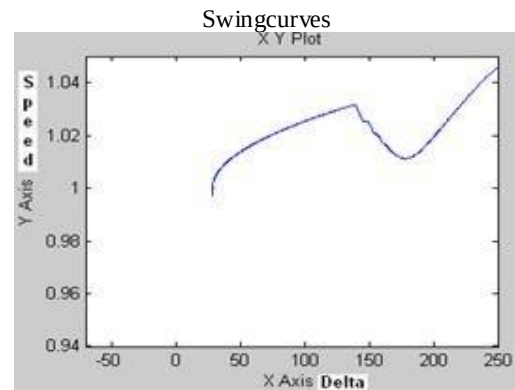


(a)

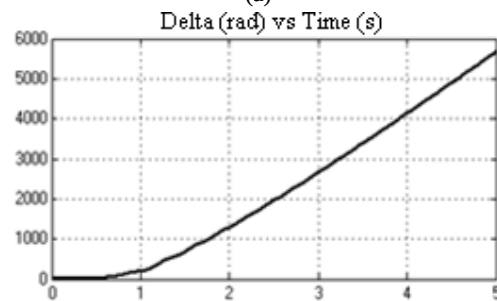


(b)

Fig.7Simulationresults(aandb)of2.1modelwhereFault Clearing Time is 0.35 second



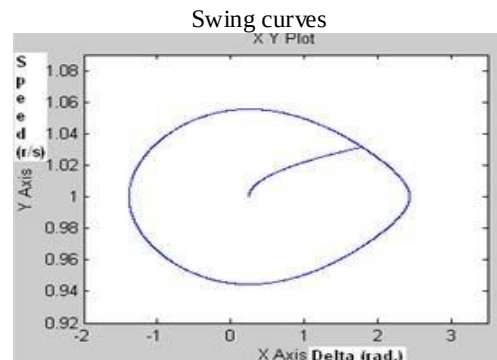
(a)



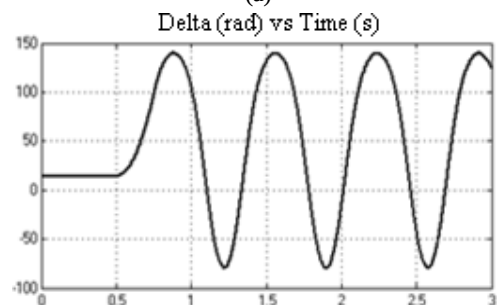
(b)

Fig.8Simulationresults(aandb)of2.1modelWhereFault Clearing Time is 0.36 second

RESULTSOFFCLASSICALMODEL



(a)



(b)

Fig.9Simulationresults(aandb)of classical modelwhere Fault Clearing Time is 0.26 second

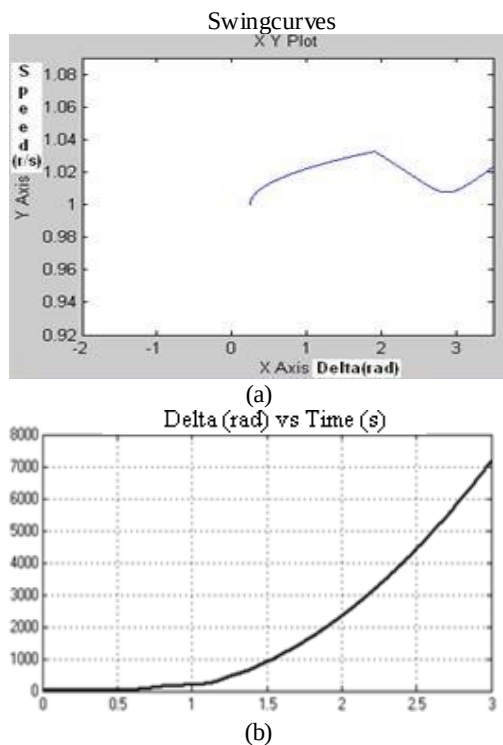


Fig.10 Simulation results (a and b) of classical model where Fault Clearing Time is 0.27 second

CONCLUSION

This paper presents transient stability analysis using time domain method for 2.1 synchronous generator model and classical model. The performance and accuracy of both models are compared in terms of Critical Clearing Time (CCT), where the classical model gives more error, because the field flux is neglected in this model and model 2.1 gives more accurate results because the effect of all damper circuits and stator transients are considered. But classical model gives results in short time than 2.1 model because in classical model dynamic equations are neglected.

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