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Introduction of Dynamic Phasor Model to analyze faults and disturbances in Power System

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***Abstract* — In power system so many disturbances and faults are there and to detect them is another problem. In actual power system to know what happen when fault is occurring is another problem. We can't check the system or operate the system in fault condition. So, to observe the system in different fault condition some simulation method is required. Dynamic phasor model of the system provide time invariant model the system which makes study easy.**

Keywords- Power system, Dynamic phasor model, MATLAB (Simulink)

I. INTRODUCTION

A power system is a very vast combination of transformers, generators and transmission lines. To simulate the system is difficult task for system operator. We can make mathematical model of the system but due to mutual coupling present in the system analysis of the system become difficult and we have to find another simulation technique. We also have park transformation model but that also not useful in unbalanced system operation as 95% system faults are unbalanced in nature.

II. DYNAMIC PHASOR MODEL

A. Introduction

"Dynamic phasors are time varying Fourier coefficients of the time domain signals. These phasors are the state variables in dynamic phasor based models. Dynamic phasor models are suitable for Eigen analysis of unbalanced systems. Moreover, they are also suited for the simulation of circuits involving periodically switched power electronic devices, which contain steady state harmonics."

Any periodic waveform can be represented in terms of the complex Fourier coefficients over a window length 'T' as given below:

$$x(\tau) = \sum_{k=-\infty}^{\infty} \langle x \rangle_k (t) e^{jk\omega_s \tau}$$

Usually Ws corresponds to the nominal supply frequency in rad/s. Moreover, kth Fourier coefficient (Dynamic Phasor) can be computed using the following equation.

$$\langle x \rangle_k (t) = \frac{1}{t} \int_{t-T}^{t} x(\tau) e^{-jk\omega_s \tau} d\tau$$

The symbol <ik> is used throughout the thesis to represent kth dynamic phasor of instantaneous signal x(t). As the window of length 'T' slides over the waveforms of interest with time, the corresponding dynamic phasors vary accordingly. Note that if x(t) is periodic with a period T, corresponding dynamic phasors are constants.

B. Important properties of dynamic phasors [1]

1.Derivative of the dynamic phasor is given by the following equation. The result can be easily verified using the definition of dynamic phasor and integration by parts.

$$\frac{d\langle x \rangle_k}{dt} = \left\langle \frac{dx}{dt} \right\rangle_k - jk\omega_s \langle x \rangle_k$$

2.Dynamic phasor of the product of two signals u(t) and v(t) can be obtained by the discrete convolution of the corresponding dynamic phasors as follows:

$$\langle \upsilon \nu \rangle_k = \sum_{l=-\infty}^{\infty} \langle \upsilon \rangle_{k-l} \langle \nu \rangle_l$$

3.Following are also the important results.

$$\langle x \rangle_k = \langle x \rangle^*_{-k}$$

$$\langle x \rangle_k = \langle y \rangle^*_{-k}$$

In order to effectively use the models, it is necessary to select the appropriate minimal set of dynamic phasors which is adequate to correctly capture the transients of interest.

C. Example of dynamic phasor model (RLC series circuit)

Consider a series RLC circuit connected to a sinusoidal voltage source. The circuit diagram for the same is given in Fig.

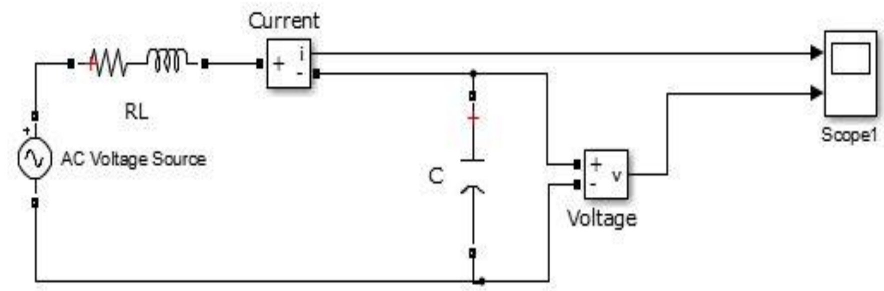

Fig.1 RLC series circuit

The time domain equation for this circuit is:

$$\frac{d}{dt}\begin{bmatrix} Vc \\ IL \end{bmatrix} = \begin{bmatrix} 0 & 1/C \\ -1/L & -R/L \end{bmatrix}\begin{bmatrix} Vc \\ IL \end{bmatrix} + \begin{bmatrix} 1/L \\ 0 \end{bmatrix}\begin{bmatrix} Vc & 0 \end{bmatrix}$$

$$\frac{d}{dt}[X] = [A][X] + [B][u]$$

The corresponding dynamic phasor model is given by:

$$\frac{d}{dt}\begin{bmatrix} < Xr > \\ < Xi > \end{bmatrix} = \begin{bmatrix} [A] & kwI \\ -kwI & [A] \end{bmatrix}\begin{bmatrix} < Xr > \\ < Xi > \end{bmatrix} + \begin{bmatrix} [B] & 0 \\ 0 & [B] \end{bmatrix}\begin{bmatrix} < Xr > \\ < Xi > \end{bmatrix}$$

$$< X > = < Xr > + j < Xi >$$

The dynamic phasor model of the above circuit considering fundamental phasors (i.e. k = ±1), is given below. The real and imaginary parts of the complex differential equations are separated and repeated equations are removed to get a second order model. i1R and i1I represent the real and imaginary parts of the dynamic phasor hii1 respectively.

Comparison result of time domain model and dynamic phasor model

From this we can say that dynamic phasor model gives quite accurate result

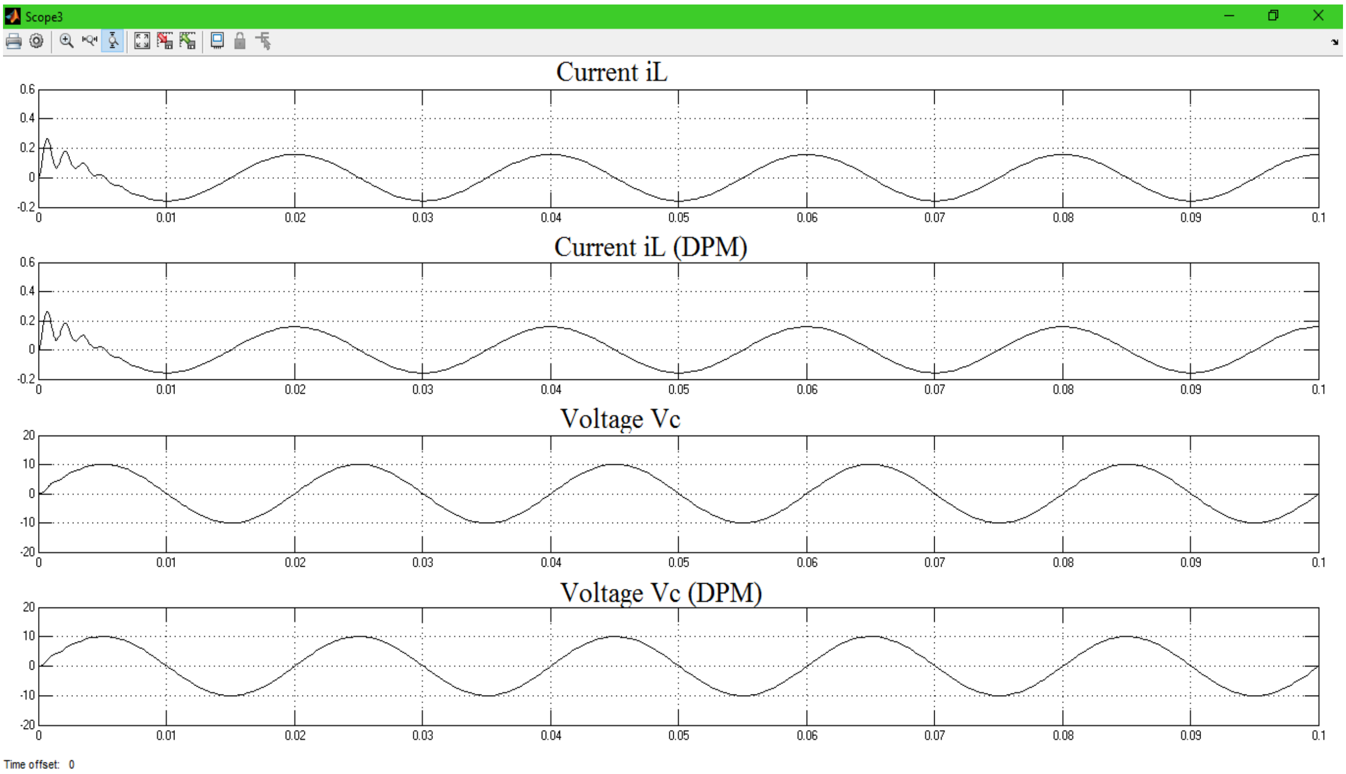

Fig.2 Result of RLC series circuit

III. DYNAMIC PHASOR MODEL OF SMIB

This example is given to explain the time invariance of the dynamic phasor model even with phase imbalance. Consider the schematic of a synchronous machine shown in Fig. 1.8. The time domain model of a synchronous machine in terms of 'abc' parameters as described in [9] is given below. For simplicity, we have neglected the saliency in the rotor, for the model discussed in this chapter.

$$\frac{d\psi_s}{dt} = -[R_s]i_s - v_s \qquad \text{and} \qquad \begin{bmatrix} \psi_s \\ \psi_r \end{bmatrix} = \begin{bmatrix} L_{ss} & L_{sr}(\theta) \\ L_{rs}(\theta) & L_{rr} \end{bmatrix} \begin{bmatrix} i_s \\ i_r \end{bmatrix}$$

$$\frac{d\psi_r}{dt} = -[R_r]i_r - v_r$$

$$\frac{d\delta}{dt} = \omega - \omega_s$$

$$\frac{d\omega}{dt} = \frac{1}{J}(T_m - T_e)$$

As the model is used for analysis with phase imbalance, the stator abc quantities are transformed to pnz quantities using following transformation.

$$\begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ a^2 & a & 1 \\ a & a^2 & 1 \end{bmatrix} \begin{bmatrix} f_p \\ f_n \\ f_z \end{bmatrix}$$

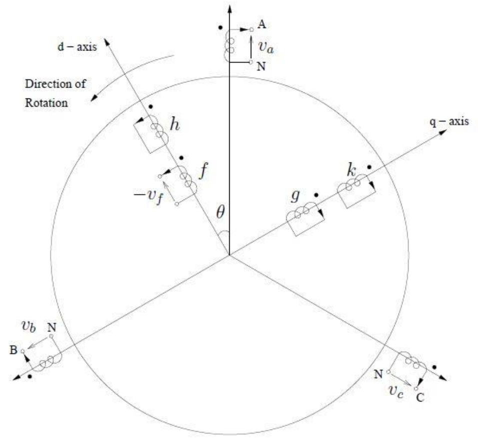

Fig.3 Schematic of a synchronous machine model

$$\frac{d}{dt}\psi_{pnz} = -[R_s]i_{pnz} - v_{pnz}$$
$$\frac{d}{dt}\psi_r = -[R_r]i_r - v_r$$

$$\psi = \begin{bmatrix} \psi_{pnz} \\ \psi_r \end{bmatrix} = Li = \begin{bmatrix} L'_{ss}(\theta) & L'_{sr}(\theta) \\ L'_{rs}(\theta) & L_{rr} \end{bmatrix} \begin{bmatrix} i_{pnz} \\ i_r \end{bmatrix}$$

IV. MATLAB (Simulink model)

Dynamic phasor model of synchronous generator connected with infinite bus is simulated using MATLAB (Simulink) and Simulink model is given below.

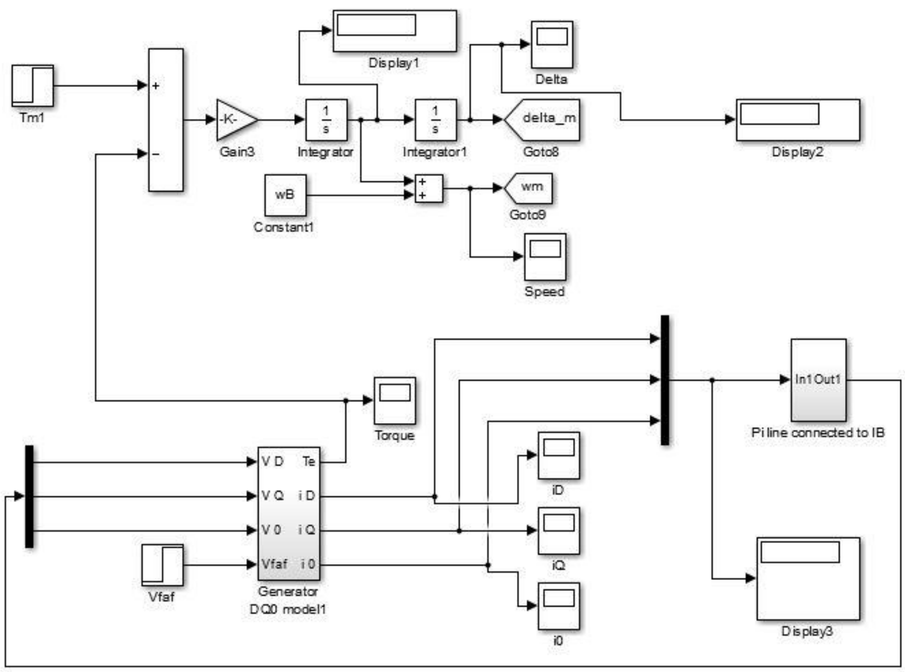

Fig.4 Simulink model of SMIB

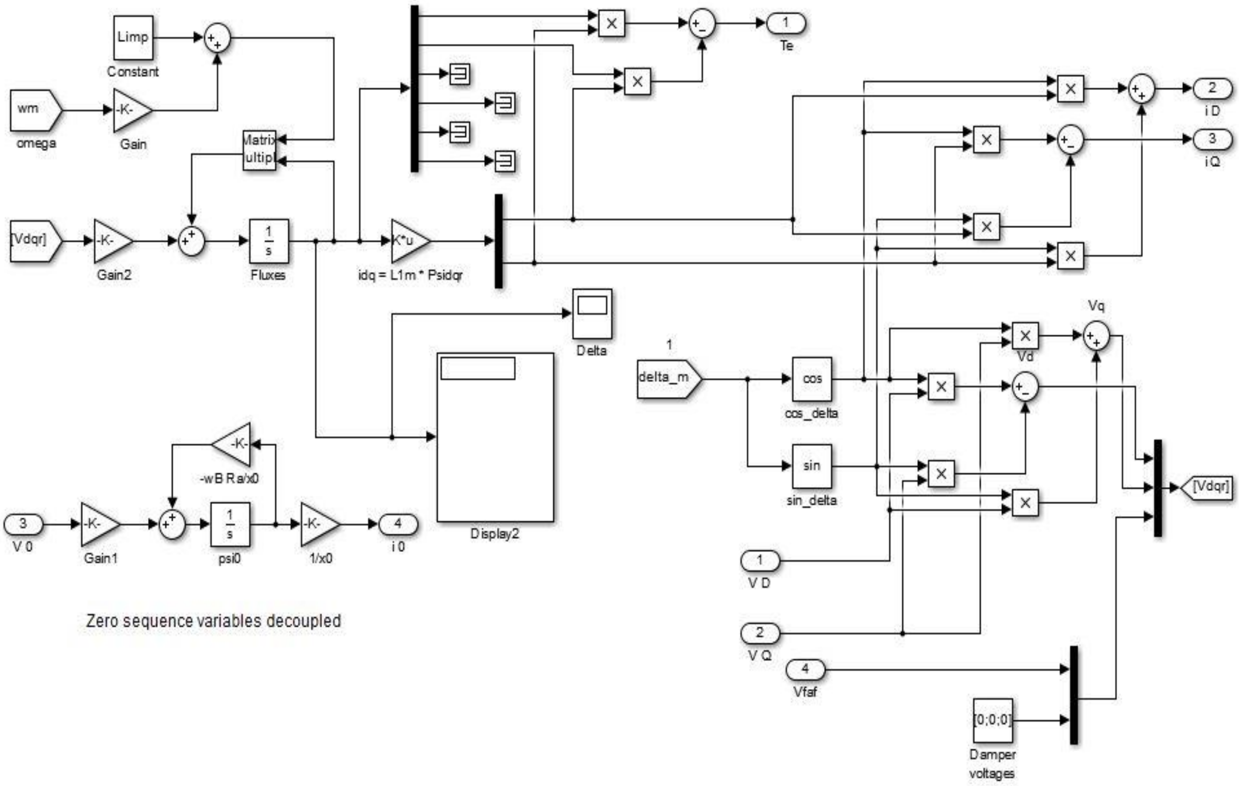

Fig.5 Simulink model of synchronous generator

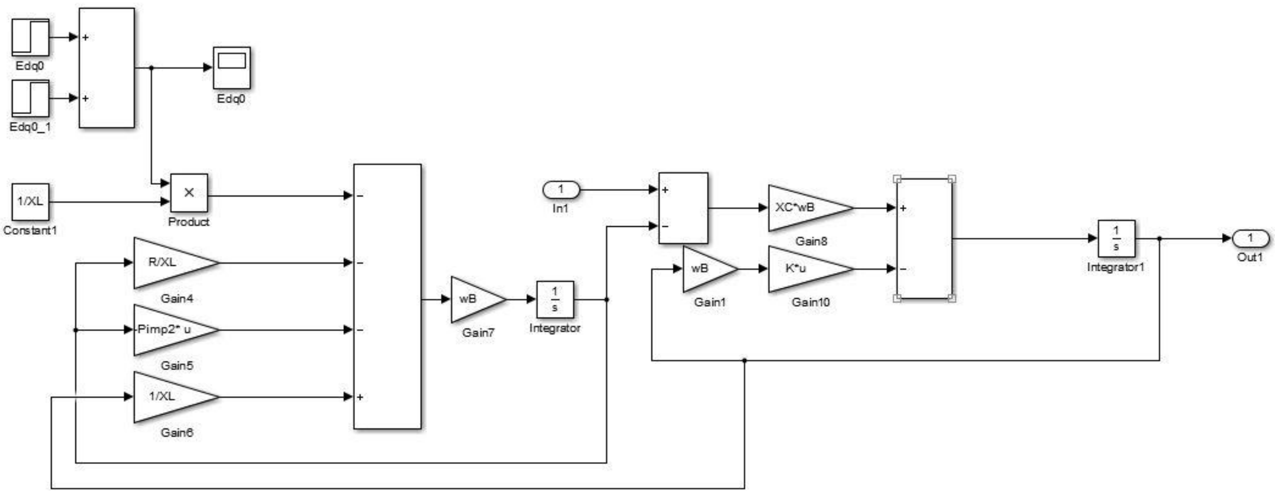

Fig.6 Simulink model of rest of the system

V. RESULTS

- Here we simulate the SMIB with two different model methods. First we simulate the system with DQ0 model and then we simulate the system with dynamic phasor model.
- And results present below are validate the dynamic phasor model for the simulation purpose.
- Also dynamic phasor model gives time invariant model with no mutual coupling between two equations
- Due to dynamic phasor modeling of the system is become easy as well as system easily become linearized so tuning of the controller become easy.
- Here, we make short circuit fault at generator terminal for 0.2 s.

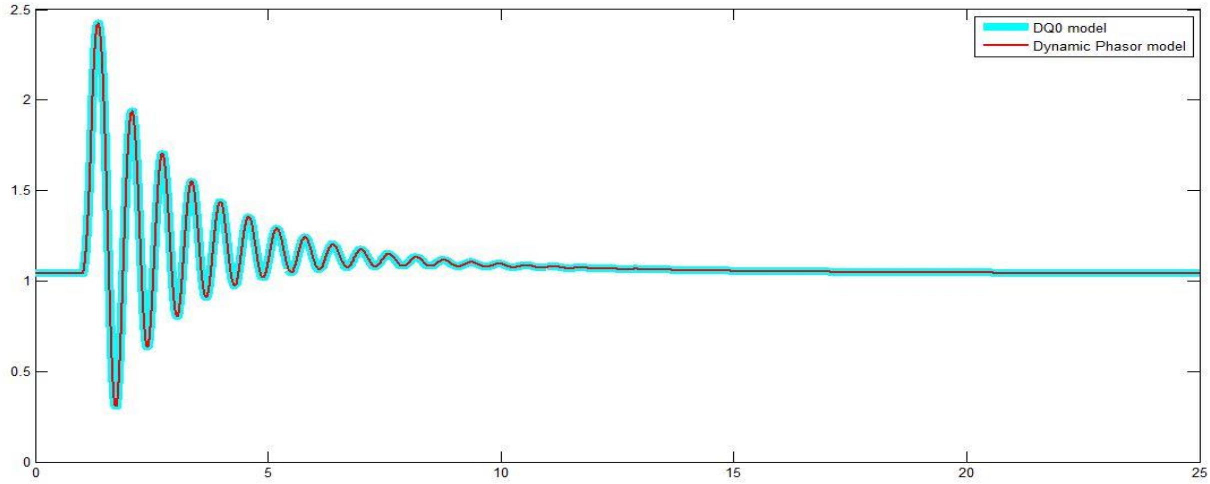

Fig.7 Load angle

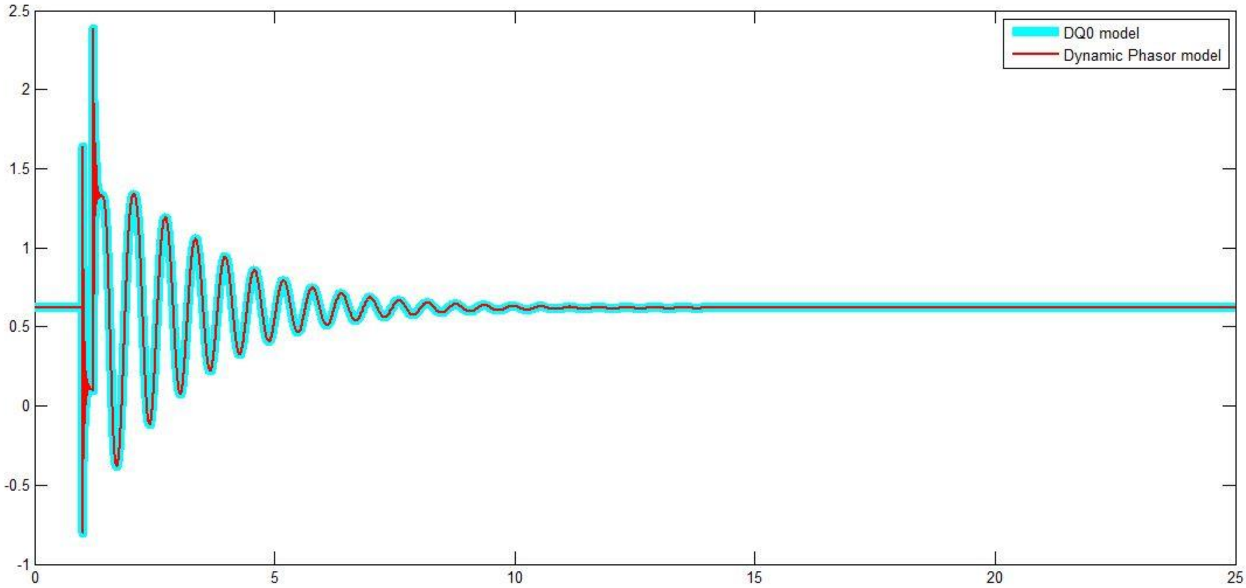

Fig.8 Electrical torque

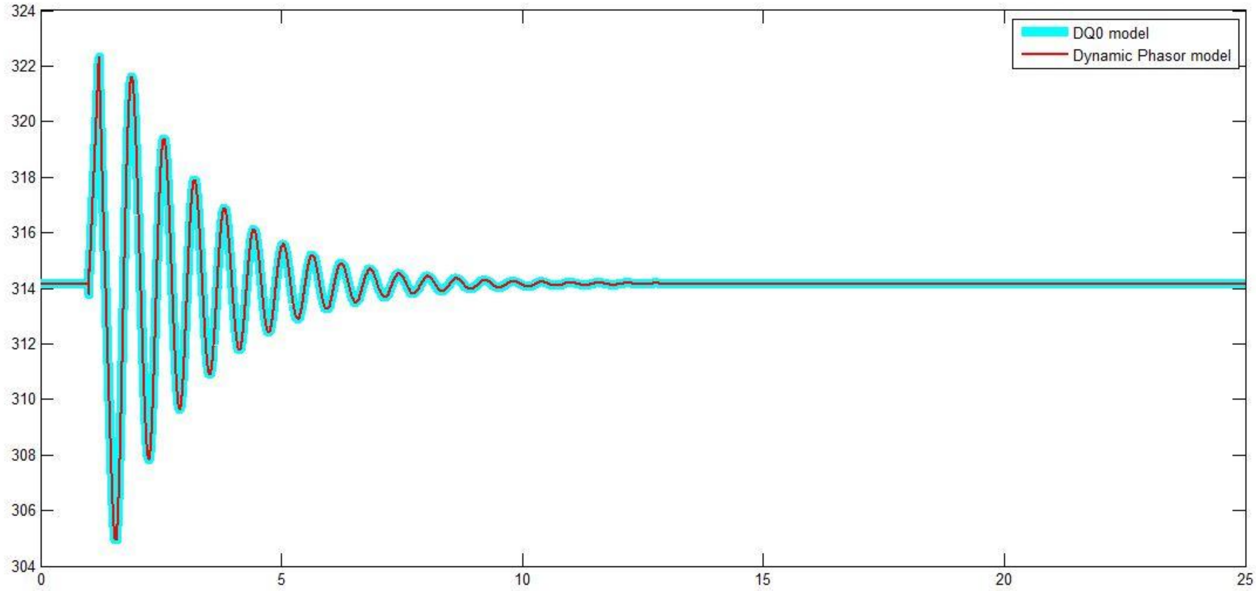

Fig.9 Speed of the generator

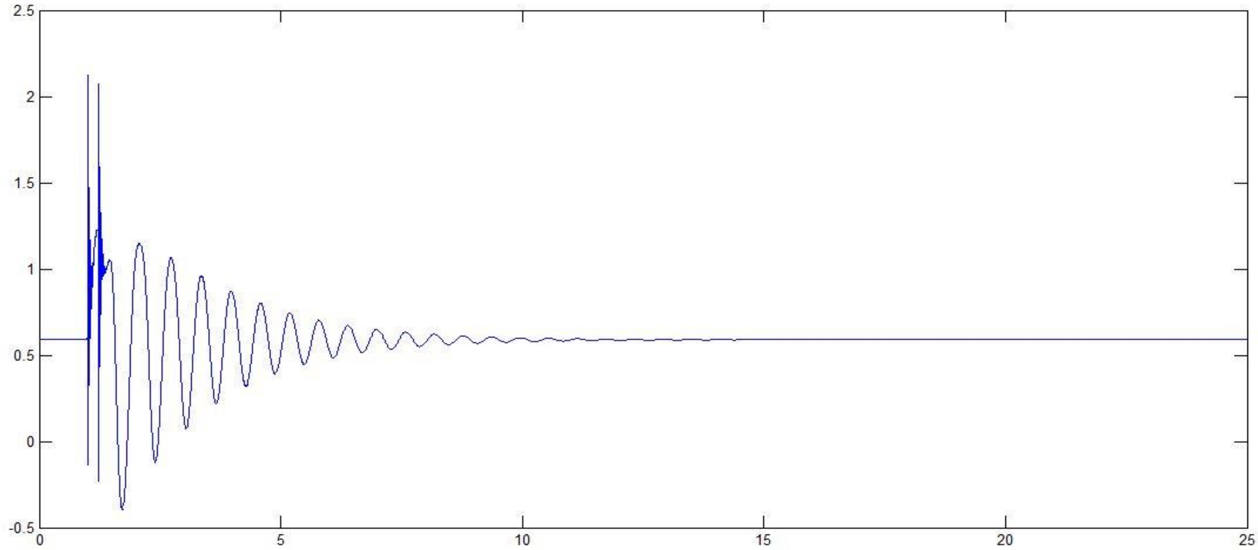

Fig.10 Current (id)

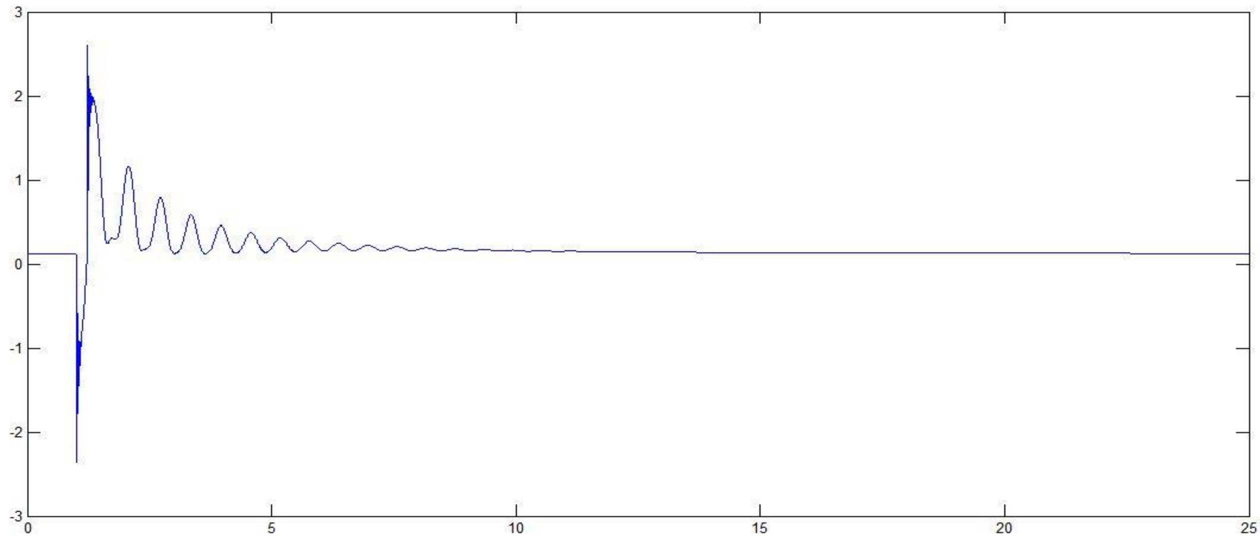

Fig.11 Current (iq)

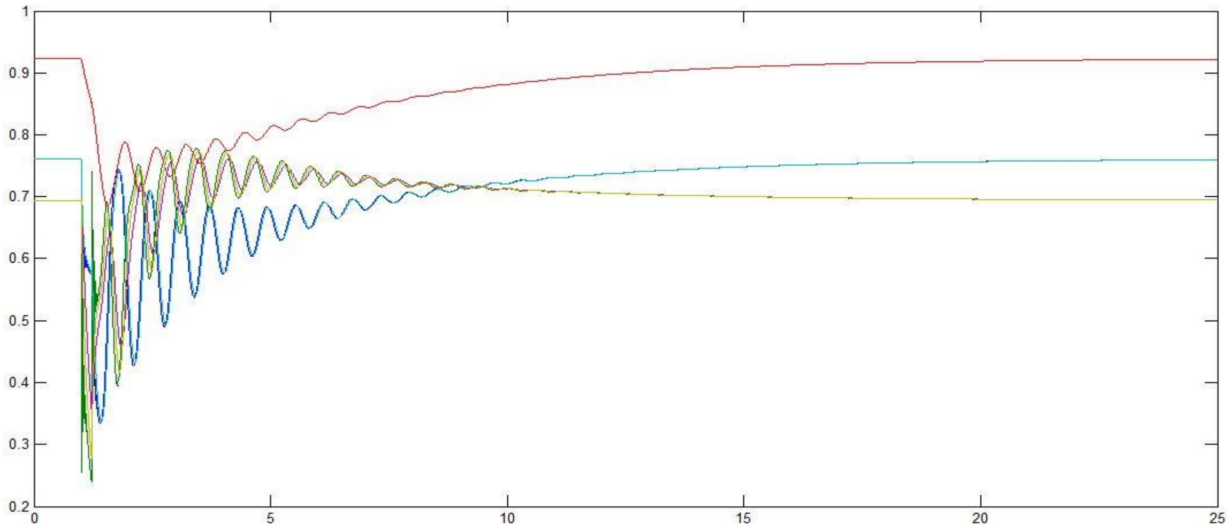

Fig.12 Rotor and stator fluxes

VI. CONCLUSION

By the simulations we observed that dynamic phasor model is faster and gives good results comparing to other modeling techniques. Dynamic phasor model gives time invariant model with no mutual coupling between the rotor and stator flux. With dynamic phasor model we can also simulate the unbalanced faults in power system. So, dynamic phasor model is good choice for system simulation.

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