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Dynamic Behaviour of Asynchronous Generator In Stand-Alone Mode Under Load Perturbation Using MATLAB/SIMULINK

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ABSTRACT:- The world's conventional resources will be depleted in few hundred years. To avoid energy crisis, uses of renewable energy resources are increasing day by day. A Asynchronous generator with stand-alone mode is the better option to produce electricity in varying speed in wind turbines. This paper deals with the dynamic behavior of Asynchronous Generator operated in stand-alone mode under load perturbation.

Keywords:- Stand-alone mode, wind turbine, asynchronous generator, capacitor bank

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I. INTRODUCTION

To avoid energy crisis in future if we use renewable energy resources such as solar, wind, wave etc. then our daily energy demand can be met. Recent trend for power generation is to use renewable resources. In wind turbines, asynchronous generators are often used in stand-alone mode to generate electricity. Asynchronous generators have some advantages over conventional synchronous generators. Usually, the major limitation of a Asynchronous Generator is that it requires reactive power from the supply for the excitation process. The asynchronous generator operation in stand-alone mode is essential to supply far districts where electrical grid extension is not economically feasible. Asynchronous generator is connected by appropriate capacitor bank across its terminals to make it self-excited. This paper gives an approach to model dynamic behavior of such generator during load perturbations. For the first time in 1935 when Basset and Potter [1] suggested that the induction machine can be operated an induction generator in isolated mode by external capacitor. They summarized that the induction machine with capacitive excitation can be build up and the final value being determined by the saturation curve of the machine. E. Muljadi et al. [2] in his paper investigate the wind turbine application in Selfexcited Induction Generators. Sutanto et al. [3] in his paper proposed that the transient behaviour of a three phase SEIG supplying a symmetrical load. They presented an approach to model performance of induction generators to maintain constant terminal voltage under resistive and reactive loads. They explained a modified and analytical method for determining the range of capacitive VAR requirements for maintaining a constant flux and for obtaining performance with a desired level of voltage regulation. The analysis used the steady state equivalent circuit to predict the performance of the generator. Doxey [4] in his paper concluded that the basic requirement for the induction motor work as self-excited induction generator is the leading current of correct magnitude.

DEVELOPED SCHEME AND MODEL EQUATIONS

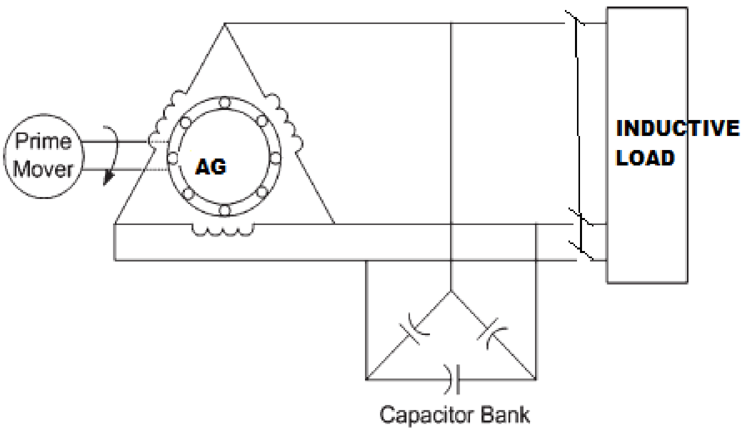


Fig. 1. Block diagram of the system

A. Mathematical Modeling of Asynchronous Generator:

The modeling of the three phase asynchronous generator is developed by using a stationary d-q axes reference frame and the relevant voltage-current equations are

$$[v] = [R][i] + [L]p[i] + w_r[G][i] \quad (1)$$

From which, the current derivative can be expressed as:

$$p[i] = [L]^{-1}\{[v] - [R][i] - w_r[G][i]\} \quad (2)$$

Where, $[v]$, $[i]$, $[R]$, $[L]$ and $[G]$ are defined in Appendix

The developed electromagnetic torque (T_e) is as

$$T_e = (3P/4)\, L_m \left(i_{qs} i_{dr} - i_{ds} i_{qr}\right) \quad (3)$$

The electromagnetic torque balance equation is as

$$T_{shaft} = J(2/P) p w_r + T_e \quad (4)$$

Where T_{shaft} is the input torque i.e. transmitted to the shaft of the generator from prime mover (typically wind turbine) and T_{shaft} is also can be expressed by,

$$T_{shaft} = a - b w_r \quad (5)$$

The values of 'a' and 'b' for the under test are given in Appendix .

The derivative of the rotor speed (w_r) from equation is as

$$p w_r = \left(\frac{1}{J}\right)\left(\frac{P}{2}\right)\left(T_{shaft} - T_e\right) \quad (6)$$

The generator operates in the saturation region and it magnetization characteristic is non-linear in nature. Hence the magnetization current (I_m) should be calculated in every step of integration is terms of stator and rotor current as

$$I_m = \frac{\left\{(i_{ds} + i_{dr})^2 + (i_{qs} + i_{qr})^2\right\}^{\frac{1}{2}}}{\sqrt{2}} \quad (7)$$

Three-phase currents are obtained by converting direct and quadrature axes components into a, b, c phase currents as follows:

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \end{bmatrix} \quad (8)$$

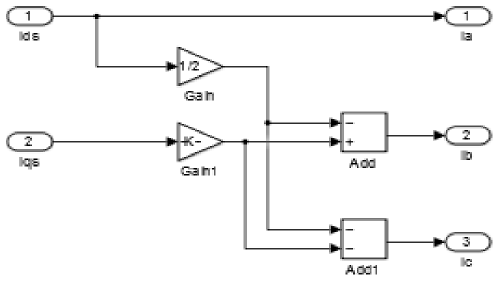
$$v_{ds} = (2/3)\left\{v_a - \left(\frac{v_b}{2}\right) - \left(\frac{v_c}{2}\right)\right\} \quad (9)$$

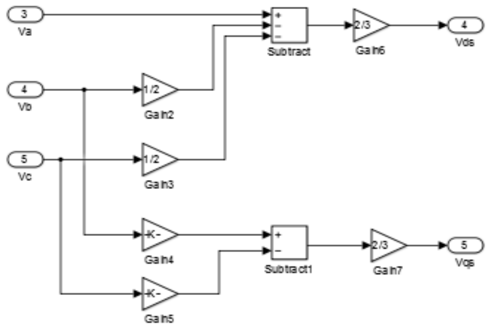
$$v_{qs} = (2/3)\left\{\left(\frac{\sqrt{3}v_b}{2}\right) - \left(\frac{\sqrt{3}v_c}{2}\right)\right\} \quad (10)$$

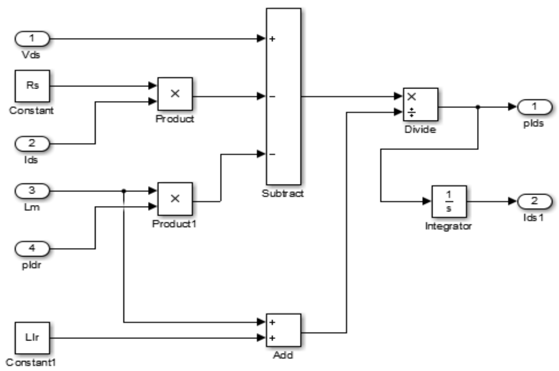
…….[5][6]

II. SIMULINK MODEL

To perform the analysis of the system, we construct a model with the help of mathematical equations. Here we used MATLAB/SIMULINK. The subsystems of proposed SIMULINK model of AG in stand-alone mode has been shown below:







III. RESULT AND DISCUSSION

Since the studied Asynchronous Generator in stand-alone mode must be excited by a fixed capacitor bank with 50µF/phase is used to supply the required reactive. A three-phase balanced inductive load is taken for this simulation. For the loading condition, a sudden change is observed in the output terminal of asynchronous generator self-excited mode. As a result the changes in phase voltage and phase current obtained after t=5sec in

fig1.

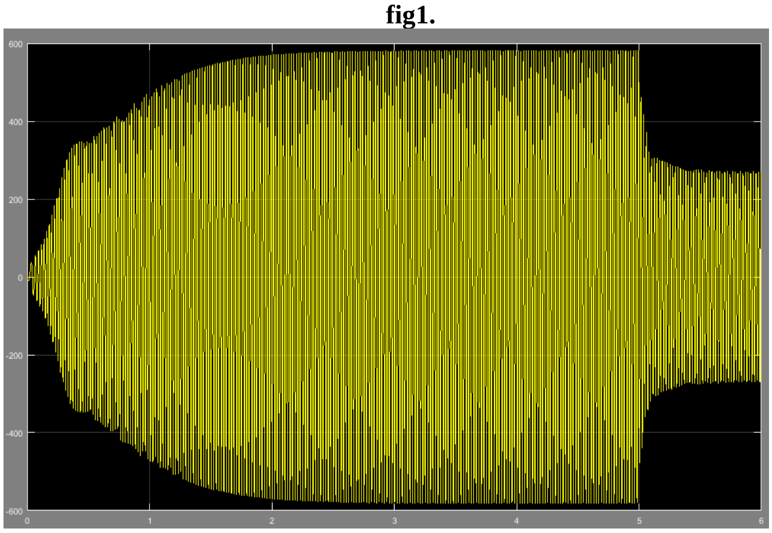


Fig 1. output voltage after applying load t=5sec

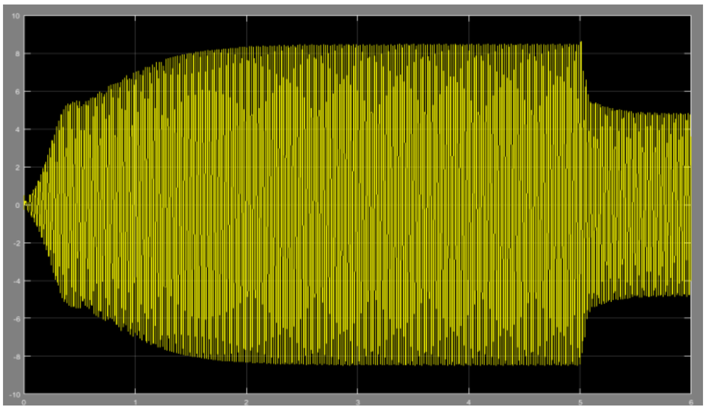


Fig.2 output current after applying load at t=5sec

Now we withdraw the load at t=5sec and suddenly terminal gets short circuited.

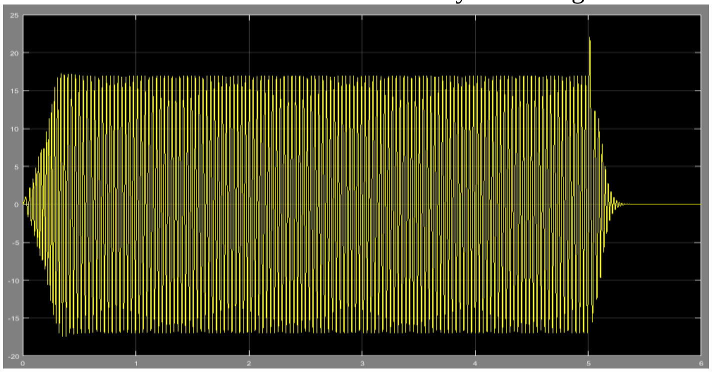


Fig.3 Output current during short circuit condition at t=5sec

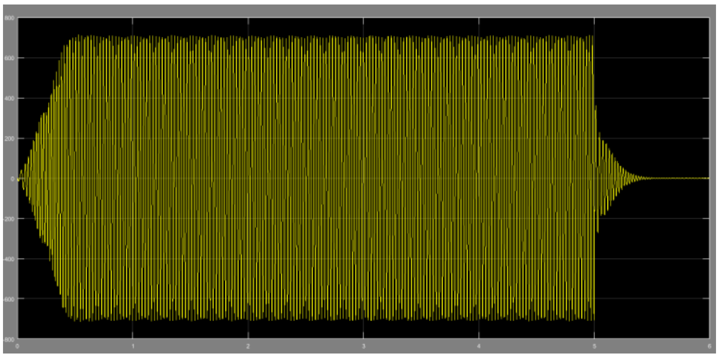


Fig4. Output voltage during short circuit condition at t=5 sec

IV. CONCLUSION

Dynamic models are developed using d-q axes stationary reference frame for determining transient response condition. The developed model is tested by simulating the dynamic behaviour during load perturbation. Voltage drop with inductive load occurs as expected. The dynamic behaviour plays a vital role to predict the operation of asynchronous generator in stand-alone mode to obtain better performance. The analysis and results presented in this paper prepare a foundation for employing the asynchronous generator in a numerous scope for further research and experimentation in the field of renewable energy.

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V. APPENDIX

Parameters of 2.2 kW, 230 V, 50 Hz,7.8 A, 4-pole, 3-ph squirrel cage asynchronous generator is operated at stand-alone mode. The parameters are as follows:

P = 4;
Lls = 0.0142H/14.2mH;
Llr = 0.0142H/14.2mH;
Rs = 2.88Ω;
Rr = 2.88Ω;
C = 0.00005F/50μF;
J = 0.0842kg/sq. m;
a = 249.39;
b = 0.7875;

$$[G]= \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -L_m & 0 & -L_{rr} \\ L_m & 0 & L_{rr} & 0 \end{pmatrix}$$

$$[L]= \begin{pmatrix} L_{ss} & 0 & L_m & 0 \\ 0 & L_{ss} & 0 & L_m \\ L_m & 0 & L_{rr} & 0 \\ 0 & L_m & 0 & L_{arrv} \end{pmatrix}$$

Where, $L_{ss} = L_{ls} + L_m$
and $L_{rr} = L_{lr} + L_m$

$$L_m = 0.3177 \quad (\text{for } I_m \leq 0.75)$$

$$= 0.3502 - 0.0349\, I_m + 0.0017\, I_m^2 \quad (\text{for } 0.75 < I_m \leq 4.25)$$

$$= 0.17677 \quad (\text{for } I_m > 4.25)$$

…..[5][6]

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