Performance Characteristics of SEIG used in Wind Energy Conversion System

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Abstract— This paper shows the wind driven self-excited induction generator used in wind turbine for drive applications. The self-excited induction generator is mathematically modeled to perform efficiently as a real time performance. Here we used voltage source inverter which is a normal pulse width modulation inverter fed with resistive load. A voltage source inverter is used which forms a bridge between the self-excited induction generator and a load .The voltage source inverter are used to provide to make a system simple and cost effective. The simple arrangement is used such that the efficiency of the system becomes high with minimized losses. The PWM Inverters (VSI) is used to convert the variable magnitude and frequency voltage into reliable constant voltage and constant frequency supply to drive the isolated load. The self-excited induction generator and other power electronic converter components are modeled through coding and simulation in MATLAB/SIMULINK 8.1.604 (R2013a).

Key words: Self excited Induction Generator (SEIG), Wind Turbine (WT), Pulse Width Modulation (PWM), Wind Energy Conversion System (WECS), Voltage Source Inverter (VSI)

I. INTRODUCTION

Nowadays renewable energy generation technology is increasing day by day in research and developments to produce a clean and green environment. The wind energy conversion system i.e the use of wind energy is the most desirable among all the renewable generation research technology. In the wind energy system, most practically, the self-excited induction generator is used in wind turbine applications because of its many advantages in terms of cost effectiveness. In rural areas wind driven self-excited induction generators with wind turbine are widely used for drive applications. The rural electrification is done or mainly dependent on this wind energy conversion system. In this paper, similar work is performed by using the self-excited induction generator used through voltage source inverter to drive a load.

II. CIRCUIT DIAGRAM

In this circuit diagram the Wind turbine is connected to the SEIG rotor through the shaft system. A braking mechanism is used during very high speed rotation due to very high wind velocity. The wind driven SEIG whose three phase output is connected to the rectifier to convert AC to DC. The rectifier rectifies the DC output and it is the source to the VSI, then the DC is converted into AC which is sufficient to drive a load. The Simulink representation as produces the same effect of a real time implementation, also shows the effect which is rectified by a power electronic circuit. The block diagram is shown in fig 1.The mathematical models developed are tested in MATLAB environments the voltage, current, active and reactive power are obtained at a wind speed of 10m/s. The initial fluctuation in the voltage shows the process of self-excitation. The machine develops the rated voltage after reaching the saturation region.

III. MODELING OF SELF EXCITED INDUCTION GENERATOR

The mathematical model which is used to study the SEIG is classified into two major categories, the per phase equivalent circuit approach which is done by loop impedance method and nodal admittance method. The other is the d-q axis model based on the generalized machine theory. The first method is used for analyzing under steady state condition. The d-q axis model of the machine is used to predict the dynamic behavior of SEIG.

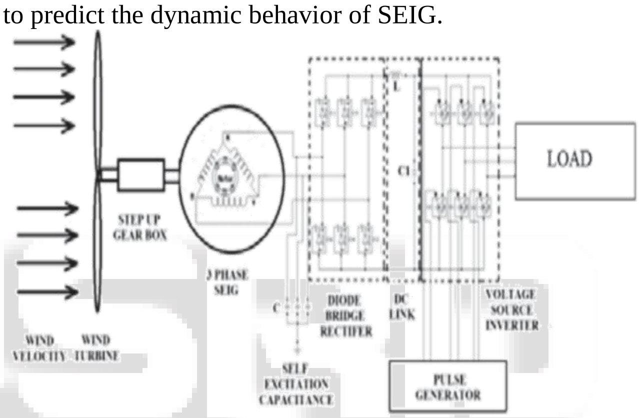

Fig. 1: Block diagram of SEIG fed wind turbine

In the equivalent circuit model shown in Figure 2 , the core losses and the effect of harmonics in neglected.

The total current at a node is given by

$$E_1 (Y_1 + Y_m + Y_R) = 0 \quad \ldots\ldots\ldots..(1)$$

Under steady state self-excitation the total admittance must be zero. Since E1 not equal to zero where,

$$(Y_1 + Y_m + Y_R) = 0 \quad \ldots\ldots\ldots\ldots..(2)$$

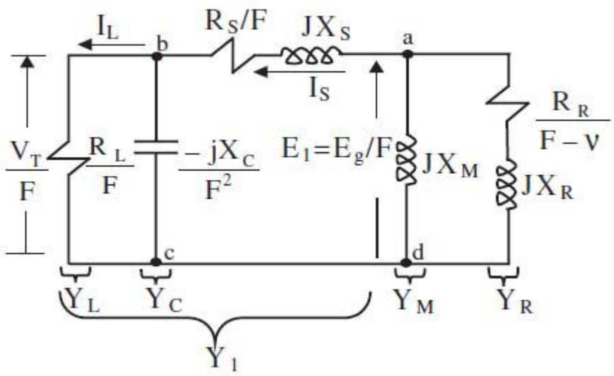

Fig. 2: Per phase equivalent circuit of SEIG

The performance characteristics of the generator are given by,

$$IS = \frac{E_S/F}{\frac{R_S}{F} + jX_s - \frac{j X_C R_L}{F^2 R_L - FX_C}} \quad \ldots..(3)$$

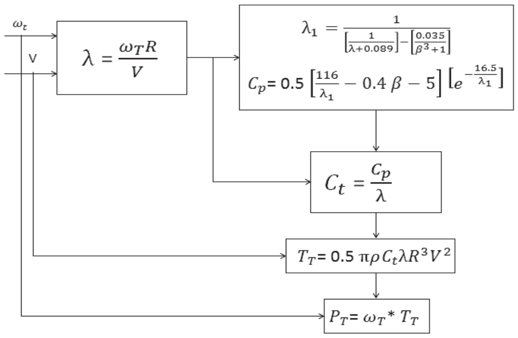

Fig. 3: Power equation of SEIG

$$I_L = \frac{-\,j X_C I_S}{R_L F - jX_C} \qquad (4)$$

$$P_{IN} = \frac{-3 R_R F\,|I_L|^2}{F - v} \qquad (5)$$

$$I_R = \frac{-E_S/F}{\frac{R_S}{F - v} + X_L} \qquad (6)$$

$$V_T = I_L . R_L \qquad (7)$$

$$P_{OUT} = 3\,|I_L|^2 R_L \qquad (8)$$

IV. WIND TURBINE MODEL

This model is based on the steady-state power characteristics of the turbine. In fact, to simulate the behavior of the wind turbine, the torque that it exerts on the mechanical shaft must verify the relation:

$$T_{turbine} = T_{em} = P_m / \Omega_t \quad .....(9)$$

Where Pm is the output power of the turbine (mechanical power extracted from the wind) given by the following:

$$P_m = \frac{1}{2} \rho\, S\, C_P(\lambda, \beta)\, v^3_{WIND} \quad .....(10)$$

Where,

ρ = Air density (kg/m)

S = Turbine swept area (m)

Cp = Performance coefficient of the turbine

V_{WIND} = Wind speed (m/s)

λ = Tip speed ratio of the rotor blade tip speed to wind speed

β = Blade pitch angle (deg)

Ωt(rad/s) is the mechanical speed of the turbine ,

$$\Omega_t = \frac{\lambda\, v_{wind}}{R_t} \quad (11)$$

By introducing another parameter, coefficient of torque,

$$C_m = \frac{C_p}{\lambda} \quad (12)$$

The mechanical shaft is defined as

$$T_{em} = \frac{1}{2} . \rho . \pi . R_t^3 . C_m . v^2_{WIND} \quad 13)$$

In our simulation case, we have adopted the relation for the evaluation of coefficient C_m as a parameter of λ.

V. MODELING OF VSI

The wind driven SEIG voltage is mainly depending upon the wind velocity and loading conditions. The dynamic modelling and the steady state performance of the voltage source inverter. The wind driven SEIG voltage is first rectified by the diode bridge rectifier. The uncontrolled bridge rectifier is used to convert the variable magnitude, variable frequency voltage at the induction generator terminal into DC supply. The DC voltage VR at its output can be expressed in terms of the peak phase voltage $V_{ds} = V_g$ of the generator and the input transformer's turns ratio 1:1

$$V_R = \left(\frac{3\ \text{sqrt}\ 2}{\pi}\right)\left(\frac{\text{sqrt}\ 3}{\text{sqrt}\ 2}\right) * \text{Vds} * \text{n} \quad ...(14)$$

$$V_R = 1.65\, V_{ds}\, \eta i \quad .....(15)$$

Ripple factor = $0.2*10^{-4}$, R= 1000 ohm , F = 50Hz

Ripple factor = 1

C = 900 µf

The series reactor reduces the current ripple content in the rectifier output current and the shunt capacitor reduces the ripple content in the DC link voltage providing a relatively stiff voltage source for the PWM inverter.

The DC link current is governed by the following differential Equation

$$Pi_{DC} = \left(\frac{1}{L_{DC}}\right)(V_R - V_1 - R_{DC}\, i_{DC}) \quad ...(16)$$

Where R_{DC} and L_{DC} are the DC link reactor's resistance and inductance respectively, i_{DC} is the DC link current (neglecting the small charging discharging filters capacitor current) and V_I is the DC voltage at the inverter Input.

The DC power transferred over the DC link to the isolated load is given by the Equation:

$$Po = V\,R\,i_{DC} \quad .....(17)$$

The DC power available at the rectifier output is filtered and converted to ac power using a PWM inverter employing double edge sinusoidal modulation.

The output consists of sinusoidally modulated train of carrier pulses, both edges of which are modulated such that the average voltage difference between any two of the output three phases varies sinusoidally.

Where *M* is the modulation index and ranges from 0 to1, subscript *x* denotes the edge being considered, *r* is the ratio of the carrier to fundamental frequency at the inverter output, *x* is the angular displacement of the un-modulated edge and max is the maximum displacement of the edge for the chosen frequency ratio *r*.

The Simulink representation as produces the same effect of a real time implementation, also shows the effect which is rectified by a power electronic circuit. The circuit diagram is shown in fig 4.

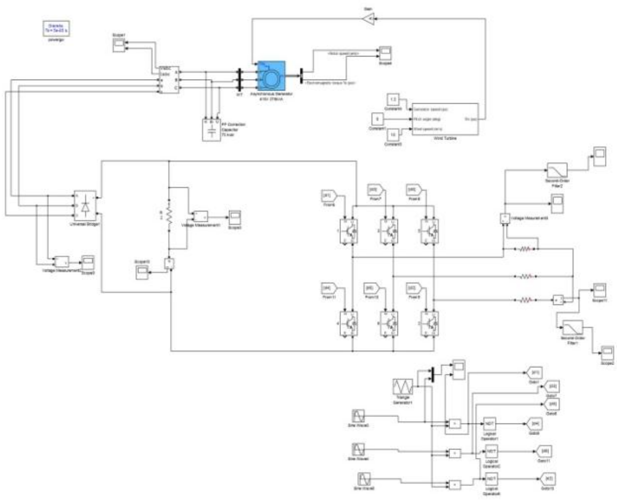

Fig. 4: Simulink model of SEIG fed with wind turbine

The mathematical models developed are tested in MATLAB environments the voltage, current, active and reactive power are obtained at a wind speed of 10m/s.

The initial fluctuation in the voltage in Fig.7 shows the process of self-excitation.

The machine develops the rated voltage after reaching the saturation region. The load should be connected after reaching the rated voltage

VI. OUTPUT WAVEFORMS

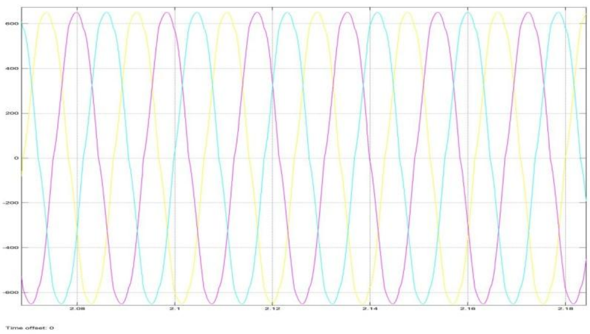

Fig. 5: Generated outputvoltage of SEIG

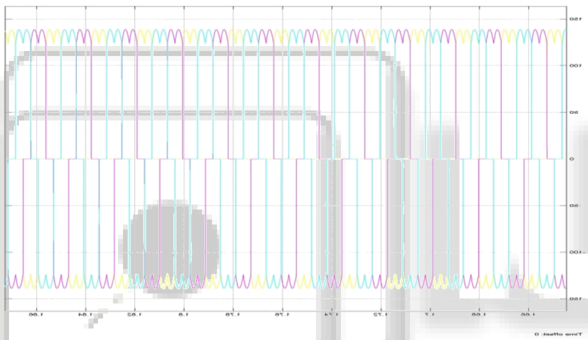

Fig. 6: Generated output current . . of SEIG

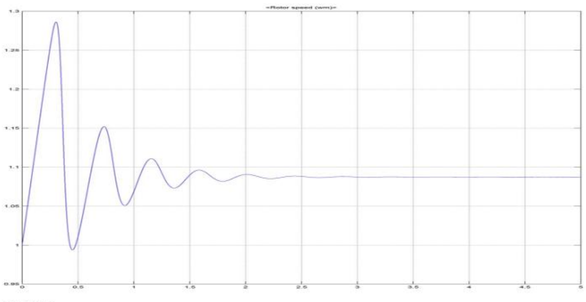

Fig. 7: Rotor speed of SEIG

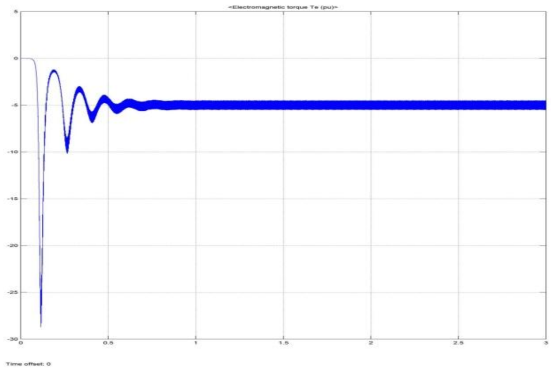

Fig. 8: Electromagnetic torque of SEIG

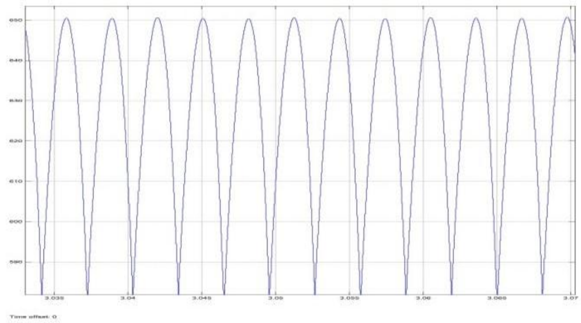

Fig. 9: Rectified d.c voltage waveform

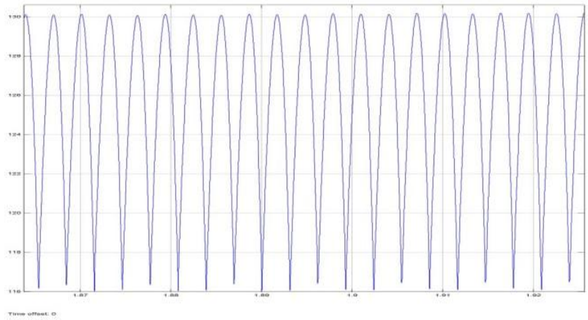

Fig. 10: Rectified d.c current waveform

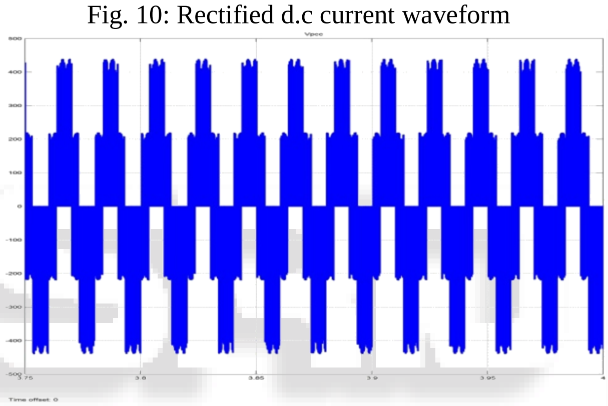

Fig. 11: Inverted line to line voltage waveform

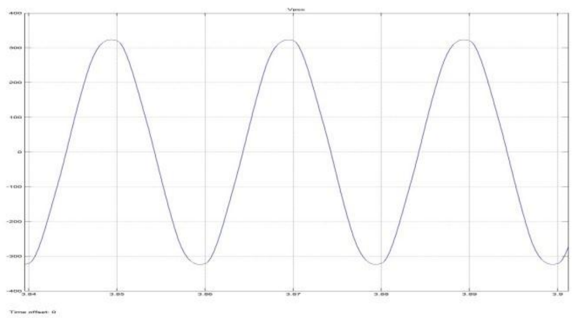

Fig. 12: Smoothen inverted output line to line voltage waveform

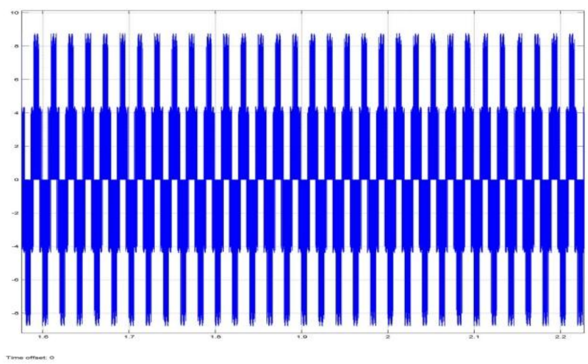

Fig. 13: Inverted output line to line current waveform

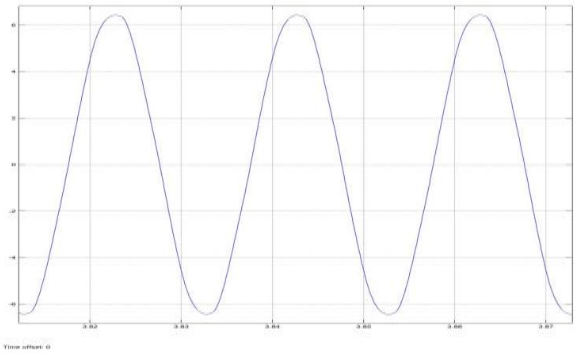

Fig. 14: Smoothen inverted output line to line current waveform

VII. CONCLUSION

The analysis and simulation results of a SEIG fed VSI for wind energy conversion system have been described. The research work is done for a wind driven SEIG connected to a VSI controlled by simple PWM technique. A wide variation in the output voltage and frequency is observed for varying wind velocities and load conditions. The SEIG is designed such that the wind speed is 10m/s. The output of the SEIG is 6kW. The system proposed is very simple and the implementation is cost effective.

VIII. SCOPE OF FUTURE WORK

The research work is proposed in the implementation of a stand-alone application driving submersible pump. The proposed work can be more efficiently performed by implementing different types of PWM inverters with reduced harmonics content of the output voltage and current, various multi – level dc-ac converter topologies are proposed and analysed in recent years. These multilevel topologies are basically derivations from the two level topology by adding additional IGBT power switches to the bridge circuit. PWM control techniques are still the most popular and efficient method for multilevel power conversion of theoretical and simulation approaches.

REFERENCES

[1] F.Max Savio, Dr. M.Sasikumar, ieee transaction session 2012 ,Performance characteristics of three phase wind driven SEIG for drive applications.
[2] Haval sardar kamil , international journal of recent technology and engineering, ISSN 2277-3878 , Volume-2 , issue -2 ,may 2013, analysis of SEIG driven by wind turbine system using CSI technology.
[3] M.Sasikumar and S. Chenthur Pandian, international journal of recent technology and engineering, ISSN 2277-3878, Volume-2, no. 6, december 2010, performance characteristics of SEIG fed CSI for wind energy conversion applications.
[4] Y. Zidani and M. Naciri, 'A numerical analytical approach for the optimal capacitor used for the self excited induction generator,' IEEE CNF,Vol. 1, pp. 216 – 220, June 2001.
[5] Sasikumar M. and Chenthur Pandian S. (2010),'Implementation of an impedance source inverter based variable speed wind driven self – excited induction generator,' Journal of Electrical Engineering (JEE), Vol.10, Edition 3, pp. 43 –47.
[6] Ahmed T., Nishida K. and Nakaoka M. (2007), 'Advanced control for PWM converter and variablespeed induction generator" IE Transactions on Electric Power Applications, Vol.1, No. 2, pp. 239 – 247.
[7] F.O.Stebbins, 'Effects of capacitors and varied voltages upon induction motor characteristics,' IEEE Transactions on Energy Conversion,Vol. 5, No. 4, pp. 725 – 732.
[8] Al-Bahrani A. H. and Malik N. H. (1993), 'Voltage control parallel operated self excited induction generators,' IEEE Transaction on Energy Conversion,Vol. 8, No. 2, pp. 236-242.
[9] Aloah A. and Alkanhal M. (2000), 'Optimizationbased steady state analysis of three phase self-excited induction generator,' IEEE Transaction on Energy Conversion, Vol. 15, No. 1, pp. 61-65. 185
[10] Li Wang and Chang – Ming Cheng,'Excitation capacitance required for an isolated three phase induction generator under single phase mode operations,'IEEE CNF, Vol. 3, pp. 1403 – 1407, Feb 2001.
[11] Borowy B. S.and Salameh Z. M. (1997), 'Dynamic response of a stand-alone wind conversion system with battery energy storage to a wind gust,' IEEE Transactions on Energy Conversion, Vol.12,No. 1, pp. 73-78.
[12] Chan T. F and Lai L. L. (2004), 'A novel excitation scheme for a stand-alone three-phase induction generator supplying single phase loads", IEEE Transactions on Energy Conversion, Vol. 19, Issue 1,pp: 136 – 143.
[13] S.P Singh, S.K Jain, and J. Sharma, 'Voltage regulations optimization of compensated self excited induction generators with dynamic load,' IEEE Transaction on Energy Conversion, Vol. 19, No. 2, pp. 724– 732, Dec 2004.
[14] Chandan Chakraborty, Sailendra Ajit K. and Chatto Padhyay (1998), 'Excitation requirements for standalone three phase induction generator", IEEE Transaction on Energy Conversion, Vol. 13, No. 4,pp. 358 – 365.