Analysis of Self Excited Induction Generator Driven By Wind Turbine System Using Current Source Inverter Technology

Haval Sardar Kamil

Abstract: ***This paper describes the simulation model and the harmonics analysis of Current Source Inverters fed RL load. The SEIG fed PWM Current Source Inverter for variable speed wind energy conversion systems are considered for various stand-alone applications. In this paper, the SEIG fed IGBT PWM Inverter for RL load system are clearly explained with the help of MATLAB/SIMULINK models. The generated voltage of wind driven self-excited induction generator (SEIG) is mainly depending on the wind velocity fluctuations, suitable capacitance magnitude and load conditions. The PWM Inverter has interface with the wind driven self-excited induction generator. The main objective of this paper is to extract maximum power from the generator to the grid connected wind energy conversion system. The variable magnitude, variable frequency voltage of the generator can be controlled by choosing the proper modulation index. The simulation analysis of the proposed inverter will be discussed and the total harmonic distortion will be evaluated.***

Index Terms: Self-Excited induction generator (SEIG), Current Source Inverter, Pulse Width Modulation (PWM), Wind Turbine, Wind Energy Conversion Application (WECs), Isolated load.

I. INTRODUCTION

Windy areas, waterfalls, reservoirs, high tide locations are extremely helpful for generating clean and economical electrical energy by proper harnessing mechanism. Throughout the globe in last three to four decades generation of electricity out of these renewable sources has created wide interest. Growing interest in water management and Sustainable environment toward a sustainable world has awakened new sources of hydro energy. Among these are the run-of-river plants to produce electricity using induction generators. The induction generator self-excitation phenomenon is reviewed in [1]. The brushless construction, robustness, low maintenance requirements, absence of DC power supply for field excitation, small size, and self-protection against short circuits are the advantages of asynchronous generator over the synchronous and DC generators. The relatively poor voltage and frequency regulation and low power factor are its weaknesses. The frequency and magnitude of voltage generated by the self-excited induction generator (SEIG) is completely governed by the rotor speed, the excitation and the load. There exist minimum and maximum capacitances for the self-excitation to occur i.e., voltage build up at a particular speed.

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Also it requires a minimum cut in speed for successful voltage build up and it has a maximum speed limit considering mechanical safety for a fixed excitation capacitance [3-4].

The effect of dynamic mutual inductance on voltage build up process of SEIG is discussed in [5]. The application of power semiconductor devices, controlled converter circuits. From the electricity company standpoint, accurate controls of voltage and frequency can limit the electrical and mechanical stresses in the power system and delivering a good quality energy. Previously many circuits are proposed to control the output voltage and/or frequency [6, 7, 8].

The SEIG become the most widely used wind turbine systems for low cost impassable machine. The generated speed of the induction generator is mostly depending on wind velocity conditions and modulation index. Due to the economic views and reliable characteristics, the CSI topologies have adopted for various applications based on the performance features such as simplicity, ruggedness, cost effectiveness, and low switching losses.

Various PWM techniques used to obtain the required voltage in inverter terminals. It can be applied to two types of control signals of IGBT switches,180º and 120º conduction modes are the types to produce required output voltage. Current source inverter has simple control circuit and good efficiency but it produces pulsating torque at low speed and they cannot deal with small capacity engines. The variable output voltage of the generator is rectified and inverted using the PWM inverter. The modulation index adjusted such that the voltage at the output has maintained. The main goal of this paper is to use such type of induction generators in order to control the electromagnetic torque, active power as well as reactive power under dynamic conditions of varied load, excitation capacitance and shaft speed using the current source inverter, voltage source inverter techniques. In this project we are presenting the analysis of such model under the various conditions.

II. SYSTEM CONFIGURATION:

In this proposed system, power generation system is made up of wind turbines with SEIG connected load isolated through electronic power converter. The variable output voltage from the generatoris first rectified using diode bridge rectifier and theninverted by using PWM inverter. In these three phaseinverters system consists of six IGBT switches. Three phaseinverters are normally used for medium and high powerapplications. Shunt capacitor is used in dc- link; it serves asa low impedance voltage source. Each switch conducts for120degrees.

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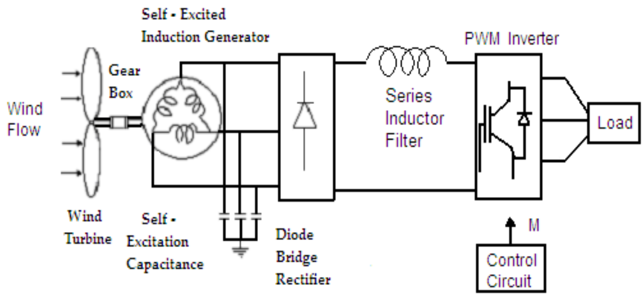

Fig 1 Block Diagram of the voltage source inverter fed Isolated Wind Energy Conversion System

The output power of SEIG depends upon thewind velocity of the horizontal axis wind turbine. The uses capacitors excitation to reduce the burden of reactive power of induction generators[8]. Capacitance value is to determine the energy production output of SEIG. The variable magnitude and variable frequency output is given to power electronic converters. The voltage source inverter is used to obtain constant voltage and constant frequency. Current source inverter is used as boost operation of inverter.
The dc link voltage ripples in the rectifier output is filtered using shunt capacitor filter. The PWMtechniques are used to control the inverter output voltage and frequency as well. It is also affected by EMI noise. The block diagram of the system is shown in Fig. 1.

A-Wind Turbine Characteristics:

A wind turbine is a turbine driven by wind. Modern wind turbines are technological advances of the traditional windmills which were used for centuries in the history of mankind in applications like water pumps, crushing seeds to extract oil, grinding grains, etc. In contrast to the windmills of the past, modern wind turbines used for generating electricity have relatively fast running rotors [9].

$$KineticEnergy = 0.5pAV.V^2 = 0.5pAV^2 \quad \ldots\ldots\ldots (1)$$

The output power of wind turbine given by:

$$Pw = 0.5pCpAV_w^3 \quad \ldots\ldots\ldots\ldots (2)$$

$C_p$is expressed as a function of (λ):

$$\lambda = \frac{R\omega_t}{V_\omega} \quad \ldots\ldots\ldots\ldots (3)$$

Dimension less power co-efficient C_p:

$$C_p = 0.5[\frac{116}{\lambda_1} - 0.4\beta - 5]e^{\frac{-16.5}{\lambda_1}} \quad \ldots\ldots\ldots (4)$$

In principle there are two different types of wind turbines: those which depend mainly on aerodynamic lift and those which use mainly aerodynamic drag. High speed wind turbines rely on lift forces to move the blades, and the linear speed of the blades is usually several times faster than the wind speed. However with wind turbines which use aerodynamic
drag the linear speed cannot exceed the wind speed as a result they are low speed wind turbines. In general wind turbines are divided by structure into horizontal axis and vertical axis.

B- Self – Excited Induction Generator:

Initially the work over SEIGs (especially three phase) excited by the three capacitors was done with goal of practical evaluation. The main methods of representing a SEIG are the steady state model and the dynamic model. The steady state analysis of SEIG is based on the steady state per-phase equivalent circuit of an induction machine with the slip and angular frequency expressed in terms of per unit frequency and per unit angular speed. The steady state analysis includes the loop-impedance method [8] and the nodal admittance method [9]. The loop-impedance method is based on setting the total impedance of the SEIG, i.e. including the exciting capacitance, equal to zero and then to find the steady state operating voltage and frequency using an iteration process. In the nodal admittance method the real and imaginary parts of the overall admittance of the SEIG are equated to zero. The equations are formulated based on the steady state conditions of the SEIG. The main drawback of using the per-phase steady state equivalent circuit model is that it cannot be used to solve transient dynamics because the model was derived from the steady state conditions of the induction machine. The dynamic characteristics of SEIG can be represented bythe electromechanical equation derived in thesynchronously rotating q-d reference frame [9-10].

$$pi_{qs} = -K_1 r_1 i_{qs} - (i_{qs}/Cv_{ds} + K_2 L_m w_m) i_{ds} + K_2 r_2 i_{qr} - K_1 L_m w_m i_{dr} \ldots\ldots (5)$$

$$pi_{ds} = (i_{qs}/Cv_{ds} + K_2 L_m w_m) i_{qs} - K_1 r_1 i_{ds} + K_1 L_m w_m i_{qr} + K_2 r_2 i_{dr} - K_1 v_{ds} \ldots\ldots (6)$$

$$pi_{qr} = -K_2 r_1 i_{qs} + L_1 K_2 w_m i_{ds} - (r_2 + K_2 L_m r_2) L_2 i_{qr} + (K_1 L_1 w_m - i_{qs}/Cv_{dc}) i_{dr} \ldots\ldots (7)$$

$$pi_{dr} = -L_1 K_2 w_m i_{qs} + K_2 r_1 i_{ds} - (L_1 K_1 w_m - I_{qs}/Cv_{ds}) i_{qr} + (r_2 + K_2 L_m r_2) L_2 i_{dr} + K_2 v_{ds} \ldots\ldots (8)$$

Where:

$$K_1 = \frac{L_r}{(L_s L_r + L_m^2)} \quad \ldots\ldots\ldots (9)$$

$$\text{and } K_2 = \frac{L_m}{(L_s L_r - L_m^2)} \quad \ldots\ldots\ldots (10)$$

C. Diode Bridge Rectifier and DC Link

Three phase uncontrolled bridge rectifier is used to convert the variable voltage and variable frequency at the induction generator terminal into rectified dc voltage [11]. To simplify the analysis, all the diodes are assumed to be ideal (no power losses or on-state voltage drop).The dc voltage *vd*contains six pulses (humps) per cycle of the supply frequency. The rectifier is, therefore, commonly known as a six-pulse

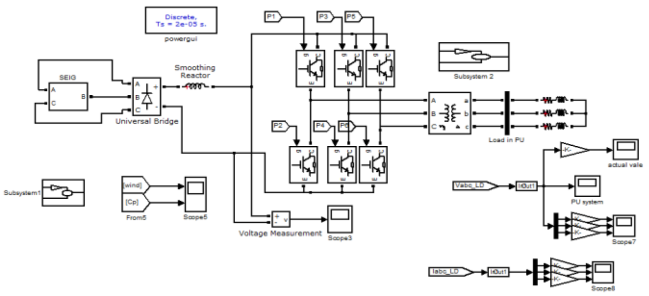

Figure 2: MATLAB/SIMULINK of the proposed SEIG Model with RL load

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Rectifier [8].The average value of the dc voltage can be calculated by input transformer's turn's ratio is 1:n

$$V_d = \left[\frac{3\sqrt{2}}{\pi}\right]\left[\frac{\sqrt{3}}{\sqrt{2}}\right] * V_{dc} * \eta_i \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Input transformer's turn's ratio is 1:ηi. The series reactor (L) and shunt reactor (*Csh) acts*as an input filter. The current ripples and voltage ripples are reduced by using the above components.

Dc-Link current is governed by the following equation:

$$pi_{dc} = (1/L_{dc})(V_r - V_i - r_{dc} i_{dc}) \ldots\ldots\ldots \quad (12)$$

Where, RDC and LDC are the reactor resistance and inductance respectively.

D. PWM Inverter

The output power of the rectifier is filtered by using LC filter. By using PWM inverter DC power is converted into AC power employing double edge sinusoidal pulse width modulation technique [10]. The PWM signals are used to switch on the IGBTs in the inverter. The IGBTs are connected anti parallel with the diodes. If diode conducts energy will fed back to the source. The carrier wave is compared with the reference signal corresponding to a phase to generate gating signals. The instantaneous line – to – line output voltage is VAB = VS (g1-g3).

III. MODELING AND RESULT DISCUSSION

The open loop control of the SEIG fed Current Source Inverter based WECS using MATLAB/SIMULINK model has been presented. The steady state and dynamic characteristics behavior of the induction generator is determined by using equivalent circuit d-q model of the generator system. The required parameters for the modeling of SEIG are determined. The parameters obtained at rated values of voltage. The Simulink model of SEIG fed Current Source Inverter with RL load is shown in Fig.2**.** The generated voltage of SEIG (375) volts, the waveforms of output voltage is shown in Fig.3**.** The three phase generated current shown in Fig.4.The output voltage of SEIG is converted to DC voltage by using uncontrolled bridge rectifier. The output voltage of the rectifier contains more voltage ripples. The smoothing reactor is used to filter out the ripple contents and to improvevoltage magnitudes. The DC voltage that obtained it by the rectifier is given to the three phase current source inverter. This inverter is being used to produce required output voltage. The inverter contains of number of IGBT switches. The IGBT switches used to reduce the output ripples as well as improving the magnitude of the voltage. The inverter output fed to the load by using three phase step up transformer. The load phase current shown in Fig.5. The obtained output voltage of the load is shown in Fig.6. And the P.U magnitude of the load voltage has shown in Fig.7. In the simulation analysis the value of R=25 ohm and the L=350mH has been used. Harmonics is presenting in the output of the load that's mostly depending upon the magnitude of the inductance. The FFT analysis of the inverter is shown in the Fig.8. And The Total Harmonic Distortion value THD is 4.54%.

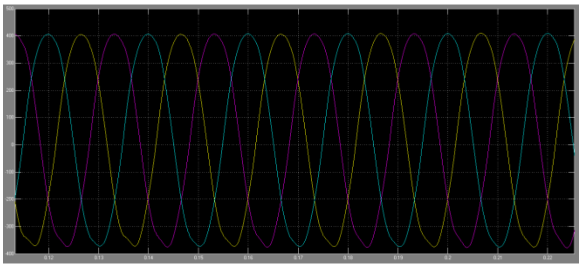

Fig.3 SEIG Generated Voltage

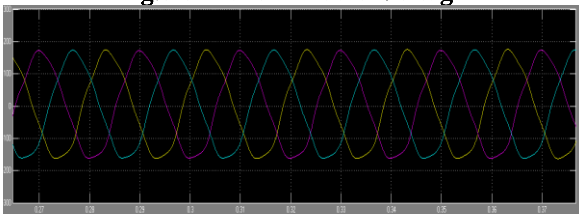

Fig.4 Three Phase Current

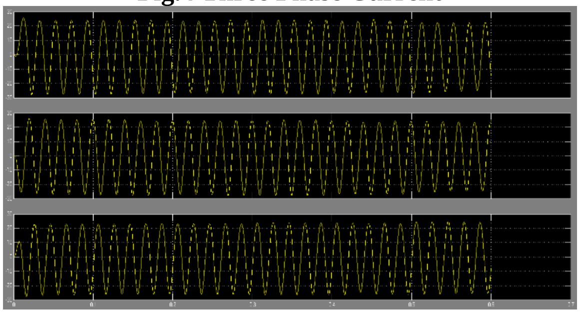

Fig.5 Phase to Phase Load Current

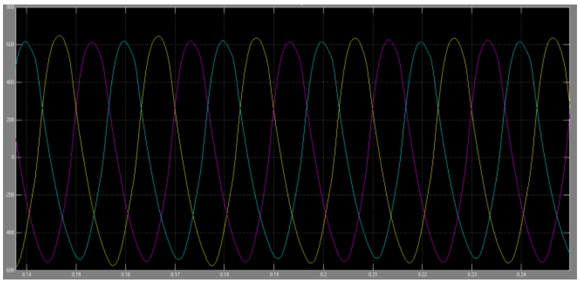

Fig.6 Three Phase Load Voltage (Actual Vale)

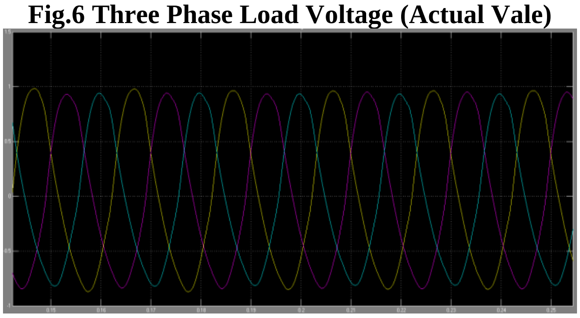

Fig.7 Three Phase Load Voltage (P.U)

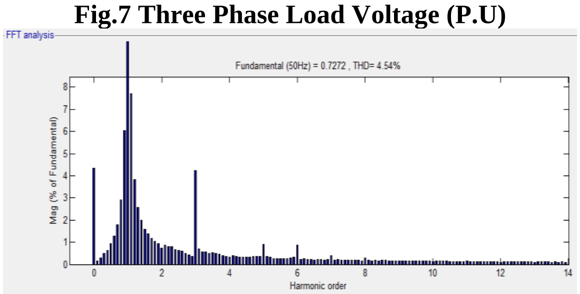

Fig.8 Simulation Result of Frequency Spectrum

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IV. CONCLUSION

The current source inverter fed wind driven self-excited induction generator based power generation system in wind energy conversion systems has been proposed and corresponding simulated waveform graphs are verified. The proposed work demonstrated the state of art ac-dc-ac power converter technology. A DC link converter is introduced in WECS model, and the effect of modulation index on the generated power is studied for a given wind velocity and load. The smoothing reactor (impedance network) is used for both buck and boost operation, and this is also acts as a second order filter. Using the current source inverter fed drive system reducing the harmonic contents.

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