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An Interconnected Wind Driven SEIG System Using SVPWM Controlled TL Z-Source Inverter Strategy for Off-Shore WECS

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Abstract

This paper discuss about the interconnection of wind driven SEIG for drive applications by using TL Z-source inverter strategy .TL Z-source consists of two coupled inductors having turns ratio γTL and four diodes are used . The wind energy system uses a two Self Excited Induction generator (SEIG) connected parallel in order to increase the reliability. The proposed system components like wind turbine SEIG, rectifier, SVM Controlled TL Z-source inverter, are modeled by matlab Simulink. The maximum power can be extracted and supplied to the load efficiently by using TL Z-source inverter with a proper value of modulation index. The simulation output is analysed experimentally using 500 W experimental setup.

***Keywords**: Self-Excited Induction Generator (SEIG), tapped-inductor Z-source inverter (TL-ZSI), Wind Turbine, wind Energy conversion Scheme (WECS), Space Vector Modulation (SVM).*

1. Introduction

Wind energy conversion system includes a wind turbine generator, interconnection apparatus and control systems. Horizontal axis type wind turbines are used. Wind turbine can be designed for a constant speed or variable speed operation. In this paper we have introduced interconnection of wind turbine with TL Z-source inverter [1].This technique mainly used in OFFSHORE WIND ENERGY CONVERSION. Offshore wind power refers to the construction of wind farm in bodies of water to generate electricity from wind. Better wind speeds are available offshore compared to on land, for lossless transmission DC transmission system is used. Offshore wind more economically viable due to reducing the weight of turbine materials. Eliminating problematic gearboxes. For offshore windmill.we mainly used self excited induction generator (SEIG)[1][2] because of following reasons. used in remote area because of low maintaince .to generate the power from variable speed as.low unit cost, reduced maintenance, rugged and brushless rotor, absence of a separate d.c . In this paper we using new interconnection technique using TL Z-source inverter we can improve the efficiency.

While comparing TL Z-source inverter with other inverters like VSI and CSI [2]. In VSI where the independently controlled ac output is a voltage waveform, it is used in many industrial applications, such as adjustable speed drives; it is a buck inverter for dc-to-ac power conversion. It is a boost converter for ac-to-dc power conversion. In CSI where the independently controlled ac output is a current waveform. These structures are still widely used in medium-voltage industrial applications, where high-quality voltage waveforms are required.

In both VSI and CSI some disadvantages are occurred they are either a boost or a buck converter and cannot be a buck–boost converter. In other words, neither the V-source converter main circuit can be used for the I-source converter.It produce EMI noise. To overcome the above problems traditional V-source and I-source converters, this paper we used an TL Z-source inverter to control PWM SVM[1][7] algorithm is used. It is most commonly used in inverters for creation of alternating waveform.

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2. Circuit Diagram and Description

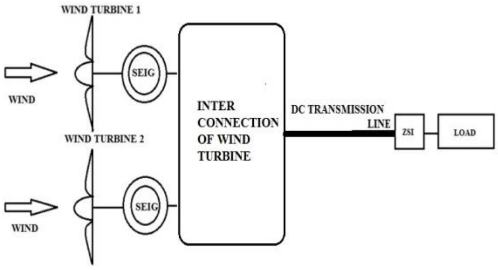

Figure 1. Block diagram for interconnected wind driven SEIG system

From the given block diagram two turbines are connected to a two separate SEIG for generating AC power .SEIG[2] offers various advantages over the conventional synchronous generators such as reduced unit cost, easy maintenance, rugged and simple construction, brushless rotor (squirrel cage) and so on . AC power is given to the separate diode rectifier is used to convert variable magnitude, variable frequency voltage at the induction generator terminal into DC voltage .The converted DC voltage are transmitted to a load through DC transmission system to avoid transmission losses for long transmission .After that the converted DC voltage are fed to the TL Z-source inverter for AC output it passed to the given load .This method gives high efficiency for off shore. TL Z-source inverter can produce any desired output ac voltage .It provides ride-through capability during voltage sags, improve the power factor and reliability, and extends output voltage range. To control PWM SVM algorithm is used .It is most commonly used in inverters for creation of alternating waveform. This system is mainly used in off-shore wind farm.

3. Modelling of Seig

An induction generator offers various advantages over the conventional synchronous generators such as reduced unit cost, easy maintenance, rugged and simple construction, brushless rotor (squirrel cage) and so on. Three-phase induction machine can be made to work as a self-excited induction generator (SEIG) [1]. The SEIG is the induction machine driven by prime mover with capacitor connected in stator terminals. The output power of SEIG depends upon the Wind velocity variations of the horizontal axis wind turbine

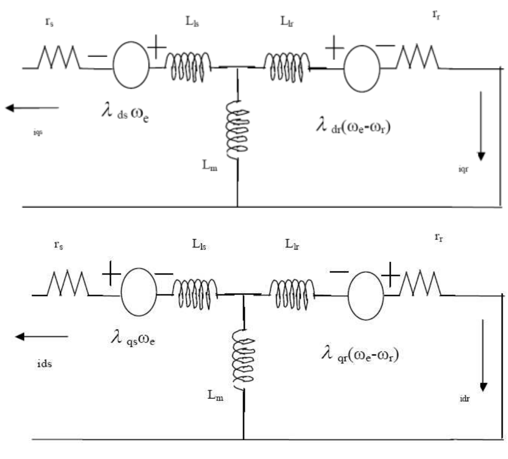

Figure 2. Equivalent circuit of SEIG in d-q reference frame

The d-axis and q-axis equation for equivalent circuits are
Vsiqs +Ls (diqs/dt) +Lm(iqr/dt) =Vds we
Vsids+Ls(dids/dt) +Lm(didr/dt) =-Vds+Vaswe
Vriqr+Lr(diqr/dt) +Lm(diqs/dt) =Vdr(we-wr)
Vriqr+Lr(didr/dt) +Lm(dids/dt) =Vqr(we-wr)

The following electromechanical equations represent the dynamics of self excited induction generator derived in d-q reference frame.
Piqs=K1rsiqs(we+K1Lmwr)ids+K2rriqrK1Lmwrr
Piqr=K2Lswrids+K2rsiqs+(K1Lswrwe)idr+[(rr+K2Lmrr)]iqr
Pids=K1rsids(we+K2Lmwr)iqs+K2rridrK1Lmwriqr-K1Vds
Pidr=K2L2wriqs+K2rsiqs+ (K1Lswrwe)iqr+
[(rr+K2Lmrr)/Lr]idr+K2Vds
PVds=idc/c;we=iqc/cvds
Where
K1=Lr/ (LsLr-L2m) and
K2=Lm/ (LsLr-L2m)

The magnitude of the generated air gap voltage in the steady state equation is given by
Vg=weLm|im|
where
|im|=√[(iqs+iqr)2+ (ids+idr)2]
Lm=f (im)

Induction generator produced electromagnetic torque Tg is expressed as
Tg=-1.5(poles/2)Lm(iqsidr-idsiqr)

Dynamic equation of motion is given as
Pwr=((Tt/Gr)-Tg)/Jg

Developed electromagnetic torque and the torque balance equations are
Te= (3/2)(P/2)Lm(idriqs-iqrids)
Tshaft=Te+J (P/2)Pwr

Torque balance equation is given by
Pwr= (P/2j) (Te-Tshaft).

4. Diode Bridge Rectifier and DC Link

Three phase diode bridge rectifier is used to convert variable magnitude, variable frequency voltage at the induction generator terminal into DC voltage. The output voltage is expressed as

Vr=(3√2⁄π)(√3⁄√2)*Vds*ni

The series reactor (L) and shunt reactor (C) acts as an input filter. The current ripples and voltage ripples are reduced by using the above components.

DC link current was governed by
Pidc=(1/Ldc)(VrViVdcidc)
where
RDC and LDC are the reactor resistance and inductor respectively.

5. TLTopology

The TL Z-source inverter is shown in Figure 4 [11], where two coupled inductors having turns ratio γTL and four diodes are

used. The TL topology is only applicable to the voltage-type Z-source inverter, and can produce the same gain and capacitor

voltage as the generalized SL topology. Its governing expressions are also represented by (3) after substituting N with γTL. The number of inductor turns needed by both topologies to produce. The same gain is, therefore, roughly the same. The TL topology however uses lesser diodes, but with higher blocking voltages than the SL topology. This can clearly be illustrated by writing down their respective blocking voltages, which are found to be independent of the source positions.

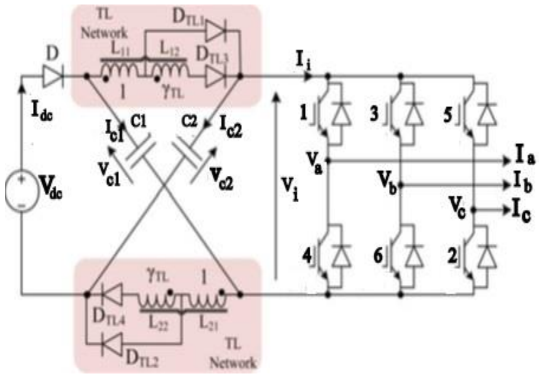

Figure 3. Topology of voltage-type TL Z-source inverter.

6. TL Inverter

Diode *D*: $V_{D\_TL} = V_D$

Diodes D_{TL1},D_{TL2}: $V_{D1\_TL} = -\frac{\gamma_{TL} d_{ST}}{1-(\gamma_{TL}+2)d_{ST}} V_{dc}$

Diodes D_{TL3},D_{TL4}: $V_{D2\_TL} = -\frac{\gamma_{TL}(1-d_{ST})}{1-(\gamma_{TL}+2)d_{ST}} V_{dc}$.

The last two expressions in (8) are clearly γTL times larger than those in (7). In other words, the TL topology reduces its diode count to four merely by making them blocked larger stresses otherwise distributed among N (=γTL) diodes in the SL topology. Other places of concentrated stresses are at the L11 and L21 windings of the TL inverter. This happens when in the shoot-through state, during which energies from the L12 and L22 windings are transferred to the L11 and L21 windings because of the blocking of diodes DTL3 and DTL4. That causes the instantaneous currents through L11 and L21 to surge greatly, which will not happen with those inductors of the generalized SL topology.

7. SVM Control Statergy

In this paper we used SVM control technique .by using this technique we can eliminate the conditions (000) and (111).

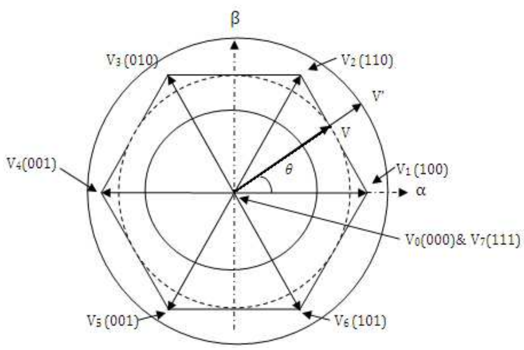

Figure 4. Voltage space vectors with shoot through States for TL Z-source inverter.

To control PWM SVM algorithm is used. It is most commonly used in inverters for creation of alternating waveform. There are various types of SVM. It results in different quality and computational requirements. Traditional approaches on SVM are mainly based on five level or seven level inverters.

Three phase system can be represented by a rotating vector as

as=2/3[ax (t)+a.ay(t)+a2.az(t)]

Vector representation are achieved by following 3/2 transformation

$$\begin{bmatrix} A_\alpha \\ A_\beta \end{bmatrix} = 2/3 \begin{pmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{pmatrix} \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$$

as=Aα+jAβ

Aα and Aβ forming orthogonal 2 phase system.

The reverse transformation is given by

ax(t)=Re(as)+a0(t)

ay(t)=Re[a2.as]+a0(t)

az(t)=Re[a.as]+a0(t)

a0=1/3[ax(t)+ay(t)+az(t)]

It represents as homopolar component and results in a unique correspondence between space vector in the complex plane and a 3 – phase system.

The below diagram shows the switching pattern of TL Z-source inverter.

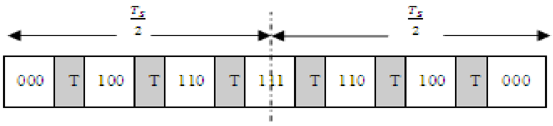

Figure 5. Traditional switching pattern for TL Z-source inverter.
Source Inverter

8. Simulation and Results

The z-source inverter with wind driven self –excited induction generator fed WECS is simulated using MAT LAB/SIMULINK and the results are presented. The minimum and maximum value of the self-excitation Capacitance requirement is previously the self-excited induction generator is used to understand the all characteristics behaviour of the generator system.

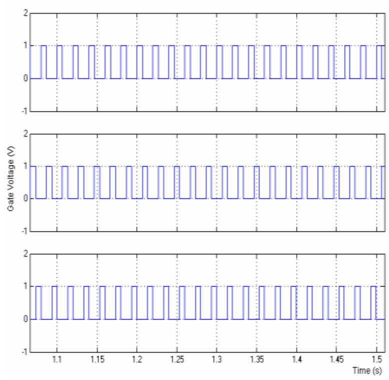

Figure 6. Gate pulse applied to the MOSFET switches M1, M3, M5

The self-excited induction generator can be simulated using Mat lab/ simulink to study the dynamic performance of the machine. Self-excitation process is initiated at t = 0s without any load at the stator terminals. It is observed that voltage build up reaches the first steady state value at t = 5.5s.As the load on the generator increases, the stator voltage decreases with an increase in the stator current. At t = 20s, a capacitor with capacitance is increased to 60 μf to compensate the voltage drop. The generated voltage is expressed as an instantaneous value and rms value.

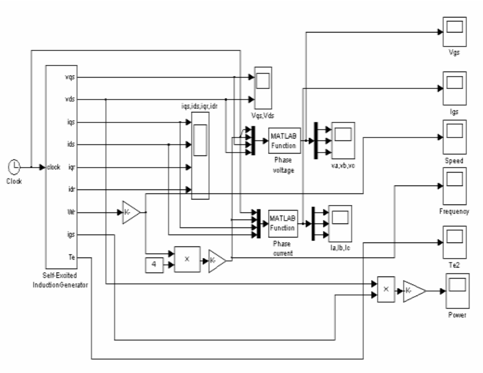

Figure 7 a. Simulink model of the self-excited induction generator

The Simulink model of the interconnected SEIG fed Z- source inverter is given below.

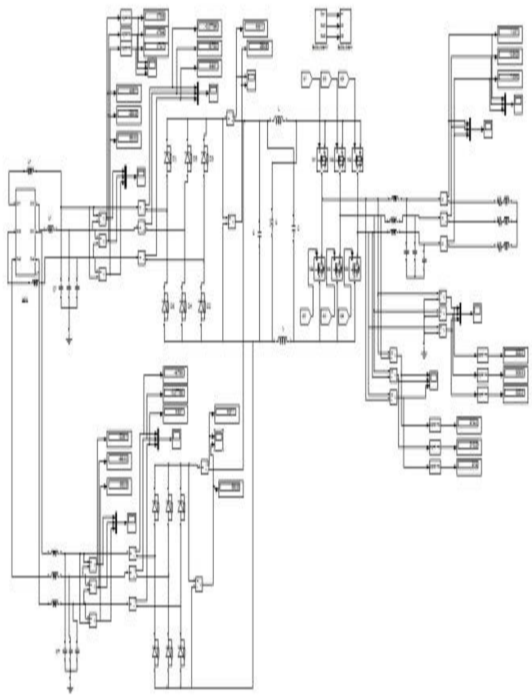

Figure 7 b. Simulink Model of the interconnected WECS

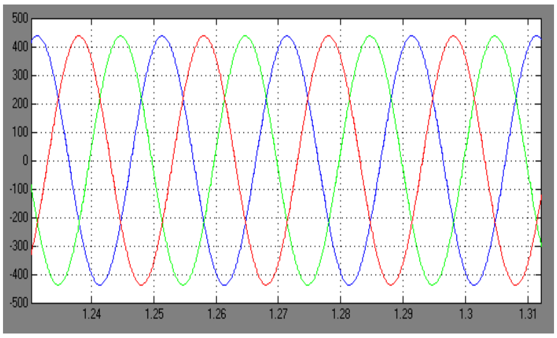

Figure 8. Output voltage waveforms of the wind driven SEIG

The SEIG output voltage is converted into DC voltage by using the diode rectifier circuits. This DC voltage is given to the three phase Z- Source inverter. The inverter is used to Produce required output voltage. The inverter output Voltage is applied to the RL load. The phase voltage of the inverter is shown.

Phase voltage Va, Vb, Vc of SEIG 580V AC Phase Current Ia, Ib, Ic of SEIG 7 A

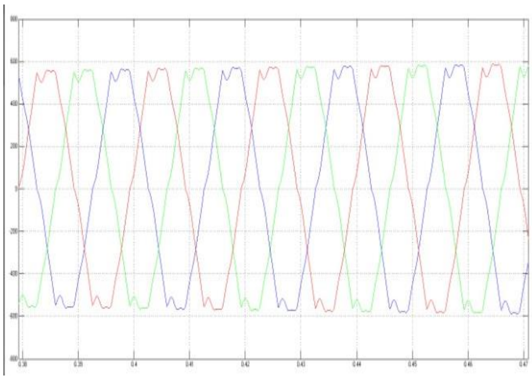

Figure 9. Phase voltage of wind driven SEIG

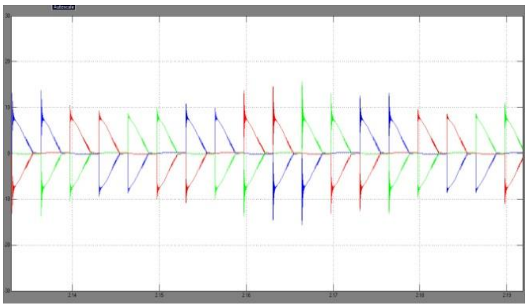

Figure 10. Phase current of SEIG

The output voltage of the AC motor is 634V. The harmonics presented in a output voltage is mainly Depending upon the inductance value Output Voltage of AC Motor 634 V AC .

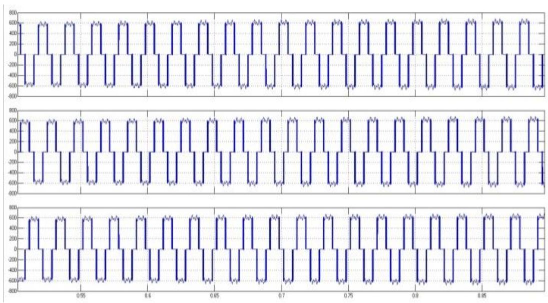

Figure 11. Load Voltage waveform

9. Experimental Set-Up of Seig with and without Rectification

The 4 pole, 415 volts, 7.5 amps, 3H.P and 50Hz squirrel cage induction generator was coupled to a separately excited D.C drive motor to provide different speeds. The prime mover can be controlled by armature rheostat of 220 ohm / 5 amps. Figure 6.4 shows the photo graph of SEIG connected with the D.C separately excited motor (Prime mover). In this generator is loaded with the proper excitation capacitance. The excitation capacitance C = 60μf connected across the terminals of the generator. As the load resistance is increased to 60ohms, the stator voltage decreases to 230 volts.

Figure 12. Photo graph of the D.C separately excited motor fed SEIG with R load

The generator voltage can be evaluated with the varying excitation capacitance of C = 50μf, 55μf and 60μf. The induction generator has been extensively simulated for various load conditions and varying excitation capacitances. The generated voltage of the studied SEIG is converted into DC voltage by using the diode bridge rectifier. The minimum, critical and maximum capacitance for self excitation process in induction generator can be calculated. The wind driven SEIG performance can be analyzed with the varying excitation capacitance and load resistance values. The condition for maintaining excitation is sufficient amount of capacitance connected to the motor terminals. The experimental set up is shown in Figure 13. At no load condition, the generated voltage of the SEIG was carried for various excitation capacitance values of 50 μf, 55 μf and 89 μf. The generated voltage of 177 volts, 190 volts and 229 volts was found from the above mentioned excitation capacitances. Figure 14 shows the stator voltage of the SEIG without DC link converter.

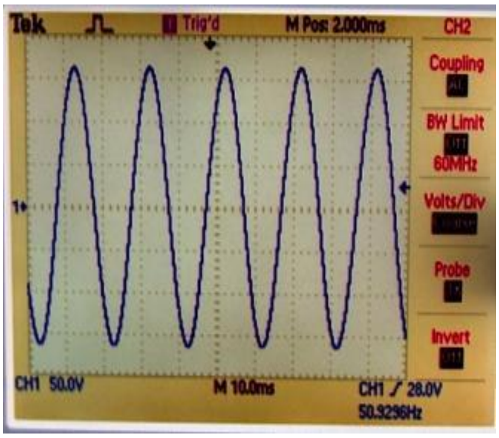

Figure 13. Experimental results of generated stator voltage 35 V/div.

The diode bridge rectifier is used to convert one phase voltage obtained from the SEIG into DC voltage. The SEIG is loaded with the load resistance of R = 60ohms. The generated voltage of Vgs = 229 volts at a speed of 1734 rpm is shown in Figure 14(a).

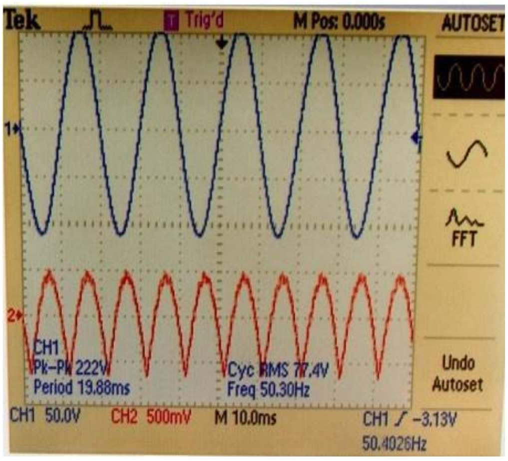

Figure 14a. Experimental results of SEIG with resistive load R =60ohms per phase (a) Terminal voltage 50 V/div.
b.DC link voltage 103V/div..

9. Conclusion

In this paper the performance analysis and simulation results of interconnection of SEIG fed ZSI for wind energy conversion system have been described. We combine two wind turbines driven SEIG and used diode rectifier for converting AC voltage to DC voltage produced by SEIG .Phase voltage produced by SEIG 580 V AC and Phase current of SEIG is 7A.In off shore wind farm for lossless transmission DC transmission is used. The converted DC voltage was fed to Z-source inverter. The Z-source inverter system provides ride-through capability during voltage sags, improves the power factor and reliability, and extends output voltage range. we can do either buck or boost .PWM SVM control technique was used for control. The output voltage of AC motor load is 634V AC. The dynamic voltage, current, rectifier voltage waveforms are developed and analysed.

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