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WEC'S USING SIX SWITCH AC/DC/AC CONVERTER

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Abstract

The wind energy is free, inexhaustible and it produces no waste or greenhouse gases. Furthermore, it is a good method of supplying energy to remote areas. With growing application of wind energy conversion systems (WECSs), various technologies are developed for them. Squirrel cage induction motors are the most commonly used electrical machine in AC drives. In this paper, a new wind energy conversion systems (WECSs) with a squirrel cage induction generator (SCIG),VSI Induction motor drive and a new six-switch AC/DC/AC converter as power electronic interface between SCIG and network is proposed. Characteristics of six-switch AC/DC/AC converter are used for maximum power tracking control. This configuration uses only six active switches and six diodes and has the lowest number of active switches among three-phase to three-phase AC/AC converters.

Key Words: Squirrel Cage Induction Generator (SCIG); Wind energy conversion system (WECS); Six-Switch AC/DC/AC Converter.

I. Introduction

As a renewable and non-polluting energy source, wind power has a role to play in reducing harmful emissions and the impact of climate change. With growing application of wind energy conversion systems (WECSs), various technologies are developed for them. Squirrel cage induction motors are the most commonly used electrical machine in AC drives, because they are robust, cheap and have low maintenance cost. These advantages make the induction machine very attractive for wind power applications both for fixed and variable speed operation [2-4]. The back-to-back PWM inverter based power electronics interface is a suitable option for cage induction machine in wind power applications.a conventional configuration of ac-dc-ac topology for squirrel cage induction generator (SCIG) This configuration includes a back-to-back PWM rectifier inverter [5]. The PWM rectifier is controlled for maximum power point tracking (MPPT) and inverter is controlled to deliver high quality power to the IM [2]-[6]. This topology requires 12 active switches and 12 diodes.

In addition to the cost reduction in power electronics based systems, reducing the system size and weight as well as providing a high degree of reliability is of utmost importance. The resultant configurations are called reduced switch count converters. A recent reduced switch count structure for WECEs proposed in [7], as three-phase to three-phase AC/DC/AC converter is achieved by combining the B6 inverter and B6 rectifier stages via sharing an entire row of switches between them (Fig. 1). This converter which is called nine-switch converter was first suggested as multi output inverter for control of two motors [8].

In this paper, a new SCIG-based WECS with six-switch three phase AC/DC/AC converter is proposed to deliver the wind power to the IM drive. The proposed topology reduces number of switches by 33% and 50% respectively compared to back-to-back and nine-switch converters without any change in the objectives of WECS. Six-switch converter was first presented in [7] as dual output inverter for control of two three phase loads and also in [7] as three-phase AC/DC/AC converter.

II. Proposed Converter

The six-switch AC/DC/AC converter is shown in Fig.2. As it is seen in the figure, this structure has two legs with three power switches in each one and it is comparable to a B4 rectifier as the active front end of a three-phase B4 inverter though a row of switches is shared between them. Two phases of the three-phase induction generator and two phases of the IM drive are connected to the two converter legs and the remaining phase of the source and load is connected to the joint of the split capacitor bank. The amount of DC link capacitors' voltage are dependent on three factors of a, b and c. These coefficients are determined so as to provide balanced three-phase outputs without any DC offset.

$V_{Cd1} = aV_{dc}$-------------------(1)
$V_{Cd2} = bV_{dc}$-------------------(2)
$V_{Cd3} = cV_{dc}$-------------------(3)

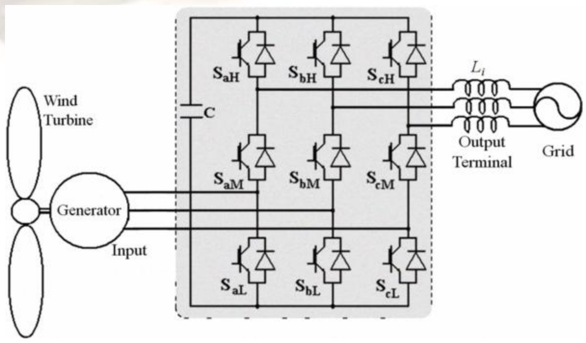

Fig.1.Nine switch Converter

Considering the structure of six-switch converter, In each leg, there are two modulating waveforms, one for the rectifier side (Vxr) and one for the inverter side (Vxi), The key point in the modulation of the proposed converter is that the interference of the rectifier and inverter reference waveforms should be avoided, i.e. Vxr> Vxi• This is achieved by adding two offset signals to the reference signals of both sides and limiting their modulation indices to prevent over-modulation [9]. The gate signal for upper switch of each leg is positive logic value generated by Vxi and Carrier. The gate signal for lower switch of each leg is negative logic value generated by V xr and Carrier.

The gate signal for mid switch is logic value generated by the logical XOR value of the gate signals for upper and lower switches. Applying this scheme, there are always two ON switches in each leg. The converter acceptable switching states and the resultant output and input phase voltages of the proposed converter are shown in Table I. The reference signals which are related to rectifier and inverter terminals can be expressed by (4) to (7).

$Var = mr \sin(\omega rt + \delta r) + offsetr$ ------(4)
$Vbr = mr \sin(\omega rt + \delta r - \varphi r) + offset$-----(5)
$Vai = mi \sin(\omega it) + offseti$ -----------(6)
$Vbi = mi \sin(\omega it + \varphi i) + offseti$ ----(7)

where mr, mi are respectively the rectifier reference amplitude and the inverter reference amplitude, ωr, ωi are angular frequencies and φr, φi are respectively phase difference between voltage references of the rectifier and phase difference between voltage reference of the inverter.

Table.I. Switch Positions

	Switch Positions			
S.No	**MaL**	**MbL**	**Mah**	**Mbh**
1	**On**	**On**	**Off**	**Off**
2	**On**	**On**	**On**	**Off**
3	**On**	**On**	**Off**	**On**
4	**Off**	**Off**	**On**	**On**
5	**On**	**Off**	**On**	**On**
6	**Off**	**On**	**On**	**On**
7	**on**	**On**	**On**	**On**

Table.II. Phase Voltages

S.No	**Phase voltages at Rectifier and Inverter side**					
	Vai(v)	**Var(v)**	**Vbi(v)**	**Vbr(v)**	**Vci(v)**	**Vcr(v)**
1	500	-125	-375	-125	750	250
2	-875	-125	625	-125	250	250
3	625	-125	-875	-125	250	250
4	125	375	125	375	-250	-750
5	125	875	125	-625	-250	-250
6	125	-625	125	875	-250	-250
7	125	-125	125	-125	-250	250

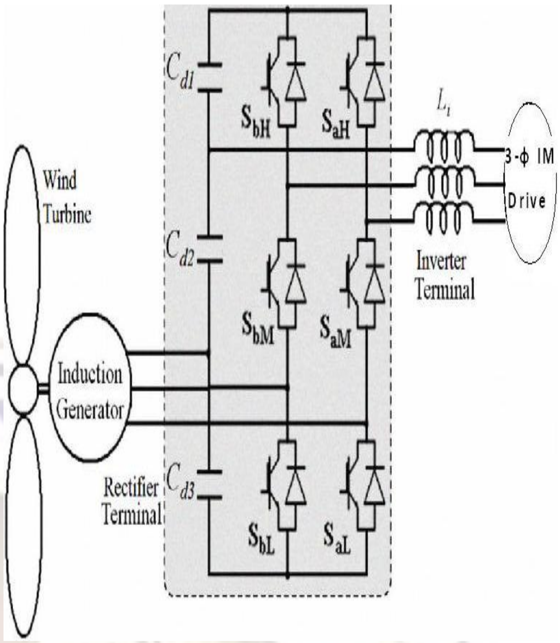

Fig.2: Proposed Circuit Diagram

Considering input and outputs of the six-switch WECS can have different frequencies and amplitude, therefore variable frequency mode should be chosen for that. To eliminate DC component and to obtain balanced input and output in, two strategies was suggested in [7]. These two different strategies are also considered for determining three coefficients of a,b and c.

III. Control of Proposed Converter

The relations for active and reactive power delivered to the grid are given by [8]:

$P = 3/2(vdId+vqIq)$------------------(8)

$Q=3/2(vqId-vd\ iq)$ -----------------(9)

where P and Q are active and reactive power respectively. V is grid voltage and i is the current to the grid. The subscripts .d' and 'q' stand for direct and quadrature components, respectively. If the reference frame is oriented along the grid voltage,vq will be equal to zero. Then, active and reactive power may be expressed as

$P = 3/2(Vdld)$ -------------------(10)

$Q = 3/2(Vdiq)$ ------------------(11)

According to earlier equations, active and reactive power control can be achieved by controlling direct and quadrature current components, respectively. DC voltage is set by controlling active power .

$$T_e = \frac{3}{2}\frac{P}{2\omega_b} x_m \left(i_{dr} i_{qs} - i_{qr} i_{ds}\right) \quad \text{-----(12)}$$

where P is number of poles, The subscripts 'ds' and 'qs' stand for direct and quadrature components in synchronously rotating reference frame, respectively.

Considering the electrical torque of generator is proportional to air gap flux, the air gap flux is maintained constant at its rating value and the value of direct current components is determined according to this rating value using (13). Furthermore, the flux axis angle is calculated using (13).

$$\theta = \int (\omega_r + \omega_m) dt \quad \text{-----(13)}$$

The gate signal for mid switch is logic value generated by the logical NAND value of the gate signals for upper and lower switches.

Neglecting the friction losses, the mechanical power available to be converted by the generator is given by (14).

$$P_m = 1/2\, \rho\, \pi R^2 c_p V^3_{wind} \text{--------(14)}$$

where VWIND is the wind speed, p is the air density, R is the blade radius of turbine and Cpis the power coefficient. The power coefficient depends on the pitch angle, the angle at the rotor blades can rotate along its long axis, and is the tip-speed ratio, A , defined by:

$$\lambda = \omega_m R / V_{wind} \text{---------------(15)}$$

where ω_m is the rotor speed (in rad/s).

To verify the performance of the proposed WECS, several tests are performed by simulink® software. The simulated system parameters are listed in Tables III. These simulations were performed using matlab Software.

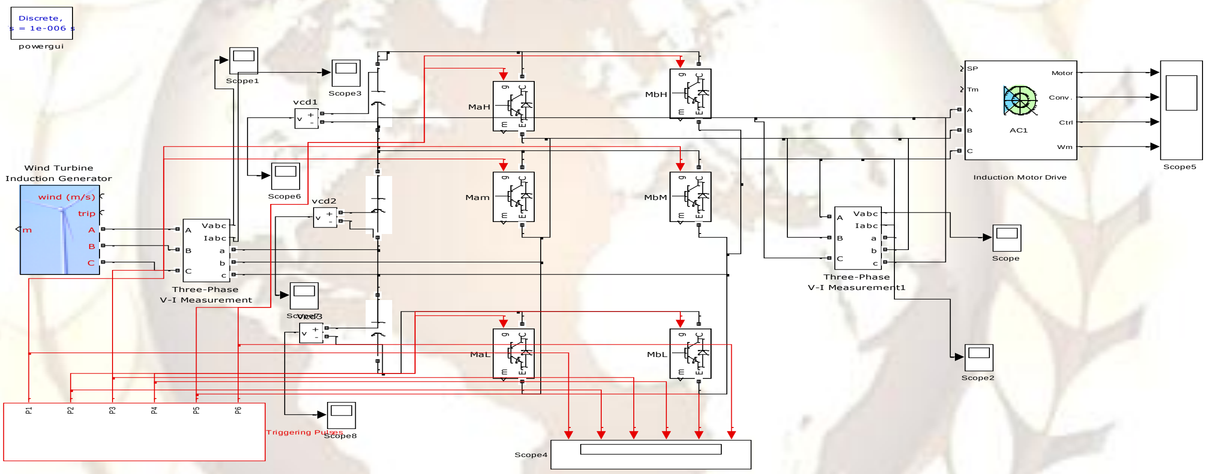

Fig:3. Simulation circuit model of the proposed topology

In order to evaluate the performance of the proposed system Fig(3), simulation is first performed using constant wind speed (10 m/s). Fig(4),Fig(5),Fig(6) shows DC link capacitors' voltages. It can be seen that the voltages have low ripple and have followed their corresponding commands, i.e. VCd1= (1/4)Vdc ,VCd2= (1/2)Vdc and VCd3=(l/4)Vdc Total DC link voltage of the converter was shown in Fig. 11. Reactive power that is kept at zero (unity power factor) is also shown in Fig.(8).,the parameters of the induction motor shown in fig (7).

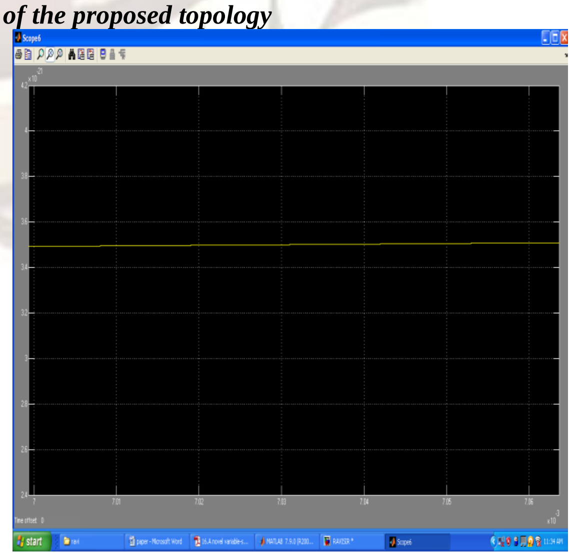

Fig.4. DC link capacitor voltage ,Vcd1.

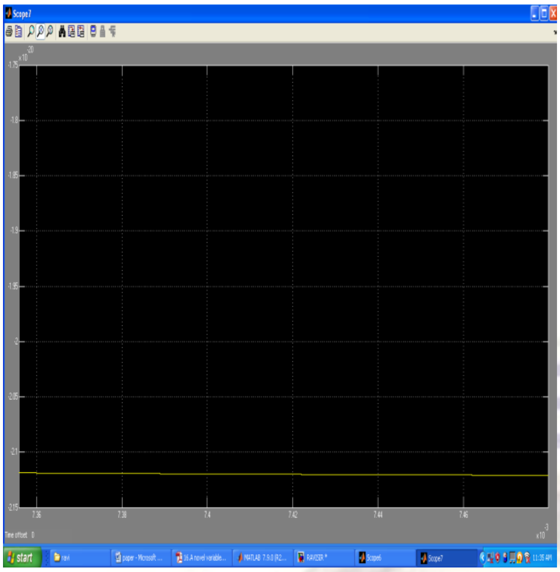

Fig.5. DC link capacitor voltage ,Vcd2.

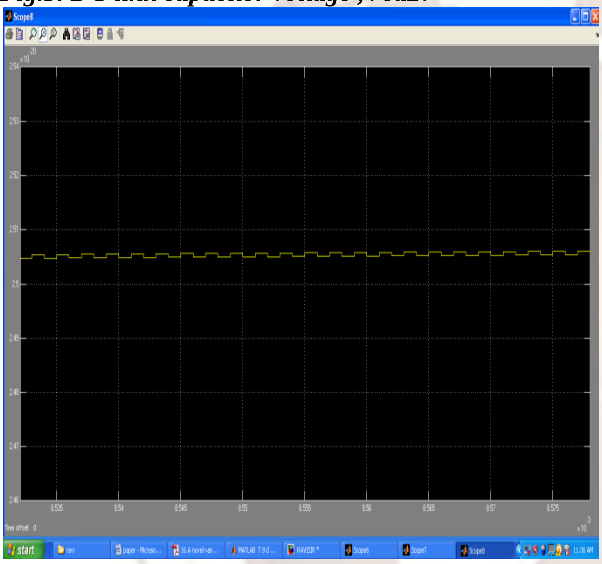

Fig.6. DC link capacitor voltage ,Vcd3.

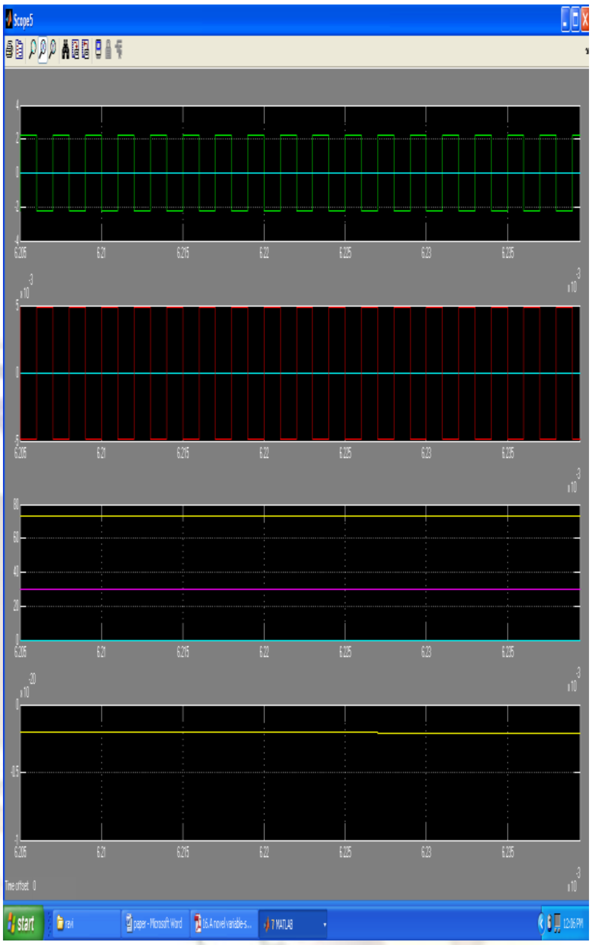

Fig.7. Parameters of IM drive

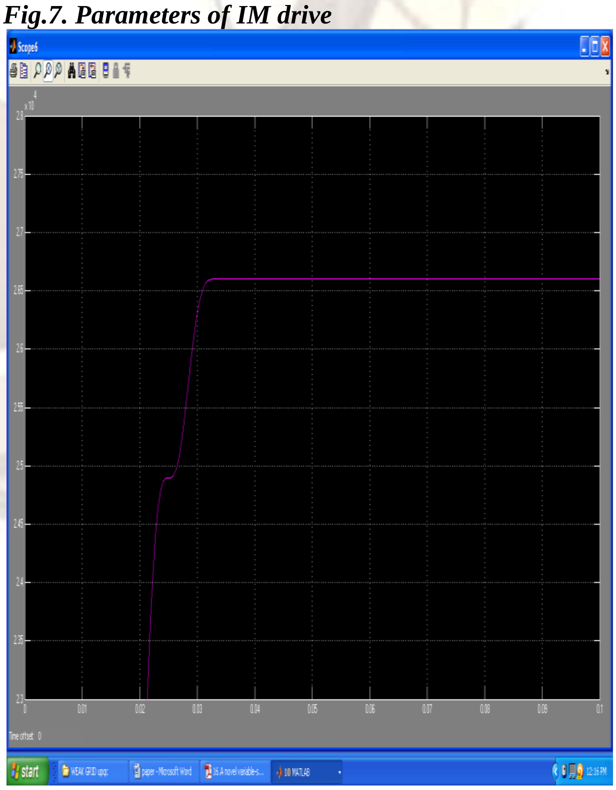

Fig.8. Active power

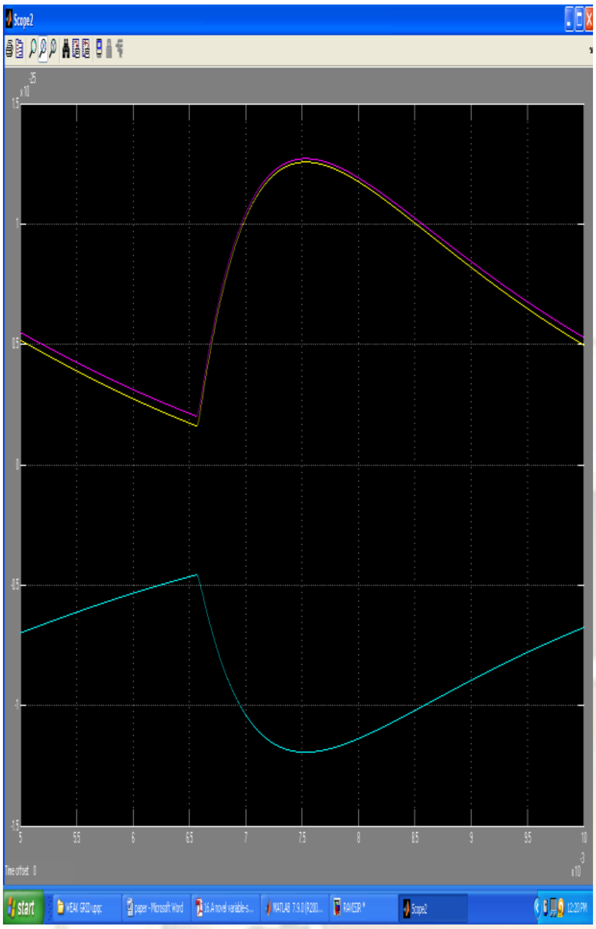

Fig.9. Currents supplied to IM drive

Table. III. Parameters

S.No	Parameter	Value
1	Nominal Mechanical Power	15 kw
2	Wind Base Speed	10m/s
3	Pole Pairs	2
4	Freequency	60hz
5	Cd1	4000uf
6	Cd2	2000uf
7	Cd3	4000uf
8	Vdc	1500v

IV. Conclusion

In this paper, a SCIG-based WECS with six-switch ACIAC converter is proposed. Six-switch converter is used for maximum power tracking control and delivering power to the IM drive, simultaneously. The proposed system has cost advantages compare to conventional WECS with back-to-back converter or with nine-switch converter, because the number of switching semiconductors is reduced from 12 and 9 to 6 respectively. With this topology, not only 3 active switches and 3 diodes is omitted than nine-switch converter but also there is not any change in the objectives of WECS.

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