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Hybrid Energy Source Fed Three Level NPC with Quasi-Z Source Network

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Abstract-*Hybrid renewable energy source is proposed which increases power reliability and improves standalone generation efficiency. Multi Level inverters find use in industrial drive applications and grid based power generation. Owing to the increasing power demand and rising conventional generation costs a new alternative in renewable energy source is gaining popularity and acceptance.A A Quasi Z source network allows inverter shoot through possibility while boosting the dc voltage fed to the Neutral Point Clamped MLI.Simulation results were obtained for two level VSI and further for NPC-TLI and verified using Matlab Simulink.*

1.Introduction

Renewable sources are gaining inceasing acceptance and implementation in energy sector mainly for solar ,wind and fuel cells.A wind PV Hybrid energy source improves their standalone efficiency and reliability besides increasing the output power capacity[11],[12].DPGS(Distributed power Generation Systems) have the additional advantage of supplying grid as well as capability of acting as standalone energy provider[3].But a dc-dc boost converter is necessary in such converter circuits to meet the output voltage requirements.A ZSI(Z-Source Inverter),as proposed by FZ Peng[1] eliminates the need for a boost converter thereby reducing the circuit complexity,size ,providing necessary dc boost ,improving inverter efficiency and allowing shoot through states.In a traditional inverter shoot through is forbidden for it causes short circuiting of the dc input components and carry a risk of damaging inverter switches.This is made possible by a ZSI.A Quasi-Z source inverter ,proposed by J Anderson[2] besides having all the forementioned ZSI advantages ,provides simpler control with lesser components and reduces voltage stresses during operaton.Maximum Boost Control ,being easy and effective is used to control the inverter switches.

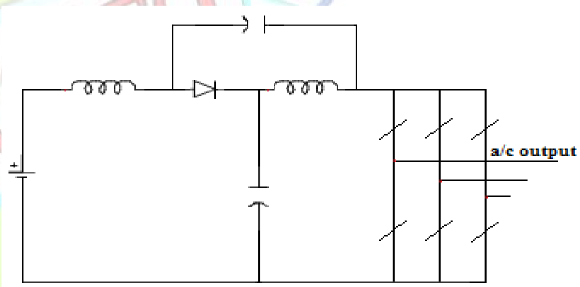

Fig.1 Q-ZSI circuit topology

2. PV-Wind Hybrid source

2.1 PVSource

Photovoltaic effect takes place when the barrier potential is overcome by electrons absorbing solar radiation.PV cell utilizes this to get dc current when irradiated with sunlight.Series or parallel connections of PV cells and arrays are used to increase power output.The equations governing the PV array current are given as

$$I=I_{sc}-I_d \quad (1.a)$$

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$$I_d=I_0\,(\exp(qVd/kT)-1) \qquad (1.b)$$

Where
I_0 is reverse saturation current of diode,
q is the electron charge
V_d is the voltage across diode
k is Boltzmann constant
T is junction temperature

A.MPPT(Maximum Power Point Tracking)

MPPT is the technique to get maximum power out of the PV arrays. P&O(Perturb and Observe) is one technique of MPPT in which the controller adjusts the array voltage every time it detects a change in it.If the calculated change in power is positive, then it keeps on shifting the voltage in that direction till the change in power becomes negative.When the incremental power increases,then a pulse is sent by the MPPT controller to the switch to deliver power to the load.If there is a decrement in power for this voltage change,then no pulse is given and the switch remains in the off state.The load is fed with the present maximum value reached earlier.Since the P-V characteristics of a PV cell approach a peak,or maximum power point , this method is also called as hill climbing method.It is a common method with easy implementation.

2.2Wind Energy Conversion System

Wind enegy is another naturally available source which can be converted into electical energy by a Wind Energy Conversion System.It consists of a wind turbine which acts as a prime mover for a generator.They share a common shaft through which mechanical power is transferred to the generator.A Permanent Magnet Synchronous Genertor does not need an excitation field which consideraly reduces energy wastage.It facilitates the wind turbine operation without a gearbox so the operatingcost is reduced.Permanent magnets which have been made easily available in the recent years contribute towards cost reduction.

A Wind-Pv hybrid source is realised by feeding the ac voltage from PMSG into a three phase diode rectifier and coupling this dc voltage with the PV array output.A renewable hybrid energy source is realised prvoding sufficient dc voltage for inverter operation.Improved reliabitily during overcast conditions or insufficient wind speed can be expected from it.

3. Review Of Two Level VSI

A Voltage source inverter is a three phase voltage buck inverter consisting of six switches.Input Voltage must be greater than the desired output for the inverter operation[2].It consists a of total eight switching states(six active and two zero).Output is a two level stepped wave obtained using common PWM methods.

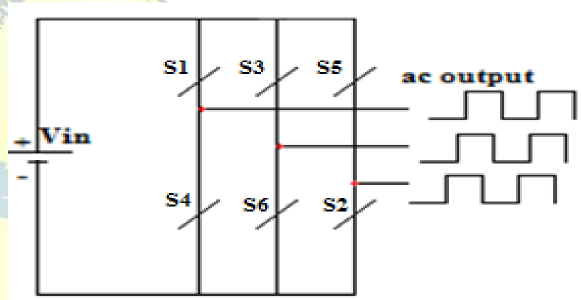

Fig.2 VSI configuration

But since the output voltage is lesser than the input,a boost converter is required when supplying loads.This increases circuit size,complexity and cost.Also an additional filter is required to remove dc and improve the waveform.There is a risk of shoot through even though it is not allowed,which could damage the inverter.A ZSI/Q-ZSI configuration handles these shortcomings in VSI[3],[5-7].

4. Review of a Quasi-Z source Inverter

A Quasi-Z source inverter ,proposed by J Anderson[2] is a modified version of a Z-souce inverter with reduced switching stresses and continuous inverter current.Two inductors and capacitors are arranged as shown in Fig.1. A Quasi Z-source inverter has two modes of operation:shoot through mode and active(non shoot through) mode.All the inverter switches of at least one leg should be on for a full shoot through to occur.

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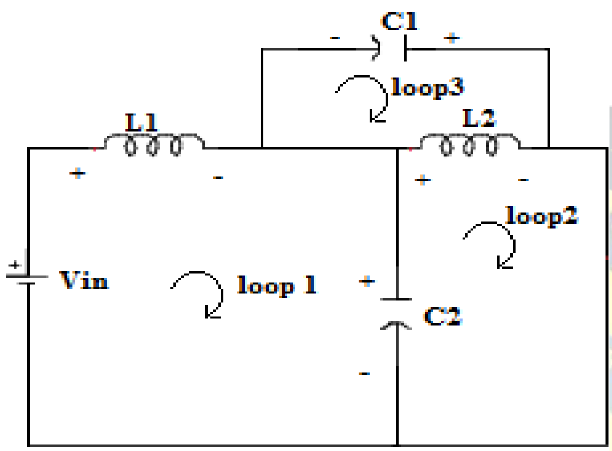
Fig.3 shows QZSI during active mode.Applying KVL to loops 1,2 and 3 ,[3]we get

Vin=VL1+Vc2 (1)

Vout=Vc2-VL2 (2)

Vc1=-VL2 (3)



4.(a)

Fig.3(a)-(c)QZSI operation

From 2 &3,we get

Vout=VC2+Vc1 (4)

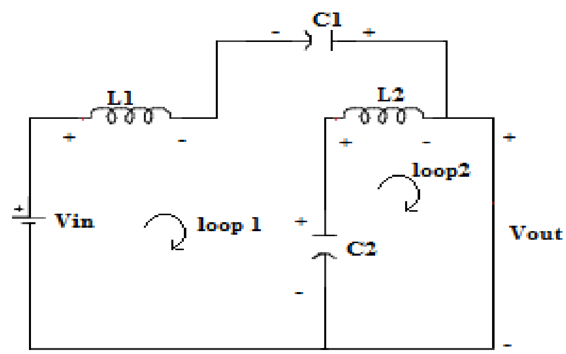
During shoot through state, diode is open circuited and we get two loops.In the next figure its equivalent circuit is shown.Applying KVL we get two equations

Vin=VL1+Vc1 (5)

VL2=Vc2 (6)

Since during shoot through,inverter leg output is zero,Vout is zero.

From (1) (2) (5) (6) we get two equations each for L1 and L2.Tsh and Tnon are the shoot through and non shoot through times respectively,their sum being the total switching time.

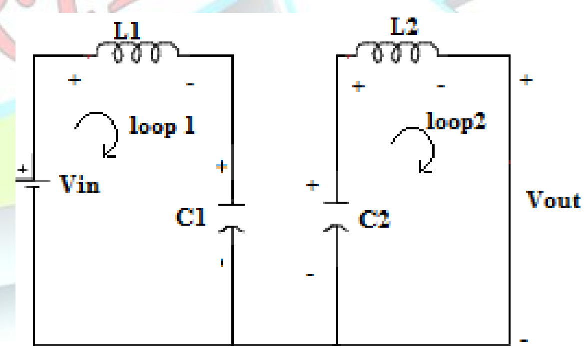


3.(b)

Calculating inductor voltage for the whole switching instant,the capacitor voltages can be rearranged and determined.Using equation (4) the output voltage equation in terms of input can be found and the duty cycle of the inverter varied to get the desired boost.

VL1(T)=(Vin-Vc2)Tnon+(VL1+Vc1)Tsh (7)

VL2(T)=(-Vc1)Tnon+(Vc2)Tsh(8)



3.(c)

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5. Control Strategy

Out of various Sinusoidal PWM techniques available,Maximum boost control is applied for the inverter.It is simple to implement and produces a significant voltage boost,[7-8].The zero inverter switching states are converted to shoot through and the active states are retained as such in MCB.

A triangle carrier is compared with a three phase reference , each phase for a positive switch .Shoot through occurs whenever the triangle peak overshoots the sinusoid peak magnitude so twice for each phase in one cycle.At other instants when the sinusoid magnitude is greater ,the inverter exhibits active switching states.As said earlier,active inverter operation is achieved by comparing sinusoid with the carrier waveform when the former's magnitude is greater.Using min/max function for the three phase sinusoid its upper and lower envelope waveforms are compared against the same carrier to generate shoot through pulses for the positive and negative carrier peaks respectively,which are then ORed together to obtain the shoot through pulse for three phases.This waveform is combined with the active state waveforms using OR gate and given to the switches.

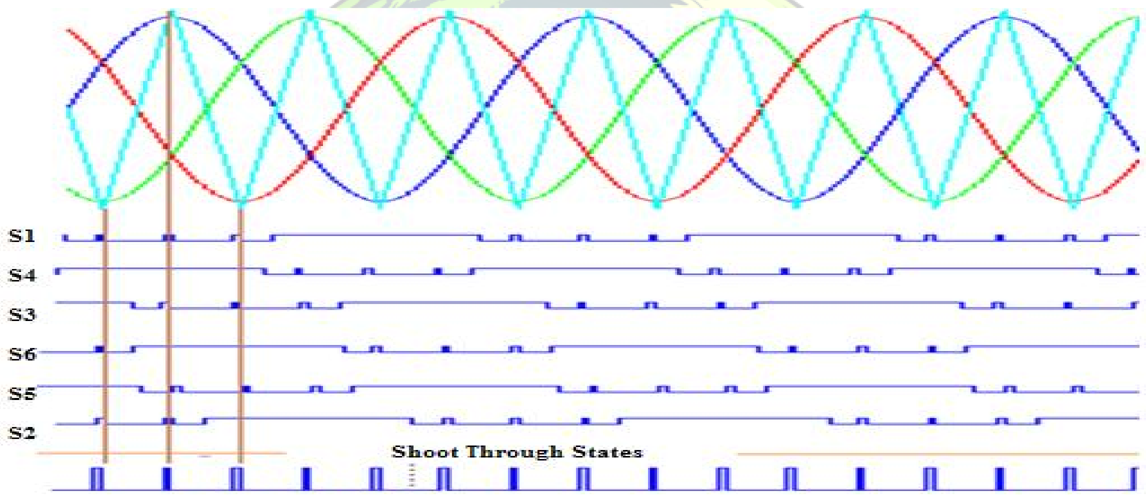

Fig.4 Maximum Boost Control

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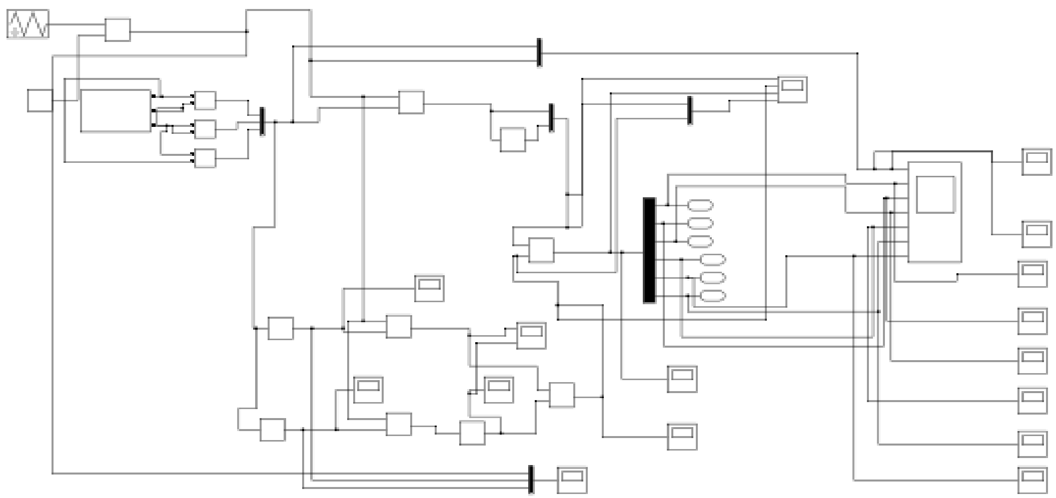

Fig.5 MBC matlab implementation

6. QZSI-NPC-TLI

A Neutral point clamped Three Level Inverter produces three level stepped ac voltage.Each inverter leg consists of Four switches and two clamping diodes for the dc neutral point connection.Half the dc voltage is shared by two capacitors thus split it into three levels +Vdc/2,0,and –Vdc/2 which would have otherwise required two dc sources.Top two or middle two or bottom two switches in each leg switch on together which produces 3×3×3=27 switching states .This is during normal NPC TLI operation.During shoot through mode all the switches of any leg ,individually or in anycombination switch on at the same instant giving rise to seven additional shoot through states.Three of them are shown in Fig.8.

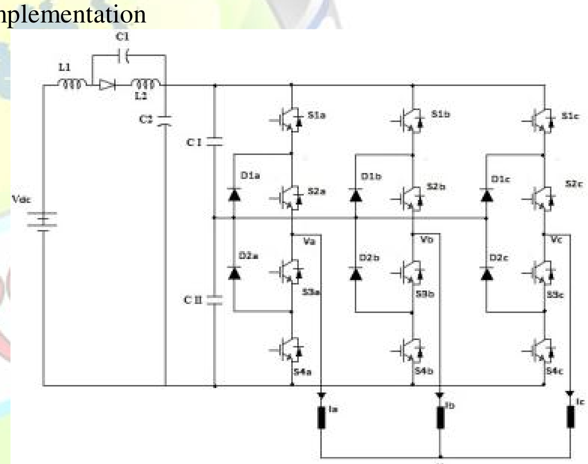

Fig.6 QZSI-NPC-TLI

This is made possible due to the inductor and capacitor arrangement in the QZSI[9].The output of that inverter leg is zero for this state[9],[10].

Table.1 NPC-MLI operation modes in active state

Modes	Leg 1	Leg 2	Leg 3	Inverter Output
Mode 1	S2a,S3a	S2b,S3b	S3c,S4c	-Vdc/2
Mode 2	S3a,S4a	S3c,S4c	S2c,S3c	-Vdc/2
Mode 3	S3a,S4a	S3b,S4b	S2c,S3c	-Vdc
Mode 4	S3a,S4a	S1b,S2b	S3c,S4c	-Vdc/2

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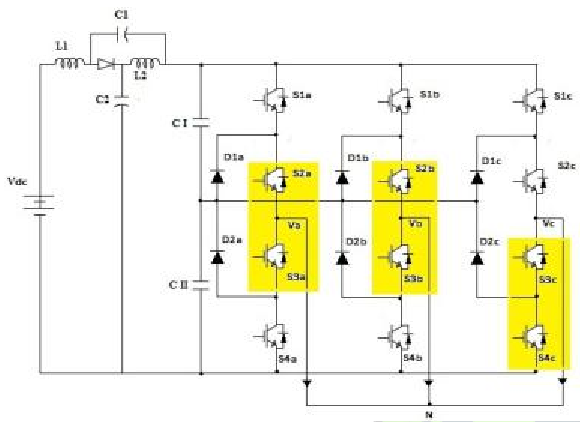
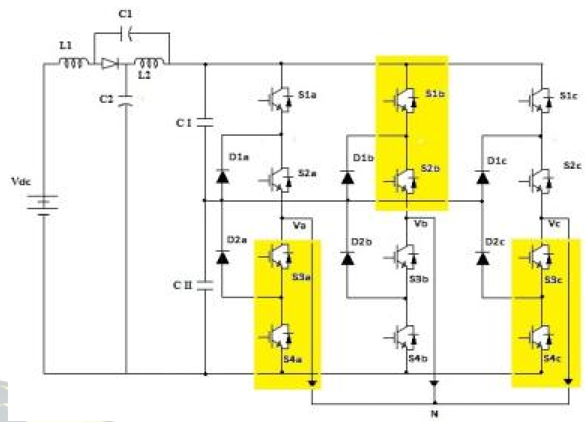
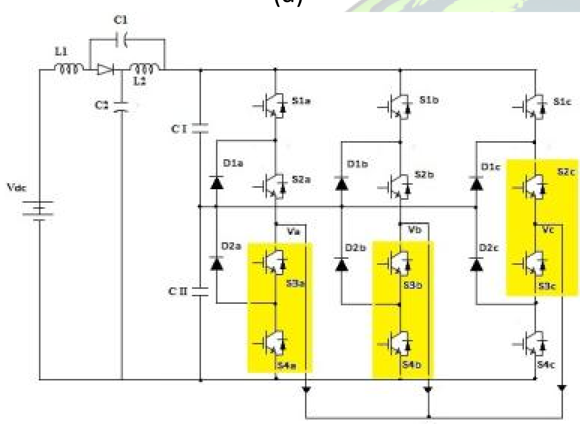


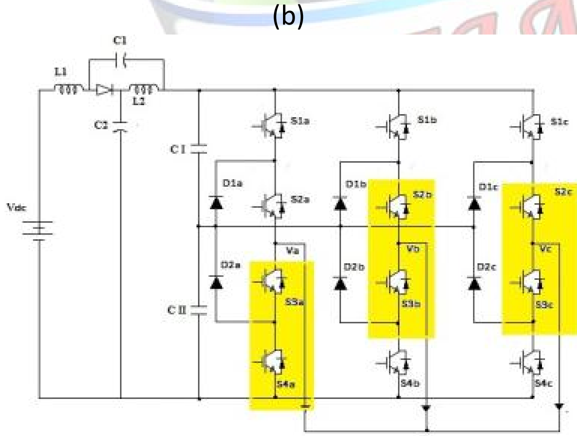
(a)



(d)

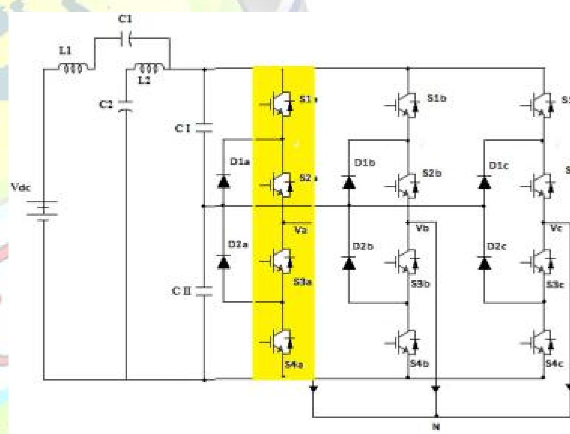


(b)



(c)

Fig.7 Modes Of Operation (a) Mode1 (b) Mode2 (c) Mode3 (d) Mode4



(a)

Fig.8 Shoot through states (a) State1 (b) State2 (c) State3

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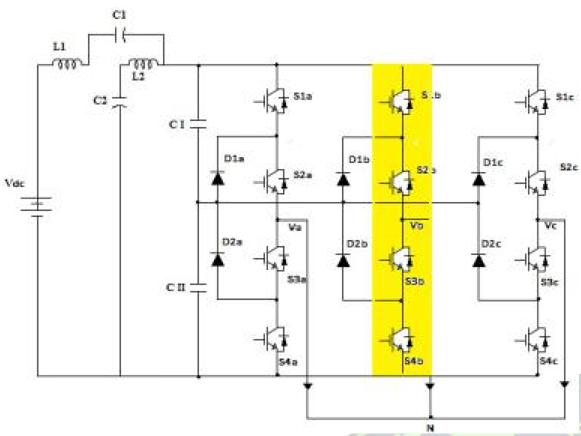
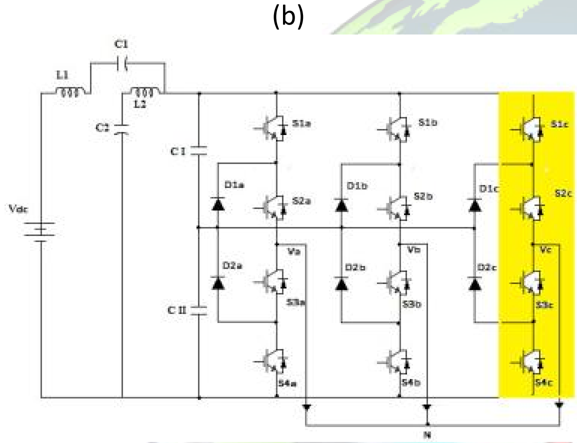


(b)



(c)

7. Simulation Results

The Simulation results were verified in Matlab R2013a.For PMSG ac Output of 120V (Fig13)and PV array dc Output of 80V (Fig14), the Cumulative dc input to the QZSI-NPCMLI was 204V.PV array was operated under varying irradiation from 400-500 W/m^2.Using QZSI,the NPC-TLI stepped ac voltage was obtained as 300V shown in Fig.10.The rectifier output and QZSI boosted voltage is as shown in Fig 15&16.Normal operation of NPC bucks the 200V input voltage level to a little less than 200V as shown in Fig.13.The PV array current and voltage are shown in Fig.14.The inverter output current is obtained as shown in Fig.12. [4] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

Capacitors of 470µF and inductors of 1µH were used for QZSI.Three phase RL load of 100Ω and 1mH was used at the inverter side.The gating pulses for six switches of two level inverter are shown in Fig.18.Based on this PWM control for three level NPC was designed. The two level QZSI output is shown in Fig.17.For a 300V dc input,ac output of 500V was obtained.

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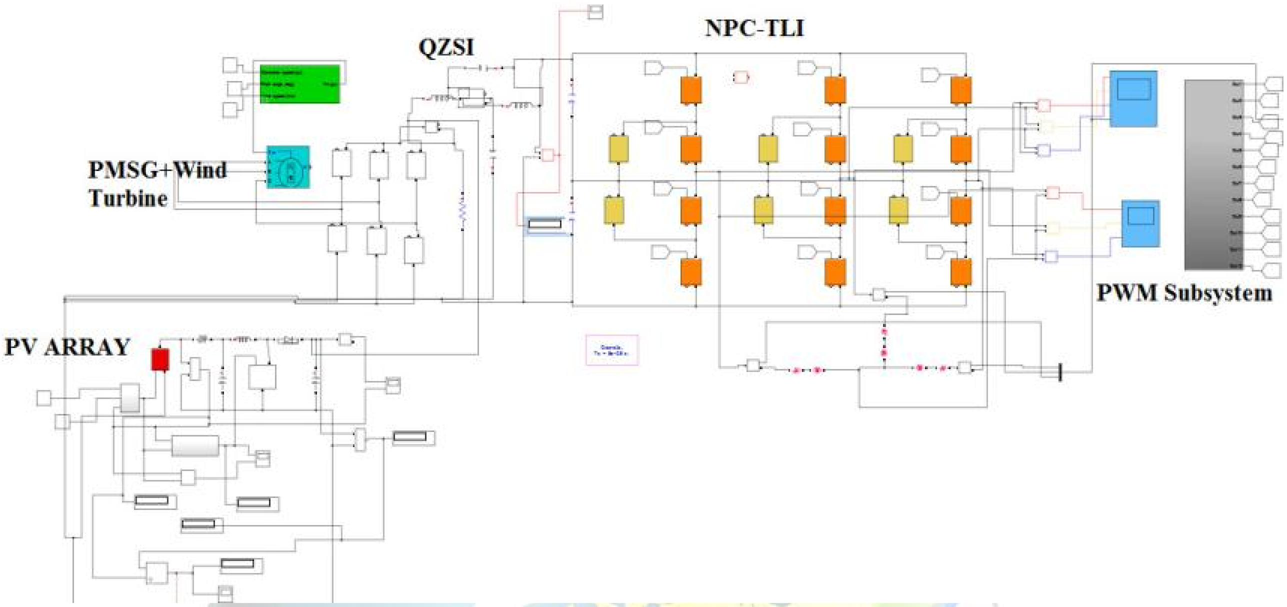

Fig.9 Matlab Simulaton Model

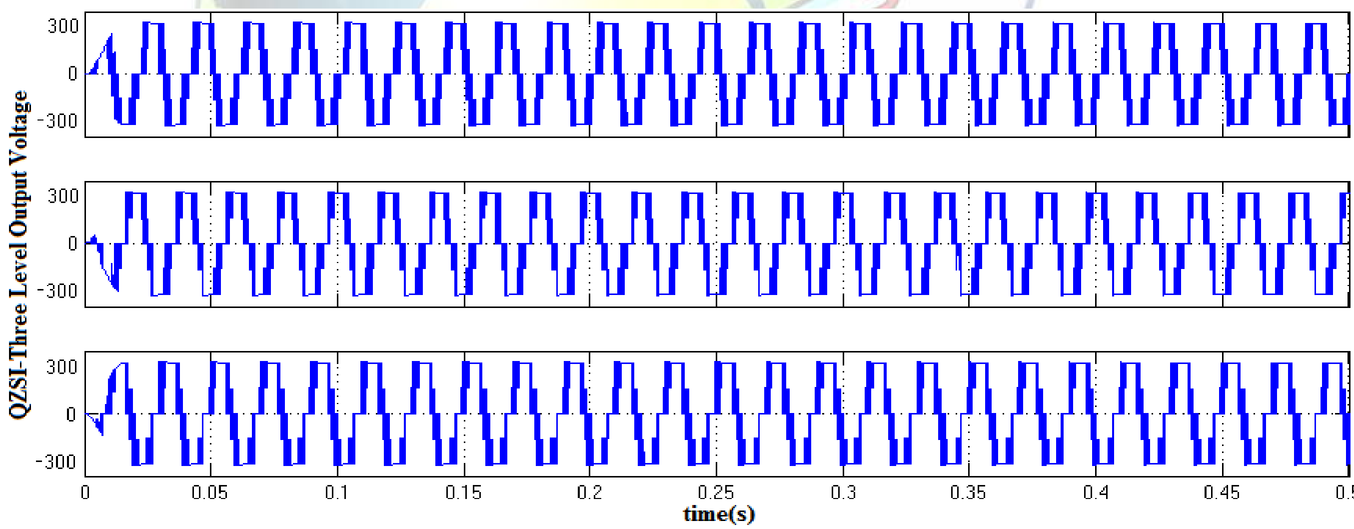

Fig.10 QZSI-NPCTLI Three level Output Voltage

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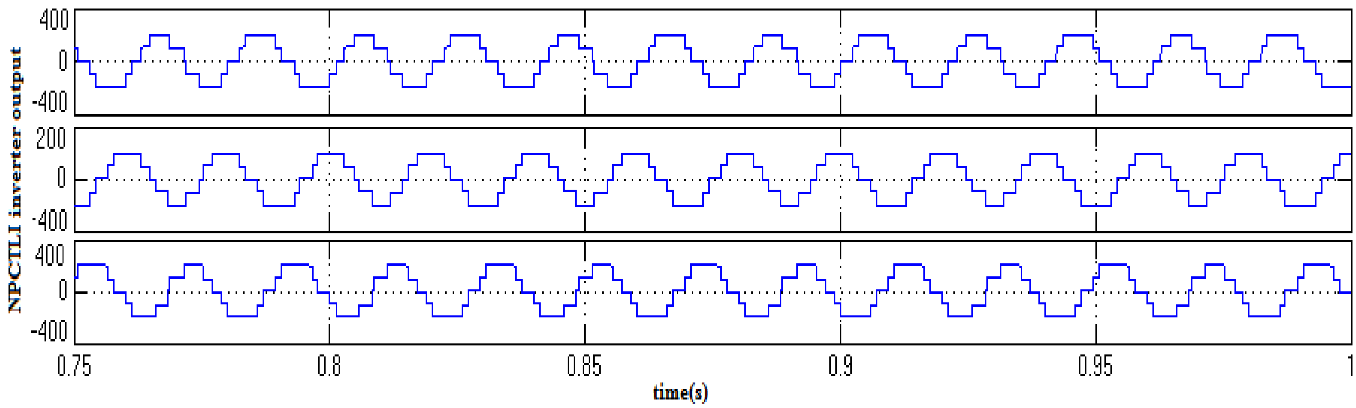

Fig.11 NPC-TLI Output Voltage

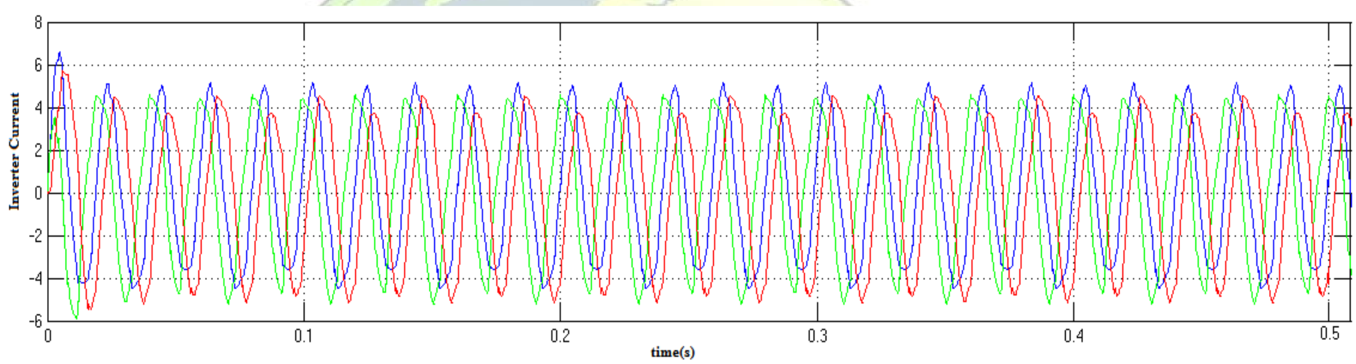

Fig.12 Inverter output current

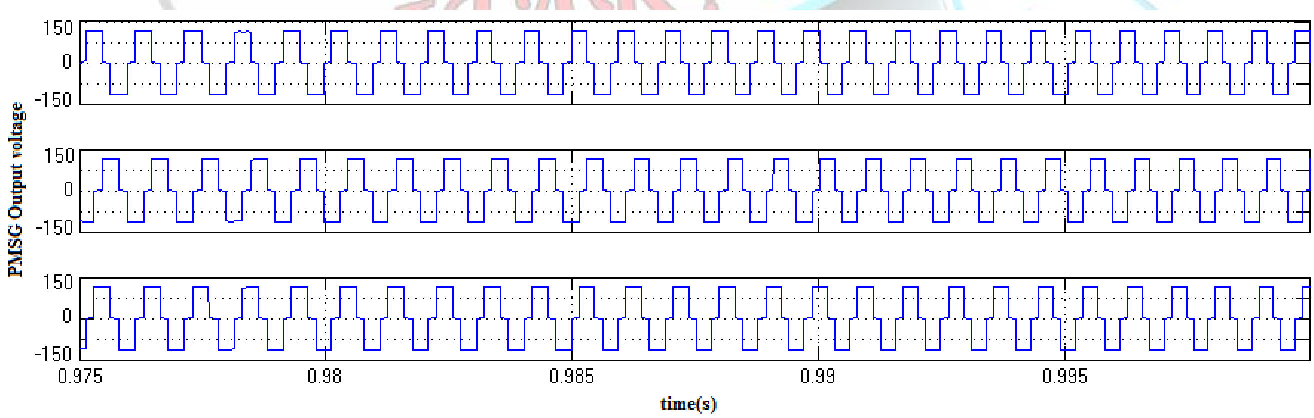

Fig.13 PMSG output voltage

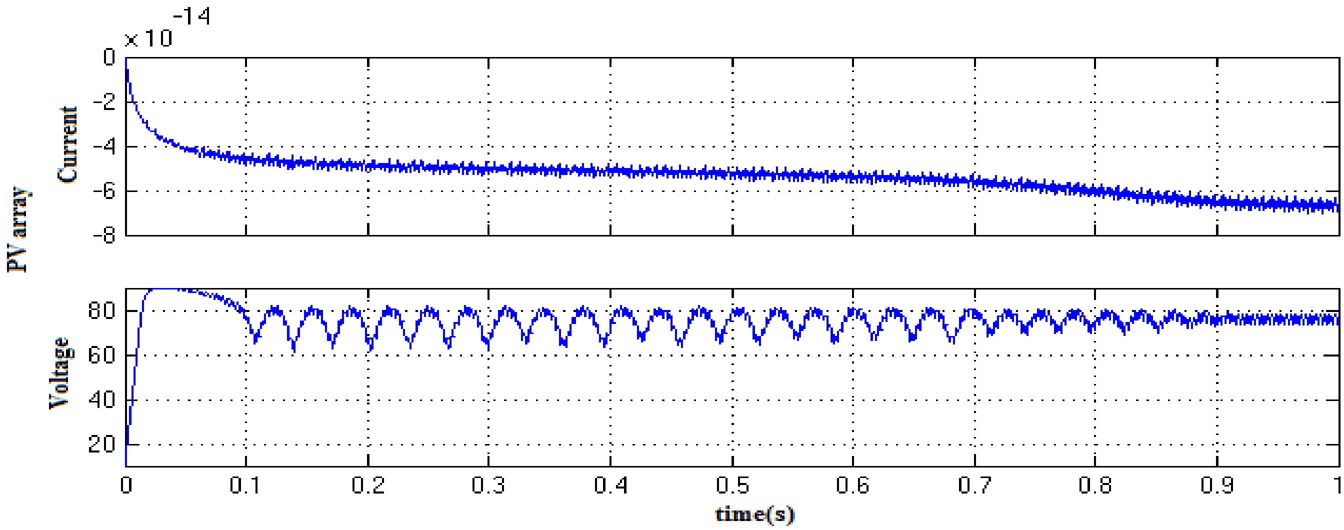

Fig.14PV array output current and voltage

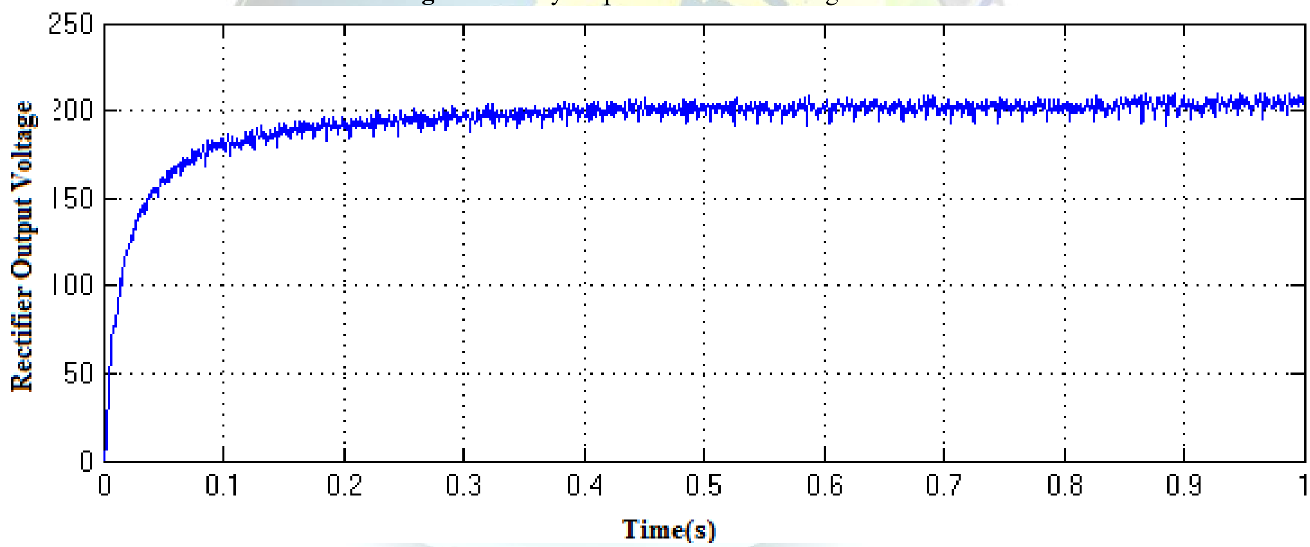

Fig.15 Rectifier Output Voltage

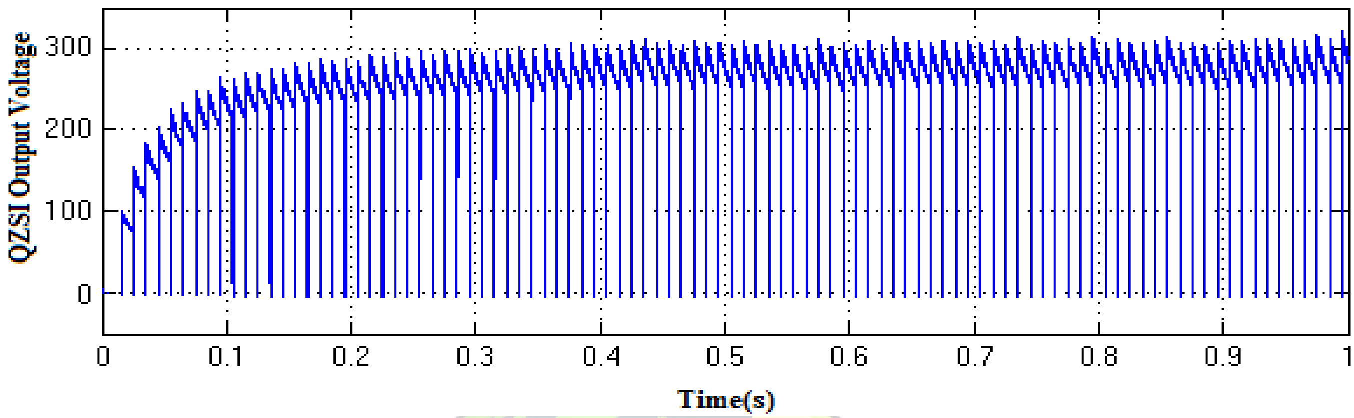

Fig.16QZSI Network boosted voltage

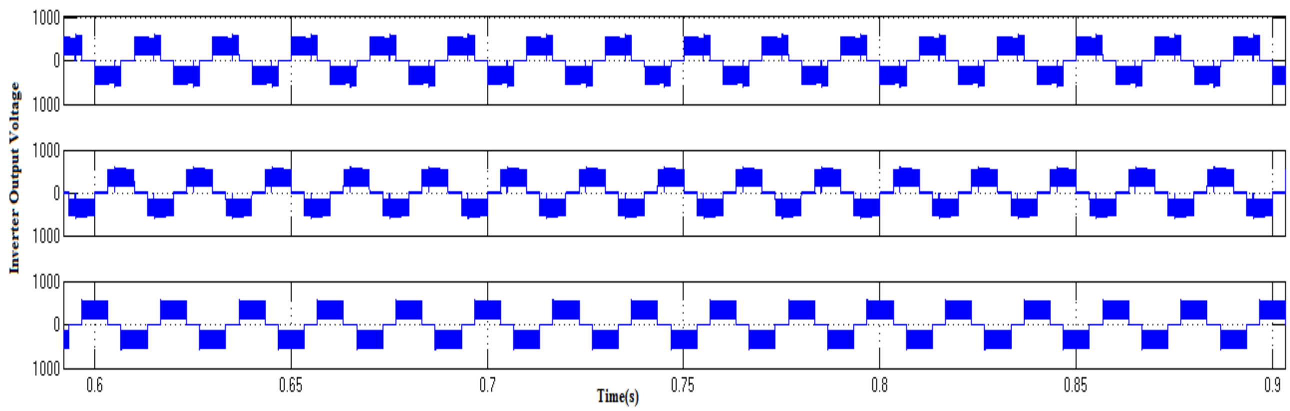

Fig.17 Two level QZSI output voltage

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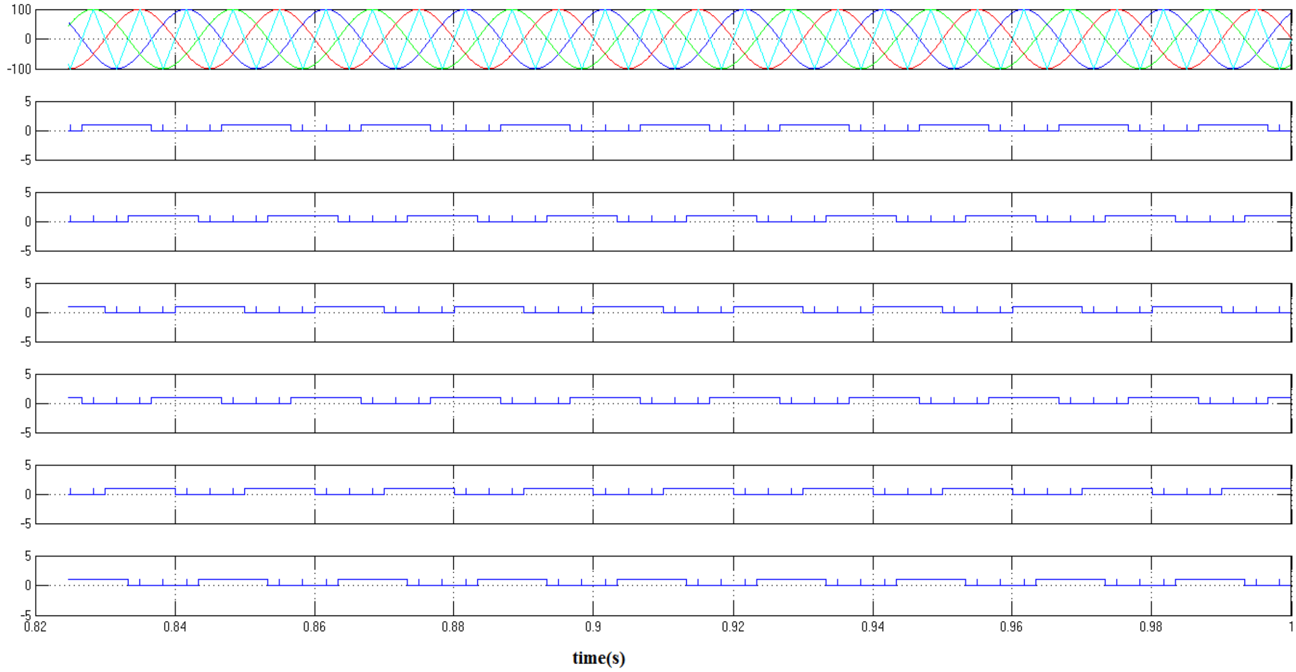

Fig.18 Gating pulses for two level QZSI

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9.Conclusion & Future work

This paper presents a Quasi-Z source network for three level inverter based on two level VSI model. Wind-PV hybrid energy source increases the dc voltage level supplied to the inverter. Using MPPT control optimum available power is obtained from the PV array. Simulation results confirm the voltage boost and shoot through capability of quazi Z source network achieved using PWM switching of TLI.

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