Matrix Converter Technology for Renewable Energy Systemsin Doubly-Fed Induction Generators

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ABSTRACT: In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands additional transmission capacity and better means ofmaintaining systemreliability.Theevolutionoftechnologyrelated towindsystemsindustryleadedtothedevelopmentof a generation of variable speed wind turbines that present manyadvantages compared to the fixed speed wind turbines. These wind energy conversion systems are connected to the grid through Voltage Source Converters (VSC) to make variable speedoperation possible. The studied system here is a variable speed wind generation system based on Doubly Fed Induction Generator (DFIG).The Matrix Converter has several advantages over traditional rectifier-inverter type power frequency converters. It provides sinusoidal input and output waveforms, with minimal higher orderharmonicsandnosubharmonics; it has inherent bi-directional energy flow capability; the input power factor can be fully controlled. The proposed converter is capable of direct ac/ac power conversion and, except for a few smalls number elements; it does not require the use of any input inductors or a dc-linkcapacitor. Here DFIG introduction and AC-AC converter control and finally the SIMULINK/MATL AB simulation for Matrix Converters well as for grid connected doubly Fed Induction Generator and corresponding waveforms are discussed.

Index Terms—Matrix Converter, Doubly fed Induction Generator, Sinusoidal Pulse Width Modulation.

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I.INTRODUCTION

Withincreasedpenetration of wind power into electrical grids, DFIG wind turbines are largelydeployed due to their variablespeedfeatureandhenceinfluencing system dynamics. DFIGs arewidely used for variable speed generation and they are the most important generators for wind energy applications. For a typical DFIG, the power converters are connected to the rotor and, forrestrictedspeedrange,arerate data fraction of the machineratedpower,typically30%of thenominalpower. Inaconventionalimplementationof agrid-connected DFIG, back-to-back converters are used to connect the DFIG rotorto the utility.Therotorsideconvertercontrolsthemagnetizingandtorquerotorcurrents.Thegridsideconverterregulatesthevoltageinthedcbusoft heback- to-back converters.In this paper, a new topology is proposed. The back-to-backconverters are replaced by a Matrix Converter. The Matrix Converter provides bidirectional power flow, sinusoidal input/output currents, and controllable input power factor. When comparedto back-to-back converters, the Matrix Converter has some significantadvantages. For instance, due to the absence of electrolytic capacitors, theMatrix Converter can potentially be robust and reliable.The space saved by an MatrixConverter, comparedtoaconventionalbackto- backconverter, hasbeenestimatedasafactorof three. Therefore,insomeapplications,the MatrixConverter can beembeddedinthemachineitself.Furthermore,thereis no intrinsic limitation to the Matrix Converter power.A sinusoidal pulse width modulation(SPWM) technique is used to control the Matrix Converter, regulatingtherotortorqueandmagnetizingcurrents.Fig.1 shows theproposed wind energy conversion system (WECS). In the MatrixConverter input side, a second- order*LC*powerfilterisusedtoimprovethe current waveform andreducetheinputvoltagedistortion.The interaction between the MatrixConverter and input power filter may produce resonances and eveninstability in the system.

II. WIND ENERGY CONVERSION SYSTEM

The last decades have seen a significant expansionof theuse of theWindEnergy Conversion System (WECS).Thisisdue,tothefactthatthisenergy yieldstheproductionof electricitywithout anygas emission. There are several reasons for using variable speedoperationofWindturbines.Amongthem the possibilities to decrease stresses of the mechanical structure and acoustic noise reduction and possibilities to control Activeand Reactive power. Most of the major wind turbine manufacturers are developing new larger wind turbines in the 3-6 MW range. These allwind turbines are based on Variable wind speed operation with pitchcontrolusingadirectdrivensynchronousgenerator or a Doubly Fed Induction Generator. The major advantageof theDFIG isthatthe PowerElectronic equipmentonly hasto driveapart of the total system power; this means that the losses in the Power Electronic converters are reduced as well as the cost
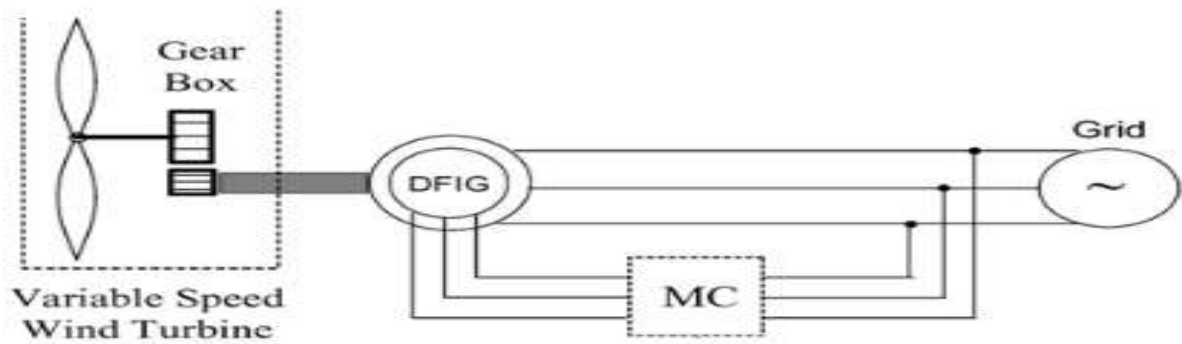
Fig 1: WECS structure

III. DOUBLY FED INDUCTION GENERATOR

A. Introduction to DFIG

Wind turbines use a doubly-fed induction generator(DFIG)consistingof awoundrotorinduction generator and an AC-AC IGBT-based Matrix Converter. The stator winding isconnected directly to the 50 Hz grid whiletherotorisfedatvariablefrequencythroughthe AC-AC converter. The DFIG technology allows extracting maximumenergy fromthe wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses onhe turbine during gusts ofwind.Theoptimum turbinespeedproducingmaximum mechanicalenergyforagivenwindspeedisproportional tothe wind speed. Anotheradvantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thuseliminatingtheneedforinstallingcapacitorbanksas values.

B. Equivalent circuit of DFIG

The induction machine can be represented by the transformer per phase equivalent circuit model whereRr andXr represent rotor resistance and reactance referredto the stator side. The primary internal stator induced voltage Esi is coupled to the secondary rotor inducedvoltageEr by anidealtransformerwithaneffectiveturnratioaeff .But the equivalent circuit differs fromthe transformer equivalentcircuitprimarilyintheeffectsof varyingrotor frequencyontherotorvoltageEr.Inthecaseofdoubly fed inductionmachines, however there is a voltage injected in to the rotor windings so that the normal induction machine equivalent circuit needsto be modified by adding a rotor injected voltage ofthe stator and rotor voltage and current respectively.
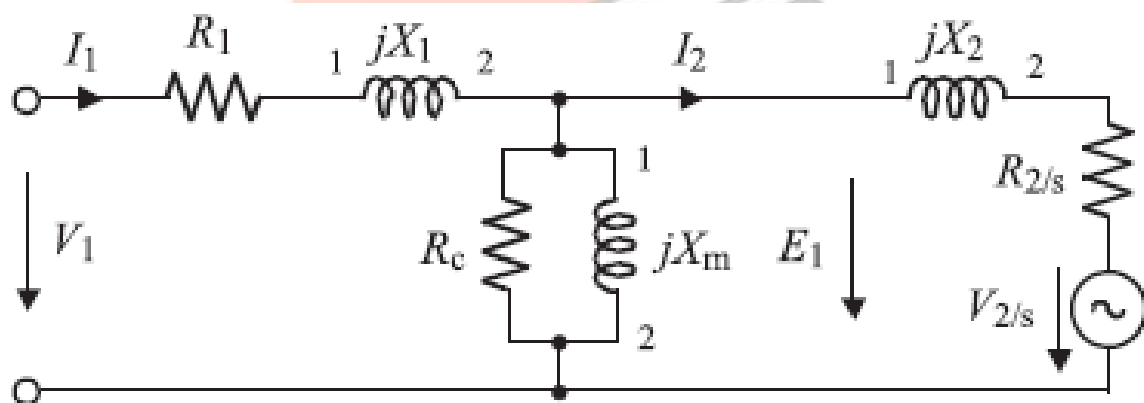

Fig 2: Equivalent circuit ofDFIG

C. Mathematical model of DFIG

From the equivalent circuit for a doubly fed induction machine the realand reactive power of stator PsW,PsQ and rotor PrW, PrQ and the torque developed Tm can be derived as follow

$$PsW = 3V1I1\cos(\phi V1 - \phi I1),$$
$$Psq = 3V1I1\sin(\phi V1 - \phi I1),$$
$$\Pr W = 3V2I2\cos(\phi V2 - \phi I2),$$
$$\Pr q = 3V2I2\sin(\phi V2 - \phi I2),$$
$$T = 3EsiIr\cos(\phi Esr - \phi I2).$$

IV. MATRIX CONVERTER

The Matrix Converter is an array of bidirectionalswitchesasthemainpowerelements,which interconnects directlythe power supply to the load, without using any dc-link or large energy storage elements.Themost importantcharacteristics of matrix convertersare: 1) simple and compact power circuit; 2) generation ofload voltage with arbitrary amplitude and frequency; 3) sinusoidalinput and output currents; 4) operation with unitypower factor; 5) regeneration capability. These highly attractivecharacteristics are the reason for the tremendous interest in this topology.

V. SINGLE PHASE MATRIX CONVERTER
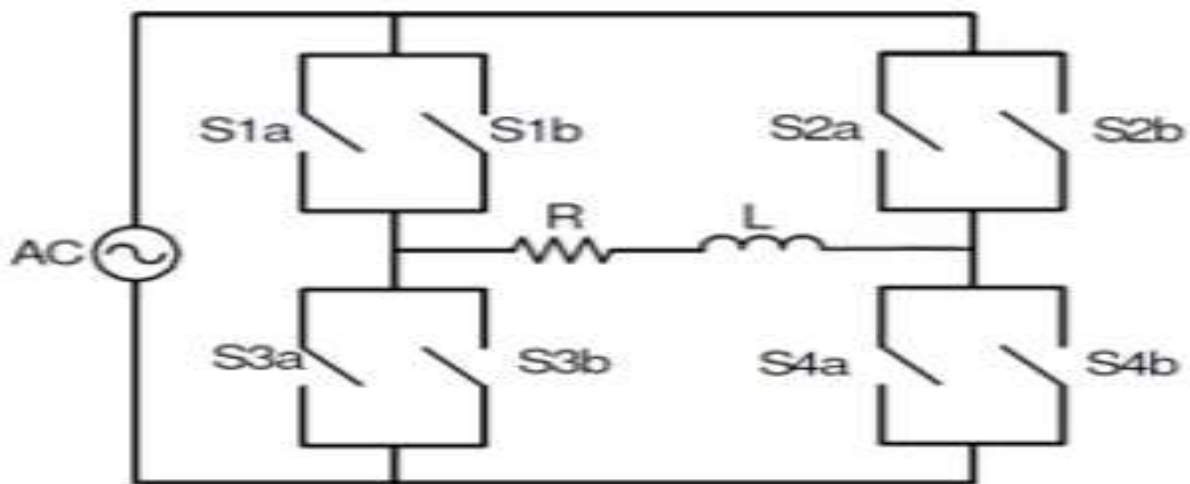
Fig 3: Single Phase Matrix converter topology
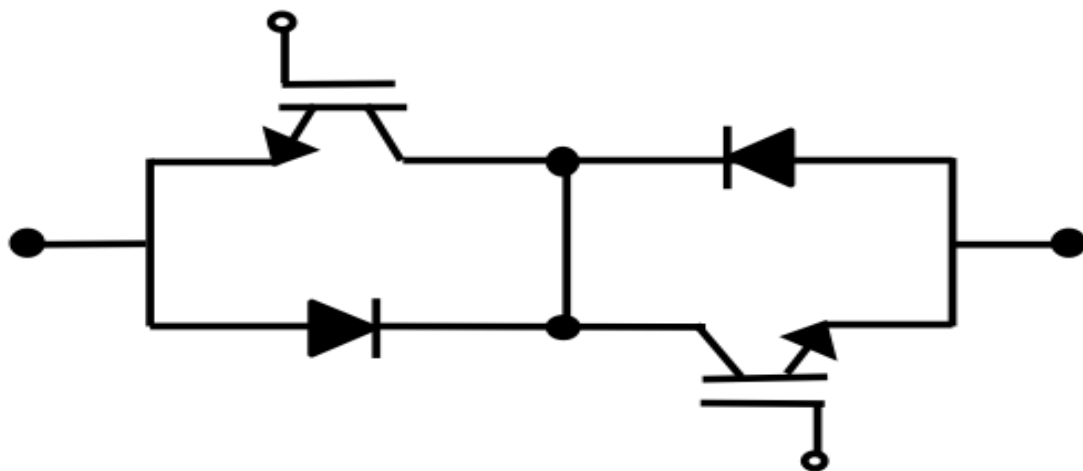
Fig 4: Bi-directional switch

The SPMC requires 4 bi-directional switches each capable of conducting current in both directions, blocking forward and reverse direction. The IGBT were used due to its popularity amongst researchers that could lead to high power applications with reasonably fast switching frequency for fine control. The circuit is arranged such that any output lines of the converter can be connected to any input lines. i denotes input, while o denotes output

$$Vi(t) = \sqrt{2}Vi \sin \omega it$$
$$Vo(t) = \sqrt{2}Vo \sin \omega ot$$
$$Vo(t) = Rio(t) + Lio(t)/dt$$

VI. SINUSOIDAL PULSE WIDTH MODULATION

The Sinusoidal Pulse Width Modulation(SPWM)is a well known wave shaping technique in power electronics. For realisation, a high frequency triangular carrier signal, V_c, is compared with a sinusoidal reference signal, V_r, of the desired frequency. The crossover points are used to determine the switch inginstants. The frequency of the output voltage depend on the reference signal frequency. The magnitude ratio of the reference signal(V_r)to that of the triangular signal(V_c)
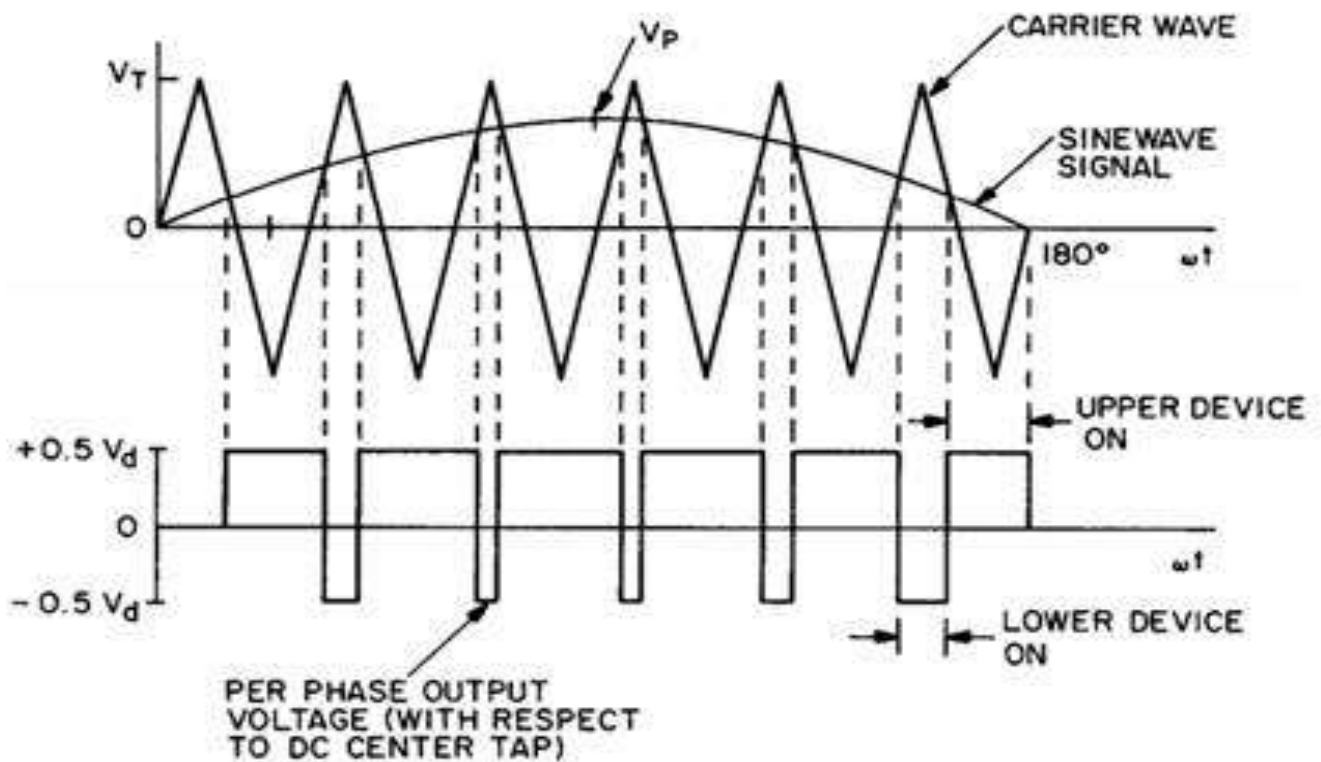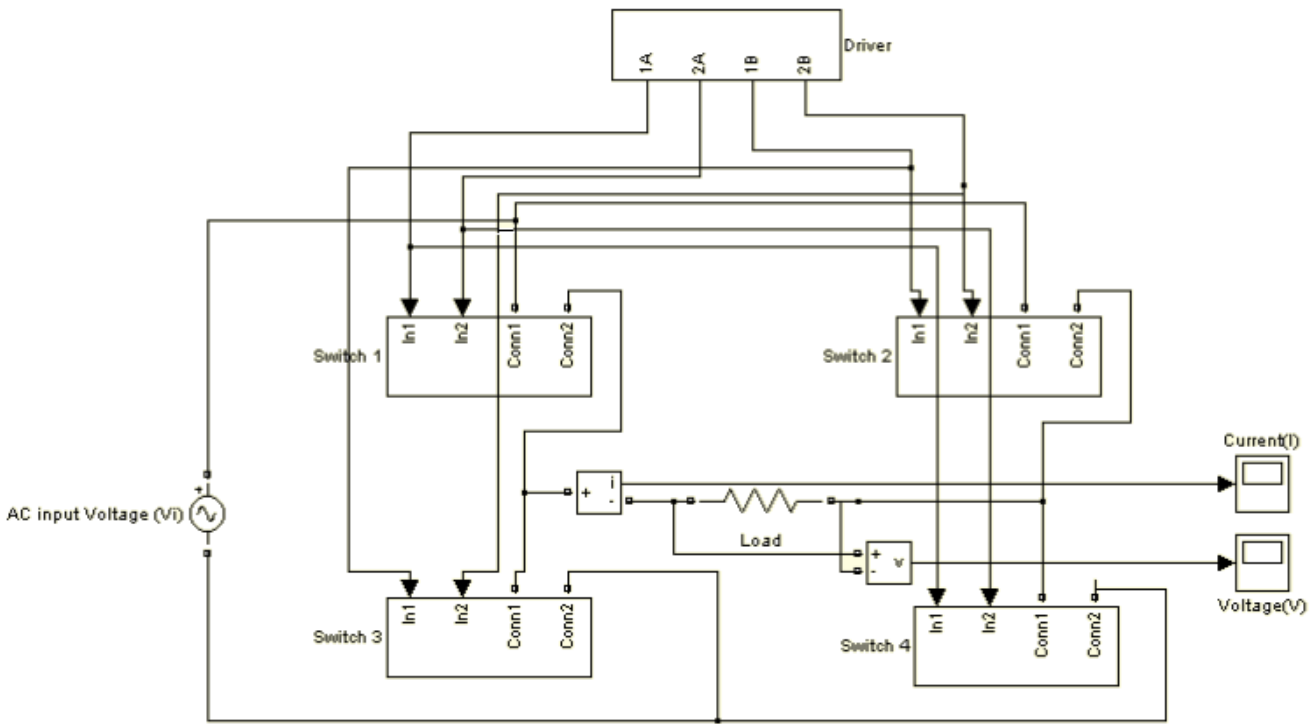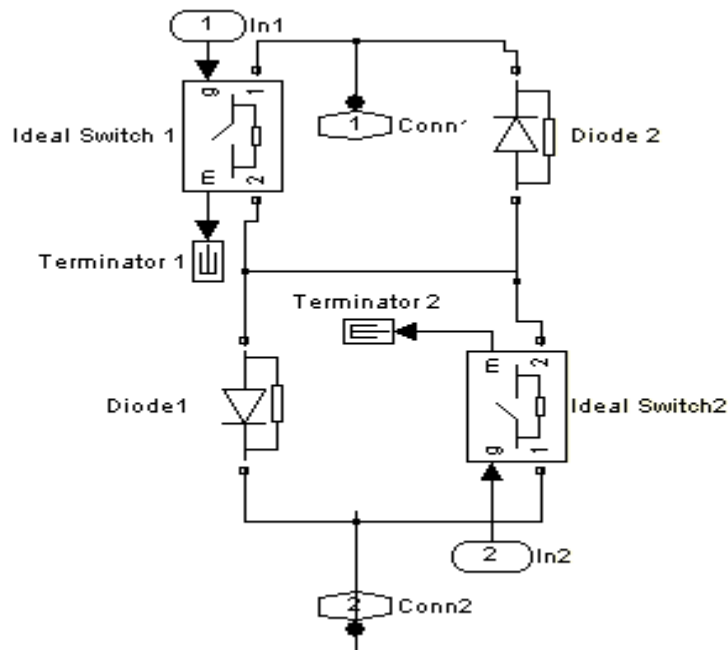

Fig 5: Formation of SPWM

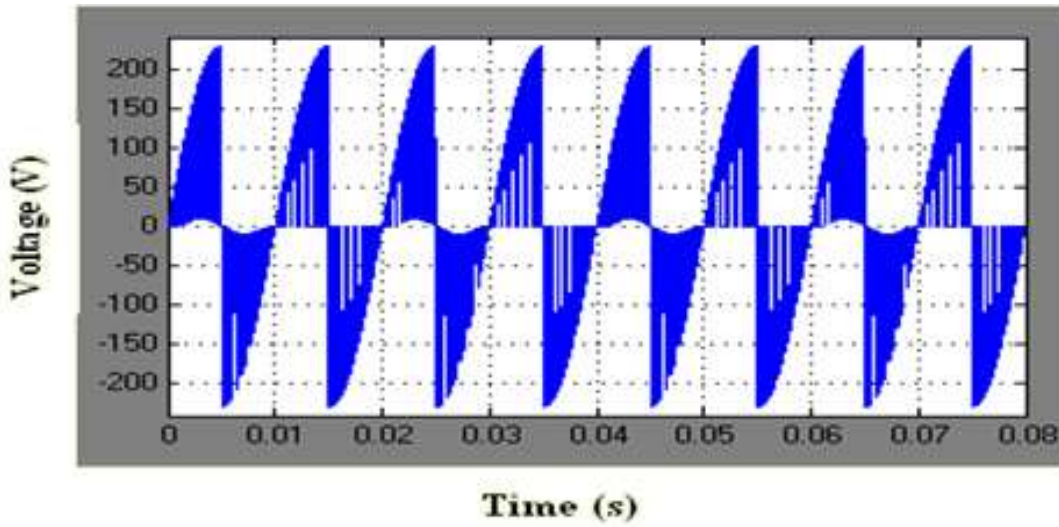## VII. MAIN MODEL OF SPMC IN MATLAB/SIMULINK

Fig 6: SPMC in MATLAB/SIMULINK

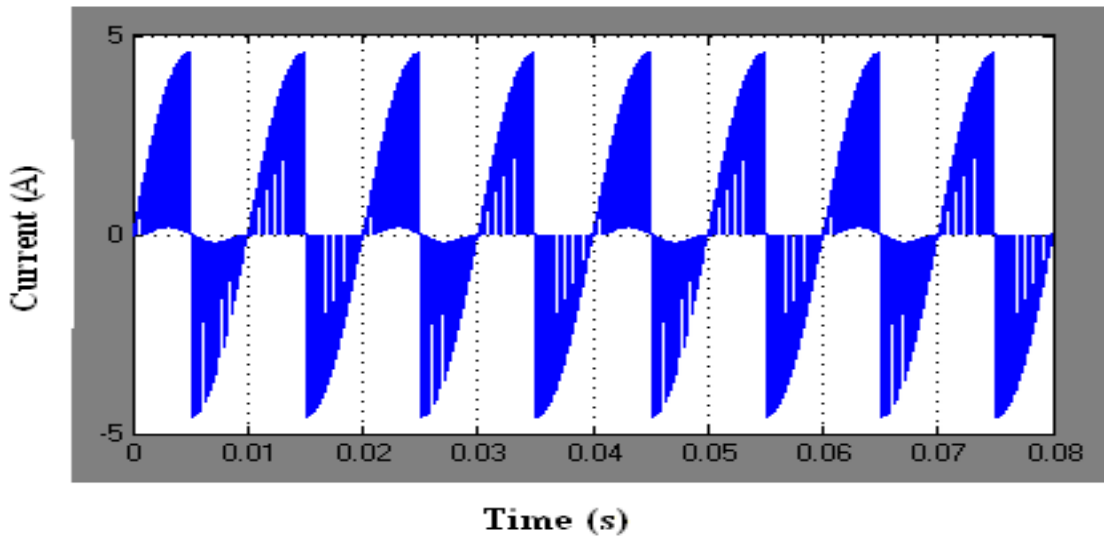## VIII. BI-DIRECTIONAL SWITCH MODULE

Fig 7: Bi-directional switch

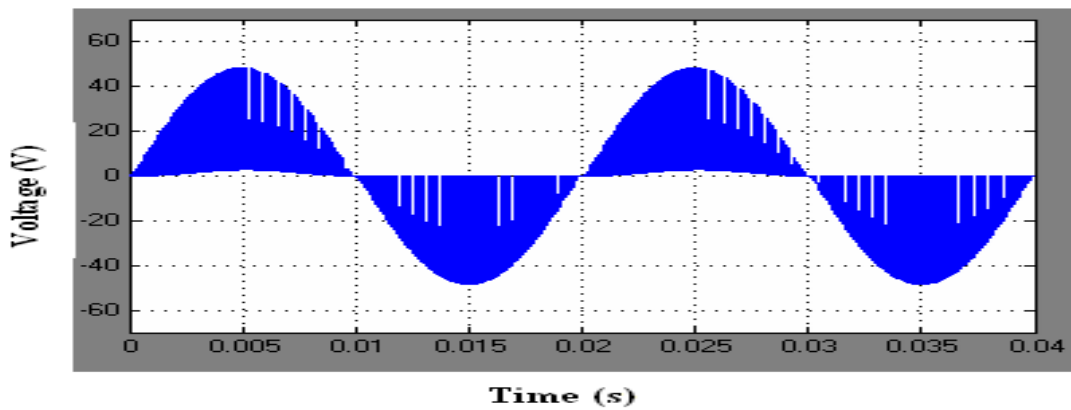## IX. SIMULATION RESULTS

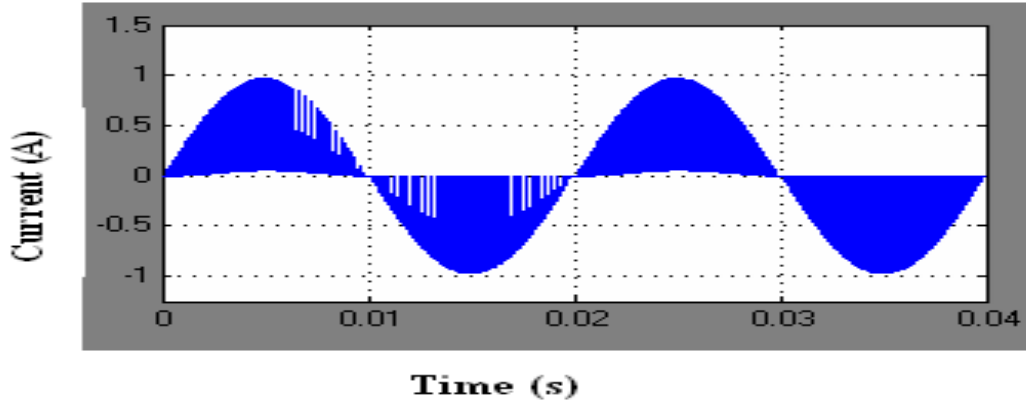a) Output voltage : Input frequency: 50Hz ,Output frequency: 100Hz

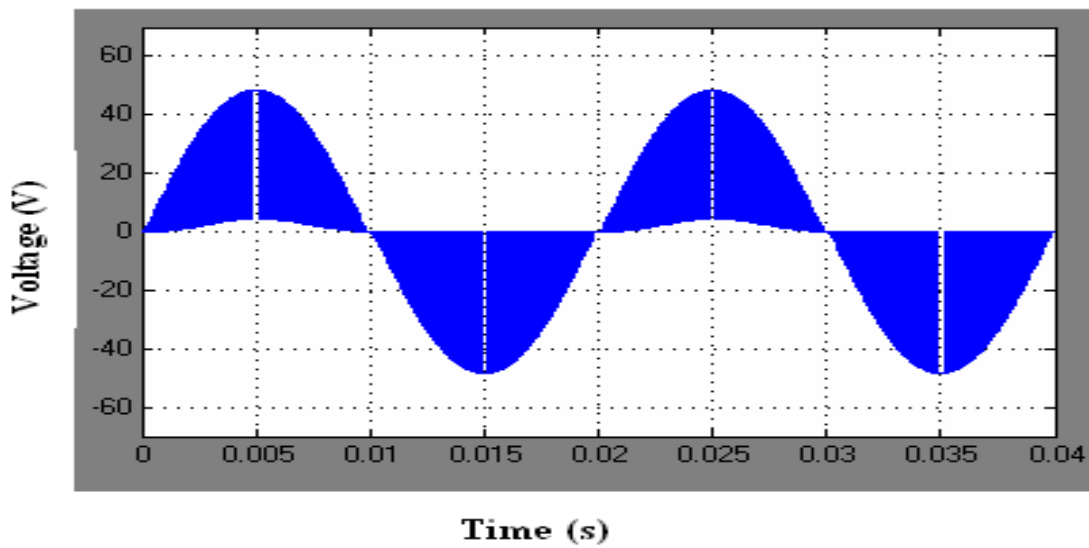b) Output current Input frequency: 50 Hz Output frequency: 100Hz

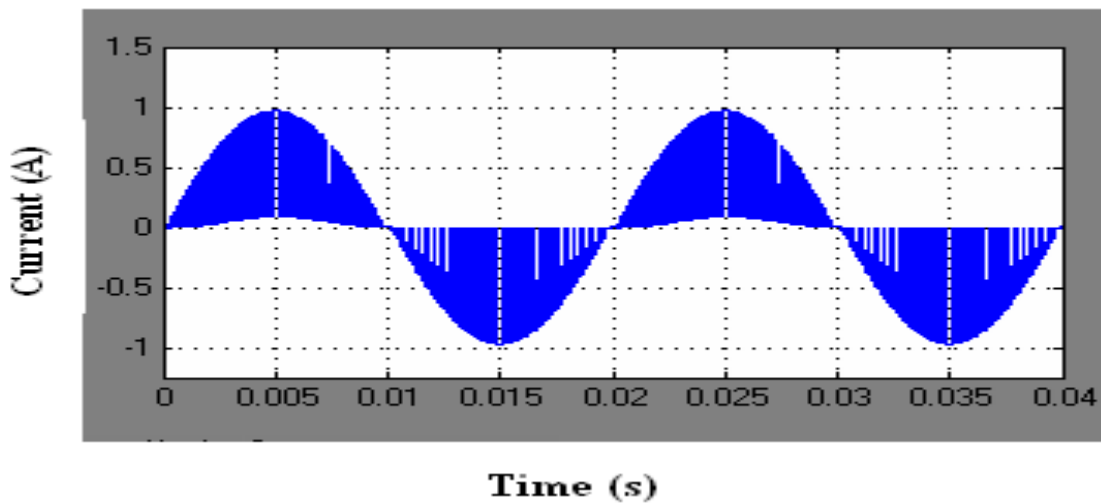**Fig 8: SPMC with varying output frequency**

a) Output voltage Input voltage: 50V Modulation Index: 0.7

b) **Output CurrentInput voltage : 50 V Modulation Index: 0.7 Input Frequency: 50 Hz Output Frequency: 50 Hz**

b) **Output voltage**

c) **Output Current: Modulation Index: 1, Input Frequency: 50 H**

X. THREE PHASE MATRIX CONVERTER

The matrix converter is a single-stage converter, which is composed of an array of m x n bidirectional power switches, each connected between one phase of the input and one phase of the output. Theoretically, the number of input phases, m must be at least three, and the number of output phases, n can be chosen from one to infinity. The basic matrix converter topology which connects a three-phase voltage source to a three-phase load is the most important converter from a practical point of view. A matrix converter is an unlimited frequency changer, which can generate both smaller and bigger output frequency than input frequency of the converter. The output voltage waveforms are constructed by piecing together selected segments of the input voltage waveforms.

Each switch is characterized by a switching function. Each switch S_{Kj}, $K=\{A,B,C\}$, $j=\{a,b,c\}$ can connect or disconnect phase K of the input stage to phase j of the load. Output voltages v_{jN} can be synthesized by switching according to a proper combination of these switches. Control of the matrix converter must comply with the following basic two rules. Firstly, any two input terminals should never be connected to the same output line to prevent short-circuit, because the MC is fed by a voltage source. The other, an output phase must never be open-circuited, owing to the absence of a path for the inductive load current which leads to the over-voltages.
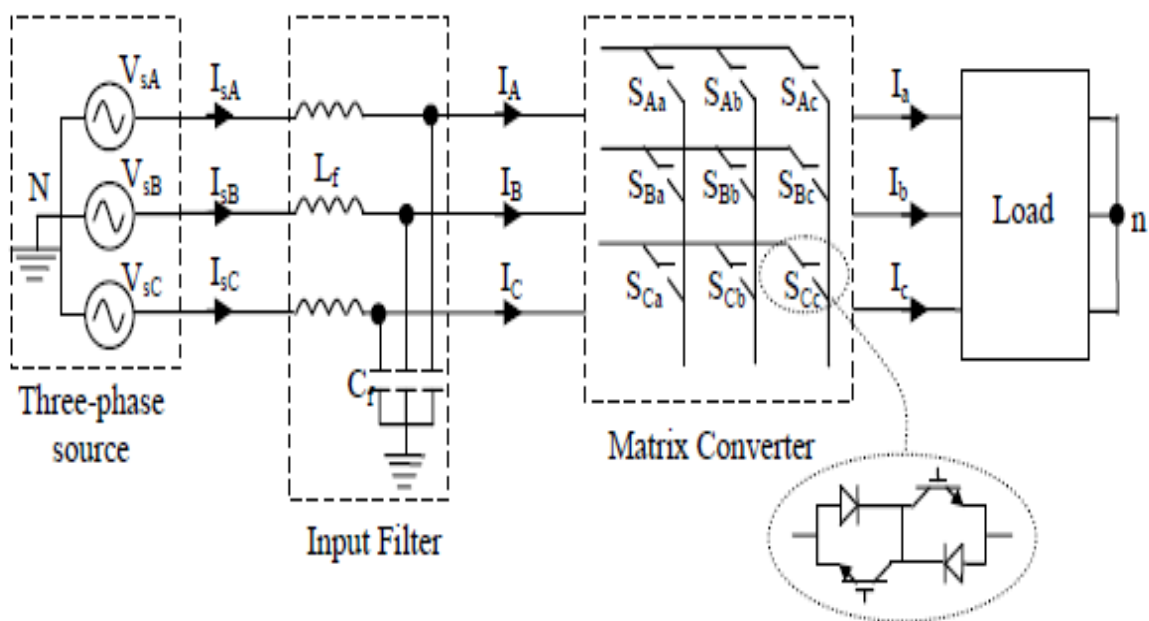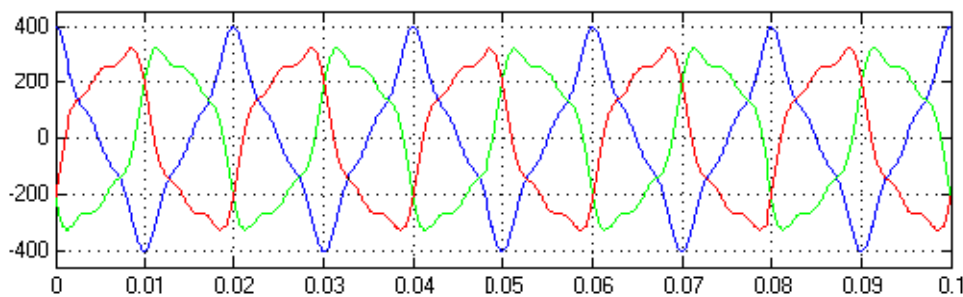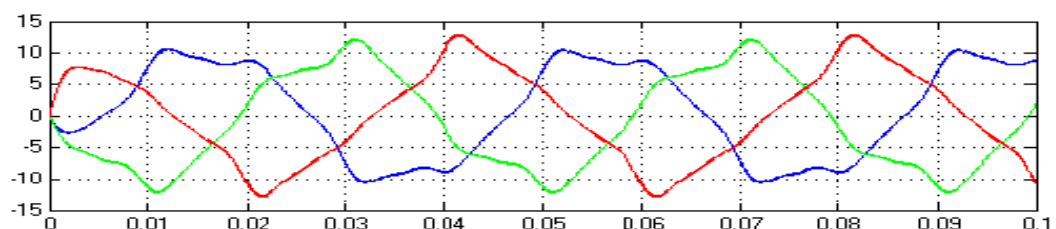

Fig 10: Three Phase Matrix Converter topology
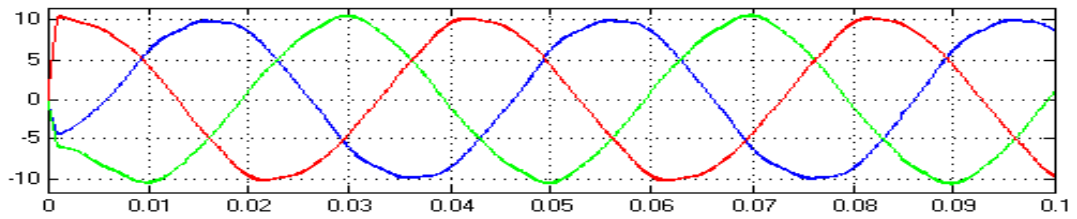
XI. SIMULATION RESULTS

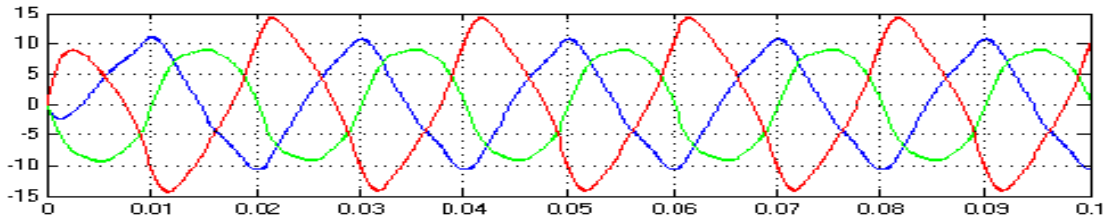a) Input voltages which have 20% third and 10% fifth harmonics

b) Output currents without compensation

c)   Output currents with compensation

d)   Fig11:Three-phaseoutputcurrentsforMCtheunder distorted input voltage conditions (fo = 25 Hz)
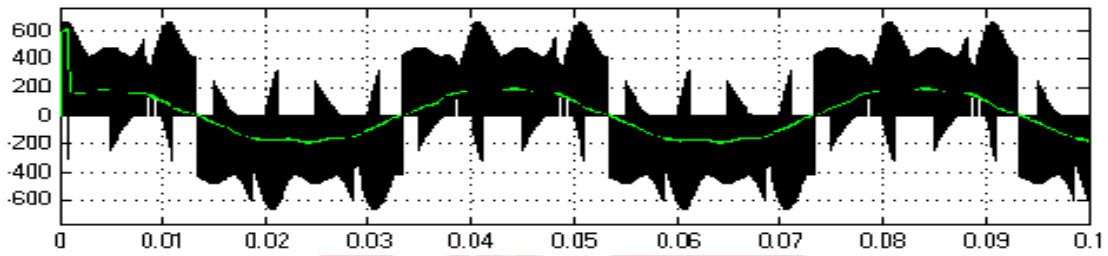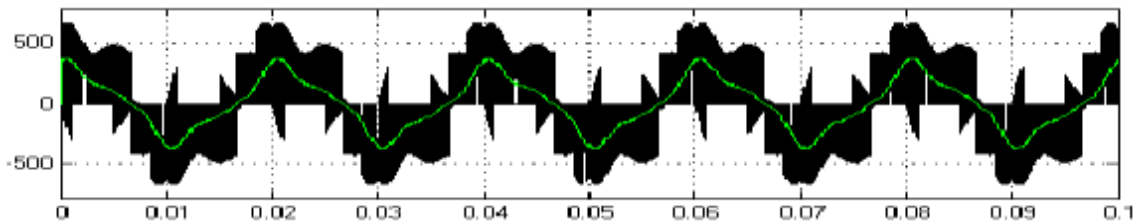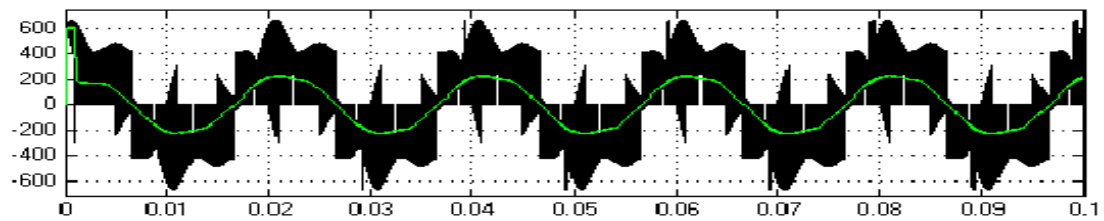

a) Output currents without compensation

Fig 13: Three-phase output voltage for MC the under distorted input voltage conditions (fo = 25Hz)

a)   Output voltage without compensation

b)   Output voltage with compensation

c)   Fig 14: Three-phase output voltage for MC the under distorted input voltage conditions (fo = 50Hz)

XII. CONCLUSION

This paper hase valueted the performance of an Matrix Converter based DFIGWECS. Underundesirable effectsof the inputsupply voltage, the proposed compensation technique is an effective method to reduce harmonicsof the output currentand voltage.TheDFIGis able to provide a considerable contribution to grid voltage support during short circuit periods.The matrix converter replacestheuseof PWMdc-linkconverterswhichreduces lossesproducedduetotheenergystorageelements. The MATLAB/ SIMULINK models of Matrix Converter results are validated.

XIII. REFERENCES

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