SVPWM based Control of SCIG-Matrix Converter for Wind Energy Power Conversion System

N. Thiyaagarajan, M. Siva Ramkumar, A. Amudha, G. Emayavaramban, M. Sivaram Krishnan, D. Kavitha

Abstract--- In this research work, space vector modulated control of Matrix Converter (MC) topology is utilized with Squirrel Cage Induction Generator (SCIG) [1] for wind power generation systems [2]. The SCIG stator frequency is suitably tuned in order to achieve active power flow into the grid. In the newly introduced topology, a gearless wind energy conversion system [10] is brought into use.

The MC functions as an interface between the grid and SCIG. Space Vector Pulse Width Modulation (SVPWM) mechanism [3] is used for controlling the MC switches. The stator and grid voltage, current waveforms and its THD spectrum are evaluated [9] by making use of the Matlab/Simulink software.

Keywords--- SCIG, Matrix Converter, THD, Three Phases SRF - PLL, Wind Turbine, MATLAB/SIMULINK.

I. INTRODUCTION

In this research work, space vector modulated control of Matrix Converter (MC)[6] topology is utilized with Squirrel Cage Induction Generator (SCIG) for wind power generation systems.

The SCIG stator frequency is suitably tuned to achieve active power flowing into the grid. In the newly introduced topology, a gearless wind energy conversion system is utilized.

The MC functions as an interface between the grid and SCIG. Space Vector Pulse Width Modulation (SVPWM) [5] approach is used for controlling the MC switches.

This research work also evaluates and then compares the results with pulse width modulation approach.

The stator and grid voltage, current waveforms and its THD spectrum are evaluated with the help of Matlab/Simulink software.

A renewable energy resource in the form of surrogate sources of energy has been considered to be a massive investment for the past few years.

Various technologies have developed in order to generate electricity from renewable sources of energy. Wind is one among the most abundant renewable sources of energy available in nature.

The wind energy can be used by a wind energy conversion system (WECS) [7] that comprises of a wind turbine, an induction generator, a power converter and a control mechanism.

Usually, AC-DC-AC converter is deployed between the stator of the generator and the electrical grid with the aim of controlling the wind turbine shaft speed and as a result the power that is generated.

These converters possess an intermediate DC link for storing energy. An alternate to these converters include Matrix Converters (MC), which do not need the DC-link and are capable of carrying out the direct AC-AC conversion.

The Matrix Converter (MC) has emerged to be more prevalent recently owing to its remarkable features such as bidirectional current flow, manageable input power factor, potential sinusoidal output and input currents, and a portable structure.

Different switching approaches for an AC-AC, MC have been developed in order to attain sinusoidal input and output current waveforms.

II. LITERATURE SURVEY

2.1. Multiphase Wind Energy Conversion Systems Based on Matrix Converter

Abdelkader Djahbar et al., This research work introduces a novel variable speed wind energy conversion systems (WECS).

It is dependent on a six-phase asymmetrical squirrel cage induction generator (SCIG) and a matrix converter (MC) in the form of power electronic interface between six-phase SCIG and electrical network.

The analysis uses a rotor flux vector control algorithm and a scalar strategy modulated MC for controlling the generator.

Features of MC are utilized for increasing the power tracking control when various wind speeds and supplying powers to the grid are taken into consideration at the same time. The MC yields sinusoidal input and output voltages and a unity power factor, but result in an asymmetry in the generator.

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A current control approach inclusive of the technique of eliminating the imbalance resulting due to this asymmetry is explained.

Few numerical simulations are performed depicting the efficiency of the newly introduced WECS topology.

2.2. Power Electronics Converters for a Wind Energy Conversion System

Vinay Kumar Dwivedi et al., This research work reviews various generator topologies with power electronics converters.

Since the needs of electricity is getting increased, the researchers are shifting from asynchronous to synchronous generator while few researchers presents the idea of asynchronous generator with wound rotor.

Owing to quick development in power electronics for providing high power, the application of power electronics converters have a vital role to play in wind energy conversion system.

This research work discusses the four kinds of generators like squirrel cage induction generator (SCIG), doubly fed induction generator (DFIG), permanent magnet synchronous generator (PMSG) and wound rotor synchronous generator (WRSG) with their power electronics converters based on their topologies, expense, circuit complexity and efficacy.

This research work reviews various kinds of generator topologies with their integration with power electronics converters for wind energy conversion system (WECS).

2.3 Matrix Converters in Wind Energy Systems

Nabiltaib et al, In the recent times, the power generation systems depending on wind turbines are rising exponentially in the world.

Therefore, intensified attempts are made by researchers for the evolving this domain.

The novel technology in power electronics has a very significant role to play in integrating renewable energy sources in power systems.

It is feasible to design interfaces based power electronics systems for important power projects to increase energy conversion, transmission and control of active and reactive power, to reduce the distortion in harmonic, attaining an economic high performance with an economic range of power and to yield a greater reliability and failure bearing components subsystems.

Matrix converters encompass the new generation of power converters that satisfy much more of the anticipated performances in power systems.

In the current chapter, matrix converters utilized in the wind power generation systems are explained.

2.4 DTC- SVPWM Method

H. Merabet Boulouiha et al, Direct torque control (DTC) theory has been used with success in several high performance industrial AC drives.

This research work introduces the application of DTC space vector modulation (DTC-SVM) to two and three level voltage source inverter (VSI) to enhance the energy efficacy of a variable speed wind energy conversion system.

Three diverse topologies are suggested to regulate the torque and flux of a squirrel-cage induction generator (SCIG) that is powered by a variable speed wind turbine.

The important goal of this research work is to enhance the quality of energy of the wind energy conversion system by minimizing the torque ripples in the SCIG.

Simulation results have demonstrated that the newly introduced DTC-SVPWM with two or three levels inverter generated enhanced transient responses and reference tracking performance of the voltage in the generator and grid sides in addition to the DC link.

The implementations of all the simulation models have been done with the help of Simulink and Sim Power Systems toolboxes.

2.5 SVPWM Based TPIM Method

Tomas Laskody et al, The research work introduces a new Space Vector Pulse Width Modulation (SVPWM) for two stage two-phase matrix converter with four legs fed two-phase induction motor (TPIM).

The control approach proposed minimizes the number of switching, switching losses and hence maximizes the efficacy.

Comparison analysis of simulated and measured stator currents THD and comparison of efficiency achieved by two stage matrix converter regulated by by SVPWM and PWM is also suggested.

III. PROPOSED MODULE

3.1 Proposed Topology and Operational Principle

- The turbine side converter is regulated by the structure called as Indirect Field Oriented Control (IFOC)
- The stator winding is connected by back-to back PWM converters (AC/DC/AC) to the grid and the rotor is powered by the wind turbine.
- In comparison with the proposed topology utilized in SCIG based variable speed system, the available systems yields a low power factor with low efficiency and high THD.
- In the available control mechanism, grid connected system shows a poor power quality in terms of the Total Harmonics Distortion (THD) of the grid injection current in comparison with the newly introduced system.

3.1.1 Existing System Drawbacks

- Coordinate transformation and decoupling between active and reactive components is necessary.
- Sophisticated algorithm.
- Input power factor lesser compared to the presented system
- Dynamic response is slower compared to the proposed system.
- Higher switching Losses & Lesser Efficiency.

3.2 Working Principle of the Proposed Converter

This technical work is chiefly focused on the operation of a gearless WECS dependent on grid connected MC-SCIG that is directly coupled to the turbine.

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The squirrel cage induction generator is the most inexpensive and robust electric machine.

Moreover, the induction generators are dependable and they have remarkable mechanical properties for wind turbines, such as slip and an extent of overload capability.

A simplified space vector mechanism for MC based on the instantaneous phase voltages has been exploited for gearless operation of a wind energy generation. The control system consists of the zero-sequence component, which facilitates the compensation of zero-sequence harmonics.

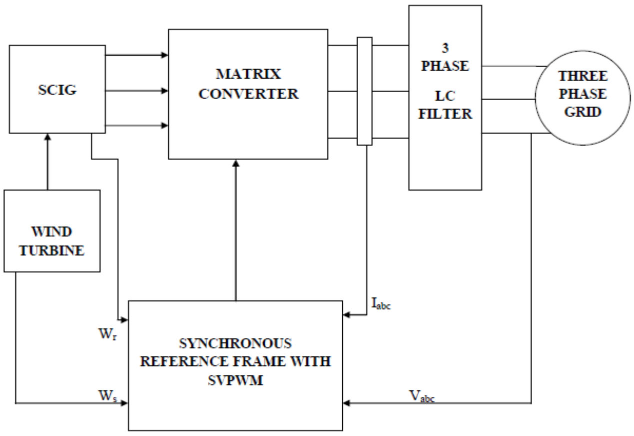

Figure 3.1: Proposed Block Diagram

It depicts that power loss reduction and mitigation of current and voltage harmonics can be achieved in the new system.

A novel modulation approach utilized is SRF- PLL control mechanism with grid loop controller and it will help in improving the output current harmonics of a wind energy conversion system, inclusive of a Squirrel cage Induction Generator (SCIG) and a matrix converter with SVPWM is introduced.

The design and analysis of a control mechanism for a SVPWM based wind energy generation under imbalanced load conditions are suggested.

The control goals include (i) reducing the ripples in the torque, (ii) to reduce the voltage deviations through converter controls and (iii) to boost the THD.

A SRF reference frame approach is presented. This technique is deployed in the converters of the SCIG to improve the voltage ride-through capabilities of SCIG-based wind turbines.

During the power quality analysis, the effects of high penetration electric vehicles and renewable energy based generator systems, inclusive of wind turbines, grid connected photovoltaic, and fuel cell power generation units are presented. A proportional control mechanism is deployed in the SRF reference frame side to reduce the machine side current harmonics and torque pulsations. The foremost goal of the control mechanism is to maintain stable voltage and frequency at the output of the generator.

A control mechanism is introduced for upgrading the SCIG based proposed system to accomplish low THD. Mitigating the voltage harmonics is an essential task, which cannot be carried out by inverters. In this research work, the novel approach is utilized for the mitigation of the harmonics [4] current of the power system.

3.3. Proposed System Advantages

- No current regulation loop.
- No coordinate transformation.
- Good dynamic performances.
- Simple algorithm.
- Decoupled active and reactive power control [8].
- Instantaneous variables with all the harmonics components estimated (enhance the Power Factor, THD and Efficiency).

IV. SIMULATION RESULTS

4.1. About MATLAB

The simulation of this project is done in MATLAB R2009b tool that is user friendly software. MATLAB is a high-level language and interactive environment used for numerical computation, visualization, and programming. Making use of MATLAB, data can be analyzed, algorithms can be developed, and models and applications can be created.

The language, tools, and built-in math functions facilitate in exploring different approaches and attain a solution quicker compared to spreadsheets or classical programming languages, like C/C++ or Java™. MATLAB can be used for an array of applications, inclusive of signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology.

Several million engineers and scientists in industry and academia exploit MATLAB, which is the language of technical computing, Simulink is basically a data flow graphical programming language tool for modeling, simulating and evaluating multi domain dynamic systems.

Its primary interface is a graphical block diagramming tool and a customizable group of block libraries. It provides a strong integration with the remaining MATLAB environment and can either help in driving MATLAB or be scripted from it. Simulink is extensively utilized in control theory and digital signal processing for multi domain simulation and Model-Based Design.

4.2. Simulation Diagram of Proposed Method

Figure 4.1 illustrates the SCIG-simulated model of a classical Matrix converter for a wind turbine driven system. The simulation of the model was done for various wind speeds. At last, the comparison of the input and output THD was done with that of the newly introduced WECS. This model comprises of a wind turbine, a Matrix Converter, DC link and with a SRF-PLL, SVPWM controller. Figure 4.7 illustrates the change of the input current THD of the proposed system. The percentage THD of the traditional system was nearly 18% higher compared to the proposed system. This results in lesser input power factor and greater switching losses.

The above mentioned disadvantages are mitigated with the help of the newly introduced system.

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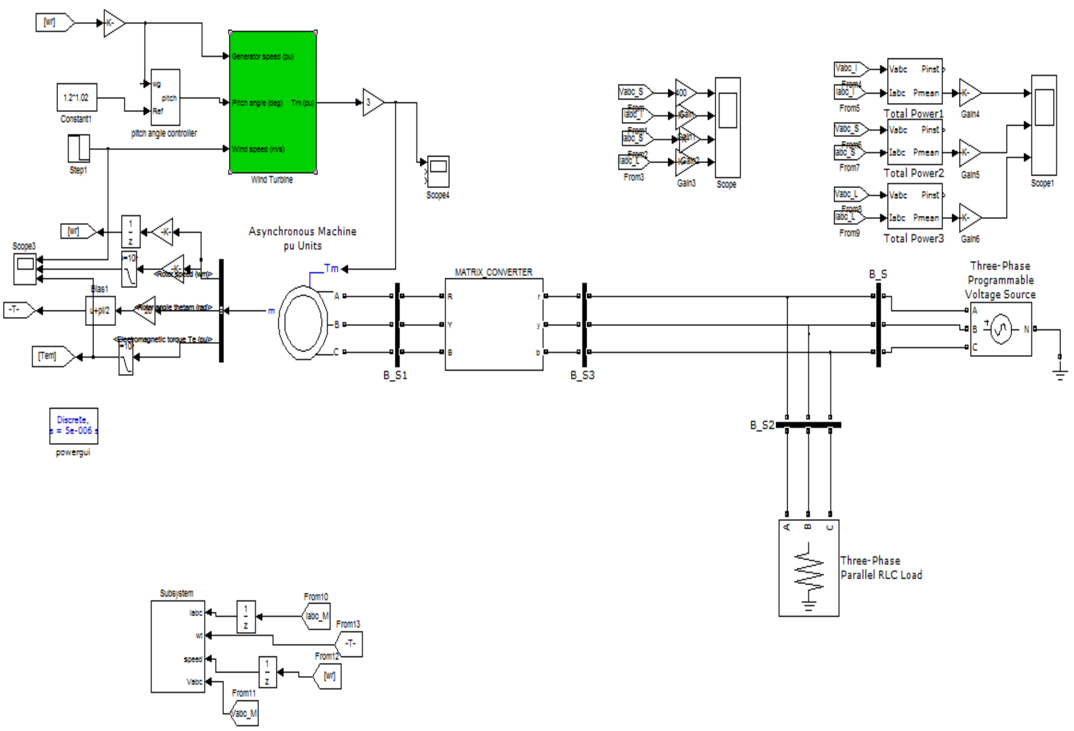

Figure 4.1: Simulation Diagram of SCIG based SRF-PLL Control

Structure with MATRIX Converter & SVPWM

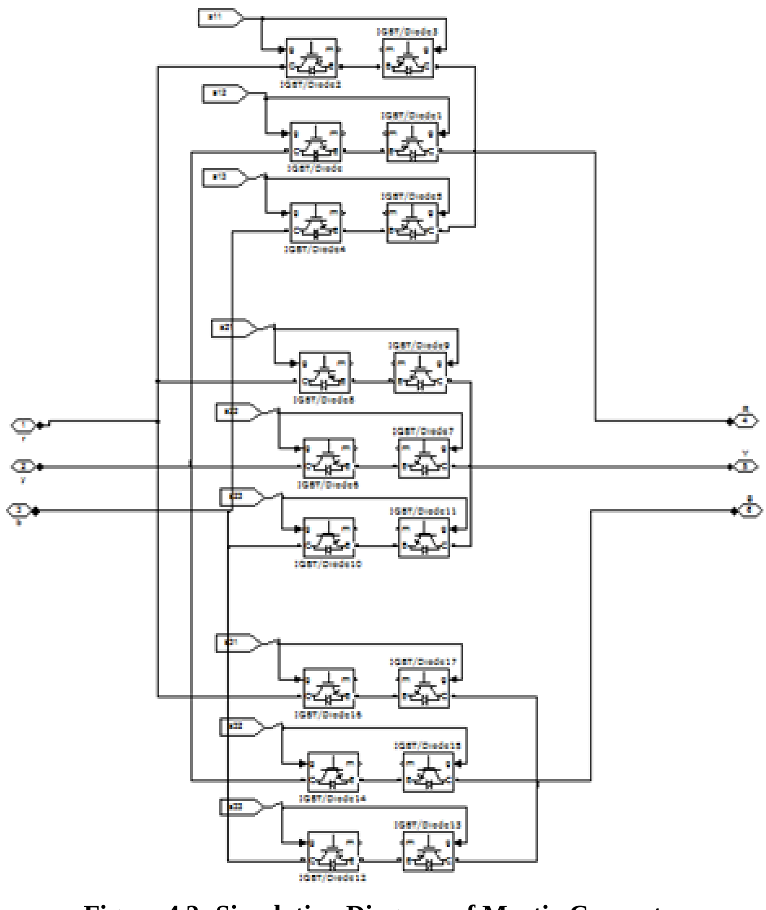

Figure 4.2: Simulation Diagram of Martix Converter

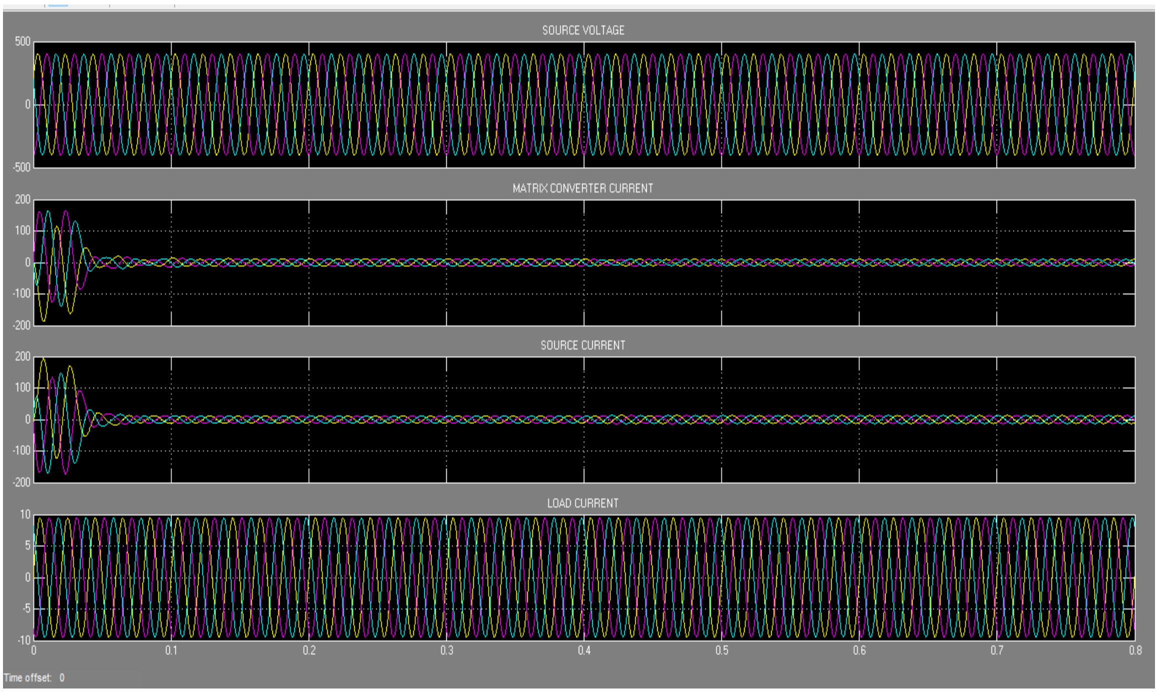

Figure 4.3: Simulation Diagram of Matrix Converter Switching Table

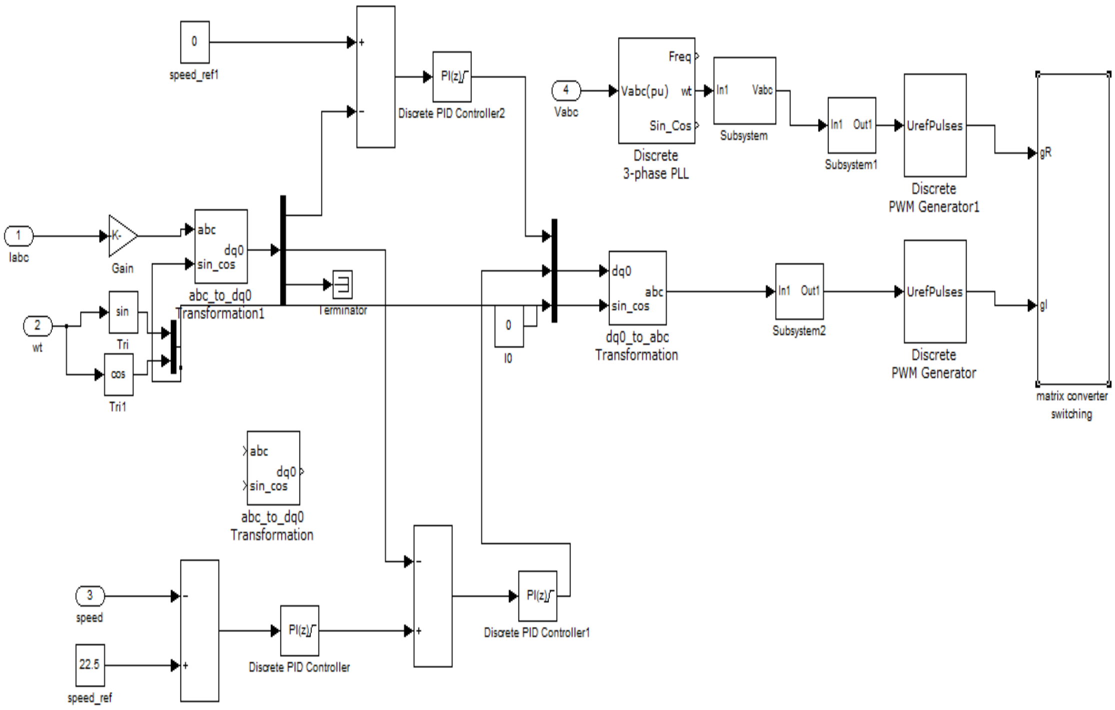

Figure 4.4: Simulation Diagram of Control Loop

Even though the terms of power quality hold true for transmission and distribution systems, their approach towards power quality has various aspects. An engineer working on transmission system works with controlling active and reactive power flow with the aim of maximizing both the loading capacity and stability limitations of the transmission system.

A technique used for overcoming the disadvantage of the available - a proposed model is developed and analyzed in this research. The technique is simple by structure and is dependent on the addition of one (or three in a three-phase case) integrator to the system.

This entirely suppresses the error, which results from the dc component. In addition, an dc component estimation is also present.

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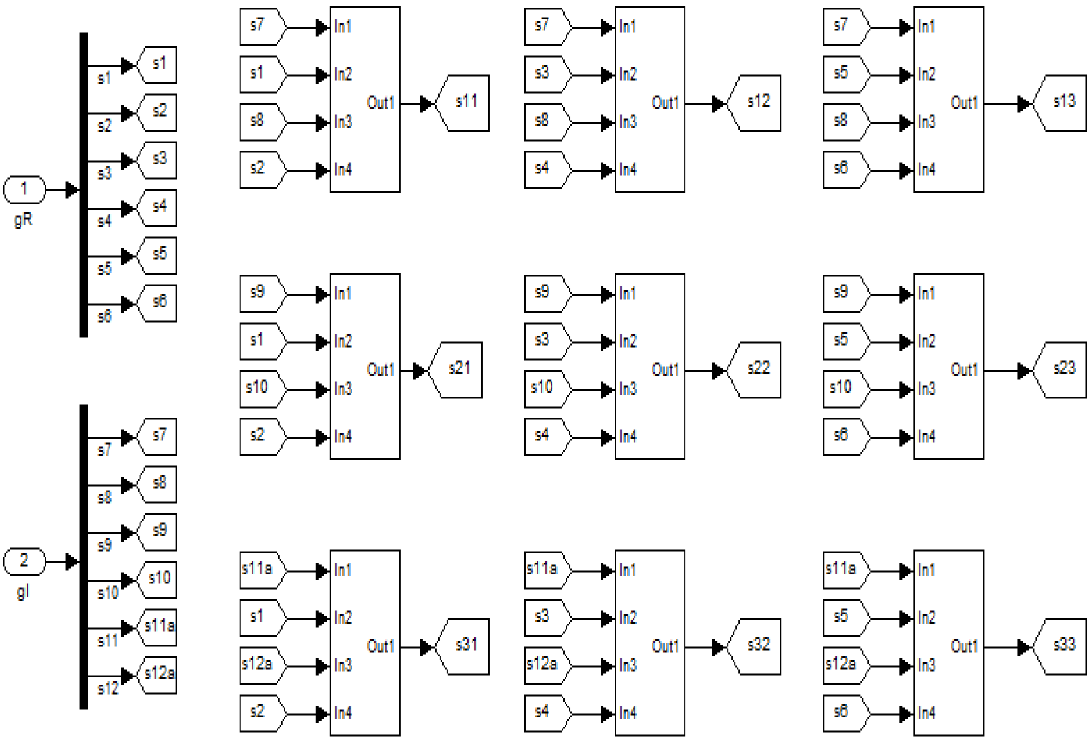

Figure 4.5: Output Waveform of Source Voltage/Matrix Current/Source Current/Load Current

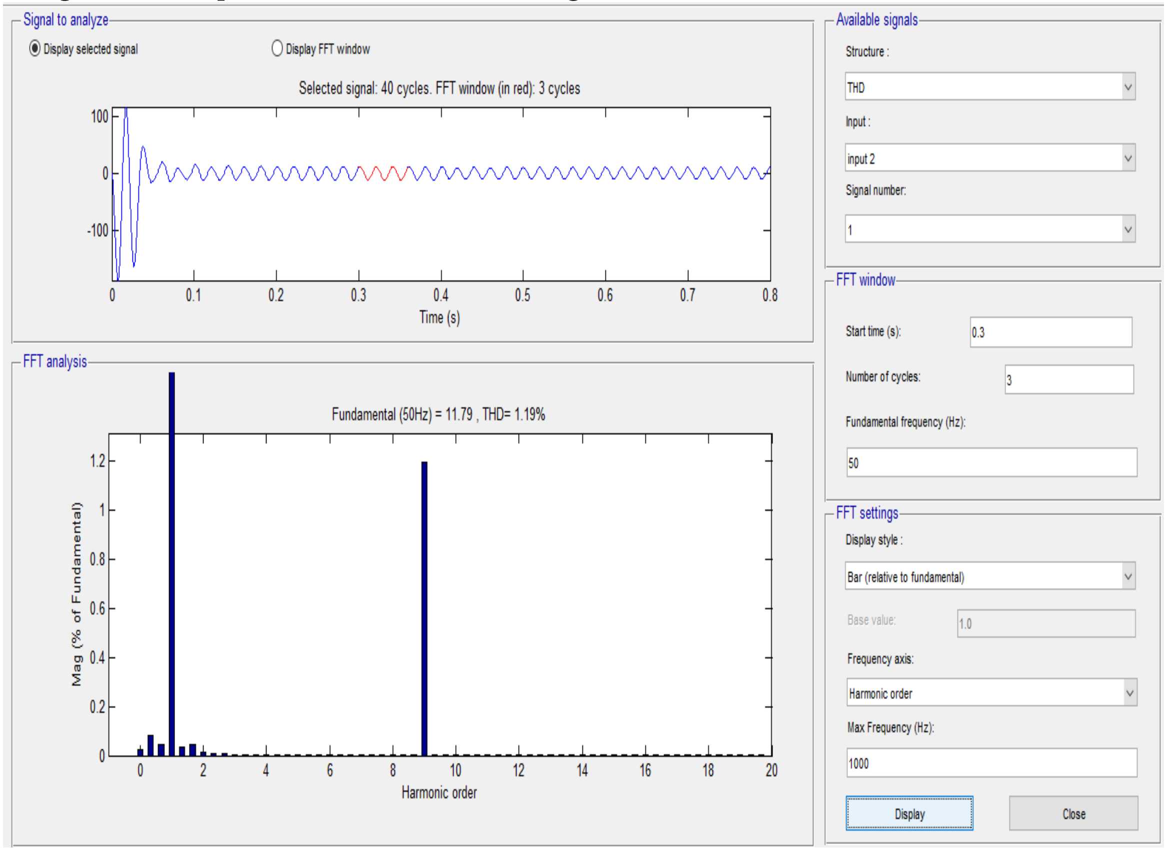

Figure 4.6: Output Waveform of Inverter/Source/Load Power

Fig.4.7 shows the fast Fourier transform (FFT) analyzes to the current injecting in the gird, and in that Figure THD is 1.19%. The grid current waveform is illustrated in the Fig.4.7.

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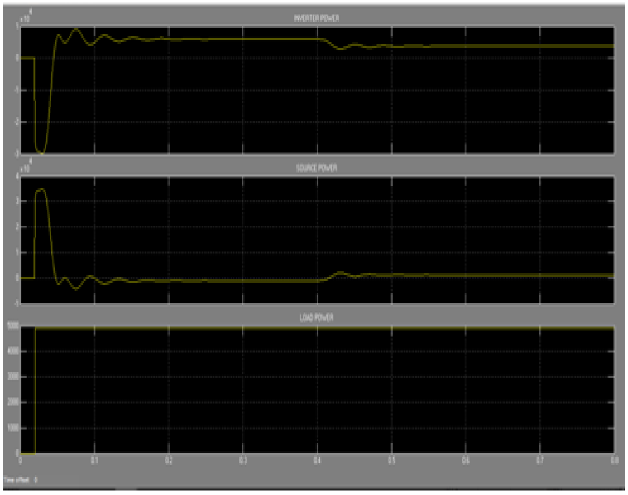

Figure 4.7: Output of FFT analysis for THD =1.19%

The dc component may inherently exist in the input signal or may be produced owing to temporary system outages or because of the structure and constraints of the measurement/conversion processes. A component such as this generates low-frequency oscillations in the loop, which cannot be eliminated with filters as such kind of filters will considerably deteriorate the dynamic response of the system. The newly introduced technique is dependent on the addition of a new loop (SRF-Matrix converter-SVPWM) inherent of the PLL structure. It is simple by structure and, dissimilar to the available techniques explained in this research work, does not settle on the high-frequency filtering level of the related algorithm. The formulation of the technique is done for three-phase systems, its design aspects are explained, and the simulations results are studied above.

V. CONCLUSION

A simplified space vector technique for MC based on the instantaneous phase voltages has been designed for gearless operation of a wind energy generation. The SCIG stator frequency is suitably adjusted and the active power flowing into the grid has been attained. The MC carried out direct AC-AC conversion with SVPWM technique in the form of the controller of the MC switches.

This research work also evaluated and then compared the results with the available pulse width modulation approaches. On the whole, the system results indicate that the system performance of the proposed system is much better compared to old systems. The lower order current harmonics is minimized with the help of SVPWM approach. The stator and grid voltage and current waveforms and THD spectrum of current waveforms was analyzed with the help of Matlab/Simulink software.

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