Application of Frequency based Matrix Converter in Wind Energy Conversion System Employing Synchronous Generator Using SVPWM Method

P. Jeyalakshmi, M. Siva Ramkumar, IR.V. Mansoor, A. Amudha, G. Emayavaramban, D. Kavitha, M. Sivaram Krishnan

Abstract--- ***Renewable energy is garnering the attention of people with rising global energy consumption and perceivable environmental pollution all across the universe. The rising size of wind farms needs power system stability analysis [7] inclusive of dynamic wind generator models. In the case of turbines with power greater than 1MW, doubly-fed induction machines are the most popularly utilized concept. But, direct-drive wind generators that depend on converter-driven synchronous generator concepts [11] have attained substantial penetration in the market. This research work introduces converter driven synchronous generator model utilizing frequency based matrix converter [9] with the aid of SVPWM approach [6] and the parameters such as stator and grid voltage/current are measured and the overall THD of the system is analyzed. The matrix converter with frequency based technique is utilized for converting the variable voltage to a stable value, which can be connected to a grid.***

Keywords--- SVPWM, THD, Matrix Converter, Synchronous Generator, MATLAB/SIMULINK.

I. INTRODUCTION

In this research work, space vector modulated control of Matrix Converter (MC) topology [1] is utilized with Synchronous Generator (SG) for wind power generation systems. The SG stator frequency is suitably tuned to achieve the active power flow 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 SG.

Space Vector Pulse Width Modulation (SVPWM) mechanism is used for controlling the MC switches. This project also evaluates and then compares the results with pulse width modulation technique. The stator and grid voltage, current waveforms and its THD spectrum are evaluated by making use of Matlab/Simulink software.

Similar to the DC generator in the earlier tutorial, the working of a **Synchronous Generator** is also dependent on Faraday's law of electromagnetic induction, operating in an identical manner to an automotive type alternator. Only difference this time is that the synchronous generator generates a three-phase AC voltage output from its stator windings, dissimilar to the DC generator that generates a single DC or direct current output. A single-phase synchronous generator also exists for low power domestic wind turbine synchronous generator systems [8].

Simply, the synchronous generator [10] is basically a synchronous electro-mechanical machine utilized in the form of a generator and comprises of a magnetic field on the rotor, which rotates and a stationary stator consisting of several windings, which provides the generated power. The rotors magnetic field system (excitation) is produced by making use of either permanent magnets that are mounted directly onto the rotor or energized electro-magnetically by means of an external DC current that flows in the rotor field windings.

II. LITERATURE SURVEY

2.1. Space Vector PWM Technique for a Three-to-Five-Phase Matrix Converter

Atif Iqbalet al., Variable-speed multiphase (greater than three phases) drive systems are observed as critical competitors to the available three-phase drives owing to their unique benefits. The power to the multiphase drives is invariably provided from a voltage source inverter. But, this project introduces an alternate solution for providing to the multiphase drive system utilizing a direct ac-ac converter known as a matrix converter.

This work suggests the pulse width modulation (PWM) algorithm for the matrix converter topology with three-phase grid input and five-phase variable-voltage and variable-frequency output. The PWM control approach designed and introduced in this project is dependent on space vector technique.

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This research work introduces the entire space vector model of the three-to-five-phase matrix converter topology.

The space vector model renders 2^{15} total switching combinations that reduce to 243 states with consideration to the enforced constraints, among which 240 are active and 3 are zero vectors. But, for space vector PWM (SVPWM) implementation, just 90 active and 3 zero vectors can be brought into use. The SVPWM algorithm is introduced in this project. The feasibility of the newly introduced solution is demonstrated with analytical, simulation, and experimental techniques.

2.2. Space Vector PWM for a Five to Three Matrix Converter

Omar AbdelRahimet al., Conversion done from AC to AC is very important challenge in Wind Energy Conversion System (WECS), and hence too many numbers of topologies have been analyzed in the literature, one among these topologies involves the direct matric converter. Direct Matrix Converter (DMC) is a good solution for AC/AC electric energy conversion. DMC is utilized for converting the ac input voltage into ac output voltage but with diverse amplitude, frequency and multiple numbers of phases. A five to three phase matrix converter with Space Vector Pulse Width Modulation (SVPWM) is introduced in this research work.

Five to three phase matrix converter is capable of converting the five phase input voltages into three phase output voltages with diverse voltage and frequency. Making use of Five to three phase matrix converters facilitates using five phase generation system that offers few benefits in comparison with three phase system like compact size, greater efficacy and higher voltage amplitude for the same power. SVPWM is utilized for controlling the fifteen switches of the matrix. SVPWM facilitates in controlling the amplitude and frequency of the converter output current and also attains unity power factor between input current and voltage. In order to examine the correct operation of the control, real time simulation on d space platform has been performed.

2.3. Modeling and Simulation of Matrix Converter Using Space Vector PWM Technique

O. Hemakesavulu et al., Matrix Converters can perform the direct conversion of an ac power supply of constant voltage into an ac voltage of differential amplitude and frequency. Matrix Converter is basically a single stage converter.

The matrix converters offers the below benefits over traditional converters with low volume, sinusoidal input current, bidirectional power flow, reduction of lower order harmonics and deficit of heavy reactive elements. All of the causes result in the design of matrix converter. Depending on the control approaches utilized in the matrix converter, the performance differs.

Therefore, this research work evaluates the performance of matrix converter with two diverse modulation approaches like PWM and SVPWM. The fundamental principle and switching series of these modulation approaches are studied in this research work. The analysis of the output voltage, output current waveforms and THD spectrum of switching waveforms connected to RL load are done with Matlab/Simulink software. The simulated results are evaluated and indicate that the THD offers better performance compared to SVPWM approach.

2.4. Matrix Converter Control Using Near State Space Vector PWM Technique

O. Hemakesavulu, Matrix Converters may at once transform an ac power supply of constant voltage into an ac voltage of differential amplitude and frequency. Matrix Converter is basically a single stage converter.

The matrix converters offers following benefits across traditional converters having low volume, sinusoidal input current, bidirectional power flow, reduction of lower order harmonics and deficit of heavy reactive elements.

All these causes result in the matrix converter design. Depending on the control approaches utilized in the matrix converter, the performance differs.

Therefore, this research work evaluates the performance of matrix converter with two diverse modulation schemes like SVPWM and Near State SVPWM. The fundamental principle and switching sequence of these modulation approaches are studied in this research work.

The output voltage, output current waveforms and THD spectrum of switching waveforms connected to RL load are evaluated with Matlab/Simulink software. The simulated results are evaluated and it indicates that the THD performance is much superior compared to Near State SVPWM technique.

2.5. Dead-Time Compensation Based On SVPWM

HU Qing-bo et al., In the case of a vector control system of a permanent magnet synchronous motor; this project work evaluates the impact of dead-time on output voltage elaborately, and explains about the association between the position of output voltage vector and the direction of three-phase current in a space vector figure.

Moreover, a technique of partitioning three-phase current into six regions and a control mechanism, which compensates just one phase voltage in each region are studied in the research work.

The proposed approach can get the direction of three-phase current by deciding the position of output voltage, and it prevents the phenomenon of various zero-crossing in current sampling. Finally, the experiments that are uncompensated and compensated are carried out with a TMS320F240, and the results verify that this technique exhibits a good compensation.

III. PROPOSED MODULE

3.1 Proposed Topology and Operational Principle

- The available control system provides the decoupling of the active and reactive components of the SG current and extracts just minimum power from the wind at a certain wind velocity and for injecting the reactive power [5] to the grid. Reactive power injected during the fault does not satisfy the grid codes.

- Power factor at the interface with the grid must not be capable of being maintained at near unity during steady-state in addition to high harmonic distortion making use of the available converter based frequency control system. In the present control mechanism, grid connected system depicts a poor power quality [2-3] in terms of the Total Harmonics Distortion (THD) of the grid injection current in comparison with the newly introduced system.

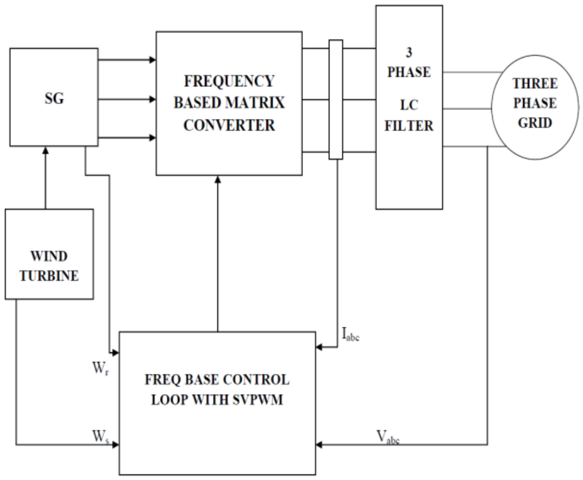

Figure 3.1: Proposed Block Diagram

3.2 Working Principle of the Proposed Converter

This project is chiefly focused on the operation of a gearless WECS based on grid connected MC-SG [12] that is directly coupled to the turbine. The synchronous generator is most cheap and robust electric machine. Moreover, the generators are rugged and they exhibit remarkable mechanical characteristics for wind turbines, such as slip and a degree of overload capability.

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 control system consists of the zero-sequence component, which facilitates the compensation of zero-sequence harmonics [4]. It indicates that reduction in the power loss and mitigation of current and voltage harmonics can be achieved in the available system.

A novel modulation approach utilized is Frequency-Current control magnitude with PLL control mechanism will boost the output current harmonics of a wind energy conversion system, the newly introduced system inclusive of a Synchronous Generator (SG) and a matrix converter with SVPWM. When the speed faces an increase, both frequency and amplitude of the output voltage from the synchronous generator also sees an increase.

With the aim of obtaining the stable output voltage with consistent frequency, the synchronous generator gets coupled with the matrix converter. The design and evaluation of a control approach for a SVPWM based wind energy generation under imbalanced load conditions are introduced.

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

A matrix converter yields a huge number of control levels, which permits for stand-alone control on the output voltage magnitude, frequency and phase angle, in addition to the input power factor. In comparison with the AC-DC-AC converter system [12], the strong feature of matrix converter involves the suppression of the DC-link reactive elements, e.g., huge capacitors and/or inductors.

The magnitude of the synchronous generator terminal voltage has been changed with frequency in accordance with the constant V/f mechanism.

It has to be observed that the displacement power factor at the interface with the grid has to be maintained at unity during steady-state, with enhanced THD utilizing matrix converter based frequency control system.

A proportional control mechanism is realized with frequency-SVPWM side to reduce the machine side current harmonics and torque pulsations. The primary goal of the control approach is with regard to maintaining the constant voltage and frequency at the generator output.

A control mechanism is introduced for upgrading the SG based proposed system for achieving the low THD. Mitigating the voltage harmonics is an essential task, which cannot be carried out by inverters. In this work, the novel mechanism is utilized for mitigating the harmonics current of the power system.

IV. SIMULATION RESULTS

4.1. Simulink

Simulink, designed by Math Works, is a data flow graphical programming language tool used for the modeling, simulation and analysis of multi domain dynamic systems.

Its primary interface is a graphical block diagramming tool and a customizable set of block libraries.

It provides a strong integration with the remaining of the MATLAB environment and can either drive 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.

Simulink yields a graphical editor, customizable block libraries, and solvers for modelling and simulating dynamic systems.

It is also integrated with MATLAB®, facilitating in incorporating the MATLAB algorithms into the models and thereafter export the simulation results to MATLAB for analysing further.

4.1.1 Features of Simulink

- Graphical editor for developing and controlling the hierarchical block diagrams.
- Libraries of predetermined blocks for the modeling of continuous-time and discrete-time systems.
- Simulation engine with fixed-step and variable-step ODE solvers. Scopes and data displays for visualizing the simulation results.

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- Project and data management tools for the management of model files and data. Model analysis tools for the refinement model architecture and increase in the simulation speed.
- MATLAB Function block for importing MATLAB algorithms into models.
- Legacy Code Tool for importing C and C++ code into models.

4.1.2 System Toolboxes for Matlab and SIMULINK

- DSP System Toolbox, which combines features of Signal Processing Block set and Filter Design Toolbox.
- Communications System Toolbox, which integrates the features of Communications Toolbox and Communications Block set.
- Computer Vision System Toolbox, which includes the functionality of Video and Image Processing Block set and also includes fresh computer vision algorithms.
- Phased Array System Toolbox, which provides algorithms and tools for designing, simulating, and analyzing phased array signal processing systems.

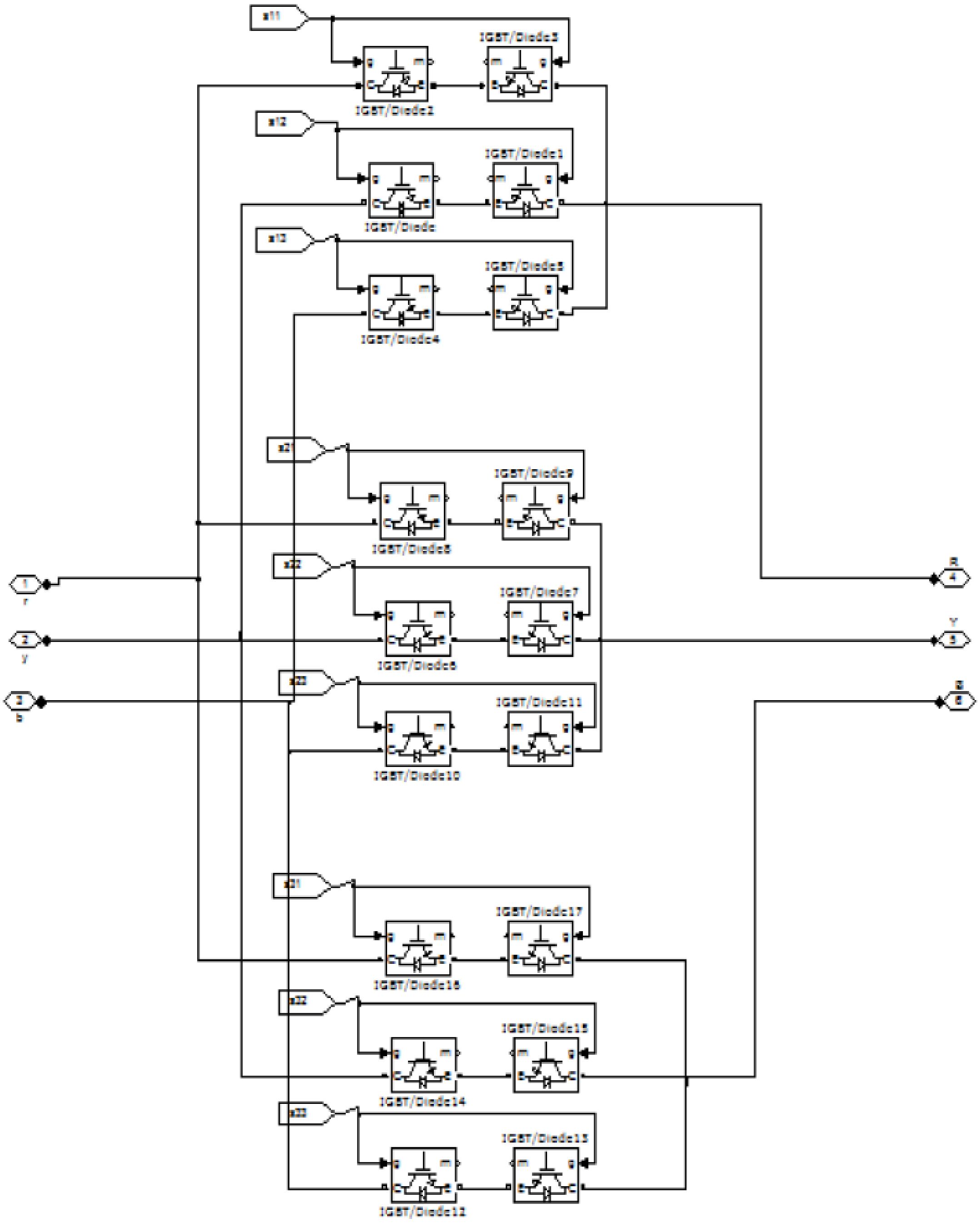

Figure 4.1: Simulation Diagram of Integrated Magnetic Three Port Converter

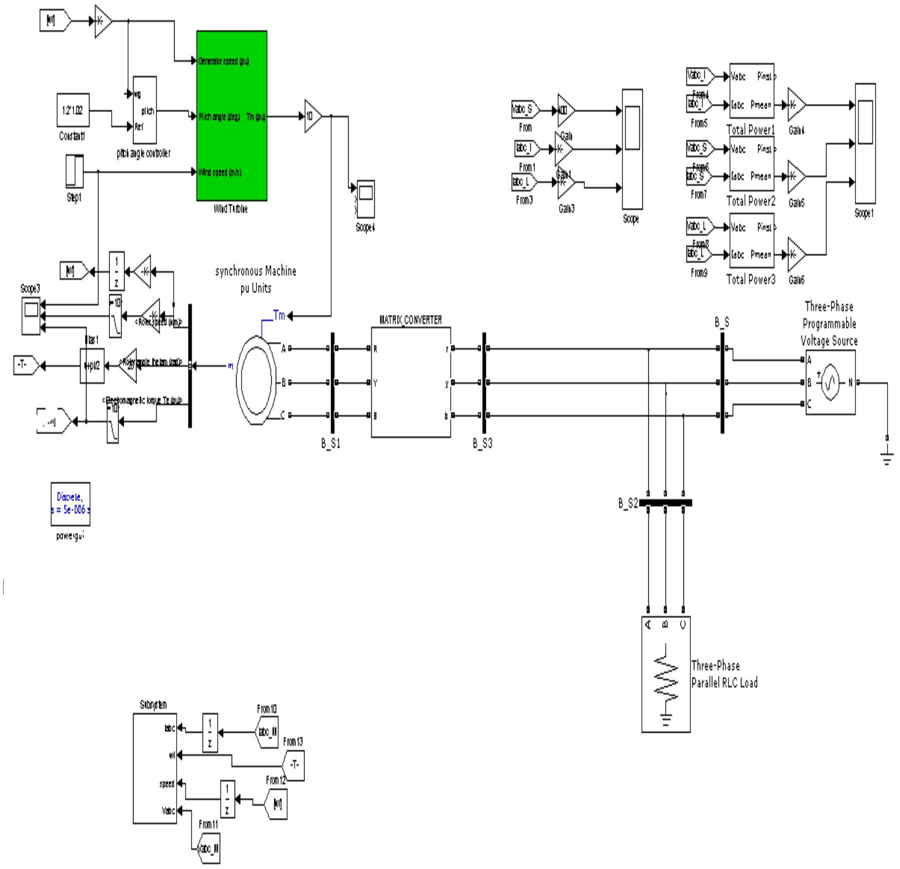

Figure 4.2: Simulation Diagram of Martix Converter

Figure 4.1 illustrates the SG-simulated model of a traditional Matrix converter for a wind turbine driven system. The simulation of the model was done for varied 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 with a frequency-current magnitude controller-PLL, SVPWM controller. Figure 4.8 illustrates the fluctuation of the input current THD of the newly introduced system. The percentage THD of the classical system was nearly 8 % lesser in the system proposed. This results in lesser input power factor and greater switching losses. The above mentioned setbacks are compensated with the proposed system.

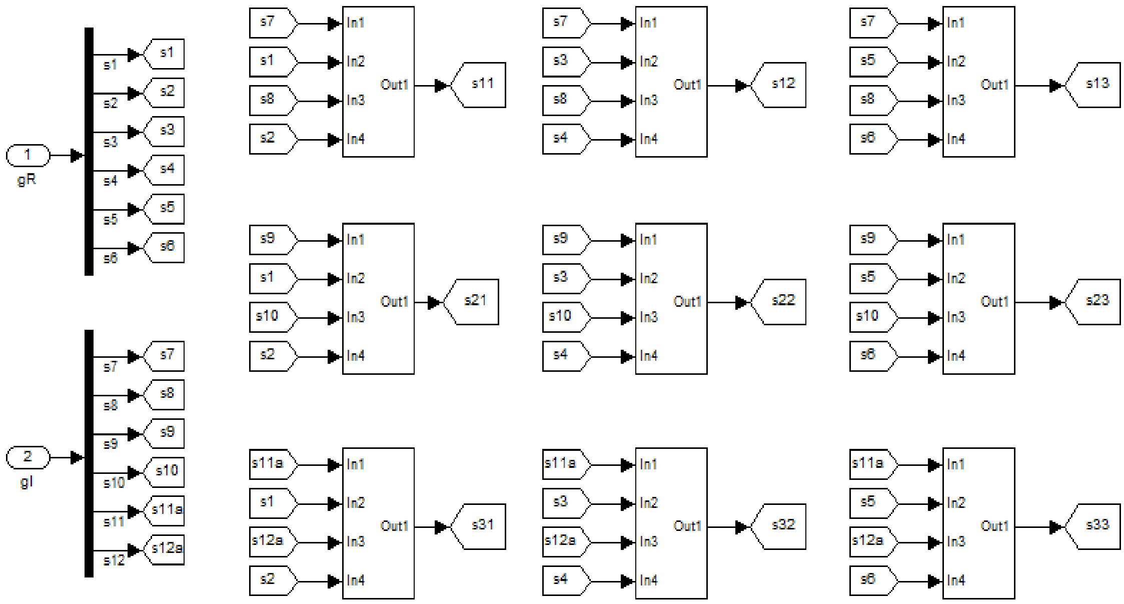

Figure 4.3: Simulation Diagram of Matrix Converter Switching Table

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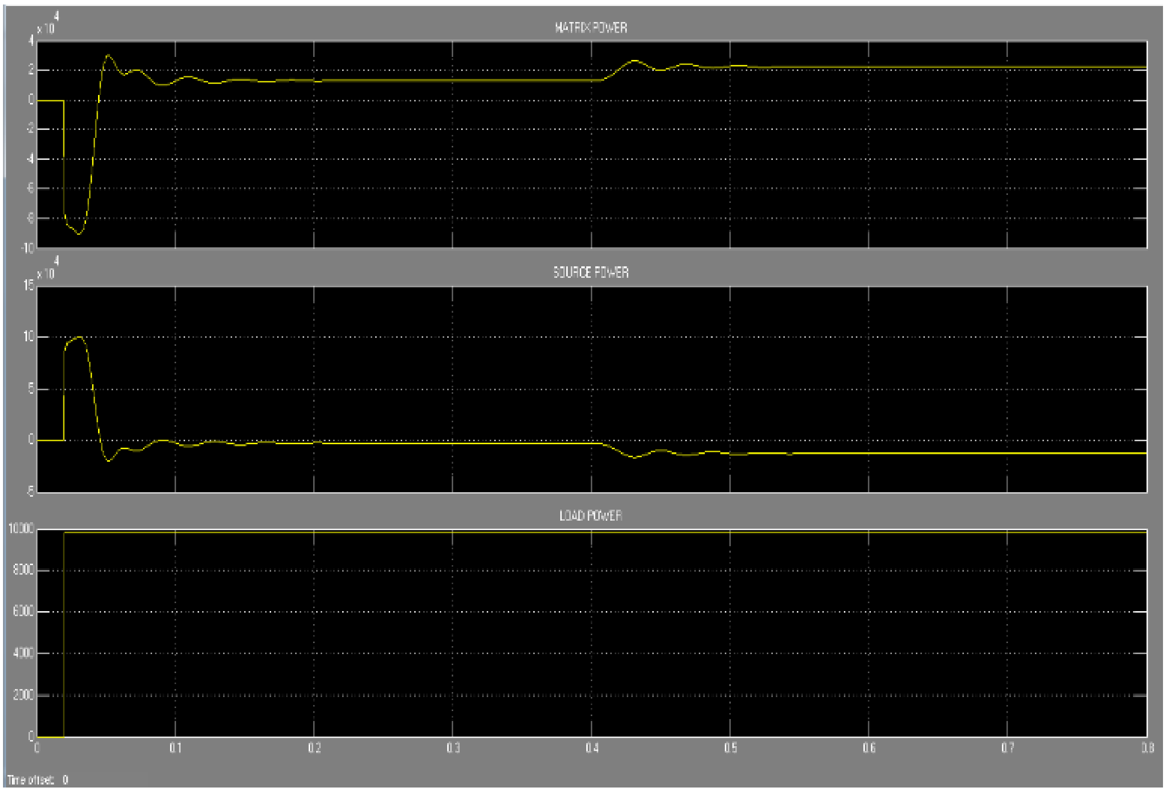

Figure 4.4: Simulation Diagram of Control Loop(Frequency and Magnitude Current)

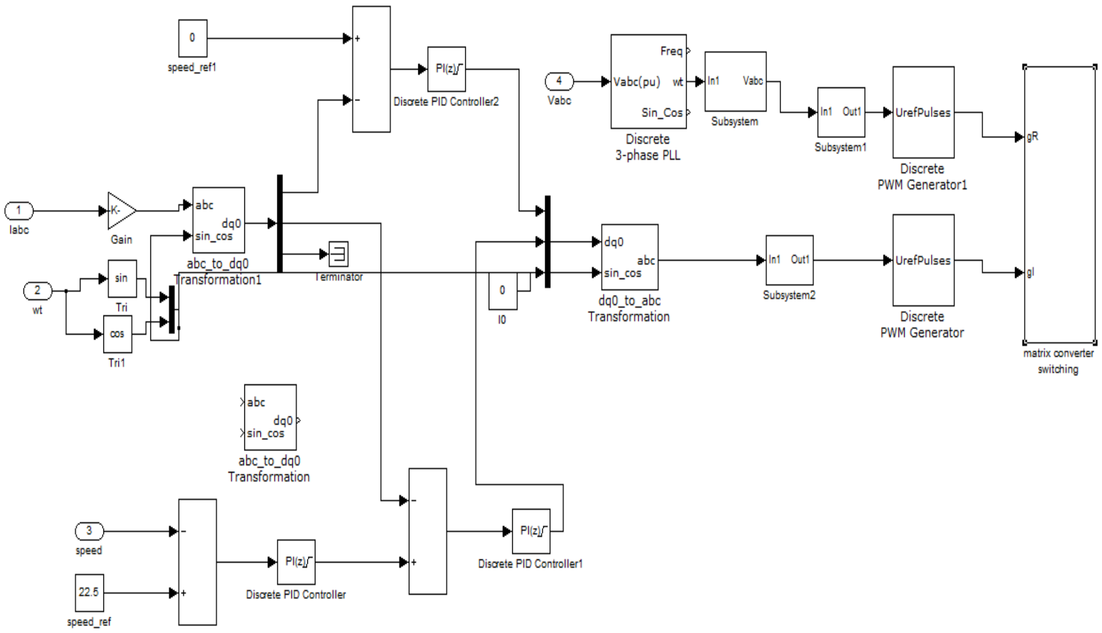

Figure 4.5: Simulation Diagram of SVPWM unit

Even though the terms of power quality hold true for transmission and distribution systems, their technique to power quality has various aspects. An engineer of transmission system works with the management of active and reactive power flow with the aim of maximizing both the loading capacity and stability constraints of the transmission system.

A technique of overcoming the disadvantage of the available - a proposed model is developed and then studied in this work. 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 eliminates the error, which results due to the dc component. In addition, an estimation of the dc component also exists.

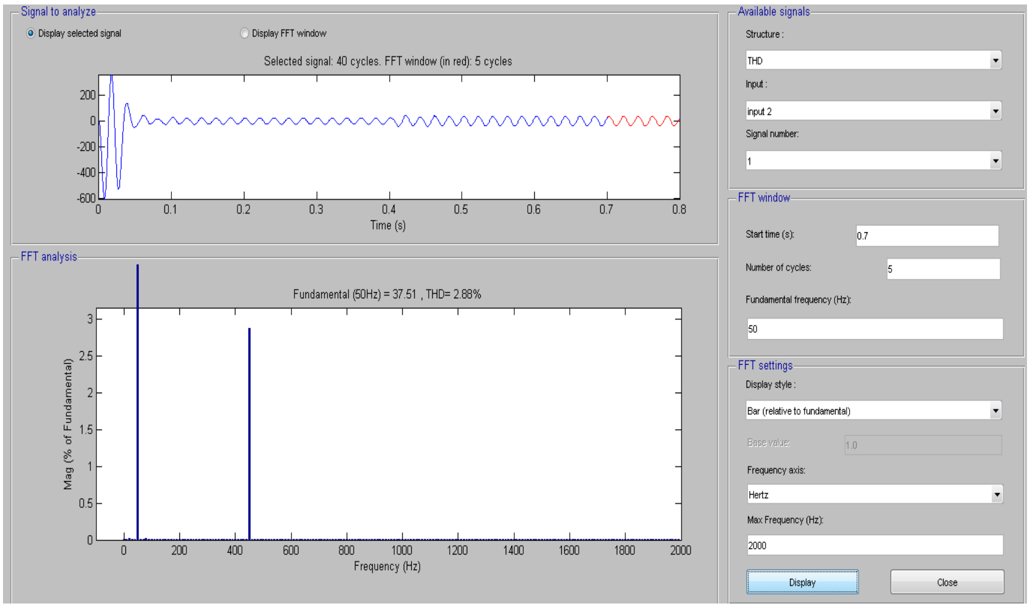

Figure 4.6: Output Waveform of Grid Voltage/Matrix Current/ Load Current

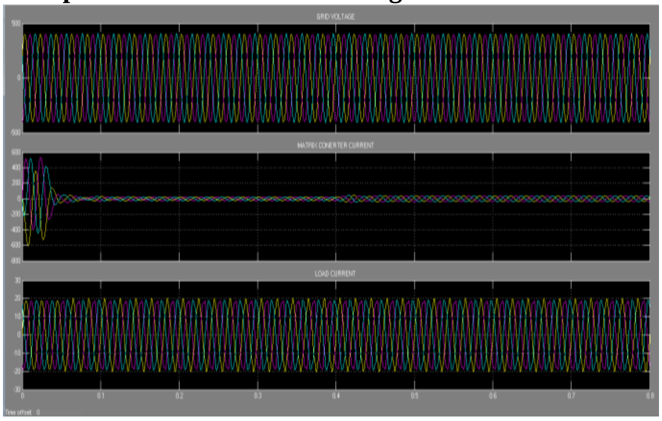

Figure 4.7: Output Waveform of Matrix/Source/Load Power

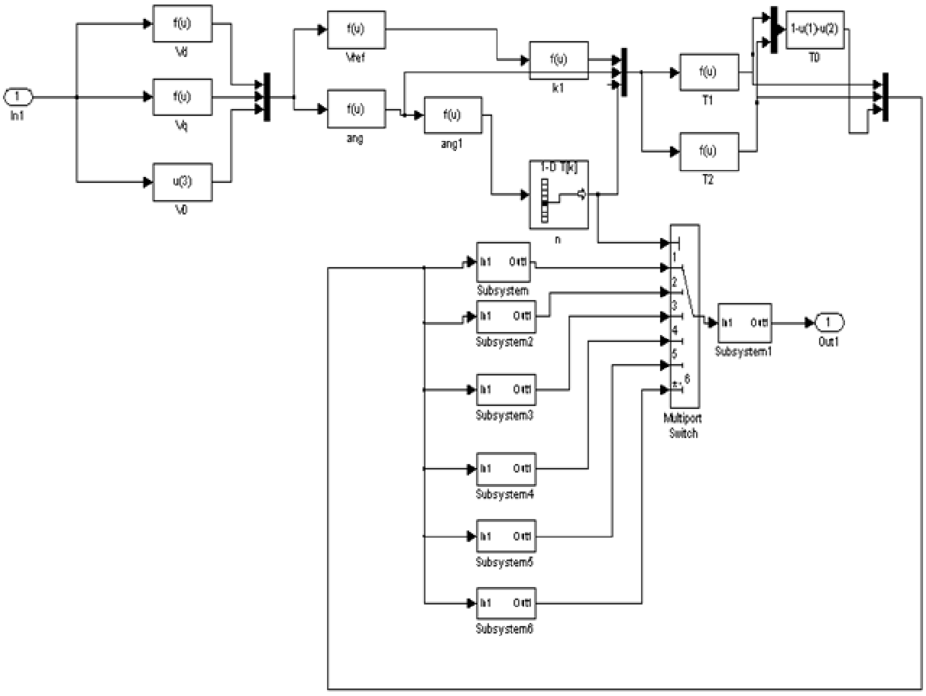

Figure 4.8: Output of FFT analysis for THD =2.88%

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The dc component may inherently exist in the input signal or may be generated 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 the help of filters as such filters will considerably deteriorate the dynamic response of the system. The proposed technique is dependent on the addition of a new loop (Frequency-Matrix converter-SVPWM) within the PLL structure.

It is simple by structure and, dissimilar to the existing techniques explained in this project, it does not make a compromise on the high-frequency filtering level of the associated algorithm. The technique is designed for three-phase systems, its design aspects are studied, and simulations results are analyzed above.

V. CONCULSION

The wind turbine driven synchronous generator is modeled with Matlab/Simulink tool and is also evaluated for different wind speeds. With the increase in the speed, there is also an increase in both frequency and amplitude of the output voltage from the synchronous generator. For getting the stable output voltage with consistent frequency, the synchronous generator is coupled with the matrix converter. A controlled rectifier carries out the rectification of the output voltage of synchronous generator and rectified output is provided to the inverter. Since no DC link element exists between the converter and the inverter, the converter generates the constant DC voltage with no regard to the wind velocities.

The stable DC voltage from the converter is supplied to the input of inverter to get an AC output voltage of constant amplitude with constant frequency. Thus, a constant output voltage along with constant frequency is achieved from the newly introduced Wind Energy Conversion approach. Simulation results depict the generation of power and output voltage from the wind at different wind velocities with success. The stator and grid voltage and current waveforms and THD spectrum of current waveforms was evaluated and the results reveal that the performance of the proposed system is much better.

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