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Harmonic Distortion Reducing of Z-source Inverters Using Pulse Width Modulation for Wind Powered Industrial Applications

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ABSTRACT

Total Harmonic Distortion (THD) measures harmonic distortion present in a signal which is employed to differentiate the audio systems linearity and the electric power systems power qualities. In this paper, for industrial drive applications THD is measured and compared from various pulse width modulation approaches and Self-Excited Induction Generator is used to model an Induction Motor (IM) which is controlled by a wind energy converter. It is necessary to maintain the output at constant frequency in order to obviate shoot-through restriction that is mentioned in other existing PWM inverter systems. For that reason, Z-Source Inverter (ZSI) is employed which is inserted between the source and the load of the circuit. Here various PWM switching approaches such as Sinusoidal PWM, Space Vector PWM and Trapezoidal PWM approaches are mathematically represented functioning at switching frequency of about 10 kHz in order to control the IM drive by pulse generation. It is essential to provide a neutral point clamped voltage source inverter circuit with or without an individually defending Z-network, in order to preserve the balance of any two voltages of capacitors in an impedance network. Our paper proposed the conception of voltage balancing capacity of impedance network based inverter circuit. Our proposed scheme is used to divide balance the capacitor voltages in an impedance network and the Z-source inverter circuit can be cheap and coherent way out for such application.Our proposed scheme is simulated at MATLAB environment and the current harmonics that are used to drive the induction motor drive is analyzed which provides the comparative analysis. From that analysis, we can illustrate the effective implementation of PWM approach for industrial drive applications and a model of hardware prototype is established for 1000W system which is based on the simulation assessment by employing Space Vector PWM approach and their results are examined.

Keywords: Total Harmonic Distortion (THD),Induction Motor(IM), Z-Source Inverter (ZSI),PWM

1. INTRODUCTION

Generally, the virtual implementation of wind energy conservation system requires Self-Excited Induction Generator for their electrical as well as mechanical characteristics with much more efficiency. The research work on several SEIG characteristics has established which conversion scheme is more efficient in a dynamic manner and the applications may vary on several necessitates. Optimum utilization is achieved by the geographic expedition on gird connections which require wind power that is preponderantly issuing for industrial oriented applications. Nevertheless the virtual implementations have demonstrated that the Self-Excited Induction Generator is used as the wind energy source leading efficiently and that is much validated. By considering the industrial oriented applications the source of the system is so sensitive to the demands of load. In balanced load conditions there is no major impression on the source disseminating the energy to the utility of grid connections. The unbalanced load conditions getting ruffles at the power lines likely

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impact the system inducing over surges, voltages sag and swell. [1, 2]. In whatever industrial oriented applications, this is one of the major issues where this consequence has to be decreased to the level of standard demand and it is one of the most significant effects in whatever industry oriented applications where this Induction Generators is employed for power production that can likely experience irregular over voltage troubles.

In attention to the above troubles wind energy conversion system that runs at fixed speed also expects circuits for power electronics running at optimized efficient conditions with voltage and frequency as constant. These power electronic circuits are employed to convert the sources of current from AC to DC and DC to AC based on their application requirement. The constant voltage and frequency are the basic demands of a three phase industrial motor drives and AC-AC conversion can be done by both direct and indirect methods through converting to DC then to AC. The DC to AC conversion is done by a simple three phase inerter system that gets shoot-through trouble while switching execution is removed by employing impedance that are connected throughout a normal inverter system by the way we can eliminate the shoot-through trouble. The switching proficiencies used in inverter circuit are relatively much more significant to the selection of inverter system. [4]. In order to reduce the power loss, the induction motor drive must possess very low harmonic level distortions while converting the current from DC to AC. Several filters are used at the output phases for each and every application that will much increase cost as well as size of the entire system. To operate efficiently whatever inverter circuit is switched by employing possible switching approaches. Single and three phase inverter circuits generally use sinusoidal pulse width modulation (SPWM) technique which is more popular in technique in inverter circuits and the Pulse Width Modulation (PWM) techniques applied several carrier waves in order to produce the pulse efficiently.

The utilization of sinusoidal pulse width modulation technique in AC to AC converter produces more efficient output in implementation. Likewise the compensation of dead time in inverter process is focused in the industry oriented applications. Most of the industries require industrial motors which are controlled using several effective control topologies are approximated in the basis of real time estimation that also

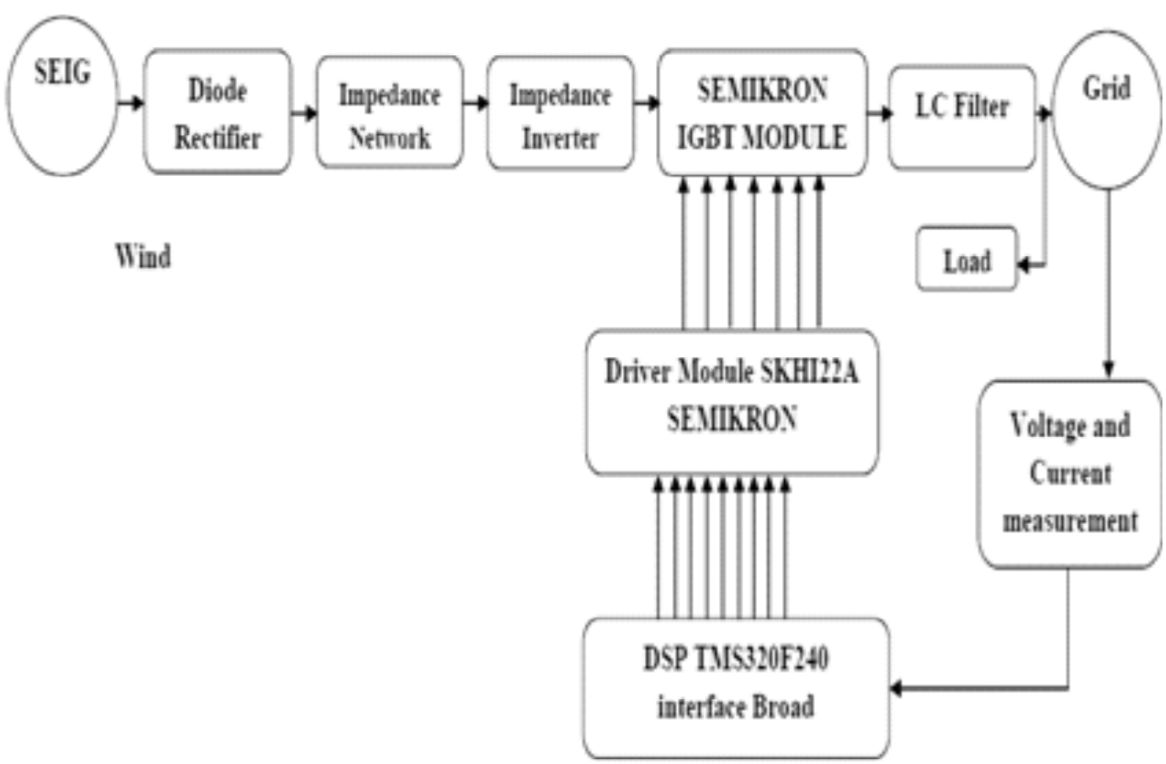

Figure 1: General Block Diagram

founded efficient. Because it turns the effect of harmonic presence in industry oriented applications and it is essential to choose an efficient technique for switching topology. There are several three phase inverters are operated under the Space Vector Pulse Width Modulation (SVPWM) in order to get better outputs which contains reduced harmonic levels. The designing of Space Vector PWM which is employed for Single Impedance Network (SIN) in three level inverter systems is addressed [3, 5] and the industrial using motors possess broad range of applications. The system level power/energy loses greatly affects the three phase induction motors while several control mechanisms are employed to control and these motors are so sensitive to power loss. In order to obtain better output, these motors are modeled to run at broad range frequencies with very high accuracy. The operation executed in our paper talks about several topologies of inverter switching and demonstrates the Total Harmonic Distortion (THD) comparison for industrial motors that are implemented at fixed loaded conditions. Such comparative analysis is executed for an inverter system that is powered utilizing the wind energy driven Self-Excited Induction Generator (SEIG) designed with an assumptions of real time implementations. [6].

This paper demonstrates enhancement technique for the quality of power for the electrical component of a wind energy generation scheme with a Self-Excited Induction Generator (SEIG) circuit that purposes to optimize the usage of wind energy interposed into the grid. In order to understand such purpose, an Un-controlled Rectifier-Digitally Controlled Inverter (URDCI) system was presented. The benefit of our proposed scheme is their restraint owing to minimum number of operated switches that leads to reduced operational complexity. [7, 9].

The inverter scheme renders economic usage of the wind energy generator by assuring the operation of unity power factor under several possible considerations. It renders entire control of active as well as reactive power interjected into the grid employing a Digitally Controlled Voltage Source Inverter (DC-VSI) and a Voltage Oriented Control (VOC) approach is demonstrated to operate the power to be interjected into that grid. In an effort to reduce the harmonic distortions in the current and voltage of the inverter and to deflect poor power character of the Wind Energy Conversion System (WECS), an low pass filter (LC filter) is introduced between Voltage Oriented Control- Voltage Source Inverter and the grid connection. The proposed approach was applied by a Digital Signal Processor (DSP TMS320F240) in order to assert the robustness of our proposed system model and demonstrate their practical high quality in applications of renewable energy. [8, 10].

2. SIMULATING OF SELF-EXCITED INDUCTION GENERATOR

The designing of Self-Excited Induction Generator (SEIG) is executed by utilizing the equations of three phase induction generator machine and the SEIG simulating is basically the operation of an induction motor which is driven by using a prime mover which is regarded denotes to the virtual wind energy impact conception on the blade theory. The prime mover inflammation is found by linking capacitor at the terminals of stator in which the capacitor that stimulates the output is mentioned as Excitation Capacitance (C_e). The value of excitation capacitance is chose by executing desirable test and the maximal and minimal values of excitation capacitance are found. The complex capacitor value is chose such that the extreme power can be received from the output of generator and the wind energy turbine is designed by utilizing the following mechanical power equation,

$$P_T = 0.5\ \rho A\ C_p(\lambda)\ V^3 \tag{1}$$

The amount of power capable of being produced by a wind turbine (P_T) is dependent on the power co-efficient (C_p) for the given turbine operating conditions and is given by Eq. (1).

$$\lambda = \frac{\omega_T R}{v} \tag{2}$$

The tip speed ratio is defined as the ratio of the linear speed of the tip of blades to the rotational speed of wind turbine (Allan Mullane *et al.* 2001) and is given by Eq. (2).

$$C_p = 0.5\left[\frac{116}{\lambda 1} - 1.4\beta - 5\right] e^{-16.5} / \lambda_1 \tag{3}$$

The value of changes with rotational speed and wind speed and can be expressed by Eq. (3) and (4).

3. MODELING OF AUTOAGITATED INDUCTION GENERATOR

The d q axis equivalent circuit model for a no-load, three-phase, symmetrical induction machine. The per-unit stator and rotor voltage equations using Krause transformation based on stationary reference frame.

The equivalent circuit in the d-q reference frame of the self-excited induction generator is shown in figure 2. The loop equations for the d-axis and q-axis equivalent circuits are

$$r_s\, i_{qs} + L_s \frac{d_{iqs}}{d_t} + L_m \frac{d_{iqr}}{d_t} = V_{ds}\ \omega_e \tag{4}$$

$$r_s\, i_{qr} + L_r \frac{d_{iqr}}{d_t} + L_m \frac{d_{iqr}}{d_t} = V_{ds}\,(\omega_e - \omega_r) \tag{5}$$

$$r_s\, i_{ds} + L_s \frac{d_i d_s}{d_t} + L_m \frac{d_i d_r}{d_t} = V_{ds} + V_{qs}\omega_e \tag{6}$$

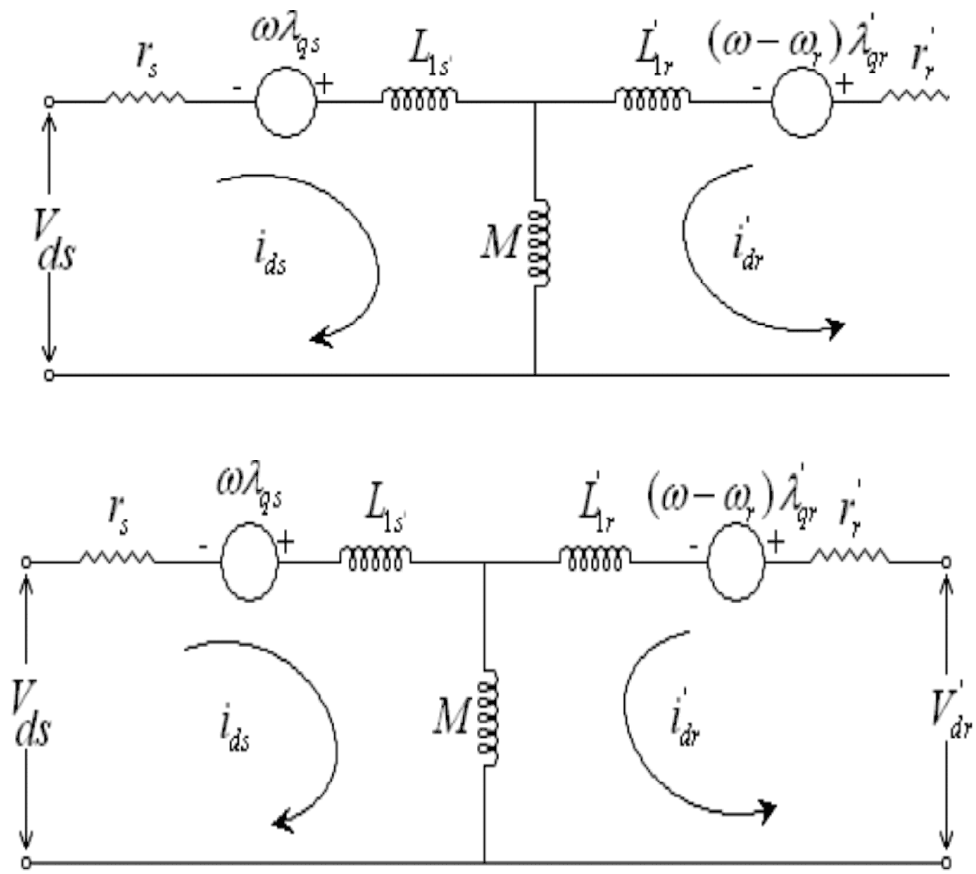

Figure 2: Equivalent Circuit of the Induction Machine in d-q Reference Frame

$$r_s\, i_{ds} + L_r \frac{d_i d_s}{d_t} + L_m \frac{d_i d_r}{d_t} = V_{qs}\,(\omega_e - \omega_r) \tag{7}$$

The dynamics of the self-excited induction generator (Krause P. C 1986) can be represented by the following electromechanical equations derived in the synchronously rotating q-d reference frame.

$$P\ i_{qs} = -K_1\, r_s\, i_{qs} - (\omega_e + K_1 L_m \omega_r) i_{ds} + K_2\, r_r\, i_{qr} - K_1\, L_m \omega_r i_{dr} \tag{8}$$

$$P\ i_{ds} = -K_1\, r_s\, i_{ds} - (\omega_e + K_2 L_m \omega_r) i_{qs} + K_2\, r_r i_{dr} - K_1\, L_m\, \omega_r\, i_{qr} - K_1 V_{ds} \tag{9}$$

$$P\ i_{dr} = -K_2\, L_s\, \omega_r\, i_{ds} + K_2\ r_r\ i_{ds} - (K_1 L_s \omega_r - \omega_e)\, i_{dr} - \left[\frac{r_r + K_2 L_m r_r}{L_r}\right] i_{qr} \tag{10}$$

$$P\ i_{dr} = -K_2\, L_s\, \omega_r\, i_{ds} + K_2\ r_s\ i_{ds} - (K_1 L_s \omega_r - \omega_e)\, i_{qr} - \left[\frac{r_r + K_2 L_m r_r}{L_r}\right] i_{dr} + K_2\, V_{ds} \tag{11}$$

4. COMBINED OF PWM INVERTERS

The Pulse Width Modulation denotes to designing of the switch performance techniques to operate the power supply implemented to whatever switches of converter circuit. The DC to AC conversion is executed by an inverter is essentially necessitating the switching proficiencies. The PWM is yielded by equating two wave signals so that one of signal will acts as a carried waveform. The carrier waveform can typically be a triangular waveform in which the reference signal is either square or sinusoidal or trapezoidal waveforms. Our proposed Z-Source Impedance is executed on several PWM techniques controlling at 10 kHz frequency of switching and the output is compared.

4. IMPEDANCE SOURCE NETWORK

The Z-source or impedance source inverter is a group of any two capacitors and any two inductors. The Z-source inverter network provides a concept of second-order filter and it is more effective to minimize the ripples of voltage and current than a capacitor or an inductor utilized only in the circuits of fixed inverters. Thus, the capacitor and inductor responsibility should be more modest than the formal inverters. The individual characteristic of the Z-source inverter circuit is which the AC output voltage could be whatever measure between zero and infinity regardless of thevoltage of fuel-cell i.e., the Z-source inverter circuit is a buck–boost inverter circuit which contains a wide range of attainable voltage level. The formal V- and I-source inverter circuits cannot provide such feature. While the two inductors as L_1 and L_2 are extremely small and near zero, the Z-source inverter reduces to two capacitors C_1 and C_2 in parallel manner and turns a formal V-source.

Thus, the capacitor of formal V-source inverter requirements and forcible size is the most terrible case responsibility for the Z-source inverter. Regarding extra filtering and power storage rendered by the inductors, the Z-source inverter should necessitate very less capacitance and small size when compared with the common V-source inverter circuit.

Correspondingly, while the two capacitors as C_a and are very small and near zero, the Z-source inverter reduces to two inductors as La and Lb in series and turns an accustomed I-source inverter. Hence, the inductor of formal I-source inverter requirements and forcible dimension is the most terrible case responsibility for the Z-source inverter. Believing extra filtering and power storage by the capacitors, the Z-source inverter should necessitate a lower amount inductance and more modest size when compared with the common I-source inverter circuit.

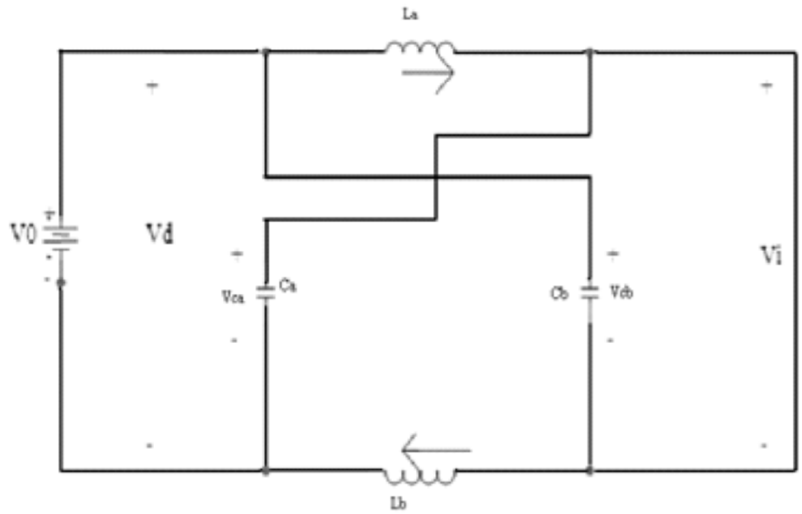

Figure 3: Impedance Inverter Circuit

Table 1
Parameters and Values

S.No	*Parameters*	*Values*
1	Wind velocity	13 m/s
2	Rotor radius	2m
3	Modulation Index	1.0
4	Gear ratio	1:45
5	Z-Source inductance	1800mH
6	Z-Source capacitance	150μf
7	Excitation capacitance	65μ
8	Load torque	82Nm
9	Switching frequency	15KHz
10	Transformer	380v/210v

4.1. Simulating PWM Technique

Sinusoidal Pulse Width Modulation (SPWM) is the most general techniques implemented in an inverter circuit for AC output and the designing is much alike to the former PWM approaches in which the signal waveform presents here is a waveform of sinusoidal signal. The pulse modulation received at several levels is much more efficient when compared to TPWM approach. The pulses close to the half cycle edges that are ever narrower than the pulses close to the half cycle center. In order to vary the efficient output voltage, the breadths of entire pulses are raised or reduced while preserving the sinusoidal proportionality. The width of the pulse is proportional with the amplitude of the sine wave and the gating pulses are produced and are implemented for the sequences of switching so that the output voltage is increased.

5. SIMULATION RESULTS

6. CONCLUSION

Most of the industrial motor drive applications suppress on the levels of harmonic distortions in which extremely high voltage applications causes the power loss. In our paper, we proposed the usage of three phase induction motor drive in industrial applications which is operated by using Pulse Width Modulation (PWM) inverter designed to remove shoot through troubles however mentioned as ZSI. There are three types of PWM switching techniques like Sinusoidal PWM, Space Vector PWM and trapezoidal PWM are designed and their Total Harmonic Distortions (THD) are found. The simulating of wind energy driven

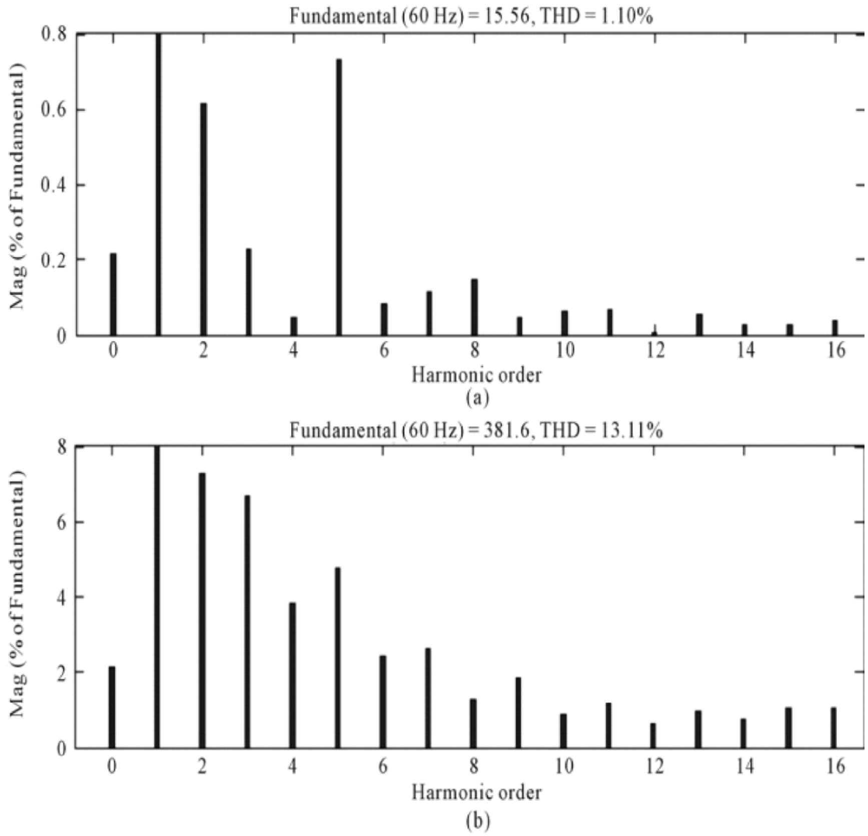

Figure 4: Harmonic Spectra of Z-source Inverter (PWM). (a) Harmonic Spectra of Output Current (b) Harmonic Spectra of Output Line Voltage

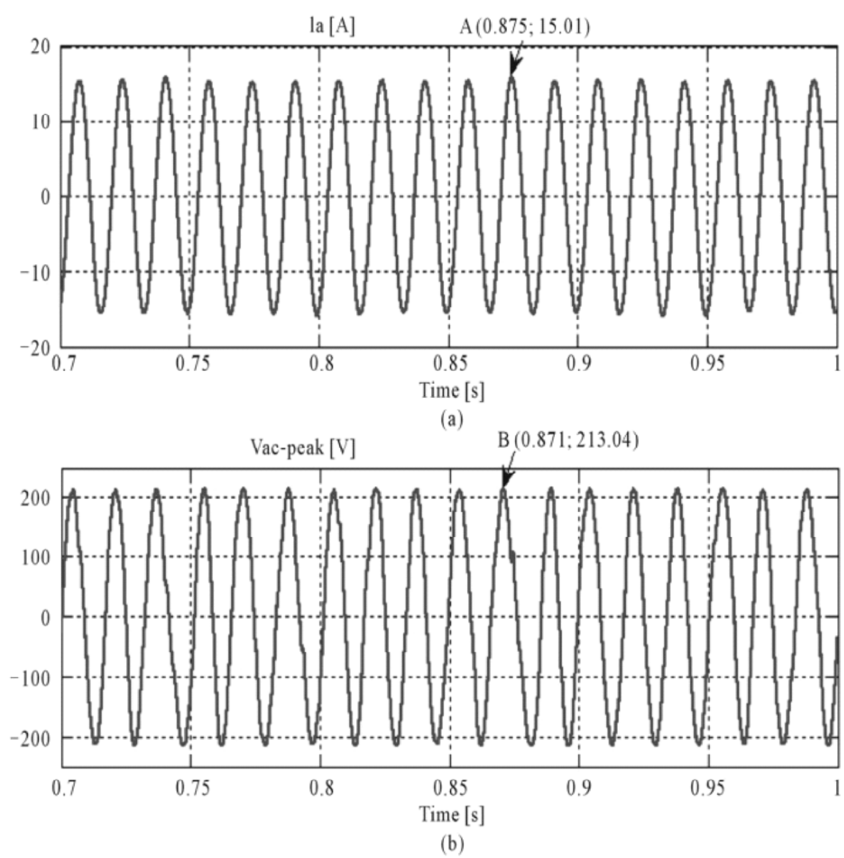

Figure 5: Output Line Voltage and Current Wave-forms of ZSI (a) Output Current (b) Output line Voltage

Self-Excited Induction Generator (SEIG) is much analytic to a DC motor employed as a prime removal firm to a SEIG. The Total Harmonic Distortion of the techniques required demonstrates the SVPWM implementation which is used for the induction motor drives that preserves 16% power loss when compared to other existing PWM techniques therefore increasing the entire system performance of the induction motor drives. The above system model is produced for a 900W prototype system model with a three phase Z-Source Inverter (ZSI) operated by using SVPWM. Comparative analysis is taken between the results obtained from simulation and hardware that indicates the three phase ZSI operated using Space Vector Pulse Width Modulation in efficient with an industrial motor drive application used for the Conversion of Wind Energy System.

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