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Power Quality Enhancement in Distribution System Using Sinusoidal and Space Vector Pulse-Width-Modulation Approaches Are Fed To Induction Motor Drive

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Abstract:
The aim of this work is to improve the power quality for Distributed Generation (DG) with power storage system. Power quality is the combination of voltage quality and current quality. Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. In this paper Voltage Source Inverter (VSI) is used to supply a variable frequency variable voltage to a three phase induction motor drive in a variable speed application. One important complication is that, Voltage Source Inverter (VSI) used in VFD causes non-sinusoidal output voltage and current due to presence of harmonics. Shunt active filter with VSI topology is proposed for current harmonic elimination. The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM and space vector PWM (SVPWM). There is an increasing trend of using space vector PWM (SVPWM) because of their easier digital realization and better dc bus utilization. This project focuses on step by step development SVPWM implemented on an Induction motor. The model of a three-phase a voltage source inverter is discussed based on space vector theory. Simulation results are obtained using MATLAB/Simulink environment for effectiveness of the study.

Key Words: Distributed generation, Droop control, Harmonic distortion, Parametric analysis, Power sharing, Space vector pulse width modulation, Induction Motor.

I. INTRODUCTION

Power quality problems to sensitive loads is one of the major concerns in electricity industry today .this is due to the advent of a large numbers of sophisticated electrical and electronics equipment, such as computers, programmable logic controllers, variable speed drives, and so forth. The use of these equipments very often requires power supplies with very high quality. Voltage sag, which is a momentary decrease in rms voltage magnitude in the range of 0.1 to 0.9 per unit (p.u) [1], is considered as the most serious problem of power quality. It is often caused by faults in power systems or by starting of large induction motors. It occurs more frequently than any other power quality phenomenon does [2].

In Variable Speed application, Voltage Source Inverter is commonly used to supply a variable frequency variable voltage to a three phase induction motor [3-5]. In this PWM drives are more efficient and typically provide higher levels of performance [6]. A suitable Pulse Width Modulation technique is employed to obtain the required output voltage of the inverter [7]. The most common AC drives today are based on sinusoidal pulse-width modulation SPWM. Induction motor is rugged, reliable, and single-fed machine; it can directly absorb the reactive power from the utility with this device, we can get two advantages: one is that we can get a low start current; the other is that we can change the motor speed conveniently by controlling the output frequency of the ASD [8-10]. Many research works are focusing in the development of the efficient control algorithms for high performance variable speed induction motor (IM) drives. Induction motor has been operated as a work horse in the industry due to its easy build, high robustness and generally satisfactory efficiency [11]. Recent development of high speed power semi conductor devices, three phase inverters take part in the key role for variable speed AC motor drives. Traditionally, Three Phase inverters with six switches (SSTP) have been commonly utilized for variable speed IM drives this involves the losses of the six switches as well as the complexity of the control algorithms and interface circuits to generate six PWM logic signals [12]. So far researchers mainly concentrated on the development of new control algorithms. However, the cost, simplicity and flexibility of the overall drive system which are some of the most important factors did not get that much attention from the researchers [13]. That is why, despite tremendous research in this area, most of the developed control system failed to attract the industry. Thus, the main issue of this work is to develop a cost effective, simple and efficient high performance IM drive.

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In this paper both SPWM and SVPWM based Induction motor drive topology is proposed. Simulation results in MATLAB/ Simulink environment demonstrate the improvement in the performance of the proposed SVPWM.

II. MOTIVATION AND RELATED WORK

"Distributed resources such as micro-turbines, fuel cells, and photovoltaic arrays are small relative to system capacity, but the smaller sizes are much more likely to achieve significant penetration levels. It is therefore reasonable to address the question of allowable penetration by assuming a harmonic injection at the limit levels specified" [5]. The motivation behind the work in this paper is the development of flexible, seamless and improved approaches for micro-grid inverters and their synchronization with the utility grid and loads and development of new and improved techniques to meet power quality benchmarks and reliability standards. Harmonic mitigation approaches of [6]-[8] are based on making the DG units of a power distribution system replicate a resistance at harmonic frequencies. For micro-grid operation, fundamental control strategies have been defined in [9]-[10] with regards to harmonic compensation and power quality improvement.

The control method described in [11] uses a modular approach in order to control power flow and share of a microgrid system with mechanism to compensate the voltage harmonics. This work is based on the same methodology for potentially using the space vector pulse width modulation for micro-grid inverters tied to the utility grid in distributed generation configuration. A parametric analysis of both SPWM and SVPWM based micro-grid inverters has been performed to show a solution oriented comparative approach for power quality enhancement. After the performance evaluation and comparison between both the techniques, appropriate conclusions have been made.

III. POWER QUALITY ENHANCEMENT

The combination of technology innovation in power electronics, electricity deregulation, economics, customer value, and energy demand is causing the electric power industry to shift from a few large concentrated generation centers to a more distributed and dispersed power generation infrastructure [12]. Power quality issues in DG systems are mainly due to the high penetration level of harmonics that disrupt voltage profile of the system. Harmonic problems are tied with the switching device technology, the nature of the characteristic harmonics, equipment ratings, and loading conditions of the host distribution feeder. Under the present framework of IEEE 519-1992, the supplier of electricity is responsible for the quality of the voltage supplied. The end user is responsible for limiting harmonic current injections based on the size of the end-use load relative to the capacity of the system [13].

Power electronic inverters are a major concern over which the possible harmonic current contributions they may make to the utility system. To some extent, this concern arises due to the use of Silicon Controlled Rectifier (SCR) technology based inverters. They are line-commutated and inject high levels of harmonic current through the distributed system. Most types of new inverter topologies are based on Insulated Gate Bipolar Transistors (IGBTs) that use pulse-width modulation (PWM) technology to generate the injected "sine" wave. They are capable of generating much cleaner output and normally meet the standards set by IEEE 519-1992 [13].
"From the harmonic modeling and simulation standpoint, a distributed generator is usually a converter-inverter type unit and can therefore be treated as a non-linear load injecting harmonics into the distribution feeder" [11]. Harmonics in output line-line voltage of three phase voltage source inverters can be calculated by the following equation

$$\mathrm{Vab} = \sum_n \left(\frac{4\mathrm{Vs}}{\mathrm{n}\pi}\right)\cos\left(\frac{\mathrm{n}\pi}{6}\right)\sin \mathrm{n}\left(\omega t + \frac{\pi}{6}\right) \qquad (1)$$

Where,
n is an odd number. It can be noticed that triplen harmonics (n = 3, 6, 9, …) would consequently be zero inline-line voltages. The other line-line voltages can be given as

$$\mathrm{Vbc} = \sum_n \left(\frac{4\mathrm{Vs}}{\mathrm{n}\pi}\right)\sin\left(\frac{\mathrm{n}\pi}{3}\right)\sin \mathrm{n}\left(\omega t - \frac{\pi}{2}\right) \qquad (2)$$

Harmonics arise from the inverter switching as well as due to the transitions of micro-grid between grid-connected and islanded modes. They must be compensated in order to get the improved voltage profile at the loads for power quality enhancement. Moreover, during the gird-connected operation, depending on the design of the generator windings (pitch of the coils), core non-linearity, grounding and other factors, there can be significant harmonics present in the system [14]. Triple harmonics are additive in the neutral; and the third harmonic is often the most prevalent. Synchronous generators are often specified with a 2/3 pitch for the windings as much less third harmonic is produced than those with other pitches. Unfortunately a 2/3 pitch machine has a lower impedance to third harmonic and may cause more harmonic current to flow from other sources connected in parallel with it [14]. The feeder penetration of harmonics is limited by the grounding arrangement of the generator and step-up transformer.

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IV. DESIGN METHODOLOGY

The DG system under consideration consists of a utility grid with bulk generation from a large generator rated at11KV and two micro-grids connected through a Point of Common Coupling (PCC) to the utility grid and distributed loads. Micro-grids have DC sources rated at 380-400V DC. Circuit breakers (reclosers) are installed for interfacing micro-grids with the utility grid forming different zones. Ingrid-connected mode, power is fed to loads through the main grid. In case of island (fault or unavailability of the grid), power demands are fulfilled through micro-grids. This adds flexibility, efficiency, and reliability to the system.

The high level schematics of system under consideration are shown above. This system has been further categorized into subsystems for modeling the distributed generators microsources and voltage source inverters. The subsystem provides a voltage and power output at the point of common coupling with the main grid. There are two types of controls for this system. One is supervisory control for the grid and other is distributed control for inverters [15]. Accurate power sharing is determined by more familiar droop control.

For power sharing using droop control, it is evidenced that active power-voltage (P-V) droop and reactive power-angle (Q-ω) boost functions are the true measure of active and reactive power sharing when the network is considered to below voltage. These functions can be modeled by the following set of equations

$$\omega = \omega o + Kq(Qo - Q) \quad (3)$$

$$E = Eo - Kp(Po - P) \quad (4)$$

Where,
kp: voltage droop coefficient
kq: frequency boost coefficient
ωo: nominal frequency
Vo: rated phase voltage magnitude
P: real power output of micro-grid inverter
Po: nominal real power output
Q: reactive power output of micro-grid inverter
Qo: nominal reactive power output

V. INDUCTION MOTOR

An induction motor (IM) is a type of asynchronous AC motor where power is supplied to the rotating device by means of electromagnetic induction. Other commonly used name is squirrel cage motor due to the fact that the rotor bars with short circuit rings resemble a squirrel cage (hamster wheel).An electric motor convert's electrical power to mechanical power in its rotor. There are several ways to supply power to the rotor. In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Induction motors are widely used, especially poly phase induction motors, which are frequently used in industrial drives. The Induction motor is a three phase AC motor and is the most widely used machine. Its characteristic features are-

- Simple and rugged construction.
- Low cost and minimum maintenance.
- High reliability and sufficiently high efficiency.
- Needs no extra starting motor and need not be synchronized.
- An Induction motor has basically two parts – Stator and Rotor.

The Stator is made up of a number of stampings with slots to carry three phase windings. It is wound for a definite number of poles. The windings are geometrically spaced 120 degrees apart. Two types of rotors are used in Induction motors - Squirrel-cage rotor and Wound rotor.

A. AC Induction Motor

The AC induction motor is a rotating electric machine designed to operate from a 3-phase source of alternating voltage. For variable speed drives, the source is normally an inverter that uses power switches to produce approximately sinusoidal voltages and currents of controllable magnitude and frequency. A cross-section of a two-pole induction motor is shown in Fig.6. Slots in the inner periphery of the stator accommodate 3-phase winding a, b, c. The turns in each winding are distributed so that a current in a stator winding produces an approximately sinusoidally-distributed flux density around the periphery of the air gap. When three currents that are sinusoidally varying in time, but displaced in phase by 120° from each other, flow through the three symmetrically-placed windings, a radially-directed air gap flux density is produced that is also sinusoidally distributed around the gap and rotates at an angular velocity equal to the angular frequency, of the stator currents. The most common type of induction motor has a squirrel cage rotor in which aluminum conductors or bars are cast into slots in the outer periphery of the rotor. These conductors or bars are shorted together at both ends of the rotor by cast aluminum end rings, which also can be shaped to act as fans. In larger induction motors, copper or copper-alloy bars are used to fabricate the rotor cage winding.

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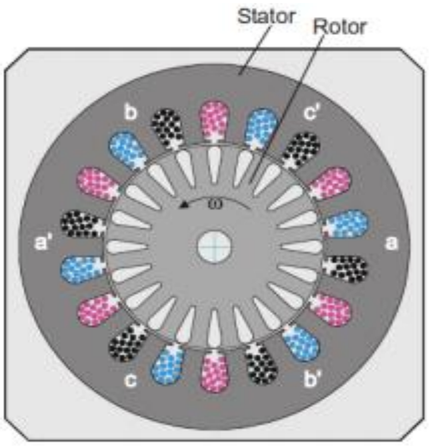

Fig.1. 3-Phase AC Induction Motor.

As the sinusoidally-distributed flux density wave produced by the stator magnetizing currents sweeps past the rotor conductors, it generates a voltage in them. The result is a sinusoidally-distributed set of currents in the short-circuited rotor bars. Because of the low resistance of these shorted bars, only a small relative angular velocity, r, between the angular velocity, s, of the flux wave and the mechanical angular velocity of the two-pole rotor is required to produce the necessary rotor current. The relative angular velocity, r, is called the slip velocity. The interaction of the sinusoidally distributed air gap flux density and induced rotor currents produces a torque on the rotor.

Squirrel-cage AC induction motors are popular for their simple construction, low cost per horsepower, and low maintenance (they contain no brushes, as do DC motors). They are available in a wide range of power ratings. With field-oriented vector control methods, AC induction motors can fully replace standard DC motors, even in high performance applications.

VI. MATLAB/SIMULINK RESULTS

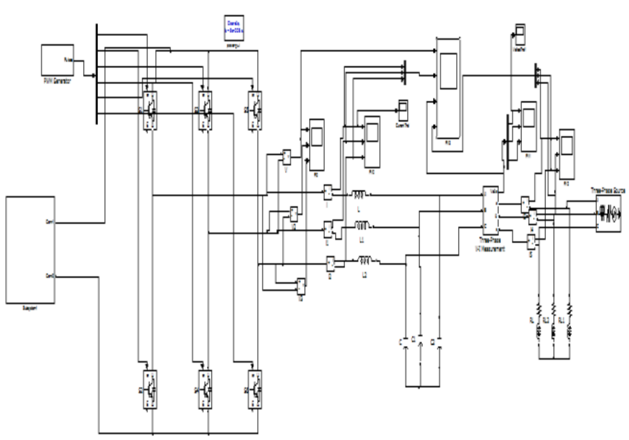

Fig.2 Matlab/Simulink model of SPWM based micro-grid inverter

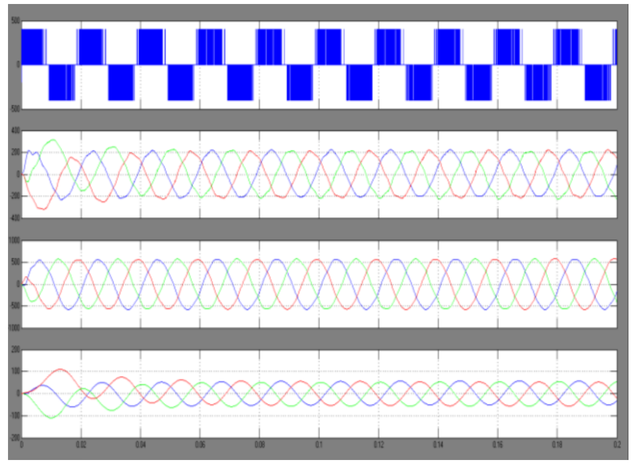

Fig.3 Inverter Voltage, Inverter Current, Grid Voltage and Grid Currents

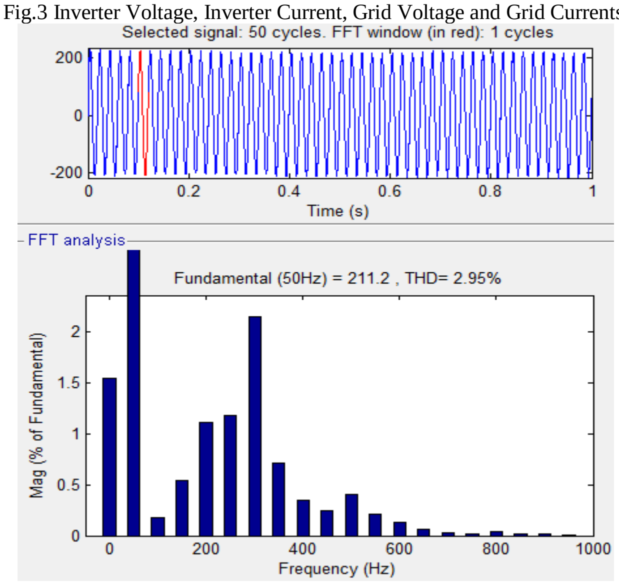

Fig.4 THD analysis of Current

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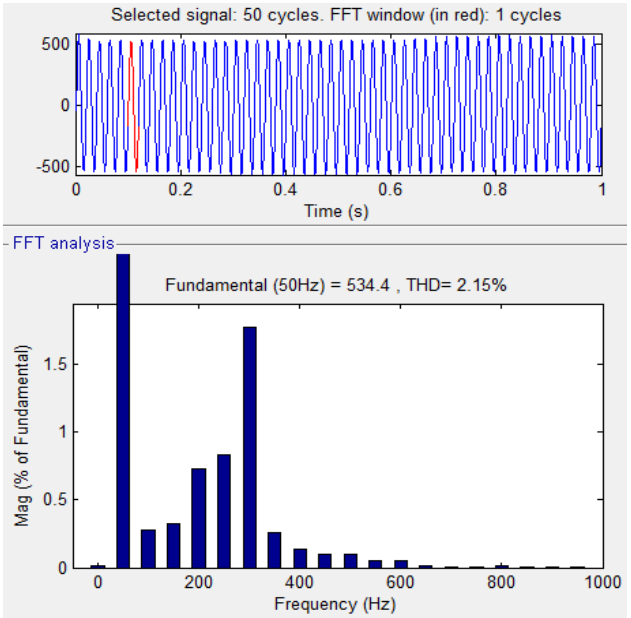

Fig.5 THD analysis of Voltage

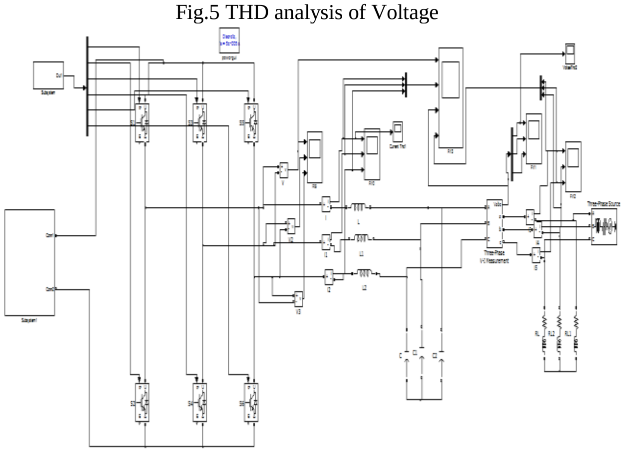

Fig.6 Matlab/Simulink model of SVPWM based micro-grid inverter

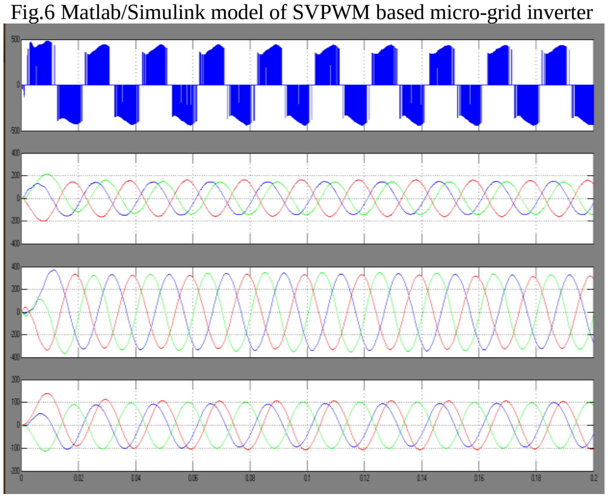

Fig.7 Inverter Voltage, Inverter Current, Grid Voltage and Grid Currents

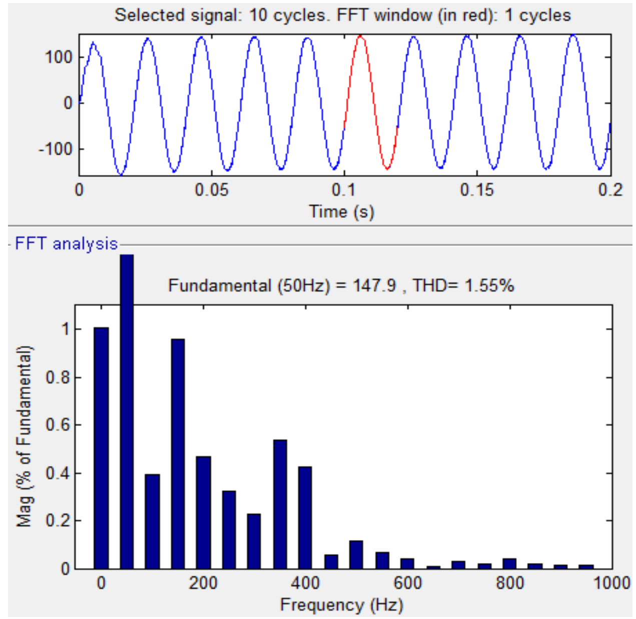

Fig.8 THD analysis of Current

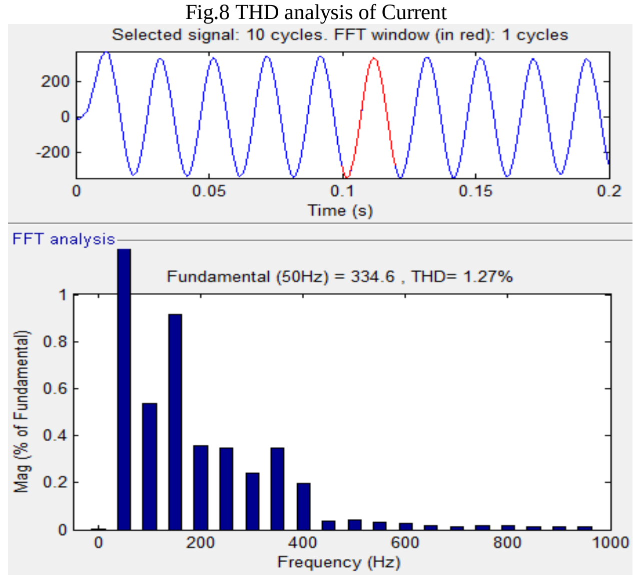

Fig.9 THD analysis of Voltage

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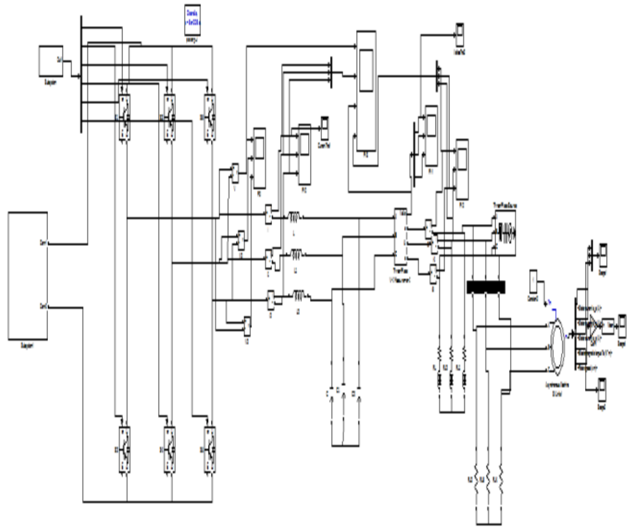
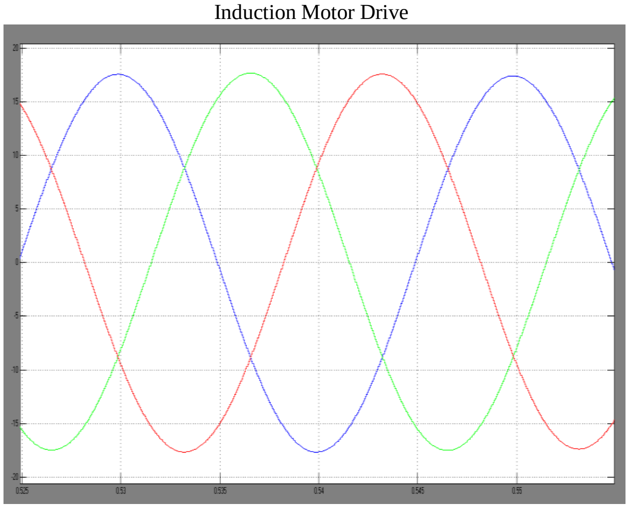


Fig.10 Matlab/Simulink model of SPWM based micro-grid inverter with Induction Motor Drive



Fit.11 Stator Currents

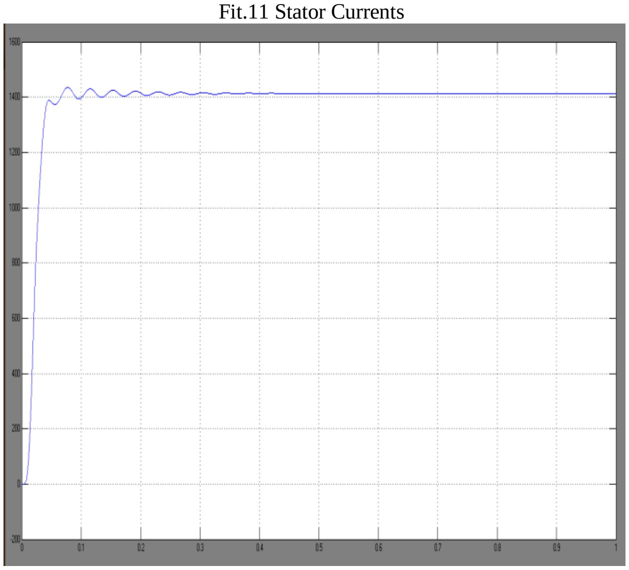


Fig.12 Speed of the Induction Motor

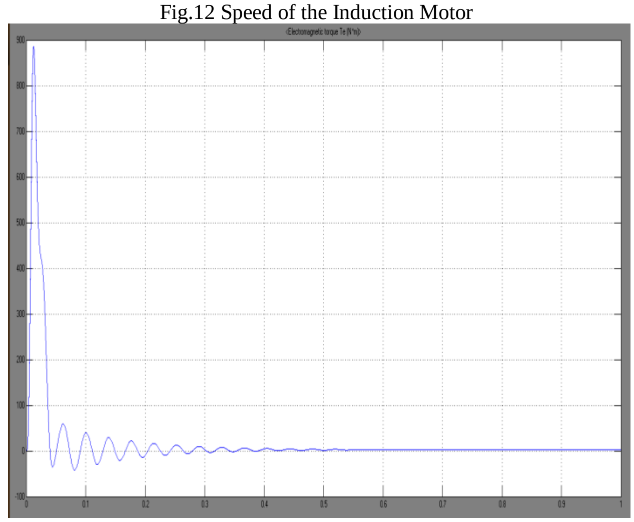


Fig.13 Torque Characteristics of the Induction Motor

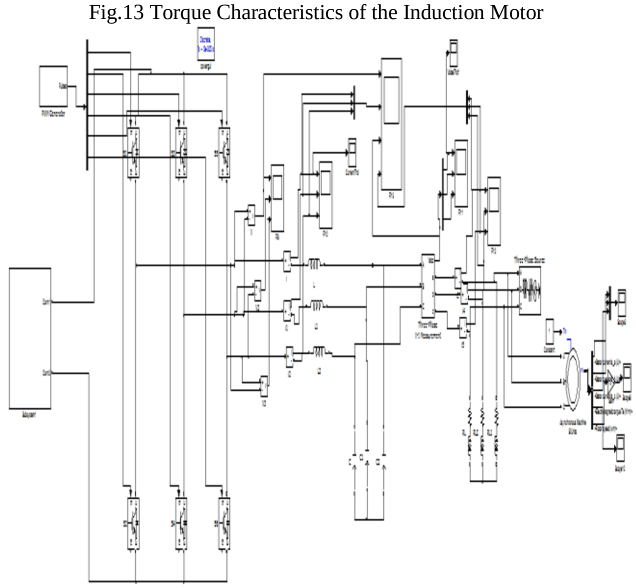


Fig.14 Matlab/Simulink model of SPWM with induction motor

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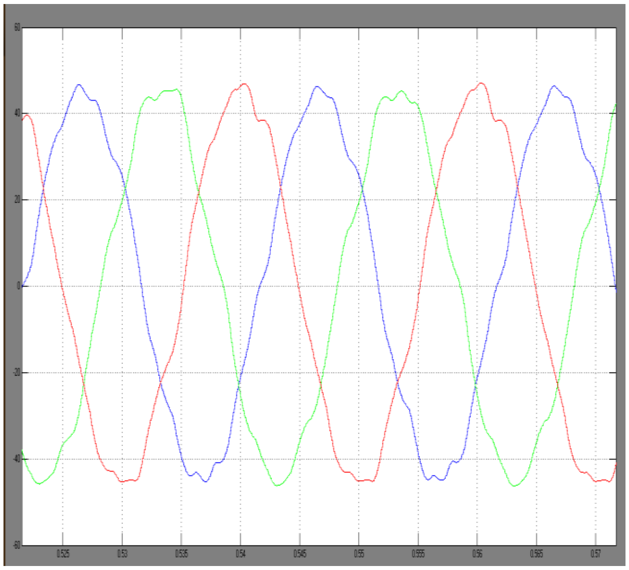
Fig.15 Stator Currents

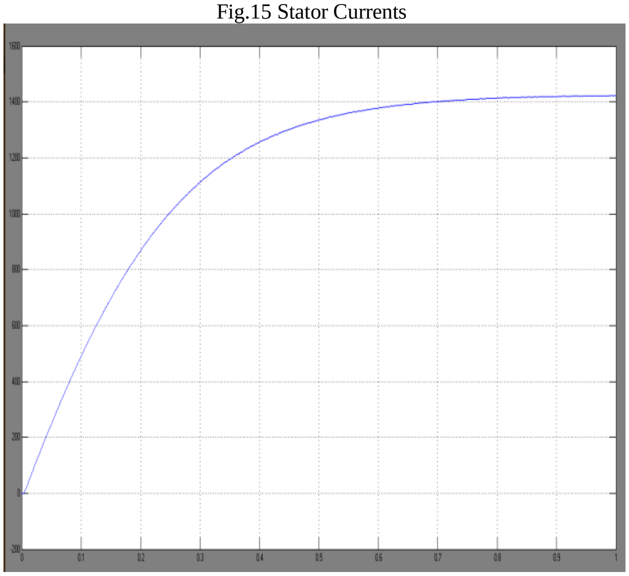
Fig.16 Speed of the Induction Motor

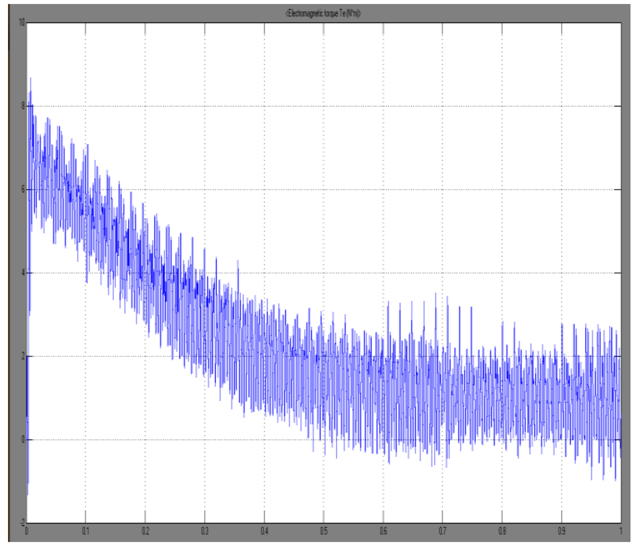
Fig.17 Torque Characteristics of the Induction Motor

VII.CONCLUSION

This paper presents a various modulation topologies are used to improve the power quality in Distributed Generation (DG) system. When the active filter is installed at a distorted and unbalanced distribution network, the harmonic are compensated by the active filter. The main advantage in this proposed method is incorporated V/F based induction motor control with Both SPWM and SVPWM based inverter. So that the advantages in 3-level with SVPWM as increased the performance and life time of drive. These advantages allow implementing controllers for electric vehicles; because, mainly electric vehicles need high starting torque so this is produce the required torque with minimum torque ripples and in electric vehicles, operation of drive is depends on variable torque with constant speed applications as well as variable speed with constant torque application.

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