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Improved Soft Start Capability of Induction Motor Using Solar Power Generation Based Z Source Inverter

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Abstract – This Paper present the photovoltaic power generation based Z Source inverter fed induction motor for enhanced soft start capability. The solar decentralization of power generation and increasing purpose of non-conventional energy sources has become requirement to assume a low cost power generating system for operating in remote areas. The Solar Power Generation System based Z Source inverter for feeding dynamic (induction motor drive) as well as static load is proposed and implemented for rural and remote areas. Hence, in this topology used to achieve better efficiency and reliability of the system while compared to conventional VSI type scheme. The solar cell model is formulated using basic single diode circuit equations of the photovoltaic cells admitting the effects of temperature changes and solar irradiation. Here, the Z-Source inverter is uses a unique impedance network coupled with inverter circuit and also used to realize the boosted DC to AC conversion. Induction motor has ability to self start outstanding to the interaction between the rotor winding flux and rotating magnetic field flux, inducing a high rotor current as torque is increased. In this paper proposed the design of soft starter fed induction motor by controlling the applied voltage. It is used to provide the low cost, size, better performance of startup machine, Controlled acceleration and improvement of efficiency. The corresponding simulation results have been verified using Matlab/Simulink Environment.

Keywords: Photovoltaic (PV) Cell, Soft Starter, Z Source Inverter, Induction Motor (IM), Voltage Source Inverter (VSI)

1. Introduction

As the uptake of the traditional sources of energy is increasing at a faster rate, it becomes destiny to find a substitute source for the property of the environment. Between the various renewable energy sources usable, here the solar energy is best alternative as it is quality free abounding energy source. In future, the applications of solar power finds in residential and industrial

purpose. The model of single diode for transparent PV modules such at any operating conditions in a simple and straightforward manner have been introduced for measuring five parameters [1-2]. The technique of parameter estimation is used to found out unknown parameter of single diode and it's based on photo generated current and diode saturation current planned under varying irradiance and temperature. In order to achieve accurate and fast applicable to all kinds of solar cells such as thin-film type and Cr-Si type solar cells [3].

The photovoltaic source based impedance source network has been designed for achieving better performance. It can be provide the both voltage buck and boost capabilities due to X shaped network between it where the VSI can be operate only in buck mode of operation. There are various switching scheme used to control Z source inverter voltage to be either smaller or greater [4-5]. The elimination of the traditional boost converter interfaced with VSI has been compared and studied with under modified SPWM based control technique. The soft start motor system consists of series connected SCR topology in each phase of the stator phases and also carried out by development of a inferred flux linkage based state space model for both 2-phase and 3-phase conduction operations [6-8]. The altered Z- source inverter for scalar V/f control from Solar PV system is analyzed for induction motor applications. Become to achieve better performance at very low speed this compared to conventional VSI and CSI type converter.

Neural network based soft starter is used to control the speed by the modification of firing angles and to eliminates the starting torque pulsations by triggering the back to back related thyristors. The detailed conventional control scheme based on delay of firing from alpha control at voltage Zero Crossing (VZC) and delay of firing from gamma control at Current Zero Crossing (CZC) are discussed. The artificial intelligence based MPPT controller used to analysis the system configuration and to extract maximum power from solar array [9-11]. The operating principles of discrete high torque frequency with soft starter were studied for broad application. The torque pulsation has been eliminated by using soft starter based self turned device. The detailed model can be capable of presenting by the different various switching states of the AC chopper. Here, modified control strategy is discussed to eliminate the electromagnetic torque pulsation and also to limit the stator current throughout entire starting period [12-13].

The selection of proper component and harmonic analysis with variation of shoot through period of Z source inverter and duty cycle is presented. Under soft start controlled condition, provides the elimination of low order harmonics and higher efficiency of energy conservation method. By using fault liberal soft starter control of induction motor has showed the reduced motor inrush current magnitude as well as reduced motor starting transient torque pulsations [14-16]. In this paper proposes the soft starter motor with PV based Z source inverter for power generation. Hence, in order to achieve the proper control of starting current and torque pulsation.

2. Solar Power Generation

The mathematical design of single diode photovoltaic array is necessity for evaluating their efficiency and under various operating conditions at improved performance. The electromagnetic radiation of solar power can be directly convinced to electricity through photovoltaic effect. Being exhibited to the sunlight, photons with energy greater than the band-gap energy of the

semiconductor produces some electron/hole pairs relative to the incidental irradiation. The electrical equivalent circuit of PV cell is shown in figure 1.

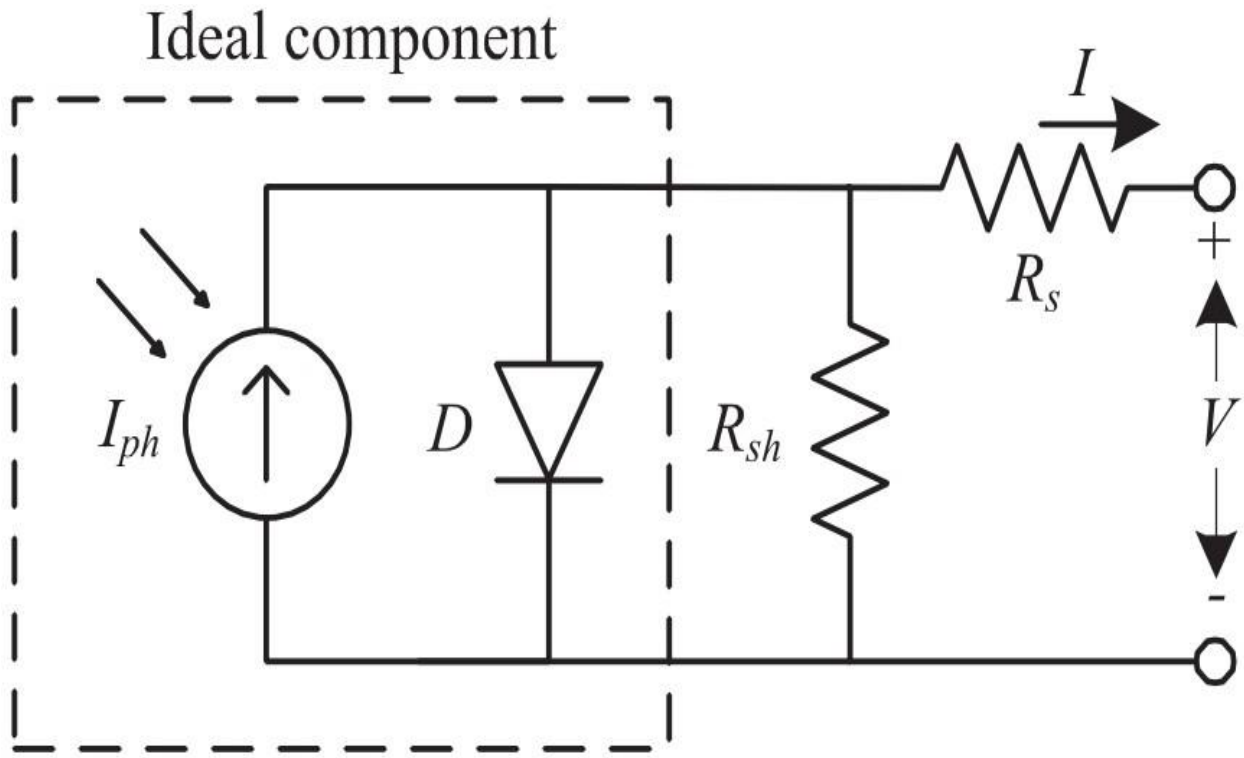

Fig 1. PV Cell Electrical Equivalent Circuit

V-I characteristic of PV Cell module are expressed below,

$$I = I_{pvi} - I_{dsi}\left(e^{\frac{q(V+IR_s)}{nKT}} - 1\right) \quad (1)$$

Where I_{pvi} = photo voltaic current, I_{dsi} =diode saturation current, q=charge of electrons, K= Boltzmann constant, T=Temperature, R_s =series resistance and n=number of PV cell module. The generated electricity current of the PV cell depends linearly on Temperature and irradiation affect by solar equation given below,

$$I_{pv} = \left(I_{pv,n} + K_I + \Delta_T\right)\frac{G}{G_n} \quad (2)$$

$$I = I_{pvi} - I_{dsi}\left[\exp\left(\frac{V+R_SI}{V_{ta}}\right) - 1\right] - \frac{V+R_SI}{R_p} \quad (3)$$

Where I_{pvi} and I_{dsi} is the photovoltaic and saturation current of array respectively, $V_t = N_S KT/q$, array is composed by N_p parallel connection of cell the photovoltaic and

saturation current can be expressed as of $I_{pvi} = I_{pvi,cell} N_p$, $I_{dsi} = I_{dsi,cell} N_p$

3. Impedance Source Network Topology

The photovoltaic system based Z source network can be provides the single stage power conversion construct where as the conventional inverter needs two stage power conversion for renewable power applications. It contains the three main reason of unique X-shaped network while compared to traditional voltage source and current source inverter topology. The two independent freedom controls consists of one is represents the modulation index and shoot through duty cycle, supplying the ability to found any desired output AC voltage. In second one is referred as same characteristics of a DC-DC boosted inverter however its single stage is more cost effective and less complexity. The third one is represent the benefits of z-source inverter used enhanced reliability due to the fact that fleeting shoot-through state. The circuit configuration of Z source inverter is shown in figure 2.

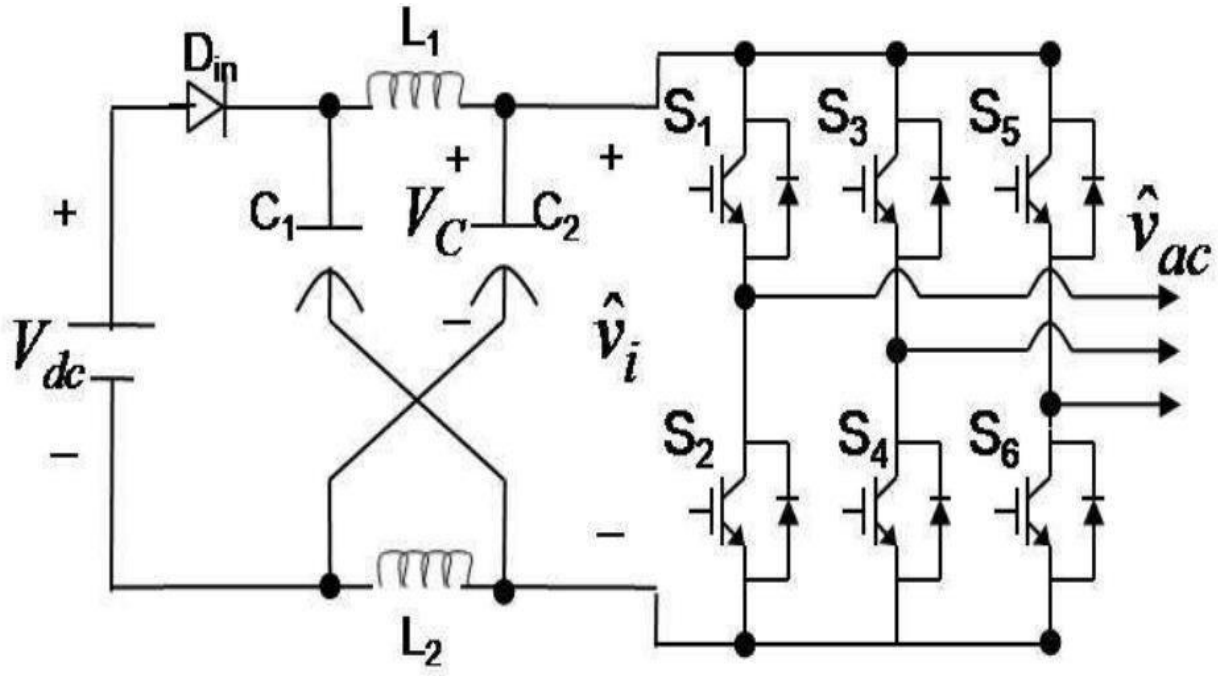

Fig 2. Circuit Representation of Z Source Inverter

The two port impedance network consists of a capacitors C1 and C2 and split inductor L1 and L2 connected in X shape is utilized to allow for a Z-source coupling the inverter to the DC source or AC load. By comparing to conventional VSI & CSI, the ZSI well employs the shoot-through states to boost the DC bus voltage by gating on both upper and lower switches of a phase leg. Thus, the ZSI can be boost voltage and also produce a desired output voltage which is greater than usable dc bus voltage. The Z source peak inverter voltage and capacitor voltage are determined by using equation given below,

$$\overset{\Lambda}{V}_{ipeak} = BV_{dc} = \frac{1}{1-2D_0}V_{dc} \quad (4)$$

$$V_{Cap} = \frac{1-D_0}{1-2D_0}V_{dc} \quad (5)$$

$$L_1 = L_2 = \frac{\left(L * T_{switch} * D_S * V_{Cap}\right)}{\left(\Delta I\right)} \quad (6)$$

$$C_1 = C_2 = \frac{\left(I_{avg} * T_{Switch} * D_S\right)}{\left(0.03 * V_{Cap}\right)} \quad (7)$$

The Z source inverter makes shoot through zero state potential. It does not affect the control of PWM inverter, because it equal produce the same zero voltage to the load terminal. Hence, the available shoot through period can be limited by the zero state periods which are found out by the modulation index.

4. Soft Starter Motor Drive

Generally, the Soft starters are frequently the more sparing choice for applications that require torque and speed control only during motor startup condition. In addition, the ideal solution for applications whereas space is pertaining, as usually carries up less space than variable frequency drives. The schematic diagram of soft starter motor system is shown in figure 3.

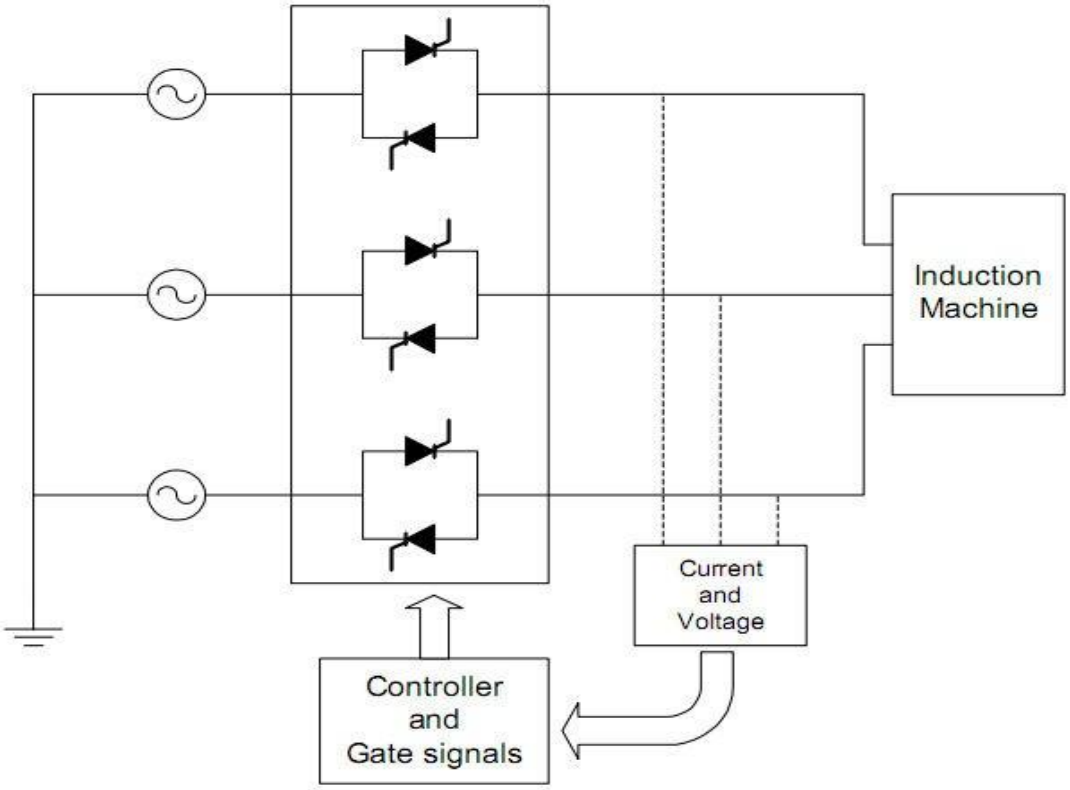

Fig 3. Schematic Configuration of Soft Starter Motor System

Induction motor can be run only the phase difference between rotor's magnetic field and stator's magnetic field if the phase difference is same induction motor cannot be run. Here, the phase difference is required for rotor magnetic field tries to catch stator magnetic field and depicts current. Whenever the induction motor runs at full speed range, current increases to a large value which in turn increases the value of torque. As an outcome of initial high current, the windings of induction motor discredited and induce overheating. In order to prevent the induction motor from damage, motor soft starter is involved. There are various techniques of soft starters each and every technique has been some limitations. In this paper proposed the technique of solid state soft starter method is used to start induction motor smoothly. The soft start speed torque characteristic curve is shown in figure 4.

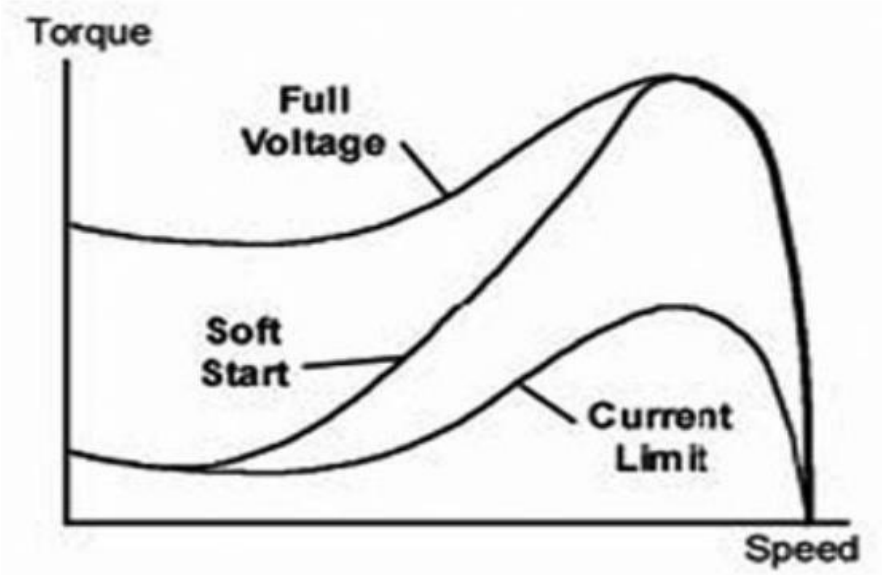

Fig 4. Characteristic Curve for soft start speed-torque

The recent uses of solid state devices such as thyristors like SCR, IGBTs, and MOSFETs are used for soft starting purpose of motor drive. It can be used to eliminate the mechanical components with electrical components. These starting methods basically allow for control of the voltages applied to an induction motor and hence control the torque. Thus, control the acceleration of a machine during starting transient time period. In this method based on the assumption that the RMS voltage supplied to the machine can be reduced during steady state and starting operation.

5. Simulation Results

The proposed topology simulation results are carried out for improved soft start capability of squirrel cage induction motor drive. The dynamic PV model is designed as using mathematical expression under variation of temperature and solar irradiation. The Z source based inverter fed soft starter induction motor has analyzed for maximum solar power generation. Since the starting torque of the motor drive is proportional to the square of the starting current. Here, it's not only the starting current can be determined but also the starting torque can be diluted when decreasing the duty cycle. The basic control strategy is presented to limit the stator current and to eliminate electromagnetic torque pulsation during the entire starting period. The overall simulink circuit configuration of proposed scheme is shown in figure 5. The generation of photovoltaic input voltage and current waveform is shown in figure 6. The Z source across the voltage waveform is shown in figure 7.

Generally, the solid state soft start motor controllers and starters have power to ability control of the starting characteristics and also to match the application requirements include such as acceleration and deceleration time, starting with overload current, motor torque.

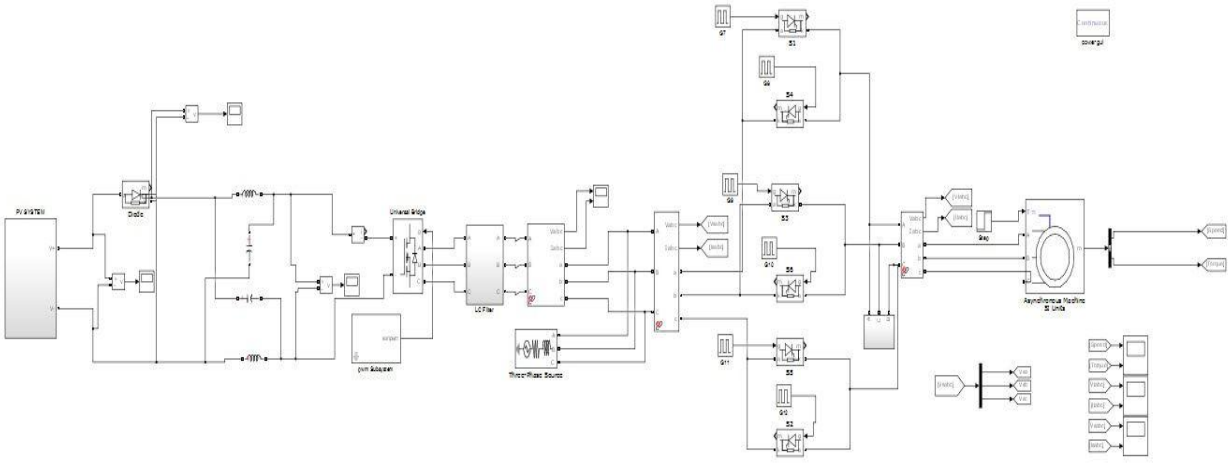

Fig 5. Proposed Overall Simulink Circuit Diagram

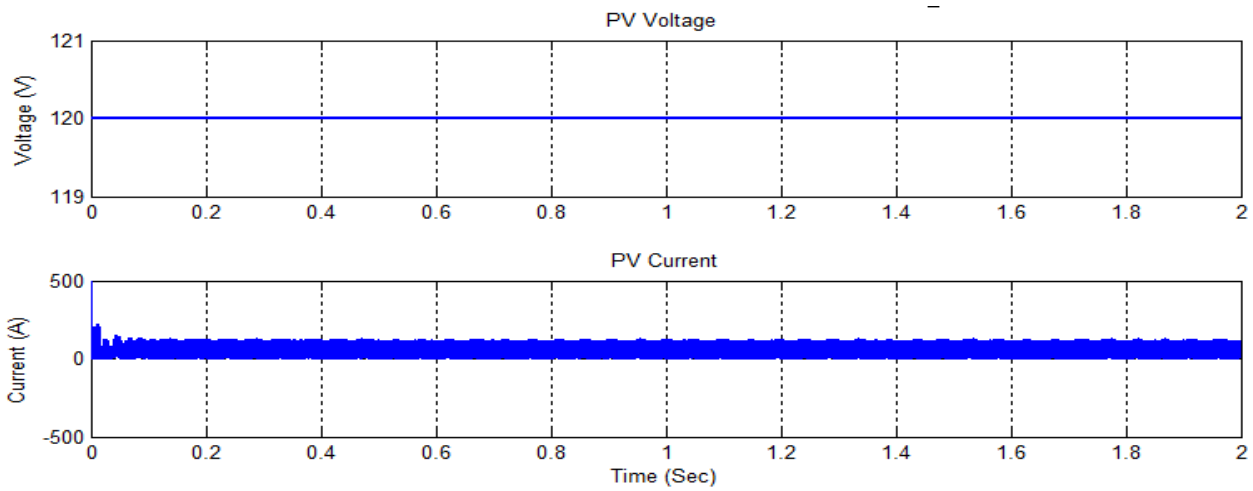

Fig 6. Photovoltaic Voltage and Current Waveform

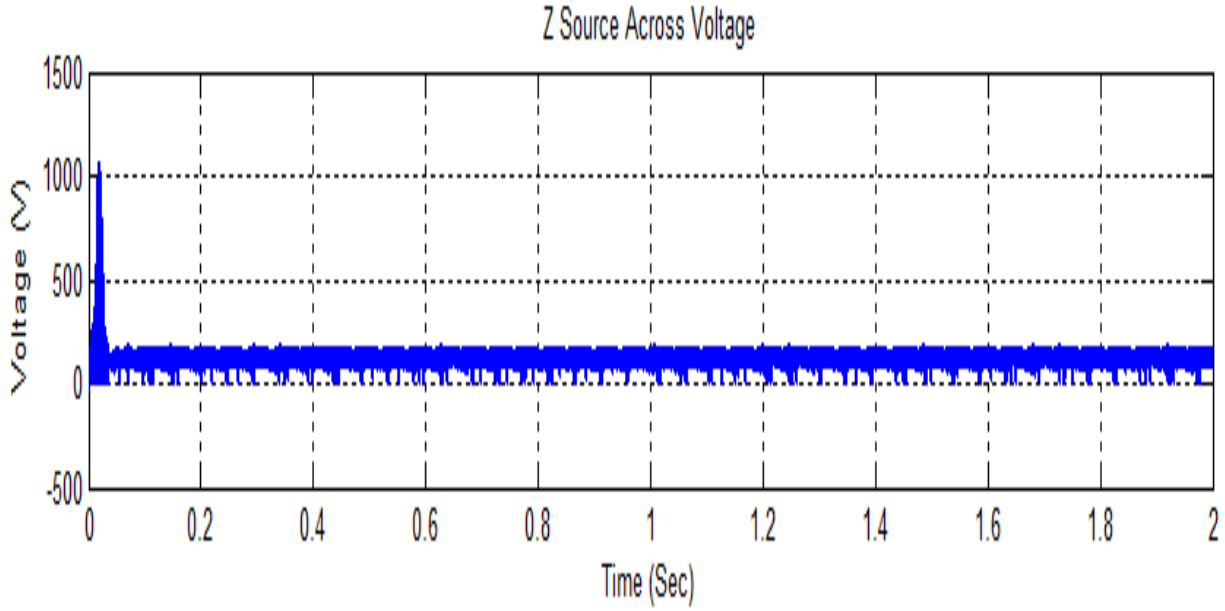

Fig 7. Z source across Voltage Waveform

Additionally, the motor protection may be provided for a number of potential damaging circumstances by the soft start controller. The performance of motor drive has analyzed with results of rotor speed and torques is depicted in figure 8

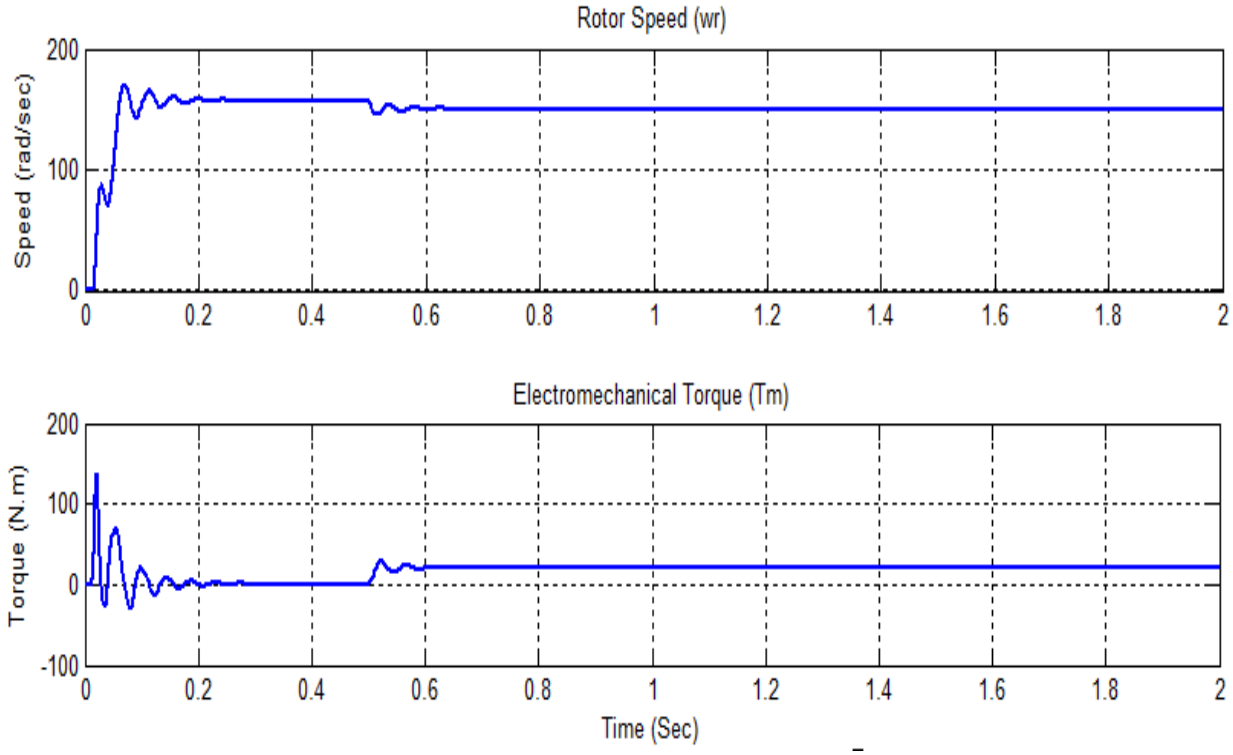

Fig 8. Performance of motor drive waveform

A gradually controlled starting is involved to avoid the torque spikes and tension in the mechanical system related with normal equipment startup. The input and output side of three phase voltage and current waveforms is shown in figure 9 and 10.

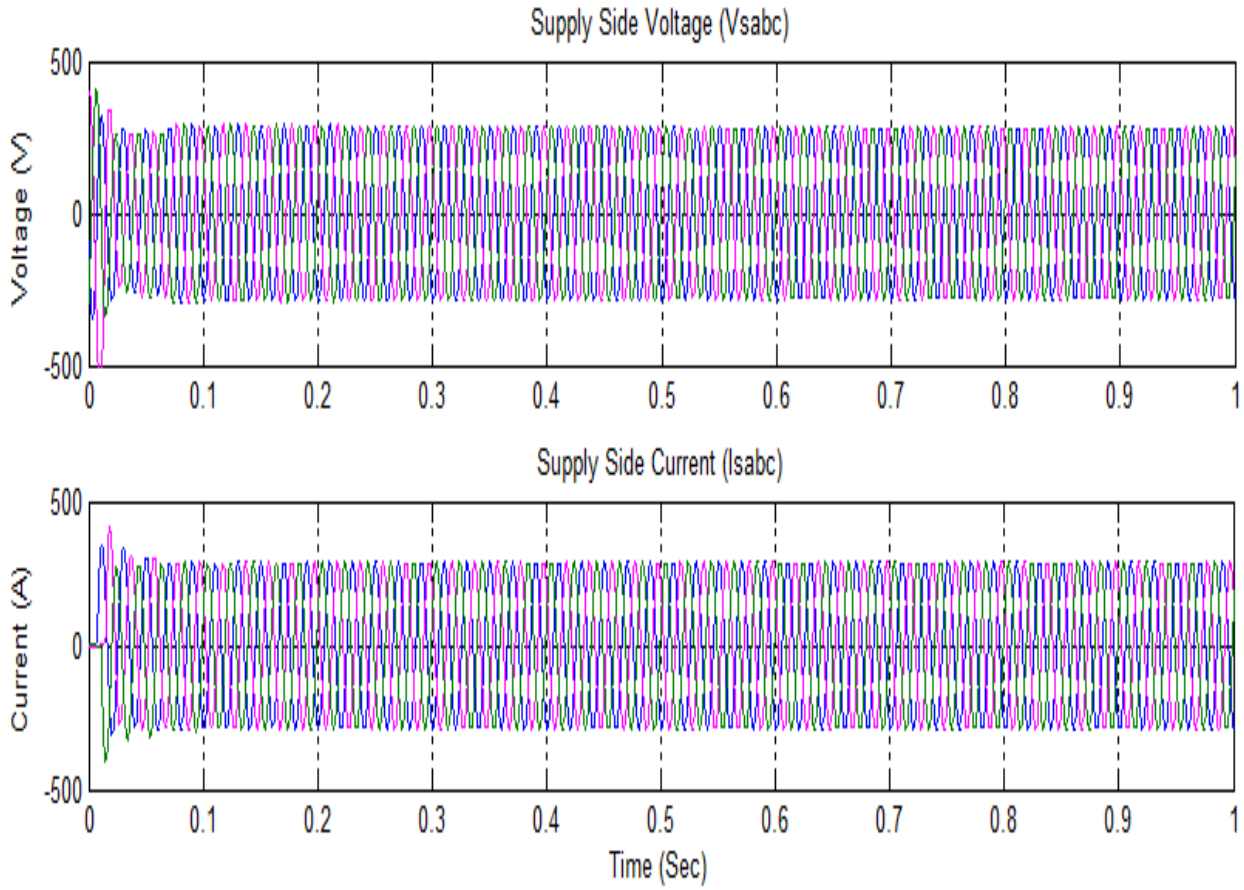

Fig 9. Supply side three phase voltage and current waveform

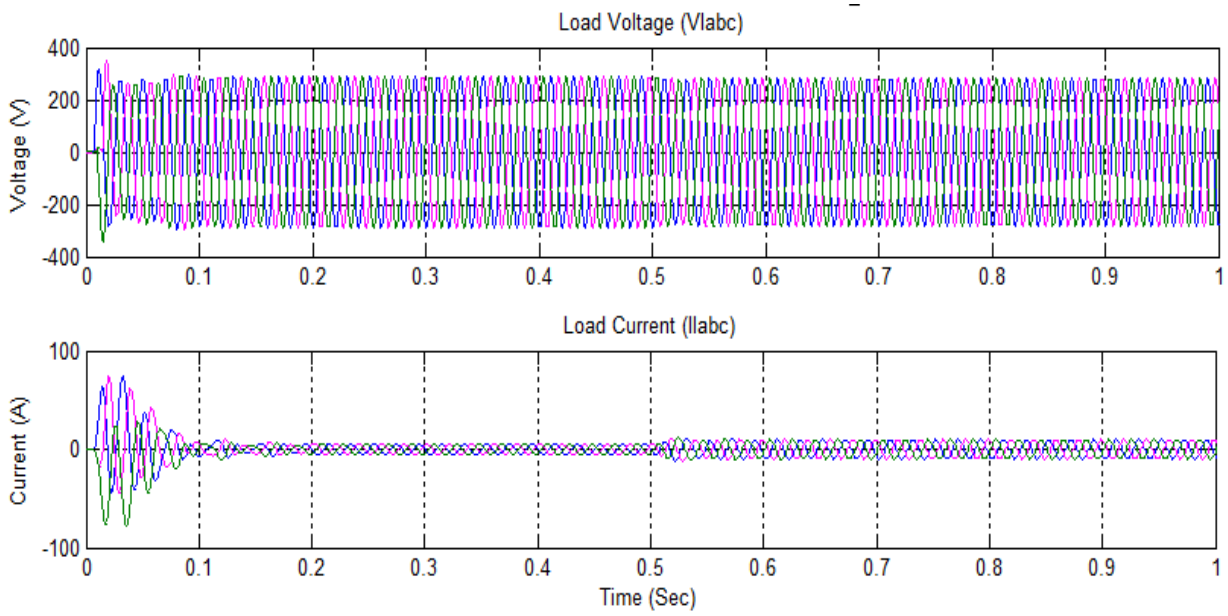

Fig 10. Load Side three phase voltage and current waveforms

The soft starter works on the reality of torque is proportional to the square of the starting current, which in turn proportional to the applied voltage. Thus the torque and current can be corrected by reducing voltage at the time of starting the motor. One method to qualify the linearity of an amplifier is used to measure the total harmonic distortion (THD). Here, the Harmonic distortion is evaluated by applying pure sine wave to the amplifier in a determined circuit form and detecting the output spectrum. The FFT analysis of output side current is described in figure 11.

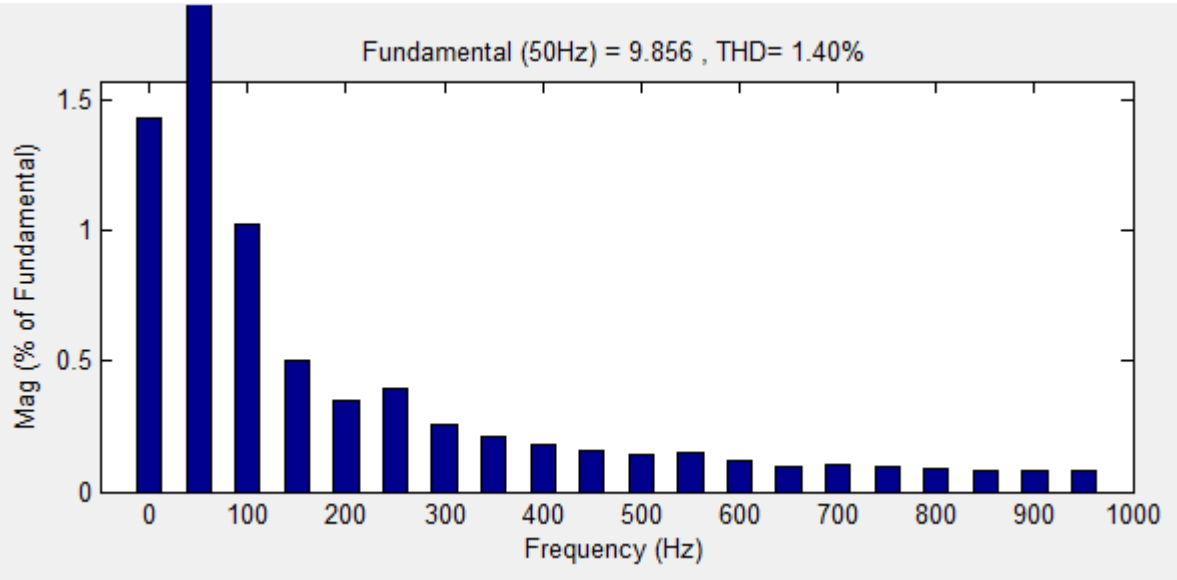

Fig 11. FFT analysis of output side waveform

6. Conclusion

This paper an improved the solar power generation based z source inverter is proposed for soft start capability of induction motor drive. By compared with conventional system, the proposed configuration has reduce the startup current, maximum boost capability while considering the inductance and capacitance with less number of switches. The single diode PV model is designed and analyzed under the variation of temperature and irradiance. The impedance source network based three phase inverter is proposed for coupled with RL load and soft starter induction motor. In order to get the increased life of motor performance and reduced the problem of maintenance cost. While the motor drive is running at less than full load, the comparative reactive component of current tired by the motor is without need high due to magnetizing and associated losses. Therefore, the qualified of voltage losses are minimized with the load proportional active current component and result of the power factor also improves at the same time. The reduction of harmonic distortion based simulation results are carried out by using the FFT based tool analysis. The proper soft start strategy of induction motor has analyzed with results of total harmonic distortion (THD) and also used for reducing the inrush current and resonance of impedance source network inverter. An improved soft start capability of induction motor has been studied and verified with best control using Matlab/Simulink software.

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