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Article

Design and Implementation of PV Fed T Source Inverter for Industrial Application

Thiruvasagam P [1,*] and Dr. Yasoda K [2]

[1] Department of Electrical and Electronics Engineering, Government College of Technology, Coimbatore
[2] Assistant Professor, Department of Electrical and Electronics Engineering, Government College of Technology, Coimbatore
* Correspondence: thiruvasagam227@gmail.com; Tel.: 9043648889

Abstract: This project presents a renewable source based T source converter topology with sine pulse width modulation control technique. The advantage of T sourceinverter over Z source Inverter is, it has reduced leakage reactive components. Thus, improves the converter efficiency. At the same time normal two stage operation is also eliminated (DC-DC-AC conversion). T Source Inverter shows betterperformance only when there is no change in input voltage. If there is any change in input voltage, the DC-DC stage could not maintain voltage stability and it will oscillate depends upon the input voltage. In case of boost converter, it boosts the supply voltage only,if there is any change in input voltage, it could not boost the output voltage. The T source inverter gives better results compared to the boost converter.

Keywords: Z Source; T source; DC-DC-AC conversion

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1. Introduction

Renewable energy sources also called non-conventional type of energy are the sources which are continuously replenished by natural processes. Harnessing renewable energy sources such as wind energy, solar energy, etc., is critical for overcoming problems due to global warming and environmental degradation caused by the use of fossil fuels. Among all renewable energy sources, solar PV is abundant, has high power density, is modular and scalable. Solar PV is used both in grid connected applications and standalone applications. It can be used in a wide range of applications from a microwatt internet of things system to a megawatt scale solar PV plant. Solar PV operates in a wide range of DC voltages, while electrical and electronic systems also have different levels of DC voltage requirements. Hence, it is necessary to use power electronic interfaces for solar PV applications.

Existing converter geographies, for example, voltage source inverter (VSI) and current source inverter (CSI) are ordinarily utilized as force electronics circuits for power change purposes. The VSI produces an air conditioner yield (in the wake of separating it) which is restricted beneath the dc input voltage, which implies that VSI is buck type converter. The buck activity nature of as far as possible its activity to control change applications and ac drive circuits. An extra dc-dc unit is connected to the dc contribution of the converter to additional expansion the dc input voltage,which prompts an expansion in the air conditioner yield voltage. Accordingly, the extra dc-dc support converter expands the framework cost, control intricacy and reduces the efficiency. Moreover, any misgating for the inverter connect switches cause cut off destroys the power exchanging gadgets. For that, a dead-time is set between the upper and the lower exchanging gadgets at the same leg to evade impede. Then again, for CSI sort of converter, the yield voltage is consistently more noteworthy than the info voltage.

To have a yield voltage which is not exactly the information an extra dc-dc buck converter is introduced at the contribution of the CSI. Which increment the cost, control intricacy and reduces the general efficiency. Other than the way that the lower and the upper switches should be turned-on simultaneously, if not; an open circuit for the dc input source cause enormous current stream and obliterates the force exchanging gadgets. The possibility of impedance-source converter (TSI) was initially evolved because of the impediment in VSIs and CSIs. The applied and theoretical restrictions in the regular converters types limited their application and confuses their control techniques. While the TSI extraordinary bit of leeway can be viewed as: it can work as VSI inverter (buck type) or as CSI inverter (support type) contingent upon the application. Where the yield voltage can in a perfect world reaches from zero to vastness.

2. Literature Survey

Eswari K et al,(2014) have proposed "Analysis of T-Source Inverter with Simple Boost Control Technique for Improving Voltage Gain", This thesis manages the Examination of T-source inverter with simple boost technique for improving voltage pick up. The T-source inverter overcomes the problems of the Z-source inverter and provides buck-support activity in a single stage. The T-source impedance network produces output voltage larger than the input voltage by proper maintaining the shoot-through duty proportion, which cannot be achieved by the voltage-source inverter and current-source inverter.The T-source inverter has less passive components in compare with ZSI. All PWM methods can be utilized to control T-source inverter. In this thesis bargains with Simple boost control strategy which is utilized to control the T-source inverter. The output of the T-source inverter is given to the acceptance engine. The output voltage can be fluctuated by changing the DC input voltage.

Hemaprabha G et al, (2014) have proposed "MATLAB/SIMULINK Based Modelling Photovoltaic Array Fed T-Source Inverter", In this paper T-source inverter with straightforward lift control strategy has been presented for photovoltaic applications. The numerical model of T-source inverter is determined and it is reenacted in MATLAB programming. The PV exhibit reproductions were finished with BP4180T information sheet. By controlling adjustment file and shoot through obligation proportion, support factor esteem gets differed; there by the planned yield voltage can be gotten. At last the proposed inverter is executed in equipment, its exhibition under change in temperature and illumination conditions were examined. The outcomes shows proposed T-source inverter gives high voltage pick up, improved transient reaction and decrease in Complete symphonious contortion when contrasted with ordinary z-source inverter.

Ryszard Strzelecki et al, (2009) have proposed "New Type T-Source Inverter", The main preferred position of the TSI is the all-inclusive chance of control of inverter yield voltage and shoot-through coefficient utilizing transformer turns proportion not the same as 1. The introduced results urge to proceed with research on TSI with various turns proportions and furthermore show the other eccentric ZSI geographies utilizing transformers. The best bit of leeway of the TSI is the utilization of a typical voltage hotspot for the inactive plan and the converter. This gives establishing of the arrangement and takes care of numerous issues including electromagnetic similarity which are available in the ZSI. In the setup using the TSI, the voltage is the equivalent. On account of this factor, the design is productive to use with various degrees of NPC VSI. The preferred position to this is that when there are diminishes in voltage levels, there are less semiconductor disappointments.

Hemaprabha G et al, (2014) have proposed "Performance Analysis of Three Phase T source Inverter", This examination manages the Investigation of T-source inverter with straightforward lift control strategy for improving voltage pick up. The T-source inverter defeats the issues of the Z-source inverter and gives buck-help activity in a solitary stage. The T-source impedance network give the yield voltage bigger than the info voltage by legitimate keeping up the obligation proportion of shoot-through state, voltage-source inverter and current-source inverter can't be give these favourable circumstances. When contrasted and ZSI, the T-source inverter has less uninvolved segments .All Pulse Width Adjustment strategies can be utilized to control T-source inverter. In this exploration manages basic lift control strategies which are utilized to control the T-source inverter.

Hemaprabha G et al, (2015) have proposed "An Effective Method over Z-Source Inverter to Reduce Voltage Stress through T-Source Inverter", The continued ideas are mimicked and executed and results are confirmed. Utilization of dynamic snubber circuit in the organization limits the impact of spillage inductance. By shifting tweak file through most extreme lift PWM control greatest voltage support is gotten. Decrease in number of segments and utilization of normal voltage hotspot for T-organization and inverter diminishes the voltage stress and sounds in the circuit. These agreeable outcomes energize the further investigates in executing various turns proportion in transformer windings for acquiring more noteworthy effectiveness.

Chitra K et al, (2019)have proposed "Design And Implementation Of Simple Boost PWM Controlled T-Source Inverter For Solar Pv Application", The usage and execution of SB PWM controlled TSI for sun oriented application has been introduced in this examination paper. Numerical displaying and recreation results for SB PWM controlled TSI boundaries like shoot through proportion d, help factor B, voltage pick up G, capacitance voltage Vc, input voltage of TSI, yield voltage of inverter and current are examined. The SB PWM controlled TSI took care of nearby planetary group gives high lift capacity, yield voltage and voltage pick up, which builds the proficiency of the framework. The THD level of voltage and current are likewise less, subsequently SB PWM controlled TSI is appropriate for solar powered applications.

Chitra K et al, (2018) have proposed "Design of Solar PV System using T-Source Inverter with Third Harmonic Injected Maximum Constant Boost PWM Control", The presentation of T-source inverter for sun oriented PV framework with THIMCB PWM has been talked about in this paper. Scientific articulations for shoot through obligation proportion, help factor, voltage pick up, Z-source capacitance voltage, DC connect voltage (inverter input voltage) and yield are introduced. The hypothetical articulations are approved with the reenactment results. The inverter yield voltage is high contrasted and the ZSI for a similar obligation proportion, tweak file and battery voltage. The voltage gain and voltage support capacity of the sun oriented PV framework with TSI by joining THIMCB PWM is expanded. The voltage are current twists are additionally less in the TSI. Subsequently, this T-Source Inverter is best reasonable for sun based PV framework.

Soumya C Sajeevan et al, (2015) have proposed "T Source Inverter Based Permanent Magnet Brushless Dc Motor", This paper has been researched the presentation of single stage T-source inverter basic lift regulator. The voltage support is conversely identified with the shoot through obligation proportion source TSI has less responsive segments when contrasted with ZSI and both the buck-help activity is performed. The single stage TSI with SB control conspire was recreated and the lower request sounds in the yield current was diminished.

3. General Description

T-source impedance network is recently acquainted with conquered the issues of Z-source inverter. T-Source inverter is like Z-Source aside from the utilization of high recurrence low spillage inductance transformer and one capacitance. It has low responsive segments in contrast and traditional ZSI. Because of this, the proficiency obviously increment. The TSI geography requires a low spillage inductance transformer which should be made with high accuracy. In such a manner, the quantity of detached components is decreased in light of the fact that solitary the transformer and the capacitor are required. Similarly as with qZ-source inverters, the TSI geography includes a typical dc rail between the source and inverter, which is not normal for conventional ZSI circuits. Additionally, utilization of a transformer with other than a 1:1 transformer proportion takes into account a difference in yield voltage Z-source converters, as appeared differently in relation to the voltage coming about because of the shoot-through list or the regulation record.

4. Operation of the Converter

The DC voltage (from PV) is fed as input to the impedance network of TSI which helps to achieve voltage buck and boost properties. Then the output of the impedance network is applied to the inverter main circuits which comprising of six switches. The voltage boost capability of TSI is facilitated byturning ON both the switches in the same phase leg simultaneously. Voltage boost capability of TSI isdue to energy transfer from capacitors to inductors, during the shoot through state. Since, thecapacitors may be charged to higher voltages than the source voltage, the diode Dpreventsdischarging of capacitors through the source.

As with conventional ZSI, the TSI can handle shoot through states when both switches in the samephase leg are turned on. The T-network is used instead of the lattice impedance-network, for boosting the output voltage by inserting the shoot through states in the pulse width modulation (PWM) schemes. The operating principle of T – Source Inverter is same as that of conventional ZSI but it differ from number of capacitor being used. In proposed TSI, only one capacitor is enough to handle shoot through state where as in ZSI two capacitor were used. The detailed operation of TSI is explained in two modes as: a) Non shoot through mode b) Shoot through mode.

4.1. Non – Shoot Through Mode

Figure.1 illustrates the equivalent circuit of TSI in Non – shoot through mode of operation. In thismode capacitor is charged, the inverter bridge operate in one of traditional active states, thus acting as a current source when viewed from T – source circuit. During active state current is zero because of open circiut. The open circuit voltage appear across inverter bridge. The diode conduct and carry current difference, between the inductor current and input DC current. Note that both the inductors have an identical current because of coupled inductors.

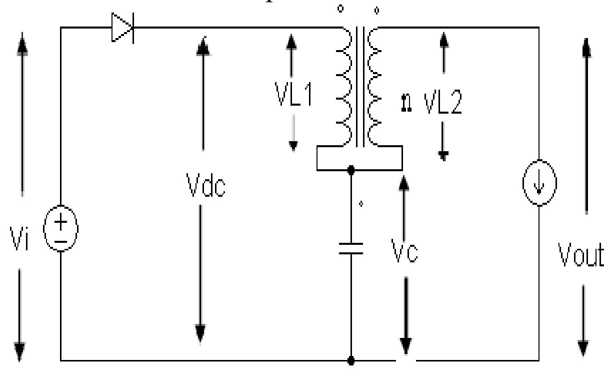

Figure 1. Non – Shoot through Mode

Assume:

Drop across diode is negligible.

For symmetrical T network

$L_1=L_2$; $V_{L1}=V_{L2}=V_L$,

Total switching period (T_t) = T_1+T_0

T_1-Non shoots through time period (active state)

T_0-Shoot through time period (zero state)

From non-shoot through mode for the time period of T_1

$V_i = V_{dc}$ (1)

$V_i = V_{L1}+V_c$

$V_c = V_i- V_L$ (2)

$V_L = V_i-V_c$

$V_{out} = V_c- V_{L2}$

$V_{out} = V_c- V_L$

$V_{out}= 2V_c-V_{dc}$; $V_i=V_{dc}$ (3)

4.2 Shoot Through Mode

This shoot through zero state prohibited in traditional voltage source inverter. It can be obtained in three different ways such as shoot through via any one phase leg or combination of two phase leg or combination of three phase leg. During this mode, Diode is reverse biased capacitor charges the inductor L2 separating DC link from the AC line.

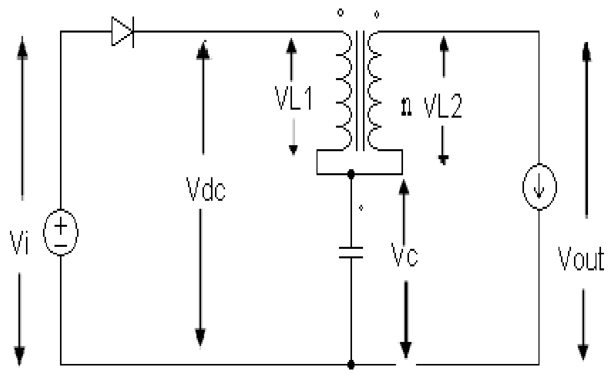

Figure 2. Shoot Through Mode

Inverter in shoot through mode for the time period of T0

$V_c = V_{L2}$ (4)

$V_C = V_L$

$V_{out} = 0$ (5)

At steady state the average voltage of the inductor for one switching period (Tt) is zero. From equation (3.2) &(3.4)

$$VL = \frac{VcTo + T1(Vdc - Vc)}{T} = 0 \quad (6)$$

$$\frac{Vc}{Vdc} = \frac{T1}{T1 - T0} \quad (7)$$

$$Vc = \frac{T1}{T1 - T0} Vdc \quad (8)$$

The average dc link voltage across T source inverter bridge is,

$$Vdclink = \frac{0T0 + (2Vc - Vdc)T1}{T} \quad (9)$$

$$Vdclink = Vdc\frac{T1}{T1 - T0} \quad (10)$$

$$Vdclink = Vc$$

The peak dc link voltage across inverter bridge can be written as

$$Vdclinkpeak = Vc - VL = 2Vc - Vdc$$

$$Vdclinkpeak = Vdc\frac{T1}{T1 - T0}$$

$$= BVdc$$

$$B = \frac{T}{T1 - T0}$$

$$B = \frac{1}{1 - 2\frac{T0}{T}} \geq 1 \quad (11)$$

$(T_o/T)=D_o$ is shooting through duty ratio.

Boost factor depends on shoot through zero time period (T_0).The peak dc-link voltage is the equivalent dc-link voltage of inverter.

$$Vac = Mi\frac{Vdclinkpeak}{2}$$

M_i – Modulation index

Peak phase Value of output voltage of inverter is

$$V^{\wedge}ac = MiB\frac{Vdc}{2}$$

$Bb = MiB$ =(0∼∞)

Bb – Buck boost (gain) factor

The capacitor voltage can be expressed as

$$Vc = \frac{1-\frac{T0}{T}}{1-2\frac{T0}{T}}Vdc \qquad (12)$$

5. Simulation Results and Discussion

Design topology of T source inverter was implemented in MATLAB-Simulink software. The simulation results are discussed in this chapter. MATLAB is a full featured technical computing environment. The Simulink (Simulation Link) is an extension of MATLAB by Math works Inc. It works with MATLAB to offer modelling, simulating, and analyzing of dynamical systems under a Graphical User Interface environment. The construction of a model is simplified with click-and-drag mouse operations. Simulink includes a comprehensive block library of toolboxes for both linear and nonlinear analyses. Models are hierarchical, which allow using both top- down and bottom approaches. As Simulink is an integral part of MATLAB, it is easy to switch back and forth during the analysis process and thus, the user may take full advantage of features offered in both environments.

5.1 Simulation Results

The overall simulation Figure 4.1 consists of solar sub system, T source converter and three phase inverter. Here solar panel acts as an input, same wise RL load was connected in inverter output. This three phase inverter simulation performance was tested in three different ways.

Case 1: Three phase inverter with simple boost converter

Case 2: T source inverter without boost stage rectification

Case 3: T source converter followed by inverter

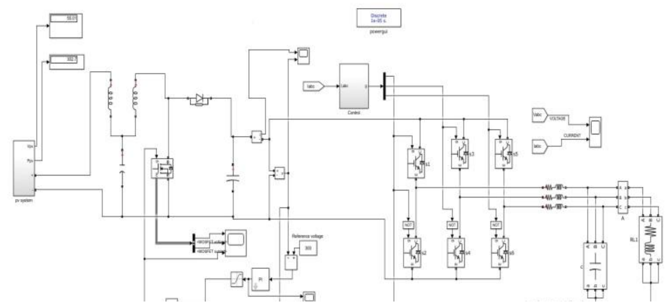

Figure 3. Overall Circuit Of The Proposed T Source Inverter

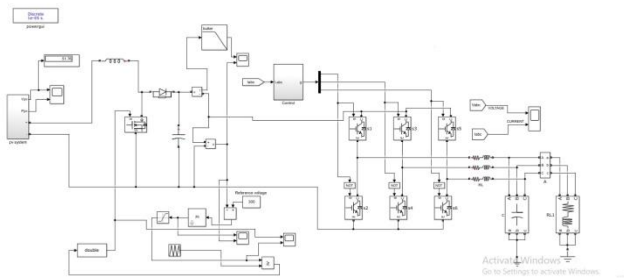

Figure 4. Overall Circuit Of The Boost Converter

Case 1: Three phase inverter with simple boost converter operation

In this case separate PWM control system is needed for both converter and inverter. Even though closed loop control system applied in boost stage, we achieved only two times boost output (Vout = 2*Vin). Which means if I give 150v DC as input from solar panel then it will give 300v DC otherwise it won't. To avoid such situation we need MPPT control system.

The Figure 4.3, explains about solar sub system. This sub system will be working based on the solar cell Characteristics. To create the real time characteristics of solar cell modelling was used. The solar system output voltage it depends on the number of series panel, output current depends on the number of parallel panel. The output power will be changing depends upon variable solar radiation and temperature changes.

Case 2: T source inverter without boost stage rectification

By comparing case 1, case 2 it doesn't need two state boost conversion operation and also it is a single stage conversion. T source resonant is used to achieve 6 times boost operation. At the same time it doesn't need separate PWM signal for boost operation. It will be operated by inverter PWM signal itself. So it avoids extra PWM circuit drivers in hardware side.

The drawback of in this case was distorted DC voltage which affects the inverter performance. So automatically THD is very high as compared to case 1.

Case 3: T source converter followed by inverter

Case 3 provides very good performance compared to case 1 and case 2. After T source resonant block Diode and capacitor was used like low pass filter. This will reduce the DC bus distortion. By the way inverter will better result under RL load. The THD was less compared to case 2.Figure 4.4. Shows that DC bus voltage and current. Here closed loop control system is achieved by using PI controller.

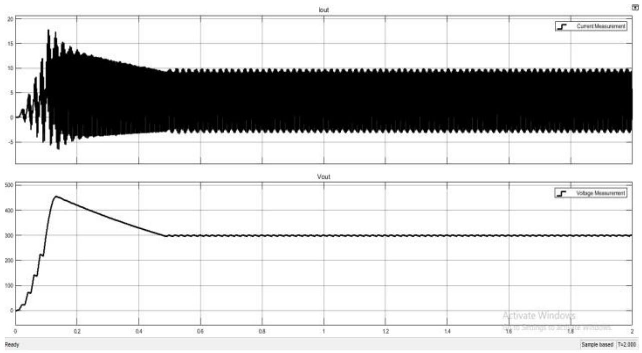

Figure 5. T Source Current and Voltage waveform

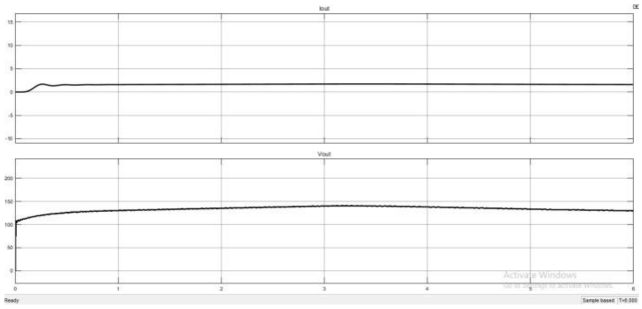

Figure 6. Boost Converter current and Voltage waveform

CONTROL OF INVERTER

Sinusoidal Pulse Width Modulation (SPWM) technique has been used for controlling the inverter as it can directly control the inverter output voltage and output frequency according to the sine functions. Sinusoidal pulse width modulation (SPWM) is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches.

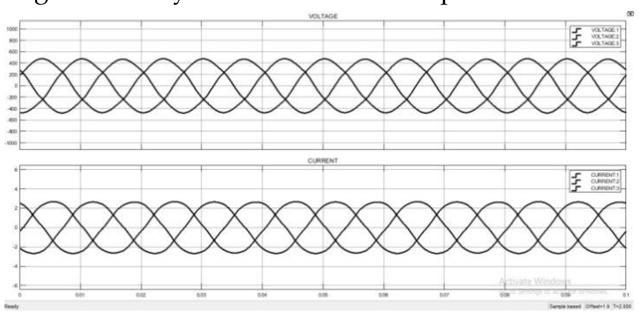

Figure 7. Three Phase Voltage And Current Waveform

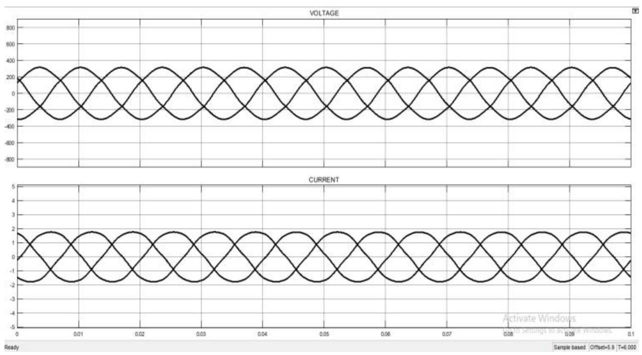

Figure 8. Three Phase Voltage And Current Waveform of Boost Operation

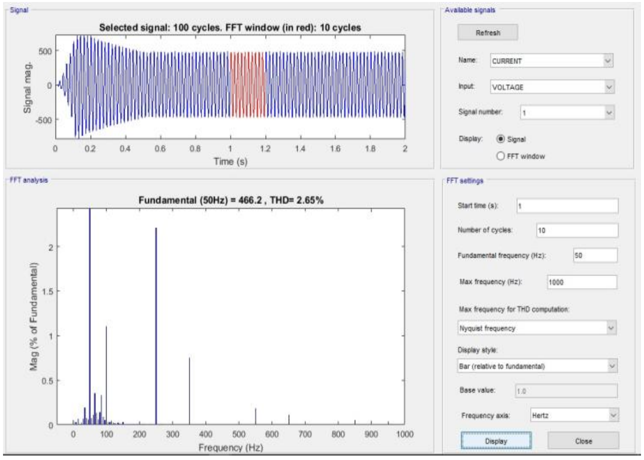

Figure 9. Total Harmonic Distortion Plot

By comparing all 3 case studies T source converter followed by inverter will provide better performance compared to other two case studies.

6. Conclusions

By analysing the different case studies we find out the T source inverter advantages over Z source, VSI and CSI. The T-source impedance network produces output voltage larger than the input voltage by proper maintaining the shoot-through duty ratio, which cannot be achieved by the voltage-source inverter and current-source inverter. Simple boost converter along with three phase inverter was developed. In that we can understood even though closed loop system developed we can't achieve larger boost output. Because of that we can implement boost converter in normal stand alone inverter. If we want dc link voltage above 300v means need to provide minimum of 120v to 150v range.

T source inverter overcomes that disadvantages. We can achieve larger output voltage boost operation. In case 2 we achieved 6 times of boost operation. Here we consider 50v-100v as input voltage, but the output voltage is 300v. Overall the case studies T source converter fed inverter gave good THD in load side compared to existing one.

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