



## Comparative Analysis of Five Level Multilevel Current Source Inverter and Bridge Configured Current Source Inverter For PV System

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**Abstract** — This paper addresses the comparative analysis of THD for conventional bridge configuration CSI with multilevel CSI such as 5 level. Multilevel Current source inverter (CSI) is an attractive solution in solar PV systems. Generally multilevel inverter produces the output by merging of DC voltages means by rising of DC voltages. Mostly the line commutated inverter has square formed waveform of line current. So it has large extent of harmonic and produces excess of heat but multilevel inverter gives the output current waveform which is almost sinusoidal in nature. This line current has smaller amount of harmonics as compared to line commutated inverter. Here two PV sources are taken and MPPT charge controller is used to extract maximum power from solar. The more applicable control and modulation methods established for such type of inverters are sinusoidal pulse width modulation technique. All the different CSI's are simulated in MATLAB with a load of 1HP as an single phase induction motor.

**Keywords**- Multilevel Current Source Inverter (MLCSI), PV system, MPPT, Current Source Inverter (CSI), Voltage Source Inverter (VSI), THD (Total Harmonic Distortion).

### I. INTRODUCTION

As we know that a solar is the most vital renewable source of energy which is broadly used in the part of power generation. There are many more progress going in solar in order to advance the PV system efficiency and decline the system losses as well as cost of the system. For this reason multilevel inverters are proposed. A multilevel inverter is more advantageous for higher power application such as reduction in harmonics [1,2]. A voltage source inverter has been commonly used multilevel inverter topology. But because of more advantages CSI are used in its place of VSI. The reason behind this is that CSI has natural enhancing and short circuit protection abilities, direct output current controllability and AC side simple filter structure [3,4,15].

As one and all knows, inductors, as the energy storage elements but they have the disadvantages of higher conducting losses and lower energy storage proficiency than capacitors. So voltage-source inverters (VSI's) have been further extensively used than current-source inverters (CSI's). Present research work about multilevel converter is mostly about VSI's. Though, with the advance of the superconducting magnetic energy storage (SMES) technology, superconducting inductors can be used as highly efficiency energy storage elements [5,8]. Compared with a VSI, a CSI has many benefits, such as working more stable, controlling the output current more directly, faster dynamic response, etc. Therefore, it is a better choice to use superconducting inductors in place of the current sources of the multilevel CSI's. A CSI topology are preferred for interfacing PV system to AC load for the next reason i) It deliver smooth DC side current. ii) CSI's energy storage element has longer lie time than VSI. iii) CSI has an natural voltage improving ability that allows integration of PV panels of lower output voltages. Generally there are mostly two kinds of grid coupled PV systems which exist centralized connected configuration as well as string connected configuration. This configuration exist series and parallel connected PV modules in order to raise power stages. But a string linked arrangement has more advantages for grid connected system. When string kind of arrangement is used in which PV modules are linked in parallel then because of cloudy environment i.e. partial shading there is deviation of maximum power point will decrease the power output which intern affect the system efficiency. By means of multilevel inverters PV array can feed enhanced quality of power even under partial shading conditions also. As there is extra number of stages in output of multilevel inverters, they can create enhanced output power [5,8,10,11].

This paper proposes a new current source multilevel inverter arrangement, which is employed with less number of power switches associated to other topologies such as 5 level MLCSI. There are different modulations methods will be used for controlling and modulation of MLCSI but here sinusoidal pulse with modulation techniques is used. Two separated MPPT charge controller are used for two separate PV sources to extract maximum power from solar. MPPT charge controller uses Incremental and Conductance algorithm to locate maximum power point [5,11]. A single phase 1 HP induction motor can be taken as a load. Different PV modules can be assumed as multiple inputs for the proposed MLCSI configuration. The key benefit of the proposed MLCSI configuration is that can work with PV modules with

different MPPTS and can still produce multi-levels without asymmetry in output current. This incapacitates the divergence problems arising out of partial shading conditions.

## II. BRIDGE CONFIGURED CSI

A below fig. shows bridge configured CSI. In this CSI MOSFET's are used as switches. This CSI is operated in two modes which give a two level current at the output.

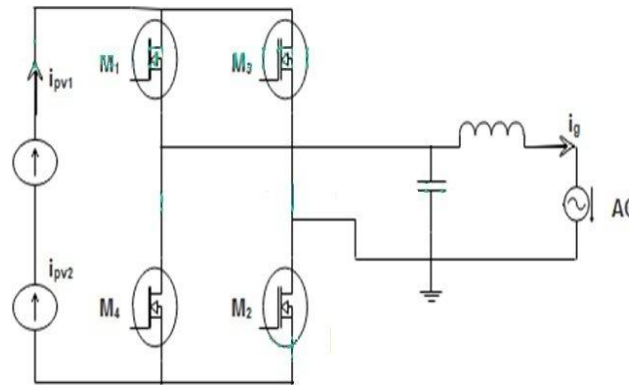


Fig.1. Bridge Configured CSI.

### 2.1 Mode of operations

A bridge type CSI can be operated in two different modes. In this mode a pair of MOSFET  $M_1$ ,  $M_2$  are  $M_3$ ,  $M_4$  are alternatively turned on by taking gate pulses and gives output in the form of square shaped waveform. The operation of this CSI explained as follows,

- **Mode 1**

At first  $M_1$  and  $M_2$  accepts gate pulses and starts conducting and current flows through the path  $M_1$ ,  $D_1$ , load,  $M_2$ ,  $D_2$  and source. Hence we get positive current in the output.

- **Mode 2**

In this mode  $M_2$  and  $M_3$  receives gate pulses and starts conducting and current flows through the path  $M_3$ ,  $D_3$ , load,  $M_4$ ,  $D_4$  and source. Hence at the output we get negative current in the form of square shape [3,15].

## I. FIVE LEVEL MULTILEVEL CSI

A multilevel inverter is power electronic structures which produce desired AC voltage from a number of DC sources as an input. The benefit of multilevel inverter is that it diminishes total harmonics distortion, gives sinusoidal waveforms at the output, reduction in EMI, and low switching losses. The five level multilevel CSI is explained as below,

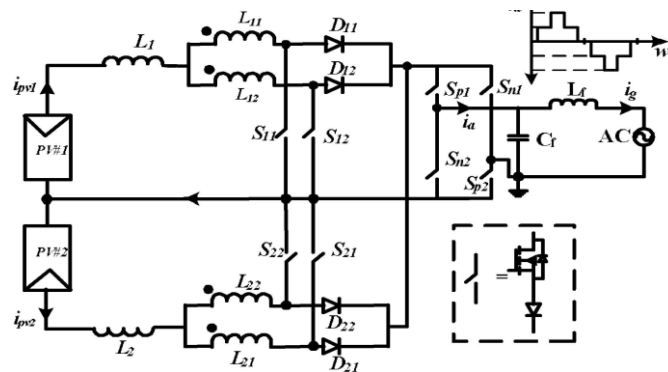


Fig.2. Five Level Multilevel Current Source Inverter [1]

### 2.1 Mode of operations

In these configurations, power switches  $S_{11}$ ,  $S_{12}$ ,  $S_{22}$  and  $S_{21}$  are performed at high frequency and  $S_{p1}$ ,  $S_{p2}$ ,  $S_{n1}$  and  $S_{n2}$  are controlled at low (grid) frequency. By means of this prearrangement, five levels  $+i_1$ ,  $+i_2$ ,  $0$ ,  $-i_2$ ,  $-i_1$  can be made in a waveform of current. Switching arrangement of devices as shown in Table I.

Table-I: Switching states of proposed 5 Level CSI [1].

| $S_{11}$ | $S_{12}$ | $S_{21}$ | $S_{22}$ | $S_{p1}$ | $S_{p2}$ | $S_{n1}$ | $S_{n2}$ | $i_A$  |
|----------|----------|----------|----------|----------|----------|----------|----------|--------|
| 0        | 0        | 0        | 1        | 1        | 1        | 0        | 0        | $+i_2$ |
| 0        | 1        | 1        | 1        | 1        | 1        | 0        | 0        | $+i_1$ |
| 1        | 1        | 1        | 0        | 0        | 0        | 0        | 0        | 0      |
| 1        | 0        | 0        | 0        | 0        | 0        | 1        | 1        | $-i_2$ |
| 0        | 0        | 0        | 0        | 0        | 0        | 1        | 1        | $-i_1$ |

- **Mode-1 ( $+i_1$  level):**

Fig.3 shows the equivalent circuit to this mode. Through this approach, the CSI is operated in positive half cycle of grid voltage to maintain the  $+i_1$  level by turning ON the power switches ( $S_{p1}$  and  $S_{p2}$ ) and modulating the switches ( $S_{11}$ ,  $S_{12}$ ,  $S_{22}$  and  $S_{21}$ ) at high frequency [1,4]. In this we get  $+i_1$  current at the output and which is termed as a first level.

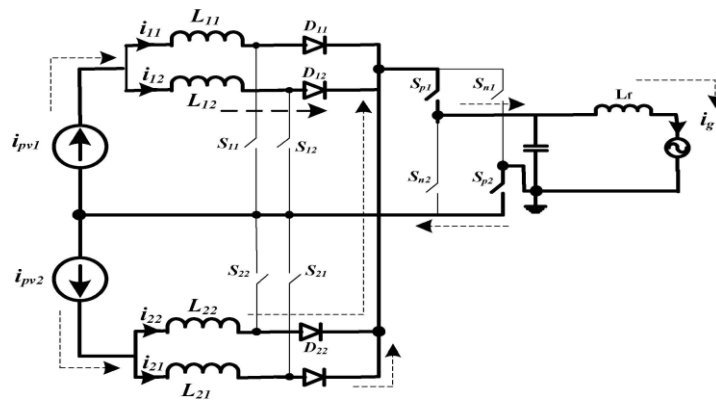


Fig.3. Equivalent circuit in Mode- I [1]

- **Mode-2 ( $+i_2$  level)**

Fig.4 shows the equivalent circuit in this mode-2. In this mode, the five level CSI is worked in positive half cycle of grid voltage to maintain the  $+i_2$  level by turning ON the power switches ( $S_{p1}$  and  $S_{p2}$ ), turning OFF the power switches ( $S_{12}$ , and  $S_{21}$ ) or ( $S_{11}$ ,  $S_{22}$ ) and modulating the switches ( $S_{11}$ ,  $S_{22}$ ) or ( $S_{12}$ , and  $S_{21}$ ) at high frequency conferring to sinusoidal grid current reference waveform [1,5,14].

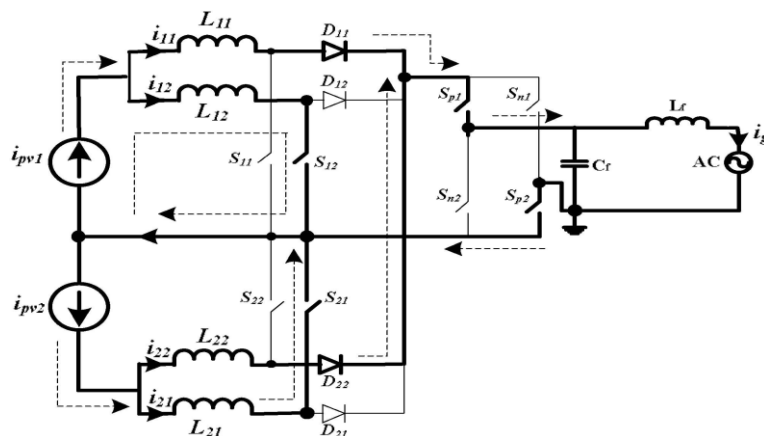


Fig.4. Equivalent circuit in Mode-2 [1]

- **Mode-3 (0 level):**

Fig.5 shows the equivalent circuit during this mode. During this mode, the power switches,  $S_{p1}$  and  $S_{p2}$  are becomes OFF, while the outstanding switches are ON. So that at the output we get magnitude of current as zero and it's operation is as shown below,

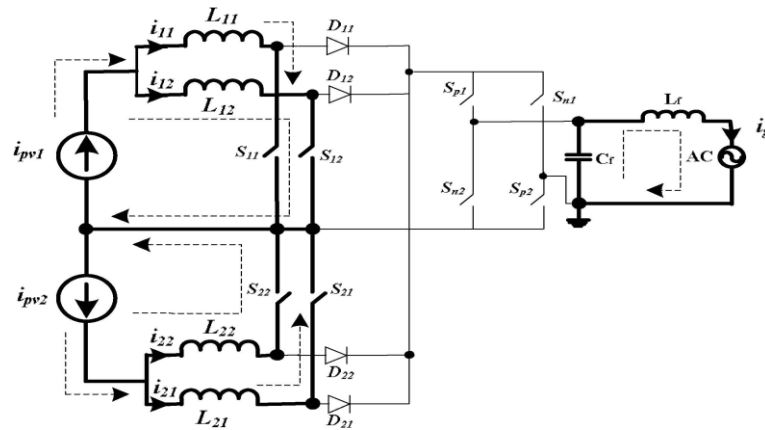


Fig.5. Mode-3 (Zero state) [1]

- **Mode-4 ( $-i_2$  level)**

Fig.6 shows the equivalent circuit during this mode. During this mode, the CSI is operated in negative half cycle of grid voltage to maintain the  $-i_2$  level by turning ON the power switches ( $S_{n1}$  and  $S_{n2}$ ), becoming OFF the power switches ( $(S_{12}, S_{21})$  or  $(S_{11}, S_{22})$ ) and controlling the switches ( $(S_{11}, S_{22})$  or  $(S_{12}, S_{21})$ ) in high frequency. So in this way we get  $-i_2$  current level at the output of CSI. So it is termed as a fourth level in the output [1-3,6].

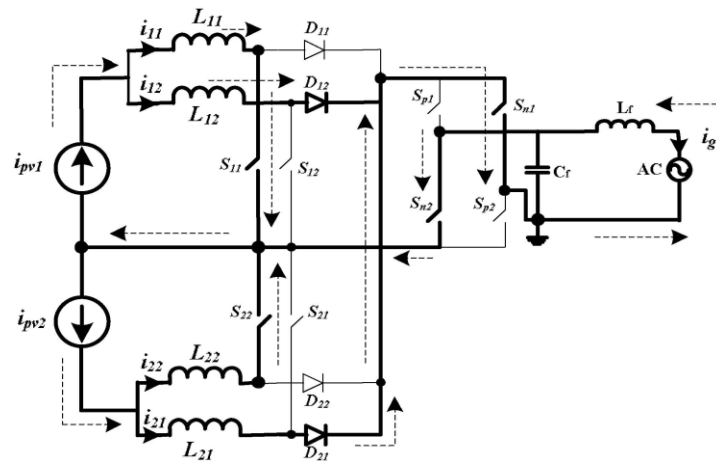


Fig. 6. Equivalent circuit in Mode-4 [1]

- **Mode-5 ( $-i_1$  level)**

Fig. 7 shows the equivalent circuit during this mode. During this mode, the CSI is operated in negative half cycle of grid voltage to maintain the  $-i_1$  level by turning ON the power switches ( $S_{n1}$  and  $S_{n2}$ ) and modulating the switches ( $S_{11}, S_{12}, S_{22}$  and  $S_{21}$ ) in high frequency. So in this way we get  $-i_1$  current level at the output of CSI. So it is termed as a fifth level in the output [2,8,10,13].

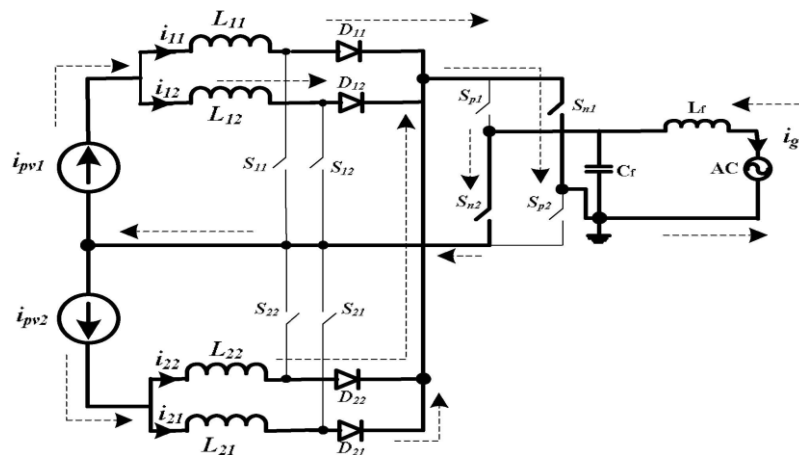


Fig.7. Equivalent circuit in Mode-5 [1]

## II. CONTROL STRATEGY

Control strategy of the five level, and bridge CSI is as shown in Fig.8

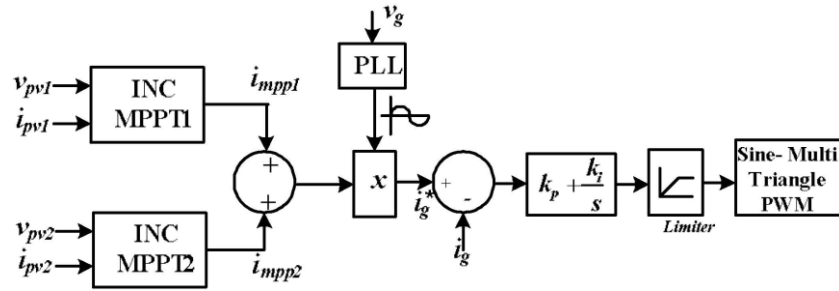


Fig.8. Control strategy used in the multilevel CSI. [1]

Existing extreme power is fed into the grid from the two PV sources based on the  $I_{mpp1}$  and  $I_{mpp2}$  references, which are produced by the Incremental Conductance MPPT algorithm. The current output of CSI is created by using the two carriers and Sinusoidal Pulse Width Modulation (SPWM) technique as per switching states shown in Table I and II. This PWM technique equates the reference current wave form with two high frequency carrier waveforms. Reference current waveform is got by the multiplication of PLL output and addition of  $I_{mpp1}$ ,  $I_{mpp2}$ . [1,7,11,14]. The following figure shows that how control strategy for these MLC SI is simulated in MATLAB.

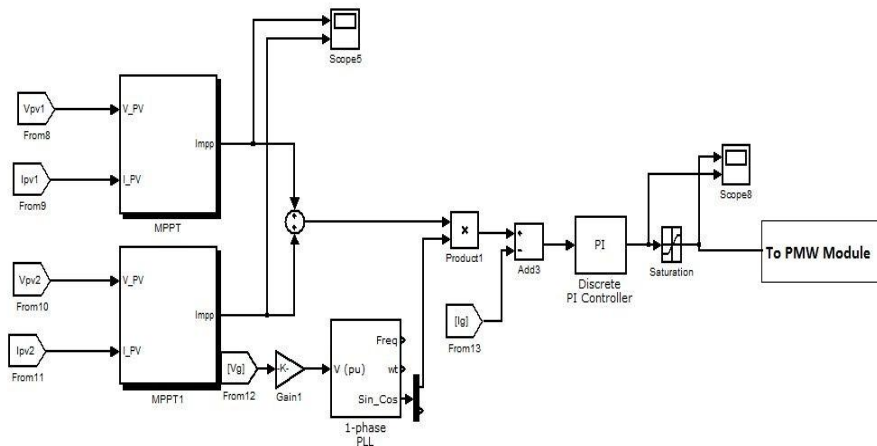


Fig.9. Simulink model of control strategy in MATLAB.

### 4.1 Switching Pulse Generation

Pulse width modulation raises to a method of ringing information on train of pulses and the information be determined in the width of pulses. The AC voltage is rest on on two factors such as amplitude and frequency and its requisites to control these parameters. The most proficient mode to control this parameter is to implement PWM techniques. In order to generate the getting signals by using PWM techniques we have to compare the reference signal amplitude with carrier signal amplitude [2,17]. The following figure shows modulation techniques for 5 level MLC SI and bridge configured CSI.

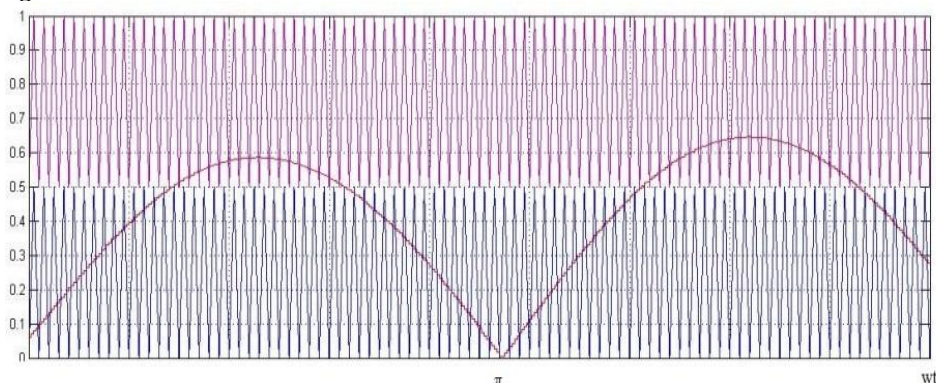


Fig10. modulation techniques for 5 level

### III. SIMULATIONS OF SYSTEMS

The following figure shows simulation of bridge configured, 5 level MLCSI in MATLAB.

#### 5.1 Bridge Configured CSI

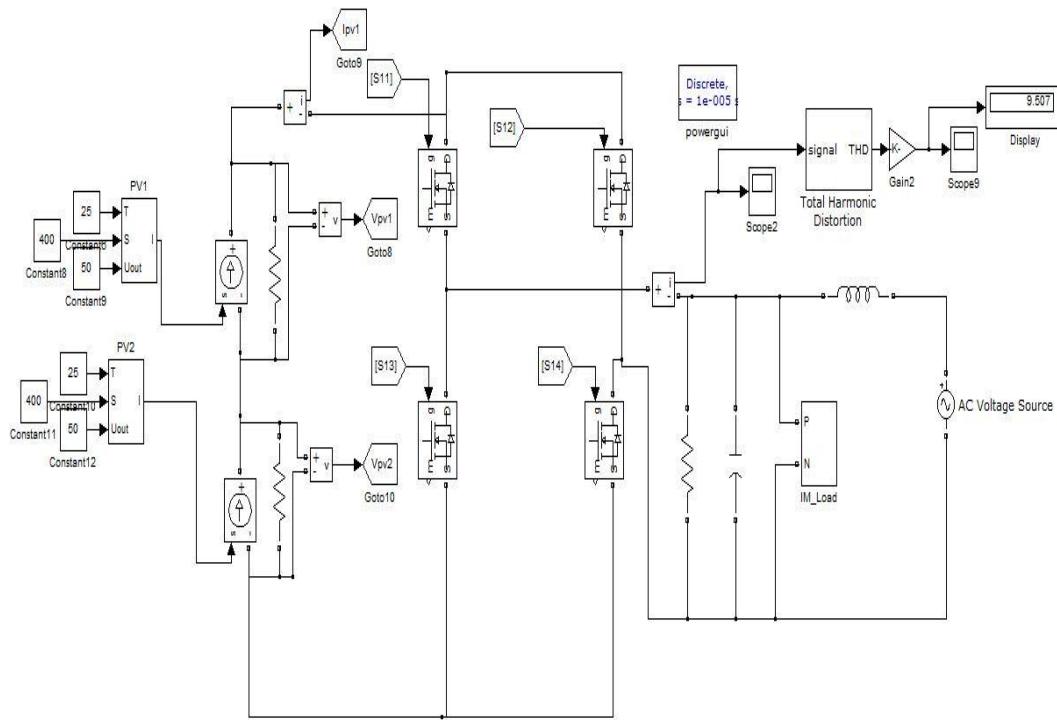


Fig.11. The simulation circuit of the bridge configured CSI.

The above figure shows MATLAB simulation of bridge configured CSI. The simulating time for module is set to 0.4 second. Here this bridge configured CSI is fed from two PV sources with uniform irradianations.

#### 5.2 Five Level Multilevel CSI

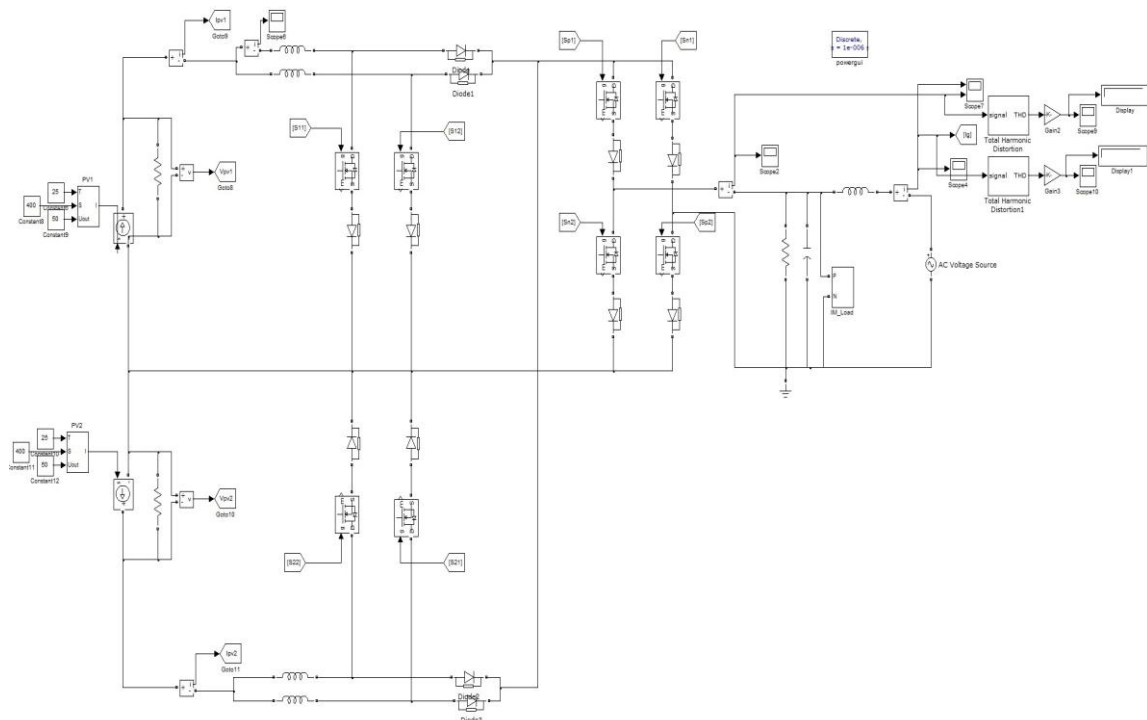


Fig.12: MATLAB Simulations of five level multilevel CSI.



The following figure shows MATLAB simulation of five level multilevel CSI. The simulating time for module is set to 0.4 second. Here five level multilevel CSI is fed from two PV sources with uniform irradianations. Here SPWM (Sinusoidal Pulse Width Modulation) Technique is implemented as a modulation technique.

## VI. RESULTS

An output current waveform and THD of all these CSI's are given in below,

### 6.1 Output Current waveform for bridge configured CSI

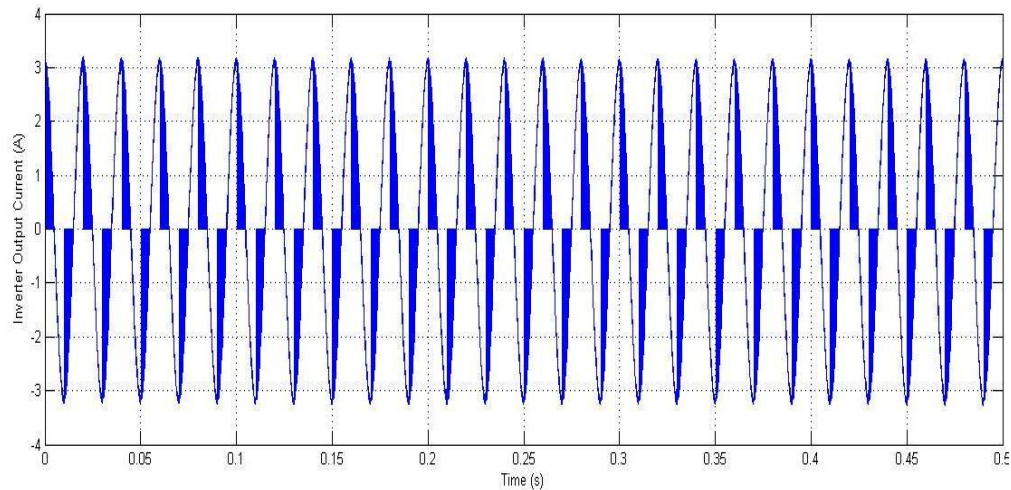


Fig.13. output current waveform of bridge configured CSI.

Here output waveform shows only two amounts of current i.e.  $+I$  and  $-I$  means inverter functioned in two modes giving square waveform as an output which has current magnitudes of  $+3A$  to  $-3A$ .

### 6.2 Output Current waveform of 5 level Multilevel CSI

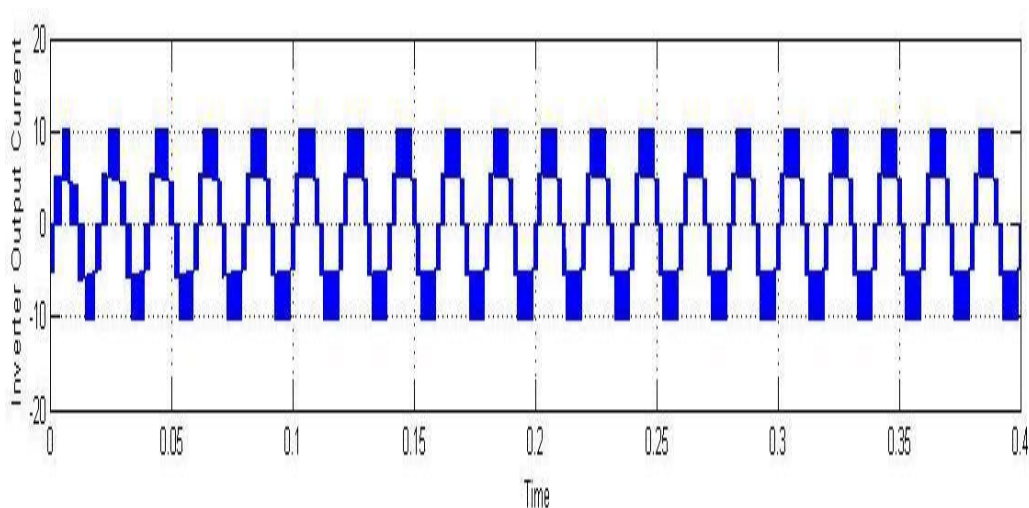


Fig.14. Output current waveform of 5 level multilevel CSI.

The output current waveform for 5 level MLCSI contain a five level such as  $+i_2$ ,  $+i_1$ ,  $0$ ,  $-i_2$ ,  $-i_1$ . Here output waveform shows that 5 level MLCSI operated in 5 mode of operations and different current magnitudes in each levels and also magnitudes of current get divided into 5 steps means each level has different current levels such as  $+10A$ ,  $+3.33A$ ,  $0A$ ,  $-3.33A$ , and  $-10A$  shows in output waveform.

### 6.3. % THD for bridge configured CSI

Below fig. shows % THD generated by bridge configured CSI.

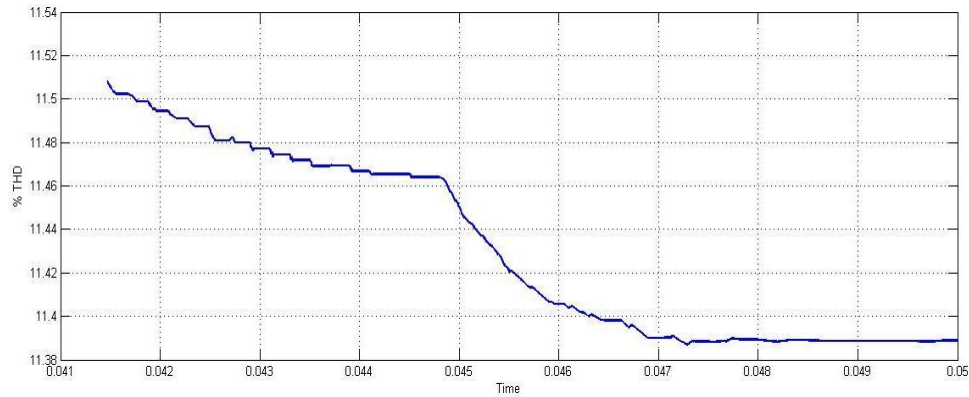


Fig.15. % THD for bridge configured CSI

The above figure shows %THD for bridge configured CSI. From above graph it is clear that the output of bridge configured CSI has % THD of 11.39% because of it has distorted current waveform at its output.

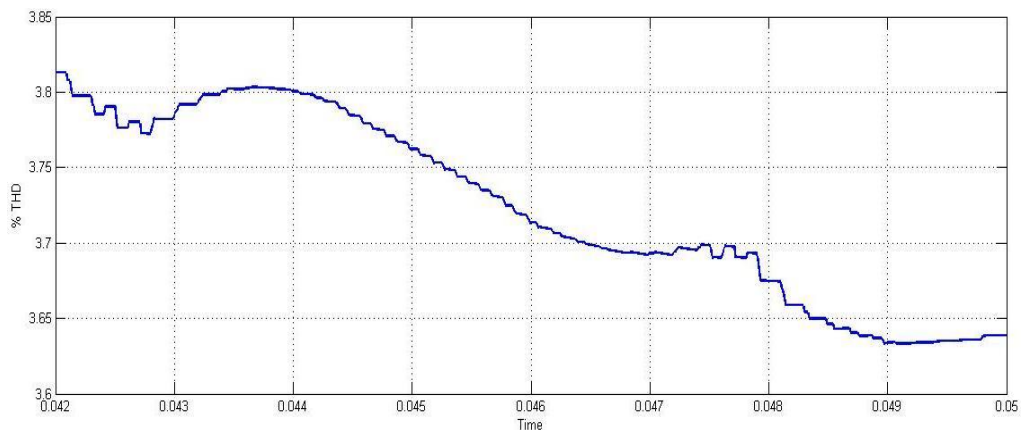


Fig.16 % THD for five level multilevel CSI

The above figure shows %THD for bridge configured CSI. From above graph it is clear that the output of bridge configured CSI has % THD of 3.64% .

#### 6.4 Comparative analysis of % THD for five level MLC SI and bridge configured CSI

The below table shows the comparative analysis of five level and bridge configured CSI.

Table-III: THD Comparison of five level and bridge configured CSI

| Sr. No. | Types of CSI              | %THD   |
|---------|---------------------------|--------|
| 1.      | Bridge configured CSI     | 11.39% |
| 2.      | Five level multilevel CSI | 3.64%  |

#### IV. CONCLUSION

From output waveform it can be seen that the output of 5 level multilevel CSI is nearly equals to sinusoidal waveform where as the output of bridge configured CSI is somewhat distorted. So from THD analysis it is concluded that bridge configured CSI has more percentage of THD than 5 level multilevel CSI. A bridge configured CSI has % THD of 11.39% and for five level multilevel CSI has 3.64% THD. From above result it is concluded that as the number of levels of multilevel inverters are increases the output waveform of inverter becomes more sinusoidal and hence amount of %THD get reduced to certain level. Here % THD get reduced from 11.39% to 3.64% means large decrement in % THD of 7.74% between bridge configured CSI and 5 level MLC SI.



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