# A Cascaded H-Bridge MLI Fed Motor By Using Fuzzy-MPPT PV System

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**ABSTRACT:** Induction Motor (IM) is utilized for variable speed control application in industries as these motors are reasonable, solid and straightforward. To get the desired speed and torque with irrelevant swells this drive needs suitable converters for better performance. Now a day's Multilevel Inverters (MLI) are picking up prevalence and widely utilized for motor drive applications and these inverters has emerged as vital option for more power and moderate voltage applications. In this topology, the speed of asynchronous motor (AM) is controlled by Cascaded H Bridge Multilevel Inverter (CHBMLI) and multicarrier PWM method is utilized to deliver pulses for the inverter. The main purpose is to create control strategy for CHBMLI fed motor with PV utilizing a fuzzy logic based Maximum Power Point Tracking (MPPT) technique and boost converter as separate source for CHBMLI. The performance of a 3-Φ CHBMLI fed motor by using PV source are verified by Matlab simulation results and are represented in terms of PV curves, MPPT power, boost converter voltage, inverter voltage, speed, current and torque.

**Keywords:** CHBMLI, PWM Methods, PV Cell, Boost Converter, Fuzzy logic Controller, Induction motor.

## 1. INTRODUCTION

Generally, control electronic devices are a significant part in the transformation and control of electric power, mostly to extract power from photovoltaic cell and wind energy. DC to AC power control, transformation should be possible by the inverters. Ordinary inverter creates the alternating waveform, however having higher harmonics and also having more switching losses and furthermore there is an energy loss. In this way the multilevel inverters were produced and these inverters are having fewer harmonics. For the most part from recent couple of years mechanical drives utilizes the acIM or asynchronous motor (AM) as that they are simple, solid and less maintenance. So acIM's are the most commonly utilized in speed control applications and particularly polyphase IM's are utilized as a part of mechanical drives. Present days, MLI's are generally utilized for drive applications in light of the fact that these inverters are having lesser THD, less electromagnetic interference, less switching losses, great influence quality. For the most part there are three multilevel inverters: they are 1. Diode Clamped MLI(DCMLI)2. Flying Capacitor MLI(FCMLI)3. Cascaded H Bridge MLI(CHBMLI). InDCMLI,huge diodes are needed per phase. In FCMLI, huge capacitors are needed per phase. Contrasted with other two MLI's,CHBMLI needs a few number of parts and broadly favoured for AC power supplies and high power applications and control of DC transport is direct. Conventional power generation causes the environmental problems, so now a day's renewable energy sources, particularly solar energy has become preferable. For CHBMLI fed motor, every h bridge cell has a separate DC source that is pv cell.

In this paper, 3-Φ CHBMLI fed motor is outlined and simulated. The Multicarrier PWM method is utilized to initiate pulses for the inverter. The performance of CHBMLI fed motor is examined and the results are justified by utilizing Matlab/Simulink software.

## 2. PHOTO VOLTAIC (PV) CELL

A PV cell is a structure which utilizes one or more solar panels to change over solar energy into electricity. It comprise of at least two thin layer of semiconductor material most generally silicon when silicon uncovered to light electric charge are created. Ordinarily solar oriented cell can be demonstrated by current source and diode associated in parallel to it. It has its own arrangement parallel resistance is because of leakage current.

Modeling of PV cell:

The output current is acquired by Kirchhoff law

$$I_{total} = I_{ph} - I_{dio} \qquad (2)$$

$$I_{dio} = I_{rev\ dio}\,[\exp(V_T/(A.N_s.V_{Temp})) - 1] \quad (3)$$

Where $I_{ph}$ is the Photon Current , $I_{dio}$ is the current for the diode which is proportional to saturation current, V is the voltage of diode and $I_{revdio}$ is reverse current of diode. $V_T$ is the voltage coefficient of temperature and

$$V_T = kT/q \qquad (4)$$

$I_{total} = I_{ph} - I_{rev\ dio}\{\exp((V + IR_s/ V_T)) - 1\} - ((V+ IR_s) / R_p)$ (5)

Photon current is based on irridance and also on temperature.

$I_{ph} = (G/ G_{ref}) *(I_{phref} +\mu_{sc}\Delta T)$ (6)

Where G is the irridance (w/m$^2$) and $G_{ref}$ is the irridance at standard test condition (STC).

$\Delta T = T-T_{ref}$. (7)

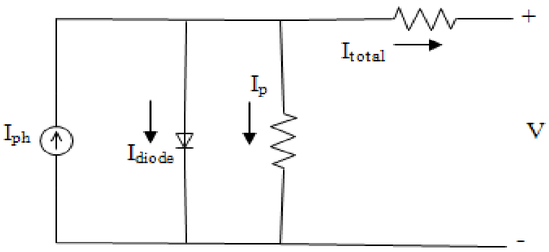


Figure 1: PV Cell Equivalent Circuit

$I_{rev\ dio} = I_{rs} (T / T_{ref})^3 \exp [(q\varepsilon_G Ak)*((1/T_{ref})- (1/T))]$ (8)

Where

$T_{ref}$ = cell reference temperature

$I_{rs}$ = reverse saturation at $T_{ref}$

A = Identity factor

$\varepsilon_G$ = Band gap energy

***Maximum Power Point Tracking (MPPT):***

MPPT is a method utilized for extracting greatest accessible power from PV module under all conditions. Thevoltage at which PV module generatesgreatest power is called MPPT. In each H bridge cell, a MPPT is added to create the dc-connect voltage reference. In this mppt technique, fuzzylogic control (FLC) based mppt technique is developed. Mostly fuzzy logic (FL) based mppt is utilized to make the system faster and more reliable.The proposed FLC is demonstratedas two inputs ,one output.The two FLC input variables are E,CE and output(U) is compared with sawtooth waveform to generate a PWM signal for duty cycle of converter where the inputs of FLC can be expressed as

$E(k)=(P_{ph(k)} - P_{ph(k-1)}) / (V_{ph(k)} - V_{ph(k-1)})$ (8)

$CE(k) = E(k) - E(k-1)$ (9)

The Fuzzification procedure changes overreal inputs E and CE into variables. Membership values are allotted asvariables with fuzzy subsets:NB,NM,NS are considered as negative big, medium and small and PB,PM,PS are considered as positive big, medium and small and ZE for zero. Fuzzy rule is accumulation of IF-THEN rules having every informationfor the parameters. Defuzzification assesses the rules based on a set of control activities for a given fuzzy inputs.

If E is NB and CE is ZE then crisp U is PB then if the operating point is far from the mppt by right side, and variation of the slope of curve is nearly zero.

Table 1 :Fuzzy Rules

| E/CE | NB | NM | NS | ZE | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| NB | ZE | ZE | ZE | NB | NB | NB | NM |
| NM | ZE | ZE | ZE | NS | NM | NM | NM |
| NS | NS | ZE | ZE | ZE | NS | NS | NS |
| ZE | NM | NS | ZE | ZE | ZE | PS | PM |
| PS | PS | PM | PM | PS | ZE | ZE | ZE |
| PM | PM | PM | PM | ZE | ZE | ZE | ZE |
| PB | PB | PB | PB | ZE | ZE | ZE | ZE |

***Boost Converter:***

A Boost converter is a change mode DC to DC converter in which the output voltage is more prominent than the input voltage. The below Figure 6 demonstrates a step up or PWM help converter. It comprises of a source voltage V, inductor L, switch S, diode D, capacitor C, and the resistance R. At the point when the switch S is in the on mode, the current in the boost inductor increments directly and the diode D is off around then. At the point when the turn S is turned off, the vitality put away in the inductor is discharged through the diode to the output RC circuit.

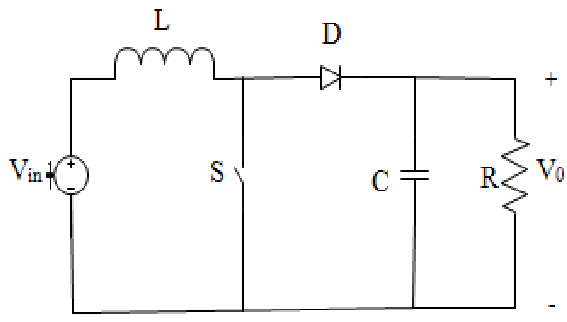


Figure 2: Boost Converter Circuit

**3.MULTICARRIER MODULATION TECHNIQUES**

By utilizing the multicarrier PWM methods the proposed CHBMLI is examined. The modulation procedure depends on the examination of sinusoidal reference signal with the carrier signals (having the same frequency) which are normally chosen triangular signals. For m level inverter, all carriers utilize same frequency $f_c$ and amplitude $A_c$ and they are arranged such that the bands they involved are contiguous to each other.

Multicarrier PWM is three sorts:

*1) Phase Disposition (PD):* If all the carriers are chosen in phase as shown in Figure 2, that is all are in phase then the technique is PD strategy.

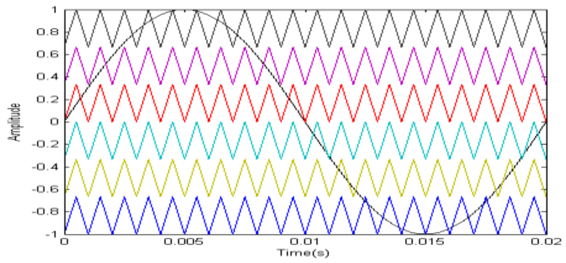


Figure 3: Reference and Carrier waveforms for PD PWM

*2) Phase Opposition Disposition (POD):* If the carriers over the zero reference are in phase, yet moved by $180^0$ beneath the zero reference.

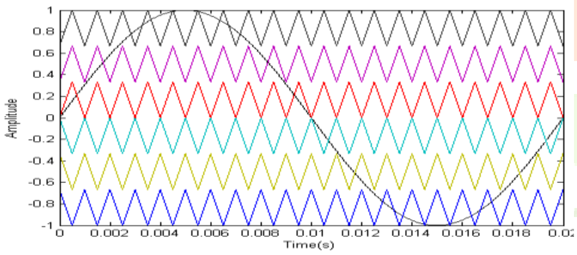


Figure 4: Reference and Carrier waveforms for POD PWM

*3) Alternate Phase Opposition Disposition (APOD):* In this technique, each triangular carrier is moved by $180^0$ from its contiguous carrier.

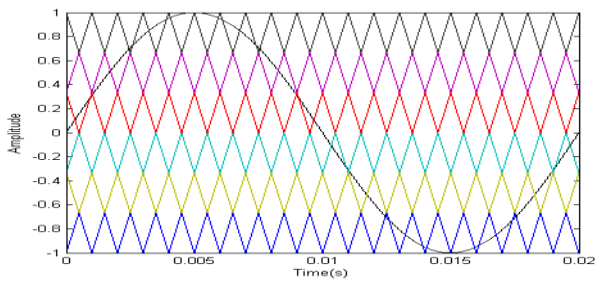


Figure 5: Reference and Carrier waveforms for APOD PWM

## 3. CASCADED H-BRIDGE MULTILEVEL INVERTER

The CHBMLI circuit is illustrated in Figure 1 and it comprises of separate, independent h bridge cell and every cell is sustained by their own DC supply like full bridge inverter. Every cell comprises of four switches and in this topology IGBT is utilized as a switch, as a result of low switching losses. Three discrete voltage outputs ($+V_{dc}$, $-V_{dc}$, 0) are produced by every h bridge cell. For seven level inverter every leg comprises of three h bridge cells and the AC output terminal voltages of every cell are coupled in series arrangement. By including the output voltage of every h bridge cell the output voltage is acquired as in condition (1).

$$V_0(t) = V_{01}(t) + V_{02}(t) + \dots\dots\dots\dots V_{0N} \qquad (1)$$

The aggregate of every h bridge cell ac voltage is the output ac voltage of CHBMLI. The achievable combination of switching sequence is illustrated in table 1 where "1" demonstrates the on condition for a switch and "0" for off condition of the switch.

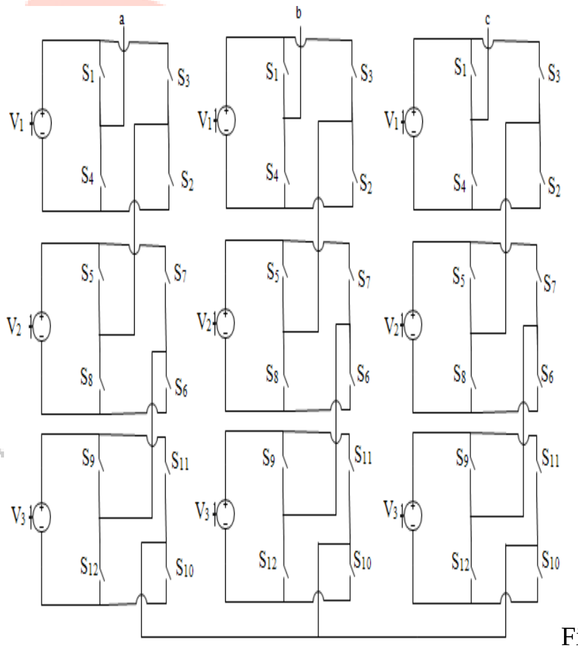


Figure 6: 3-Φ seven level CHBMLI

Table 2: Switching Sequence for one leg Seven level CHBMLI

| **$V_0$** | **+V** | **+2V** | **+3V** | **0** | **-V** | **-2V** | **-3V** |
|---|---|---|---|---|---|---|---|
| **$S_1$** | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **$S_2$** | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| **$S_3$** | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| **$S_4$** | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **$S_5$** | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| **$S_6$** | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| **$S_7$** | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **$S_8$** | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| **$S_9$** | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **$S_{10}$** | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **$S_{11}$** | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **$S_{12}$** | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

## 4. PROPOSED TOPOLOGY

To demonstrate the execution of the proposed CHBMLI fed IM by using PV Source, a adjustable speed IM drive is examined. The Matlab/ Simulink is utilized to execute 3-phase seven-level inverter fed IM drives by PV source. The block diagram of CHBMLI fed IM by using PV source is illustrated Figure 7.

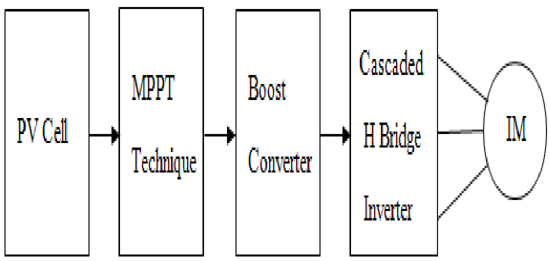


Figure 7: Block diagram for proposed topology

A 3-Φ CHBMLI has been created by utilizing an IGBT, in fact of that IGBT is a very preferable device among high power switches. This 3-phase seven level inverter is given as source to the 3-phase squirrel cage IM.

The Multicarrier PWM strategy is utilized to create pulses for the inverter and the THD is analyzed. In this topology pv cell is utilized as dc source for CHBMLI and every pv cell has a separate boost converter with FL based mppt technique. The source voltage of every h bridge cell is 133 volts. In this topology 3-phase IM is treated as a load to the inverter.

## 5. SIMULATION RESULTS

In this paper, the simulation model of CHBMLI fed motor by using PV source isdeveloped by MATLAB/SIMULINK software. The simulation circuit & results of the CHBMLI fed IM and converter with PV cell as a source for CHBMLI fed motor is designed and executed by utilizing a FLC based mppt technique in Simulink and results are accompanied below.

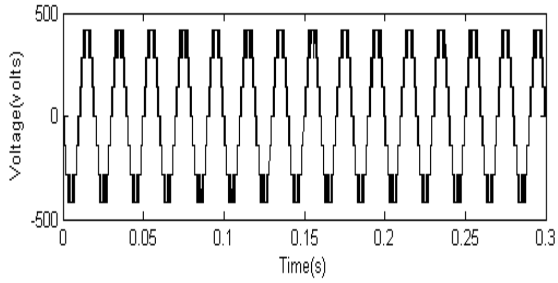


Figure 8: Seven level AC Voltage under PD PWM

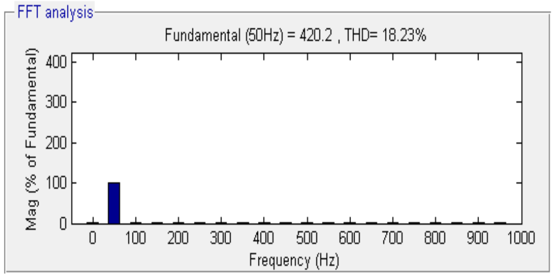


Figure 9: Seven level FFT analysis under PD PWM

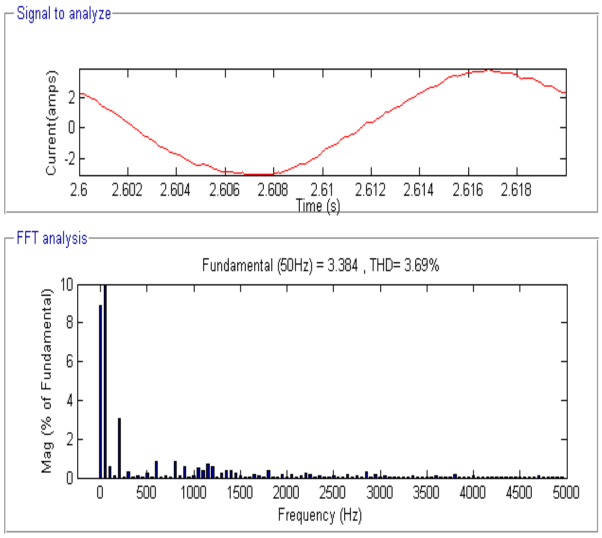


Figure 10 :FFT Analysis for Motor Current under PD PWM

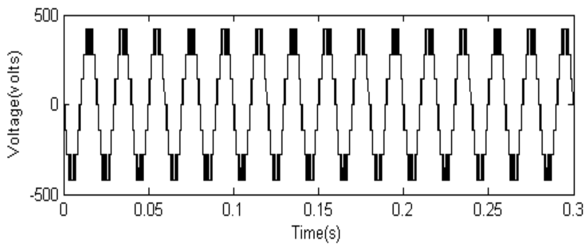


Figure 11: Seven level AC Voltage uunder POD PWM

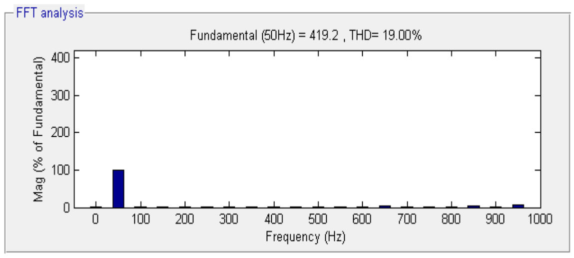

Figure 12: Seven level FFT analysis under POD PWM

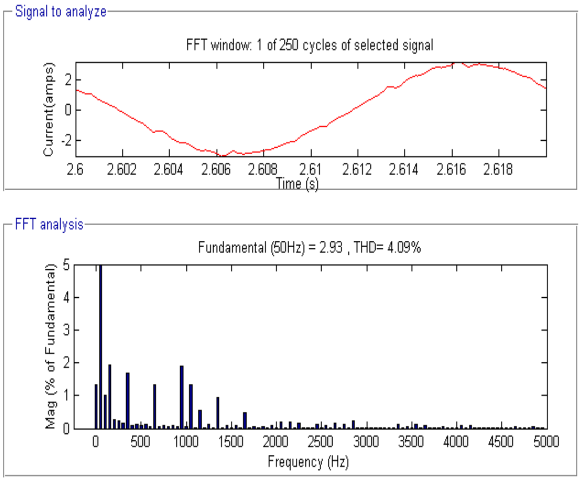


Figure 13 :FFT Analysis for Motor Current under POD PWM

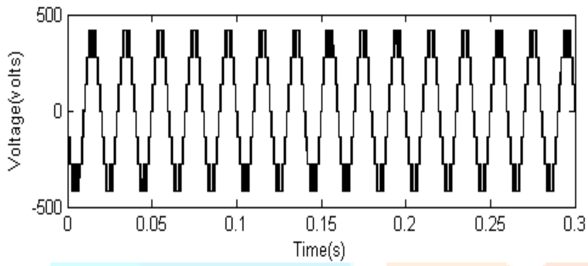


Figure 14: Seven level AC Voltage underAPOD PWM

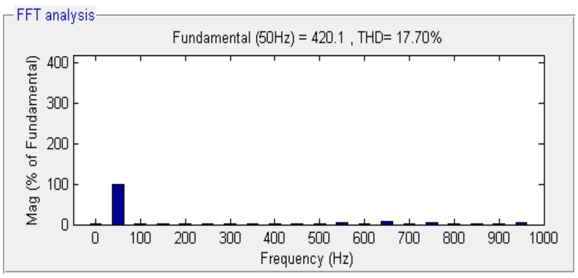


Figure 15: Seven level FFT analysis under APOD PWM

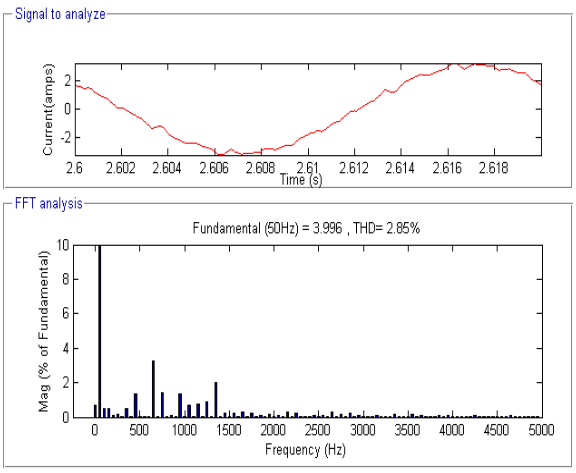


Figure 16 :FFT Analysis for Motor Current under APOD PWM

**Table 3: Comparison of Multicarrier PWM techniquesfor Voltage and Motor Current THD%**

| PWM | PD | POD | APOD |
|---|---|---|---|
| Voltage THD% | 18.23% | 19.00% | 17.70% |
| Current THD% | 3.69% | 4.09% | 2.85% |

The current, speed and torque of theac IM are examined by utilizing pv source with boost converter for seven level h bridge inverterfed motor and are illustrated in below figures under apod technique.

Current-Voltage (I-V) Curve

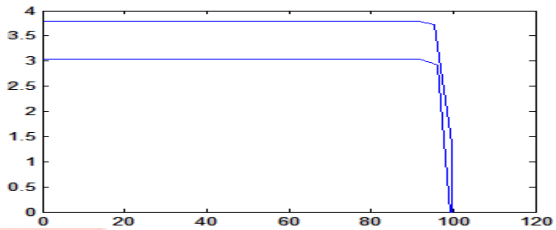

Figure 17: I-V curve for PV cell

Power-Voltage (P-V) Curve

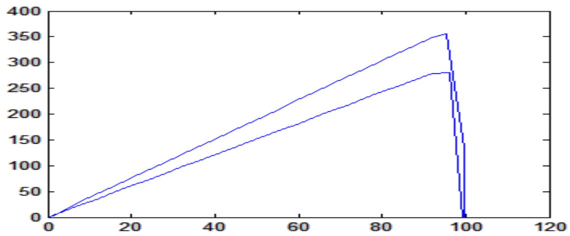

Figure 18: P-V curve for PV cell

**Boost Converter Results:**

During transient period, the boost converter and MPPT power is varied from 0 to 0.13 seconds and remains constant after 0.15 seconds as appeared in the Figure 19 and CHBMLI voltage is varied and remains constant after 0.15 seconds as in Figure 22.

During step response, the boost converter and MPPT power is constant from 0.3 seconds to 0.5 seconds and from 0.5 seconds boost converter and MPPT power goes on rising as in Figure 20 and CHBMLI voltage is constant from 0.3 to 0.5 seconds and from 0.5 seconds voltage goes on rising as in Figure 23.

During steady state period, the boost converter and MPPT power is constant from 1.4 to 1.6 seconds as appearedin Figure 21 and CHBMLI voltage is also constant at 400 volts from 1.4 to 1.6 seconds as in Figure 24.

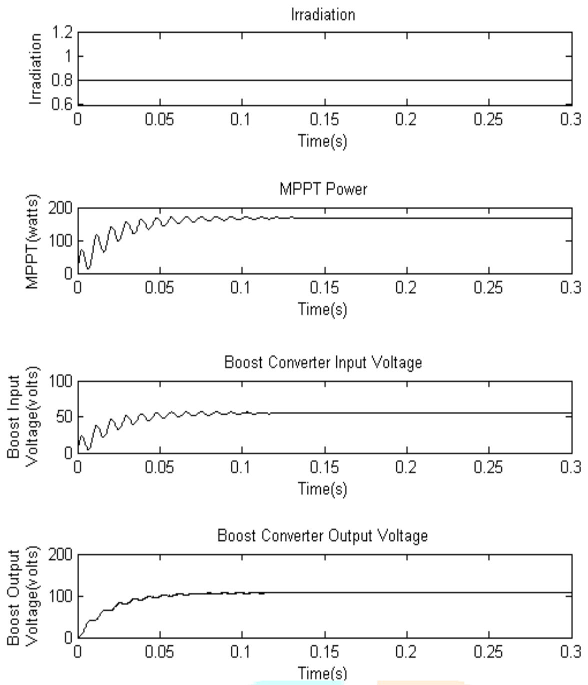


Figure 19:Transient Period of Boost Converter

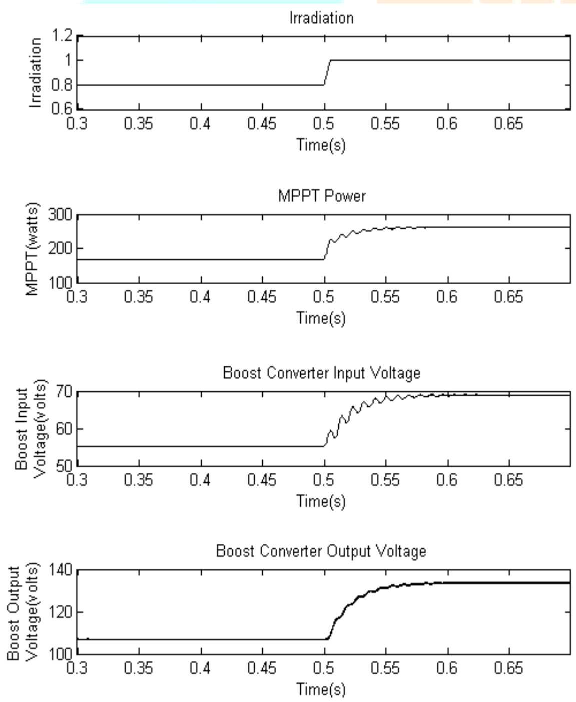


Figure 20: Step Response of Boost Converter

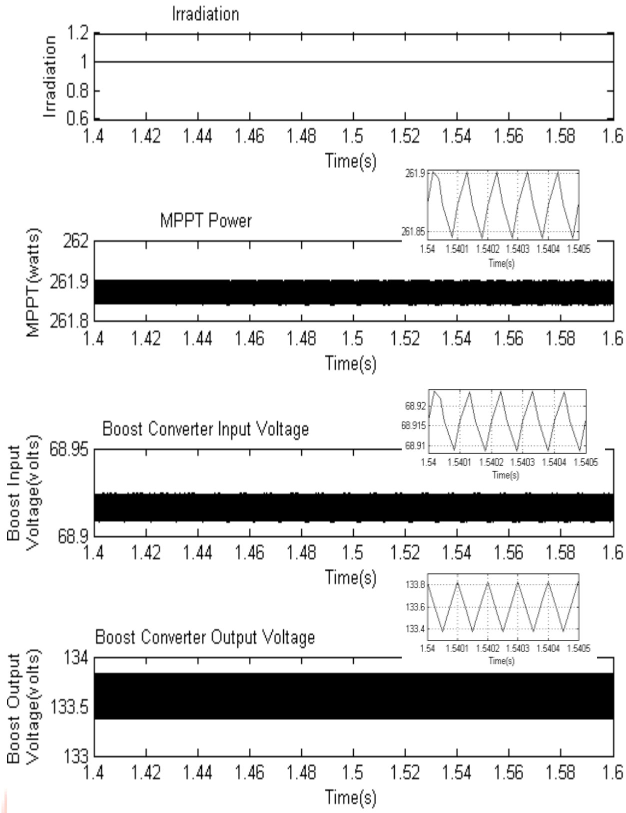


Figure 20:Steady State Period of Boost Converter

**Cascaded H-Bridge InverterResults:**

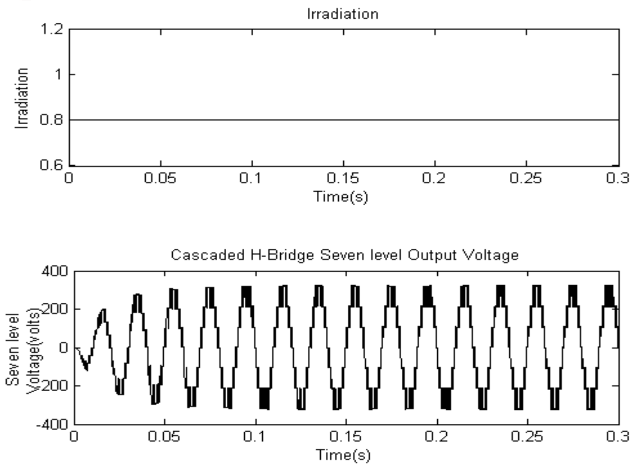


Figure 21:Transient Period of CHBMLI Output Voltage

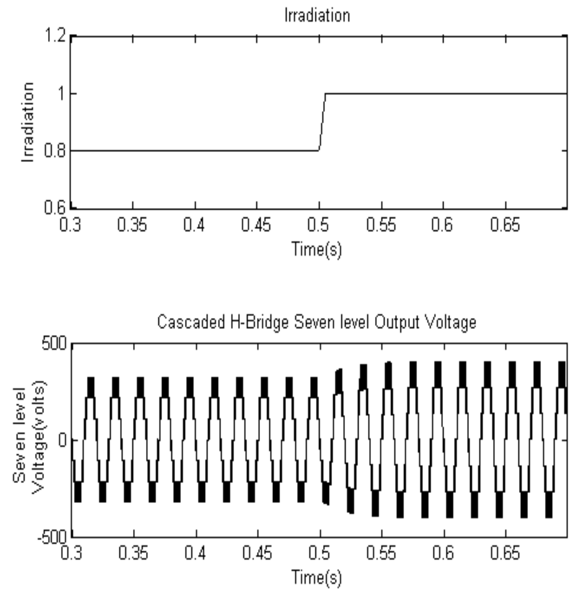


Figure 22:Step Response of CHBMLI Output Voltage

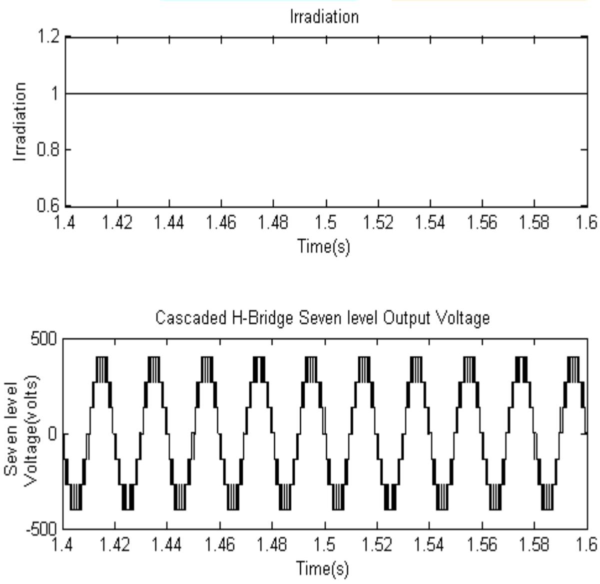


Figure 23:Steady State Period of CHBMLI Output voltage

**Induction Motor Results:**

During the transient period, torque &current will be varied and speed goes on rising from 0 to 1.9 seconds and remains constant.Torque and current remains steady after 1.9 seconds as in Figure 24.

During step response, torque&current will be increased after 2.5 seconds and speed decreases after 2.5 seconds and remains constant.After 2.5 seconds torque and current decreases and at that time speed increases as appeared in Figure 25.

During steady state period speed,current and torque remains constant at 4.2 seconds to 4.4 seconds as in Figure 26.

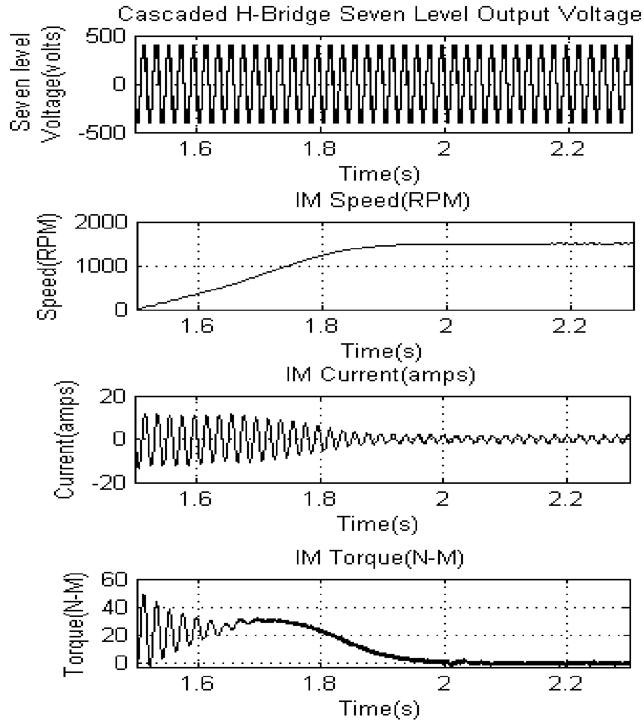


Figure 24:Transient Period of IM

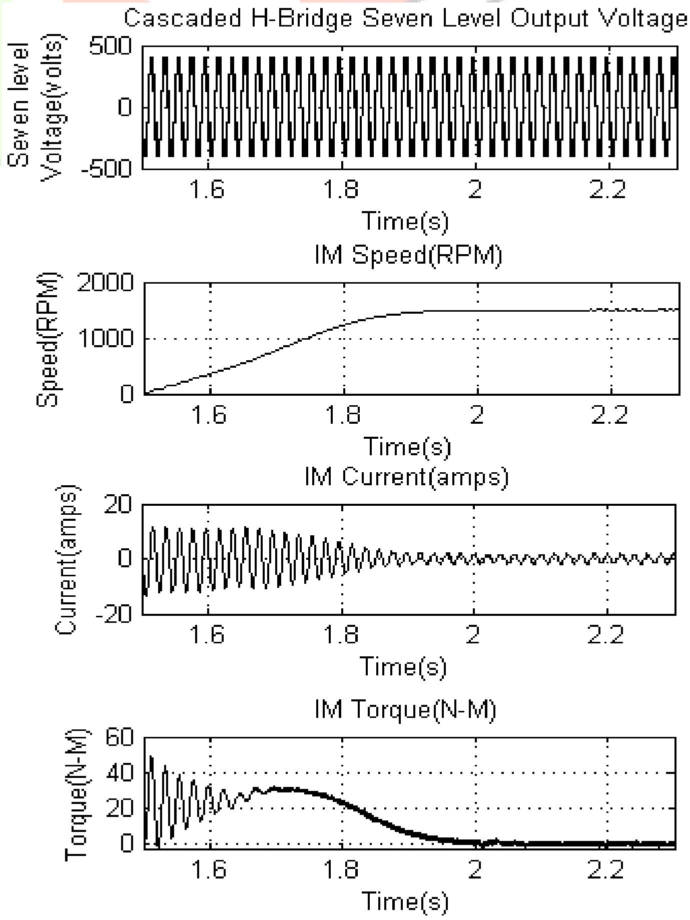

Figure 25:Step Response of IM

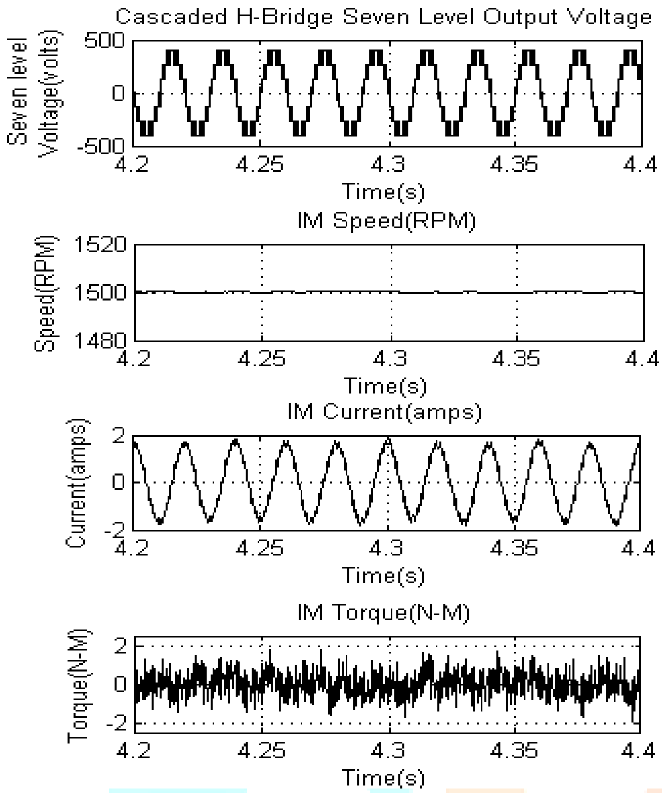


Figure 26:Steady State Period of IM

## 6. CONCLUSION

The inverter fed motor can be utilized in industries where adjustable speed drives are needed. The multi carrier PWM method for the 3-ΦCHBMLI has been developed by utilizing Matlab/Simulink. Among the three PWM procedures, APOD PWM method has given better THD over other two strategies. So for the inverter fed motor, APOD PWM method is better under desired speed-torque. A MPPT based FLC strategy is associated in a PV cell and it concluded that the MPPT method modifies the duty cycleof the converter in varying irradiance to extract the MPPT from PV and distributes it to load. The execution of PV with MPPT is approved with a boost converter for this cascaded inverter fed motor by utilizing APOD PWM procedure to initiate the pulses for the inverter and these simulation results shows that CHBMLI adequately controls the Motor speed.

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