Research Article

Development and Implementation of Embedded DSP Controllers for Cascaded H-Bridge Multilevel Inverter based Drive

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Abstract

Paper discusses about the design and implementation of a DSP based Induction motor drive using Hybrid Multilevel Inverter configuration focusing mainly on total harmonic distortion (THD). The purpose of the circuits presented here is to minimize the reverse voltage stress that affects the power switches and decrease the harmonic distortion of the voltage applied to the load. Paper discusses DSP based scheme for 5 levels HMLI .

Keywords: HMLI-Hybrid Mulilevel Inverter

1. Introduction

This paper presents four different sequential switchihybrid-modulation strategies and cascaded multilevel inverters. With hybrid modulation techniques we can use less no of switches as compared to cascaded multilevel inverter so switching losses are reduced.
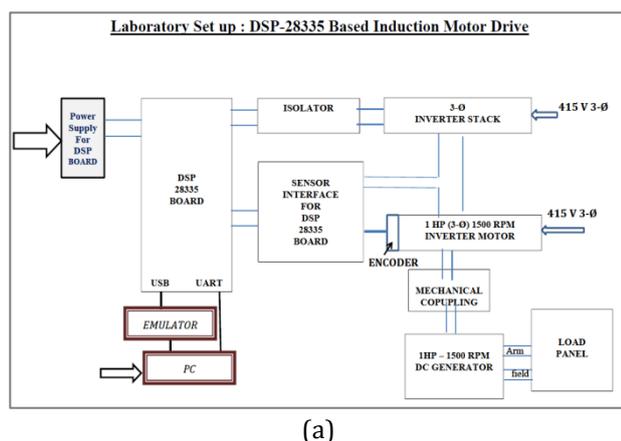

Fig.1 Block diagram: DSP Based Drive using HMLI

(a)

Fig 1 shows hardware setup for a DSP 28335 based drive using HMLI (K. A. Corzine, 2004), (M.D. Manjrekar and T.A. Lipo, 1998) the DC generator with load panel is used to load the IM which is controlled by a DSP 28335 based controller and a three phase HMLI stack. PC is used to select the control technique for the HMLI by the user.
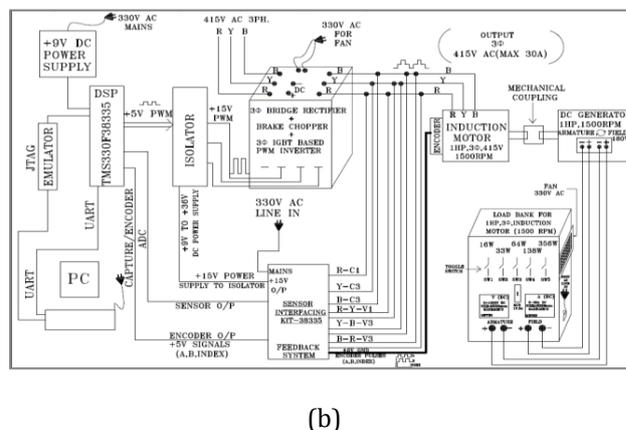

(b)

Fig.1 System Setup: DSP Based Drive using HMLI

Based on the load feedback signals are generated through sensor interface are applied to DSP board. DSP 28335 based on the control selected method, computes firing angles and generates control signals for the HMLI which are applied to inverter through isolator. The inverter output is used to control speed of the drive. Emulator is used for hardware testing of the DSP signals.

Full H-bridge (T. A. Lipo and M. D. Manjrekar,1999) is connected in series with half bridge. MOSFETS are used as a switch, output voltage is addition of H-bridge and half bridge output as shown in fig 2. The angles are found by resultant theory method for particular switching time. Elimination for third harmonics the relations are:

$$\text{Cos}\,\theta1 + \cos\theta2 = m \qquad (1)$$
$$\text{Cos}3\,\theta1 + \cos 3\theta2 = 0 \qquad (2)$$

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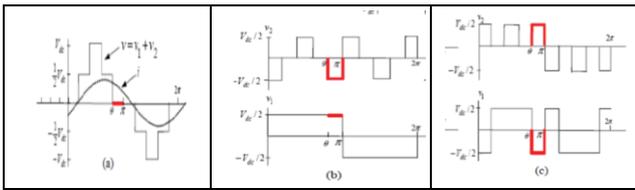
Where, m is the Modulation Index.

Fig.2 Five level output voltage for HMLI

2. Power Circuit

The power circuit(H. Liu, L. M. Tolbert, B. Ozpineci, Z. Du, 2008) Fig 3 blocks consist of one isolated power supply H- bridge, half bridge and R load. The H- bridge inverter consist of four power MOSFETs. These switches are made on and off at desired instant as per requirement of output frequency and voltage. The upper switches from positive group and lower switches from negative group.

The half bridge inverter consists of two power MOSFETs. These switches are made on and off at desire instant as per requirement of output frequency and voltage. The upper switch from positive group and lower switch from negative group. Resistive load is considered as a load to the output of the inverter which is connected in series.
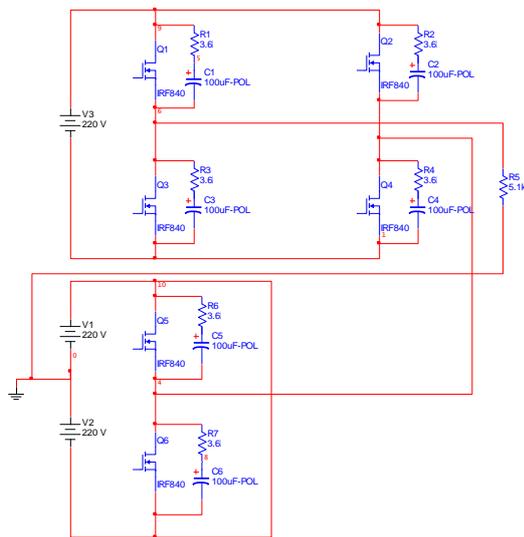

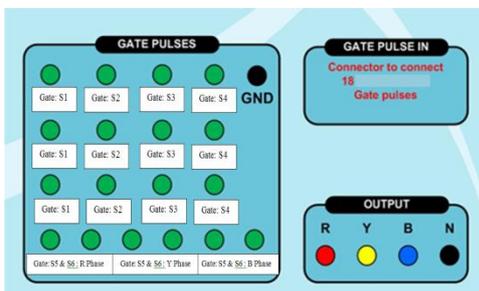**Fig 3-a:** Circuit configuration of the proposed hybrid multilevel inverter

Fig.3-b: Front Panel Diagram :HMLI Stack

3. Control Circuit

In this Section chapter discusses various simulation models and responses for single phase hybrid multilevel inverter, employing PWM method (B. P. McGrath, D. G. Holmes, M. Manjrekar, et al,2000) and Hybrid modulation technique (B. P. McGrath and D. G. Holmes,2002) . The simulation and FFT analysis for PWMwith optimal angle control method is carried out for different modulation index at different angles.

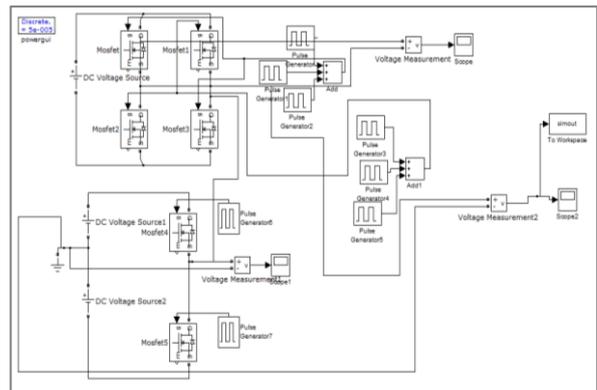### 3.1 PWM with optimal angle control method

Fig.4 Simulation model for optimal angle control method

The result is shown for modulation index is 0.9. The angles are 33° and 86.4°. Its FFT analysis is shown below. The THD Total harmonic distortion (THD) is 43.06%.
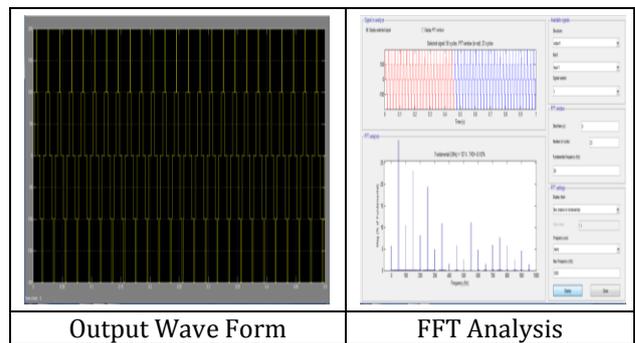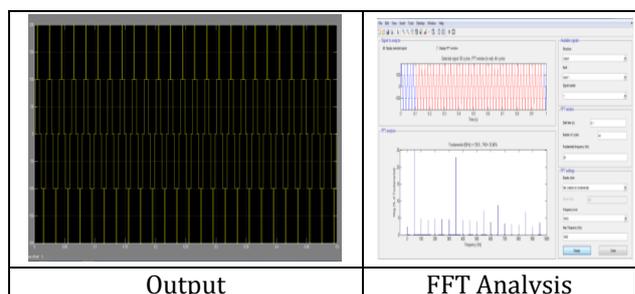

| Output Wave Form | FFT Analysis |

Fig.5 PWM method with m=0.9

| Output | FFT Analysis |

Fig.6 PWM method, m= 1.0
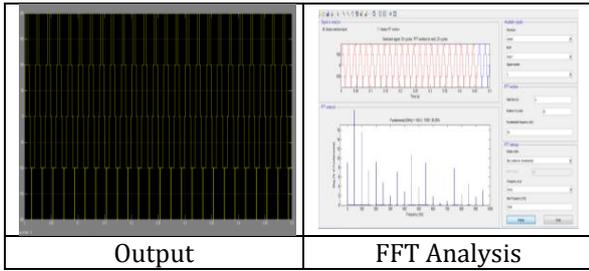
| Output | FFT Analysis |

Fig.7 PWM method, m= 1.52

3.2 Hybrid Modulation Technique

3.2.1 Simulation model of gate pulses for Hybrid Technique
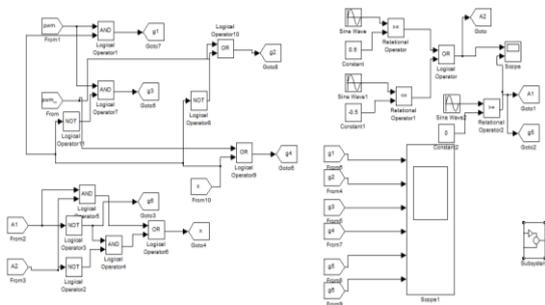

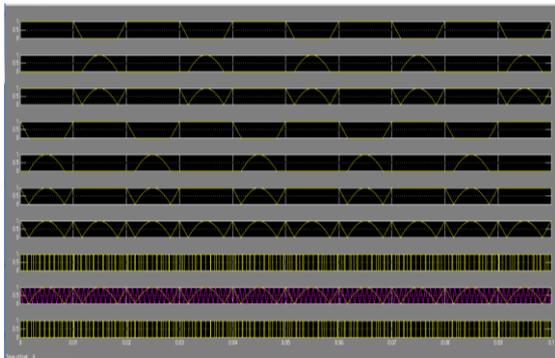**Fig.8** Simulation model: Gate pulse

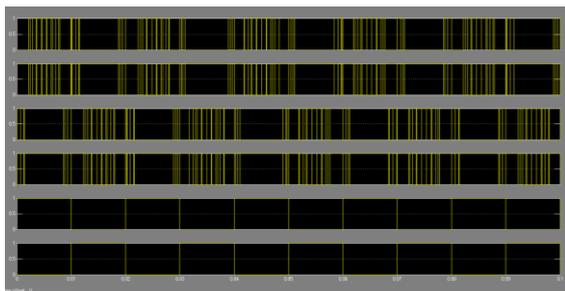**Fig.9** Control signals: Hybrid modulation technique

Fig.10 Gating signals: Hybrid modulation Technique

4. CCS link for Software Upload

The Code Composer Studio (Code Composer Studio-User manual) does not accept continuous signals. It only works for discrete signals. So, it is required to convert the continuous simulation into discrete simulation.
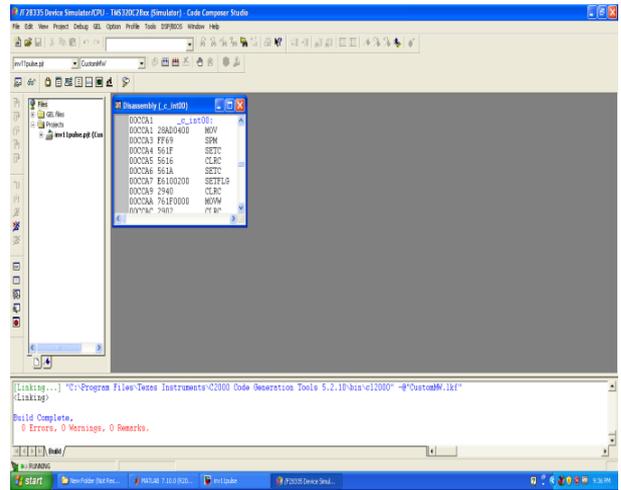

Fig.11 CCS Link for PWM with optimal angle control method

4.1 Discrete Simulation: Hybrid Modulation Technique

The main characteristic of these modulations are the reduction of switching losses with good harmonic performance, balanced power loss dissipation among the devices with in a cell, and among the series-connected cells. Here we are doing a discrete simulation and generate signal for all six Gate of single phases.
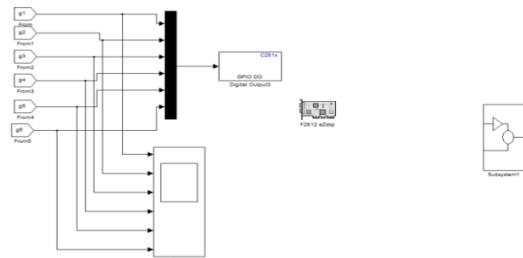

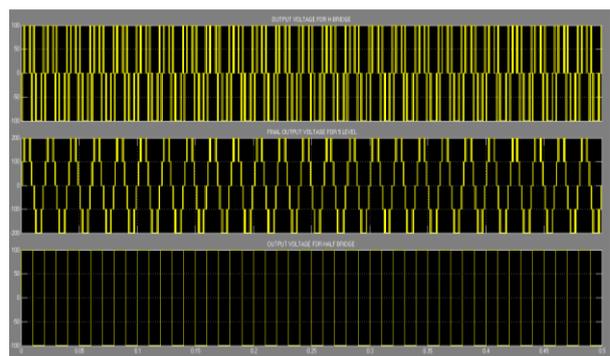**Fig.12** Discrete Simulation: Hybrid Modulation Technique

Fig.13 Result for Discrete Hybrid Modulation Technique

4.2 Hybrid method

MSPWM and its base modulator design are implemented on a TMS320F28335 digital signal processor (DSP). Complex programmable logic device realizes hybrid-modulation algorithm with base pulse width modulation (PWM) circulation, and is integrated with DSP for sequential switching hybrid PWM generation. Here we are ccs studio 3.3. Matlab to CCS to DSP RTDX and XDS 510PP. Exhange real-time data between MATLAB and a running DSP via RTDX without halting the DSP program.
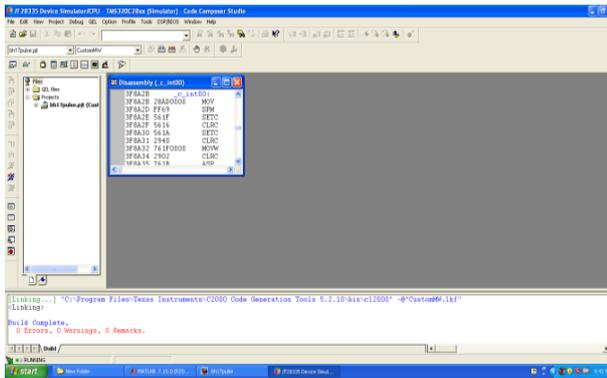

Fig.14 CCS Link for Hybrid Modulation Technique

5. Hardware Design: Power Circuit, Driver, Interfacing Circuit

This section describes design of control circuit which consists of (Mathworks Manual), (Texas Instruments CCS Link for MATLAB) DSP Controller kit – TMS320X28335, Code Composer Studio 3.3,Emulator – XDS510PP for generating gate pulse and driver circuit. It is necessary to provide isolation between power circuit and control circuit for safety purpose. Optocoupler is used for isolation. MCT6 optocoupler is used as an isolator. DSP kit output voltage (3.3V) and current (5.45 mA), while forward voltage of MCT6 = 1.5 and R = 330Ω.
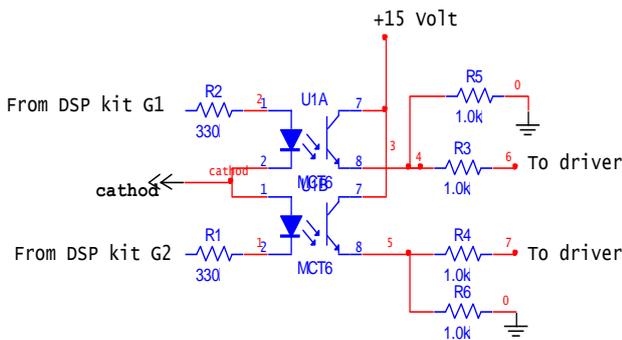

Fig.15 Isolation circuit

The IR2110 is high voltage, high speed driver for power MOSFET with independent high and low side referenced

output channels. With the help of application note value of floating capacitor, fast switching diode and pull up resistor are computed.

Inverter configuration uses one H- Bridge and a half bridge connected in series. Both circuits need their separate supply, floating and isolated. H Bridge has only one supply but the half bridge has two separate supply. IRF840 MOSFETs (voltage rating is 500V and current rating is 8Amp_ are selected Due to on- state and switching loss heat is generated within the power device. Appropriate heat sink used 2 Amp current carrying capacity for cooling purpose of MOSFET.A snubber circuit consist of series combination of resistor(3.7 Ω) and capacitor (100 µF)is connected across the MOSFETs.[RC-time constant (37 nSec)].
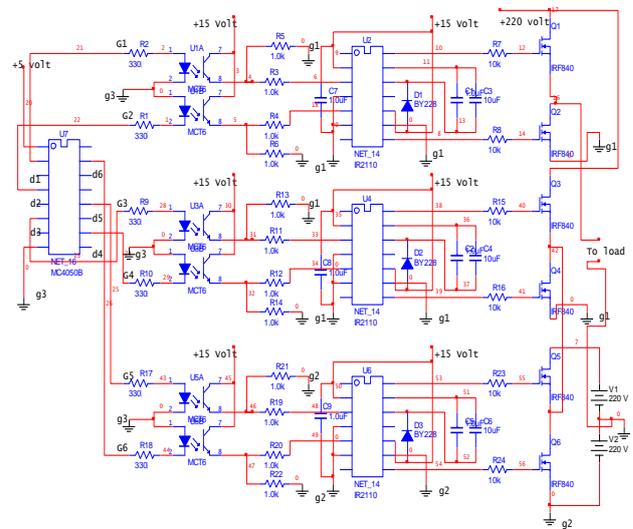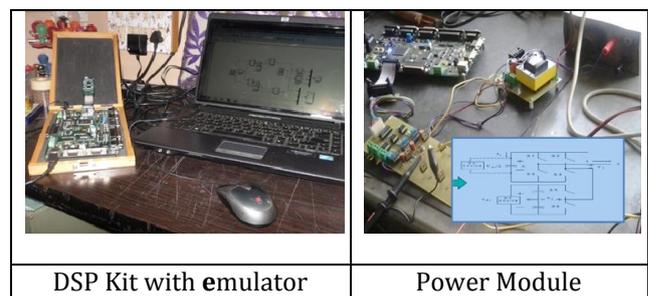

Fig.16 Power Circuit

6. Hardware Testing and Wave-Form

DSP Controller kit–TMS320X28335 (Texas Instruments CCS Link for MATLAB) is used for the control signal and these control signals are given to the MOSFETs of the power circuit. Experiment has been carried out to check the results with R and R-L load.

| DSP Kit with emulator | Power Module |

Fig.17 Test setup: R & R-L load

| THD: Phase voltage & Phase Current | THD : Line to Line Voltage |

Fig.18: Test Results with Motor Drive

Fig 18 represents waveforms including phase voltage, phase current and Line-to-Line voltages for the test setup of Fig 17.

Fig 19: System Setup: Drive with DSP, Inverter and Load panel

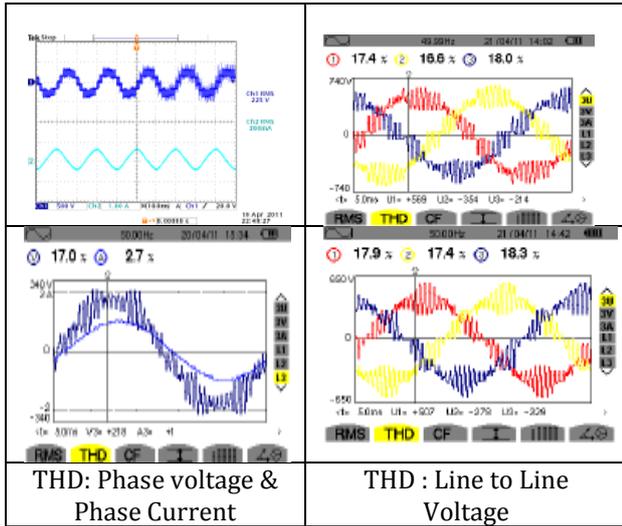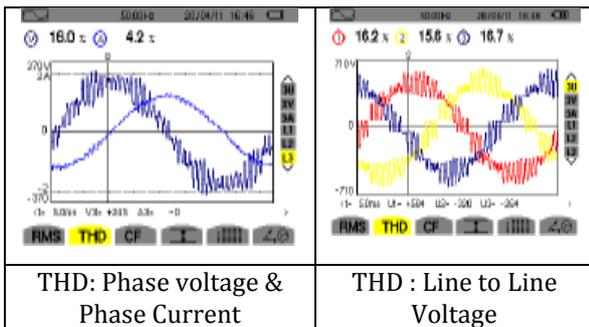| THD: Phase voltage & Phase Current | THD : Line to Line Voltage |

Fig 20: Test Results with Motor Drive

Fig 20 represents waveforms including phase voltage, phase current and Line-to-Line voltages for the test setup of Fig 19.

Conclusion

The control signals for power circuit of the 5-level three-phase HMLI are generated by DSP 28335 controller using digital techniques for $m_a = 0.8$. The prototype is tested with R and R-L load and used for motor drive. Results of the test are presented in Table-1. It shows that the output line-line and phase voltages has 5 levels that its THD voltage is between 15.6% and 16.7%, the output waveform of phase current is close to sinusoidal that its THD current is between 3.2% and 4.2%.

Table:1 Result of THD on R,R-L load and Induction Motor

Type of Load	Phase Voltage (RMS)	Phase Current (RMS)	THD (%)	
			Phase Current	Line to Line Voltage
R Load	225	360 mA	5.2	17.4%, 16.6%, and 18%.
R-L Load (150 ; 0.125 H)	195	708 mA	4.5	17.9%, 17.4%, and 18.3%.
Induction Motor Drive	206 volts	786 mA	4.2	16.2%,15.6% and 16.7%

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Texas Instruments: Code Composer Studio- *User manual*
Texas Instruments CCS Link for MATLA

Biography

Prof.D.P.Maheshwari is associate professor in electrical engineering department at Vishwkarma Government Engineering College, Chandkheda. He received his BE and ME degree from Saurastra University and Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal respectively. He has over 15 years of teaching experience. His areas of interest are Power Electronics and Drives.

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