CHAPTER 6

CONCLUSION AND SCOPE FOR FUTURE WORK

6.1 CONCLUSION

Many industrial processes such as assembly lines have to operate at different speeds for different products. Process control may demand adjustment of flow from a pump or fan by varying the speed of the drive. The energy may be saved in comparison with other techniques for flow control by using ASIMD. The most important power quality problem faced by many commercial and industrial customers is voltage sag. During voltage sag period, the motor stops and the industrial process disturbed. To improve the performance of the ASIMD, an attempt has been made in this research work to adopt the following controls and techniques:

- Single-phase neutral linked Vienna rectifier in the front end of ASIMD.
- Z-source inverter in the back end of ASIMD.

The hardware has been developed based on the simulation model to fulfil this objective. The hardware output of the normal bridge rectifier is compared with the output of the proposed Vienna rectifier connected to a Z-source inverter fed three-phase 1 hp Induction Motor.

The output speed variation shows that Vienna rectifier has better performance compared to bridge rectifier during voltage sag condition. Various other performance quantities discussed in Table 5.1 also prove the same.
6.2 OUTCOME AND ADVANTAGE

- The single-phase neutral linked Vienna rectifier with Z-source inverter fed adjustable speed induction motor drive is very effective to mitigate voltage sag.
- The proposed circuit also provides the better ride-through capability due to the combination of Z-source network.
- This proposed system is able to drive the three-phase IM during voltage sag conditions from the single-phase AC supply.
- DC-link voltage is maintained at 315V even under sag condition which is the nominal voltage to drive the ASIMD.

6.3 SCOPE FOR FUTURE WORK

- The relays can be replaced with solid state switches for more accurate applications.
- In the research work, single-phase Vienna rectifier with neutral linked circuit is implemented to mitigate voltage sag effect on ASIMD. This can be modified with three-phase Vienna rectifier to obtain better efficiency.
- To enhance the switching frequency and performance of the inverter systems, MOSFET switches can be replaced by IGBT switches.
- The controllers can be constructed using ARM or Digital Signal Processor instead of microcontroller thereby achieving higher accuracy and better performance.
APPENDIX 1

A1.1 HEXA CODE AND FLOW CHART

The following Table A1.1 gives the hex code values for the microcontroller to produce the firing pulses to the MOSFET switches in Vienna rectifier and Z-source inverter and also explains how the controller works and how the next cycle continues.

Figure A1.1 shows the flow chart diagram of micro controller. The delay command and jump commands bring the cyclic firing of each switch and make the continuous running of the induction motor which is connected as the load.

<table>
<thead>
<tr>
<th>V2</th>
<th>V1</th>
<th>I6</th>
<th>I5</th>
<th>I4</th>
<th>I3</th>
<th>I2</th>
<th>I1</th>
<th>Hex value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>69h</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>61h</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>83h</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>46h</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>8ch</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>58h</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>b0h</td>
</tr>
</tbody>
</table>
The flow chart for three-phase induction motor drive is shown in Figure A1.1.

Figure A1.1 Flow chart of microcontroller 16F84A
The switching state Hexa code address is given to the microcontroller with respect to their delay values as per the microcontroller program (V2- no connection).

A1.2 MICROCONTROLLER PIC 16F84A (INVERTER PROGRAM) PROGRAM

del equ 40h

del1 equ 41h

org 000h

bsf status, 5

movlw 0x00

movwf trisb

bcf status, 5

start:

    movlw 69h

    movwf portb

    call delay1

    movlw 61h

    movwf portb

    call delay1

    movlw 83h

    movwf portb
call delay
movlw 46h
movwf portb
call delay
movlw 8ch
movwf portb
call delay
movlw 58h
movwf portb
call delay
movlw b0h
movwf portb
call delay
goto start
delay: movlw 0x0f
movwf del
loop5: decfsz del, 1
        goto loop5
return
delay1: movlw 0x08
        movwf del
loop6: decfsz del, 1
    goto loop6

return

DELAY PROGRAM

mov A0, #250

loop
    nop
    nop
    djnz A0, loop
return

A1.3 MICROCONTROLLER ATMEGA16 (VOLTAGE SAG GENERATOR PROGRAM) PROGRAM

#define F_CPU 1000000UL
#include <avr/io.h>
#include <util/delay.h>
#include <avr/sfr_defs.h>

int main(void)
{

    DDRB |= (1 << PB0) | (1 << PB1) | (1 << PB2) | (1 << PB3) | (1 << PB4) |
        (1 << PB5) | (1 << PB6) | (1 << PB7);
    PORTB&=~(1<<PB0);
    PORTB&=~(1<<PB1);
PORTB&=~(1<<PB2);
PORTB&=~(1<<PB3);
PORTB&=~(1<<PB4);

while(1)
{
    if(bit_is_set(PINB,PB1))
    {
        PORTB|=(1<<PB0) | (1<<PB4);
        _delay_ms(1000);
        PORTB&=~(1<<PB0);
        PORTB&=~(1<<PB4);
    }
    else if(bit_is_set(PINB,PB2))
    {
        PORTB|=(1<<PB0) | (1<<PB4);
        _delay_ms(5000);
        PORTB&=~(1<<PB0);
        PORTB&=~(1<<PB4);
    }
    else if(bit_is_set(PINB,PB3))
    {
        PORTB|=(1<<PB0) | (1<<PB4);
_delay_ms(10000);

PORTB&=~(1<<PB0);

PORTB&=~(1<<PB4);

}
}

return 0;

}
A2.1 IR2110 DRIVER

Pin configuration and typical operating circuit

Figure A2.1 Pin and connection diagram of driver IC IR2110
Product Summary

- Floating channel designed for bootstrap operation fully operational to +500V or +600V OFFSET (IR2110) 500V max.
- Tolerant to negative transient voltage (IR2113) 600V max. dV/dt immune
- Gate drive supply range from 10 to 20V IO+/−2A / 2A
- Under voltage lockout for both channels 3.3V logic compatible VOUT 10 - 20V Separate logic supply range
Table A2.1 Absolute maximum ratings of IR2210

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
<th>Min.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_B$</td>
<td>High side floating supply voltage (IR2110)</td>
<td>-0.3</td>
<td>525</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(IR2113)</td>
<td>-0.3</td>
<td>625</td>
<td></td>
</tr>
<tr>
<td>$V_S$</td>
<td>High side floating supply offset voltage</td>
<td>$V_S - 25$</td>
<td>$V_S + 0.3$</td>
<td></td>
</tr>
<tr>
<td>$V_{HD}$</td>
<td>High side floating output voltage</td>
<td>$V_S - 0.3$</td>
<td>$V_B + 0.3$</td>
<td></td>
</tr>
<tr>
<td>$V_{CC}$</td>
<td>Low side fixed supply voltage</td>
<td>-0.3</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>$V_{LO}$</td>
<td>Low side output voltage</td>
<td>-0.3</td>
<td>$V_{CC} + 0.3$</td>
<td></td>
</tr>
<tr>
<td>$V_{DD}$</td>
<td>Logic supply voltage</td>
<td>-0.3</td>
<td>$V_{SS} + 25$</td>
<td></td>
</tr>
<tr>
<td>$V_{SS}$</td>
<td>Logic supply offset voltage</td>
<td>$V_{CC} - 25$</td>
<td>$V_{CC} + 0.3$</td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Logic input voltage (HIN, LIN &amp; SD)</td>
<td>$V_{SS} - 0.3$</td>
<td>$V_{DD} + 0.3$</td>
<td></td>
</tr>
</tbody>
</table>

$\frac{dV_g}{dt}$ Allowable offset supply voltage transient (figure 2) | — | 50 | V/ns |

$P_D$ Package power dissipation @ $T_A, 5 + 25^\circ C$ | (14 lead DIP) | 1.6 | W |
|        | (16 lead SOIC) | 1.25 | |

$R_{THJA}$ Thermal resistance, junction to ambient | (14 lead DIP) | 75 | °C/W |
|        | (16 lead SOIC) | 100 | |

$T_J$ Junction temperature | — | 150 | °C |

$T_S$ Storage temperature | -55 | 150 | |

$T_L$ Lead temperature (soldering, 10 seconds) | — | 300 | |

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
<th>Min.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_B$</td>
<td>High side floating supply absolute voltage</td>
<td>$V_S + 10$</td>
<td>$V_S + 20$</td>
<td></td>
</tr>
<tr>
<td>$V_S$</td>
<td>High side floating supply offset voltage</td>
<td>Note 1</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(IR2110)</td>
<td>Note 1</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>$V_{HD}$</td>
<td>High side floating output voltage</td>
<td>$V_S$</td>
<td>$V_B$</td>
<td></td>
</tr>
<tr>
<td>$V_{CC}$</td>
<td>Low side fixed supply voltage</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>$V_{LO}$</td>
<td>Low side output voltage</td>
<td>0</td>
<td>$V_{CC}$</td>
<td></td>
</tr>
<tr>
<td>$V_{DD}$</td>
<td>Logic supply voltage</td>
<td>$V_{SS} + 3$</td>
<td>$V_{SS} + 20$</td>
<td></td>
</tr>
<tr>
<td>$V_{SS}$</td>
<td>Logic supply offset voltage</td>
<td>-5 (Note 2)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Logic input voltage (HIN, LIN &amp; SD)</td>
<td>$V_{SS}$</td>
<td>$V_{DD}$</td>
<td></td>
</tr>
<tr>
<td>$T_A$</td>
<td>Ambient temperature</td>
<td>-40</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>
A2.2 MICROCONTROLLER - PIC16F84A

18-pin Enhanced Flash/EEPROM 8-Bit Microcontroller

High Performance RISC CPU Features:

- Only 35 single word instructions to learn
- All instructions single cycle except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle
- 1024 words of program memory
- 68 bytes of data RAM
- 64 bytes of data EEPROM
- 14-bit wide instruction words
- 8-bit wide data bytes

Special Microcontroller Features:

- 1000 erase/write cycles Enhanced Flash program memory
- EEPROM Data Retention > 40 years
- In-Circuit Serial Programming (ICSP™) - via two pins
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Code-protection
- Power saving SLEEP mode
- Selectable oscillator options
Figure A2.2 Pin diagram of microcontroller PIC16F84A
Commercial: 2.0V to 5.5V - Industrial: 2.0V to 5.5V
Low power consumption: < 2 mA typical @ 5V, 4 MHz
15 μA typical @ 2V, 32 kHz <= 0.5 μA typical standby current @ 2V

The PIC16F84A belongs to the mid-range family of the PIC microcontroller devices. The block diagram of the device is explained in data sheet. The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data EEPROM is 64 bytes. There are also 13 I/O pins that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions.

These functions include:

- External interrupt
- Change on PORTB interrupts
- Timer0 clock input

Special Features of PIC16F84A

The PIC16F84A has a host of features intended to maximize system reliability, minimize cost through elimination of external components, provide power saving operating modes and offer code protection. These features are:

- OSC Selection
- RESET
- Interrupts
- Watchdog Timer (WDT)
- SLEEP
- Code Protection
The PIC16F84A has a Watchdog Timer which can be shut-off only through configuration bits. It runs off its own RC oscillator for added reliability. There are two timers that offer necessary delays on power-up.

ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings

Ambient temperature under bias..............................................-55°C to +125°C
Storage temperature .................................................................-65°C to +150°C
Voltage on any pin with respect to VSS (except VDD, MCLR, and RA4) ......................... -0.3V to (VDD + 0.3V)
Voltage on VDD with respect to VSS ..........................................-0.3 to +7.5V
Voltage on MCLR with respect to VSS(1) .....................................-0.3 to +14V
Voltage on RA4 with respect to VSS ...........................................-0.3 to +8.5V
Total power dissipation(2) ..........................................................800 mW
Maximum current out of VSS pin ..............................................150 mA
Maximum current into VDD pin .....................................................100 mA
Input clamp current, IIK (VI < 0 or VI > VDD)............................± 20 mA
Output clamp current, IIK (VO < 0 or VO > VDD) ......................± 20 mA
Maximum output current sunk by any I/O pin .............................25 mA
Maximum output current sourced by any I/O pin ......................25 mA
Maximum current sunk by PORTA ...............................................80 mA
Maximum current sourced by PORTA ........................................50 mA
Maximum current sunk by PORTB .............................................150 mA
Maximum current sourced by PORTB .................................100 mA

Note: Voltage spikes below VSS at the MCLR pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100W should be used when applying a “low” level to the MCLR pin rather than pulling this pin directly to VSS.
Figure A2.3 Pin diagram of microcontroller ATMEGA 16
Electrical Characteristics

- Operating Temperature: -55°C to +125°C
- Storage Temperature: -65°C to +150°C
- Voltage on any Pin except RESET with respect to Ground: -0.5V to Vcc + 0.5V
- Voltage on RESET with respect to Ground: -0.5V to +13.0V
- Maximum Operating Voltage: 6.0V
- DC Current per I/O Pin: 40.0 mA
- DC Current Vcc and GND Pins: 200.0 mA PDIP and 400.0 mA TQFP/MLF

*NOTICE:* Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table A2.2 Absolute maximum ratings of ATMEGA 16

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIL</td>
<td>Input Low Voltage except XTAL1 and RESET pins</td>
<td>Vcc = 2.7 - 5.5</td>
<td>-0.5</td>
<td></td>
<td>0.2 Vcc(1)</td>
<td>V</td>
</tr>
<tr>
<td>VIH</td>
<td>Input High Voltage except XTAL1 and RESET pins</td>
<td>Vcc = 2.7 - 5.5</td>
<td>0.6 Vcc(2)</td>
<td>Vcc +0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIH1</td>
<td>Input High Voltage XTAL1 pin</td>
<td>Vcc = 2.7 - 5.5</td>
<td>0.7 Vcc(2)</td>
<td>Vcc +0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIL1</td>
<td>Input Low Voltage XTAL1 pin</td>
<td>Vcc = 2.7 - 5.5</td>
<td>-0.5</td>
<td></td>
<td>0.1 Vcc(1)</td>
<td>V</td>
</tr>
<tr>
<td>VIH2</td>
<td>Input High Voltage RESET pin</td>
<td>Vcc = 2.7 - 5.5</td>
<td>0.9 Vcc(2)</td>
<td>Vcc +0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIL2</td>
<td>Input Low Voltage RESET pin</td>
<td>Vcc = 2.7 - 5.5</td>
<td>-0.5</td>
<td></td>
<td>0.2 Vcc</td>
<td>V</td>
</tr>
<tr>
<td>VIL</td>
<td>Output Low Voltage (Pins A,B,C,D)</td>
<td>IOL = 20 mA, Vcc = 5V VIL = 10 mA, VCC = 3V</td>
<td>0.7</td>
<td>0.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>VIL</td>
<td>Output High Voltage (Pins A,B,C,D)</td>
<td>IOLH = -20 mA, Vcc = 5V IOLH = -10 mA, VCC = 3V</td>
<td>4.2</td>
<td>2.2</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>IIL</td>
<td>Input Leakage Current I/O Pin</td>
<td>Vcc = 5.5V, pin low (absolute value)</td>
<td>1</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>IIL</td>
<td>Input Leakage Current I/O Pin</td>
<td>Vcc = 5.5V, pin high (absolute value)</td>
<td>1</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
</tbody>
</table>
Figure A2.4 Pin and internal diagram of power MOSFET IRF840

Features

- 8A, 500V
- $r_{DS(ON)} = 0.850\Omega$
- Single Pulse Avalanche Energy rated
- SOA is Power Dissipation Limited
- Nanosecond Switching Speeds
- Linear Transfer Characteristics
### Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Limit</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain-Source Voltage</td>
<td>$V_{DS}$</td>
<td>500</td>
<td>V</td>
</tr>
<tr>
<td>Gate-Source Voltage</td>
<td>$V_{GS}$</td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Continuous Drain Current</td>
<td>$V_{DS}$ at 10 V, $T_{C} = 25^\circ C$</td>
<td>8.0</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>$T_{C} = 100^\circ C$</td>
<td>5.1</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed Drain Current$^a$</td>
<td>$I_{DM}$</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Linear Derating Factor</td>
<td></td>
<td>1.0</td>
<td>W/°C</td>
</tr>
<tr>
<td>Single Pulse Avalanche Energy$^b$</td>
<td>$E_{AS}$</td>
<td>510</td>
<td>mJ</td>
</tr>
<tr>
<td>Repetitive Avalanche Current$^a$</td>
<td>$I_{AR}$</td>
<td>8.0</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive Avalanche Energy$^a$</td>
<td>$E_{AR}$</td>
<td>13</td>
<td>mJ</td>
</tr>
<tr>
<td>Maximum Power Dissipation</td>
<td>$T_{C} = 25^\circ C$</td>
<td>125</td>
<td>W</td>
</tr>
<tr>
<td>Peak Diode Recovery dv/dt$^c$</td>
<td></td>
<td>3.5</td>
<td>W/Us</td>
</tr>
<tr>
<td>Operating Junction and Storage Temperature Range</td>
<td>$T_{J}, T_{STG}$</td>
<td>-55 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Soldering Recommendations (Peak Temperature)</td>
<td>for 10 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mounting Torque</td>
<td>6-32 or M3 screw</td>
<td>10</td>
<td>lbf-in</td>
</tr>
</tbody>
</table>

Notes:

- a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
- b. $V_{DD} = 50 V$, starting $T_{J} = 25^\circ C$, $L = 14 mH$, $R_{G} = 25 \Omega$, $I_{DS} = 8.0 A$ (see fig. 12).
- c. $I_{DD} \leq 8.0 A$, $dv/dt \leq 100 A/us$, $V_{DD} \leq V_{DS}$, $T_{J} \leq 150^\circ C$.
- d. 1.6 mm from case.
A2.5  LM78XX Series Voltage Regulators

Output Voltage:

5V,  
12V and  
15V.

Input Voltage:

10V,  
19V and  
23V

<table>
<thead>
<tr>
<th>LM7805C</th>
<th>5V</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM7812C</td>
<td>12V</td>
</tr>
<tr>
<td>LM7815C</td>
<td>15V</td>
</tr>
</tbody>
</table>