

CHAPTER 5

SIMULATION AND EXPERIMENTAL STUDIES

5.1 SIMULATION STUDIES

Cascaded multilevel inverter is composed of a number of H-Bridge inverter cells connected in series in each phase with a separate DC source for each cell. Figure 5.1 shows a typical 3 ϕ cascaded multilevel inverter with three H-bridge cells in each phase connected to a 3 ϕ induction motor load.

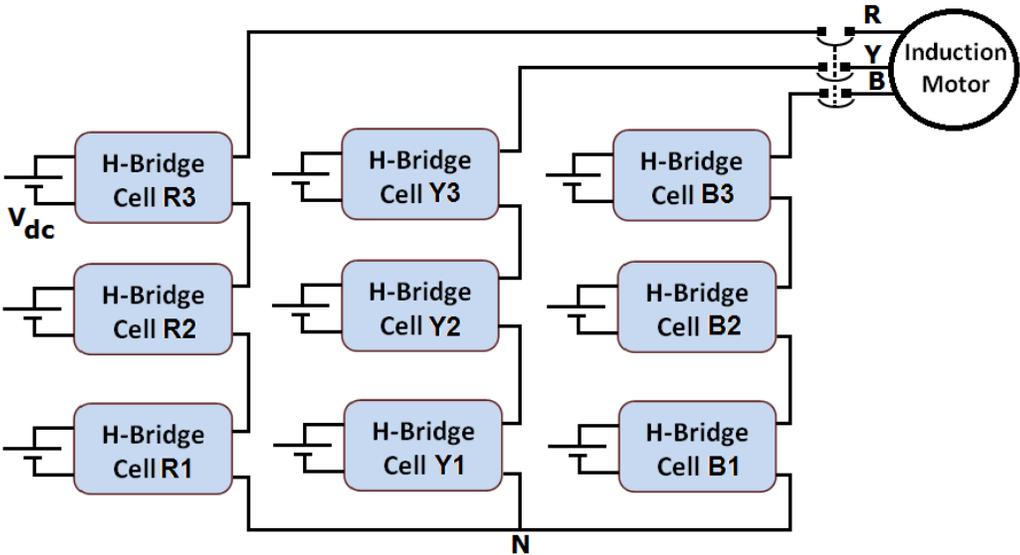


Figure 5.1 Schematic of a typical 3 ϕ cascaded H-Bridge multilevel inverter with induction motor load

Cascaded multilevel inverter is composed of a number of H-Bridge inverter units with a separate DC source for each unit to obtain a desired

single or three phase near sinusoidal voltage waveform. The number of levels in the output voltage waveform can be evaluated by $2S+1$, where ‘S’ is the number of H-Bridge units used in the system. Figure 5.2 shows the configuration of five level multilevel inverter used in the present study consisting of two H-Bridges and eight IGBT switches. Even though three phase multilevel inverter system is commonly used in industrial drives, in the present work, single phase multilevel inverter is considered since the proposed diagnostic system can be extended for three phase system.

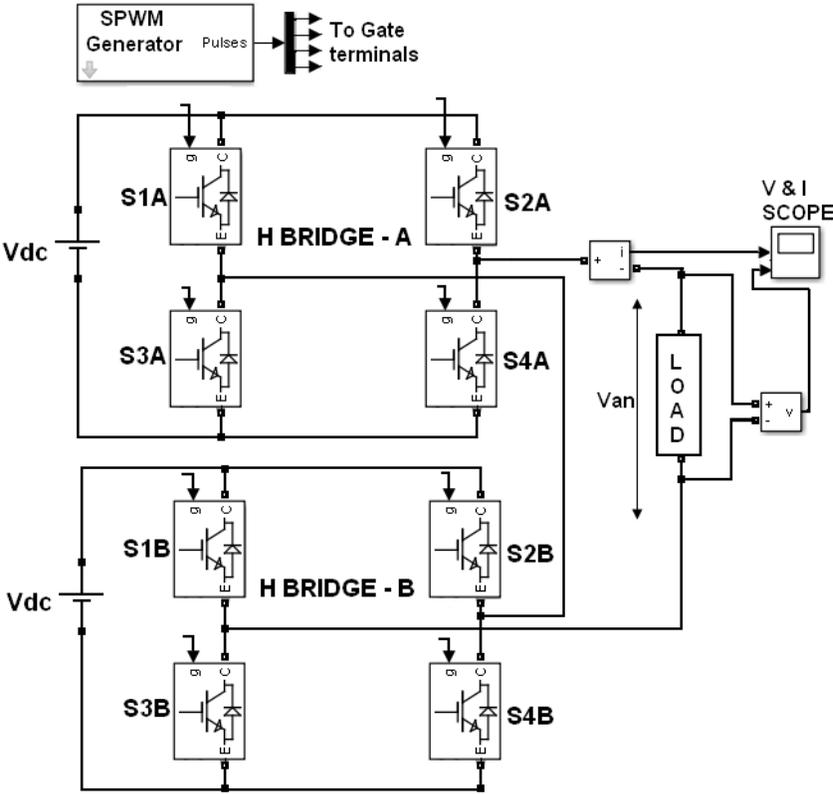


Figure 5.2 Schematic diagram of single phase cascaded H-Bridge Five level inverter with Z_L load

Figure 5.3 shows the schematic of single phase (1 ϕ) five level cascaded H-bridge inverter used in the present work connected with induction motor load. Each IGBT switch is labeled according to their cell position as

S1A, S1B, etc. All the simulation studies are carried out using MATLAB SIMULINK software. Inverter is connected with a SIMULINK model of a dynamic load of 1 ϕ , 0.5 HP, 50 Hz, 220 V induction motor.

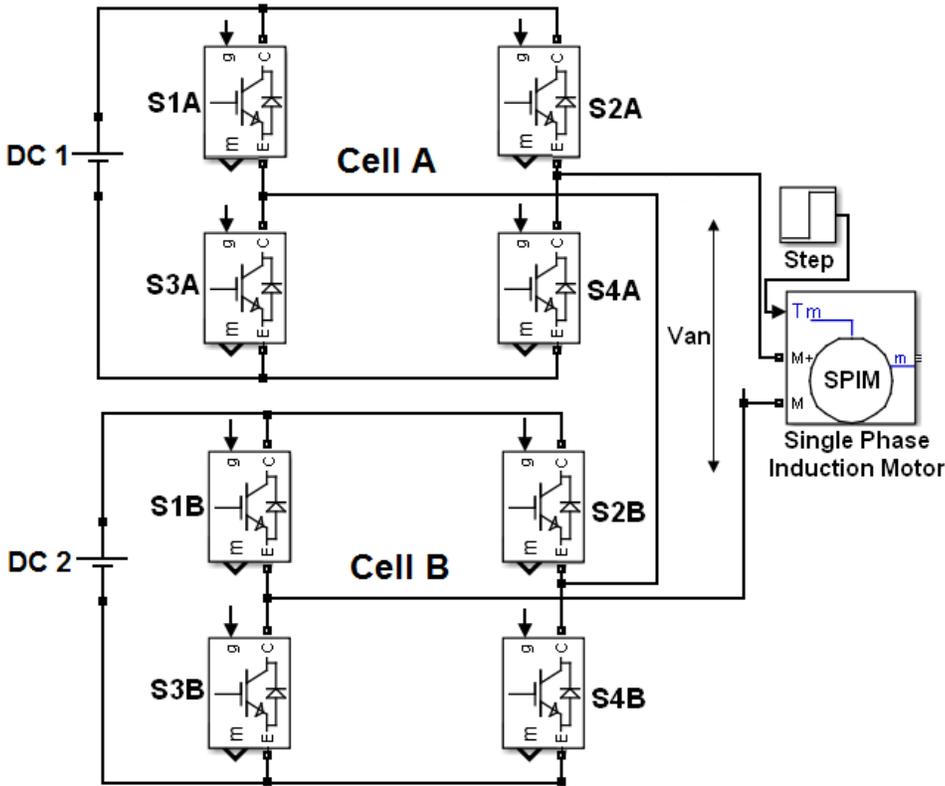


Figure 5.3 Schematic diagram of 1 ϕ cascaded H-Bridge five level inverter connected with induction motor load

Sinusoidal pulse width modulation (SPWM) technique is used as a switching strategy to produce the required switching pulses of IGBT switches. In the case of SPWM, high frequency triangular carrier signal is compared with a reference sinusoidal signal. Triangular carrier signals and sinusoidal signal with modulation index 0.85 used for the generation of trains of switching pulses are shown in Figure 5.4. MATLAB Simulink software is used for the entire simulation studies. Figure 5.5 shows the generation of trains of switching pulses of cell A at a carrier frequency (f_c) of 3 kHz and

modulation index (m) of sinusoidal signal 0.85. In the present work, m is varied in the range of 0.8 to 0.95.

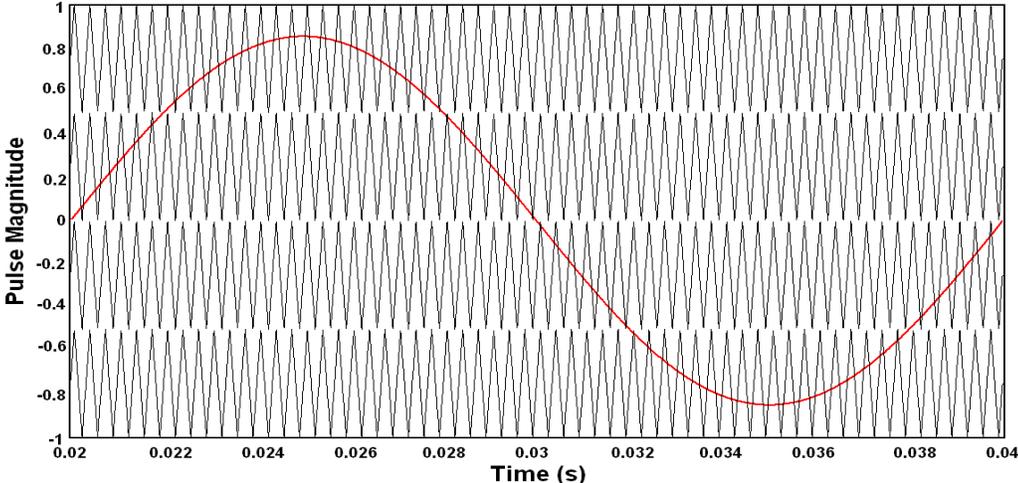


Figure 5.4 Triangular carrier signals and sinusoidal reference signal used in the pulse width modulation. $m=0.85, f_c=3$ kHz

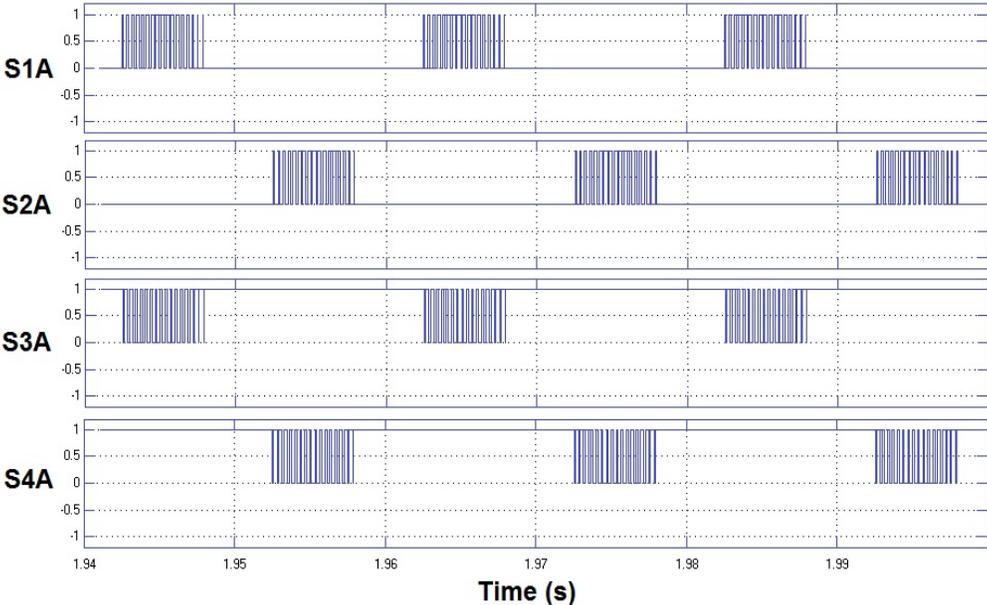


Figure 5.5 Sinusoidal pulse width modulated switching pulses of cell A generated with carrier frequency 3 kHz and modulation index 0.85.

5.2 LABORATORY EXPERIMENTAL STUDIES

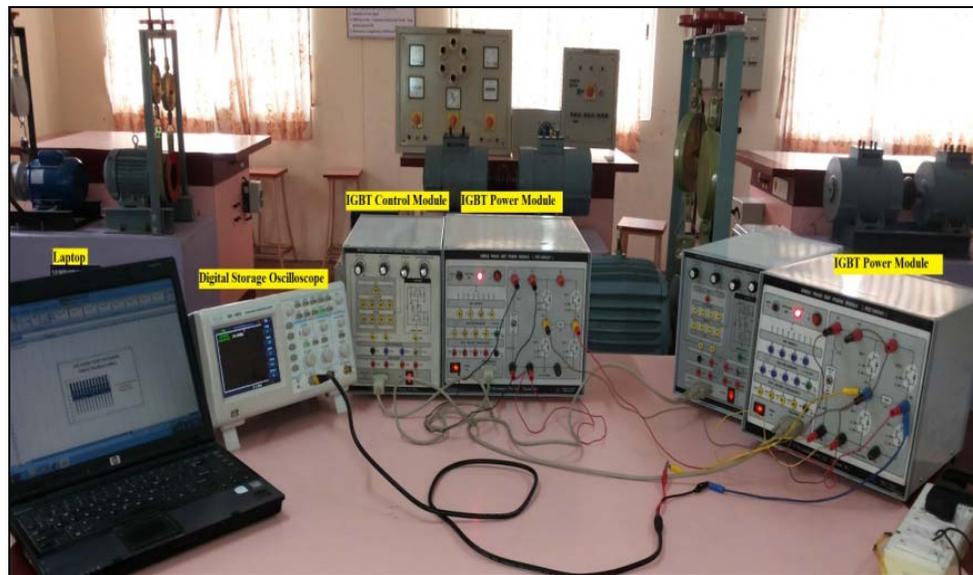


Figure 5.6 Laboratory experimental setup

For practical real time applications, it is essential to validate the results obtained from the simulation studies through laboratory measurements. Figure 5.6 shows the photograph of laboratory experimental setup used to collect the output voltage signals of multilevel inverter at different switch fault conditions. It shows both hardware system and software system. Hardware system consists of the DC power supply, multilevel inverter, Induction Motor (IM) and data acquisition systems. Two H-bridge single phase PWM inverter modules are cascaded to get the five level output voltage waveform. IGBTs of rating 600 V, 25 A are used as a switching devices. PWM control module consisting of reference wave and carrier wave selection, modulation index and switching frequency adjustment is used to get the required gate pulses for the IGBT switches. Open circuit and short circuit faults are created on each switch and corresponding output voltage waveform is recorded. In order to compare the results with simulation, all the experimental parameters are maintained similar to simulation work.



Figure 5.7 Data acquisition system interfaced with LabVIEW software in PC



Figure 5.8 National Instruments USB-6251 hardware for collecting output voltage signals

Figure 5.7 shows the photograph of the data acquisition system interfaced with LabVIEW software in PC for real time applications. Figure 5.8 shows the National Instruments (NI) USB-6251 (1.25 MSa/sec) hardware which is used as a data acquisition system and connected with PC for storing and further processing of signals. This system is capable of measuring 16

analog input signals, 16 bits. The graphical user interface developed in LabVIEW displays the acquired output voltage waveforms in the front panel of the program. The front panel acts like a user interface where the user can input and extract data. Once the NI USB device is properly interfaced with this LabVIEW front panel, device communication indicator will blink in green. Front panel has control over output voltage signal parameters such as time scale, magnitude scale, sampling frequency and number of samples of each signal. Also, it is possible to set the number of signals to be captured at a particular time using the acquisition settings.

A digital storage oscilloscope, Agilent make (1 GigaSamples/sec), is also used to visualize the output voltage waveforms. Open circuit and short circuit faults are created on each switch and corresponding output voltage waveform is recorded. Voltage sensor is used to collect the output voltage signals and it is connected with NI USB-6251. Output voltage signal is measured in the inverter at different modulation index values and important feature of the voltage signal are extracted.