CHAPTER 5
EXPERIMENTAL RESULTS

5.1 Introduction

The block diagram and the prototype system of 3-phase 4-wire 4-leg voltage sag compensation based on three-dimensional space vector modulation technique in *abc* coordinates show in Fig. 5.1 and Fig. 5.2 respectively. The 3-phase transformer and voltage sag controlled circuit provided for the preferred source(voltage sag generator). The picture of voltage sag generator show in Fig. 5.3.

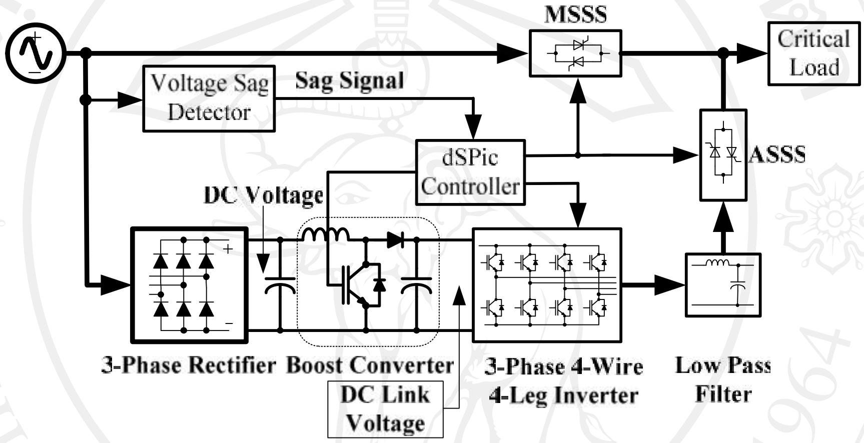


Figure 5.1 The block diagram of 3-phase, 4-wire, 4-leg voltage sag compensator.

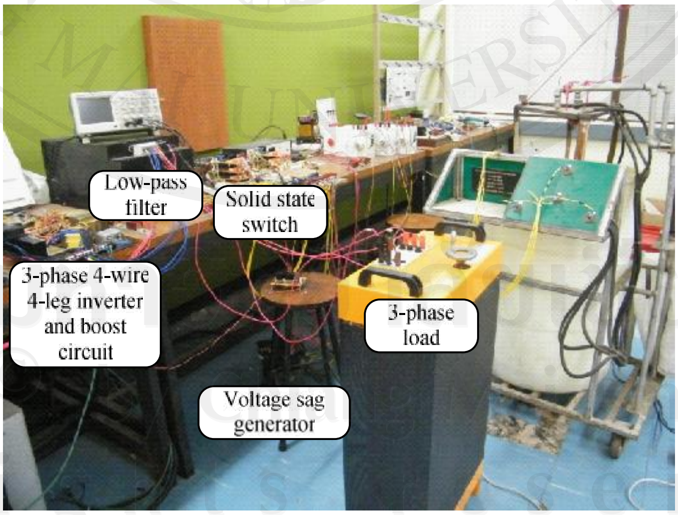


Figure 5.2 The overall hardware of this thesis.

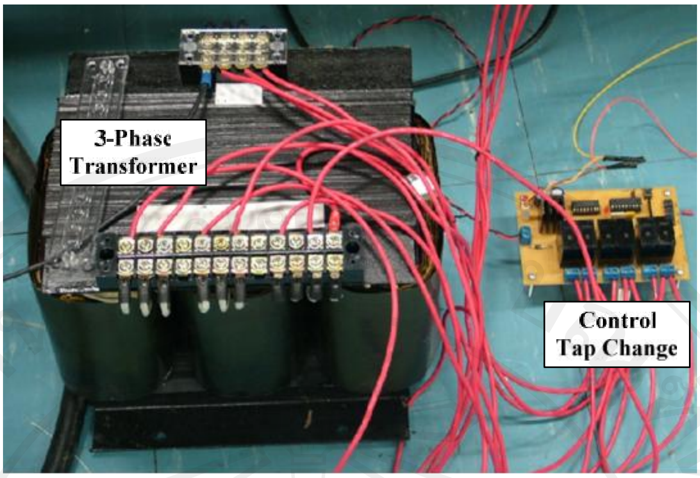


Figure 5.3 Voltage sag generator used in this thesis.

The main system parameter of 3-phase 4-wire 4-leg voltage sag compensator connected to a 3-phase 4-wire 400 V with load of 3 kVA are given in Table. 5.1.

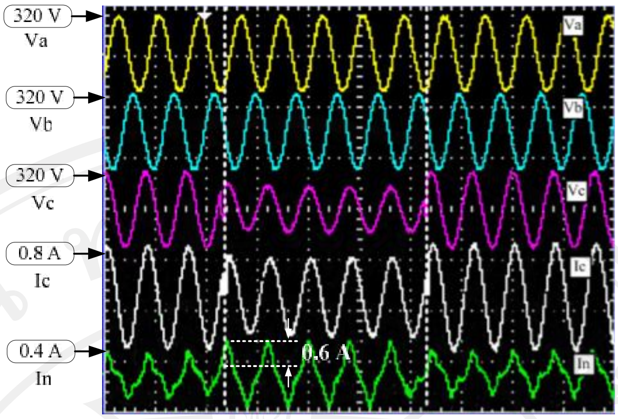
Table 5.1 The components used in implementing the system shown in Fig. 5.1.

3-Phase rectifier	Full bridge rectifier	37A/600V
	Capacitor ($C_{rectifier}$)	3600 μF
Boost converter	Controllable switch	20A/600V
	Diode	20A/600V
	Inductor (L_{boost})	403 μH
	Capacitor (C_{boost})	470 μF
Voltage sag compensator	Controllable switch	20A/600V
	dsPIC controller	dsPIC30F6010
	Switching frequency (f_{sw})	3 kHz
Low pass filter	Filter Inductor (L_f)	4 mH
	Filter Capacitor (C_f)	470 μF
Transfer switch	Main solid state switch (MSSS)	45A/600V
	Auxiliary solid state switch (ASSS)	45A/600V
Critical load	Inductive load (L_a=L_b=L_c)	61.2 mH
	Resistor load (R_a=R_b)	777 Ω
	Resistor load (R_c)	388.5 Ω

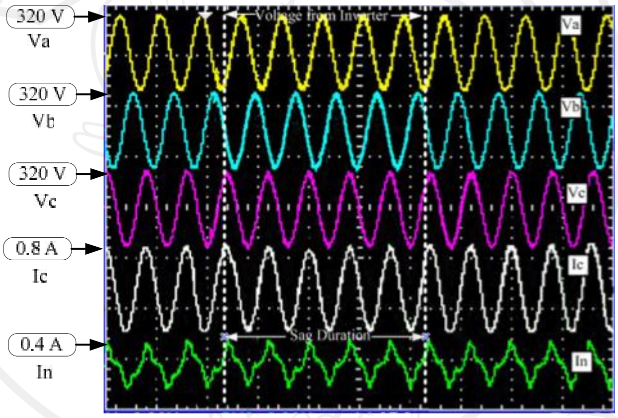
5.2 The experimental results of single-phase voltage sag 60% on unbalance load.

The most frequent voltage disturbances in the power system are single-phase voltage sag. Under the single-phase voltage sag 100 ms duration, V_c has been setup to 60% of normal voltage and V_a, V_b are 100% of normal voltage. In this case, the experiment has been setup to unbalance load condition.

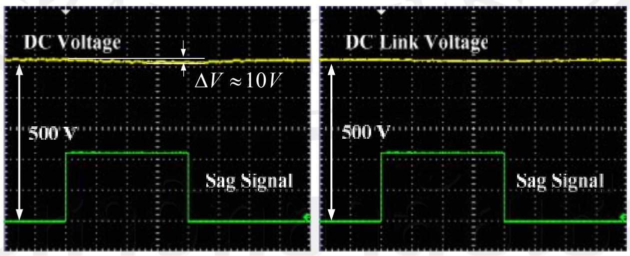
The experimental results in Fig 5.4(a) has shown the 3-phase voltage and current I_c and I_n of the critical load without compensation. During sag duration, voltage on phase C (V_c) reduces to 60% and DC voltage reduces about 10 V(V$V \approx 10\,\mathbf{V}$) from normal voltage. The current on phase C (I_c) also reduces to 60%. The sag condition and unbalance load increase the neutral current (I_n) during sag. Fig 5.4(b) has shown the 3-phase voltage and current I_c and I_n of critical load with voltage sag compensator. The voltage and current on sag duration in Fig 5.4(b) has been compensated from the 3-phase, 4-wire, 4-leg inverter, so the critical load is supplied with almost constant voltage. Fig 5.4(c) is shown DC bus voltage and the sag signal for MSSS and ASSS. DC link is constant due to the operation of boost converter.



(a) The 3-phase voltage, I_c, and I_n of critical load without compensation.



(b) The 3-phase voltage, I_c, and I_n of critical load with voltage sag compensator.

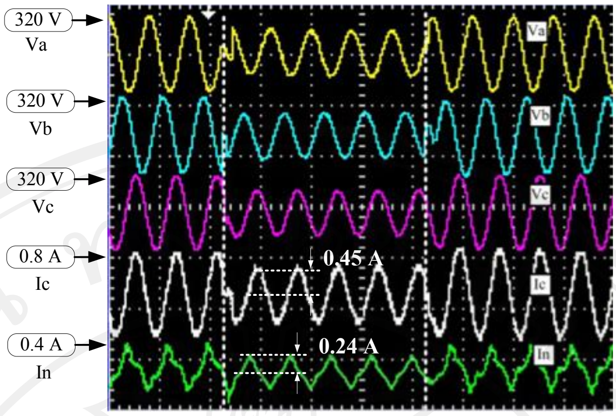


(c) DC Voltage and sag signal for MSSS and ASSS.

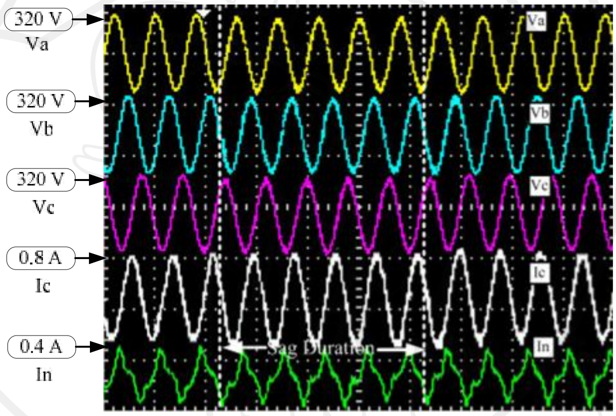
Figure 5.4. The experimental results of single-phase 60% voltage sag, 100 ms duration, unbalance load condition.

5.3 The experimental results of three-phase voltage sag 60% on unbalance load.

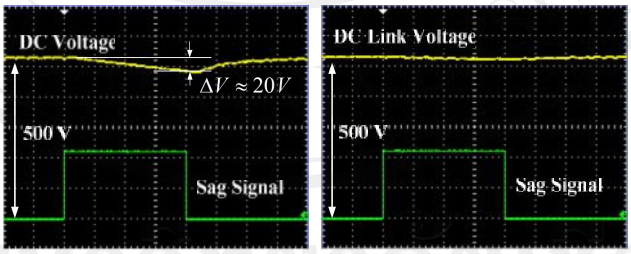
In this case, the three voltage are reduced simultaneously. Under the three-phase voltage sag 100 ms duration, V_a, V_b and V_c magnitude has been reduced to 60% of normal values and DC voltage reduces about 20 V($VV \approx 20\mathbf{V}$) from normal voltage. The experimental results of three-phase 60% sag has shown in Fig.5.5. Fig. 5.5(a) show that all phase voltages and currents have been reduced to 60% of normal value . Under this unbalance load and sag condition, the neutral current is reduced as shown in Fig. 5.5(a) due to reduced load current. Fig 5.5(b) shows the V_a, V_b, V_c, I_c and I_n magnitude has been compensated from the 3-phase 4-leg 4-wire inverter, so the load is supplied with almost constant voltage and current. Fig. 5.5(c) shows the DC bus voltage and the sag signal for MSSS and ASSS. As seen from Fig. 5.5(c), DC voltage in three phase sag is dipped more than the case of single phase sag. DC link voltage is also constant due to the operation of boost converter.



(a) The 3-phase voltage, I_c, and I_n of critical load without compensation.



(b) The 3-phase voltage, I_c, and I_n of critical load with voltage sag compensator.



(c) DC Voltage and sag signal for MSSS and ASSS.

Figure 5.5. The experimental results of three-phase 60% voltage sag unbalance load condition, 100 ms duration.

5.4 The experimental results of single-phase voltage sag 60% on nonlinear load.

The system is also simulated with a nonlinear load simulating a adjustable speed drive. The nonlinear load consists of a 3-phase rectifier with capacitor and resistor as shown in Fig. 5.6.

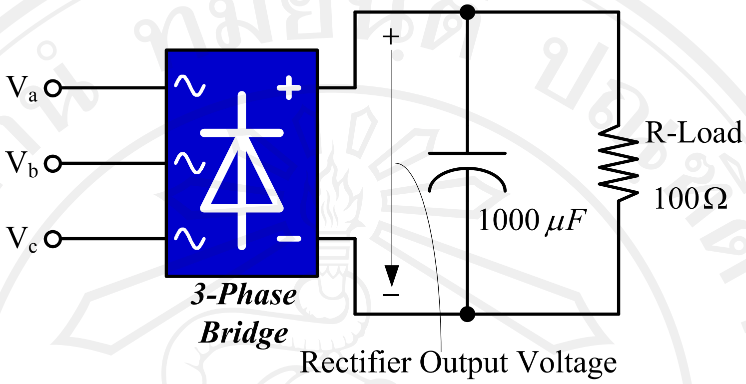
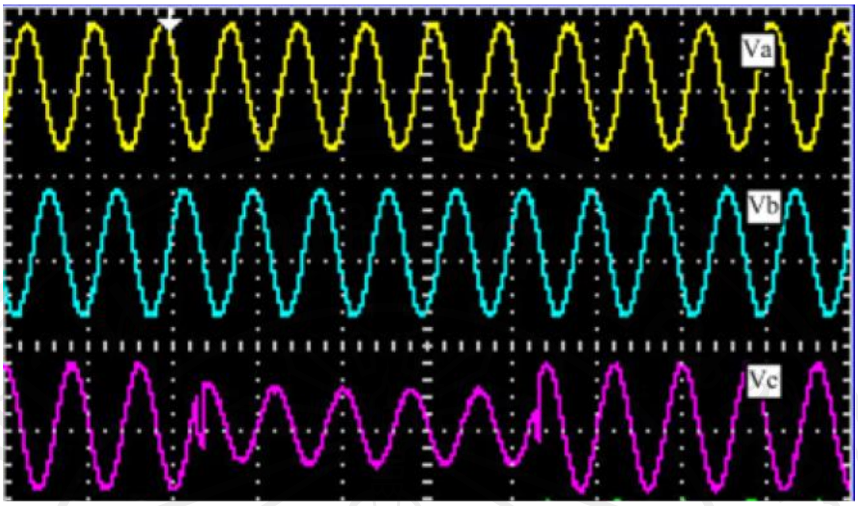


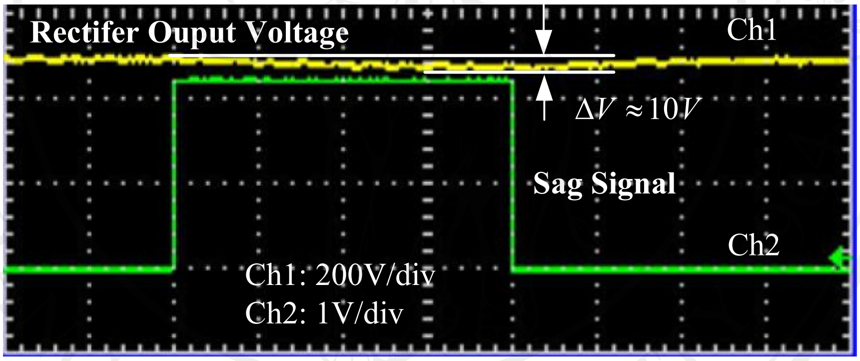
Figure 5.6 The nonlinear load circuit.

In the experiment, a voltage sag compensator connected to a nonlinear load with a 1-phase 60% sag for 5 cycles (100 ms) shown in Fig 5.7. The experimental results in Fig. 5.7 (a) has shown the 3-phase voltage of the 3-phase bridge without compensation. During sag duration, voltage on phase C (Vc) reduces to 60%. Fig. 5.7 (b) shows rectifier output voltage of 3-phase bridge and the sag signal for MSSS and ASSS. During sag duration the rectifier output voltage reduce about 10 V $(VV \approx 10\,\mathbf{V})$ from the normal voltage.

Fig. 5.8 (a) shows the magnitudes of Va, Vb, Vc have been compensated by the 3-phase 4-leg 4-wire inverter so the 3-phase bridge is supplied with almost constant voltage. Fig. 5.8 (b) the rectifier output voltage is also constant due to the input voltage of 3-phase bridge.

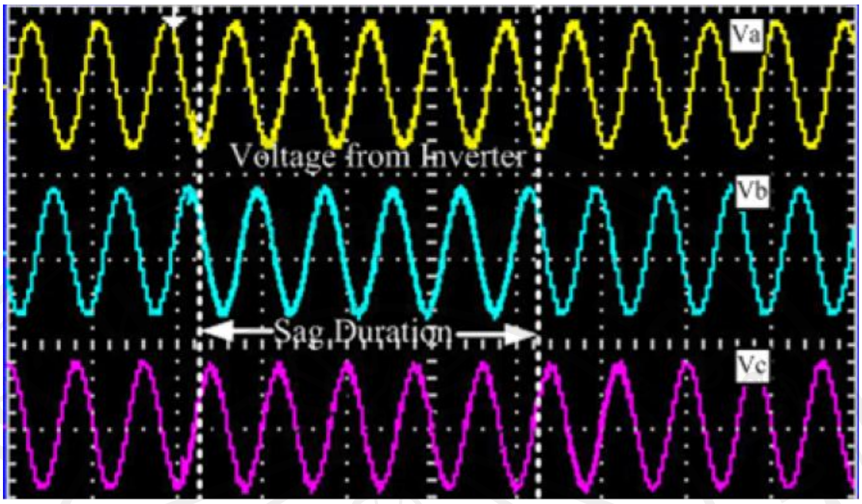


(a) The 3-phase voltage of the 3-phase bridge without compensation.

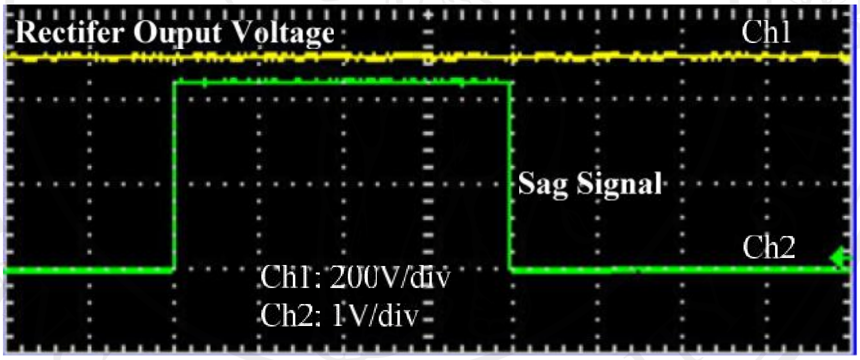


(b) The rectifier output voltage and sag signal for MSSS and ASSS.

Figure 5.7 The experimental results of single-phase 60% voltage sag, 100 ms duration, nonlinear load condition without compensation.



(a) The 3-phase voltage of the 3-phase bridge with compensation.



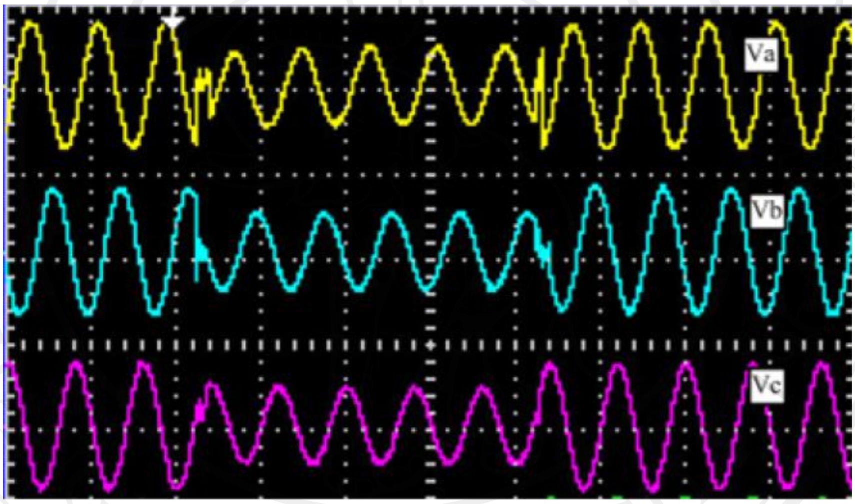
(b) The rectifier output voltage with compensation.

Figure 5.8 The experimental results of single-phase 60% voltage sag, 100 ms duration, nonlinear load condition with compensation.

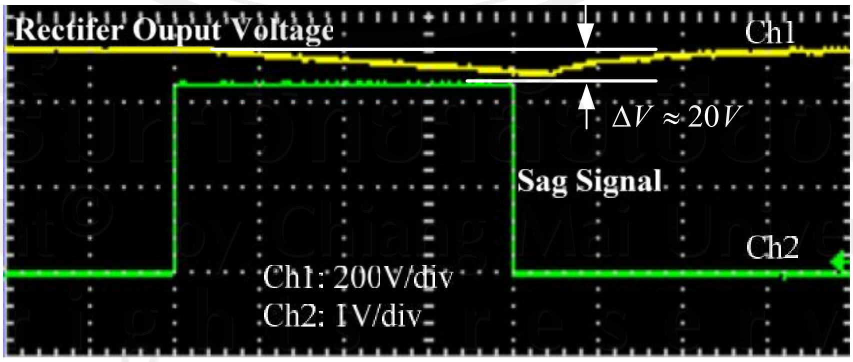
5.5 The experimental results of three-phase voltage sag 60% on nonlinear load.

In this experiment, a voltage sag compensator is connected to a nonlinear load with a 1-phase 60% sag for 5 cycles (100 ms) as shown in Fig 5.9. The experimental results in Fig. 5.9 (a) has shown the 3-phase voltage of the 3-phase bridge without compensation. During sag duration, magnitude of Va, Vb and Vc have been reduced to 60% of the normal value. Fig. 5.9 (b) shows rectifier output voltage of 3-phase bridge and the sag signal for MSSS and ASSS. During sag duration the rectifier output voltage reduce about 20 V ($VV \approx 20\,\mathbf{V}$) from the normal voltage.

Fig. 5.10 (a) shows the magnitudes of Va, Vb, Vc have been compensated by the 3-phase 4-leg 4-wire inverter so the 3-phase bridge is supplied with almost constant voltage. Fig. 5.10 (b) the rectifier output voltage is also constant due to the input voltage of 3-phase bridge.

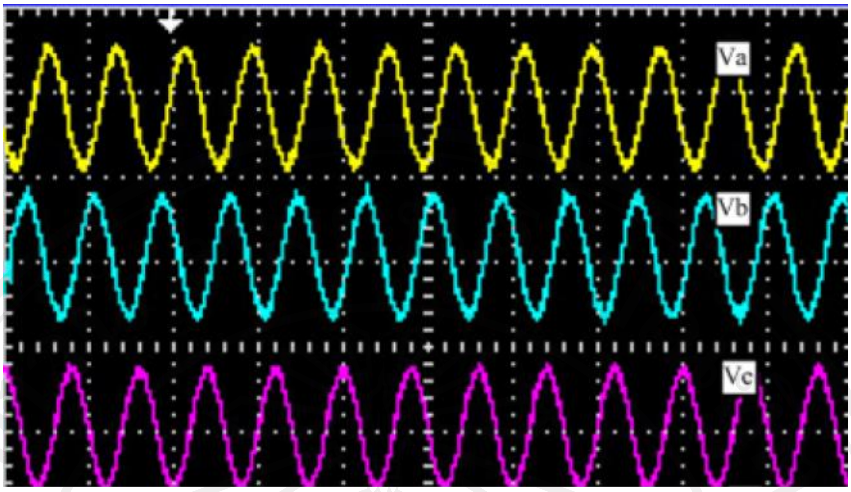


(a) The 3-phase voltage of the 3-phase bridge without compensation.

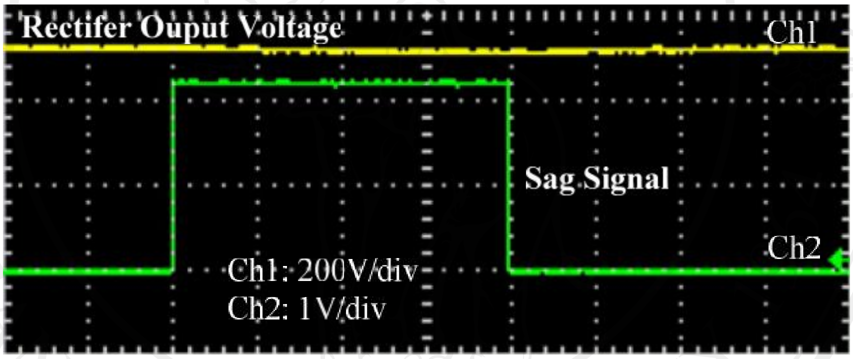


(b) The rectifier output voltage and sag signal for MSSS and ASSS.

Figure 5.9 The experimental results of three-phase 60% voltage sag, 100 ms duration, nonlinear load condition without compensation.



(a) The 3-phase voltage of the 3-phase bridge with compensation.



(b) The rectifier output voltage with compensation.

Figure 5.10 The experimental results of three-phase 60% voltage sag, 100 ms duration, nonlinear load condition with compensation.

5.6 Conclusion

This chapter has presented the experimental results of 3-phase 4-wire 4-leg voltage sag compensator based on three dimensional space vector modulation in abc algorithm. The operation of voltage sag compensator has been verified through voltage sag of 1-phase and 3-phase under unbalance and nonlinear load. The experimental results have shown that the voltage sag compensator is able to supply constant voltages to the loads under unbalanced and nonlinear load conditions and voltage sags. In addition, it is able to regulate the DC-Link voltage during the occurrence of voltage sags. Therefore, this voltage sag compensator is able to mitigate power quality problem when supplying to critical loads.