

Controlling of Induction Motor By Using 18 Switch Sparse AC-Link Buck-Boost Inverter

M.Sreenath¹(M.TECH), C.Praveen² M.TECH

Dept of Power Electronics and Electrical Drives, C.R.E.C, Tirupati, Andhra Pradesh, India¹ Dept of Electrical & Electronics Engg, C.R.E.C, Tirupati, Andhra Pradesh, India²
¹mangirisreenath@gmail.com, ²praveenchukkala37@gmail.com

Abstract—

During the last few years the soft-switching ac-link universal power converters have received noticeable attention. These converters can be configured as dc-dc, dc-ac, ac-dc, or ac-ac and these are compact, reliable, and offer longer life time compared to the other types of converters. However, they have more advantages they require more switches, which make the control process more complicated. In this project we have proposed a modified configuration for the dc-ac power conversion, which reduces the actual number of switches without changing the principles of operation. Despite of reducing the number of switches from 20 to 18, the partial resonant time, during which no power is transferred, is as short as the original configuration. In this project we have presented the operation configuration of Induction motor, how it is controlled by using 18 switch sparse AC-link buck boost inverter and compares the efficiency, the failure rate, and the current rating of the switches in the proposed and original inverters. The sparse configuration shows that failure rates are lower than the original configuration. If we use reverse blocking IGBT's in the sparse configuration then the efficiency of the proposed inverter will be improved significantly. The performance of the proposed inverter through simulation and experiment were evaluated.

Index Terms—Bidirectional, buck--boost converter, inverter, Induction motor, soft-switching.

I. INTRODUCTION

Partial resonant ac-link converters were also called as soft-switching AC-link universal power converters. The input and output of this converter can be in any form. Therefore it can be in the form of dc-dc, dc-ac, ac-dc, or ac-ac configurations. The soft-switching ac-link universal power converters have many advantages when compared to other types of converters. The 18 switch sparse ac-link converter is an extension of the dc-dc buck-boost converter. This converter is capable of both stepping up and stepping down the voltages, where as matrix converters and three-phase voltage source inverters are not. Because of the complementary switches and modified switching scheme, the link inductor, which is the main energy storage element will have the alternating current instead of direct current. This approach improves the performance of the converter and significantly increases the utilization of the link inductor. The frequency of the link current and voltage of the converter are only limited by the characteristics of the switches. There it has high frequency. The converter benefits from the soft switching when by placing a small capacitor in parallel with the link inductor. In this converter the link resonates just for a short time in each link cycle.

Therefore, the LC pair has small reactive ratings.

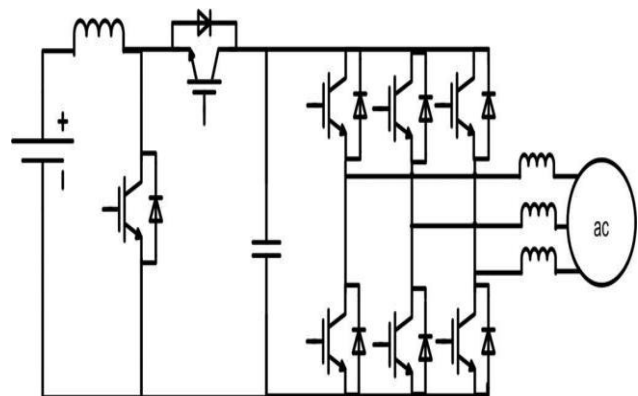


Fig.1. Conventional bidirectional inverter (two-stage).

There is no need for the dc electrolytic capacitors at the link in this soft-switching ac-link universal power converter because of its alternating link current and voltage. The integral parts of the conventional dc-link ac-ac converters and the two-stage bidirectional inverters are electrolytic capacitors which are formed by bidirectional dc-dc converters and voltage source inverters to provide the possibility of regulating the

dc-side current as shown in Fig. 1. The high-failure rate is the main problem with the electrolytic capacitor and is especially at high temperatures. The converters with electrolytic capacitors are expected to have shorter lifetime when compared to others. The advantage of the ac-link converters is the possibility of having galvanic isolation with a single-phase high-frequency transformer. Where as in three-phase voltage source inverter, galvanic isolation is provided by a three-phase low-frequency transformer. The schematic of the dc-ac configuration, called ac-link buck-boost inverter in this paper, is represented in Fig. 2. Even though this inverter is still a new technology, it has a very promising future. In spite of all the advantages of the ac-link buck-boost inverter, it requires more switches compared to the further inverters, which makes the control process more complex. In this paper, a modified configuration that has all the advantages of the ac-link buck-boost inverter but requires less switches is proposed.

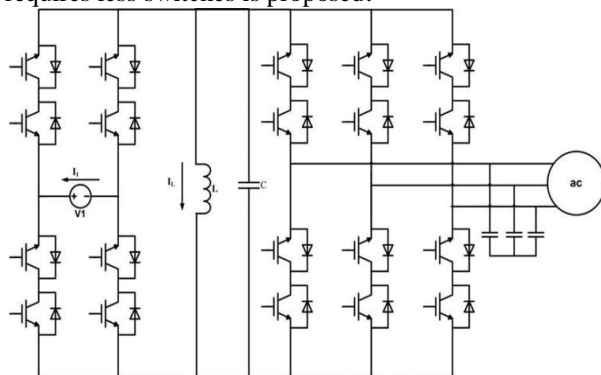


Fig. 2. AC-link buck-boost inverter

The fig.5 shows the proposed inverter which has higher reliability compared to the ac-link buck-boost inverter. The important feature of the sparse configuration is that due to using unidirectional switches, it can be fabricated by switch modules. These are more compact and more cost-effective.

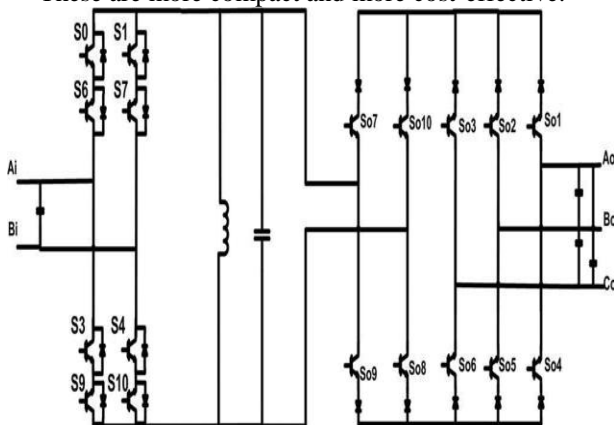


Fig. 3. Proposed inverter when keeping the dc side similar to the ac-link buck-boost inverter.

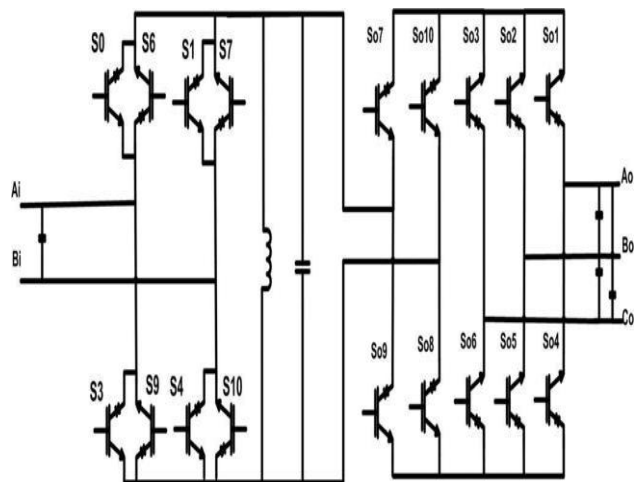


Fig. 4. Proposed inverter with reverse-blocking IGBTs.

The Fig. 5, shows the proposed inverter which has higher reliability compared to the ac-link buck-boost inverter. The important feature of the sparse configuration is that due to using unidirectional switches, it can be fabricated by switch modules. These are more compact and more cost-effective. For this reason, the sparse configuration is expected to be less expensive, less complicated, and more compact compared to the existing inverter. Although using uni-directional switches, the sparse ac-link buck-boost inverter can also support bidirectional power flow. Fig. 5 shows that this method of switch reduction has not led to any switch count reduction at the input side.

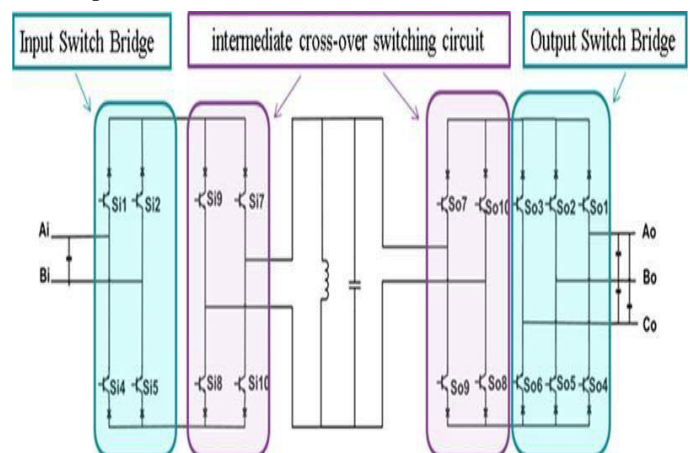


Fig. 5. Proposed inverter.

so, we may keep the dc side as the original converter, as shown in Fig. 3. There is a diode in series with each IGBT in the figs.5 and fig.3. Since conventional IGBTs cannot block the reverse voltage, a diode is connected in series with each IGBT. In case reverse-blocking IGBTs are used, the sparse configuration can be simplified further, as represented in Fig. 4.

II. PROPOSED CONFIGURATION AND PRINCIPLES OF OPERATION

The ac-link buck–boost inverter, shown in Fig. 2, the complementary switches are added to provide the link with alternating current. Here the 18 switch sparse configuration, the complementary switches are removed; however, the link current is still alternating. In Fig. 3 it represents the configuration that the number of switches is reduced from 20 to 18. The unidirectional switches are present in both input and output switch bridges, and in order to provide the link with alternating current, the intermediate cross-over switching circuits have been added to both the input side and the output side. Switches Si7, Si8, Si9, and Si10, which form the input-side intermediate cross-over switching circuit, and switches So7, So8, So9, and So10, which form the output-side intermediate cross-over switching circuit, allow the partially resonant circuit to operate bidirectional, which affords the advantages discussed earlier. The performance of the proposed configurations is similar to that of the ac-link buck–boost inverter. The link current and voltage are exactly the same as that of the original configuration, and the partial resonance time is as short as in the original converter. As mentioned before the method used for reducing the number of switches does not lead to any switch count reduction at the input side. To improve the efficiency, the dc side may be kept similar to that of the original existing inverter.

The fig.6 shows the modes of operation of the existing inverter which has 20 switches and the inverter operates in 6 modes. The each mode of operation is shown in the above circuits. There will be 8 switches in the input side i.e is Dc side and there will be 12 switches in the output side i.e is Ac side.

The behavior of the sparse ac-link buck–boost inverter is represented in fig.9. The current/voltage waveforms at different modes are the same as those of the ac-link buck–boost inverter, shown in Fig. 7. As shown in Fig. 8 by adding a single-phase, high-frequency transformer to the link, the sparse ac-link buck–boost inverter can provide galvanic isolation. Due to leakage inductance of the transformer, the link capacitor needs to be split into two capacitors placed at the primary and the secondary of the transformer. if not at the end of the charging or discharging mode, depending on which side the capacitor is located at the current of the leakage inductance will have an

immediate change, which outcome in voltage spike.

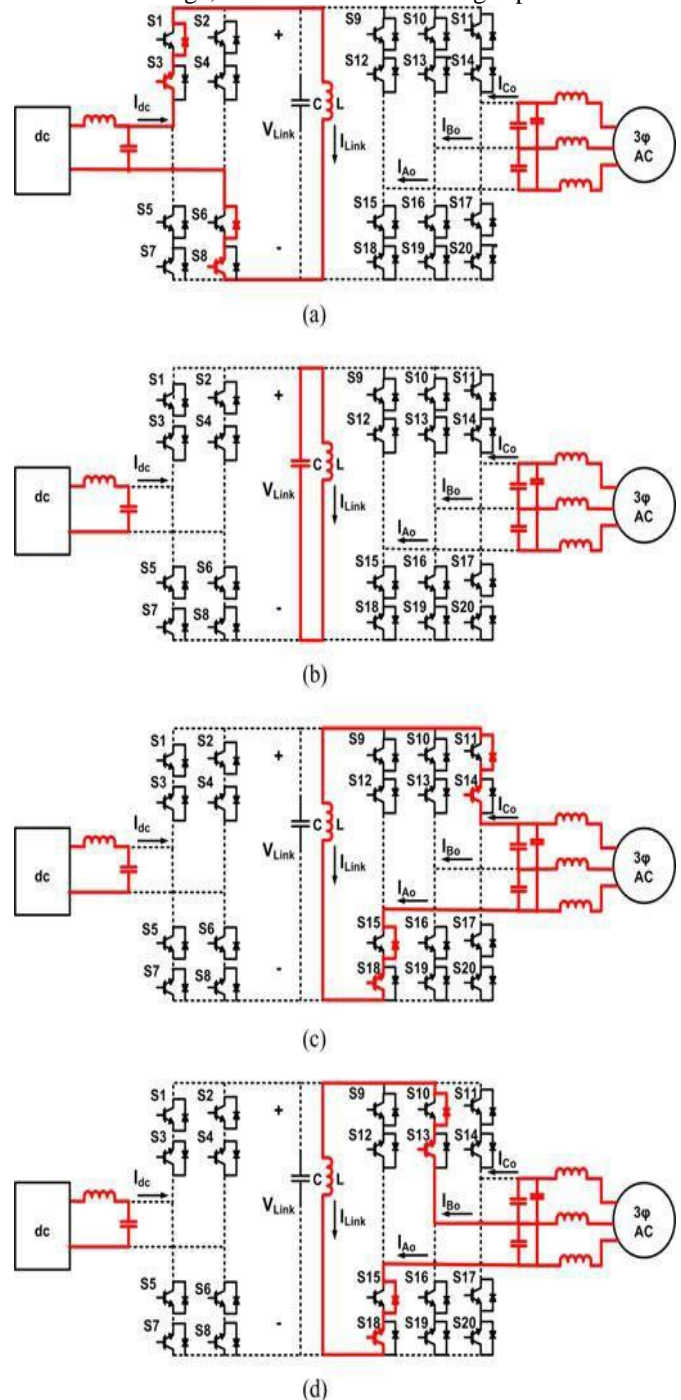


Fig. 6. Behavior of the ac-link buck–boost inverter in different modes of operation: (a) Mode 1. (b) Mode 2, 4, and 6. (c) Mode 3. (d) Mode 5.

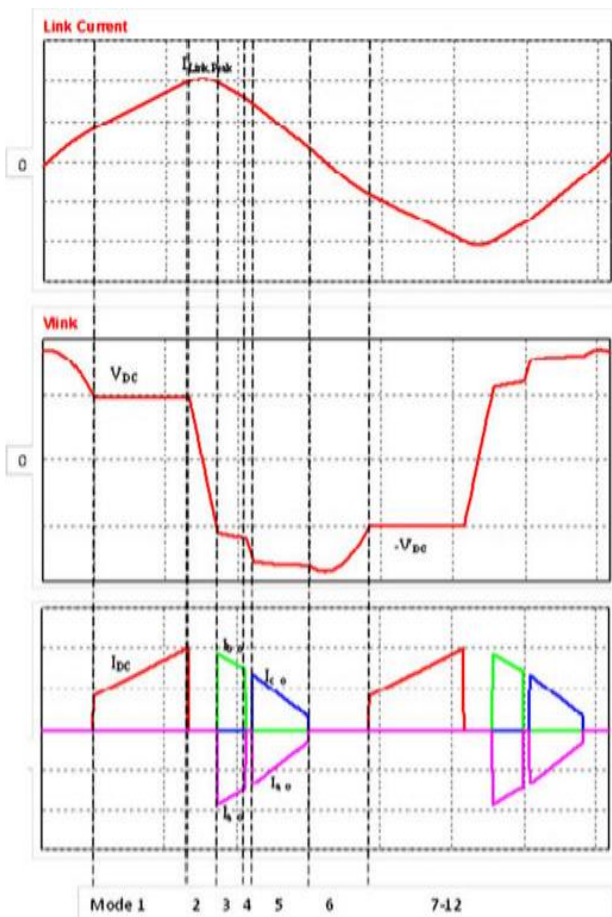


Fig. 7. Link current, link voltage, and unfiltered input and output currents in the ac-link buck-boost inverter.

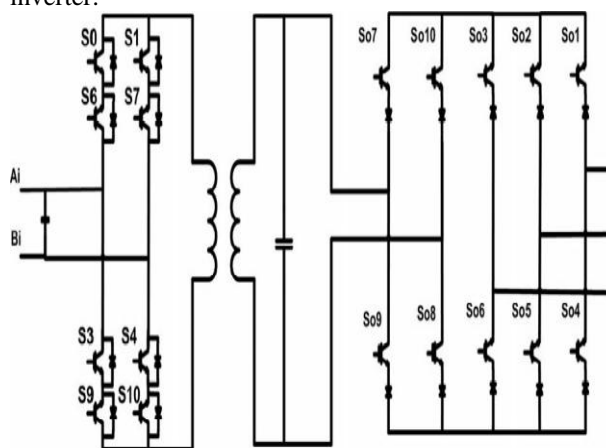


Fig. 8. Sparse ac-link buck-boost inverter with galvanic isolation.

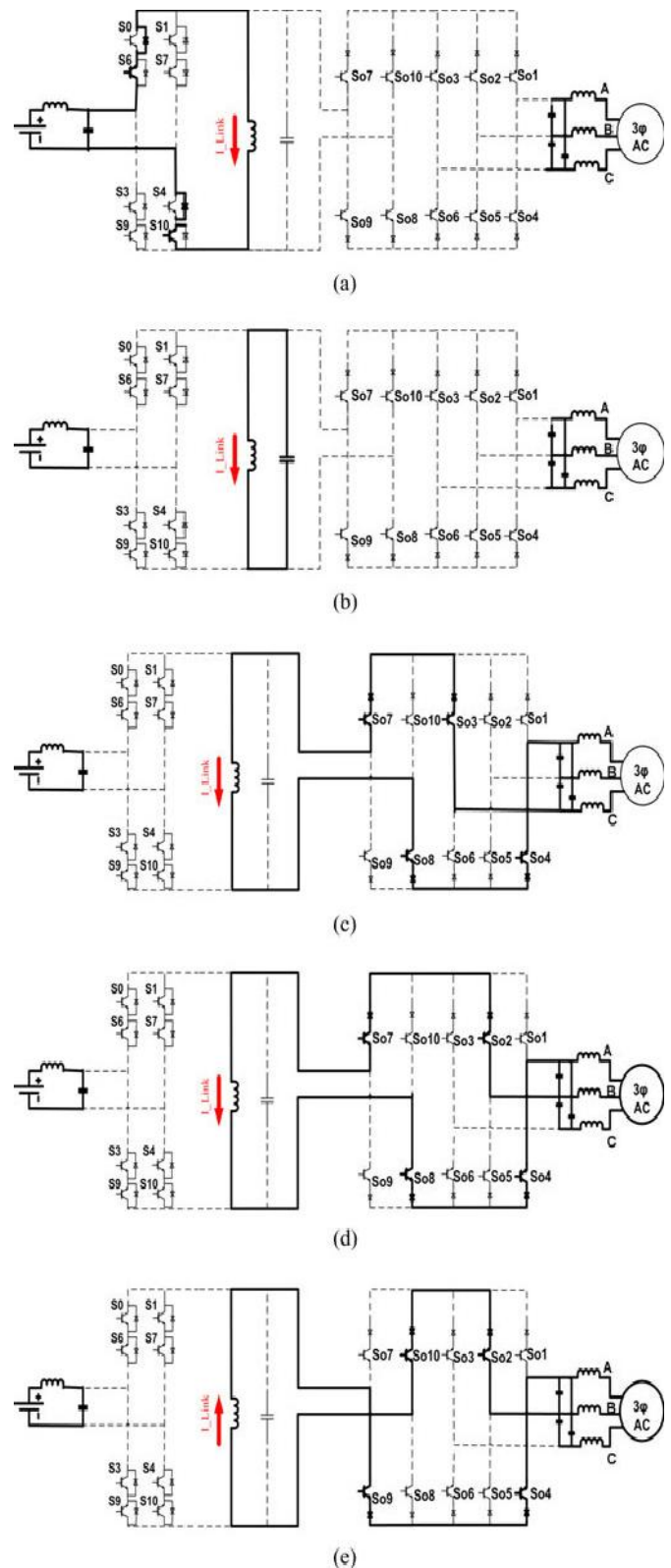


Fig. 9. Behavior of the sparse ac-link buck-boost inverter during different modes of operation: (a) Mode 1. (b) Mode 2, Mode 4, and Mode 6. (c) Mode 3. (d) Mode 5. (e) Mode 11.

III. COMPARISON OF THE AC-LINK BUCK– BOOST INVERTER AND THE SPARSE AC- LINK BUCK–BOOST INVERTER.

The detailed design procedure of the Ac-link buck- boost inverter may be found in [6].In sparse and original ac-link buck–boost inverter the designing link parameters is same. Due to the unequal number of switches at the output side and consequently different switch conduction periods in these converters, the ac-side switch ratings will be different. In both converters the link current is the same. As a result, the peak of current each switch should tolerate is the same, but, the average currents passing through the switches in the original and the sparse ac-link buck–boost inverters are dissimilar.

A. Efficiency, B. Reliability

In this part, the efficiency of the original and the sparse ac-link buck–boost inverters will be estimated and compared. We will start with the ac-link buck–boost inverter, as shown in Fig. 2. In this inverter switches S2 and S5 at the input side and S9, S10,S11, S15, S16, and S17 at the output side, may conduct only during the half-cycles that the link current is negative. Switches S12, S13, S14, S18, S19, S20, S3, and S8 may conduct during the half cycles that the link current is positive. If the reverse blocking IGBTs are used, as shown in Fig. 4.The conduction loss will be reduced.

TABLE I
PARAMETERS OF THE DESIGNED INVERTERS

Parameter/Component	Value/ Part number
Power rating	1.5 kW
Input voltage (dc)	200 V
Output voltage (three-phase ac)	208 V
Link Inductance (L)	884 μ H
Link Capacitance (C)	400 nF
IGBT	IRG7PH42UDPBF-ND $V_{CES}=1200$ V, $I_C=45$ A

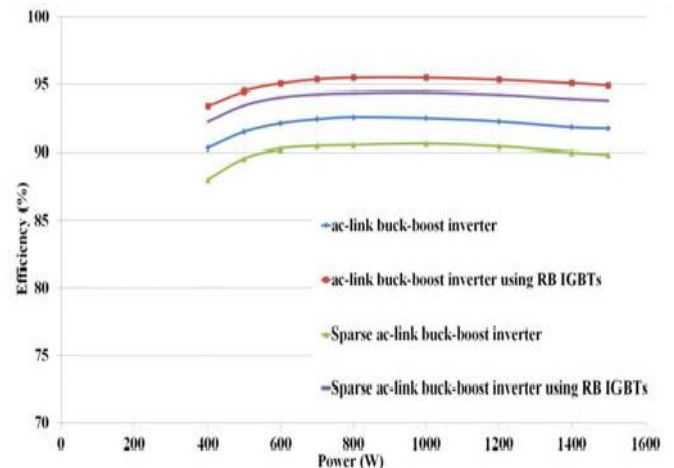


Fig. 10. Efficiency of the sparse and conventional ac-link buck–boost inverters.

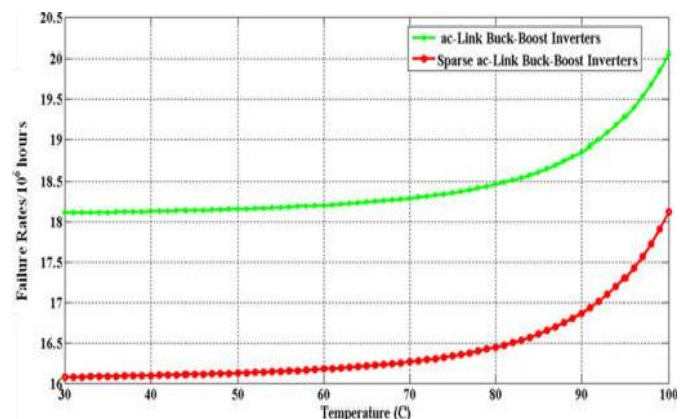


Fig. 11. Failure rates of the sparse ac-link buck–boost inverter and the conventional ac-link buck–boost inverter.

IV. SIMULATION AND EXPERIMENTAL RESULTS

Here the performance of the bidirectional sparse ac-link buck–boost inverter will be evaluated during simulations and experiments. These results will be compared with the experimental results of the original configuration. The parameters of the simulated and tested inverters are listed in Table I.

Figs. 12–14 shows the simulation results corresponding to the dc–ac mode of operation in the sparse ac-link buck–boost inverter operating at 800 W. Fig. 12 represents the dc-side current and the scaled voltage in this inverter. The dc voltage is 200 V, and the dc-side current is regulated at 4.4

- A. The losses have been modeled in the simulation. The ac-side currents and the link current/voltage are represented in Figs. 13 and 14, respectively. As seen in this figure, the peak and the frequency of the link current are 17.75 A and 3.77 kHz, respectively.

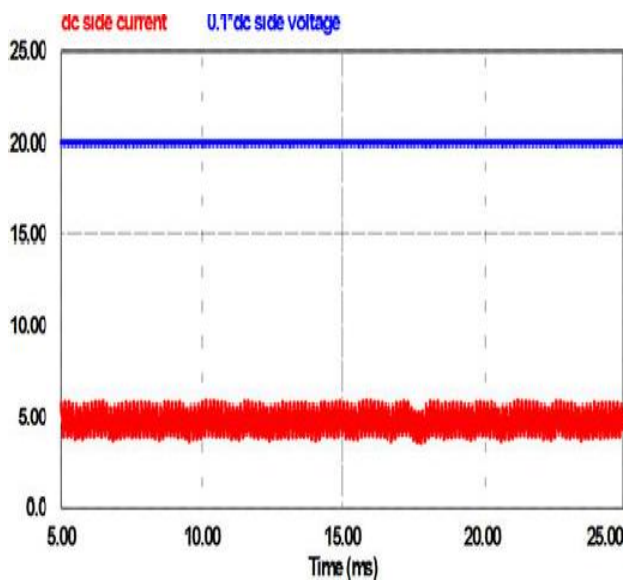


Fig. 12. DC-side current and scaled voltage in the sparse ac-link buck-boost inverter (simulation, dc-ac power flow).

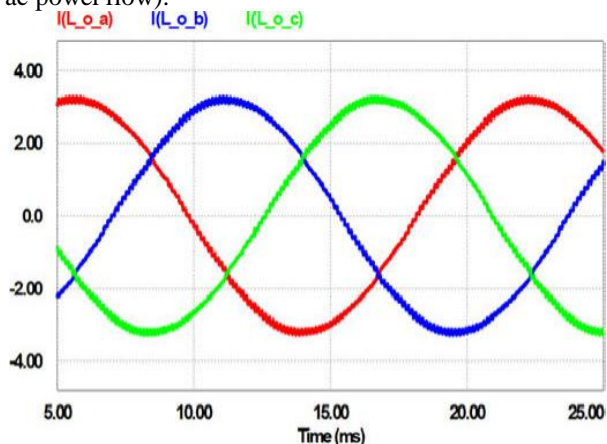


Fig. 13. AC-side currents in the sparse ac-link buck-boost inverter (simulation, dc-ac power flow).

Fig. 15 shows the dc-side voltage/current. Similar to the simulation, the input voltage is 200 V. The ac-side current is represented in Fig. 16. A three-phase Induction motor has been used in this test as load; however, this inverter does not have any limitations on the type of the load. Link current and voltage are illustrated in Fig. 17. The peak of the link current is 17.39 A, which is very close to the simulation results of the sparse configuration. The maximum link voltage is 326 V, and the link frequency is 3.75 kHz in this case.

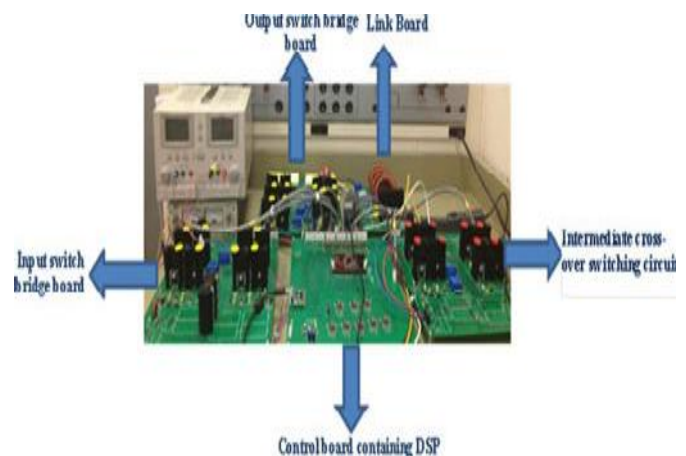


Fig. 14. Low power prototype

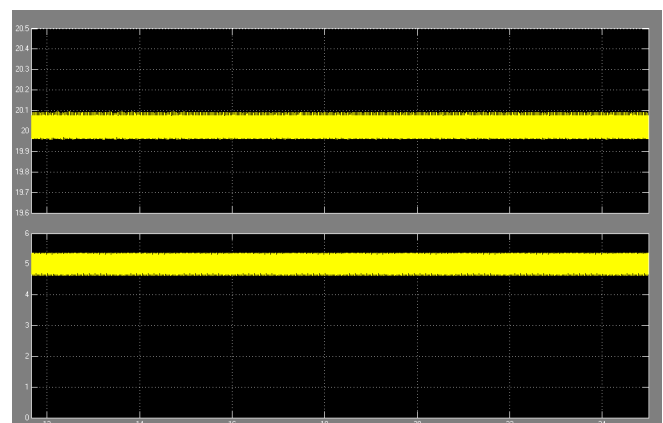


Fig. 15. DC-side current and voltage in the ac-link buck-boost inverter (dc-ac operation, experimental results), time scale: 20 ms/div, voltage scale: 50 V/div, current scale: 2 A/div.

Figs. 15–17 represent the experimental results corresponding to this inverter when the prototype is operating in the dc-ac mode at 800 W. The input side will be the dc and the output side will be the ac. Both the original and sparse ac-link buck-boost inverters have been experimentally evaluated. Fig. 14 show the prototype it consists of four boards and five boards for testing the original and the sparse ac-link buck-boost inverters.

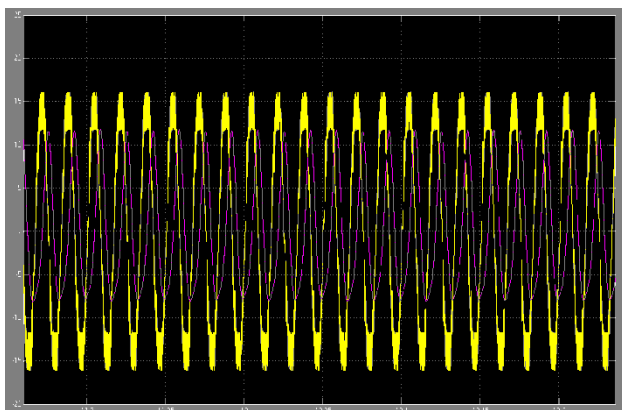


Fig. 16. AC side currents in the ac-link buck–boost inverter (dc–ac operation, experimental results), time scale: 2 ms/div, current scale: 1 A/div.

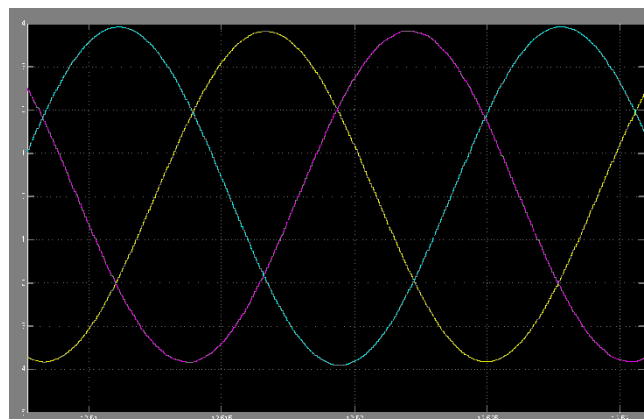


Fig. 19. AC-side currents in the sparse ac-link buck–boost inverter (experiment, dc-ac power flow), time scale: 2 ms/div, current scale: 1 A/div.

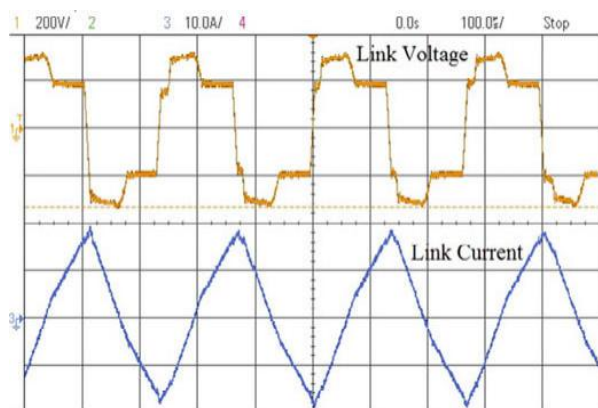


Fig. 17. Link voltage and current in the ac-link buck–boost inverter (dc–ac operation, experimental results), time scale: 100 μ s/div, voltage scale: 200 V/div, current scale: 10 A/div.

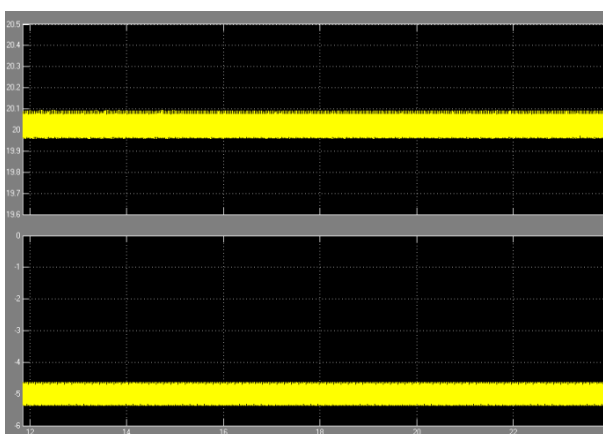


Fig. 18. DC-side current (top) and voltage (voltage) in the sparse ac-link buck– boost inverter (experiment, dc–ac power flow), time scale: 2 ms/div, voltage scale: 50 V/div, current scale: 2 A/div.

V. CONCLUSION

In this project we have reduced the switches from 20 to 18. The switch current rating, the efficiency, and the failure rates of the proposed inverter were compared with those of the original configuration. The efficiency of the system is improved and failure rates of the system were decreased. It was shown that the switches in the proposed configuration should withstand higher average current; however, the peak current they tolerate is the same as the peak current switches in the ac-link buck–boost inverter tolerate. The characteristics of the Induction motor were improved.

REFERENCES

- [1.] Mahshid Amirabadi “Sparse AC-Link Buck–Boost Inverter” *IEEE Transactions on Power Electronics*, vol. 29, no. 8, August 2014
- [2.] W. C. Alexander, “Universal power converter,” U.S. Patent 2008/ 0013351A1, Jan. 17, 2008.
- [3.] A. Balakrishnan, H. A. Toliyat, and W. C. Alexander, “Soft switched ac link buck boost converter,” in *Proc. Twenty-Third Ann. IEEE Appl. Power Electron. Conf. Expo.*, Feb. 2008, pp. 1334–1339.
- [4.] H. A. Toliyat, A. Balakrishnan, M. Amirabadi, and W. Alexander, “Soft switched ac-link AC/AC and AC/DC buck-boost converter,” in *Proc. IEEE Power Electron. Spec. Conf.*, 2008, pp. 4168–4176.
- [5.] M. Amirabadi, H. A. Toliyat, and W. Alexander, “Battery-utility interface using soft switched AC link supporting low voltage ride through,” in *Proc. IEEE Energy Convers. Congr. Expo. Conf.*, 2009, pp. 2606–2613.
- [6.] M. Amirabadi, A. Balakrishnan, H. Toliyat,

- and W. Alexander, "High frequency ac-link PV inverter," *IEEE Trans. Ind. Electron.*, vol. 61, no. 1, pp. 281–291, Jan. 2014.
- [7.] M. Amirabadi, "Soft-switching high-frequency ac-link universal power converters with galvanic isolation," Ph.D. dissertation, Texas A&M Uni-versity, College Station, TX, USA, 2013.
- [8.] T. A. Lipo, "Resonant link converters: A new direction in solid state power conversion," presented at Second Int. Conf. Electrical Drives, Eforie Nord, Romania, Sep. 1988.
- [9.] P. K. Sood, T. A. Lipo, and I. G. Hansen, "A versatile power converter for high frequency link systems," *IEEE Trans. Power Electron.*, vol. 3, no. 4, pp. 383–390, Oct. 1988.
- [10.] F. C. Schwarz, "An improved method of resonant current pulse modulation for power converters," *IEEE Trans. Ind. Electron. Control Instrum.*, vol. 23, no. 2, pp. 133–141, May 1976.

AUTHOR BIOGRAPHY



M.SREENATH received B.Tech degree in EEE from KMMITS engineering college, Tirupati in 2013 and Presently pursuing M.Tech in Power Electronics and Drives from CREC, Tirupati, Andhra Pradesh, India.



C.PRAVEEN received B.Tech degree in EEE from SKIT engineering college, Srikalahasti in 2009, M.Tech degree in Electrical power systems from SVP CET college, Puttur in 2012 and currently working as an Asst. Professor in Department of EEE, CREC, Tirupati, Andhra Pradesh, India.