A Three phase Transformerless Buck Boost AC/AC converter for Induction motor fed drive applications

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ABSTRACT
This paper proposes a three phase transformerless AC/AC converter which can perform both buck and boost operations based on the voltage requirements. This AC/AC converter is mainly proposed for the three phase induction motor drives with the intention to reduce the high inrush current of the conventional motor used in industrial applications. The merits of the proposed AC/AC converter can be understood with the fact that the use of magnetic elements are eliminated and the voltage stress of the active switches can be reduced to half the supply voltage by carefully choosing the capacitor values. In addition, the voltage applied to the load increases/decreases gradually thereby preventing the high inrush current from affecting the load. The bidirectional operation of this converter is possible by taking a common reference point between the supply and the load side voltages. This particular feature points out an added advantage for this proposed converter. In this paper the performance of the proposed converter is analyzed by simulating the results for a 110/220 V, 1 KW induction motor.

Keywords: Transformerless, AC/AC converter, inrush current, bidirectional

I. INTRODUCTION
In the present scenario the use of three phase induction motor is widely used in industrial applications. The conventional AC/AC converter uses an auto transformer which like any other electromagnetic transformers causes interferences resulting in noise. There are also problems associated with copper and core losses. In addition frequent maintenance of transformers is required. In order to overcome the above drawbacks, the use of auto transformer is ignored in the proposed converter.
The use of multilevel inverters reduces the voltage stress to a higher rate thus reducing the size of the semiconductor switches. With the addition of switched capacitors along with the multilevel level inverters can be used to regulate the output voltage. In addition, with the common reference point taken between the input and voltage makes the AC/AC converter to operate in both buck and boost modes. And also the voltage applied to the load increases/ decreases gradually the high inrush current is avoided during the starting period.

In a three phase induction motor, the induced emf in the rotor circuit depends on the slip of the induction motor and the magnitude of the rotor current depends upon this induced emf. When the motor is started, the slip is equal to 1 as the rotor speed is zero, so the induced emf in the rotor is large. As a result, a very high current flows through the rotor. This is similar to a transformer with the secondary coil short circuited, which causes the primary coil to draw a high current from the mains. Similarly, when an induction motor starts, a very high current is drawn by the stator, on the order of 5 to 9 times the full load current.

II. PROPOSED SYSTEM
The proposed converter consists of a three, single phase bidirectional AC/AC converter which is powered by a three phase supply. Each phase consists of a three level inverter with four switches namely S₁, S₂, S₃ and S₄. There are three switch capacitors namely C₁, C₂ and C₃. The voltage stress across the active switch is reduced to one half of the input supply voltage. Finally the converter is connected to the three phase induction motor load. A common reference point is taken between the input and output supply voltages, thus providing an ease in bidirectional operation.

A. Block Diagram of the proposed system
The block diagram of the proposed system is shown below in Fig.1

![Fig.1 Block diagram of the proposed system](image-url)

The three phase supply of 110/220 V is given to AC/AC converter where the voltage is either stepped up or stepped down based on the input side connections. The output voltage is given to the three phase induction motor load.

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The block diagram (Fig.1) illustrates the connection of the three phase supply to the AC/AC converter and then to the induction motor. The converter is designed to operate in both buck and boost modes, allowing for variable voltage control.

The details within the block diagram are as follows:
- **Three Phase AC supply**: The input source for the converter.
- **Transformerless AC/AC converter**: The central component that performs the voltage conversion.
- **Three Phase Induction Motor**: The output device that receives the converted voltage.

In the diagram, the flow of energy is depicted from the AC supply to the motor, highlighting the bidirectional nature of the converter.
B. Circuit Diagram of proposed system

Fig. 2 Single phase representation of the Proposed AC/AC converter: (a) step-down configuration, (b) step-up configuration, (c) gate drive signals, and (d) bidirectional switch model and its practical implementation using two MOSFETs.

The single phase representation of the proposed converter is shown in Fig. 2. Three such structures are required for operating the AC/AC converter for a three phase supply. In order to perform the buck operation, the input supply is connected across both the capacitors, whereas to operate the converter in boost mode, the input voltage supply is connected across $C_3$.

Fig. 3 Performance of the proposed AC/AC converter during the positive and negative half cycle of the input supply while performing the Buck operation.

The proposed AC–AC converter operating as a buck converter presents two operation stages per switching period. During the positive half of the voltage, with the converter in the step-down configuration, these stages can be described as follows. First stage starts when switches $S_1$ and $S_3$ are turned ON. Capacitor $C_2$ discharges and capacitor $C_3$ charges during the first part of this stage ($\Delta t_1$ A). When their currents reach zero, $C_2$ starts to charge and $C_3$ starts to discharge until the end of the stage ($\Delta t_1$ B). Capacitor $C_1$ charges throughout this stage and the power source $v_H$ delivers energy to the circuit. Switches $S_1$ and $S_3$
are turned OFF at the end of the first stage. This topological stage is shown in Fig. 3(a). Second stage starts when switches S₂ and S₄ are turned ON. Initially, the power source receives energy from the circuit, capacitor C₂ discharges, and capacitor C₃ charges until their currents reach zero (Δt₂ A). After this, the power source delivers energy to the circuit, capacitor C₂ charges and capacitor C₃ discharges until the end of the stage (Δt₂ A). Capacitor C₁ discharges throughout this stage. Switches S₂ and S₄ are turned OFF at the end of the second stage. This topological stage is shown in Fig.3(b). After the second stage, another switching period starts from the first stage. In the negative half-cycle of the grid, the converter has similar operation stages with different current directions, as can be seen in Fig. 3(c) and (d).

III. SIMULATION RESULTS AND DISCUSSIONS
The performance of the proposed AC/AC converter is analyzed for both Boost operation.

An input voltage of 110 V is applied to the three phase AC/AC converter.

Fig.4.1 Three phase Input voltage for boost operation

Fig.4.2 Three phase Stator voltage

Fig.4.3 Three phase stator current

Fig.4.4 Three phase rotor current
The waveforms obtained in the simulation are shown in Fig.4.1, 4.2, 4.3, 4.4, 4.5 and 4.6.

### TABLE I
Simulation Results

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Input voltage</td>
<td>110 V</td>
</tr>
<tr>
<td>2.</td>
<td>Stator voltage</td>
<td>220 V</td>
</tr>
<tr>
<td>3.</td>
<td>Stator current</td>
<td>2 A</td>
</tr>
<tr>
<td>4.</td>
<td>Rotor current</td>
<td>10 A</td>
</tr>
<tr>
<td>5.</td>
<td>Speed</td>
<td>1760</td>
</tr>
</tbody>
</table>

### IV. CONCLUSION

Thus, the performance of the is analyzed by simulating the results for a 110/220 V, 1 KW induction motor. The proposed three phase transformerless AC/AC converter can perform both buck and boost operations based on the voltage requirements. The high inrush current of the conventional motor is highly reduced due to the implementation of this AC/AC converter. The main advantage of the proposed AC/AC converter is that the use of magnetic elements are eliminated and the voltage stress of the active switches are reduced to half the supply voltage by suitable capacitor values. In addition, the voltage applied to the load increases/decreases gradually thereby preventing the high inrush current from affecting the load. The bidirectional operation of this converter is possible by taking a common reference point between the supply and the load side voltages. This particular feature points out an added advantage for this proposed converter.

### REFERENCES


