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Research Article

Efficiency Enhancement of DC to DC Multilevel Boost Converter and Its Applications

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Abstract: The aim of this study is to propose a experimental verification for single-phase to three phase drive system composed of two parallel single-phase rectifiers, a three-phase inverter and an induction motor. Apart from traditional application in dc motor drives, new applications of BDC include energy storage in renewable energy systems, fuel cell energy systems, Hybrid Electric Vehicles (HEV) and Uninterruptible Power Supplies (UPS). A dc-dc converter is always required to allow energy exchange between storage device and the rest of system. In HEV applications, BDCs are required to link different dc voltage buses and transfer energy between them. A non-isolated bi-directional dc-dc converters is used in our project to achieve better efficiency.

Keywords: Bidirectional DC-DC converter, efficiency, induction motor, non isolated

INTRODUCTION

Basic dc-dc converters such as buck and boost converters do not have bidirectional power flow capability. This limitation is due to the presence of diodes in their structure which prevents reverse current flow (Amir *et al*., 2013). In general, a unidirectional dc-dc converter can be turned into a bidirectional converter by replacing the diodes with a controllable switch in its structure (Ahmad *et al*., 2011).

BDCs can be classified into non-isolated and isolated types. Non-isolated BDCs (NBDC) are simpler than Isolated BDCs (IBDC) and can achieve better efficiency. Non-isolated BDC consists controllable switch (Bai and Mi, 2008).

The conventional single phase to three phase drive system with one rectifier produces high rectifier switch current. The proposed topology with two rectifier permits to reduce the rectifier switch currents, the harmonic distortion at the input converter side and presents improvements on the fault tolerance characteristics (Inoue and Akagi, 2007). The model of the system is derived and it is shown that the reduction of circulating current is an important objective in the system design.

Block diagram: The input 230 V single phase supply is given to the transformer circuit which is a step down transformer. A 24 V supply from the transformer is given to the power handler circuit of the PIC controller from which 5 V is given as an operating voltage for the PIC controller. Figure 1 shows the block diagram of DC-DC converter for any load (Rodríguez *et al*., 2007). Stepped down voltage of 110 V is given as the input for the integrated circuit comprising of a rectifier and booster. The rectifier whose input is 110 V AC rectifies the input as 120 V DC output. PIC controller generates a 5 V dc pulse and passes it to the driver circuit (Rosas-Caro *et al*., 2008).

The driver circuit output can be stored in battery and can be used for various DC power applications. The driver circuit output is fed to inverter and converted into AC and AC supply can be driving the three phase induction motor.

Basic dc-dc converters such as buck and boost converters (and their derivatives) do not have bidirectional power flow capability. This limitation is due to the presence of diodes in their structure which prevents reverse current flow. In general, a unidirectional dc-dc converter can be turned into a bidirectional converter by replacing the diodes with a controllable switch in its structure (Salamah *et al*., 2009).

As an example, Fig. 2 shows the structure of elementary buck and boost converters and how they can be transformed into bidirectional converters by replacing the diodes in their structure (Yi-Ping *et al*., 2012). It is noteworthy that the resulted converter has the same structure in both cases.

In the buck mode of operation, i.e., when the power is transferred from the High Voltage (HV) to the Low Voltage (LV) side, Tim (2005) $Q1$ is the active switch while $Q2$ is kept off. In the boost mode, i.e., when the power is transferred from LV to HV side, $Q2$ acts as a controlled switch and $Q1$ is kept off. The switching pattern during power (current) reversal is also shown in Fig. 3 (Yi-Ping *et al*., 2011).

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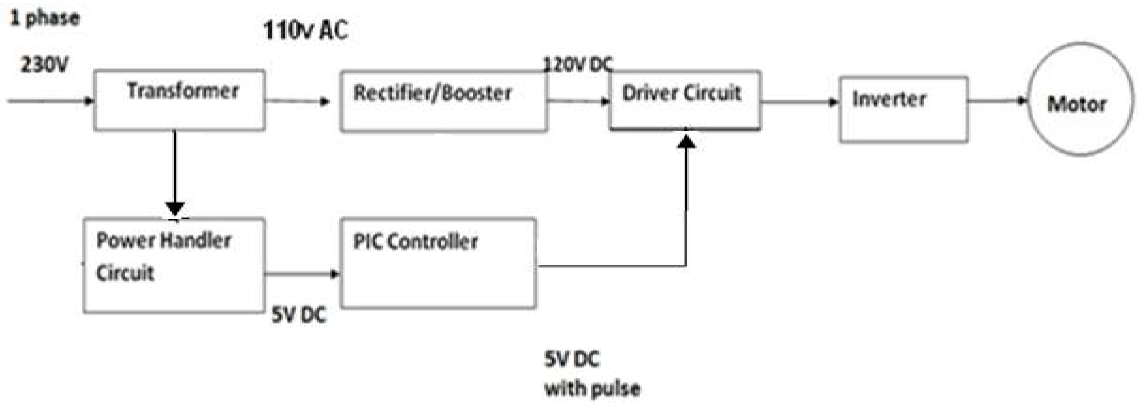

Fig. 1: Block diagram of DC-DC converter for any load

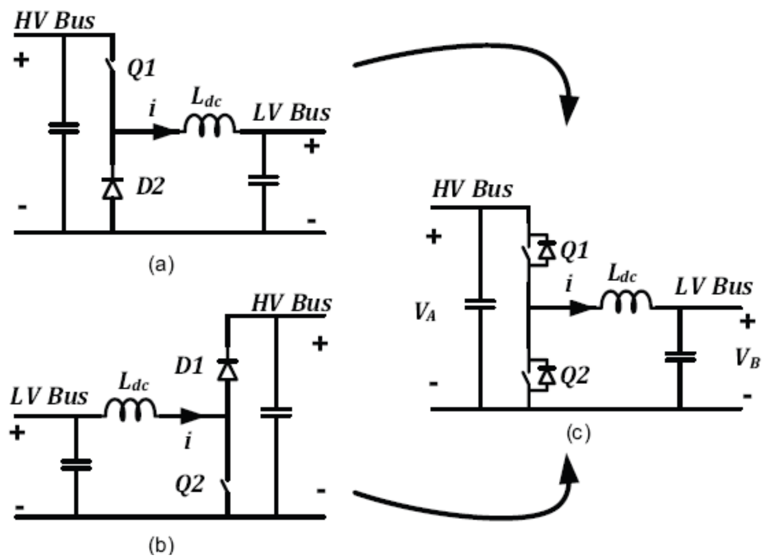

Fig. 2: Non-isolated BDC, (a) elementary unidirectional buck converter, (b) elementary unidirectional boost converter, (c) transformation to bi-directional converter by substituting diodes with controllable switch

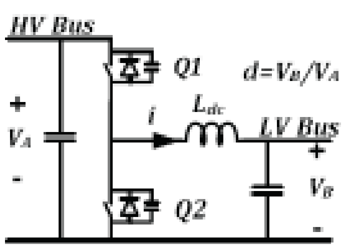

Fig. 3: Basic non-isolated BDC

The presence of inductor in the LV side results in lower ripple current which is advantageous in some applications. For example, it is usually preferred to charge/discharge batteries with low ripple current in order to achieve higher efficiency and longer life time. The objective of this study is to use non-isolated bi-directional dc-dc converter to achieve better efficiency (Fig. 4).

EXPERIMENTAL METHODOLOGY

Single phase to three phase drive system: Several solutions have been proposed when the objective is to supply a three phase motors from a single-phase ac mains. It is quite common to have only a single-phase power grid in residential, commercial, manufacturing and mainly in rural areas, while the adjustable speed drives may request a three-phase power grid.

Conventional single phase to three phase drive system: Single-phase to three-phase ac-dc-ac conversion usually employs a full-bridge topology, which implies in ten power switches. This converter is denoted here as conventional topology. Parallel converters have been used to improve the power capability, reliability, efficiency and redundancy.

Parallel converter techniques can be employed to improve the performance of active power filters,

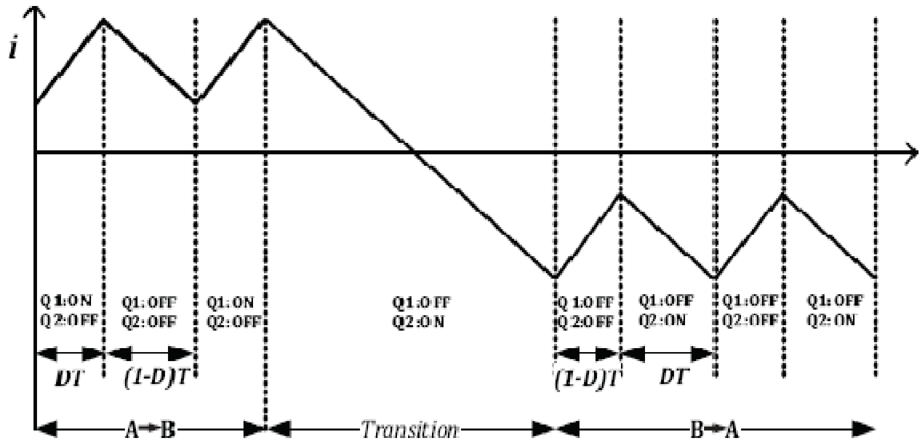

Fig. 4: Operating waveform

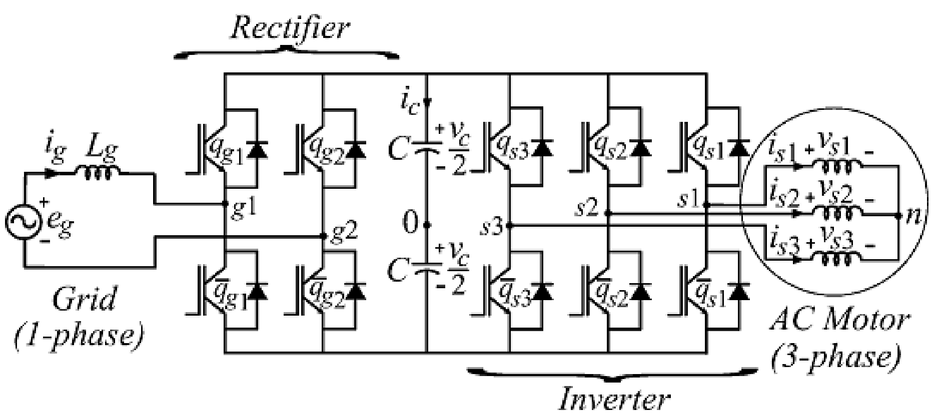

Fig. 5: Conventional drive system

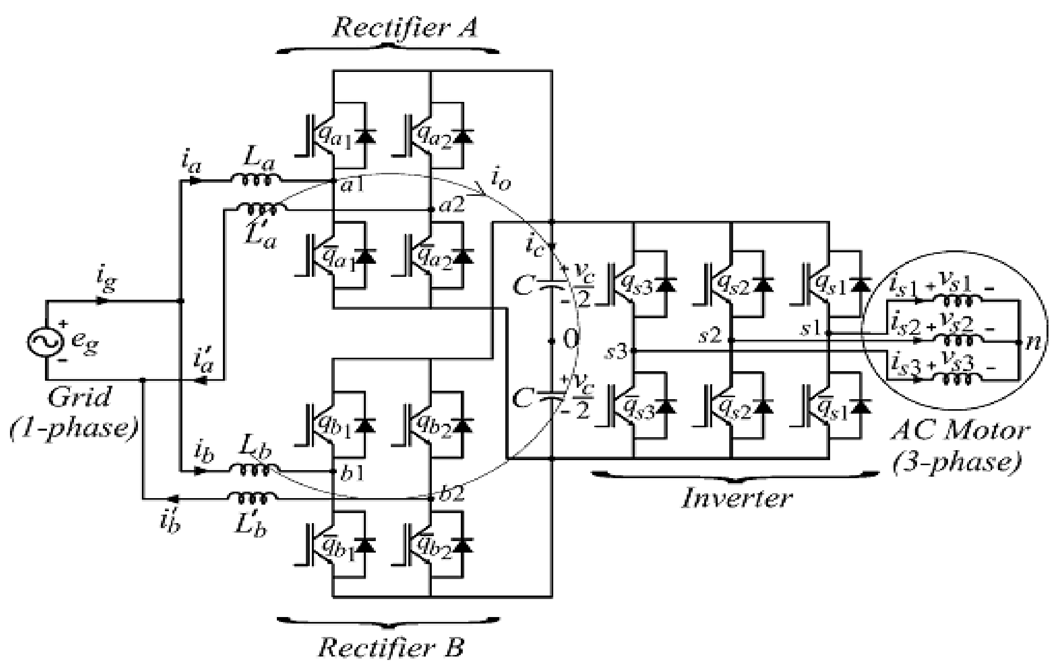

Fig. 6: Proposed drive systems

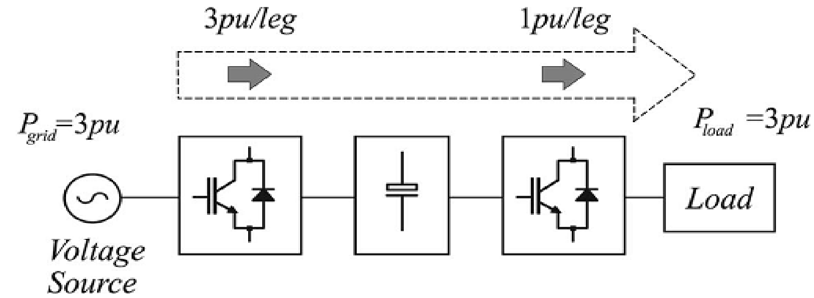

Fig. 7: Conventional single phase to three phase converter

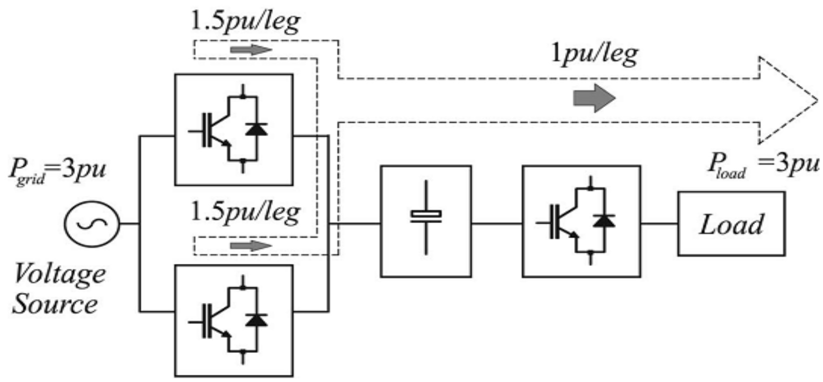

Fig. 8: Proposed system with two rectifiers

Uninterruptible Power Supplies (UPS), fault tolerance of doubly fed induction generators and three-phase drives. Usually the operation of converters in parallel requires a transformer for isolation. Figure 5 shows conventional drive system for AC Motor (3-phase).

However, weight, size and cost associated with the transformer may make such a solution undesirable. When an isolation transformer is not used, the reduction of circulating currents among different converter stages is an important objective in the system design.

Proposed single phase to three phase drive system: A single-phase to three-phase drive system composed of two parallel single-phase rectifiers and a three-phase inverter is proposed (Fig. 6). The proposed system is conceived to operate where the single-phase utility grid is the unique option available (De Doncker *et al*., 1991). Compared to the conventional topology, the proposed system permits: to reduce the rectifier switch currents; the Total Harmonic Distortion (THD) of the grid current with same switching frequency or the switching frequency with same THD of the grid current; and to increase the fault tolerance characteristics (Shih-Ming *et al*., 2011).

In addition, the losses of the proposed system may be lower than that of the conventional counterpart. The aforementioned benefits justify the initial investment of the proposed system, due to the increase of number of switches (Fig. 7 and 8).

RESULTS AND DISCUSSION

The dc-link capacitor current behavior is examined in this section. Figure 9 illustrates the harmonic spectrums of the dc-link capacitor current for the conventional converter (μ = 0.5) and for the proposed converter using single-carrier with μ = 0.5, double-carrier with μ = 0.5 and double-carrier with μ = 0.

The proposed converter using double-carrier with μ = 0 provides the best reduction of the high frequency harmonics. The highest reduction of THD is obtained for the converter using double-carrier with μ = 0. The THD obtained for μ = 1 is equal to that for μ = 0. It is possible to reduce the second order harmonic introduced by single-phase operation, but this is not of interest be-cause it requires unbalancing and increasing rectifier currents.

The harmonic distortion of the converter voltages has been evaluated by using the Weighted THD (WTHD) (Fig. 10):

$$\mathrm{WTHD}(p) = \frac{100}{a_1}\sqrt{\sum_{i=2}^{p}\left(\frac{a_i}{i}\right)^2}$$

where,

a_1 = The amplitude of the fundamental voltage

P = Number of harmonics taken into consideration

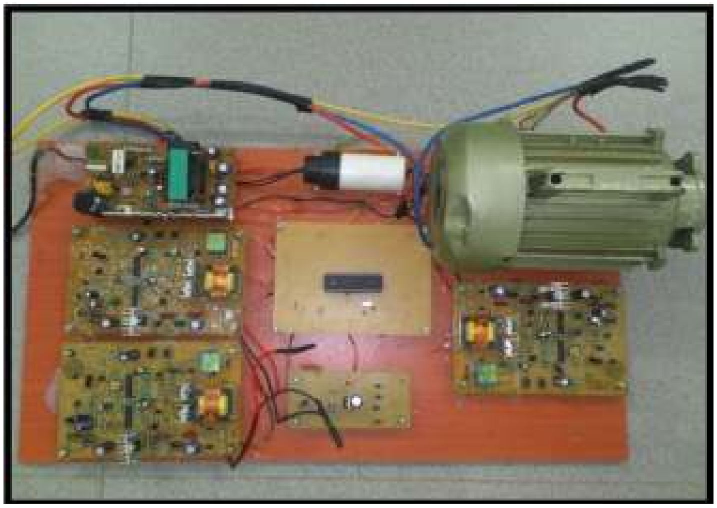

Fig. 9: Experimental setup for Dc-Dc converter for load application

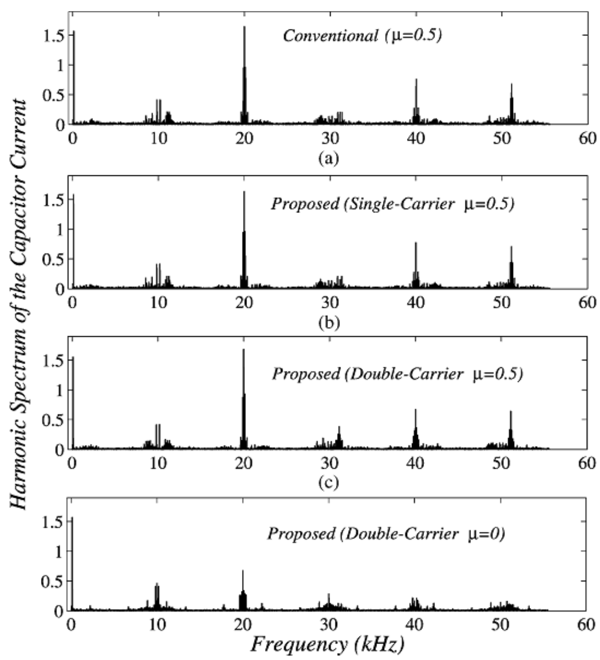

Fig. 10: Harmonic distortion of DC-link capacitor current

Program:

```
#include<pic.h>
static bit pulse1 @ ((unsigned) &PORTB*8+0);
static bit pulse2 @ ((unsigned) &PORTB*8+1);
static bit pulse3 @ ((unsigned) &PORTB*8+2);
static bit pulse4 @ ((unsigned) &PORTB*8+3);
unsigned char count;
void interrupt timer2 (void)
{
    if (T0IF == 1)
    {
        T0IF = 0;
        count++;
        if (count>56) count = 0;
        if (count>1 && count<27) {pulse2 = pulse4 =
        1; pulse1 = pulse3 = 0;}
        else pulse2 = pulse4 = 0;
        if (count>28 && count<55) {pulse1 = pulse3
        = 1; pulse2 = pulse4 = 0;}
        else pulse1 = pulse3 = 0;
        TMR0 = 0xFF;
    }
}
void main()
{
    TRISD = TRISC = 0X00;
    TRISB = 0x00;
GIE = 1;
```

```
    PEIE = 1;
    T0IE = 1; // enable timer0 interrupt
    OPTION = 0x07; // set prescale (256)
    TMR0 = 0xFF;
while (1)
    {
    }
}
```

CONCLUSION

Bidirectional Dc-Dc Converter (BDC) is one of the key elements in electrical energy storage systems. They provide a flexible power processing interface between an energy storage device and the rest of system. Two main families of BDCs are non-isolated and isolated structures, to get high efficiency we use non-isolated BDC. The BDC can be used in renewable energy systems, fuel cell energy systems, Hybrid Electric Vehicles (HEV) and Uninterruptible Power Supplies (UPS).

The complete comparison between the proposed and standard configuration has been carried out in this project. Compared to the conventional topology, the proposed system permits to reduce the rectifier switch currents, to decrease the harmonic distortion and to increase the fault tolerance characteristics. The three phase induction motor cab used in Robotics, Billet Shearing Machines, section Straightening Machines in Rolling mills, grinding machine and varying load machine.

Future scope of this project is, it will be worked along with new technologies like artificial intelligence, fourth generation optical disc, 3D integrated circuit, virtual reality and claytronics.

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