ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Modelling of High Efficient High Step down Single Stage AC/DC Converter for DC Motor Applications

Ch.Rushikeswara Rao
Department of Electronics and
Electrical Engineering,
Sarada Institute of Science Technology and
Management, Srikakulam (Dt), Andhra Pradesh
532404, India.

P.Shiva
Department of Electronics and
Electrical Engineering,
Sarada Institute of Science Technology and
Management, Srikakulam (Dt), Andhra Pradesh
532404, India.

Abstract:

A single stage single switch AC/DC converter is an integration of input current shaper and a DC/DC cell with a shared controller and one active switch. The converter is applicable for digital input power supply with high input power factor and tight output voltage regulation. An ac to dc converter is an integral part of any power supply unit used in the all electronic equipments. In recent years, single-phase switch-mode AC/DC power converters have been increasingly used in the industrial, commercial, residential, aerospace, and military environment due to advantages of high efficiency, smaller size and weight. However, the proliferation of the power converters draw pulsating input current from the utility line, this not only reduce the input power factor of the converters but also injects a significant amount of harmonic current into the utility line. To improve the power quality, various PFC schemes have been proposed. In this project a buck type power factor correction (PFC) circuit with a buck boost DC/DC circuit is presented. The main switch of the boost type PFC circuit converter handles the peak inductor current of DC/DC circuit rather than the super position of both the inductor currents. In this project the circuit is designed and simulated by using Matlab/Simulink software. The proposed converter can be applied for DC motor.

Keywords:

DC Motor, Direct Power Transfer(DPT), Integrated Buck–Buck–Boost Converter(Ibububo), Power-Factor Corr ection (PFC), Single-Stage (SS), Transformer Less.

I. INTRODUCTION:

The use of rectifiers in industrial applications started at the era of mercury converters with the electromechanical contact converter. DC machines are common in day to day use. But the supply that we get from power companies is AC. To use those machines AC supply has to be turned into DC supply by the use of a rectifier. A rectifier is an electrical device that converts the incoming AC (alternating current) from a transformer or any other ac power source to pulsating DC (direct current). Rectifier may be made of diodes, solid states, vacuum tube, mercury arc valves and other components. All rectifier circuits may be classified into one of two categories, i) half wave rectifiers and ii) full wave rectifier. Rectifiers are also used for 3-phase inputs [1]. Rectifiers can further be classified into two categories i. e. Controlled and uncontrolled rectifier. The dc output always remain constant if ac input voltage is constant in an uncontrolled rectifier whereas the output voltage can be controlled in a controlled rectifier. Rectifiers are widely used in non linear loads which are connected with distribution systems which plays an important role in power system network (ex: UPS, discharge lamp, television, computer, fax machines, ferromagnetic devices, arc furnaces, energy savers etc). A further application of the rectifier is driving a DC motor [2].

Cite this article as: Ch.Rushikeswara Rao & P.Shiva, "Modelling of High Efficient High Step down Single Stage AC/DC Converter for DC Motor Applications", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 5, Issue 6, 2018, Page 17-24.

Speed control in DC motor is an important issue. With time the need of flexible speed control for motor is becoming essential. One way to control the speed of the motor is by varying its input voltage. Thus this project aims on designing a rectifier circuit that can supply a voltage as required and can be adjusted if necessary even after the operation starts. An integrated buck–buck–boost (IBuBuBo) converter with low output voltage is proposed. The converter utilizes a buck converter as a PFC cell [3]. It is able to reduce the bus voltage below the line input voltage effectively. In addition, by sharing voltages between the intermediate bus and output capacitors, further reduction of the bus voltage can be achieved. Therefore, a transformer is not needed to obtain the low output voltage. To sum up, the converter is able to achieve:

- Low intermediate bus and output voltages in the absence of transformer;
- Simple control structure with a single-switch;
- Positive output voltage;
- High conversion efficiency due to part of input power is processed once and
- Input surge current protection because of series connection of input source and switch.

II. PROPOSED CIRCUIT AND ITS OPERATING PRINCIPLE

The proposed IBuBuBo converter, which consists of the merging of a buck PFC cell (L_1, S_1, D_1, C_o, and C_B) and a buck–buck–boost dc/dc cell (L_2, S_1, D_2, D_3, C_o, and CB) is illustrated in Fig. 1(a). Although L_2 is on the return path of the buck PFC cell, it will be shown later in Section III-A that it does not contribute to the cell electrically. Thus, L is not considered as in the PFC cell [4]. Moreover, both cells are operated in discontinuous conduction mode (DCM) so there are no currents in both inductors L_1 and L_2 at the beginning of each switching cycle t_0. Due to the characteristic of buck PFC cell, there are two operating modes in the circuit.

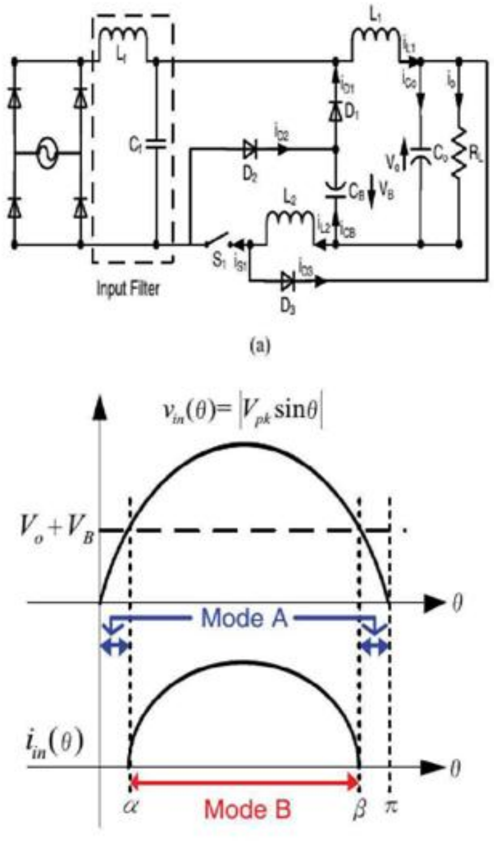


Fig.1. (a) Proposed IBuBuBo SS ac/dc converter. (b) Input voltage and current waveforms.

A.Mode A ($V_{in}(\theta) \leq V_B+V_o$)

When the input voltage $V_{in}(\theta)$is smaller than the sum of intermediate bus voltage V_B, and output voltage V_o, the buck PFC cell becomes inactive and does not shape the line current around zero-crossing line voltage [20], owing to the reverse biased of the bridge rectifier. Only the buck–boost dc/dc cell sustains all the output power to the load [5]. Therefore, two dead-angle zones are present in a half-line period and no input current is drawn as shown in Fig. 1(b). The circuit operation within a switching period can be divided into three stages and the corresponding sequence is Fig. 2(a),(b), and (f). Fig. 3(a) shows its key current waveforms.

Stage 1 (period d_1T_s in Fig. 3) [see Fig. 2(a)]:
When switch
$S_1$is turned ON, inductor L_2 is charged linearly by the bus

voltage V_B while diodeD2is conducting. Output capacitor Co delivers power to the load.

Stage 2 (period d_2T_s in Fig. 3) [see Fig. 2(b)]:
When switch
S_1 is switched OFF, diode D_3 becomes forward biased and energy stored inL2 is released to Co and the load.

Stage 3 (period d_3T_s - d_4T_s in Fig. 3) [see Fig. 2(f)]:
The
inductor currentiL2is totally discharged and only Co sustains the load current.

B. Mode B (V_{in} (θ)>V_B+V_o)

This mode occurs when the input voltage is greater than the sum of the bus voltage and output voltage. The circuit operation over a switching period can be divided into four stages and the corresponding sequence is Fig. 2(c), (d), (e), and (f). The key waveforms are shown in Fig. 3(b).

Stage 1 (period d_1Ts in Fig. 3) [see Fig. 2(c)]:
When switch S_1
is turned ON, both inductors L_1 and L_2 are charged linearly by the input voltage minus the sum of the bus voltage and output voltage(vin(θ)−VB−Vo), while diode D_2 is conducting.

Stage 2 (period d_2 Ts in Fig. 3) [see Fig. 2(d)]:
When switch S_1 is switched OFF, inductor current iL1 decreases linearly to charge CB and Co through diode D1 as well as transferring part of the input power to the load directly. Meanwhile, the energy stored in L_2 is released to Co and the current is supplied to the load through diode D3.This stage ends once inductor L_2 is fully discharged [6].

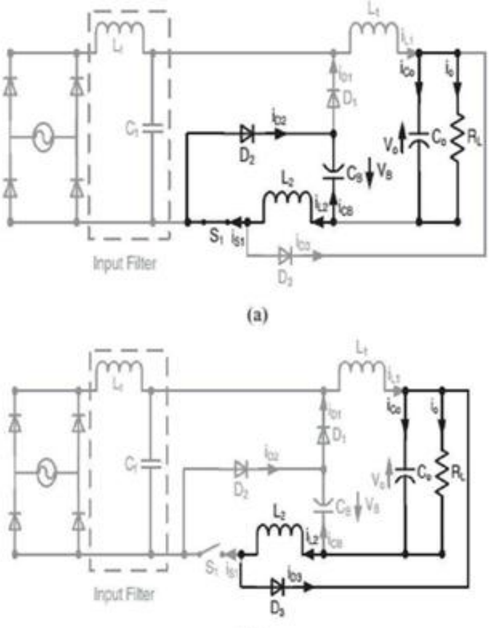
Stage 3 (period d_3 Ts in Fig. 3) [see Fig. 2(e)]:
Inductor L1 continues to deliver current to Co and the load until its current reaches zero.

Stage4 (period d_4 Ts in Fig3)[see Fig.2(f)]:
Only Co delivers all the output power.

III. DESIGN CONSIDERATIONS

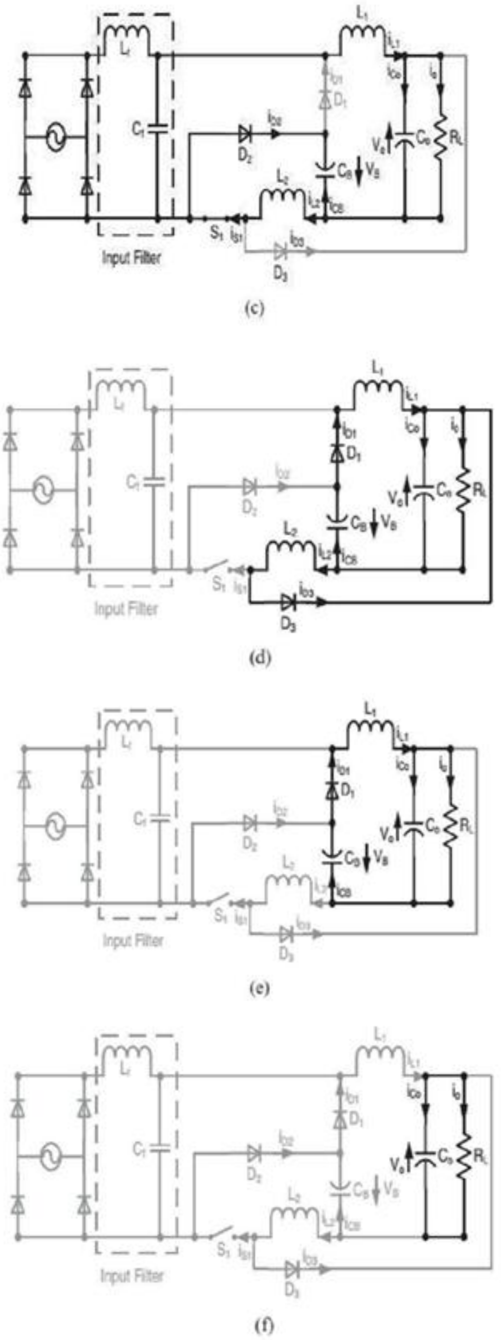
To simplify the circuit analysis, some assumptions are made as follows:

- All components are ideal;
- Line input source is pure sinusoidal, i.e. $V_{in}(\theta)=V_{pk}\sin(\theta)$ where V_{pk} and θ are denoted as its peak voltage and phase angle, respectively;
- Both capacitors CB and Co are sufficiently large such that they can be treated as constant DC voltage sources without any ripples;
- The switching frequency fs is much higher than the line frequency such that the rectified line input voltage |Vin(θ)| is constant within a switching period.



(a)

(b)



(c)

(d)

(e)

(f)

Fig. 2. Circuit operation stages of the proposed ac/dc converter.

A .Circuit Characteristics:

According to Fig. 1(b), there is no input current drawn from the source in Mode A, and the phase angles of the dead-time α and β can be expressed as

$$\alpha = \arcsin\left(\frac{V_T}{V_{\mathrm{pk}}}\right)$$

$$\beta = \pi - \alpha = \pi - \arcsin\left(\frac{V_T}{V_{\mathrm{pk}}}\right) \qquad (1)$$

Where VT is the sum of VB and Vo. Thus, the conduction angle of the converter is

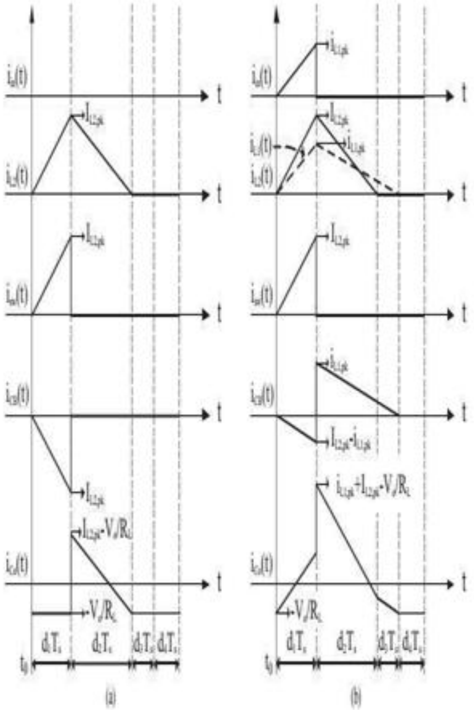
$$\gamma = \beta - \alpha = \pi - 2\arcsin\left(\frac{V_T}{V_{\mathrm{pk}}}\right) \qquad (2)$$

From the key waveforms (see Fig. 3), the peak currents of the two inductors are

$$i_{L1\_\mathrm{pk}} = \begin{cases} \dfrac{v_{\mathrm{in}}(\theta) - V_T}{L_1} d_1 T_s, & \alpha < \theta < \beta \\ 0, & \text{otherwise} \end{cases} \qquad (3)$$

$$I_{L2\_\mathrm{pk}} = \frac{V_B}{L_2} d_1 T_s \qquad (4)$$

Where Ts (1/fs) is a switching period of the converter. In (3) and (4), the dependency of iL1_pk on θ has been omitted for clarity. It is noted thatL2does not contribute in (3) even though it is on the current return path of the PFC cell.



(a)

(b)

Fig.3.Key waveforms of the proposed circuit.

In addition, by considering volt–second balance of the L_1 and L_2, respectively, the important duty ratio relationships can be expressed as follows:

$$d_2 + d_3 = \begin{cases} \dfrac{v_{\text{in}}(\theta) - V_T}{V_T} d_1, & \alpha < \theta < \beta \\ 0, & \text{otherwise} \end{cases} \tag{5}$$

$$d_2 = \frac{V_B}{V_o} d_1 \tag{6}$$

By applying charge balance of CB over a half-line period, the bus voltage VB can be determined. From Fig. 3, the average current of CB over a switching and half-line periods are expressed as follows:

$$\begin{aligned} < i_{CB} >_{sw} &= \frac{1}{2}(i_{L1\_\text{pk}}(d_1 + d_2 + d_3) - I_{L2\_}\text{pk}d_1) \\ &= \frac{d_1^2 T_s}{2}\left[\frac{(v_{\text{in}}(\theta) - V_T)v_{\text{in}}(\theta)}{L_1 V_T} - \frac{V_B}{L_2}\right] \end{aligned} \tag{7}$$

$$\begin{aligned} < i_{CB} >_{\pi} &= \frac{1}{\pi}\int_0^{\pi} < i_{CB} >_{sw} d\theta \\ &= \frac{d_1^2 T_s}{2\pi}\left[\frac{V_{\text{pk}}}{L_1}\left(V_{\text{pk}} V_T(\frac{\gamma}{2} + \frac{A}{4}) - B\right) - \frac{\pi V_B}{L_2}\right] \end{aligned} \tag{8}$$

Where the constants A and B are

$$A = \sin(2\alpha) - \sin(2\beta) \tag{9}$$

$$B = \cos(\alpha) - \cos(\beta) \tag{10}$$

Putting (8) to zero due to the steady-state operation, this leads to

$$V_B = \frac{MV_{\text{pk}}^2}{2\pi(V_B + V_o)} \times \left[\pi - 2\arcsin(\frac{V_B + V_o}{V_{\text{pk}}}) - \frac{2(V_B + V_o)\sqrt{(V_{\text{pk}} + V_B + V_o)(V_{\text{pk}} - V_B - V_o)}}{V_{\text{pk}}^2}\right] \tag{11}$$

Where M is the inductance ratio L2/L1.

IV. DC MOTOR:

In DC drives (or in other type of electrical drives), it is normally necessary to control the motor current since it is, in most of the cases, proportional to the developed motor torque. This is especially true for a DC motor as shown in Fig.4.

The reference current (or reference torque) is compared with actual current and the error is fed to the current controller to generate the control signal Vc. The firing circuit is responsible in generating the pulses used to trigger the SCRs so that the desired average voltage is produced at the output of the converter [7]. As we have seen before, the relation between a and the average voltage Va is non-linear due to the cosine term present in the expression.

If the relationship between Vc and a is linear, obviously the relationship between Vc and Va will be non-linear. While it is true that we can linearized (1) for the purpose of designing the controller, this however only valid for a small perturbation around an operating point of the delay angle. On the other hand, if we can establish an inverse cosine relation between vc and a, then the relation between Vc and Va will become linear [8].

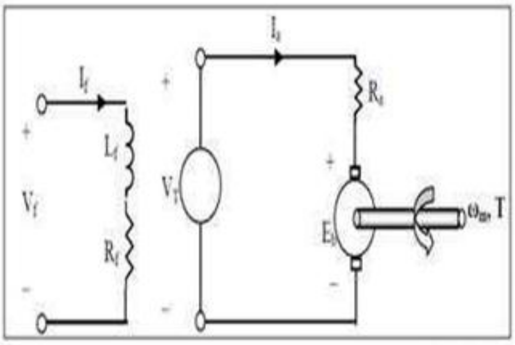


Fig.4 shows the dc motor diagram.

V.SIMULATION RESULTS:

Here the simulation is carried out by three different cases

1) proposed ac/dc converter with 90 Vrms condition
2) proposed ac/dc converter with 270 Vrms condition
3) proposed converter (8) with DC motor condition and results as shown in Figs.5 to 15.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

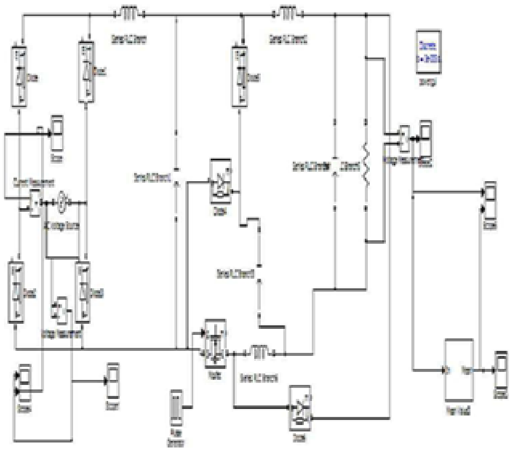


Fig.5 Matlab/simulink model of ac/dc converter with 90 $V_{rms.}$

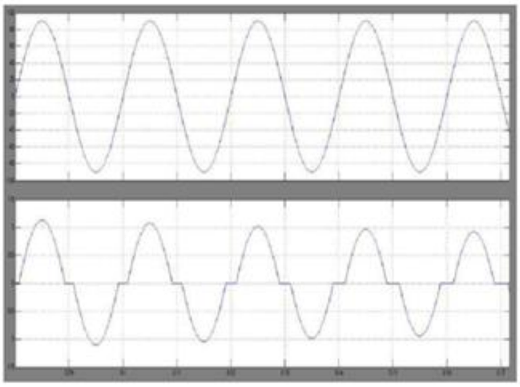


Fig.6 Measured input characteristic of the converter at 90 Vrms and.

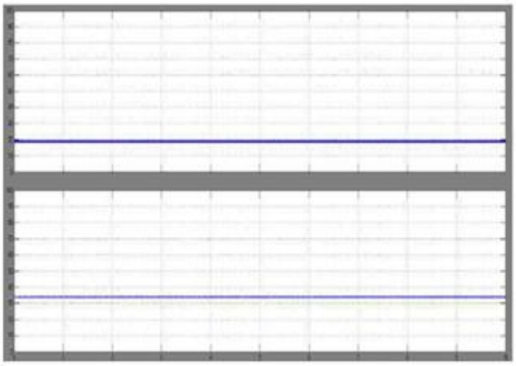


Fig. 7. Measured output voltage and intermediate bus voltage at 90 V_{rms}.

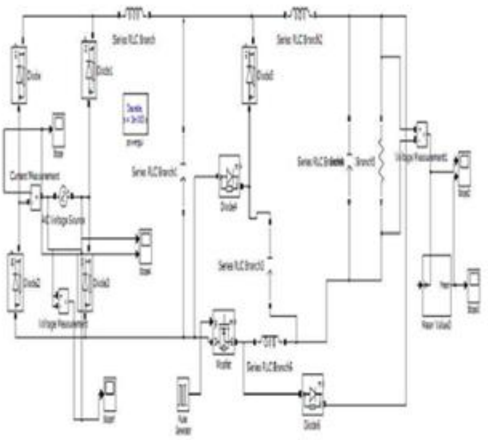


Fig.8. Matlab/simulink model of ac/dc converter with 270

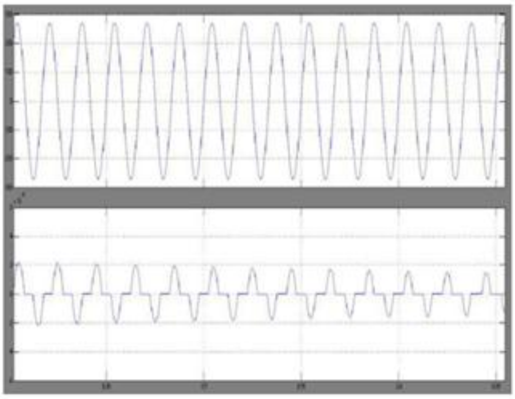


Fig.9. Measured input characteristic of the converter at 270 Vrms under 100-W condition.

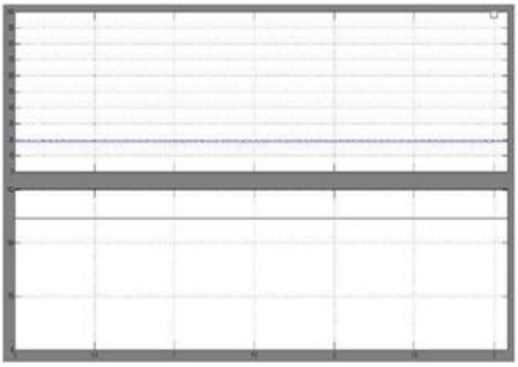


Fig.10. Measured output voltage and intermediate bus voltage at 270 Vrms under full load condition.

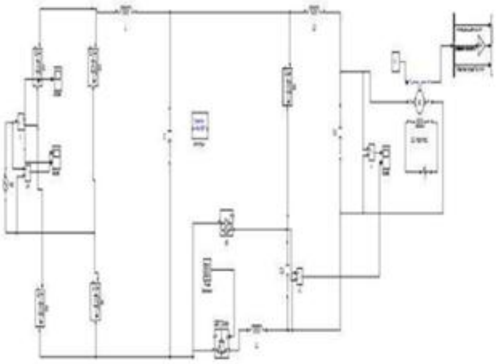


Fig.11. Simulink model of the Dc Motor with the proposed PFC ac/dc converter.

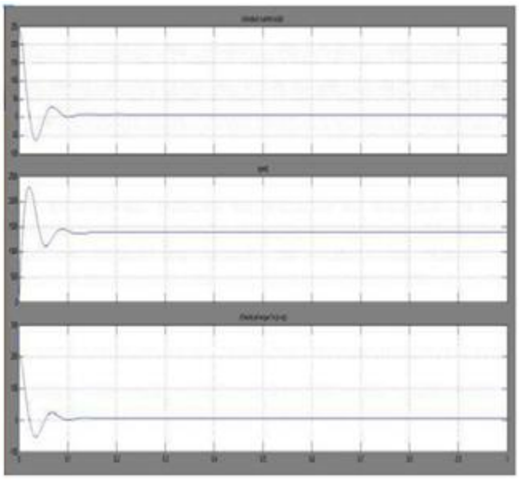


Fig.12. Simulated output wave form of Motor Current, Speed and torque.

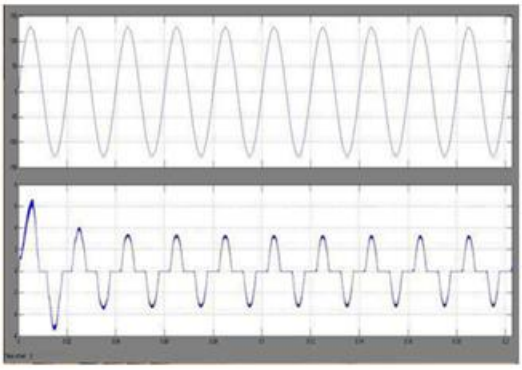


Fig.13. Source voltage and current with Dc motor

VI. CONCLUSION:

The proposed IBuBuBo single-stage ac/dc converter with DC motor has been verified by using simulation analysis, and the results have shown good agreements with the predicted values. The intermediate bus voltage of the circuit is able to keep below150Vat all input and output conditions, and is lower than that of the most reported converters. Thus, the lower voltage rating of capacitor can be used. Moreover, the topology is able to obtain low output voltage without high step-down transformer. Owing to the absence of transformer, the demagnetizing circuit, the associated circuit dealing with leakage inductance, and the cost of the proposed circuit are reduced compared with the isolated counterparts. It is analyzed that voltage magnitude variation done by using proposed converter under normal loads, input power factor and voltage variation also done under Dc motor loading conditions.

VII. REFERENCES:

[1] Q. Zhao, F. C. Lee, and F.-s. Tsai, “Voltage and current stress reduction in single-stage power-factor correction AC/DC converters with bulk capacitor voltage feedback,” IEEE Trans. Power Electron., vol. 17, no. 4, pp. 477–484, Jul. 2002.

[2] O. Garcia, J. A. Cobos, R. Prieto, P. Alou, and J. Uceda, “Single phase power factor correction: A survey, ”IEEE Trans. Power Electron., vol. 18, no. 3, pp. 749–755 , May 2003.

[3] S. Luo, W. Qiu, W. Wu, and I. Batarseh, “Fly boost power factor correction cell and a new family of single-stage AC/DC converters,” IEEE Trans. Power Electron., vol. 20, no. 1, pp. 25–34, Jan. 2005.

[4] D. D. C. Lu, H. H. C. Iu, and V. Pjevalica, “A Single-Stage AC/DC converter With high power factor, regulated bus voltage, and output voltage,” IEEE Trans. Power Electron., vol. 23, no. 1, pp. 218–228, Jan. 2008.

[5] M. K. H. Cheung, M. H. L. Chow, and C. K. Tse, "Practical design and evaluation of a 1 kW PFC powe r supply based on reduced redundant power processing principle," IEEE Trans. Ind. Electron., vol. 55, no. 2, pp. 665–673, Feb. 2008.

[6] D. D. C. Lu, H. H. C. Iu, and V. Pjevalica, "Single -Stage AC/DC Boost: Forward converter with high power factor and regulated bus and output voltages,"IEEE Trans. Ind.Electron., vol. 56, no. 6, pp. 2128–2132, Jun. 2009 .

[7] H.-Y. Li and H.-C. Chen, "Dynamic modeling and controller design for a single-stage single-switch parallel boost-fly back–fly back converter," IEEE Trans. Pow er Electron., vol. 27, no. 2, pp. 816–827, Feb. 2012.

[8] R. Redl and L. Balogh, "Design considerations for s ingle-stage isolated power-factor-corrected power supplies with fast regulation of the output voltage," inProc. IEEE App l. Power Electron. Conf. Expo., 1995, vol. 1, pp. 454–458.