Performance of Buck-Boost Converter with Induction Motor Drive

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Abstract—This paper presents the performance of Buck-Boost converter with induction motor drive system. The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. The use of Buck-Boost converter to change the voltage level to desired value was analyzed in this paper. The basic operation of buck-boost converter along with the designing of PI controller was discussed. The models were developed using Matlab/Simulink software and the output results for buck-boost converter were shown.

I. Introduction

The three basic topologies to change voltage level in common use are the buck, boost, and buck-boost. These topologies are non-isolated, i.e., the input and output voltages share a common ground. There are, however, isolated derivations of these non-isolated topologies. The topology refers to how the switches, output inductor, and output capacitor are connected. Each topology has unique properties. These properties include the steady-state voltage conversion ratios, the nature of the input and output currents, and the character of the output voltage ripple. Another important property is the frequency response of the duty-cycle-to-output-voltage transfer function. The buck-boost is a popular non-isolated, inverting power stage topology, sometimes called a step-up/down power stage. Power supply designers choose the buck-boost power stage because the output voltage is inverted from the input voltage, and the output voltage can be either higher or lower than the input voltage. The topology gets its name from producing an output voltage that can be higher (like a boost power stage) or lower (like a buck power stage) in magnitude than the input voltage. However, the output voltage is opposite in polarity from the input voltage. The input current for a buck-boost power stage is discontinuous or pulsating due to the power switch (Q1) current that pulses from zero to IL every switching cycle. The output current for a buck-boost power stage is also discontinuous or pulsating. This is because the output diode only conducts during a portion of the switching cycle. The output capacitor supplies the entire load current for the rest of the switching cycle.

II. Positive buck boost converter and its operation

This converter can work as a buck converter or a boost converter depending on input– output voltages. The problem of output regulation with guaranteed transient performances for non-inverting buck–boost converter topology is discussed. Various digital control techniques are addressed, which can smoothly perform the transition job. In the first two modes, the operation principles are the same as those of the buck converter.

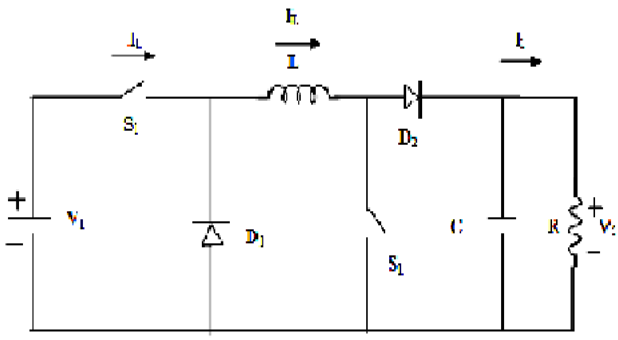

Fig.1.Positive output buck-boost converter

When the input voltageV1 is higher than the output voltage V2 the positive buck–boost converter can be operated in the "Buck Operation Mode." In this case, the switchS2is constantly open, and the diodeD2will be constantly on. The remaining components are the same as those of a buck converter. When the input voltageV1 is lower than the output voltage V2 the positive buck–boost converter can be operated in the "Boost Operation Mode." In this case, the switchS1is constantly on, and the diodeD1will be constantly blocked. When the input voltageV1is nearly equal to the output voltage V2 the positive buck–boost converter can be operated in the "buck–boost operation mode." In this case, both the switchesS1andS2switch on and switch off simultaneously.

When the switches are on, the inductor current increases:

$$\Delta i_L = \frac{V1}{L} kT \tag{1}$$

When the switches are off, the inductor current decreases:

$$\Delta i_L = \frac{V1}{L}(1-k) \tag{2}$$

Hence,

$$V_2 = \frac{k}{1-k} V_1 \tag{3}$$

The basic operation of the buck boost converter is illustrated.

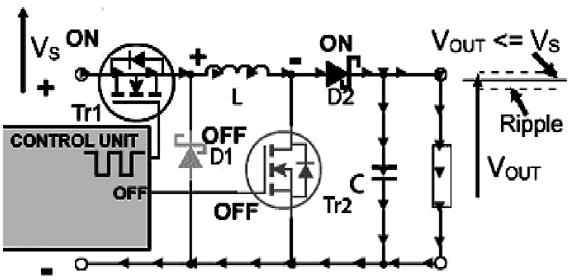

Fig.2.Operation as a Buck Converter during Tr1 „on‟ Period

The circuit operating as a Buck Converter. In this mode Tr2 is turned off, and Tr1 is switched on and off by a high frequency square wave from the control unit. When the gate of Tr1 is high, current flows though L, charging its magnetic field, charging C and supplying the load. The Schottky diode D1 is turned off due to the positive voltage on its cathode.

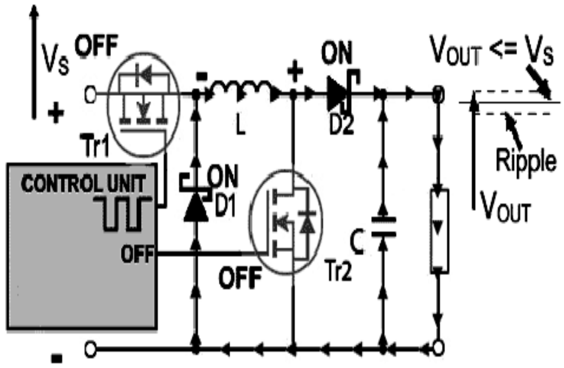

Fig.3.Operation as a Buck Converter during Tr1 „off‟ Period

The current flow during the buck operation of the circuit when the control unit switches Tr1 off. The initial source of current is now the inductor L. Its magnetic field is collapsing, the back e.m.f. generated by the collapsing field reverses the polarity of the voltage across L, which turns on D1 and current flows through D2 and the load. As the current due to the discharge of L decreases, the charge accumulated in C during the on period of Tr1 now also adds to the current flowing through the load, keeping VOUT reasonably constant during the off period. This helps keep the ripple amplitude to a minimum and VOUT close to the value of VS.

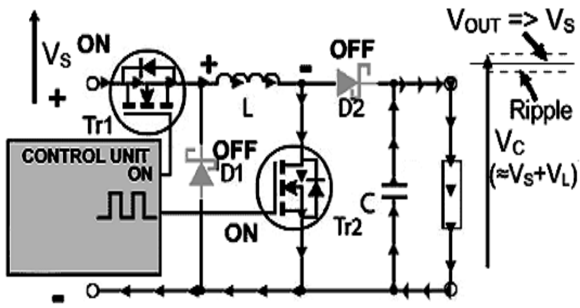

Fig.4.Operation as a Boost Converter during Tr2 „on‟ Period

In Boost Converter mode, Tr1 is turned on continually and the high frequency square wave applied to Tr2 gate.

During the on periods when Tr2 is conducting, the input current flows through the inductor L and via Tr2, directly back to the supply negative terminal charging up the magnetic field around L. whilst this is happening D2 cannot conduct as its anode is being held at ground potential by the heavily conducting Tr2. For the duration of the on period, the load is being supplied entirely by the charge on the capacitor C, built up on previous oscillator cycles. The gradual discharge of C during the on period (and its subsequent recharging) accounts for the amount of high frequency ripple on the output voltage, which is at a potential of approximately VS + VL.

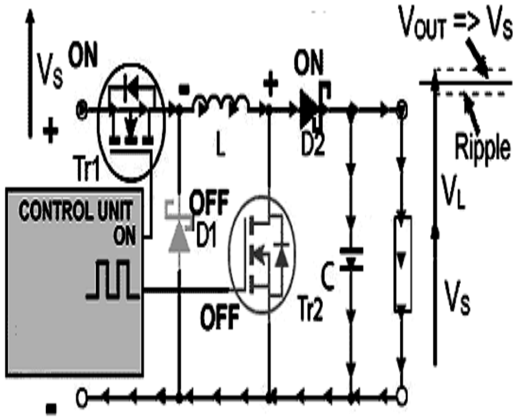

Fig.5.Operation as a Boost Converter during Tr2 „off‟ Period

At the start of the off period of Tr2, L is charged and C is partially discharged. The inductor L now generates a back e.m.f. and its value that depends on the rate of change of current as Tr2 switches of and on the amount of inductance the coil possesses;

therefore the back e.m.f can be any voltage over a wide range, depending on the design of the circuit. Notice particularly that the polarity of the voltage across L has now reversed, and so adds to the input voltage VS giving an output voltage that is at least equal to or greater than the input voltage. D2 is now forward biased and so the circuit current supplies the load current, and at the same time re-charges the capacitor to VS + VL ready for the next on period of Tr2.

III. Design of pi control

PI controller is a well-known controller which is used in the most application. PI controller becomes a most popular industrial controller due to its simplicity and the ability to tune a few parameters automatically. As an example for the application of PI controller in industry, slow industrial process can be pointed; low percentage overshoot and small settling time can be obtained by using this controller

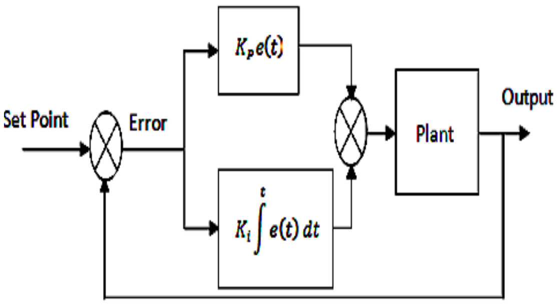

Fig.6. Structure of PI controller

PI most widely-used type of controller for industrial applications and exhibit robust performance over a wide range of operating conditions. The parameters involved are Proportional (P) and Integral (I). Fig.5.1 show the basic structure of PI controller. The proportional part is responsible for following the desired set-point, while the integral part account for the accumulation of past errors and the rate of change of error in the process respectively. In spite of simplicity, they can be used to solve even a very complex control problem, especially when combined with different functional blocks, filters (compensators or correction blocks), selectors etc.

PI control is designed to ensure the specifying desired nominal operating point. The PI control settings proportional gain (kp) and (ki) are designed using artificial bee colony algorithm which is the best optimization technique

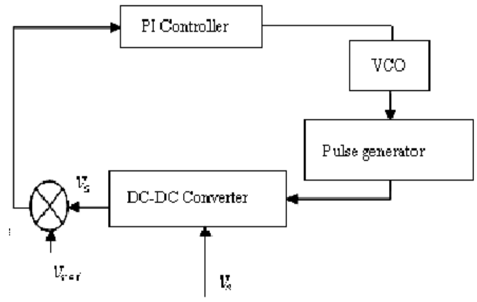

Fig.7. Block diagram of PI control for P/N DC-DC converter

In artificial beecolony algorithm bee represents a potential solution to the design problem which has a fitness value.In a real bee colony, some tasks are performed by specialized individuals. These specialized bees try to maximize the nectar amount stored in the hive using efficient division of labour and self-organization. The Artificial Bee Colony (ABC) algorithm, proposed by Karaboga in 2005 for real-parameter optimization, is a recently introduced optimization algorithm which simulates the foraging behaviour of a bee colony. The minimal model of swarm-intelligent forage selection in a honey bee colony which the ABC algorithm simulates consists of three kinds of bees: employed bees, onlooker bees and scout bees. Half of the colony consists of employed bees, and the other half includes onlooker bees. Employed bees are responsible for exploiting the nectar sources explored before and giving information to the waiting bees (onlooker bees) in the hive about the quality of the food source sites which they are exploiting. Onlooker bees wait in the hive and decide on a food source to exploit based on the information shared by the employed bees. Scouts either randomly search the environment in order to find a new food source depending on an internal motivation or based on possible external clues.

1.At the initial phase of the foraging process, the bees start to explore the environment randomly in order to find a food source.

2.After finding a food source, the bee becomes an employed forager and starts to exploit the discovered source. The employed bee returns to the hive with the nectar and unloads the nectar. After unloading the nectar, she can go back to her discovered source site directly or she can share information about her source site by performing a dance on the dance area. If her source is exhausted, she becomes a scout and starts to randomly search for a new source.

3.Onlooker bees waiting in the hive watch the dances advertising the profitable sources and choose a source site depending on the frequency of a dance proportional to the quality of the source.

In the ABC algorithm proposed by Karaboga, the position of a food source represents a possible solution to the optimization problem, and the nectar amount of a food source corresponds to the profitability (fitness) of the associated solution. Each food source is exploited by only one employed bee. In other words, the number of employed bees is equal to the number of food sources existing around the hive (number of solutions in the population). The employed bee whose food source has been abandoned becomes a scout. If the search space is considered to be the environment of the hive that contains the food source sites, the algorithm starts with randomly producing food source sites that correspond to the solutions in the search space. Initial food sources are produced randomly within the range of the boundaries of the parameters.

$$X_{ij} = Xij^{min} + rand(0,1)(Xj^{max} - Xj^{min})$$
(4)

Where i=1...SN, j=1...D. SN is the number of food sources and D is the number of optimization parameters. In addition, counters which store the numbers of trials of solutions are reset to 0 in this phase. After initialization, the population of the food sources (solutions) is subjected to repeat cycles of the search processes of the employed bees, the onlooker bees and the scout bees. Termination criteria for the ABC algorithm might be reaching a maximum cycle number (MCN) or meeting an error tolerance (ϵ). As mentioned earlier, each employed bee is associated with only one food source site. Hence, the number of food source sites is equal to the number of employed bees. An employed bee produces a modification on the position of the food source (solution) in her memory depending on local information (visual information) and finds a neigh bouring food source, and then evaluates its quality. In ABC, finding a neigh bouring food source is defined below.

$$V_{ij} = X_{ij} + \varphi_{ij}(X_{ij} - X_{kj}) \quad (5)$$

IV. MATLAB/SIMULINK RESULTS

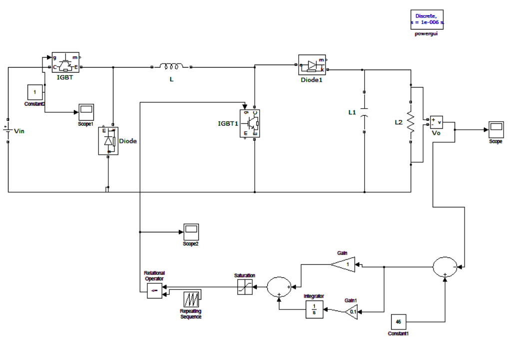

Fig.8. Simulink model for Proposed positive output Buck-Boost Converter.

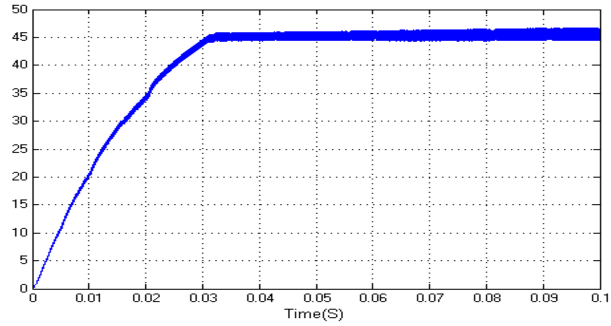

Fig.9. Simulated Response of Voltage waveform

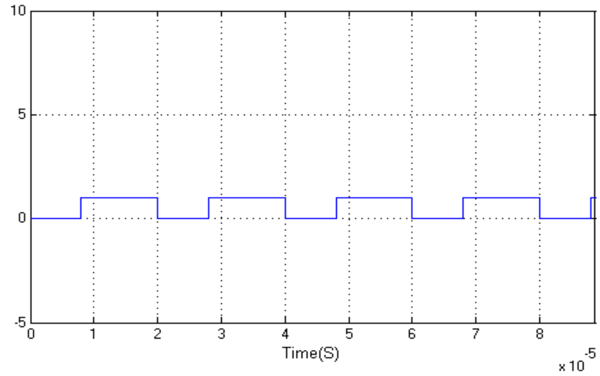

Fig.10. Simulated Response of GATE PULSES FOR S1.

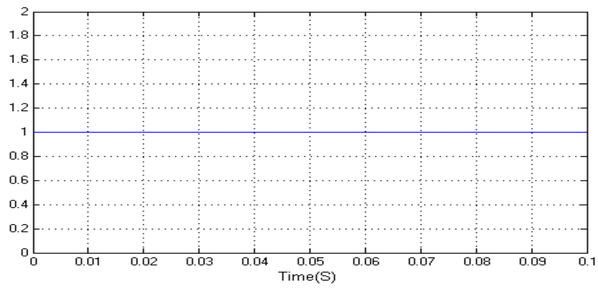

Fig.10. Simulated Response of GATE PULSES FOR S2.

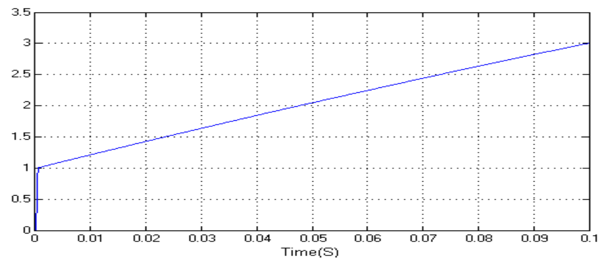

Fig.11. Simulated Response of Voltage waveform for set value of 3 V

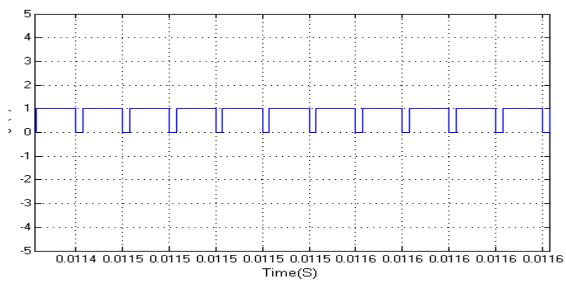

Fig.12. Simulated Response of GATE PULSES FOR S1

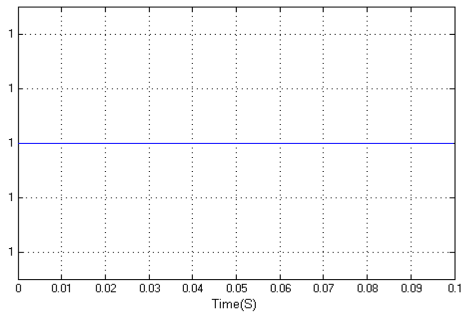

Fig.12. Simulated Response of GATE PULSES FOR S2

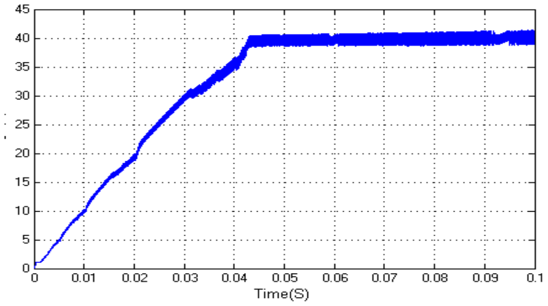

Fig.13. Simulated Response of Voltage waveform for set value of 40 V.

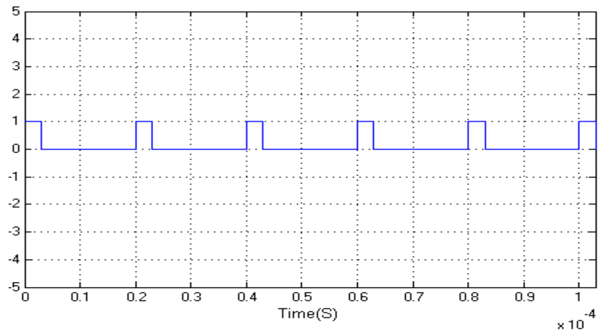

Fig.14. Simulated Response of GATE PULSES FOR S1.

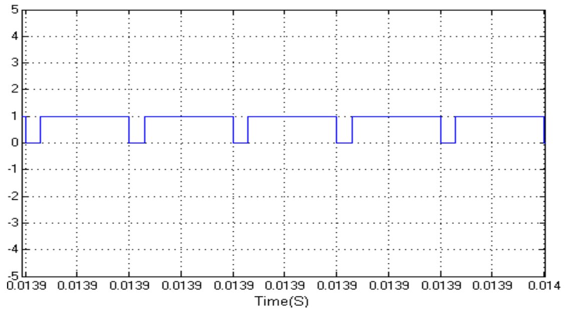

Fig.14. Simulated Response of GATE PULSES FOR S2.

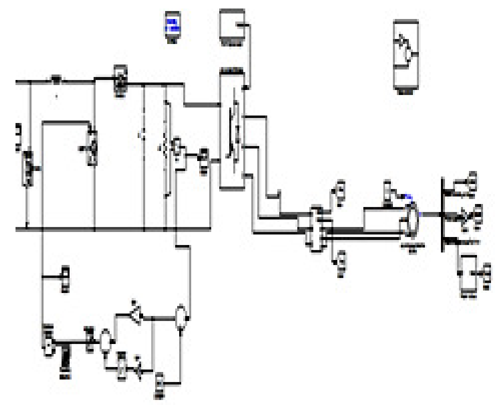

Fig.8. Simulink model for Proposed positive output Buck-Boost Converter and inverter with Induction motor drive.

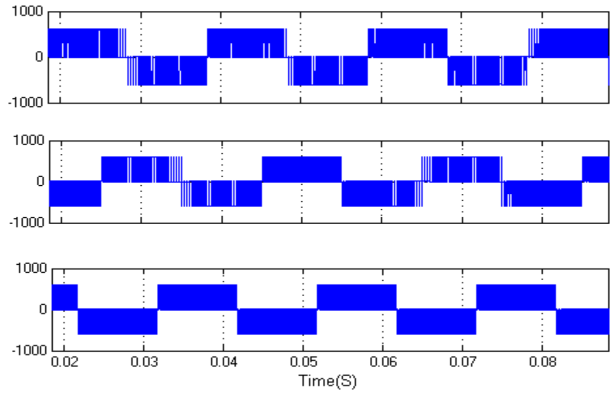

Fig..inverter phase to phase Voltage.

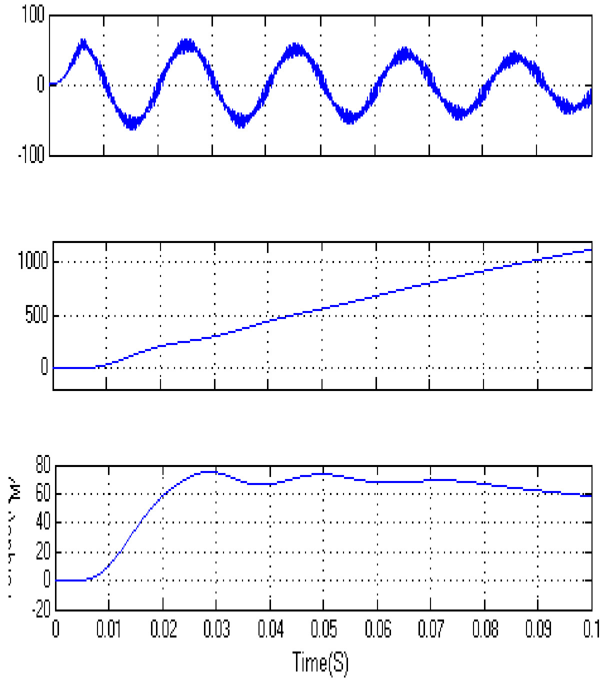

Fig..Induction Motor Current, Speed and Torque.

V. CONCLUSION

Due to the time variations and switching nature of power converters, their dynamic behavior becomes highly non-linear. This work has successfully demonstrated the design, analysis and suitability of PI controlled positive output buck boost converter..PI control with soft computing techniques such as artificial bee colony algorithm has proved to be robust and suited for line and load disturbances. Among the soft computing technique it is seen that ABC possess best result. Bick-Boost converter basic principle was explained along with the design procedure of PI controller. Matlab/Simulink results were obtained for the converter.

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