International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)), Volume 2, Special Issue 3, February 2014)
International Conference on Trends in Mechanical, Aeronautical, Computer, Civil, Electrical and Electronics Engineering (ICMACE14)

# Improved Control Strategy on Cuk Converter fed DC Motor using Artificial Bee Colony Algorithm

***B.Ragavendra*[1], *S.Vijayanand*[2] , *B.Jayaprakash*[3],**

[1] *Assistant professor, Erode Sengunthar Engineering College, Thudupathi, Erode*
[2] *Assistant professor, Erode Sengunthar Engineering College, Thudupathi, Erode*
[3] *PG Scholar, Erode Sengunthar Engineering College, Thudupathi, Erode*

[1]ragavendraboopathi@gmail.com
[2]svijayanandme@gmail.com
[3]jaayam1989@gmail.com

***Abstract*— The proposed model is to control the speed of the DC Motor based on Cuk converter by using Artificial Bees Colony algorithm with soft starter. The Cuk converter is an alternative power conversion topology instead of buck or boost (i.e.) step-down or step-up the output voltage. The variable Pulse Area Modulation technique is used to regulate the voltage at the end of Cuk converter. PAM based rectifiers are efficiently employed in low to high power applications. The Cuk converter can produce the voltage higher or lower than the supply voltage, they are mostly useful in variable DC drives. In traditional DC Motor system a resistance starter is used to monitor the armature current of the Motor. The high starting armature current will damage the insulation which affects the motor and also efficiency has to be reduced. Instead of resistance starter, a power semiconductor based soft starter is used to limit the starting current. ABC algorithm gives less computation time to complete the specific task. The speed of the DC Motor is controlled by using Artificial Bees Colony algorithm which is connected to the soft starter. The artificial bee's colony algorithm act as a controller emerged as a tool for difficult control problems of unknown nonlinear system. The bee's implementation or artificial bee's colony algorithm is one of the artificial intelligence techniques to control the speed, detect the error and correct the error of the motor. The main advantage of soft starter is that the motor become independent of input voltage level also it can be adjusted. The efficiency and power factor of the motor has been improved. When using PAM technique, the settling time period of Motor speed is less and the life time of the Motor speed is also increased by using soft starter.**

***Index Terms*—PWM, PAM, Cuk converter, Soft starter, ABC, PI Controller and DC motor.**

## I. INTRODUCTION

Normally an ac source is converted into a dc source using a bridge rectifier and a large filter capacitor used to remove the ripples. Such a conversion has many disadvantages, including high input current harmonic components and an invariable output dc voltage. To remove this short comings Pulse Area Modulation based switching devices are used. Here a cuk converter with a single switching device is used to produce variable voltage levels. This makes the converter circuit compact and simple. Based on the duty cycle ratio formula a system can be developed which gives pulses to the switching device based on the reference output voltage. It is also known that when a dc motor is started the initial armature current is very high. This is because of the absence of the back emf in the motor. The back emf is directly proportional to the speed of the motor. Such high armature current can cause insulation failure as well as motor damage as well as reduce the life of the motor. To overcome such problems, a power semiconductor based soft starter is used to limit the starting current. In the industrial processes, there are many systems having nonlinear properties. Moreover, these properties are often unknown and time varying.

The most commonly used controller for the speed control of dc motor is Proportional- Integral (P-I) controller. However, the P-I controller has some disadvantages such as: the high starting overshoot, sensitivity to controller gains and sluggish response due to sudden disturbance if there are uncertainties and nonlinearities. The artificial bee's colony algorithm act as a controller emerged as a tool for difficult control problems of unknown nonlinear system.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)), Volume 2, Special Issue 3, February 2014)
International Conference on Trends in Mechanical, Aeronautical, Computer, Civil, Electrical and Electronics Engineering (ICMACE14)

The bee's implementation or artificial bee's colony algorithm is one of the artificial intelligence techniques to control the speed, detect the error and correct the error of the motor.

Section II describes the block diagram, Circuit diagram and operating principle of ABC algorithm based cuk converter fed dc motor with variable PAM technique in closed-loop.

## II. CIRCUIT DESCRIPTION AND PRINCIPLE OF OPERATION

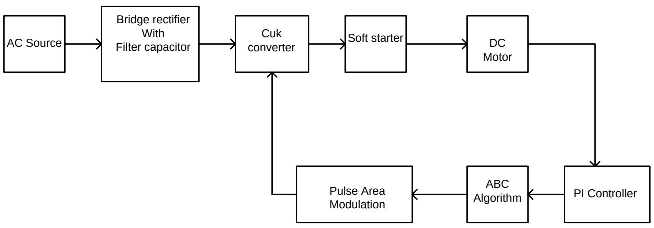


Fig 1. Block diagram of proposed method

The fig 2 shows the basic circuit diagram of the entire model of dc motor drive with cuk converter. The circuit diagram is consists of a ac-dc converter and it converts the ac source in to fixed dc source. In this converter consists of four diodes are connected like bridge (i.e.) two in series and the two series of parallel which gives full wave rectification and the filter capacitor is used to remove the ripples from the output voltage. After this it will be input of the cuk converter which converts the fixed dc source in to variable dc source required for the dc motor drive speed control.

Like buck-boost converter, cuk converter is also delivers an inverted output but the only difference it has an additional inductor and capacitor. Note that virtually all of the output current must pass through C1, and as ripple current. So C1 is usually a large electrolytic with a high ripple current rating and low ESR (equivalent series resistance) to minimize the losses. The fig shows the basic circuit diagram of the entire model of dc motor drive with cuk converter. The circuit diagram is consists of a ac-dc converter and it converts the ac source in to fixed dc source. In this converter consists of four diodes are connected like bridge (i.e.) two in series and the two series of parallel which gives full wave rectification and the filter capacitor is used to remove the ripples from the output voltage.

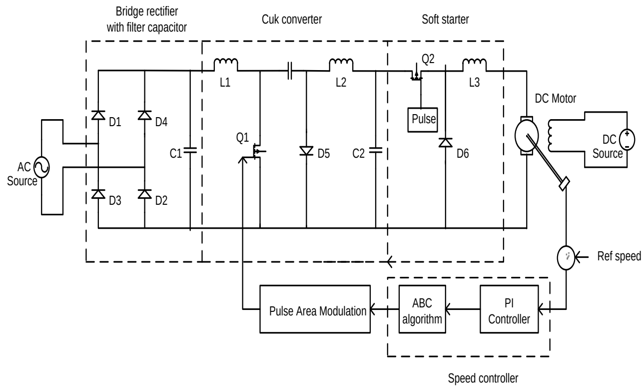


Fig 2. Circuit diagram of proposed method

After this it will be input of the cuk converter which converts the fixed dc source in to variable dc source required for the dc motor drive speed control. Like buck-boost converter, cuk converter is also delivers an inverted output but the only difference it has an additional inductor and capacitor. Note that virtually all of the output current must pass through C1, and as ripple current. So C1 is usually a large electrolytic with a high ripple current rating and low ESR (equivalent series resistance) to minimize the losses.

When Q1 is turned on, current flows from the input source through L1 and Q1, storing energy in L1.s magnetic field. Then when Q1 is turned off, the voltage across L1reverses to maintain current flow. As in the boost converter current then flows from the input source, through L1 and D1, charging up C1 to a voltage somewhat higher than Vin and transferring to it some of the energy that was stored in L1.

Then Q1 is turned on again, C1 discharges through via L2 into the load, with L2 and C2 acting as a smoothing filter. Meanwhile energy is being stored again in L1, ready for the next cycle. As with the buck-boost converter, the ratio between the output voltage and the input voltage again turns out to be:

$$\frac{\mathbf{Vout}}{\mathbf{Vin}} = -\frac{\mathbf{D}}{\mathbf{1-D}} = -\mathbf{Ton/Toff}$$

So like the buck-boost converter, the Cuk converter can step the voltage either up or down, depending on the switching duty cycle. The main difference between the two is that because of the series inductors at both input and output, the Cuk converter has much lower current ripple in both circuits. In fact by careful adjustment of the inductor values, the ripple in either input or output can be nulled completely.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)), Volume 2, Special Issue 3, February 2014)
International Conference on Trends in Mechanical, Aeronautical, Computer, Civil, Electrical and Electronics Engineering (ICMACE14)

Once the variable dc voltage is generated, that voltage acts as input to the soft starter. The soft starter is basically a switch (e.g. MOSFET, GTO) based starter which uses hysteresis control for controlling the armature current.

The hysteresis controller comprises of a relay which gives one or zero, based on the comparison between the input value and threshold value of the controller. In this starter the armature current is compared with the reference current. If the difference between the armature current and reference current is more than the upper limit of the hysteresis controller the switch turns off. When the difference is lesser than the lower limit of the hysteresis controller the switch turns on, thus closing the circuit. A smoothing inductor is connected in series to the switch. The inductor prevents sudden change of armature current when the switch turns on and off. A diode is connected in parallel to the motor to bypass any currents flowing in the reverse direction.

A speed controller is also used to control the speed of the motor to a desired level. The artificial bee's colony algorithm act as a controller emerged as a tool for difficult control problems of unknown nonlinear system. The bee's implementation or artificial bee's colony algorithm is one of the artificial intelligence techniques to control the speed, detect the error and correct the error of the motor.

## III. THEORETICAL CONCEPTS

### *A. Comparison of PWM & PAM techniques*

*Pulse Width Modulation technique*

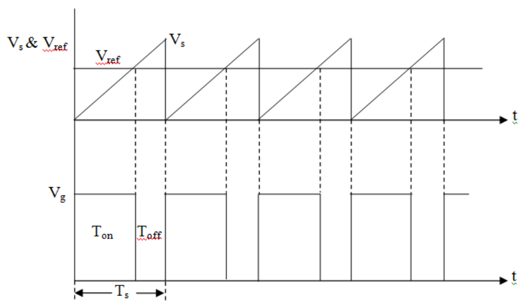


Fig 3. PWM generation

In Cuk converter the Pulse Width Modulation technique is most commonly used to regulate the output voltage. Here ON time and the OFF time is varied but the chopping frequency is kept, the width of the pulse is varied hence it is PWM technique.

The generation of the IGBT driving signal is accomplished by comparing a dc reference signal, having variable amplitude Vref, with a saw tooth carrier wave, having fixed amplitude Vs and frequency fs known as the switching frequency. The ratio between Vref and Vs is called the duty cycle, D = Vref / Vs, which is defined as the ratio of the ON time TON to the total switching period TS = TON + TOFF. The average output voltage is varied by changing the amplitude of reference signal Vref to control the duty cycle D as shown in Fig 3.

*Pulse Area Modulation technique*

The alternate method of varying the output voltage in the Cuk converter with the help of PAM technique. This section presents a closed loop controller based on Pulse Area Modulation technique for Cuk converter fed dc motor. Fig 4 illustrates the generation of gating signals using Pulse Area Modulation technique which is employed for the control of cuk converter.

Because the saw-tooth wave used in the modulation is created by integrating reactor current, its gradient varies proportionally to reactor current. When reactor current gradually increases, the current becomes a saw-tooth wave whose gradient increases gradually as shown in Fig.5 Assuming that the reference wave has a constant voltage as shown in Fig.4, the duty ratio gradually decreases. So, the input current waveform becomes square wave in which peak value gradually increases and the pulse width gradually decreases.

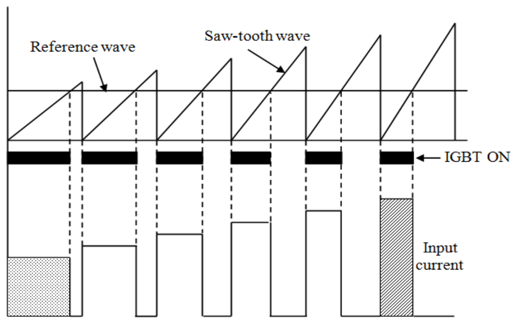


Fig 4. PAM Generation

If the reference waveform is constant, the areas of these pulses will not change, but if the reference waveform increases or decreases, the pulse areas increase or decrease proportionally and pulse area is equal to the instantaneous value of the input current.

Thus, if the reference waveform is changed into a sine wave as shown in Fig 4 the input current will change into sine wave. Thus this controller also improves the input power factor.

*B. Cuk converter*

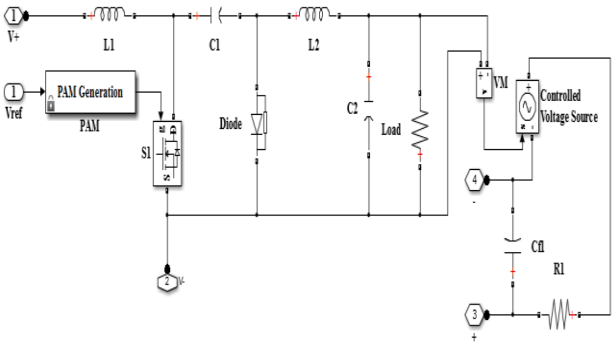


Fig 5. Cuk converter circuit diagram

It is one of the types of DC to DC converter used to convert the fixed DC voltage in to variable DC voltage. It is also an alternative power conversion topology instead of buck or boost (i.e.) step-down or step-up the output voltage. The output voltage is depends on duty cycle. The cuk converter steps the voltage down when it is less than 50% (i.e., $T_{on} < T_{off}$) and step the voltage up when it is greater than 50% (i.e., $T_{on} > T_{off}$). The variable pulse area modulation technique is used to regulate the voltage at the end of cuk converter.

*Design details of Cuk converter*

*During switch turn on period:*

*Condition 1:*

$$V_L = V_S = L_1 \frac{di}{dt}$$

$$V_S = L_1 \frac{\Delta I}{T_{ON}}$$

$$T_{ON} = L_1 \frac{\Delta I}{V_S} \quad (1)$$

$$\Delta I = V_S \frac{T_{ON}}{L_1} \quad (2)$$

*Condition 2:*

$$V_L = V_{c1} + V_o = L_2 \frac{di}{dt}$$

$$V_{c1} + V_o = L_2 \frac{\Delta I}{T_{ON}}$$

$$T_{ON} = L_2 \frac{\Delta I}{V_{c1} + V_o} \quad (3)$$

$$\Delta I = (V_{c1} + V_o) \frac{T_{ON}}{L_2} \quad (4)$$

*During switch turn off period:*

*Condition 1:*

$$V_{L1} = V_S - V_{c1} = -L_1 \frac{\Delta I}{T_{OFF}}$$

$$\Delta I = -(V_S - V_{C1}) \frac{T_{OFF}}{\Delta I} \quad (5)$$

$$T_{Off} = -L_1 \frac{\Delta I}{V_s - V_{c1}} \quad (6)$$

*Condition 2:*

$$V_L = V_o = -L_2 \frac{\Delta I}{T_{OFF}}$$

$$\Delta I = -V_O \frac{T_{OFF}}{L_2} \quad (7)$$

$$T_{OFF} = -L_2 \frac{\Delta I}{V_O} \quad (8)$$

*By equating $\Delta I$ value during turn on & off period:*

*Condition 1:*

$$V_S \frac{T_{ON}}{L_1} = -(V_S - V_{C1}) \frac{T_{OFF}}{\Delta I}$$

$$V_S(T_{ON} + T_{OFF}) = V_{C1} T_{OFF}$$

$$V_{C1} = V_S \frac{T}{T_{OFF}}$$

$$V_{C1} = \frac{V_S}{(1-\alpha)} \quad (9)$$

*Condition 2:*

$$(V_{c1} + V_o) \frac{T_{ON}}{L_2} = -V_O \frac{T_{OFF}}{L_2}$$

$$V_{c1} T_{ON} = -V_O (T_{ON} + T_{OFF})$$

$$V_{C1} = \frac{-V_O}{\alpha} \quad (10)$$

*By equating $V_{c1}$ in both the conditions:*

$$\frac{V_S}{(1-\alpha)} = \frac{-V_O}{\alpha}$$

$$V_O = \frac{V_S . \alpha}{(\alpha - 1)} \quad (11)$$

*Assume no losses in the circuit:*

$$V_O I_O = V_S I_S$$

$$V_S I_S = -\frac{V_S . \alpha}{(\alpha - 1)} I_O$$

$$I_S = \frac{I_O . \alpha}{(1-\alpha)} \quad (12)$$

*The peak to peak ripple current through the inductor $L_1$ & $L_2$ is:*

$$\Delta I_1 = \frac{V_S . \alpha}{f L_1} \quad (13)$$

$$\Delta I_2 = \frac{V_S . \alpha}{f L_2} \quad (14)$$

*The peak to peak ripple voltage across the capacitor $C_1$ & $C_2$ is:*

$$\Delta V_{c1} = \frac{I_S (1-\alpha)}{f C_1} \quad (15)$$

$$\Delta V_{c2} = \frac{\alpha V_S}{8 C_2 L_2 F^2} \quad (16)$$

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)), Volume 2, Special Issue 3, February 2014)
International Conference on Trends in Mechanical, Aeronautical, Computer, Civil, Electrical and Electronics Engineering (ICMACE14)

*C. Design Soft starter*

The most commonly used way of limiting the starting current is used the starting resistance. The introduction of the starter increases the net resistance value in the circuit, since the starter is in series to the motor. As a result the armature current value reduces to a limit which is not harmful to the motor. Once the work of the starter is done the starter has to be gradually removed. The time taken to slowly tap out the resistance, as well as the resistance value of the starter is determined from the steady state analysis of the motor. The disadvantage of using a resistance starter is increasing the settling time of the current, as well as the energy loss through the resistor. Also the limiting value cannot be changed in a commercial starter and always predetermined. In other words it is an invariable current limiter.

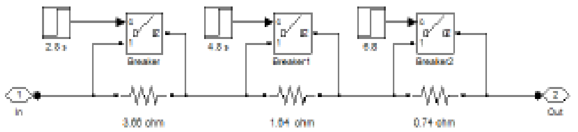


Fig 6. Circuit dram of 3 point starter

The alternate method of limiting the armature current is to use a chopping circuit. The chopping circuit uses a switch (in this model an Gate Turn On (GTO) is used). The functioning of the switch is controlled by a hysteresis controller. The hysteresis controller determines the value of the gate pulse which is to be used in the switch. The hysteresis controller consists of a relay which compares the input signal with the threshold value which is also called the hysteresis band controller. In this controller a reference current, iref (maximum current allowed for the armature) is taken and compared with the actual armature current. Hband can also be called the tolerance band. Based on the reference current the soft starter works. As a result the limiting current can be changed as per the requirement of the user.

*D. Bees implementation*

The bees algorithm is a new population based search algorithm, which it mimics the food foraging behavior of swarms of honey bee and also it simulates the intelligence foraging behavior of honey bee swarms. In most commonly the speed of the dc motor is controlled by PI controller but its having some drawbacks such as; Undesirable speed overshoot, Sluggish response due to sudden change in load torque, Sensitivity to controller gains. To overcome this limitations introducing the advanced artificial intelligence technique to control the speed.

In ABC optimization, the steps given below are repeated until a stopping criterion is satisfied.

- ✓ Each employed bee determines a food source, which is also representative of a site, within the neighborhood of the food source in her memory and evaluates its profitability.
- ✓ Each employed bee shares her food source information with onlookers waiting in the hive and then each onlooker selects a food source site depending on the information taken from employed bees.
- ✓ Each onlooker determines a food source within the selected site by herself and evaluates its profitability.
- ✓ Employed bees whose sources have been abandoned become scout and start to search a new food source randomly.

## IV. SIMULATION RESULTS

*A. Simulink model*

This section presents the simulink model and the results of the entire model of cuk converter fed dc motor using the bee's algorithm. This simulink model has six main parts;

1. Bridge rectifier and filter capacitor
2. Cuk converter
3. Soft starter
4. DC Motor
5. Speed controller
6. Pulse Area Modulation

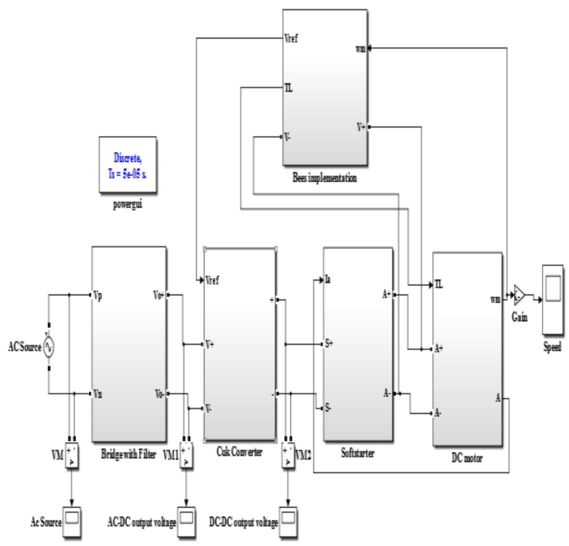


Fig 7. Simulink model of a proposed method

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)), Volume 2, Special Issue 3, February 2014)
International Conference on Trends in Mechanical, Aeronautical, Computer, Civil, Electrical and Electronics Engineering (ICMACE14)

*B. Simulation results*

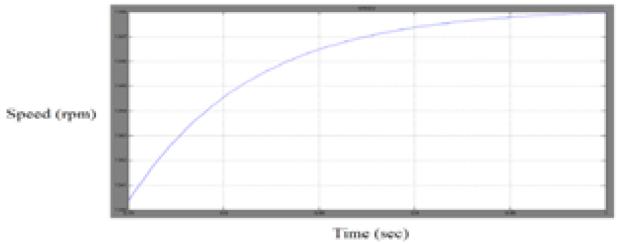


Fig 8. Output speed before controller is applied

Fig 12 shows the waveform relation b/w the Speed and the time before the controller is applied to the motor. The speed is gradually increased but it will take some time to settle the speed. Show fig 13 the curve drawn b/w the speed and time after the controller is applied to the motor. The speed settling time is very less compared to the conventional approach (i.e.) it reached 1500 rpm at 0.5 seconds. Fig 15 and 16 shows the output waveforms of the fixed and variable dc voltages. The applied input ac voltage is 120V, and then it is rectified into 116.4V dc voltage. With the help of chopper circuit it is again converted into 240V dc voltage.

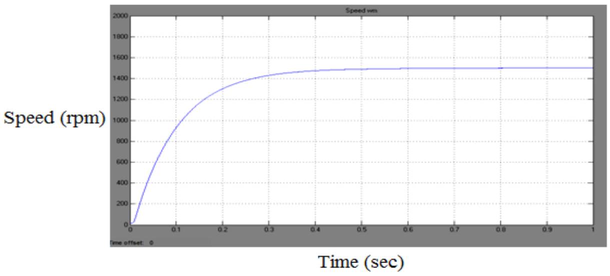


Fig 9. Output Speed after the controller is applied

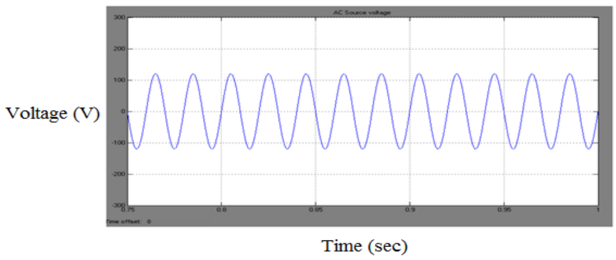


Fig 10. Input ac voltage waveform

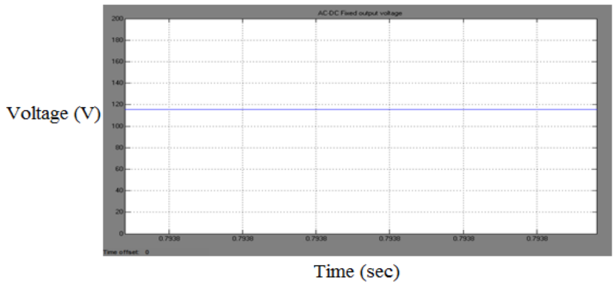


Fig 11. Output dc voltage waveform

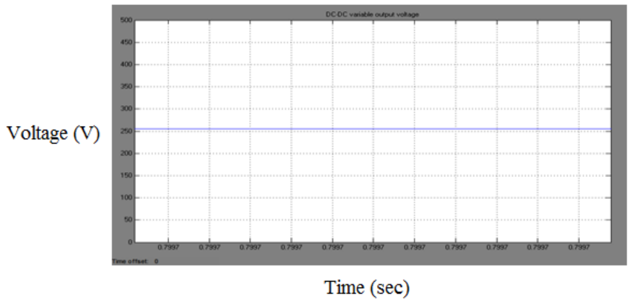


Fig 12. Output boost voltage waveform

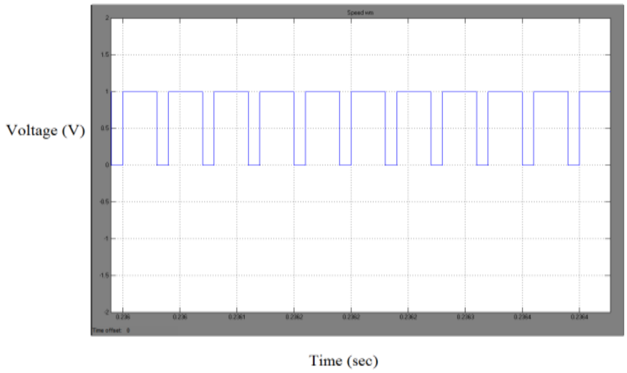


Fig 13. Output gate pulse waveform

*Table 2 Input voltage vs Speed*

| Input voltage | ABC controller | PI controller |
|---|---|---|
| | Speed | Speed |
| 0 | 0 | 0 |
| 50 | 1084 | 1000 |
| 80 | 1492 | 1200 |
| 100 | 1497 | 1320 |
| 120 | 1500 | 1420 |

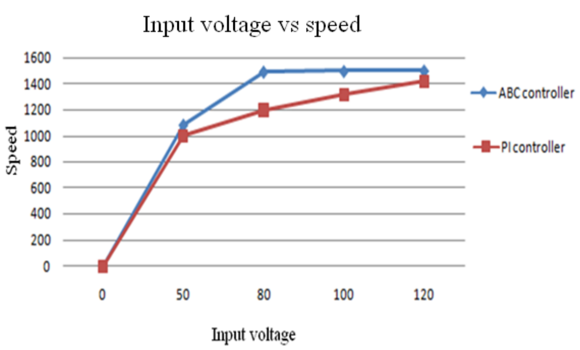


Fig 14. Input voltage vs Speed

*Table 3. Input voltage vs % Efficiency*

| Input voltage | Output voltage | %Efficiency |
|---|---|---|
| 30 | 28 | 93 |
| 50 | 48 | 96 |
| 80 | 77 | 96.25 |
| 100 | 96 | 97 |
| 120 | 116 | 97.5 |

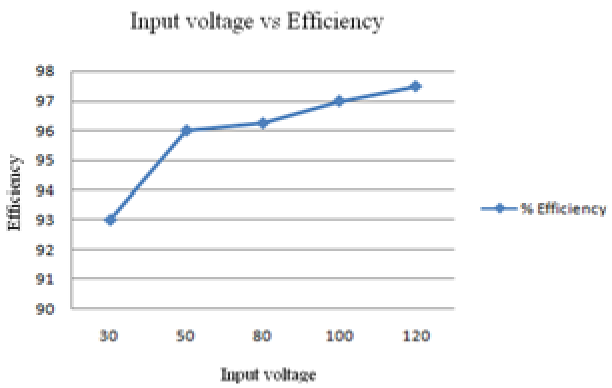


Fig 15. Input voltage vs Efficiency

Fig 20 shows the efficiency curve of the proposed system. The waveform represents the input voltage gradually increased, and then the efficiency of the system is also gradually increased.

| Input voltage | Output voltage |
|---|---|
| 30 | 58 |
| 50 | 96 |
| 80 | 157 |
| 100 | 202 |
| 120 | 264 |

## IV. CONCLUSION

This paper presented the application of artificial bees colony algorithm in the control of cuk converter fed dc motor, highlighting its superior performance compared to the conventional methods. The proposed converter contributes to a reduced number of power switching devices. This may result in advantages such as small installation size and less energy loss. One-switch converter is very convenient for an economical variable dc voltage supply since the number of switches does not highly affect the characteristics of the ac-dc converters. The settling time of the speed of motor is less in models using closed loop controller based on Pulse Area Modulation when compared to other models using conventional control techniques.

Thus, the performance of the artificial bee colony algorithm is superior to the conventional control techniques.

## V. REFERENCE

[1] Subhajit Samanta, Tanya Tanesha, Vijayakumar, "Design and simulation of speed controller for ac-dc buck-boost converter for dc motor drive with soft starter", International Conference on Energy Efficient Technologies for Sustainability (ICEETS), March 2013.

[2] Astha Tiwari, Dr.S.P.Dubey, "Performance analysis of fuzzy based DC motor drives", International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 2, March 2013.

[3] Amit Atri, Md. Ilyas, "Speed control of DC motor using neural network configuration", International Journal of Advanced Research in Computer Science and Software Engineering, May 2012.

[4] K.Sundareswaran, V.T. Sreedevi, "DC motor speed controller design through a colony of honey bees", TENCON IEEE Region 10 Conference, November 2012.

[5] Byamakesh Nayak, Saswati Swapna Dash, "Battery operated closed loop speed control of DC separately excited motor by boost-buck converter", IEEE 5th India International Conference on Power Electronics (IICPE), December 2012.

[6] S. Ben John Stephen, T. Ruban Devaprakash, "Improved Control Strategy on Buck-Boost Converter Fed DC Motor", International Conference on Recent Advancements in Electrical, Electronics and d Control Engineering, 2011.

[7] S.R. Khuntia, K.B. Mohanty, S. Panda and C. Ardil, "A comparative study of PI, IP, fuzzy & neuro fuzzy controller for speed control of dc motor drive", International Journal of Electrical Systems Science and Engineering , 2009.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)), Volume 2, Special Issue 3, February 2014)
International Conference on Trends in Mechanical, Aeronautical, Computer, Civil, Electrical and Electronics Engineering (ICMACE14)

[8] Young-Song Jeon, Sangwook Nam and Kyungheon Koo, "Pulse Area Modulation for High-Efficiency Power Amplifier", in IEEE Microwave and Wireless components letters. Power Electron, 2005.
[10] A. Mechi, S. Funabiki, "Step-up/down voltage PWM ac-dc converter with one switching device", in IEEE Proc., 1993, pp. 35-43.
[11] O. Stihi, B.T. Ooi, "A Single-phase controlled current PWM rectifier", in IEEE Trans. Power Electron., 1988, pp.453.

## BIOGRAPHY

**B. Ragavendra** was born in 1987. He received the B.E. degree in Electrical and Electronics Engineering from K.S.Rangasamy College of Technology, Tiruchengode, affiliated to Anna University, Chennai, Tamilnadu, India in 2009 and M.E. degree in Power Electronics and Drives from St.Joseph's College of Engineering, Chennai, affiliated to Anna University, Chennai, Tamilnadu, India in 2011. He joined as a Lecture in the department of Electrical and Electronics Engineering from Erode Sengunthar Engineering College, Thudupathi upto 2012. He is currently as a Assistant Professor of Electrical and Electronics Engineering from Erode Sengunthar Engineering College, Thudupathi, Tamilnadu, India. His research interests include analysis, design, and innovations in electric motor drives, electric machines, and power converters for motor drives. He guided many under graduate and post graduate projects.

**S.Vijayanand** was born in 1987. He received the B.E. degree in Electrical and Electronics Engineering from Erode Sengunthar Engineering College, Erode, affiliated to Anna University, Chennai, Tamilnadu, India in 2009 and M.E. degree in VLSI from M.P Nachimuthu and M Jeganathan Engineering College, Chennai, affiliated to Anna University, Chennai, Tamilnadu, India in 2013. He joined as a Lecture in the department of Electrical and Electronics Engineering from Sri Rajiv Gandhi Polytechnic College, Chennimalai upto 2011. He is currently as a Assistant Professor of Electrical and Electronics Engineering from Erode Sengunthar Engineering College, Thudupathi, Tamilnadu, India. His research interests include analysis, design, and innovations in low power VLSI. He guided many under graduate projects.

**Jayaprakash.B** was born on Nov 20, 1989. He received his B.E Degree in Electrical and Electronics Engineering from Erode Sengunthar Engineering College, Perundurai, Erode, Anna University, Coimbatore. He is doing M.E in Power Electronics and Drives at Erode Sengunthar Engineering College, Anna University, Chennai.