

# Power Quality Improvement using Modified Cuk-Converter with Artificial Neural Network Controller Fed Brushless Dc Motor Drive



Ch.Vijaya Sree, P.Krishna Chaitanya, B.Rajesh

**Abstract:** Power factor rectification converter (PFRC) hinged bridgeless modified CUK (MCUK) converter supplied to brushless DC engine drive utilizing an Artificial Neural Network controller. Presently, alteration for traditional CUK converter can be obtained through adding a voltage multiplier circuit, to decrease converter losses for wide variation of speed to accomplish most extreme Power Factor and to limit the Total Harmonic Distortion (THD). The designed bridgeless PFRC based converter was investigated hypothetically to obtain the circumstances, for example, Power factor (PF) and Total Harmonic Distortion (THD) are assessed and contrasted with traditional Diode Bridge Rectifier hinged CUK converter supplying to brushless DC motor drive and bridgeless altered CUK using PI controller driven brushless DC motor. Here, simulation results uncover that the ANN controllers are viable and productive contrasted with PI controller, as the steady state error when ANN control used is less and the stabilization of the system is better while using it. Additionally in ANN system, the time to perform calculation is less as there are no numerical models. The performance of the designed framework is simulated in MATLAB/Simulink environment.

**Keywords:** Artificial Neural Network (ANN), Brushless DC motor, modified CUK-converter (M-CUK), Power factor rectification Converter (PFRC).

## I. INTRODUCTION

Today, the brushless DC motor become famous for having advantages such as great reliability, great efficiency, unusual torque to inertia ratio, low maintenance, and immense energy density, and so on. It was found applications in industry tools [1] huge space, air conditioners [2], the E.V's [3], Artificial Intelligence [4], space applications. The BRUSHLESS DC engine drive is by and large provided through Diode Bridge Rectifier alongside DC connect capacitor that brings about low power factor and also more THD [5] that doesn't fulfill the worldwide power quality measures such as IEC-61000

standards [6]. Thus, the power factor correcting converters came, to produce very less THD and to improve power factor when used as front end converters for a brushless DC engine drives. Boost converter, driving the brushless DC motor placed utilizes direct torque control power factor correction discussed in [8], which has a mind boggling regulation technique. Significant expense Digital Signal Processor's are utilized to actualize it, so it isn't reasonable for less cost operations. A functioning power factor correction which utilizes PWM switching was suggested in [9] this, possess a huge switching misfortunes. A step up-down converter sustained brushless DC engine drive for PFRC is designed [10] which experiences huge switching misfortunes and lessens the general framework effectiveness. Power factor correction converter utilizing SEPIC converter bolstered brushless DC engine drive explained in [11] which additionally experiences huge switching misfortunes. A functioning PFRC to drive brushless DC engine dependent CUK converter was designed in [12] that utilizes 3 sensors to regulate direct current voltage, which fits uniquely for immense power operations. Each and every topologies discussed above utilize a Diode bridge rectifier circuit as front end converter. This out comes in circuit multifaceted nature with diminished effectiveness. Consequently numerous bridgeless converters configuration designs are came for PFRC converters supplying brushless DC engine drive so as to keep away from circuit multifaceted nature with improved productivity. Bridgeless PFRC placed step up-down, CUK, Zero energy thermonuclear and Single Ended Primary inductor Converter designs for brushless DC engine drives came into existence [13-16]. These topologies experience the ill effects of low gain and huge current strains because of flows streaming collectively from input and yield currents. Moreover, traditional bridgeless Cuk converter brings about more noteworthy switch operation losses and the current strains prompts decline the rating and survival capacity of the converter. In this way, an adjusted Cuk network is essential to improve proficiency and to lessen switch losses. Here, a power factor correction based bridgeless alternating current – direct current altered CUK working in irregular operating condition is acquainted for Brushless DC engine drive to diminish present losses and to improve the productivity of the general framework. The benefits of this described brushless DC engine drive can be dissected with respect to the terminology such as power factor and total harmonic distortion over immense capacity of acceleration.

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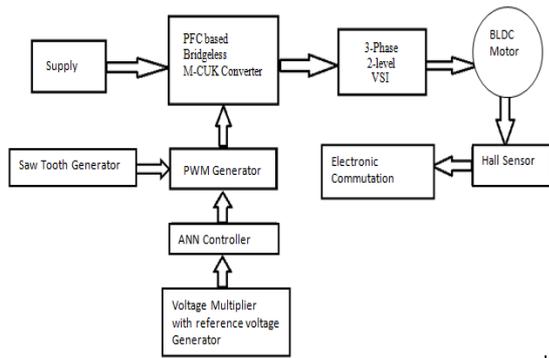
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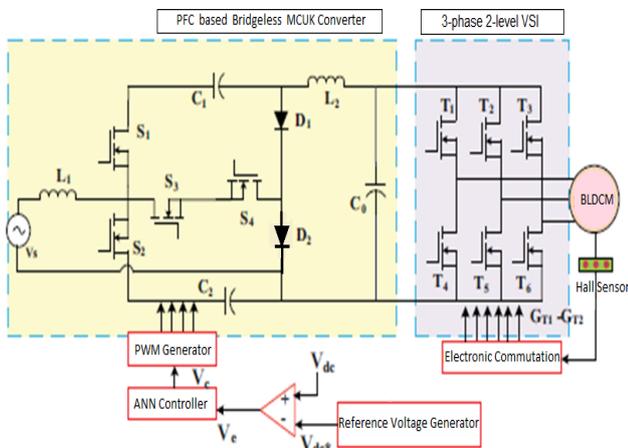
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**II. BRIDGELESS MODIFIED-CUK CONVERTER SUPPLIED TO BRUSHLESS DC MOTOR DRIVE SYSTEM**

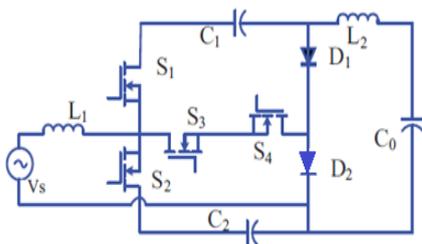


**Fig 2.1: Layout of Proposed Technique**

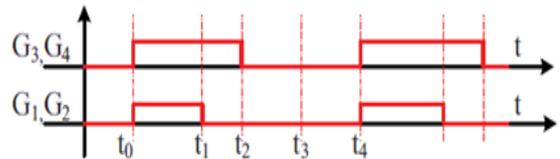
The Layout of the brushless DC engine drive system supplied through M-Cuk bridgeless converter is shown in the figure 2.1 .Stator phase windings of brushless DC motor can be powered using a voltage sources inverter, where in  $(T_1 - T_6)$  switching conduction of the inverter is done through detecting the rotor position by using a Hall signal obtained by Hall sensor. In Fig. 2.1 to generate particular pulses to the voltage source inverter in order to regulate or control the voltage an Artificial Neural Network controller is employed. Volatile DC connect potential difference of voltage source inverter empowers the speed regulation of engine. Exhibition inferred with working specifications in following Table 1 and planned subtleties were clarified in consequent segment.



**Fig: 2.2- PFC based Bridgeless M-CUK Converter with ANN Controller supplied BRUSHLESS DC Motor Drive**

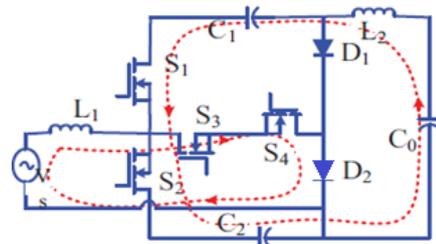


**Fig 2.3-Bridgeless changed cuk converter**



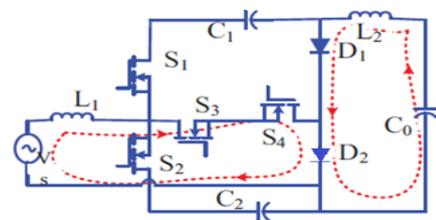
**Fig -2.4: Pattern of switches in M-CUK converter supplying brushless DC engine drive**

*Mode I* ( $T_0 < T < T_1$ ): Here, each of the switches are kept in conduction mode, for example, the output voltage switching module and PFRC module are in conduction as appears in FIG. 2.5 (i). Currently, the information side placed inductor  $L_1$  deposits energy. The stored energy of capacitors  $C_1$  and capacitor  $C_2$  are moved to output side inductor  $L_2$  and to output..



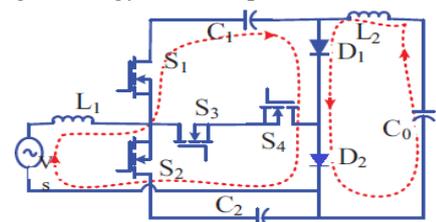
**Fig 2.5(i): Mode 1 Operation**

*Mode II* ( $T_1 < T < T_2$ ): Here, the switches  $S_3, S_4$  are in conduction and  $S_1, S_2$  remains open, for example, PFRC module is held in non-conduction mode and the output voltage of the switching module is in conduction mode as it appears in Fig. 2.5 (ii). Right now moment, the inductance  $L_1$  keeps on putting energy in the mean time the inductor  $L_2$  discharges its energy to the output.



**Fig 2.5(ii): Mode 2 Operation**

*Mode III* ( $T_2 < T < T_3$ ): In this mode, each switch is turned off, for example, PFRC switching module and the output voltage switching module is held in OFF position, as appears in Fig. 2.5 (iii). Right now moment, the inductor  $L_1$  discharges its energy to the capacitor  $C_1$ . What's more, inductor  $L_2$  keeps on discharging its energy to the output.



**Fig 2.5(iii): Mode 3 Operation**

Mode IV( $T_3 < T < T_4$ ): In this span of time, as each switch appears in Fig 2.5 (iv) stays OFF. Right now,  $L_1$  energy continuously discharged to the capacitor  $C_1$ . Current  $I_{L2}$  is reduced to zero. Output is provided through the output capacitor  $C_0$ .

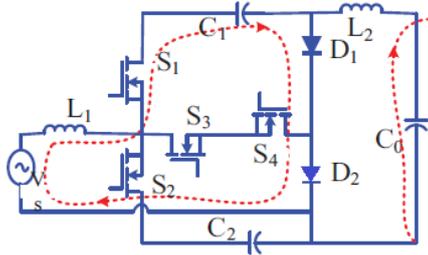


Fig 2.5(iv): Mode 4 Operation

The bridgeless altered cuk nourished brushless DC engine drive is intended to improve the power quality at AC mains along dc interface to regulate the voltage for a range of 30V - 310V. The expressions for the above designed converter topology is displayed beneath.

The Supply voltage  $V_s$  of the system is,  
 $V_s = V_m \sin(2\pi f_L t)$  (i)

Here,  $V_m$  is the maximum supply voltage,  $f_L$  is line frequency.

The output voltage of altered cuk converter can be expressed as,

$$V_{dc} = \frac{2D}{1-D} \times V_{in} \quad (ii)$$

Here  $D$  represents duty cycle,  $V_{dc}$  represents dc out coming voltage and  $V_{in}$  gives average value of the supply voltage.

Duty cycle of the proposed converter is,

$$D = \frac{V_{dc}}{V_{dc} + 2V_{in}} \quad (iii)$$

The input inductance  $L_1$  and output inductance  $L_2$  are expressed using the following equations

$$L_1 = \frac{V_{in} D}{\Delta i_{L1} f_s} \quad (iv)$$

$$L_2 = \frac{V_{dc} (1-D)}{\Delta i_{L2} f_s} \quad (v)$$

Here  $\Delta i_{L1}$  and  $\Delta i_{L2}$  represents the ripple current allowed in the inductance  $L_1$  and  $L_2$  respectively,  $V_m$  represents maximum voltage supplied and  $f_s$  indicates frequency of switches.

Values of capacitance  $C_1$ ,  $C_2$  are determined through the below equations,

$$C_1 = C_2 = \frac{1}{\omega_r^2 (L_1 + L_2)} \quad (vi)$$

Here,  $\omega_r$  represents resonance frequency of intermediary capacitors  $C_1$  and  $C_2$

Value of yield capacitor  $C_0$  value can be obtained as,

$$C_0 = \frac{I_d}{4\pi f_L \Delta v_{dc}} \quad (vii)$$

Here  $I_d$  represents dc link current,  $\Delta v_{dc}$  gives the value of ripple voltage allowed in capacitor  $C_0$  and  $f_L$  is the line frequency.

Using these derived equations, A bridgeless modified cuk converter was modeled at 1000watts using parameters given in the following Table I.

Table No.1: Specifications of modified CUK Converter fed brushless DC Motor Drive

S.No	Parameter	Value
1.	Output Voltage( $V_o$ )	1000watts
2.	Supply Voltage( $V_s$ )	220V
3.	Frequency of Line( $f_L$ )	50Hz
4.	Inductor $L_1$	4mH
5.	Inductor $L_2$	500mH
6.	Switching frequency( $f_s$ )	50KHz
7.	Capacitor $C_0$	3000 $\mu$ F
8.	Capacitor $C_1, C_2$	0.327mF

### III. EXISTED TECHNIQUE

PI is an input controller that uses the weighted summation of error and its necessary incentive to play out the control activity. The corresponding reaction can be balanced by multiplying the error by constant  $K_p$ , called proportional gain. The commitment from essential term is relative to both the greatness of error and span of error. The error is first multiplied by the gain,  $K_i$  and afterward was coordinated to give an amassed balance that has been rectified beforehand. The contribution to the PI controller is contrast between the reference esteem and error estimation of voltage. According to the correlation of reference esteem and error estimation of voltage, linear PI modifies its proportional and integral gain  $K_p=2\& K_i=0.98$  so as to diminish the consistent state error to zero for a stage contribution as appeared in fig.5.4. It is broadly utilized because of straightforward control structure however endures a drawback of fixed gains for example it can't adjust to the fluctuating parameters and states of the framework.

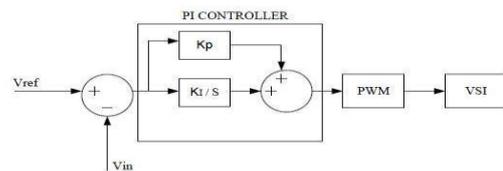


Fig 3: Basic PI control

### IV. PROPOSED TECHNIQUE

Placing Artificial Neural Network (ANN) Controller, Artificial Neural Networks are acclaimed learning models for their capacity to adapt to the requests of a changing domain. In this process, we dissect the utilization of Artificial Neural Network (ANN) controller in process industry as a substitution of PI control (or other comparative controls) to control the speed of a BRUSHLESS DC engine.

This system works with administered realizing where informational collection is displayed to prepare the system before reproduction is raced to get yield results. This ANN controller has two units inside.

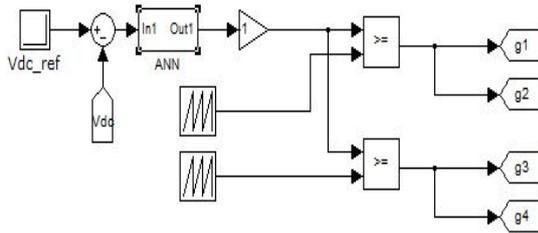


Fig 7: Representation of controller used in proposed system

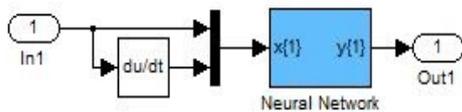


Fig 8: Layout of ANN controller

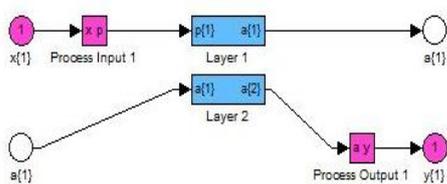


Fig 9: Back propagation of ANN used

Fig 7 shows the outline of ANN controller utilized in this investigation. NN controller controls the contribution of framework as per training information. The framework additionally forms contribution as indicated by the training information in NN Model. The difference provides the error whereas system output and control error contribute towards model's output. Since output of plant is nourished back to NN controller's info, it takes a shot at back-propagation model of neural systems. Back-propagation neural system is a multilayer feed forward system with back-propogating of error work. A basic back-propagation neural system has just three layers for example input, output and center layer. The transfer function in feed forward neural neural systems is typically sigmoid function which has constant and nonlinear properties. It is spoken to by the accompanying condition:

$$f(x) = \frac{1}{1 + e^{-ax}} \quad (8)$$

## V. RESULTS

In order to check the adequacy for designed system, the m- Cuk converter feeding a brushless DC engine drive was reproduced utilizing MATLAB / Simulink by taking into account evaluation parameters referenced in Table II use.

Table II. Simulated Motor Parameters

Voltage	310V
Rated Current	4.52A
Rated speed	4600rpm
Rated power	1 horsepower

Using the ANN controller at 4600 rpm speed with torque as 0.5 Nm of brushless DC motor fed trough altered cuk converter output waveforms are shown in the figures below. The harmonic range of input current with dc voltage 300V of the designed m-cuk converter individually is shown in Fig 17(a). Here, THD of designed altered Cuk converter is 1.82%, which is as far as possible in accordance with IEC standards.

Supply Voltage and Supply Current of brushless DC motor drive at rated speed

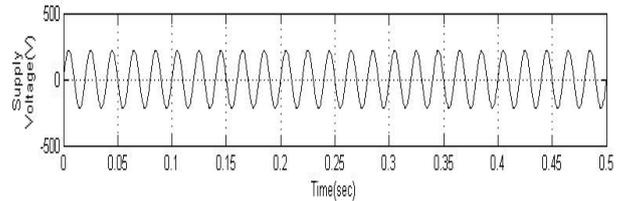


Fig 10(a): Supply Voltage for brushless DC Motor

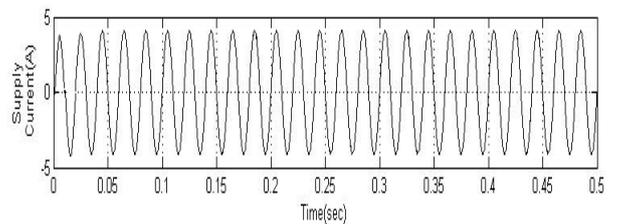


Fig 10(b): Supply Current for brushless DC Motor

A.Comparison of DC Link Voltage of Conventional, M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive

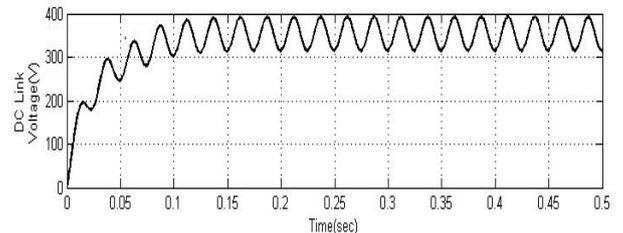


Fig 11(a): DC Link Voltage of Conventional Topology

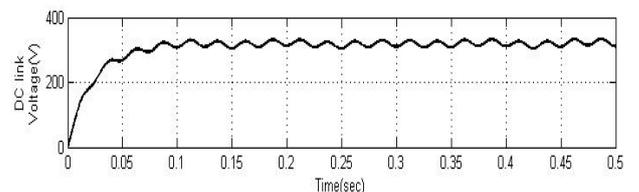


Fig 11(b): DC Link Voltage of M-CUK with PI

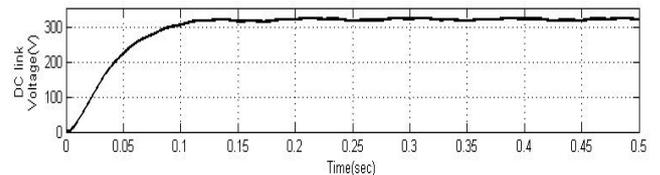
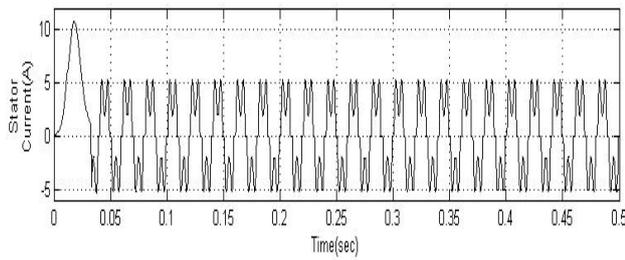
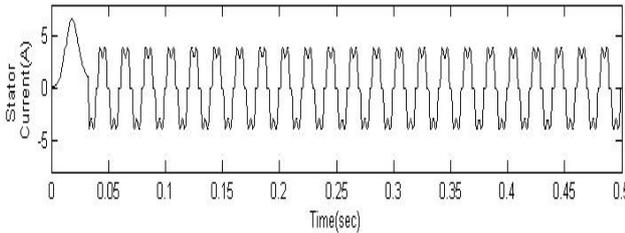


Fig 11(c): DC Link Voltage of M-CUK with ANN

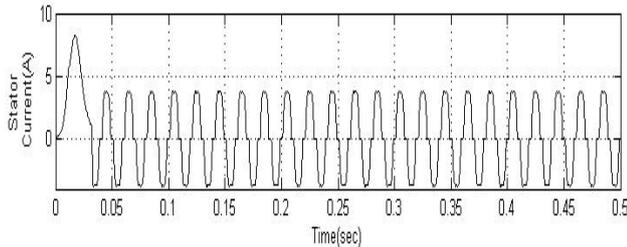
**B. Comparison of Stator Current of Conventional, M-CUK with PI controller and M-CUK with ANN controller supplied brushless DC engine drive**



**Fig 12(a): Stator Current of Conventional Topology**

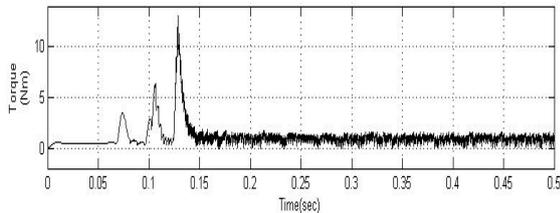


**Fig 12(b): Stator Current of M-CUK with PI**

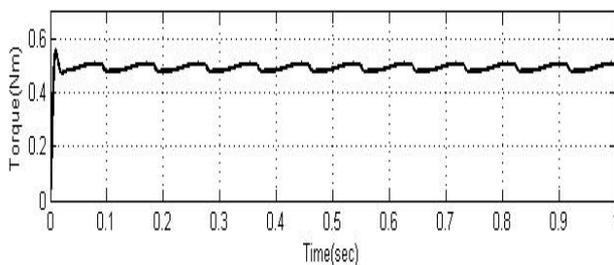


**Fig 12(c): Stator Current of M-CUK with ANN**

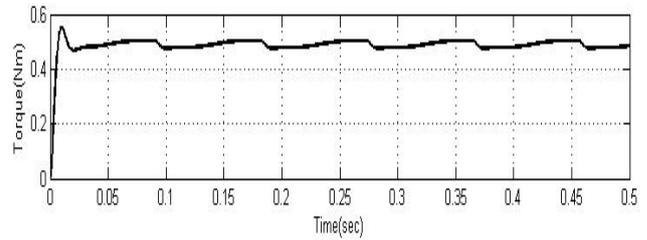
**C. Comparison of Torque of Conventional, M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive**



**Fig 13(a): Torque of Conventional Topology fed brushless DC motor**

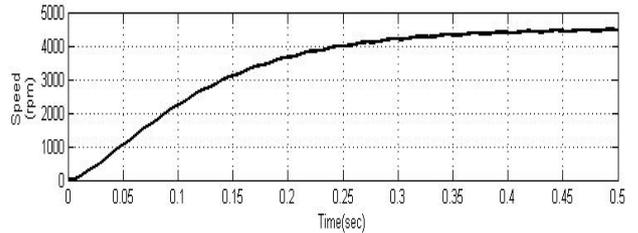


**Fig 13(b): Torque of M-CUK with PI fed brushless DC motor**

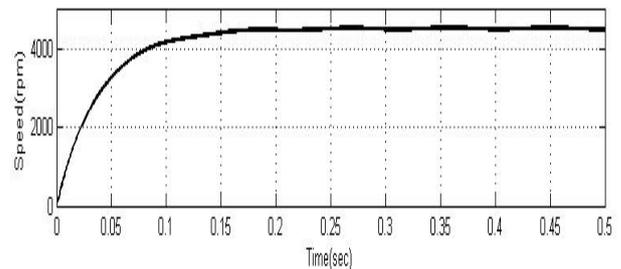


**Fig 13(c): Torque of M-CUK with ANN fed brushless DC motor**

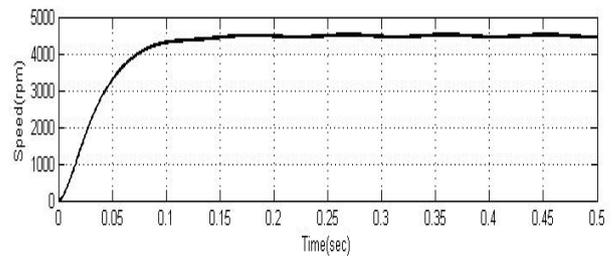
**D. Comparison of Speed of Conventional CUK, M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive**



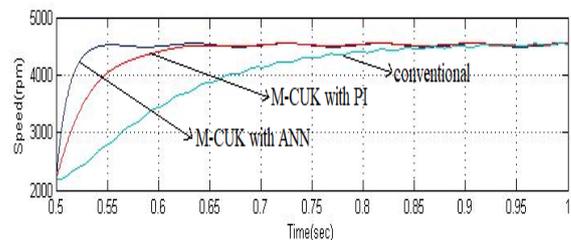
**Fig 14(a): Speed of Conventional CUK Topology fed brushless DC motor**



**Fig 14(b): Speed of M-CUK with PI fed brushless DC motor**

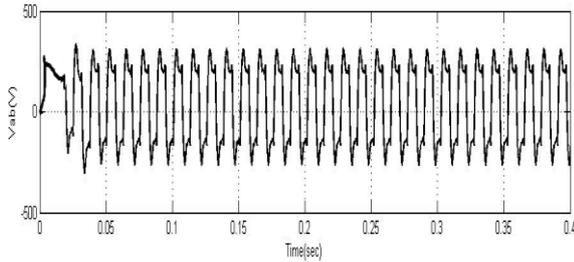


**Fig 14(c): Speed of M-CUK with ANN fed brushless DC motor**

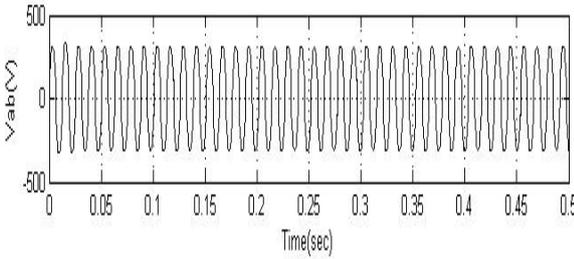


**Fig 14(d): Speed comparison of Conventional CUK, M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive**

**E. Comparison of Line Voltage( $V_{ab}$ ) of M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive**

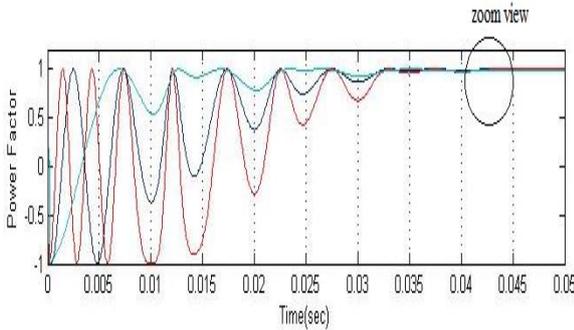


**Fig 15(a): Line Voltage ( $V_{ab}$ ) of M-CUK with PI controller fed brushless DC motor**

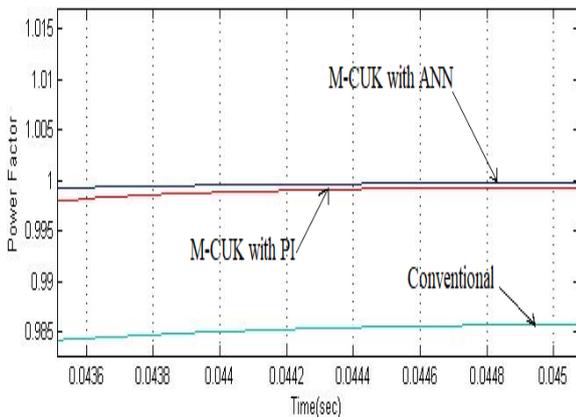


**Fig 15(b): Line Voltage ( $V_{ab}$ ) of M-CUK with ANN controller fed brushless DC motor**

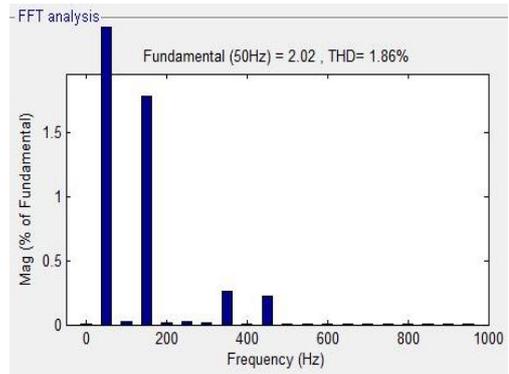
**F. Comparison of Power Factor of Conventional CUK, M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive**



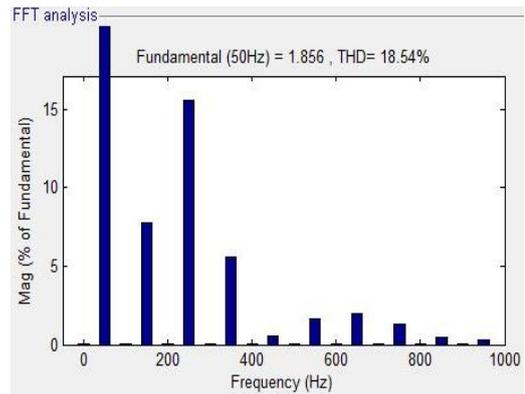
**Fig 16(a): Comparison of Power Factor of Conventional CUK, M-CUK with PI controller and M-CUK with ANN controller fed brushless DC engine drive**



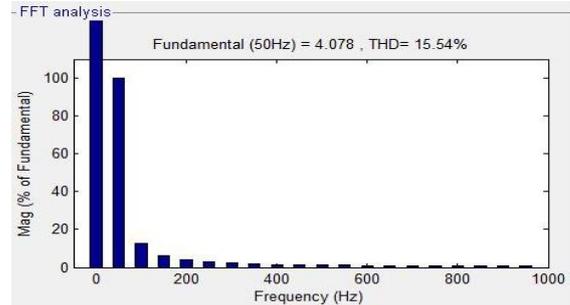
**Fig 16(b): Enlarged view of above PF comparison wave**



**Fig 17(a): THD of Supply current of M-CUK converter with ANN Controller fed brushless DC drive**



**Fig 17(b): THD of Stator current of M-CUK converter with ANN controller fed brushless DC motor**



**Fig 17(c): THD of DC Link Voltage of PFRC based M-CUK converter with ANN controller fed brushless DC motor**

**Table- 3 THD comparison table based on simulation results**

Parameters	DBR based CUK converter	M-CUK with PI controller	M-CUK with ANN controller
Supply Current	5.13%	3.24%	1.86%
Stator Current	49.87%	25.29%	18.54%
Dc link voltage	20.16%	15.54%	14.58%

**Table-4 Power factor comparison table based on simulation results**

Parameters	DBR based CUK converter	M-CUK with PI controller	M-CUK with ANN controller
Power factor	0.98	0.99	0.999

## VI. CONCLUSION

From the simulation results, presumed that the brushless DC Motor Drive supplied through Bridgeless Modified CUK converter with

ANN Controller have decreased all out total harmonic distortion (THD) when contrasted with other traditional topologies. The accentuation of the present paper is focused on enhancing power quality specifications of brushless DC drive utilizing bridgeless converters as front side converter. Power factor and THD of ordinary Diode Bridge Rectifier based CUK converter supplying brushless DC motor drive, bridgeless altered CUK utilizing PI controller based brushless DC engine drive and bridgeless M-CUK utilizing ANN controller supplied brushless DC motor drive have been broke down and the outcomes are looked at for different parameters. Designed topology was depicted to explain the benefits of bridgeless M-CUK converter in empowering the power factor to almost the value 1, with a THD of 1.86% which is too low. The investigation has been additionally fortified through a decrease in the switch current stresses using a similar topology. The outcomes have been appointed to guarantee an utilization for the designed converter in developing brushless DC motor driven applications and fashion to ricochet with viable utilization of accessible power.

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