International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 4, June 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Power Factor Improved using CSC Converter in PMBLDC Motor

Radhika S, Nisha P

Assistant Professor, Department of Electrical and Electronics Engineering,
Mohamed Sathak A.J. College of Engineering, Siruseri, Chennai, Tamil Nadu, India

ABSTRACT

This Project deals with a highly reliable electrical drive utilizing the Brushless DC Motor. The motor is fed by Voltage source Inverter (VSI) with a dc-dc converter power factor correction circuit (PFC) as the VSI's predecessor. The Performance of dc-dc converters is analyzed and the results are discussed to arrive at the best suited converter. Neuro fuzzy Logic Controller is used as the Intelligent Controller for the BLDC motor. Reliable, low cost arrangement is thus provided to achieve unity power factor and speed regulation with accuracy. The Bridgeless PFC-Modified SEPIC Rectifier performs power factor correction and DC voltage control in single stage using only one controller. The designed PFC converter results in an improved power quality at AC mains in a wide range of speed control and input AC voltage. Power factor is improved by using CSC converter. Proposed method works with better power factor. The proposed method is analyzed in MATLAB simulation and hardware is implemented.

KEYWORDS: *Brushless DC Motor, Voltage Source Inverter, Neuro fuzzy Logic Controller, PFC Converter, CSC Converter, MATLAB*

How to cite this paper: Radhika S | Nisha P "Power Factor Improved using CSC Converter in PMBLDC Motor" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-4, June 2020, pp.43-53, URL: www.ijtsrd.com/papers/ijtsrd30863.pdf

IJTSRD30863

1. INTRODUCTION

The air-conditioning is energy intensive application which normally uses single phase induction motors for driving its compressor and fans. The efficiency is between 70-80%. Moreover the on-off control employed for the temperature control is not energy efficient and introduces many disturbances in the distribution system along with increased wear and tear of the motor and reduce power factor. The use of Permanent magnet DC Motor for driving the compressor results in energy efficiency improvement of air conditioner. Moreover, the temperature in the air conditioner under speed control. This paper presents to improve the power factor using bridgeless SEPIC converter for Permanent Magnet Brush Less DC motor application. Mainly in air conditioning systems to achieve the below, which is difficult in conventional system. Smooth start-up of air conditioning systems without fluctuations in input voltage. Achieve the study and smooth speed control to maintain the constant room temperature. Avoid the harmonics in the power system due to the continuous switching millions of air conditioners and main higher efficiency.

2. BLOCK DIAGRAM OF EXISTING SYSTEM TECHNIQUE

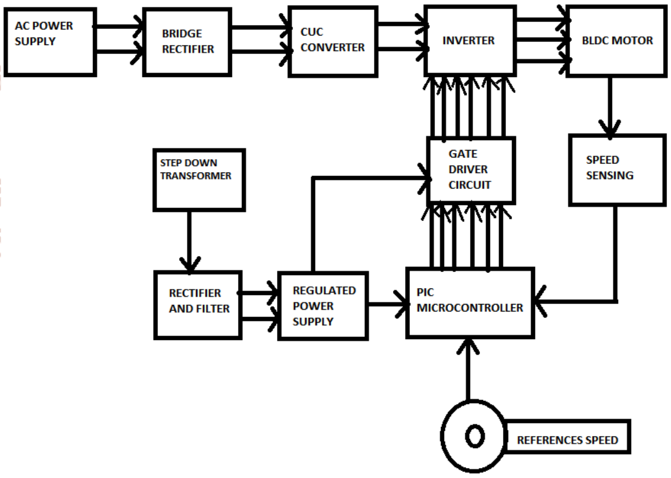


Fig 1: Block diagram for Existing system

The AC supply is given to the bridge rectifier which converts from AC to DC and it is given to the CUK converter which boosts the given voltage. This voltage is fed to the inverter which again converts from DC to AC and it is given to the BLDC motor at which the motor runs. Thus for the controller circuit, the AC voltage is stepped down using transformer and the stepped down voltage is given to the rectifier and filter. Now the DC supply is given to the regulated power supply which maintains the constant voltage. This constant voltage is fed to the microcontroller and the gate driver. The gate driver accepts the low voltage and gives the required voltage to the inverter. The speed of the motor is sensed using hall sensing and it is given to the microcontroller. The speed of the motor and the reference speed is supplied to the microcontroller which compares both the speed and it is given to the inverter. Thus the speed is controlled.

2.1. Disadvantages Of Existing System
- There will be a interrupt during fault condition.
- Power factor is low.
- Bridge rectifier is implemented which reduces power factor and loss is high.
- low efficiency.
- low reliability.
- low ruggedness.

3. BLOCK DIAGRAM OF PROPOSED SYSTEM
In this project to improve the power factor using bridgeless SEPIC converter for BLDC motor application. The bridgeless SEPIC converter is configured from a buck controller that drives a high-side PMOS FET. The bridgeless SEPIC converter is another option for regulating an unregulated input-power supply. The rotor position signals are required only for electronic commutation of BLDC using switching of voltage source inverter.

The AC supply is given to the CSC converter which rectifies from AC to DC and also boosts the given voltage. This voltage is fed to the 6 pulse converter which again converts from DC to AC and it is given to the BLDC motor at which the motor runs. Thus for the controller circuit, the AC voltage is stepped down using transformer and the stepped down voltage is given to the rectifier and filter. Now the DC supply is given to the regulated power supply which maintains the constant voltage.

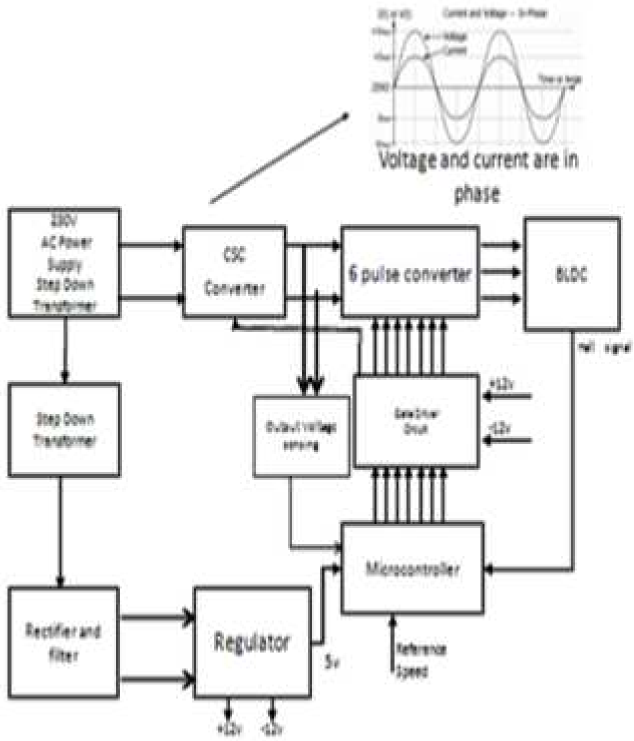


Fig 2: Block diagram of Proposed System

This constant voltage is fed to the microcontroller and the gate driver. The given output voltage is sensed using output voltage sensing. The gate driver accepts the low voltage and gives the required voltage to the inverter. The speed of the motor is sensed using hall sensing and it is given to the microcontroller. The speed of the motor and the reference speed is supplied to the microcontroller which compares both the speed and eliminates the error and it is given to the inverter. Thus the speed is controlled.

3.1. Advantages of Proposed System.
- Power factor is improved .
- Speed control is achieved.
- No interrupt occurred.
- Overall voltage regulation is better due to CSC converter.
- high efficiency.
- high reliability.
- high ruggedness.
- low electromagnetic interference (EMI) problems.
- excellent performance.

4. CSC TOPOLOGY
4.1. CSC Converter:

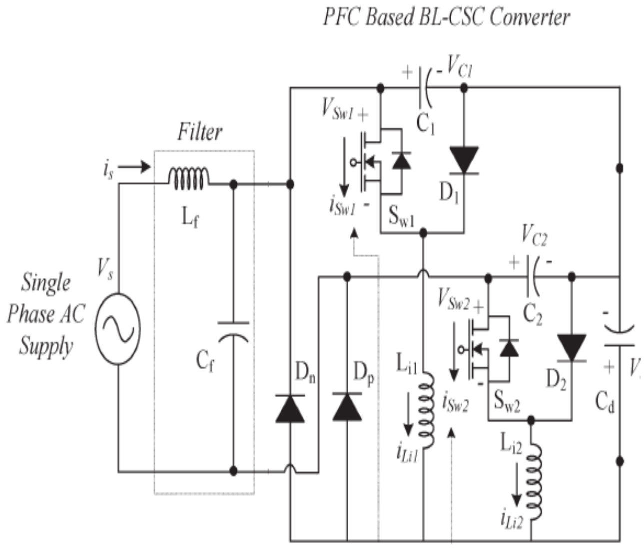


Fig 3: CSC converter

The changing current will produce a change in voltage across the inductor, and now inductor be a voltage source. The stored energy in the inductor's magnetic field supports current flow through the load. During this time, the inductor is discharging its into the rest of the circuit. If the switch is closed again before the inductor fully discharges (on-state), the voltage at the load will always be greater than zero.

4.2. Modes of Operation:
4.2.1. Mode I-A:

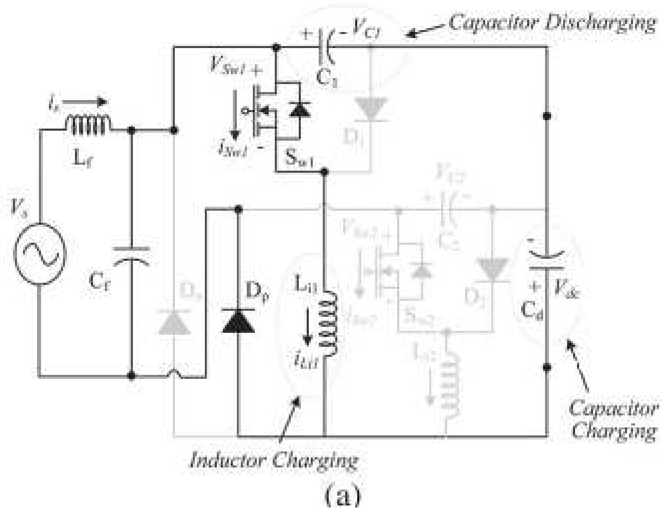
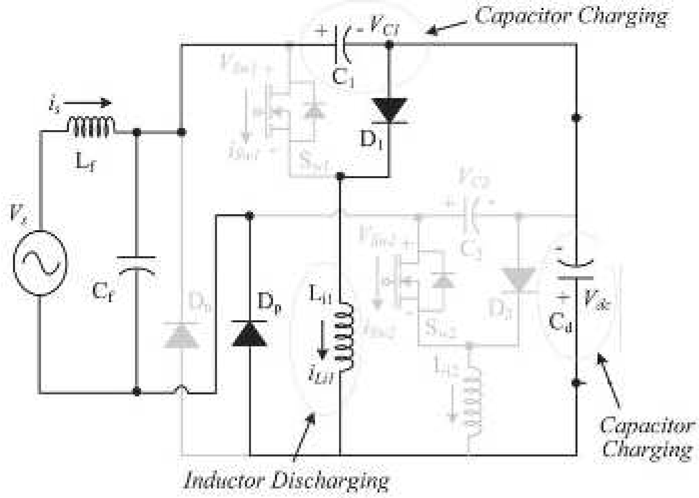


Fig 4: Mode I-A

As shown in Fig. 3.2, when switch Sw1 is turned on, the input side inductor Li1 starts charging via diode Dp, and current iLincreases, whereas the intermediate capacitor C1 starts discharging via switch Sw1 to charge the dc link capacitor Cd. Therefore, the voltage across intermediate capacitor VC1 decreases, whereas the dc link voltage Vdc increases.

4.2.2. Mode I-B:

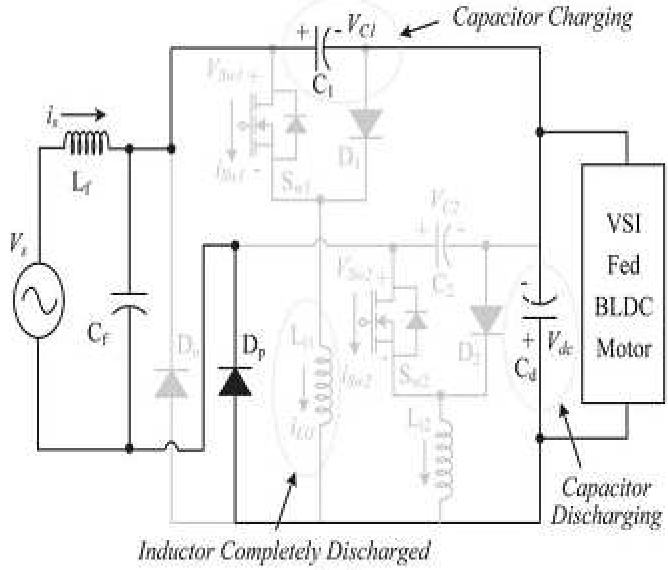


(b)

Fig 5: Mode I-B

When switch *Sw*1 is turned off, the energy stored in inductor *Li*1 discharges to dc link capacitor *Cd* via diode *D*1, as shown in Fig. 3(b). The current *iLi*reduces, whereas the dc link voltage continues to increase in this mode of operation. Intermediate capacitor *C*1 starts charging, and voltage *VC*1 increases, as shown in Fig 3.3.

4.2.3. Mode I-C:



(c)

Fig 6: Mode I-C

This mode is the DCM of operation as the current in input inductor *Li*1 becomes zero, as shown in Fig 3.4. The intermediate capacitor *C*1 continues to hold energy and retains its charge, whereas the dc link capacitor *Cd* supplies the required energy to the load. The similar behaviour of the converter is realized for the other negative half-cycle of the supply voltage. An inductor *Li*2, an intermediate capacitor *C*2, and diodes *Dn*and *D*2 conduct in a similar way, as shown in Fig. (d)–(f).

4.3. ADVANTAGES OF CSC

- Converter which operates in Discontinuous Inductor Current Mode (DICM).
- It operates the Voltage Source Inverter in low frequency switching.
- It operates in Discontinuous Inductor Current Mode to achieve unity power factor.
- maintains the DC link voltage control at ac mains by using PWM technique
- converter helps in reducing overall system losses.

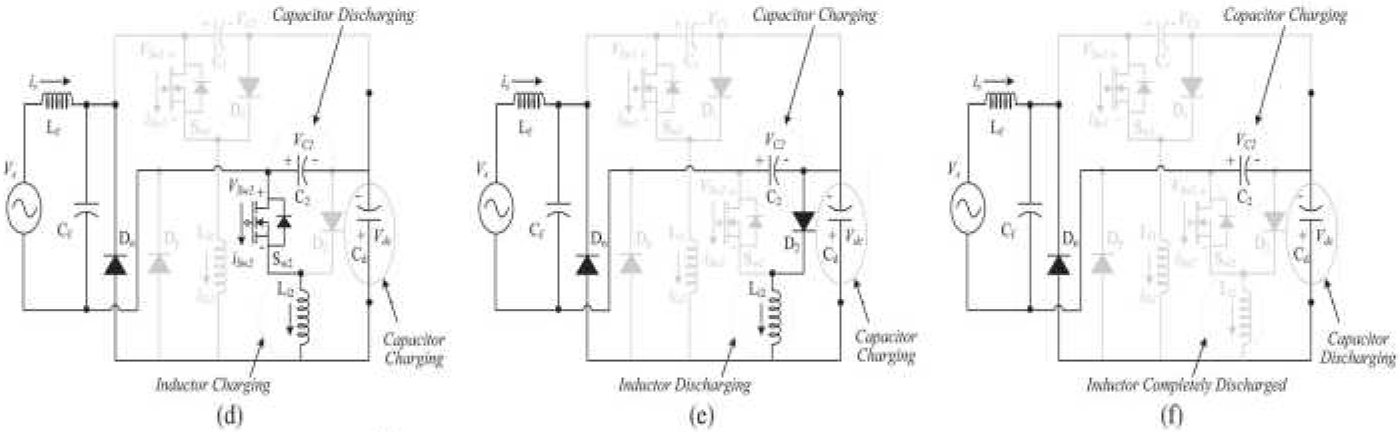


Fig 7: charging and discharging

4.4. APPLICATIONS OF CSC

- PV array based centrifugal water pumping system utilizing **canonical switching cell** (CSC)
- applicable to multi-output **switched mode power supply** (SMPS) used in personal computers (PCs).
- converter-fed brushless dc motor drive for low-power household applications
- multiport bidirectional DC–DC converters

5. CONVENTIONAL INVERTER TOPOLOGY

This project is implemented by a 3 Phase full bridge inverter topology with six switches in order to drive the BLDC Motor. The 3-phase full bridge arrangement was chosen for the power interface between the motor and controller. The full bridge was chosen for it higher torque output capability over a half bridge arrangement. The purpose of the bridge circuit is to enable each of the three motor phases to be switched on as required by the motor. And another new implementation of this project is RF-link, which is used to drive the motor from remote.

6. INVERTERS

A device that converts dc power to ac power at desired output voltage and frequency is called an inverter. Inverters can broadly classify into two types: VSI and CSI .

6.1. SIX STEP THREE PHASE VOLTAGE SOURCE INVERTER

Where, S1 to S6 are the MOSFETs and the three phase load is assumed to be star connected. The MOSFETs are numbered in the sequence in which they are triggered to obtain voltages v_{ab},v_{bc},v_{ca} at the output terminals a, b and c of the inverter.

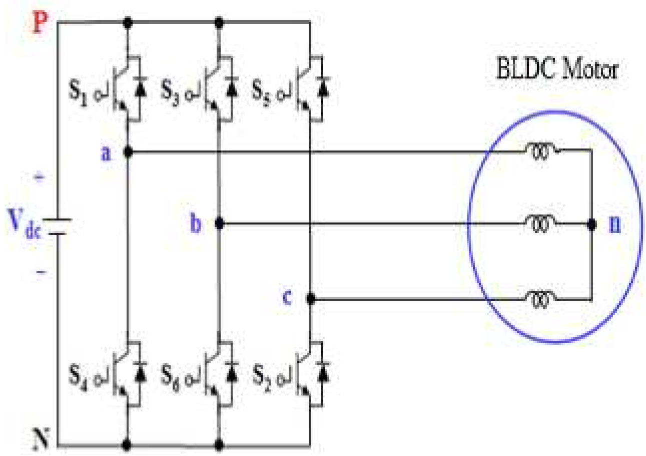


Fig 8: Three-Phase Voltage Source Inverter.

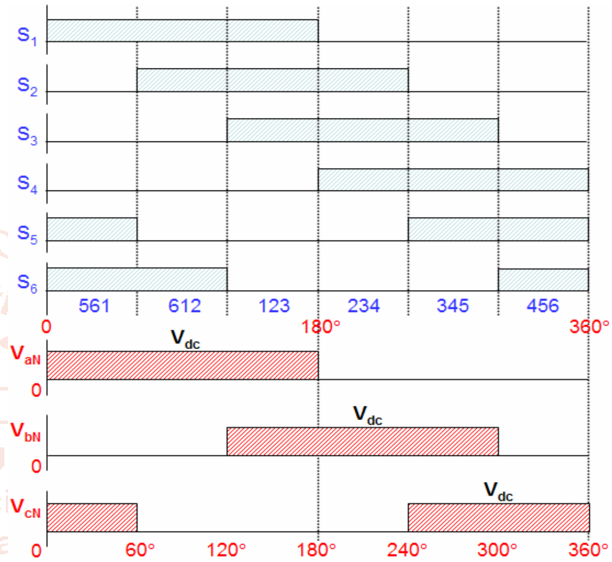


Fig 9: Waveforms of Gating Signals, Switching Sequence, Line to Negative

6.2. 180 MODE INVERTER

180° CONDUCTION

In 180^0 conduction scheme, each device conducts for 180^0. They are turned ON at regular interval of 60^0 in the sequence Q_1,Q_2,Q_3,Q_4,Q_5,Q_6.The output terminals A B and C of this bridge are connected to the terminals of a 3-phase star or delta connected load.

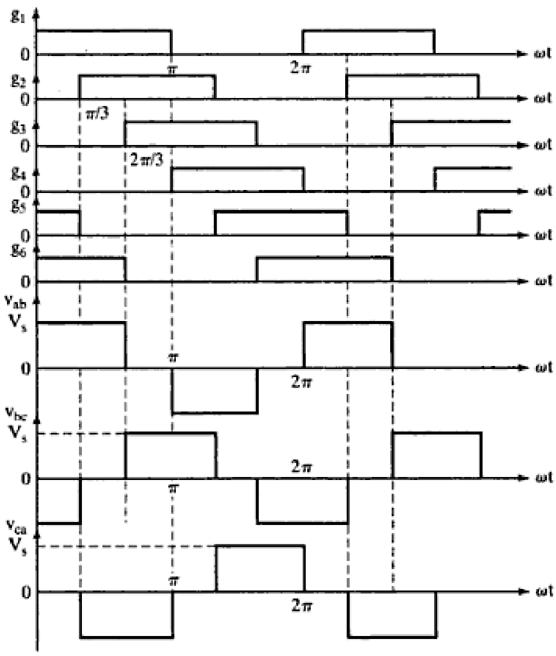


Fig 10: Wave forms for 180˚conduction mode

6.3. 120 MODE INVERTER
In 120^0 conduction scheme each device conducts for 120^0.It is preferable for a delta connected load because it provides a six step waveform across any phase. As each device conducts for 120^0, only two devices are in conduction state at any instant.

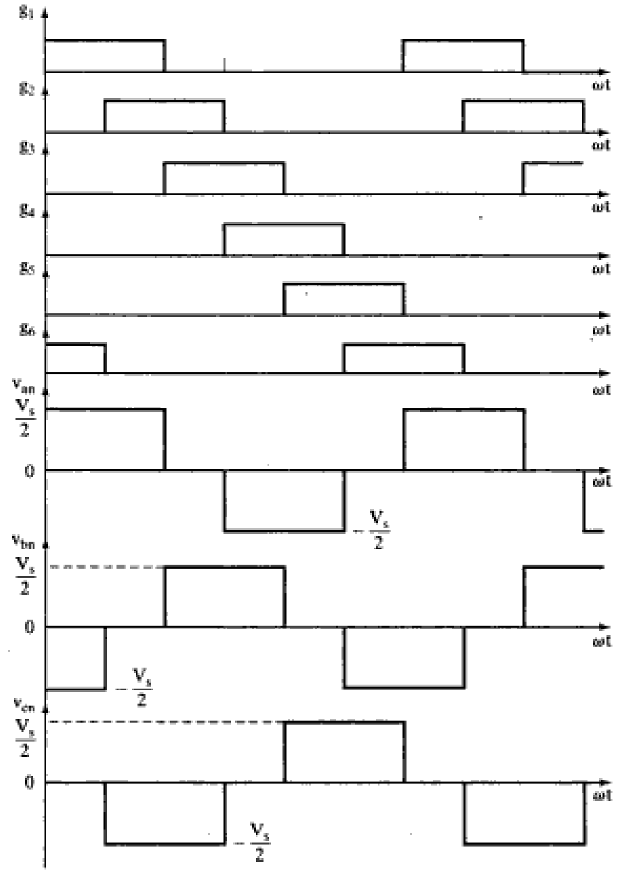


Fig 11: Wave forms for 120°conduction mode

6.4. VOLTAGES FOR SIX-STEP VOLTAGE SOURCE INVERTER.

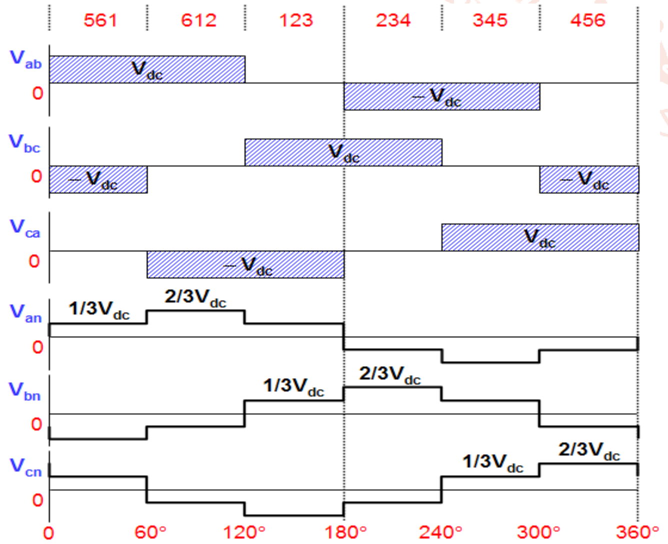


Fig 12: Waveforms of Line to Neutral (Phase) Voltages and Line to Line Voltages for Six-Step Voltage Source Inverter.

6.5. MERITS AND DEMERITS OF 120° MODE INVERTER OVER 180° MODE INVERTER
For the simulation of the permanent magnet synchronous Motor in this project we use a six step inverter in 120° mode because of its advantages over 180 ° modes.

7. NEURO FUZZY
7.1. Introduction
NEURO Fuzzy Systems Since the moment that fuzzy systems become popular in industrial application, the community perceived that the development of a fuzzy system with good performance is not an easy task. The problem of finding membership functions and appropriate rules is frequently a tiring process of attempt and error.

This lead to the idea of applying learning algorithms to the fuzzy systems. The neural networks, that have efficient learning algorithms, had been presented as an alternative to automate or to support the development of tuning fuzzy systems.

7.2. Types Of Neuro-Fuzzy Systems
In general, all the combinations of techniques based on neural networks and fuzzy logic can be called NEURO-fuzzy systems. The different combinations of these techniques can be divided, in accordance with, in the following classes:
- Cooperative NEURO-Fuzzy System
- Concurrent NEURO-Fuzzy System
- Hybrid NEURO-Fuzzy System

7.2.1. Cooperative Neuro-Fuzzy System:

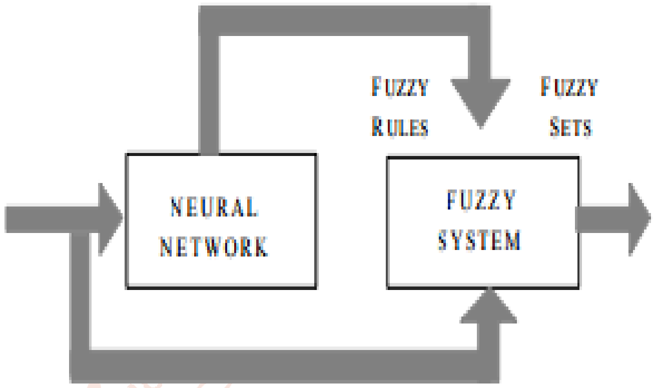


Fig 13: cooperative systems

In the cooperative systems there is a pre-processing phase where the neural networks mechanisms of learning determine some sub-blocks of the fuzzy system. For instance, the fuzzy sets and/or fuzzy rules (fuzzy associative memories or the use of clustering algorithms to determine the rules and fuzzy sets position). After the fuzzy sub-blocks are calculated the neural network learning methods are taken away, executing only the fuzzy system.

7.2.2. Concurrent Neuro-Fuzzy System:
In the concurrent systems the neural network and the fuzzy system work continuously together. In general, the neural networks pre-processes the inputs (or pos-processes the outputs) of the fuzzy system.

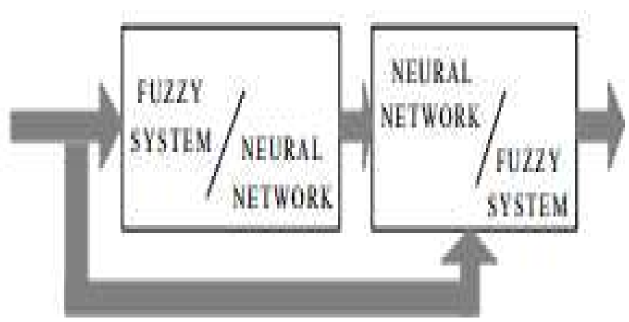


Fig 14: Concurrent systems

7.2.3. Hybrid Neuro-Fuzzy System:
"A hybrid NEURO-fuzzy system is a fuzzy system that uses a learning algorithm based on gradients or inspired by the neural networks theory (heuristically learning strategies) to determine its parameters (fuzzy sets and fuzzy rules) through the patterns processing(input and output)".

7.2.4. The Neuro-Fuzzy Controller
We consider a multi-input, single-output dynamic system whose states at any instant can be defined by "n" variables X1, X2,...,Xn.

The control action that derives the system to a desired state can be described by a well known concept of "if-then" rules, where input variables are first transformed into their respective linguistic variables, also called **FUZZIFICATION.**

Then, conjunction of these rules, called inference process, determines the linguistic value for the output. This linguistic value of the output also called FUZZIFIED output is then converted to a crisp value by using **DEFUZZIFICATION** scheme.

7.3. Various Fuzzy Membership Generation Algorithms
- Learning Vector Quantization (LVQ)
- Fuzzy KOHONEN Partitioning (FKP) or Discrete Incremental Clustering (DIC).
- Generally the POP algorithm and its variant Lazy POP are used to identify the fuzzy rules.

7.4. NEURO FUZZY APPROACH
7.4.1. Characteristics
Compared to a common neural network, connection weights and propagation and activation functions of fuzzy neural networks differ a lot. Although there are many different approaches to model a fuzzy neural network (Buckley and Hayashi, 1994, 1995; NAUCK and Kruse, 1996), most of them agree on certain characteristics such as the following:

A NEURO-fuzzy system is represented as special three-layer feed forward neural network as it is shown in Figure.

- The first layer corresponds to the input variables.
- The second layer symbolizes the fuzzy rules.
- The third layer represents the output variables.
- The fuzzy sets are converted as (fuzzy) connection weights.
- Some approaches also use five layers where the fuzzy sets are encoded in the units of the second and fourth layer, respectively. However, these models can be transformed into three-layer architecture.

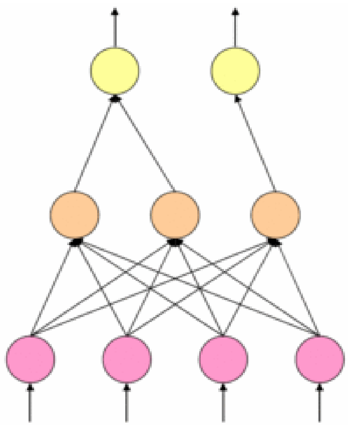


Fig 15: The architecture of a neuro-fuzzy system

8. SIMULATION
8.1. MATLAB
MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include
- Math and computation
- Algorithm development
- Data acquisition
- Modelling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building.

8.2. SIMULATION DIAGRAM FOR EXISTING SYSTEM

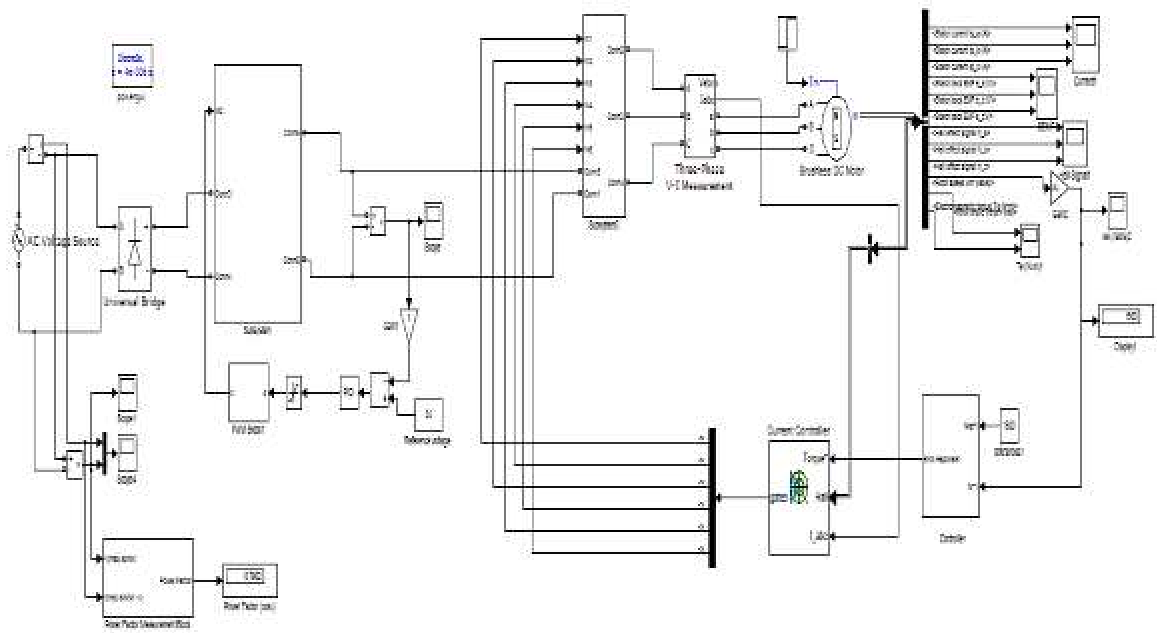


Fig 16: Simulation diagram for Existing System

8.2.1. CUK CONVERTER

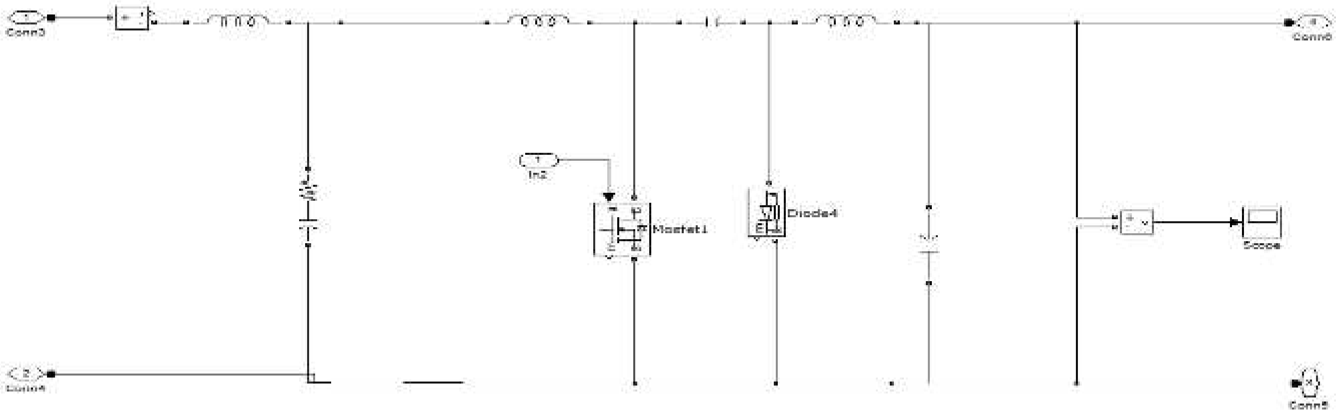


Fig 17: Simulation diagram for CUK Converter

8.2.2. INVERTER

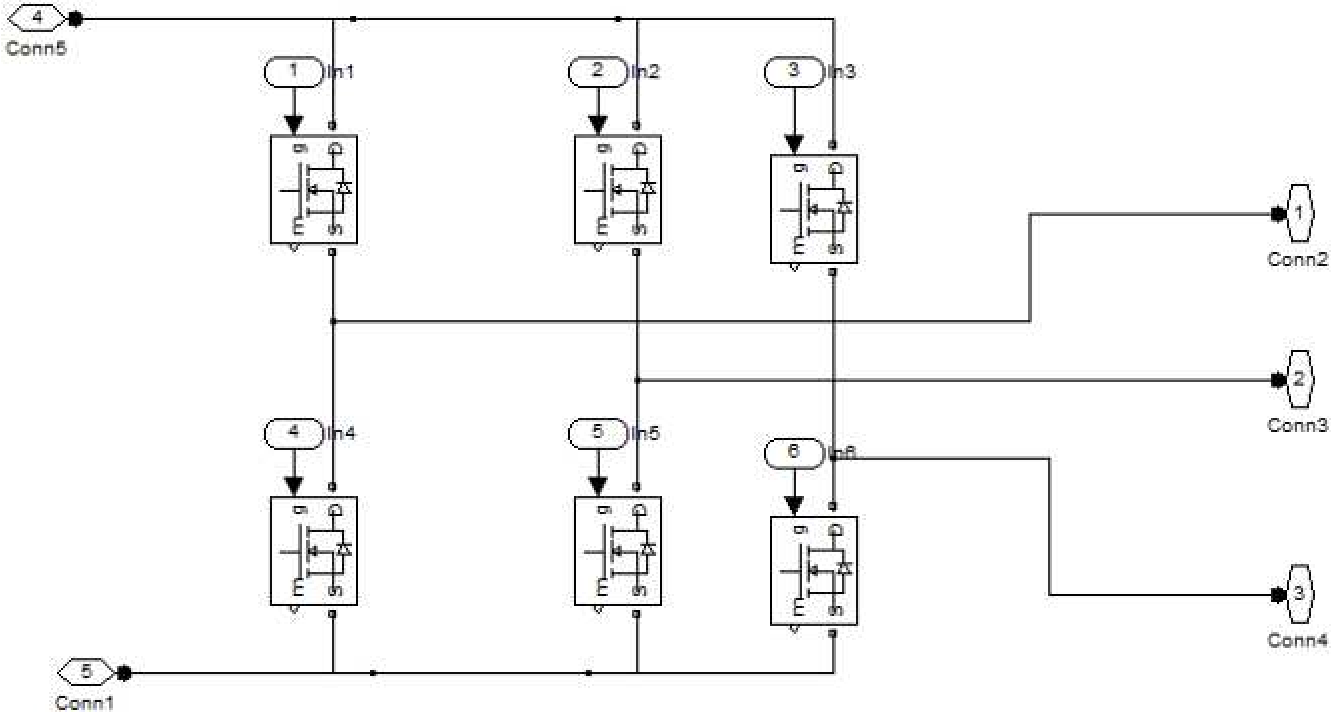


Fig 18: Simulation diagram for Inverter

8.2.3. RESULTS

8.2.3.1. INPUT VOLTAGE AND CURRENT

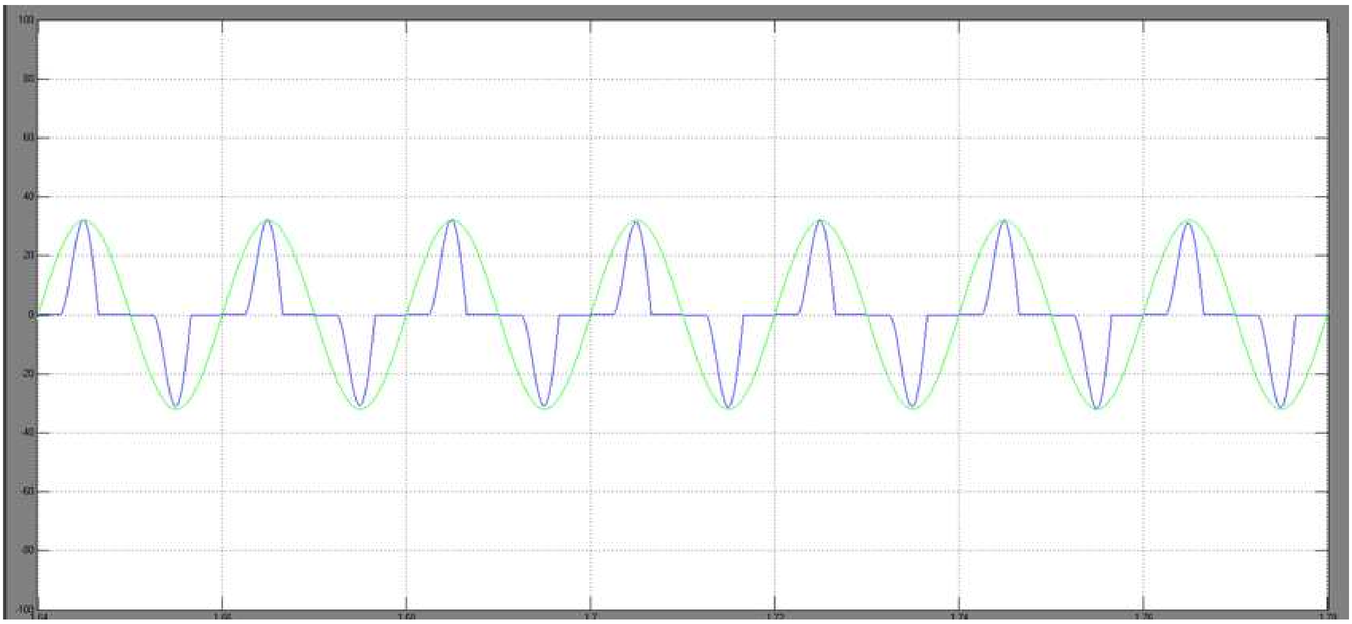


Fig 19: input voltage and current

8.2.3.2. SPEED

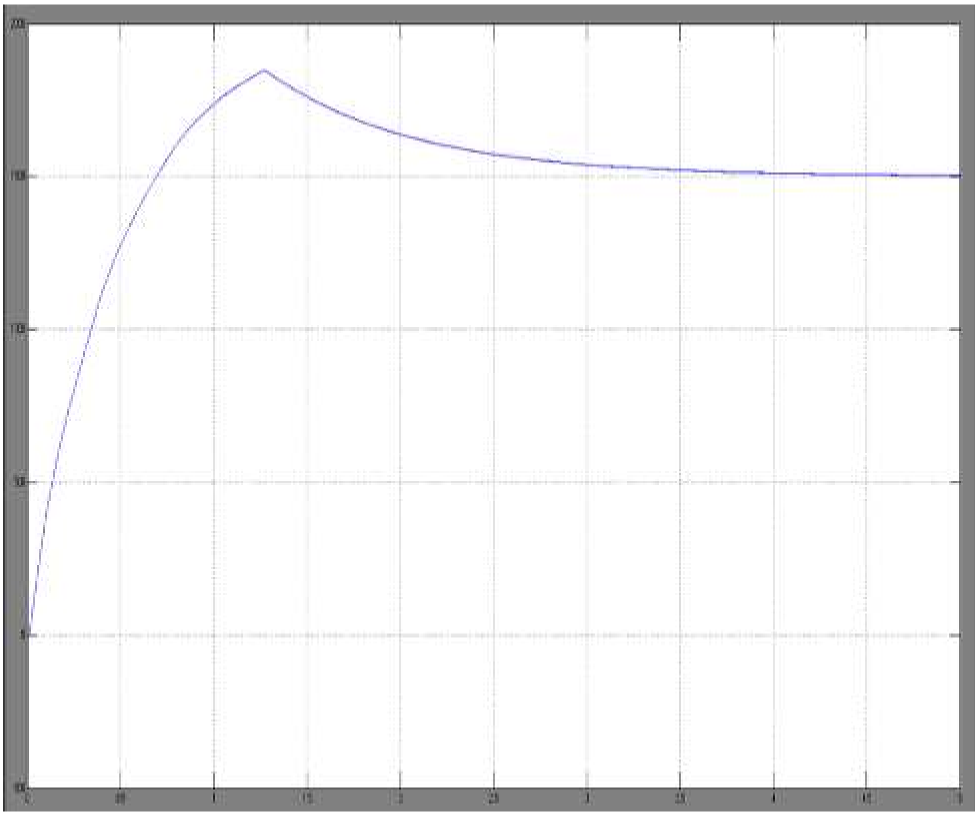


Fig 20: Speed curve

8.2.3.3. POWER FACTOR

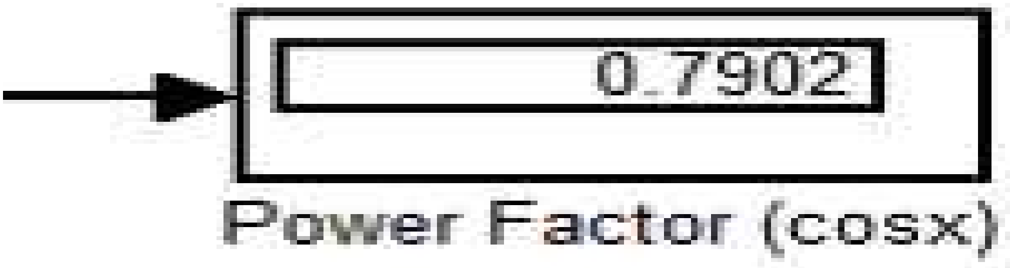


Fig 21: Power factor

8.3. SIMULATION DIAGRAM FOR PROPOSED SYSTEM

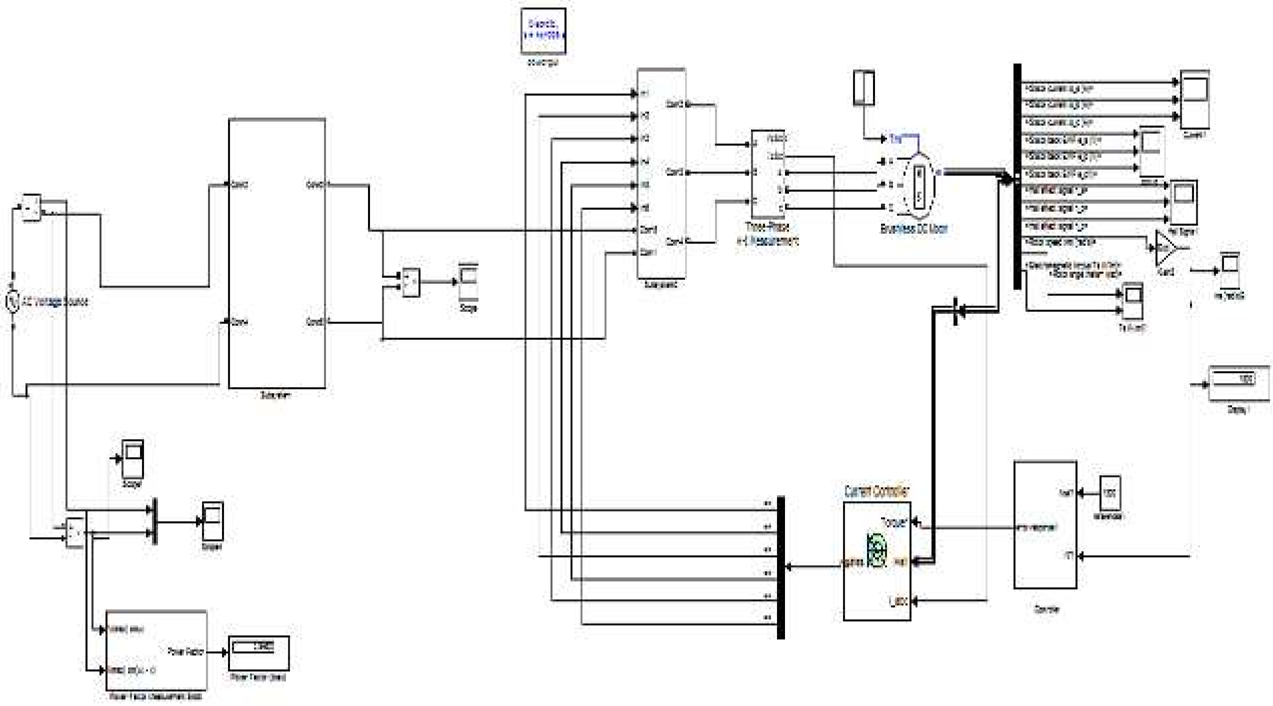


Fig 22: Proposed Simulation Diagram

8.3.1. CSC

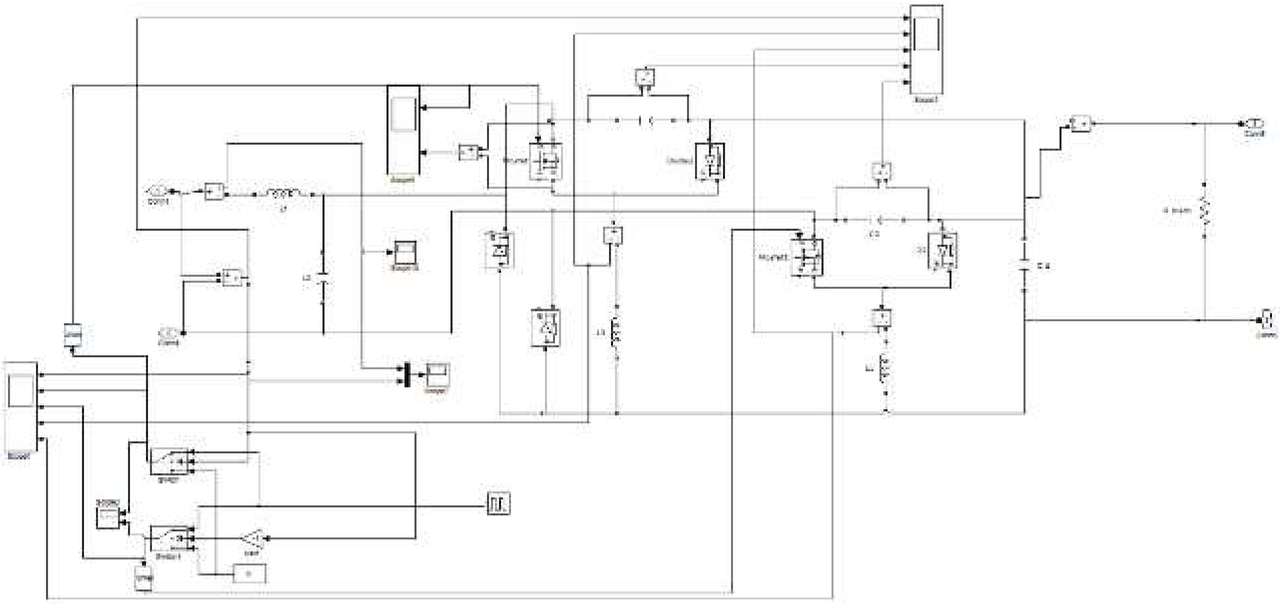


Fig 23: Canonical Switching Cell

8.3.2. RESULTS

8.3.2.1. INPUT VOLTAGE & CURRENT

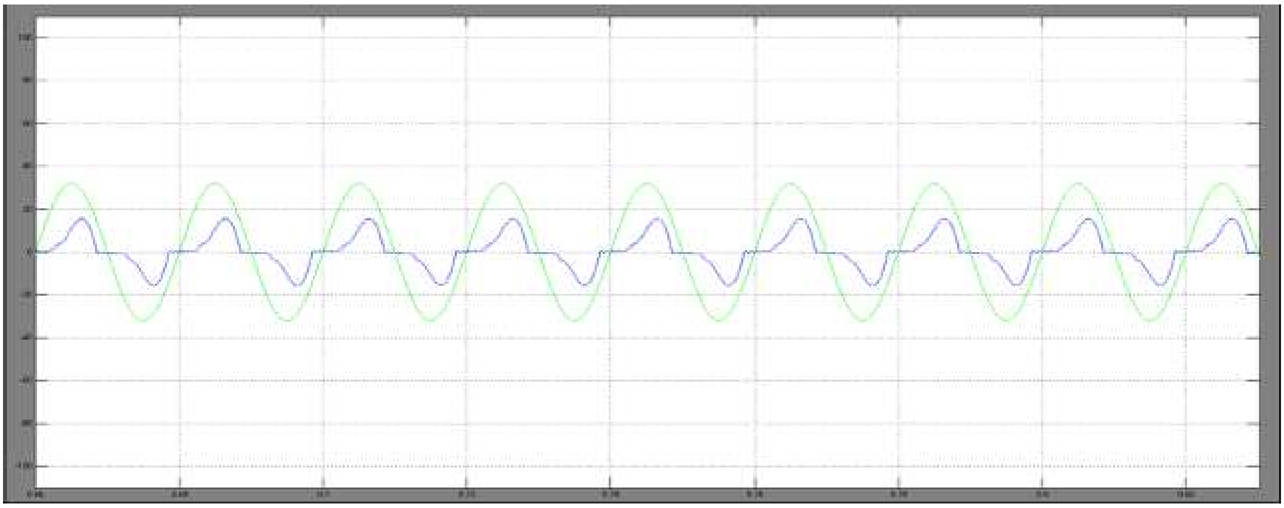


Fig 24: Input voltage & current

8.3.2.2. SPEED

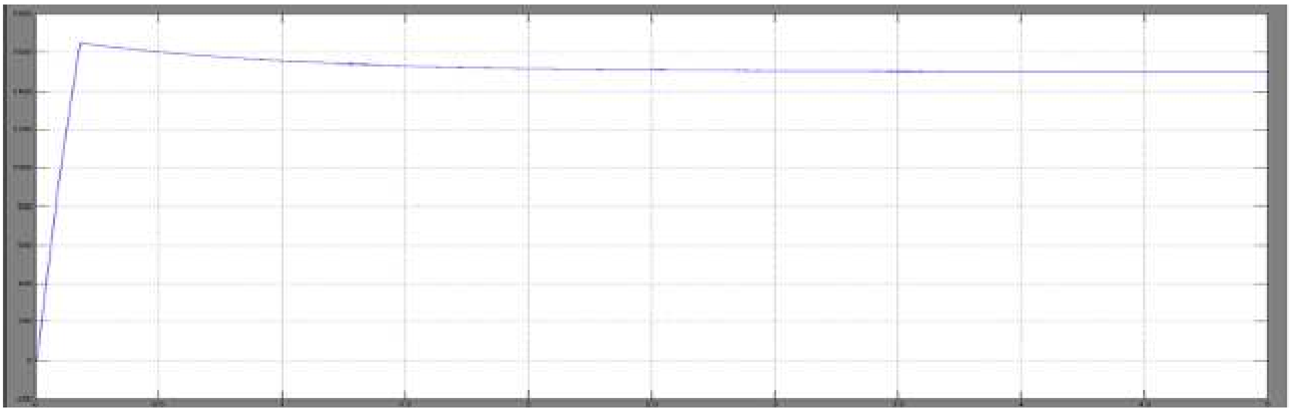


Fig 25: Speed curve

8.3.2.3. POWER FACTOR

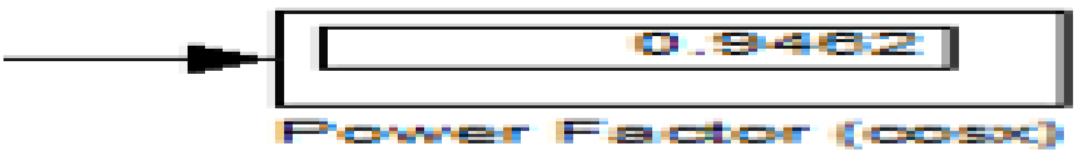


Fig 26: Power factor

9. CODING

```
#include <16f883.h>
#device ADC=10
#use delay (clock=20000000)
#fuses HS,NOPUT,NOBROWNOUT,PROTECT
unsigned
long output_voltage_adc,input_voltage_adc,ref_voltage_adc;
signed long error;
static unsigned long GP=0;
unsigned int16 pwm_count=2;
//16 - 1.246 - 255
//18.5 - 2.14 - 510
//14.7 - 5 - 1023
#define  INPUT_LIMIT_LOW_VOLTGAE  120  //2v
#define  INPUT_LIMIT_HIGH_VOLTGAE 700  //20v
voidpwm_intial()
{  setup_ccp1(CCP_PWM);
   setup_timer_2(T2_DIV_BY_1,249,1); //4=9.7k}
voidset_voltage_scan()
{
floatref_voltage_input,ref_voltage_output;
set_adc_channel(0);
delay_ms(50);
ref_voltage_adc= read_adc() * 0.646;
set_adc_channel(2);
delay_ms(50);
output_voltage_adc=read_adc() ;
set_adc_channel(1);
delay_ms(50);

input_voltage_adc=read_adc() ;
}
voidadc_inti()
{
setup_adc_ports(AN0_AN1_AN2_AN3_AN4);
setup_adc(ADC_CLOCK_INTERNAL);
delay_ms(100);
}
voidfuzzy_control()
{
error= ref_voltage_adc - output_voltage_adc;
if(error<0)
  {
if(error> -10)
pwm_count=  error * 0.5;
if(error> -25)
pwm_count=  error * 1.5;
if(error> -35)
pwm_count=  error * 1.8;
if(error> -60)
pwm_count=  error * 2.3;
if(error> -61)
pwm_count=  error * 2.5;
       GP=GP - pwm_count;
if(GP<1) GP=0;
   }
else
  {
if(error< 10)
pwm_count=  error * 0.5;
if(error< 25)
pwm_count=  error * 1.5;
if(error< 35)
pwm_count=  error * 1.8;
if(error< 60)
pwm_count=  error * 2.3;
if(error< 61)
pwm_count=  error * 2.5;
     GP=GP + pwm_count;
if(GP>1000) GP=1000;
  }
 }
void main()
{
io_init(0xff,0xf0,0x00,0x00,0x00);
adc_inti();
pwm_intial();
set_voltage_scan();
while(true)
  {
set_voltage_scan();
if(input_voltage_adc>INPUT_LIMIT_LOW_VOLTGAE
&&input_voltage_adc<INPUT_LIMIT_HIGH_VOLTGAE )
{
fuzzy_control();
set_pwm1_duty(GP);
          }
else
          {
GP=0;pwm_count=0;
             pwm_on_1=pwm_pulse=0;
             set_pwm1_duty(pwm_pulse);
fl=1;
           }
  }
}
```

10. IMPLEMENTATION

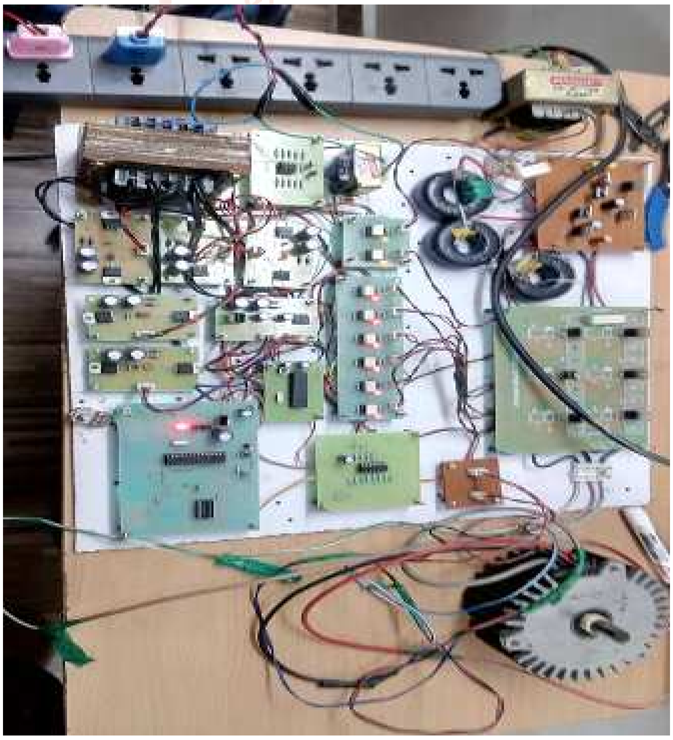


Fig 27: Implementation Setup

11. CONCLUSION

The power factor correction has been successfully implemented using the Bridgeless PFC-Modified SEPIC Rectifier. It shows a much improved result as it not only provides better power quality, but also the converter removes the necessity to smooth out the dc output from ripples. The NEURO fuzzy logic controller widely increases application range of the motor by increasing the reliability. The motor is presently used in areas such as aerospace, aircraft and mining applications because of the enhanced reliability that the motor offers. This is further enhancedby the usage of NFLC and the PFC converters. The NFLC is used to control the motor speed and the Bridgeless PFC-Modified SEPIC Rectifier is used for the power factor improvement. It is found that the Bridgeless PFC-Modified SEPIC Rectifier is found to provide better power quality. The Analysis has been done for Continuous conduction in the Bridgeless PFC-Modified SEPIC Rectifier as both are not capable of self PFC. A prototype model is implemented in laboratory and detailed experimental studies are carried out. It is observed that the experimental results are consistent with the simulation results.

12. Reference-

[1] R. Shanmugasundram, K. Muhammad Zakariah and N. Yadaiah, "Implementation and Performance Analysis of Digital Controllers for Brushless DC Motor Drives," *IEEE/ASME Trans. Mechatronics,* vol. 19, no. 1, Feb. 2014.

[2] T. Kenjo and S. Nagamori, *Permanent Magnet Brushless DC Motors*.Oxford, U.K.: Clarendon Press, 1985.

[3] Sanjeev Singh and Bhim Singh, "A Voltage-Controlled PFC Cuk Converter-Based PMBLDCM Drive for Air-Conditioners," *IEEE Trans. Ind. Appl.* vol. 48, no. 2, Mar. /Apr. 2012.

[4] VashistBist and Bhim Singh, "PFC CUK Converter-Fed BLDC Motor Drive," *IEEE Trans. Power Electron.*, vol. 30, no 2, Feb. 2015.

[5] "Limits for harmonic current emissions (equipment input current ≤16 A per phase)," International Standard IEC 61000-3-2, 2000

[6] A. Rubaai, D. Ricketts, and M. D. Kankam, "Laboratory implementation of a microprocessor-based fuzzy logic tracking controller for motion controls and drives," *IEEE Trans. Ind.Appl.*, vol. 38, no. 2, pp. 448–456, Mar./Apr. 2002.

[7] Pierre Guillemin, "Fuzzy logic applied to motor control," *IEEE Trans. Ind. Appl.*, vol. 32, no. 1, pp. 51–56, Jan./Feb. 1996.

[8] M. A. Akcayol, A. Cetin, and C. Elmas, "An educational tool for fuzzy logic-controlled BDCM," *IEEE Trans. Edu.*, vol. 45, no. 1, pp. 33–42, Feb. 2002.

[9] Zengshi Chen, "PI and Sliding Mode Control of a Cuk Converter", *IEEE Trans. Ind. Electron.*, vol. 27, no. 8, Aug. 2012

[10] Ahmed Rubaai and Paul Young, "Hardware / Software Implementation of Fuzzy-Neural-Network Self-Learning Control Methods for Brushless DC Motor Drives", *IEEE Trans. Ind. Appl.*, DOI 10.1109/TIA.2015.2468191.

[11] *Harmonic Current Emissions Guidelines,* European Power Supply Manufactures Association Standard EN 61000-3–2 Nov. 2010.

[12] H. Wang, Y. Tang, and A. Khaligh, "A bridgeless boost rectifier for lowvoltage energy harvesting applications," *IEEE Trans. Power Electron.*, vol. 28, no. 11, pp. 5206–5214, Nov. 2013.

[13] W. Choi, J. Kwon, E. kim, J. Lee, and B. Kwon, "Bridgeless boost rectifier with low conduction losses and reduced diode reverse-recovery problems," *IEEE Trans. Ind. Electron.*, vol. 54, no. 2, pp. 769–780, Apr. 2007.

[14] L. Huber, Y. Jang, and M. Jovanovi´c, "Performance evaluation of bridgeless PFC boost rectifiers," *IEEE Trans. Power Electron.*, vol. 23, no. 3, pp. 1381–1390, May 2008.