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Power Factor Correction And Speed Control In Bldc Motor By A Bridgeless Cuk Rectifier

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ABSTRACT

In this paper a bridgeless Cuk rectifier is used for Power factor correction (PFC) for a BLDC motor and to improve the rectifier power density and/or to reduce noise emission via soft-switching techniques or coupled magnetic topologies. The Cuk converter has several advantages in power factor correction applications Bridgeless Cuk converter has only two semiconductor switches in the current flowing path. During each interval of the switching cycle it result in less conduction losses and an improved thermal management compared to the conventional Cuk PFC rectifier. To achieve almost unity power factor and to reduce the input current stress, the topologies are designed to work in discontinuous conduction mode (DCM). The DCM has additional advantage such as zero-current turn-on in the power switches, zero current turn-off in the output diode. The ac-dc conversion of electric power is usually required for the BLDCM drive; it causes many current harmonics and results in poor power factor at input ac mains. By using PID controller we can able to control the temperature of the motor, input to the sensor is the motor and the output has been taken from the sensor either we can use the comparator to check the sensor output with the permissible temperature of the BLDCM. This paper deals with power factor correction of BLDCM with bridgeless Cuk converter. A three phase voltage source inverter is used as an electronic commutator to operate BLDCM

KEYWORDS: Bridgeless rectifier, Cuk converter, low conduction losses, power factor correction (PFC), PID controller, Brushless dc motor (BLDCM), Voltage Source Inverter (VSI).

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I. INTRODUCTION

For power supplies with active power factor correction (PFC) techniques are very essential for many type of electronic equipment to meet harmonic regulations. Most of the PFC rectifiers utilize a boost converter at front end. A conventional PFC technique has lower efficiency because of significant losses in the diode bridge. A conventional PFC Cuk rectifier is shown in fig 1. The current flows through two rectifier bridge diodes and the power switch (Q) during the switch ON-time, and through two rectifier bridge diodes and the output diodes (D_0) during the switch OFF- time.

During each switching cycle, the current flows through three semiconductor devices. As a result, a significant conduction loss, caused by the forward voltage drop across the bridge diode. In a bridgeless PFC circuits, where the number of semiconductors generating losses will be reduced by eliminating the full bridge input diode rectifier. A bridgeless PFC rectifier allows the current to flow through a minimum number of switching devices compared to the conventional Cuk rectifier. It also reduces the converter conduction losses and which improves the efficiency and reducing the cost. A bridgeless power factor correction rectifier is introduced to improve the rectifier power density and/or to reduce noise emission via soft-switching techniques or coupled magnetic topologies. The Cuk converter has several advantages in power factor correction applications, such as easy implementation of transformer isolation, natural protection against inrush current occurring at start-up or overload current, lower input current ripple, and less electromagnetic interference(EMI) associated with discontinuous conduction mode topology. Thus for applications, which require a low current ripple at the input and output ports of the converter, Cuk converter is efficient.

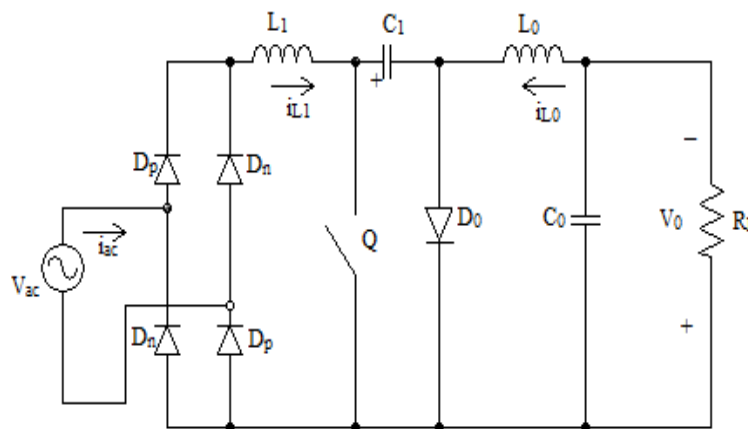


Fig 1. Conventional Cuk Rectifier

II. BRIDGELESS CUK POWER FACTOR CORRECTION RECTIFIERS

The bridgeless power factor correction rectifiers are shown in fig 2. The topology is formed by connecting two DC-DC Cuk converters. Note that there are one or two semiconductors in current

flowing path. Hence, the current stresses in the active and passive switches are further reduced and the circuit efficiency is improved compared to the conventional Cuk rectifier. Here, the output voltage bus is always connected to the input AC line through the slow-recovery diodes D_p and D_n .

The bridge less rectifiers of Fig.2 consists of two semiconductor switches (Q_1 and Q_2). However, the two semiconductor switches can be driven by the same control circuitry. Compared to conventional Cuk converter topology, the structure of topologies utilizes additional inductor, which is often described as a disadvantage in terms of size and cost. However, a better thermal performance can be achieved with the two inductors compared to a single inductor.

It should be mentioned here that the three inductors in the topologies can be coupled on same magnetic core allowing considerable size and cost reduction. Additionally, the “near zero-ripple-current” condition at input or output port of the rectifier can be achieved without compromising performance.

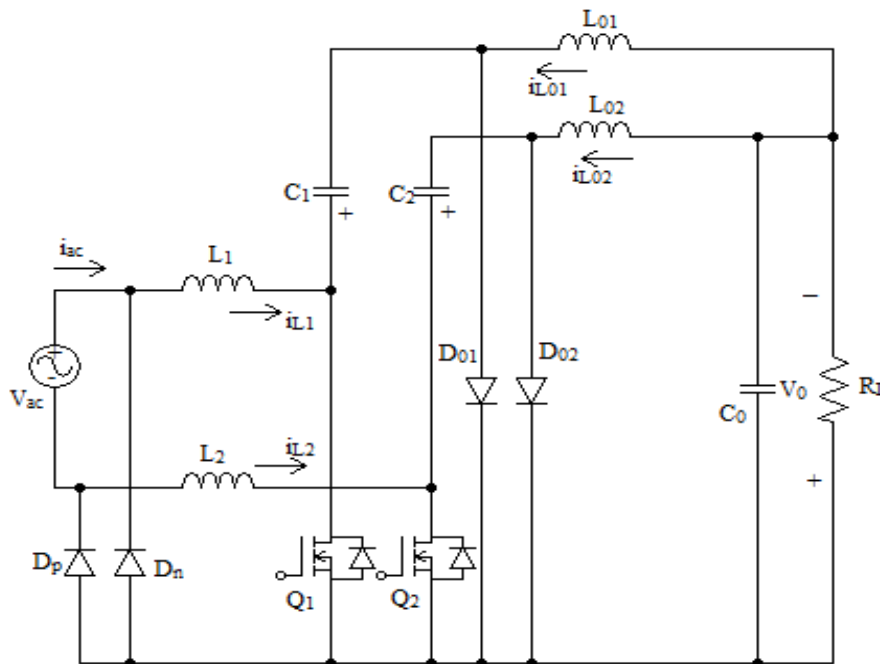


Fig 2. Bridgeless Cuk PFC rectifiers.

III. PRINCIPLE OF OPERATION

The bridgeless Cuk rectifier of fig.2 will be considered in this paper. The converter is operating at a steady state in addition to the following assumptions: pure sinusoidal input voltage, ideal lossless components, and all ripples are negligible during the switching period T_s . Here, the output filter capacitor C_0 has a large capacitance such that the voltage across it is constant over the entire line period.

Note that by referring fig.3, there are one or two semiconductors in the current flowing path; therefore, the current stresses in the active and passive switches are reduced and the circuit efficiency is improved. During the positive half-line cycle as shown in fig 3(a), the first DC-DC cuk circuit, L_1 - Q_1 - C_1 - L_{O1} - D_{O1} , is the active through diode D_p , which connects the input AC source to the output. During the negative half-line cycle as shown in fig 3(b), the second DC-DC cuk circuit, L_2 - Q_2 - C_2 - L_{O2} - D_{O2} , is active through diode D_n , which connects the input AC source to the output. The average voltage across capacitor C_1 during the line cycle can be expressed as follows:

$$V_{C1}(t) = \begin{cases} V_{ac}(t) + V_0, & 0 \leq t \leq T/2 \\ V_0, & T/2 \leq t \leq T \end{cases}$$

Due to the symmetry of the circuit, it is sufficient to analyze the circuit during the positive half cycle of the input voltage. The operation of the rectifiers of fig.2 will be explained assuming that the three inductors are operating in DCM. By operating the rectifier in DCM, there are several advantages can be gained. These advantages included natural near-unity power factor, the power switches are turned ON at zero current, and the output diodes are considerably reduced. DCM operation significantly increases the conduction losses due to the increased current stress through circuit components.

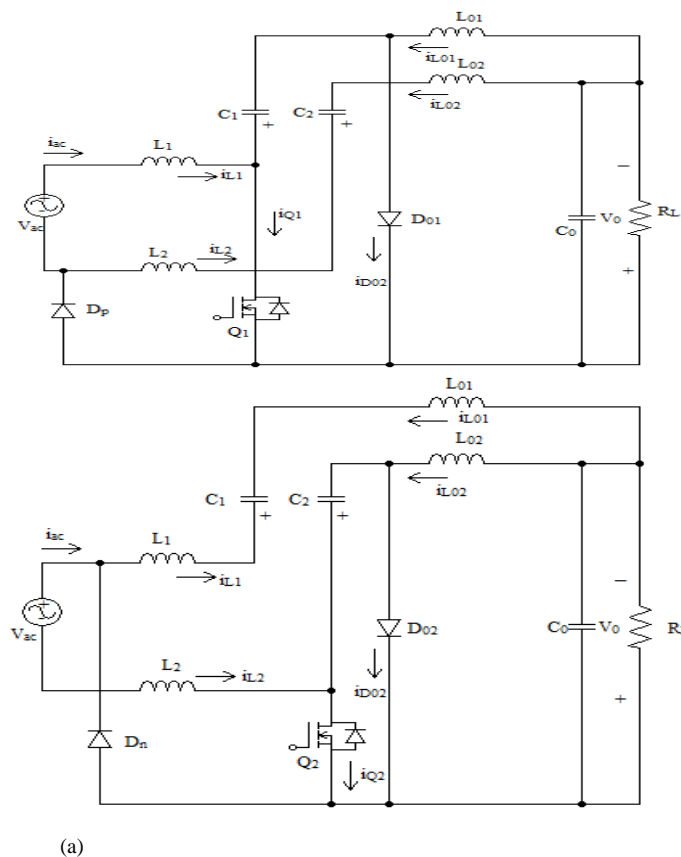


Fig.3. Equivalent circuits of bridgeless rectifier. (a) during positive half-line period. (b) during negative half-line period of the input voltage.

IV. BRIDGELESS CUK CONVERTER WITH AND WITHOUT PID CONTROLLER

The converter without PID controller will not give required constant output voltage whenever some changes or disturbances occur in the input side. Thus the closed loop system can maintain the constant output voltage by comparing the given reference voltage (48V) and the actual output voltage. Here, the PID controller is used in closed loop system. The difference between without and with PID controller is shown in the table 1 and table 2 respectively.

TABLE 1
Bridgeless Cuk Converter without using PID Controller

S.NO	Input voltage	Output voltage
1	110	52
2	120	58
3	130	62
4	140	68
5	150	72
6	160	78

TABLE 2
Bridgeless Cuk Converter with using PID Controller

S.NO	Input Voltage	Output Voltage
1	110	48
2	120	48
3	130	48
4	140	48
5	150	48
6	160	48

V. BRIDGELESS CUK CONVERTER FOR POWER FATOR CORRECTION IN BLDC MOTOR

Power factor correction method is good for ac to dc power conversion in order to reduce the line current harmonics as well as increase the efficiency and capacity of motor drives. Here, a bridgeless Cuk converter is act as PFC converter because of its continuous input and output currents, small output filter, and wide range as compared to other signal switch converters; also it forces the drive to draw sinusoidal ac mains current in phase with its voltage.

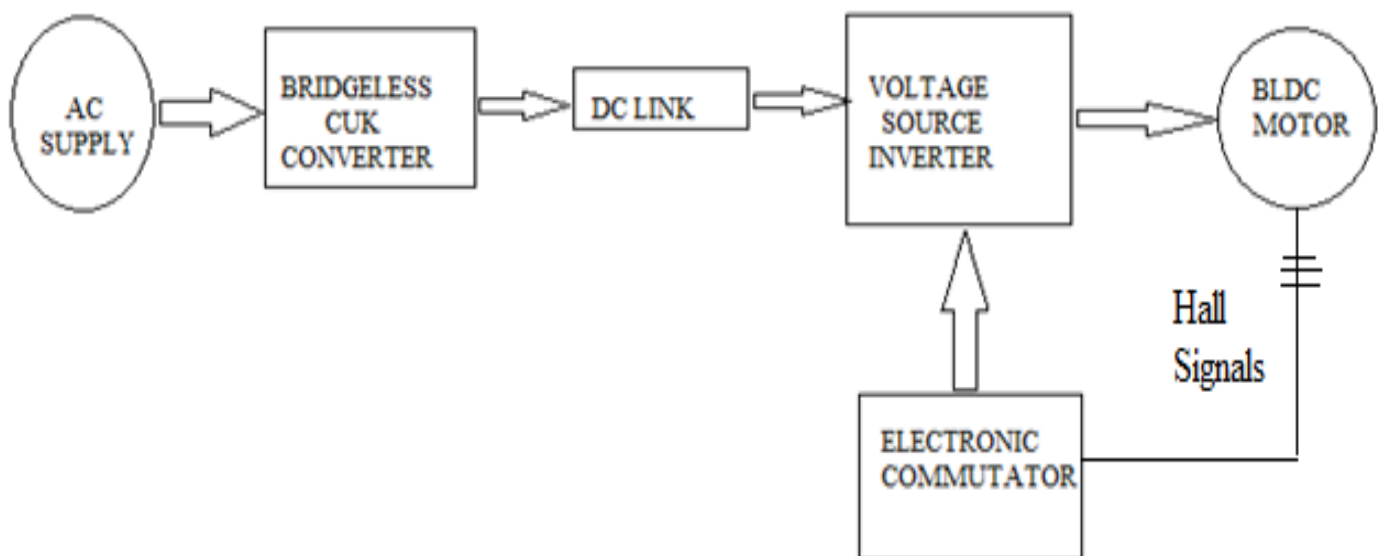


Fig.4 Block Diagram of bridgeless Cuk Converter Fed BLDC Motor Drive

To generate switching sequence for the VSI feeding the BLDC motor, the rotor position signals, are taken by Hall-effect sensors and therefore, rotor position is required only at the commutation points.

VI. SIMULATION RESULT

Fig.5 shows that simulation of bridgeless Cuk converter with and without PID controller respectively with input of 100 Vrms line voltage and output voltage of 48Vdc. Fig. shows the input voltage, current and power factor of bridgeless Cuk converter with PID controller and fig shows that the output voltage and current of bridgeless power factor correction with PID controller. Fig shows the simulation diagram of bridgeless Cuk converter for power factor correction in BLDC motor by speed controlling using PID controller.

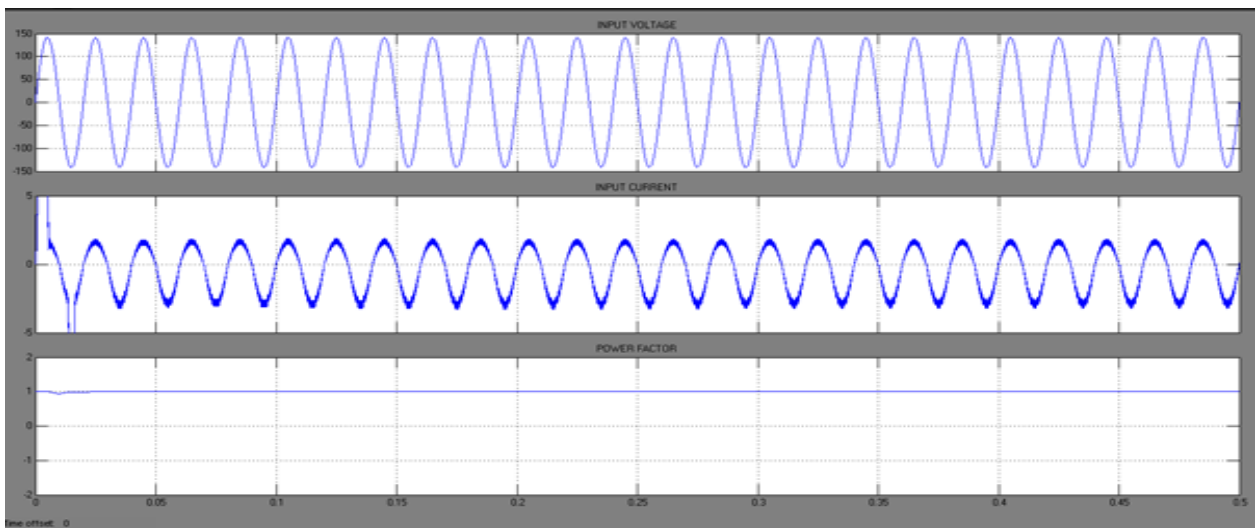


Fig.5. Input Voltage, Current and Power Factor of bridgeless Cuk converter with PID controller

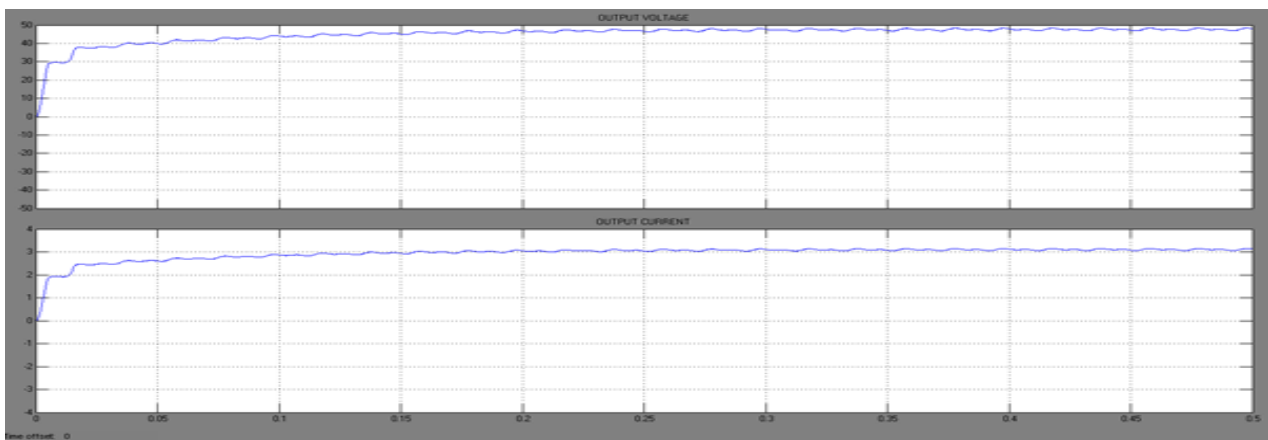


Fig.6. Output Voltage and Current of bridgeless Cuk converter with PID controller

It is clear from the fig. the input voltage and current are sinusoidal and in-phase. The figure shows that a bridgeless Cuk converter for power factor correction in BLDC motor. The power factor

for the bridgeless Cuk converter for power factor correction in BLDC motor is 0.9933. Fig.1 shows the proposed speed control scheme which is based on the control of the dc link voltage reference as an equivalent to the reference speed. However, the rotor position signals acquired by Hall effect sensors are used by an electronic commutator to generate switching sequence for the VSI feeding the PBLDC motor, and therefore, rotor position is required only at the commutation points.

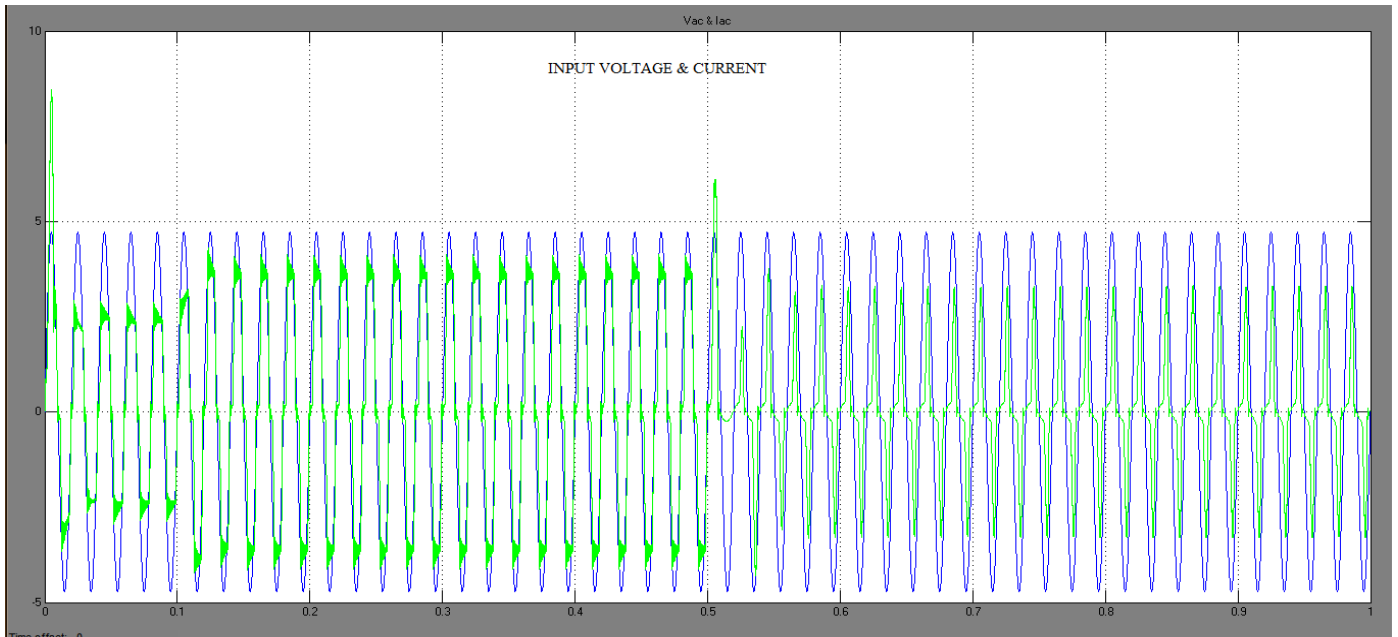


Fig 7. Input Voltage and Current of a Bridgeless Cuk Converter for Power Factor Correction in BLDC Motor

The Fig.7 shows that the input current and voltage is in-phase and sinusoidal by using a bridgeless Cuk converter for power factor correction in BLDC motor.

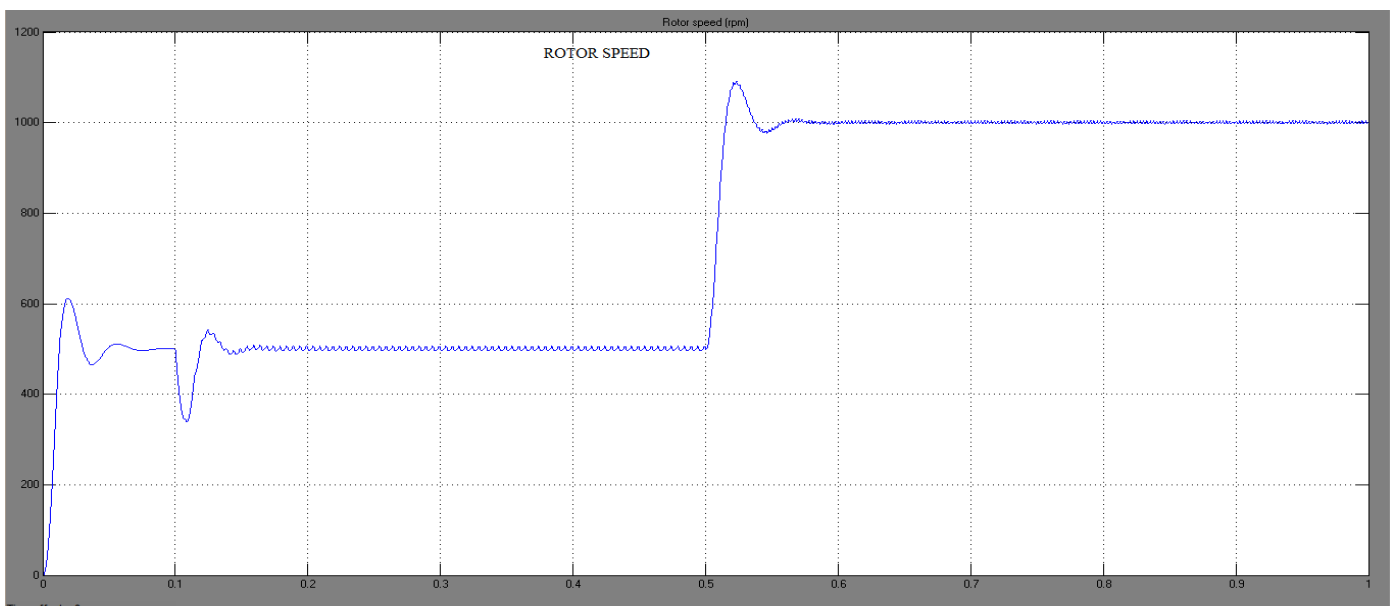


Fig.8. Controlled Speed of the Rotor using PID Controller

The Fig.8 shows that the rotor speed of the BLDC motor. From the fig.8, it is very clear that the speed of the motor is controlled using PID controller. Here from time period 0 to 0.5 sec the speed is controlled and maintained constant speed of 500 rpm and from 0.5 to 1 sec the speed of the motor is controlled to 1000 rpm and maintained constant.

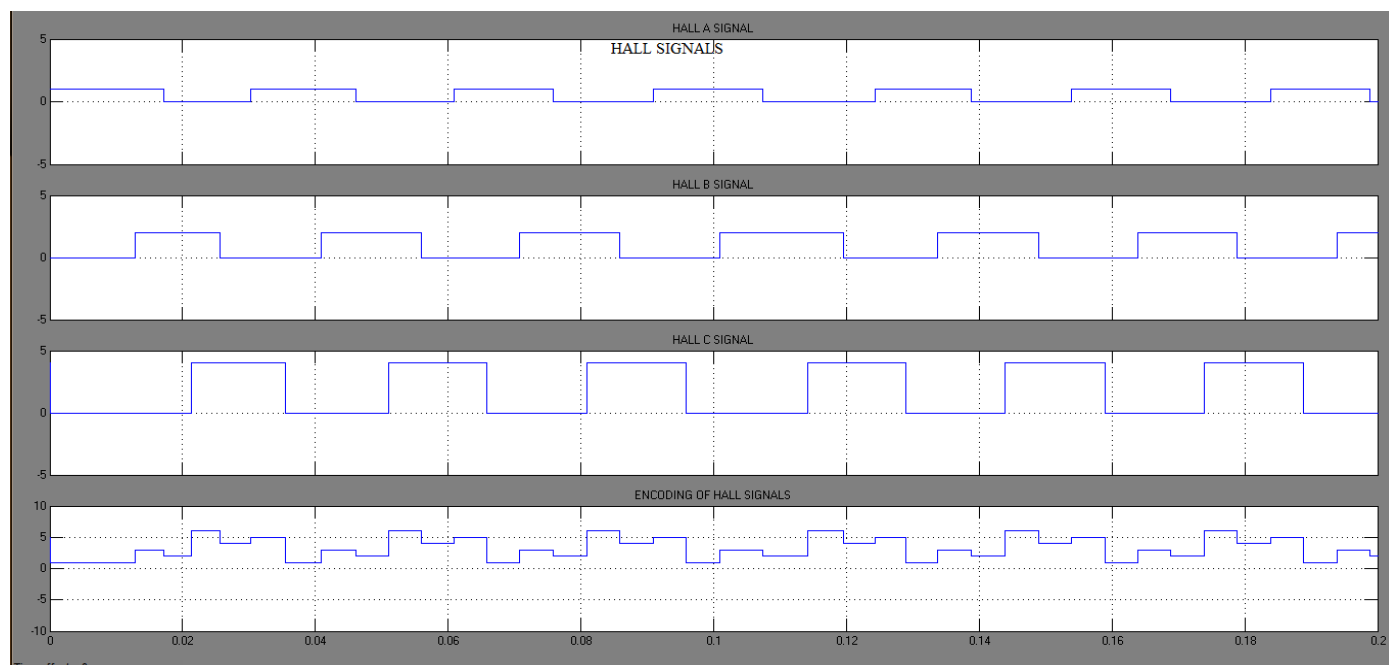


Fig.9. Hall Signals of the BLDC Motor

VII. CONCLUSION

This paper presents Single-phase AC-DC bridgeless rectifier based on Cuk topology with and without PID controller. The comparison of single-phase ac-dc bridgeless rectifier based on Cuk topology with and without PID controller is discussed. From the result it is clear the bridgeless Cuk converter with PID controller has constant output voltage. By operating the rectifier in DCM, there are several advantages, which includes natural near-unity power factor. Thus, the losses due to turn-ON switching and the reverse recovery of the output diodes are considerably reduced. The performance of the system was verified in the simulation. In this new single-phase AC-DC bridgeless rectifier based on Cuk topology have a better efficiency and power factor. The proposed Cuk converter is designed to reduce the input current stress and to bring almost unity power factor in the input side. The design of bridgeless Cuk converter fed BLDC motor drive is also performed and is modelled in Matlab. The speed of the motor drive is varied by changing the dc link voltage of bridgeless Cuk converter. The speed of the BLDC motor is proportional to the dc link voltage; thereby, a smooth speed control is observed while controlling the dc link voltage. The PFC bridgeless Cuk converter has ensured near unity power factor in a wide range of the speed and the input ac voltage.

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