IJSEAT
International Journal of
Science Engineering and Advance Technology

A new Adaptation in Bridgeless Interleaved Power Factor Correction design for High Efficiency

K.Aswani,M.Uma Rani
M.Tech(Research Scholar),Assistant Professor in Dept. of EEE,
Godhavari Institute Of Engineering & Technology,AP,
Email Id: aswini.kanchi@gmail.com

Abstract:

Seeking the requirements of world's energy conversions, developments are tracked. The research and development of the AC-DC conversion circuit for variable frequency control, which is closely related to human life. It uses the bridgeless rectifier circuit, coupled with the Interleaved Boost and "PFC" (Power Factor Correction) technology to design a high-efficiency AC/DC conversion circuit, to provide a load of 400V, 2KW. The system efficiency can reach up to 96%. The power factor is close to 1, the input current ripple is below 0.8A and the output voltage ripple is below 6V. This paper presents the comparison of various current control techniques employed for a bridgeless interleaved boost converter for improving the power quality. The major control strategies discussed in this paper are: peak current, average current mode and borderline current control.

Keywords: Bridgeless Rectification Circuit, Interleaved, Power Factor Correction, Rectifier, Boost, Energy Conversion.

I. Introduction

In the present world's prerequisite is energy towards the mankind. The sustainable development of living environments, energy saving and carbon reduction have become the top priority for global development. The R&D on green energy sources and carbon reduction has become an inevitable trend. However, before the new generation of green energy can replace conventional energy, energy saving must be first realized to slow down the deterioration of energy depletion and the greenhouse effect. Household energy consumption includes that from lighting appliances, electric appliances, motors and other electrical appliances. Electrical lighting appliances and electrical motors account for the vast majority of power consumption, and the load for electric motors is about twice that of the lighting load. Therefore, air-conditioning systems should be the focus of household power conservation, as they account for the majority of the electric motor load; hence, the energy saving effects is influential. An air conditioner is powered by an AC induction motor, and its speed control is realized by the number of pole controls, the power control and the frequency control. The wiring for changing the number of poles is very complex, and the power control requires a stable load. Therefore, frequency variability control is the best method for controlling the speed of the AC induction motor.

Changing the speed of the frequency control requires the conversion of the AC current to DC, which allows the control circuit of the inverter motor to switch into alternating currents of different frequencies to drive the motor. Using this method to control the induction motor allows the maximal rate range and provides a stable control effect. At present, this method has been widely used in various products requiring variable speed control. Hence, it is important to provide an AC/DC converter that is highly efficiency, has a high power factor, a low ripple current and a high capacity for the variable frequency motor. In conventional motor variable frequency drive technology, the AC power is rectified to DC power through a bridge rectifier [7-9], and then an oscillator generates variable frequency signals that trigger the power crystal to convert the DC current into an AC current with controllable frequency to drive the induction motor. The process of converting AC to DC needs to overcome problems such as low efficiency, a low power factor, a large input ripple current, a large output ripple voltage and unsuitability for providing a high current load.

The variable frequency drive technology of conventional motors can derive problems, such as harmonic interference and the resulting 50~60% lower power factor. Harmonic interference causes interference in audio, video, and other communications, affects control and increases energy loss. Electrical loads with a low power factor will discount the transmission capacity of the power supply system and reduce the power transmission efficiency. Hence, this study proposed a new circuit structure using the coupled inductor design combined with bridgeless PFC technology and interleaved PFC to develop bridgeless interleaved power factor correction (BIPFC). The characteristics of this circuit are as follows: (1) it uses PFC technology, allowing the input power factor to be close to 1; (2) it uses a bridgeless rectifier, allowing the efficiency to be improved form 94% to above 96%; (3) it uses the interleaved PFC, allowing the ripple current to be reduced to 50% of the general level; (4) it does not use a rectifier, allowing the cost to be reduced; and (5) the output voltage is more stable and can cope with the load of a larger current. The proposed design is an excellent variable frequency controller power supply with a high degree of operational stability and market competitiveness.

II. PFC open loop circuit

The conventional PFC open loop circuit is as shown in Figure 1. Such a circuit structure must have a bridge rectifier and a single inductor, but it can only have a good effect when used in a s mall-capacity load. In the case of a large capacity load above thousands of Kw, it will generate a large voltage drop and a high ripple voltage and current, leading to a poor output voltage, harmonic interference and lowered efficiency. Hence, a better PFC power supply circuit is needed for large-capacity electrical loads. The designed PFC circuit specifications are based on the largest window-type air-conditioning on the market capacity of 2 tons, and its power requirement is about 2KW; the selected input voltage is in the range of 110V~220V, and the output voltage is increased to 400V to reduce the current load of the power supply lines, so that the design of the circuit can meet practicality. Therefore, the load resistor RL=80O is selected as the design goal.

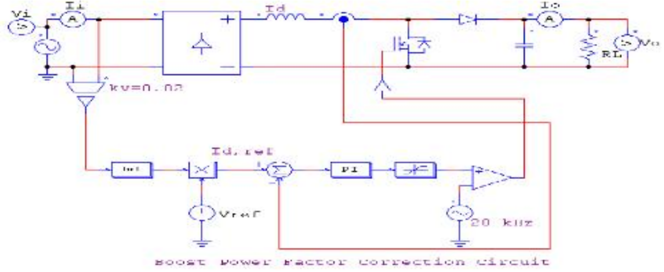


Fig. 1 Conventional PFC open loop circuit

Characteristics of the Bridgeless Interleaved PFC Main Circuit Structure:

The main driving circuit of the bridgeless interleaved PFC is as shown in Figure 2. It includes two coupled inductors; the upper coupled inductor is the primary side and the lower coupled inductor is the secondary part. The inductors control the alternating conduction of S**1** and S**2** in the positive half-cycle and the alternating conduction of S_3 and S_4 in the negative half-cycle. For example, when S**1** is on, the primary side current flows through S**1** and S_3 to form a circuit, and the secondary side inductance current flows through D**2** to the output load and back to the power source through S_4, as shown by the arrows in Figure 2. The output capacitor can be charged to provide the output voltage.

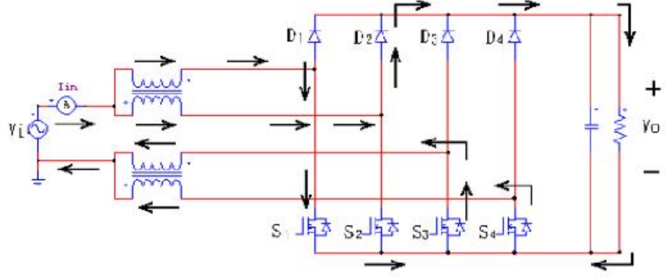


Fig. 2 The current flow path SEM (positive half-cycle) when S_1 is ON

When S_2 is on, the secondary side current flows through S**2** and S**4** to form the loop, and the primary side inductance current flows through D**1** to the output load and back to the power source through S_3, as shown by the arrows in Figure 3. During this time, the output capacitor can be recharged to provide the output voltage. During the negative half-cycle, it controls the alternating conduction of S**3** and S**4**. The working conditions are the same as those for the positive half-cycle.

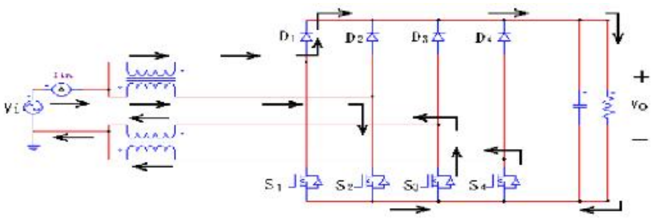


Fig. 3 The current flow path SEM (positive half-cycle) when S_2 is ON

The alternating switching of S**1** and S**2**, and S**3** and S_4 can double the frequency of conduction, as well as reduce the output ripple voltage and the conduction ripple current by half. The changes in the output voltage are as shown in Figure 4.

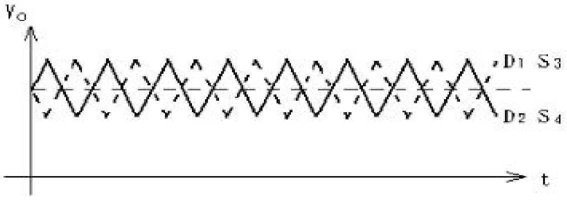


Fig. 4 Output voltage ripple SEM.

When S_1 is on, the output voltage is provided by the current flowing through D**2** and S_4, as shown by the solid lines in Figure 4. When S**2** is on, the output voltage is provided by the current flowing through D**1** and S_3, as shown by the dotted lines in Figure 4.

III. Control Circuit Description

Figure 5 illustrates the control process of the closed-loop control circuit, as described below: 1) After the reduction of input voltage Vs by Vsen**1**, the full wave rectification signals with a positive absolute value can be found. By multiplying the feedback voltage, the modified signal of the stable output voltage can be determined.

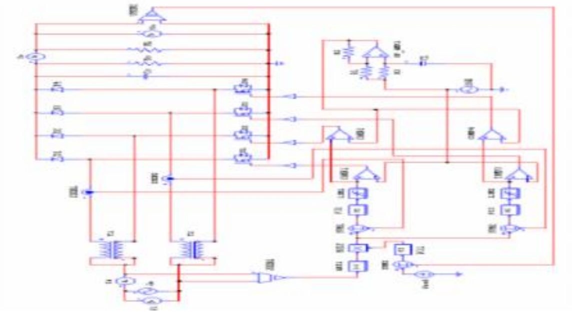
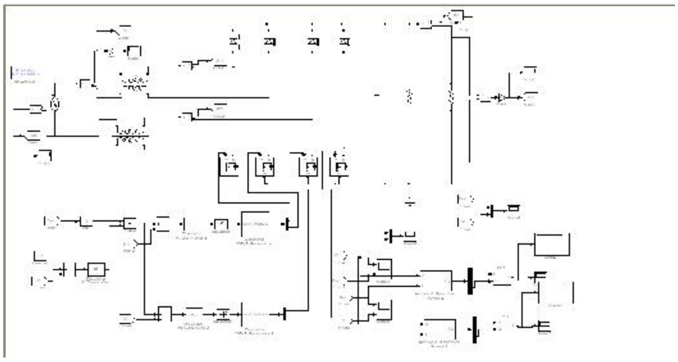


Fig. 5 Bridgeless Interleaves PFC closed-loop control circuit (the main circuit & the control circuit)

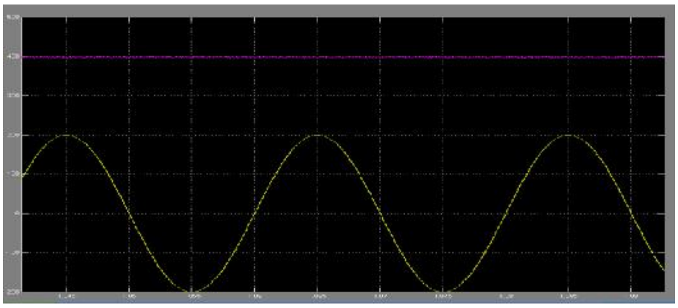
2) After the reduction of the output voltage V**o** (S) by Vsen**2**, it is fed back to sum**3** and added to the reference voltage V**ref** to obtain the modified value of the control output voltage. After being adjusted by PI**1**, the value is input into mult as the feedback signal to adjust the output voltage. 3) The output signals of mult are output to sum**1** and sum**2**. After comparing the former with the positive half-cycle current feedback signal, it is amplified and adjusted by PI**2** to generate the control signals that cause the current and voltage to be consistent in waveform. After comparing the later with the negative half-cycle current feedback signals, it is amplified and adjusted by PI**3** to generate the control signals that cause the current and voltage to be consistent in waveform. 4) A triangular wave generator generates a triangular wave with a signal of 20KHz, which is transmitted to comp**1** for the comparison with the positive half-cycle control signals to generate the 20KHz PWM sine wave control signals that switch S**1**. It is then transmitted to comp**3** for a comparison with the negative half-cycle control signals to generate the 20KHz PWM sine wave control signals that switch S**3**. 20KHz triangular wave signals are simultaneously transmitted after the phase change of 180 degrees by OP-AMP**1** to comp**2** for the comparison with the positive half-cycle control signals, which generate the 20KHz PWM sine wave control signals that switch S**2**. This is transmitted to comp**4** for the comparison with the negative half-cycle control signals that generate the 20KHz PWM sine wave control signals to switch S**4**. 5) OP-AMP**1** causes a phase displacement of the 20KHz triangular wave by 180 degrees to provide the alternating driving signals to S**1** and S**2,** and to S**3** and S**4,** in order to realize the alternating conduction of S**1** and S**2**, and S**3** and S**4**. 6) The power input end Vi and Ii, and the output end Vo and Io, are meters to measure voltage and current, and thus they have no impact on the circuit.

IV. Simulation results

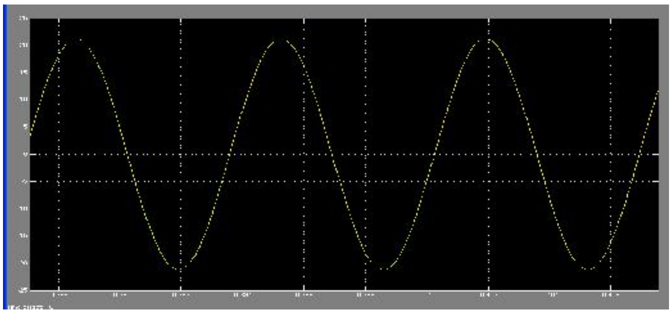
These strategies are implemented in MATLAB/SIMULINK and the performance of the proposed converter is compared under open loop and closed loop operation.



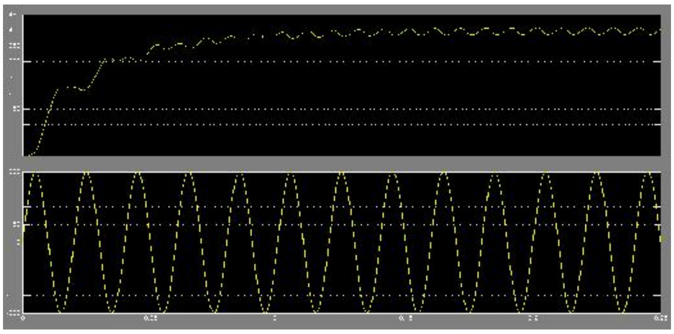
Simulink model



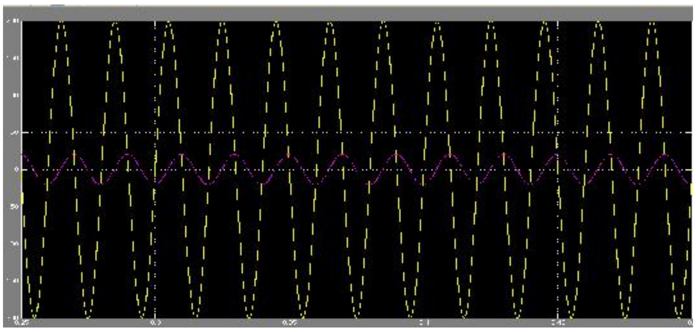
Conventional PFC Simulation Results



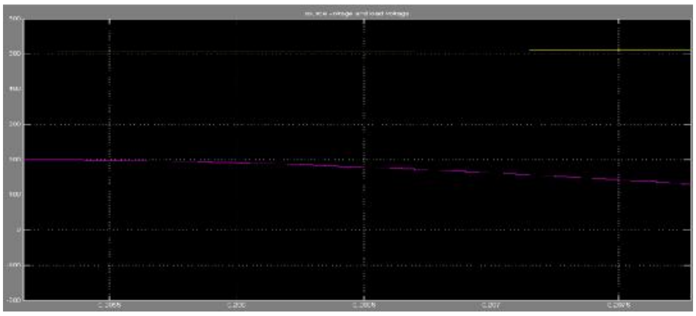
Simulation result s of the open-loop bridgeless interleaved PFC circuit



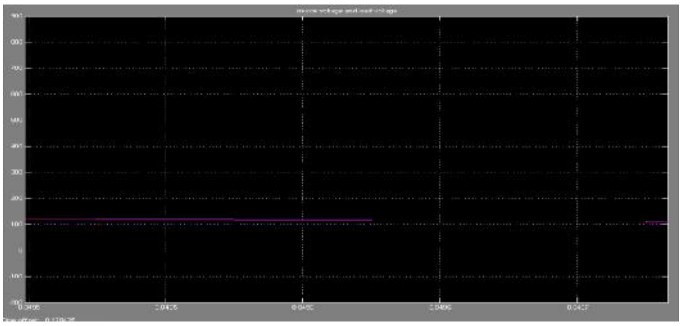
Vref=12V, RL=80Ω simulation results (input voltage and current PF=1)



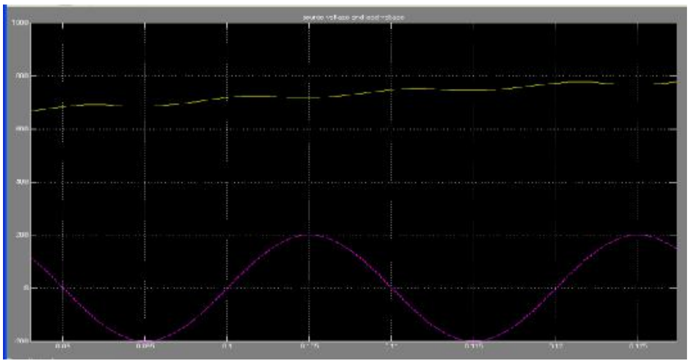
Vref=12V, RL=80Ω simulation results (input voltage and current PF=1)



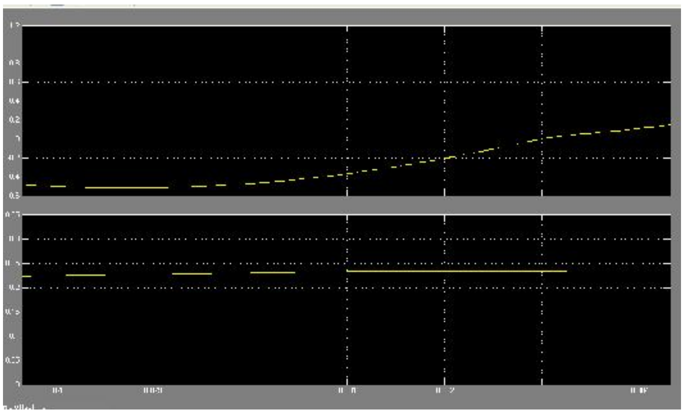
Simulation results of the closed-loop BIP FC circuit, in the case of a load of 2 000W (RL=80Ω)



Simulation results of the closed-loop BIP FC circuit, in the case of a load of 2000W (RL=80 Ω)



Simulation results of the closed-loop bridgeless inter leaved PFC circuit (Rl =580 Ω)



Vref =12 V, RL=80 Ω simulation result (output voltage ripple Vp-p=12V)

Conclusion

In this proposed paper, DC bridgeless interleaved PFC circuit was shown to have excellent performances as the efficiency was η 95.7%. It could maintain extremely small voltage and current ripple factors in the case of a large load output while maintaining excellent efficiency and power factors. The simulation results in terms of the power factor, voltage, and current ripple. However, the efficiency was only 94.7% and was 1% short of the simulation results. The interleaved switch boosting technology could substantially reduce the input ripple current to 0.8A, which is about one-fifth that of conventional circuits. The output ripple voltage was reduced by about one quarter as compared with the same type of conventional circuits. Lastly, the tolerance to the change in the output load (the voltage adjustment rate) was very good. The above benefits confirmed that before new energy sources can replace conventional ones, the active development of power saving technology is still the most direct and important option. Using DSP to control these errors could result in the realization of 96% efficiency.

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