Alinteri J. of Agr. Sci. (2022) 37(1): 33-47
e-ISSN: 2587-2249
info@alinteridergisi.com

http://dergipark.gov.tr/alinterizbd
http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V37I1/AJAS22007

Review on **A Hybrid Resonant pulse-width modulation bridgeless AC-DC power factor correction converter**

[1]K.Sumalatha, [2]Rumana Abideen

[1]Assistant Professor, Department of Electrical & Electronics Engineering, Kakatiya University Campus,Warangal, India

[2]Academic Consultant,Department of Electrical & Electronics Engineering, Kakatiya University India

suma.kucet@gmail.com, rumanaphd786@gmail.com

Abstract:

A bridgeless boost resonant converter with a hybrid pulse width modulation technique is mainly used for the application in power supplies and battery chargers. Especially in Continuous Conduction Mode (CCM) It has two active switches: a pulse width modulation switch and a hybrid modulation switch, with both switches' gates connected. There is no need for an extra circuit to gauge the AC input-line cycle activity since a pulse width modulation switch and a hybrid modulation switch are coupled together. The Inrush current can be limited by incorporating the PWM switches (especially while operating at a maximum duty cycle) by gradually increasing the voltage. Generally, the Totem pole power factor correction (PFC) is a popular topology as it uses different circuits for the correction of the power factor but HRPWM is chosen over the Totempole PFC because of the pulse width modulation operation will eventually reduce the reverse recovery losses of the diodes. The resonant tank components are extremely tiny. Can quickly turn off the di/dt of the output diodes during resonance operation to reduce reverse recovery losses and the electromagnetic interface. The proposed design is utilized to make lightning and surge protection systems simple to implement, and we can also employ zero voltage switching to reduce switching losses and increase efficiency.

1. Introduction:

In power supply and battery chargers, a bridge-less ac-dc PFC boost converter using hybrid resonant pulse width modulation (HRPWM) is used. For industrial and electric vehicle battery charging, an ac-dc PFC converter is essential. For applications requiring more than 400 watts, cascaded PFC switching ac-dc and isolated dc-dc converters are usually used. A bridge rectifier, which is extensively used, is included in a single step boost converter. A single staged boost converter is operated in continuous conduction mode (CCM). Using CCM, we can increase efficiency by reducing losses. The presence of a diode bridge rectifier, which produces substantial conduction losses and heat management concerns, is the drawback of the single staged converter.

A dual boost converter uses no bridge. As a result, the conduction losses seen in boost PFC converters are absent in dual boost and bridgeless converters. However, it needs the use of three current sensors, making the circuit more complicated. A totem pole converter is used for PFC a bridge-less converter requires the same number of semiconductor components. The load current is carried by a MOSFET diode, which causes reverse recovery losses. Using it in continuous conduction mode (CCM) is inconvenient . The disadvantage of these converters is the high number of semiconductor devices and the usage of additional positive elements in this circuit

A vast inrush current occurs in boost-derived PFC. It also lacks lightning. It doesn't protect from surges as its input voltage is directly connected to bus capacitors. The inrush current is due to input voltage greater than instantaneous DC bus voltage. Additional circuitry and complexity are needed for boost converters. As a result, in terms of practical applications High inrush current and surge limiting are needed for boost generated PFCs. For high efficiency (>400w), the inrush current and surge limiting can be achieved by placing a current-controlled device(example: a resistor) in series with PFC. Surge limiting circuits, on the other hand, add complexity and cost.

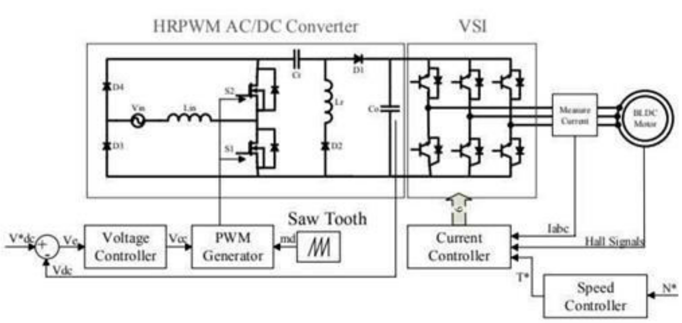


Fig: proposed system configuration of a BLDC motor drive fed by a HRPWM converter

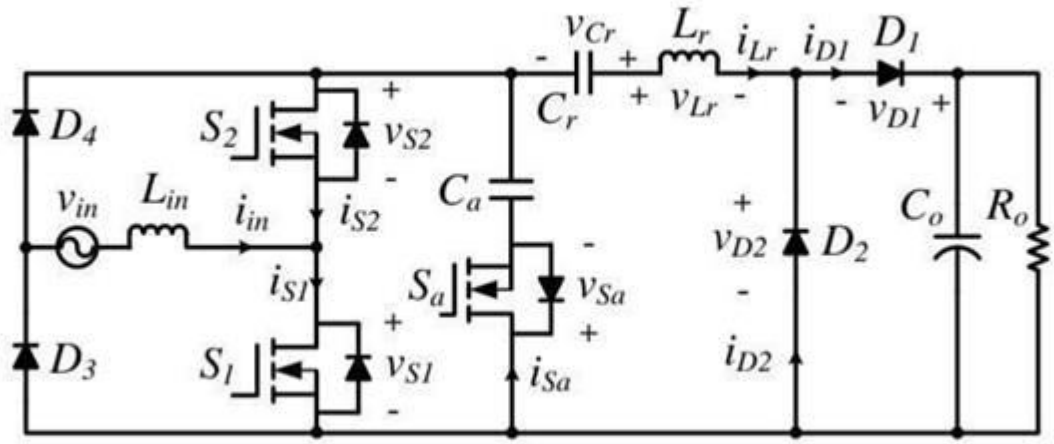


Fig: Proposed ZVS HRPWM ac-dc PFC technology

To protect the charger from overvoltage transients in boost generated PFC, a metal-oxide- varistor (MOV) is used. The current handling capability of MOV is very high. It limits current by shorting AC lines. It limits up to thousands of amperes of current under 700v. Series capacitors in the load current path limit the Cuk, SEPIC's inrush current. Cuk and SEPIC use very large inductors, which limit power density. But, they contain a high number of passive components, increasing the circuit's cost and complexity.

The DC-DC converter has galvanic isolation and can decrease initial inrush current. To convert AC to DC, An additional bridge rectifier is required for the DC-DC converter, which increases conduction losses. The disadvantages which are boost derived, DC-DC and totem pole, etc can be fulfilled by using HRPWM. There is no requirement for a diode bridge rectifier. It also has a higher capacity for limiting inrush current. It can handle up to 650 watts of charging power.

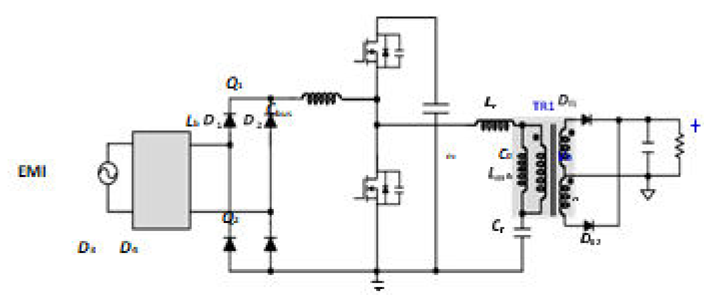


Fig: proposed AC DC converter topology

2. Proposed scheme operating principle :

The HRPWM is a bridgeless converter with only one inductor at the input. There is no need to sense the AC-line functioning because switches S1 and S2 are powered by the same PWM signal. HRPWM has a voltage conversion ratio that is similar to a boost converter. The converter starts out with stepdown characteristics and short duty cycles, which minimizes the inrush current even more. The input voltage is clamped by diodes D3 and D4.

Figure 2: HRPWM ac-dc converter topology

When the switches are turned on, the system operates in hybrid resonant mode. When the switches are turned off, the device operates in pulse width modulation mode. Both modes are activated in a single switching cycle. So we have further three modes in Hybrid resonant modes that explain resonance, above resonance, and below resonance operations.

2.1 At resonance operation:

This operation takes place when the resonant frequency is equal to the switching frequency.

T_r = Resonant time period for L_r - C_r Resonant tank

$$T_r = 2T_{ON}$$

$$T_r = 2\pi\sqrt{L_r C_r}$$

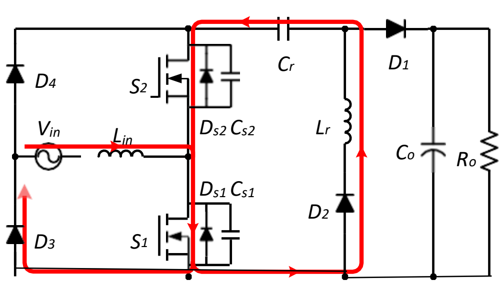


Figure 3:

The diode D2 shuts off during resonance operation, lowering the turn-off current at switch S1. This decreases the switching losses at S1 even more. The duty cycle D of the AC-DC converter varies.

2.2 Above resonance operation:

The resonant time period is longer than the switching period in this resonance operation. The condition is as follows:

$T_r > 2T_{on}$

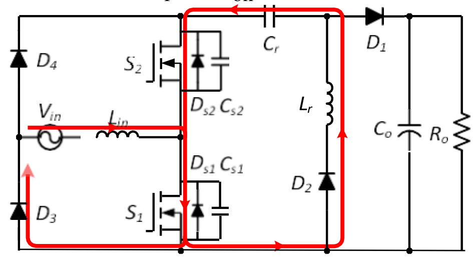


Figure 4:

The switch S1 will be switched off even if there is current in the Lr-Cr resonant branch tank. Losses and electromagnetic interference will arise from the switch S1 being switched off. This mode has the advantage of not requiring variable frequency operation, which is required in resonant frequency operation. The control is implemented using a standard average current mode control integrated circuit (IC).

2.3 Below resonance operation:

The switching period is longer than the resonant period in this operation. The condition is as follows:

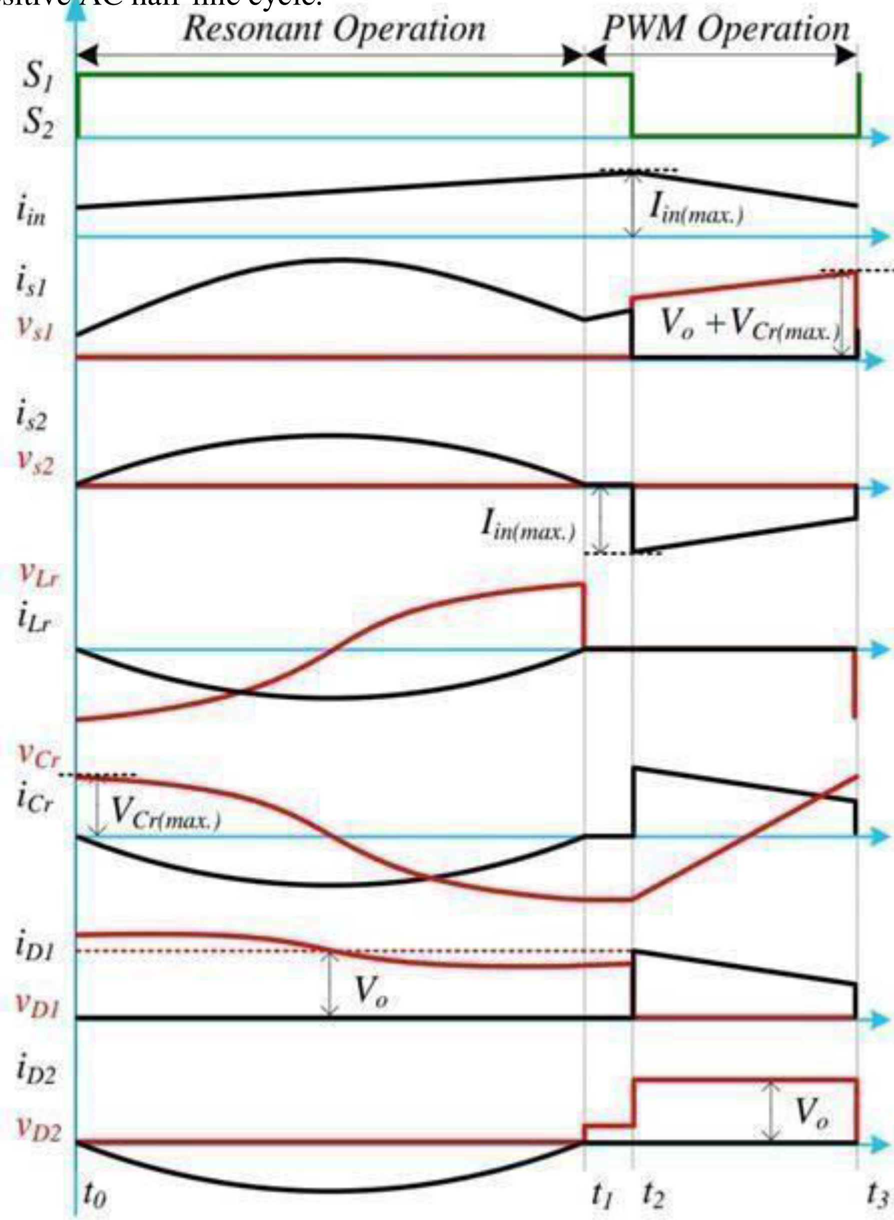
$T_r < 2T_{on}$

When the converter is operating at below resonance it doesn't require varied frequency operation. High input voltage is one main flaw, and peak current is correspondingly high at extremely very low duty cycles .

- In order to have an integrated circuit, it must operate at a set switching frequency.

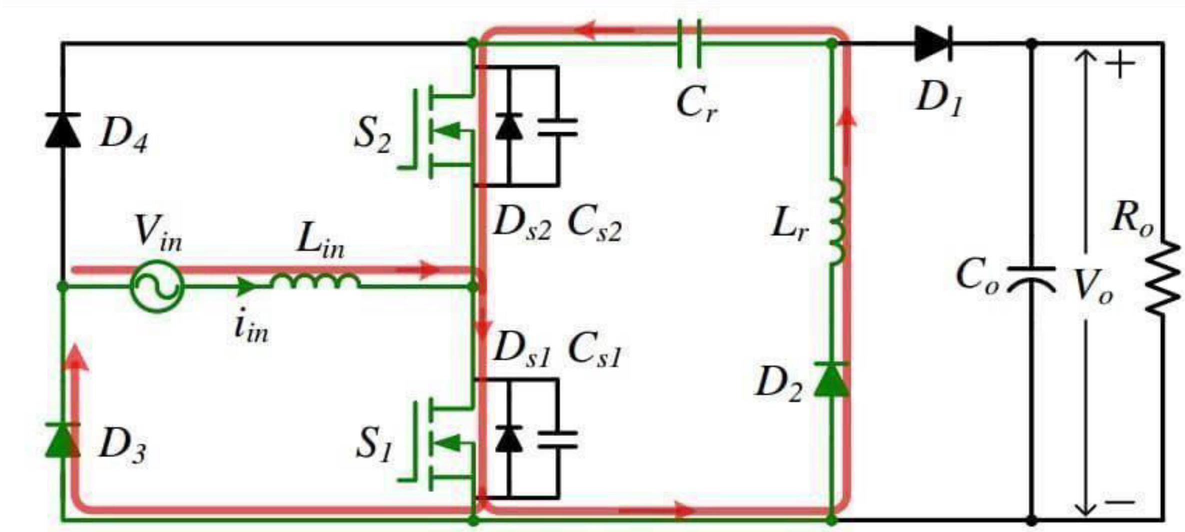
3. Operating Modes of the Proposed scheme:

The waveforms of the converter are given below. For the sake of simplicity, consider the functioning of a positive AC half-line cycle.



Mode-I (Interval t_0-t_1) :

When the S1 and S2 switches are switched on, this mode is activated. The energy of the input current , in , is stored in the input inductor ,Lin .When the resonant current I_{Lr} reaches zero, the interval comes to end .The equations (1),(2),and (3) give the input current in, the resonant current I_{Lr} and the voltage across the resonant capacitor V_{cr}



HRPWM bridgeless topology conduction path during *Interval-1*

$$I_{in}(t)=V_{in}/L_{in}(t-t_0) + i_{in}(t_0) \quad (1)$$

$$I_{Lr}(t)=-i_{Cr}(t)=V_{Cr(max)}/Z\ (\sin(w_r(t-t_0))) \quad (2)$$

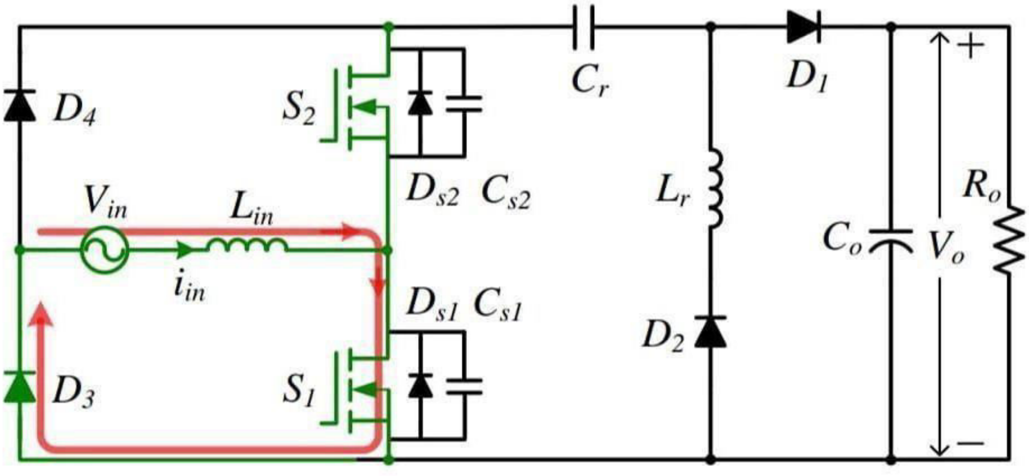
$$v_{Cr}(t)=v_{Cr(max)}[\cos(w_r(t-t_0))-1]+v_{cr}(t_0) \quad (3)$$

where, $z=(L_r/C_r)^{1/2}$ and $w=1/(L_rC_r)^{1/2}$

Mode-II (Interval t_1-t_2):

When D2 ceases conducting and there is no current in the resonant branch, then this mode begins. Lin continues to store energy because the boost converter's operation is to store energy.

When S1 and S2 are switched off, the interval terminates.



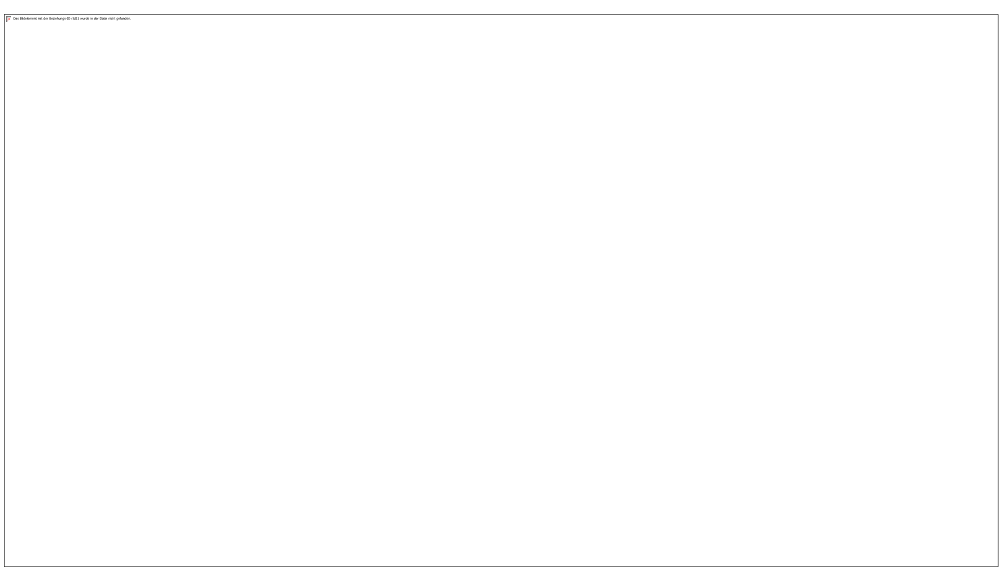
HRPWM bridgeless topology conduction path during *Interval-2*

Mode-III (Interval t2-t3):

The energy held in the input inductor, Lin, is transmitted to the load in this mode. When S1 and S2 are turned on at t3/t0 this interval ends, and interval-1 begins, and the process repeats.

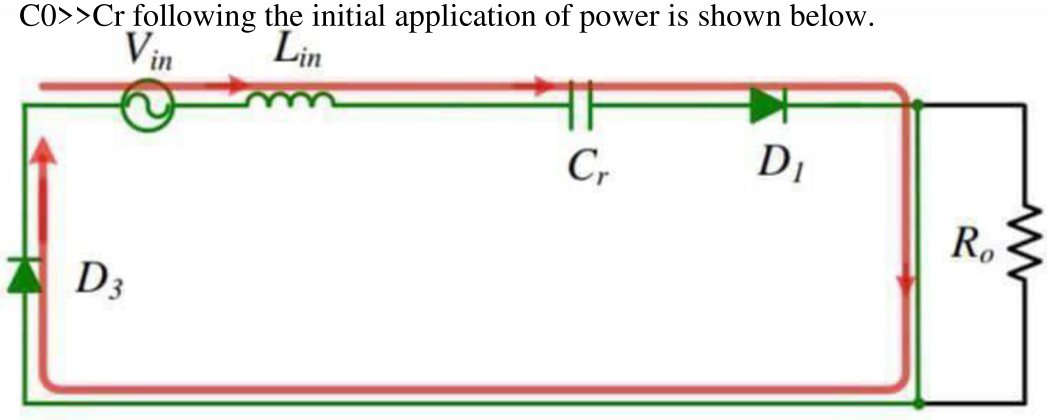
The input current, in, is calculated using the equation below.

$$I_{in}(t) = (V_{in} - V_{Cr(min)} - V_0/L_{in})\ (t-t_2) + i_{in}(t_2)$$



Operation During Startup and Inrush Considerations:

When the PWM switches are not activated, the input current of the converter flows through the resonant capacitor, Cr, and the bus capacitor, C0, unlike a traditional boost converter. The equivalent circuit for C0>>Cr following the initial application of power is shown below.



Equivalent circuit during startup neglecting the low impedance of C_o

The worst inrush current can be calculated by assuming the following conditions: high line input voltage to the PFC converter at a phase angle equivalent to the highest peak; Cr<<C0 ideal Lin and Cr; no starting currents in Lin voltages on Cr and C0; and no source impedance or converter resistance.

$$I_{inrush}(t) = (2)^{1/2} V_{in(max)} (C_r/L_{in})^{1/2} \sin(wt)$$

Where $w=(1/L_{in}C_r)^{1/2}$

4.Key Equations:

4.1.DC Voltage Conversion Ratio

At normal operating conditions the DC voltage conversion ratio of the HRPWM is similar to that of a Boost. So we can use a standard DC converter control.

Vo/Vin= 1/1-D

4.2. Voltage stress:

The output voltage, Vo is the voltage stress of the resonant components and diodes. The voltage stress on switches S1, S2 and on MOSFETs is given as

$V_{s1\_s2(max)} = Vo + V_{cr(max)}$

diodes D1 and D2, at steady-state conditions

Average Current = Average load current

The average load current is calculated using the formula:

$$I_{D2(avg)} = [\frac{1}{Ts}\int_0^{Tr/2} Vcr(max)\sqrt{\frac{Cr}{Lr}}\sin(w_r t)dt]$$

$V_{cr\ (max)}$ is given by:

$$V_{cr\ (max)} = Io/2C_rF_r$$

4.3. Resonant frequency:

The resonant frequency of the resonant tank , Lr – Cr:

$$fr \geq \frac{fsVo}{2(Vo - Vin(nom))}$$

The resonant capacitance ,

$$C_r = \frac{Io}{2(max)}$$

The resonant inductance ,

$$L_r = \frac{1}{4\pi^2 f_r^2 C_r}$$

The inrush current is ,

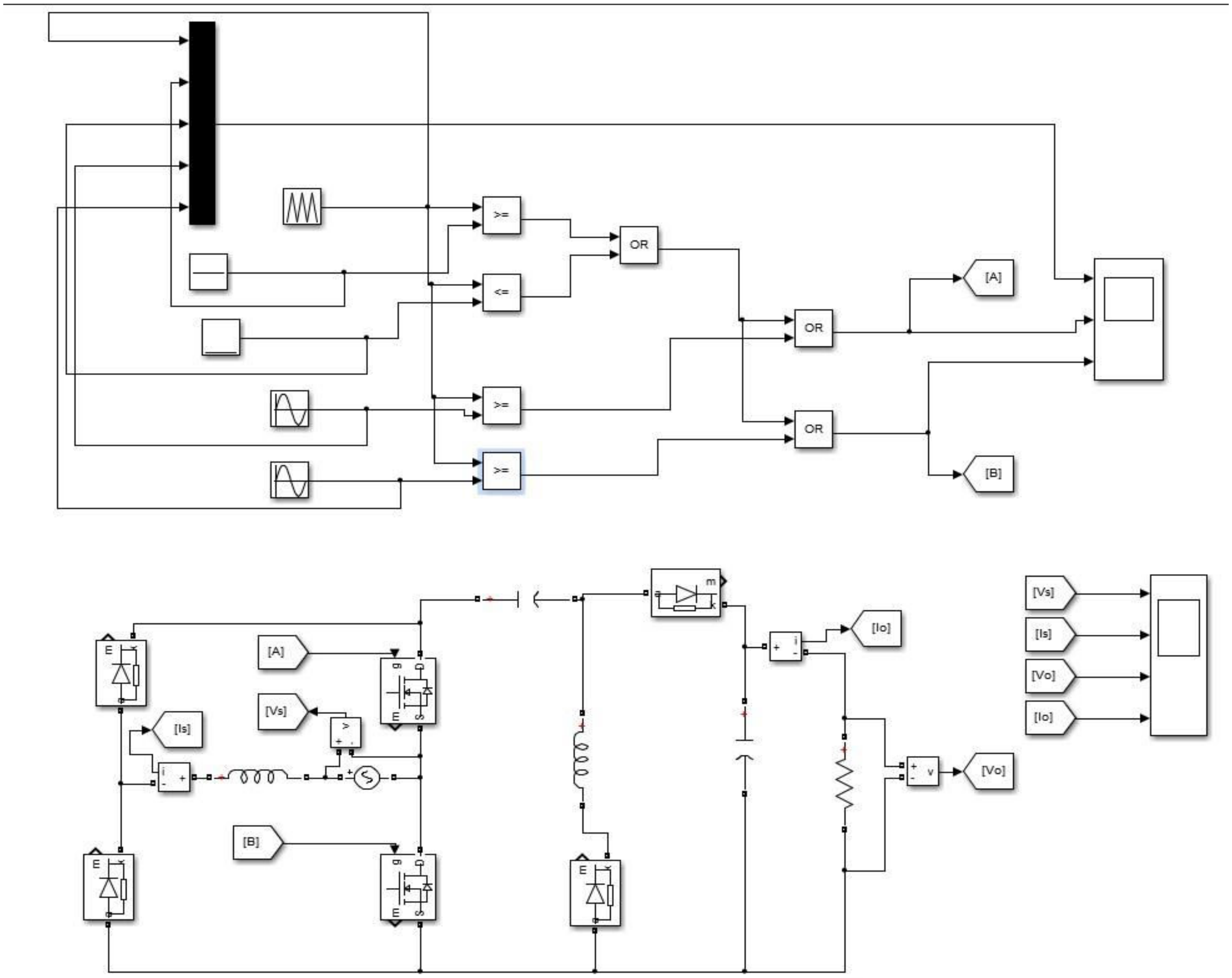
$$I_{inrush}(peak) = \sqrt{2}\, V_{in(max)} \sqrt{Cr}\ {}_{Lin}$$

The energy associated with peak inrush current ,

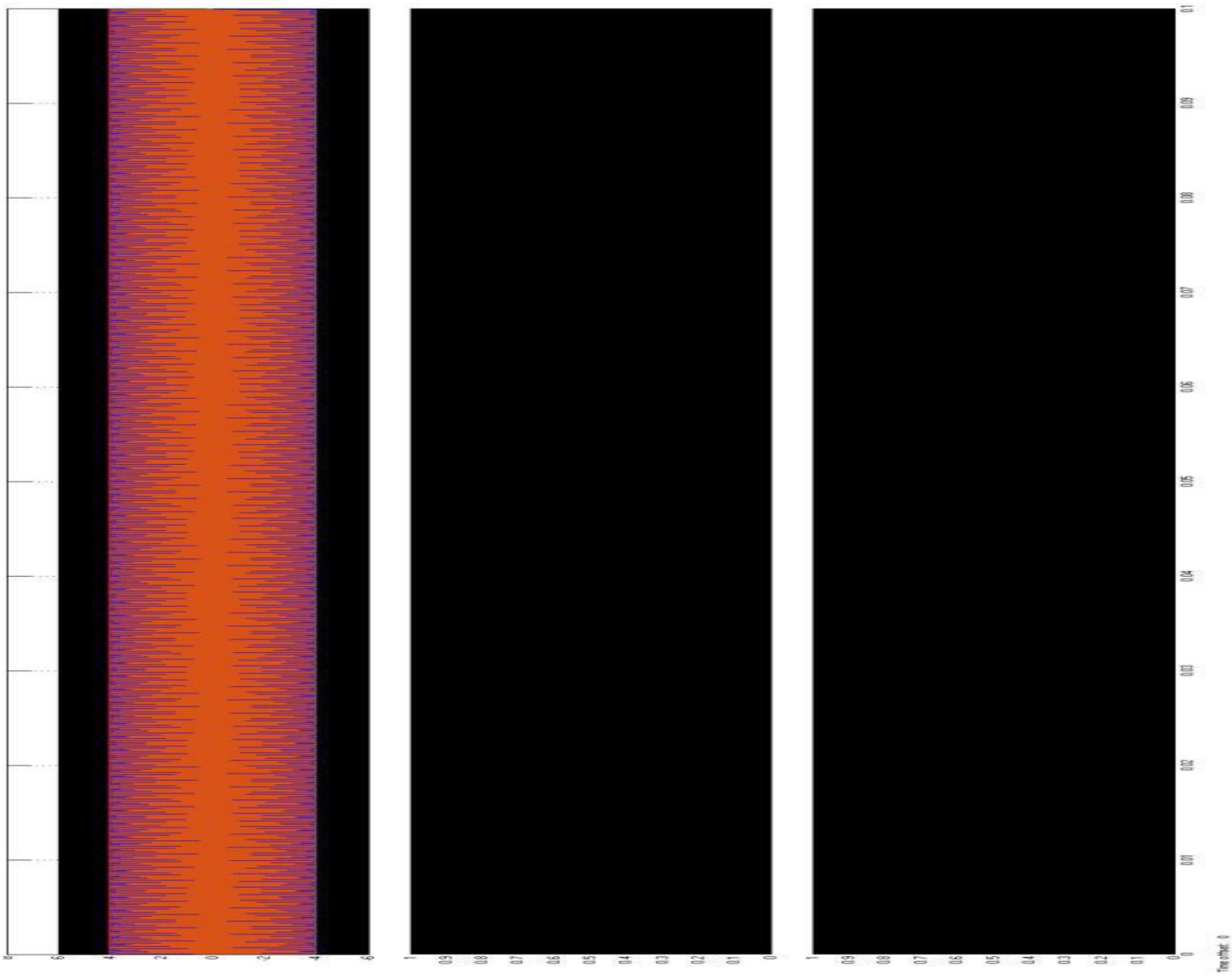
$$I^2_{inrush}(peak)Tr = (\sqrt{2}\, V_{in(max)} \sqrt{Cr/Lin})^2\, \pi \sqrt{L_{in}C_r}$$

5. Simulation

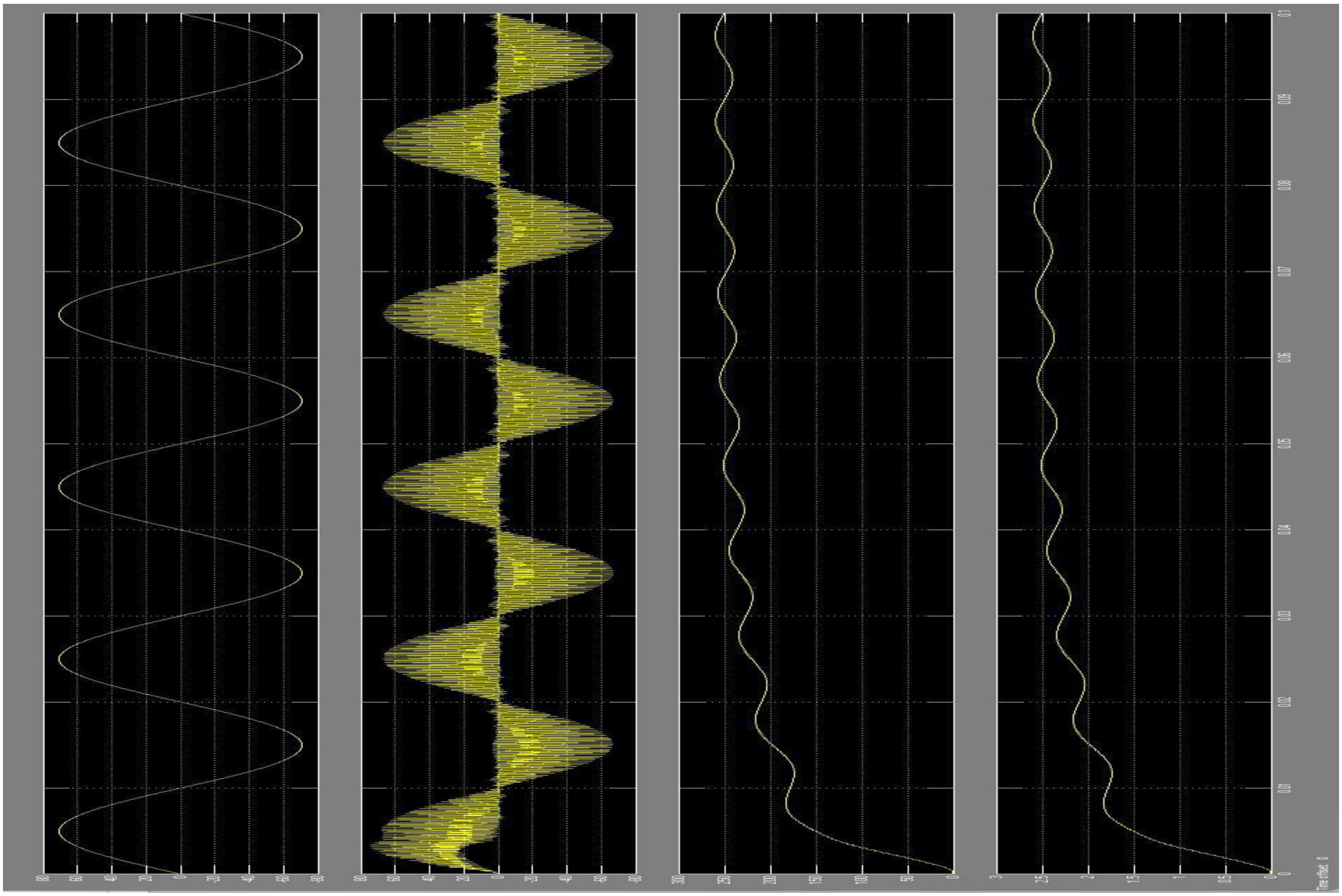
5.1 Circuit:



5.2 Output of logic circuit:



5.3 Simulation result:



Conclusion:

This modern HRPWM AC-DC power factor correction converter is mostly used in frontend applications. The standard average current control IC may easily construct the HRPWM converter. Because the switches may be operated with the same PWM signal, there is no requirement for an additional circuit to sense the positive or negative half cycle action.

This converter includes an inrush current limiting feature built in, which improves the converter's reliability the large number of applications

Furthermore, the bridgeless operation alleviates heat management issues.

References:

[1] A. F. Souza and I. Barbi, "A new ZCS quasi-resonant unity power factor rectifier with reduced conduction losses," in Proc. IEEE Power Electronics Specialists., Jun. 1995, vol. 2, pp. 1171-1177.

[2] A. F. Souza and I. Barbi, "A new ZVS-PWM unity power factor rectifier with reduced conduction losses," IEEE Trans. Power Electron., vol. 10, no. 6, pp. 746-752, Nov. 1995.

[3] C. M. Wang, "A novel ZCS-PWM power-factor pre-regulator with reduced conduction losses," IEEE Trans. Ind. Electron., vol. 52, no. 3, pp. 689-700, Jun. 2005.

[4] F. Musavi, W. Eberle, and W. G. Dunford, “A high-performance single-phase bridgeless interleaved PFC converter for plug-in hybrid electric vehicle battery chargers,” IEEE Trans. Ind. Appl., vol. 47, no. 4, pp. 1833–1843, Jul./Aug. 2011.

[5] Q. Tao, X. Lei, and S. Jian, “Dual-boost single-phase PFC input current control based on output current sensing,” IEEE Trans. Power Electron., vol. 24, no. 11, pp. 2523–2530, Nov. 2009.

[6] Y. Cho and J.-S. Lai, “Digital plug-in repetitive controller for single-phase bridgeless PFC converters,” IEEE Trans. Power Electron., vol. 28, no. 1, pp. 165–175, Jan. 2013.

[7] L. Huber, Y. Jang and M. M. Jovanovic, "Performance evaluation of bridgeless PFC boost rectifiers," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1381-1390, May 2008.

[8] A. F. Souza and I. Barbi, "High power factor rectifier with reduced conduction and commutation losses," in Proc. Int. Telecommunication Energy Conf., Jun. 1999, pp. 8.1.1-8.1.5.

[9] Y. Jang and M. M. Jovanovic, “A bridgeless PFC boost Rectifier with optimized magnetic utilization,” IEEE Trans. Power Electron., vol. 24, no. 1, pp. 85–93, Jan. 2009.

[10] M. M. U. Alam, W. Eberle and F. Musavi, "A zero voltage switching semi-bridgeless boost power factor corrected converter for plug-in hybrid electric vehicle battery chargers," in Proc. IEEE Applied

Power Electronics Conf., Feb. 2012, pp. 2625-2630.

[11] simplified current sensing for the semi-bridgeless AC– DC converter," IEEE Trans. Veh. Technol., vol. 62, no. 4, pp. 1568-1576, May 2013.

[12] P. Kong, S. Wang, and F. C. Lee, "Common mode EMI noise suppression for bridgeless PFC converters," IEEE Trans. Power Electron., vol. 23, no. 1, pp. 291–297, Jan. 2008.

[13] P. Praveen, K. Srilatha, M. Sathvika, E. Nishitha and M. Nikhil, "Prediction of Alzheimer's Disease using Deep Learning Algorithms," 2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAAIC), Salem, India, 2023, pp. 587-594, doi: 10.1109/ICAAIC56838.2023.10140746.

[14] P. Praveen, S. Shravani, R. Srija and M. Tajuddin, "A Model to Stock Price Prediction using Deep Learning," 2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS), Coimbatore, India, 2023, pp. 242-252, doi: 10.1109/ICSCSS57650.2023.10169558.

[15] P. Praveen, P. Akshitha, S. Samreen, R. Kumar and Y. Shashank, "Evaluation of Digital Banking Implementation Using Programming Paradigm," 2023 International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS), Erode, India, 2023, pp. 1019-1024, doi: 10.1109/ICSSAS57918.2023.10331646.

[16] P. Praveen and S. Madihabanu, "A Real Time Multiple Object Tracking in Videos using CNN Algorithm," 2023 International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS), Erode, India, 2023, pp. 1-6, doi: 10.1109/ICSSAS57918.2023.10331876.

[17] Mohammed Ali Shaik, Praveen Pappula, T. Sampath Kumar, Battu Chiranjeevi,"Ensemble model based prediction of hypothyroid disease using through ML approaches", AIP Conference Proceedings, 2971, 020038 (2024), https://doi.org/10.1063/5.0196055

[18] Mohammed Ali, P. Praveen, Sampath Kumar, Sallauddin Mohmmad, M. Sruthi, "A survey report on cloud based cryptography and steganography procedures", International Conference on Research in Sciences, Engineering, and Technology, AIP Conf. Proc. 2971, 020040-1–020040-8; https://doi.org/10.1063/5.0196050

[19] Mohammed Ali Shaik, P. Praveen, T. Sampath Kumar, Masrath Parveen, Swetha Mucha, "Machine learning based approach for predicting house price in real estate", International Conference on Research in Sciences, Engineering, and Technology, AIP Conf. Proc. 2971, 020041-1–020041-5; https://doi.org/10.1063/5.0196051

[20] Praveen Pappula, Mohammed Ali Shaik, Sampath Kumar Tallapally, Vadlakonda Anitha, Nagavelli Yogendernath, "A new method to detect brain tumor using with convolution neural networks", AIP Conference Proceedings, 2971, 020048 (2024), https://doi.org/10.1063/5.0196060