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SINGLE PHASE AC-DC POWER FACTOR IMPROVEMENT WITH HIGH FREQUENCY ISOLATION USING BOOST CONVERTERS

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ABSTRACT

A comparative analysis of the improved power quality HF isolated transformer AC-DC buck converters has been made to present a detailed exposure on their various topologies. The detailed classification of these AC-DC boost converters have 4 categories with number of circuits and concepts has been carried out to provide easy selection of proper topology for a specific application. These AC-DC converters provide a high level of power quality at the AC mains, well-regulated and also free ripple isolated DC outputs. Moreover, these converters have been operated very satisfactorily with very wide AC mains voltage and frequency variations resulting in a concept of universal input..

INTRODUCTION

Switching power supply provide not only higher efficiencies but also greater flexibility to the designer. Recent advances in semiconductors, magnetic and passive technologies make the switching power supply an ever more popular choice in the power conversion arena. AC-DC converter with high frequency transformer is most widely used in SMPS (switched mode power supply), UPS (uninterrupted power supply), battery charging, induction heater, electronic ballast. This ac-dc converter is implemented with two stages at first stage, the ac voltage is converted into uncontrolled dc voltage with the help of diode bridge rectifier circuits, followed by the second stage of dc-dc converter using high frequency transformer. On the basis of high frequency single phase ac-dc converters like buck, boost and buck-boost. isolation transformer the converter design is classified into nine different converter such as Simultaneously these buck converters are also further classified into push-pull, half bridge and full bridge configuration.

Similarly the boost type converters are classified into forward, push-pull, half and full bridge topologies. Finally the buck- boost converters are classified into cuk, fly back, SEPIC, and ZETA converters. AC-DC converter having high frequency isolation transformer are developed in the range of some watts to several KW for the application of DC power in computer power supplies, UPS, battery charger, induction heater, electronic ballast etc. The above mentioned application of power supplies is used to develop the power quality of low value of total harmonic distortion, and peak factor, high power factor, low value of EMI and RFI at ac mains are regulated and to reduce the ripple components and stabilize the dc voltage under varying loads.

Linear versus SwitchingPower Supplies

Switching of the linear regulators uses fundamentally different technique to produce a regulated output from an unregulated input voltage. Different techniques has its own advantages and disadvantages, so this application will determine the most suitable choice. The linear regulator design is simple, cheap and requires few external components. The linear design is quite easy than switcher as there is no high−frequency switching noise. Switching power supply can be obtained by rapidly switching the pass units between two efficient operating states: *cut-off*, means a high voltage across the pass unit and no current flow; *saturation* where a high current through the pass unit but there is a very small voltage drop.

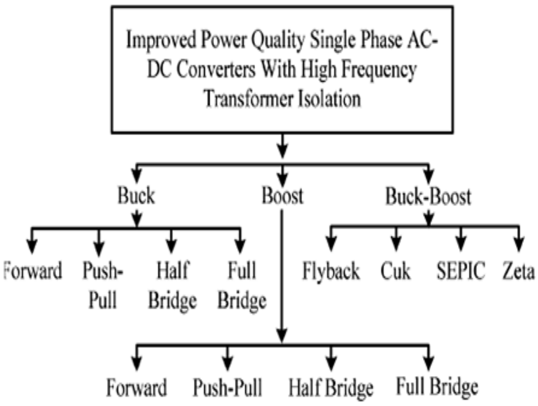
Thus the semiconductor power switches create an AC voltage from the input DC voltage. The AC voltage obtained can be stepped−up or down by transformers and then finally filtered back to DC as an output voltage.

Switching power supplies having efficiency ranging from 65 to 95 percent are more efficient. The downside of a switching design is considerably more complex. In addition, the output voltage contains switching noise that must be removed for many applications. Although there is a visible difference between linear and switching regulators, many applications require both types of regulators. For example, a switching regulator provides the initial regulation and the linear regulator provides post−regulation for a noise−sensitive part of the design such as a sensor, interface circuit.

CIRCUIT CONFIGURATION

Single phase improved power quality converter are classified basis on the voltage levels at the input and output as buck, boost converter are further classified with forward, push-pull, half bridge, full bridge converter.

Similarly buck-boost converter are classified into fly back, cuk, SEPIC, and ZETA converter. This converter are constructed with diode bridgeat input side used to convert single phase ac-dc feeding various type of load.

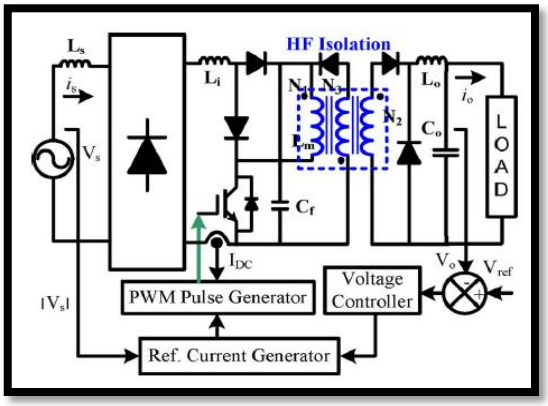


1. Boost AC-DC CONVERTER

Hear the boost chopper is taken up for first discussion followed by the choppers derived from name push-pull, half-bridge, full-bridge and forward chopper.

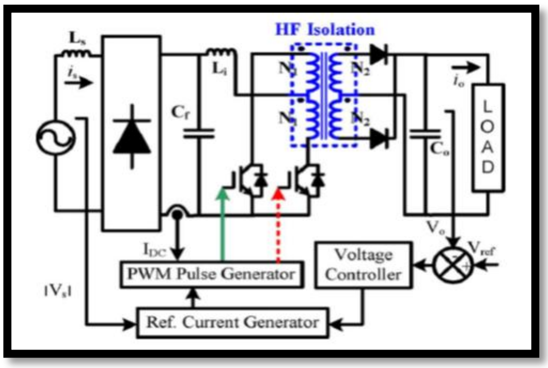
- ***Boost forward ac-dc converter***

The boost converter is used for board−level (i.e.,non−isolated) step−up applications and is limited to less than 100−150 watts due to high peak currents.



2. Boost Push-Pull AC-DC Converter

In this converter only a small valu of inductor (Li) is added in the conventional push pull converter. The HF output of the transformer can be rectified to DC either using push-pull or bridge converter or may be used directly in some typical applications.



3. Boost Half-Bridge AC-DC Converter

This converter can be viewed as two back-to-back forward converters that are feed by the same input voltage, each delivering power to the load at each alternate half-cycle.

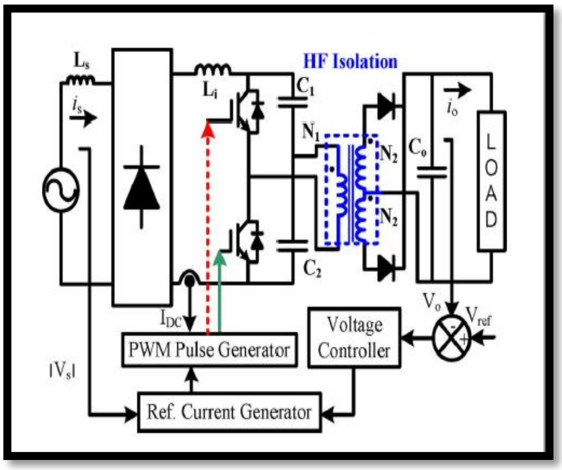


Figure 1 Half-bridge buck AC-DC converter with voltage follower control

4. Boost Full-Bridge AC-DC Converter

shows a basic topology of a single-phase boost half-bridge AC-DC converter, which has also used only an additional inductor (L_i) of low value to provide a current source for boosting voltage level of conventional half-bridge DC-AC HF converter. In some applications of very low output DC voltage, it uses self-driven synchronous rectifier at output stage to enhance the efficiency of this converter. Normally, this converter is operated in discontinuous current mode through input inductor for reducing harmonics of AC mains current and achieving high power factor.

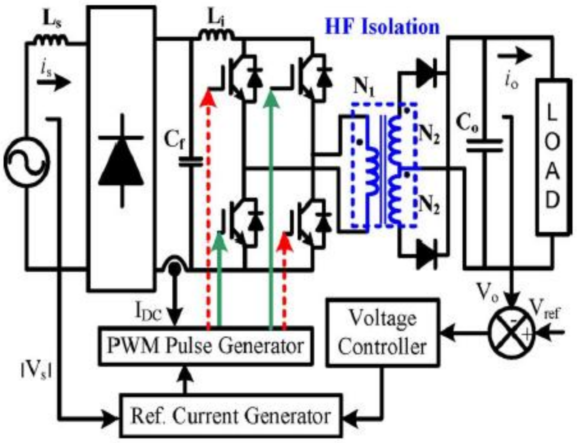


Figure 2 Boost full-bridge AC-DC converter with voltage follower control

SIMULATION STUDY

Buck Forward AC-DC Converter

Simulation Parameters

(1) Input voltage (V_s) = 311 V (Peak value), Supply Frequency = 50 Hz
Switching Frequency = 10 KH
(2) C_f = 155nF, L_i = 25mH, L_o =
60µH C_o = 24mF, K_p = 0.119, K_i = 1.19
(3) Load = 100 Watt

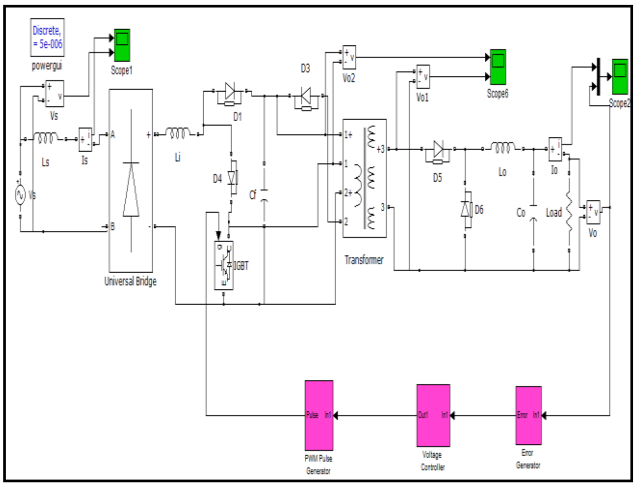


Figure 3 Simulation circuit diagram of boost forward converter

Buck Push-Pull AC-DC Converter

Simulation Parameters

(1) Input voltage (V_s) = 311 V (Peak value), Supply Frequency = 50 Hz
Switching Frequency = 10 KHz
(2) C_f = 12.5nF, L_i = 0.75mH, C_o = 24mF, K_p = 0.385, K_i = 4.85
(3) Load = 100 Watt

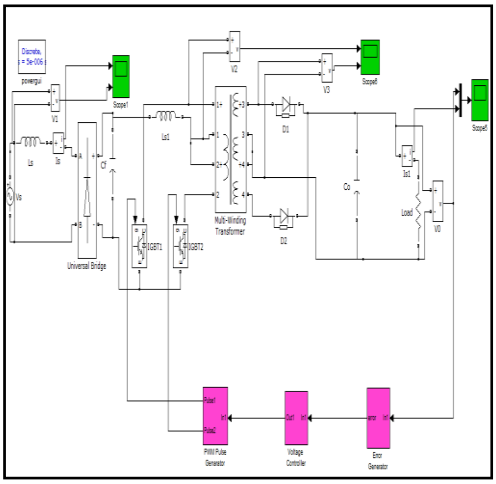


Figure 4 Simulation circuit diagram of buck push-pull converter

Buck Half-Bridge AC-DC Converter

Simulation Parameters

(1) Input voltage (V_s) = 311 V (Peak value), Supply Frequency = 50 Hz
Switching Frequency = 10 KHz
(2) C_1=C_2=5μF, L_i=27mH, C_o=24mF,
K_p=0.185,K_i=2.15
(3) Load = 100 Watt

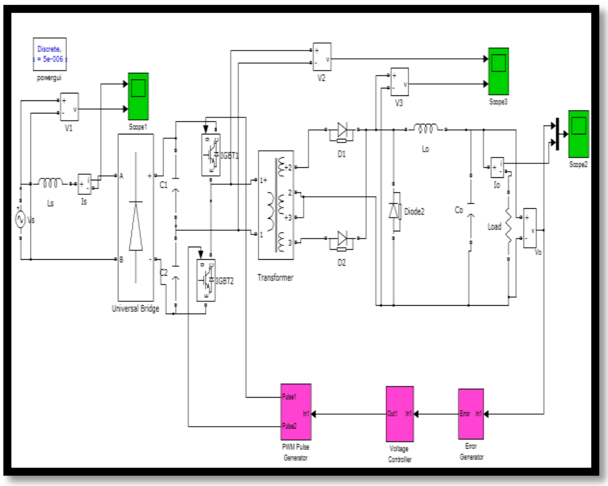


Figure 5 Simulation circuit diagram of buck half-bridge converter

Buck Full-Bridge AC-DC Converter

Simulation Parameters

(1) Input voltage (V_s) = 311 V (Peak value), Supply Frequency = 50 Hz
Switching Frequency = 10 KHz
(2) C_f = 50pF, L_o = 55μH, C_o = 24mF, K_p = 0.0815, K_i = 2.815
(3) Load = 100 Watt

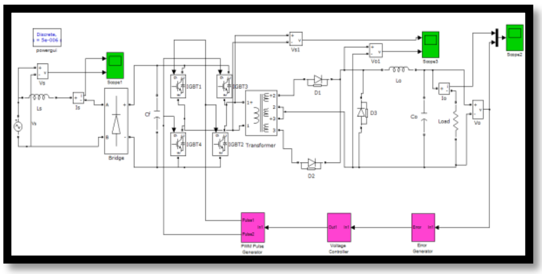


Figure 6 Simulation circuit diagram of buck full-bridge converter

RESULTS

Buck Forward AC-DC Converter

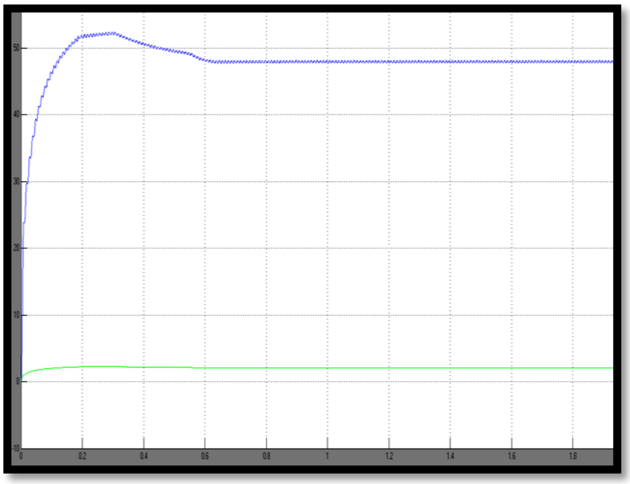
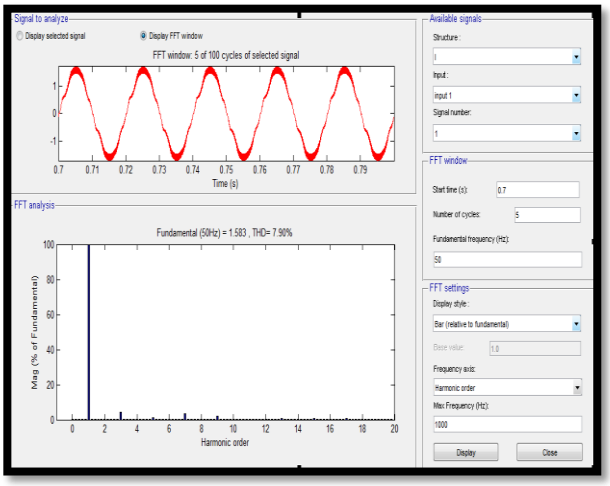


Figure 7 Output voltage and output current of buck forward converter


Signal to analyze

○ Display selected signal ● Display FFT window

FFT window: 5 of 100 cycles of selected signal

FFT analysis

Fundamental (50Hz) = 1.583 , THD= 7.90%

Available signals

Structure : I

Input : input 1

Signal number: 1

FFT window

Start time (s): 0.7

Number of cycles: 5

Fundamental frequency (Hz): 50

FFT settings

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Harmonic order

Max Frequency (Hz): 1000

Figure 8 Harmonic analysis of buck forward converter

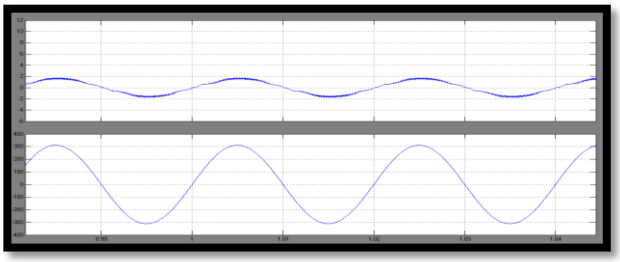


Figure 9 Power factor of input side for buck forward converter

Analysis of Result
Output voltage (V_o) = 48 volt, Output Current = 2.08 Amp
Total Harmonic Distortion (THD) = 7.90%, Input Power Factor = 0.994
The Power density and Cost is lowest for this converter as compare to other topologies.

Buck Push-Pull AC-DC Converter

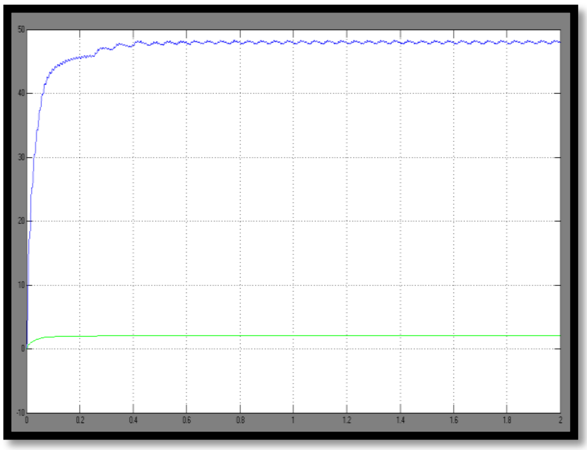


Figure 10 Output voltage and output current of buck push-pull converter

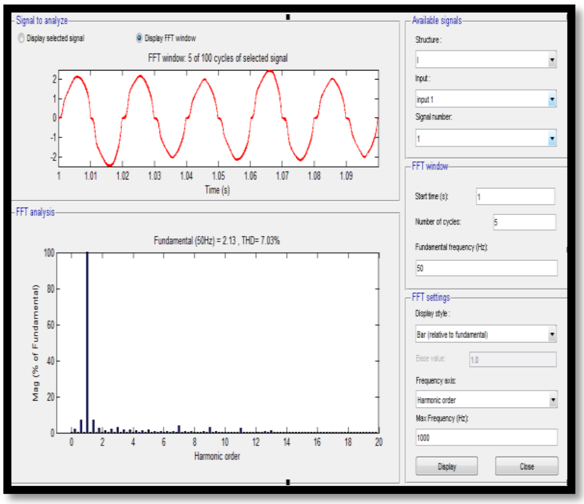

Signal to analyze
○ Display selected signal ● Display FFT window
FFT window: 5 of 100 cycles of selected signal
FFT analysis
Fundamental (50Hz) = 2.13 , THD= 7.03%
Available signals
Structure : I
Input : input 1
Signal number: 1
FFT window
Start time (s): 1
Number of cycles: 5
Fundamental frequency (Hz): 50
FFT settings
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Harmonic order
Max Frequency (Hz): 1000

Figure 11 Harmonic analysis of buck push-pull converter

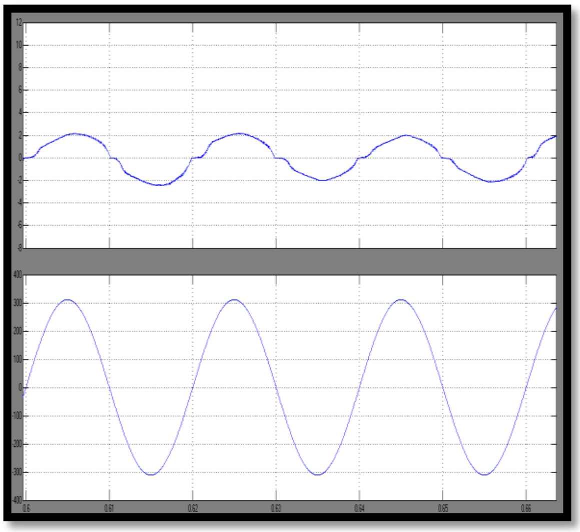


Figure 12 Power factor of input side for buck push-pull converter

Analysis of Result
Output voltage (V_o) = 48 volt, Output Current = 2.08 Amp
Total Harmonic Distortion (THD) = 7.03%, Input Power Factor = 0.995
The Power density and Cost is medium for this converter.

Buck Half-Bridge AC-DC Converter

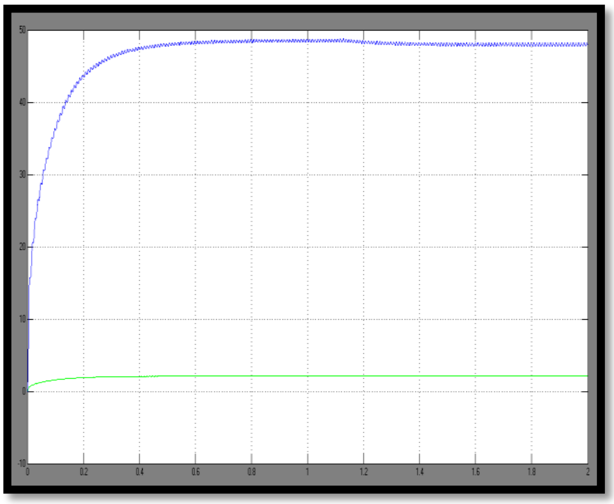
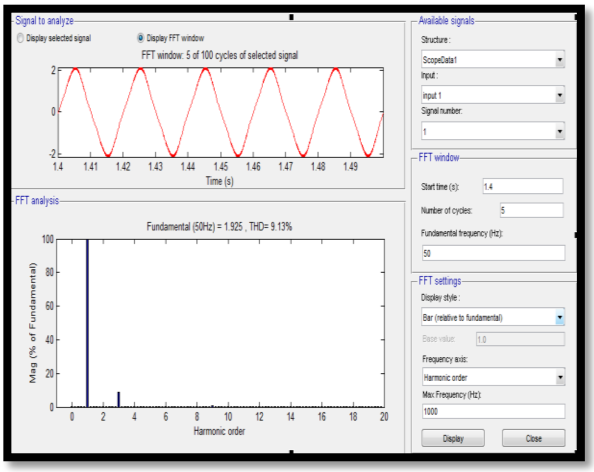


Figure 13 Output voltage and output current of buck half-bridge converter



Structure : ScopeData1

Input : input 1

Signal number: 1

Start time (s): 1.4

Number of cycles: 5

Fundamental frequency (Hz): 50

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Harmonic order

Max Frequency (Hz): 1000

Figure 14 Harmonic analysis of buck half-bridge converter

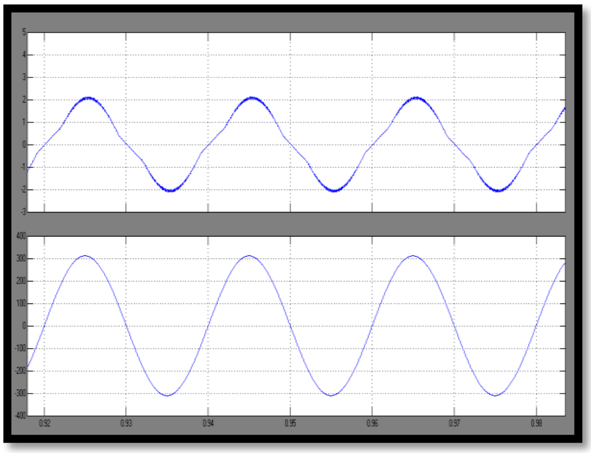


Figure 15 Power factor of input side for buck Half-bridge converter

Analysis of Result

Output voltage (V_o) = 48 volt, Output Current = 2.08 Amp
Total Harmonic Distortion (THD) = 9.13%, Input Power Factor = 0.997
The Power density and Cost is medium for this converter.

Buck Full-Bridge AC-DC Converter

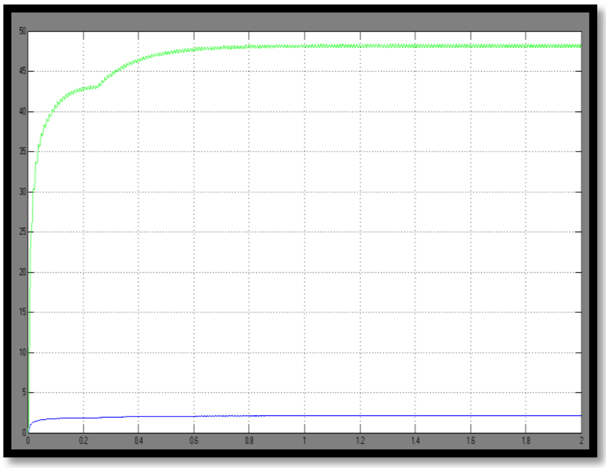
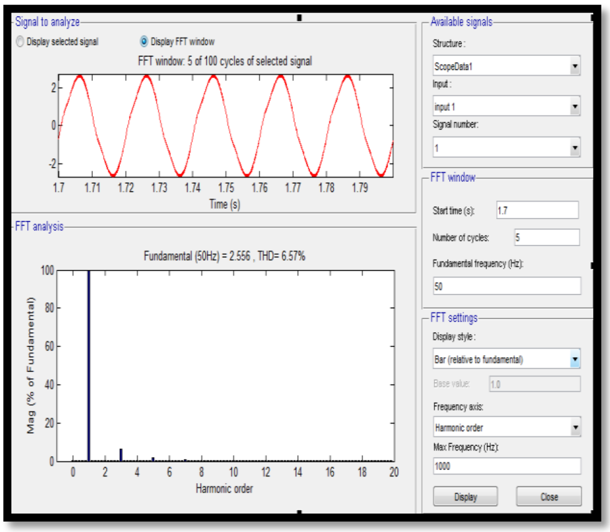


Figure 16 Output voltage and output current of buck full-bridge converter.



Structure : ScopeData1
Input : input 1
Signal number: 1
Start time (s): 1.7
Number of cycles: 5
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Harmonic order
Max Frequency (Hz): 1000

Figure 17 Harmonic analysis of buck full-bridge converter

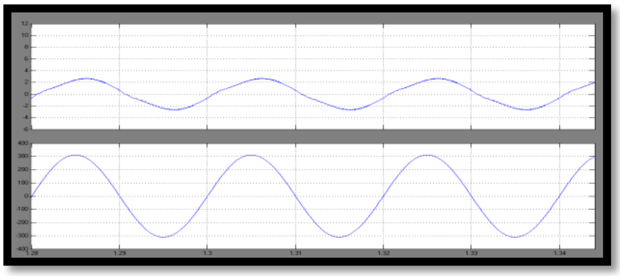


Figure 18 Power factor of input side for buck full-bridge converter

Analysis of Result
Output voltage (V_o) = 48 volt, Output Current = 2.08 Amp
Total Harmonic Distortion (THD) = 6.57%, Input Power Factor = 0.997
The Power density and Cost is high for this converter.

CONCLUSION

A comparative analysis of the improved power quality HF transformer isolated AC-DC buck converters has been made to present a detailed exposure on their various topologies and its design to the application engineers, manufacturers, users and researchers. A detailed classification of these AC-DC buck converters into 4 categories with number of circuits and concepts has been carried out to provide easy selection of proper topology for a specific application. From the Simulink model we observed that the Full-Bridge Buck converter THD is less than as compare to Forward Buck converter, Push-Pull Buck Converter and Half-Bridge Buck Converter. And the power factor of Full-Bridge Buck Converter is better than all other Buck converter. And the THD of Half-Bridge Buck Converter is inferior to all other Buck converter but the power factor of Half-Bridge Converter is better than all other converter.

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