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Active Power Factor Correction in Power Converter for Single Phase Power Supply

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Abstract

Due to nonlinear load, Electrical appliances with switching devices draw high input current in short period of time. Low power factor results in poor output voltage regulation and increased total harmonic distortion. Power factor correction is frequently adopted to rectify this problem, which when on applied, Improves the power factor, and hence the efficiency. This paper describes choice of suitable power converters and the power factor correction methods applied on them

Keywords; *CUK Convertor, Distortion, and Power Factor.*

I. INTRODUCTION

Withincreaseofinductiveload,thepoorpowerfactorleadstohighpowerdemand in places like industries. With the inculcation of power electronics and lot of switching devices, we find that the inductive loads are vital and it is necessary to correct the power factor. In cases of poor power factor, the appliances draw high input current and the amount of usable power is very low. This is a loss to the power suppliers. The presence of harmonic content is a threat to the appliances. So this phase difference must be corrected, the harmonic content should be reduced and the power factor must be brought to unity.

Thismethodofbringingthepowerfactortounityiscalled powerfactorcorrection. This is achieved in active and passive methods. Passive method of power factor cor- rection is preferable for lower loads of 100 watts (approx.) and they correct the power factor to about 70-80 %. Active power factor correction techniques are used toachieve better power factor. Here, APFC is applied on CUK Converter due to its different ad- vantages.[1]

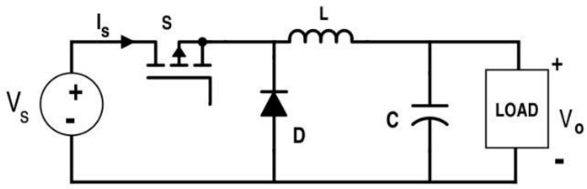
The summary of what is power factor, how it is calculated is studied, Different types of power converters are studied and compared. One of the converter is chosen, simulatedandAPFCalgorithmisapplied.Finallycomparisonofharmoniccontentwith and without APFC algorithm is compared andstudied.

II. POWERCONVERTERS

2.1Types of Converters

2.1.1Buck Converter (Step Downconverter)

These type of converters convert to the voltage to less than the input voltage and do not allow more than the input voltage but dissipate power as heat. Buck converters areasefficientas90%,makingthemusefulformanyelectronicgadgetslikecomputer, usually from 12 V to 1.8Volts.



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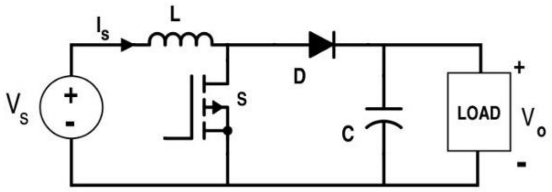
$$(V_{\mathrm{i}} - V_{\mathrm{o}})\,DT - V_{\mathrm{o}}(1-D)T = 0$$
$$DV_{\mathrm{i}} - V_{\mathrm{o}} = 0$$
$$\Rightarrow D = \frac{V_{\mathrm{o}}}{V_{\mathrm{i}}}$$

2.1.2 Boost Converter (Step upConverter)

Theseconvertersconvertvoltagestohigherthantheinputvoltages.Whenswitchis OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. Boost convertors are used in wide applications such as automotive engineering for lighting and otherthings.[2]

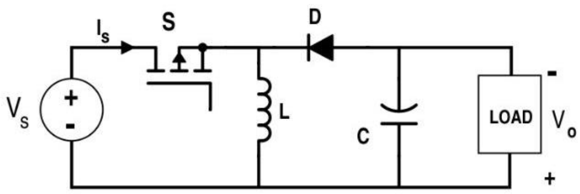


$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

$$D = 1 - \frac{V_i}{V_o}$$

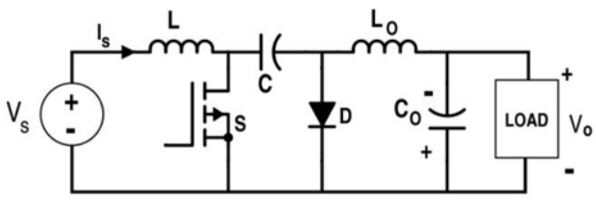
2.1.3 Buck BoostConverter

Thistypeofconverterhasanoutputvoltagethatiseitherhigherorlower.Theoutput voltageisoftheoppositepolaritythantheinput.Thisisaswitched-modepowersupply withasimilarcircuittopologytotheboostconverterandthebuckconverter.Theoutput voltage is adjustable based on the duty cycle of the switchingtransistor.



2.1.4 CUKConverter

Similar to the buck–boost converter with inverting topology, the output voltage of non-isolatedĆUKistypicallyalsoinverting,andcanbeloweror higherthantheinput. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use aninductor.



2.2 Comparison of different converters

Table 1. Comparison of converters

	Buck	**Boost**	**Buck-Boost**	**CUK**
InputCurrent	Pulsed	Continuous	Pulsed	Continuous
Output Current	Continuous	Pulsed	Pulsed	Continuous
Output Voltage	Lesser	Higher	Lesser or Higher	lesser or Higher
Output polarity	Same	Same	Reversed	**Reversed**

2.2 Disadvantages of various powerconverters

Choosing the right convertor for conversion is very vital for efficient power distri- bution. Some of the disadvantages of the above mentioned converters are mentioned below.[2]

– Buck converter is always less than input and it requires an additional passive filter andoutputofbuckconverterisdiscontinuousandinputcurrentdoesnotfollowline voltage at zerocrossing.

– Boost and SEPIC converters are operated the output of both converters arediscon- tinuous with highripple.

– Buck-Boost converter is when it operated there is high current stress on semicon- ductor devices and discontinuous input current which increase theTHD.

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– CUK converter gives continuous input and output current with low currentripple.[3]

III. SIMULATION OF THE CUKCONVERTER

FigshowsthebasicsimulationmodelofaCUKconverter. Itsinputvoltage,inductor currents and output voltage waveforms are given below for various dutycycle.[4]

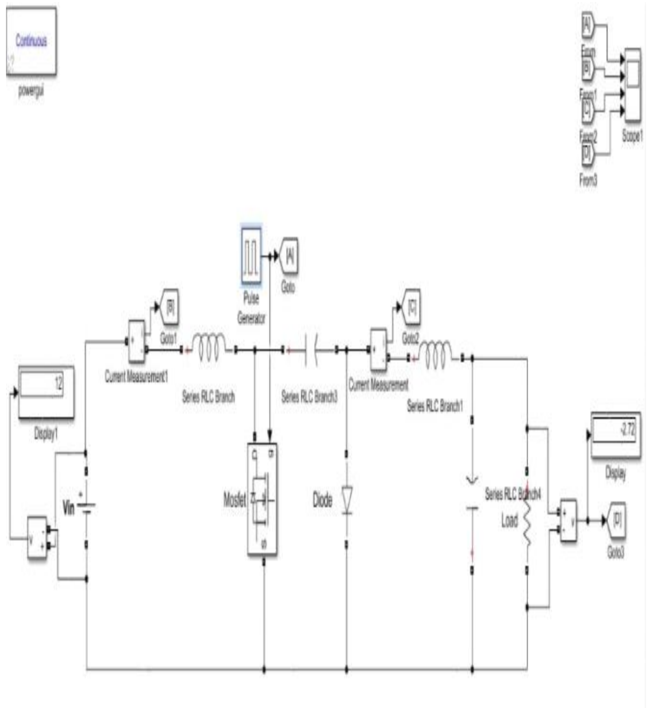
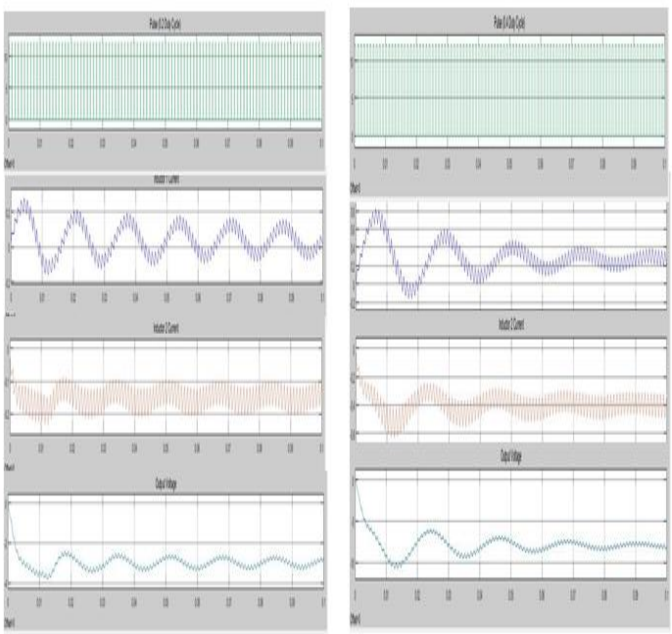
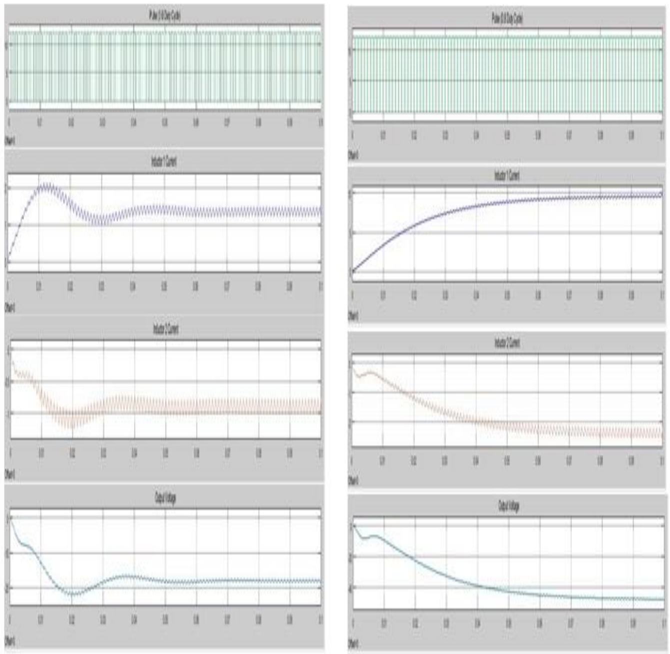


Fig 1. Simulation of a CUK converter



Duty Cycle 0.2 Duty Cycle 0.4 . (Output voltage -2.72) (Output Voltage -8.077)



Duty Cycle 0.6 Duty Cycle 0.8 c (Output Voltage -18.03) (Output Voltage -47.89)

Asyoucansee,theoutputoftheCUKconvertorcanbeeitherhigherorlesserthan the input voltage. The output voltage is less than the input voltage when the duty cycle is less than 50% and the output voltage is more than input voltage when the dutycycle is more than50%.

5.2 Proposed method of APFCAlgorithm

Theprocedureisexplainedwiththehelpofaflowchart.Theinputparameterswhich aretaken,theprocess,calculationandtheoutputgenerationisneatlyexplainedwiththe helpofdifferentbocks.Thecontrollerblockcomparesthereadingtothereferencevalue and then gives the difference to a PI Controller. The pulse is generated with compari- son of the calculated value and a step input signal. This generated signal controls the switchingoftheswitchandhencecontrollingthephasedifferenceandthepowerfactor.

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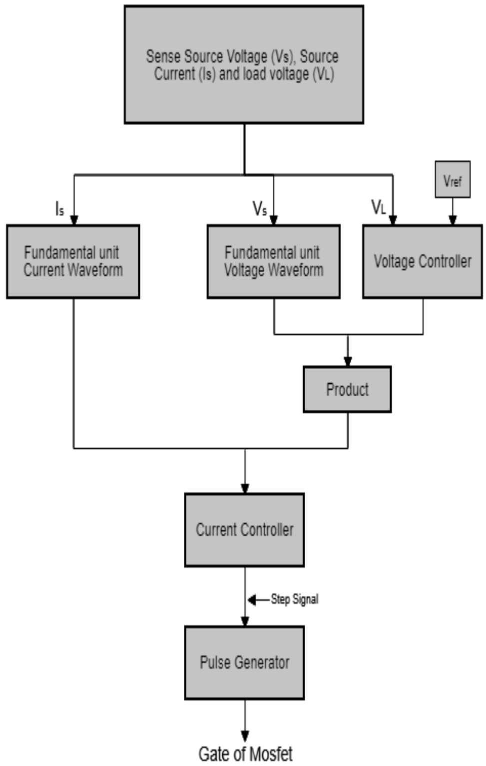

Fig 3: Flowchart of the Proposed APFC Algorithm

5.3Simulink Model ofAPFC

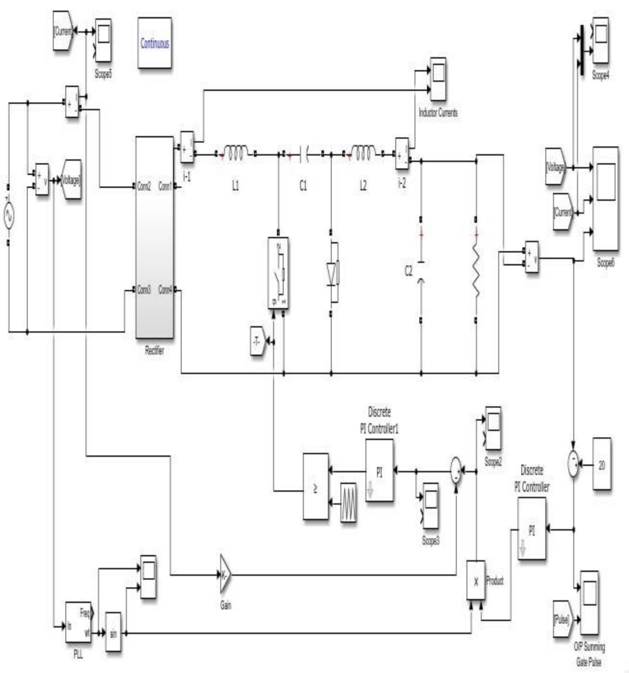

Fig 4: Simulation of Proposed APFC Algorithm

Ac source is rectified using a bridge rectifier and then given as input to the CUK converter. The output of converter depends upon the gate pulse given to theMOSFET.

Differentalgorithmsareavailabletocontrolthepowerfactor.Thealgorithmthatisused in this paper is explained with a help of a flowchart. Source voltage Vs, current $I_L$and load voltage $V_L$are sensed from the line. The Desired voltage is given as the input in thecircuitasreferencevoltageVref.Thealgorithmworksintwoloops,oneforcurrentloop and one for voltage loop. The calculated pulse signal is given as a pulse signal to the gate of the mosfet generated with the help of stepsignal.

The Distortion is measured with the help of the FFT analysis tool isMATLABSimulink.Thetoolshowsthedifferentlevelsofharmoniccontentpresentinthesupply. The THD Is measured in percentile. Lower the THD better the powerfactor.

5.4 OutputWaveforms

The outputs of different duty cycles with and without APFC algorithm. The wave- forms are given below.

5.4.1 Output waveforms with APFCAlgorithm

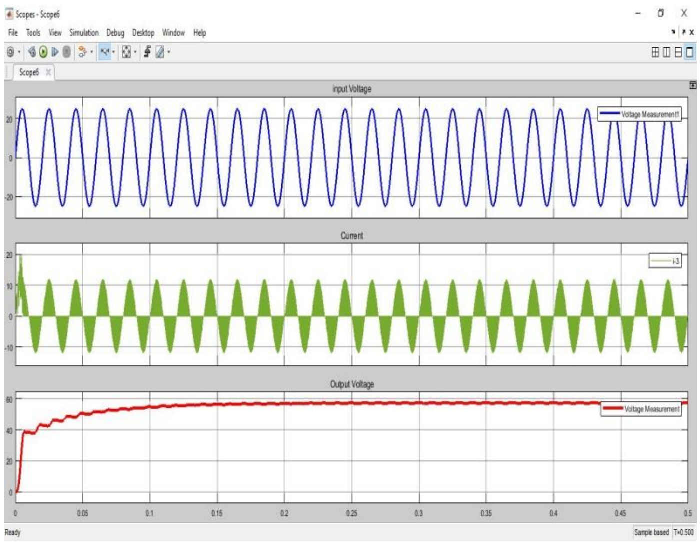

Fig 5: The output waveforms in normal mode without APFC

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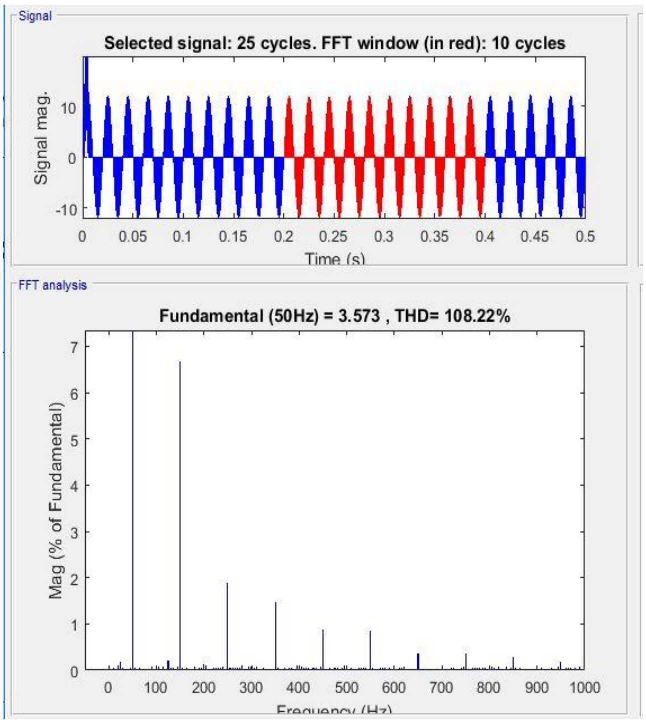

Fig 6: Current THD without APFC

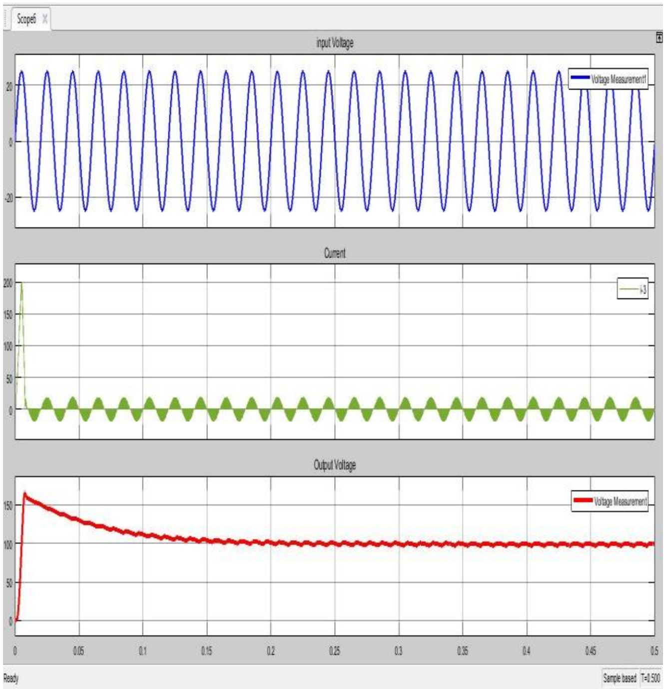

Fig 7: The Output waveforms in boost mode withoutAPFC

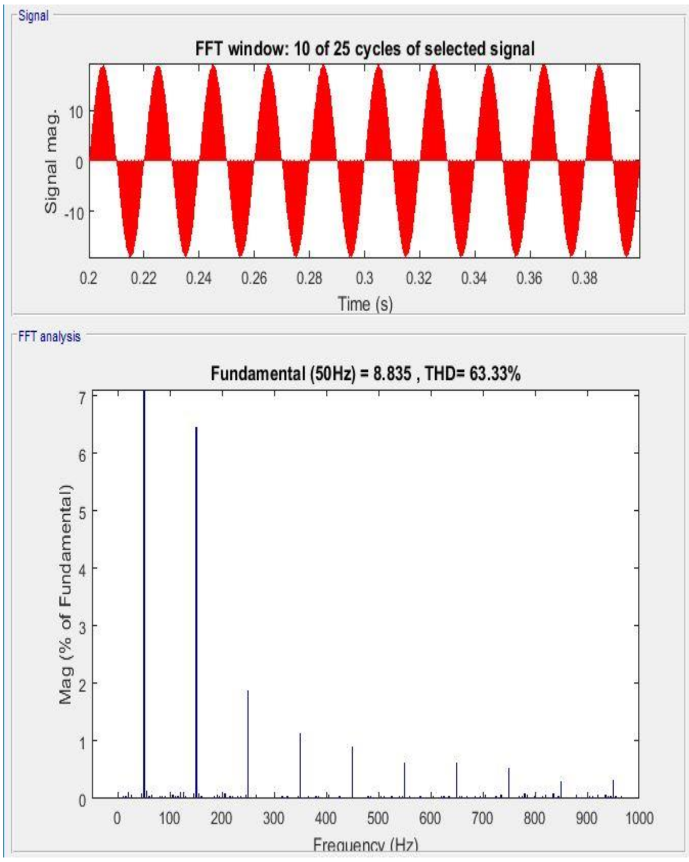

Fig 8: The Current THD for Boost mode without APFC

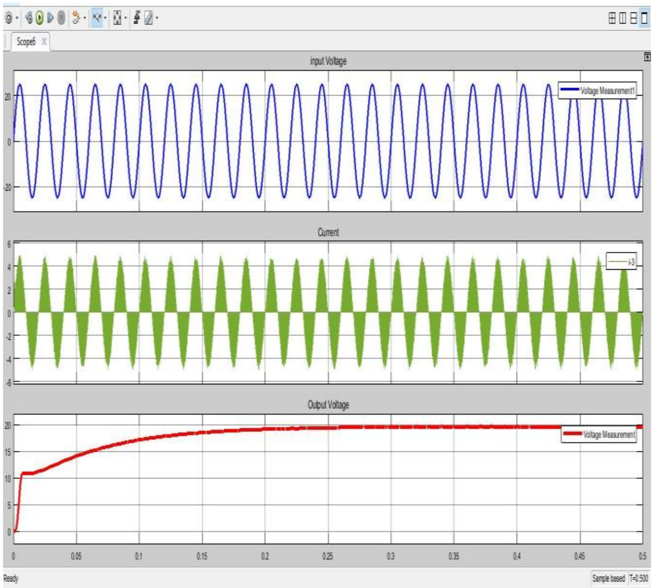

Fig 9: The Output waveforms in buck mode without APFC

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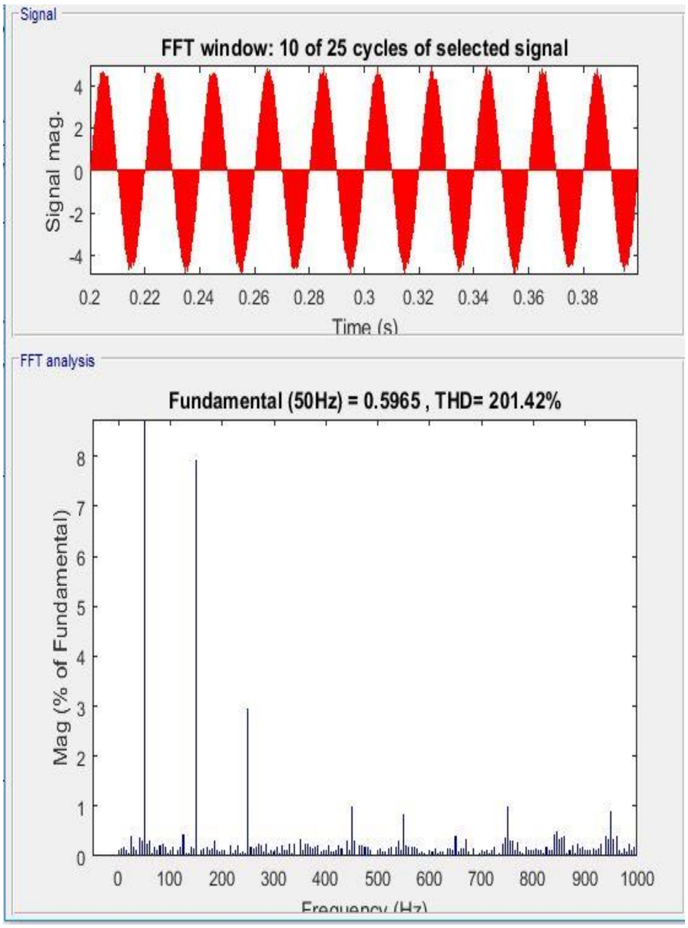

Fig 10: The Current THD for Buck mode withoutAPFC

5.4.2 Output waveforms with APFCAlgorithm

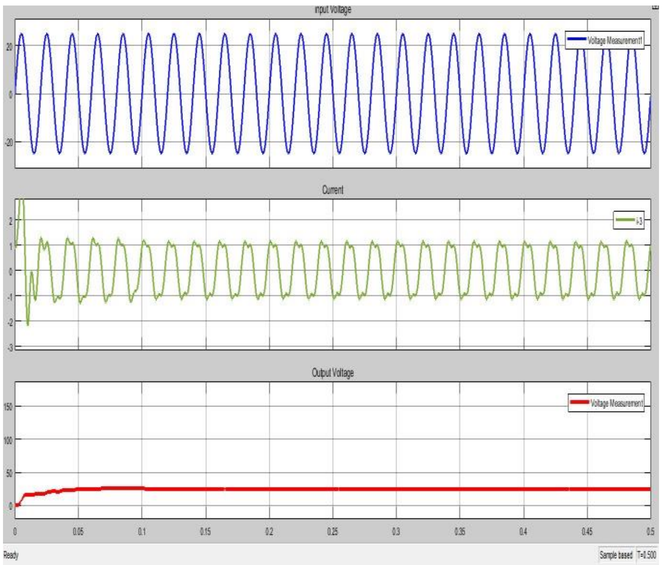

Fig 11: The Output waveforms in boost mode with APFC

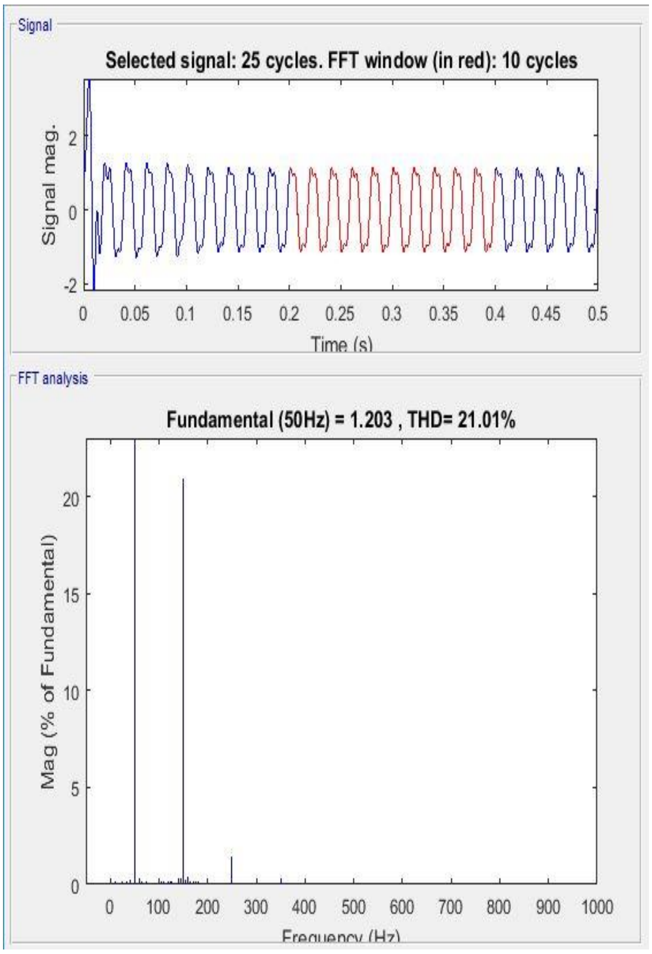

Fig 12: Current THD with APFC

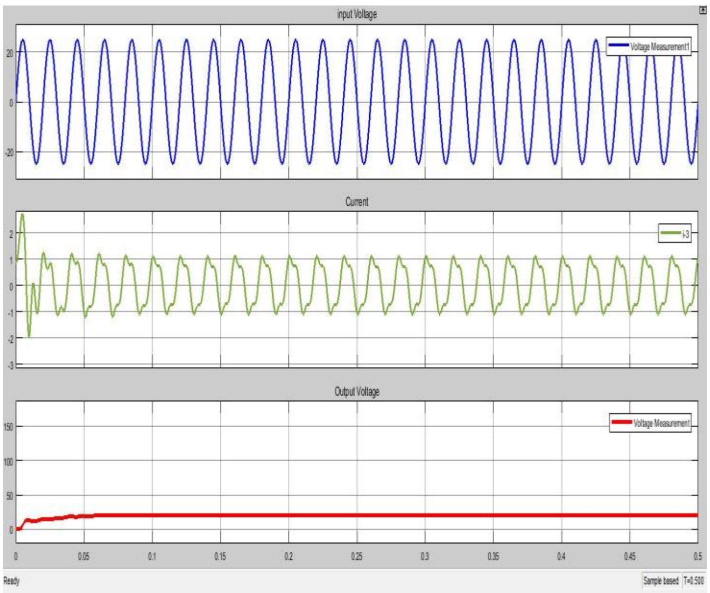

Fig 13: The Output waveforms in boost mode withAPFC

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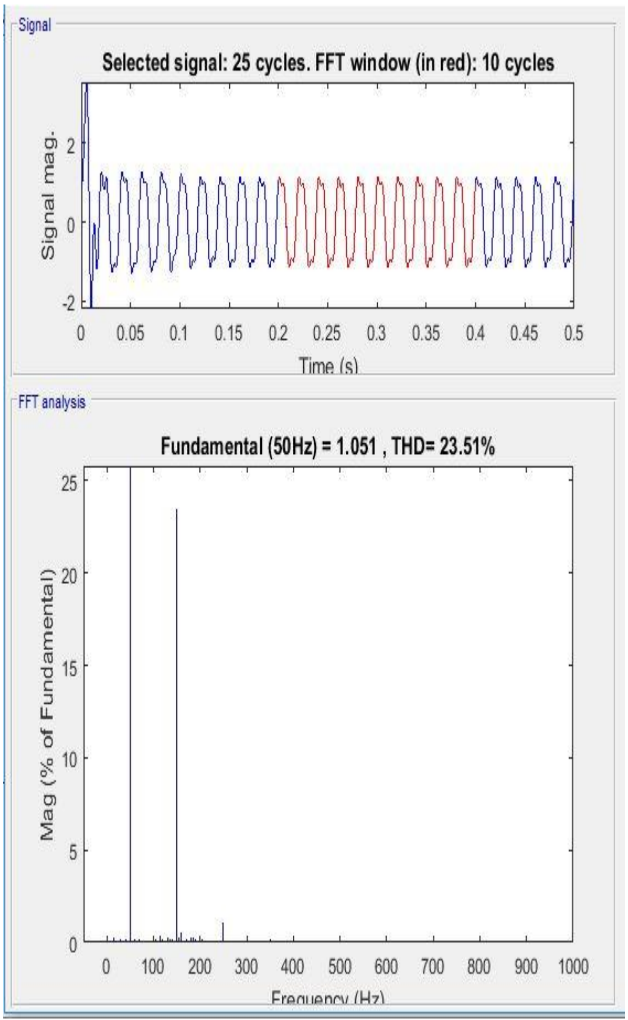

Fig 14: The Current THD for Boost mode with APFC

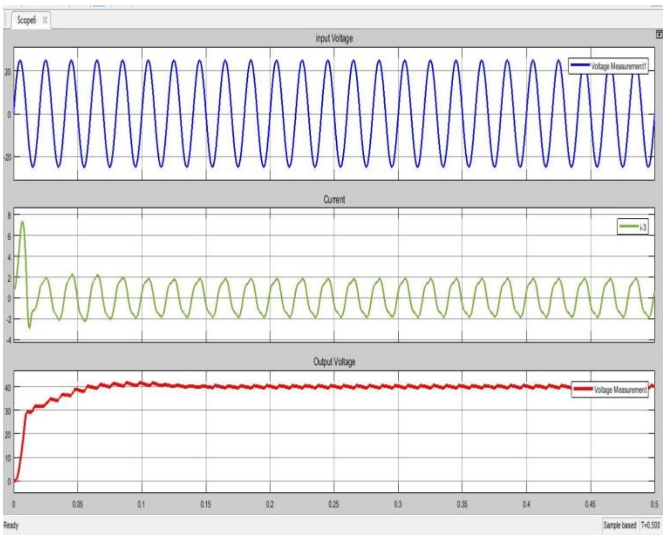

Fig 15: The Output waveforms in buck mode with APFC

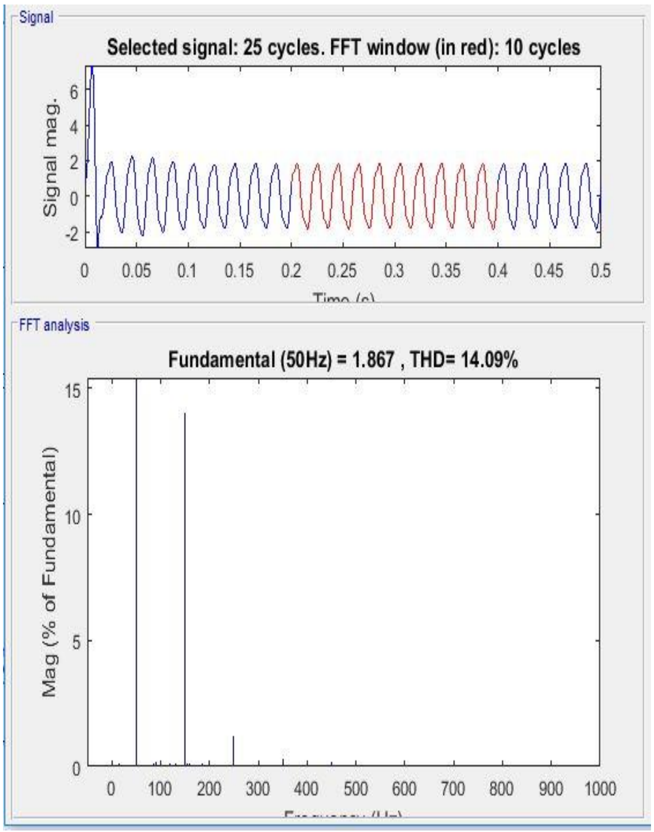

Fig 16: The Current THD for Buck mode withAPFC

From the simulation results we can see how the harmonics have been reduced, through the APFC algorithm. Reducing the harmonic content improves the power fac- tortoalargeextendandhenceimprovethepowerefficiency.Thetablesummarizesthe simulationresults.

Table 2. Comparison of harmonics with and without APFC

Converter Mode	Without APFC	WithAPFC
ConstantVoltage	108.22	21.01
BoostMode	63.33	23.51
BuckMode	201.42	14.09

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Fig. 17. Prototype of APFC converter

Fig. 18.performance of APFC converter

IV. CONCLUSION

When we improve the power factor, we can get the maximum usable power for our homes. All the energy produced from the power station can be used in an effective manner.Theenergysupplierscanreducetheirlossesduet opoorpowerfactor. We have seen how the power factor has been improved and the present day techniques used to improvethepowerfactor.Researchesinthisfieldwilllea dtostillimprovingthepower factor to unity and give us an efficient power system network. New algorithms and methodscanhelpinthisregard.Engineersmustnotonlyf ocusonpowergenerationbut also on the availability of usable power that is distributed to the consumers.

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