A Comparative Study Of Harmonic Reduction Technique For Non-Linear Load Applications

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Abstract
In this paper,three controllers are designed in order to reduce the total harmonic distortion in the system. These controllers are specially designed to operate in collaboration with non linear loads. Non linear loads are mostly responsible for the generation of harmonics in the system and create a number of power quality problems. Hence it becomes necessary to control the harmonic content in the system. Initially a model is designed on MATLAB/Simulink with linear load which resulted in THD content of less than 1%. Another model designed with non linear load shows THD 146.6%. To reduce this harmonic content three controllers are used and a comparative analysis is carried out. Three controllers are low pass filter (LPF), high pass filter (HPF) and proportional integral & derivative (PID) controller which reduces the THD to 11.05%, 5.548% and 4.75% respectively. Hence it is found that PID controller proved out to be the best among all converters.
Keywords: Harmonics, Power Quality, MATLAB/Simulink, HPF, LPF, PID controller.

1- INTRODUCTION

It is being observed that the increasing nonlinear loads whose operations are basically based on power electronic devices have increased a number of power quality problems. The uneven distribution of dynamically changing single-phase loads gives rise to the additional problems of excessive neutral current and current unbalance [1]. These nonlinear loads may be like power supplies, rectifier equipment used in telecommunication networks, domestic appliances, adjustable speed drives, etc. and they offer highly nonlinear characteristics [2]. Hence PQ monitoring has become an important aspect for measuring the effectiveness of smart grid implementations and trial projects [3]. Increase of numerous nonlinear industrial, commercial and residential types of loads that are generating pollution has led to 100% total current harmonic distortions into the grids [4]. Rapid increase energy efficient solid state semiconductor switches in nonlinear electrical loads such as arc furnaces, rectifier, and

adjustable speed drives, etc. has resulted in various undesirable effects on electrical power systems [5]. Nonlinear loads are mainly of two type's current-source and voltage-source fed loads [6]. PQ problems are like harmonics, flicker, and imbalance in system, transients, voltage sag/swell, and interruption [7]. Various methods and algorithm are applied to control the flow of active and reactive power and also to reduce the PQ problems [8]. Active filters are one of such devices which allow the coexistence of nonlinear loads and good energy quality in distribution networks [9]. Optimization of the overall performance of the electrical grid is one of the most important aspects for the viability of distributed generation systems [10]. Different converters are also used for this purpose and implementing the modulation in multiphase converters becomes costly and time consuming [11]. As now a days importance is been given to the renewable energy based power generation methods which makes use of a large number of diesel generator operating on power

electronic devices. Controlling of interfacing converters introduces resonance related issues in the system [12-13]. This increase in nonlinear loading is also responsible for unsymmetrical single-phase topologies like large harmonic currents, reactive power, and negative sequence current (NSC) are injected in the grid which adversely affects the safety of grid [14]. To reduce these type of problems researchers have introduced Modulation in Space vector but it increased switching complexity. So, multilevel inverters were employed to improve drive performance but it proved to be expensive and increased switching losses of inverter [15]. Active power filter are mostly used to improve the power quality in the power system. These filters are used in shunt, series and a combination of shunt and series connection to compensate the voltage and current based distortions [16]. Installing Tuned Passive Filter (TPF) is the simplest and the oldest method of improving PQ. This makes a low impedance patch at the tuned frequency. Due to its low cost and robustness it is used widely but along with aging its filtering efficacy reduces [17]. PI, PID and Fuzzy Logic Controller (FLC) based shunt active filter are also used for power line conditioners (PLC) to improve the power quality in the distribution network. These types of filters are implemented with current controlled cascaded multilevel voltage source inverter (VSI) [18]. As multilevel inverters can generate cleaner voltage and reduces switching losses, they have become very popular to use for improving the power quality in the last few years [19]. In the applications in which low and medium voltage is required, multilevel converters allows the use of low cost components with lower voltage ratings that are produced commercially at higher quantities than high-voltage components [20]. Some other methods to deal with PQ problems which can be carried out by means of active power line conditioners, like unified power quality conditioners (UPQCs), shunt, series and hybrid active power filters (APFs) and dynamic voltage restorers [21]. Along with the power system, in transportation sectors several types of controllers are used to control the speed, like PID controller [22]. This is the era where industrial development is at its peak hence preserving the environment has also become equally important. So hybrid electric vehicles (HEVs) have been developed for achieving these goals as they do not necessarily requires external battery charging or new infrastructure [23]. Some of the conventional methods commonly used in industrial APF are hysteresis control and proportional-integral (PI) control. Although new control methods have also been proposed, such as fuzzy control, sliding mode variable structure control, adaptive control methods [24]. Fuzzy logic based controllers being increasingly applied to many systems with nonlinearity and uncertainty [25].

2- POWER QUALITY ANALYSIS WITH LINEAR LOAD APPLICATIONS

In linear circuit, the output response is directly proportional to input. Simulink model is given in figure 1 which shows the effect of linear load on power quality. Theoretical as well as practical realization of this model shows smooth current waveform. The result of this model is basically used to compare the power quality with nonlinear load applications.
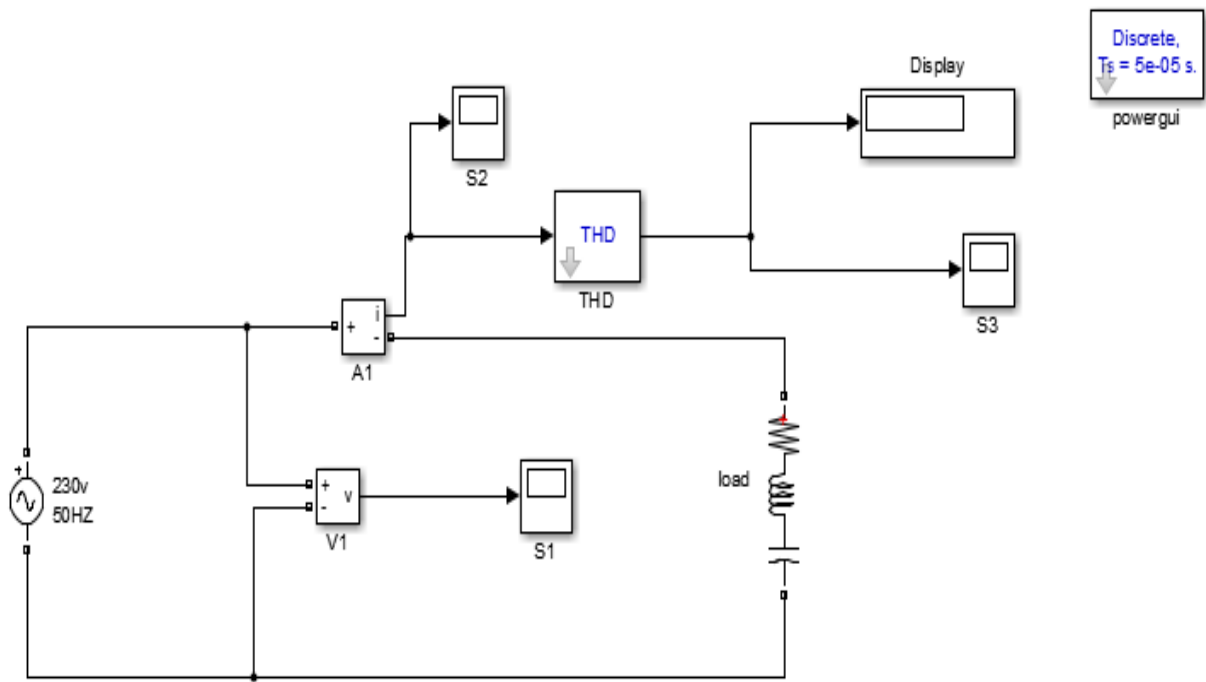
Figure 1:- Simulink model withlinearload

2.1- SIMULATION RESULTS AT LINEAR LOAD

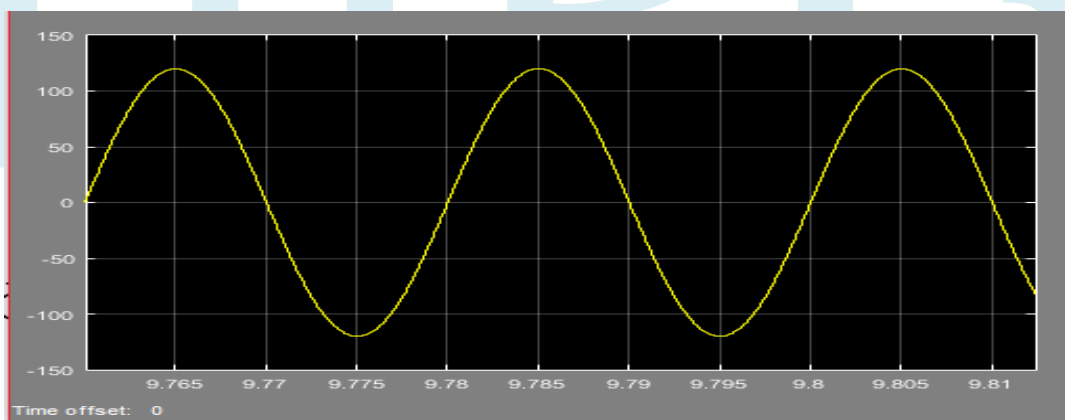The voltage waveform at the input side is shown in figure 2, and load current waveform is shown in figure 3.
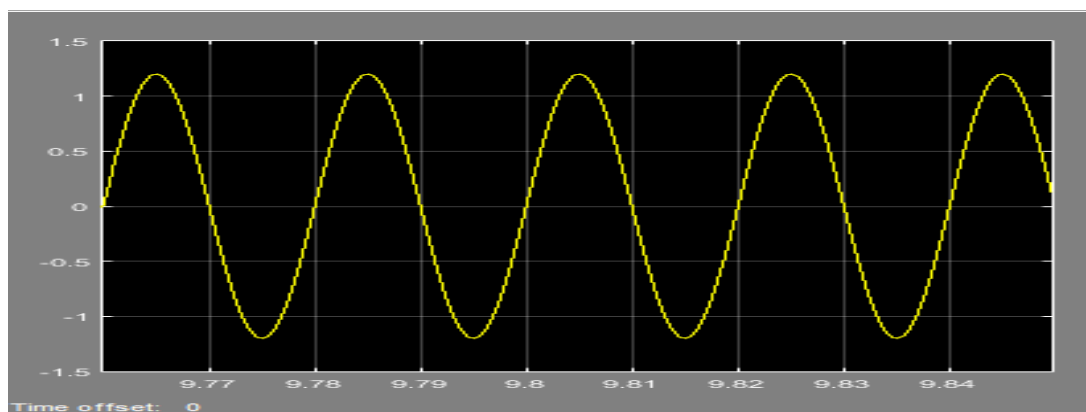

Figure 2: -Source voltage

Figure 3:- Load current

3- POWER QUALITY PROBLEMS WITH NONLINEAR LOAD APPLICATION

A nonlinear element is one which does not have a linear input-output relation. Simulink model is given in figure 4 which show the effect of nonlinear load (rectifier) on power quality in terms ofharmonic distortion. Source voltage waveform is given in figure 5 and the distorted load current waveform is depicted in figure 6.
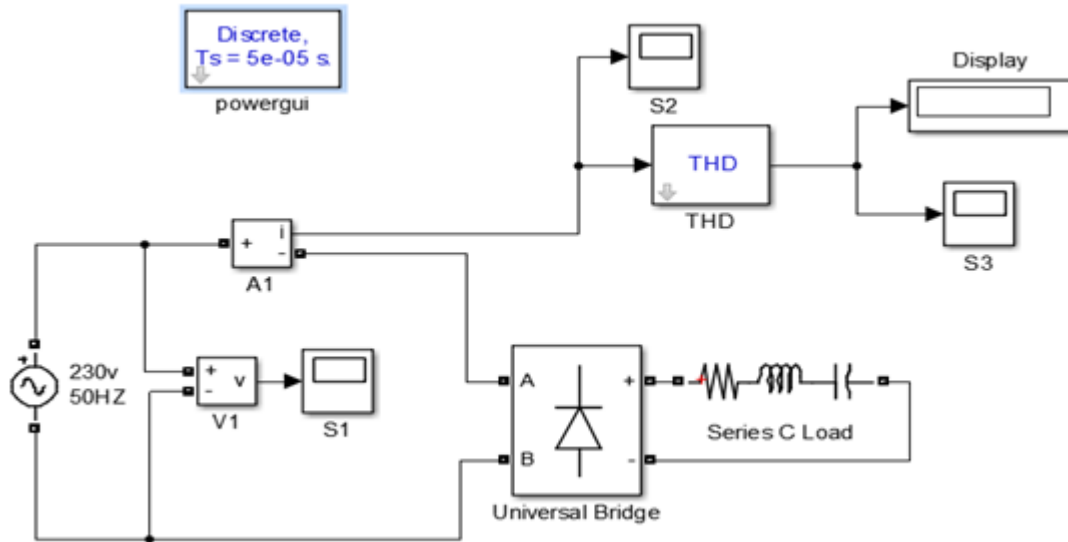
Figure 4:- Simulink model for nonlinear load
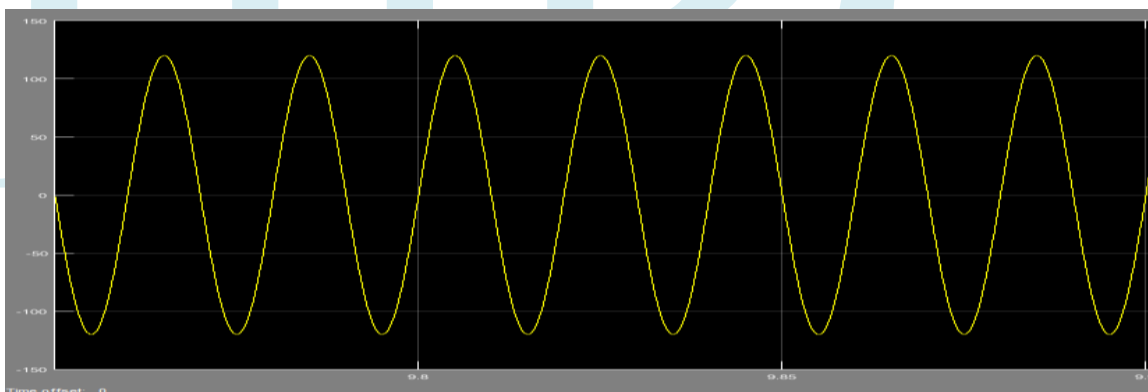
3.1- SIMULATION RESULTS AT NONLINEAR LOAD
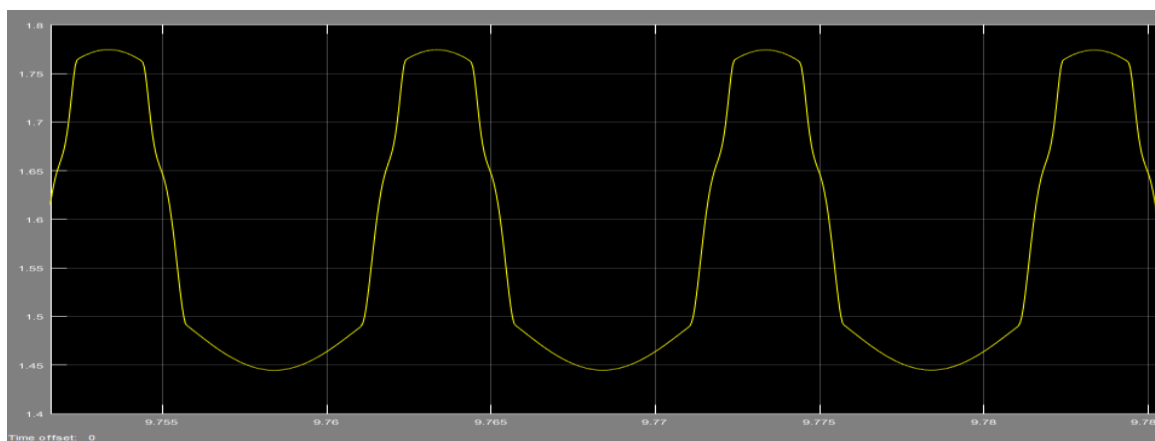

Figure 5:-Source voltage

Figure 6:- Line current with total harmonic distortion

4- POWER QUALITY IMPROVEMENT WITH NONLINEAR LOAD USING LOW PASS FILTER

Nonlinear load produces a very high level of distortion in power quality which is shown in terms of percent THD. A Simulink based model is proposed to reduce these harmonics from input current to provide significant improvement in overall THD. The proposed methodology consists of low pass filter (LPF) and the corresponding model is shown in figure 7.
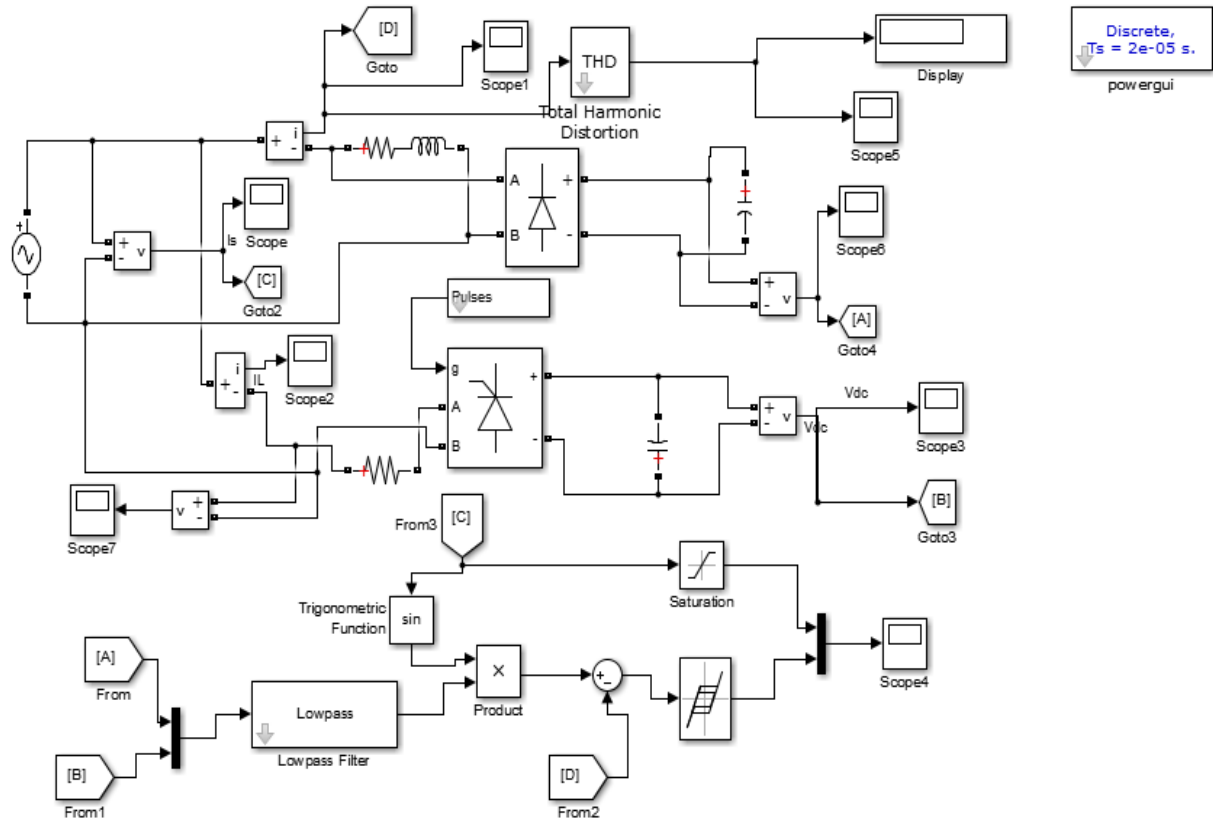

Figure 7:- Simulink model of proposed Harmonic Reduction scheme using LPF

4.1- SIMULATION RESULTS OF PROPOSED SCHEME WITH LPF

The voltage waveform at the input side is shown in figure 8, distorted line current waveform is shown in figure 9 and total harmonic distortions are shown in figure 10.
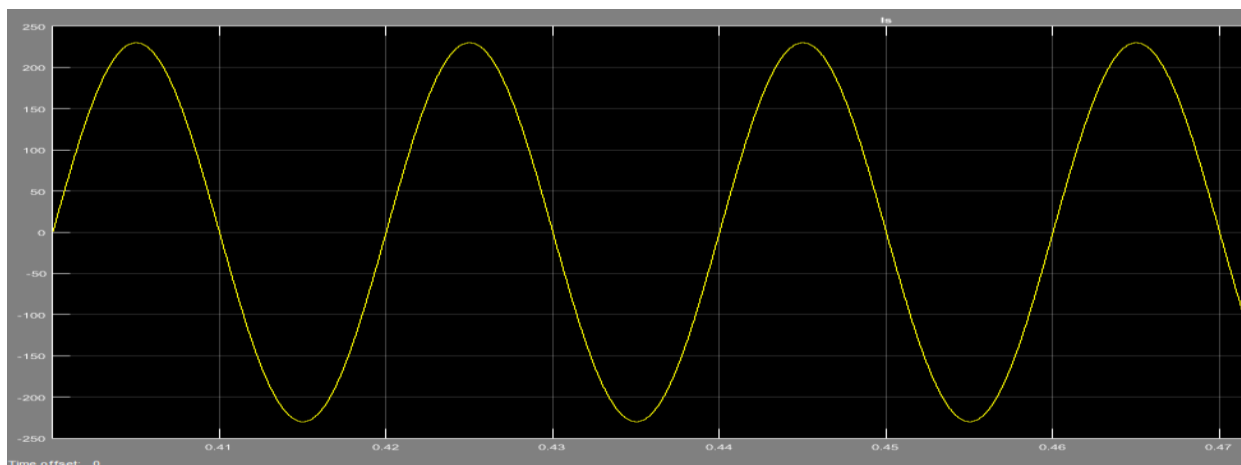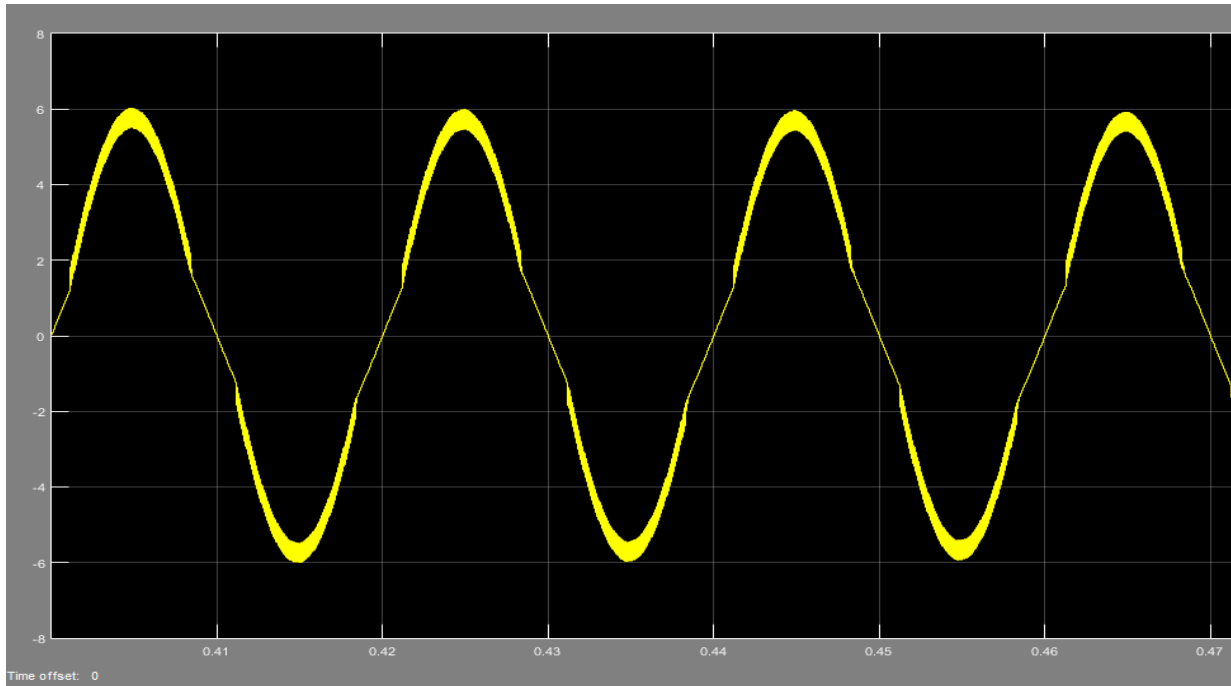

Figure 8:- Source voltage

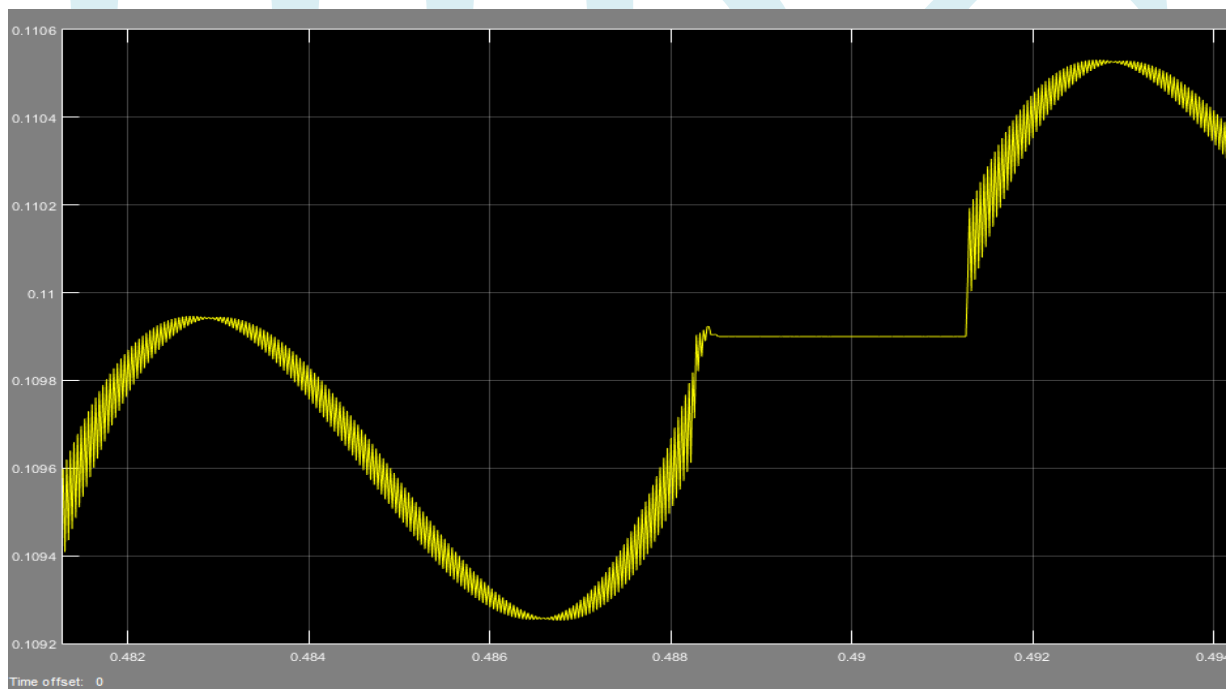**Figure 9:- Harmonic distortion in line current**

Figure 10:- Total harmonic distortion

5- POWER QUALITY IMPROVEMENT WITH NONLINEAR LOAD USING HIGH PASS FILTER

Low pass filter produces high level of distortion in power quality which is shown in terms of percent THD. In order to further reduce harmonic distortiona Simulink based model is proposed to reduce these harmonics from input current to provide significant improvement in overall THD.The proposed methodology consists of high pass filter (HPF) and the corresponding model is shown in figure 11.
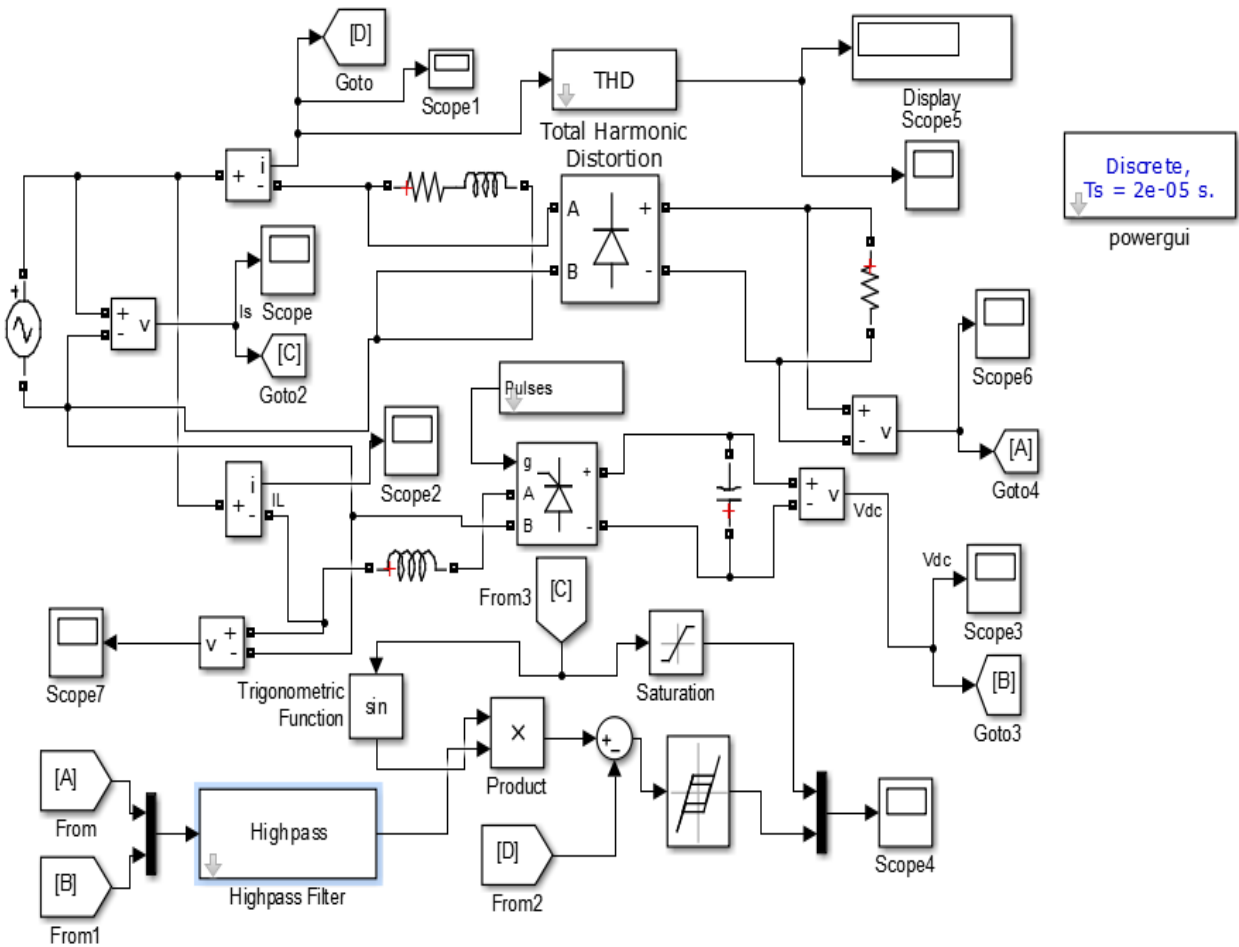
Figure 11:- Simulink model of proposed Harmonic Reduction scheme using HPF

5.1-SIMULATION RESULTS OF PROPOSED SCHEME WITH HPF

The voltage waveform at the input side is shown in figure 12; distorted line current waveform is shown in figure 13 and total harmonic distortions are shown in figure 14.
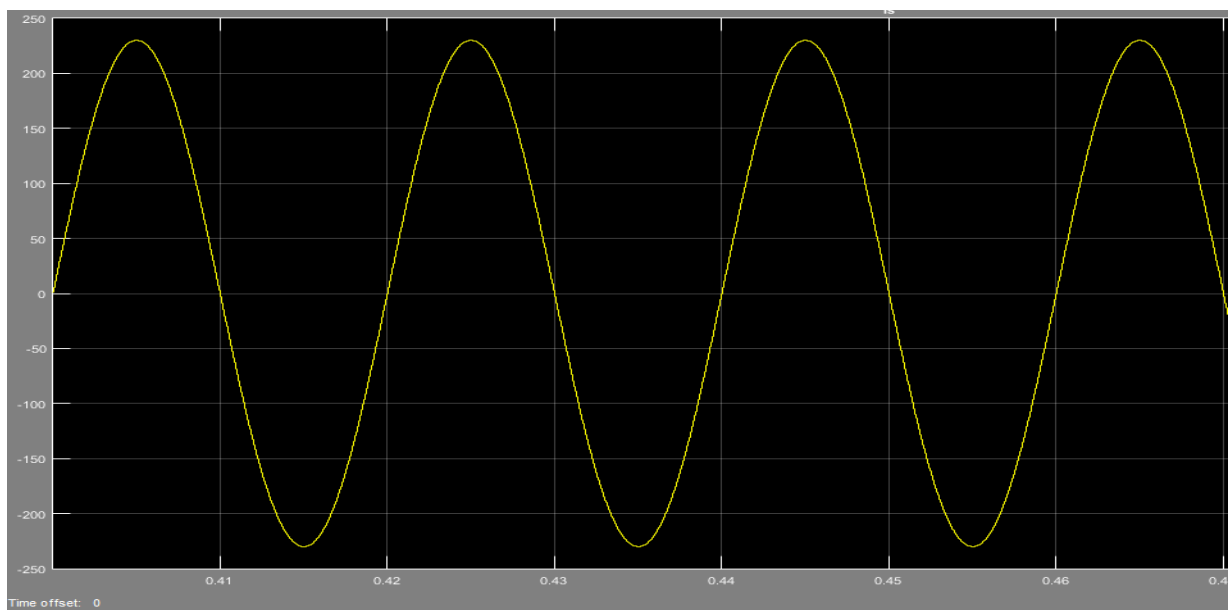

Figure 12:- Source voltage
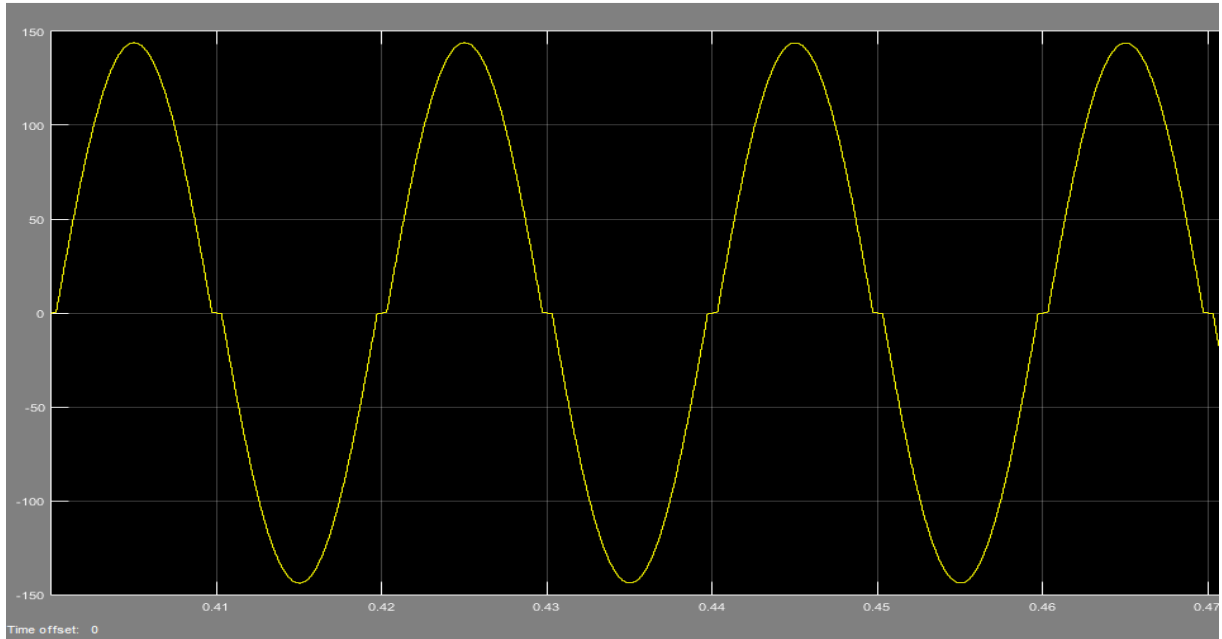
Figure 13:- Harmonic distortion in line current

Figure 14:- Total harmonic distortion

6- POWER QUALITY IMPROVEMENT WITH NONLINEAR LOAD USING PID CONTROLLER

High pass filteralso produces a small level of distortion in power quality that is shown in terms of percent THD. Finally a Simulink based model is proposed to reduce these harmonics from input current and hence to provide significant improvement in overall THD.The proposed methodology consists of proportional integral derivative(PID) and corresponding model is shown in figure 15.

Figure 15:- Simulink Model of Proposed Harmonic Reduction scheme with PID controller

6.1- SIMULATION RESULTS OF PID CONTROLLER

The voltage waveform at the input side is shown in figure 16; distorted line current waveform is shown in figure 17 and total harmonic distortions are shown in figure 18.


Figure 16:- Source voltage

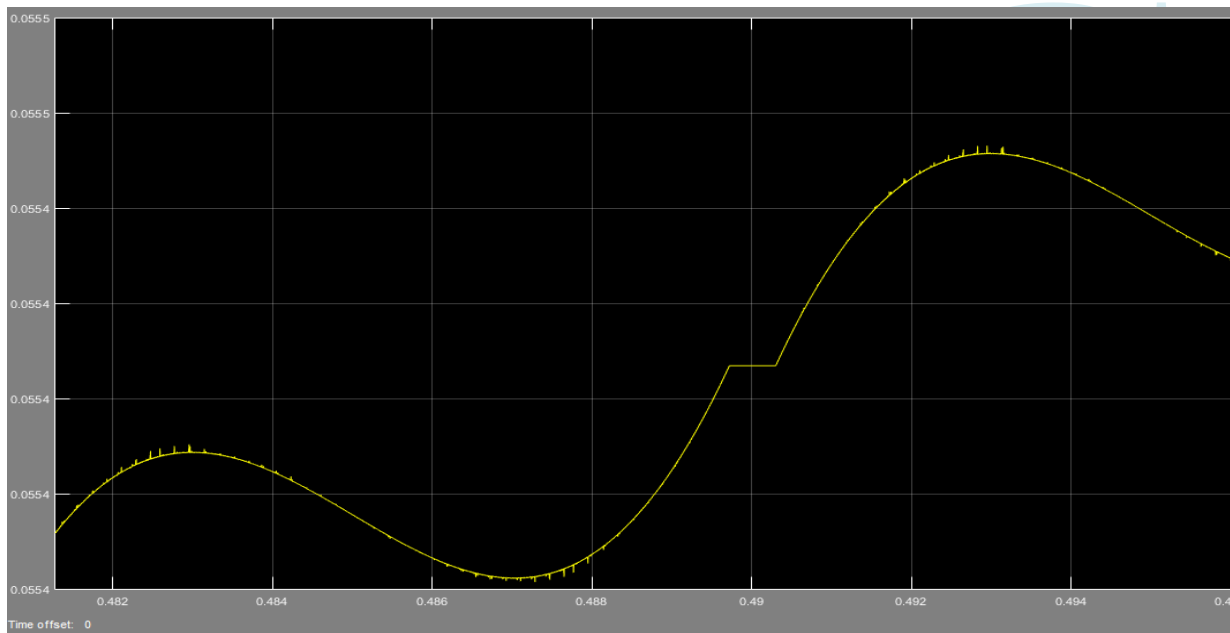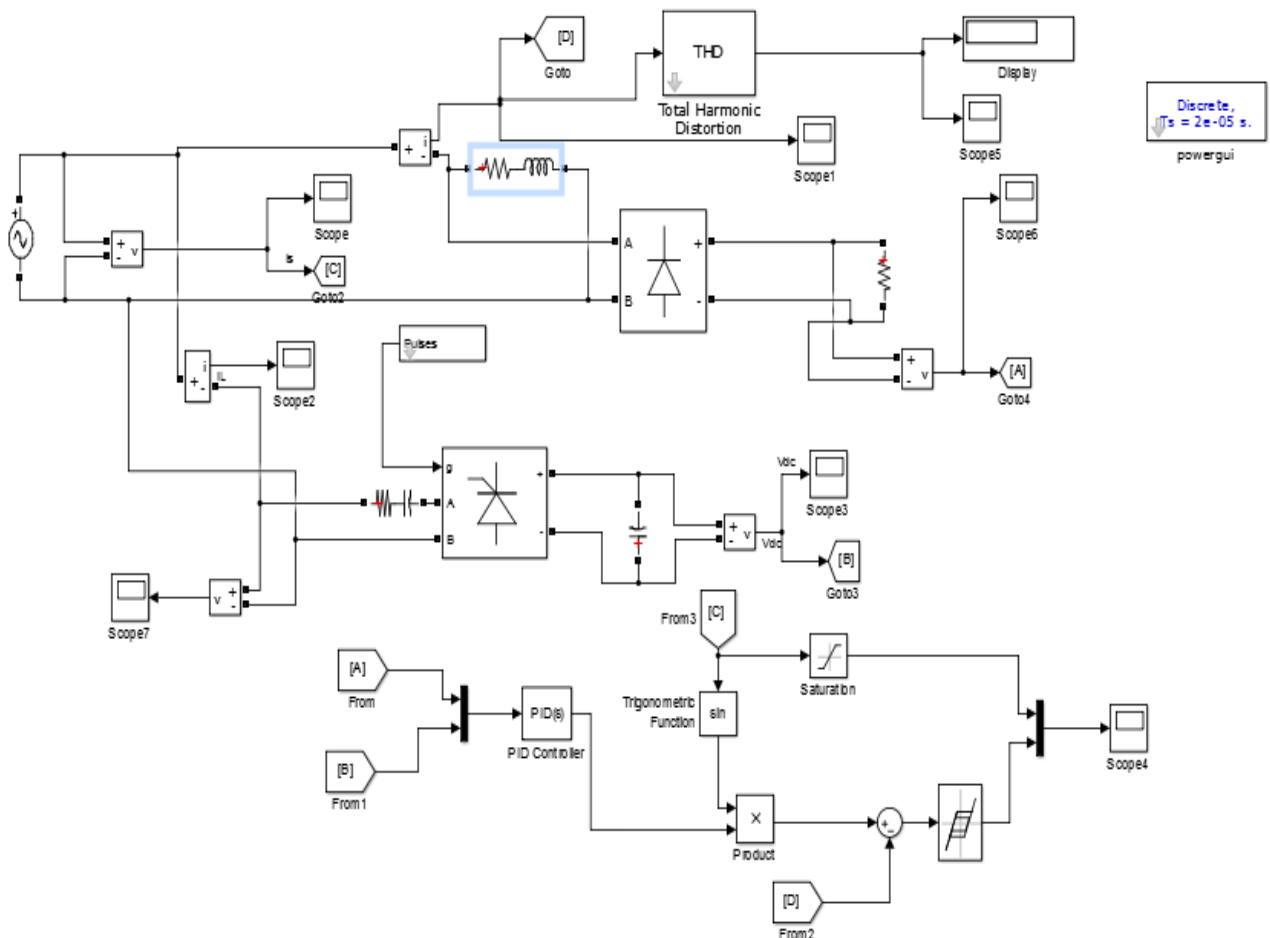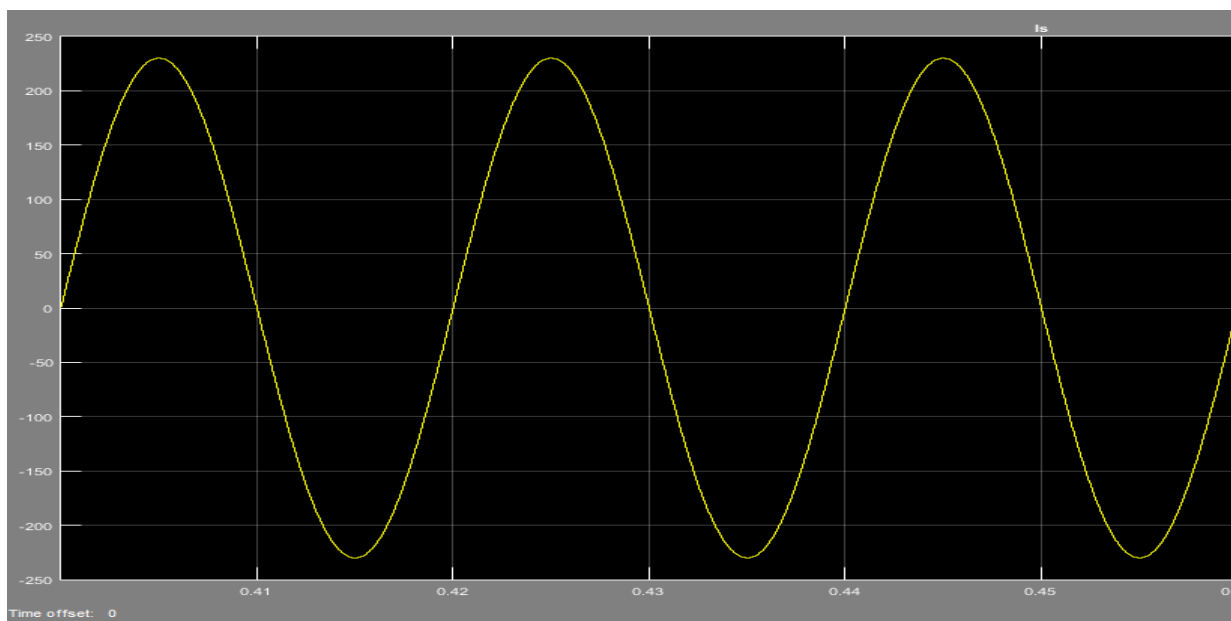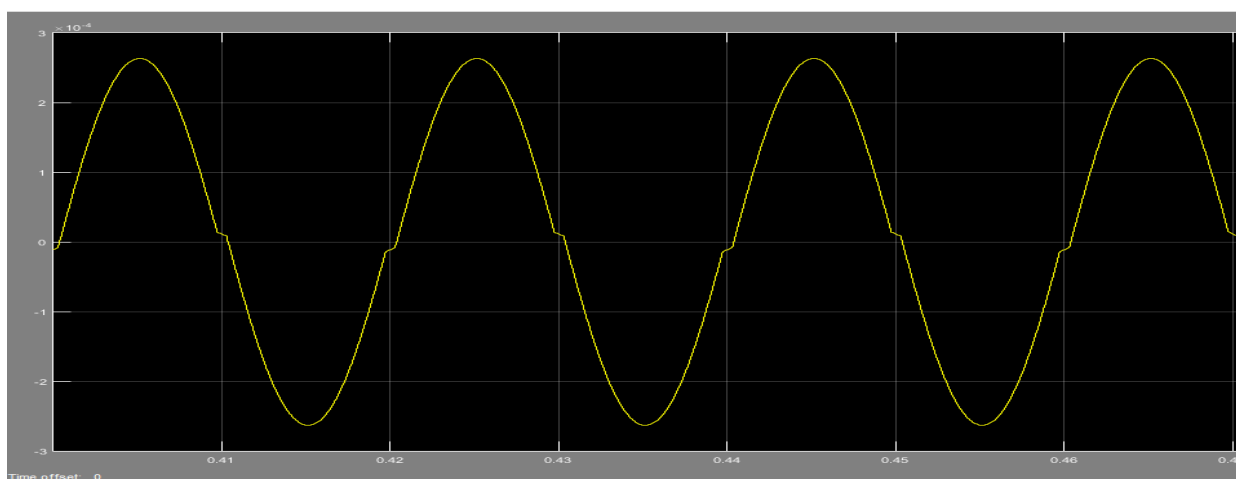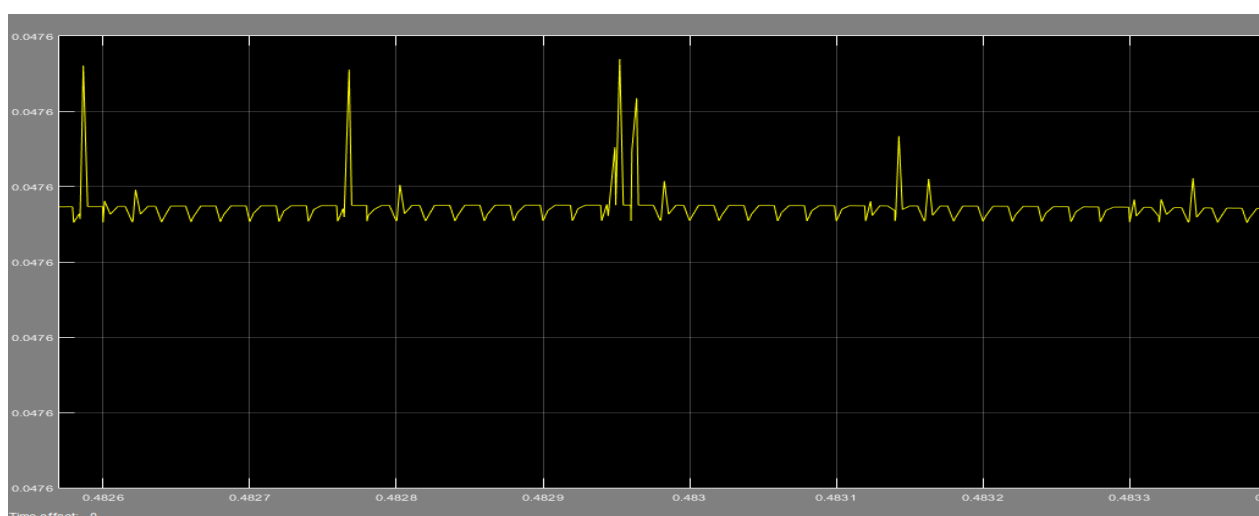**Figure 17:- Harmonic distortion in line current**

Figure 18:- Total harmonic distortion

7- RESULT AND DISCUSSION

A comparative analysis is carried out for both linear and non linear loads with different types of controllers. Percent THD obtained for different conditions is shown in table 1.

Table 1: Comparative analysis of power quality improvement

Type of Load	Controller Used	Applied voltage (peak value) (Vs)	THD
Linear	None	230 V	Less than 1%
Non-Linear	None	230 V	146.6%
Non-Linear	LPF	230 V	11.05%
Non-Linear	HPF	230 V	5.548%
Non-Linear	PID	230 V	4.75%

8- CONCLUSION

In this study an analysis is carried out for developing and implementing a controller which is capable for reducing the totalharmonic distortion to a preferable amount. Firstly THD is calculated for a simple circuit having a linear load without any controller. Simulation is carried out on MATLAB and it is found that percent THD in load current is less than 1%.This means that linear loads are not responsible for harmonic distortion and deteriorating power quality. Another model is

preparedon MATLAB with nonlinear loads and simulation results shows that the THD% in line currentis extensively high and noted to be 146.6%. To reduce the harmonic content, a low pass filter is used as a controller. Model is prepared on MATLAB and simulation results of this model show that THD in line current is greatly reduced to 11.05%. In general this value of harmoniccontent is also high and needed to be reduced further. Now another model is prepared on MATLAB using a high pass filter as a controller. The simulation result showsthat THD in line current is further reduced to 5.548%. For further reducing harmonic content another controller is used i.e. PID controller. Finally a model is prepared on MATLAB and simulation results show that THDin line current is reduced to4.75%, which is under the preferred permissible value of harmonic content. Hence it can be said that the power quality is improved.

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