# Analysis of Uncontrolled Rectifier with Different Passive Filters

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***Abstract – Power electronics, which is a rapidly growing area in terms of research and applications, uses modern electronics technology to convert electric power from one form to another. The 'current' drawn by these devices is distorted so there is a need for filters to reduce the distortion. In this paper a comparative evaluation of different types of passive filters used to reduce the distortion and improve the power factor in AC–DC converter. Performance improvement is shown using simulation software.***

***Keywords - AC-DC, Passive Filter, Power Factor, Total Harmonic Distortion.***

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## 1. INTRODUCTION

Single phase diode rectifiers are widely used for industrial applications .In this input AC voltage is rectified and filtered using filtering circuit which consists of large electrolytic capacitors. They are inexpensive and reliable but the ac line current has high harmonics content and low power factor. The Electrolytic capacitors draw a large amount of current and the efficiency of the converter system decreases drastically. Low power factor, high harmonic distortion and large ripple factor (Gupta & Ruchika, 2012, Basu and Supratim, 2004, Mohan, et. al., 1995) have made the converter system inefficient An ideal single phase supply for domestic use is given by 230 V, 50 Hz which has a proper sinusoidal shape. So passive filters on AC and DC sides are required to reduce the harmonics and improve the power factor The better the power factor the better is the degree of power utilization and lesser is the waste. Hence it is always required to improve the power factor by some means or other and reduce THD (Arthur and William, 1992). In this paper diode rectifier with different types of passive filters are compared for power factor improvement and THD reduction Simulation is carried out in MATLAB.

## 2. POWER FACTOR

Power factor is defined as the cosine of the angle between voltage and current in an ace circuit. If the circuit is inductive current lags behind the voltage and power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading. In simple terms, power factor can be defined as the ratio of real power to apparent power. Power factor (PF) is defined as the ratio of the real power (Prasad, et. al., 1990).

PF = Real Power / Apparent Power

Real power (watts) produces real work; this is the energy transfer component. Reactive power is the power required to produce the magnetic fields (lost power) to enable the real work to be done, where apparent power is considered the total power that the power company supplies. This total power is the power supplied through the power mains to produce the required amount of real power.

### 2.1. For linear load

Linear load draws pure sinusoidal current and voltage from the mains so the power factor can be calculated only by finding the phase difference between voltage and current.

### 2.2 Non-linear load

Generally, rectifiers that are used in power supplies, or in certain arc discharge device like fluorescent lamps, electric welding machines, arc furnaces constitute the non-linear load in a power system. The problem with this kind of equipment is other than current of fundamental frequency, current of frequencies which are multiples of power system frequency also flow through them. This is an outcome of regular interruption of current due to the switching action in the rectifiers. Due to the presence of this harmonic current the shape of the current waveform gets changed. To convert AC input voltage into DC output voltage line frequency diode rectifiers are used. In relatively low power equipment that needs some kind of power conditioning, such as electronic equipment and household appliances, we make use of single phase diode rectifiers. In devices with higher power rating, three-phase diode rectifiers are used. In both of these cases, to smoothen out the ripple and obtain a more or less constant DC output voltage, a large filtering capacitor is connected across the rectifier. Due to this, the line current becomes non-sinusoidal. In most cases, the amplitude of odd harmonics of the line current is considerable with respect to the fundamental and cannot be neglected.

## 3. FORMS OF POWER FACTOR

Power factor consists of two components:

- Displacement power factor
- Distortion power factor

The displacement power factor is related to the phase angle while the distortion power factor is related to the shape of the waveform

$$PF = \frac{I1rms}{Irms} COS\boldsymbol{\phi}$$

$$Kp = \frac{I1rms}{Irms}$$

$$Kd = COS\boldsymbol{\phi}$$

$$PF = Kd * Kp$$

where I1rms is the current's fundamental component and

IRMS is the current's RMS(root mean square) value $\phi$ is the phase angle displacement between the voltage waveform and the current waveform $K_p$ is called as the distortion power factor and $K_p$ is known as the displacement power factor.

If the waveform of both current and voltage are purely sinusoidal, then power factor is calculated as the cosine of the phase angle between the voltage and current waveforms. However, in reality always a non-sinusoidal current is drawn by most of the power supplies. When the current is not sinusoidal and the voltage is sinusoidal, distortion power factor comes into play which usually is the case. Displacement power factor comes due to the phase displacement between the current and voltage waveforms. This displacement is caused by the presence of reactance in the power supply system. On the other hand harmonic distortion is responsible for distortion power factor. What happens in reality is the rms value gets increased without any increase in the amount of power drawn. With increase of these effects the power factor of the power supply system reduces. These have the effect of pulling the power factor below the value of one. Another important parameter that measures the percentage of distortion is known as the current total harmonic distortion (THDi) which is defined as follows

$$Kp = \frac{1}{\sqrt{1 + (THDi)\ ^2}}$$

$$THDi = \frac{\sqrt{\sum_{n=1}^{\infty} In\ rms^2}}{I1rms}$$

## 4. EFFECTS OF HARMONICS

The non-linear loads result in production of harmonic currents in the power system. These harmonics in turn result in various undesirable effects on consumers.

- The line voltage that gets distorted due to the harmonics may affect other consumers connected to the electricity distribution network.
- The power factor gets reduced. Due to this the active power that is available is less than the apparent power supplied.
- Low rectifier efficiency due to large rms value of the input current other effects include - telephone interference, extra audio noise, cogging and crawling of induction motors, errors observed in metering equipment's.

## 5. STANDARDS FOR LINE CURRENT HARMONICS

For limiting the line current harmonics in the current waveform standards are set for regulating them. One such standard was IEC 555-2, which was published by the International Electro-technical Committee in 1982. In 1987, European Committee for Electro-Technical Standardization – CENELEC, adopted this as an European Standard EN 60555-

2. Then standard IEC 555-2 has been replaced by standard IEC 1000-3-2 in 1995. The same has been adopted as an European standard EN 61000-3-2 by CENELEC.

Hence, these limitations are kept in mind while designing any instrument. So that there is no violation and the negative effects of harmonics are not highly magnified

## 6. PASSIVE FILTER FOR POWER FACTOR CORRECTION

In Passive PFC (Basu and Supratim, 2004, Sokal and Nathan, 1998, Redl and Richard, 1998, Dewan, 1981), only passive elements are used in addition to the diode bridge rectifier, to improve the shape of the line current. By use of this category of power factor correction, power factor can be increased to a value of 0.7 to 0.8 approximately. With increase in the voltage of power supply, the sizes of PFC components increase in size. The concept behind passive PFC is to filter out the harmonic currents by use of a low pass filter and only leave the 50 Hz basic wave in order to increase the power factor. Power supply can only decrease the current wave within the standard. Passive filters are used in low power application (Prasad, et. al., 1991).

### 6.1 Assumptions for analyzing the circuits are as follows:-

1. Purely resistive load.

2. Ideal filters components.

3. The forward voltage drop and reverse leakage current of diodes are neglected

### 6.2 Following are the Topologies compared for THD reduction:-

1. Conventional single phase diode rectifier

2. Conventional single phase diode rectifier with filter capacitor.

3. Single phase diode rectifier with LC filter.

4. Single phase diode rectifier circuit with series input resonant filter.

5. Single phase diode rectifier circuit with improved parallel input resonant filter.

All methods are compared in terms of THD (Total harmonic distortion), and Power factor.

#### 6.2.1 Conventional single phase diode rectifier

Rectifiers convert the AC supply into DC voltage source for either directly connecting to loads such as heater coils, furnaces, DC motors, etc., or for further conversion as in the case of UPS systems, variable frequency AC drives (VFD), switched mode power supplies (SMPSs), induction heating inverters, etc. (Dewan, 1981, Prasad, et. al., 1991, Garcia, et. al., 2003).

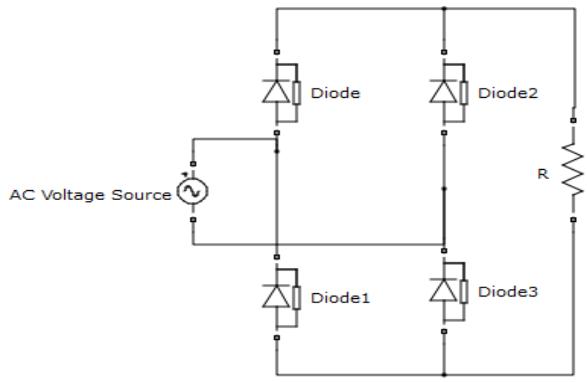


**Fig.1 Conventional single phase diode rectifier**

**Simulation and Result of conventional rectifier**

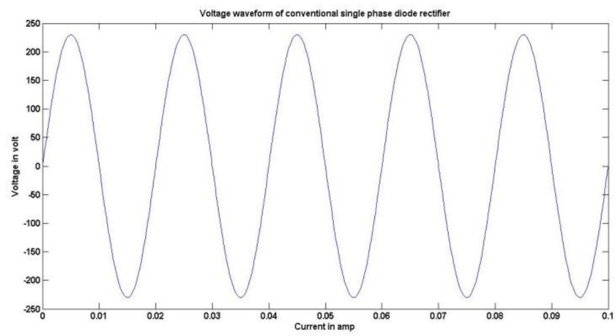


**Fig 2. Voltage waveform of Conventional single phase diode rectifier**

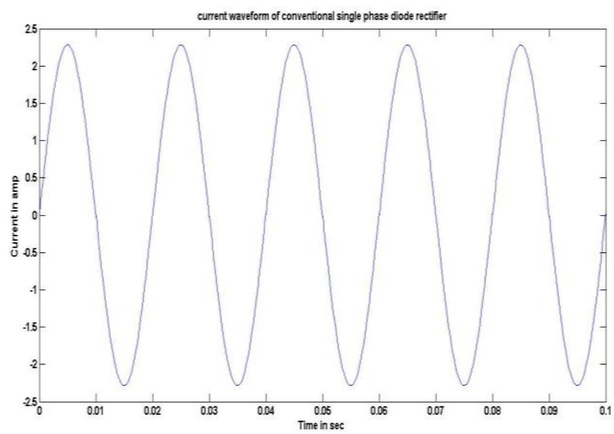


**Fig 3. Current waveform of Conventional single phase diode rectifier**

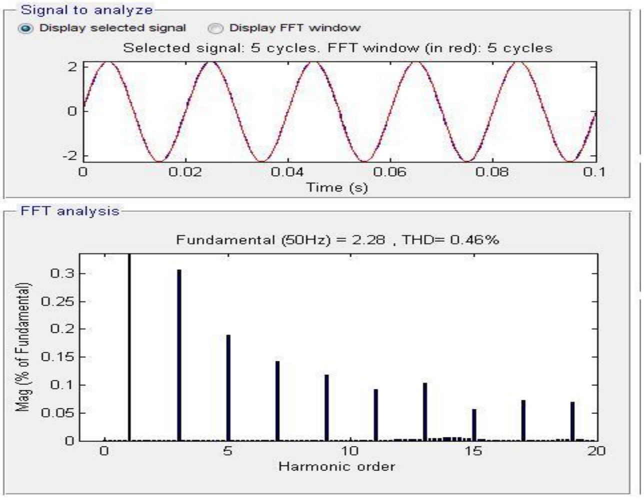


Fig 4. FFT analysis of Conventional single phase diode rectifier

### 6.2.2 Conventional single phase diode rectifier with filter capacitor

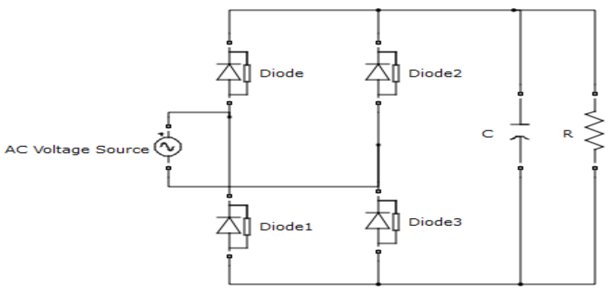


Fig.5 Conventional single phase diode rectifier with filter capacitor

**Simulation and Result of Conventional single phase diode rectifier with filter capacitor**

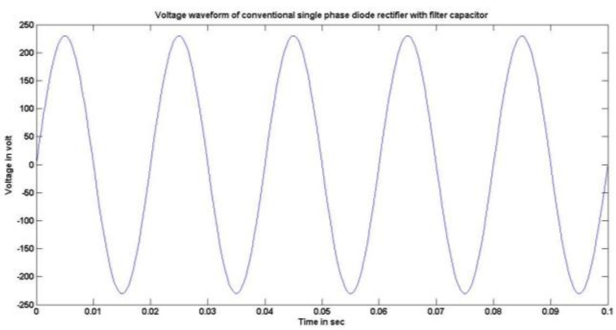


Fig. 6 voltage waveform of Conventional single phase diode rectifier with filter capacitor

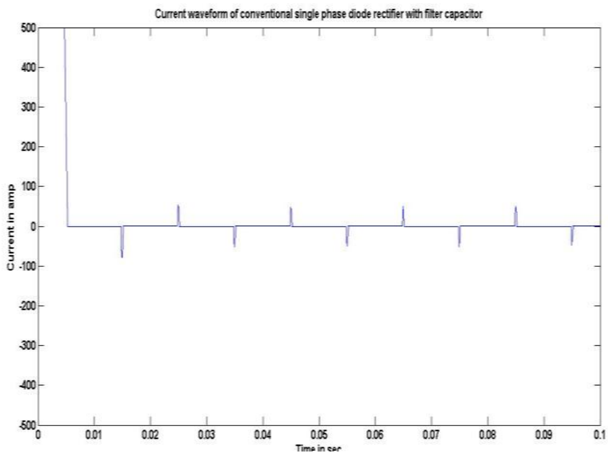


Fig. 7 Current waveform of Conventional single phase diode rectifier with filter capacitor

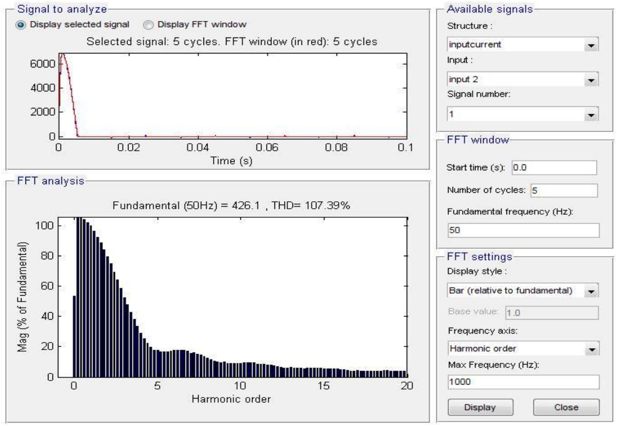


Fig.8 FFT analysis of Conventional single phase diode rectifier with filter capacitor

### 6.2.3 Single phase diode rectifier with LC filter

Fig 9 Shows the diode rectifier with LC filter. Passive methods of PFC use additional passive components in addition to diode bridge rectifier with capacitor .One of the simplest methods is to add an inductor in series with the output. It will make a LC filter. The addition of the inductor results in larger conduction angle of the current pulse and reduced peak and rms value.

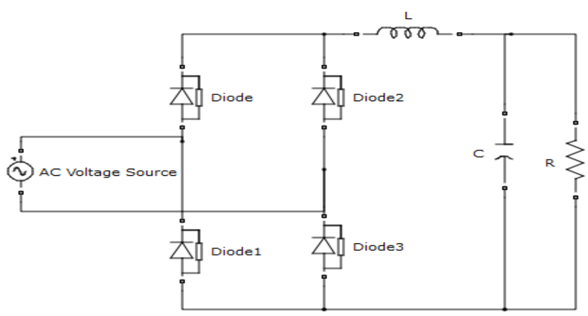


Fig 9 Single phase diode rectifier with LC filter.

**Simulation and Result of Single phase diode rectifier with LC filter**

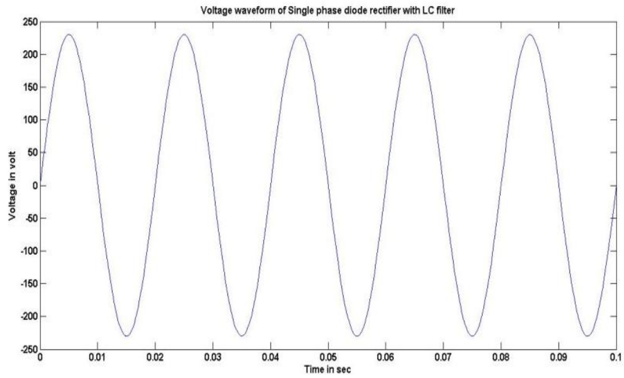


**Fig. 10 Voltage waveform of Conventional single phase diode rectifier with LC filter**

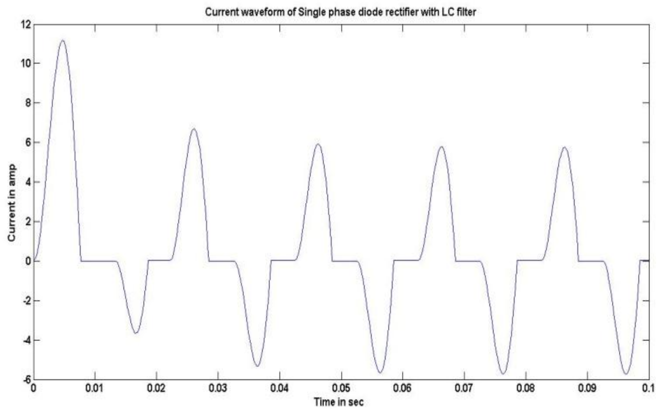


**Fig. 11 Current waveform of Conventional single phase diode rectifier with LC filter**

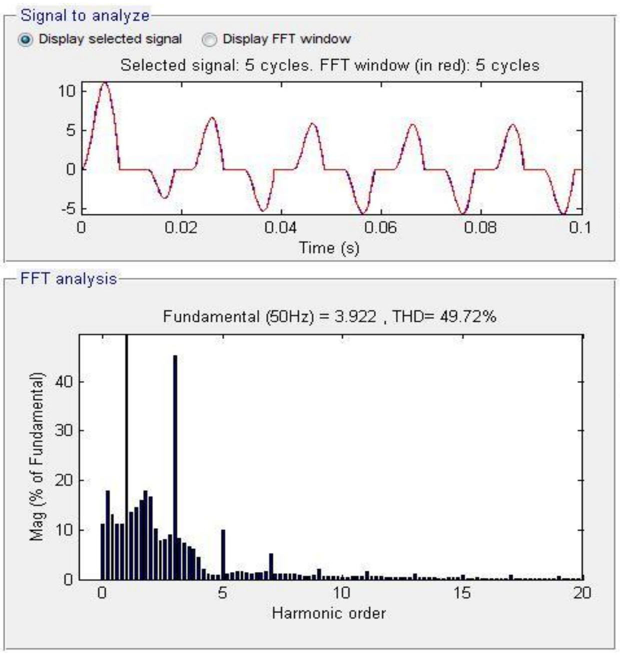


**Fig.12 FFT analysis of Conventional single phase diode rectifier with LC filter**

**6.2.4 Single phase diode rectifier circuit with series input resonant filter**

Fig 13 Shows the diode rectifier with series resonant filter on the input side. It will further improve the THD

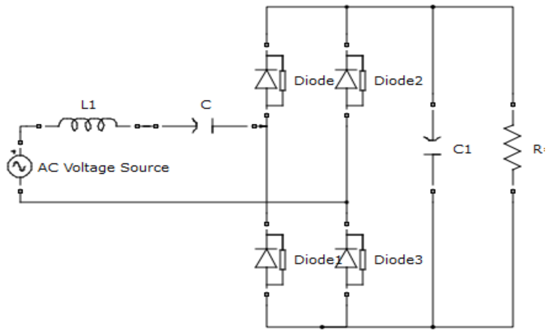


**Fig. 14 Single phase diode rectifier circuit with series input resonant filter**

**Simulation and Result of Single phase diode rectifier circuit with series input resonant filter**

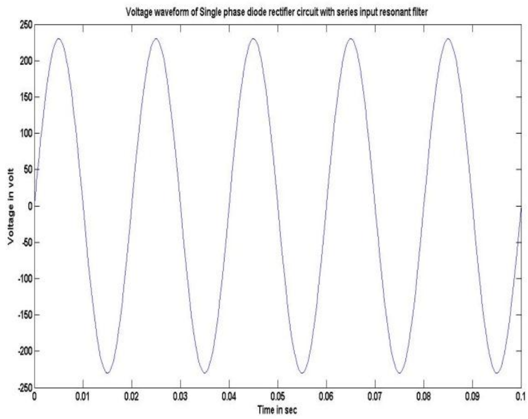


**Fig 15 Voltage waveform of Single phase diode rectifier circuit with series input resonant filter**

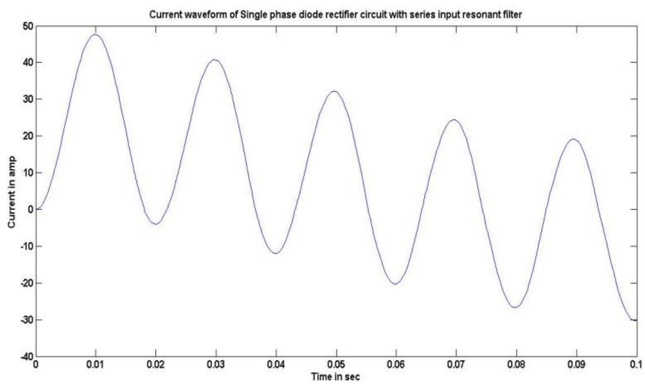


**Fig 16 Current waveform of Single phase diode rectifier circuit with series input resonant filter**

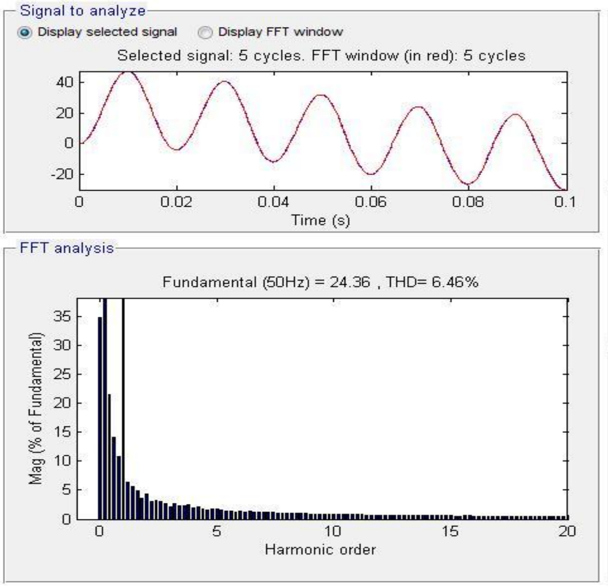


**Fig 17 FFT analysis of Single phase diode rectifier circuit with series input resonant filter**

### 6.2.5 Single phase diode rectifier circuit with improved parallel input resonant filter

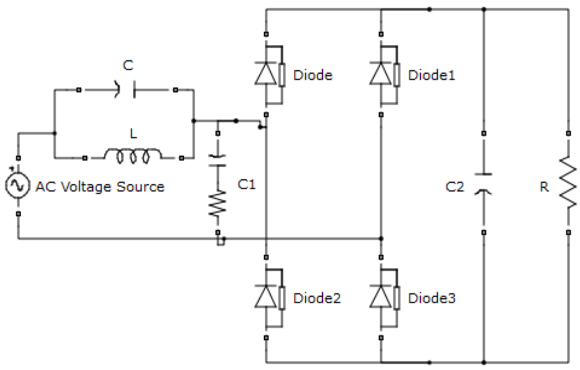


**Fig. 18 Single phase diode rectifier circuit with improved parallel input resonant filter**

**Simulation and Result of Single phase diode rectifier circuit with improved parallel input resonant filter**

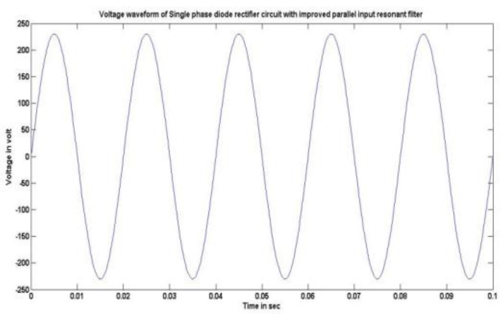


**Fig. 19 Voltage waveform of Single phase diode rectifier circuit with improved parallel input resonant filter**

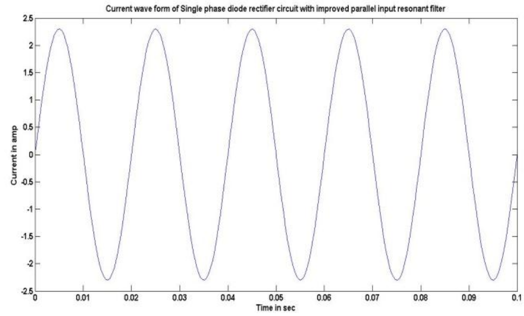


**Fig. 20 Current waveform of Single phase diode rectifier circuit with improved parallel input resonant filter**

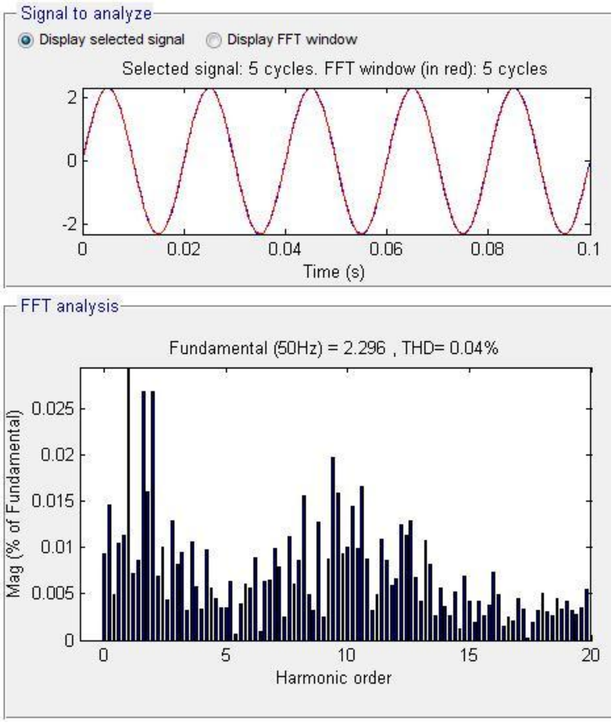


**Fig. 21 FFT analysis of Single phase diode rectifier circuit with improved parallel input resonant filter**

**TABLE I**

| S. NO. | POWER FACTOR & TOTAL HARMINIC DISTORTION | | |
|---|---|---|---|
| | ***TYPES*** | ***PF*** | ***THD%*** |
| 1 | Conventional single phase diode rectifier | 0.9999 | 0.46 |
| 2 | Conventional single phase diode rectifier with filter capacitor. | 0.68 | 107.39 |
| 3 | Single phase diode rectifier with LC filter. | 0.89 | 49.72 |
| 4 | Single phase diode rectifier circuit with series input resonant filter. | 0.9979 | 6.46 |


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| S. NO. | POWER FACTOR & TOTAL HARMINIC DISTORTION | | |
|---|---|---|---|
| | ***TYPES*** | ***PF*** | ***THD%*** |
| 5 | Single phase diode rectifier circuit with series input resonant filter. | 0.9999 | 0.04 |

## 7. CONCLUSION

All the above discussed topologies are used for low power output. These can be used with three phase circuit for higher power output. From the above discussion, it is clear that among above five topologies last topology with improved parallel input resonant filter gives the reduced THD and improved power factor.

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