

Comparative Study of Outputs Generated by Different Filtering Circuits

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ABSTRACT: Conventionally, AC power is the most common source of power used as a standard of consumption in almost every corner of the world. But the transmission, distribution and maintenance of AC power is proven to be a pretty tough task. Moreover, there are many electronic equipments which need the DC power source to be active. Another important issue is to store the AC power which is practically not possible. Hence the need of changing the generated AC power into the DC is evidently obligatory. This article gives a case study/research report on the use of the various electronic rectifiers which can be used for the AC to DC conversion. It also gives a highlight on the variation and ambiguity of the ripple factor of filters which are used to normalize the output from the rectifiers.

KEYWORDS: AC to DC converters, Filter, Rectifiers, Ripple Filter.

I. INTRODUCTION

AC power is the most common mode of power consumption as of today. The use of AC sources comes at the cost of high capital costs, maintenance issues and distribution errors. But the main problem is the storage of power which is practically impossible with AC power. Hence the need of the conversion of AC to DC is mandatory. This is done using fundamentally, rectifiers. The type of the rectifier (half-wave or full-wave) is decided upon the output need.

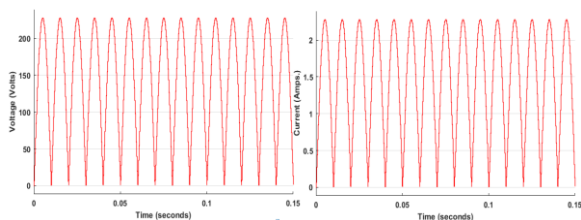


Figure 1: Full wave rectifier output voltage and current waveform

As seen from the Figure 1, the output of this system is not smooth and is unfit for use. In order to obtain a pure DC output, the filter circuits are used. The use of rectifiers creates ripples in the circuit. This induces some undesired noise in the output. The amount of noise depends on the sensitivity and the ripple factor count of the rectifier. The capacitance and inductance for the reduction of these values can be calculated

using a simple mathematical model enforced using a computer simulated model. This article focuses on exhibiting a comparative study of the different types of filter circuits. Depending on the application, the filters are classified as C-filter, L-filter, LC-filter and Pi-filter

II. DESIGN OF FILTERS

C-Filter: The output produced by the rectifying circuit is always a pulsating DC; the pulsating nature of the output can be stabilized by the usage of capacitor as C-filters. The charging and discharging property of the capacitor smoothens the output. The following block diagram shows the sequential operation of following components.

As the load at the end changes the input current waveforms, so the input side should also be considered. A C-filter works on the smoothing of output voltage and as a result increases the average voltage of the output. But the overall disadvantage of this filter is that the current of the output remains pulsating. The value of ripple factor generated in the process of conversion changes with the change in the values of capacitor used in the filter and the resistor used in parallel. The formula to find the ripple factor for a given value of capacitance is

$$\text{Ripple Factor} = 1/\sqrt{2} (2fRC-1)] \quad (1)$$

Inductive Filter: Using inductor as L-Filter is another way of smoothing and stabilizing the output. The following diagram shows the sequential operation. L-filter mostly works on the smoothing of current. So, the inductive filter overall increases the output current of the output. This filter does not have much effect in the smoothing of the voltage as a result of which the voltage remains pulsating which is a disadvantage of L-filter. Just like c-filter the value of the ripple factor generated can be easily altered by changing the values of inductor and the resistor connected in series. The formula to calculate the ripple factor for a given value of inductance is

$$\text{Ripple Factor} = 0.4714/\sqrt{[1+(4\pi fL/R)^2]} \quad (2)$$

LC-Filter: As it is known that the capacitor or the inductor alone if used in the filter cannot be used for the smoothing of both current and voltage, so combination of both the filters are used. The block diagram is as follows. A capacitive-inductive filter is used to smoothen the current along with

voltage. Fig shows LC-filter. This filter is more advantageous than the individual C or L filter. Unlike L-filter and C-filter the LC-filter do not have any specific formula for the calculation of ripple factor. So for the calculation of ripple factor of LC-filter we calculate the vales for L and C filters individually and then we apply those to the LC-filter.

π -Filter: Consisting of two capacitors and one inductor. The Fig-4 shows the pi-filter. In this filter the first capacitor does the main filtering action and whatever the left out ripple will be reduced by the LC-filter connected in series across it. Like LC-filter pi-filter also works on the smoothening of both current and voltage. The below Figure 4 depicts the block diagram of converter with LC filter the sequencial connections.



Figure 2: Single phase converter with LC filter

III. SIMULATION RESULTS

A bridge rectifier which is connected to a single phase AC supply with a frequency of 50 Hz with different loads attached to the circuit. During the positive cycle diode 2 and 4 will conduct and during the negative half cycle the diode 1 and 3

will be conducting, as a result we get a pulsating DC output from the bridge rectifier. These filters are connected with calculated value of loads for which the results are compared. **C-Filter:** The value of c is calculated using the formulae. The graphs shows the output of voltage and current which the load is supplied with. As a pulsating DC is received by the capacitor its starts to get charge up and then it discharges until the value of voltage raises up the beyond the value that the capacitor is discharging in this process the output can be stabilized. The graph shows the output for 5% ripple when connected with a resistive load.

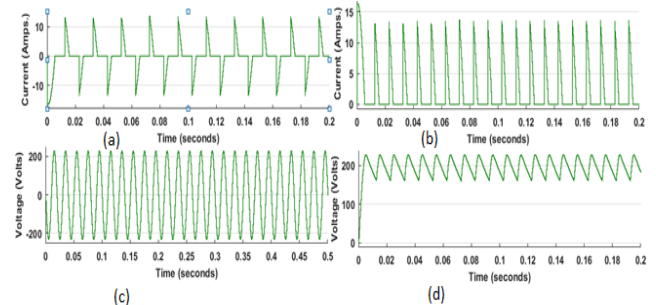


Figure 3: Voltage and current waveform of rectifier with R load

- (a)input current (b)load current
- (c)input voltage (d)load voltage

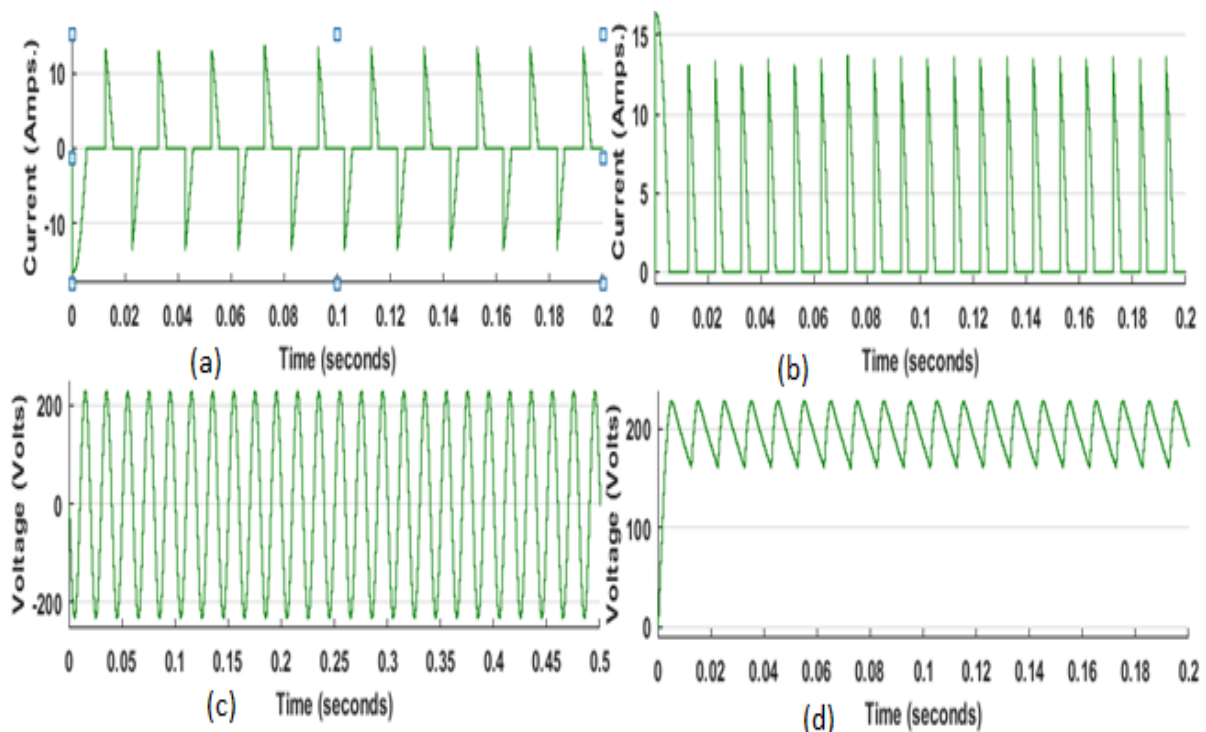


Figure 4: Rectifier output results with RL load

- (a)input current (b)load current (c)input voltage (d)load voltage

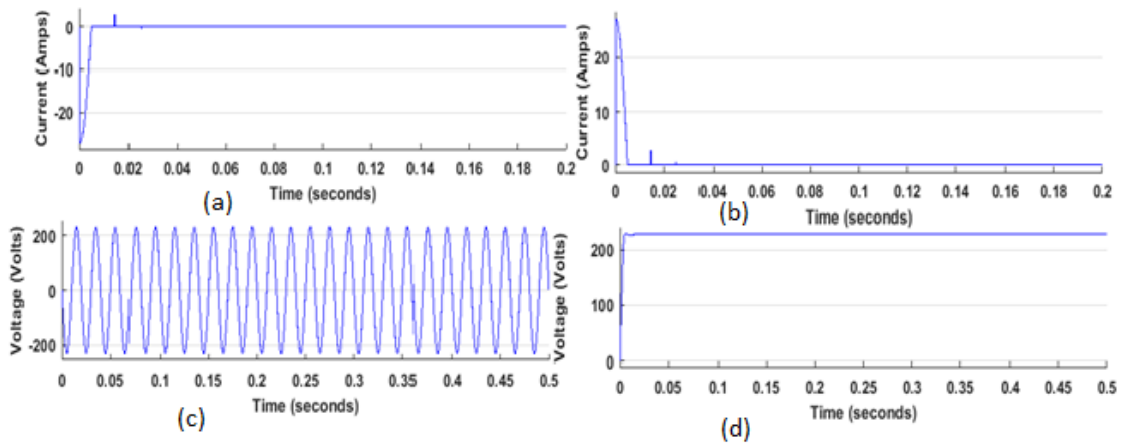


Figure 5: Rectifier output results with RC load

(a)input current (b)load current (c)input voltage (d)load voltage

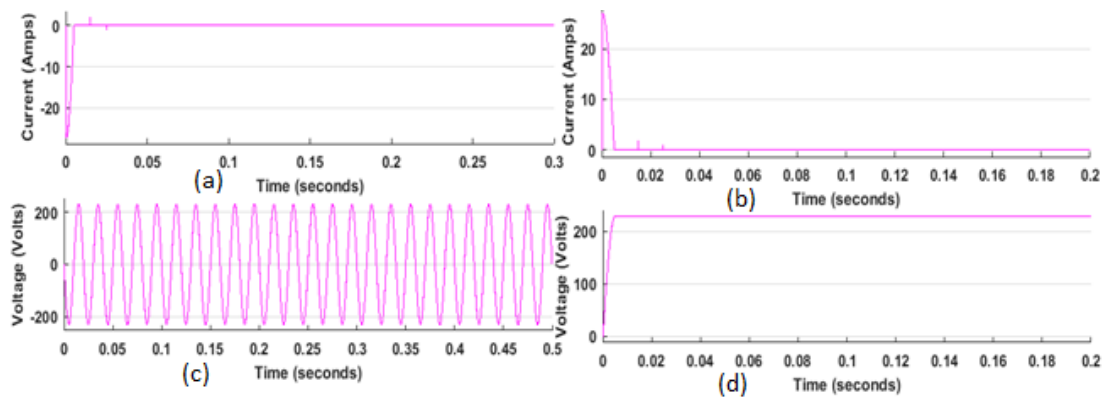


Figure 6: Output voltage and current for RLC load

(a)input current (b)load current (c)input voltage (d)load voltage

As even after rectification the supply contains ac components called the ripple, this ripple factor could be adjusted by changing different values of capacitor calculated by the formula. The different values of voltages and currents for different ripple factors calculated by the formula from equation are given in the table-1.

Table 1 Calculated capacitor values for various values of Percentage Ripple factor

RIPPLE FACTOR	C-VALUE(xe-4)	AVG VOLTAGE	LOAD CURRENT	MAX. CURRENT
1%	28.8	230	52	213
2%	14.4	230	38	150
3%	9.62	230	31	70
4%	7.21	230	26	51.2
5%	5.77	230	23.5	2.13

L-Filter: The main use of inductor is that it does not all allow the current to grow up or die too quick. And if the value is too high then it will be making the current constant and it will not allow it to reach the peak value. As a result of it the voltage also gets affected and could not reach the maximum of the normal sin wave which gets created. So the output voltage of the inductive filter always remains less than the output of capacitive filter. The major advantage of this filter over capacitive filter is, it allows higher value of current to pass through it without much change in the voltage level. So it is very use useful for higher power applications. For 5% ripple factor when the circuit is connected across a pure resistive load the following graph is obtained.

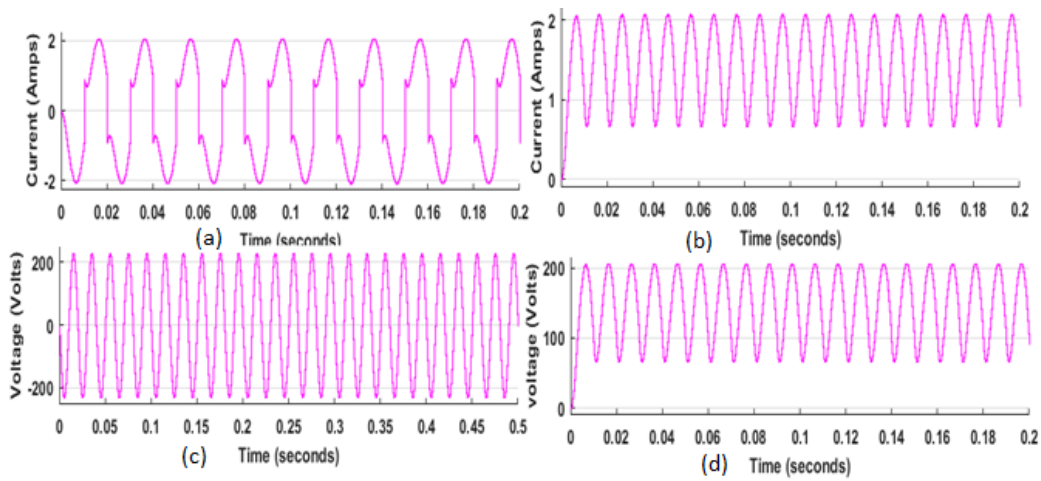


Figure 7: Inductor filter with R load

(a)input current (b)load current (c)input voltage (d)load voltage

The top two graphs shows the input current and the current across the load(from left to right) and the below graph shows the the input voltage and the voltage across the load(from left to right).

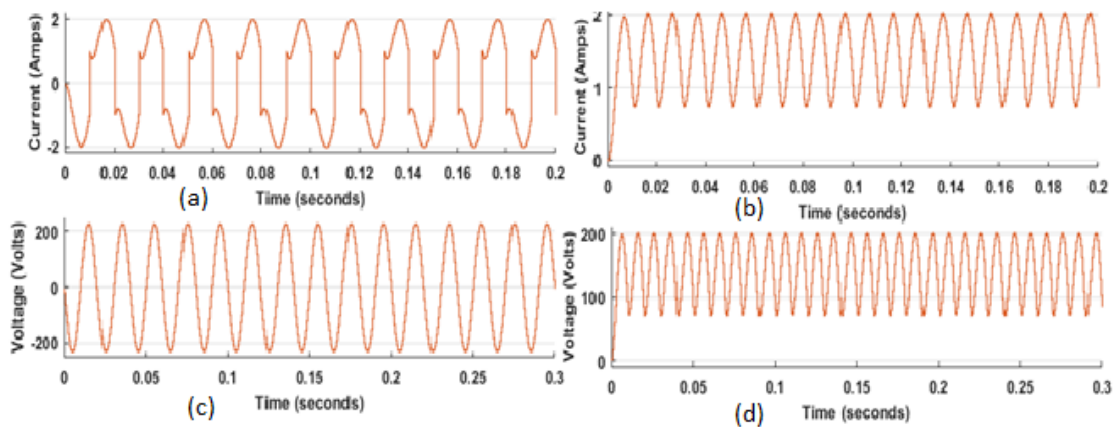


Figure 8: Inductor filter with RL load

(a)input current (b)load current (c)input voltage (d)load voltage

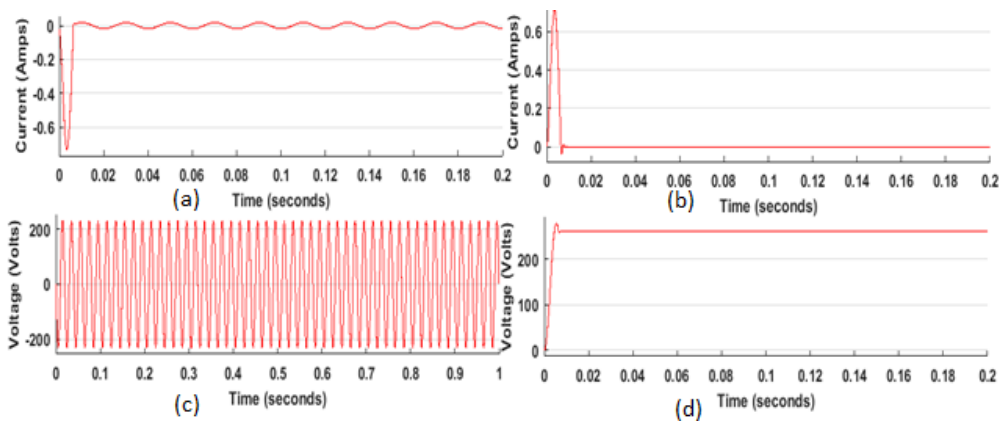


Figure 9: Inductor filter with RC load

(a)input current (b)load current (c)input voltage (d)load voltage

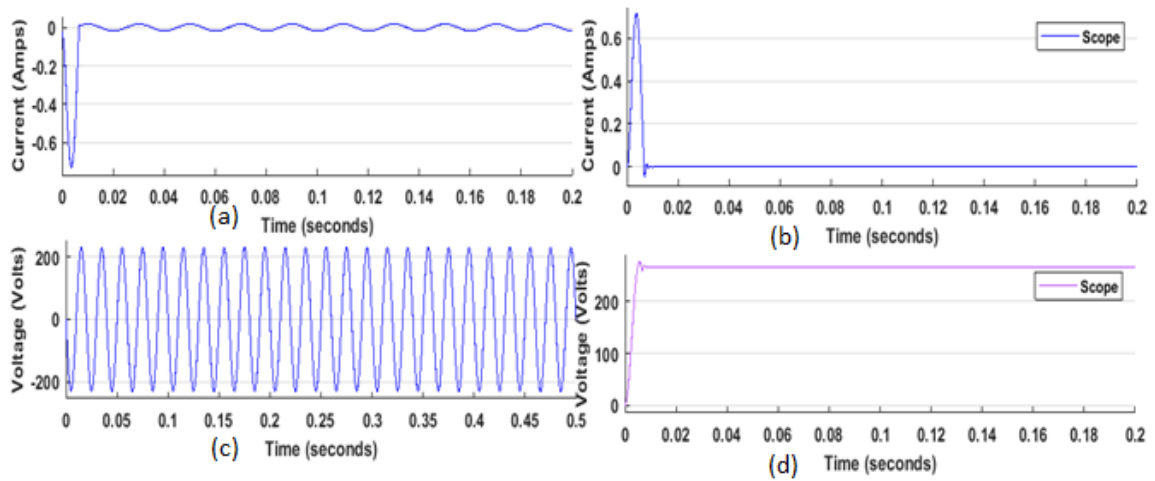


Figure 10: inductor filter with RLC load

(a)input current (b)load current (c)input voltage (d)load voltage

The different values of voltage and current for different ripple factors calculated by the formula of equation is given in the table-2

Table 2 Inductor filter values for different ripple factor

RIPPLE FACTOR	L-VALUE(xe5)	AVG VALUE	LOAD CURRENT	MAX. CURRENT
1%	7.4	230	2.3	2.3
2%	3.70	230	2.3	2.3
3%	2.47	230	2.3	2.3
4%	1.85	230	2.3	2.3
5%	1.48	230	2.3	2.3

LC Filter: The use of capacitive-inductive filter improves the filtering action by improving and producing a quality current and voltage due to the presence of both inductor and capacitor. Capacitive-inductive filter is used to deliver high power applications.

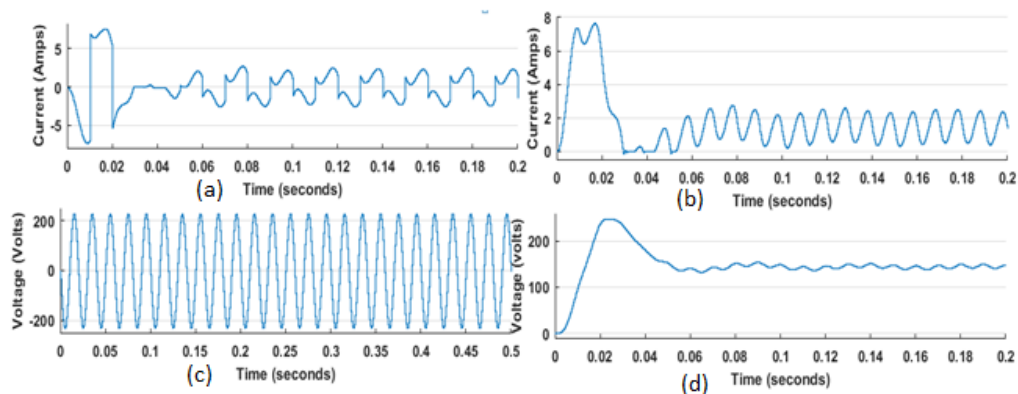


Figure 11:LC-filter with only R load

(a)input current (b)load current (c)input voltage (d)load voltage

The top two graphs shows the shows the input current and the current across the load(from left to right) and the below graph shows the input voltage and the voltage across the load(from left to right).

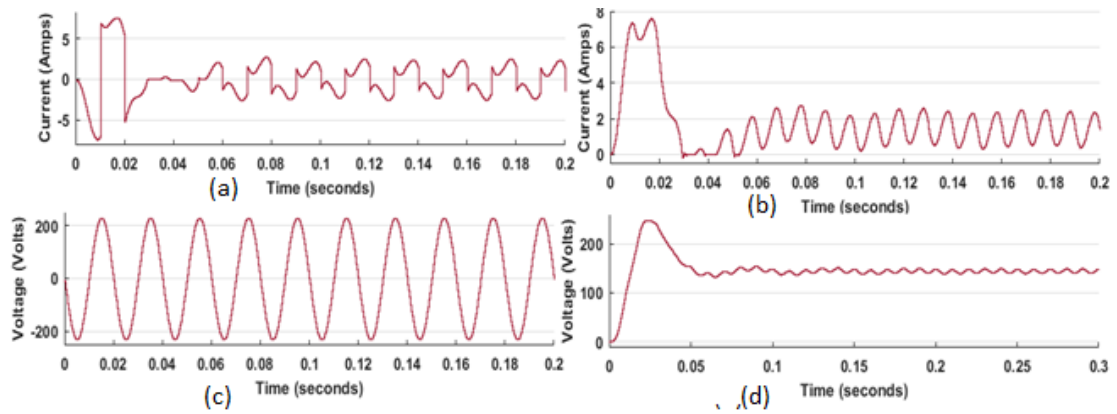


Figure 12: LC-filter with RL load

(a)input current (b)load current (c)input voltage (d)load voltage

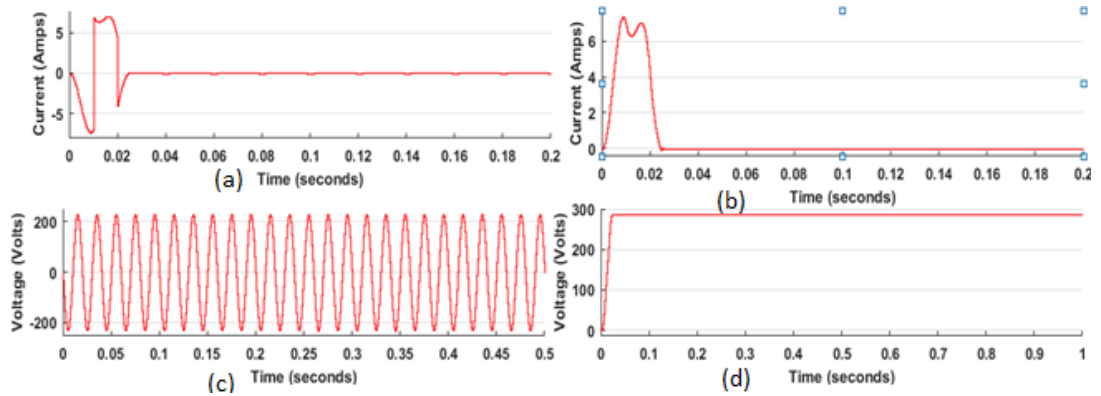


Figure 13: LC-filter with RC load

(a)input current (b)load current (c)input voltage (d)load voltage

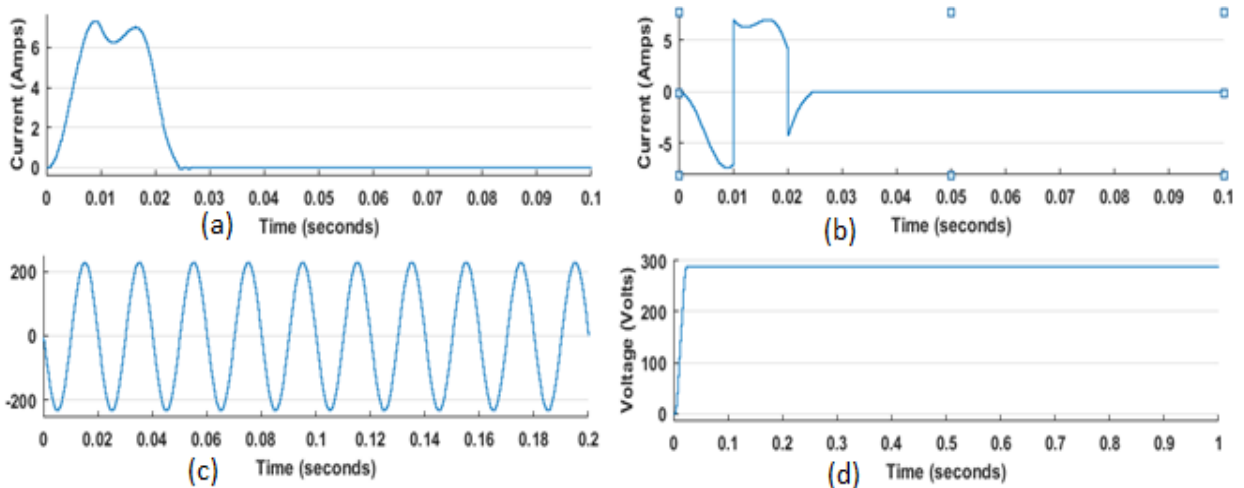


Figure 14: LC-filter with RLC load

(a)load current (b) input current (c)input voltage (d)load voltage

As there is no specific formula to calculate the value of inductance and capacitance of a capacitive-inductive filter. The only way to calculate these values is to calculate the value of $L \times C$ from equation. Table-3 shows the different values of inductor and capacitor which wear used for in the LC-filter and the values of current and voltages for different ripple factors.

Table 3 L and C values for different ripple factor

RIPPLE FACTOR	CAPICATOR VALUE xe-4	INDUCTOR VALUE	AVG. VOLTAGE	PEAK CURRENT	AVG. CURRENT
1%	11.25	0.10610	184	17.1	3.1
2%	5.627	0.10610	152	11.5	3.1
3%	3.75	0.10610	155	7.9	3.2
4%	2.81	0.10610	158	9.7	3.1
5%	2.25	0.10610	161	9.2	3.1

II-FILTER: The Pi-filter consisting of two capacitors and one inductor connected in the way as in the figure Fig-5. In this type of filter the main filtering action is done by the first capacitor C1 and the remaining ripple is removed by the combine action of LC. The output of the pi filter is better than the output of LC-filter .But the main disadvantage of this filter is as the capacitor C1 is connected in directly to the supply so a large pulse of current is needed if the connected load is large

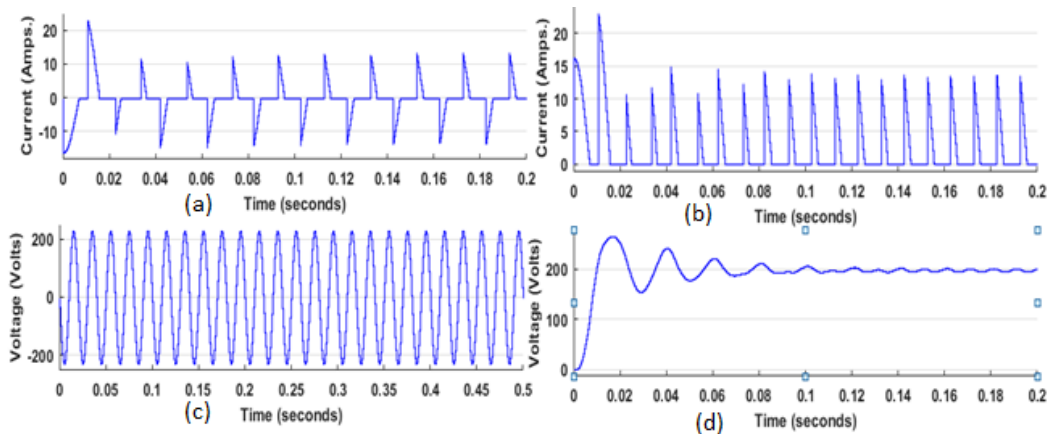


Figure 15: Pi-filter with pure resistive load

(a)input current (b)load current (c)input voltage (d)load voltage

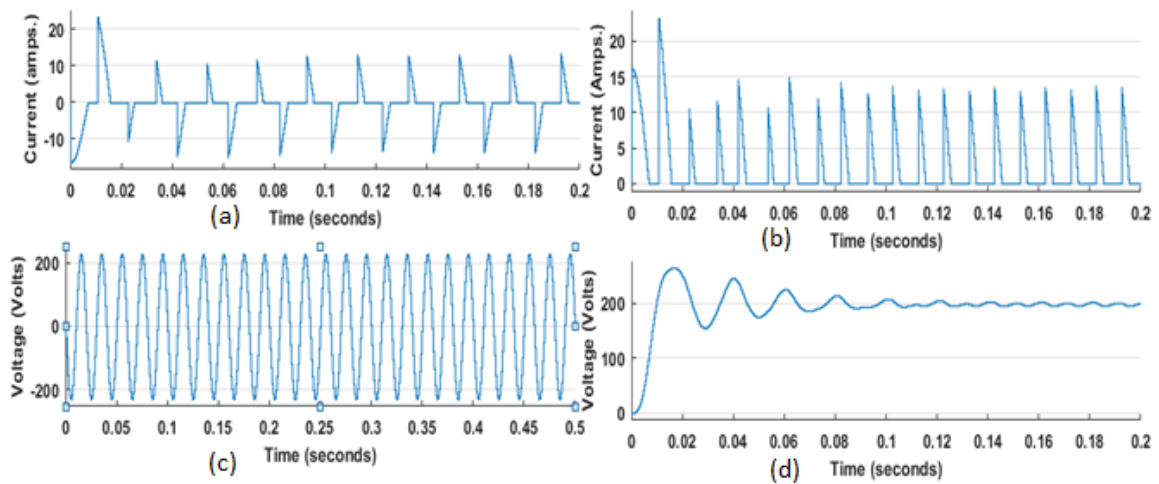


Figure 16: Pi-filter with RL load

(a)input current (b)load current (c)input voltage (d)load voltage

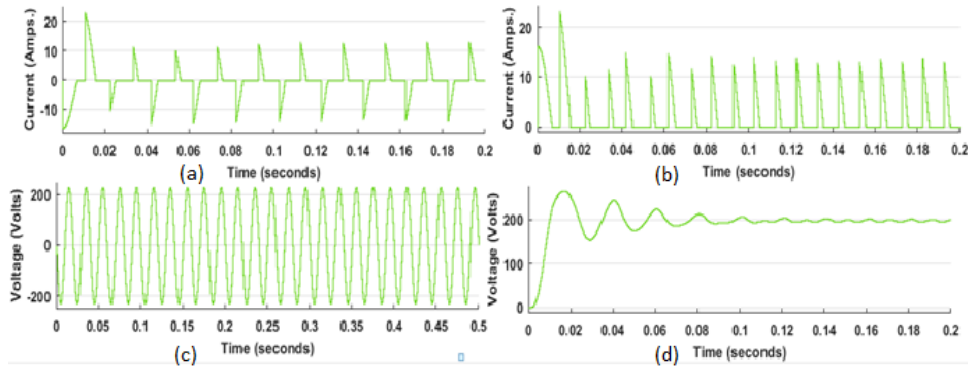


Figure 17: Pi-filter with RC load

(a)input current (b)load current (c)input voltage (d)load voltage

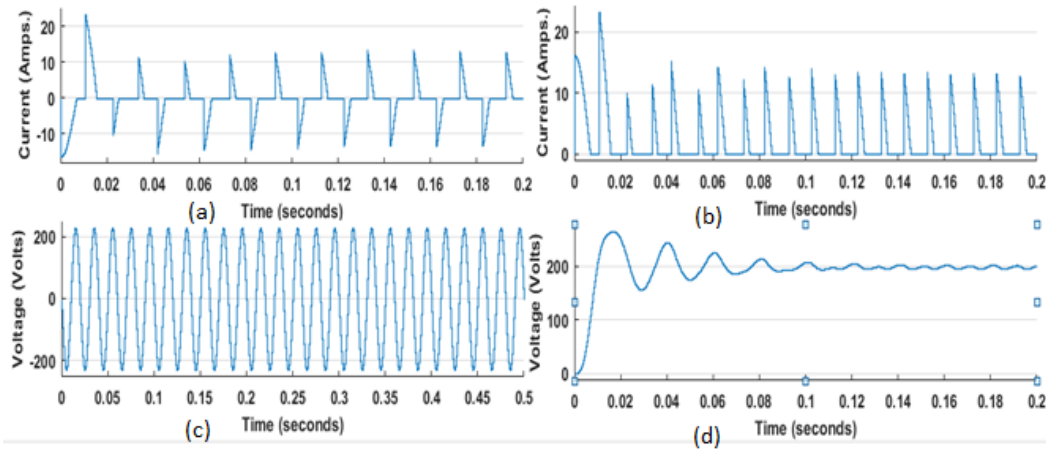


Figure 18: Pi-filter with RLC load

(a)input current (b)load current (c)input voltage (d)load voltage

As there is no particular formula to calculate the values of capacitor and inductor, the values are taken from the individual filters. The different values of voltage and current for different ripple factors calculated by the formula of equation is given in the table-4.

Table 4 Calculated Land C values of Pi-filter

RIPPLE FACTOR	CAPICATOR VALUE xe-4	INDUCTOR VALUE	AVG. VOLTAGE	PEAK CURRENT	AVG. CURRENT
1%	11.25	0.10610	222	90	33
2%	5.627	0.10610	215	51	24
3%	3.75	0.10610	210	37	18
4%	2.81	0.10610	206	29	16
5%	2.25	0.10610	202.5	23.5	13.5

III.RESULT

With the change in the value of ripple factor for different filters the value of capacitor and inductor should be changed to get desired value of current or voltage as per the requirement. As in case of C-filter the value of capacitor keeps on decreasing as the ripple factor rises and similar thing is observed in L-filter i.e., for the increasing ripple factor the value of inductance is decreased . And in case of LC and Pi filters the value of capacitor and inductor are adjusted accordingly. When dc ripple is restricted to 5%

the values of inductor and capacitor that will be will be comparatively small and these will be used alone in case of L-filter and C-filter respectively. But in case of LC and Pi-filters the values will be changing according to the required current and voltage values. Table-5 shows different values of capacitor and inductor values used in the filters to get a 5% ripple factor.

Table 5 Different filter values for 5 % ripple factor

FILTER	CAPICATOR VALUE	INDUCTOR VALUE
C-filter	5.77xe-4	----
L-filter	----	1.48xe5
LC-filter	2.25xe-4	0.10610
Pi-filter	2.25xe-4	0.10610

Along with the above mentioned changes, the input current graph also changes drastically with the change in the type of load. While a pure resistive load or a RL is connected across the circuit the current remains in a small range comparatively but it will be pulsating and the voltage also do not show much constancy. Whereas when a RC or RLC load is connected across\ the circuit then there will a overshoot in the current after which it will have almost constant value, the voltage obtained as output has a desired constant value.

The Total Harmonic Distortion (THD) of the source current for different types of load with different filter is tabulated in the table 6. For 5% ripple factor the circuit is simulated in different load conditions. From the table it is clear that capacitor filter and LC with R load and RC load is having high percentage of THD. By observing the table, Inductor filter is having only 5.35% for all the types of load.

Table 6: THD % of source current for different types of load

Harmonic order	C filter with R load	C filter with RC load	L filter with R load	L filter with RC load	LC filter R Load thd%	LC filter RC Load thd%
1	100	100	100	100	100	100
3	92.6	94.5	2.33	2.35	34.2	34.8
5	79.4	84.7	2.24	2.25	12.5	9.06
7	62.6	71.65	2.1	2.1	7.6	4.3
9	45.2	56.88	1.93	1.9	6.18	3.13
11	30.81	42.46	1.72	1.72	5.39	2.39
13	22.8	30.61	1.5	1.49	4.72	1.82
15	21.24	23.41	1.26	1.23	4.14	1.47
17	21.19	21.08	1.04	1	3.66	1.27
19	19.7	20.96	0.82	0.78	3.2	1.15
overall Thd%	153.78	170.1	5.35	5.35	38.96	36.76

V. CONCLUSION

By comparison of the four type of filters the following results were found: There will be a vast change the input as well as the output current waveforms with the change in type of load connected i.e., where ever there is a capacitor connected in the load side it tends it smoothen both the output

current and voltage removing the pulsating nature. **C-filter** works on the smoothening of voltage and it almost stabilizes it by limiting the voltage in between two values, in this process there will be no major change in the current values. **L-filter** works on the smoothening of current vale and it almost stabilizes it by limiting the current between to value, in this process there will be no major effect on the current values.**LC-filter** as a combination of both L and C filters, this type of

filter stabilizes both current and voltage values limiting those in between two vales which stabilizes them. **PI-filter** works very much similar to LC-filter instead of one major difference, that the capacitor c1 limits the output, so a larger pulse of current is required in input for meeting the needs of large output load.

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