

# Experimental Analysis of Harmonics Reduction in Single Phase Battery Charger

<sup>1</sup>Dr. M.Narendra Kumar, <sup>2</sup>Mr. Kuldip Singh and <sup>3</sup>Dr.K.S.R. Anjaneyulu

<sup>1,2</sup>GNIT, Hyderabad, <sup>3</sup>JNTU Anantapur,

Email: vp.gnit@gniindia.org, Phone: +91-8096609840

**Abstract**— The harmonic distortion is one of the most important problem associated with power quality and creates several disturbances in the power system. This paper includes the harmonic reduction technique to improve the power quality and includes the simulation for the same. Mobile/Laptops battery chargers are non-linear devices that inject harmonic currents and pollute network voltage [1]. Distorted current or voltage waveforms from its ideal form will be treated as harmonic distortion. Harmonics are generated due to non-linear load. In this paper we simulated the battery charging process, the methods to reduce the harmonic effects and analyze the impact of harmonics.

**Index Terms**— Battery charger, Harmonics, Filters, Power quality.

## I. INTRODUCTION

The growing presence of non-linear loads in commercial, industrial and residential installations has lead to a rise in harmonic levels in power distribution system [1]. The mobile phone/Laptops battery are charged by single phase supply. Due to this charging process the harmonic current are injected and create the power quality problem. The harmonic distortion is a form of electrical pollution that can cause problems if the sum of the harmonic currents increases above certain limits. A harmonic current is one with multiples of fundamental frequency, for instance a 250 Hz current on a 50 Hz network is the 5th harmonic. The 250 Hz current represents energy that cannot be used by devices on the network. It will be converting in to heat. According to the International Electro technical Commission (IEC), the level of harmonics is described by the total harmonic distortion (THD). THD is expressed as a percentage of the total voltage or current. In the standard IEEE 519 it is referred to as total demand distortion (TDD)[2].

The harmonics may cause cables to overheat and damage their insulation. Capacitors overheat with-in, is the most severe case and the risk of explosion due to the dielectric breaks-down. Electronic displays and lighting may flicker, circuit breakers can trip, and computers fail and meters give false readings.

Harmonic currents and voltages are created by non-linear loads connected on the phone chargers/ Laptops. All power electronic components used in different types of electronic systems can increase harmonic disturbances by injecting harmonic currents directly into the supply network. The Different level of Harmonics are shown in Fig.1.

This paper analyzes the use of capacitors and inductances to reduce the harmonic emission of single phase mobile phone/Laptop battery chargers. The study is supported by experimental measurements in actual installations.

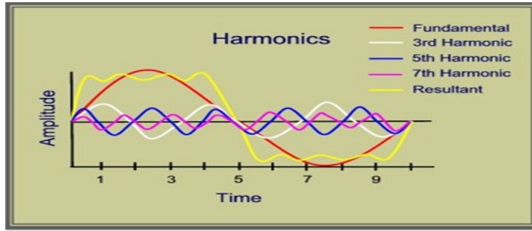


Fig. 1 Different level of harmonics.

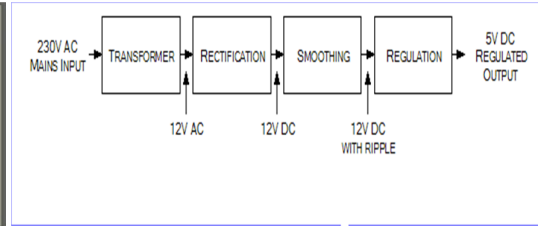


Fig.2 Block diagram of a single phase chargers

## II. SINGLE PHASE BATTERY CHARGERS

The single phase phone/laptop charger is used for cell phone/Laptops battery charging. The Fig.2 is shown the block diagram of single phase charger. It consists of single phase transformer which step down the 230V to 12V AC .The single phase diode bridge is used as a rectification from 12V AC to 12V DC and LC components are used as a smoothing circuit to remove the ripple and by using regulation circuit the 12DC is regulated to 5V DC. The supply voltage  $V$  and the battery voltage  $E$  are also plotted as reference is shown in Fig 3 This circuit operates in discontinuous conduction mode where two different states can be distinguished:

- The diodes are off and the current "i" is zero.
- The current "i" flow through the rectifier diodes and charge the battery.

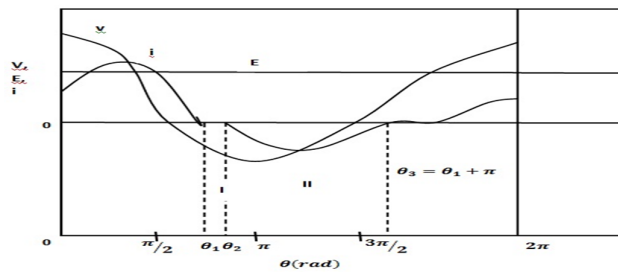


Fig. 3 Voltage and current waveform

The commutation angles  $\theta_1$  and  $\theta_2$  which define the charges AC current considering half-wave symmetry conditions. To obtain the instantaneous wave shape of the current, these angles must be determined by analyzing the circuit states corresponding to the current segment I and II. The  $E$  is the voltage in battery. [1]

$$\sqrt{2} V_1 \cos(\theta_2 - \pi) = E \quad (1)$$

$$\sqrt{2} V_1 (\sin(\theta_1) + \sin(\theta_2)) = E(\pi - \theta_2 + \theta_1) \quad (2)$$

Where  $V_1$  is the rms value of the fundamental supply voltage  $v$ . The circuit diagram for single phase cell phone charger is show in Fig-4 and the input voltage waveform with harmonics feedback to network is shown in Fig-5.

## III. FILTER DESIGN CONSTRAINTS

There are various issues in the design of a passive filter for its proper functioning in harmonic reduction. The key issues are mentioned here:

- Minimizing harmonic source current.

The prime objective of the filter design is to minimize the harmonic current in ac mains. This is ensured by minimizing the filter impedance at the harmonic frequencies so that the harmonic filter acts as a sink for the harmonic currents.

- Minimizing fundamental current in passive filter

To ensure that the installation of passive filter does not cause the system loading, the

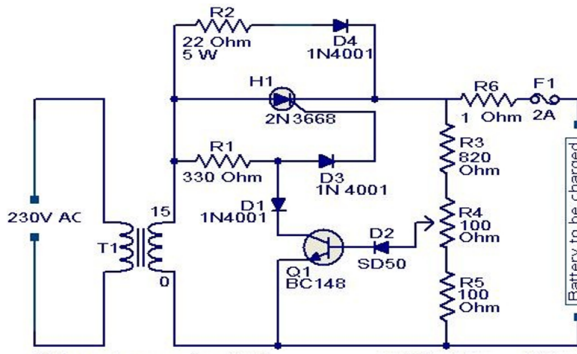


Fig-4 Circuit diagram for Cell phone chargers

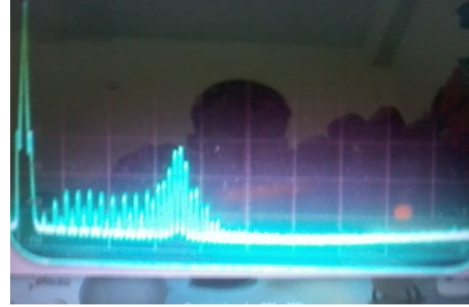


Fig: 5 voltage with Harmonics feeding back to network

fundamental current in the passive filter is minimized by the maximizing the passive filter impedance at the fundamental frequency.

- Environment and ageing effect

The capacitors with metalized film construction lose capacitance as they age. Similarly the manufacturer tolerance of the harmonic filter reactor may result in tuned frequency higher than the nominal. IEEE Standard recommends that the passive filters are tuned at 6% below the rated frequency so that it will exhibit acceptable tuning at the end of its 20 year life.

The resonant frequency for the  $n^{\text{th}}$  harmonic is given as:

$$F = 1/2 \cdot \pi \cdot n \cdot C \cdot R \quad (3)$$

The values of filter components can be calculated from above equations

Quality factor can be defined as

$$Q = L / (CR)^2 \quad (4)$$

The values of filter components can be calculated from above equations.

#### IV. MITIGATION OF SINGLE PHASE CHARGER HARMONICS BY LINE INDUCTANCE AND CAPACITANCE

The mitigation method is based on the increase in AC side inductance L Henry. This leads to a growth in current pulse width and thus to a decrease in the harmonics contents of the current wave [1]. From eq. 1 & 2, we can derive that the commutation angles approximately depends on the ratio  $E/V$  only. In the boundary

between the commutation angles coincide ( $\theta_1 = \theta_2 = \theta_b$ ), and the boundary conditions are obtained from eq. 1 & 2 [2].

$$\left. \begin{aligned} \sqrt{2} V_1 \cos(\theta_b - \pi) &= E_b \\ \sqrt{2} V_1 \sin(\theta_b) &= E_b \pi / 2 \end{aligned} \right\} \Rightarrow \theta_b = 2.14 \text{ rad} \quad (5)$$

For commutation angle  $\theta_1$  smaller than  $\theta_b$ , the current extinguishes when the emf  $E$  is greater than the instantaneous supply voltage and the current through the diodes stop at this point. On the other hand, for commutation angle  $\theta_1$  greater than  $\theta_b$ , the emf  $E$  is always smaller than the supply voltage and current continues flowing through the diodes all the time. [1]

#### V. SIMULATION ANALYSIS

In experimental analysis we have simulated the battery charger with different filters for single phase charging. The results are analyzed based on the impact of filter on input side and output voltage side. We used different filters to know the voltage level. Simulation is done with the help of circuit shown in Fig 6.

a.) Capacitor filter C connected both Input Side and Output side of transformer: As shown below in Fig. 7 we have shown the impact of C filter on the output voltage. This contains the harmonics.

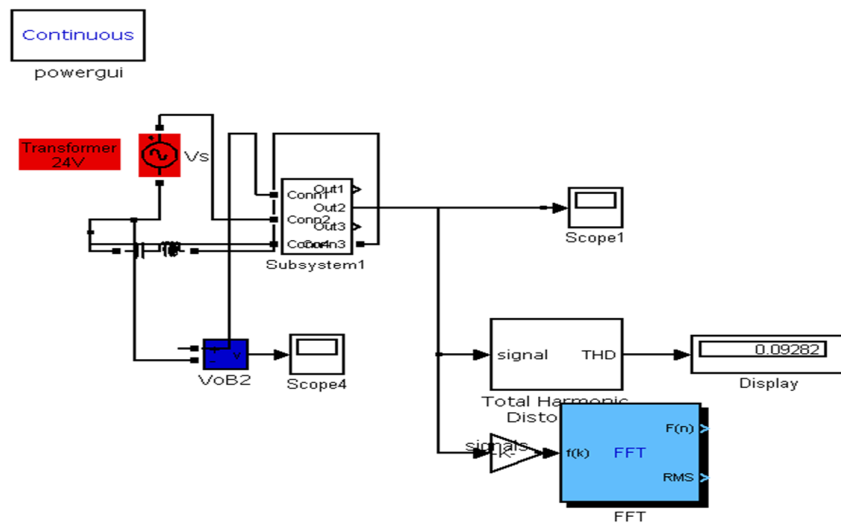


Fig 6. Simulink circuit for simulation

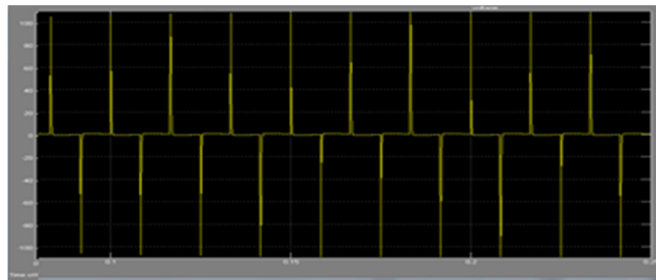


Fig: 7 Output Voltage with C-Filter

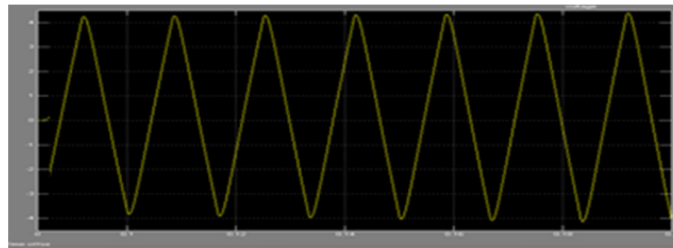


Fig: 8 Output voltage with LC filter

b.) Output Side LC filter and input of transformer is with Inductance  $L$ . we have shown the impact of inductance  $L$  on the output voltage and impact of LC filter on DC voltage side in Fig. 8

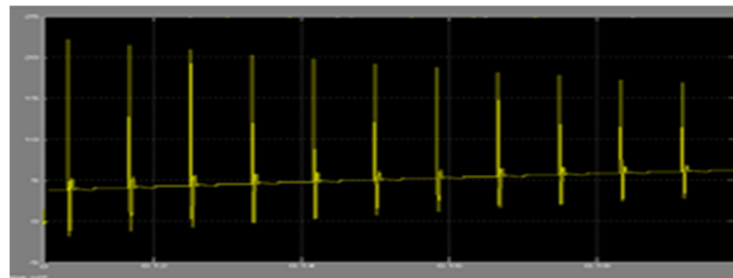


Fig. 9 DC voltage with LC

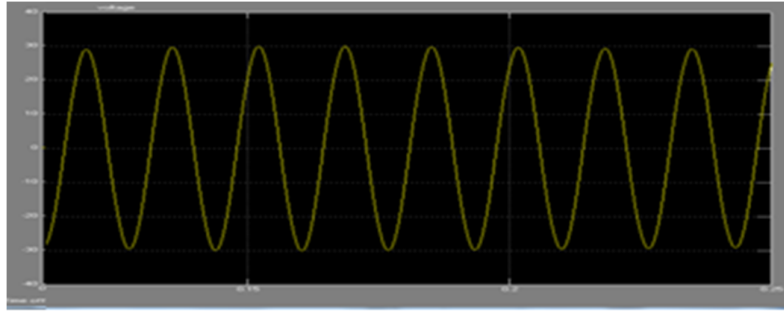


Fig:10 Output voltage with LC filter

c.) Output side Capacitance C and input side LC filter: As given below Fig 9 & Fig-10 the impact of inductance LC on the Reverse voltage.

The THD is defined as the root mean square (RMS) value of the total harmonics of the signal, divided by the RMS value of its fundamental signal. For example, for currents, the THD is defined as

$$\text{Total harmonic distortion (THD)} = I_H/I_F, \quad (5)$$

$$I_H = \sqrt{I_2^2 + I_3^2 + \dots + I_n^2}, \quad (6)$$

Where

and

$I_n$  = RMS value of the harmonic  $n$

$I_F$  = RMS value of the fundamental current.

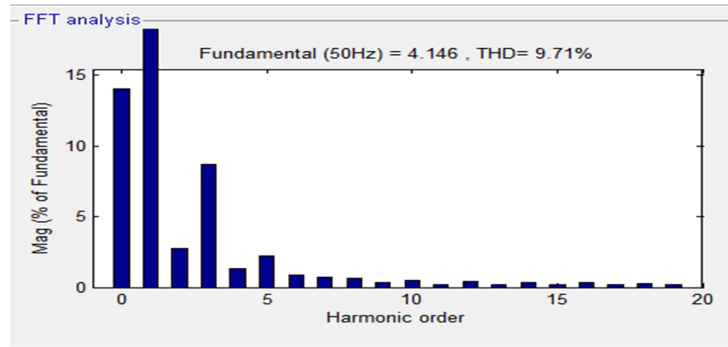


Fig. 11 FFT analysis of C-L filters

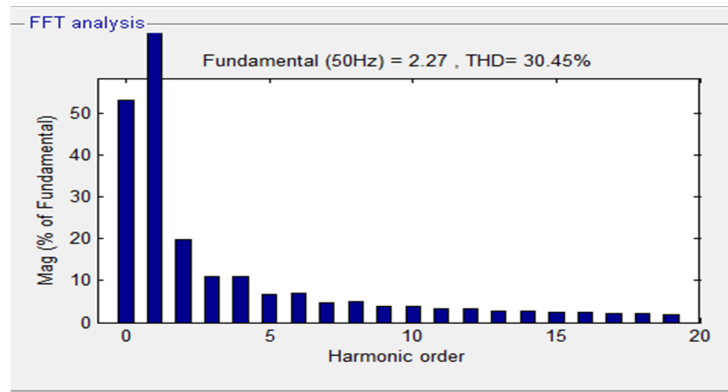


Fig. 12 FFT analysis of LC-C filters

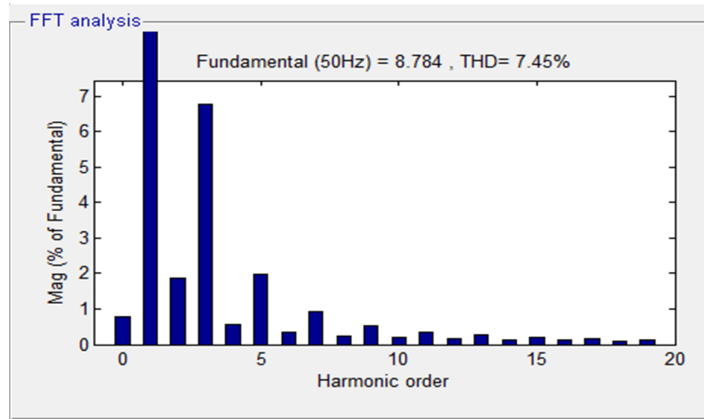


Fig. 13 FFT analysis of C-LC filters

The THD has a null value for a pure sinusoidal voltage or current.

TABLE I. WITH DIFFERENT FILTER THD VALUES

S.NO	Filter Type	THD (DC)	THD (AC)
1	C-L	0.603	9.71%
3	LC-C	11	30.45%
4	C-LC	0.523	7.45%

As per experimental analysis of single phase battery charger with different filters to reduce the harmonic effects on DC and AC voltage, we find out the different values of THD by simulation as shown in Table.1. When the tupe of filter is changing the harmonic values also changing in AC and DC voltage. From simulation results we found that the Capacitance (C) filter is more efficient to remove the harmonics in DC voltage and LC filter is more efficient to remove harmonics in reverse AC voltage. By using these filters the power quality in single phase battery charger in improving.

From above experimental analysis we have seen the impact of LC filter on output voltage and impact of Capacitance filter on DC voltage.

## VI. CONCLUSION

This paper studies the use of inductance (L) and Capacitance (C) to reduce the harmonics emission of single phase mobile/laptop charger. The modified circuit is simulated and thus obtained results are without harmonics in AC and DC .In this paper we simulated the single phase Battery charging process and analyzed the impact of harmonics and the methods to reduce the harmonic effects. The C-LC filter is more effective filter to reduce the Harmonics from reverse AC and DC voltage.

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