STUDY OF BATTERY CHARGER'S EFFICIENCY AND ITS IMPROVEMENT

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Abstract—**This paper presents an analysis of different battery chargers or power supplies in the market and its efficiencies. The study involves the usage of power supplies from different companies that exists in Malaysia either from the phone's manufacturer or fake charger that is sold in market. This analysis is to determine the reliability and the effectiveness of the normal type of power supply AC adapter used in daily life in Malaysia. Since most of the power supply is a switched mode power supply, the second part of this paper will illustrate on how to improve its efficiency (power factor and harmonic distortion). Efficiencies here are related to voltage, current, power factor, and total harmonic distortion. However, this paper is only specified in the study of active power filter to minimize the harmonic distortion and its power factor. Active filter is famous in harmonics mitigation as well as reactive power compensation, voltage regulation, load-balancing and load balancing. The results of Total Harmonic Distortion and Power Factor and its operation were examined with MATLAB.**

Keywords-component; Switched-Mode Power Supply (SMPS); Efficiencies; Power Factor Correction; Total Harmonic Distortion (THD)

I. INTRODUCTION

Switched Mode Power Supply (SMPS) is used in many types of electronics' application. Since there are many types of SMPS in Malaysia, the efficiencies of the product also could vary based on the components in each SMPS. The manufacturers in Malaysia for SMPS are such as NOKIA, Sony Ericsson, and SAMSUNG while the fake SMPSs are excessively plentiful in the market. There are several types of SMPS battery charger such as travel adapter and Multicharger. Generally the output voltage of the chargers is in the range of 5 to 12 Volts DC. But some local-made chargers or fake chargers give an output voltage beyond this level. Most people do not bother much about these technical details and just connect the phone to the supply without knowing whether the cellphone is getting exposed to conditions which are beyond the permissible limits. This might actually reduce the life of the cellphone or the battery.

SMPS function is to rectify the AC line to convert to DC line before transformer stepping down the voltage to the acquired voltage[1]. SMPS in battery charger is an AC-DC converter which converts single phase ac voltage from supply to dc voltage output. The rectifiers convert the AC sinusoidal voltage to DC voltage and a non-sinusoidal line current because of interruptions of non-linear input characteristic [1, 2]. The characteristic behavior of non-linear loads is that they draw a distorted current waveform even though the supply voltage is sinusoidal. Most equipment only produces odd harmonics but some devices have a fluctuating power consumption, from half cycle to half cycle or shorter, which then generates odd, even and interharmonic currents. The current distortion, for each device, changes due to the consumption of active power, background voltage distortion and changes in the source impedance. This interruption is known as harmonic distortion. The existing of harmonic distortion will affect and limit the power factor of the supply thus reduce the efficiencies. This inefficiency could damage the battery Lithium Ion and this has gained many attentions to discover for the best SMPS circuit that has the lowest harmonic distortion[3].

From P.D Ziogas proposal in 1990 stated that to reduce the harmonic distortion, passive and active filters could be used. Power factor correction (PFC) is becoming a very important field in power electronic world[4]. Adding more generating capacity to the world's electrical companies due to higher demand recently is very costly and would consume additional resources. One method of using extra power capacity is to use the AC power more efficiently through the widen usage of power factor correction (Brown, 1994). The common Active Power Filters (APFs) is the combination of power electronics circuit design that construct from power switching devices and passive energy storage element like inductors and capacitors. The functions of this element used for controlling the current harmonics in supplying networks at the low to medium voltage distribution level or for reactive power[5].

There are three distinct types of Active Power Filter which are shunt active power filter, hybrid active filter and fuzzy active power filter[4]. This filter functions as a strain to reduce the harmonic distortion. With this active power filter installed, the resulting total current drawn from the AC single phase will be sinusoidal. Ideally the APF can generate just enough reactive and harmonic current to counter the harmonics without fundamental frequency reactive power concerns.

II. SWITCHED MODE POWER SUPPLY

A. Operation Mode of Switched-Mode Power Supply for Phone Battery Charger

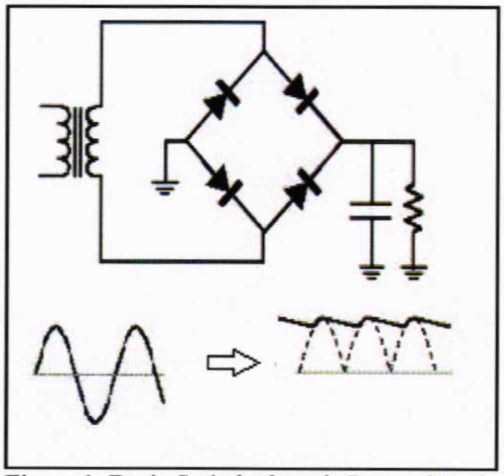


Figure 1: Basic Switched mode Power Supply

The AC supply (230V) first enters through rectifiers and line filters. Rectifiers used usually a full wave bridge rectifier while the line filters in the charger[6]. Line filters are the electronic filters placed between an electronic device and an external line to attenuate the electromagnetic interference (EMI) effect. Transformer lower the voltage to the required voltage based on the application. Pulse transformers are categorized into two categories – power and signal transformers. The one used here is a power transformer. It reduces the voltage level of the input power and gives a low voltage power that is exactly required to charge the battery. Output DC voltage from rectifier circuit passes through another filter to smooth the wave before DC voltage is supplied to the battery. Controller works as a feedback to compare the output voltage with the reference voltage. Optocoupler is generally used as the feedback[7].

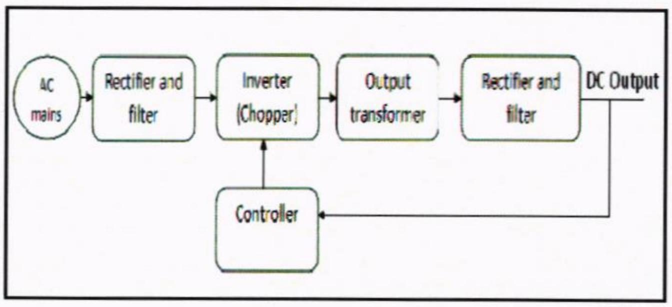


Figure 2: Operation of Switched Mode Power Supply

B. Total Harmonic Distortion

Harmonic Distortion is caused by the nonlinear loads that alter the current waveform to be a distorted and not sinusoidal. The alteration of the sinusoidal wave to non-sinusoidal wave is because of multiple waveforms called harmonics[3].

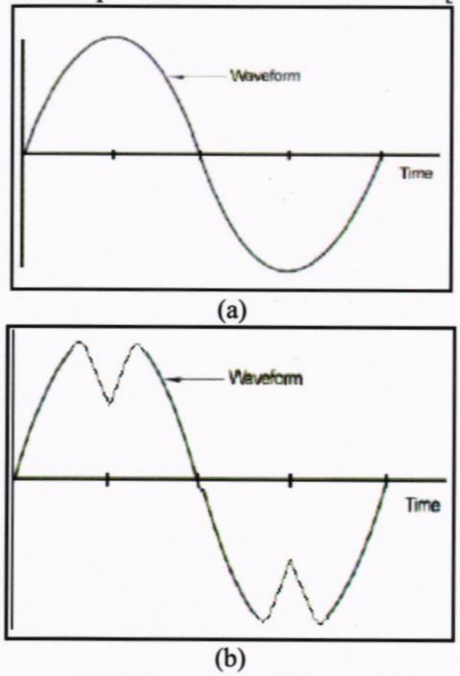


Figure 3: Ideal Wave (a) and Distorted Wave (b)

Total harmonic distortion, or THD, is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave. The triplen harmonics are defined as the most detriment harmonics. Triplen harmonic is the harmonic of multiple of 3 (ex. 3^{rd}, 9^{th}, 15^{th}, 21^{st} etc.).

$$\boxed{THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 \ldots + I_{13}^2}}{I_1}} \quad (1)$$

C. Power Factor

Power Factor is a number, which describes the deviation from the ideally desired condition of ac line current being proportional to ac line voltage and is defined as:

Power Factor (PF) = P / (Vrms Irms) (2) or
Power Factor (PF) = P/S (3)

Where
P = Real or Active Power in Watt
Vrms = RMS (root-mean-square) voltage
Irms = RMS (root-mean-square) current
S = Vrms x Irms in VA

Power factor is characteristic of alternating current (AC) circuits. The power factor value is between (0.0) and (1.0), the higher the number the greater and better the power factor. Therefore, the ideal condition for the system is to have a unity power factor which is 1[8].

D. Operation Mode for Shunt Active Power Filter

Shunt active power filter compensate current harmonics by injecting equal but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered a harmonic source.

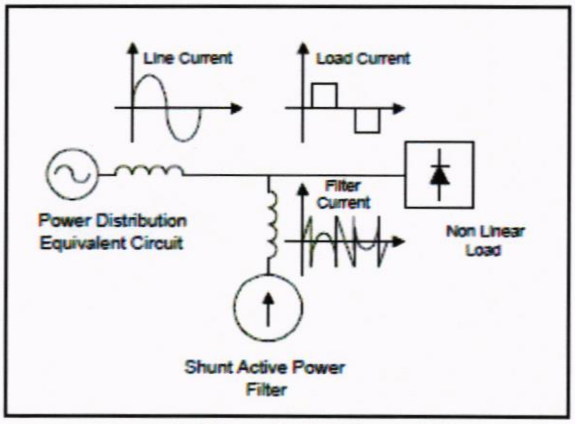


Figure 4: Shunt Active Power Filter

From Fig 3, Shunt active power filter inject compensating current so that the waveform will become sinusoidal again. Shunt active power filters are normally implemented with pulse-width modulated voltage source inverters. In this type of applications, the PWM operates as a current controlled voltage source. PWM circuit is used over a resistive power controller because of its efficiency, since the power loss is very minimal.

The load current is expressed as:

$$i_{load} = i_1 + i_h \quad (4)$$

Where i_1 is the line current while i_h is the harmonic current.

Active filter current is given as:

$$i_{af} = i_h \quad (5)$$

By applying KCL at point of common coupling:

$$i_s = i - i_{af} \quad (6)$$

Therefore, by combining equation (4), (5) and (6):

$$i_s = i_1 \quad (7)$$

Thus equation (7) proving theoretically that the supply current harmonics can be fully compensated with Active Power Filter (Shunt)

III. METHODOLOGY

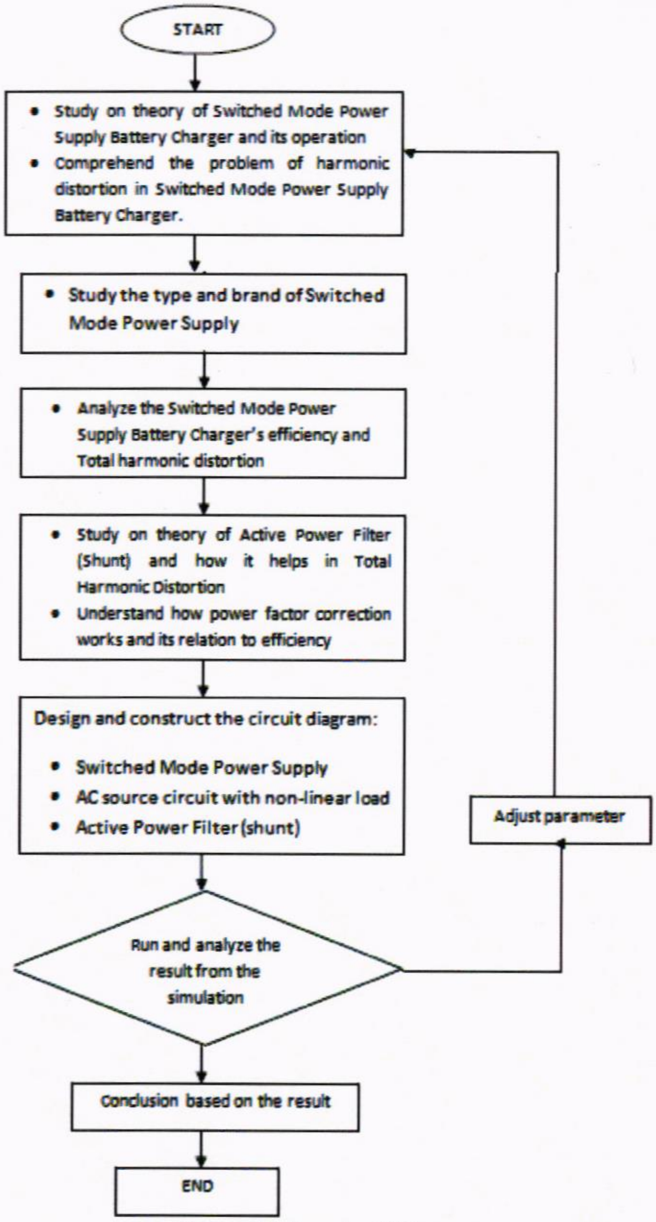


Figure 5:Flowchart Diagram

A. Analyze Switch Mode Battery Charger in the market

There are three types of original brand of Switched Mode Power Supply and 3 types of fake branded Switched Mode Power Supply were used which are Sony Ericsson, NOKIA, SAMSUNG, and fake of the branded respectively. The circuit for the switched mode power supply is as in Figure 6. The main objective of this analysis is to get its Total Harmonic Distortion, Power Factor, input/output current, input/output voltage and waveforms. The entire THD and power factor is arranged in the table to get the vivid view of general efficiencies of Switched Mode Power Supply Battery charger in Malaysia.

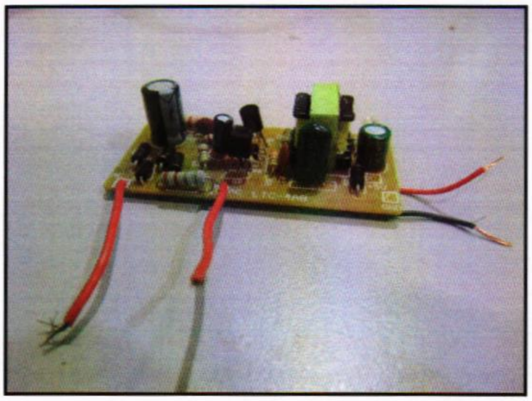


Figure 6: Hardware of Samsung Switched Mode Power Supply

B. Simulation Design

The general Switched Power Supply is connected to Active Power Filter see the affect of the filter. The non-linear load comes from the AC-DC converter that uses rectifier[4]. To make a shunt power filter the active power filter is connected in series with an inductor and then connected parallel with the diode bridge rectifier (AC-DC converter) as in Figure 7.

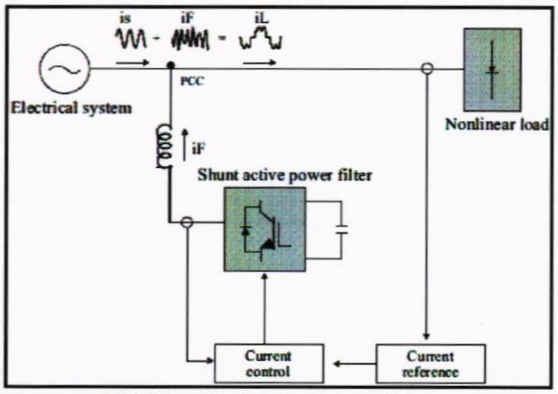


Figure 7: SMPS with Active Power Filter

IV. RESULT AND DISCUSSION

A. Hardware Analysis

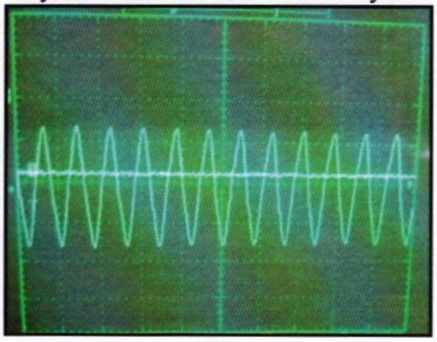
Charger (SMPS)	Rated Output		Measured Output		Total Harmonic Distortion(THD) (%)	Power Factor
	Current (mA)	Voltage (V)	Current (mA)	Voltage (V)		
Samsung (Original)	550	4.75	496.6	4.88	108	0.766
Samsung (Fake)	500	5	428.6	4.20	150	0.452
Sony Ericsson (Original)	550	5	520.5	4.85	118	0.676
Sony Ericsson (Fake)	600	5	440.4	3.90	145	0.544
NOKIA (Original)	350	5	380.4	4.88	109	0.778
NOKIA (Fake)	500	5	510.6	5.15	123	0.615

Table 1: With Load – NOKIA 6330 Battery (BL-5C)

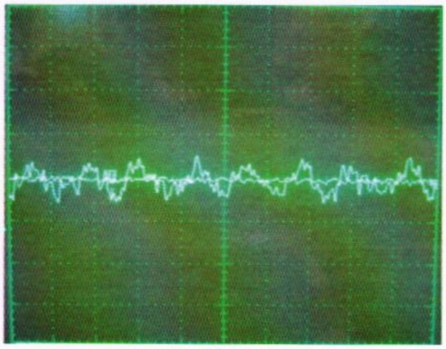
Charger (SMPS)	Rated Output		Measured Output		Total Harmonic Distortion(THD) (%)	Power Factor
	Current (mA)	Voltage (V)	Current (mA)	Voltage (V)		
Samsung (Original)	550	4.75	510.4	4.60	122	0.686
Samsung (Fake)	500	5	458.2	4.40	144	0.566
Sony Ericsson (Original)	550	5	492.4	4.74	102	0.590
Sony Ericsson (Fake)	600	5	488.0	2.90	164	0.462
NOKIA (Original)	350	5	334.2	4.96	103	0.650
NOKIA (Fake)	500	5	496.2	4.92	177	0.580

Table 2: With Load – NOKIA 705 Battery (NEBAE1)

The graphs in Figure 7 and 8 show the voltage waveform is also affected by harmonic distortion caused by rectifier.



(a)

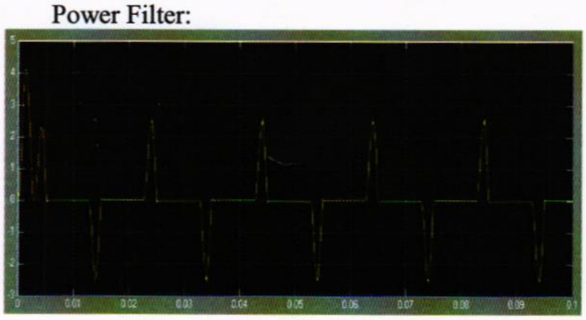


(b)

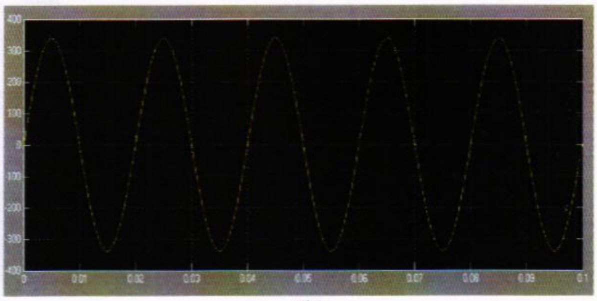
Figure 8: AC Voltage Input (a) DC Voltage Output (b)

B. Simulation Analysis

i) Basic Switched Mode Power Supply Without Active Power Filter:



(a)



(b)

Figure 9: AC Supply Current (a) and AC Supply Voltage (b) for circuit without Power Filter (Shunt)

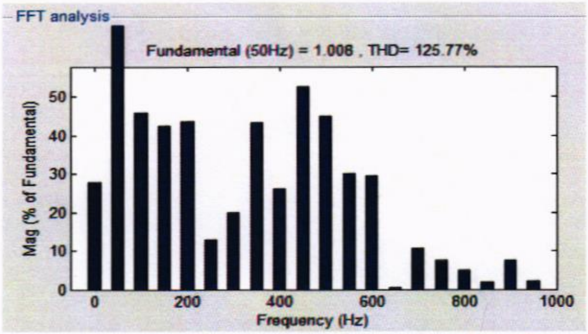
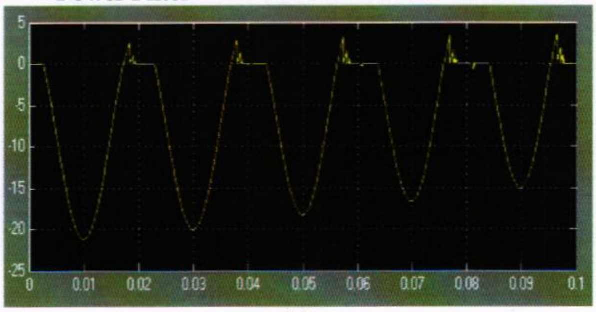


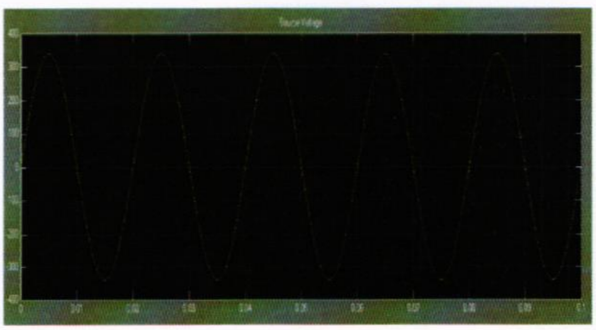
Figure 10: FFT analysis without Power Filter (Shunt)

$$\begin{aligned}\text{Power Factor} &= P/S\\ &= P/(P+jQ)\\ &= 0.835\end{aligned}$$

ii) Basic Switched Mode Power Supply with Active Power Filter



(a)



(b)

Figure 11: AC Supply Current (a) and AC Supply Voltage (b) for circuit with Active Power Filter (Shunt)

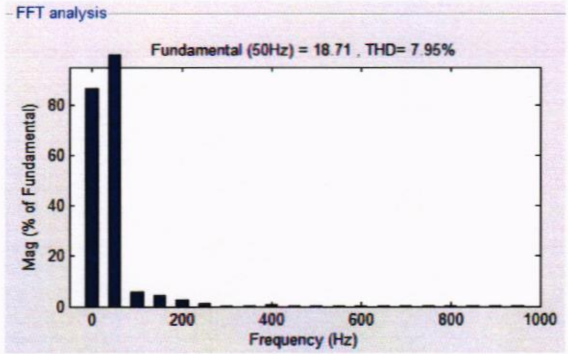


Figure 12: FFT analysis with Active Power Filter (Shunt)

$$\begin{aligned}\text{Power Factor} &= P/S\\ &= P/(P+jQ)\\ &= 0.987\end{aligned}$$

	Analysis			
	Hardware		Simulation MATLAB	
	BL-5C	NEBAE1	Without APF	With APF
Total Harmonic Distortion (%)	Average: 125.5	Average: 135.33	125.77	7.95
Power Factor (PF)	Average: 0.639	Average: 0.686	0.835	0.987

Table 3: Full Analysis and Results

From Table 3, the Power factor of the simulation with APF is increasing to almost unity (0.987) while the Total harmonic Distortion drops from 125.77% to 7.95%.

V. CONCLUSION

This paper presents the Study of comparisons of battery chargers efficiency in the market and also the way to improve its efficiency. From the result it shows that power factor and total harmonic distortion in the Switched-Mode Power Supply in the market are not really proficient. By using Active Power Filter (Shunt) the Total Harmonic Distortion can be reduced while the increasing the power factor to almost unity.

VI. ACKNOWLEDGEMENT

Firstly, I would like to thank my project's supervisor, En Mustafar Kamal Hamzah for his kind helps, supports and guidance in helping to complete this project. I would also like to thank En. Muhamad Nabil Bin Hidayat (Dr) for assisting me to finish this project. My gratitude also is to my family parents, family members and all friends for their supports, encouragements and also their warm prayers. Lastly, I would like to acknowledge all the lectures in the faculty who has helped me a lot throughout completing this project.

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