A Single Phase Ac-Dc Converter With Improved Power Factor And Harmonic Reduction

R. Navaneethan, E. Annie Elisabeth Jebaseel i

PG Scholar Department of EEE, Sathyabama University, 600119,Chennai, India,
Faculty, Department of EEE, Sathyabama University, 600119,Chennai, India
Email: navaneethaneee@gmail.com

Abstract: In this paper discussed about several issues regarding the analysis, design, modeling, simulation and development of Single Phase Ac-Dc Converter With Improved Power Factor And Harmonic Reduction with high frequency transformer isolation. The large harmonic input currents generated of such converters are well-known problems that can lead to voltage distortion and increased losses in distribution system.

Keywords:Single-Switch, Power Factor Correction, Power quality improvement, Total Harmonic reduction, Efficiency

1 INTRODUCTION

Most power conversion applications consist of an AC-to-DC conversion stage immediately following the AC source. The DC output obtained after rectification is subsequently used for further stages. Thereby an ac to dc converter has become an integral part of mostly all the electronic equipments. Mainly, it is used as an interface between utility and most of the power electronic equipments[1]. These electronic equipments also form a major part of load on the utility. Two factors that provide a quantitative measure of the power quality in an electrical system are Power Factor (PF) and Total Harmonic Distortion (THD). The amount of useful power being consumed by an electrical system is predominantly decided by the PF of the system. Generally, to convert line frequency ac to dc, a line frequency diode bridge rectifier is used. To reduce the ripple in the dc output voltage, a suitable filter capacitor and/or an inductor is used at the rectifier output[2]-[3]. But due to these reactive components, the current drawn by this converter is peaky in nature, very much differed from a sinusoidal shape. This input current is rich in lower order harmonics. Also, as power electronics equipments are increasingly being used in power conversion, they inject low order harmonics into the utility. Due to the presence of these harmonics, the total harmonic distortion is high when so many converters are put together in a huge electronic system. Additionally, the input power factor becomes poorer. Due to the disadvantages associated with low power factor and harmonics, utilities enforces (in some countries) harmonic standards and guidelines which will limit the amount of current distortion allowed into the utility. Looking into the serious effects generated by conventional converters, the simple diode rectifiers should not be used. There is a need to achieve rectification at close to unity power factor and low input current distortion. The challenges to be faced in the design of such AC/DC power supply are in achieving

- high power factor,
- low THD,
- high efficiency along with particular line and load conditions,
- high power density or reduced size,
- high reliability, and
- low system cost

2 POWER FACTOR CORRECTION

Power factor correction is the method of improving the power factor of a system by using suitable devices. The objective of power factor correction circuits is to make the input to a power supply behave like purely resistive or a resistor[4]. When the ratio between the voltage and current is a constant, then the input will be resistive hence the power factor will be 1.0. When the ratio between voltage and current is other than one due to the presence of non-linear loads, the input will contain phase displacement, harmonic distortion and thus, the power factor gets degraded.

$$PF = \frac{Power}{(V_{rms} * I_{rms})} = \frac{WATTS}{V.A} \longrightarrow \enspace \textcircled{1}$$

P is the real input power and Vrms and Irms are the root mean square (RMS) voltage and current of the load.
Disadvantages of having Low power factor

- Poor voltage regulation and large voltage drop
- Low efficiency
- Penalty from electrical department
- Large line loss
- Drags more current

Switched mode power supply: Power factor correction of non-linear loads.

A typical switched-mode power supply first makes a DC bus, using a bridge rectifier or similar circuit. The output voltage is then derived from this DC bus. The problem with this is that the rectifier is a non-linear device, so the input current is highly non-linear[5]. That means that the input current has energy at harmonics of the frequency of the voltage. This presents a particular problem for the power companies, because they cannot compensate for the harmonic current by adding capacitors or inductors, as they could for the reactive power drawn by a linear load. Many jurisdictions are beginning to legally require PFC for all power supplies above a certain power level. The simplest way to control the harmonic current is to use a filter: it is possible to design a filter that passes current only at line frequency (e.g. 50 or 60 Hz). This filter kills the harmonic current, which means that the non-linear device now looks like a linear load. At this point the power factor can be brought to near unity, using capacitors or inductors as

required. This filter requires large-value high-current inductors, however, which are bulky and expensive.

3 AC LINE CURRENT HARMONICS STANDARDS

Thus, a pure voltage or current sine wave has no distortion and no harmonics, and a non sinusoidal wave has distortion and harmonics. To quantify the distortion, the term total harmonic distortion (THD) is used. The term is the ratio of the harmonic components of voltage (or current) to the voltage (or current) of the fundamental.

$$HF \doteq \frac{I_H}{I_{s1}} = \frac{\sqrt{(I_S^2 - I_{S1}^2)}}{I_{S1}} = \frac{\sum_{N=2}^{\infty} I_{SN}}{I_{S1}} \longrightarrow \quad (2)$$

Where HF Is Harmonic factor

I_H Is rms value of all the harmonics combined

I_{S1} is the fundamental component

I_S is the rms value of input supply current

Considering the adverse effects of harmonic, a number of organizations have adopted standards that limit the magnitudes of the harmonic currents that a load is allowed to inject into the ac line[6]-[8].The US military was one of the early organizations to recognize these problems; and the very strict 3% limit on harmonics was initially adopted. The standards adopted by the IEC and IEEE are more recent, and are intended for conventional utility systems.

International Electro-technical Commission Standard 1000

The IEC 1000-3-2 standard covers a number of different types of low power equipment, with differing harmonic limits. It specifically limits harmonics for equipment having an input current of up to 16 A, connected to 50 or 60 Hz, 220 V to 240 V single phase circuits (two or three wire), as well as 380 V to 415 V three phase (three or four wire) circuits.

IEEE/ANSI Standard 519

In 1993, IEEE published a revised draft standard, IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters limiting the amplitudes of current harmonics. More strict limits are imposed on large loads than on small loads. The limits are similar in magnitude to IEC 1000, and cover high voltage loads (of much higher power) which are not addressed by IEC 1000. The Fig1 shows varoius IEEE standards of line current harmonics.
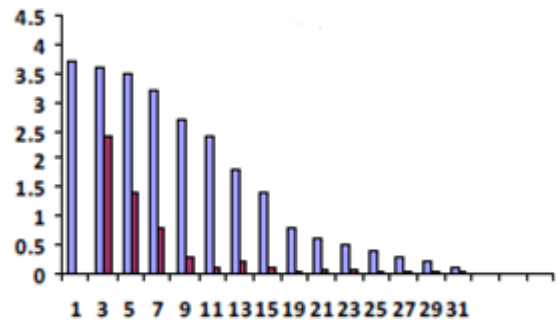

Fig.1. Standards of line current Harmonics

Active Shaping of Input (line) Current

By using a power electronic converter for current shaping, as shown in Fig. 2 it is possible to shape the input current drawn by the single phase bridge converter (rectifier) to be sinusoidal and also in phase with the input voltage. The choice of the power electronic converter is based on the following considerations: No need for electrical isolation between the input (dc) and output (dc) sides , the power flow is always unidirectional from the utility side to the equipment and the cost, power losses and size of the circuit used should be small. Fig. 3.shows the Harmonics in the input current of the rectifier.
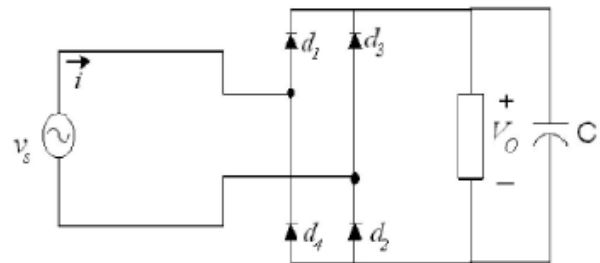

Fig.2. Standard bridge rectification of line current
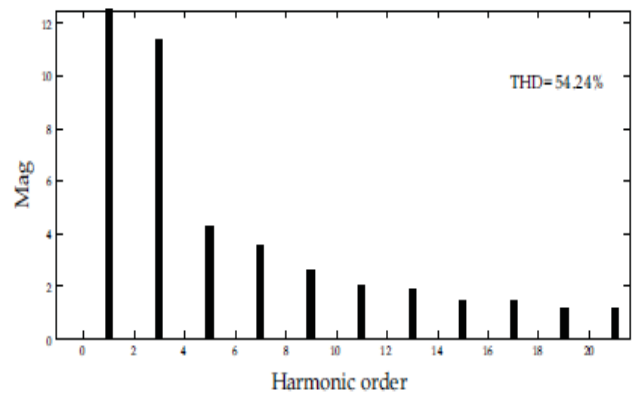

**Fig.3.** Harmonics in the input current of the rectifier.

4 SIMULATION CIRCUIT AND RESULTS

Digital simulation is done by using the elements of MATLAB Simulink and the results are presented here. The Simulink Diagram PFC And THD Correction In Single Phase AC- DC Converter is shown in Fig 4. The voltage and current measurement blocks are connected to measure the output voltage and output current. The scopes are connected to measure the driving pulse and voltage across the switch.
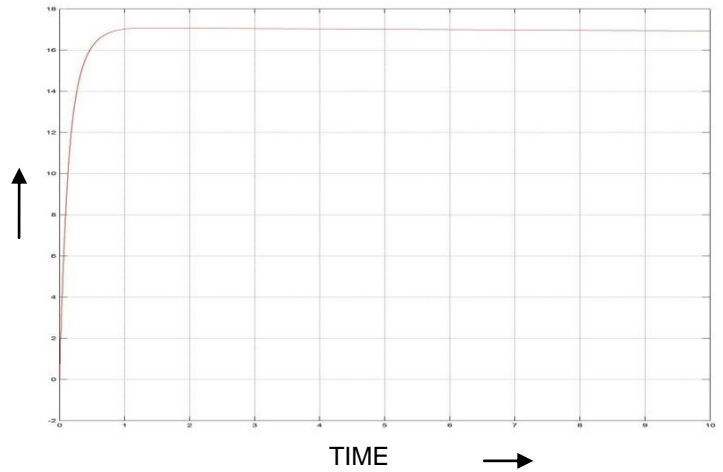
AC input voltage is shown in the Fig .5. The output voltage and output current is shown in the Fig. 6 & Fig. 7 resp. Fig. 8shows the THD correction level.
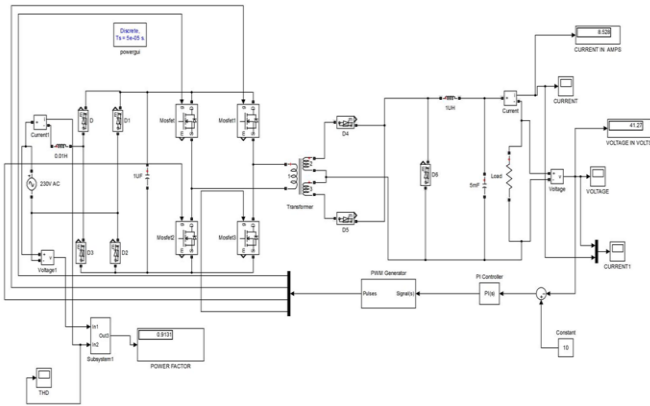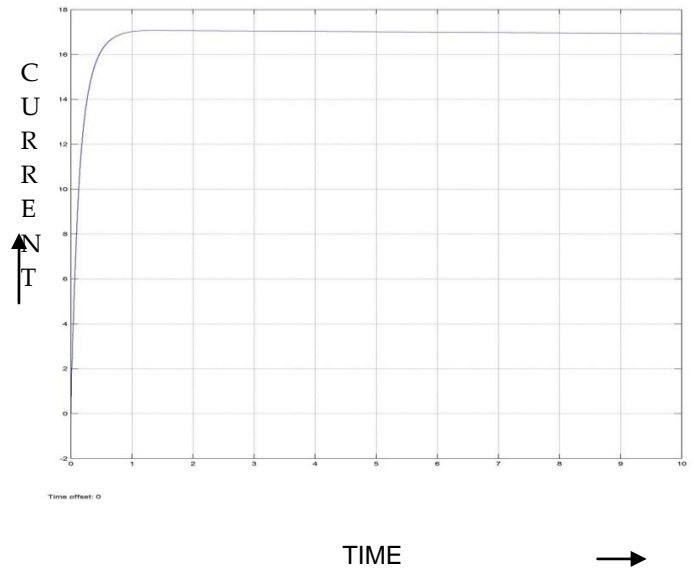

Fig.4 Simulink Diagram PFC And THD Correction In Single Phase AC- DC Converter.
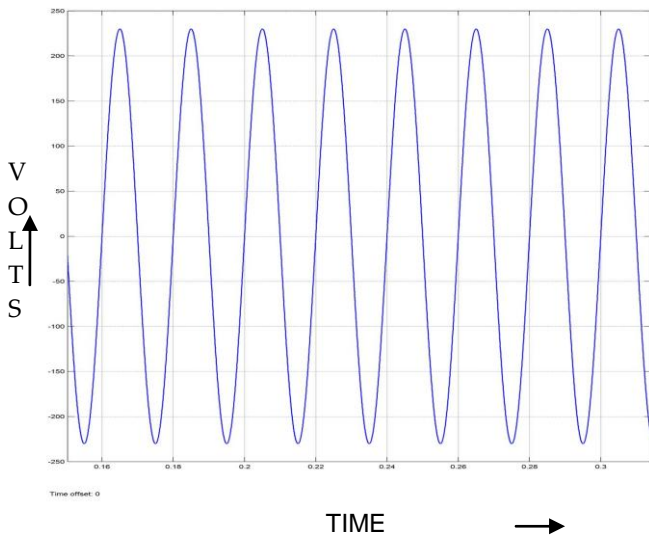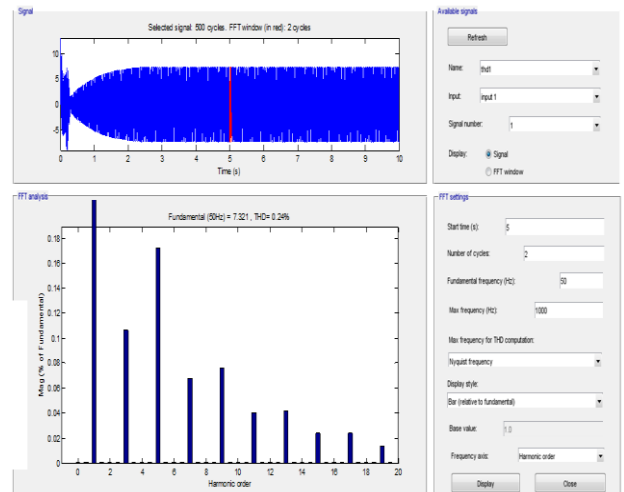

Fig 5 Input Voltage

Fig.6 Output Voltage

Fig.7 Output Current

Fig.8 THD Correction level

5 DESIGN SELECTION FOR SIMULATION

Selection of right converter for specific application is an important task for the users. The following are the few criteria to be considered in the selection of appropriate topology of the converter for a particular application.

V_{in}=230v

Frequency of PWM 1080 hz

$V_o = D(N_{21}/N_1)V_{in,}$

$N_{21}=N_{22}$

$L_0 = V_0(0.5-D)/f_s$

C_f=200nf

C_0= 24mf

L_0= 1.6mh

F_s= 50-100 hz

K_p= 0.1285 K_i=1.95

6 FUTURE DEVELOPMENTS

The HF transformer isolated AC-DC converters have been developed to a reasonably matured level and are extensively used in fraction of Watt to several kWs rating in power supplies, ASDs, etc. Apart from it, there are newer developments in these converters for improving their performance in terms of high level of power quality, high efficiency, and compact size. One of the new trends is soft switching technology to reduce the switching losses, which permits these converters to operate at further high switching frequency to improve dynamic response and to reduce the size of transformers and filter components by operating at higher frequency. The magnetic integration is used to integrate magnetic components in one single core and therefore to help in using higher flux density material. Another important trend is the sensor reduction, which has revolutionized these converters to reduce cost, component count and enhanced reliability

7 CONCLUSION

Most electronic equipment is supplied by 50 Hz or 60 Hz utility power, and in almost all of them power is processed through some kind of power converter. Usually, power converters use a diode rectifier followed by a bulk capacitor to convert AC voltage to DC voltage. Unless some correction circuit is used, the input rectifier with a capacitive filter circuit will draw pulsating currents from the utility grid resulting in poor power quality and high harmonic contents that adversely affect other users. Improvements in power factor and total harmonic distortion can be achieved by modifying the input stage of the diode rectifier filter capacitor circuit. Passive solutions can be used to achieve this objective for low power applications. With a filter inductor connected in series with the input circuit, the current conduction angle of the single-phase full-wave rectifier is increased leading to a higher power factor and lower input current distortion. With smaller values of inductance, these achievements are degraded. However, the large size and weight of these elements, in addition to their inability to achieve unity power factor or lower current distortion is achieved.

ACKNOWLEDGMENT

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