Simulation and Study of AC-AC Converter with Improved Power Quality

Prof. Sanjay R. Patel | Prof. Nigam K. Prajapati
[1](Electrical Engineering Department, GTU, Ahmedabad, India, sanjaypatel265@gmail.com)
[2](Electrical Engineering Department, GTU, Ahmedabad, India, nigamprajapati.ee@hcet.gtc.ac.in)

***Abstract*—Purpose of this paper is to simulate and study an "AC-AC Converter" with improved input power quality and its output parameters. Reduced Input current harmonics and enhanced input power factor are met by involving active front end converter. Output stability, repeatability and its real time control in dynamic situation were prime parameters to be designed. Power topology includes double power conversion, viz. AC to DC and DC to AC. A PWM control method is selected for both power conversions. In this paper, a full focus is applied to explain my design work related to simulation and study of an AC-AC converter topology along with a principle goal of improved power quality management. Content of this document is enriched by the way of adding suitably tabulations, graphics and schematics for the reader to easily digest.*

Keywords*— Pulse Width Modulation(PWM), SAF(Shunt Active Filter), Sinusoidal Pulse Width Modulation(SPWM), Total Harmonics Distortion(THD)

1. Introduction

Normally, various loads in industrial and domestic applications need electrical power in the form of dc or a variable/high frequency ac. These loads are mostly non-linear in nature. In addition to nonlinearity offered by loads, switching converters inherently contribute additional nonlinearity to the utility grid. Since utility grids offer electrical power by sourcing alternating sinusoidal voltage at 50 Hz, it is necessary to convert it by suitable power converter in required form. Unfortunately, input current drawn from source becomes either distorted or non-sinusoidal, depending upon a topology of front end of the converter and/or nonlinearity of load.

For understanding the issue, consider a 1 phase bridge rectifier with a non-linear load R and C in parallel as shown in Fig.1.When AC voltage is applied to the diode bridge, this voltage is rectified by the bridge, and the capacitor (C) charges to near the peak of the input AC voltage wave.

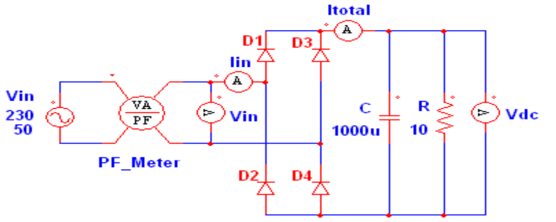

Fig.1

Fig.2 shows that the analysis of power factor and THD.

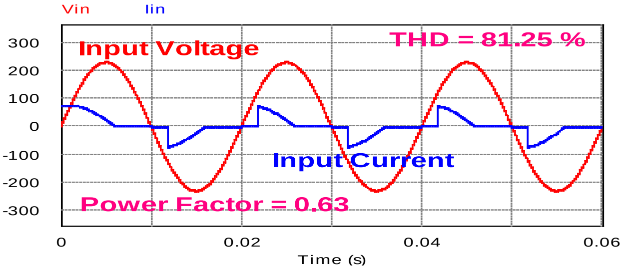

Fig.2

Fig.3 shows that, while converting utility ac power, source current must be approaching sinusoidal shape in order to minimize harmonic power reflected to grid. The deviation in current shape is a qualitative measure of harmonics of higher order other than the fundamental.

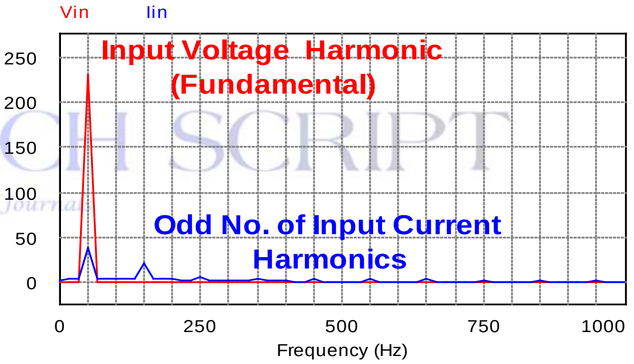

Fig.3

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2. Harmonics Reduction Techniques for Power Quality Management

A. Power Quality Management

A simpler and perhaps more concise definition might state: "Power quality is a set of parameters defining the properties of power quality as delivered to the user in normal operating condition in terms of continuity of supply and characteristic of voltage." The term Power quality is used to describe the extent variation of voltage, current and frequency in the power system. The variation of voltage and current can either be in terms of magnitude or distortion [1].

B. *Factor Deciding Power Quality*

Depending upon the following factors Power Quality is decided;

- Voltage Stability
- Continuity of Supplying of Power
- Voltage Waveform

C. *Harmonics Reduction Techniques*

A harmonic component in an AC power system is defined as a sinusoidal component of a periodic waveform that has a frequency equal to an integer multiple of the fundamental frequency of the system. Basically harmonic Reduction Techniques classified in to two main groups:

i. Devices for cancellation of existing harmonics
   - Filters
   - Mixing Single and Three Phase Diode Rectifier

ii. Grid friendly devices, which do not generate harmonics
   - Multi pulse Rectifier
   - PWM Rectifier

Table No.1 shows that the comparison of various techniques for selecting a particular method.

Table No.1

	Harmonic Reduction Techniques			
Parameters	**Filters**	**Mixed Single and Three-phase Non-linear load**	**Multiples Rectifier**	**PWM Rectifier**
Power Factor	Unity	Not Unity	Nearly unity	Unity
THD	Nearly 5%	Above 5 % (7 to 11%)	depends on no. of pulse rectifier	Below 5 %
Power Flow	Conventional	Conventional	Conventional	Bi-Directional
Efficiency	High	Low	Low	High
Voltage Drop	Low	Higher	Higher	Very Less
Control strategy	Complex	NIL	NIL	Simple
Switching Losses	High	NIL	NIL	Low
Practical Implementation	Easy	Complex	Easy	Complex
Harmonic content of Input current	Not Present	Present	Present	Not Present

3. SIMULATION & RESULTS

For the reduction of harmonics PWM method is the better solution.

A. *Controlled AC to DC converter:*

Fig.4 shows an active single phase AC to DC converter for a nonlinear load having R and C in parallel. **Circuit Operation:** Circuit diagram consists of 4 IGBTs, which form a full bridge, the input inductance and the capacitor at the output. IGBTs are triggered by applying pulse width modulated signals. Using a bipolar PWM switching strategy; this converter may have two conduction states [2]:

I. Transistors T1 and T4 in the on-state and T2 and T3 in the off-state;

II. Transistors T2 and T3 in the on-state and T1 and T4 in the off-state.

In this topology, the output voltage V_0 must is higher than the peak value of the ac source voltage, to ensure a proper control of the input current.

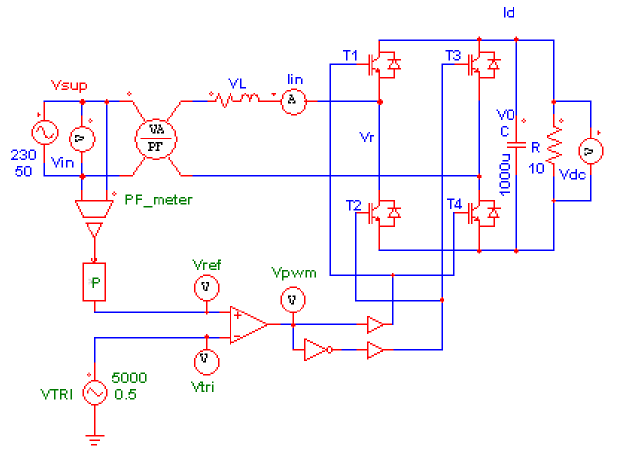

Fig.4

PWM rectifier with IGBTs is now simulated for its input current and results for THD, Power Factor and FFT analysis are shown in Fig.5

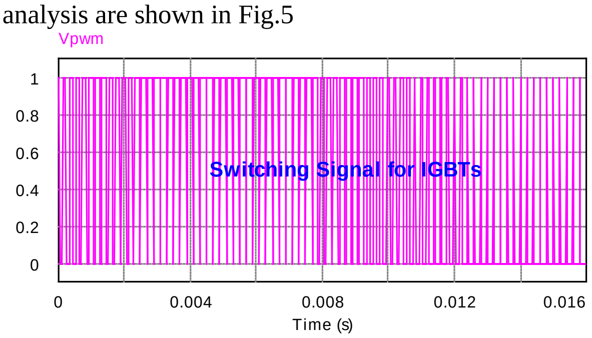

Fig.5

The input current shape approaches a sine wave and simulator shows values for current harmonics and Power Factor as mentioned, which is shown in the Fig.6.

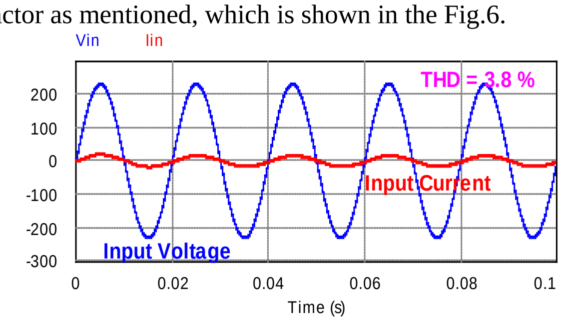

Fig.6

It is to be noted that a Power Factor is approximately unity and no higher order odd current harmonics are present,which is shown in the Fig.7.

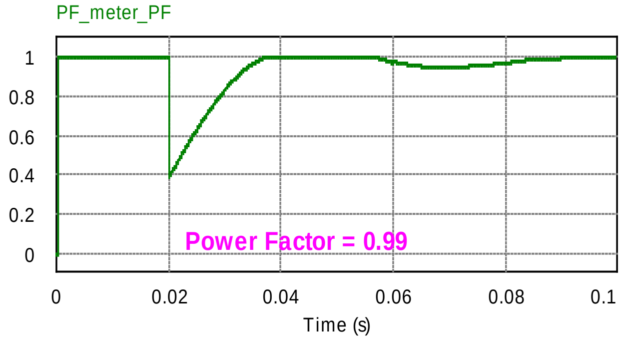

Fig.7

B. Single Phase DC-AC Inverter

Fig. 8 shows the model of single phase full bridge DC-AC converter is made with all the parameter are assumed. A unipolar SPWM technique is used for a biasing of IGBTs. Input reference signal of comparator 2 is 180^0 out of phase with respect to reference signal of comparator 2.Primary of the Step-up transformer is connected at output of the Inverter and secondary side load is connected.

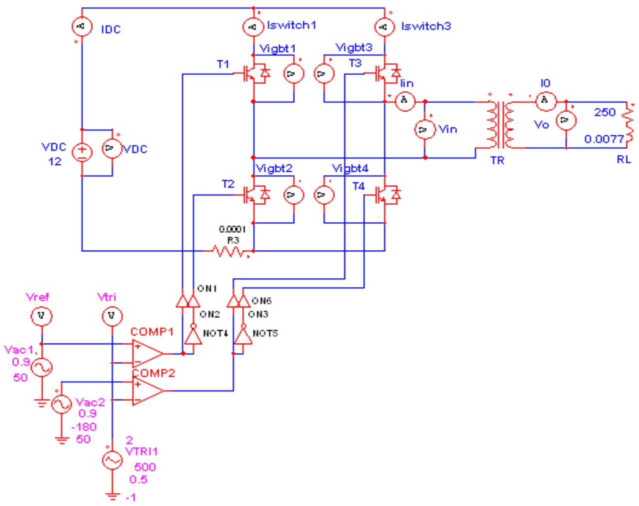

Fig.8

In the Fig.9 shows that the output waveform of single phase DC-AC inverter.

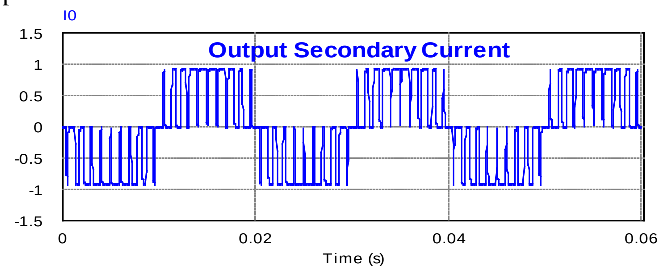

Fig.9

C. Three phase AC-DC converter:

Fig.10 shows the fully Current Controlled Three Phase AC-DC Converter using Bipolar SPWM technique (refer Ch-4).Resistive load is connected across capacitive load at output. For smooth waveform of input current and output voltage proper filtering is used at input and output.

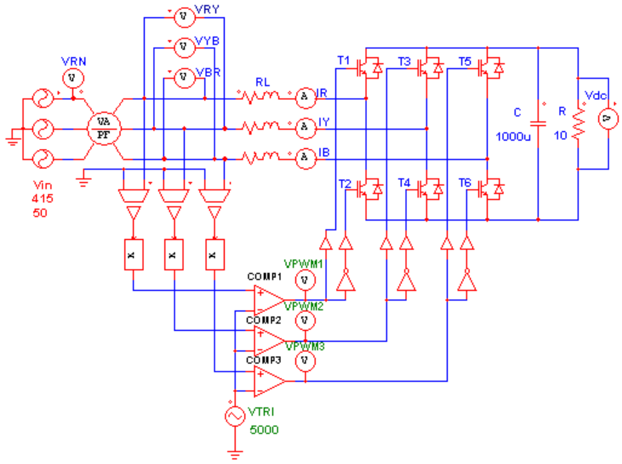

Fig.10

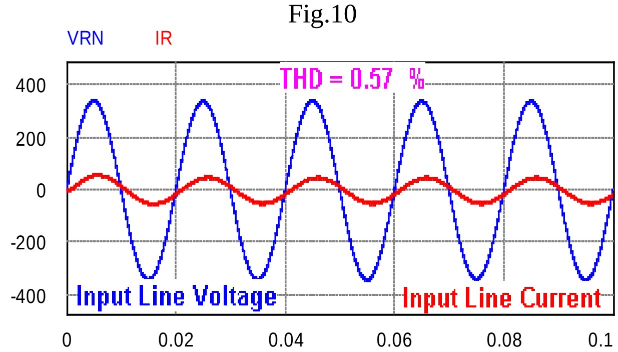

Fig.11

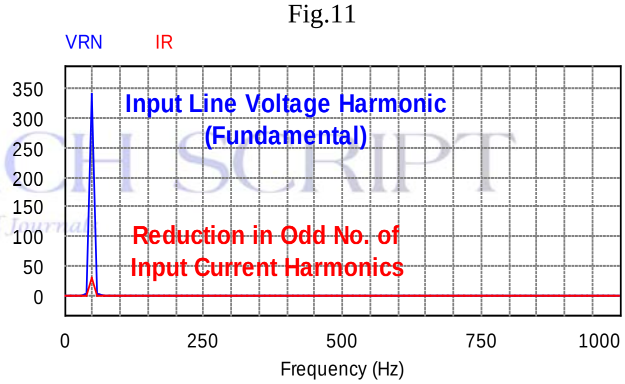

Fig.12

D. Three phase DC-AC Inverter:

Consider a three phase full bridge DC-AC inverter as shown in Fig.13.

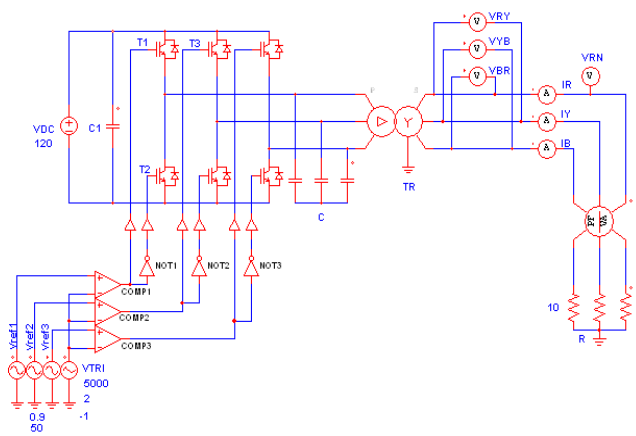

Fig.13

To obtain a set of balanced line-to-line output voltages, the switching sequence of switches S_1-S_6 should produce a sequence of pulses whose summation at any given time is zero. Filter is widely used in power electronics to reduce harmonic components at the output waveform. It is also used for smoothing the voltage wave of a load fed from a rectifier in reducing the harmonic content of an inverter output , preventing unwanted harmonic component being reflected into AC system and eliminating RF interference. Output of the inverter is a "chopped DC voltage with zero DC components" [6]. In certain types of application, "high purity" sine wave output is required such as UPS, which is shown in the Fig.14.

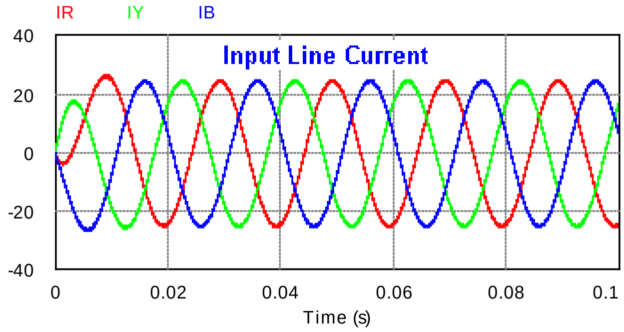

Fig.14

Also shows in the Fig.15 the Simulation Results for THD, Power Factor and FFT analysis.

Total Harmonic Distortion, THD: A measure of closeness in shape between a waveform and its fundamental component [5].

$$THD = \frac{1}{V_1}\sqrt{\sum_{n=2,3,\ldots}^{\infty} V_n^2} \times 100$$

$$= \frac{1}{230}\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + V_6^2}$$

=0.004381 100

= 0.43%

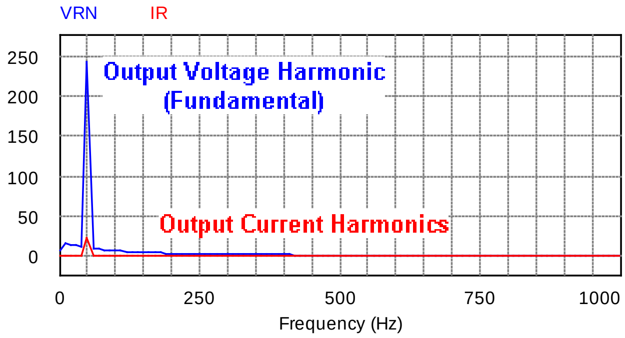

Fig.15

4. Conclusion

By simulating and real time implementation the no. of harmonic order are very high. This is still issue for researcher to found the harmonic reduction techniques for this converter. A novel experiment was also carried out to realize a heater power supply at lower rating with "Uncommon AC to AC converter topology". An IGBT based true bi-directional AC switch is operated by PWM control to stabilize rms value of output voltage. Main focus of this work is on the insertion of harmonics for very high order. Without aiming any mitigation method, it is shown that distortion of mains current at high frequency in repeated order generates so many harmonics.

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