Harmonic Analysis of AC-DC Topologies and their Impacts on Power Systems

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ABSTRACT

Power Electronic Converters are commonly used in different applications because of high efficiency and low cost. Due to latest advancement in semiconductor devices it is difficult to draw the boundaries for applications of power electronic topologies. These topologies are variable structure systems and generate harmonics during the operation which will affect the power quality when are connected to system network.

Rectifier is a big family of converters and used when ac-dc conversion is needed. These converters are widely used in distribution system. Therefore, it is necessary to predict the harmonic levels of these converters and also observe their impacts on system network.

Pakistan now days facing serious energy crises specially, in power sector due to increase in load demand. To bridge the gap between load demand and generation of electricity, various steps are taken by power companies and government. The steps include the up gradation of existing power plants, generation of power from rental power plants, installation of renewable power sources, taking different steps of demand side management etc. But efforts of power companies on power quality is still lacking.

This research work focuses on power quality of the system network. In this work, harmonics of single phase and three phase full bridge diode rectifiers are analyzed by using the fast fourier transform method of MATLAB. The effects of harmonics on the system network are also discussed.

Key Words: AC-DC Converters, Harmonic Analysis, Non Linear Loads, Power Quality.

1. INTRODUCTION

AC-DC converters also referred as rectifiers are classified into two main categories i.e. controlled and uncontrolled rectifiers. In an uncontrolled rectifier, the dc output is always remain constant if ac input voltage is constant. These converters are classified according to their input supply and the way the diodes are connected. They are half wave, full wave bridge type and full wave centre tapped transformer type [1-5].

Rectifiers are widely used in non linear loads which are connected with distribution systems. The distribution system plays vital role in the power system network, which carries electricity from the transmission system and delivers it to various types of consumers. Many types of non linear loads such as, UPS (Uninterruptible Power Supply) units, discharge lamps, television sets, computers, fax machines, ferromagnetic devices, arc furnaces, energy savers,

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fluorescent lamps, and battery chargers are generally connected with system network [3-8].

Due to these nonlinear loads, harmonics are generated in the system network, which leads to affect the power quality of the system [3-8]. Due to switching of these nonlinear loads, power quality of the system network will be affected. Non-linear loads generate harmonics and produce voltage distortion. The main problems associated with power quality such as voltage sags and swells, transients, frequency variation and harmonics [3,6-7,9-13].

Pakistan is a developing country and its growth in industrial, commercial and, as well as, in domestic sector, has enhanced load so tremendously that the demand on power sector has been increased to such a level that the Pakistan is facing severe power shortage [14]. It is an alarming situation of energy crisis in Pakistan. Because of this short fall, load shedding is inevitable and the severe load shedding has badly affected the economic growth of the country.

In Pakistan, the rate of nonlinear loads is increased so tremendously by different consumers during the last couple of years. The rate of use of UPS (especially local made) is increasing rapidly due to load shedding. On the other hand power companies launch the projects on demand side management in which the incandescent lamps are replaced by energy savers.

The effect of generation of harmonics of these loads is more significant when operating in large numbers in distribution system [4, 6-7, 13].

Therefore, this research work hence focuses the issues of power quality and presents the results of harmonics of single and three phase uncontrolled rectifier circuits used in various nonlinear loads. The effects of harmonics on system network are also discussed.

2. HARMONICS

A harmonic is a sinusoidal component of a complex wave or quantity having a frequency that is an integral multiple of the fundamental frequency [3, 6, 13, 15]. Any distorted wave which is neither pure sine wave nor leveled dc will consist of harmonics. The word complex wave includes all the repeatating waveforms which are not sinusoidal. The second harmonic has a frequency of twice the fundamental; the third harmonic frequency is three times the fundamental frequency and so on. Harmonics are classified as odd and even harmonics. If a complex wave has half wave symmetry that is the negative half of wave is a reproduction of positive half, it consist of only odd (third, fifth, etc.) harmonics and such wave form has no any dc component. Similarly, if a complex wave does not have half wave symmetry, it has even harmonics (i.e. second, fourth, etc.) and may also consist of odd harmonics. Therefore a complex wave consist of different harmonics, having in general, different amplitudes, different frequencies and are out of phase from one another.

The harmonics are determined by the method of Fourier analysis. General expression for Fourier series, periodic function f (t) of any complex wave over the period of 2π can be written as follows:

$$f(t) = a_o + \sum_{n=1,2,...}^{\infty} (a_n \, Cos \, n\omega t + b_n \, Sin \, n\omega t) \quad (1)$$

Where a_o is the DC component of the original wave, (a_n Cos nωt + b_n Sin nωt) is the n^{th} harmonic of the function

The values of a_o, a_n and b_n can be determined by the following relations.

$$a_o = \frac{1}{2\pi} \int_0^{2\pi} v_L(\omega t) d\omega t$$

$$a_n = \frac{1}{\pi} \int_0^{2\pi} v_L(\omega t) \, Cosn \, \omega t \, d\omega t$$

$$b_n = \frac{1}{\pi} \int_0^{2\pi} v_L(\omega t) \, \text{Sin} \, n \, \omega t \, d\omega t$$

Equation (1) further can be given as under:

$$f(t) = a_o + \sum_{n=1,2,...}^{\infty} (c_n \, Sin\,(n\omega t + \phi_n) \quad (2)$$

Where $C_n = \sqrt{a_n^2 + b_n^2}$, and $\phi_n = \tan^{-1}\frac{a_n}{b_n}$ C_n is magnitude of n^{th} harmonic component and ϕ_n is phase angle of the nth harmonic component

3. SIMULATION MODELS OF RECTIFIERS

The simulation models of uncontrolled rectifiers are implemented in MATLAB/Simulink software. The software versions are mentioned as under:

MATLAB	7.5
SIMULINK	7.0
SIMPOWER SYSTEMS	4.5

The simulation model of single phase rectifier is given in Fig. 1. The input ac voltage is converted into dc output voltage (Vdc) with the help of four diodes.

The simulation model of three phase full bridge rectifier is given in Fig. 2. The three phase power supply is obtained by connecting three single phase ac voltage sources. Three sources are 120 degrees are apart to each other. The three phase circuit consists of six diodes is masked under subsystem (Universal bridge).

The powerful tool of SIM power systems in both circuits are used to analyse the harmonics.

4. RESULTS AND DISCUSSION

The performance of converters was simulated in time domain as well as frequency domain. Parameters for the simulation of converters are given in Table 1.

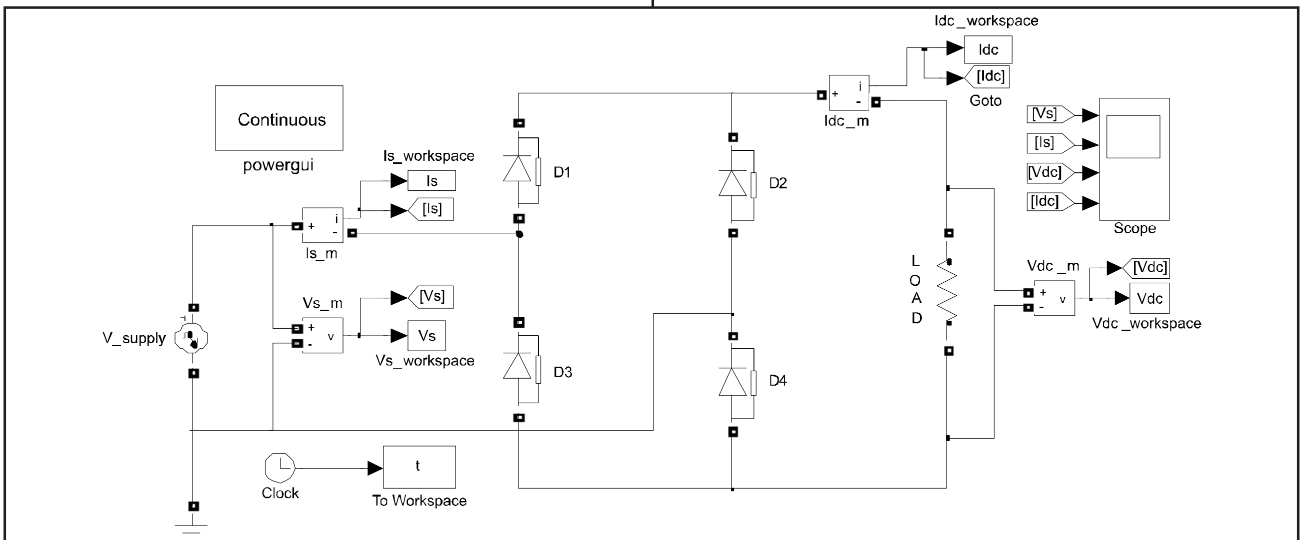

FIG. 1. SIMULATION MODEL OF SINGLE PHASE FULL BRIDGE RECTIFIER

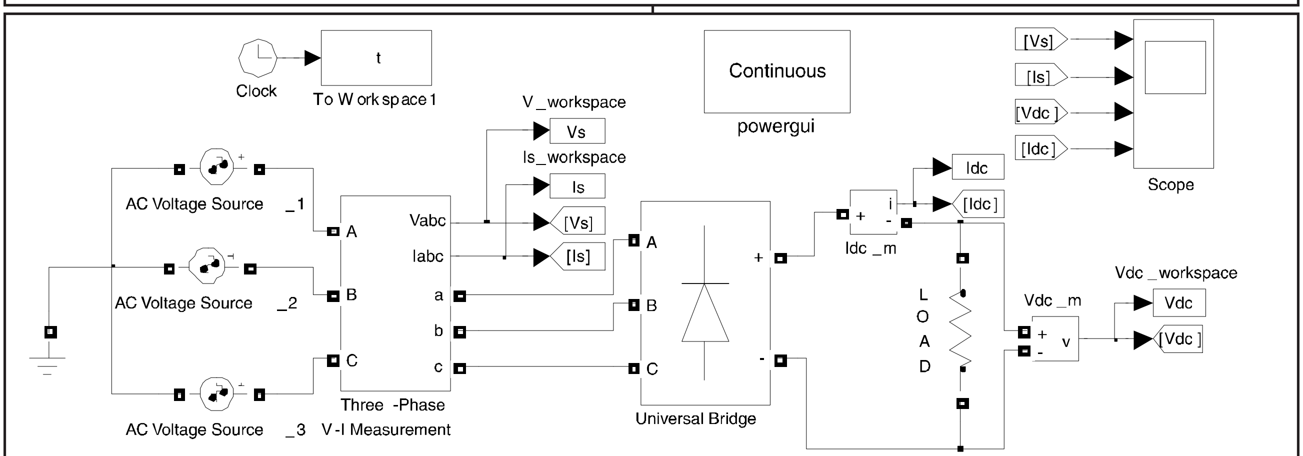

FIG. 2. SIMULATION MODEL OF THREE PHASE FULL BRIDGE RECTIFIER

The supply voltage, load voltage and load current of single phase full bridge converter with resistive load is shown in Fig. 3.

Similarly, the line voltages, line current, load current and load voltage of three phase full bridge converter with resistive load is given in Fig. 4.

TABLE 1. PARAMETERS OF SINGLE AND THREE PHASE RECTIFIERS

Parameter Name	Symbol	Value
For Single Phase Rectifier		
Input Voltage	V_supply	125V
Load Resistance	R	10Ω
Supply Frequency	f	50Hz
For Three Phase Rectifier		
Load Resistance	R	10Ω
Supply Frequency	f	50Hz

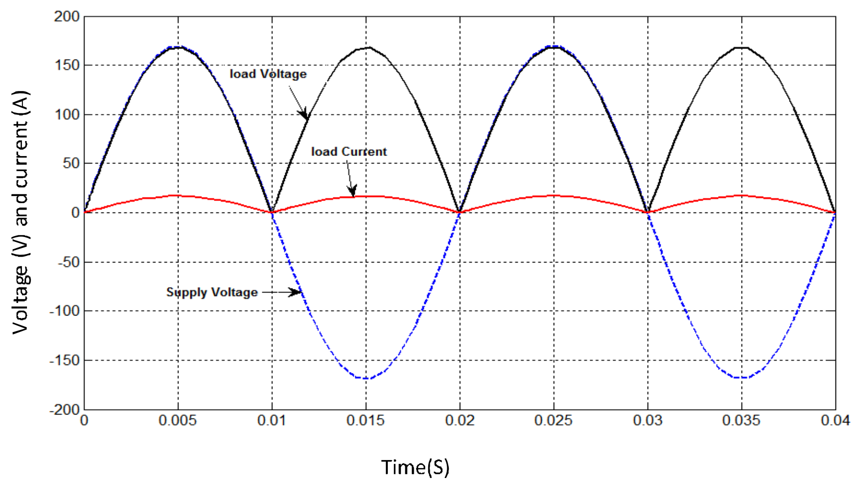

FIG. 3. WAVEFORMS OF SINGLE PHASE FULL BRIDGE CONVERTER

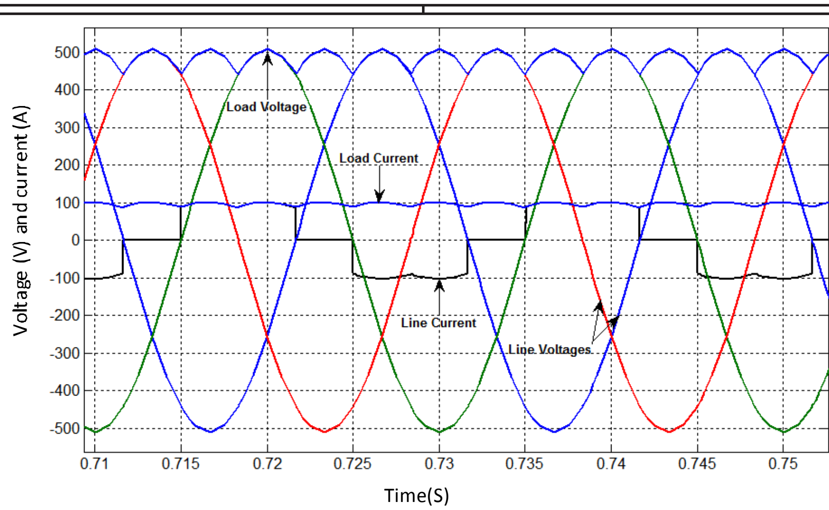

FIG.4 WAVEFORMS OF THREE PHASE FULL BRIDGE CONVERTER

The harmonics of single and three phase full bridge rectifiers are analyzed using the FFT (Fast Fourier Transform) function of MATLAB.

The simulated result of the harmonics of current of single phase full bridge rectifier is shown in Fig. 5. This type of converter contains even harmonics because there is no any half wave symmetry. Such converter has also dc component. Fig. 6 presents the harmonic order profile of input current of three phase full bridge rectifier. The negative cycle of input current as shown in Fig. 4 of such converter is similar to positive half cycle that is why it has half wave symmetry which contains only odd harmonics.

It is clear from the simulated results; these types of converters generate harmonics. The consumers of power system network when operating in large numbers of power electronic converter based loads, they inject harmonics in distribution networks. The adverse effects of the harmonic distortion will lead to the problems of power quality. These harmonics overloaded the neutral conductors and transformers, causing additional losses and reduced power factor.

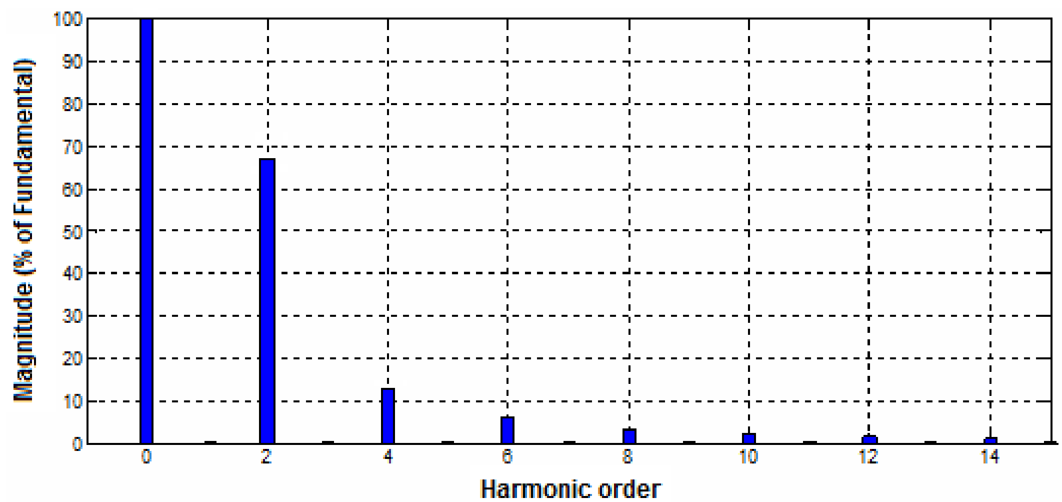

FIG. 5. HARMONIC SPECTRUM OF SINGLE PHASE FULL BRIDGE RECTIFIER

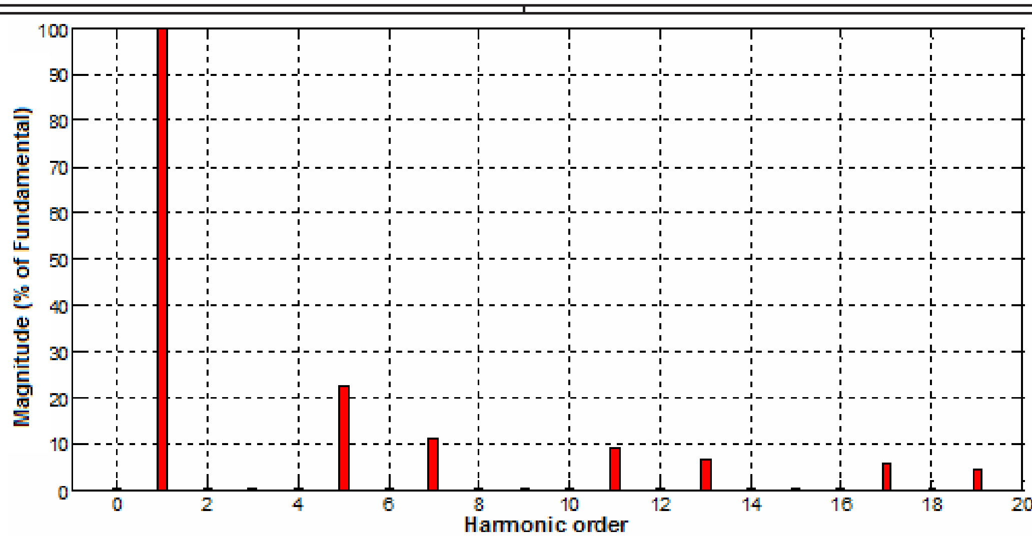

FIG. 6. HARMONIC SPECTRUM OF THREE PHASE FULL BRIDGE RECTIFIER

The line current harmonics lead to voltage distortion due to line impedance. When they reach at the distribution transformers may increase the hysteressis and eddy current losses and heat up the transformer due to higher frequencies of harmonics. Furthermore, the voltage distortion also produces the voltage regulation problems of various consumers. In the end, these effects can add up and cause larger issues to the entire power system.

In our country the design of distribution system may differ, e.g. in some cases the length of 11kV feeder is very large. At present, in our country the conventional instruments are used by various companies for checking only the amount/quantity of voltage and current and not focusing the other parameters which affect the power quality. Therefore it is necessary for our power supply companies to pay attention on the issues of power quality.

5. CONCLUSIONS

In this research paper, the work was carried out on AC-DC converters and their impacts on power system network. The simulation models of single phase and three phase full bridge ac dc converters developed and analyzed with MATLAB software. Harmonic analysis of ac dc converters was investigated. The main issues of power quality are also mentioned. An important aspect of this work is to lay foundation to carry further applied research in order to ideally improve the national power system by increasing its reliability, and improving its efficiency and power quality. Certainly it needs indigenous effort and not merely rely on the results of foreign environment.

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