24 PULSE AC-DC CONVERTERS FOR IMPROVED POWER QUALITY

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ABSTRACT

Issues of power quality are mainly concerned with the deviation of the current or voltage from its ideal waveform. The major cause of this deviation is because of the harmonics introduced by the switching of solid state devices. Such devices are of vital importance in the multiple pulse power electronic converter devices. All the switches used for power conversion will inject harmonics and all together leads to a power quality issue or event accordingly. In the present work power quality of such converters are improved by increasing the number pulses required for their operation. The present paper brings out 24 pulse controlled converter and the results obtained are compared with the performance of 18 pulse controlled converter. Fast Fourier Transform analysis is carried out on all the said converters and found that with the increase in number of pulses, total harmonic distortion is having a considerable reduction leading to improved power quality.

KEYWORDS: Converters, Harmonics, Multiple Pulse, Power Quality

1. INTRODUCTION

Large amount of harmonics, poor power factor and high total harmonic distortion (THD) in the utility interface are common problems when non-linear loads such as adjustable speed drives, power supplies, induction heating systems, UPS systems and SMPS are connected to the electric utility. In several cases, the interface to the electric utility is processed with three-phase uncontrolled diode bridge rectifier. Due to the nonlinear nature of load, the input line currents have significant harmonics. The power quality of power supply of an ideal power system means to supply electric energy with perfect sinusoidal wave form at a constant frequency of a specified voltage with least amount of disturbances. However the harmonic is one of the major factor due to which none of condition is fulfilled in practice. The presence of harmonics disturbs the waveform shape of voltage and current and increases the current level and changes the power factor of supply and which in turn creates many problems.

The electricity is produced and distributed in its fundamental form as 50 Hz in India. A harmonics is defined as the content of signal whose frequency is integral multiple of the system fundamental frequency. Due to harmonic effect the sinusoidal wave form is no longer have stand and it become non-sinusoidal or complex wave form. The complex waveform consists of a fundamental wave of 50 Hz and a number of other sinusoidal waves whose frequencies are integral multiple of fundamental wave like 2f(100hz), 3f (150 Hz), 4f (200 Hz) etc. Wave having frequency of 2f, 4f, 6f etc are called the even harmonics and those having frequency of 3f, 5f, 7f etc are called as odd harmonics. When fundamental frequency is super imposed with high-level harmonics it results into complex wave and which is non sinusoidal. Many methodologies have appeared in the field of multi-pulse converters, many giving new concepts and verifying their claims by simulations and experimental work. Paice [1, 7] proposed maximizing the efficiency of a 12 pulse AC-DC...
converter based on a hexagonal autotransformer arrangement. Choi [2] has presented new autotransformer arrangements with reduced KVA capacities are presented for harmonic current reduction and to improve AC power quality of high current DC power supplies. Simulation results are given in the paper. Falcondes and Babri [3] has proposed a new isolated high power factor 12 KW power supply based on 18-pulse transformer arrangement the topology used involves a simple control strategy. S.Kim Etal [4] has given an analysis and design of a passive and novel interconnection of a star/delta transformer approach to improve power factor and reduce harmonics generated by a three phase diode rectifier.

The present work introduces 24 pulses AC-DC controlled converter and analyzing their impact on harmonics for improvement of power quality Output by comparing its output with 18 pulse AC-DC controlled converter. This paper has been organized as with Introduction in Section-I and Power Quality and HVDC in Section-II followed by Results and discussion in Section –III and Conclusions drawn were cited finally in section-IV.

2. POWER QUALITY AND HVDC

There are many different reasons as to why HVDC is to chosen instead of ac transmission. A few of them are listed below. Cost effective HVDC transmission requires only two conductors compared to the three wire ac transmission system [5]. One-third less wire is used, thus readily reducing the cost of the conductors. This corresponds to reduced tower and insulation cost, thereby resulting in cheaper construction. However, the ac converters stations involve high cost for installation; thus the earlier advantage is offset by the increase in cost. If the transmission distance is long, a break-even distance is reached above which total cost of HVDC transmission is less than the ac. Asynchronous tie HVDC transmission has the ability to connect ac systems of different frequencies. Thus it can be used for intercontinental asynchronous ties. For example, in Japan HVDC could be used to connect an ac system operating at 60 Hz with one operating at 50 Hz. Lower line losses similar to ac transmission, HVDC transmission has I2R losses too. However, for the same amount of power transfer, DC losses are less due to the lower resistance of the conductors because of only two-thirds of the conductor length. The main losses are converter losses that offer better stability and control ensures low environmental impact and reduces construction time [6].

A number of low-power electronic based appliances such as TV sets, personal computers and adjustable speed heat pumps generate a large amount of harmonic current in power systems even though a single low power electronic based appliance, in which a single-phase diode rectifier with a DC link capacitor is used as utility interface, produces a negligible amount of harmonic current [8]. Three-phase diode or thyristor rectifiers and cycloconverters for industry applications. Also generate a large amount of harmonic current. Voltage distortion or harmonics resulting from current harmonics produced by power electronic equipment has become a serious problem to be solved in many countries. Power system harmonics are not a new problem. Due to the widespread proliferation of nonlinear distorting loads such as power-electronic controlled devices, the problems caused by harmonics are of increasing importance. Unlike the conventional load, the power-electronic device controls the flow of power by chopping. Flattening or shaping the waveforms of the voltage and current [9]. Therefore, harmonics are generated during the process. These waveform distortions can cause problems for neighboring loads and they tend to have an overall opposite effect on the quality of electric power. a concept that can improve the power quality is the active power filter.

It may be seen that an inverter has a leading power factor & an additional reactive power is provided by static shunt & synchronous capacitors. But rectifier has a lagging power factor & an required harmonic filters are there on both
AC & DC sides of the converters to prevent the harmonics generated by the rectifier & inverter from entering into the AC & DC systems

The order of harmonics in DC voltage are given by

\[ N = pq \]

The order of harmonics in the AC are given by

\[ N = pq \pm 1 \]

Where \( p \) = number of pulses
\( q \) = number of integers

3. MULTIPLE PULSE CONVERTERS

The term multi-pulse method is not defined precisely. In principle, it could be imagined to be simply more than one pulse. The converters with multi levels were been used for the decremental of odd harmonic contents. By increasing the number of pulses harmonics was reduced. The multi pulses were applied by phase shifting transformers. They are an essential ingredient and provide the mechanism for cancellation of harmonic current pairs, e.g. the 3rd, 5th and 7th harmonics or the 11th and 13th so on [10]. Thus for harmonic current reduction the multi-pulse converters are fed from phase shifting transformers. The phase shift has to be appropriate.

3.1 Eighteen Pulse Converter-Controlled

For the simulation of controlled eighteen pulse converters having three thyristor bridge rectifiers are used and each thyristor bridge having six thyristors are there. The pulses operate with an firing angle of below 90\(^0\)(i.e., \( 0<\alpha<90^0 \)) only. If it is operated with an firing angle of above 90\(^0\) (i.e., \( 90^0<\alpha<180^0 \)) it workes as an inverter. All three six-pulse converters can be connected on the DC side in parallel. Each six-pulse bridge rectifier will have a separate transformer. Here we are used the zig-zag transformer for phase shifting purpose. The primaries of all three are connected in series and secondaries of all three are star connected. In order to avoid lower order harmonic contents below eighteen like 3rd, 5th, 7th, 11th, 13th, 15th we are used the eighteen pulse converter. The circuit connections and output waveforms obtained are as in Figure 1 and Figure 2 respectively.

Figure 1: Eighteen Pulse Controller-Converter
3.2 Twenty Four Pulse Converter-Controlled

The connection for 24-pulse converter and the corresponding connections are shown in figure 3. Two twelve pulse converters phase shifted by 15 degrees from each other, can provide a twenty four. That means having four thyristor bridge rectifiers are used and each thyristor bridge having six thyristors are there. All four six-pulse converters can be connected on the DC side in parallel. Each six-pulse bridge rectifier will have a separate transformer. Here we are used the zig-zag transformer for phase shifting purpose. The primaries of all four are connected in series and secondaries of all four are star connected. Its ac output voltage would have $24n \pm 1$ order harmonics i.e., $23^{rd}$, $25^{th}$, $47^{th}$, $49^{th}$ harmonics with magnitudes of $1/23^{rd}$, $1/25^{th}$, $1/47^{th}$, $1/49^{th}$ respectively, of the phase shift. The circuit connections and output waveforms obtained are as in Figure 3 and Figure 4 respectively.
4. RESULTS AND DISCUSSIONS

The obtained output voltages and output currents were analysed for harmonic content that is total harmonic distortion by using fast fourier transformation and the analysis of current and voltage for eighteen pulse is as shown in Figure 5 and for twenty four pulse it is shown in Figure 6.

![Figure 5: FFT Analysis of 18 Pulse Converter](image1)

![Figure 6: FFT Analysis of 24 Pulse Converter](image2)

Total Harmonic Distortion values obtained from fast Fourier transform analysis has been tabulated in Table 1 and the same were drawn in comparison for clear representation of THD values. It is observed that THD values output voltage of 18 pulse controlled converter is 18.07 and THD value of output of 24 pulse converter is 7.88. THD values output voltage of 24 pulse controlled converter is 13.34 and THD value of output of 24 pulse converter is 7.

<table>
<thead>
<tr>
<th>S. No</th>
<th>THD Parameters</th>
<th>18 Pulse Controlled</th>
<th>24 Pulse Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Output voltage($V_o$)</td>
<td>18.07</td>
<td>7.88</td>
</tr>
<tr>
<td>2</td>
<td>Input current</td>
<td>13.34</td>
<td>7</td>
</tr>
</tbody>
</table>
5. CONCLUSIONS

The main objective of this work is to investigate the performance of controlled multi-pulse converters. These converters are studied in terms of harmonic spectrum of ac mains current, THD. It is concluded therefore that in general with increase in number of pulses in multi-pulse case the performance parameters of these converters are remarkably improved, Which shows a considerable effect on the power quality enhancement. Investigation is carried out on eighteen pulse converter and 24 pulse converter and harmonic analysis has been carried by fast Fourier transform and the observation has been discussed and it is observed that 24 pulse converter performance is involved with enhancement of power quality.

REFERENCES


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