Harmonic Analysis in the Power System to Reduce Transmission losses and Save Energy

Apurva Ganguli¹, Abhay Kumar Sharma², Raajdeep Ganguli³
Gyan Ganga Institute of Engg.& Tech.(G.G.I.T.S), Jabalpur, M.P., India
¹(Scholar, M. Tech. (Energy Technology) G.G.I.T.S, Jabalpur, M.P., India)
²(Associate Professor Department of Mechanical, G.G.I.T.S, Jabalpur (M.P.), India)
³(Student, B. E (Electrical) Shri Shankaracharya College of Engg. And Technology Bhilai,(C.G.),India

ABSTRACT
This paper is about the harmonics related to the power system. How it affects the whole transmission, loads connected etc that is whole system. In the below article we have discussed about the harmonic limits for the power system required and the method to mitigate it from the power system. To reduce harmonics from the system we have used 48 pulse Statcom in the substation of 132KV/33KV. The source convertor is being applied to the 33KV side of the system. After the techno-economic analysis, their is about approximately Rs. 2 lakh yearly saving has been calculated.

Keywords - Harmonic mitigation in Power System, Power Factor Correction and Improve MVA Rating of transformer

I. INTRODUCTION
In any alternating current network, flow of current depends upon the voltage applied and the impedance (resistance to AC) provided by elements like resistances, reactances of inductive and capacitive nature. As the value of impedance in above devices is constant, they are called linear whereby the voltage and current relation is of linear nature.

However in real life situation, various devices like diodes, silicon controlled rectifiers, PWM systems, thyristors, voltage & current chopping saturated core reactors, induction & arc furnaces are also deployed for various requirements and due to their varying impedance characteristic, these NON LINEAR devices cause distortion in voltage and current waveforms which is of increasing concern in recent times. Harmonics occurs as spikes at intervals which are multiples of the mains (supply) frequency and these distort the pure sine wave form of the supply voltage & current.

Harmonics are multiples of the fundamental frequency of an electrical power system. If, for example, the fundamental frequency is 50 Hz, then the 5th harmonic is five times that frequency, or 250 Hz. Likewise, the 7th harmonic is seven times the fundamental or 350 Hz, and so on for higher order harmonics.

Harmonics can be discussed in terms of current or voltage. A 5th harmonic current is simply a current flowing at 250 Hz on a 50 Hz system. The 5th harmonic current flowing through the system impedance creates a 5th harmonic voltage. Total Harmonic Distortion (THD) expresses the amount of harmonics. The following is the formula for calculating the THD for current:

\[ THD(current) = \sqrt{\sum_{n=2}^{\infty} \left(\frac{V_n}{V_1}\right)^2} \times 100 \]

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When harmonic currents flow in a power system, they are known as “poor power quality” or “dirty power”. Other causes of poor power quality include transients such as voltage spikes, surges, sags, and ringing. Because they repeat every cycle, harmonics are regarded as a steady state cause of poor power quality.

When expressed as a percentage of fundamental voltage THD is given by,

\[ THD(current) = \sqrt{\sum_{n=2}^{\infty} \left(\frac{V_n}{V_1}\right)^2} \times 100 \]

where \( V_1 \) is the fundamental frequency voltage and \( V_n \) is nth harmonic voltage component

II. LITERATURE SURVEY
1996 Multi-pulse methods are characterized by the use of multiple converters or multiple semiconductor devices with a common load. Fig. 1 & Fig. 2 given below depict the various techniques used widely for the reduction of harmonics.[1]

1998 Commercial availability of Gate Turn-Off thyristor (GTO) devices with high power handling capability, and the advancement of other types of power semiconductor devices such as IGBT’s, have
led to the development of controllable reactive power sources utilizing electronic switching converter technology [2].

**2000**The interaction between these compensating devices and the grid network is preferably studied by digital simulation. Flexible alternating current transmission systems (FACTS) devices are usually used for fast dynamic control of voltage, impedance, and phase angle of high-voltage ac lines. FACTS devices provided strategic benefits for improved transmission system power flow management through better utilization of existing transmission assets, increased transmission system security and reliability as well as availability, increased dynamic and transient grid stability, and increased power quality for sensitive industries [3].

**2000** When the StatCom is used as compensator, the move from capacitive to inductive mode, is very fast [4].

**2000** The Static Synchronous Compensator (StatCom) is a shunt device of the Flexible AC Transmission Systems (FACTS) family it is based on power electronics devices to control voltage to compensate reactive power, and improve transient stability [5][4].

**2001** One of the important requirements in high voltage power applications is that harmonics be kept at some satisfactory level [6]. One way of reducing the level of harmonics presents in the converter output waveforms is to increase the number of converters [7], [8].

**2003** The Voltage Source Converter is the basic building block of FACTS devices such as StatCom and UPFC. Single phase voltage source converters can be inter-connected to form complex schemes. Combined with appropriate controllers, certain harmonics can be eliminated [9].

**2004** The results of applying a StatCom are similar to those by a rotating synchronous condenser, but without its mechanical all inertia and slow time response [6].

**2004** An elementary voltage source converter, based on a phase control scheme, consists of six self-commutate semiconductor switches. Each switch is shunted by a reverse parallel-connected diode; with a DC voltage source, the converter can generate a balanced set of three phase voltage waveforms at a given frequency, [10].

**2004** By combining two 24-pulses VSC, phase-shifted 7.5° from each other, an equivalent 48-pulse converter [10]

**2005** The 48-pulse converter; It is formed by four three-level converter linked by four phase shifting transformers. The quality of the output voltage obtained from such converter. It can be deduced that the harmonics are reduced by increasing the number of pulses [7] [11]. This kind of converter give rises to a better voltage control on modern power systems [11].

**2005** The StatCom basically consists of a step-down transformer with a leakage reactance, a three-phase GTO voltage source converter (VSC), and a DC capacitor [12].

**2006** These technologies additionally offer considerable advantages over the existing ones, in terms of space reductions and performance. FACTS are a result of the development in the power electronics area and aim to rapidly control electrical signals [13].

**2007** Losses in distribution transformers account for almost one third of overall transmission and distribution losses [4].

**2008** The precise impact of a harmonic current on load loss depends on the harmonic frequency and the way the transformer is designed. In a transformer that is heavily loaded with harmonic currents, the excess loss can cause high temperature at some locations in the windings. This can seriously reduce the life span of the transformer and even cause immediate damage and sometimes fire. A number of methods exist to prevent overloading or failure of the distribution system, either by accommodation or elimination of the harmonic currents [14].

**2008** Multi-pulse methods involve multiple converters connected so that the harmonics generated by one converter are cancelled by harmonics produced by other converters. By this means, certain harmonics related to number of converters are eliminated from the power source. In multi-pulse converters, reduction of AC input line current harmonics is important as regards to the impact the converter has on the power system [15].

### III. METHODS OF HARMONIC MITIGATION

Many methods are being used to reduce harmonics in the present paper 48 pulse Statcom is being used to reduce harmonics in the power system.
Symatic arrangement of 48-pulse voltage converter with the 33KV power system

V. SYSTEM PARAMETERS

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Equipments list</th>
<th>Parameter description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Three-phase voltage source</td>
<td>Voltage ph-ph =130KV</td>
</tr>
<tr>
<td>2</td>
<td>System transformer step down</td>
<td>40MVA,132/33KV</td>
</tr>
<tr>
<td>3</td>
<td>Three phase constant voltage at 33KV side</td>
<td>Voltage 31.36Kv, Frequency 50Hz</td>
</tr>
<tr>
<td>4</td>
<td>Statcom</td>
<td>Frequency 50Hz, Capacitance 3000 µF</td>
</tr>
<tr>
<td>5</td>
<td>4 numbers phase shift zig-zag transformer</td>
<td>1 MVA (each)</td>
</tr>
<tr>
<td>6</td>
<td>GTO switch</td>
<td>Snubber resistance 1e-5 (ohm), Snubber capacitance 1nf, Internal resistance 1e-4 (ohm), No. of bridge arm 3</td>
</tr>
<tr>
<td>7</td>
<td>4 number of pulse generator</td>
<td>12 pulse (each)</td>
</tr>
</tbody>
</table>

VI. SIMULATION RESULT

Voltage $V_{abc}$ without Harmonic Correction(Y axis
– Voltage in V, X axis - time in millisecond)
VII. CONCLUSION

The 48 pulse Statcom is a source convertor that is connected shuntly to the transmission system to improve the voltage contents in the system. The Statcom can also able to generate voltage waveform to reduce harmonic effects from the system. Statcom response is very fast i.e in few cycle it can able to pass from capacitive mode to inductive mode of operation. Statcom also help to increase the MVA rating of the transformer upto 6.5% by improving the power factor of the transmission line.

REFERENCE


