DESIGN OF UPQC BASED ON MODULAR MULTILEVEL MATRIX CONVERTER FOR MITIGATION OF VOLTAGE SAG AND CURRENT HARMONICS

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Abstract

The broadside of this paper is to presents a model aim to design a Single Phase Unified Power Quality Conditioner (UPQC) based on Modular Multilevel Matrix converter (M3C) which is used to mitigate Voltage Sag and Current Harmonics in the medium voltage power distribution system. This Modular Multilevel Matrix converter based UPQC consists of four identical multilevel converter arms and its corresponding filtering inductors and capacitors. In this context a five level multilevel converter is chosen as modular multilevel matrix converter which is controlled by integrated control strategy which uses the arm currents and voltages so as to reduce the Total Harmonic Distortion of load voltage and current. The simulation of Modular Multilevel Matrix converter based UPQC has been carried out using MATLAB / SIMULINK 2013. The effectiveness of the proposed methodology is validated by comparing the THD values of proposed methodology and the system with ordinary UPQC.

Keywords—Unified Power Quality Conditioner, Modular Multilevel Matrix Converter, Five level Multilevel Converter, Voltage Sag, Current Harmonics.

1. Introduction

The broad-spectrum features of voltage and current are that it would not be equal to the desired or nominal value. These
deviations are so-called voltage variations and current variations. The variation can be in the form of change in magnitude or frequency. Voltage magnitude variation could be increase or decrease of the voltage magnitude and the common causes include changes in total load of the system, variations in transformer tap changers, sudden switching of large capacitor banks and reactors. Similar to magnitude, frequency also changes and it won't remain constant. This voltage frequency variation is mainly due to unbalance between source and load. On load side, the magnitude of current will not remain constant. The main reason for voltage magnitude variation is due to variation in current magnitude [1]. The design of power system is based on this current magnitude variation. Hence the design of the system would be based on its average value. When the current magnitude remains constant then the cost required to design the system would be low. The known factor is that ideally, current and voltage are in phase and hence this condition ensures that the active power is transferred efficiently.

A single phase UPQC is designed to mitigate power quality issues that occur in a system. The system is provided with a single phase AC source of 220V AC, 50Hz and has RL load. Initially, voltage sag is created in this system and THD of the load current is also obtained with the help of FFT analysis. For this system, the FACTS device UPQC is introduced. The proposed UPQC is designed based on the concept of the multilevel converter [2-5]. The voltage source and the nonlinear loads are connected to two cater corners of the proposed UPQC. The proposed UPQC can also be termed as single phase Modular Multilevel Matrix Converter (M3C) as it has identical multilevel converter arms along with its corresponding filtering inductors[6-9]. Each arm has cascade H-bridge submodules with the number N. The proposed system has a five level converter of which 3 converters are connected in cascaded connection. This topology offers good merits in
maintaining aspects and consistent redundancy concept [10]. On comparing to other multilevel UPQC, this topology features identical two terminal submodules along with their simple and robust interconnections.

2. Cascaded H-Bridge Multilevel Converter

![Fig. 1. Layout of Multilevel converter](image)

Advantages of multilevel converters are low harmonics, low voltage stress on power switches and increased efficiency. In this project, five level converter has been designed [11, 12]. It has two H-Bridges inverters connected in series to provide a sinusoidal output voltage along with filtering inductors. Each converter arm has two H-Bridges and so the number of output voltage levels would be, \((2 \times 2 + 1 = 5)\) five levels. Number of switches used is reduced when compared with other types of multilevel inverters [13].

3. M3C based UPQC

The proposed UPQC topology is a single phase device which consists of four converter arms and filtering inductors and capacitors. Each converter arm has the multilevel converter with five level output waveform [14,15]. The multilevel converter is fired using an appropriate control circuit. The control circuit uses PI controller to produce suitable pulses along with repeating sequence and NOT block. Separate DC sources are provided for each H-Bridges. The output from each H-Bridge is added up hence the output obtained is a square wave. Hence the output voltage has to be filtered and so the proposed UPQC is provided with
filtering inductors and capacitors of suitable values. The voltage sag produced by the system is completely mitigated and Total Harmonic Distortion of the load current has been reduced and it is within the IEEE standard 519.

Fig. 2. Block diagram for Proposed UPQC

4. Control Circuit

Predominantly, the source voltage and current values are measured and introduced with some delay so that they can be decomposed into three components. Using discrete PLL the sine and cosine terms of the phase angle is determined. Instead of reference signals, values are directly given as input to this PLL. The three current reference values are then converted to direct and quadrature axis components with the help of sine and cosine values of phase angle [16]. The average values of three reference voltage are identified. The d-component of current is delayed and then applied to the PI controller. The average value of voltage is provided to the PI controller which gives current value as output which is collective q-component of the current value after passing through the PI controller. A signal is produced from the output of both the PI controllers. The produced signal is then compared with the repeating sequence so that appropriate pulses for the converter would be generated [17, 18]. The pulse so generated is
applied to a pair of switches in each H-bridge and for the remaining pair, the same pulse is given through NOT block.

Fig. 3. Simulink model for Pulse generation

The pulses generated by this way when applied to the four converter arms completely mitigates the voltage sag generated by the system and also the Total harmonic Distortion of the load current is also reduced to a small value. Thus the performance of the system has been improved.

Fig. 4. Gate pulses for Converter

Fig. 5. System with proposed UPQC
From the above simulation results obtained it is evident that both the ordinary UPQC and proposed UPQC mitigate voltage sag completely. In comparison the Total Harmonic Distortion of load current in both the cases it is clear that the proposed UPQC has less harmonic distortion when compared with the ordinary UPQC.
Performance comparison of the two systems are stated in the below table.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>System</th>
<th>Voltage Sag (V)</th>
<th>THD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System without FACTS device</td>
<td>195</td>
<td>17.08</td>
</tr>
<tr>
<td>2</td>
<td>System with UPQC</td>
<td>225</td>
<td>10.64</td>
</tr>
<tr>
<td>3</td>
<td>System with Proposed UPQC</td>
<td>224</td>
<td>4.52</td>
</tr>
</tbody>
</table>

5. Conclusion

Thus the proposed topology of UPQC which is a Modular Multilevel converter based Unified Power Quality Conditioner has been developed in MATLAB successfully. Since the proposed device is a single phase device, it has been introduced in a system which is fed from single phase AC source and has a nonlinear load which creates voltage sag and current harmonics. Mitigation of the voltage sag and the Total harmonic Distortion of the load current have been reduced and it is within the IEEE standard bounds with the proposed topology. Comparison of the system without any FACTS device and the system with ordinary UPQC are also observed by comparing the simulation results. The proposed UPQC system finds better performance an acceptable than the other devices.

Reference


