An Approach to Voltage Quality Enhancement by Introduction of CWVM for Distribution System

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ABSTRACT
This paper presented with problems related with voltage flicker in power system networks. Several international standard issued to control the voltage flicker are briefly described and some important methods to analyse electrical circuits with sinusoidal and non-sinusoidal waveforms are introduced and evaluated. One of these methods-Cockcroft Walton Voltage Multiplier (CWVM) has been used to increase the voltage of a filter, which is also described in this paper as a practical application. The filter can compensate for harmonic currents, power factor, and unbalance voltage. The simulation results using Multisim are presented, showing that good dynamic and steady-state response can be achieved with this approach.

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1. INTRODUCTION
Voltage interruption and fluctuation are the most significant power quality disturbances for consumers due to their significant unfavourable impact on electronic equipment. The system voltage fluctuation mainly caused by the faults in the power system and sometimes by the energization of large Induction Motors. In the early 90s, the impact of voltage fluctuation was measured using magnitude and duration indices and compared with the power quality envelope. Therefore, fluctuation creates competition among utilities to provide their customers with reliable power quality (PQ). PQ means voltage quality (VQ) from the customers’ perspective [1]. This perspective motivates PQ research towards the mitigation of VQ problems in order to improve PQ in distribution systems. Although much work has been done in the extraction and compensation of each common PQ disturbance, few compensation strategies for several VQ problems have been developed [2]. In fact, there is a tremendous need for such generalised compensation strategies because of high probability for finding several VQ problems existing at the same bus, the same feeder or at the same load [3-9]. On the other hand, a utility is likely to take sufficient measures that limit the interruptions due to voltage fluctuations. The utility should evaluate the voltage performance of the distribution system by performing studies that will provide it with information on the voltage magnitude, duration, and frequency at a node where a sensitive load is likely to be connected. If the sag performance is inadequate, the utility should take measures to improve that performance. An alternate approach to assess the voltage performance is by means of computer simulation. Two methods that are generally used are the method of fault positions and the method of critical distances [10]. The voltage sag performance of a hypothetical distribution system has been assessed in reference [11]. This study uses the Kalman filter, the

least absolute value and the Teaser energy operator along with the Hilbert transform [12] have been employed to separate between the fundamental voltage and the flicker disturbance for the sake of flicker mitigation. Also, the adaptive perception-based compensating strategy is developed to compensate for voltage sags, swells and harmonics. The Kalman filter has been used to track the envelope of voltage sags and flicker but the proposed extraction technique is very complicated to be practically implemented [13-17].

Therefore this paper introduces an efficient and simple compensation strategy for several VQ problems. The proposed method for each phase system is applied to a series mitigation device which is a single phase Cockcroft Walton Voltage Multiplier Circuit (CWVM). Some measurements are also presented to validate the estimation procedure. It has been shown that the voltage performance of the distribution system with respect to a critical load could be significantly improved. A technique for enhancing the voltage performance in the distribution systems has been described.

2. PROPOSED CIRCUIT MODEL

This section explicates how the Cockcroft Walton Voltage Multiplier Circuit is formulated in a recursive manner to extract and mitigate the VQ disturbances in distribution systems. This section has two levels; the level I shown in Figure 1 demonstrates the stage by stage circuit connections to track and extract the voltage disturbances. The level II shown in the Figure 2 explain the structure of the proposed scheme, and explains how it works to mitigate the voltage flickers.

![Figure 1. Block diagram for Steady Power Supply System](image)

The CWVM shown in the Figure 2 has a low capacitance coil with a specific end goal to improve better results. The series CWVM operates in two modes. The first mode is charging mode and the second one is the discharging mode. When the circuit is charged, one pair of diodes (e.g. D1 and D4 or D2 and D3) is on, so the DC current drives in series with source and Cockcroft Walton Voltage Multiplier Circuit. For the protection of diodes a current limiter circuit R, is connected in series with the source voltage and pair of diodes. It should be noted that the zener diode is connected across the bridge to maintain the steady state voltage and polarised capacitor is connected for smooth operation. After several cycles the two transistors Q1 and Q2 are coupled in anti parallel to produce pulsating DC i.e.; DC to AC conversion as the output is connected with the centre tap transformer. At this stage the two diodes D11 and D22 are linked in opposite direction for the protection of transistors Q1 and Q2.

3. COCKROFT WALTON VOLTAGE MULTIPLIER CIRCUIT

Another parameter which plays a vital role in the voltage enhancement is the Cockcroft Walton Voltage Multiplier. When the centre tap transformer is energised one terminal becomes positive with respect to other terminal at the output side, therefore the potential of the c1, c2 and c3 junction point falls. Also the potential of c2 and c4 junction points reduces, hence c2 is charged through adjacent diode. In the next half cycle the potential at junction point of c3 and c5 becomes more positive than potential at c2 and c4, thus c3 is charging through next adjacent diode. Finally all the capacitors shown in the Figure 2 i.e; c4 to c24 are charged. The voltage across the column of capacitors consisting of c3 to c23, keeps on oscillating as the supply voltage alternates. However, the voltage across the capacitances c2 to c24 remains constant. Thus, the use of multistage arranged in the manner shown in the Figure 2 enables very high voltage to be obtained. The equal stress of the elements (both capacitors and diodes) used is very helpful and promotes a modular design of such voltage multiplier circuit.

4. MATHEMATICAL MODELLING

As shown in the Figure 2 initially current is passed through rectifier circuit. Therefore, the operation of circuit shown in the Figure 2 can be divided into two operation modes; charging and discharging modes.
At first diode D₁ and D₄ in the on state. Then, the loop is formed and the input voltage can be obtained, as follows. Nomenclature as shown in Table 1.

\[ V_{in\, max} = V_{zbr} + \sqrt{(P_r \times R_1)} \]  (1)

\[ V_{in\, min} = V_{xbr} + V_{r\, min} \]  (2)

Using (1) and (2), the following equation can be written

\[ V_{input} = (V_{in\, max} - V_{in\, min}) \]  (3)

Similarly the output voltage can be written in the following form

\[ V_{output} = V_{zbr} \times N_{CWVM} \]  (4)

4.1. Desired Value of \( P_r \)

Since the calculation of \( P_r \) from the quadratic equation is time consuming, by equation (1) can be expressed by the following equation.

\[ P_r = \frac{(V_{in\, max} - V_{zbr})}{R_1} \]  (5)

4.2. Preferred Value of \( N_{CWVM} \)

\[ N = \frac{V_{output}}{V_{xbr}} \]  (6)

You can refer to the figure below for the circuit diagram for steady power supply.

Figure 2. Circuit diagram for steady power supply

NOMENCLATURE:

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>( V_{in, min} ): Minimum input volt for proper output</td>
</tr>
<tr>
<td>2.</td>
<td>( V_{in, max} ): Maximum allowed input volt for proper output.</td>
</tr>
<tr>
<td>3.</td>
<td>( V_{xbr} ): Zener breakdown volt.</td>
</tr>
<tr>
<td>4.</td>
<td>( V_{input} ): Range of input voltage.</td>
</tr>
<tr>
<td>5.</td>
<td>( V_{output} ): Output voltage.</td>
</tr>
<tr>
<td>6.</td>
<td>( N_{CWVM} ): Multiplying factor or No. of capacitor in CWVM</td>
</tr>
<tr>
<td>7.</td>
<td>( P_r ): Power rating of series resistance of rectifier circuit.</td>
</tr>
<tr>
<td>8.</td>
<td>( R_1 ): Series resistance of the rectifier circuit</td>
</tr>
</tbody>
</table>
5. SIMULATION RESULTS

The simulation results are carried out in a PSPICE environment. The simulation parameters are given in Table 2. The circuit shown in the Figure 2 is tested for different input voltage. Figure 3, Figure 4, and Figure 5 show the output voltage is purely sinusoidal, also the magnitude of the voltage is constant for the different input voltage. Figure 6 illustrates the relationship between the output voltage, input voltage and zener voltage, such that input is varying from 0 to 200V but the output is almost constant. The system outputs are listed in Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>C11, C22</td>
<td>Tantalum Capacitor</td>
<td>68 uf, 25 V</td>
</tr>
<tr>
<td>R11, R22</td>
<td>Resistor</td>
<td>10 Ohm, 5 Watt</td>
</tr>
<tr>
<td>R33, R44</td>
<td>Resistor</td>
<td>180 Ohm, 1 Watt</td>
</tr>
<tr>
<td>D11, D22</td>
<td>Silicon Diode</td>
<td>HEP 154</td>
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<tr>
<td>Q1, Q2</td>
<td>NPN Transistor</td>
<td>2N3055</td>
</tr>
<tr>
<td>T1</td>
<td>Center Tapped Transformer</td>
<td>20 V</td>
</tr>
</tbody>
</table>

Figure 3. Voltage Magnitude of CWVM

Figure 4. Voltage Magnitude of CWVM
6. CONCLUSION

In this paper, a novel methodology CWVM based on a single-phase Diode Bridge for the mitigation of voltage flicker has been proposed. The proposed system model has a simple topology, does not need any controlling circuit and uses fewer diodes. In addition, it leads to lower ripple and voltage drop and lower voltage distortion. The simulation results show the effectiveness of the proposed system model. And it should be noted that the Authors have focused on the primary winding of the CWVM. The secondary side is open circuit. Moreover, the suggested structure of the compensation strategy is being able to accommodate more modules for mitigating more VQ problems because each module is working independently of the other modules.
REFERENCES


BIOGRAPHIES OF AUTHORS

Alok Kumar Shrivastav received his B.Tech degree in Electrical & Electronics Engineering from West Bengal University of Technology, West Bengal, India, in 2009, the M.Tech degree in Electrical Engineering from NIT Durgapur, West Bengal, India, in 2013, and presently pursuing Ph.D. programme at the Department of Electrical Engineering, Indian School of Mines, Dhanbad-826004, India. He is presently Assistant Professor, Techno India Batanagar, Maheshtala, Kolkata. His special field of interest is in power quality in distribution system, power flow monitoring and stability analysis.

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