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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 Multisimare 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.

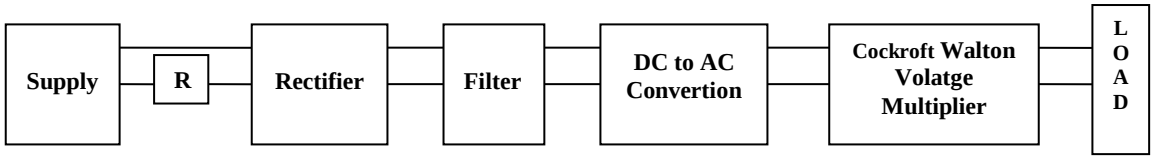

Figure 1. Block diagram for Steady Power Supply System

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. D_1 and D_4 or D_2 and D_3) 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 Q_1 and Q_2 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 D_{11} and D_{22} are linked in opposite direction for the protection of transistors Q_1 and Q_2.

3. COCKROFT WALTON VOLATGE 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 c_1, c_2 and c_3 junction point falls. Also the potential of c_2 and c_4 junction points reduces, hence c_2 is charged through adjacent diode. In the next half cycle the potential at junction point of c_3 and c_5 becomes more positive than potential at c_2 and c_4, thus c_3 is charging through next adjacent diode. Finally all the capacitors shown in the Figure 2 i.e; c_4 to c_{24} are charged. The voltage across the column of capacitors consisting of c_3 to c_{23}, keeps on oscillating as the supply voltage alternates. However, the voltage across the capacitances c_2 to c_{24} 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 D_1 and D_4 in the on state. Then, the loop is formed and the input voltage can be obtained, as follows. Nomenclature as shown in Table 1.

$$V_{in\,max} = V_{zbr} + \sqrt{(P_r * R_1)} \quad (1)$$

$$V_{in\,min} = V_{xbr} + V_{r\,min} \quad (2)$$

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

$$V_{input} = (V_{in\,max} - V_{in\,min}) \quad (3)$$

Similarly the output voltage can be written in the following form

$$V_{output} = V_{zbr} * N_{CWVM} \quad (4)$$

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.

$$P_r = \frac{(V_{in\,max} - V_{xbr})}{R_1} \quad (5)$$

4.2. Preferred Value of N_{CWVM}

$$N = V_{output}/V_{xbr} \quad (6)$$

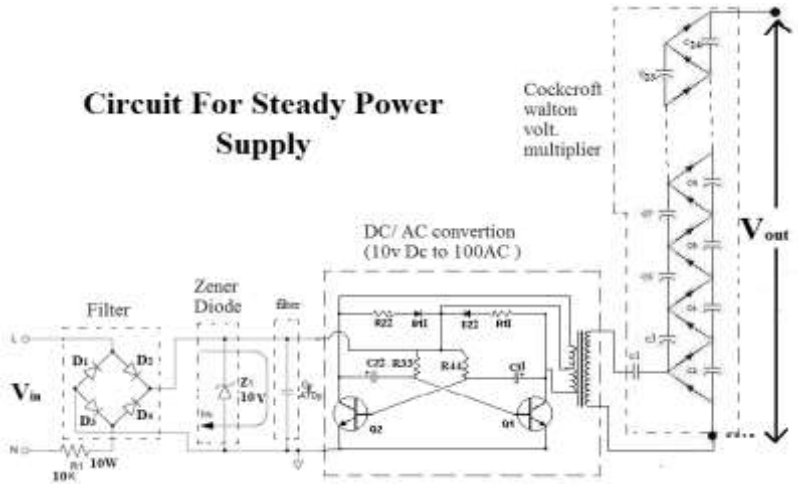

Figure 2. Circuit diagram for steady power supply

NOMENCLATURE:

Table 1. Nomenclature

Sl No.	Details
1.	V_{inmin}: Minimum input volt for proper output
2.	V_{inmax}: Maximum allowed input volt for proper output.
3.	V_{zbr}: Zener breakdown volt.
4.	V_{input}: Range of input voltage.
5.	V_{output}: Output voltage.
6.	N_{CWVM} : Multiplying factor or No. of capacitor in CWVM
7.	P_r: Power rating of series resistance of rectifier circuit.
8.	R_1 : Series resistance of the rectifier circuit

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 2 Simulation parameters

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

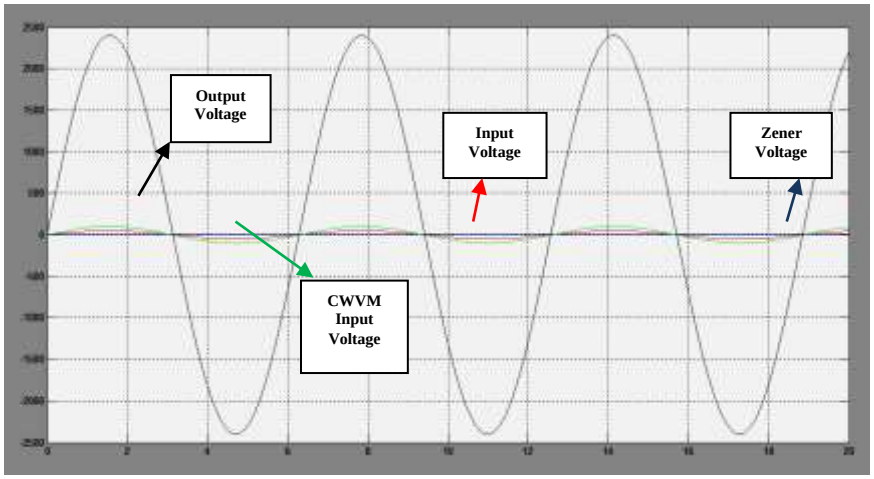

Figure 3. Voltage Magnitude of CWVM

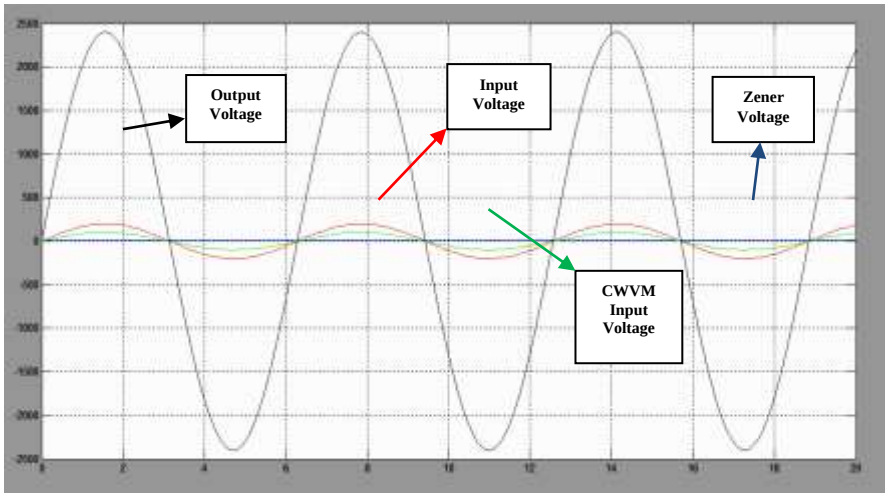

Figure 4. Voltage Magnitude of CWVM

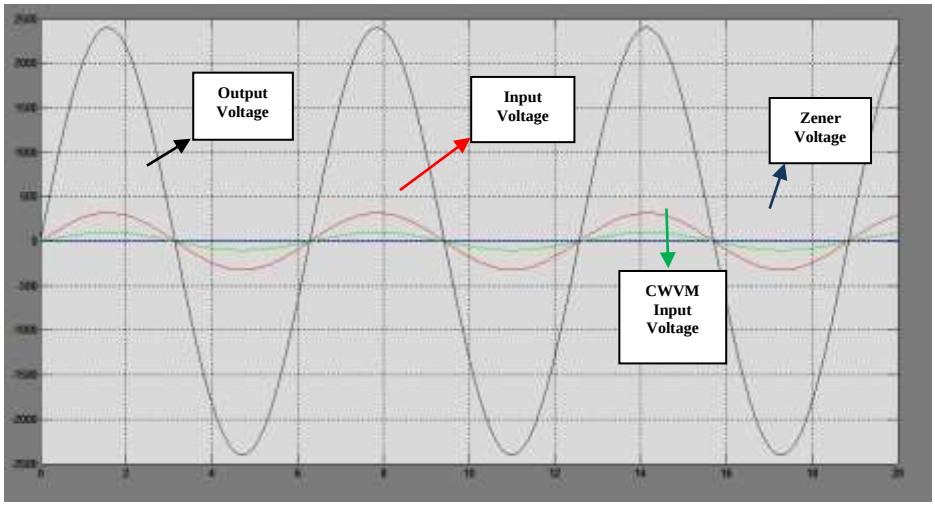

Figure 5. Voltage Magnitude of CWVM

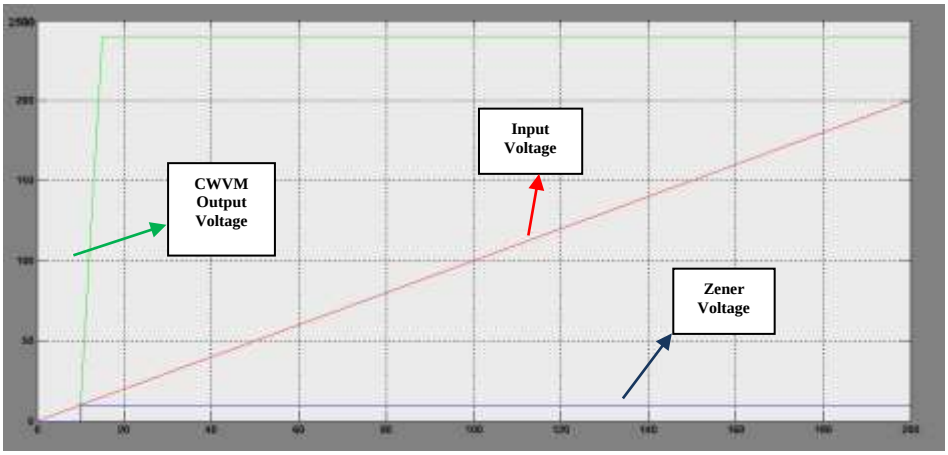

Figure 6. Voltage Magnitude of CWVM

Table 3. Simulation output of CWVM

Description	Value		
	Figure 3	Figure 4	Figure 5
Output Voltage	2400V (AC)	2400V (AC)	2400V (AC)
Input Voltage	50V (AC)	200V (AC)	320V (AC)
Volt. across zener diode	10V (DC)	10V (DC)	10V (DC)
Input volt across CWVM	100V (AC)	100V (AC)	100V (AC)

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 secondry 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.

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