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Analysis and Comparison of Capacitor Diode Voltage Multiplier Fed with a High Frequency and a Low Frequency Voltage Source

Devesh Malviya[1], A.K. Bhardwaj[2]

PG Student, Department of Electrical Engineering, SHIATS, Allahabad (U.P.), India[1]

Professor, Department of Electrical Engineering, SHIATS, Allahabad (U.P.), India[2]

Abstract: This paper presents the analysis and comparison of Capacitor Diode Voltage Multiplier fed with a high and low frequency voltage source. The characteristic of this multiplier has been studied using PSpice simulations. The behavior of the multiplier especially the multipliers response time has been studied, when it is fed with high frequency voltage source and a low frequency voltage source. The voltage multiplier fed with a high frequency voltage results in an appreciable reduction in the size, weight and the price of the power supply developed using such a voltage multiplier.

Keywords: Cockcroft Walton Multiplier, PSpice, ac, dc, cascading circuit.

1. INTRODUCTION

A Capacitor Diode Voltage Multiplier has been widely used for generating the high voltage dc. It converts the ac voltage applied at the input into the dc voltage, received at the output. A simple voltage doubler converts an ac voltage of amplitude V into a dc voltage of amplitude 2V. Hence, by cascading more number of stages say n, the output voltage can be increased by n times i.e. 2nV [3]. The high voltage dc power supplies found several applications in the field of scientific research, space and is widely used by the engineers and physicists [1], [2]. It has played an outstanding role in the development of fundamentals of physics. High voltage dc is also required for the insulation testing of various components of the power system. Also, the impulse generator charging units require high voltage dc [6].

There are several applications of high voltage dc, such as electron microscopes, X-rays, dust filtering systems, electrostatic precipitators, oscilloscopes, photomultiplier tubes, particle accelerators etc. [1], [5]. But, the basic voltage multiplier circuits are very slow in response and this response time even become more with the increase in the number of stages. This happens mainly because of the low frequency voltage source applied at the input. This problem can be easily eliminated if a high frequency voltage source is used in place of a low frequency voltage source. By taking the advantages of the high frequency switching technologies such as high frequency pulse width modulated converters can be used for designing the high frequency voltage source.

2. VOLTAGE MULTIPLIERS

A transformer is capable of stepping-up and - down of the input voltage. Also, it provides isolation between the input and the output. However, if high voltage is required at the output side, voltage multiplier can be a good alternative [7]. Voltage multiplier circuits are generally used where, there is a requirement for high output voltage and low output current. Voltage multipliers are used where load is constant and has high impedance or where input voltage stability is not critical [4]. The Cockcroft-Walton Multiplier is one such circuit, which has been used from decades for generating high voltage dc. In this paper, the Capacitor-Diode Voltage Multiplier, which is more or unless is a Cockcroft-Walton Multiplier, is fed with high and low frequency voltage-source.

The behavior of this multiplier with high and low frequency voltage source has been studied and its characteristics has been observed. The basic Capacitor-Diode Voltage Multiplier is usually fed with low frequency voltage source i.e. 50-60 Hz. But, it has been observed that when, it is fed with high frequency voltage-source, an appreciative improvement has been observed in terms of multipliers response. To prove this, several simulations has been carried out on PSpice for Capacitor-Diode Voltage Multiplier of different number of stages and response-time for each number of stages has been observed. Also, the increase in the output voltage with the increase in the number of stages has also been observed, while keeping the input voltage and transformers turns-ratio same. A graph has also been plotted between the output-voltage and the number of stages, showing, this particular behavior of the Capacitor-Diode Voltage Multiplier.

3. CAPACITOR DIODE VOLTAGE MULTIPLIER

In 1932 Cockcroft-Walton proposed an improved version of the circuit developed by Greinacher, for the generation of high voltage dc. It is a cascade of capacitors and diodes.

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It has eliminated the transformers from the high voltage circuits. Thus, the size, weight and the cost of the power supply can be reduced. The capacitor diode voltage multiplier circuit is one such circuit which, only uses capacitors and diodes for generating very high voltage [3]. Figure 1 shows a two-stage capacitor diode voltage multiplier circuit. This is the same schematic which has been drawn on PSpice for running the simulation.

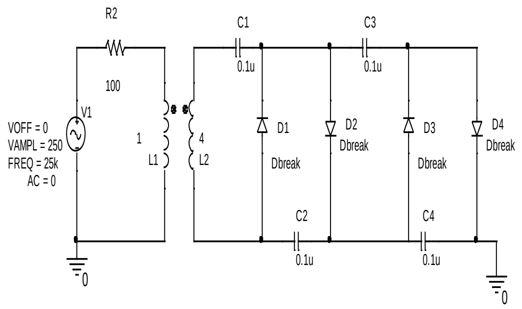

Fig 1: Capacitor Diode Voltage Multiplier circuit.

Operation of two-stage Capacitor Diode Voltage Multiplier:
When, the alternating input voltage applied at the primary of the transformer is negative, the capacitor C1 gets charged through D1 and during the next half cycle, when input voltage become positive, C2 gets charged through D2. Similarly, C3 is charged through D3 and C4 is charged through D4.
The voltage developed across each capacitor is 2Vm except C1 which is stressed with only Vm and the voltage developed across each diode is 2Vm. The output voltage increases with respect to the increase in the number of stages.
The output voltage for this circuit is given by the following formula:

$$V_o = 2nNV_m \qquad (1)$$

Where, V_o = Output voltage
V_m = Peak value of the input voltage
n = Number of stages
N = Transformers turn's ratio
The same characteristics has also been observed in Capacitor-Diode Voltage Multiplier circuit fed with high frequency voltage source. The charging and discharging of capacitors follows the same pattern and the conduction of diodes are also same.
But, here, appreciable reduction in terms of multipliers size has been achieved as the transformers designed for high frequency purpose are relatively smaller than the transformer designed for operation at lower frequencies
.

4. SIMULATION RESULTS

To study the behavior of the capacitor-diode voltage multiplier fed with high frequency voltage source, several simulations has been carried out on PSpice software for different number of stages (n), such as n=2,3,4,5. Irrespective of the low frequency voltage sources that are usually used to fed the Cockcroft-Walton multiplier which, operates at 50-60Hz, the capacitor-diode voltage multiplier has been fed with the voltage source operating at high frequency of 25kHz. The operation of capacitor-diode voltage multiplier for different number of stages has been discussed in detail in the upcoming sections:

4.1 Two stage
A two-stage capacitor-diode voltage multiplier consists of four capacitors and four diodes. Its input is connected with the secondary of a transformer having turns ratio 2, whose primary is connected with a high frequency voltage source having amplitude 250V. The value of capacitors is chosen to be 0.1u and an ideal diode has been selected for the purpose.
Using equation 1, the output voltage for this circuit is found to be 2kV. Figure 2(a), shows the rise in the output voltage with respect to time and it clearly shows that the output voltage finally reaches to 2 kV and become stable at this value. Thus, this simulation results validates the formula given in equation 1 and this result also shows that the output voltage become stable and reaches its final value in nearly 20ms, which is a very less time. This result is obtained when high frequency voltage source has been used to drive the capacitor diode voltage multiplier.
However, the capacitor-diode voltage multiplier being fed with a low frequency voltage source i.e. 50Hz, has higher response time and the output voltage is relatively less as compared to a high frequency voltage source driven capacitor diode voltage multiplier and this behavior can easily be understood by comparing the simulation results shown in fig.2(b).

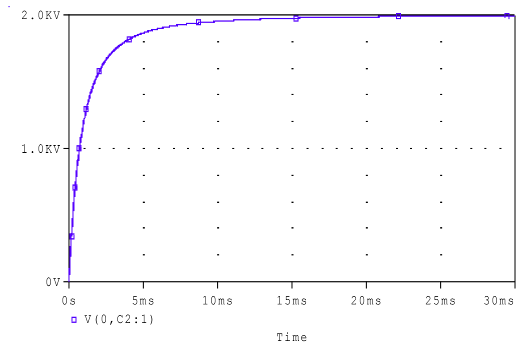

Fig 2(a): Output voltage for a high frequency voltage source driven capacitor diode voltage multiplier

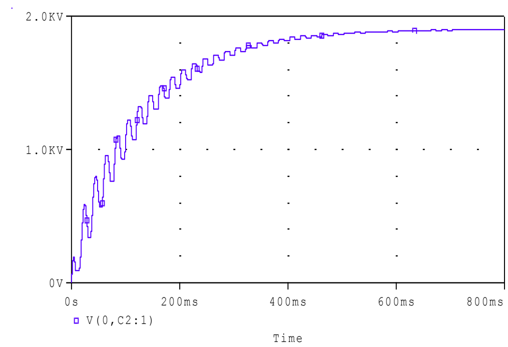

Fig 2(b): Output voltage for a low frequency voltage source driven capacitor diode voltage multiplier

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4.2 Three stage

A three-stage capacitor-diode voltage multiplier consists of six capacitors and six diodes. Its input is connected with the secondary of a transformer having turns ratio 2, whose primary is connected with a high frequency voltage source having amplitude 250V. The value of capacitors is chosen to be 0.1u and an ideal diode has been selected for the purpose.

Using equation 1, the output voltage for this circuit is found to be 3kV. Figure 3(a), shows the rise in the output voltage with respect to time and it clearly shows that the output voltage finally reaches to 3 kV and become stable at this value. Thus, this simulation results validates the formula given in equation 1 and this result also shows that the output voltage become stable and reaches its final value in nearly 40ms, which is a very less time. This result is obtained when high frequency voltage source has been used to drive the capacitor diode voltage multiplier.

However, when this voltage multiplier is fed with a low frequency voltage source i.e. 50Hz, has higher response time and the output voltage is relatively less than that is observed when, this multiplier if fed with a high frequency voltage source and it is clearly depicted in fig.3(b).

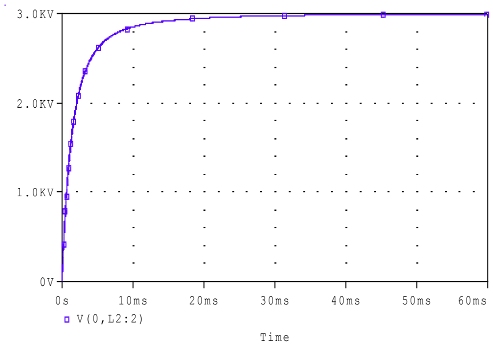

Fig 3(a): Output voltage for a high frequency voltage source driven capacitor diode voltage multiplier

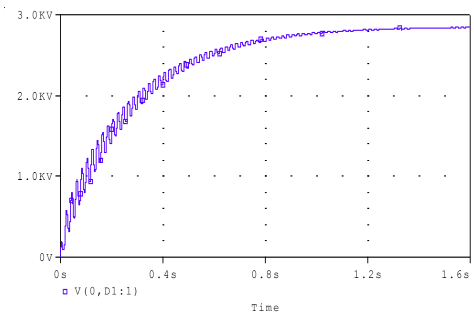

Fig 3(b): Output voltage for a low frequency voltage source driven capacitor diode voltage multiplier

4.3 Four stage

A four-stage capacitor-diode voltage multiplier consists of eight capacitors and eight diodes. Its input is connected with the secondary of a transformer having turns ratio 2, whose primary is connected with a high frequency voltage source having amplitude 250V. The value of capacitors is chosen to be 0.1u and an ideal diode has been selected for the purpose. Using equation 1, the output voltage for this circuit is found to be 4kV. Figure 4(a), shows the rise in the output voltage with respect to time and it clearly shows that the output voltage finally reaches to 4 kV and become stable at this value. Thus, this simulation results validates the formula given in equation 1 and this result also shows that the output voltage become stable and reaches its final value in nearly 60ms, which is a very less time. This result is obtained when high frequency voltage source is used to fed this voltage multiplier.Also, the same behavior has been observed when this multiplier is fed with a low frequency (50Hz) voltage source i.e. delay in response and relatively less output voltage and it is clearly depicted in fig.4(b).

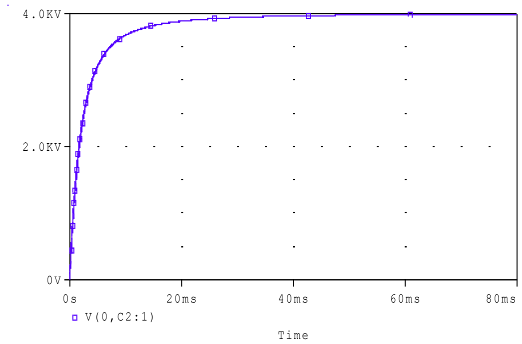

Fig 4(a): Output voltage for a high frequency voltage source driven capacitor diode voltage multiplier

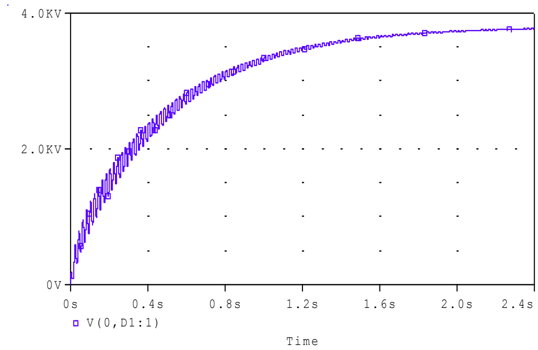

Fig 4(b): Output voltage for a low frequency voltage source driven capacitor diode voltage multiplier

4.4 Five stage

A five-stage capacitor-diode voltage multiplier consists of ten capacitors and ten diodes. Its input is connected with the secondary of a transformer having turns ratio 2, whose primary is connected with a high frequency voltage source having amplitude 250V. The value of capacitors is chosen to be 0.1u and an ideal diode has been selected for the purpose. Using equation 1, the output voltage for this circuit is found to be 5kV. Figure 5(a), shows the rise in the output voltage with respect to time and it clearly shows that the output voltage finally reaches to 5 kV and become stable at this value. Thus, this simulation results validates the formula given in equation 1 and this result also shows that the output voltage become stable and reaches its final value in nearly 80ms, which is a very less time. This result is obtained when high frequency voltage source has been used to drive the capacitor diode voltage multiplier. Similarly, here also the same behavior has been observed when this multiplier is fed with a low frequency (50Hz) voltage source i.e. delay in response and relatively less output voltage and it has been clearly shown in fig.5(b).

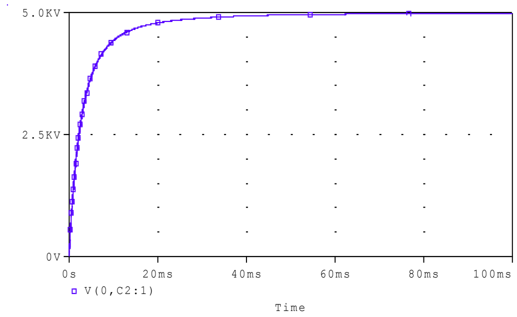

Fig 5(a): Output voltage for a high frequency voltage source driven capacitor diode voltage multiplier

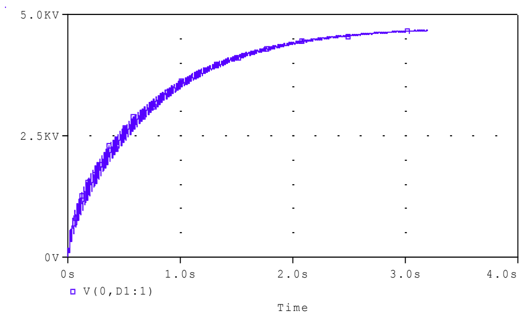

Fig 5(b): Output voltage for a low frequency voltage source driven capacitor diode voltage multiplier

A graph has been plotted between the output voltage of the capacitor diode voltage multiplier fed with a high frequency voltage source and the number of stages, which has been shown in fig.6. It shows that the output voltage is linearly dependent on the number of stages.

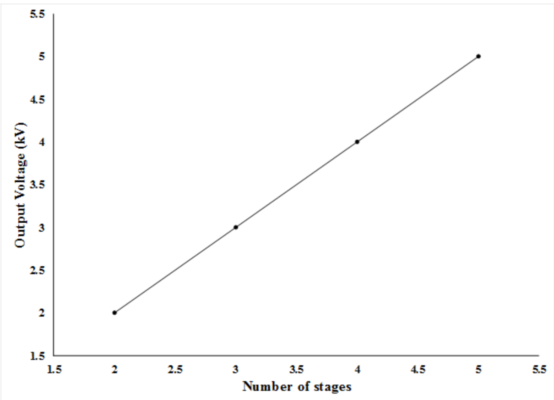

Fig 6: Output voltage for a high frequency voltage source driven capacitor diode voltage multiplier for different number of stages.

5. CONCLUSION

After performing the simulations and analyzing the results, it can be clearly said that a high frequency voltage source driven capacitor diode voltage multiplier has very less response time in comparison to its counterpart fed with a low frequency voltage source. Also, it is well known that a high frequency operation facilitates reduction in the size of the components such as inductors and transformers. Hence, the high voltage dc power supply developed using capacitor diode voltage multiplier fed with high frequency voltage source results in a great reduction in size and weight of the high voltage dc power supply.

6. REFERENCES

[1] C. M. Young, M. H. Chen, S. H. Yeh and K. H. You, "A single-phase-single-stage high step-up ac-dc matrix converter based on Cockcroft-Walton voltage multiplier with PFC," IEEE Trans. Power Electron., vol. 27, no. 12, pp. 4894-4905, Dec. 2012.

[2]. J. S. Burgler (1971). Theoretical performance of voltage multiplier circuits" June, IEEE. J. solid state circuits publications, 6 (3):132-135.

[3] M. M. Weiner, "Analysis of Cockcroft-Walton voltage multipliers with an arbitrary number of stages," Rev. Sci. Instrum., vol. 40, no. 2, pp. 330-333, 1969.

[4] I. C. Kobougias and E. C. Tatakis, "Optimal design of a Half Wave Cockcroft-Walton voltage multiplier with different capacitances per stage," in Proc. IEEE Power Electronics and Motion Control Conf., Sept.,2008, pp. 1274-1279.

[5]. C. K. Dwivedi, M. B. Daigavane," Multi-purpose low cost DC high voltage generator (60 kV output), using Cockcroft-Walton voltage multiplier circuit‖, International Journal of Science and Technology Education Research Vol. 2(7), pp. 109 - 119, July 2011.

[6]. E. Kuffel, W. S. Zaengl, J Kuffel (2000). High Voltage Engineering fundamental. Second edition, published by Butterworth-, Oxford. pp.10-20.

[6]. M. S. Naidu, V. Kamaraju (2004). High Voltage Engineering. Third Edn. McGraw- Hill Company Ltd. pp. 146-156

[7]. Spencer DFR (2001). Aryaeinejad and E.L. Reber. Using the Cockcroft-Walton Voltage Multiplier Design in Handheld Devices. Idaho National Engineering and Environmental Laboratory, P.O. Box 1625, Idaho Falls, ID 83415.

[8]. I. Yamamoto, K. Matsui, F. Ueda (2000). A power factor correction with voltage doubler rectifier. Chubu University, Dep. Electrical Eng. Japan, IEEE. 137(3): 52–58.

BIOGRAPHIES

Devesh Malviya belongs to Allahabad and received his Bachelor of Technology degree from SHIATS, Allahabad, U.P.-India in 2014. He is pursuing M.Tech. in Electrical Engineering with specialization in Power System from SHIATS, Allahabad. His area of interest includes Power System and Power Electronics etc.

Prof. (Dr.) A. K. Bhardwaj belongs to Allahabad. He received diploma and degree in Electrical Engineering in 1985 and 1998 from B.T.E., Lucknow and JMI, New Delhi respectively. He has done M.Tech. in Energy and Environment Management from IIT Delhi in 2005 and Ph.D. in Electrical Engineering from SHIATS, Allahabad in 2010. He has 17, 14 and 3 years of teaching, industry and research experience respectively. His research interest includes Power System, Power Electronics and Electrical Machines etc.