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High Voltage DC Generator For Insulation Testing Using Step Up Converter And Voltage Multiplier

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Abstract— In power systems the electrical equipment and insulating materials must be capable of withstanding over voltages during operation. Normally high Direct Current (DC) voltage is used in testing a variety of insulating material. In this paper a high DC voltage generator with voltage multiplier element is developed also analyzed. A 12 stage cascaded voltage multiplier module is designed and the multi-module circuit also developed by connecting the output voltage of each module in series using MATLAB SIMULINK software. The maximum DC output voltage of 50.93 kV is generated using this compact converter in simulation. The hardware of compact converter using modern power semiconductor switches is constructed that produce maximum output DC voltage of 3.43 kV with maximum duty cycle of the MOSFET switch varied up to 84.30%. The PIC microcontroller is used to achieve PWM generation for switching the MOSFET.

Index Terms— boost converter, DC-DC converter, insulation testing, step-up converter, voltage multiplier circuit.

1 INTRODUCTION

IN electrical power system the testing of insulating material is done by high DC voltages to ensure the withstanding capacity. Conventional method of obtaining this high DC voltage is using conversion circuit in conjunction with step up transformers [1]. The use of transformer in converter circuit for high voltages increases the losses due to the leakage inductance as it reduces the overall operating efficiency [2]. The conventional topologies to get high yield voltage utilize fly back DC-DC converters causes additional multifaceted nature and greater expense [3]. They have the spillage segments that cause pressure and loss of vitality that outcome in low proficiency. The mix of voltage multiplier with high advance up converter expands the voltage change proportion and addition required for testing the protecting materials [4]. The voltage multipliers are given capacitors and diodes in the circuit for changing over the info voltage to another elevated level yield. The issue of utilizing a transformer can be overwhelmed by the use of an appropriate promoter converter without a transformer and a multiplier circuit having fell associated multiplier unit. A high advance up converter dependent on Cockcroft Walton voltage multiplier gives higher voltage proportion [5]. It is a Pulse Width Modulation (PWM) based DC to DC converter joins with the lift converter and the exchanged capacitor. Its capacity is to give diverse yield voltages utilizing just one driven switch and one inductor with fell diodes and capacitors [6]. This paper clarifies the structure parts of a advanced DC to DC converter which having 12 phase fell voltage multiplier module. The multi-module circuit is created utilizing MATLAB programming by associating the yield voltage of every module in arrangement. The PWM technique for control is utilized to shift the yield voltage. A minimal converter utilizing MOSFET is developed to deliver most extreme yield DC voltage of 3.43 kV utilizing PIC microcontroller.

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2 HIGH VOLTAGE DC GENERATOR

2.1 Step-Up Converter

Renewable energy sources normally generate low output voltages that been stepped-up with the help of DC to DC converters [7-8]. They are boost converters which gives the output voltage higher than the input voltage [9]. The same concept is utilized to generate high DC voltage with the use of voltage multiplier circuit.

2.2 Voltage Multiplier

The circuit graph for support converter with voltage multiplier is appeared in Figure 1.

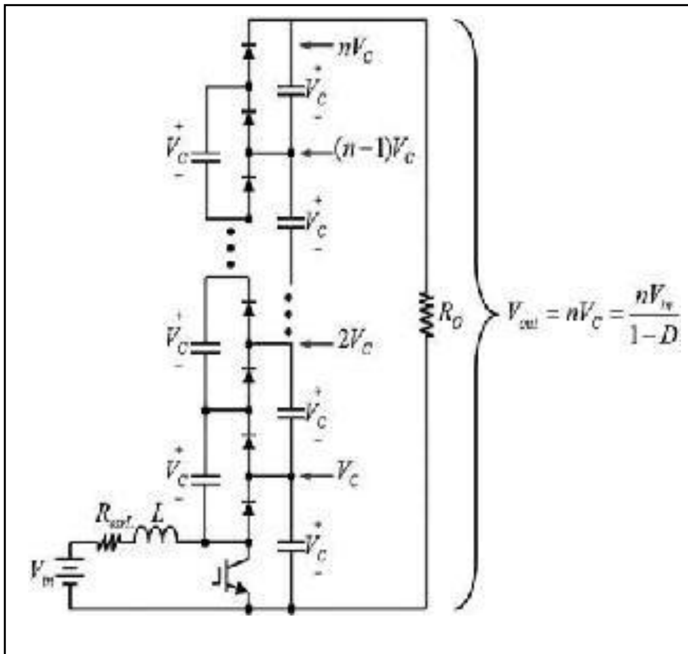

Fig. 1. Circuit diagram for boost converter with voltage multiplier

The high voltage generator is nothing but a DC to DC converter dependent on a driven switch an inductor with fell diodes and capacitors. The fundamental preferred position of this circuit is that the quantity of levels can be reached out by basically including capacitors and diodes without changing the principle circuit [10].The activity of the circuit during SWITCH- ON state is appeared in the Figure 2[11].

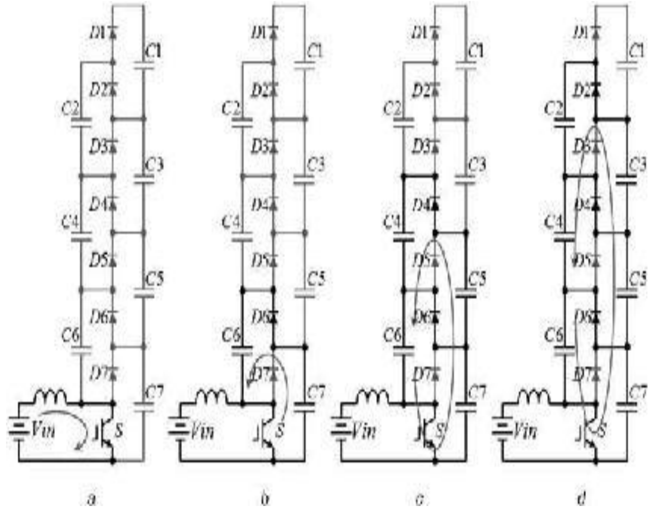

Fig. 2. Operation of circuit during SWITCH-ON state

When the SWITCH-ON express, the inductor coil 'L' is associated with the voltage, Vin. The capacitor ‘C7’ interfaces capacitor C6's voltage through diode ‘D6’ and the switch ‘S’ during capacitor ‘C6's’ voltage is under capacitor ‘C7's’ voltage. But, if the voltage across capacitors ‘C4’ and ‘C6’ is not exactly the voltage across capacitors ‘C5’ and ‘C7’, at that point capacitors ‘C5’ and ‘C7’ interfaces the voltage across capacitors ‘C4’ and ‘C6’ through diode ‘D4’ and ‘S’. Along these lines, capacitors ‘C3’, ‘C5’ and ‘C7’ associate the voltage across capacitors ‘C2’, ‘C4’ and ‘C6’.

The activity of the circuit during SWITCH -OFF state is appeared in the Figure 3[11]. When the SWITCH-OFF express, the inductor coil current goes through diode ‘D7’ and charges the capacitor ‘C7’. When diode ‘D7’ closes the capacitor ‘C6’, the voltage ‘Vin’ in addition to the inductor's voltage interface the voltage across capacitors ‘C5’ and ‘C7’ through diode ‘D5’. Also, the voltage over the coil inductor ‘L’ in addition to Vin, capacitors ‘C4’ and ‘C6’ associate the voltage across capacitors ‘C3’, ‘C5’ and ‘C7’ through the diode ‘D3’. At long last, the voltage across capacitors ‘C1’, ‘C3’, ‘C5’ and ‘C7’ are associated by capacitors ‘C2’, ‘C4’, ‘C6’, ‘Vin’ and the inductor's voltage. The diodes ‘D1’, ‘D3’, ‘D5’ and ‘D7’ switches simultaneously supplemented with diodes ‘D2’, ‘D4’, ‘D6’ and switch ‘S’.

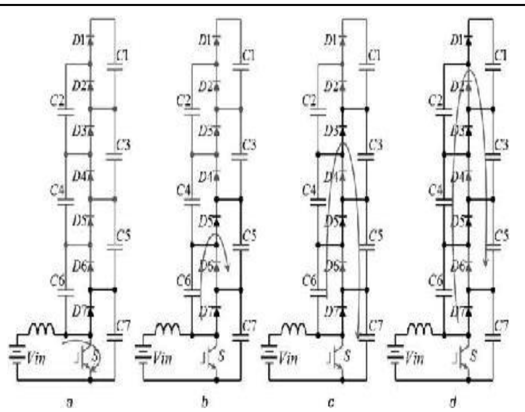

Fig. 3. Operation of circuit during SWITCH -OFF state

3 Design aspects of High Voltage DCGenerator

A 12 stage cascaded electrical energy multiplier module in conjunction with DC to DC converter is constructed and simulated with the help of MATLAB SIMULINK software. The parameters used in circuit such as inductor, capacitor and duty cycle values are calculated theoretically then used for simulation. The theoretical calculation carried out for the boost converter with12 stage cascaded voltage multiplier circuits are given in the Table1. The output voltage of the module is connected in series to get a maximum voltage of 50.93 kV. The maximum output voltage is obtained by changing the duty cycle of the MOSFET switch. The block circuit of the entire high voltage generator module is shown in Figure 4. and the MATLAB SIMULINK module is shown in the Figure 5.

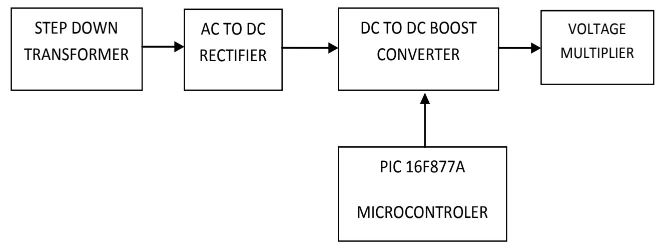

Fig. 4. Block diagram of converter circuit

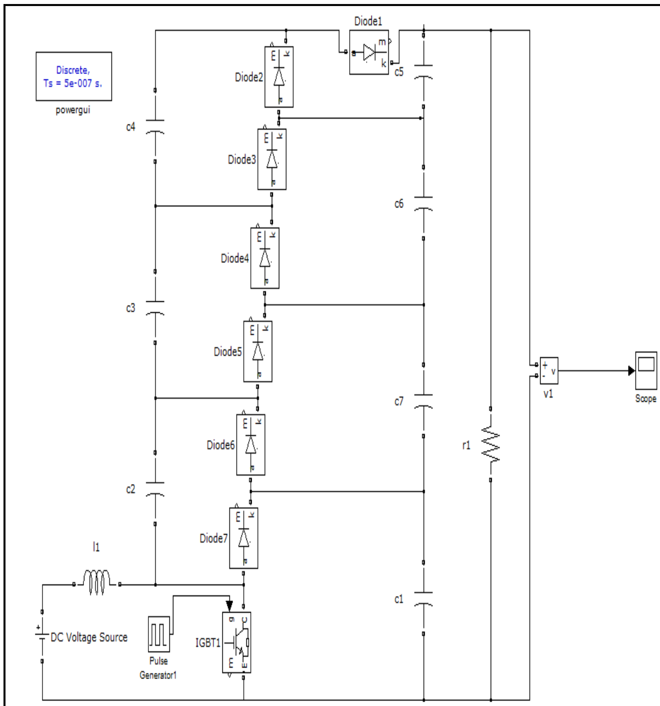

Fig. 5. MATLAB SIMULINK of the multi module circuit

4. Test Results of the High Voltage Generator

The test results of the simulated cascaded voltage multiplier module with various duty cycles are shown in the Table 2

The maximum output voltage and output current wave forms for both module 1 and multi module circuit of 12 stage cascaded voltage multiplier module with duty cycle 0.76 are shown in the Figure 6 and 7 respectively. The parameters required for boost converter with cascaded voltage multiplier module 1 is calculated theoretically for output voltage of 15 kV. The output voltage of 12.73 kV is obtained with duty cycle of 0.76 in voltage multiplier module 1 from simulation. The multi module circuit produces the maximum output voltage of 50.93 kV. The current rating and power rating is identified from simulation for hardware implementation.

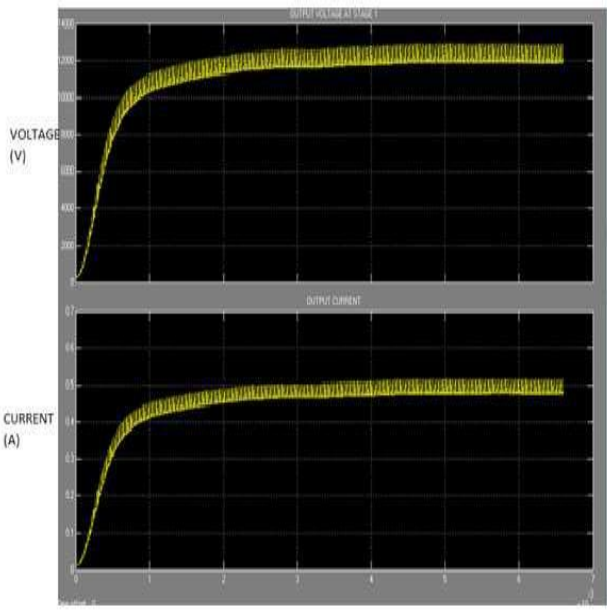

Fig. 6. Voltage and current waveforms of module 1

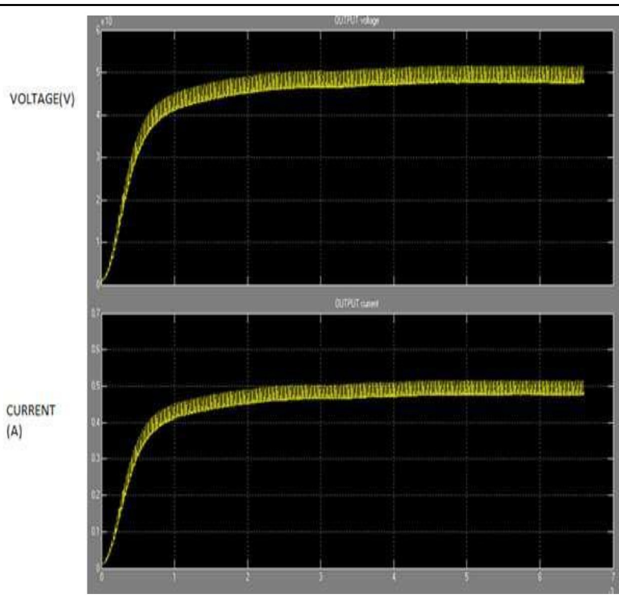

Fig. 7. Voltage and current waveforms of multi module

TABLE 1
SIMULATION RESULTS OF OUTPUT VOLTAGE AND CURRENT

Duty Cycle	Output voltage in kV		Output current in Amps
	Module 1	Multi Module Circuit	
0.50	05.65	22.63	0.30
0.60	06.75	27.00	0.29
0.70	09.25	37.02	0.40
0.76	12.73	50.93	0.53

5. HARDWARE MODEL OF THE HIGH VOLTAGE GENERATOR

This hardware model of the proposed high voltage DC generator having cascaded voltage multiplier consist of power supply circuit, boost converter circuit and voltage multiplier circuit.The initial stage of the converter circuit requires DC input voltage from which the AC supply will be converted in to DC using AC to DC rectifier circuit. The 230V AC supply is step downward to 110V using step downward transformer in order avoid the stress in the circuit. Then this voltage is converted to DC using full wave bridge rectifier circuit. The components used in the rectifier circuit are step down transformer, diodes and electrolytic capacitor. The output DC voltage obtained from the rectifier circuit is 153V. The 3 stage cascaded voltage multiplier is constructed using diodes and capacitors. Four 1 MΩ resistors are joined in cycle at the output terminal to acts as the load. The voltage increase in each stage of the voltage multiplier path for an input voltage of 153V is 253V. The voltage available in the first stage of the boost converter is 389V. The voltage in second and third stage is 619V and 910V respectively. The voltage is multiplied two times of the number of period. Hardware model of high DC voltage generator circuit having step up converter with voltage multiplier is depicted in the Figure 8. The high voltage output is varied by changing the duty ratio with the help of PIC microcontroller.
The total output voltage developed by the circuit is measured using Digital Storage Oscilloscope (DSO). The maximum output voltage obtained from the circuit is 3.43kV for a duty cycle of 84.30%. The output voltage variation with increase in duty cycle using the push button is given in Table 3. The increase in output voltage with increase in duty cycle is shown in Figure 9. In order to decrease ripple contented in the output voltage 8 numbers of 47µF/450V rating capacitor are related in series at the output area and the ripple content are reduced to 2.6 %.

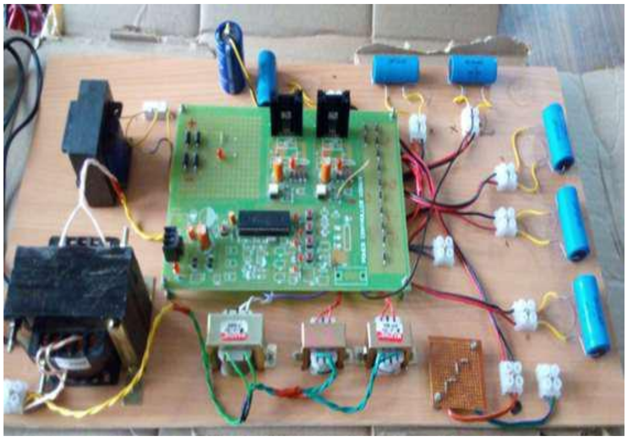

Figure 8.Hardware model of high voltage DC generator circuit.

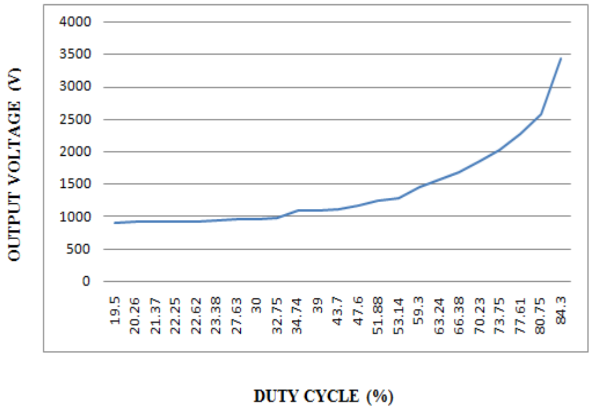

Figure 9 Variation of output voltage versus duty cycle

TABLE 3. VARIATION OF OUTPUT VOLTAGE WITH DUTY CYCLE

Duty cycle (%)	Total output voltage (V)
9.5	0910
20.26	0923
21.37	0928
22.25	0933
22.62	0938
23.38	0939
27.63	0962
30.00	0968
32.75	0987
34.74	1101
39.00	1107
43.70	1119
47.60	1170
51.88	1250
53.14	1290
59.30	1460
63.24	1570
66.38	1680
70.23	1860
73.75	2020
77.61	2270
80.75	2570
84.30	3430

5. CONCLUSION

The basic design aspect of the high voltage DC generator with voltage multiplier is simulated using MATLAB software that produces output voltage of 50.93 kV. The parameters required for designing the circuit is calculated theoretically. The hardware model of the compact converter is fabricated that produces the output voltage of 3.43 kV by connecting the output voltage of each module in series. The required high DC voltage is obtained from this circuit by varying the gate pulse of the switch. The main future of the circuit is it produces high DC voltage for testing of insulating materials with compact size.

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