International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 12, December-2014

Development of High Voltage Solid State Marx Generator for Liquid Applications

[1] Bhargav M. Patel, [2]Shemal H. Devmurari, [3] Mulav P. Rathod
[1, 2]Students, [3]Asst.Prof, Electrical Engineering Dept.,
SVIT, Gujarat, India

***Abstract*- This paper presents new solid state Marx generator topology. Higher pulse repetition rate and higher efficiency can be achieved by replacing the sphere gap assembly of conventional Marx generator with solid state switches like IGBTs and MOSFETs.Each Marx stage includes a capacitor or pulse forming network, and a high voltage switches. The structure of proposed topology can control the Output pulse frequency and magnitude. The circuit can be easily obtain a high voltage pulse without using any a pulse transformer. The operation and performance of new solid state Marx generator have been evaluated with simulation results of PSCAD. The results are obtained and verified that the proposed PSCAD circuit is capable to produce a reliable output and can be further be implemented in practical application.**

Keywords: IGBTs, Pulse repetition rate, Simulation, Voltage droop

INTRODUCTION

Today, high voltage Pulsed power supplies have a wide range of applications [1],[3]. The widely used method for generating high-voltage pulses is the Marx generator circuit.

A Marx generator is made up of a number of capacitors that are charged in parallel to a given voltage, V, and then discharged in series. This produces an output voltage of V multiplied by the number of capacitors stages. The conventional Marx generator for high-voltage pulsed applications, uses passive power components (inductors or resistors), to supply the energy storage capacitors. The conventional Marx generator has some disadvantages like cost, size, power losses and limited frequency operation. In the proposed circuit the bulky passive power elements are replaced by power semiconductor switches, increasing the performance of the classical circuit, strongly reducing cost, losses and increasing the pulse repetition rate.

In conventional circuit, the output pulse repetition rate is limited. The solution of this problem is replacing the sphere gaps by solid state power electronics switches. The development of economical, compact, high voltage, high di/dt, and fast turn-on solid-state switches make it easy to build economical, long lifetime, high voltage Marx generators capable of high pulse repetition rate.[2]

SIMULATION AND RESULTS

The following figure shows Power Circuit diagram of High Voltage solid state Marx Generator.

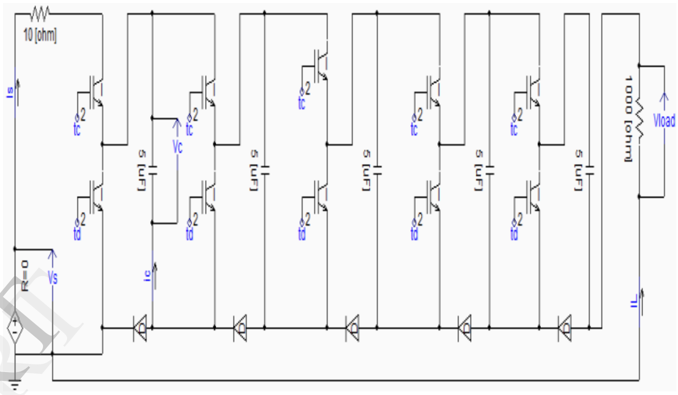

Fig. 1. Power circuit diagram

As shown in Fig.1, no of stages = 5, per stage Capacitance (C) = 5 uF, Source Voltage (Vdc) = 1 kV, Load (R) = 1000 Ω, Current Limiting Resistor = 10Ω.

Per stage , 2 IGBTs and 1 capacitor is used. The current limiting resistor is placed in series with supply voltage.

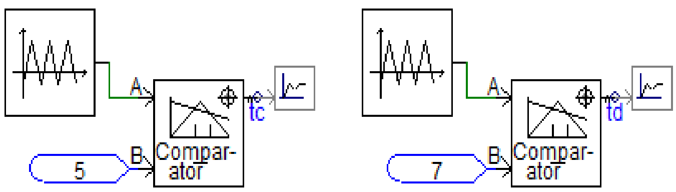

Fig. 2. Control Circuit diagram

In above control Circuit, Two Gate Signal (tc1 & td1) is formed by using Comparators.

Gate signal tc1:

Bidirectional 100 Hz Triangular waves with magnitude 10 Volt is compared with constant dc voltage of magnitude 5 Volt. Hence comparator generate gate signal (tc1) of 50% Duty cycle.

Gate signal td1:

Bidirectional 100 Hz Triangular waves with magnitude 10 Volt is compared with constant dc voltage of magnitude 7 Volt. Hence comparator generate gate signal (tc1) of 30% Duty cycle.

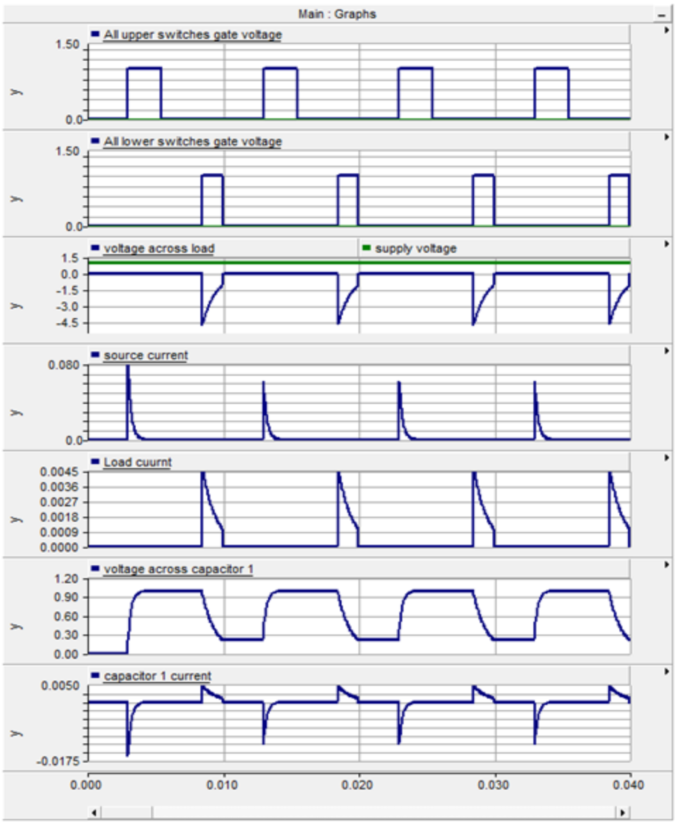

Fig. 3. Output Waveforms for Load(R) = 1000 Ω, Output pulse frequency (f) =100Hz

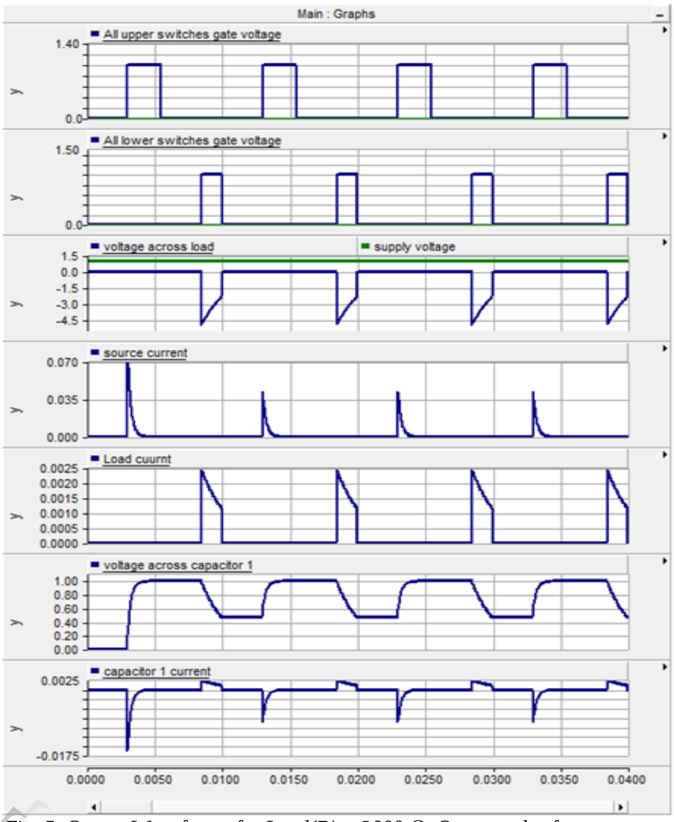

Fig. 5. Output Waveforms for Load(R) = 2000 Ω, Output pulse frequency (f) = 100Hz

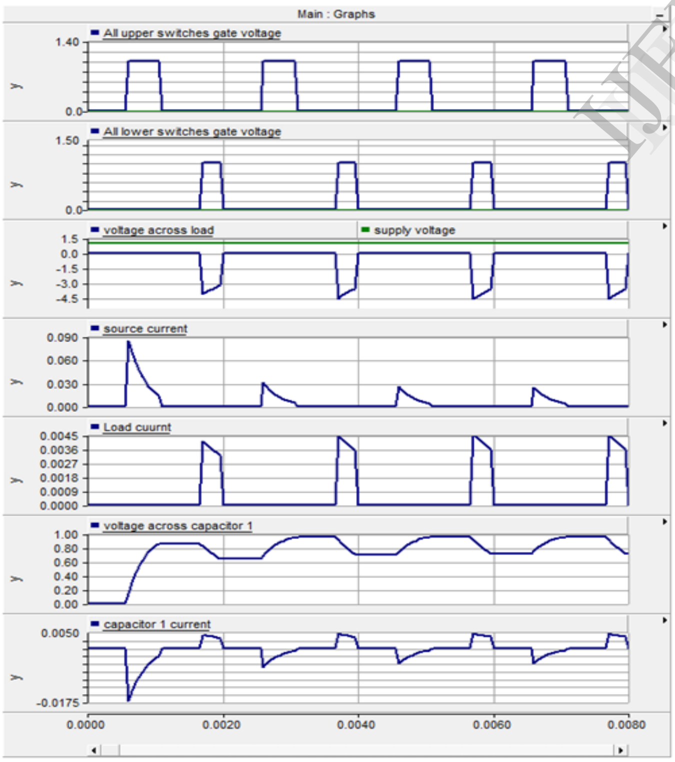

Fig. 4. Output Waveforms for Load(R) = 1000 Ω, Output pulse frequency (f) = 500Hz

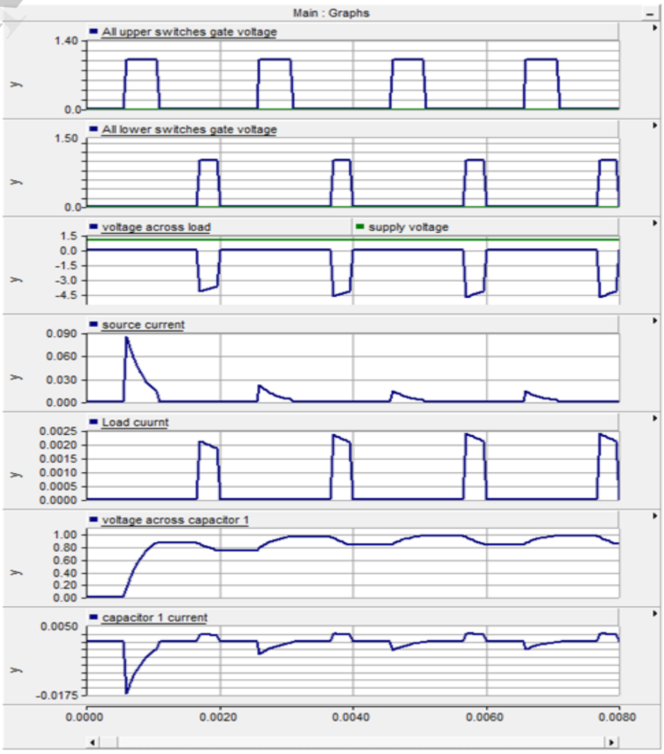

Fig. 6. Output Waveforms for Load(R) = 2000 Ω, Output pulse frequency (f) = 500Hz

Table 1: Result Data of Simulation on PSCAD

Parameter	R_{LOAD} = 1kΩ	R_{LOAD} = 1kΩ	R_{LOAD} = 2kΩ	R_{LOAD} = 2kΩ
Frequency(Hz)	100	500	100	500
Output pulse duration Td(on)(ms)	1.7	0.5	1.7	0.5
Tc(on)(ms)	2.75	0.7	2.75	0.7
V_{LOAD} (kV)	-4.48	-4.38	-4.72	-4.66
I_{LOAD} (A)	4.48	4.38	2.36	2.33
V_C (max)	1000	960	999	979
V_C(min)	223.20	711	471	840
I_C (discharge)	4.48	4.38	2.36	2.33
I_C (charge)	10.13	2.718	6.89	1.60
$\Delta Vo = \frac{Vc(min)}{Vc(max)}$	0.223	0.740	0.471	0.858
%Voltage decrease (%)	77.680	25.937	52.852	14.198
Energy delivered to load $E = \frac{n^2 x Vc(max)^2 x Td(on)}{R_{load}}$	42.5	11.52	42.41	11.98

From Table 1. , By comparing the data for f = 100Hz and f = 500Hz for same load (R_{LOAD} = 1000 Ω), we can observe following points:

1. As the frequency of output pulse increases, the load voltage (V_{LOAD}) almost remain same.
2. As the frequency increase 100Hz to 500Hz , Charging current of each capacitor taken from the source decreases from 10.13Ampere to 2.718Ampere .Thus, as the frequency increases, the burden on each capacitor decreases and so the size of capacitor reduces.
3. Here, % Voltage decrease of each capacitor is inversely proportional to voltage droop (ΔVo). It's necessary to have a % Voltage decrease as low as possible for satisfactory operation of solid state marx generator.[4] As frequency increases from 100Hz to 500Hz , % Voltage decrease changes from 77.68% to 25.937% respectively.
4. From (3), the energy delivered to the load (E) is directly proportional to Td (on).Thus as frequency increases from 100Hz to 500Hz, Energy delivered to the load per pulse decrease from 42.5 Joule to 11.52 Joule.
5. Thus, as the pulse repetition rate (frequency) is higher. Over all energy saving is achieved for same load and load voltage.

All above points can be applied to any other load, like R_{LOAD} = 2kΩ as shown in table 1.

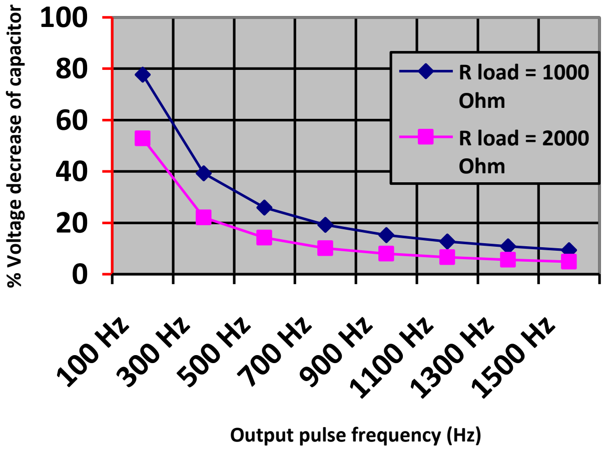

Fig. 7. Graph of % Voltage decrease V/s Output Pulse frequency with two different loads.

From above graph, as the frequency increase for fixed load, % Voltage decrease of capacitor is gradually decrease. Hence, for effective pulse applications, the high voltage solid state Marx generator is used with higher pulse repetition rate.

Higher output pulse frequency can be achieved by replacing the sphere gap of conventional marx generator with solid state switches (IGBTs) which lead us to the new concept of solid state marx generator. In this circuit highest operating frequency is limited only by the frequency of solid state switches.

APPLICATIONS

Output pulses of the solid state Marx Generator is applied to the Load as liquid. Here liquid can be the waste water or liquid food. The liquid is flowing through or placed between two electrodes, which constitute a treatment chamber gap where two electrodes are placed at certain distance.

By controlling duty cycle of device output pulse waveform can be control. Bacteria in liquid can be eliminated by high voltage pulse electric field (PEF).

Especially hospital waste water contains enormous amount of harmful bacteria, which spreads diseases if they are not removed. According to WHO it should be processed before goes into drainage system. Thus indirectly it controls the water pollution.

The damage of micro-organism cell and bacteria membrane will occur if high voltage is applied. With the advantages of Pulse Electric Field (PEF) preservation technology, PEF is the most required manner by food processing industries in the future.

A Pulsed high voltage is used to remove microorganisms in liquid. The generated high voltage and high repetition rate pulses produces strong Pulse electric field through liquid. This applied Pulse electric field (PEF) will physically damage the micro-organism cell & bacteria membrane. In the PEF technology, the process can be done without increasing temperature of liquid so that we can prevent the loss of vitamins, taste, and color from the product.

CONCLUSION AND FUTURE SCOPE

Based on the research and results presented in this paper, the following conclusions are reached:

1) As the pulse repetition rate is higher, the energy taken from the source is decreases and hence overall economy can be achieved.

2) The output voltage remains constant where as required energy is considerably reduced.

3) Source rating, size of capacitors (rating), IGBTs current rating and losses reduces hence Compaq size of whole module is achieved.

4) By replacing the bulky passive components, Voltage efficiency and pulse repetition rate is higher also the higher voltage can be achieved without using pulse transformer.

5) With higher Pulse frequencies, the % Voltage decrease of capacitors less than 10% can be achieved.

This compact, efficient, Cost effective Marx generator can be made with five stages, constructed using 1200 Volt IGBTs and 1kV diodes operating with 1kV variable d-c input voltage and at higher frequency.

As from results nearly square waveform of around 5kV, 500 Hz pulses are generated with very low rise time and satisfactory voltage droop.

New non thermal pasteurization process on liquid can be done with reduced overall cost and saving in energy. The presented topology cab bring a completely new extent of capability in bacterial inactivation process for liquid food and waste water.

REFERANCES

1. M.P.J Gaudreau, T. Hawkey, J. Petry and M. Kempkes, 'A solid state pulsed power system for food processing' in Proceed. Pulsed Power Plasm Science,2001,vol.2,pp.1174-1177
2. 'Solid State Marx Generator' Gidden, S.C;Appl. Pulse Power Inc., Freeville,NY;Sanders, H. D. ; Power Modulator Symposium, 2006.pg - 314 to 317.
3. E.G. Cook, 'Review of Solid State Modulators' "Presented at the XX International Linac Conferance, Monterey, Aug,2000.
4. 'Solid state puled power electronics' by Luis Redondo, J. Fernando Silva,Lisbon University,Portugal.
5. 'Power electronics hand book' by M. H. Rashid.