A Review Paper on the Design, Optimization and Application of Marx Generator

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***Abstract*- Marx Generator's designing for different purpose, its Optimization and its applications in different fields are discussed. The results of a Solid State Marx generator of 50kV, 50A are shown which was made by Harshada C. Bhosale, Bindu S. and Sincy G. [1]. To show the importance of the Spark Gap a Compact Marx Generator is analyzed [2]. Applications of Marx Generator in dv/dt testing of Power semiconductor devices [3], direct energy and effects testing applications[4] and for industrial food applications[5] are explained in the paper. The software which is used to get the results are MATLAB and Proteus. Experimental results are presented and discussed.**

***Index Terms*- Marx Generator, spark gap, breakdown, high voltage, rise time.**

I. INTRODUCTION

In different fields like industrial, medical, environmental, agricultural etc. high voltage pulsed power supplies are used for many kind of applications. To generate high voltage pulses Marx generator is used. It works on the circuit described by Erwin Otto Marx in 1924. Marx generator's working is based on charging capacitors in parallel and then connecting them in series by using spark gaps of switching devices to generate a high voltage pulse in the output, as shown in the fig. 1.

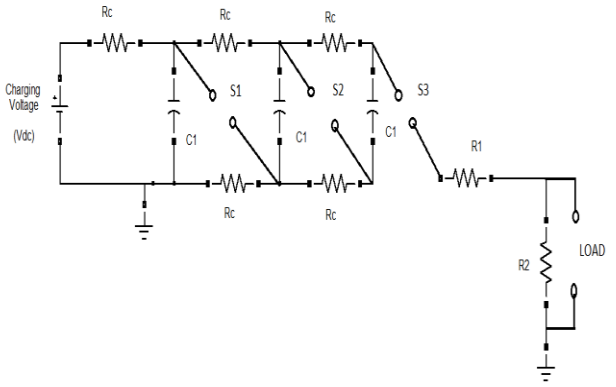

Fig. 1. Conventional Marx Generator

In this paper we have shown the result of a Marx generator which can generate 50kv in output which is designed by employing 50 stages. In each stage of this Marx generator there is one switch, capacitor and two diodes. It was made to be used for Electron gun application. The explanation, circuit design and the simulation results of this Marx generator is in section II.

The impact of Spark Gap breakdown on output voltage of the Marx generator is discussed in section III. Applications of the Marx generator in Industrial food applications, for use in directed energy and effects testing applications and for dv/dt testing of power semiconductor devices are explained in brief in section IV.

II. SOLID STATE MARX GENERATOR

In the conventional Marx generators spark gap switches are used to connect the charged capacitors in series to generate the high voltage pulse. These spark gap switches have certain problems like small life, low switching frequency, large size etc. Now due to development of semiconductors the semiconductor switches like IGBT and MOSFET are being used which have high voltage blocking capabilities.

Replacing spark gap switches with the solid state switches increases the repetition rate of pulses, helps in changing of amplitude and pulse width of output pulses by controlling the gate control pulses.

Marx generator designed by Harshada C. Bhosale, Bindu S. and Sincy G. [1] is shown in fig. 2.

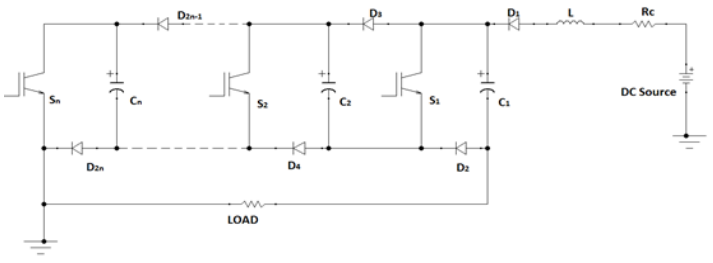

Fig. 2. Solid State Marx generator

The circuit shown above consists diodes, IGBT switches, inductor and capacitors. Its input is high voltage DC supply.

The inductor is used as current limiter at the time of pulse generation. Its working is divided into two modes in which first is charging mode in which capacitors were charged with the input dc voltage. The charging time constant is controlled by the input resistance (R_c).

The second mode is the discharging mode of the capacitors by connecting them using IGBT switches. All the switches operate at
the same time to connect the capacitors in series. The output voltage is equal to the number of stages in the Marx generator multiplied by the input voltage i.e. $V_o = nV_{dc}$. The Clamping circuit is shown in fig.3 which is done by the diode at the time of delay in the switching ON of any switch to save the switch overvoltage.

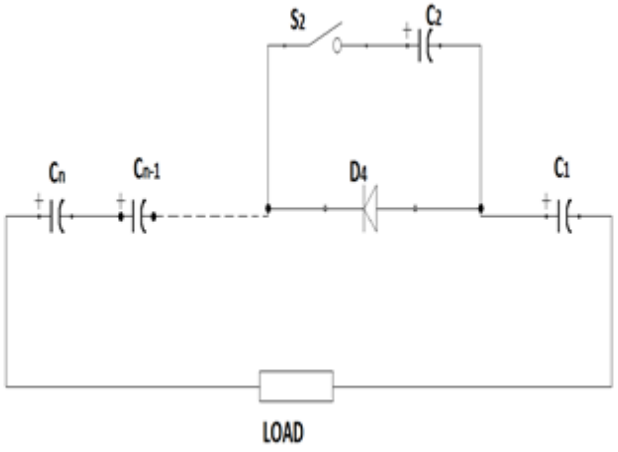

Fig.3 Clamping operation of diode and Capacitor

The features of the purposed Marx circuit, IGBT driver circuit , clamping operation of the diode and capacitor and the selection of the component are explained by Harshada C. Bhosale, Bindu S. and Sincy G. in [1].

The Simulation of the Marx generator[1] was done in Proteus software whose parameters were explained in [1]. The pulse width is 6.4 µs (fig. 4) and the peak voltage V_o of the circuit is -47.3. The voltage efficiency (η) can be calculated by the formula given where output voltage is V_O, input voltage is V_{in} and the number of stages are n.

$$\eta = \frac{V_o}{n \times V_{in}}$$

The calculated voltage efficiency is 94.6%.

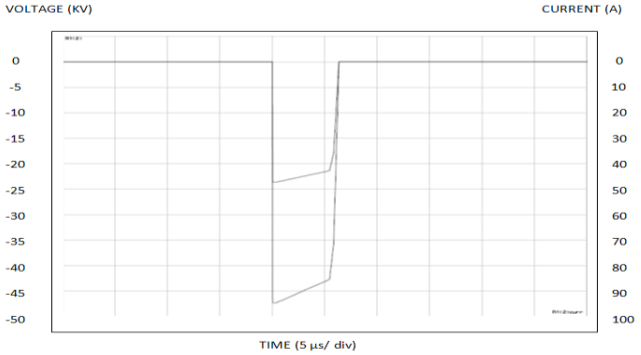

Fig.4 Single output voltage and current pulse

The results shown above and the complete results shown in the reference paper [1] confirm the validity of the design.
For the mathematical explanation paper [1] can be considered.

III. IMPACT OF SPARK GAP BREAK-DOWN

In the paper [2] the statistical behavior of the breakdown incident was discussed. It works on output voltage characteristics. The results shown in the paper state that the parallel connections may be efficiently utilized to increase the transfer of energy and current to the load. The statistical behavior of the closing spark gaps was taken into account so the breakdown voltage of the switches were to selected as values which are randomly variable with normal probability distribution functions [2].

The closing delay completely relies on the voltage of breakdown, pressure and temperature of the medium. To study the impact of time delay on the fluctuations of output voltage simulations were performed [2] also the dependency of the breakdown voltage of spark gaps were shown by an exponential function.

$$V_b = 8.84\ pd\ (kV/\ mmbar) + 0.5\ kV$$

The simulation results indicate that the closing delay time has an effect on the rise time of the Marx generator's output voltage. When the CMG (compact Marx generator) [2] is to be used for sub- nanosecond breakdown the standard fluctuations of output voltage's rise time will occur smaller than the old applications.

As the result of [2] the delay time of closing switches were also statistical and the voltage- dependent parameters because breakdown of the spark gaps is also a statistical process.

Simulation results also have shown that the parameters of the probability distribution function of the spark gap's breakdown voltage and the time delay on the voltage rise have impact on the CMG [2].

IV. SOME APPLICATIONS OF MARX GENERATOR

The Marx generator is being used in many areas which influence our lives some of them are discussed in this paper.

1. For the industrial food applications

Marx generator are used to generate Pulsed Electric Fields for bacteriological inactivation. The industrial bipolar generator which was discussed in [3] is based on Marx principle which decreases the complexity and the cost of the circuit which is used to generate positive and negative pulses into food processing uses for microorganism cleaning.

2. For the dV/dt testing of the power semiconductor devices

A solid state modular Marx generator was used for the dV/dt testing of the power semiconductor devices (MOSFET), which produces voltage transients upto 1kV with the rise time of the order of 10 ns [4]. The testing was done to know the dV/dt rating of the power semiconductor devices because the dV/dt induced turn-on can result in the sudden failure of the device. The results which were shown include the dV/dt testing of resistive and power semiconductor loads [4].

V. CONCLUSION

The basic Marx generator was introduced and the by the 50kV/ 50A solid state Marx generator [1] circuit its optimization was discussed by replacing the spark gap switches with the semiconductor switches which gave the better results from the basic circuit. Importance of the spark gap breakdown was shown in the efficiency of a Marx generator and the rise time of the output voltage. Marx generator's applications in the field of food processing and testing power semiconductor devices were also discussed in brief. The future scope of the Marx generator that it will be used always as a HV pulse generator and a testing equipment in many fields because of its cost effectiveness and good concept. The efficiency can be further increased by using more fast and controlled switches and increasing the number of stages.

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