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Implementation of Four Stage Marx Generator

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Abstract - This research paper presents the implementation of a four-stage Marx generator with PFN (Pulse Forming Network) topology and solid-state switches using a resistive load. The project aims to generate high-voltage output using a cascaded arrangement of stages, with each stage amplifying the voltage obtained from the previous stage. The power supply circuit, trigger pulse generator, and voltage booster circuit are integrated to provide the required input voltages and triggering signals. The results show that the fourth stage, with a voltage booster circuit, achieves an output voltage of up to 170V. The advantages of this project include compact design, solid-state switch reliability, and efficient power conversion. The research paper concludes with a discussion on the potential applications of the implemented four-stage Marx generator and suggests future directions for research.

Index Terms - Marx generator, PFN topology, solid-state switches, voltage booster circuit, resistive load, high-voltage generation

I. INTRODUCTION

The demand for high-voltage pulse generation has seen significant growth in recent years, driven by applications in various fields. Marx generators have emerged as a popular choice for generating high-voltage pulses due to their simple yet efficient design. This research paper presents the implementation of a four-stage Marx generator with PFN topology and solid-state switches using a resistive load. The project aims to design a compact and reliable pulse generator capable of delivering substantial output voltage.

The primary objective of this project is to design and construct a compact and efficient high-voltage pulse generator capable of delivering a substantial output voltage. The Marx generator operates on the principle of voltage multiplication through cascaded stages, wherein each stage amplifies the voltage obtained from the previous stage. This cascade configuration allows for the generation of significantly higher voltages than the input voltage.

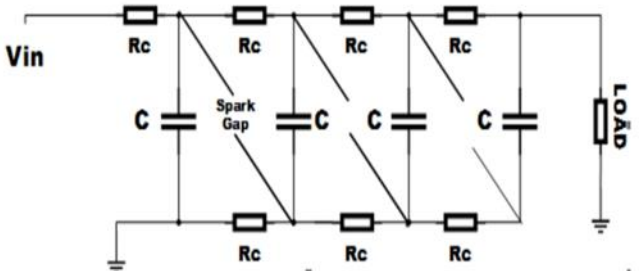

Fig.1 Schematic of four stage Marx generator

To achieve the desired voltage amplification, several key components and circuits are incorporated into the system. The power supply circuit, consisting of a step-down transformer and a bridge rectifier, converts the main power supply voltage of 220V AC to a stable 12V DC. This low-voltage DC supply is then utilized to power the trigger pulse generator circuit, which generates the necessary triggering signals for the solid-state switches.
The four-stage Marx generator is the core component of the project. Each stage consists of capacitors, inductors, and solid-state switches, which work in coordination to amplify the input voltage received from the previous stage. The resistive load, in the form of a 60W electric bulb, is connected to the output of the fourth stage. Additionally, the voltage booster circuit is implemented in the fourth stage to overcome limitations in voltage amplification and ensure the desired output voltage is achieved.

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The project holds potential applications in various fields where high-voltage pulses are required, including industrial processes, scientific experiments, and medical devices. The compact design and efficient power conversion of the implemented Marx generator make it suitable for diverse applications.

The project contributes to the academic and research community by expanding the knowledge and understanding of high-voltage pulse generation technology. The successful implementation of the four-stage Marx generator with power device switches using a resistive load will contribute to the advancement of high-voltage generation technology. The resulting generator can find applications in various fields, including scientific research, industrial testing, and beyond.

II. The Proposed System

III. Marx generators produce high voltage pulses using multiple identical stages that operate at a fraction of the total output voltage without the need of a step-up transformer that limits the pulse rise time and lowers the efficiency of the system. Each Marx stage includes a capacitor or pulse forming network and a high voltage switch. The basic principle of Marx generators is charging of the capacitors through resistor R up to a primary voltage level in parallel mode, and then they are connected in series mode by controlling the switches, and finally the energy stored in the capacitors is discharged.

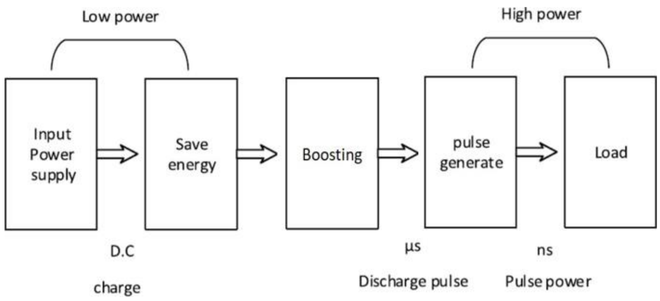


Fig.2.1: Block diagram of BCPFN Marx generator

Boost converters steps up the DC input by a specific ratio which depends on the duty cycle of the switches. Similar concept is adapted here along with a pulse forming network which will yield high magnitude pulses. This main process used in the all-pulsed power systems is to collect and store energy temporarily, and then to suddenly discharge the energy as a pulse on the intended load. Fig. shows the block diagram of the basic structure of a typical high-power pulse facility. The required energy is commonly accumulated from the energy source at relatively low-power levels and it is stored. Depending on the applications and requirements, the storage may be either in a capacitive form. an inductive form, or a combination of both forms. Then, the energy is rapidly released from the storage and converted into power pulsed in form. DC-DC converters have limitations that cannot be replaced with impulse generators such as Marx for generating the pulsed power. Specified energy with settled pulse width and even with specified rise time and fall time can be generated by pulse-forming networks. High voltage pulse power supply using Marx generator and solid-state switches is proposed in diagram below.

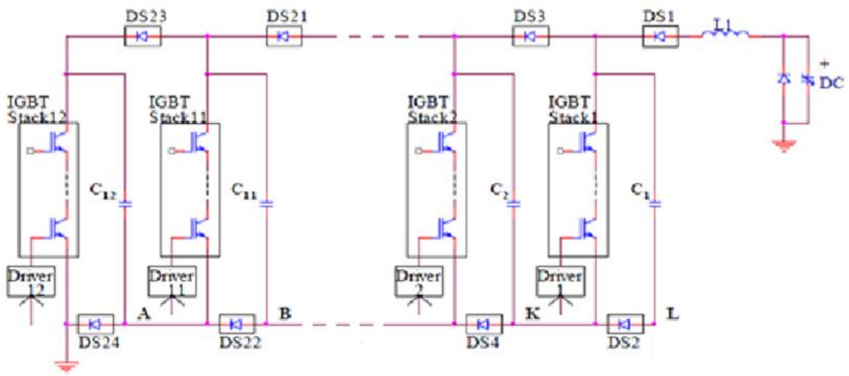


Fig.2.2: Proposed Simulation Circuits

Use of high-power semiconductors such as IGBTs have become an area of interest. A boost converter array using series-connected switches is presented. The electrical circuit is made up of a boost converter array to produce high voltage pulses. The proposed circuit had various advantages over the conventional pulse generators. The developed system has the advantages of high efficiency, long life-time, and high parameter flexibility such as voltage magnitude, and the pulse width.

IV. LITERATURE SURVEY

SR. NO.	YEAR	NAME OF PAPER	NAME OF AUTHOR	DESCRIPTION
1	2017	Pulse Forming Network for Marx Generator with Boosting Operation	Ruchi Harchandani Pramila Gorade	This paper presents Solid State Marx Generator in which capacitors are replaced by Pulse Forming Network (PFN) through which we can get controlled pulse. The magnitude of output square impulse wave can be increased to high value with the low supply voltage without using converter or transformer. To achieve high voltage the PFN inductors and capacitors are connected in boost converter mode temporarily.
2	2018	Modeling and Construction of Marx Impulse Generator Based on BC-PFN.	Seyed Mohammad Hassan Hosseini, Hamid Reza Ghafourinam, and Mohammad Hossein Oshtaghi.	This paper presents the design and construction of sample of Marx pulsed generator based on boost converter (BC) pulse-forming networks (BCPFNs). BCPFN is used instead of the conventional Marx floors for constructing this pulsed generator.
3	2019	Implementation of Ultra-wide band Marx generator with PFN topology for antenna load	Aqsa Shaikh, Ruchi Harchandani	This paper consists of a Marx Generator merged with PFN along with boosting technique. Solid State switches undergoes periodic switching to enable charging and discharging cycles of inductors and capacitors. A hardware prototype also designed and assembled to verify simulation results.

4	2018	Generation of HVDC By Using Marx Generator Principle.	K.N. Y. Sai Madhuri, L. Naga Laxmi, N. Santhi Kumari.	This paper aims to generate high voltage DC using Marx generator principle by using MOSFET and capacitor. This concept in future can be extended to Generate High voltages (KV) using a greater number of capacitors. This technique is adopted for insulation testing of the electronic components, wires, gadgets etc.

V. HARDWARE COMPONENTS USED WITH SPECIFICATIONS:

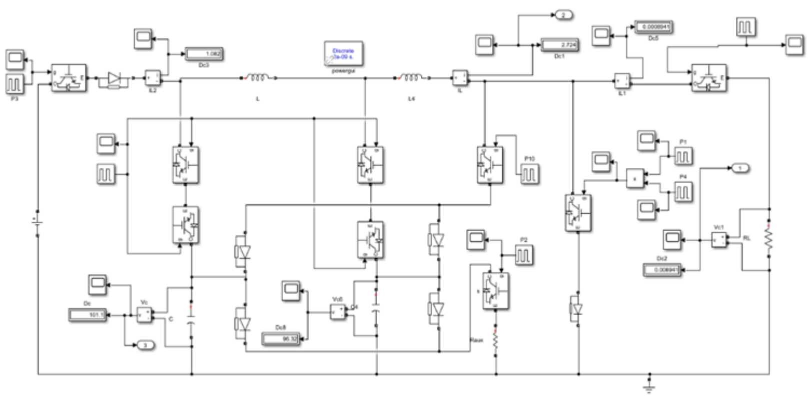
S. No.	Component	Specification	Quantity
1	IGBT	250N120	6
2	MOSFET	IRFP250N	2
3	CAPACITOR	2.5 µF 1 µF	4 10
4	INDUCTOR (Transformer core)	060V 500 mA	4
5	DC ADAPTER	12V	2
6	REGULATOR	7805	1
7	RESISTOR	1 K ohm 70 ohm	24 4
8	DIODE	IN4007	8
9	TRANSFORMER	15015V ; 2A	1
10	PHOENIX CONNECTOR	2 Pin	12
11	TRANSISTOR	-	2
12	LED	-	1

VI. SOFTWARE & HARDWARE IMPLEMENTATION

SOFTWARE IMPLEMENTATION

To evaluate the performance of the proposed Marx generator, MATLAB/ Simu- link models were built and simulated. A single-staged structure shown in Fig. is a six sectioned PFN based Marx generator Fig. is a multi-staged comparative model. The 2,3 and 4 staged Marx Generator models are connected to a scope to verify and compare the outputs. Input is a 6kV, DC source with a load resistance of 10 ohms per stage. The expected output of 15kV per stage is obtained as shown in Fig. Thus, on comparing the models with varying no. of stages we observe that the output pulse voltage also varies. As the number of stages increases, the amplitude of output voltage increases without any change in the pulse-width.

Fig.5.1: Simulation of two stage Marx generator



Here, Multi-sectioned model is presented, were number of sections is varied in order to compare the difference in output waveforms. An input of 6kV was given, for a load of 10 ohms. All the sub-systems are single staged but with varying number of sections. The Output in shows that as we increase the no. of sections, the pulse-width increases. But there is no difference in output voltage of the generator. As observed, increasing the number of stages, multiplies the output voltage.

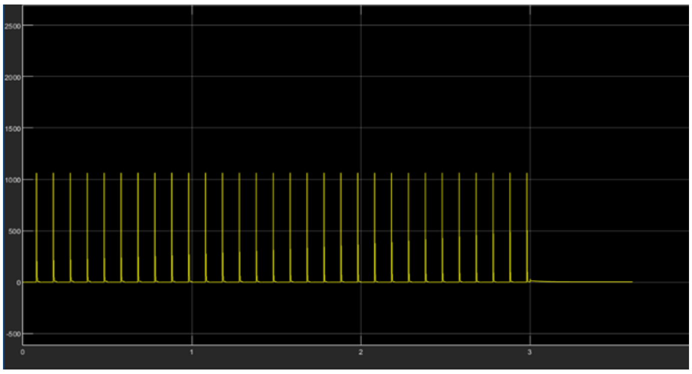


Fig.5.2: Shows the waveform of simulation result of two stage Marx generator.

Hardware Implementation:

A laboratory level prototype of the circuit with two sections (one stage) has been developed and tested. Circuit consists of capacitors, switches, and diodes. Selection of switches and diodes has been done based on input source and transients to be experienced

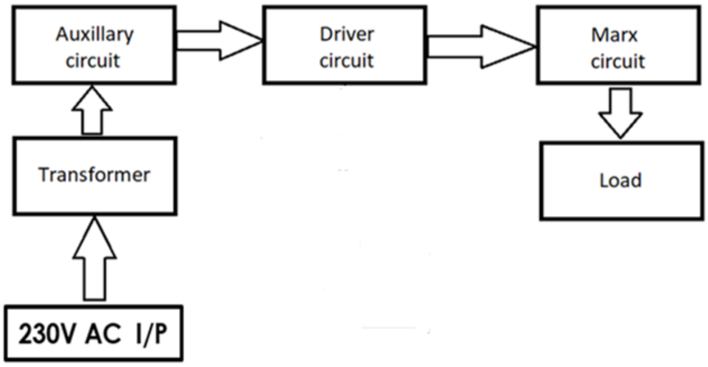


Fig.5.3: Block diagram for Proposed Topology in Hardware

The system is designed for 12 V input supply. Thus, for considering a safety factor, the ratings have been selected 5 to 10 times more than the input supply. Thus, high voltage rating IGBTs has been selected. The hardware model shown in Fig.4.3 comprises of auxiliary circuits along with the main power circuit as well as the driver circuit for the switches.

Modes of Operation

First Stage:
Input: 12V DC
Components: A capacitor, a solid-state switch (e.g., MOSFET or IGBT), and a resistive load (e.g., a current-limiting resistor)
Operation: When triggered, the capacitor charges to 12V through the solid-state switch. Upon discharge, the stored energy is released, resulting in an output voltage of around 15V.

Second Stage:
Input: 15V (output from the first stage)
Components: Another capacitor, solid-state switch, and resistive load
Operation: Like the first stage, the capacitor charges to 15V and discharges, resulting in an output voltage of approximately 24V.

Third Stage:
Input: 24V (output from the second stage)
Components: Capacitor, solid-state switch, and resistive load
Operation: The capacitor charges to 24V and discharges, yielding an output voltage of around 33V

Fourth Stage:

Input: 33V (output from the third stage)
Components: Capacitor, solid-state switch (MOSFETs), and resistive load (60W electric bulb)
Operation: The capacitor charges to 30V and discharges, producing an output voltage of approximately 36V. But the resistive load connected to fourth stage is represented by the 60W electric bulb, for satisfying this load we needed to boost the output voltage with help of using the voltage booster circuit and step-up transformer using 2 MOSFETs. As a result, voltage boosted up to 171V and the load was satisfied as the electric bulb glows.

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VII. Hardware results –

In order to evaluate the performance of the implemented four-stage Marx generator with power devices using a resistive load, a hardware experiment was conducted. The experimental setup consisted of the Marx generator circuit connected to a resistive load and appropriate safety measures were taken to ensure safe operation.

During the experiment, several measurements were taken to assess the output voltage of each stage. The output of the fourth stage was found to be approximately 171V. This value was obtained by connecting a voltage measurement probe across the load resistor connected to the output of the fourth stage.

Additionally, to demonstrate the functionality of the Marx generator, an electric bulb was connected to the output of the fourth stage. As a result, the bulb was observed to glow, indicating the successful generation of high-voltage pulses by the Marx generator

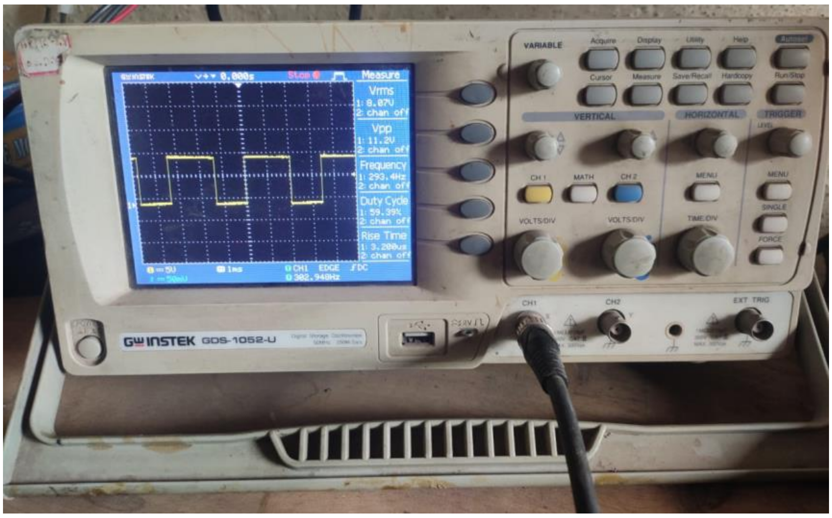

Fig.6.1: Waveforms for Triggering pulses of Marx generator

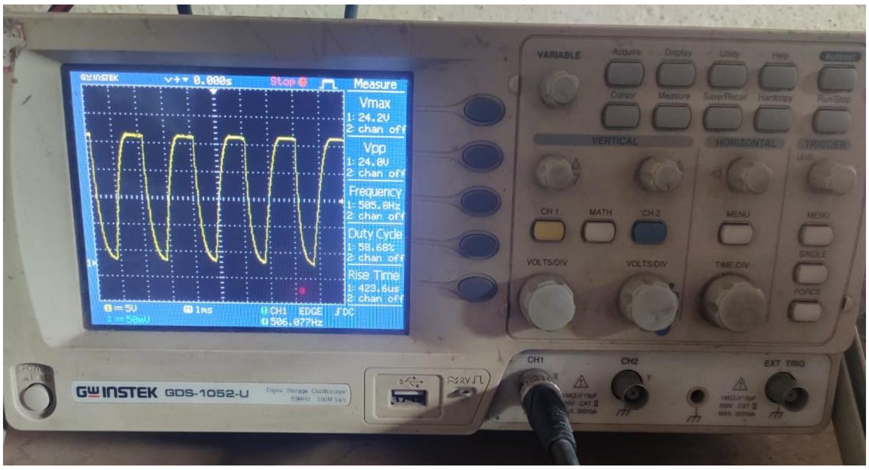

Fig.6.2: Waveforms of boosted voltage pulses of Marx generator

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These hardware results validate the effectiveness of the four-stage Marx generator with power devices using a resistive load in generating high-voltage pulses and powering practical loads such as the electric bulb."

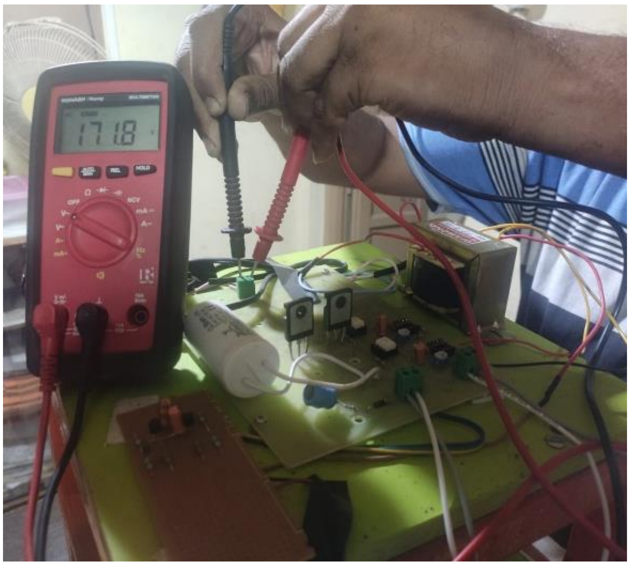

Fig.6.3 Output of Fourth Stage

Complete Hardware Model with Electric Bulb as Resistive load –

Fig.6.4: Complete Hardware Model

VIII. Conclusion

Thus, this research project successfully implemented a four-stage Marx generator with PFN topology and solid-state switches using a resistive load. The project aimed to design a compact and efficient high-voltage pulse generator. Through the integration of various components and circuits, including the power supply, trigger pulse generator, and voltage booster circuit, the system was able to generate high-voltage pulses with satisfactory results. Future work could focus on further enhancing the voltage amplification and efficiency of the system, optimizing component selection, and exploring advanced triggering techniques. This research project contributes to the field of high-voltage pulse generation by presenting a practical implementation of a four-stage Marx generator and providing insights into its performance and potential applications.

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