Generation of High Voltage DC by Modified Marx Generator

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Abstract: The principle used to generate HVDC by using Marx generator was introduced by ERWIN OTTO MARX in 1923.The principle is known as Marx principle. This principle is used to generate high voltage by charging capacitors in parallel and taking the output voltage by connecting the capacitor in series at the time of discharging. This project includes 60 stages and each stage consists of one IGBT/MOSFET, one capacitor and two diodes. Additionally IC 555 also used to generate pulses for capacitor charging in parallel during ON time through diodes. And during OFF time the output of capacitors is brought in series with the help of IGBT/MOSFET switches. At last, the number of capacitors used in series adds up the voltage approximately 60 times of applied voltage. This system is advantageous in generation of HVDC for high voltage testing of equipment. Our challenge offers a compact and smooth device from a DC deliver of 18 V to get an approx. (1000) Volts.

Keywords: IC555, Opto-coupler, MOSFET/IGBT, Marx generator.

I. INTRODUCTION

With the improvement of solid-state electronics, solid-state devices are becoming more appropriate for pulsed power application. They could supply the pulsed power systems with compression, consistency, high reverberation rate, and elongated life time. The increasing of pulsed power generators using solid-state devices eliminates restrictions of predictable components, and promises pulsed power technology to be extensively used in commercial applications. However, solid-state switching devices such as MOSFET obtainable now are only rated up to a few kilo Volts. Most of pulsed power systems require much higher voltage ratings.[1][2]

Quick discharge of stored energy in petite period as electrical pulses into a load produces large amount of immediate power. The behavior of pulse as rise time, fall time, pulse width, replication charge, a voltage and power level varies with sole applications. High voltage pulsed electricity have broad variety of programs in limited fields like industrial, scientific, agricultural, environmental etc. Marx Generator is an large voltage pulse generator. The necessary principle of Marx Generator is that the capacitors are charged in parallel in its input DC voltage stage. Those capacitors are then connected in series the use of switches to generate an extreme voltage pulse all through the burden technology. With the development of solid state electronics, solid-state devices have turn into more and more suitable for pulsed power application. They might offer the pulsed energy systems with compression, consistency, excessive recurrence fee, and long-lasting existence time.[1]

The increasing of pulsed electricity generators the practice of solid-state gadgets gets relieve of barriers of conventional additives, and promises pulsed power era to be expansively used in business packages. However, strong-state switching devices all-encompassing of MOSFET now are best rated up to 3 kilo volts. Switching devices are very important additives in pulsed power system. Conventional Marx Generator employ spark gas switches. These switches have barriers like petite lifestyle time in provisions of number of process cycles, short switching frequency, massive length, more maintenance and many others. In present years the physically powerful country switches like MOSFET or IGBT is utilized in position of spark gaps. The reimbursement of solid country switches are compressed, consistent, flexible, more capable, extensive lifestyles time, short charges and decreased losses. The output pulse width and amplitude may be varied by scheming the gate control pulses to the switches.[1]

Both MOSFET and IGBT give changeable pulse width and can produce a fast pulse rise time within a few ns athwart the load. The switching time of MOSFET is much minor than IGBT (usually 20 ns for MOSFET, 200 ns for an IGBT). IGBT are accessible at superior voltage ratings (up to 6500 V), whereas the MOSFETs are restricted to 1200 V. Solid state Marx Generator has replaced the charging resistors in predictable Marx with high energy diodes. Many new topologies with solid state Marx Generators are planned in literature. Yifan Wu has planned recurring and high voltage Marx Generator by solid-state devices with inductive based charging. Inductor here acts as a current limiter at the time of pulse generation. Problem of this topology is that it restrictions the pulse frequency due to extensive charging time constant. Also it provides no isolation from input supply source throughout discharging mode. A narrative solid-state pulsed power modulator driving by magnetic ring transformers is introduced by Jian Qiu. The charging power supply here is a full bridge resonant inverter. There is condition of isolation between charging and discharging loops implemented by magnetic rings. But the drawback is that due to the use of magnetic rings, the stray parameters alter the output voltage waveforms. Ju Won Baek proposed a novel recurring impulse voltage generator of unipolar configuration by using a boost converter array. The circuit can simply get a high voltage pulse without pulse transformer. The proposed circuit allows operation at kilohertz frequency with high efficiency. The disadvantage is that if the number of boost stacks increases the line inductance increases and hence the rise time of the output pulse increases. [1][4]L.M. Redondo have proposed a topology of solid state Marx Generator with energy recuperation reset

circuit using transformer connected at the output. This scheme provides galvanic isolation to the load. But a limitation is that leakage inductance of transformer limits the rise time of output pulse. The efficiency of the system decreases due to losses and size of transformer. [1][3]

II. CONVENTIONAL MARX GENERATOR

The generator capacitance C is to be initially charged and then discharged into the wave seminal circuits. A single capacitor C may be used for voltage up to 200 kV. For generating very extreme voltages, bank of capacitor are charged in parallel and then discharged in series connection. The relationship for charging the capacitors in parallel and then connecting them in series for discharging was at first planned with the aid of Erwin Otto Marx in 1923 as well-known in Fig.1. Typically the charging resistance is chosen to limit the charging modern about 50 to 100 mA, and generator capacitance C is chosen such that the product CRs is nearly 10s to 1 min. the gap spacing is selected such that the breakdown voltage of the space G is greater than the charging voltage V. As a result, all of the capacitances are charged to the voltage V with reference to 1 minute. When the impulse generator is to be discharged, the gaps G are made to spark over concurrently by way of a little exterior approach. Thus, all the capacitors C get connected in series and then they discharge into the weight capacitance or the take an appear at item. The discharge time stable CR1/n (for n stages) will be very petite in relationship to charging time stable CRs a good way to be few be extremely small as compare to charging time stable CRs for you to be a small number of seconds.[1]

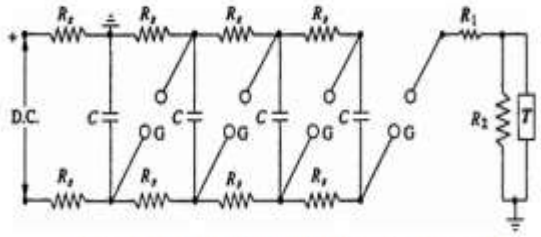

Fig.1: Conventional Marx Generator

There are some drawbacks in the conventional Marx generator circuit as follows:[1]

- Extensive charging time because the charging current flows throughout the charging resistors
- Less effectiveness because of the same reason mentioned above.
- Less recurrence rate because of the same reason.
- Low output voltage emergence in charging time because the charging current flows through the charging resistors and a load Turn-off is not possible as of using the spark gap switches
- Petite life time of the spark gap switches.
- In turn to solve these problems, a number of new Marx circuits are planned. These new enhanced circuits use semiconductor switches such as MOSFETs or IGBTs.

III. MODIFIED MARX GENERATOR

With the improvement of solid-state electronics, solid-state devices are becoming morepopular for pulsed power function. They might offer the pulsed power systems with compression, dependability, high reverberation rate and extended life time. The busting of pulsed power generators with solid-state electronic devices eliminates limits of conventional workings, and promises pulsed power technology to be highly used in various vapplication. Though, Solid-state switching devices like Metal Oxide Semiconductor Field Effect Transistor (MOSFET) obtainable now are merely rated up to a few kilo Volts.

Beforehand, it used spark gaps as switches which are replaced by electronic switches like (MOSFETs) and resistors as isolator is replaced with diodes. Thus, Conventional Marx generator had disadvantages such as low repetition rate, less life time, low efficiency are reduced by modern Marx generator as shown in Fig.2.[1]

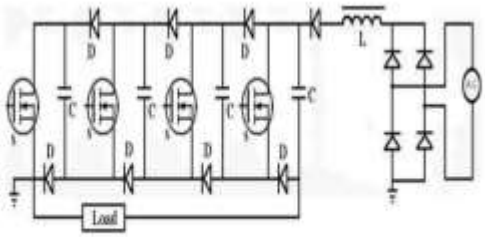

Fig.2: Contemporary Structure of Marx Generator

3.1Charging Mode

In this mode, IGBTs are not in operation. As shown in Figure 2, the high frequency transformer T passes the power to the secondary windings through a generator of high recurrence rates alternating voltage through the large inductor L and diodes D, the capacitors C

in parallel are charged by the large amount of voltage (HV) and high frequency rectify bridge. The large inductor behaves as a current limiter and cause increase of the voltage of the capacitors.[1]

3.2 Discharging Mode

In this mode, IGBTs comes in operation all together. Then they are at on-state and, as a result, the capacitors are connected together in series. Thus, the load might acquire a negative high voltage which is the addition of the voltage of capacitors. Via IGBTs, the capacitors release their energy to the loads. Diode comes in place of resistors as the isolator in conventional Marx generator. Capacitors C, inductor L and diode D1 create another discharge loop. In this mode, the inductor L isolates high output voltage separately from the rectify bridge. [1]

Some disadvantages of conventional Marx circuit are enhanced as follows: [1]

- Comparatively less charging time because the charging current flows through the diodes as an alternative of the charging resistors.
- Comparatively much high efficiency because of the same reason which is mentioned above.
- Comparatively high recurrence rate because of the same reason.
- Turn-off is achievable because of using the semiconductor switches in place of the spark gap switches.
- Long life time of the switches.

IV. PROPOSED METHOD

The Marx principle changed into advanced by way of Erwin Otto Marx. Its principle is to generate an extreme voltage pulse. The use of some of capacitors in parallel to charge up throughout the on time after which connected in collection to increase higher voltage during the off length. This principle is used to generate voltages within the range of KV's in actual-time for testing the insulation of the digital residence equipment like transformers and the insulation of the power transportation lines. This task includes 4 degrees and each degree is manufactured from one MOSFET, two diodes, and one capacitor. MOSFET is used as a switch; diodes are used to charge the capacitor at every degree with no power loss. A 555 timer generates pulses for the capacitors to charge in parallel during ON time. During OFF time of the pulses the capacitors are brought in series with the help of MOSFET switches. Subsequently, broad variety of capacitors utilized in series (four in our challenge) adds up the voltage to around 3 (4 capacitors-1 capacitor) instances the supply voltage.[2]

This device shape gives compactness and easiness to make whole system. Primary energy supply is taken as a step down AC supply. Its means step down to appropriate voltage and rectified to get consistent DC supply for charging of capacitors. Capacitors are charge storage tool. The charging of capacitor takes place as they are parallel connected to the rectifier.When capacitor is having suitable charge saved in it, switches are used to connect all capacitor in series and discharge of capacitor take region and we get n times of rectifier voltage across the load. Because of numerous reasonable constraints, the output voltage is extremely much less than n×V (in which n is a degree) [2]

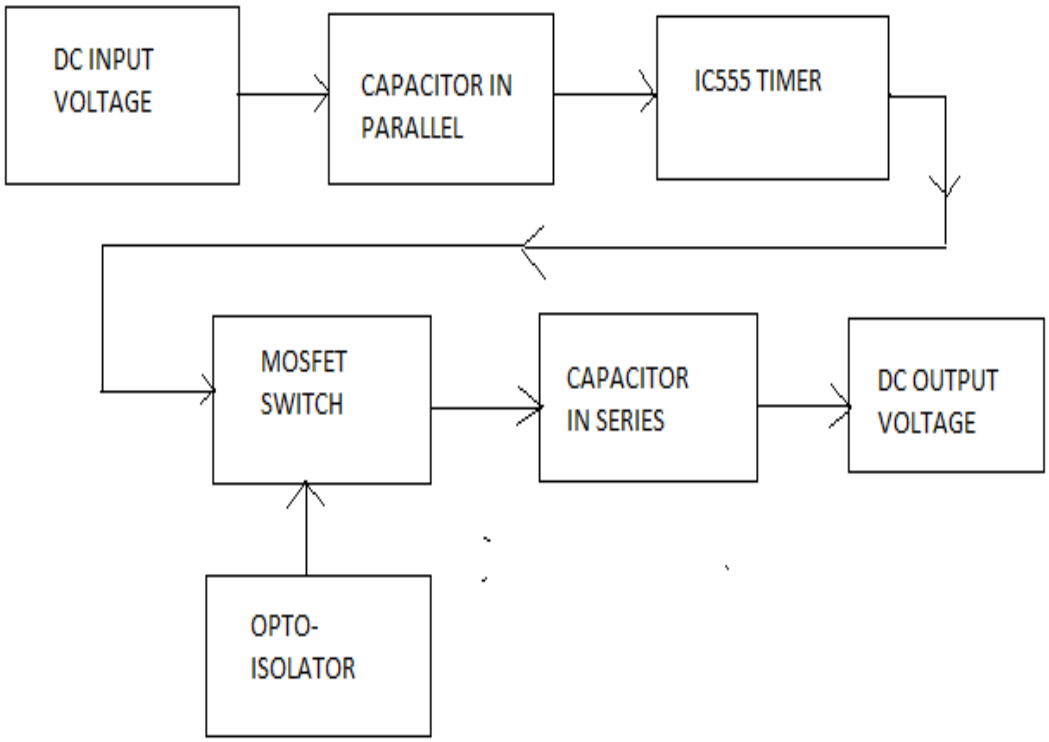

FIG.3: BLOCK DIAGRAM OF GENERATION OF HVDC USING MARX GENERATOR [2]

V. CIRCUIT DIAGRAM

A 555 timer is used as stable mode, i.e., pin 2 and 6 are shorted and output is connected to base of BC547 Q6. Collector of Q6 is connected to base of Q5. Pin 3 of timer is also connected to base of Q12 which drives Q11. Collector of Q11 is connected to base of Q7, Q8, Q9 and Q10. Collectors of Q7, Q8, Q9 and Q10 are connected to pin 2 of U4, U3, U2, U1 opto-isolator IC resp. pin 1 of U4, U3, U2 and U1 is connected to Vcc. Emitters of Q7, Q8, Q9 and Q10 are grounded.[1]

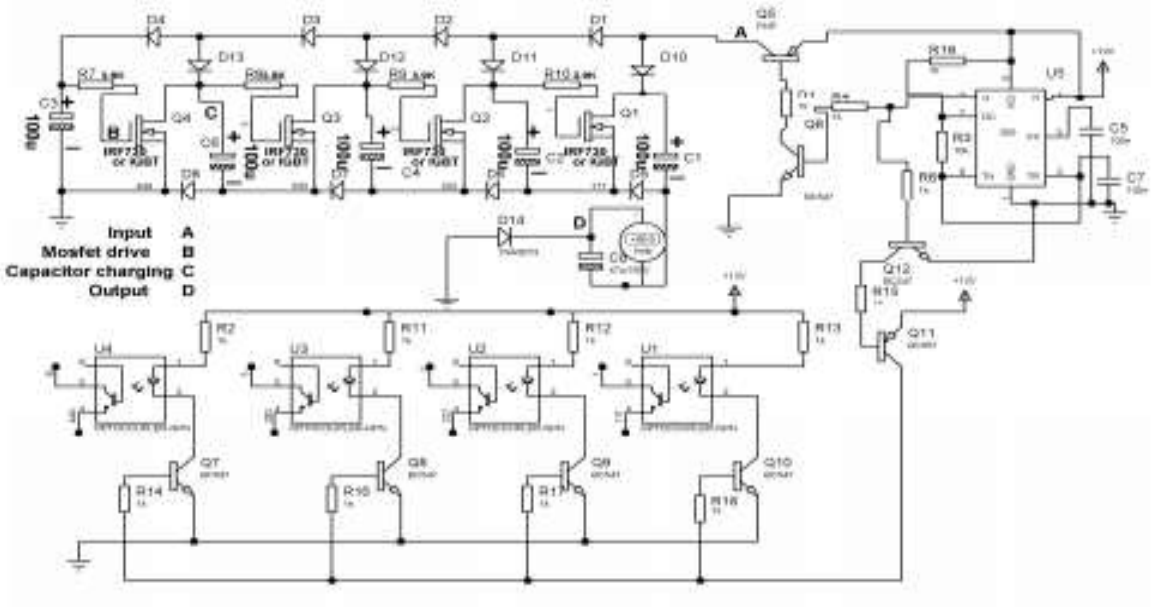

FIG.4: Circuit diagram of modified MARX Generator [1]

Capacitors C1 to C6 used supply the dynamic power to the MOSFETs while C1, C2, C4, C6 are used also for store the charge in parallel mode while Q5 delivers positive pulses throughout diodes D1 to D4, D5 to D8 and D10-D13. A 555 timer is used in as stable

multi-vibrator mode close to 50% duty cycle whose ON period delivers the power at point 'A' by 2 switching transistors Q5 & Q6. The ON period also switches to other switching transistors Q10 & Q11 which eventually switch ON Q7 to Q10 which are used for driving the LEDs of the opto-isolators (MCT2E) U1 to U4. The output of the opto-isolators are connected to gate and supply of individual MOSFETs which are thus kept switched OFF as their gate and supply are at ground potential. During the OFF time period of the timer all the switching transistor Q5, Q6, Q11, Q12,& Q7 to Q10 remain OFF . This causes the capacitors C2, C3, C4 and C6 to begin. [1]

VI. CALCULATIONS

6.1. TIMER

• Ton = 0.693 (R1+R2) C ---------- (1)
= 0.693 (10000+1000) 100*10^-9
= 0.7ms

• Toff = 0.693*R2*C ---------- (2)
= 0.693*10000*100*10^-9
= 0.6ms

• Duty cycle = Ton/ (Ton + Toff) ---------- (3)
= 0.7ms/ (0.7ms+0.6ms)
= 53.8%

6.2. CIRCUIT SPECIFICATIONS

•C = (Vo*Δt)/(R)
= (48*10^-3)/(3900)
= 98.6uF≈100uF

•Capacitor - 47uF/160V, 100uF/35V, 0.1uF

- Resistors - 1k, 10k, 3.9k [range (10-100k);max voltage(50-100kV)]
- MOSFET - IRFZ44
- Diode - 1N4007
- Opto-coupler - MCT2E

VII. CONCLUSION

The reproduction gives the concept of HVDC generation i.e., 2kV the use of sphere gaps. In the study of solid state devices consisting of MOSFET/IGBT and diodes are used in Marx generator to change of switches and resistors. Additionally, its miles sensible that MOSFET/IGBT drivers make use of method of self-provided power. The Marx generator is used to multiply voltage by way of the usage of MOSFETS. The number of MOSFETS used comes to a decision the wide variety of times the voltage needs to be increased. In this project we've got used 60 stages in hardware and the circuit multiplies the enter voltage effectively.

VIII. ACKNOWLEDGEMENT

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