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Marx Generator Based High Voltage Using MOSFETs: A Review

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ABSTRACT

This paper shows the development of areliable and easy to carry compact 4 stages Marx Generator that can produce impulse voltage 4 times of input voltage with some minor losses. In addition, three different experimental circuits of DC supplies have been made. The highest output was 100 V DC for which input was taken as the main supply for the experimental and simulated Marx generator circuit. This generator is useful in small scale industries and academic institutions to demonstrate impulse voltages and also to perform testing on insulators and transformers of lower rating in laboratory. A total of 4 stages of both simulated, experimental Marx impulse generator circuit is designed and the impulse waves are recorded. The simulated recorded impulse waveform, is compared with the standard impulse wave. Both of circuits, the efficiency of each stage was calculated and the percentage of error in the front and tail time was also found out as well as the effects of the circuit parameters on the impulse waveform characteristics were also studied. The simulation was done with the help of Proteus 8 Professional. In this work, the comparison in terms of magnitude of the experimental and simulated 4 stages Marx generator circuit has been carried out.

I. Introduction

Various high voltage equipments such as surge arresters, power transformers, circuit breakers, high tension transmission line towers and isolators are present in transmission substations. Since these kind of equipments are so costly also important for maintaining continuous power supply, there protection should be the higher priority for an electrical engineer. These equipment should not only tolerate the rated voltage which is the highest voltage of a system, but also over voltages. In this work, an attempt has been made to develop a compact, inexpensive, portable 4 stages Marx impulse generator circuit for demonstration of high voltage impulses in academic institutions. This 4 stages Marx generator circuit, was simulated by using PROTEUS software and the same circuit was Accordingly, it is compulsory to test high voltage (HV) apparatus during its making stage. Power system protection is an important thing for the maintained service of the electrical power system. Normally the protection of electrical power depends on the performance of insulation systems under transient over voltage conditions arises due to switching applications and lightning. Transient over voltages along with the abrupt changes in the state of power systems, e.g. switching operations or faults are known as switching impulse voltages and that due to lightning are known as lightning impulse voltages. It has become generally identified that switching impulse voltages are usually the prevalent factor affecting the design of insulation in HV power systems for rated voltages of about 300 kV and above. So attention is required for these two types of over voltages. Hence in order to protect these equipments a prototype of the same can be used to test against lightning strikes.

A Marx Impulse generator is able to generate lightning impulse voltage. This generator consists of multiple capacitors that are first charged in parallel through charging resistors by a high-voltage, direct-current source and then connected in series and discharged through a test object by a concurrent spark-over between the sphere gaps. The generated voltage from impulse generator must satisfy the standard values of voltage defined by the International Electro techno Commission in order to qualify as a standard impulse voltage that can be used for testing purposes. The standard methods of measurement of high-voltage and the basic methods for application of all types of apparatus for direct voltages, alternating voltages, switching impulse voltages and lightning impulse voltages are laid down in the important national and international standards made practically. In addition, three different sorts of HV DC supply were made to test the practical circuit as well as to provide HV DC supply in laboratory. Finally, the simulated and experimental results were compared in terms of their magnitudes

II. Project Objectives

i. To design 4 stage Marx Generator circuit using PROTEUS software to generate a waveform of impulse voltage.

ii. To provide different kinds of high voltage DC supply in HVE laboratory.

iii. To compare the theoretical values of peak voltage obtained in simulation with those recorded inpractical circuit.

III. Distributed Generator

Due to the difficulties experienced in very high voltage switching of the spark gap, increase in circuit element size, need of high direct current voltage to charge capacitor and difficulties in corona discharge suppression from the structures during charging period the extension of the single stage to multistage impulse generator is made.

A multistage generator is developed by cascading smaller single stage to generate high magnitude of output voltage.

The primary requirement is to charge capacitors through the rectifier circuit and when all the capacitor reaches to the fully charged state then spark gaps are allowed to break down causing the capacitors to add in series. As a result the nominal output voltage is equal to the input voltage multiplied by the number of stages in the impulse generator circuit. At first, n capacitors are charged in parallel to a voltage (V) by a high voltage DC power supply through the resistors. The spark gaps used as switches have the voltage V across them, but the gaps have a breakdown voltage greater than V, so they all behave as open circuits while the capacitors charge. The last gap isolates the output of the generator from the load; without that gap, the load would prevent the capacitors from charging. To create the output pulse, the first spark gap is caused to break down (triggered); the breakdown effectively shorts the gap, placing the first two capacitors in series, applying a voltage of about 2V across the second spark gap. Consequently, the second gap breaks down to add the third capacitor to the stack, and the process continues to sequentially break down all of the gaps. The last gap connects the output of the series stack of capacitors to the load. Ideally, the output voltage will be nV, the number of capacitors times the charging voltage, but in practice the value is less than expected because of losses.

Voltage Doubling Principle:-

In this paper, the main concept of this work is to study the voltage doubler circuit based on simulation and hardware implementation and finally based on CockcroftWalton (C-W) voltage multiplier circuits to fabricate a DC power supply in the laboratory. The conventional technique is used because the designed multiplier circuit is intended to be applied for impulse generator charging units. The main components of the DC power supply are rectifier diodes and capacitors. The simplest unregulated power supply consists of three parts namely, the transformer unit, the rectifiers unit and the capacitors unit.

Figure 1 shows the schematic for a half-wave voltage doubler. In fact, the doubler shown is made up of two half-wave voltage rectifiers. Here C_1 and D_1 make up one half-wave rectifier and C_2 and D_2 make up the other rectifier.

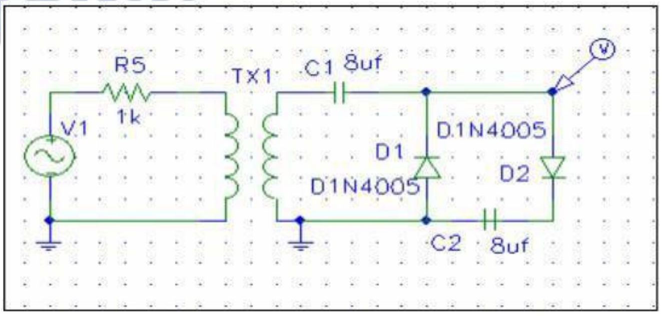

Figure 1: Voltage Doubling Circuit

IV. Implementation of 4 Stage MARX Generator

The circuit generates a high-voltage pulse by charging a number of capacitors in parallel, then suddenly connecting them in series. See the Figure 3.1. At first, n capacitors (C) are charged in parallel to a voltage V by a high-voltage DC power supply through the resistors (R_C). The spark gaps used as switches have the voltage V across them, but the gaps have a breakdown voltage greater than V, so they all behave as open circuits while the capacitors charge. The last gap isolates the output of the generator from the load; without that gap, the load would prevent the capacitors from charging. To create the output pulse, the first spark gap is caused to break down (triggered); the breakdown effectively shorts the gap, placing the first two capacitors in series.

The above voltage quadrupler circuit uses minimum components to approximately multiply (quadrupler) the AC voltage (Vin) across the input terminals. The resulting output voltage is DC (Direct Current). Capacitors, C2 and C3, charges to double the value of Vin. The series combination of C2 and C3 produces a DC voltage equivalent to two batteries connected in series. The result is an output DC voltage that is four times the value of Vin. The voltage rating of the diodes and capacitors used should be within safe level, preferably, double the value of the input voltage. You may use capacitance values of 1000mF or higher. The higher the value of the capacitance, the smoother (non-fluctuating) the resulting output DC voltage.

Assuming that the peak voltage of the AC source is $+U_s$, and that the C values are sufficiently high to allow, when charged, that a current flows with no significant change in voltage, then the (simplified) working of the cascade is as follows:

1. **Negative peak ($-U_s$)**: The C_1capacitor is charged through diode D_1 to U_sV (potential differencebetween left and right plate of the capacitor is U_s
2. Positive peak ($+U_s$): the potential of C_1 adds with that of the source, thus charging C_2 to $2U_s$ through D_2
3. Negative peak: potential of C_1 has dropped to 0 V thus allowing C_3 to be charged through D_3 to $2U_s$.
4. Positive peak: potential of C_2 rises to $2U_s$ (analogously to step 2), also charging C_4 to $2U_s$. The output voltage (the sum of voltages under C_2 and C_4) rises until $4U_s$ is reached.

In reality more cycles are required for C_4 to reach the full voltage. Each additional stage of two diodes and two capacitors increases the output voltage by twice the peak AC supply voltage.

While the multiplier can be used to produce thousands of volts of output, the individual components do not need to be rated to withstand the entire voltage range. Each component only needs to be concerned with the relative voltage differences directly across its own terminals and of the components immediately adjacent to it.

Typically a voltage multiplier will be physically arranged like a ladder, so that the progressively increasing voltage potential is not given the opportunity to arc across to the much lower potential sections of the circuit.

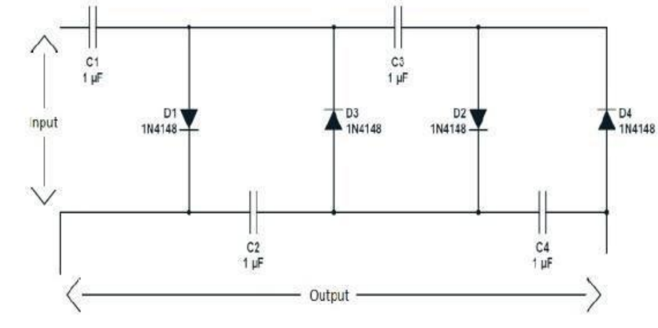

Figure 2: Four Stage Marx Generator Circuit.

V. Working of MARX Generator

The project is designed to generate high voltage DC using Marx generator principle by using MOSFET and capacitor stacks. The Marx Principle was developed by Erwin Otto Marx. Its principle is to generate a high voltage pulse using a number of capacitors in parallel to charge up during the on time and then connected in series to develop higher voltage during the off period.

This principle is used to generate voltages in the **range of KV's in real**-time for testing the insulation of the electronic appliances like transformers and the insulation of the power carrying lines. This demo project consists of 4 stages and each stage is made of one MOSFET, two diodes, and one capacitor. MOSFET is used as a switch; diodes are used to charge the capacitor at each stage without 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. Finally, number of capacitors used in series(4 in our project) add up the voltage to approximately 3 (Due to some losses) times the supply voltage. This system structure gives compactness and easiness to implement the total system from a DC supply of V to get approximately 3-3.6 times. This concept in future can be extended to Generate High voltages (KV) using more number of capacitors. This technique is adopted for insulation testing of the electronic components, wires, transformer, gadgets etc.

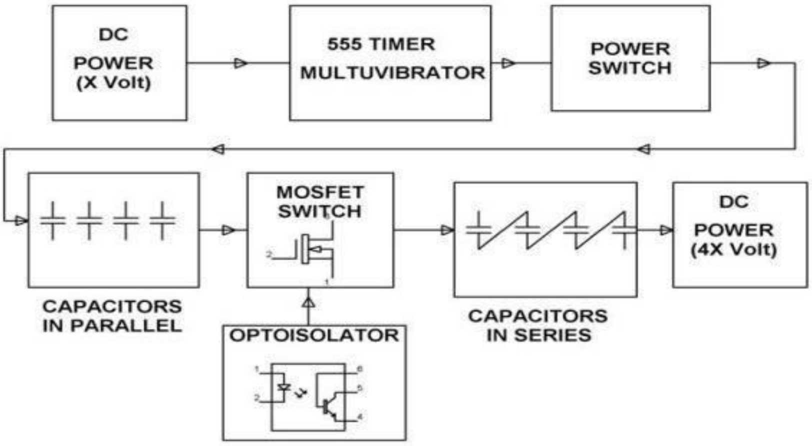

Figure 3: Block Diagram of Marx Generator Circuit.

VI. Circuit Diagram

The designed circuit diagram is made by combining all the required circuits that are Fixed voltage circuit (12V & 5V), Variable voltage circuit (1V to 30V), 555 timer circuit, MOSFET H-bridge circuit and Four stage Marx Generator circuit.

This circuit is then simulated on Proteus 8 Professional simulation tool which is shown in fig. 4.

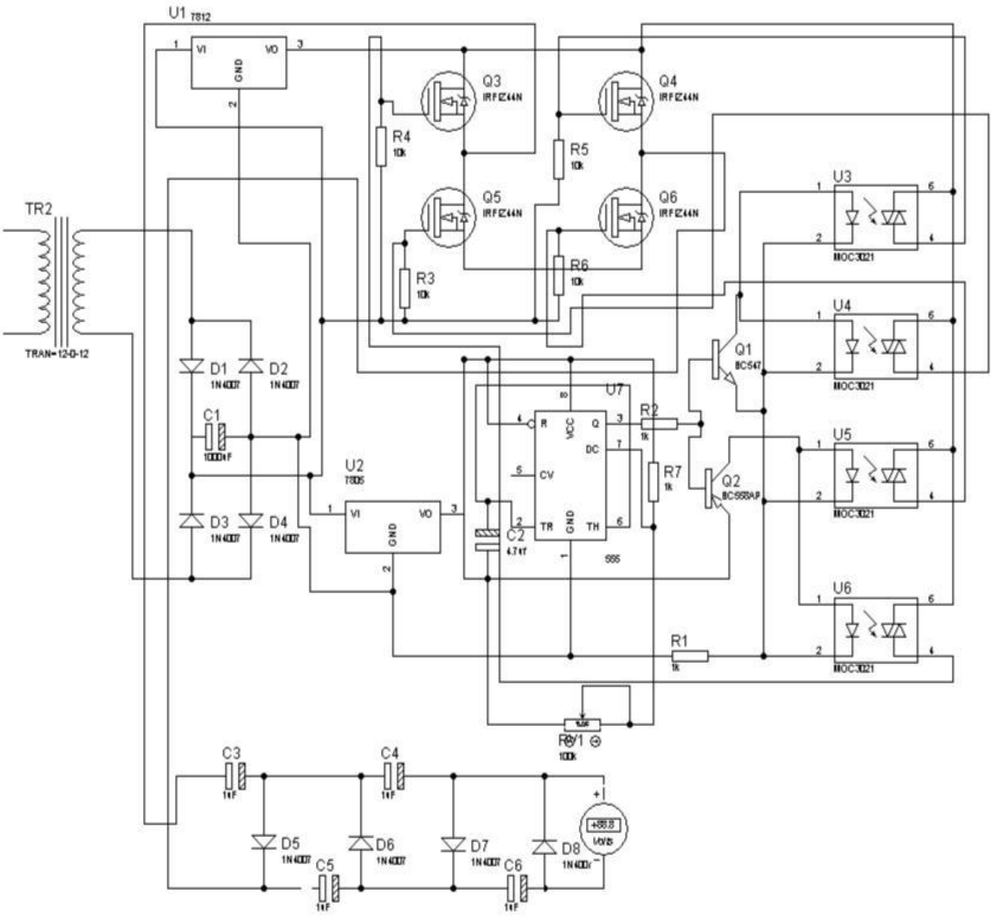

Figure 4: Marx Generator Circuit.

VII. Conclusion

A prototype of high impulse voltage generator is performed and is based on the simulation results performed in PROTEUS software. The wave shape results are matched for up to four stages. The practical implementation of four stages Marx impulse voltage generator is done. The simulated result and the practical circuit result are close to the IEC standard wave shape for lightning impulse testing. The ratio between C1 and C2 for each stage is taken as 40 and waveforms similar to standard impulse voltage are produced. By varying the values of front and tail resistance in accordance with the ratio. The errors come in the range of allowed standard tolerance levels. Acceptable assumption of replacing a spark gap with a switch was made. In this work, the entire circuit is simulated and modelled based on the circuit parameters which were methodically calculated. The calculated parameters and their effect on characteristics of the impulse wave was studied and it was found that by the proper assumptions and the method followed in the work, the standard impulse wave can be generated. The acquired data from the circuit model has also been studied in CRO. This work can be further extended by making improvements in the circuit through modified Marx circuits which will not only make the design more compact and mobile but also the control over the wave shapes will increase as the resistances are more distributed throughout the circuit. The control of the switch in the circuit can also be done using a PC through proper hardware and software interfaces which will enable instantaneous observation of impulse voltage in a computer

References

[1] Suthar, J. L., Laghari, J. R., Saluzzo, T. J., “Usefulness of Spice in High Voltage Engineering Education”, Transactions on power system, Vol.6 (August 1991): pp. 1272-1278.

[2] Zhou, J. Y. and Boggs, S. A., “Low Energy Single Stage High Voltage Impulse Generator”, IEEE Transactions onDielectrics and Electrical Insulation, Vol.11 (August 2004): pp.507-603

[3] Vecchio, M. D. R., “Determining Ideal Impulse Generator Settings from a Generator Transformer Circuit Model”, IEEE Transactions on Power Delivery, Vol.17, (January 2002): pp.142-148

[4] Mondal, Jolly. Modelling and Simulation of Impulse Voltage Generator using Marx Circuit. Diss. National Institute of Technology, Rourkela, 2014.

[5] Kuffel, John, E. Kuffel, and Walter S. Zaengl. High voltage engineering fundamentals. Newnes, 2000.

[6] Wadhwa, C.L., “High Voltage Engineering” New Delhi, New Age International Publishers, 2007.

[7] Kamarudin, Muhammad Saufi, et al. "Impulse generator and lightning characteristics simulation using Orcad MATLAB software." (2008).

[8] R.A. Fitch, “Marx and Marx like High Voltage generators”, IEEE Trans. Nuclear Science, Vol. 19 (1971): pp. 190-198.

[9] A. G. Halim, “High Voltage measurement technique”, Master of Applied Science thesis, Dept. of Electrical Eng., University of Britiths Columbia, Vancuver, Canada (June 2007).

[10] Neuber, A.A., Chen, Y.J., Dickens, J.C., Kristiansen, M.: A compact, repetitive, 500kV, 500J, Marx generator. In: IEEE Pulsed Power conference, Monterey, A, 2005, pp 1203-1206.

[11] Prabaharan, T., Shyam, A., Shukla, R., Banerjee, P., Sharma, S., Deb, P., Verma, R., Kumar, R., Das, R., Das, B., Adhikary, B.: Development of 2.4ns rise time, 300kV, 500MW compact co-axial Marx generator. In: Indian journal of Pure & Applied Physics, Volume 49, January 2011, pp 64-72

[12] Anders, A., Brown, I. G., MacGill, R. A., Dickinson, M., R., “Vacuum-Spark Metal Ion Source Based on a Modified Marx Generator”, IEEE Transactions on Plasma Science, Vol. 25 (August 1997): pp.718-721.

[13] Baek, J. W, Yoo, D. W., Rim, G. H., Lai, J. S., “Solid State Marx Generator Using Series-Connected IGBTs”, IEEE Transactions on Plasma Science, Vol. 33 (August 2005): pp.1198-1204