Development of 1MV Marx Generator

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Abstract – A 1 Mega volt, 6KJ Marx Generator has been developed. The system consists of the Marx generator, demineralised co–axial water pulse forming line for Pulse compression, SF_6 High Pressure Spark gap and the load. 20 capacitors each of rating 50kV DC, 0.24μF, plastic case, make of NWL, USA are used to form a twenty stage Marx Generator. The unit has single polarity charging. Initial four spark gaps (Trigatron Type) are triggered by a trigger generator giving 50KV pulse form a capacitor bank of 0.5micro farad, 0.6KJ. Rests of the 16 spark gaps are self triggering type. The system called AMBICA 6000 would give an output voltage pulse of 1 Mega Volt, 6KJ, 250ns duration at a matched load. This system is to be used in a single pulse mode with one shot in 1 to 4 minutes because of this low repetition rate it is used for research applications.

1. Introduction

The Marx generator is widely used as a high voltage pulse generation device.There are various other methods of high voltage pulse generation like Tesla Transformer, Capacitor banks etc. But these methods have their own technical problems of low energy, insulation problem, low voltage etc.

A typical Marx generator consists of N number of modules, each module comprising of two resistors, a capacitor and a switching device, which is essentially a spark gap. All modules are connected together, such that the capacitors are charged in parallel with the spark gaps in non-conducting condition. A D.C. charging power supply is used for charging the capacitors, when all the capacitors are charged upto the desired voltages, first few spark gaps are triggered this makes the rest of the spark gaps to be over volted and causing self break down, all the capacitors are thus connected in series resulting in an output voltage N times the charging voltage [1]. In this paper we report the gradual development of a twenty stage Marx generator designed to give an output voltage of 1Mega volt, 250 ns on a matched load.

2. Description

Power supply: A 50kV DC, 100 mA power supply is used for charging the Marx capacitor. It consists of a HV transformer of 230V/35KV, a 100mA HV diode for rectification. It works as a half wave rectifier. Since our load is very high (capacitance of 0.24μf, 20 in parallel), hence half wave rectifier will solve our purpose. For monitoring the charging voltage a 50kV DC HV probe has been developed.

Master trigger generator: It consists of a HV pulsed transformer 1kV/100kV. A trigger generator module generates a pulse of 1kV, which is fed to pulsed transformer.

Sub master trigger generator: Here two capacitor is charged to a desired voltage and discharged through a spark gap switch to the third electrode of the trigatron switch. A pulse from the master trigger generator triggers the spark gap switch.

Marx Resistor: HV ceramic resistors being used in Marx generator with following specifications.

Resistance:500Ω, Energy: 300 joules, Impulse voltage: 20 kV in air. A series of four resistors are used with a total value of 2000Ω.

Capacitor: 50kV DC, 0.24μF, plastic case type capacitors of NWL, USA make being used. 20 such capacitors are used to form the twenty stage Marx generator.

Spark Gap switch: Trigatron type spark gap switch has been employed for the first four gaps which are triggered. The other 16 switches are two electrode spark gaps encased within delrin housing. The gap between the two main electrodes has been kept such that they break at 20-22kV at atmospheric pressure. To raise the break down voltage nitrogen gas has been used to pressurize the spark gaps.

Water pulse forming Line: A S.S. 304 made coaxial water pulse forming line has been developed. The 2MV. 60ns PFL has impedance of 9Ω and uses demineralised water as the dielectric.

SF_6 Switch: An epoxy casted SF_6 switch has been developed which is to be coupled to the PFL output to be used for switching energy stored in the transmission line.

Load: A highly concentrated copper sulphate solution encased in an acrylic tube has been used as load. The load thus formed has a value of 12Ω.

HV probe: A high-energy high voltage resistor chain was developed for this purpose. The resistor chain consists of ceramic resistors of 200Ω (70J and 7.5kV in air) each. The chain is so made that it can handle up to 160 kV (pulsed) in air. Attenuation of this divider is 20. The output of this divider is fed to another HV probe of North Star make rated for 60 kV (pulsed), with an attenuation of 1000. Thus a total attenuation of 20000 is achieved. A copper sulphate probe is under development stage to measure voltages upto 1MV.

3. Results

At first an eight stage Marx generator was assembled to check out the problems regarding diagnostics and measurements.

That Marx generator had been charged up to 26 kV. The energy of the generator at 26 kV is 648.96 Joules. For the purpose of measuring the output voltage a high-energy high voltage resistive divider was developed. The resistive divider could measure the voltages up to 150kV (pulsed). Beyond this voltage, spherical spark gap measurement has been employed. For spherical spark gap measurement, a pair of 150mm diameter aluminium sphere has been employed. The gap between the spheres was varied as per [2]. Two sample waveforms have been shown in Figures 1 and 2 obtained from the resistive divider.

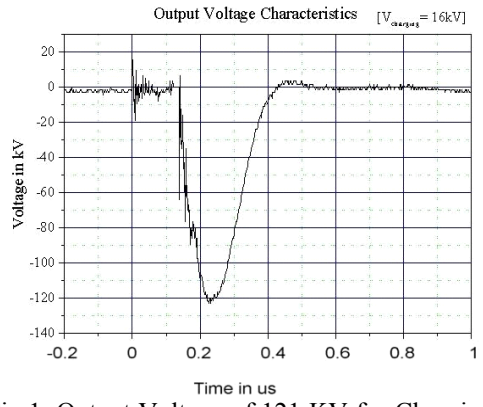

Fig.1. Output Voltage of 121 KV for Charging Voltage of 16 KV

4. Discussion and Conclusion

The Waveform shows the output voltage of eight stages Marx generator at different charging voltages.

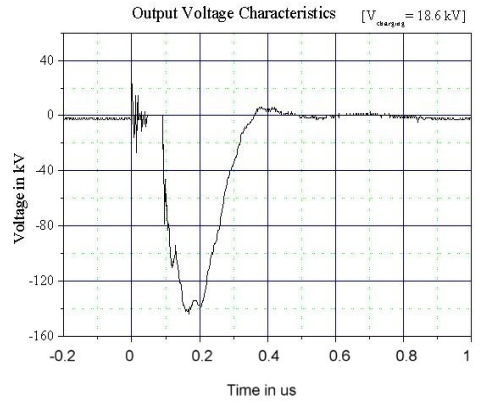

Fig.2. Output Voltage of 142 KV for Charging Voltage of 16 KV

Fig. 3. Marx tank with PFL

Fig. 4. Eight stage Marx generator in air

In Fig.1.output voltage is 121kV, while capacitor charging voltage is 16 kV. Ideally the output voltage for 16 kV charging must be 128 kV, but some voltage drops occurs across each spark gap switch. In Figure 2 charging voltage has been increased from 16 kV to 18.6 kV. For this charging voltage output is 142 kV. A copper sulphate voltage divider is under development stage, when completed it could measure upto 1MV. Beyond 150 kV, spherical spark gap measurement has been employed for voltage measurement.

The four spark gaps are triggered while only one spark gap triggering could erect the Marx voltage as this has the advantage of lower jitter and faster operation. The Marx generator consisting of 8 stage was later extended to a 20 stage in air and output voltage upto 350kV is measured by sphere gaps of sphere diameter 300mm. The insulation is further to be improved by using SF_6 or transformer oil and placing the whole generator within a tank containing SF_6 or oil. The above insulation will be sufficient enough to erect Marx Output upto 1MV.

Table I. Marx output voltage and measuring technique used.

Charging Voltage (KV)	Marx Output	Measuring Technique
16.0	121.0	Resistive Divider
18.6	142.0	Resistive Divider
22.5	172.0	Spherical gap (gap=70mm)
24.0	188.0	Spherical gap (gap=80mm)
26.0	202.0	Spherical gap (gap=90mm)

References

[1] P. H. Ron, *in Proc. of the Workshop Course on Technology of Electrical Insulation & High Voltage Pulse Technique, BARC*, Mumbai, March 1982, pp. – 275 – 305.

[2] "High Speed Pulse Technology", by Frank B. A. Früngel, Vol. II, pp. – 338.

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