Small Scale System for Harvesting Lightning Stroke using Impulse Voltage Generator

Mr. Ravi Kumar K. N
Asst. Professor
EEE Department
GMIT, Bharathinagara

Mr. Kumaraswamy L.
Associate Professor
EEE Department
MCE, Hassan

Ms. Sumitha C.
Asst. Professor
EEE Department
GMIT, Bharathinagara

Mr. Chetan R
Assistant professor
EEE Department
GMIT, Bharathinagara

***Abstract* - A small-scale laboratory is set up based on natural characteristics of lightning to determine the performance and capability of the sample capacitor accurately, since a ultra capacitor nowadays becomes the most widespread, economical and reliable energy storage device. The ultra capacitors are subjected to approximately 1.2/50µs single-stroke impulse voltages of magnitude about 5000V generated by a single stage impulse generator. The proposed system shows that the impulse voltage able to transferred and stored the energy in the storage capacitors. Hence, it gives a positive indicator to the proposed system referring to the concept of capturing energy from lightning return strokes, which can be a potential source of renewable energy.**

Key words: Lightning stroke, Ultra capacitors, Impulse voltage.

I. INTRODUCTION

Energy is one of the most valuable and desired resources. Besides that, it is already becoming an enormous concern for some countries due to the oil price. In general, almost all countries in the world suffer a negative impact from the increasing oil prices. Due to this matter, a new energy source has to obtain from any possible resources. Some renewable energy such as from natural gas, hydro and the wind already established especially in the developed countries. However, harvesting the lightning energy can be an alternative source and this becomes additional energy that can be used at least for a brief period. On the other hand, until now the mature technology in harvesting the lightning stroke for the large-scale system is still not yet ready. One flash of lightning are equal to four strokes which each stroke has approximately one giga-watts. This means that, when the efforts to capture one flash succeed, and transforms it to electricity, it is equal to a power station of twenty megawatts working continuously for fifty hours. A new source of renewable energy from lightning return stroke with a small scale system will give a new contribution to solve the energy crisis and this research will be very challenging.

A. *Natural Lightning History*

BENJAMIN FRANKLIN, more than 200 years ago, proved that lightning was an electrical discharge and measured the sign of the cloud charge that produced it. Modem research on the physics of lightning began in the early 20th century with the work of C.T.R. Wilson, the same scientist who received the Nobel Prize for his invention of the cloud chamber. Wilson, by making and analyzing remote measurements of thunderstorm electric fields, was the first to infer the charge structure of the thundercloud and the amount of charge involved in lightning. In the 1930's, lightning research was motivated primarily by the need to reduce the effects of lightning on electric power systems and by the desire to understand an important meteorological process.

B. *Lightning Theory*

Lightning is a transient, high-current discharge whose path length is measured in kilometers. Well over half of all flashes occur wholly within the cloud and are called intra-cloud (IC) discharges. Cloud-to-ground (CG) lightning has been studied more extensively than other forms of lightning because of its practical importance (for instance, as the cause of injuries and death, disturbances in power and communication systems, and the ignition of forest fires) and because lightning in the clear air below the cloud base is more easily studied with optical techniques. Cloud-to-cloud and cloud-to-air discharges occur less frequently than either IC or CG lightning. All discharges other than CG are often combined under the general term cloud discharges.

Figure.1. Major types lightning (i) cloud-to-ground lightning (ii) intra-cloud lightning

Briefly, clouds carry positive and negative charges. Through the dynamic nature of clouds distribute these charges, collect negative charges at its bottom and positive charges at the top. After going through all the processes, charge at the bottom of the cloud draws and equal in magnitude but opposite polarity charge at the ground level. Then, this creates a look like capacitor system between the cloud and the ground where the dielectric is air. It is known that lightning strike involves very large and very fast impulse voltage and current. It is the flow to the ground, which in turn produces the corresponding electromagnetic fields. In addition, this research purposely desires to determine the performance of sample capacitor in term of electrical characteristics against the impulse voltage.

C. *Impulse Voltage*

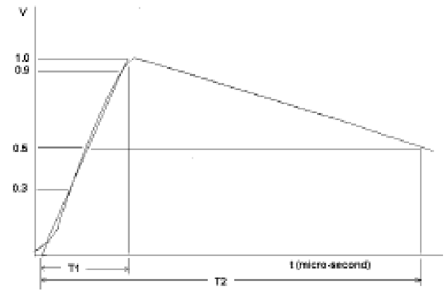

Figure 2. Typical impulse voltage waveform

An impulse voltage is a unidirectional voltage, which rises rapidly to a maximum value without appreciable oscillations and then decays slowly to zero. The maximum value of the impulse voltage is called the peak value of the impulse and the impulse voltage is specified by this value. Due to that, the system proposed must capable to attract and stored the voltage at this peak time. A full impulse voltage is characterized by two time intervals which is wave front time (tf) and wave tail time(tt).

D. *Capacitor as Energy Storage*

Energy storage technologies do not represent energy sources, but they provide valuable added benefits to improve power quality, stability and reliability of supply. In this modern power application, practicable storage technologies also known as viable storage technologies like batteries, flywheels, ultra capacitors and superconducting energy storage system was rapidly used. Figure 2 shows specific power versus specific energy ranges.

II. DESIGN AND METHODOLOGY

The very first challenge in the proceeding path seems to be the creation of artificial lightning in a high voltage laboratory to bring our ideas into reality. This demanded for the design of the single stage impulse generator which can produce the standard lightning impulse of magnitude approximately equal to 5kV.

A. *Small Scale System Planning*

In this project, the experimental work is divided into two stages. Stage 1 is to generate impulse voltage as a mock lightning. Then, in stage 2, the impulse voltage generated during stage 1 is applied to the sample capacitor.

Stage 1

As mentioned before, the purpose of stage 1 is to obtain and generate the impulse voltage. The impulse voltage must fulfill the wave shape specification 1.2/50_s. This generated impulse voltage need to be used for the next experimental work, which is in stage (2).

The value of capacitors (CS and CB) and resistances (RD and RE) in the Figure 7 are based on the calculations that are shown under the design aspects below. Some of the compromises are made with respect to the design parameter and components to encounter the economic difficulties and components availability. The actual voltage of approximately the front time is 1.5μs (30% of 1.2μs) and the tail time is 45μs (± 20% of 50μs) with the peak impulse voltage of 5kV is what the desired output expected from this stage .

Stage 2

In stage 2, the process and the equipment involved in stage 1 remain the same. It has an additional circuit, which is connected parallel with the load capacitor CB The additional circuit is consisted of three units of porcelain insulator and one unit of sample capacitor

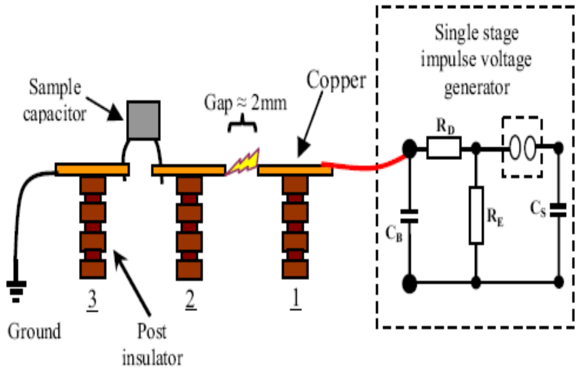

Figure 3. Connection of sample capacitor with impulse voltage generator

B.Design of Impulse voltage generator circuit parameters

Following are the points which are considered at the most of interest in order to obtain the efficient and desired design.

- The capacitances are considered such that they able to withstand the supply voltage.
- Low inductance, low height, low mechanical stability, ease of access and adjustment of movable all moving parts and ease of extension
- Voltage across the capacitor selected should be preferably about 10 to 15% more than the open circuit voltage of DC set if the time charging is kept down to a reasonable value eg: if the DC charging voltage is 5kV then the voltage rating of the stage capacitor must be 10% to 15% greater than the 5kV.
- Resistors can be placed either outside, partly within and partly outside or wholly within it (wave front control resistors are addressed). But placing from completely
  within the generator is proves to be advantageous because they distributes the need for an external resistors capable of withstanding full voltage.
- Wave tail resistors are to be used on the load side of the wave front resistor
- Cost of the condenser is the main part of the total cost of the equipment. So that the arrangement giving minimum condenser cost is employed.
- As the ratio of the generator capacitance to load capacitance is increased, the required open circuit voltage decreases and the circuit characteristics become less and less dependent on the external load. However, the gain is subjected to the technical, economical and constructional requirements combine to make the optimum capacitance ratio somewhere between 4:1 and 10:1 for a pure capacitance load such as a bushing or a cable. Due to the non availability of the required capacitor in market we compromised with our design to choose this ratio to be 60:1.
- A considerable improvement in operating convenience is given by a remotely controlled motor which varies the setting of the generator spark gaps in conjunction with the remote indicator of the setting. Since only two adjustable items were there in our project module we thought that its uneconomical to go for such remote adjustments.
- The simplest method of operating the impulse generator is to allow it to self tripping. Thus, the lowest spark gap is set to flash over at a predetermined charging voltage.

Taking into consideration of the above factors we began our design of the circuit parameters by setting the specification for the generator as below:

Number of stages: 1
Nominal output voltage: 8.5kV
Impulse ratio (as per the IS): 1.2μs/50 μs
DC charging voltage: 10kV

B. Control Panel

It is advisable to conduct any test on high voltage we are required to have the separate control room which is perfectly grounded (faradays cage). The very first function of the control panel is to obtain the controlled source voltage to energize the high voltage equipments. The control panel in our lab will provide a high voltage AC of 100kV rms and the high voltage DC of 140kV. The common switches found on the control panel are;

- MAINS; To switch on the unit.
- HT ON; This to apply the high voltage to the hv equipment.
- HTOFF; this is to de-energize the hv equipment.
- INCREASE; internal arrangement consist of a auto transformer which applies a voltage across the hv equipment. Action of the auto transformer is controlled by using this button.
- DECERASE; this is used to decrease the applied voltage across the hv equipment.
- MEMORY; this button aids in knowing recorded value

Figure.4. Control panel in the High Voltage laboratory

C. Oscilloscope and high voltage probe

To measure the impulse voltage generator it is required to have the oscilloscope. The one which we have adopted is digital oscilloscope from aplab electronics which has the facility to measure the peak voltage up to 8kV by selecting 100x option under probe. this oscilloscope have the power rating 45VA thus we can see that it should not exceed more than 150mA for its safe operation.

High voltage probe consists of HV electrode and ground electrode spacing between these two are approx 30cm. probe here is a make of tektronics private limited from USA. It can measure to the peak voltage of 2.5kV this probe has been connected digital storage oscilloscope through the delay cable of approx length of 14m,

Figure.5.digital storage oscilloscope from aplab USA

III. RESULTS

The project model has been tested for the two different gap spacing two check performance capability

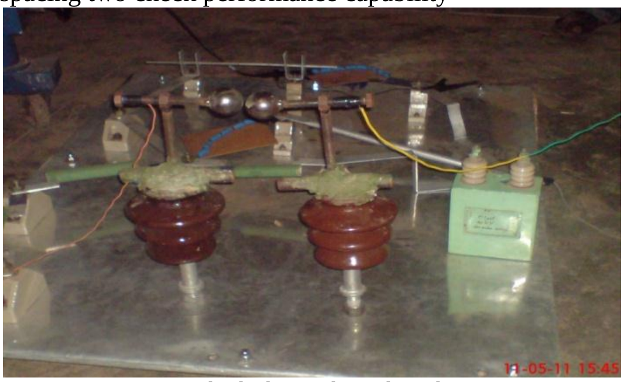

Figure 6. Completely designed impulse voltage generator

(i) Gap spacing: 0.05cm across the rod-rod electrode

For this gap spacing input voltage provided was approx 4kV and the break down occurred bit earlier to 4kV around 3kV. The approximation is mainly due to the lack of calibration of the control panel meter board for the initial portion of the reading. The digital storage oscilloscope(DSO) is initially set as follow

Probe: 100X

The transient signals has voltage magnitude of about 1.76kV as shown by the blue ink encirclement on the figure. This transient mayn't remain same for the next trial test. It mainly depends on the circuit parameter and how they stores the energy during the previous trial test.

After the breakdown of the sphere gaps impulse voltage started to break the gap b/w the rod-rod electrodes which in-turn applied across the storage capacitor these impulses were recorded as shown

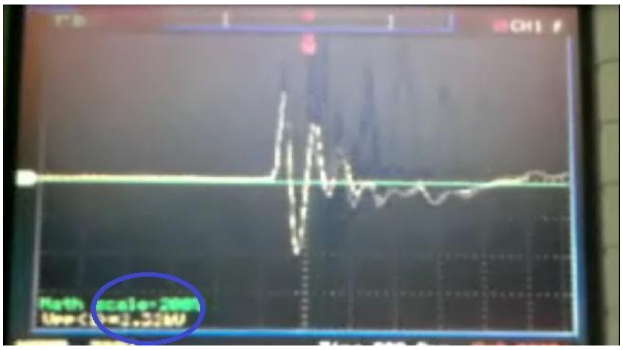

Figure.7. impulse voltage across the storage capacitor of magnitude approx 2.32kV

The sparking is allowed for about 10sec and later the DECREASE button on the control panel was pressed so that the sparking gets diminishes. Now it's the crucial part our experiment to see what is the voltage that is stored across the storage capacitor. Interestingly we have observed after few millisecond a continuous happens to be appeared across the storage capacitor which is as shown.

IV. CONCLUSIONS

- Our design consideration is to obtain the desired impulse wave form of 1.2/50 µs, but acceptable compromise is made with respect to the design parameters of the IG components possibly this could be the reason for which we are getting distortion in the output wave form.
- Gap distance have been varied through the threaded nuts and bolt adjustments this could question the factor of safety but as ours is the small scale implementation in which voltage is limited within 10kV this doesn't requires the motorized gap adjusting arrangement and we have used the grounding stick to discharge the residual charges that are accumulated on the surface of the high voltage terminal of the components.
- We conducted the test for two different trials having different gap distances and observed that as the gap distance increases the spark over voltage increases proportionally.
- Simultaneous spark between the sphere gaps and the rod rod electrode is observed which perfectly coincides with our design.
- Storage capacitor designed by using the series combination of eight capacitors of individual value 0.001µF were been successfully tested against the generated impulse for two different gap distance across rod - rod electrode and we found that it can hold the charge for a minimum period of time.
- No spark over has been observed between the components and the ground, this assured the successful working of the model to achieve this we have mounted the base plate at a height of about 7cm above the ground level and also avoided the wire sag wherever required in the circuit.
- Oscillations are noticed in the output wave form using the digital storage oscilloscope..

- Finally we can conclude that further work in this field with the use of high value capacitances and the voltage rating with proper constructional care can results with large charge storage systems which can be harvested later to solve the energy crisis

REFERENCES

[1] M. F. M. Basar, M.H. Jamaluddin, H. Zainuddin, A. Jidin, M.S.M. Aras ,"Design and Development of A Small Scale System for Harvesting the Lightning Stroke Using the Impulse Voltage Generator at HV Lab, UTeM",IEEE Transaction,Vol 5, pp 161-165,2010..

[2] Martin A. Uman,"Natural Lightning", IEEETransaction Of IndustryApplications, Vol 30, Issue 3, pp 785-790, May-June 1994.

[3] M.S Naidu and V. Kamaraju,"High Voltage Engineering", 3rd Edition,McGraw-Hill Publishing Company Limited, 2000.

[4] P. Chowdori, "Parameter of Lightning Stroke and Their Effect on Power System", Transmission and Distribution Conference and Exposition, 2001 IEEE/PES, Vol 2, pp 1047-1051, 2001

[5] P.F.Ribeiro, B.K. Johnson, M.L. Crow, A. Arsoy and Y. Liu, "Energy Storage Systems for Advanced Power Applications", Procedings of the IEEE, Vol 89, Issue 12, pp 1744-1756, December 2001.