DEVELOPMENT OF A SOLID STATE POWER SUPPLY FOR MULTI LEVEL CORONA DISCHARGE

[1]Annie Macwan, [2]Chirag S. Dalal
[1]PG Student, [2] Associate Professor
[1]Instrumentation and Control Engineering
[1]Dharmsinh Desai University, Nadiad, India.

Abstract: This paper documents the design of a corona discharge demonstration unit. This paper is the prototype model built to find the changes of the discharge on varying the input voltage provided at the collector junction, frequency and duty cycle provided to the base of the switching device. Here, different switches are used to study the behavior of the corona discharge and have tried to find the applications through it. The model uses some of the basic switches for switching e.g. Transistor, MOSFET, and IGBT. The color TV EHT (LOT) for HV generation and the protection module for protection from HV shock, over current, thermal overload, force cooling failure. This is a simple and elegant design. The results are noted by varying different parameters on the input side and seeing its effect on the output discharge phenomenon.

***Index Terms*–Switching Devices, Multi Level voltages & frequency, High Voltage**

I. INTRODUCTION

Over the last decade, there are many different areas where plasma generated at atmospheric pressure in air has achieved many good results. Corona discharge can be presented by simple design of the circuit and can be used for the various applications. A corona discharge is an electrical discharge brought on by the ionization of a discharge media such as air surrounding a conductor that is electrically charged. Spontaneous corona discharges occur naturally in high-voltage systems unless care is taken to limit the electric field strength. Since the days of Townsend, gaseous discharges, and among them corona discharges, have been the subjects of intensive studies. Loeb has made an excellent contribution to the field of incomplete discharges, providing a critical synthesis of widely scattered and often inaccessible literature of physical interest. Significant progress has been made in understanding the fundamental processes responsible for the ionization growth. AC corona discharge at atmospheric pressure represents one of the most complex forms of electric discharges. Its main advantage is that they are rich sources of chemically active radicals, excited and ionized species.

They are suitable for some applications of volume plasma chemical processing where only small concentrations of excited or charged particles are needed. Subsequently, the corona discharges are being extensively used in electrostatic precipitators, spray coating copy machines, drying separation systems, and in radiation detectors. Recently, important applications of the corona discharges include the surface treatment of hazard gases and in the field of food industry. [15]

Corona discharges are spatially non-uniform and the ionization, electric field and luminosity are located near the pin-shaped electrode. The rest of the discharge gap is reported to be dark, with no radiation visible from this outer region. The electric field in this region is also weak. For a negative corona (sharp-tip cathode) in electronegative gases like air, there are no electrons outside the cathode region and the main charge carrying species are negative ions. [14]The second method is to use an asymmetric electrode pair. Then the discharge develops in the high field region near the sharp electrode and it spreads out towards the cathode. In this case there are two possibilities to avoid the transition into an arc.

First the voltage can be made low enough to stop the spreading of the discharge somewhere before the cathode is reached. Second one can stop or lower the voltage when the cathode is reached. In the second way more energy can be put on to the discharge but it is more difficult to make the power supply. This type of discharge is called corona. It is a positive corona when the electrode with the strongest curvature is connected to the positive output of the power supply and a negative corona when this electrode is connected to the negative terminal of the power supply.In corona discharges at relatively low voltages the discharge stops itself due to the buildup of space charge near the sharp electrode. This space charge then disappears due to diffusion and recombination and a new discharge pulse appears. This is the self-repetitive corona and it occurs in the positive and in the negative case. [16]

II. PROPOSED POWER SUPPLY CONFIGURATION FOR AIR CORONA GENERATION

The model consists of the high voltage corona generation circuit, protection modules, and Corona load discharge plates. This circuit consists of various stages like

1. Low Voltage Power Supply module
2. Frequency generator module
3. Voltage and current indicator
4. EHT or Line Output Transformer
5. ON OFF control Module
6. Switching Device used MOSFET IRF630NFP
7. Protection Module

   a. Door Logic
   b. Fan Logic
   c. Temperature Logic
8. Load Electrodes

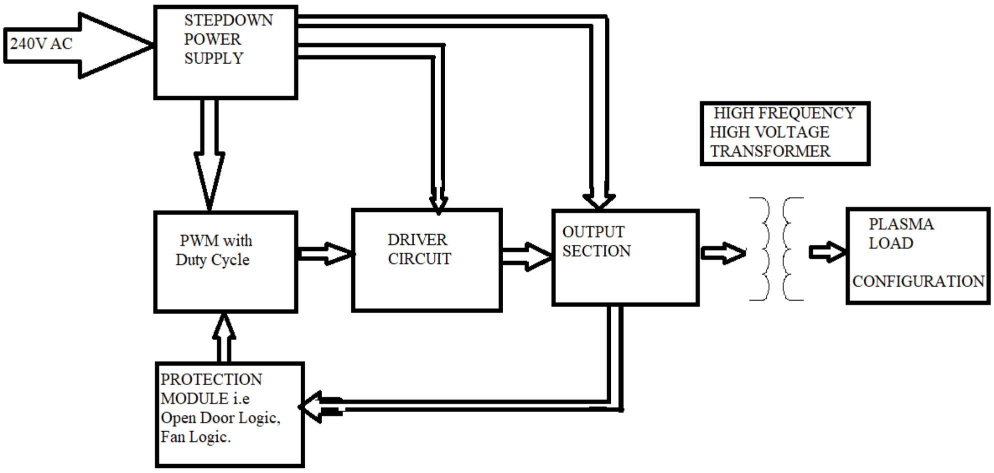

Fig.1 Proposed Block Diagram

1. Low Voltage Power Supply Module: This stage consists of multi output SMPS which are operated in for different modules. +15v dc for the voltage regulation circuit, +12v dc for the fan operation and +5v dc for PWM oscillator module.

2. Frequency Generator Module: this is signal generator module adjustable PWM pulse frequency, duty cycle square wave**.**
key features**:**
- LCD display frequency and duty cycle, very clear, PWM output can be set to the frequency and duty cycle;
- wide frequency range, high precision; duty cycle range: 0 ~ 100%; serial communication, TTL level
- The module has four independent keys, used to set the frequency and duty cycle, support touch (increase or decrease a unit) and long press (fast increase or decrease), set the parameters automatically save, power down not lost.

3. Voltage and current meter: It is used to monitor the input voltage and current.

4. EHT or line output transformer: A flyback transformer is a coupled inductor with a gapped core. During each cycle, when the input voltage is applied to the primary winding, energy is stored in the gap of the core. It is then transferred to the secondary winding to provide energy to the load. The primary winding of the flyback transformer is driven by a switch from a dc supply (usually a transistor). When the switch is switched on, the primary inductance causes the current to build up in a ramp. An integral diode connected in series with the secondary winding prevents the formation of secondary current that would eventually oppose the primary current ramp.

5. On-Off Control Module: This module consists of NAND gates as push to on and off. The operation of the switch is used to control the on and off of the model. After pushing it to ON then only the protection module allows it to start the system.

6. MOSFET IRF630NFP: Features of this device: Dynamic dv/dt rating, repetitive avalanche rated, fast switching, ease of paralleling, simple drive requirements.

7. Protection Module: this stage consists of three modules for the protection of this whole model. The circuit logic is same in design but inputs of these modules are different.
- Door logic: this protection is used for human error handling. This prototype model consists of high voltage at the output side across the load electrodes. Hence, here proximity switch is used for the unattended door opening for checking the corona discharge. This operation will help humans from electric shock.
- Fan logic: this is used for the fan fail condition. A fan is attached in the model to cool down the temperature of the built in circuit. If the speed of the fan slows down or it stops working then it indicates the signal to stop the whole operation.
- Temperature logic: this protection is used for the overheating of the output stage and power switches. Temperature sensing devices can be used for the RTD, thermocouple, or Thermistor. If the temperature crosses a limit, the operation will stop for safety purposes.

8. Load Electrodes: The load electrodes are two conductive plates. When the HV is applied to these plates a corona discharge is generated between the plates which also have the property of the plasma wave. The distance between these plates is approximately 1mm.

This model is used to observe that varying the different parameters at input side can generate different voltage and current generation at the output side. We can say that this could be prototype for different applications. For the different application we need various voltage levels for various applications. This model can be a prototype for such applications.

III. CORONA DISCHARGE MODEL

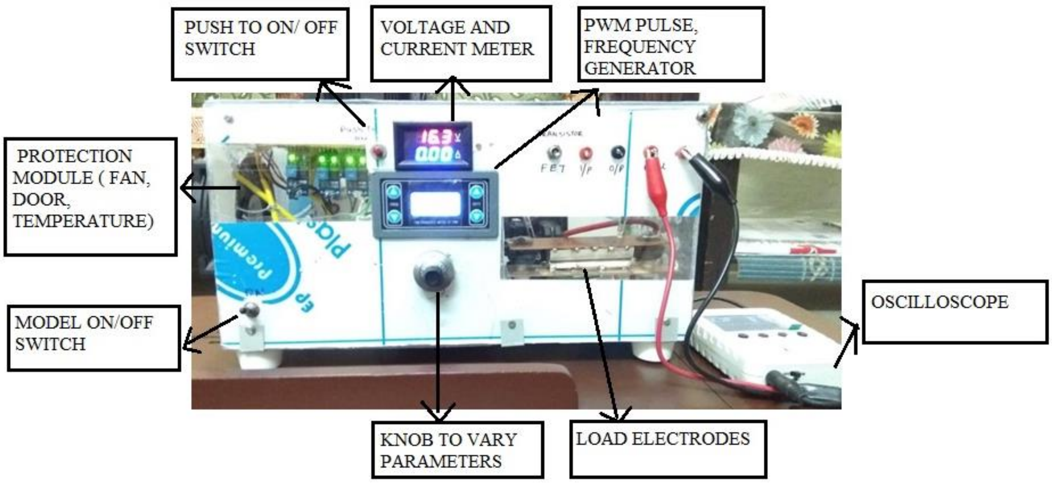

Fig.2 Fabrication of multi level corona discharge model

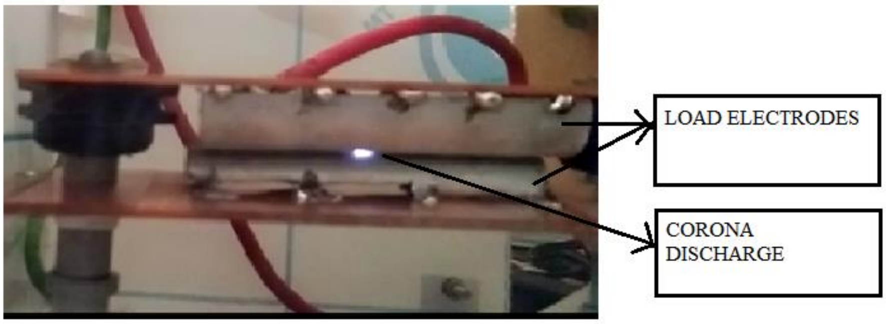

Fig.3 Corona Discharge shown between plates kept at 1mm distances

IV. APPLICATIONS

Here we have tested this model on the carbon film printing paper to see the effect of corona on the material kept between the electrodes. In the fig.4 we can observe the change in the surface properties of the carbon film printing paper. A thin white line can be observed in the film paper.

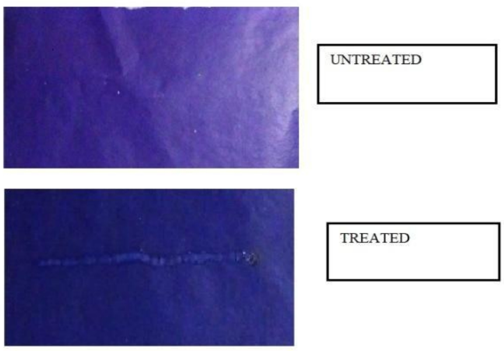

Fig.4 Application on the carbon film printing paper

V. CONCLUSIONS

A variable frequency, voltage and duty cycle plasma generator- experimental setup is designed and built to study the behavior of the corona discharge at some frequencies. The generator is built using only general purpose components that are readily available. The unit is portable and easy to setup for the demonstration. This simplified RF plasma unit is built for several reasons: to prove that it could be done, despite many technical difficulties, to see how the appearance and behavior of the electrical discharge differ at various frequencies, to make the system compact, portable and easy to setup for demonstration.

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