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Design and Construction of a High-Frequency Electrosurgical Unit for Rural Application

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Abstract
This report highlights steps taken from the beginning to the conclusion of the design and development of a functional high-Frequency electrosurgical unit, a device which uses high-frequency electric current to cut, coagulate and desiccate tissue for surgical effects by increasing intracellular temperature. Electrosurgical units have been around since the late nineteenth century but weren't commercialized until 1928 by William.T.Bovie and have advanced over the years but most electrosurgical units in developing countries are imported and thus are quite expensive. Because of this, electrosurgical units are scarce in most community clinics and rural healthcare facilities. These conditions inspired the conception of this project. The device was constructed using highly affordable materials and all work was done following three main objectives which were; parts and materials selection, CAD of both the circuitry and outer covering and the construction. The electrosurgical unit in this project uses a resonance and flyback driver mechanism to convert 220v 13A of A.C into 1Kv 5A current. By this method, a damped sinusoidal wave of a high frequency between 40 kHz - 60kHz was achieved. The device was tested using a piece of meat and the frequency of current was measured using an oscilloscope. Several challenges were met along the way but the project was successful and a high-frequency electrosurgical unit was achieved.

Keywords: *Electrosurgical unit, Hyfrecator, Rural Application, Proteus 8*

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I. INTRODUCTION

The use of high-frequency electrical current for the cutting and coagulation of tissue is called electrosurgery explains [1]. Coagulation is usually used to achieve hemostasis, occlusion of lumen-containing structures and the destruction of large volumes of tissue such as soft tissue neoplasms [2]. According to Holmes *et al.*[3], Electrosurgery is usually applied in debulking procedures like rhinophyma excision, treatment of benign and malignant skin conditions like acrochordons (skin tags), warts and even basal cell carcinoma (BCC). Benias and Carr-Locke [4] list four major forms of Electrosurgery namely Electrocautery, Electrolysis, Coblation, High-Frequency Electrosurgery. High-frequency electrosurgical devices can be used for the removal of warts and pearly penile papules, epilation, destruction of small superficial veins, and many other dermatological tasks. It can also be used in the destruction of skin cancers such as basal cell carcinoma (BCC) [5]. Electrosurgical units (ESU) like the Hyfrecator can be used in the coagulation of small discrete bleeding points in areas which are intentionally kept wet with an isotonic solution like saline solution [6]. It is employed in fulguration which is a more extensive form of coagulation which causes death to tissues and can be used to remove small tumors and warts [7]. It is used in veterinary medicine to shrink papules on animals like horses and snakes. In dentistry, it is used to control bleeding during tooth removal. It can be used in cosmetic surgery to get rid of skin blemishes and varicose veins [8]. Its application in gynecology serves to shrink genital papules [8]. While the development of ESU goes far back as in 1905, there has been considerable progress on the design of ESU over the years. In 2001, Eggers and Hira made an electrosurgical device for selective application of electrical energy to structures on the external surface of a patient's body. The device was invented for use in dermatological procedures, i.e., surface treatment of the patient's outer skin and underlying skin [8]. In 2001, Gines [9] invented an electrosurgical generator for treating tissue by applying energy to tissue . In 2005, Thompson [10] invented an electrosurgical generator which comprised of a current mode power supply operative for the conversion of pulses of input current occurring at a predetermined switching frequency into a DC output voltage. In 2011 [11], Hamel and colleagues created an electrosurgical generator that was capable of coagulating and ablating tissue. The device comprised of a control console, an electrosurgical probe that detachably connects to the control console, a generator disposed of in the control console for generating a variable power signal for energizing the electrosurgical probe, a first monitoring system disposed of in the control console and in communication with the generator [11]. The increased need of ESU in rural areas of developing countries [12] is a call to develop low cost and easy to operate units for use in those areas.

II. METHODOLOGY

Each fabrication step was approached with a thorough understanding of the systems and knowledge of the operation of the electrosurgical unit. Amongst the steps followed are parts and materials selection, CAD and Proteus model of the proposed Electrosurgical Unit and finally the construction of the Electrosurgical Unit. The following flowchart (Figure 1) shows in details the steps followed to fabricate the unit.

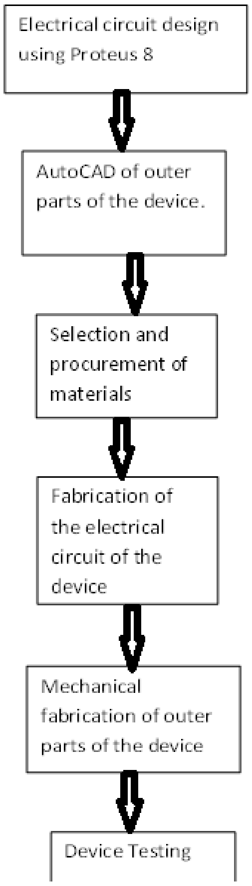

Fig 1 Flow chart showing the design process for the proposed electrosurgical unit

The fabrication steps include the diagrammatic representation of the electrical circuit using proteus8 software, after which the Mechanical parts are designed using AutoCAD software. Taking the design into consideration, the materials are then procured and construction begins on the electrical circuit. Upon completion of the electrical circuit, testing is done to determine whether the machine works the way it is supposed to. After this, Mechanical fabrication is done

Proteus 8 is a software developed by Lab center Electronics and can be used to generate schematic captures, simulate microprocessor and develop PCB [13]. It and has a simple user interface which simplifies tasks. The following steps were observed in designing the electrical circuit via an ISIS schematic background on which circuits are designed in Proteus 8 software: selection of a format while indicating whether a PCB version of the circuit will also be designed, selection of components from a vast library of components and placing them on the schematic capture, linking components via a wire cursor and putting output and input in their proper positions.

According to Techopedia [14], AutoCAD is a computer-aided design (CAD) program used for 2-D and 3-D design and drafting. It is developed and marketed by Autodesk Inc. and was one of the initial CAD programs that could be executed on personal computers. It was used here to design the outer part of the device after which testing of the complete device was done.

A detailed list of the components used including their specification and quantity is expressed Table 1

Table 1. Parts and materials

S/N	Component	Specification	Quantity
1	Resistor	470Ω	2
2	Resistor	10kΩ	1
3	Resistor	2.5Ω	1
4	Resistor	3Ω	1
5	MOSFET Transistor	IR250	2
6	Capacitor	0.68uF Polyester layer	1
7	Schottky diode		2
8	Diode	1N759A	3
9	Inductor	1H	1
10	DC battery	40V	1
11	Knob operating potentiometer	5Ω	1
12	Loudspeaker	12Ω	1
13	Fuse	2A	1
14	LED		1
15	Cable		1
16	Jack and jack port		3
17	Plug	3A	1
18	switch		1
19	Dial		1
20	Ferrite core transformer	110v,1kv	1
21	Step down transformer	220v, 110v	1

The circuit design can be divided into the input (power supply), flyback driver and the resonant circuit and the output [15] as represented in the block diagram in figure 2 below.

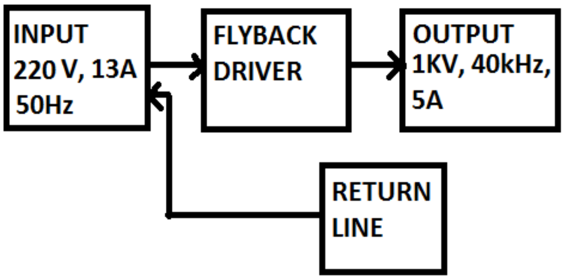

Fig 2. Block diagram of the electrosurgical unit

The electrosurgical unit consists of the power supply having a fuse, live, neutral and earth wires, A power generator consisting of a step-down transformer, a resonant circuit and flyback driver circuit connected to a ferrite transformer which all work together to produce a high-frequency current between 40 kHz-60kHz.

The power supply consists of the live and neutral power channels which supply current to the device. 13A of current at a voltage of 220V and a frequency of 50Hz enters the electrosurgical unit. In the power supply block, there is a fuse of 2A to protect the device from high current surges and an indicator lamp to show when the device is 'ON'.

The power generator of the HF Electrosurgical unit consists of one step down transformer with an input of 220v on the primary winding and 110v on the secondary winding. The step-down transformer acts as an isolation transformer which isolates the body of the device from the power supply reducing the chances of electrocution.

According to Electrical4u [16], a resonant circuit consists of a resistor, inductor, and a capacitor. A series RLC circuit resonates at a specific frequency called resonant frequency. The resonant circuit in the electrosurgical unit is a series RLC circuit as seen in figure 3 and can store energy in two ways; One is when a current flows in an inductor, energy gets stored in a magnetic field. Two is when a capacitor is charged, energy gets stored in a static electric field.

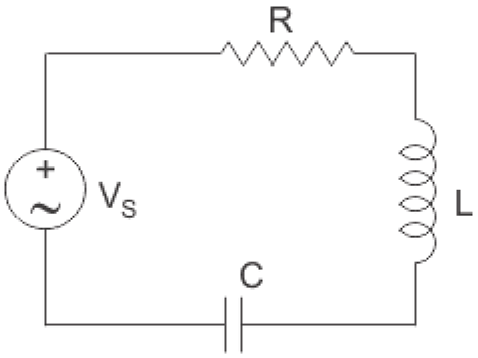

Fig 3 Series RLC circuit

III. RESULTS AND DISCUSSION

Figure 4 was designed using Proteus 8 software [17]. It consists of a flyback oscillator connected to a high voltage transformer, the Flyback oscillator consists of resistors, diodes and MOSFET transistors connected in of 220 V and output of 110V. The new voltage goes into an RF choke of 110V input and series and in parallel. It amplifies the direct current fed into the circuit by a 40V DC battery and converts it to 220v AC current. This current then gets fed into the step-down transformer with an input 2KV output. The output current is a damped sine wave.

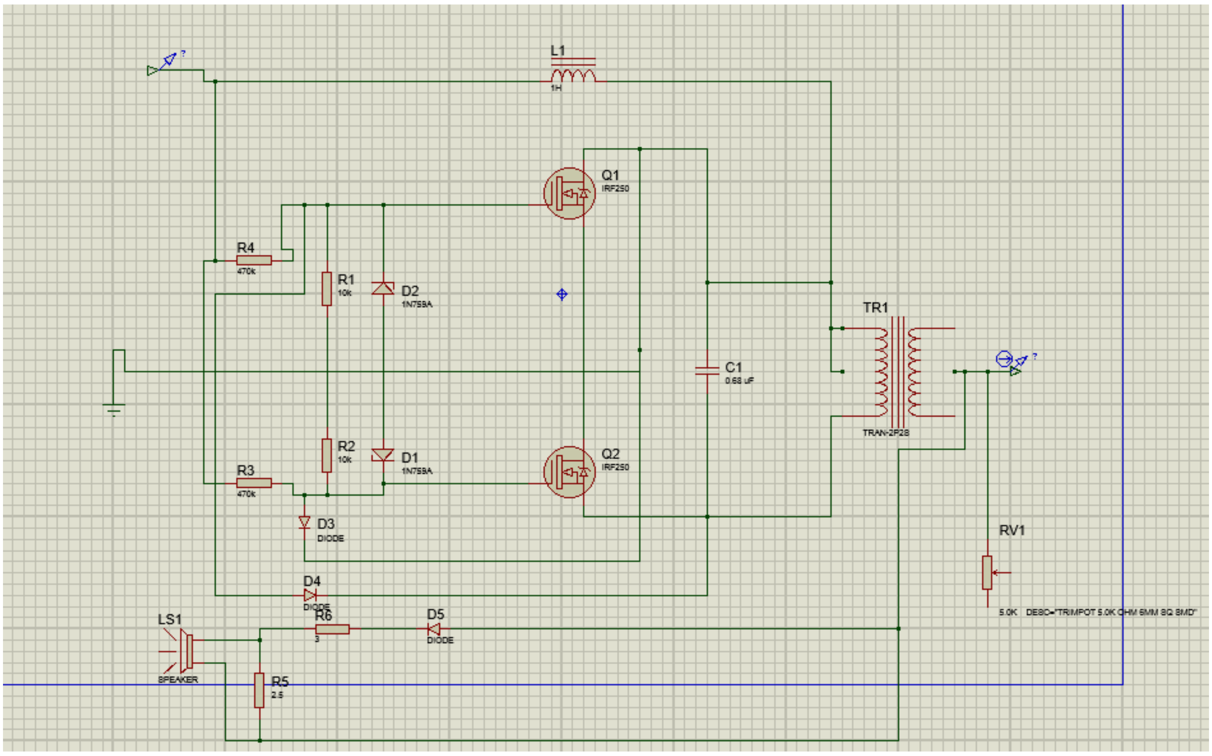

Fig 4 Circuit design of the high-frequency electrosurgical unit

Figure 5 shows the outer part of the unit as designed using the CAD software. This is a three dimensional view [18]. The various operating buttons can be seen as well the cooling vanes on the body of the unit. The electrical components for the inner part of the equipment are shown in figure 6.

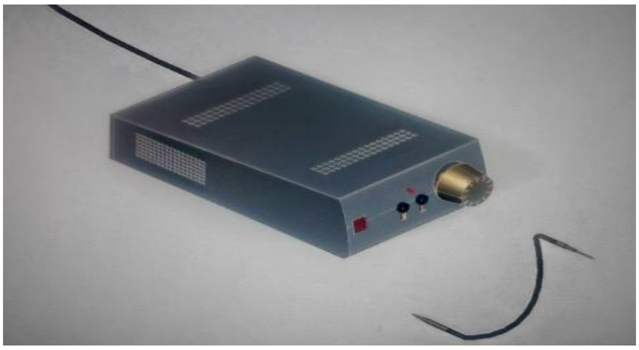

Fig 5-D AutoCAD model of the ESU

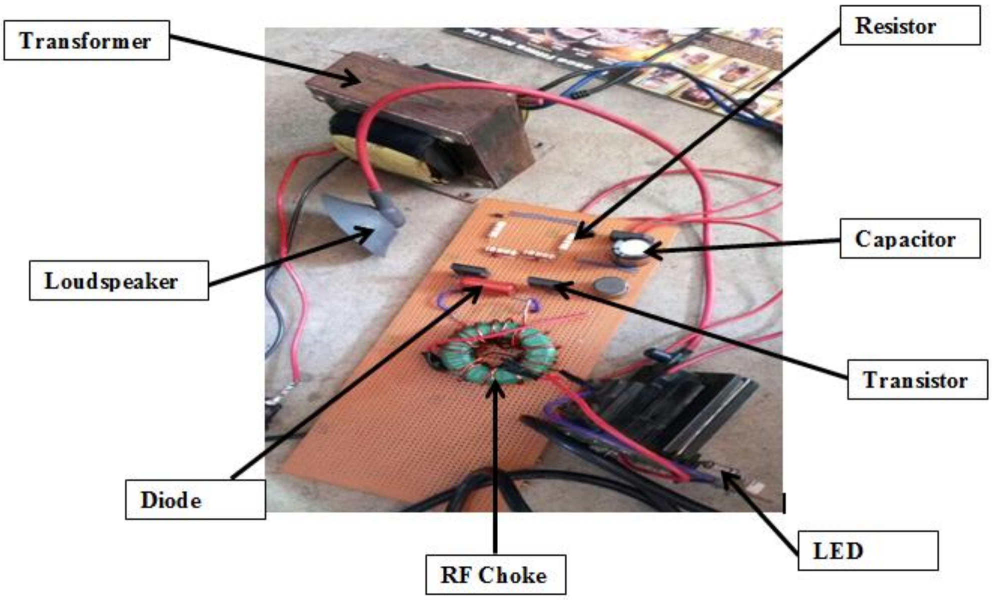

Fig 6 Constructed circuit of the electrosurgical unit showing electric components

In order to test the constructed unit as seen in figure 7, the following accessories and apparatus are needed; Oscilloscope, a piece of fresh moist meat, electrosurgical unit, gloves. The process includes heating a piece of fresh moist meat to a warm state, almost to the temperature of the human body. Afterward, laying the meat is laid on a plate and firmly holding it while the active needle slightly touches the meat. This is to ensure that the meat acquires the holder's capacity, thereby simulating an actual patient.

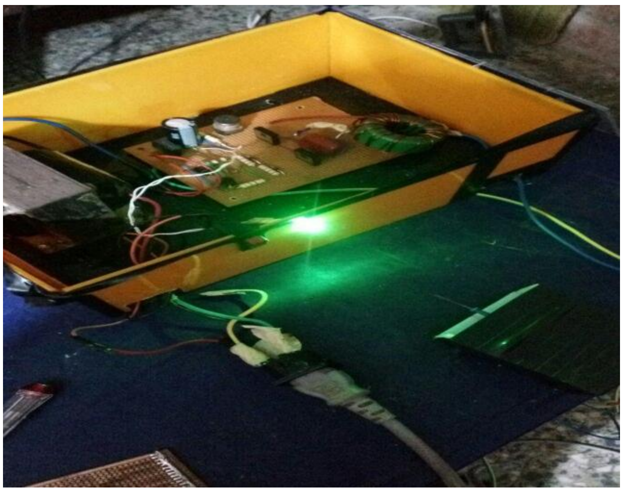

Fig 7. The coupled electrosurgical unit turned "ON" for testing

The experimental procedure to show the working of the electrosurgical unit in this study are namely fulguration and desiccation [19]. In fulguration, the active electrode was held at a distance of about 1 mm - 3 mm from the meat while in desiccation, the needle was inserted into the piece of meat at a depth of 3mm and turned out to 5 mm.

IV. CONCLUSION

This study shows the possibility of designing and constructing a high-frequency electrosurgical unit for the smaller community clinics where small office surgery may need to be performed. The Materials used in the construction of this unit are readily available and affordable. Moreover, the unit is lightweight, portable, easy to maintain. The unit needs to be improved esthetically. More experiments need to be conducted both on dead and living animals prior to using it on humans

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