Invasive and Non Invasive Sensor for Thermal Control of Bipolar Electrosurgical Device

Ali Idham Alzaidi, Azli Yahya, Tan Tian Swee, Norhalimah Idris

Abstract: Electro surgery, which also known as radiosurgery, has been utilized as a part of various types of surgery for more than 100 years. Surprisingly, it has been recorded hat electro surgery is a medium for surgery since 50 years prior. The most frequent complications after high frequency electro surgery are tissue burns. Thus, minimization of thermal injuries becomes one of the most important goals in development of electrosurgical devices. The problem is made difficult by continuous variation of the exposure parameters. Based on the current issue of ESU generator system, there is a demand of research for developing thermal control on the electrosurgical process. This paper has the following objectives to develop the self-, regulate output power as a function of load to manage the thermal of Skin tissue by using thermal camera sensor. To implement advance control system such as PID controller for the hybrid ESU thermal control.

Index Terms: **- Electrosurgical, Burn tissue, PID, Self-regulated.**

I. INTRODUCTION

There are several different types of surgery, which can be carried out by utilizing high frequency instruments. For example, Bipolar, Monopolar and wide range of high frequency surgery instruments. Bipolar differs from Monopolar in terms of the electrical current heats a metallic probe that is then applied to the tissue (hot iron cautery). Heat generation occurs within the tissue as the treatment electrode acts as a conductor that only passes certain amount of current but remains cooler than the treated medium. There is different category of the ESG such as input power voltage, RF frequency generator, and active electrode. Electricity is transformed into high frequency electrical energy by the power generator (Jensen and Maksimovic, 2017). The energy that is delivered from the electrosurgical electrode can be either type of current, meaning monopolar or bipolar. The current is returned from the patient to the ES unit via the grounding pad. Beforehand, electrosurgical units were assured ground-referenced systems. The electrical current can pass though the ground via any object that is in contact with the patient, such as stirrups or electrocardiogram electrodes, this is in addition of the current that can go through via the dispersive pad that is attached to the patient (Feldman et al., 2012). The chance and risk of burn is increased because of this, and it can cause alternate site burns or even electrode

burns. This can particularly be an issue if there is inadequate dispersion for the current. However, it should be noted that this observation and happening, only occurs in monopolar units. Besides, the risk of electrocution is greatly reduced at higher frequencies as the skin function to force the current flow to the exterior of the conduction path (Feldman et al., 2013). This control of the current path reduces the risk of the current crossing the heart leading to electrocution. Electrosurgical generators must operate at an adequate frequency to prevent neuromuscular stimulations, and to reduce the risk of electrocution (Madani et al., 2014).

Control of feedback system of a high frequencies for new generator that currently exist, allows the electrode to return feedback signal rapidly to varying situations that come across during cutting. According to the characteristics of the new systems, it is worthy to try to develop a power supply as well as a generator and combine them both, in order to take advantages from the strength of each system while eliminate any possible weakness. Several combinations should be tested, analyzed, and returned to find the best configuration respectively. The right combination will utilize the benefits of both systems that will improve the ESU properties especially for cutting and coagulation. This project aims to design and develop a new electrosurgical high frequency generator and power supply with multiple output voltage. The RF Generator plays an important role to control the connections between power supply and electrode by producing a suitable signal that connected to the switch in the Buck circuit as shown in Fig. 1.

Figure I. Early Prototype

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II. EFFECT OF TEMPERATURE ON CELLS AND TISSUE

The normal body temperature for a human being is roughly around 37°C. When this temperature is increased even slightly, the body will fall into illness. This can happen during fevers or infections where the body temperature can reach 40°C (Madani et al., 2014). While the aforementioned temperature is for the body as a whole, when locally this temperature is increased, the integrity of the cells starts to shift and the organic molecules are changed. For example, if a temperature reaches 100°C or more, the structures of the molecules start to collapse and fall apart, leading to a state called carbonization. However, the first denaturation occurs with the proteins, which the temperature would break the hydrothermal bond that exists between protein molecules. At this stage, the temperature is as low as 60°C. The consequent monstrous intracellular development brings about touchy vaporization of the phone with a billow of steam, particles, and natural issue (Nduka et al., 1994). On the off chance that the intracellular temperature ascends to at least 100°c, a liquid– vaporous transformation happens as the intracellular water bubbles shaping steam. Understanding the surgical utilizations of RF power requires a fundamental comprehension of the impacts of temperature on cells and tissue(Busnardo et al., 1983).

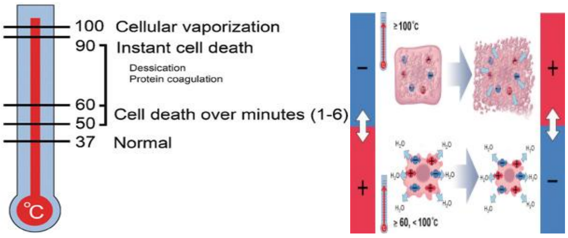

Fig. II. Type of ESU generators

III. MATERIALS AND METHODS

This section is divided into two sub-sections. The first section is the simulation of the newly thermal sensor with the use of image processing in order to detect on the temperature values and the second section is to design the control system to control the thermal through regulator the electrical voltage output of the ESG.

A. Non-Invasive Thermal Sensor

The circuit design of control is first described and the behavior model of the system is implemented using the SIMULINK in MATLAB. Simulink models are block diagram consisting of sources, sinks and various functional blocks for modelling a system. The overall system describes the control condition when it is in work.

Fig. 3. Level 0 Data Flow Diagram for Self Regulating Thermal Controller

Data Flow Diagram is illustrated in Figure 3. The two interacting entities are the thermal sensor and the power supply. The thermal sensor in this case is the thermal camera that reads the information from the incision and sends the data into the process. If the information conveyed to the system indicates that the temperature is too high, then the process would order the power supply to reduce the voltage accordingly.

B. Invasive Thermal Sensor

Thermistors and Thermocouple are broadly utilized as inrush current limiters, temperature sensors (Negative Temperature Coefficient or NTC write commonly), self-resetting overcurrent defenders, and automatic warming components (Positive Temperature Coefficient or PTC compose normally). Thermistors are of two inverse essential composes such as NTC thermistors, protection diminishes as temperature rises. Thermocouple which consist of two part of different metal types each one has different heat expand which is used in different application of heat control there are more than one kind of thermocouple but the most common one is Type K .Figure 4 show the electrical circuit of thermocouple which took the signal from the target to amplifier then send it to Arduino circuit which can read and display the temperature.

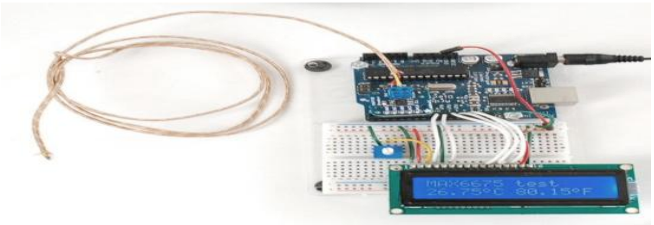

Fig. 4. Thermocouple circuit

IV. EXPERIMENTAL SETUP AND RESULT

The experiment aims on validating the cameras' ability to monitor the temperature of the tissue. The experimental setup is shown in Fig. 5. The tissue used in the experiment is an ex vivo meat tissue. This tissue is then used for localized coagulation. To perform the experiment, the tip of the ESG would be placed on the surface of the tissue for experimentation. The heat is applied on a continuous phase for 10 seconds. The procedure is recorded with a thermal camera, which is positioned ten centimeters from the tissue. The readings performed by the thermal camera are processed for extraction.

Fig. 5 ESU

Once the images are collected by the FLIR camera, they are processed in order for the temperature to be extracted. In the first rounds of the simulation the image

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processing is performed offline, however in later implementations the image processing section would be performed live.

A. Thermocouple Design Circuit

Thermocouple is an electrical device that produces a voltage depending on the temperature. The device itself consist of two electrical conductors that are dissimilar. The voltage is used for the interpretation of the temperature. These devices are popularly used as a form of temperature sensor, and commercially they are inexpensive. They are often supplied with a standard connector and are able to measure a variety range of temperatures. One of the other benefits of thermocouple is that they do not require any external form of excitation, and are generally self-powered. The only issue with this device however, is that they are not very accurate, as reducing the system error to less than one degree Celsius is very difficult. In the figure 6 we connect the thermocouple type k with and we build the circuit to measure and read the real time temperature for ESU during the cut process by using forceps. It connected to amplifier type max to amplifying the signal collected from tissue and electrode then the input will be feed to microcontroller Arduino Uno we build the code to reading then attach the thermocouple tip on the area required. We monitor and record the reading of thermocouple and compare with camera sensor.

Fig. 6. Experiment Design

V. DISCUSSION

The first round of results show that the process is able to extract the images and process them successfully. This means that the heat source is identified and the temperature is extracted from it. The readings performed were matched with the real tissue temperature. This can be seen in Figure7. Which all the images took during the ESU cutting process send it to image processing tools to detect the hottest point in each second and read the temperature as show in the images below the green spot indicate the hottest point and we detect the temperature reading which can lead to feedback system as the part of thermal control system . System will compare between the reference temperature and reading temperature.

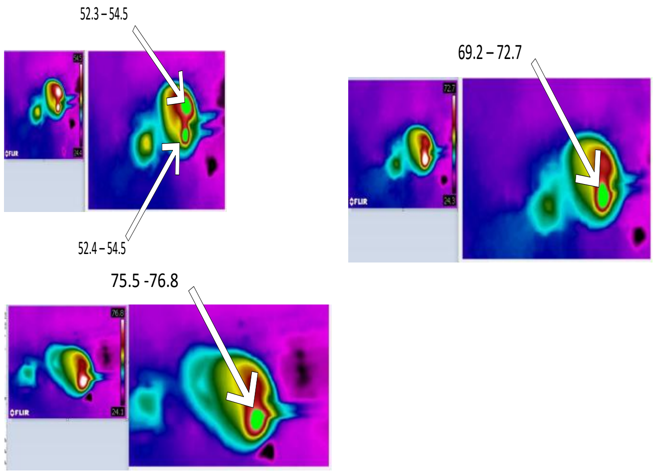

Fig. 7. Thermal Camera Images

In the table below compares the averaged heating rate (°C/s) for both sensor measurement points between the two methods. The analyses showed that the temperature increasing rate significantly varied for both measurement points (camera and thermocouple sensor. comparison tests were then carried out to compare the difference of temperature-increasing rate of the voltage output (Abu-Rafea et al., 2011). There was not that much difference between the regular thermos sensor and the infra-red mage sensor for all measurement points There was also no difference between the time response for methods.

Table V.1: Power/Temperature Relationship

No	Time in second (s)	Temperature from image C^0	Temperature from thermocouple	Voltage (mv)	
				25 w	50 w
1	1	42	43	1.2	2.3
2	2	54	54	1.8	2.8
3	3	62	64	2.3	3.2
4	4	79.7	78.1	2.8	3.9
5	5	86.6	85.4	3.6	5

As show in the table above temporal temperature at the locations using the bipolar forceps during coagulation of tissue by using Thermal image camera and thermocouple. Each temperature curve is the result of the two coagulations process. The starting internal temperature of the tissue was 42°C. For thermistor #1, the temperature increased about 1°C, and 1.5°C for the thermal camera with same forceps, tissue, at the end of each 5-second activation cycle. The temperature then dropped after activation. Temperature of the noninvasive sensor decreased most rapidly, as it had the greatest temperature gradient to the ambient environment. For thermistor, the temperature increased by about 42°C, 54°C, 62°C, and 86°C for same condition and forceps, respectively, at the end of the activation. Temperature of all these the heat was increase gradually for each second.

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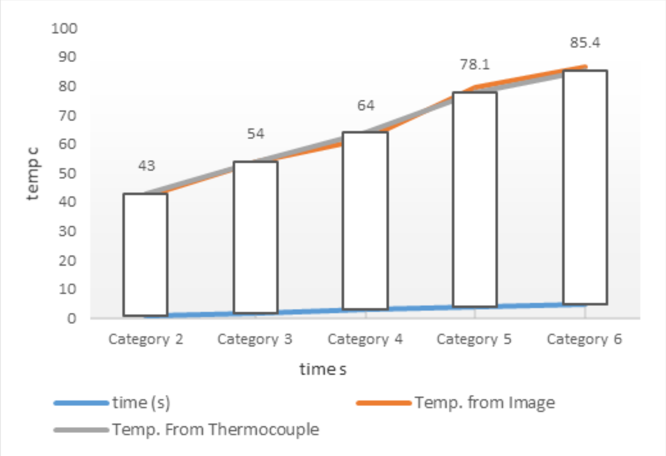

Fig. 8. The relationship Between the Tem and Time

The major limitation of this study is that the experiment was not conducted with live animals. Thus, the efficacy of coagulation could not be studied. However, the main purpose of this study was to compare and use different thermal sensor to measure and read the temperature profiles and the effect tissue. For the camera, the temperatures measured may not response immediately in this stage thereby requiring a longer activation time. This may be a concern and requires further study

VI. CONCLUSION

Recently, rapid growth of biomedical engineering technologies has improved the quality and performance of biomedical equipment as well as healthcare services. In medical surgery specifically, ESU machine has a potential to be utilized into cutting and coagulation device which involves Monopolar and Bipolar. RF electro surgery enables the specialist to carry out a wide range of systems securely, viably, and without negligence that cause undesired tissue injury. If it is utilized without legitimate care, instruction, and preparing, electrosurgery, has as different instruments and vitality sources, can possibly cause inordinate tissue injury, and expanded agent dismalness. This research furnishes the users with a basic learning of the logical standards of RF electrosurgery that will encourage comprehension of the frameworks and its strategies.

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