CONTROLLED VOLTAGE OF HOT SNARE POLYPECTOMY DEVICE IN ELECTROSURGICAL DEVICE

by

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ABSTRACT

The study aimed to understand the working procedure of the Olympus PSD-30 Electrosurgical Unit, in which a high-frequency alternating current measures the voltage and power output from the unit when used for a surgical operation to determine the extent of tissue damage. In examining this, power and voltage were analyzed using a stopwatch output, then with an Arduino time based for 1, 2, and 3 seconds to understand the different modes of the cut and coagulation feedback with an RCC circuit used to mimic the human body. This shows a pattern in which the feedback power increases, and voltage decrease as the cut and coagulation mode increases. The percentage between the stopwatch and Arduino is 29% for the 1 and 2 seconds. With this information, Arduino Uno timing was used to experiment with the device for the different power settings for both the cut and coagulation mode from 2W to 50W at 5W intervals. Based on each trial, the signal was measured for a magnitude of 1Vpp, and the crest factor obtained was 1.5 with a voltage of 1.088v and 1.0519v for both the LabView and oscilloscope, respectively for the Electrosurgical Unit of 350kHz. The power control gives 0.4W, 2.04W, and 3.01W for the power peak at 1, 2, and 3 seconds for the 50W cut mode of the electrosurgical devices.

INDEX WORDS: Electrosurgical Unit (ESU), Polypectomy, Snare, Power, Voltage, Feedback control, Crest factor

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DEDICATION

I like to dedicate this project to everyone that contributes directly or indirectly to its successful completion, especially my wife, Amina Abdulazeez. Also, I would like to thank my parent for their moral support and prayers towards the completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 Purpose of Study

The widely accepted method for screening and evaluating colorectal cancer and polyps is a colonoscopy which is generally safe with an estimated rate of complication of 0.3%. The discovery of polyps leads to a process called polypectomy (Nelson 2002). The polypectomy discovery had a massive reduction in mortality from colorectal cancer. But this process comes with some complications, which are internal bleeding, coagulation syndrome, and perforation, which are the most severe (Anderloni et al. 2014) to human health.

Based on different studies regarding the mortality rate and complications experienced, it is generally believed that the surgeon's experience plays a significant factor in the post-polypectomy difficulties and the patient's lives. In order to make the process safer by protecting the lives of patients and making the medical practitioners' work more accessible and secure, there is a need to assist in reducing the complication to the barest minimum. Then the need to improve the Electrosurgical Unit is essential by analyzing the processes and improving the existing process to lower the surgeon's experience and reduce the complications and mortality rate.

The main objective of this study is to analyze the design and construction of the feedback system, which will be used to control the voltage of the cut section of the Electrosurgical Unit. Firstly, the circuit will be built to act as the human colon while the microcontroller will be used to control the foot switch pressed, which gives 5V and, when unpressed, provides 0V. Then, the cutting process should be able to stop when a certain voltage is reached based on the footswitch.

1.2 Modeling

There are three different ways to model the inside of a human colon, which can be done by living organisms' tissue sample, gel block, and an electric circuit which is a resistor-resistor-capacitor (RRC). The RRC will be deployed to act as the human body for the experimental procedure to understand the variation in the voltage and power of the Electrosurgical Unit.

Tissue has both the properties of conductors and dielectrics. The complexity that arises from the body entails both resistance and reactance. The resistance arises from both the extracellular water (ECW) and intracellular water (ICW), while the reactance arises from the cell membranes (Kyle 2004).

The resistance of the ICW is denoted by R_I, the resistance of the ECW is denoted by R_E, and the cell membrane is denoted by C_M.

This study focuses on monitoring the change in voltage during the operation of the ESU, which is not a new idea. Electrosurgical Unit producers have this feature integrated into their devices which is mostly for the bipolar method with both sending and receiving electrodes of the current flow through the accessory. This study will use a hot snare using the monopolar method. This brings on additional complications in the accuracy of the measurements due to the length of the wire of the snare and grounding patch by integrating the patient’s body, not just the polyp, into the measurements. In this case, the circuit would be the path the current takes from the ESU through the snare, then through the polyp and patient, and back to the ESU through the ground patch.

The cell membrane is composed of mainly proteins and lipids and determines how the current flows inside of the cell. It is expected that the voltage will increase with increasing frequency, but tissue is not completely homogeneous or isotropic; it is anisotropic; meaning that the conductivity term is different if taken in different directions. With further analysis, additional variables such as temperature, electrode, tissue interface impedance, and even the type of electrode are all relevant factors because of these complex situations inside of the cell, which makes numerical modeling difficult.

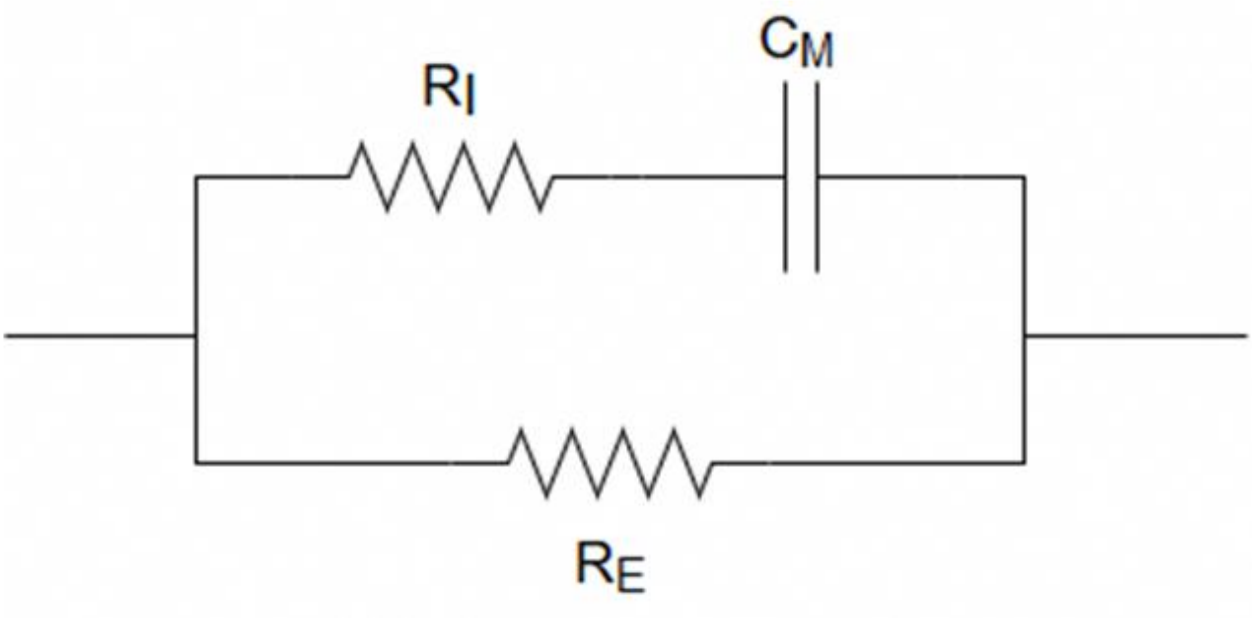

Figure 1. 1: Human body equivalency circuit RRC (Ursula G. Kyle, 2004)

CHAPTER 2

LITERATURE REVIEW

2.1 History Background, Process, Application

Electrosurgical generator units (ESUs) work with therapeutic endoscopy by providing the high-frequency electrical flow needed to utilize numerous endoscopic embellishments. The term electrosurgical energy depicts the change of alternating electrical flow created by the ESU into thermal energy inside the tissue. In endoscopy, for example, polypectomy snares, forceps, and sphincterotomes fill in as conductors that convey electrical energy to the expected therapeutic site. The most presently accessible ESUs have refined chips and programming empowering them to create different electrosurgical waveforms that impact the final product of the electrosurgical energy. ESUs have highlights that upgrade both patient security and usability (ASGE 2013).

Cancer is broadly known as a significant medical condition generally having a presence in every part of the world; about one-fourth of mortality results from cancer growth. Among a wide range of cancer growth, colorectal is the third most common cancer affecting people (male and female) in 2014. Also, around 136,830 cases and 50,310 mortalities were recorded according to the American Cancer Society because of colorectal cancer growth in 2014 (Rebecca Siegel et al. 2014). Colonoscopy is generally recognized as the ideal methodology used to screen precancerous injuries and forestall colorectal cancer growth (Gregory G. Ginsberg 2008) (Cynthia W. KO 2010). Although there have been difficulties in the procedure, colonoscopy is yet thought to be, for the most part, a safe technique (Cynthia W. Ko 2007). Importantly, both the experience of an endoscopist and the number of colonoscopy systems performed by an endoscopist influence the occurrence of complications experienced (V. Panteris 2009). Additionally, the proof shows that the complexity pace of an endoscopy methodology performed by an unpracticed endoscopist is nearly high when contrasted with those performed by an accomplished endoscopist (Linda Rabeneck 2008) (George Dafnis 2001). That is, some unfavorable occasions might happen during or after the colonoscopy system because of inexperienced endoscopists. Consequently, it is important and doable to look for a way that assists unpracticed endoscopists with further developing their method of execution. Since some normal difficulties are almost certainly brought about by exorbitant tissue warm injury, like bleeding, perforation, and post polypectomy consumption condition, the amount of warm tissue injury created by monopolar colonoscopy removal merits additional consideration by endoscopists (Akiko Chino 2004). This review looks for a technique to help unpracticed endoscopists in working on their presentation during colonoscopy methods by diminishing the event of exorbitant tissue warm injury. It offers an overall foundation of colonoscopy. The issue proclamation is then introduced dependent on the foundation. Subsequently, the unbiased and fundamental construction of this proposition is introduced together.

Cooled-tip Radiofrequency Ablation (RFA) produces bigger and more profound epicardial sores than standard RFA. The presence of epicardial fat mediated between the catheter tip and the myocardial tissue forestalls sore development with standard RFA yet just modestly constricts the viability of cooled-tip removal. Over infarcted epicardial tissue targets, cooled tip RFA had the option to create sores of generous profundity (Christopher Houghtaling, Paulo Gutierrez and Olivera Vragovic 2004). Early conclusion and coordinated treatment are basic to limiting the effect of methodology-related complexities. In recent years, other uncommon and unfavorable occasions have been credited to colonoscopy and supported by case reports or case series in the distributed journals. Instances of these include splenic cut, intense cholecystitis, intense ruptured appendix, and ischemic colitis (Gregory G. Ginsberg 2008).

An electrosurgery generator unit is a basic piece of hardware in any therapeutic endoscopy setting. Electrosurgery generators produce high frequency alternating electric flow and vary from electrocautery units in that both cutting, and coagulation impacts can be accomplished. This capacity to cut and coagulate simultaneously makes electrosurgery an optimal therapeutic instrument for gastrointestinal endoscopy (Marcia L. Morris 2009). Even though colonoscopy has set up benefits for the discovery of colorectal cancer and adenomatous polyps, the method is related to dangers of genuine complexities, including mortality. More seasoned aged male patients, having a polypectomy and having the methodology done by a low-volume endoscopist were autonomously exposed to colonoscopy-related perforation and bleeding (Linda

Rabeneck 2008). Current polypectomy devices and procedures are insufficient to forestall all post-polypectomy bleeding, perforation, and post-polypectomy conditions, but adherence to specific standards can significantly lessen the danger of these confusions. The utilization of electrocautery can be limited in the resection of little colorectal polyps. The hot forceps method, whenever utilized by any means, ought to be bound to polyps lower or equivalent to 5 mm in size. Sessile polyps, something like 2 cm, ought to be eliminated piecemeal in many cases, and submucosal infusion ought to be thought about however isn't needed for all cases. Submucosal infusion of epinephrine is compelling in forestalling prompt draining from the evacuation of enormous sessile or pedunculated polyps, and separable snares can be considered for all or chosen instances of pedunculated polyps for anticipation of both prompt and postponed bleeding. Clipping is not powerful yet is a sensible thought for the avoidance of bleeding in chosen patients, and the conclusion of polypectomy deformities could be anticipated to forestall perforation and may forestall bleeding in chosen cases. New advancements that could additionally lessen or dispense the bleeding and perforation after polypectomy are woefully required (Hala Fatima 2007). The evacuation of colon polyps is the most common remedial move acted in the huge entrail. The procedure for polypectomy of little or huge polyps is fundamentally something similar, with redundant, however, comparable activities needed for bigger injuries. A few stages are portrayed that make polypectomy more productive. These incorporate fixing the colonoscope, setting the polyp in the right position, keeping the catch level on the divider during conclusion, and desire for air. Bleeding can be controlled with an infusion of a vasoconstrictor or the utilization of clips and loops. Not all polyps may be taken out, but rather in case a medical procedure is examined, infusion of a careful marker will be of help to the specialist when looking for the space requiring resection (Jerome D. Waye 2003). In 6066 colonoscopies, the general complexity was 0.4% (indicative 0.2%, restorative 1.2%). The most successive complexities were bleeding (0.2%) and perforation (0.1%), with no colonoscopy-related death. Bleeding was restricted to therapeutic colonoscopy and happened quickly, mostly after the evacuation of enormous polyps with thick stalks. Perforation at analytic colonoscopy happened in the left can be detected sooner than perforation related to therapeutic colonoscopy where the cecum was the most continuous site. The bleeding rate was related to the experience of the endoscopists (George Dafnis 2001). The profundity of tissue injury brought about by coagulation current was more prominent than blended current (p = 0.0157). The profundity of injury with coagulation current additionally was more noteworthy than with pure cut current (p = 0.0461 in a solitary factual test; importance eliminated by Bonferroni-Dunn revision). With the hot biopsy forceps, the profundity of tissue injury was more profound contrasted than those delivered with a snare, paying little heed to the width of the snare loop. Pinnacle power at a setting of 30 W was 1154 W for coagulation, 90.2 W for pure cut, and 227.8 W for blend current. When a high-frequency electrosurgical current gadget is utilized, a cutting current in the blend mode is suggested rather than a coagulation current since this waveform is appropriate for cutting and gives successful hemostasis. A capable strategy is needed for the protected utilization of hot biopsy forceps because this gadget has a huge potential for more profound tissue injury (Akiko Chino 2004). Monopolar Hot Biopsy Forceps (HBF) had higher paces of intense serosal brightening and histologic transmural harm than bipolar HBF or cold biopsy. Based on these outcomes, monopolar HBF should avoid coagulation of little or level right colon injuries like small polyps (Thomas J. Savides 1995). Colonoscopy polypectomy is a persistently advancing treatment that has been amazing at lessening the danger of colorectal cancer. Gastroenterologists should be smart and capable in methods, for example, snaring, infusion, inking, and any remaining devices identified with polypectomy for endoscopic achievement. Cold forceps appear to be preferred for little polyps and snares than bigger ones. Coagulation current might be the electrocautery decision method for polypectomy, even though it is related to a higher risk of deferred hemorrhage. It can be difficult to arrive at polyps and will required different endoscopic stunts and a capacity to have a successful resection. There are a few choices for the counteraction of bleeding in huge polyps, including infusion, end loops, and end clips. Numerous difficulties can be overseen endoscopically. In the exploration stage, there is yet a lack of learning about numerous parts of polypectomy, and there is a huge requirement for greater quality investigations (Christopher J Fyock 2010).

The electrosurgery therapeutic is the creation of hotness at the cell level, which is delivered when a high-frequency current, created by an electrosurgery generator unit (ESU), goes through tissue as the current moves along a circuit. Tissue opposing this progression of current leads to the creation of hotness (DE Barlow 1982) (LE Curtiss 1973). The current flow should change between positive and negative at a frequency of more than 100,000 times each second (100,000 Hz) to stay away from the neuromuscular reactions and shocks that happen with a 60 Hz current wall socket. If the current is sufficiently high, cell water will heat quickly, bringing about bubbling of cell films. At the point when these blasting cells are adjusted along a wire, the outcome is portrayed as electrosurgical cutting. For regions farther from the wire, or when the applied energy is less extreme, the current is lower. Therefore, cells heat gradually, and coagulation results in cells shrinking without exploding and separating the tissue.

By controlling the variable effects of the tissues, the proportion of cells cut to those coagulated can be controlled, but cold snare polypectomy has no coagulation. Electrocautery uses a direct current to heat electrode, which can be applied to a tissue to produce coagulation with no cutting, but electrosurgery gives both cutting and coagulation simultaneously. Electrosurgery arises, hence, as the best innovation for delivering helpful coagulation, resection, and tissue removal in the body (LE Curtiss 1973).

2.2 Previous Work done

The bleeding during colonoscopy is related to tissue testing, and it is the most well-known difficulty of colonoscopy with polypectomy (Rex DK 1992). The huge bleeding associated with colonoscopy and polypectomy in clinical operation is overwhelming. A touch of overflow from a resection site is of no result except for when it darkens the field to such an extent that fulfillment of resection is compromised. Clinically bleeding is intense bleeding that requires attention and deferred bleeding that prompts re-assessment of the patient. Generally, post-polypectomy bleeding has been identified between 0.85% to 2.7% of all polypectomy procedures, the larger part being postponed while the minor undergoes transfusions (Carpenter S 2007). Postpolypectomy bleeding might be serious and dangerous with stroke, resultant shock, myocardial necrosis, and ischemic injury to different organs, which need to be given full attention.

Bleeding after forceps biopsy is extremely common and reasonable and shows an unnoticed coagulation problem. Additionally, clinically bleeding doesn't happen after cold forceps and snare resection of small (2-7 mm) polyps (Tappero G 1992). It is the hot forceps biopsy that is related to an expanded danger of postponed bleeding inferable from thermal-induced ulceration. Generally, there is no benefit of hot over cold forceps biopsy; just that hot isn't suggested (Barkun A 2006).

Postpolypectomy bleeding is considered intense or postponed and happens in roughly 1.5% and 2%, individually, of polypectomies (Sorbi D 2000). Instant bleeding is believed to be identified with deficient use of electrosurgical coagulation during snare resection, given untimely mechanical snare crosscut of the cutting versus coagulation parts of the electrosurgical current. Prompt bleeding is even more frequent in pure and blended cutting, but delayed bleeding is often experienced in coagulation current. A review investigation of pure against blend coagulation current for colonoscopic polypectomy has no critical contrasts in the general difficulty rates, albeit a huge distinction was found in the bleeding time; most hemorrhages happened promptly in 12 hours when the blended current was utilized, and all were postponed (2-8 days) when pure coagulation current was used (Van Gossum 1992). Postpolypectomy bleeding is more normal (up to 20%) after evacuation of bigger lesions have been removed (Ahmad N 2002).

2.3 Parameters

The governing principles for electrosurgery are current, voltage, circuit, and impedance, which are the fundamental electrical concepts used. When negative charges move from one atom within a circuit to another with less impedance at neutral ground, an electric current is formed. The product of current (I) and Voltage (V) is the Power (P), while the impedance, which is Ohms, is the proportion of resistance to the flow of current. In living tissue, voltage increment should be higher than 200 Vpp before current can be sufficient to make electrosurgical cutting. Some ESUs have power yields that hold voltage continually beneath the 200 Vpp limit, thereby facilitating coagulation with no cutting irrespective of the power setting. In monopolar circuits, these yields are regularly named Soft Coag, which is normal for bipolar applications.

Voltages over 200 Vpp produce current densities that can deliver electrosurgical cutting utilization to supersede impedance and drive tissue coagulation (Blackwood WD 1971).

The fundamental terminologies used in the electrosurgical device are the current, voltage, and resistance, which possess basic principles and units. The current is the progression of electrons during a timeframe and is estimated in amperes which move through a pathway called the circuit. The resistance act as an obstacle to the flow of current for both direct and alternating and is estimated in ohms. This is like the impedance acting against current flow. Based on the resistance acting as an obstacle to current flow, a force is needed to push the current, and voltage acts in this capacity. Voltage fills in as the main impetus that pushes current flow forward. Higher voltages increment the profundity of the injury, which can work with the ideal endoscopic impact, yet can likewise damage the tissue zones. The relationship between terminologies is described by Ohm's law which states that voltage is directly proportional to the current ($V=IR$).

Likewise, the power addresses how much energy moved in a period, while the temperature change is inspired when current flows. The power is given by ($P=VI$), while the temperature is governed by Joule's law given by ($Q=I^2RT$). Based on the laws, V is the voltage, I is current, R is the resistance, P is the power, Q is the generated heat by current flow, and T is the time frame (Tucker 2000).

Based on an improved Electrosurgical Unit device with predefined voltages levels and tissue impedance levels controlled by the processors, ending the output power by the Electrosurgical Unit is easier, possibly diminishing the accidental tissue injury.

Neuromuscular and myocardial reactions are prominent when the frequency is low and can cause much damage or even death. This is why alternating current in the homes, which is 60Hz, is not suitable for Electrosurgical Units. The Electrosurgical Unit operates at a higher frequency between 300Hz to 1MHz (Tucker 2000).

2.4 Cut and Coagulation

The Electrosurgical Unit possesses two fundamental currents, coagulation and cut flows, which are contrasted principally in the rate and extent to which they instigate a temperature increment on the tissue. Ultimately, the coagulation flow gives slower expansion temperature in the cells with temperature ranges from 70 and 100C and make them to dried out and shrivel without exploding. The outcome is tissue parching when the electrode is in direct contact with the tissue or tissue fulguration on the off chance that the cathode isn't in direct contact with the tissue. While for the cut flows, it causes faster hotness expansions on the tissue, which is over 100C, making the cell water bubble and burst, prompting tissue cleavage.

The duty cycle implies to the time covered for an electrical flow to be conveyed. This is reliant upon the pause's frequency and duration that is customized into the cycle. Flows that are conveyed consistently for the whole actuation time frame without any pause are described as having a 100% duty cycle. A pure cut is a 100% duty cycle current with a higher voltage of more than 200 V, and the cutting impact has the absence of tissue cooling time. When there are interferences or pauses, the target tissue has a greater chance to cool, advancing more levels of tissue coagulation as opposed to cut. A duty cycle of a current flow at 6%, meaning power conveyed is frequently described as pure coag current. The blended current flow suggests a waveform with duty cycles in the range of 12% and 80% showing that there is a mix of the extent of cells that have exploded described as cut and those that have been desiccated described as coag.

2.5 Variables of Tissue Effect

The current density is impacted by various variables. The tissue impedance is one variable that can't be controlled which generally relies upon the water content of a specific tissue type. High water content tissues like blood have less resistance to current from the bone. Current density is lower when spread over a volume of tissue, and the subsequent impact will be more slow heating. Energy spread at the flat forceps jaw advances coagulation by diminishing the current density rather than promoting cutting when it is concentrated along with the snare.

The variable that can be controlled is the power output in which the power settings increase with current density. Numerous advanced ESUs have some type of chip that contrasts the power output and a proportion of the impedance of the tissue with the electrode. Impedance increases as the tissue become coagulated, which influences a decrease in current flow. These ESUs have a choice that endeavors to hold power steady as intently as conceivable to the chosen watts over a scope of impedances. The output power is particularly valuable during polypectomy and assists with lessening snare entrap by giving enough power during the whole resection.

The endocut is intended to change current due to changes in impedances and pulse to yield advanced control of the cut. The instant response highlight in cut mode is intended to convey power rapidly when the impedance is low toward the beginning of the cut and keeps the power constant, despite changes in impedance.

Each ESU is intended to offer the user a few distinctive waveform modes with marks, like 'Pure Cut,' 'Blend1 Cut', 'Blend2 Cut', 'Soft Coag,' 'Auto Stop Coag,' and 'Forced Coag.'

A huge variable that is controlled totally by the user is time by the foot pedal. Power increased by time leads to heat energy conveyed (energy (joules) = power (watts) × time (seconds)). In any case, the clinical aftereffect of conveying 50 W of force for 2 s is different from that of conveying 20 W for 5s, even though the total heat energy conveyed (100 J) is similar (DJ 2000). Additionally, it is vital to note that if the time and power settings are similar, either for cut or coag waveform will convey similar energy yet with a different result. When the ideal waveform and power setting have been chosen, the time the foot pedal is pressed will generally decide the eventual outcome.

2.6 Current density and power density

ESUs are influenced by many variables that affect the electric circuit and the ideal tissue effect. The most significant of these is the current density, which decides the intensity of the impact accomplished during electrosurgery. Current density is characterized by how much current moves through a cross-sectional area of tissue. Current density can be expanded by either expanding the intensity of the current conveyed into a similar cross-part of tissue or by diminishing the cross-sectional area of tissue to which a current is being conveyed. The heat created in the tissue is relative to the power disseminated by the tissue. Applying current to a little region of a polyp causes excessively high hotness against a similar current applied to a bigger region of a similar polyp. Likewise, to produce how much hotness is expected to cut across a polyp with a bigger diameter, more current power is required (Morris 2009).

2.7 Tissue effect

The tissue effect is affected by various constraints, which include voltage, power, current density, resistance, impedance, and waveform properties. The power output is the most important variable used by the ESU over the years. The endoscopist would choose an ideal power setting, and the ESU would convey that power yield, no matter what the tissue properties are. The tissue resistance is initially low, allowing current to flow freely during electrosurgery. Nonetheless, moderate tissue desiccation builds the impedance to current. The generator endeavors to keep the output power steady as tissue changes happen, leading to huge voltage instability. Lately, ESU improvement has led to the better observation of the changes in voltage that happen during the conveyance of electrosurgical energy. With this advancement, ESUs are fit to maintain voltage consistent while the power changes to provide better output because of the circuit resistance. This assists in managing the electrosurgical process during tissue effects.

The tissue effect is also impacted by the electrosurgical waveform properties. ESUs need to supply higher power output to start a cut but are not necessarily required to keep up with the incision. Some output modes have been developed to control tissue cutting during different applications. Some of the instances include:

The ConMed Beamer ESU (ConMed Corp, Utica, NY) offers an Endo-Mode, promoted as a powerful interaction controlled cutting mode with flow pulses that give controlled cutting with flexible levels of coagulation. The applications possess different settings, including PapillaCut, PolypCut, and so on.

Endocut (ERBE USA, Marietta, Ga) is a mode that quickly adjusts the current because of changes in the tissue impedance and fractionates the electrosurgical

result to work with the controlled cutting of tissue. Endocut depends on an arranged interaction, including an underlying cut stage followed by periods of cutting, currently mixed with periods of coagulation current.

While Genii's gi4000 (Genii Inc, St. Paul, Minn) provides two controlled cutting modes with two levels of coagulation, the two modes utilize tissue detection to convey the output power over a scope of impedances.

Some Covidien ESUs join Valleylab Instant Response (Boulder, Colo), which endeavors to work with controlled cutting by conveying an output power rapidly when tissue impedance is low, then, at that point, keeping up with steady output power despite changes in impedance that happen all through the cut (Morris 2009).

2.8 Monopolar or Bipolar Circuit

In endoscopy, both monopolar and bipolar circuits are used to make the circuit complete. During monopolar assembly, the circuit uses a grounding pad through a remote return electrode to be completed. Energy from the electrode moves at least resistance through the patient's body to be gathered at the grounding pad and returned to the generator to finish the circuit. As the whole circuit adds to the complete impedance, contrasts in the impacts of the power settings might be observable in patients based on changes in size and body. It must be ensured that the circuit is small by making sure the grounding pad is close to the treatment location.

A grounding pad is not required with bipolar because it possesses both the active and return electrodes at the probe tip (Tucker RD 1992) (Singh N 2004).

2.9 Snare polypectomy

Based on an overview of 189 US endoscopists, the current utilized for polypectomy changed and entailed 'Pure Coagulation 'for 46 %, 'Blend' in 46 %, and 'Pure Cut' in 3 %. Four percent of responders differed from the current during polypectomy (Singh N 2004). In a similar report, cold or hot biopsy forceps were mostly utilized for polyps 1 – 3 mm in size, while electrosurgical snare resection was used for polyps 7 – 9 mm in size ($P < 0.0001$).

In many examples, depictions of the electrosurgical waveform utilized during polypectomy are accounted for in a subjective for 'Blend' as opposed to quantitative, which is a duty cycle of 6 %. In many investigations, a 'Pure Coagulation' or 'Blend' current is chosen for catch polypectomy (Van Gossum 1992).

'Pure Coagulation' current has been utilized effectively for the resection of enormous polyps which are greater than 2 cm at variable power settings between 2 – 50 W and without snare entrapment (Binmoeller KF 1996). In a preliminary study relating 'Blend' current (n = 758) to that of 'Continuous Coagulation' current (n = 727), the difficulty rate for snare polypectomy was comparable. In any case, a huge distinction in the circumstance of post polypectomy bleeding was noted. Every single bleeding (n = 8) happened when blend current was utilized, though completely delayed post polypectomy bleeds (n = 6) happened with the utilization of coagulation current (Van Gossum 1992). In a review study including 4735 polyps resected with 'Pure Cut' current at 40 W, the pace of post polypectomy bleeding was generally low at 1.1 %, albeit prophylactic measures; for example, clipping was embraced in 12 % of the polypectomies to diminish the danger of bleeding (Parra-Blanco 2000). In one more review study, polypectomy utilizing Endocut brought about better histologic nature of resected samples than polypectomy utilizing a 'Blend' current at 30 W (Fry LC 2006). Yet, imminent investigations on the clinical results of polypectomy utilizing Endocut are justified. Generally, 'Pure Cutting' current might prompt quick bleeding, while abuse of deep coagulation might lead to slow bleeding (Chino A 2004).

2.10 Hot biopsy

The vital sign for monopolar hot biopsy forceps is the concurrent coagulation and biopsy of modest polyps (< 5 mm) (Gilbert DA 1992). Most clinical involvement in hot biopsy forceps identifies with a 'Coagulation' waveform, then produces suggestions to utilize a 'Cutting' waveform, and later to use a 'Soft Coag' waveform, the two of which have lower voltage and less severe bleeding. The restricted utilization of hot biopsy forceps in endoscopic practice might identify with discoveries from the creature and clinical examinations that showed a higher pace of transmural harm, hole, and bleeding, especially in the right colon (Chino 2004). Others have viewed the strategy as safe for the evacuation of tiny polyps, as exemplified by the shortfall of confusion following hot biopsy forceps of 907 polyps (mean size 3.7 mm) in one review (Mann NS 1999).

During a hot biopsy technique, the waveform mode, power setting, time of utilization, volume of tissue, level of 'rising' of the submucosal layer, the thickness of the fundamental tissue, and the point of forceps application are, for the most part, factors that impact the general result (Gilbert DA 1992). Key electrosurgical standards to consider are that hot biopsy forceps present a more extensive electrode region to tissue than a snare wire and, in this manner, spread the current over a more extensive area. Waveforms with higher voltages drive energy more profound into tissue than lower voltage flows.

2.11 Sphincterotomy

Sphincterotomy initiation is influenced by wire contact length, choice of the waveform, power setting, and force on the sphincterotome (Ratani RS 1999). Generally, it is accepted that ‘Pure Cut’ waveforms are likely to result in bleeding, while ‘Coag’ results in pancreatitis risk from thermal tissue injury, local edema, and limited pancreatic outflow. Most endoscopists choose waveforms that bring more cutting and less coagulation than those chosen for polypectomy (ML 2006). Waveforms with a low voltage of 100 % duty cycle ‘Pure Cut’ types or modulated waveforms with a duty cycle of 40 % or higher are used. Cutting increases with power (Ratani RS 1999), which is between 30 to 50 W compared to power settings used for polypectomy. Importantly, chip-controlled outputs like Endocut and other generators with ‘pulse’ modes are utilized to reduce uncontrolled cutting, which can give a zipper effect and resultant perforation (Akiho H 2006).

CHAPTER 3

METHODOLOGY

3.1 Experimental Overview

The Olympus PSD-30 Electrosurgical Unit has 295 mm (W) × 160 mm (H) × 420 mm (L) in dimension, a weight of 7.8 kg, fundamental frequency of 350kHz, open circuit output voltage of 900v, outputting power range of 2W to 50W, voltage fluctuation within ±10%, fuse rating 3.15A, 250 V, fuse size 5.0 × 20 mm. Some components for its operation include a power cord, foot switch, P cord, S cord, Spare fuse, and P plate. The nomenclature of the Electrosurgical Unit has different sections, which include the Warning section (Refer to instructions, Patient Plate, S-cord, High-frequency output, and Output timer), Coagulation section (Soft, Auto stop, and Forced), Cut section (Pure, Blend1, and Blend2), Power switch (Power ON/OFF), Front panel (Type CF applied part, Stand-By, and Program), Connector section (Active, S-cord, Patient plate, Refer to instructions, Connection for neutral electrode), and Rear panel (Potential equalization terminal, Footswitch, Fuse and Alternating current) as shown in Figure 3.1, 3.2, 3.3, 3.4 and 3.5.

The Electrosurgical Unit PSD-30 has cut and coagulation modes with a power rating ranging from 2W to 50W in a range of 5W. The Electrosurgical Unit has connecting components for its operation: Foot Switch, Power Cord, P-cord, S-cord, Fuse, and P-plate. The warning section of the unit entails a Patient plate, S-cord, High-frequency output, and Output timer. The coagulation section entails Soft, Auto stop, and forced, and the cut section has Pure, Blend1, and Blend2.

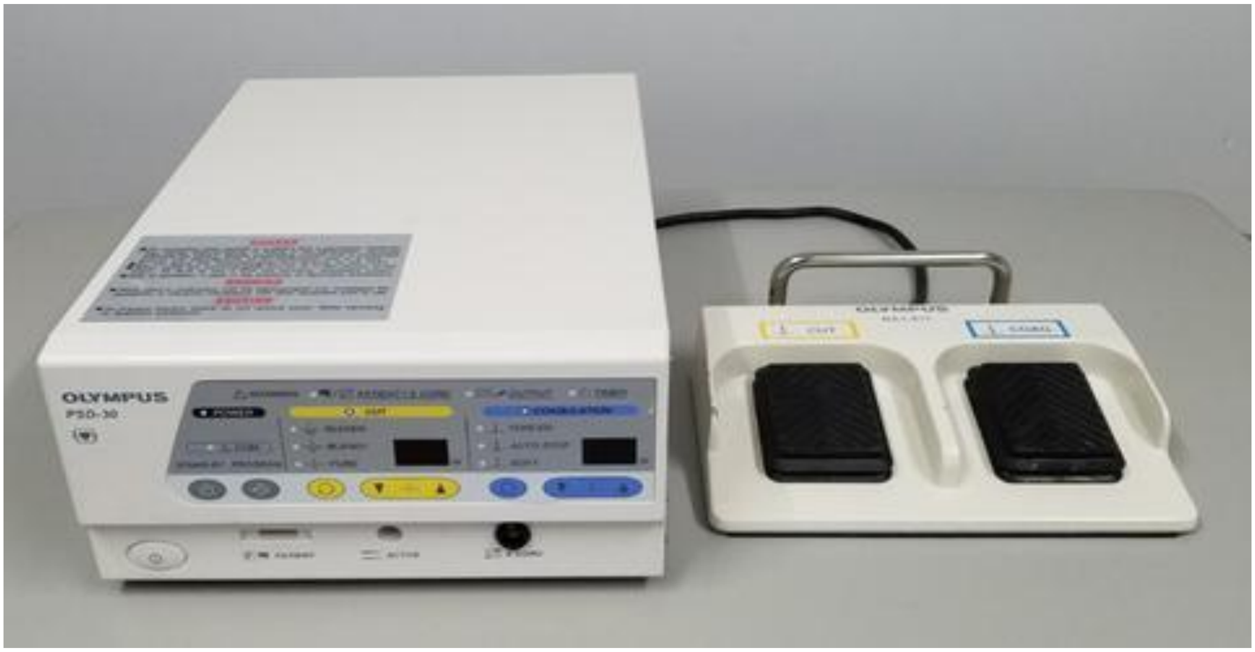

Figure 3. 1: Pictorial view of the Electrosurgical Unit (Primis Medical, 2021)

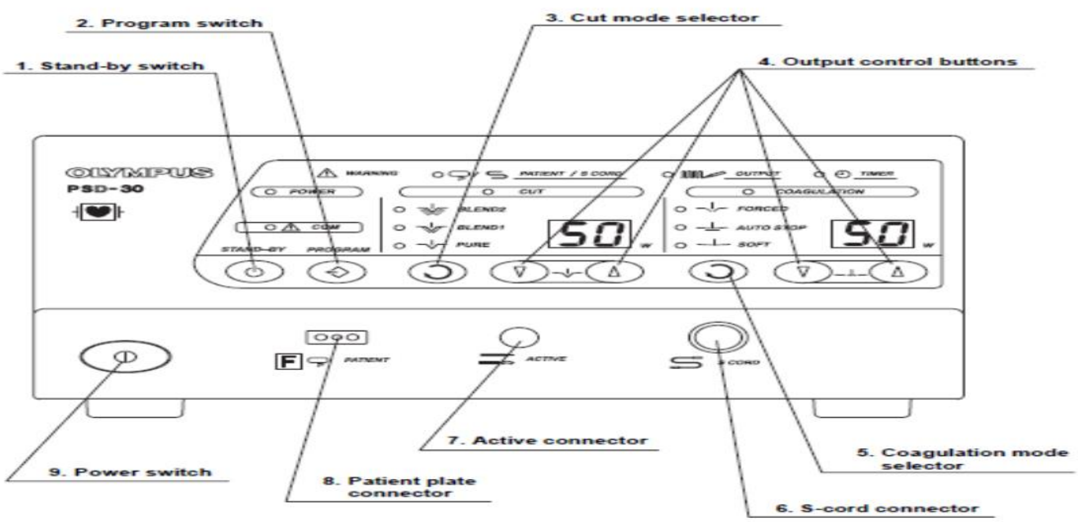

Figure 3. 2: Front Panel labeling 1 of the Electrosurgical Unit (Olympus Electrosurgical Unit PSD-30 Instructions)

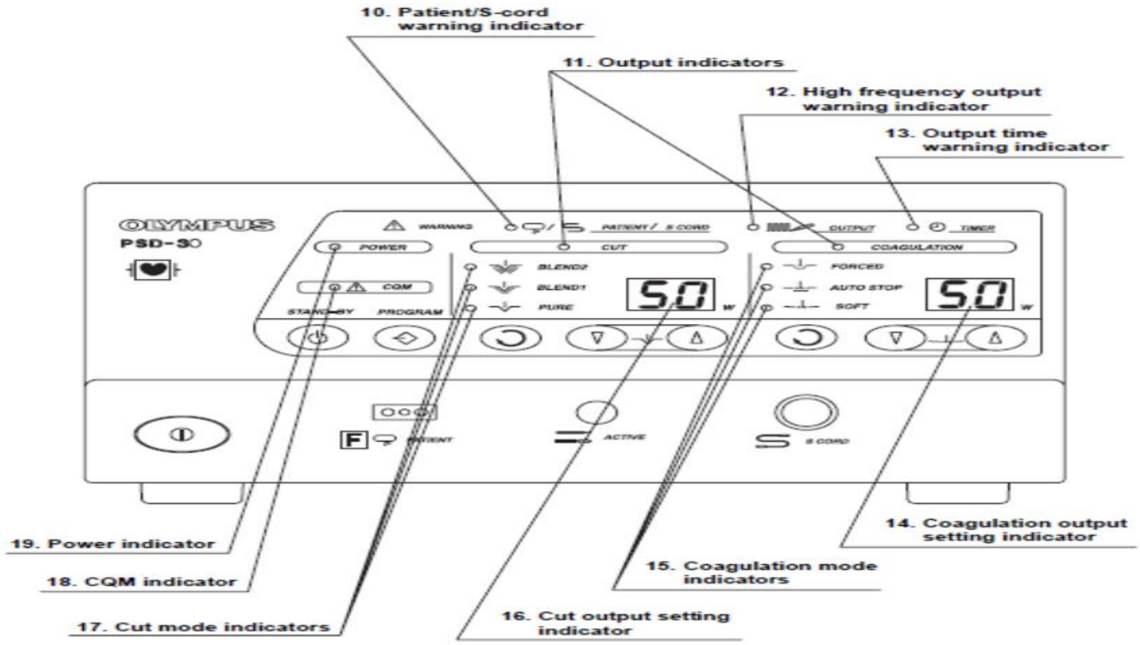

Figure 3. 3: Front Panel labeling 2 of the Electrosurgical Unit (Olympus Electrosurgical Unit PSD-30 Instructions)

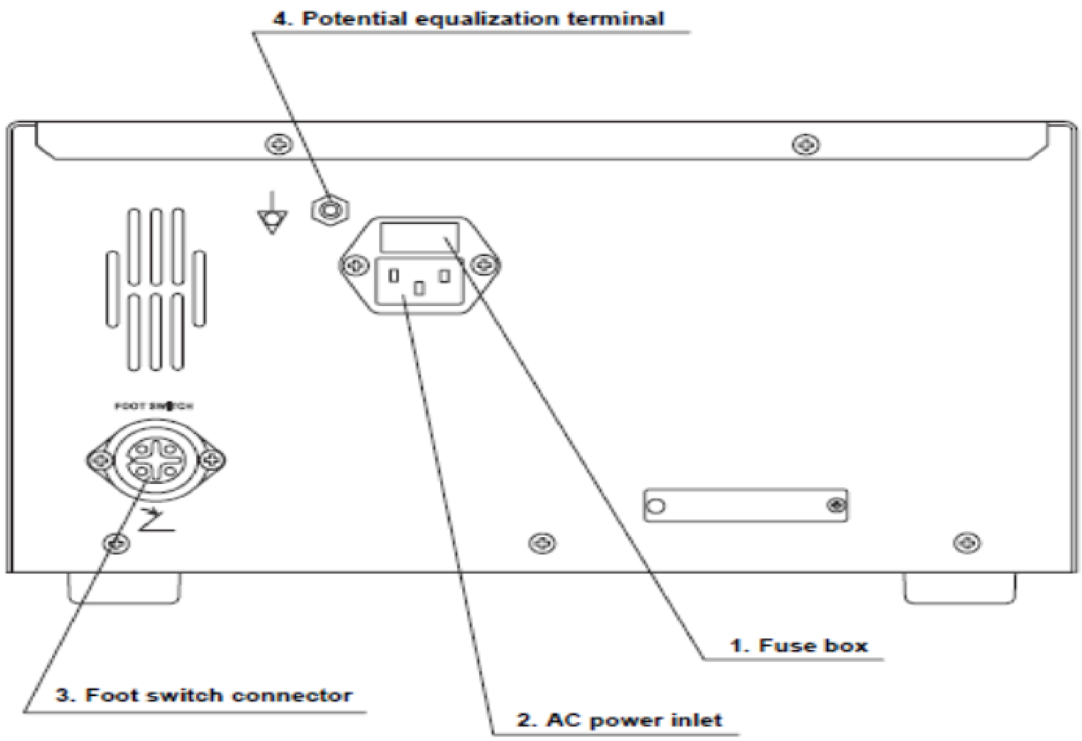

Figure 3. 4: Rear Panel labeling 3 of the Electrosurgical Unit (Olympus Electrosurgical Unit PSD-30 Instructions)

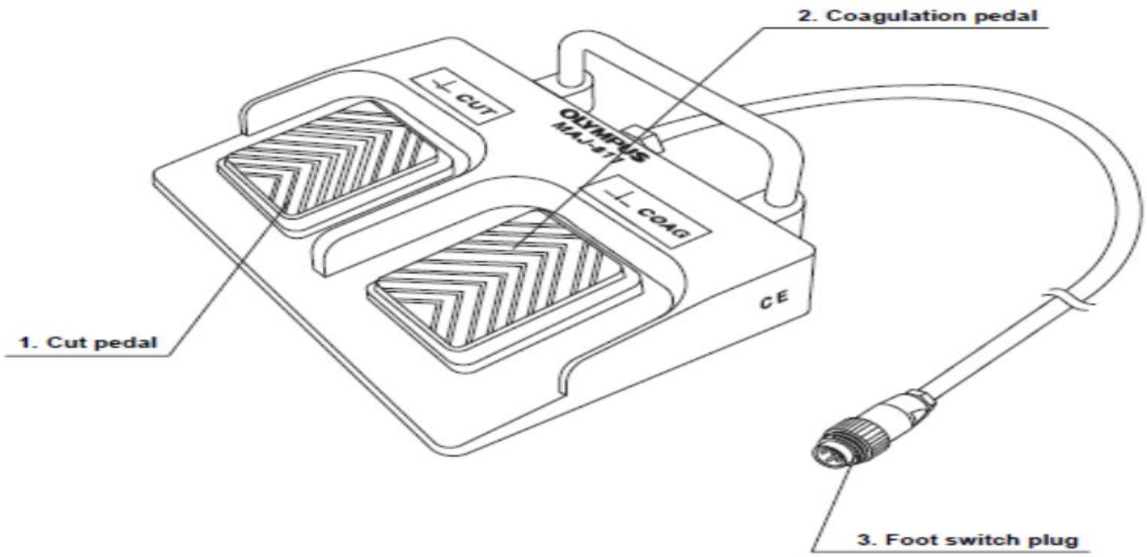

Figure 3. 5: Foot Switch labeling (Olympus Electrosurgical Unit PSD-30 Instructions)

The electrical circuit has a frequency of (50/60 Hz) which is converted to the high frequency of the Electrosurgical Unit of 350kHz with the ability to change the power settings from 2W-50W in 5W increments with power voltage at 220, 230, and 240 V.

The voltage amplitude and phase difference were measured using the Keysight DSOX1202G Digital Storage Oscilloscope with a frequency of 100MHz. The oscilloscope has three probes channel 1, channel 2, and the external trigger. The oscilloscope sample rate is at 2GSa/s at a point of 2M. The built-in oscilloscope generator is at 20MHz.

The Arduino UNO microcontroller was used to manage the footswitch timing for different time series (1s, 2s, and 3s). This microcontroller possesses 14 digital input/output pins with six analog input pins. There is a maximum DC of 20mA per pin, and it runs with a clock speed of 16Mhz (Arduino 2019).

3.2 Modified Electrosurgical Unit

The modification was done for the Electrosurgical Unit with an RRC circuit of 1.2k resistor, 600 resistors, and 1n farad circuit to mimic the human body (Kyle 2004). The 600 resistors are connected in series with the capacitor, then in parallel with the 1.2k resistor. One end of the circuit is connected to a common ground with the PSD-30 ESU, while the other end is connected to the patient plate acting as the body. This can be seen in Figures 3.6 and 3.7.

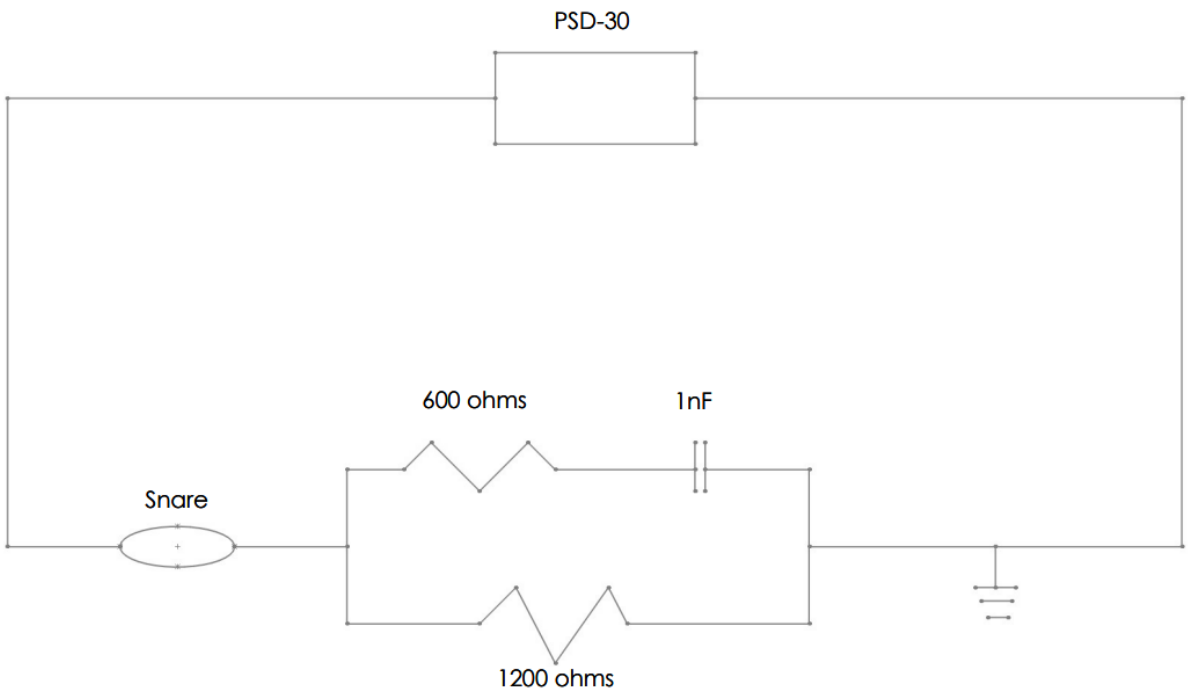

Figure 3. 6: Schematic Diagram of the Built Circuit

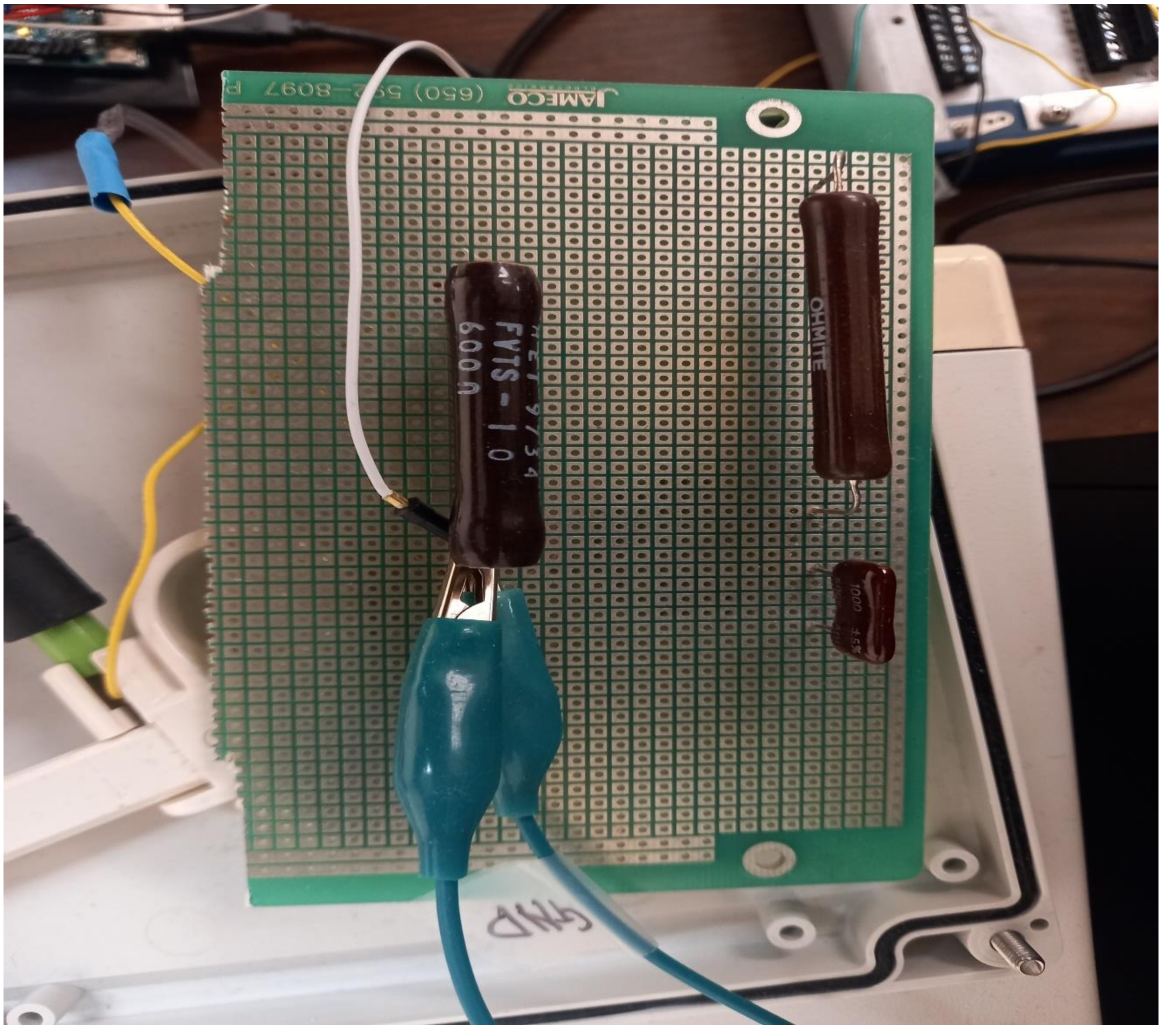

Figure 3. 7: Built Circuit connected to the snare

This setup allows the reading of the power and voltage when the footswitch is pressed down to initiate the firing and a place to stop the ESU from firing by interrupting the signal sent to it. The footswitch setup works with two normally switches momentarily. One of the switches is used to control the cutting mode, while the other is used to manage the coagulation mode. The modification was performed with these two switches whereby the wires connecting from the switches were cut, and then in between, the microcontroller was used, which provides two inputs and output for the microcontroller. When a pedal is pressed, a 5V signal is passed, while when the pedal is depressed, the signal reads 0V. This makes the microcontroller control the time for the pedal pressed, which are in 1 second, 2 seconds, and 3 seconds. Based on this, the microcontroller is the intermediary between the ESU and the footswitch.

3.3 Modified Footswitch with Arduino

The footswitch was modified with the Arduino to manage the timing when pressed, as seen in Figure 3.8. The Arduino provides a better timing sequence for the footswitch. The footswitch has the cut+, coag+, cut-, coag-, +5v, and GRND. The +5v is connected to the Vin on the Arduino, while the cut- or coag- is connected to the breadboard based on the mode power to be measured.

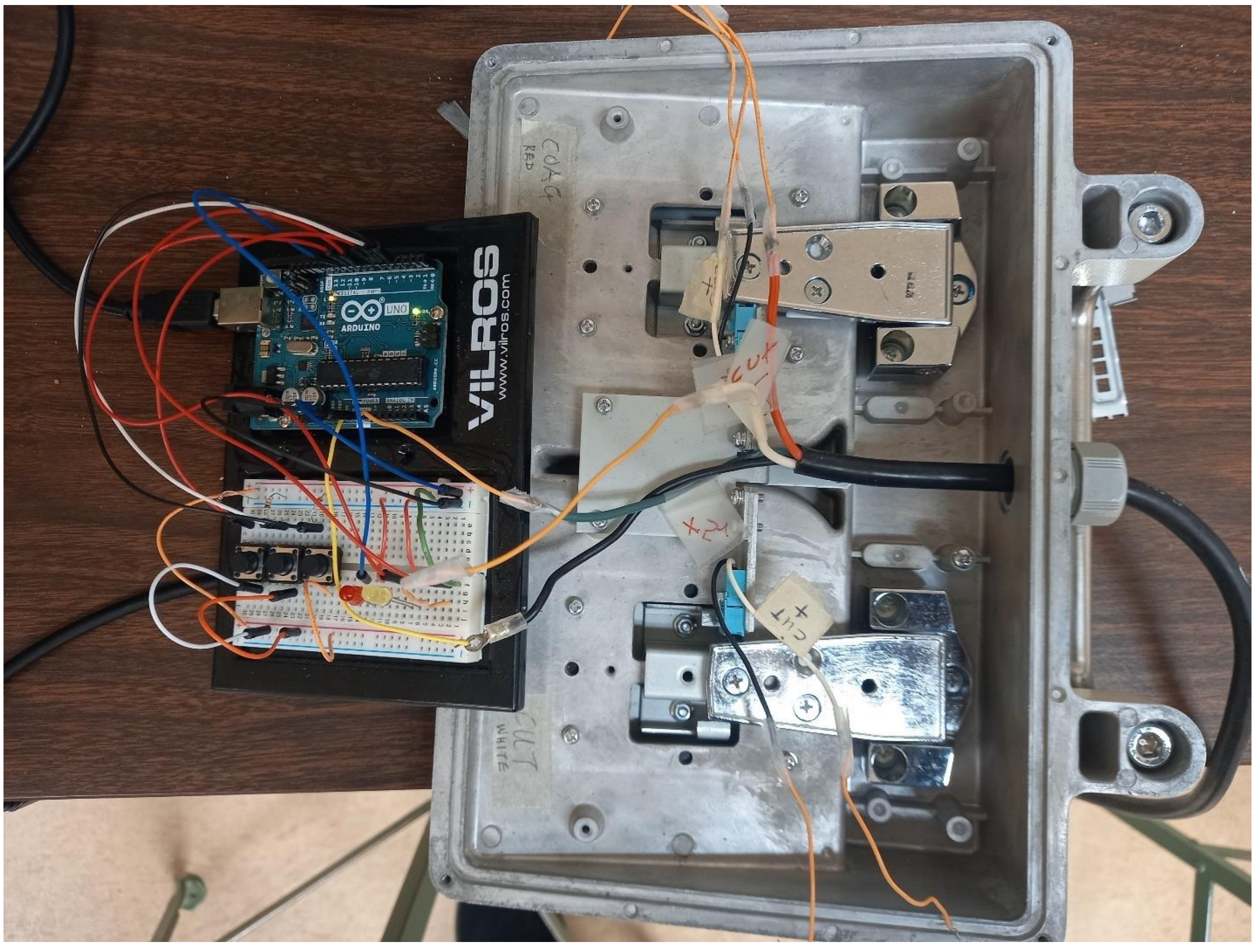

Figure 3. 8: Modified Footswitch of the Electrosurgical Unit

3.4 Oscilloscope

The oscilloscope used is the Keysight DSOX1202G Digital Storage Oscilloscope has 100 MHz, 2 GSa/s sample rate, 2M points, Built-in 20 MHz function generator (standard). It is used to make professional measurements, including Bode plots (FRA), mask testing, math, FFT, and serial protocol analysis, all standards as shown in Figure 3.9.

The oscilloscope was used in conjunction with the ADC to create the DAQ signal of the LabView stimulator to test the signal from the function generator experimentally. The output signal from the function generator was displayed on the oscilloscope as a waveform. The output signal waveform varied with time series and was displayed graphically on the oscilloscope screen. This is used to analyze the signal distribution based on the frequencies and the peak-to-peak voltage. The probes are polarized cable connectors that transfer electrical signals between the devices. They are used to connect a stimulator and the circuit under test. The probe act in the signal modification and reduction in the noise effect.

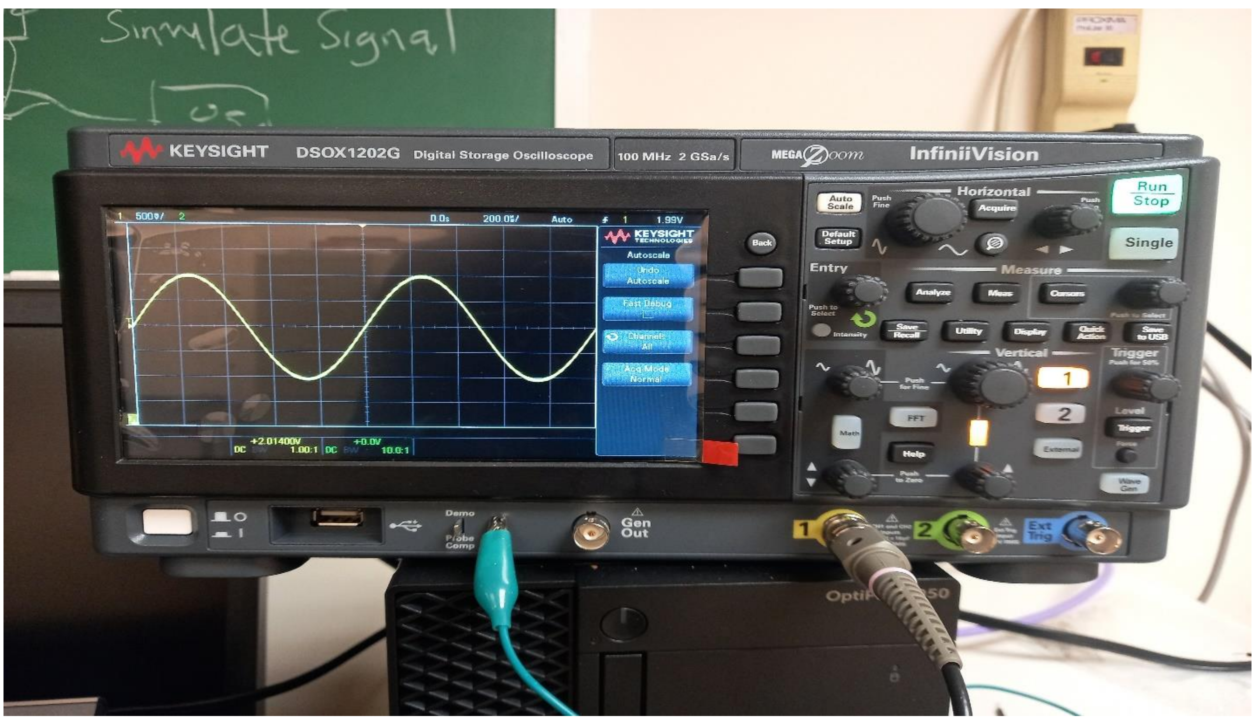

Figure 3. 9: Oscilloscope view

3.5 Function Generator

An Agilent function generator 33220A, as seen in Figure 3.10, is a piece of electronic test instrument used to generate and deliver standard waveforms, typically sine and square waves, to a device under test. It can be used to test a design or confirm that a piece of electronic equipment is working as intended.

It is fully compliant with LXI Class C specifications and possesses 20 MHz Sine and Square waveforms for pulse, ramp, triangle, noise, and DC waveforms. It has 14-bit, 50 MSa/s, 64 k-point arbitrary waveforms with AM, FM, PM, FSK, and PWM modulation types of linear & logarithmic sweeps and burst operation from 10 mVpp to 10 Vpp amplitude range coupled with graph mode for visual verification of signal settings.

Figure 3. 10: Function Generator view

3.6 Measuring System

The measuring part entails both the voltage measurement from the oscilloscope and the DC power measurement. Firstly, the oscilloscope is used for the voltage measurement that will be read for both the cut and coagulation to understudy the pattern and control the amount used by ESU. Understanding the voltage pattern will assist in analyzing the time series for 1 second, 2 seconds, and 3 seconds.

The second part is the DC power measurement to understand the power consumption for each process involved in the cut and coagulation. Since the ESU has a power range from 2W to 50W, each power rating will be analyzed to understand the DC power supply to the ESU.

This second part of the feedback system will utilize the voltage measurement of the device under test (DUT), in which the model is the alternating current passing through. The measuring system will consist of multiple parts with different roles: firstly, the function generator will be used to send signals with frequencies in the oscilloscope range of 1kHz to 500kHz. The voltage peak-to-peak measurement will be set to 1Vpp while the offset current will be at 1Vdc for the DC-DC converter that supplies the oscilloscope and the ADC converter.

The basic idea is to measure the pure cut for the electrosurgical process but with the limitation, which is its high voltage. The voltage will be controlled by analyzing the voltage through the DC-DC converter to reduce the effect of the pure cut mode.

3.7 PSD – 30 System Identification

The experiment performed was used to include an autostop based on time settings in the Electrosurgical Unit. The process involves a preliminary stage of identifying the PSD-30 device and how its operation works, then an autostop setup to set the timing of the firing of the Electrosurgical Unit. Lastly, the firing management using the LabView based on the timing series.

Firstly, the RRC circuit designed to mimic a body was connected to the snare and earth of the Electrosurgical Unit. The footswitch is connected to the electrosurgical device, acting as the foot pedal for the firing sequence of the Electrosurgical Unit. While the oscilloscope was connected to the positive end of the RRC circuit using the probe to read the signal from the Electrosurgical Unit. The oscilloscope was set to continue while the foot pedal was pressed to release a 5v while pressed and return to 0v when released. This was performed with a stopwatch for 1, 2, and 3 seconds of pedal pressed with the cut and coagulation mode of the electrosurgical device. The measurement taken is the power output from the Electrosurgical Unit when fired and the unit's output voltage from the oscilloscope.

Then, to further improve the output voltage and power from the Electrosurgical Unit, an Arduino was developed to give an accurate timing for the firing of the Electrosurgical Unit through the foot switch. The foot switch was modified as seen in Figure 3.8, with the footswitch having the cut+, coag+, cut-, coag-, +5v, and GRND based on the cut and coagulation pedal of the foot switch. The +5v is connected to the Vin on the Arduino, while the cut- or coag- is connected to the breadboard based on the mode power to be measured. The measured output power and voltage are like the preliminary stage, and it was measured for both the cut and coagulation mode for a power range of 2W to 50W at an interval of 5W.

Lastly, based on the crest factor, the Electrosurgical Unit used is PSD-30 with a frequency of 350kHz. The frequency range from 1kHz to 500kHz was generated from the function generator for the sine and square signal to ensure the signals are similar for the oscilloscope and LabView. Generally, the oscilloscope result is the baseline, while the LabView signal is modified based on the frequency rate, read sample, terminal configuration, signal input range, and acquisition mode to ensure the signal obtained is the same as the oscilloscope signal. Table 3.1 below shows the LabView configuration for the different frequencies.

Function Generator Frequency (kHz)	LabView Rate (kHz)		Sample to Read		Terminal Configuration (v)		Signal Input range		Acquisition Mode
	Square	Sine	Square	Sine	Square	Sine	Max	Min	
1	7	15	20	80	Differential	Differential	1	-1	Continuous
10	5.5	10.5	20	90	Differential	Differential	1	-1	Continuous
30	3.4	10.3	10	50	Differential	Differential	1	-1	Continuous
50	3.3	7.1	30	100	Differential	Differential	1	-1	Continuous
80	3.35	6.13	50	100	Differential	Differential	1	-1	Continuous
100	3.33	5.9	100	100	Differential	Differential	1	-1	Continuous
200	2.9	2.9	100	100	Differential	Differential	1	-1	Continuous
300	2.7	2.75	50	40	Differential	Differential	1	-1	Continuous
350	2.65	2.65	50	40	Differential	Differential	1	-1	Continuous
400	2.9	2.9	40	40	Differential	Differential	1	-1	Continuous
500	2.05	2.1	50	50	Differential	Differential	1	-1	Continuous

Table 3.1: LabView Configuration for Different Frequencies

Based on the Crest Factor (CF), which is the ratio of the voltage peak (Vp) to the root mean square (RMS) (Vp/RMS=CF). The crest factor is used instead of the duty cycle to measure the signals because it gives a precise outcome for the voltage measured. For continuous motion, 100% of the duty cycle gives a 1.4 crest factor. Since the RMS constant for a sine wave is 0.7, and the CF constant for a sine wave is 1.4, if a crest greater than the CF constant is produced, it shows more hemostasis depth (Marcia L. Morris, 2009). The crest factor and duty cycle were provided in table 3.2 for different Electrosurgical Units.

Duty cycle	Crest factor	Conmed 5000	Conmed 7500	EndoStat	EndoStat III	Erbe ICC200	Erbe VIO300	Meditron 3000B/pentax	Valleylab SurgiStat II	Valleylab force EZ-C	Valleylab force 2	Valleylab force FX
100%	1.4	Pure cut Pulse cut	Pure cut Pulse cut	Cut	Cut and control cut	Soft Coag (190) Autocut and EndoCut	Soft Coag (190) Autocut, EndoCut I, Q	Cut			Cut	
	1.5									Pure cut (2000), dessicate low 2 (660) low 3 (1100)		Low cut (1350) Pure cut (2300)
92%			Blend 1									
84%			Blend 2									
76%			Blend 3									
70%	1.7	Blend 1			Blend							
68%			Blend 4									
60%			Blend 5									
52%			Blend 6									
50%				Blend				Blend 1			Blend 1	
50%	2.5											Blend
44%			Blend 7									
37%											Blend 2	
38%			Blend 8									
	2.1	Blend 2								Blend		
30%	2.7	Blend 3	Blend 9		Coag							
	2.9								Cut			
	3.0						Dry cut Effect 1–4					
	3.2						Dry cut Effect 5–6					
	3.3								Blend			
	3.8	Pinpoint Coag					Dry cut Effect 7–8					
25%								Blend 2			Blend 3	
12%			Pinpoint Coag	Coag				Blend 3				
8%	5.0									Desiccate low 1 (3500)		Desiccate
	5.0									Fulgurate high 1 (6200)		
	5.4						Swift Coag					

Table 3.2: Monopolar Output Mode for different Electrosurgical Units (ML, Morris. 2006)

CHAPTER 4

RESULTS

Majorly, the electrical circuit polarity switches between positive and negative at a frequency which is 60 times per second (60Hz). This can cause myocardial and neuromuscular responses making the frequency unsuitable for electrosurgery. The PSD-30 used for this experiment generates 350kHz frequency so that when in operation, it will eliminate these complications. The experiment was performed using the Electrosurgical Unit (ESU), which conducts the surgical process, an oscilloscope and ADC converter for measuring the voltage and signals, and a circuit with two resistors and a capacitor to mimic the human colon of the body. The ESU has power ranges from 2W to 50W for both the cut and coagulation mode.

4.1 Building the circuit

The circuit was built using the RRC with 600 ohms and 1200 ohms resistors with one nano farad. The 600 ohms were connected in series with the capacitance acting as the intracellular water, then with a parallel connection to the 1.2k ohms working as the extracellular water. The capacitor end was connected to the ground on the Electrosurgical Unit, while the 600 ohms end was connected to the snare of the Electrosurgical Unit. This gives a close loop circuit between the Electrosurgical Unit and the circuit, as shown in Figure 4.1. This circuit is used to mimic the human body's colon (Kyle 2004).

The signal was read using the oscilloscope with the probe connected to the RRC circuit. The footswitch is connected to the Electrosurgical Unit in which, for every second, the pedal is pressed, and there are corresponding changes in the power used by the Electrosurgical Unit with changes in the voltage from the oscilloscope. On pedal press, a 5v is released to the Electrosurgical Unit.

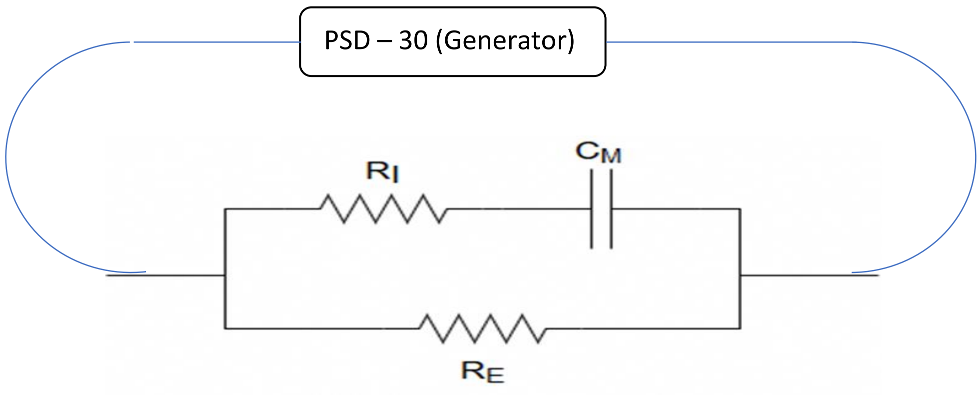

Figure 4. 1: Closed Circuit for the System

4.2 Firing with Foot Switch

The Electrosurgical Unit converts the standard electrical frequency between 50 and 60 Hz to 350kHz. The footswitch has a cut and coagulation pedal to initiate an active connector on the unit. The footswitch pressed activates the voltage increase while the unpressed return to zero, as shown in Figure 4.2.

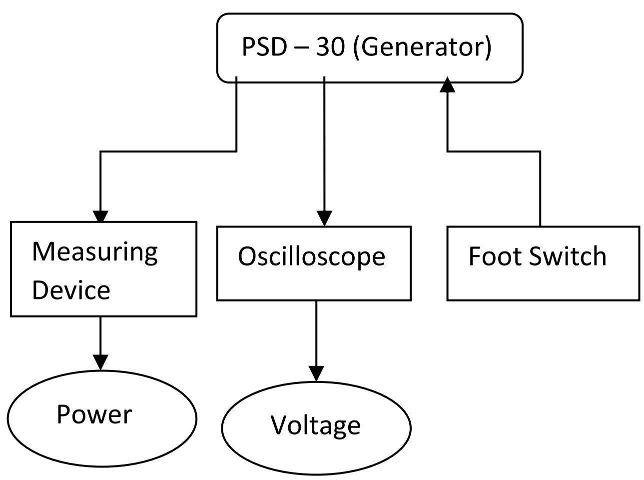

Figure 4. 2: Schematic Diagram for Electrosurgical Unit measurement

4.3 Measuring the Time Series with a Stopwatch

The experiment was performed with the stopwatch to manage the time series for 1, 2, and 3 seconds of firing the generator through the footswitch, as seen in Figure 4.3. The Electrosurgical Unit power has initial readings for both the power and voltage. The initial power was at 15.5W, and the voltage was at 5mV.

The footswitch is connected to the PSD-30 in which for every second the pedal was pressed using the stopwatch; there are corresponding changes in the power used by the Electrosurgical Unit with changes in the voltage measured by the oscilloscope. On pedal press, a 5v is released to the Electrosurgical Unit.

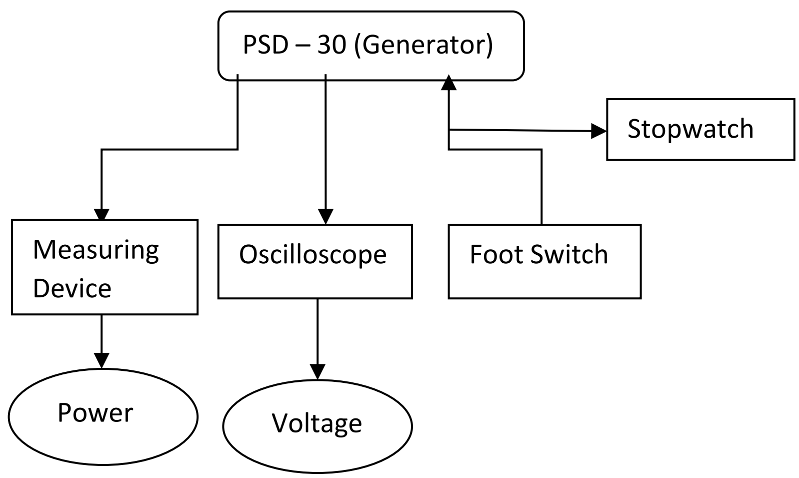

Figure 4. 3: Schematic Diagram for Electrosurgical Unit measurement with Stopwatch

4.4 Preliminary Results

4.4.1 Identification of PSD-30

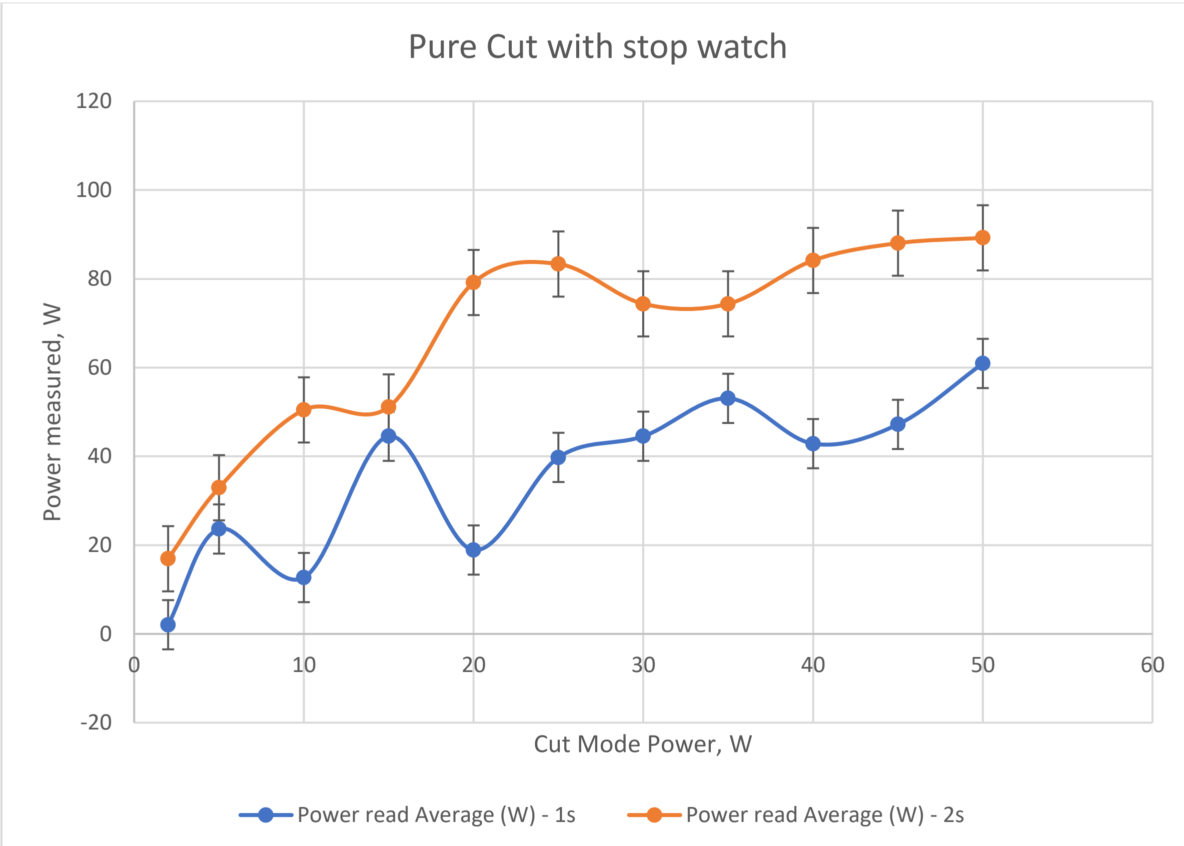

Figure 4. 4: Power read to Cut mode Power

The power range for the cut mode used to test the Electrosurgical Unit was from 2W to 50W. The overall upward trend can be seen in Figure 4.4. The minimum power was found at 2W cut mode power with a corresponding measurement of 2.066W at 1 second and 16.933W at 2 seconds pedal pressed. While the maximum capacity obtained was at 50W cut mode power with a power output of 60.933W at 1 second and 89.233W at 2 seconds footswitch.

But the voltage measured shows a drastic decline in the cut mode power of the Electrosurgical Unit. The lowest voltage was seen at the 35W cut mode power of the PSD-30 at 186.433mV at 1 second and 486.766mV at 2 seconds from the oscilloscope, as shown in Figure 4.5.

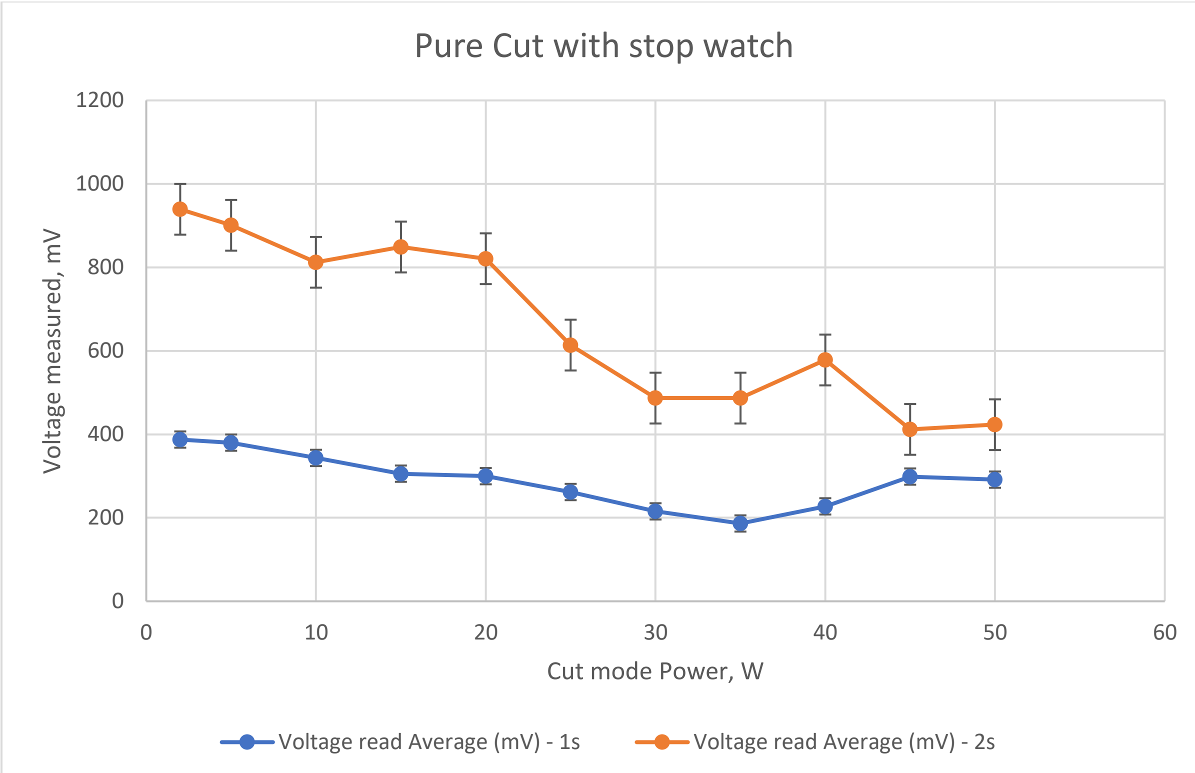

Figure 4. 5: Voltage read to Cut mode Power

Based on the typical ESU power settings recommendation, the hot biopsy forceps power settings range from 15W to 25W. From Figure 4.5, the power settings between 15W – 25W give a measured voltage of 305v to 261v, showing a decline for a second, while 848v to 613v in fall for two seconds. This indicates that the voltage spike is above 200v before an electrosurgical cutting can occur (Marcia L. Morris, 2009).

4.5 Autostop by Time Settings

An Arduino was developed to manage the time series for three different times (1 second, 2 seconds, and 3 seconds). The Arduino was connected to the footswitch with cut -, +5v, and GND from the footswitch connected to the 5v, Vin, and GND of the Arduino, respectively.

The Arduino was built with three different push buttons with LEDs for three other time series (1s, 2s, and 3s). This was conducted for all the power ratings (2W - 50W) for both the cut and coagulation modes of the Electrosurgical Unit.

4.5.1 Pure Cut

The result shows a consistent increment in the cut power rating from the Electrosurgical Unit to the power read from the measuring device, as shown in Figure 4.6. The lower the time for the footswitch pressed, the lower the power output of the ESU. Likewise, there is a constant increment of the power measured until 25W cut mode, when it experiences a slight decrease for all the time series (1 second, 2 seconds, and 3 seconds).

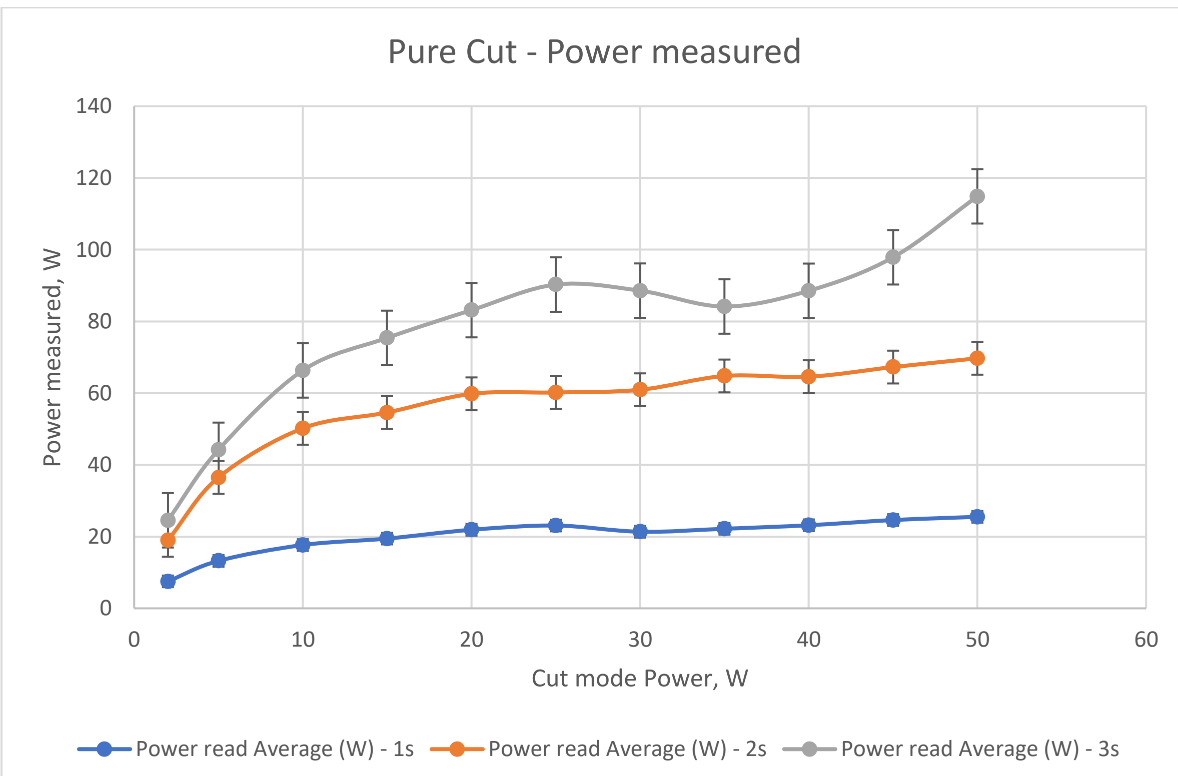

Figure 4. 6: Power read to Cut Power rating for Pure Cutting Mode

Figure 4.7 shows the downward fluctuation in the representation between voltage read and cut power for the pure cutting mode. The pedal timing for 1 second shows better consistency from the representation compared to the 2 and 3 seconds. But there is a lot of fluctuation in the voltage read, which increases as the timing of the footswitch increases. The maximum voltage was experienced at 20W cut power which is 248.43mV, 857.76mV, and 1142.1mV for 1, 2, and 3 seconds respectively.

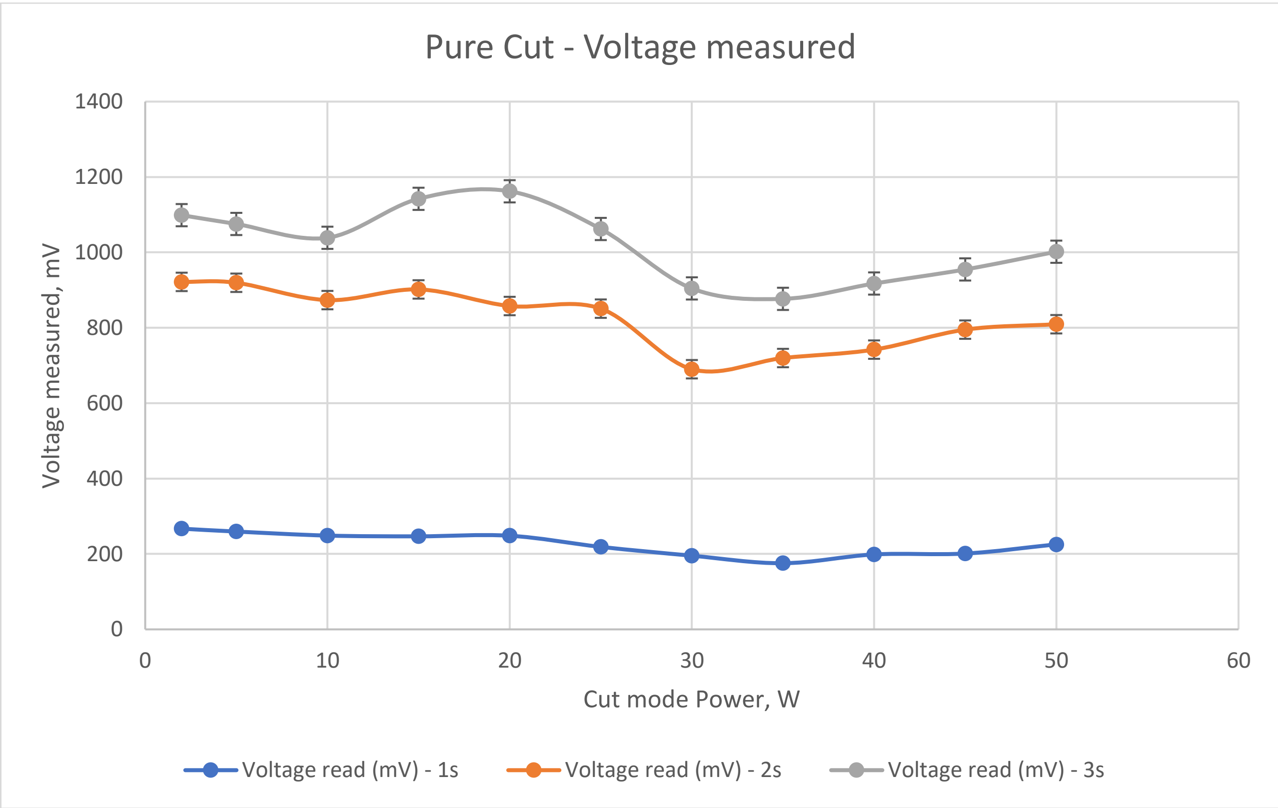

Figure 4. 7: Voltage read to Cut Power rating for Pure Cutting Mode

The above Figure 4.7 for power settings between 15W to 25W gives a voltage higher than 200v for the 3-time series, which produces current densities adequate to provide electrosurgical cutting.

4.5.2 Blend1 Cut

Figure 4.8 shows incremental patterns from the representation for all the time series. This implies that the lower the pedal press timing, the better the results obtained for the ESU. The continuous increment shows different patterns for the 3-time series: 1-second footswitch gives constant increment for cut power 2W to 50W from 7.96W to 26.1W measured power, 2 seconds shows increment from 2W to 25W cut power from 19.26W to 64.88W measured power before a slight decline. In comparison, 3 seconds experience an increase from 2W to 15W cut power from 21.78W to 54.51W measured power.

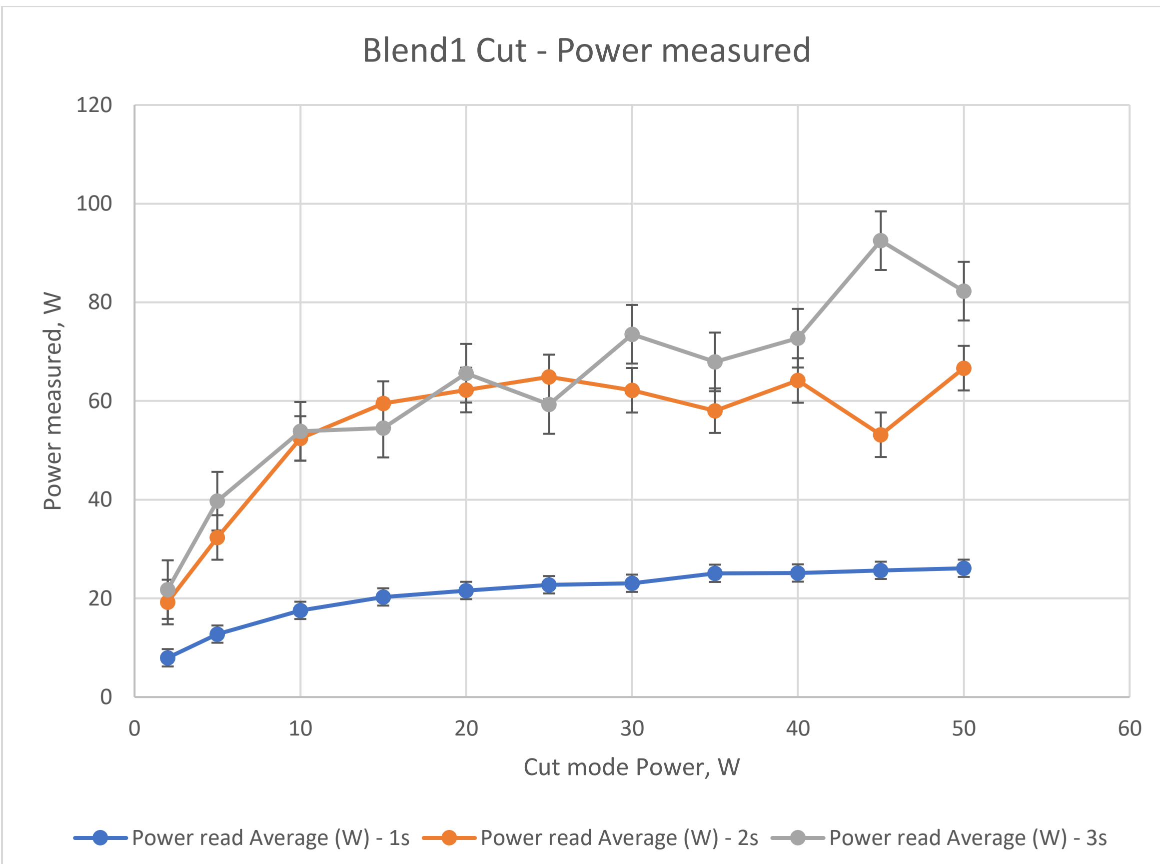

Figure 4. 8: Power read to Cut Power rating for Blend1 Cutting Mode

In Figure 4.9, there is a gradual decrease in the voltage read as the cut power increases. The 1-second voltage read shows better results than the 2 and 3 seconds. It is noticeable that the highest decrement is seen at the 25W to 30W cut power ratings for all the time series.

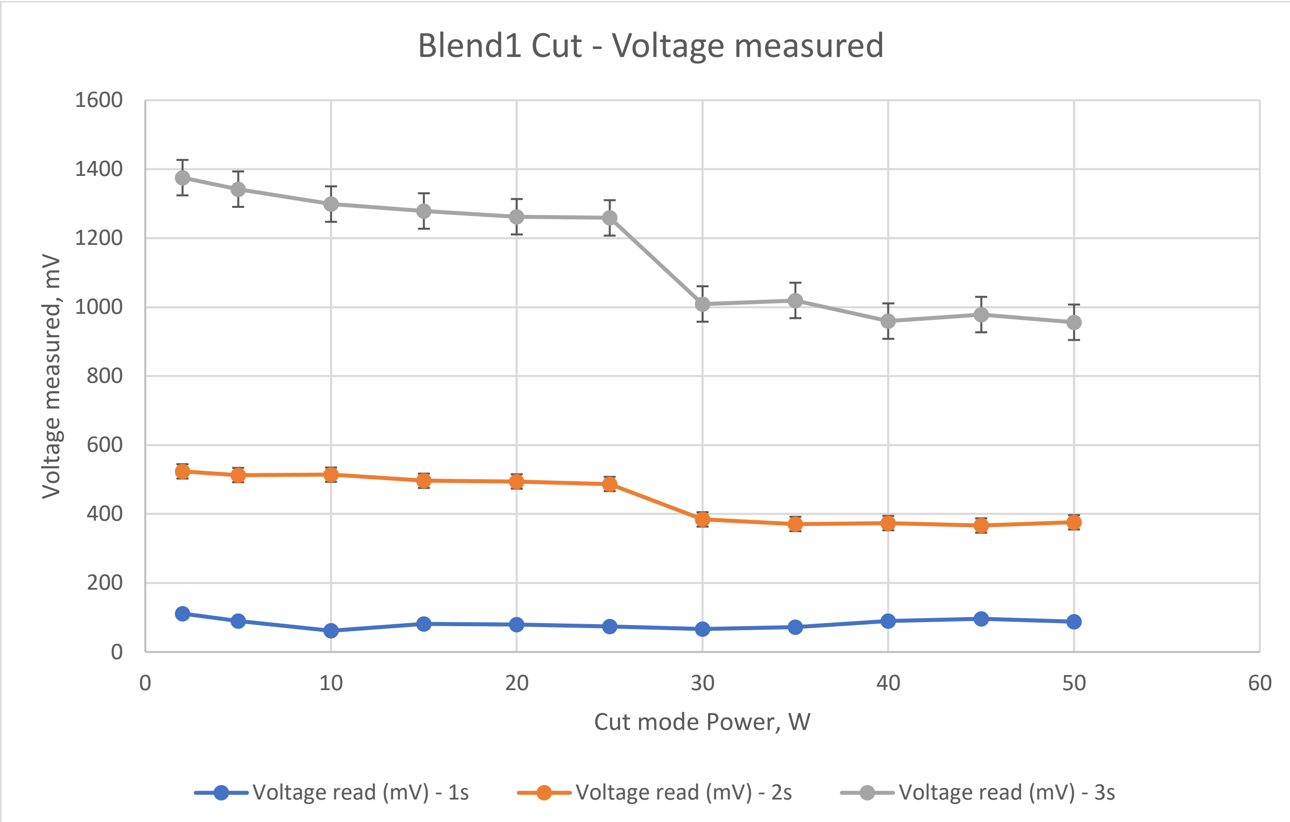

Figure 4. 9: Voltage read to Cut Power rating for Blend1 Cutting Mode

The voltage at one second is below 200v, showing tissue coagulation without any cutting regardless of the power settings. But with an increase in the firing time, the blend1 can produce electrosurgical cutting.

4.5.3 Blend2 Cut

Figure 4.10 representation for the power read and cut power rating shows an incremental pattern. It offers a continuous increment from 2W to 25W cut mode for all the time series before a slight decrement for 2 and 3 seconds.

While in Figure 4.11, voltage read for 1 second and 2 seconds gives a unilateral representation, unlike the 3 seconds. This means the lower the pedal pressed timing, the lower the voltage and the better the ESU blend2 cutting mode results.

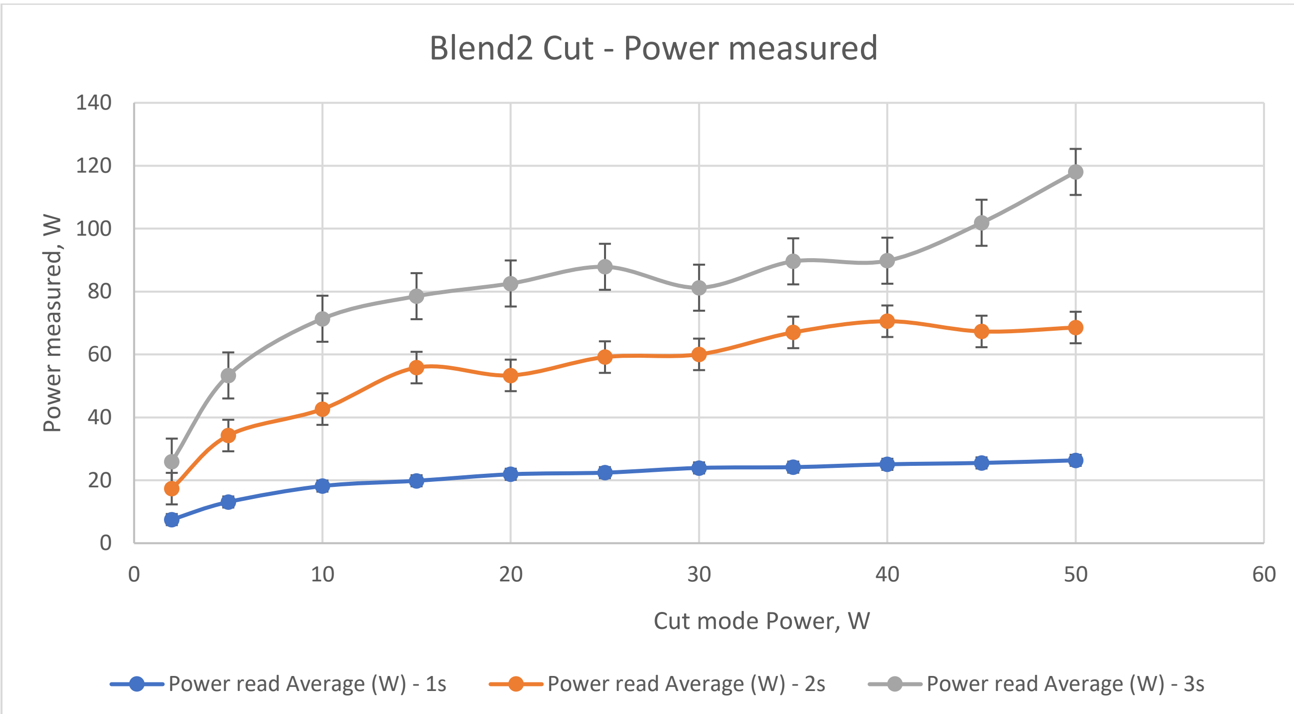

Figure 4. 10: Power read to Cut Power rating for Blend2 Cutting Mode

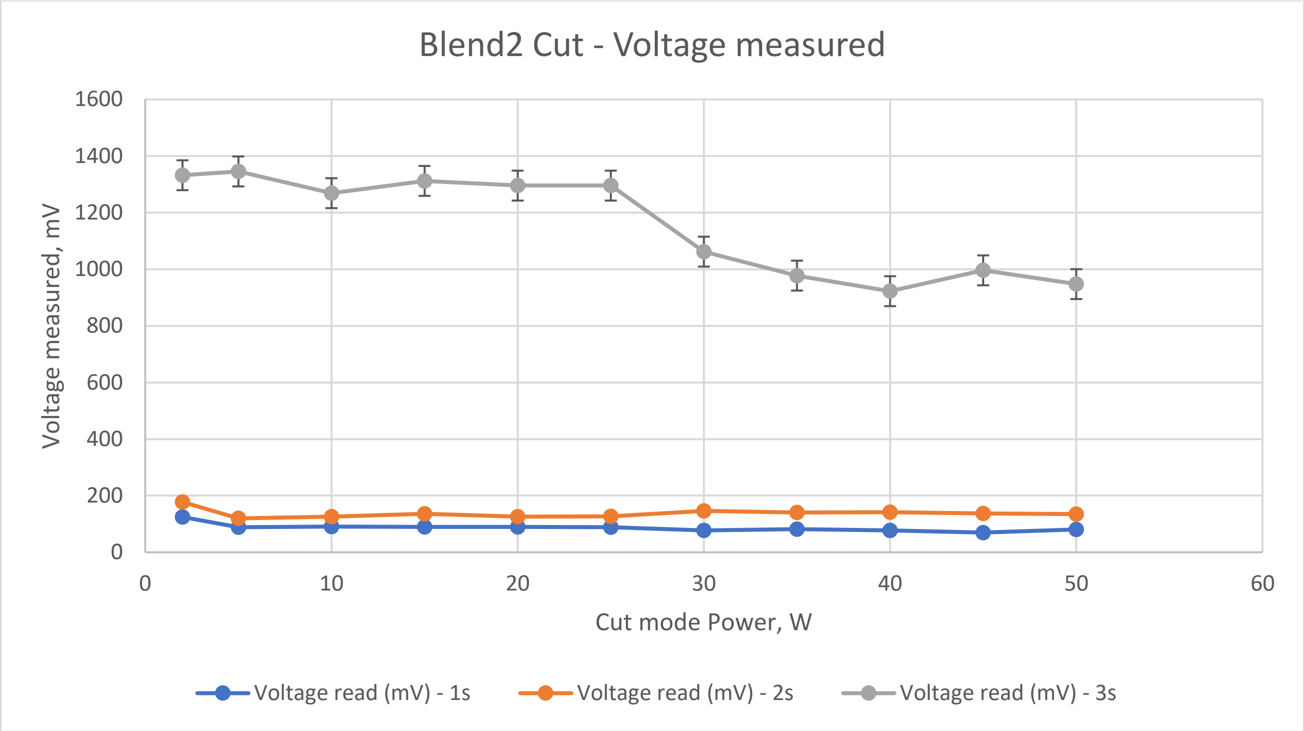

Figure 4. 11: Voltage read to Cut Power rating for Blend2 Cutting Mode

For blend2 cut, the voltage measured is below 200v for both the 1 and 2 seconds showing the tissue coagulation without cutting irrespective of the power settings. This depicts that blend2 shows coagulation properties.

4.5.4 Soft Coagulation

Figure 4.12 for the power read and coagulation power rating shows an incremental pattern like the cutting modes. There is a drastic increment between coagulation power rating of 5W and 10W for all the three different time series (1s, 2s, 3s) for the power read.

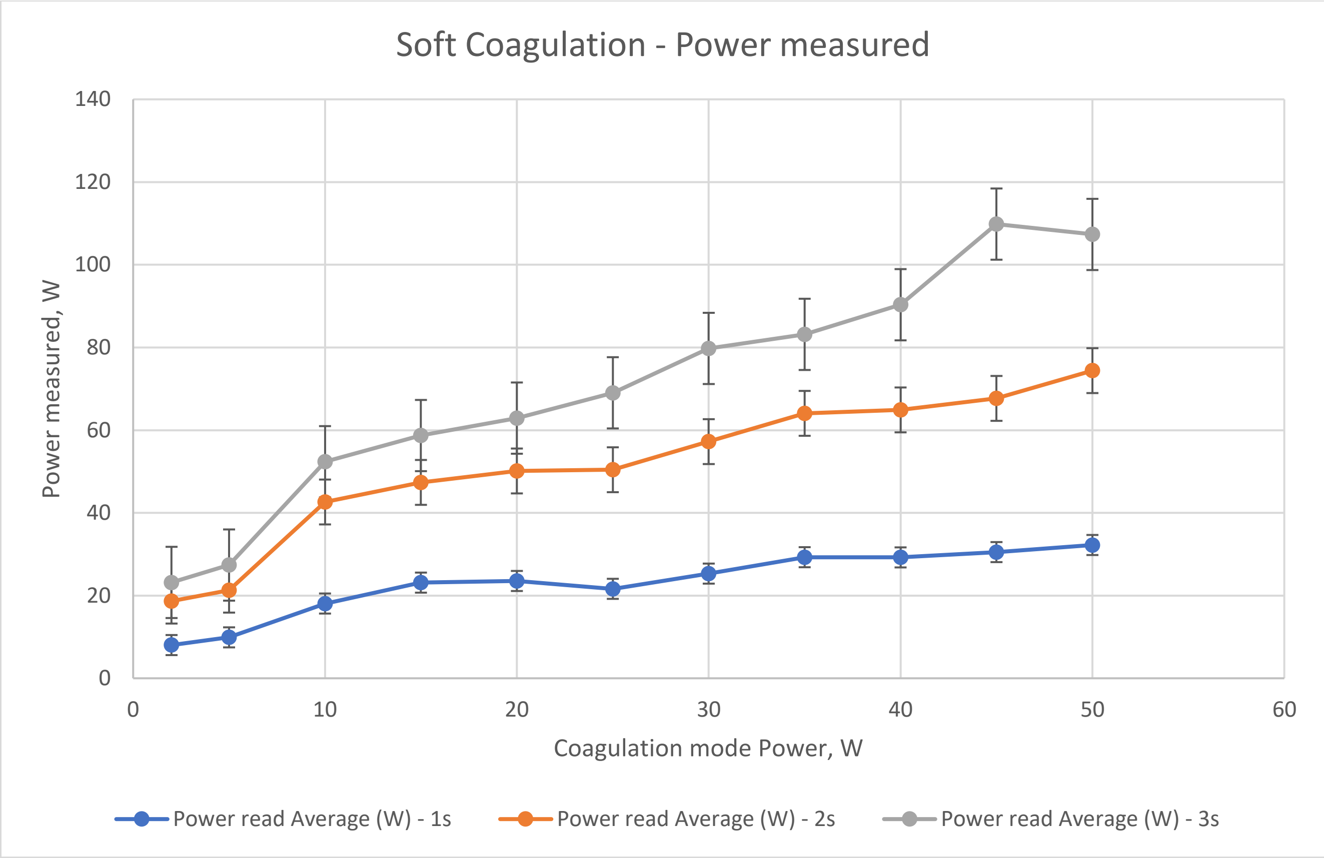

Figure 4. 12: Power read to Cut Power rating for Soft Coagulation Mode

The representation for Figure 4.13 shows a drastic decline in the voltage read between 2W and 5W for the coagulation power rating. This is noticed for all the three different time series with the difference in 73.35mV, 206mV, and 264.2mV for 1, 2, and 3 seconds respectively. But in general, the pattern for all the time series is similar.

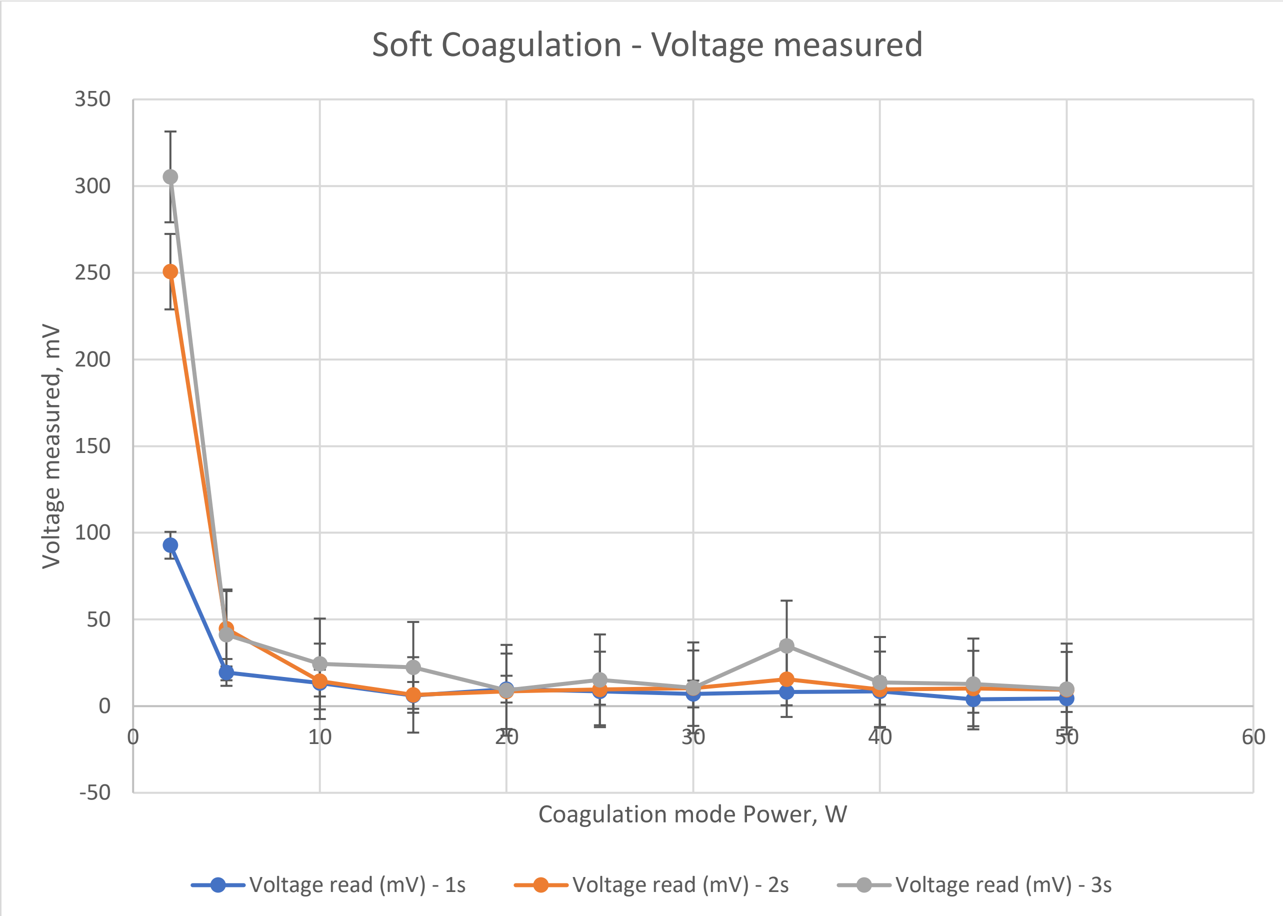

Figure 4. 13: Voltage read to Cut Power rating for Soft Coagulation Mode

4.5.5 AutoStop Coagulation

In Figure 4.14 representation, there is an increment pattern in the power read for all the three types of time series like soft coagulation. There is an increment experienced at 5W to 10W coagulation mode power.

While Figure 4.15 shows a similar pattern to the soft coagulation in which the voltage at the 2W coagulation power rating is highest. Also, there is a huge decline between 2W and 5W for the voltage read, with the difference at 29.62mV, 126.2mV, and 160.28mV for 1, 2, and 3 seconds respectively.

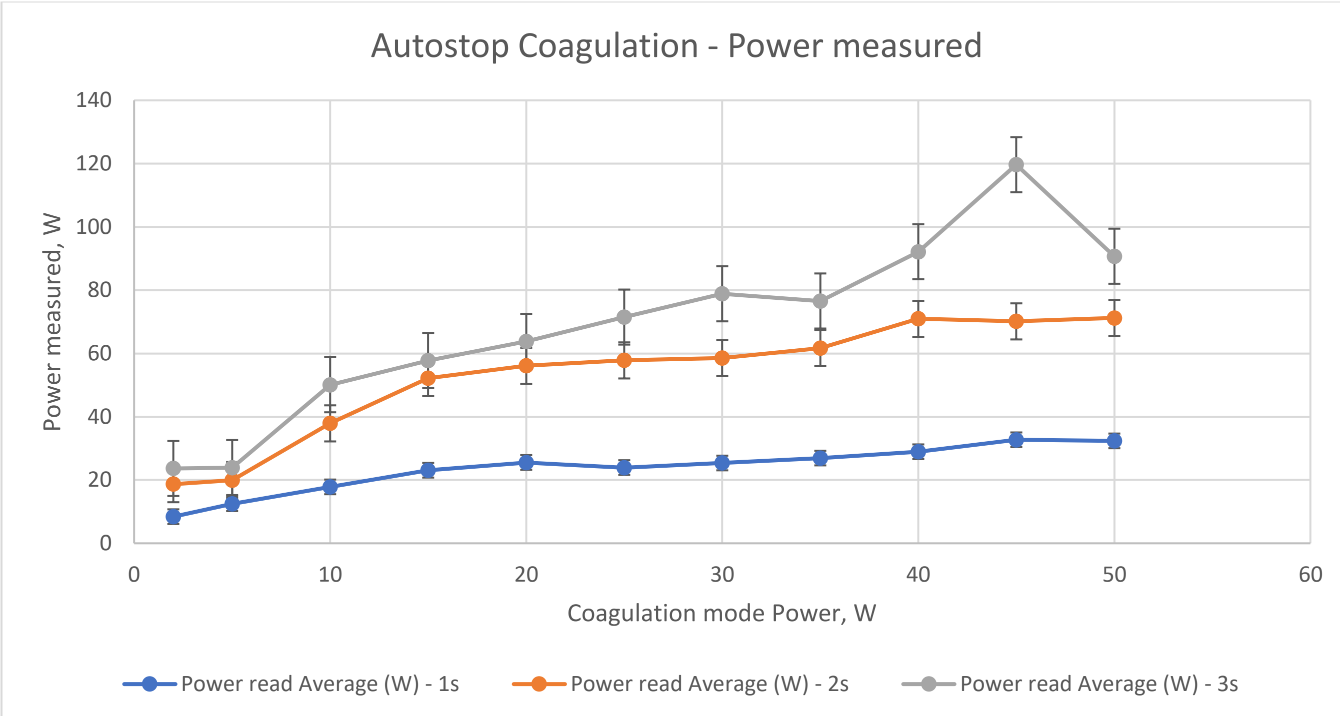

Figure 4. 14: Power read to Cut Power rating for AutoStop Coagulation Mode

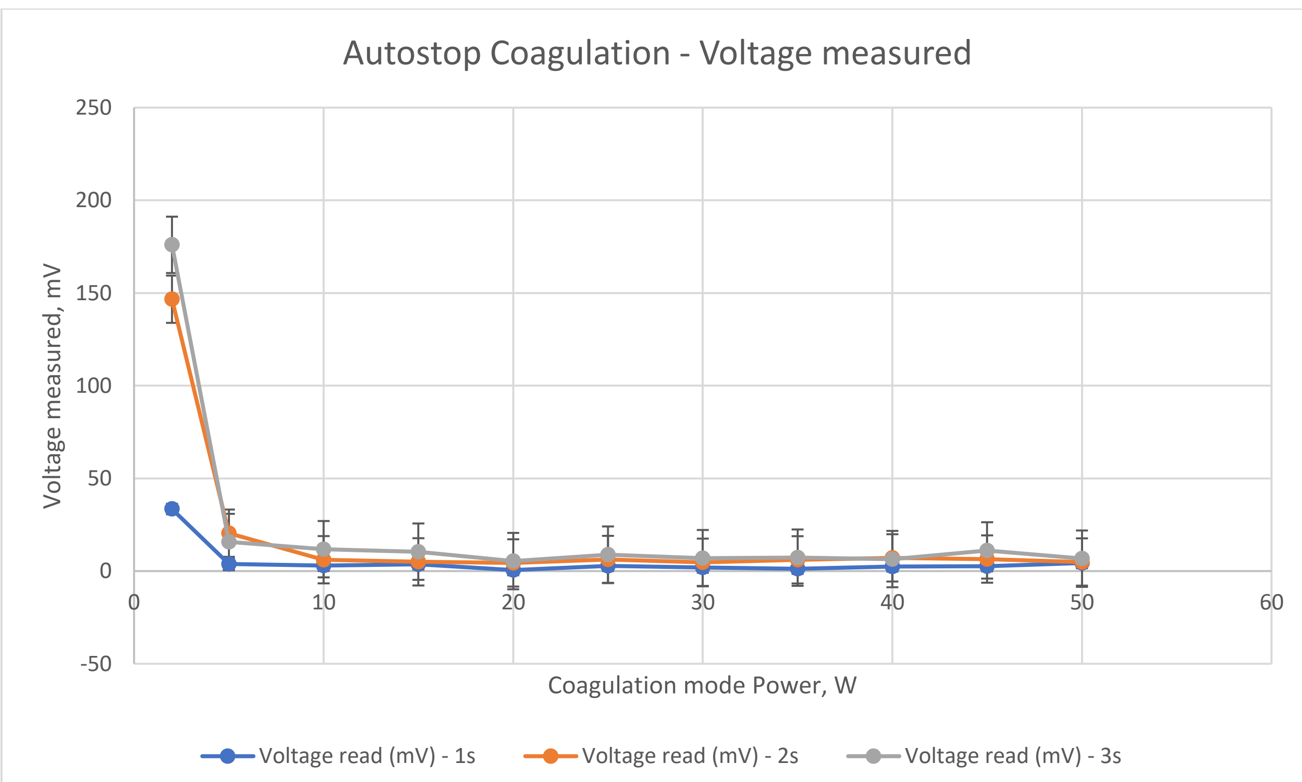

Figure 4. 15: Voltage read to Cut Power rating for AutoStop Coagulation Mode

4.5.6 Forced Coagulation

In Figure 4.16, the incremental pattern is noticeable between the power read and coagulation power which shows that both power increase with the pedal timing. Likewise, the pattern is like Soft and Autostop coagulation.

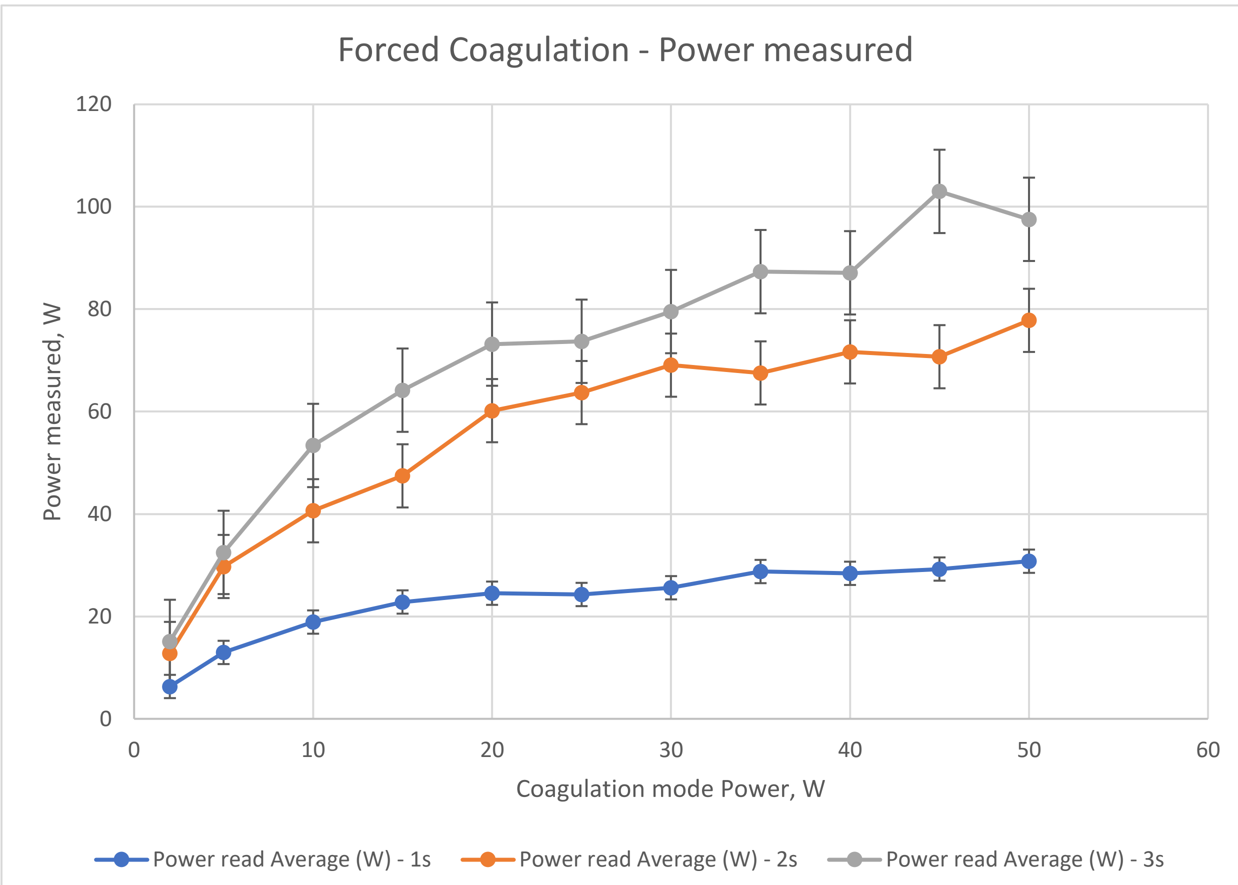

Figure 4. 16: Power read to Cut Power rating for Forced Coagulation Mode

Figure 4.17 gives an irregular pattern for all the three different time series shown. It shows that there is strong coagulation experienced in this mode which is applying more forces. The mode shows limited control of the voltage by the ESU.

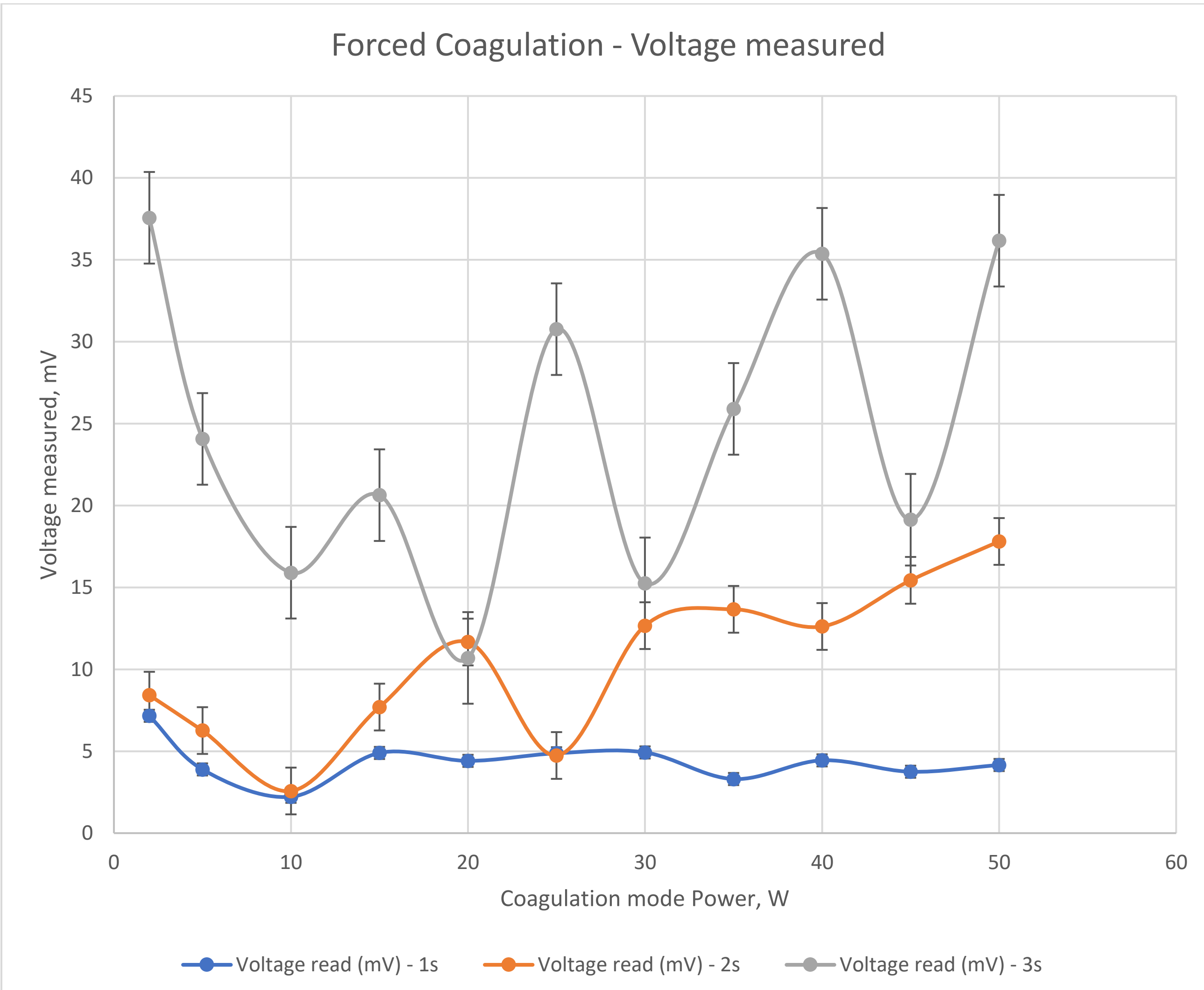

Figure 4. 17: Voltage read to Cut Power rating for Forced Coagulation Mode

As the measurement is shown in Figure 4.18, based on the footswitch firing with the Arduino for the RRC circuit, we can identify the series pattern which shows the power increase for the cut mode power of the Electrosurgical Unit. The increase in Time leads to more output power from the Electrosurgical Unit as the cut mode power increases.

The coagulation (soft, autostop, and forced) shows a voltage below the cutting volts of 200v, which propagate the tissue coagulation properties.

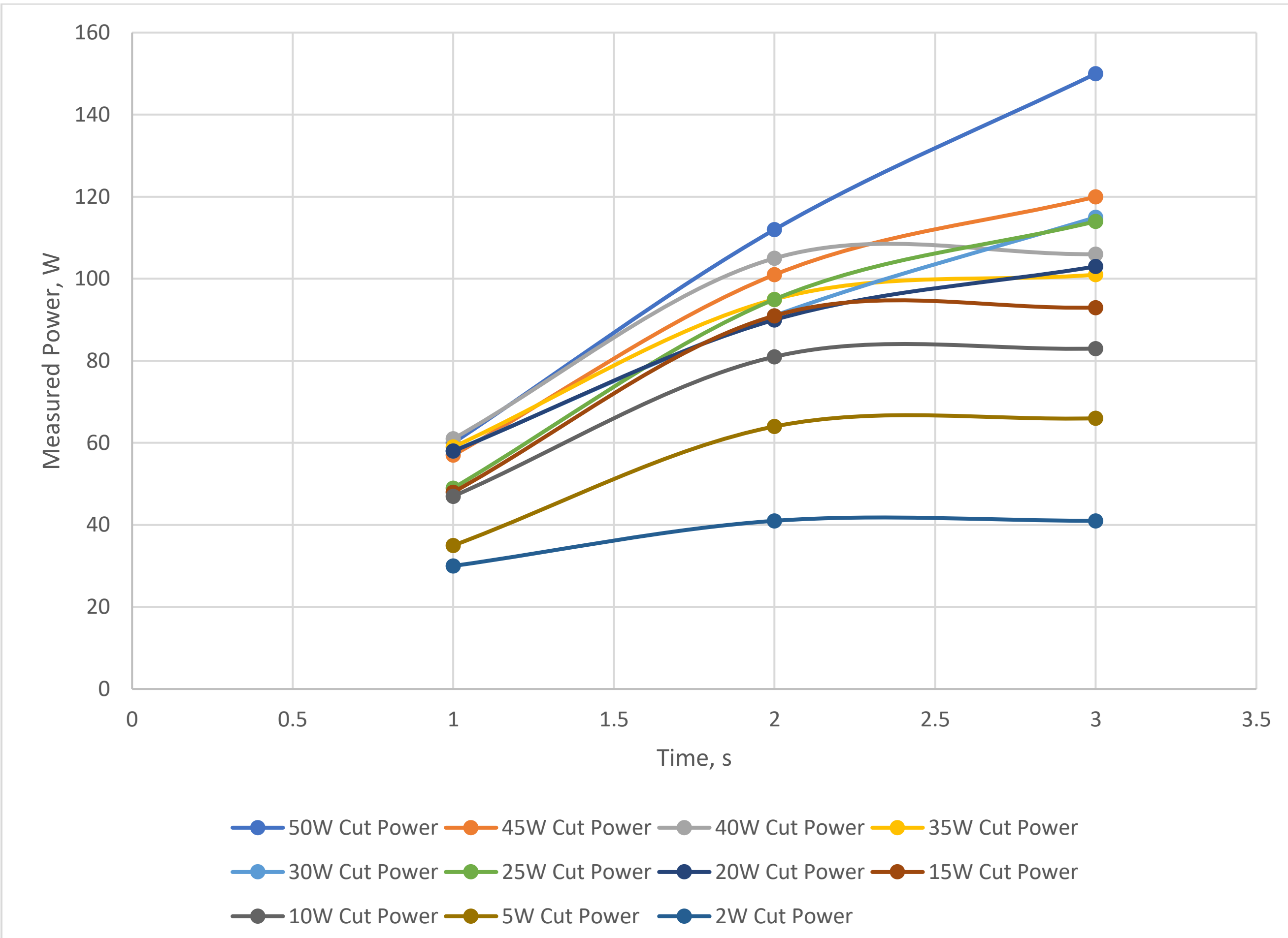

Figure 4. 18: Electrosurgical Unit power output with time series

4.6 Crest Factor Signal

The crest factor is used instead of the duty cycle to measure the signals because it gives a precise outcome for the voltage measured. For continuous signal, 100% of the duty cycle gives a 1.4 crest factor (Marcia L. Morris, 2009). The function generator was used to generate the signal to be read by the oscilloscope and LabView. The function generator gives a sine and square signal with frequencies ranging from 1kHz to 500kHz with the PSD-30 fundamental frequency at 350kHz. The signal magnitude is set at 1Vpp while the offset is at 1Vdc.

The oscilloscope was used to analyze the signal from the function generator with the amplitude set to 1Vpp and a starting frequency of 10Hz while the output load was at 50 ohms. The ADC is used to create the connection to the LabView DAQ signal was used to generate the signal with the terminal configuration set at differential for a sample read of 100. The data acquisition mode was continuous to capture the signal over a period. The differential signal was used because it minimizes noise pickup and avoids the ground loop.

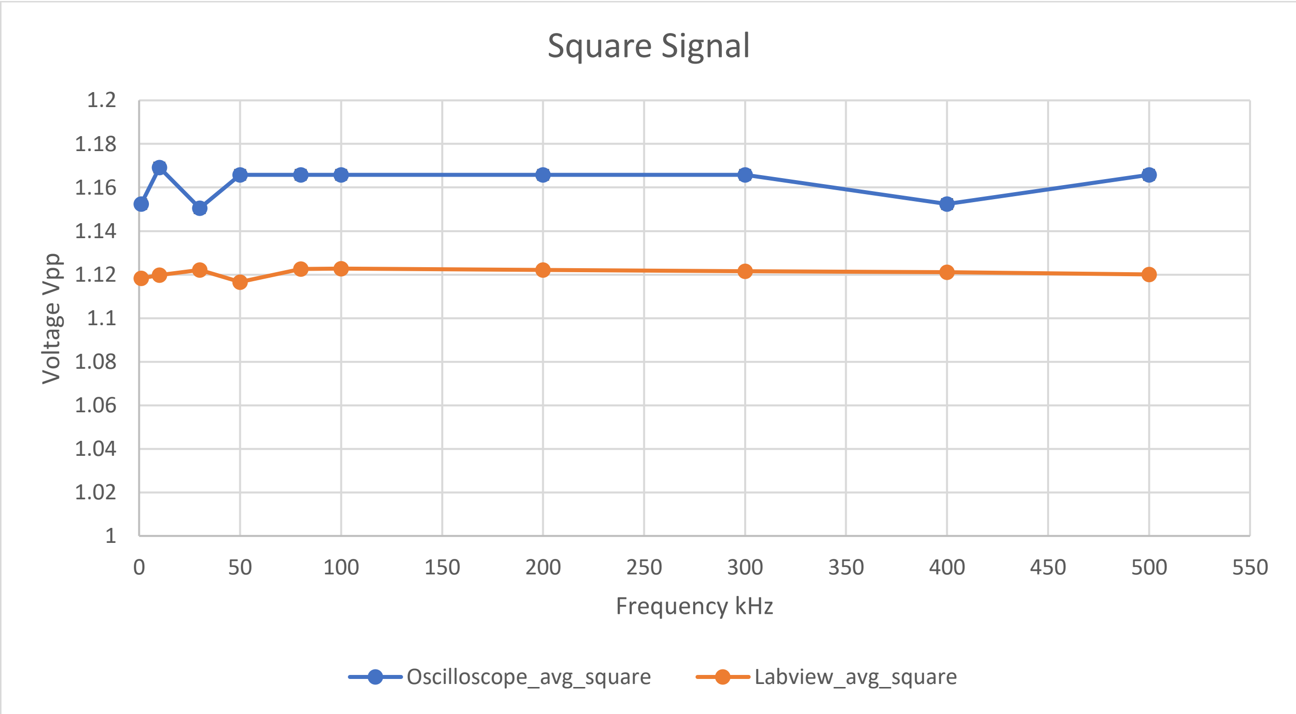

Figure 4. 19: Square Signal from the Function Generator

The square signal in Figure 4.19 shows the minimum voltage peak-to-peak difference between the oscilloscope and LabView. The difference for square signal is at 0.04V for the frequencies while the sine signal shows a difference of 0.033V for the frequencies, as seen in Figure 4.20.

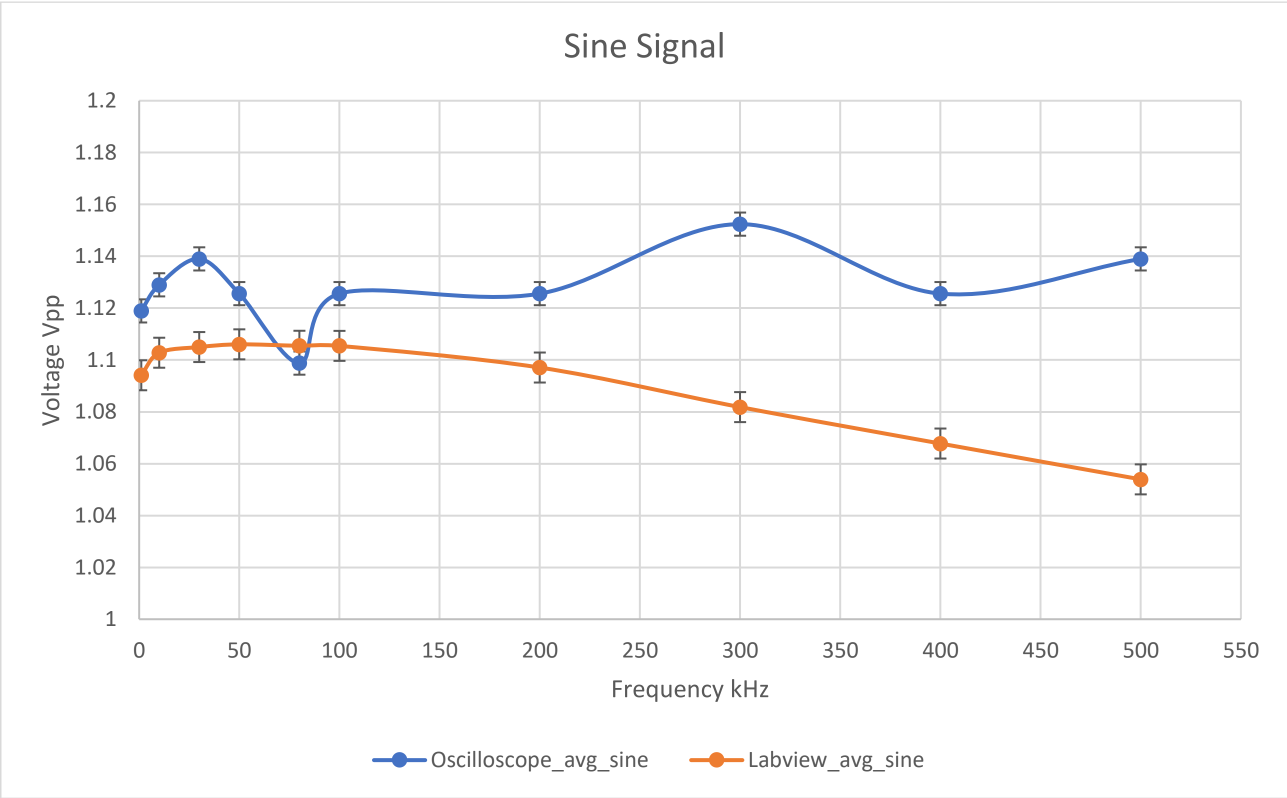

Figure 4. 20: Sine Signal from the Function Generator

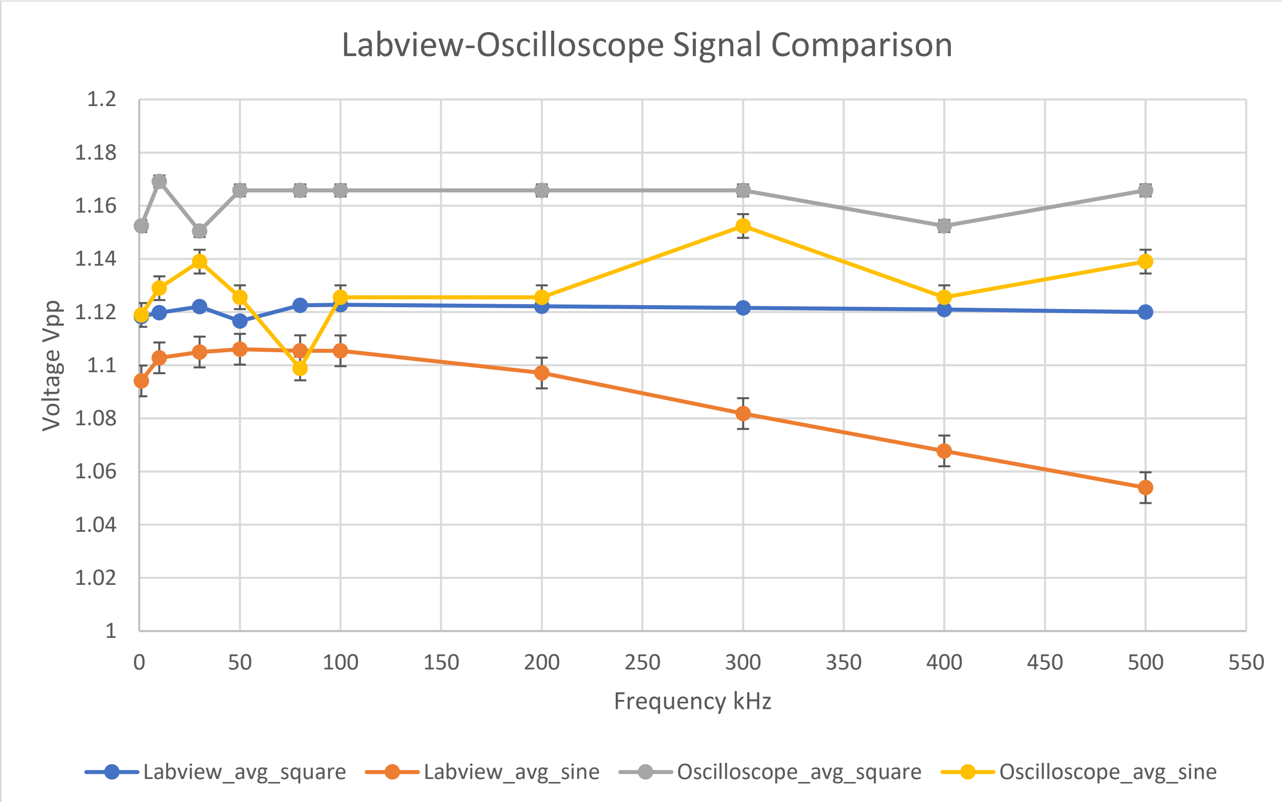

Figure 4. 21: LabView – Oscilloscope Signal Comparison

As shown above, in Figure 4.21, the voltage peak-to-peak difference for both the LabView and oscilloscope concerning sine and square signal are 0.033V and 0.04V, respectively. This signifies a similar pattern in the signal, with the oscilloscope showing a better output when compared to the LabView. For the sine signal, the oscilloscope gives the maximum voltage peak-to-peak of 1.1524V at 300kHz to LabView, which is 1.1060V at 50kHz, while the minimum is 1.0988V at 80kHz for the oscilloscope and 1.05395V at 500kHz for LabView.

Crest factors (CF) are the measure of peak and average voltage, as well as the frequency of the modulation. The CF is the ratio of the voltage peak to root mean square. The root means square for a sine wave is a constant of 0.7, and the CF of the pure sine wave is a constant of 1.4

For the electrosurgical device at 350kHz, the CF for the sine wave is 1.5 for oscilloscope and 1.55 for LabView. This shows that the value is close to the CF constant.

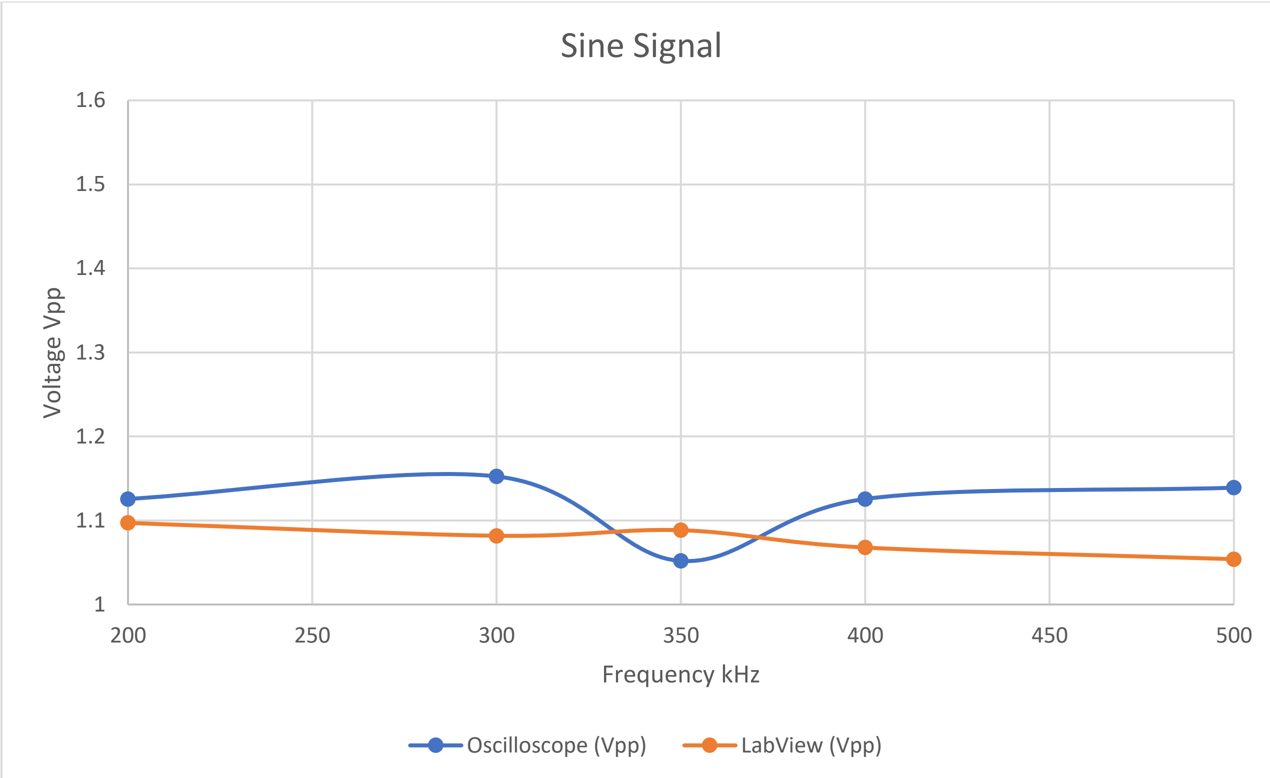

Figure 4. 22: Electrosurgical Unit Fundamental Frequency Signal at 350kHz

The Electrosurgical Unit fundamental frequency of 350kHz signal shows a difference of 0.036V between the LabView and oscilloscope sine signal. The voltage peak-to-peak experienced by both the LabView and oscilloscope were 1.088V and 1.0519V, respectively, as shown in Figure 4.22.

4.7 Time-Based Output from LabView

Figure 4. 23: Waveform of Voltage measurement at 1 second

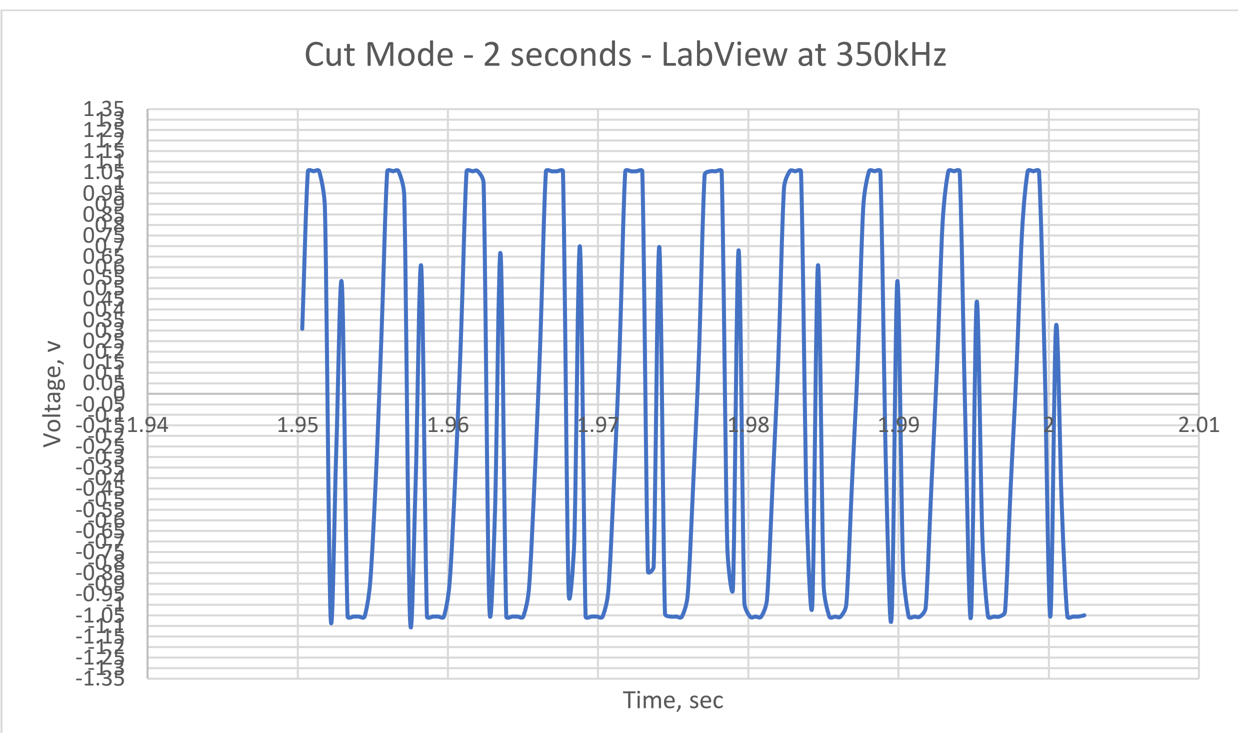

Figure 4. 24: Waveform of Voltage measurement at 2 seconds

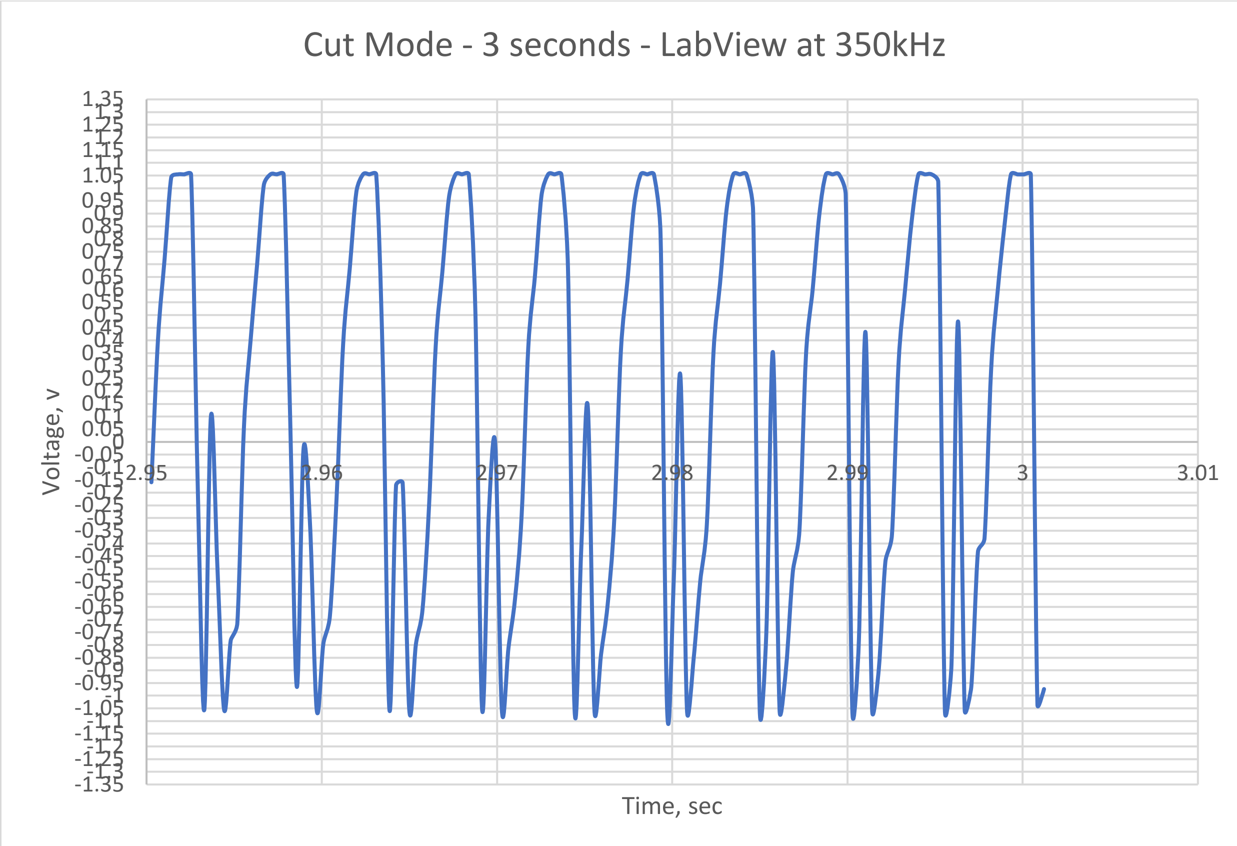

Figure 4. 25: Waveform of Voltage measurement at 3 seconds

Based on Figure 4.23, 4.24, and 4.25 shows that the only variable that is controlled by the operator is time. The power multiplied by the time is equivalent to the energy dissipated. The crest factor calculated (CF= Vp/RMS) in which RMS for the sine waves is 0.707 multiplied by 1.0544 (peak voltage) gives 0.745. The crest factor shows similarity for the 1, 2, and 3 seconds with a value of 1.4, which is the same as the pure sine waves with a constant value of 1.40.

4.8 Power and Voltage relationship to Time

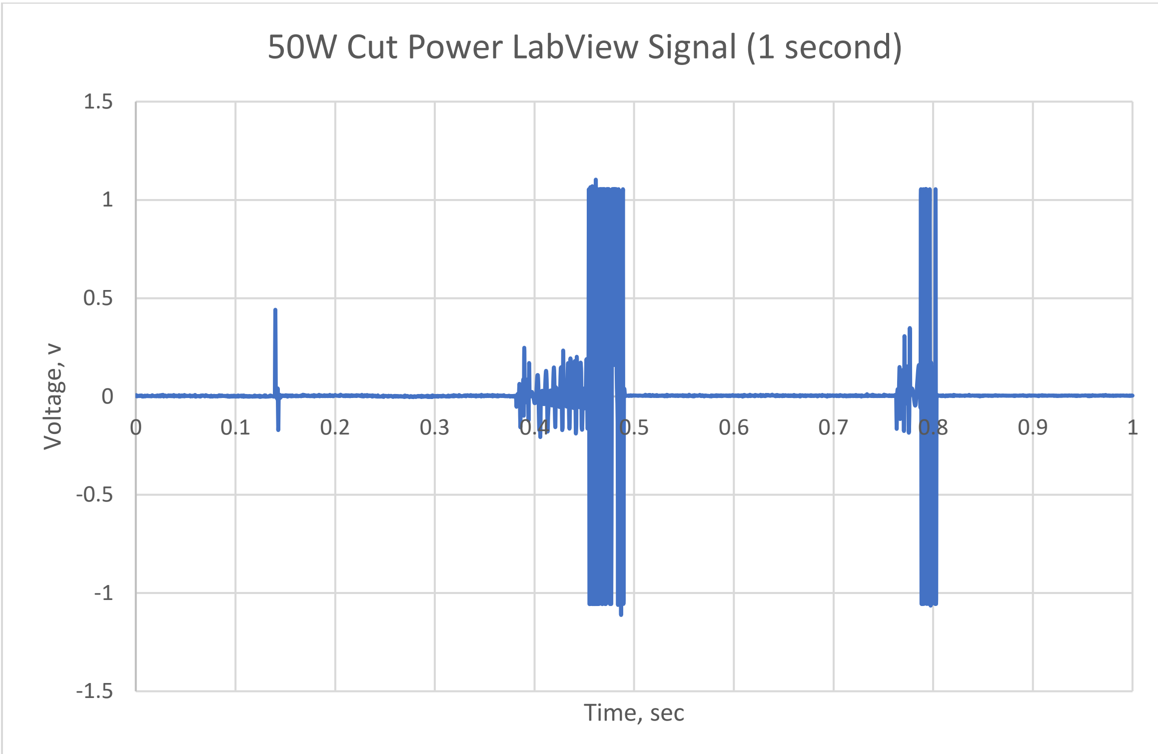

Figure 4. 26: Signal Intensity of Voltage measurement at 1 second

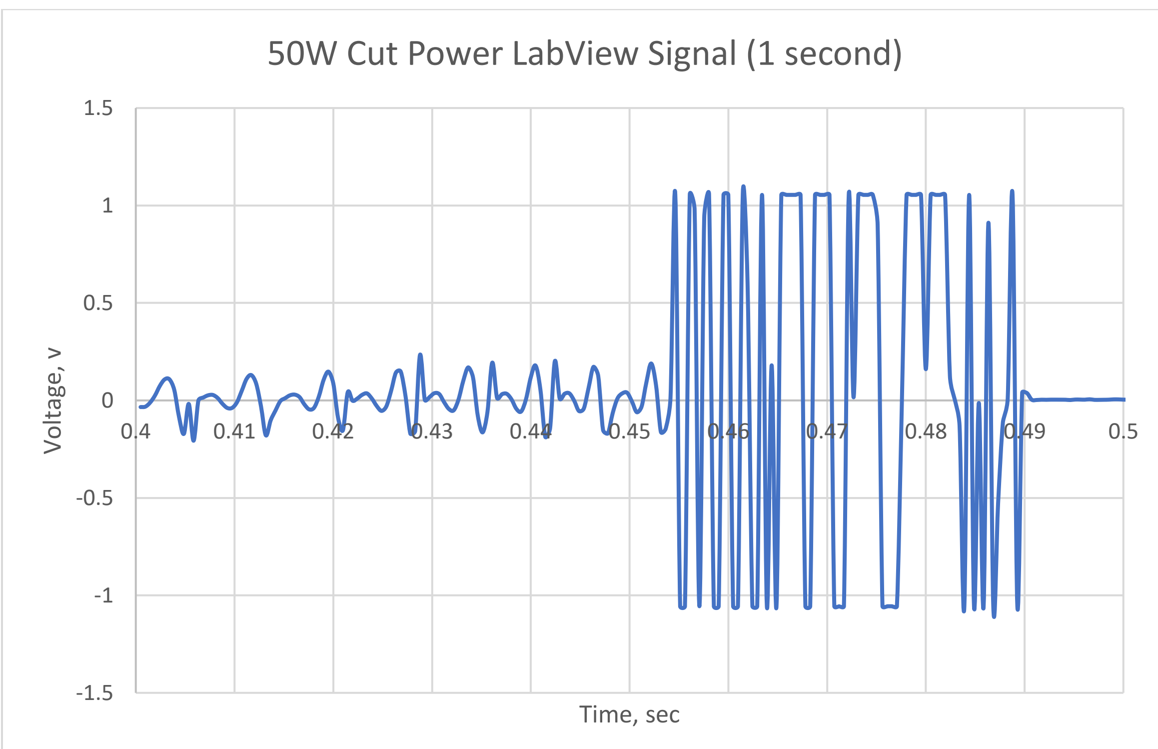

Figure 4. 27: Selected portion of the Voltage Intensity at 1 second

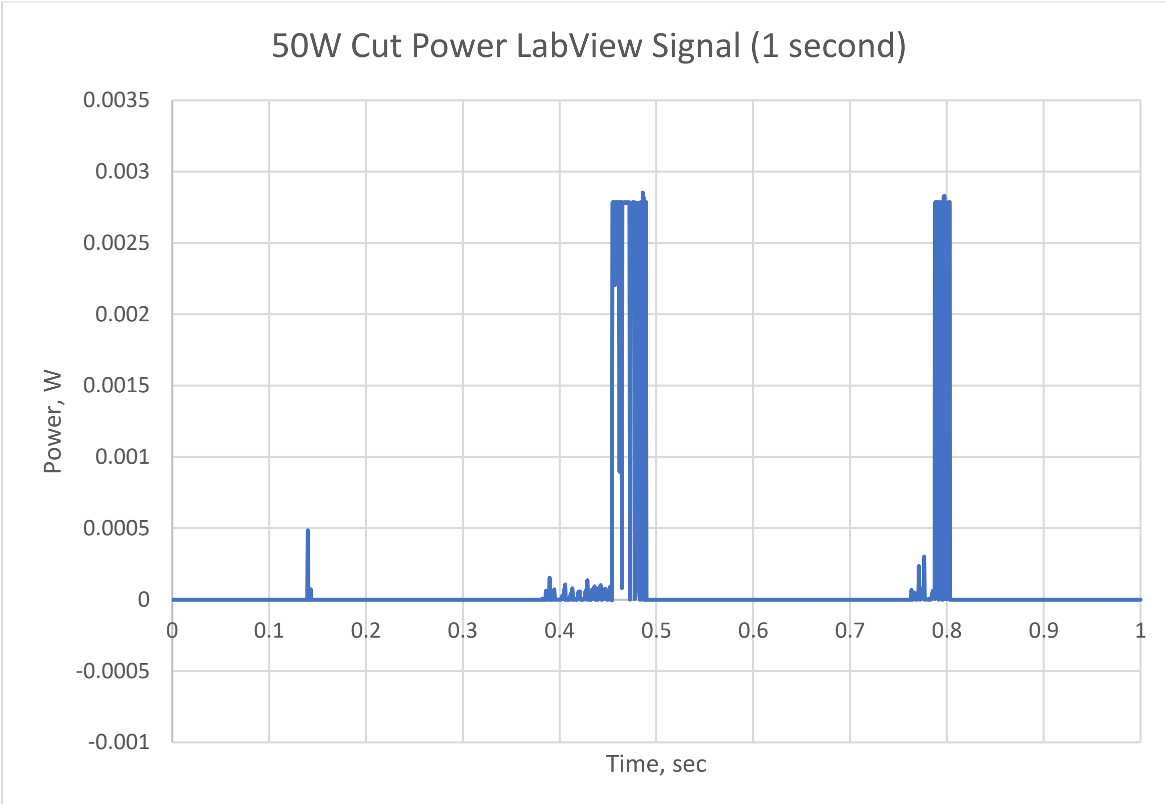

Figure 4. 28: Signal Intensity of Power measurement at 1 second

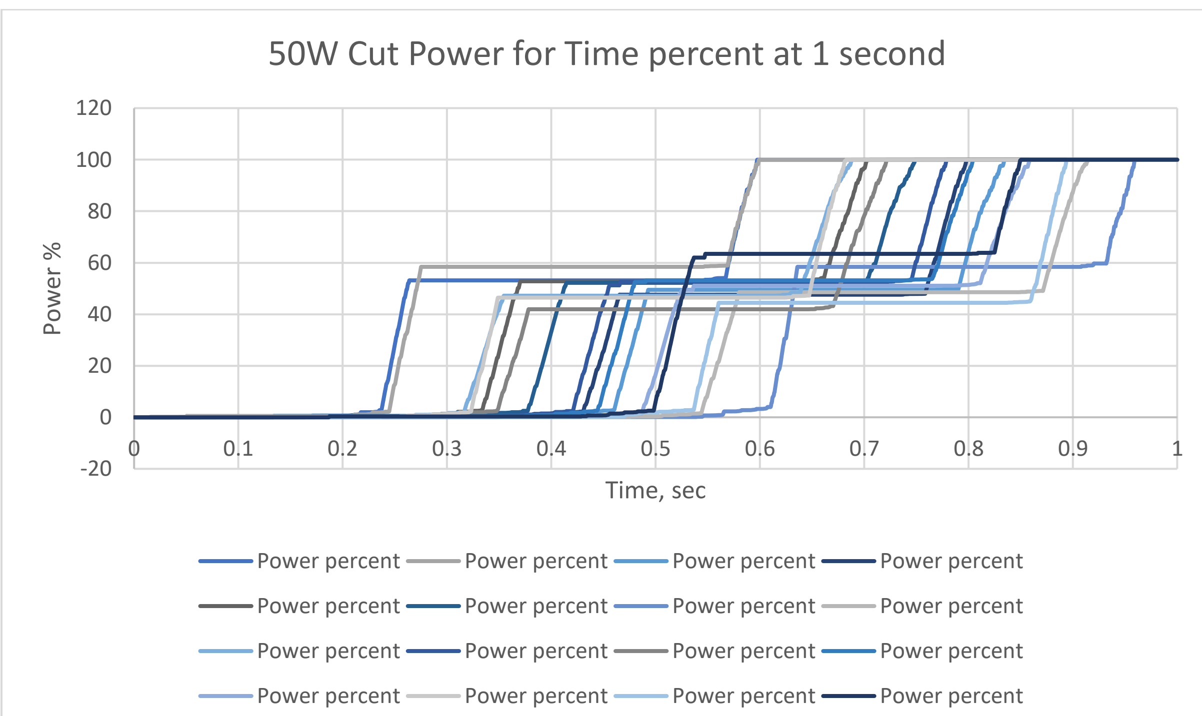

Figure 4. 29: Signal Intensity for Time percent at 1 second

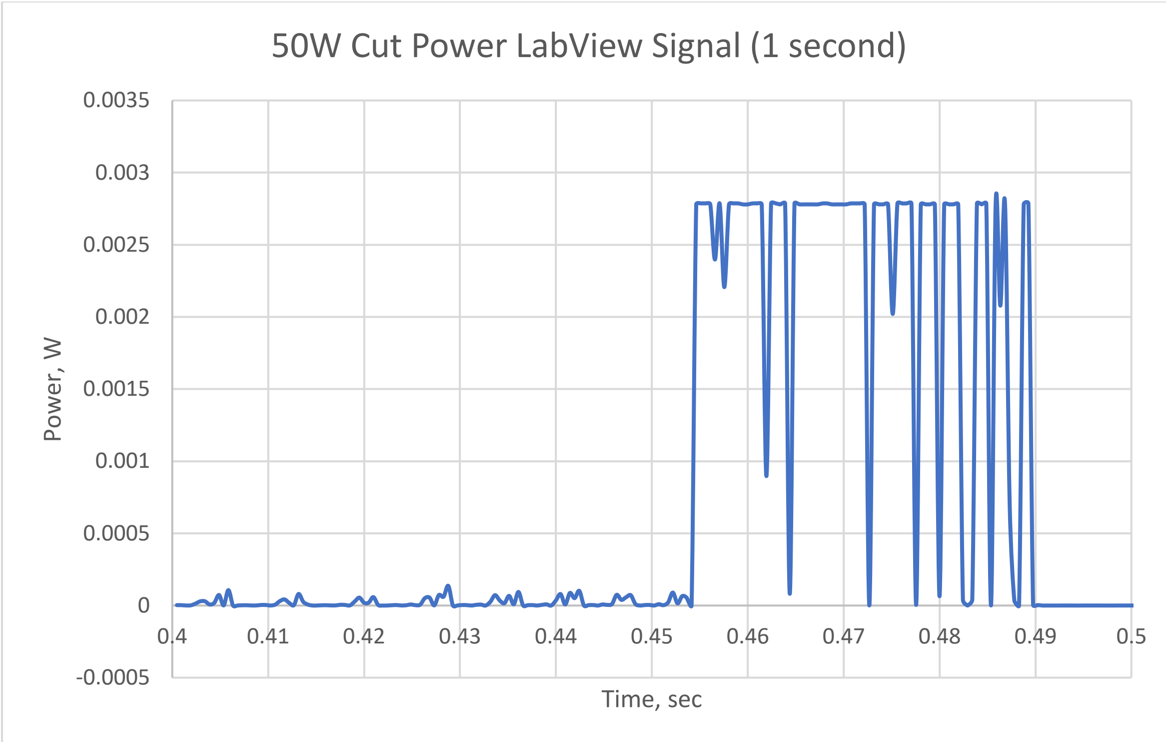

Figure 4. 30: Selected portion of the Power Intensity at 1 second

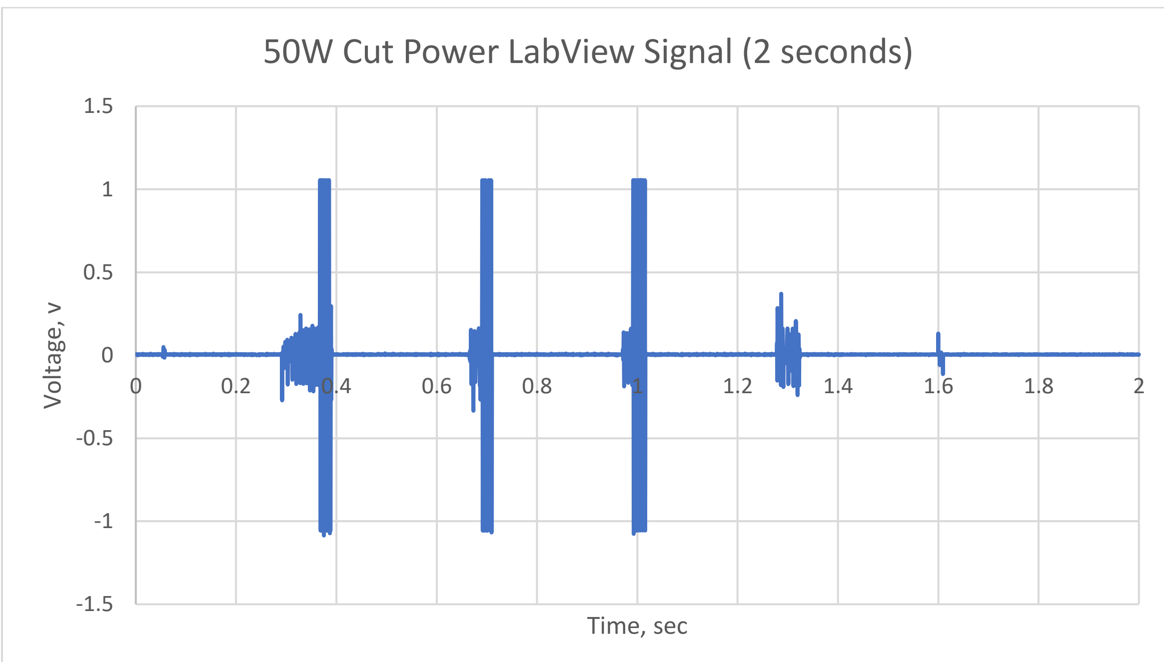

Figure 4. 31: Signal Intensity of Voltage measurement at 2 seconds

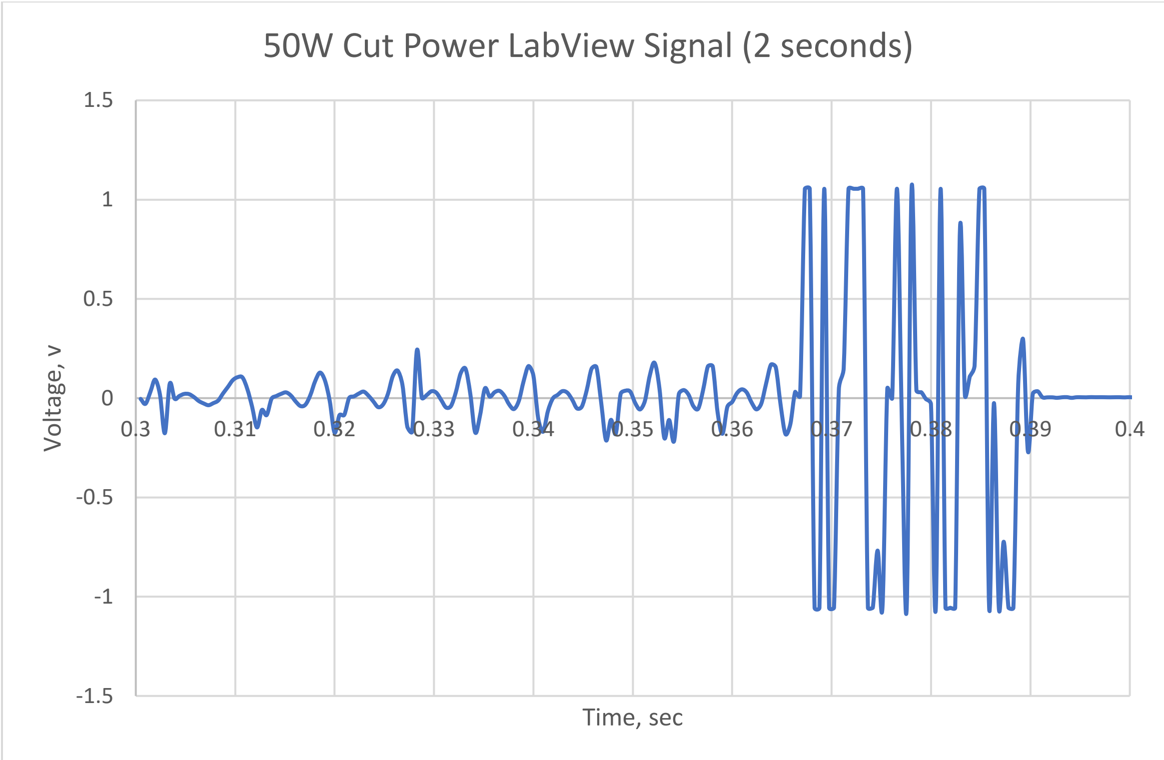

Figure 4. 32: Selected portion of the Voltage Intensity at 2 seconds

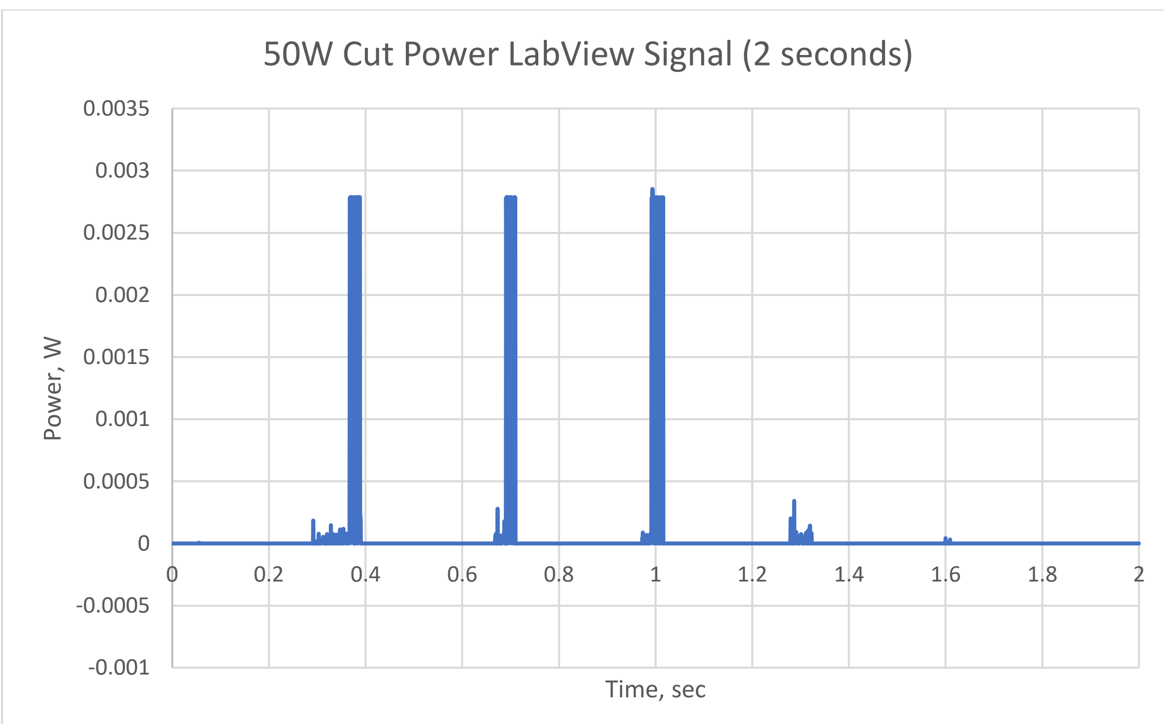

Figure 4. 33: Signal Intensity of Power measurement at 2 seconds

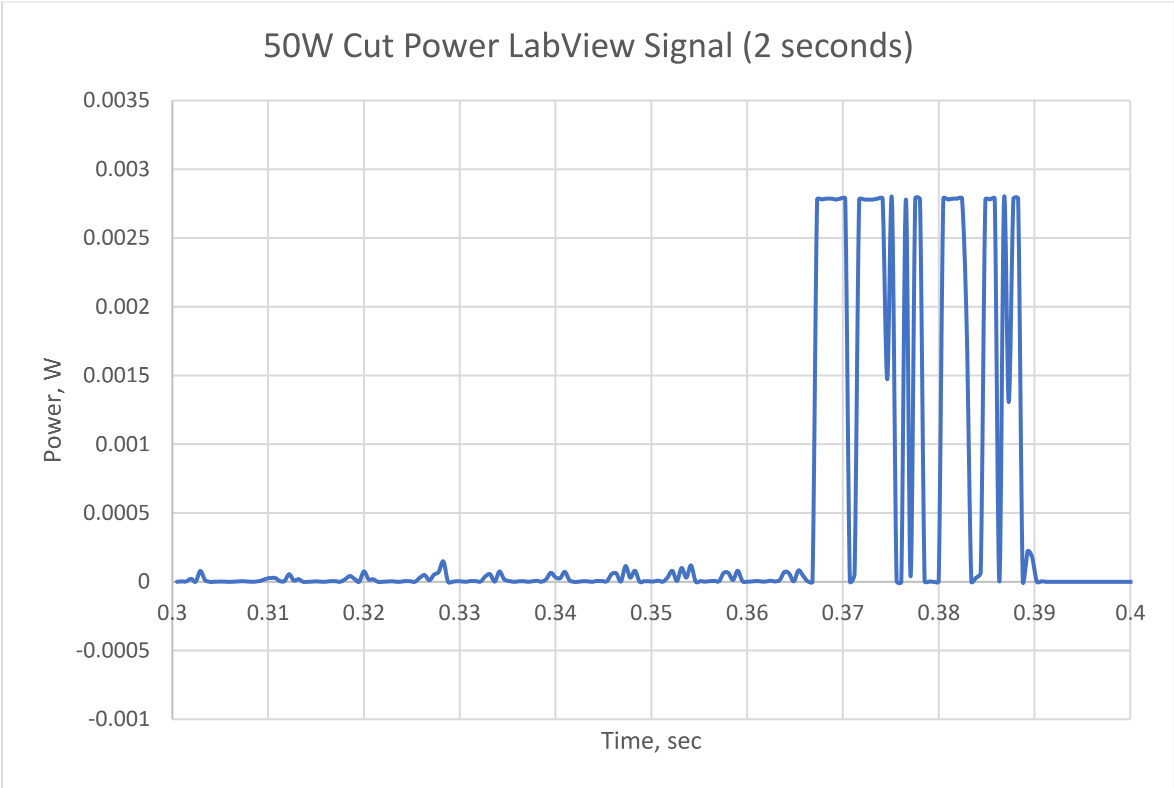

Figure 4. 34: Selected portion of the Power Intensity at 2 seconds

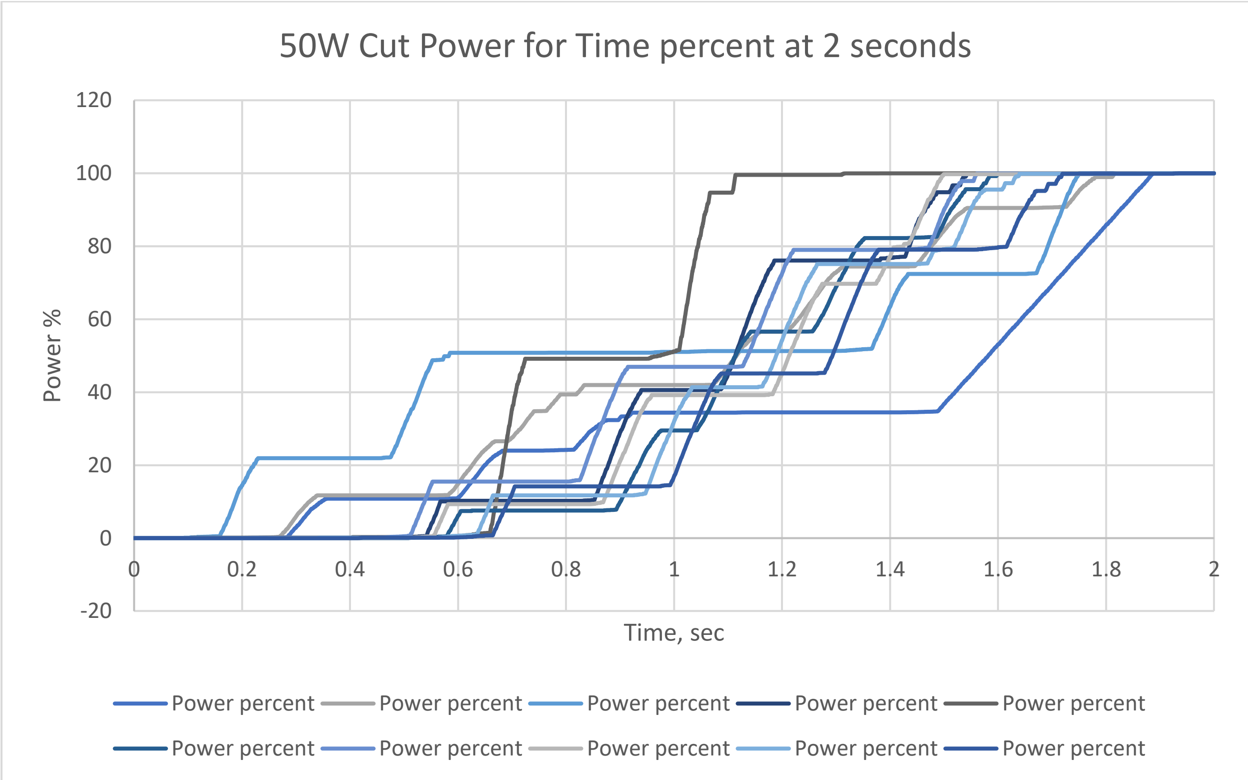

Figure 4. 35: Signal Intensity for Time percent at 2 seconds

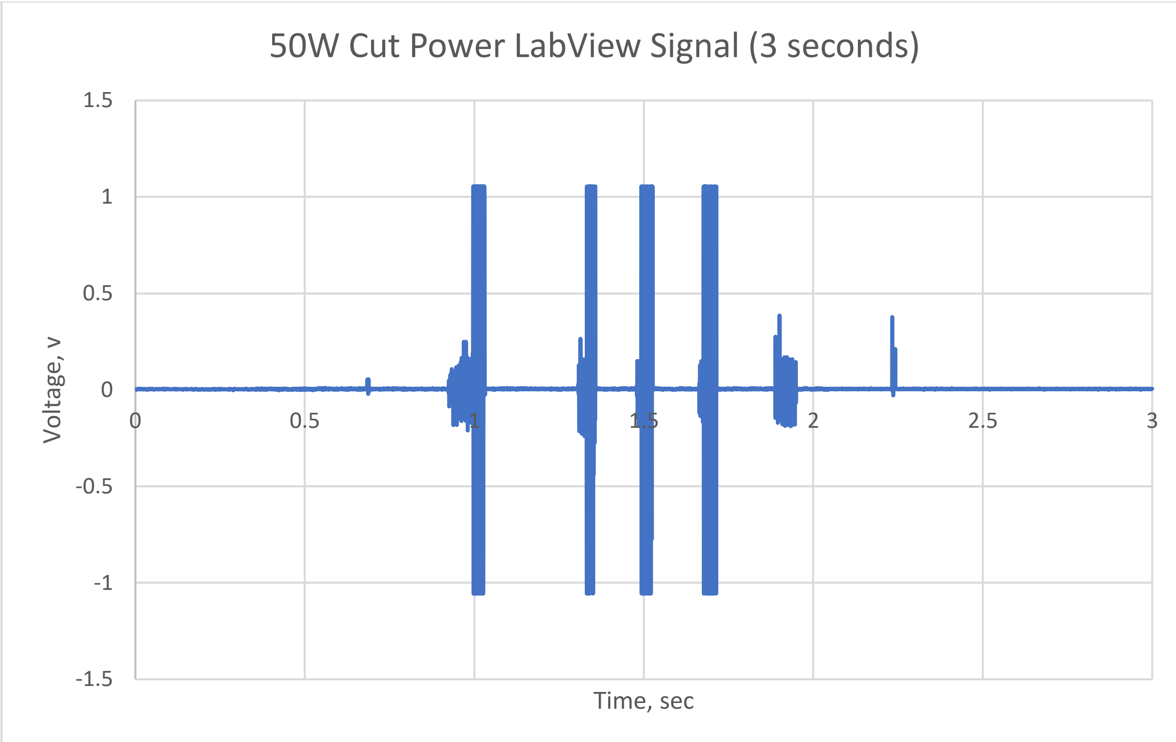

Figure 4. 36: Signal Intensity of Voltage measurement at 3 seconds

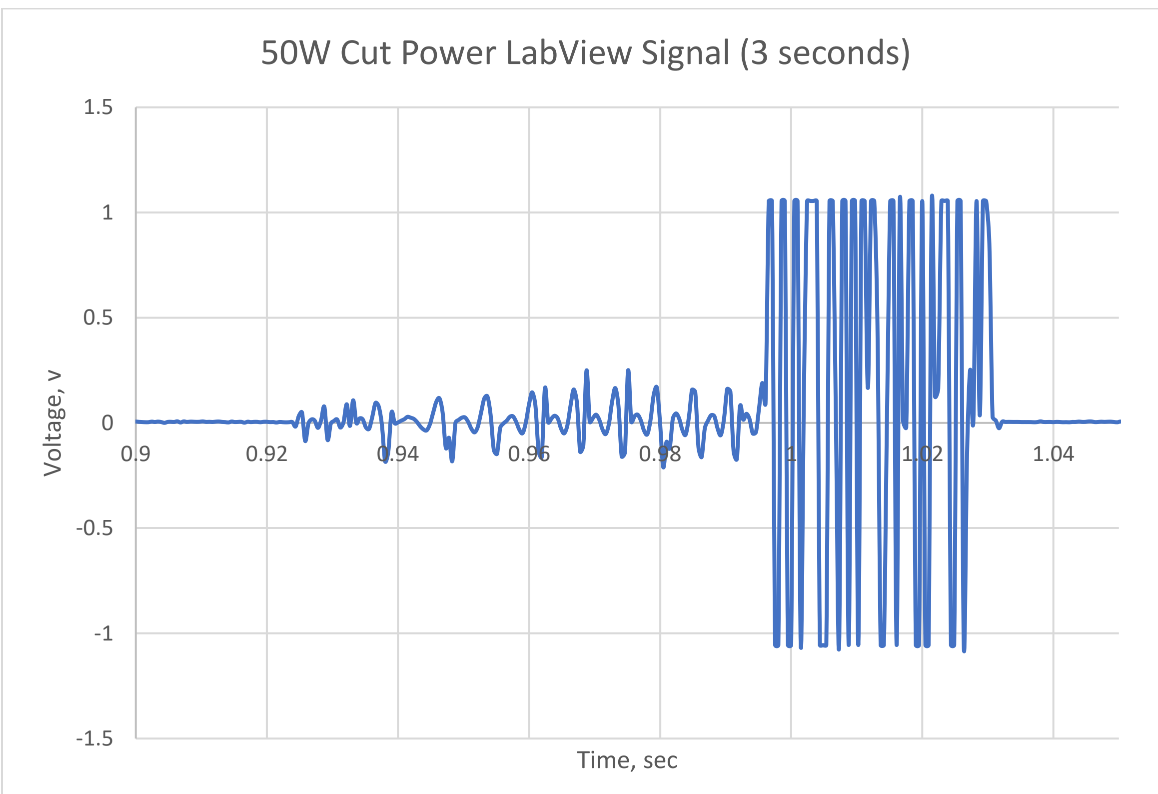

Figure 4. 37: Selected portion of the Voltage Intensity at 3 seconds

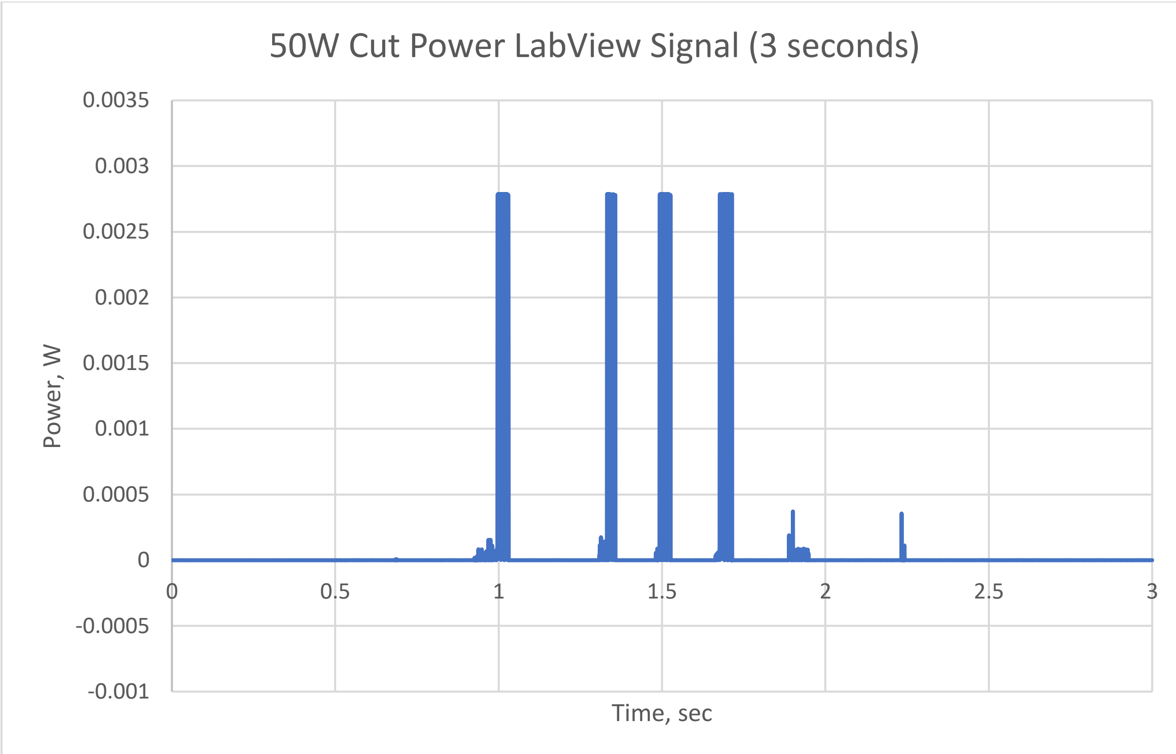

Figure 4. 38: Signal Intensity of Power measurement at 3 seconds

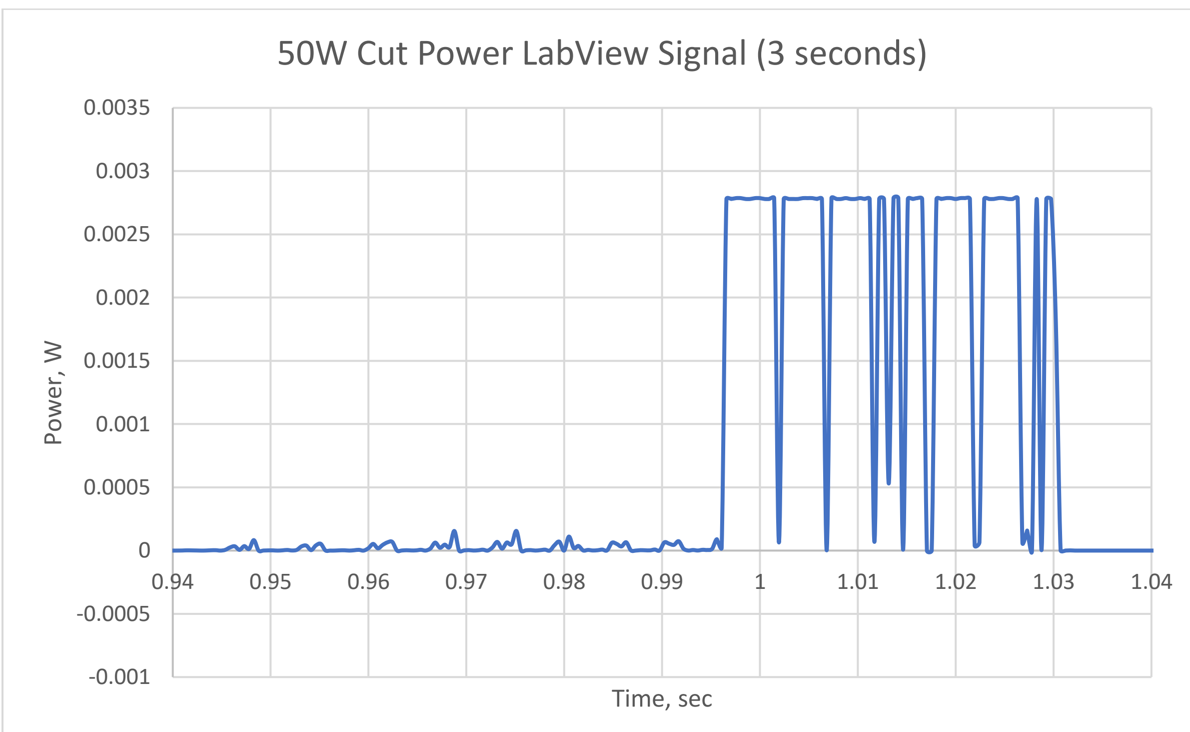

Figure 4. 39: Selected portion of the Power Intensity at 3 seconds

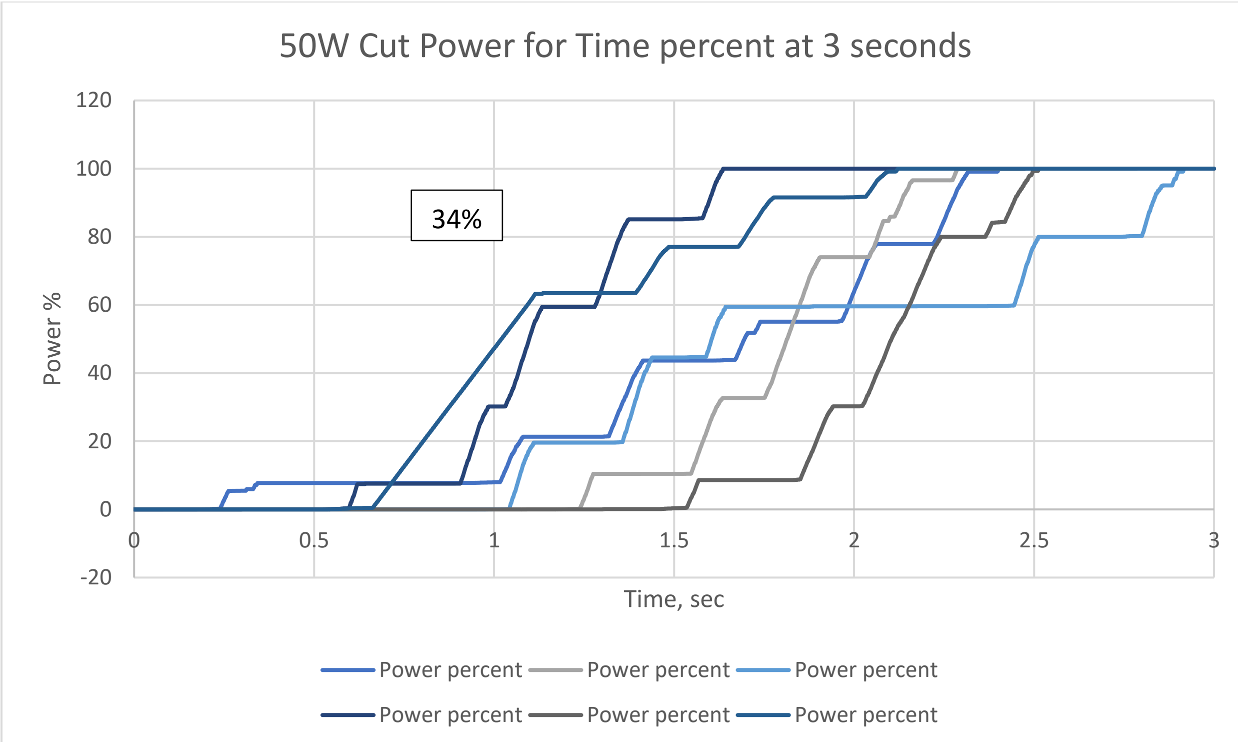

Figure 4. 40: Signal Intensity for Time percent at 3 seconds

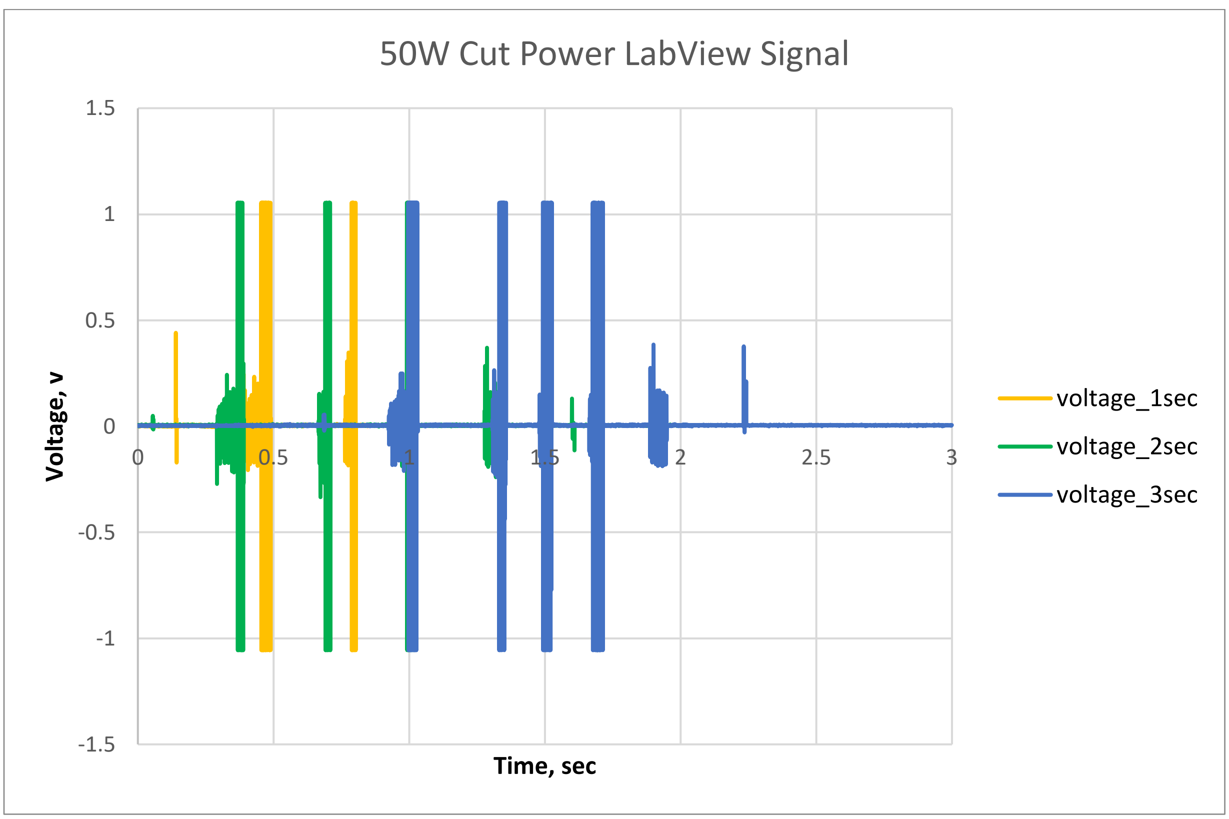

Figure 4. 41: Signal Intensity of Voltage measurement for 1, 2, and 3 seconds

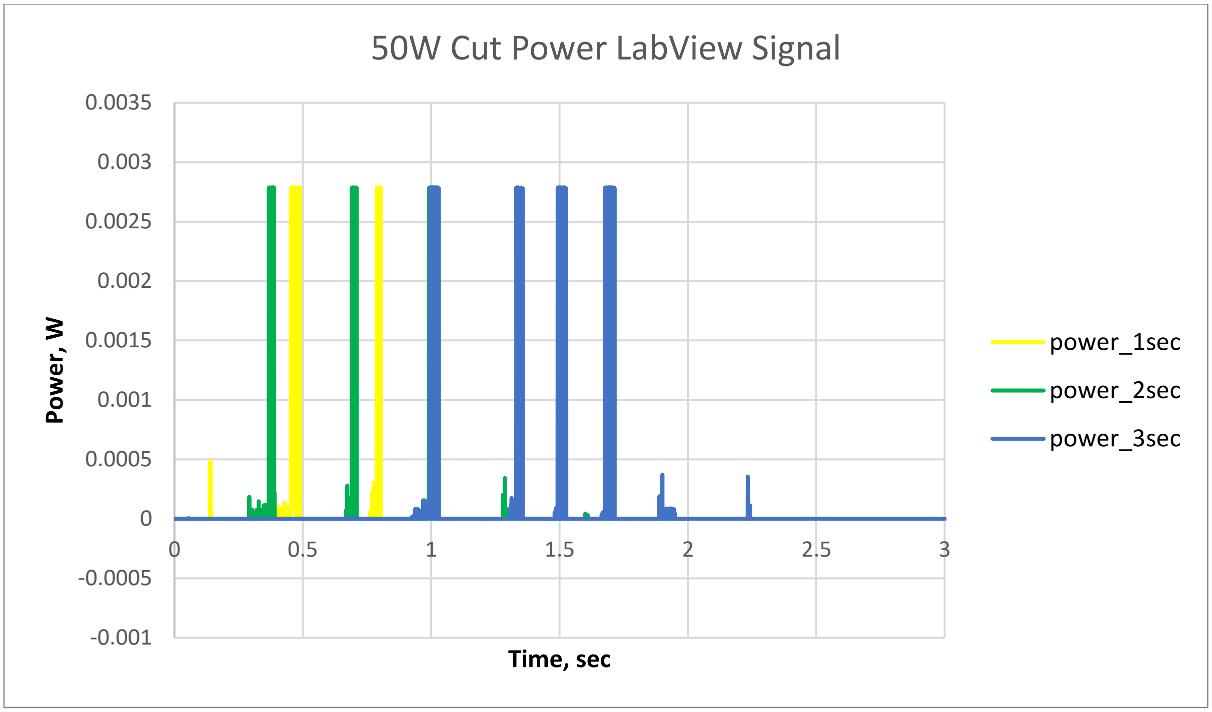

Figure 4. 42: Signal Intensity of Power measurement for 1, 2, and 3 seconds

Based on the voltage measurement for the three different time series (1, 2, and 3 seconds), as shown in Figure 4.26, 4.27, 4.30, 4.31, 4.34, and 4.35. The intensities experienced by 1-, 2-, and 3-seconds voltage measurements are 2, 3, and 4 signal peaks, respectively. This shows an increase in the intensity as the timing increases.

Likewise, Figure 4.28, 4.29, 4.32, 4.33, 4.36, and 4.37 gives the power measurement for the time series showing the intensities increment with the timing.

From the power output (P = V^2/R_T), R_T is the total resistance of the 600Ω and 1.2kΩ connection in parallel.

At 1 second firing, the signal experienced two signals intensity, with the first at approximately 50% at a power output of 0.2W while the second which is 100% at 0.4W, as shown in Figure 4.29.

At 2 seconds of firing, the signal experienced different intensities, with the highest cumulated power at 2.19W and 4.14W for 100% power percent for 2 and 3 seconds, respectively.

4.9 Power Control

The power control is based on getting the correct power output from the electrosurgical device so that it can be controlled to prevent patient complication and enhances the operator's judgment. The firing is done with the timing series from the Arduino for 1, 2, and 3 seconds. The response was obtained from the LabView based on the amplitude (voltage). The power calculation was based on the RRC circuit, which mimics the human body. The cumulative signal of power output was obtained for the different firing times. Then, the power control was identified with the comparison method based on different percentage of power output on the polyps and largely dependent on the firing time of the electrosurgical devices.

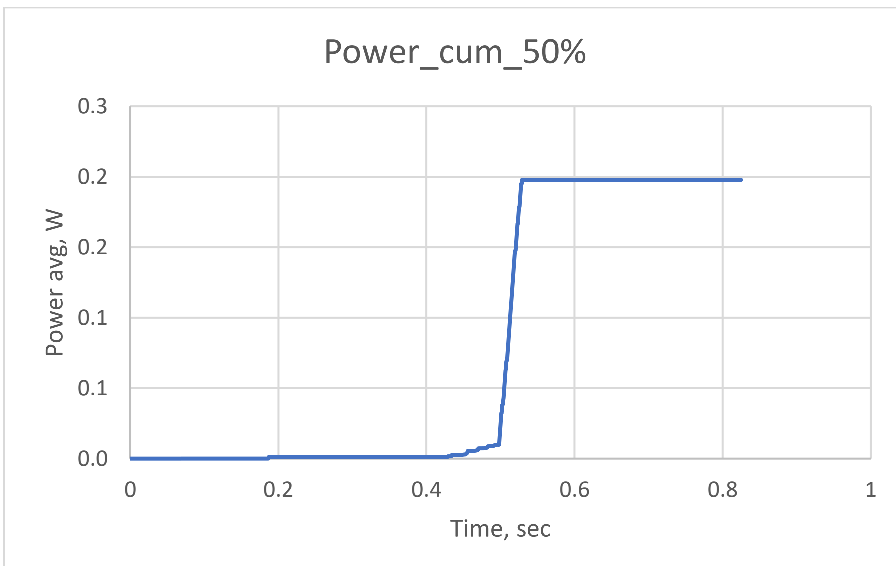

Figure 4. 43: Power control at 50% for 1 second of 50W Cut mode

The feedback signal of the voltage shows 1.05v with a cumulative power at 0.4W (100%) for a second 50W cut mode which shows that the firing interception is at 0.2W (50%). This is shown in Figure 4.43.

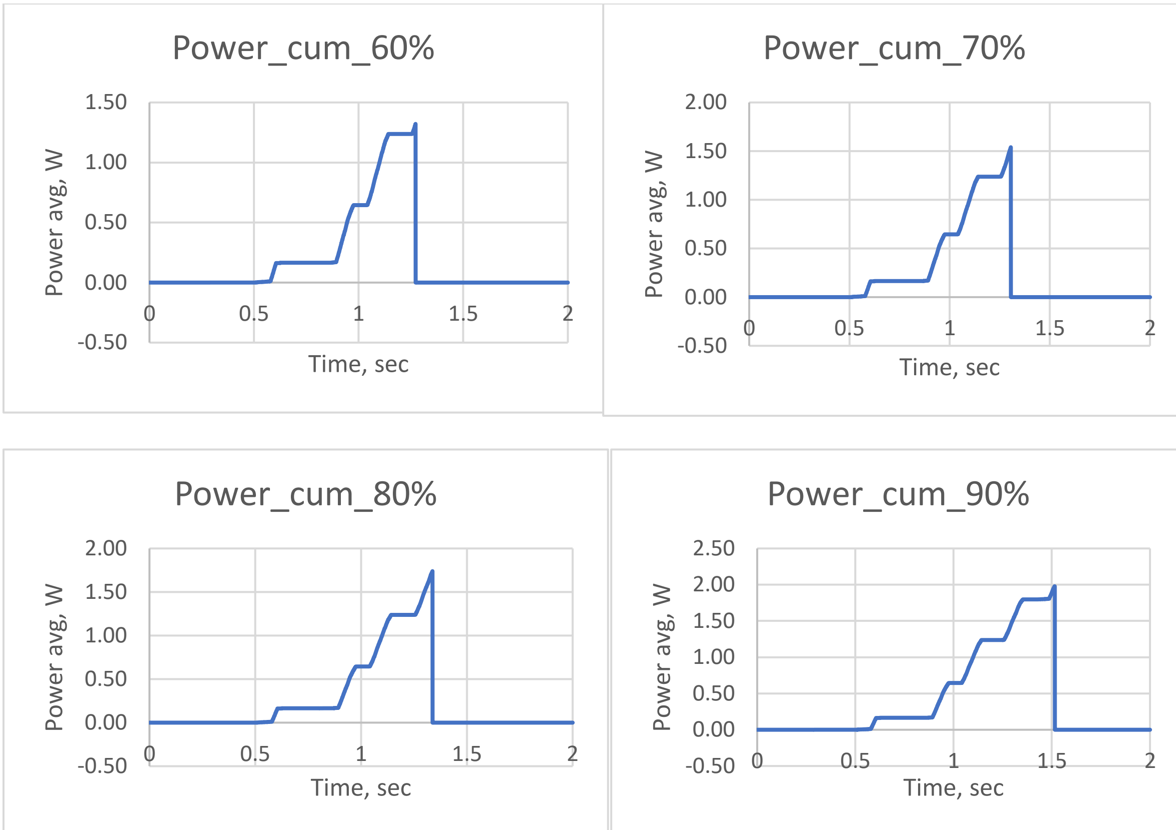

Figure 4. 44: Power control for 2 seconds at 50W Cut mode

The power measured for 2 seconds shows different power control of 60%, 70%, 80%, and 90% at 1.31W, 1.49W, 1.70W, and 1.95W, respectively. This shows an increase in the intensity of the power cumulated based on the power control. The average power is 2.19W, as shown in Figure 4.44

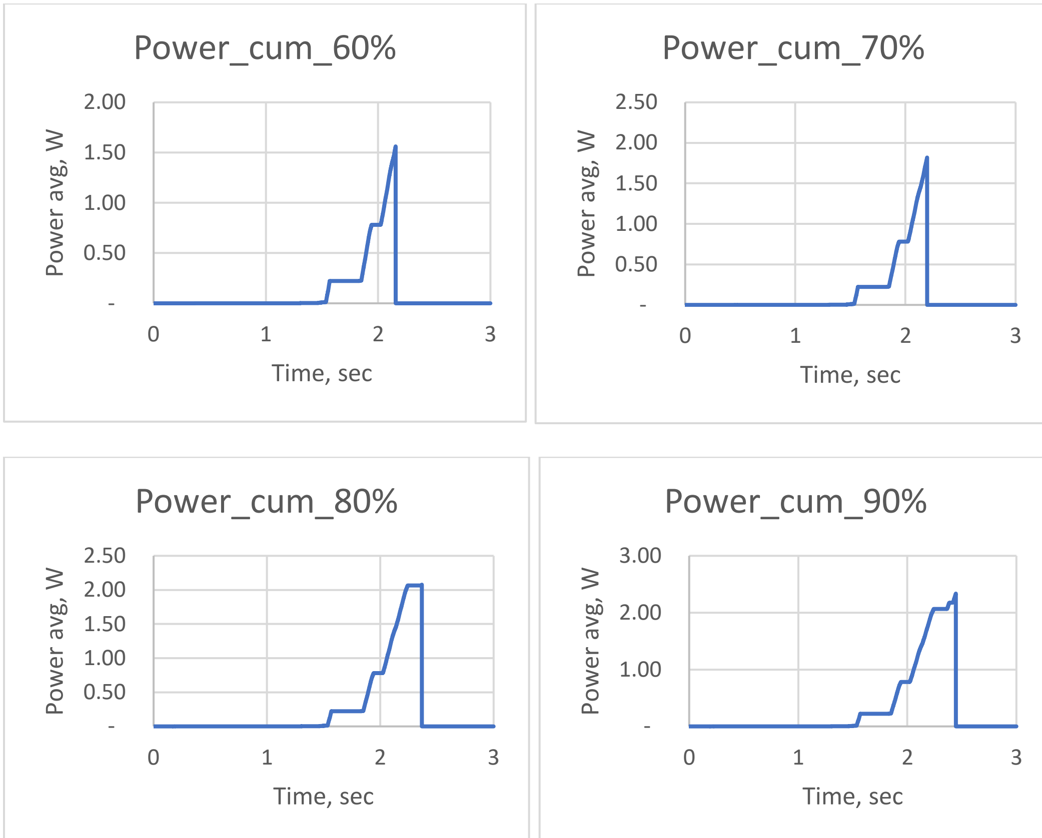

Figure 4. 45: Power control for 3 seconds at 50W Cut mode

Figure 4.45 shows a power measured for the 3 seconds with control at 60%, 70%, 80% and 90% with 1.56W, 1.82W, 2.08W and 2.34W. The average power is 2.74W experienced at 50W cut power for 3 seconds. This shows that the increase in polyp will determine the power control of the Electrosurgical Unit.

	1sec	2sec	3sec
Power Average (W)	0.393947	2.04385	3.018509
Power Standard Dev (W)	0.065388	0.845216	0.898931
Power max (W)	0.492668	3.57434	4.441914
Power min (W)	0.273431	0.73457	1.850638

Table 4.1: The average power for the 50W Cut mode of ESU

CHAPTER 5

5.1 CONCLUSION

The experiment was performed in three different methods to compare the results and confirm the signal effect for the Electrosurgical Unit for the cut mode (pure, blend1, and blend2) and the coagulation mode (soft, autostop, and forced).

The first trial performed was the setup where the Electrosurgical Unit was fired using a stopwatch for the time series of 1, 2, and 3 seconds. The measurement was obtained using an oscilloscope to measure the voltage and an output power device to measure the power from the electrosurgical device. There is a significant increase in the power output from the electrosurgical device, which is dependent on the timing of the footswitch. The output power increases as the cut mode power and timing increase. The signal shows fluctuation in the output power obtained, which is due to the limited control on the external stopwatch creating certain inconsistencies in the measurement. The positivity is the fact that the power output increase and the voltage decrease as the cut mode power and time increase.

Due to the uncertainty in the first trial, an improvement was made to remove the uncertainty and better the power output and voltage results. This led to the second trial, where an Arduino was developed to control the timing of the footswitch to improve the accuracy of the signal. The firing was performed using the Arduino Uno designed to manage the timing of the sequence for three different times (1, 2, and 3 seconds). This was performed for the cut and coagulation mode while measuring the output power and voltage with the power measuring device and oscilloscope, respectively. It was observed that the pure cutting mode shows the highest voltage at the least time is 267.1mV when compared to blend1 and blend2, which shows the reason it is used for quick cutting. The blend2 shows the highest voltage at the maximum time of 3 seconds at 1332.1mV, which explains why it can cut and coagulate. While for the coagulation mode, the three coagulation mode experiences high voltage at the 2W coagulation mode power, which explained that the setting for coagulation should be set at a minimum of 5W coagulation mode power to avoid the high current since soft coagulation is recommended for stopping of light bleeding. Likewise, the soft and autostop show similar traits.

Based on the manufacturer specification for Electrosurgical Unit (PSD-30 Olympus) used for this experiment; for the cutting mode, the pure cut is used for quick cutting, blend1 cut is for moderate cutting and hemostasis, while blend2 cut is used for cutting with coagulation ability. While for the coagulation mode, soft coagulation is used to stop light bleeding, autostop is used to reduce tissue carbonization, and forced coagulation is for strong coagulation and hemostasis.

The type of power output released by the Electrosurgical Unit is very important to the surgeon, with the controlled variables increasing with the mode power setting from the PSD-30. There are different Electrosurgical Units with several waveform modes for the cutting and coagulation modes. But there is no standardized method, but it depends on the manufacturers. For this experiment, the PSD-30 Olympus was used for the experiment. The same experiment applies to other devices with different waveforms to be achieved for the cut and coagulation mode.

The experiment is to modulate the waveform by halting the current flow in which tissue gets an opportunity to cool and the part of cells that desiccate without detonating. By adjusting the duty cycle with voltage increases, the waveform will anticipate tissue impacts which lead to coagulation depth, thereby leading to hemostasis. A constant wave has a 100 percent obligation cycle and is frequently called cut. On the other hand, a current of a fraction of the time and rest with off time has a 50 % duty cycle. At the same time, 20 - 80 % duty cycle refers to blend cut. The crest factor is used in this analysis because it gives better results and understanding of the process. The power control was performed for the cut mode at 50W to understand the firing time concerning the power output in which at 1 second, the power output is 0.4W. While 2.19W and 4.14W for 2 and 3 seconds for the 50W cut mode of the electrosurgical devices. This provides a limit for the operator in better understanding the operation of the device, which is also typically dependent on the polyps’ size, which is not considered in this research.

Every manufacturer has suggested settings for the power mode, but it is noticeable that the selected watt may differ from the output signal given by the Electrosurgical Units, and adjustment relies on the experience and preferences of the operator.

The operator has a lot of influence on the accessories type, settings of the power mode, and the time series to be used, which determine the current flow. The time is the only variable controlled by the operator which determines the amount of heat generated.

5.2 Limitations and Future Plans

The limitation of the experiment is the fluctuation experienced in the power output device of the Electrosurgical Unit, which is due to the electrical point on the wall socket. If this can be managed or the fluctuation reduced to the barest, then the output power will be stable. For future work, improving on the measuring methods and device while verifying with an organ, especially the coagulation mode, which shows drastic voltage drop. Likewise, the polyp size was not considered in this research.

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APPENDIX A

Arduino Code for Timing Series

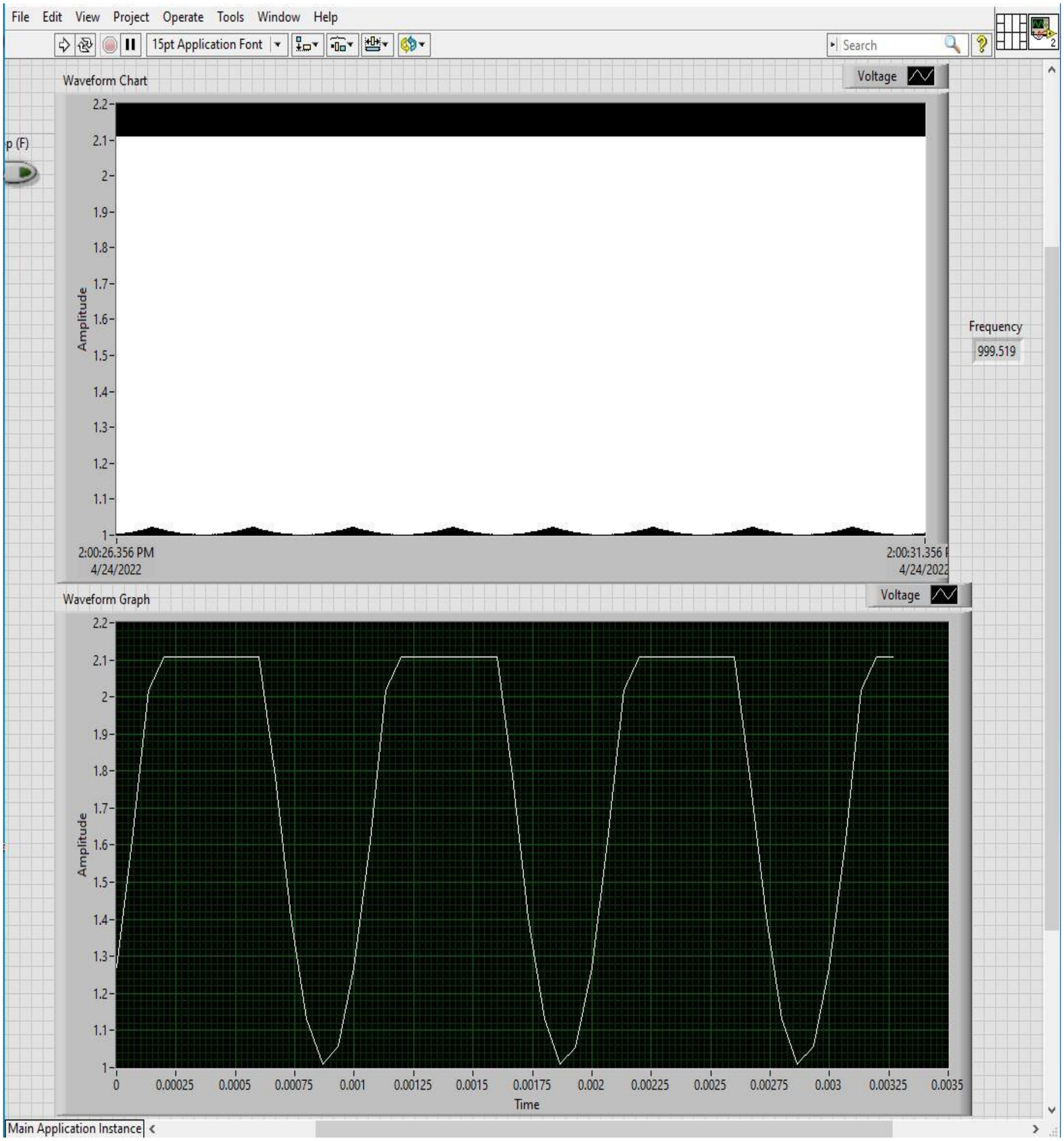
```
const int BUTTON1 = 6;
const int BUTTON2 = 5;
const int BUTTON3 =4;
const int LED1 = 8;
const int LED2 = 9;
const int LED3 = 10;
int BUTTONstate1 = 0;
int BUTTONstate2 = 0;
int BUTTONstate3 = 0;

void setup() {
  // put your setup code here, to run once:
  pinMode(BUTTON1, INPUT);
  pinMode(BUTTON2, INPUT);
  pinMode(BUTTON3, INPUT);
  pinMode(LED1, OUTPUT);
  pinMode(LED2, OUTPUT);
  pinMode(LED3, OUTPUT);
}
void loop() {
  BUTTONstate1 = digitalRead(BUTTON1);
  if (digitalRead(BUTTON1))
  {
    digitalWrite(LED1, digitalRead(BUTTON1));
    delay(1000);
    }
    digitalWrite(LED1, 0);
    delay(0);
```

```
BUTTONstate2 = digitalRead(BUTTON2);
if (digitalRead(BUTTON2))
{
  digitalWrite(LED2, digitalRead(BUTTON2));
  delay(2000);
  }
  digitalWrite(LED2, 0);
  delay(0);
BUTTONstate3 = digitalRead(BUTTON3);
if (digitalRead(BUTTON3))
{
  digitalWrite(LED3, digitalRead(BUTTON3));
  delay(3000);
  }
  digitalWrite(LED3, 0);
  delay(0);
}
```

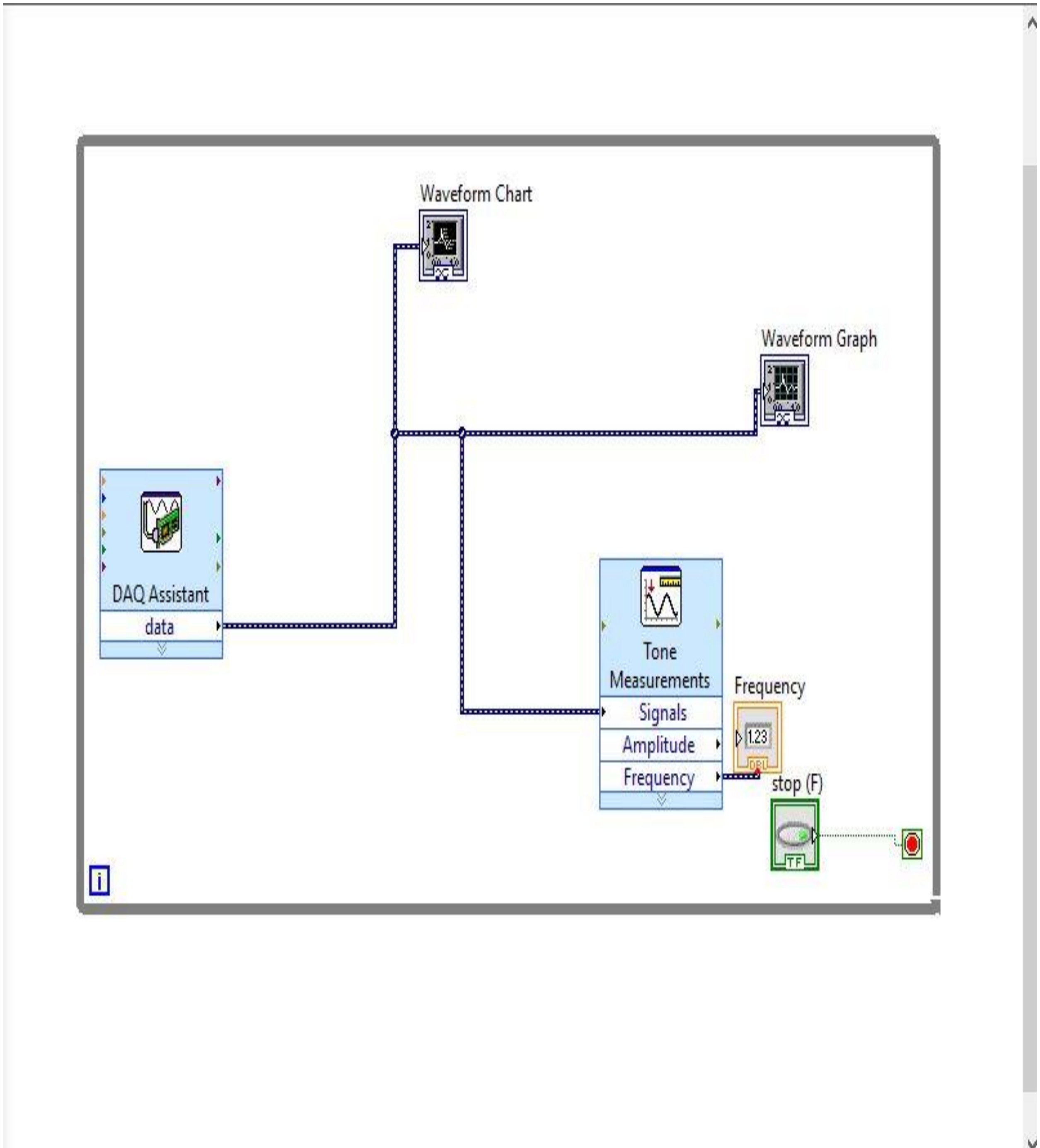
APPENDIX B

LabView VI and Block Diagram



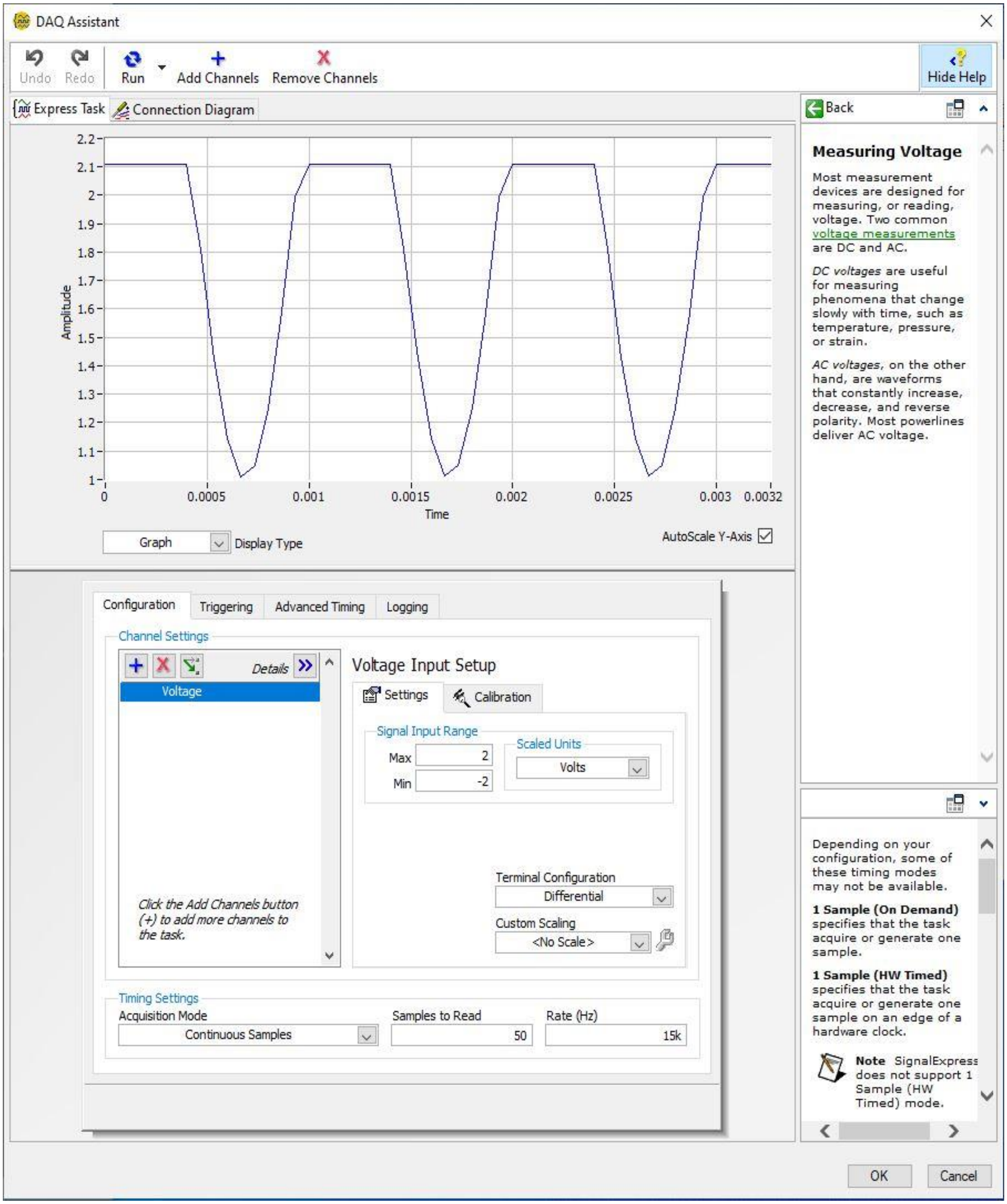
APPENDIX C

LabView Virtual Instrument Block Diagram



APPENDIX D

LabView DAQ Assistant and Configuration Setup



APPENDIX E

LabView DAQ Assistant Pin Connect for ADC Converter