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Design of Automatic Power measuring Electrosurgical Unit

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Abstract:

Even after the introduction of Electrosurgery a hundred years ago, very few electrosurgical units (ESU) were able to measure and regulate the power delivered to the body. Normally surgeries are performed for specific applications based on the output power delivered from ESU to human body.This paper presents the design of an ESU which can automatically measure the power and stops the system once it exceeds the acceptable range of power. This approach will help to reduce the damage caused to the biological tissue since power is monitored continuously. The role of analyser will be decreased to some extent as the device itself can monitor power. Proper regulation of power is required to produce the desired results. The model is designed and simulated to ensure the working of the circuit. Simulation results show that power is monitored continuously and once it exceeds the acceptable range, the system will go for a complete shutdown thereby indicating variation.The above mentionedactionisperformedwiththehelpofmotor.

Keywords: *Buck converter, Electrosurgery,Inverter,Medical equipment,Radio frequency current*

I. INTRODUCTION

Electrosurgical units (ESU) are a category of medicalequip- ment used in operation theatres and also the most common and useful piece of instrument used by surgeons while performing surgery. They differ from Electrocautery unit where cutting and coagulation is performed by two piece of instrument. Also known as surgical diathermy, the treatment method involves the utilisation of heat produced as a result of the application of high-frequency AC to biological tissue. This high -frequency current allows to cut and coagulate tissue while minimizing blood loss. A high-frequency AC could overcome the effects of muscle and nerve stimulation[1]. At present ESUs use frequency ranges of 200 000Hz to 5 000 000Hz to have proper muscle stimulation. As this frequency lies in the range of AM radio waves, they are referred to as radiofrequency current or RF current. Modification of AC waves is complex and hence a DC source is used as the input source which then generates AC with the required frequency. High-frequency AC is passed from the active electrode to the body in order to heat tissues with minimum neuromuscular stimulation. An ESU has two modes of operation namely Bipolar and Monopolar modes. In Monopolar mode, the electrical current flows through the human body whilst in bipolar mode, the current flows from one side to other through the tissue held between the forceps [2].The frequency of radio waves applied may vary depending on the purpose which may be cardio vascular surgery, thoracicsurgery, gynaecology etc. In some case, the desired result may be the fusion of tissue and in other, it may be the disruption of tissues[3]. Sometimes the exposure of high frequency current to the tissue may lead to its damage. The main goal of an electrosurgery unit is the minimization of these tissue burns which is dependent on the performance of the equipment [4]. The parameter which directly controls the tissue burns of an ESU unit is the output power.Normally ESU manufacturers have methods for regulating power.

The power is usually measured with the help of analyser which consists of complex circuits and not easily portable.They utilize AC power delivered from the equipment for heating of tissue. All ESUs are programmed to deliver power in watts which is the product of 1V and 1A[5]. Mainly surgeries are accomplished by delivering power from the ESU to the specified body part.The power for these surgeries range from tens tohundreds of watts. Optimum output power is set for each tissue typethat needs to be regulated. Regular performance and safety tests need to be done for maintaining the equipment. Any change in output power can change the whole application which leads to undesired effects[6]. In one of the existing technique, AC output power is measured and averaged over several cycles, the duty cycle of a PWM is adjusted over several cycles using low bandwidth control loop. This logic seemed to be complex due to its slow regulation during arcing and poor regulation of ac output power[7]. Due to this slow dynamic response, power was regulated imperfectly resulting in undesirable tissue damage and heating.In another technique power is regulated around a setpoint adjusted in the equipment panel[8].However they actually do not measure the active power and also disregard the energy delivered to tissue.This may unnecessarily causes additional burns to tissue causing injury. Instead, this paper proposes a system where a dual current mode control system produces constant power output [9]. The controller displays the ability to adjust current and voltage limits thus helping in more precise control of tissue effect. Also, the system produces constant power output without the need to measure the output voltage and current. A buck converter along with inverter topology making use of the IGBT device is applied here. The proposed system is made advanced by making ESU measure and regulate the output power using a motor automatically. By measuring the speed ofthemotorattachedattheloadandprovidingfeedback,t he whole system can be controlled by preventing the system from working, once it exceeds the normal range of power.

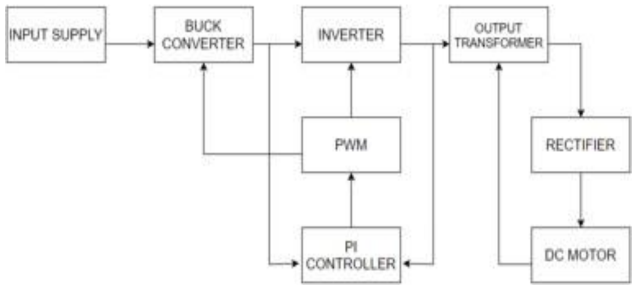

Fig. 1. Design blocks of new model ESU

II. TOOLS

A. Matlab

The well-known and widely distributed MATLAB SIMULINK software is used for simulation.MATLAB has SIMULINK as its graphical programming platform for modelling, simulating and analysing various dynamic system. Here the required system is modelled and then simulated to understand the dynamic behaviour of the system.

III. DESIGN ANDDEVELOPMENT

The end goal is to make a system where power is monitored continuously. To achieve this goal certain topologies like a buck converter, inverter, triggering circuits are used.Thenewly developed ESU consists of 6 stages as illustrated in Fig.1. The role of a (Pulse Width Modulation)PWM generator and the PI controller is to drive the buck converter and inverter. They act as triggering circuits. The inverted output from the inverter is given to transformer for stepdown. The rectifier converts the AC to DC for giving input to the motor. The purpose of DC motor after the transformer is to control the power output as well as the system if it exceeds the normal acceptabl erange.

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A. Buckconverter

A class of SMPS with atleast two semiconductor and one energy storage element like inductor or capacitor or both.It usually stepdown voltage while stepping up current from its input(supply) to output(load).Mainly they have two configurations such as ON state and OFF state[10].The two switches namely transistor and diode controls the current in the inductor.In ON state,switch and diode have zero voltage drop whereas in OFF state they have zero current flow.It is assumed that input and output voltage does not change over acourse ofcycle.

B. Single phaseInverter

An Inverter is a circuit that converts DC to AC at desired output voltage and frequency. The conversion is achieved using controlled turn ON and OFF device like IGBT(Insulated gate bipolar transistor).The circuit of a single phase unipolar inverter consists of 4 IGBTs arranged in bridge form.IGBTs are triggered continuously using pulses from PWM[11].When supply is given,two IGBTs will be turned on after the gate is being triggered by pulses. As a result current starts flowing frompositiveofsupply2IGBTs,loadandnegativeofsupply.In the next phase the other two IGBTs are turned ON after the gate is triggered by the pulses.The direction of current starts from IGBTs,load and to the negative of the supply.These two cycles continue and positive and negative voltage is applied at the load which changes the current direction.As a result of change in current direction,alternating voltage is obtained at the load thus converting DC voltage to AC voltage.

C. PWM

The average power delivered by an electrical signal will be reduced by chopping it into discrete parts[12].They directly controls the buck converter and inverter by continously giving pulses.Average value of voltage and current fed to load is controlled by turning the switch connected between load and supply ON and OFF at a faster rate.The switching frequency has to be high enough to not affect the load.

D. PIcontroller

A PI controller is a feedback control loop that calculates an error signal between the output and the set point of the system by taking difference.It also plays a major role in controlling the convertor andinverter.

E. Rectifier andMotor

The role of a rectifier is to convert the AC to DC. The converted values will be given to DC motor. Once the output power value exceeds the acceptable range, the system will go for a shutdown which is controlled by the DC motor. A circuit breaker attached to the motor helps in stopping the system if power is exceeded.

IV. Circuit Model

Fig.2 shows the converter and inverter part along with the triggering circuit as well as the output transformer. An input DC supply provides sufficient voltage for the system to work efficiently. This input voltage is given to a DC to DC buck converter which stepdown the voltage. The next stage of the circuit is a single-phase inverter, where the DC gets converted to AC voltage. Since the whole system requires AC as output this stage is essential. The output from the inverter is given to the output transformer where the voltage is stepdown. The output will be an AC from the transformer. The output power will be measured with the help of scope setup available in SIMULINK.In order to drive the buck converter as well as the inverter, triggering circuits are used. A PWM and a PI controller is used as the triggering circuit for providing continuouspulsestoconverterandinverter.

Fig.3 shows the output part where power is monitored. A DC motor is shown along with a breaker to make the system inactive once the power exceeds the acceptable range. Nowthe obtained output power is measured with the help of scope setup in SIMULINK. Once the power value exceeds

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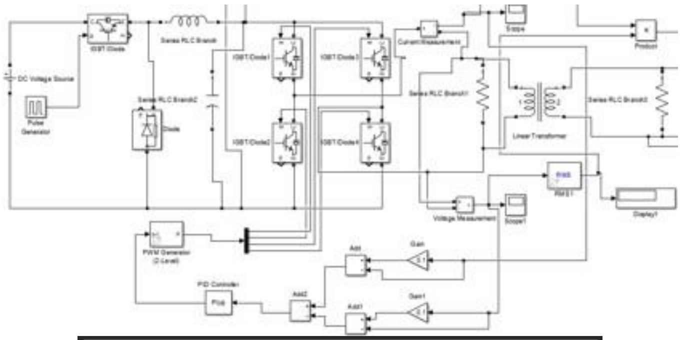

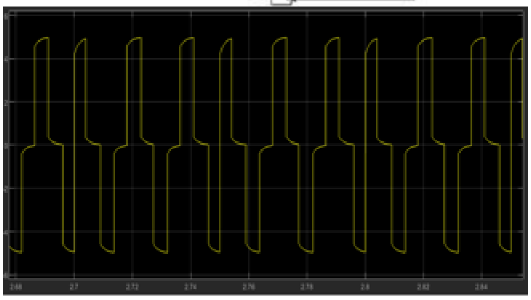

Fig. 2. Converter blocks

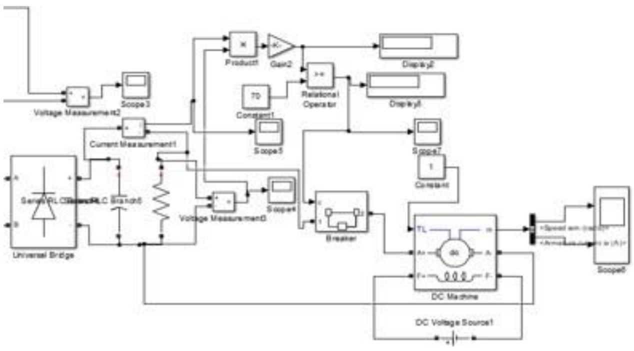

Fig. 3. Monitoring blocks

the acceptable range, the DC motor will come into action. The AC output will be converted to DC with the help of rectifier. The converted output from the rectifier will be supplied to the DC motor. A circuit breaker is attached to the motor which helps the system to shut down whenever required. When the power value deviates from its acceptable range, the breaker will be active and cutoff the load thereby stopping the system. This indicates that power is varied and should be subjected to calibration.

V. Results and Discussion

The circuit design of the system is described in Fig.2 and Fig.3 and the behaviour model is implemented using SIMULINK in MATLAB. SIMULINK models are block dia- gram consisting of source, sink and various functional models of a dynamicsystem.

A. Output after converter and inverter stage

Fig.4 and Fig.5 shows the variation of current and voltage with respect to time.It shows waveform from the inverter in constant power mode which delivers 50W to a resistor. Here even if we change the load value the product of current and voltage remains the same, resulting in constant power mode. For 76 load,Vrms=64.5, Irms=0.811 resulting in 52.3W power For 125 load, Vrms=79.5,Irms=0.658 resulting in 52.3W power.

Fig. 4. Output currentwaveform

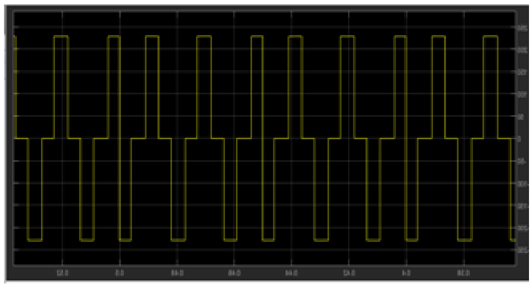

Fig. 5. Output voltagewaveform

B. Transformeroutput

A 60 Hz transformer with turn ratio 2:1 was used toobtain the desired AC output as shown in the Fig.6.Input to the transformer is a square wave and hence the output willalso be a square wave.A sinusoidal voltage is induced at the secondary of the transformer in response to the sinusoidal input.The output waveform that shows relationship of voltage with respect to time is shown in Fig.6 is obtained as a result of its summation. The frequency and shape of the output will bethesameastheinput.

C. Relationship between speed andcurrent

Fig.7 illustrates the relationship between speed and armature current of the DC motor.The top line indicates the armature current and the bottom line indicates the speed of the motor.As we know, power is expressed as the product of voltage and current.Since the voltage is constant, power can directly be related to the current.The speed of

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the DC motor is measured and is controlled with the help of current.A particular threshold value is set for armature current based on the power.Once this value of current exceeds the threshold value,the breaker attached to the motor comes into action and stops the system from working thus preventing it from exceeding its threshold value.The increasing of current indicates an increase in power value.Thus from the graph
,it can be observed that after an overshoot is formed,the speed went back to zero.The speed is shown as negative to show the impact of reverse voltage formed when the system stops working.This indicates that once the current exceeds

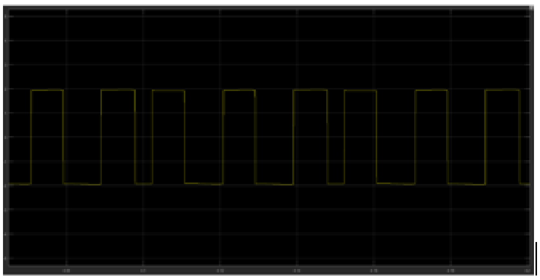

Fig. 6. Output AC

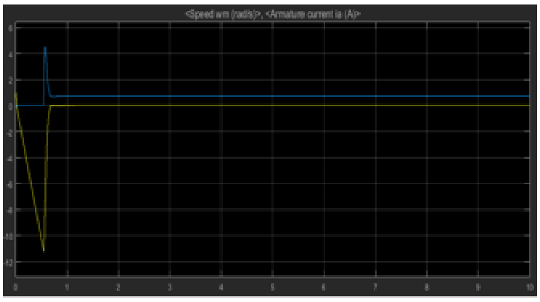

Fig. 7. Motor output waveform

a particular threshold value,the system will automatically stop.

VI. Conclusions

In this research, an ESU circuit with the ability to check power automatically is proposed. Proper regulation of ESU's output power is important for achieving the required clinical results. To verify the proposed model, a design was made and simulated in MATLAB with the help of SIMULINK. The results of the simulated experiment shows that the proposed design is able to meet the required target and also able to perform with high efficiency. As the power gets increased DC motor comes into action which makes the system to automatically shutdown indicating a variation in power. This replaces the role of the analyser and helps to test power without it. Once the system goes for a shutdown, it can be subjected to calibration for making power values in the appro- priate range. Also, the system combines current mode control and voltage mode control thus obtaining the desired output. The next step in this research is to develop hardware using the proposed design. The simulation of the designed circuit will be implemented using hardware. The performance of the hardware is expected to improve using the newly developed technique and also able to detect any power variation.

References

[1] Vilos and C. Rajakumar,"Electrosurgical Generators and Monopolar and Bipolar Electrosurgery", Journal of Minimally Invasive Gynecology, vol. 20, no. 3, pp. 279-287, 2013.

[2] NasimUllah, M. Rafiq, M. Ishfaq, M. Ali, A. Ibeas and J. Herrera, "A closed loop robust control system for electrosurgical generators", Control Applications for Biomedical Engineering Systems, pp. 149-168, 2020.

[3] A.Idham alzaidi, A. Yahya, T. Tian Swee and N. Idris, "Development of high frequency generator for bipolar electrosurgical unit",International Journal of Engineering Technology, vol. 7, no. 229, p. 20, 2018..

[4] A.Monteiro, K. Grande, R. Faria and B. Schneider Junior, "A simple approach to calculate active power of electrosurgical units", Research onBiomedicalEngineering,vol.32,no.1,pp.14-27,2016.

[5] Belik, I. Kustov, K. Belik and A. Shekalov, "Correction of the Output Parameters of an Electrosurgical Unit for Minimizing Thermal Damage to Tissues", Biomedical Engineering,

vol. 51, no. 4, pp. 258-261, 2017.

[6] Belik, A. Shekalov, N. Dmitriyev, S. Bogavev and K. Dornhopf, ”Development of Radio-Frequency Electrosurgical Unit EHVCh-1.76”, 2018 XIV International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), 2018.

[7] R. Thompson, “Electrosurgical generator and method with voltage and frequency regulated high-voltage current mode power supply,” U.S.Patent6939347,Sep.6,2005.

[8] J. Dums, B. Schneider Junior and A. Badin, ”Low cost system to measure active power in electrosurgical units”, Research on Biomedical Engineering,vol.33,no.4,pp.313-323,2017.

[9] D. Friedrichs, R. Erickson and J. Gilbert, ”A New Dual Current-Mode Controller Improves Power Regulation in Electrosurgical Generators”, IEEE Transactions on Biomedical Circuits and Systems, vol. 6, no. 1, pp. 39-44,2012.

[10] K. Khan and A. Vijayakumari, ”A dual mode control for bridgeless SEPIC power factor correction rectifier”, 2016 International Conference onEmergingTechnologicalTrends(ICETT),2016.

[11] N. Geetha, S. Parvathy and K. Thampatty, ”Output voltage regulation of controlled rectifiers using feedback linearization control algorithm”, 2017 IEEE International Conference on Signal Processing, Informatics, CommunicationandEnergySystems(SPICES),2017.

[12] N. Sanajit and W. Meesrisuk,”A High-Frequency PWM Half-Bridge Inverter for Electrosurgical Cutting Applications”, 2018 21st International Conference on Electrical Machines and Systems (ICEMS), 2018.