플라이백방식의 충·방전 제어기법을 적용한 경두개 자기자극장치

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Transcranial Magnetic Stimulation with repetive charge-discharge ability flyback

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요 약

자기 자극장치 펄스트레인 기술이 비연속 전도모드에서 플라이백 컨버터로 응용되는 방식을 제안 하고자 한다. 전통적인 펄스폭 제어 방식과는 달리, 자기 자극 펄스 트레인의 주요한 방식은 저전력과 고전력에서 출력전압조절로 구할 수가 있다. 제안한 기술은 불연속 유도에 있는 어떤 변환기에도 적용 가능하다. 그러나, 본 연구에서는 Flyback 연구에 주로 초점을 맞추었다. 본 논문에서, 새로운 제어 연산 논리의 주요 수학 개념은 실험적인 결과가 산출되어 소개 하고자 한다.

ABSTRACT

In this study, A Magnetic stimulation Pulse Train control technique is introduced and applied to Flyback converter operating in discontinuous conduction mode . In contrast to the conventional pulse width modulation control scheme, the principal idea of a Magnetic stimulation Pulse Train is to achieve output voltage regulation using high and low power pulses. The proposed technique is applicable to any converter operating in discontinuous conduction . However, this work mainly focuses on Flyback topology. In this paper, the main mathematical concept of the new control algorithm is introduced and simulations as well as experimental results are presented.

키워드 자기자극장치 (magnetic stimulation), 플라이백 컨버터(flyback), 불연속(discontinuous), 전계(electric feild)

I. INTRODUCTION

The use of non-invasive neuro-imaging has increased explosively in recent years. Details of the functioning of the human brain are revealed by measuring electromagnetic fields outside the head or metabolic and hemodynamic changes using electroence phalography (EEG), magnetoence phalography (MEG), positron emission tomography (PET), near-infrared spectroscopy (NIRS) or functional magnetic resonance imaging (fMRI). This thesis deals with transcranial magnetic brain stimulation (TMS), which is a direct way of manipulating and interfering with the function of the cortex, thus complementing conventional neuroimaging. For this power level the most suitable isolated topology is the flyback converter.

These converters can provide either single or multiple outputs. Flyback converters are more suitable than forward converters for relatively low power levels because Block diagram of magnetic stimulation as shown in Fig 1. Their relative simplicity results from the elimination of the output inductor and freewheel diode that would be present in the secondary stage of a forward converter. The energy acquired by the transformer during the on−time of the primary IGBT is delivered to the output in the non−conducting period of the primary switch.

The secondary winding is connected with reverse polarity, so there can be no current flow to the output, due to the blocking diode. Since the number of semiconductor and magnetic components of Flyback converter is less than the other SMPS and, furthermore, it providesinput/output isolation; therefore, this topology perfectly suits off−line low−cost power supply applications. Critical conduction mode enjoys benefits such as zero current turn−on of the switch and zero current turn−off of the freewheeling diode.

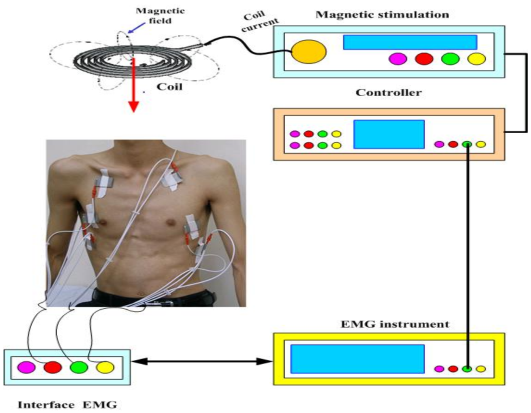

Fig. 1 Block diagram of magnetic stimulation

Dynamic response compared with pulse width modulation method, but also improves the efficiency by lowering the switch turn−on loss at the end of each power pulse based on choosing the right turn−on time instant. The required information for this action is provided from the measured signals of the converter during the sense pulses. From a Transcranial Magnetic Stimulation Pulse Train is simple, cost effective, and robust against the variations of the parameters of the converter. A method that shows some similarity to a Transcranial Magnetic Stimulation Pulse Train technique was recently introduced with inferior characteristics. To achieve fixed frequency operation, proposes skip cycle modulation, which is basically an on/off control mode to regulate the output voltage.

II. CIRCUIT DESIGN

A Transcranial Magnetic Stimulation Pulse Train control algorithm regulates the output voltage based on the presence and absence of power pulses, rather than employing PWM. Fig 2 depicts the block diagram of a Transcranial Magnetic Stimulation Pulse Train regulation scheme. If the output voltage is higher than the desired level, low−power sense pulses are generated sequentially until the desired voltage level is reached. On the other hand, if the output voltage is lower than the desired level, instead of sense pulses, high−power power *pulses* are generated. The time duration of the power and sense pulses are the same; but, due to the longer on time of the switch during a power pulse, compared to a sense pulse, more power will be delivered to the load. The ratio between the on−time duration of the switch in a power pulse and the on−time

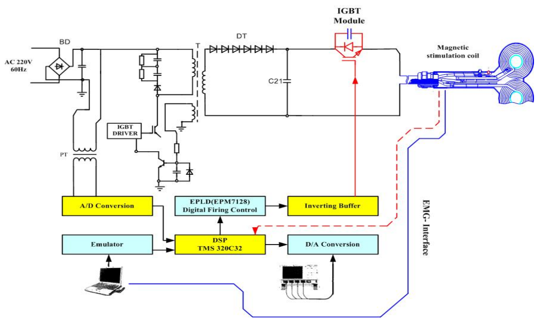

Fig. 2 The concept which it proposes with a flyback converter

duration of the switch in a sense pulse is chosen by making a compromise between the output voltage ripple and the power regulation range from full power to low power. Operating in constant peak current mode control, in a power pulse, the switch remains on and the primary current is allowed to increase until it reaches a designated constant peak level. At this point, the switch turns off and the next cycle starts when the secondary current reaches zero. The controller measures the time duration of the power pulses and makes the subsequent sense pulses to have the same time duration; hence the switching frequency of the converter is fairly constant when the load changes. A Transcranial Magnetic Stimulation Pulse Train enjoys on−line waveform analysis and hence, fast dynamic response. response.

III. HARDARE IMPLEMENTATION

The flyback converter in this circuit is designed to operate in discontinuous operation. To ensure this, the primary inductance Lp needs to be limited to a maximum value. Therefore, the maximum primary inductance for discontinuous conduction at maximum load needs to be determined. The input power is defined as

$$P_{IN} = \frac{P_{OUT}}{\eta} \text{-----------------------}(1)$$

where η is the efficiency of the inductor. The input power can also be defined as the product of the stored energy E in the magnetic field and the switching frequency fs

$$P_{IN} = Ef_s = \frac{L_p I^2_{pk} f_s}{2} \text{------------------}(2)$$

This allows the required primary inductance to be determined, but it is also necessary to know the peak current *Ipk* to be able to calculate this. The peak current is defined by 1.

$$L_{p(\max)} = \frac{V^2_{\in(\max)}\delta^2_{\max}T_s}{2P_{\in(\max)}} \text{------------}(3)$$

where Vin(min) is the minimum supply voltage and ton(max) is the maximum on-time of the switch. Therefore, to limit the primary inductance to ensure discontinuous operation, the maximum inductance is determined, where δmax is the maximum duty cycle and Ts is the PWM switching period. By combining equations (2) and (4) it is possible to determine the maximum primary inductance

$$I_{pk} = \frac{V_{\in(\min)}t_{ON(\max)}}{L_p} \quad \text{---}(4)$$

$$L_{p(\max)} \le \frac{V_{\in(\min)}t_{ON(\max)}}{I_{pk}} = \frac{V_{\in(\max)}}{I_{pk}}\delta_{\max}T_s$$

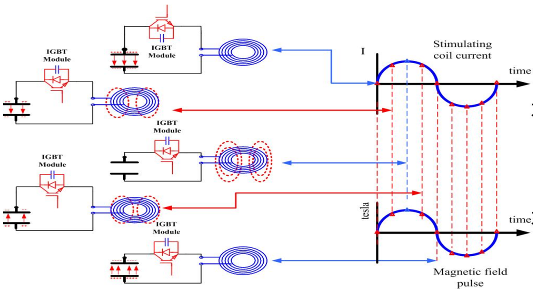

Fig. 3 The concept of discharge circuit with a flyback converter

To compare the efficiency and coil heating of the near-rectangular Magnetic Stimulation electric field pulses to those of conventional stimulators, the Magnetic Stimulation device was reconfigure to produce damped cosine pulses. As can be seen in Fig. 8, the closed loop system has two equilibrium points and the operation is oscillating between the two points. Both of the equilibrium points are stable. However, the operation between these two equilibrium points is oscillatory and yet stable. Because of this behavior, there are offsets from the reference signals. The output voltage ripple is a function of the circuit parameters. Stability analysis does not determine the output voltage ripple. Hence, the circuit differential equations need to be solved to predict the output voltage ripple. Simulation results of the output voltage variation after a step load change of 30% to 65% of full-load: Magnetic stimulation pulse train and PWM. Continuing the same procedure for a sense cycle, we can easily get that the total changes of the output voltage after applying a sense pulse is equal to the load resistance are sketched in Fig. 7. As we can observe, the control scheme tries to regulate the output voltage by generating the right number of sense and power pulses in each regulation cycle. In addition, this switching point is always reached just after the transformer has reset allowing the circuit to operate very close to the critical conduction mode, where the switch is turned on immediately after reset optimizing circuit efficiency and reducing the size of the transformer.

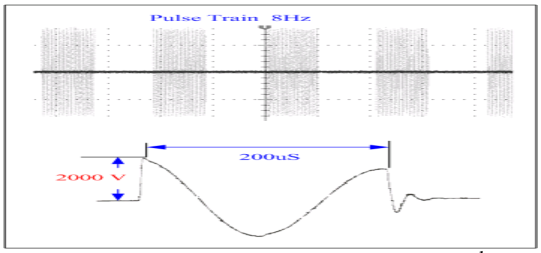

Fig. 4 Experimental waveforms for discharge voltage (8hz)

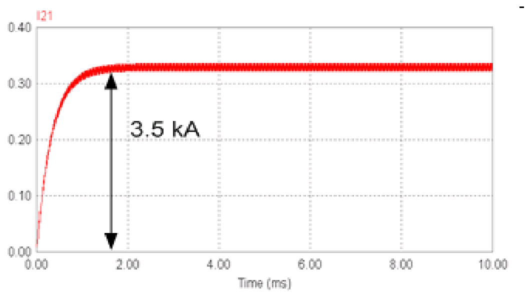

Fig. 5 Experimental waveforms for discharge voltage (3.5kA)

value of the load resistance at full load is equal to using for can be calculated as, this value also meets the switch current ratings. results of the output voltage ripple for a 30% to 65% step load change. The horizontal arrow shows the output voltage dc level, which is 600 V, whereas the vertical arrow specifies the instant at which the step change is applied.

IV. EXPERIMENTAL RESULTS

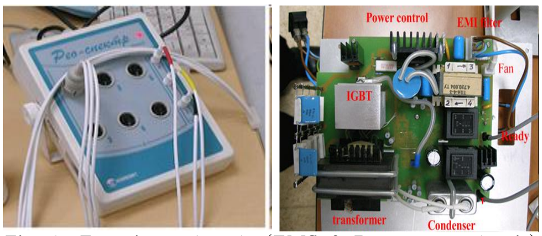

Fig. 6 Experimental tools (EMG & Power control unit)

As we already mentioned, the peak inductor current in a power pulse is times the peak inductor current in a sense Fig 10. Output voltage ripple for a step load change of 30% to 65% of full load. Pulse; therefore, a sense pulse delivers as much power as a power pulse.

A continuous stream of sense pulses thus delivers of the full load. If the load is lighter than this level, the controller enters Smart, when the circuit alternates between the sense pulses and no pulses at all. This mode is similar to pulse skipping techniques. The controller decides to enter the smart-skip mode when the sense pulses reveal that the output voltage is remaining above the desired level, though no power pulses have been sent recently. This is also shown in the current on the second pulse, which starts at a non zero value. However, the controller's peak current limiting causes the second power pulse to be much shorter than the first one.

V. CONCLUSION

Flyback power converter has found its way into many applications. To address the challenge of designing a simple controller for this type of converters, this paper introduces the new a Transcranial Magnetic Stimulation Pulse Train control technique. This control method has several advantages over conventional techniques, such as simplicity, accuracy, and fast transient response. Simulation as well as experimental results completely match with the theoretical concept..

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