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Araştırma Makalesi / Research Article

An Effective Flyback Converter Design for PMDC Motor Control

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Abstract

In this study, a low cost, small size and flexible Flyback DC converter has been developed. The designed system has high power quality, superior dynamic performance, galvanic isolation and high efficiency. It has been decided to develop a reactive type system as a transformer which operates a permanent magnet direct current (SMDA) motor with high power and high efficiency. In order to achieve high power and low noise levels in return architecture, mathematical equations have been obtained by performing flyback transducer circuit analysis. System design was made according to the parameters of a selected SMDA engine, and the converter was simulated by modeling in Matlab / Simulink digital environment.

Keywords: Flyback Converter, PMDC Motor, DC Converter, Matlab / Simulink simulation

SMDA Motor Kontrolü için Etkili bir Flyback Dönüştürücü Tasarımı

Öz

Bu çalışmada, düşük maliyetli, küçük boyutlu ve esnek bir Flyback DC dönüştürücü geliştirilmiştir. Tasarlanan sistem, yüksek güç kalitesi, üstün dinamik performans, galvanik izolasyon ve yüksek verime sahiptir. Kalıcı Mıknatıslı Doğru Akım (SMDA) motoru yüksek güç ve yüksek verimlilikle çalıştıran dönüştürücü olarak tepkili tipte bir sistem geliştirilmesine karar verilmiştir. Geri dönüş mimarisinde yüksek güç ve düşük gürültü seviyelerine ulaşmak için, Flyback dönüştürücü devre analizi yapılarak matematiksel eşitlikleri elde edilmiştir. Seçilen bir SMDA motorunun parametrelerine göre sistem tasarımı yapılmış, Matlab/Simulink ortamında modelleme yapılarak konvertörün benzetimi yapılmıştır.

Anahtar Kelimeler: Tepkili (Flyback) konvertör, SMDA Motoru, DA Çevirici, Matlab/Simulink Simülasyonu

1. Introduction

A DC chopper, also known as DC/DC converters, converts DC directly into DC (Yanmaz, 2018). A converter can also be considered the equivalent DC circuit of an AC transformer with a continuously switchable winding ratio. As the transformer can increase or decrease the AC voltage, the DC/DC converter can also increase or decrease the voltage value of a DC source (Rashid, 2016).

Switch mode DC/DC converters are non-linear and time-varying systems. The appropriate protective properties of the converter application are indicated together with the design criteria. DC/DC converters can be classified as Buck Converter (Step-Down), Boost Converter (Step-Up), Buck-Boost Converter (Step (Down / Up), Cúk Converter, Zeta Converters, Sepic Converters, Interleaved Buck Converter, Push-Pull Converters, Flyback Converter (Mohan et al., 1995).

2. Flyback Converter

Figure 1 shows the circuit shape of the flyback converter, which is one of the insulated converter types. In flyback transducers, the polarity of the windings is such that current does not flow from one another to the other (Çoruh, N.). Therefore, a transformer movement is not realized. Accordingly, the Vin voltage is applied to the primary winding when the S switch is in communication. Due to the inverse polarization of the secondary winding relative to the primary winding, the D diode is also polarized and therefore no current flows from the secondary. The load current is supplied by capacitor C (Figure 2.a). Increased primary current due to constant voltage at L_p tips will be linear (Zhang et al., 2003) When the switch Q is cut, the energy stored in the air gap and the magnetic core is transmitted to the load via the coil L_s. (Figure 2.b). Since there is a constant voltage at the ends of L_s, the current decreases linearly. The energy stored in the air range is obtained from the primary inductance and the primary current according to Equation (1);

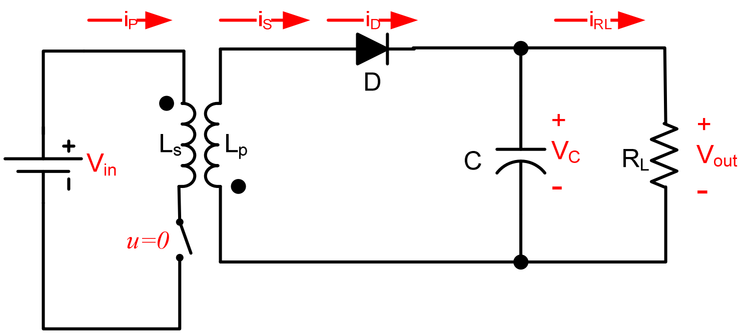

Figure 1. The block diagram of the Flyback converter

$$V_{Lp} = \frac{L_P I_P^2}{2} \quad (1)$$

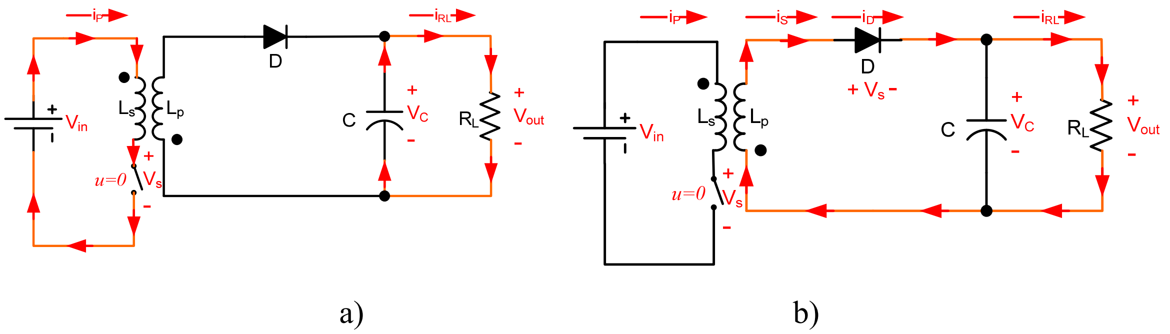

Figure 2. Flyback converter operating modes, a) switch on status, b) switch off status

As with other transducers, there are continuous, discontinuous and boundary operating conditions in flyback transducers (Zhang et al., 2003). In the case of a discontinuous state, the secondary current drops to zero and the switch remains at zero for a certain time before the next transmission state is reached. The sum of T_{on} and T_{off} times is about 80% of the period. The remaining 20% is called dead time (t_d) (Pressman A.I.). In the case of continuous, there is no TD. The secondary current does not drop to zero until the next transmission state.Since the average voltage drop on the transformer winding inductances in steady state will be zero. In the equation, V_{in}: Input voltage, V_{out}: Output voltage, T_{on}: Transmission time of the semiconductor, T_{off}: Breakdown time of the semiconductor, V_d: Transmission voltage drop of the diode, V_s: Voltage drop in the conduction state of the semiconductor, a: Winding ratio between transformer windings, definitions.

$$V_{in} - V_s)T_{on} = (V_{out} + V_d)\frac{L_P I_P^2}{2} T_{off}\, a \quad (2)$$

$$T = T_{off} + T_{on} + T_d \quad (3)$$

$$T_{on} = \frac{(V_{out} + V_d)Ta}{(V_{in} + V_s) + (V_{out} + V_d)a} \quad (4)$$

Since the values outside the input voltage are constant in Equation (4), the maximum value of the switching time is obtained with the smallest input voltage.

$$T_{on_{\max}} = \frac{(V_{out} + V_d)Ta}{(V_{in_{\min}} + V_s) + (V_{out} + V_d)a} \quad (5)$$

The primary current will increase linearly as the switch has a constant voltage on the primary coil in the transmission state. The current reaches its maximum value, the largest transmission time reaches t_{onmax}. It should be noted that the largest transmission time is possible at the smallest input voltage. According to this, the maximum prime r current I_{pmax} value is given in equation (6).

$$I_{p_{\max}} = \frac{(V_{in_{\max}} + V_s)T_{on_{\max}}}{L_P} \quad (6)$$

Here, L_p is the primary inductance. This current value is stored in the primary winding (in the magnetic core and air gap) for transfer to the secondary winding;

$$P_{in} = \frac{L_P + I_{P\max}^2}{2T} \quad (6)$$

When equality (5) is replaced in equality (6), input power equality (7) is obtained.

$$P_{in} = \frac{[V_{in_{\min}} + T_{on\ mac}]}{2TL_P} \quad (7)$$

3. Permanent Magnet DC Motor

A DC motor, armature circuit diagram of the electrical circuit and the mechanical rotor shown in Figure 3. In this model, the engine torque T_e, I_A armature current, armature construction constant (K_t) by multiplying the ($T_e = K_t.i_a$) is obtained. Armature voltage (e_a), the rotational speed (ω_m) and motor construction constant (K_e) by multiplying ($e_a = K_e.\omega_m$) are available. Rotational speed of the motor shaft, the position change over time, sewage, equation (8) is expressed. Mechanical and electrical components of the motor equations, equations (9) and (10) are expressed (Akyazi and Sesli, 2011).

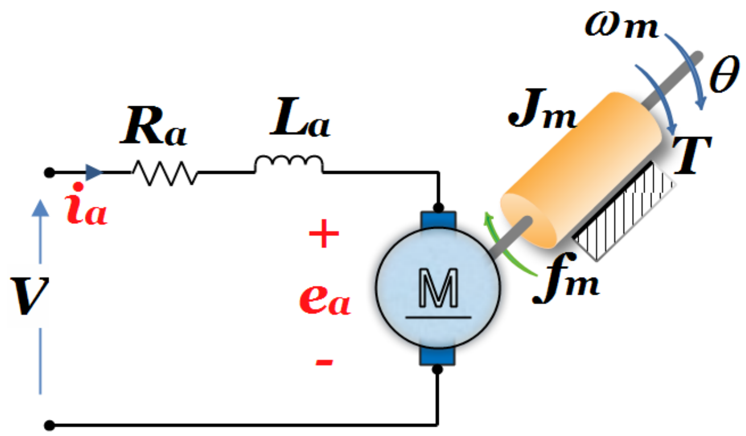

Figure 3. PMDC motor equivalent circuit.

$$d\theta/dt = \dot{\theta} = \omega_m \tag{8}$$

$$J_m \, d\omega_m/dt = K_m.\phi.I_a - f_m.\omega_m - M_{load} \tag{9}$$

$$L_a \, di_a/dt = V - R_a.i_a - K_b.\phi.\omega_m \tag{10}$$

4. Control Systems Models

A DC converter output voltage for a given input voltage, the value of the switch is controlled by setting the duration of the transmission and cutting. In these periods, Pulse Width Modulation (PWM) method is called is set (Elmas et al., 2007). DC converters, the input voltage and output load are changed, even if the desired average value of the output voltage that is requested. It is designed for different control models (Şekkeli et al., 2010). The most important of these is the PI, PID and Fuzzy Logic control (Zadeh, 1963). This control models desired, and comparing the actual voltage values are the error and the error change (Zenk, 2016). These two values form input control models (Yanmaz et al, 2017). The output of the model is used for switching the PWM control voltage (V_k). Control model, the inverter sets the value of the actual output voltage V_k in order to deliver the desired voltage.

5. Simulation of the Main System

In Figure 4, shown the whole system, in turn, is connected to the PI and FLC. These controllers, variable voltage error between the reference and the output signal audited by the flyback converter is PMDC motor actual speed with PWM method determines the position of the

MOSFET or ideal switches. Flyback converter determines the output voltage of the switch position. This voltage determines the speed of the motor.

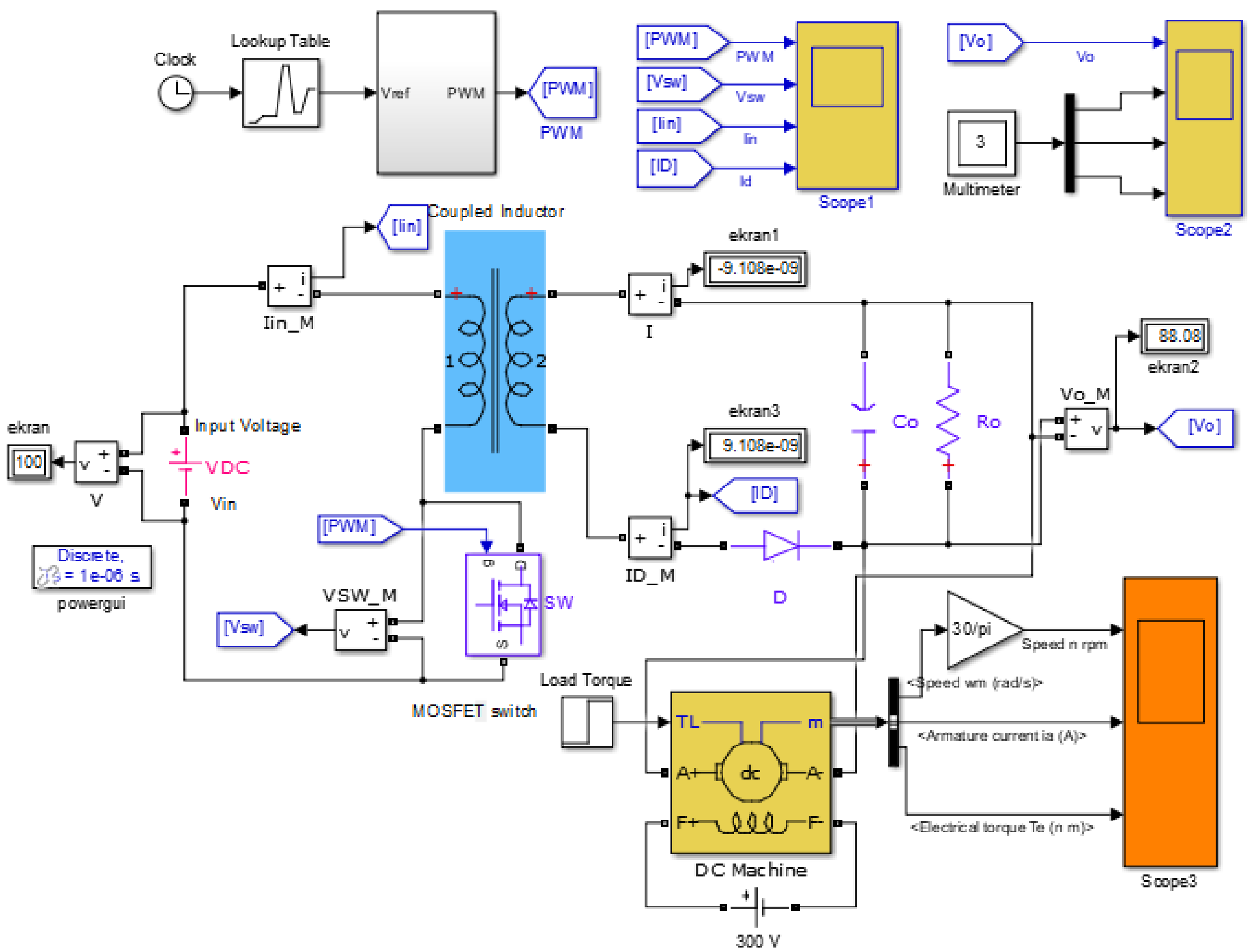

Figure 4. The block diagram of the whole system

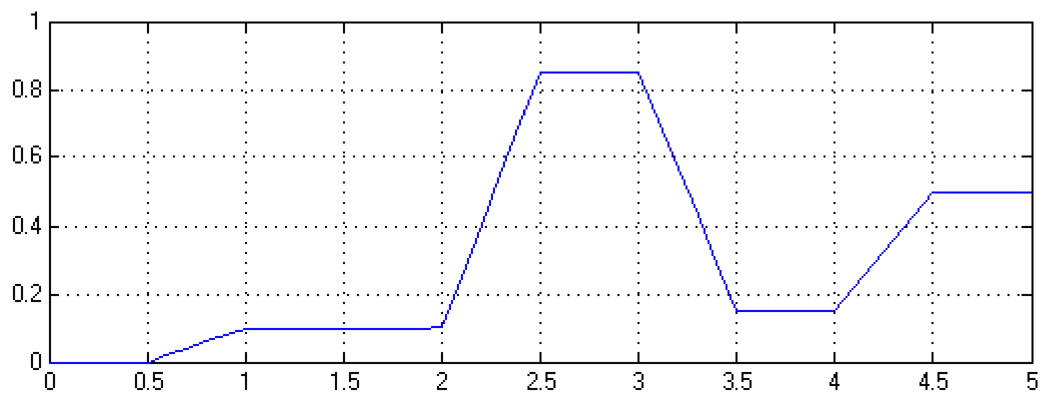

Figure 5. A variable duty cycle reference signal applied to the flyback converter.

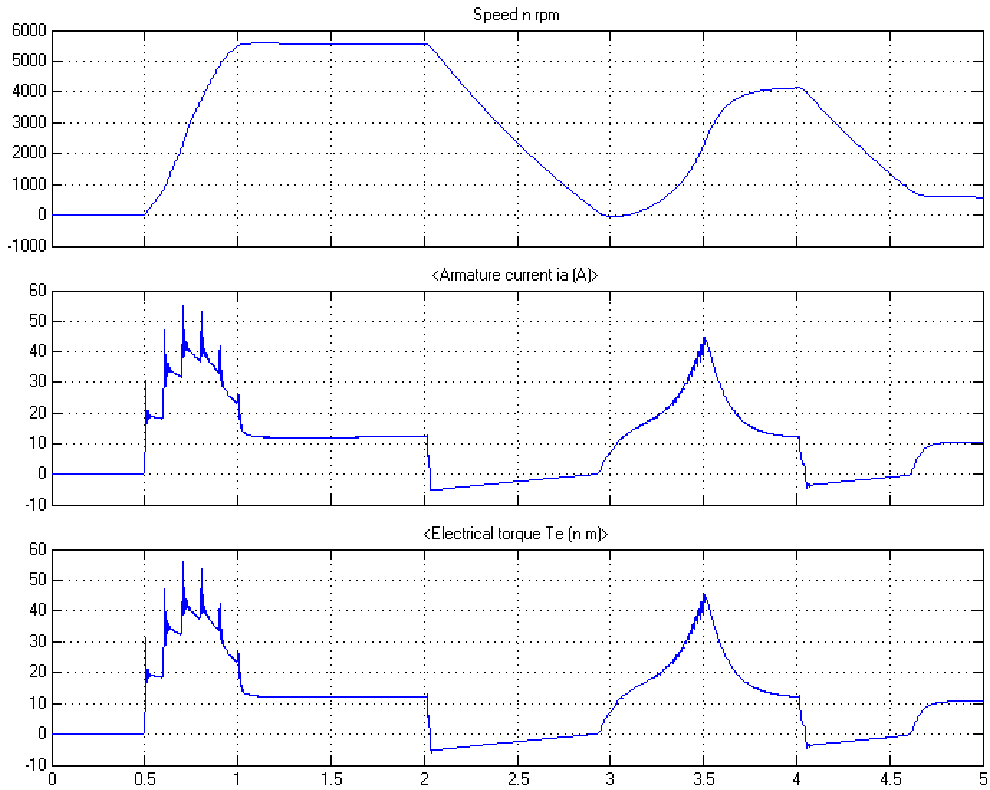

Figure 6. Graph of a 5-second variable duty cycle reference signal applied to a flyback converter as a result of a change in PMDC output speed (rpm), armature current (A), and output torque (Nm) parameters

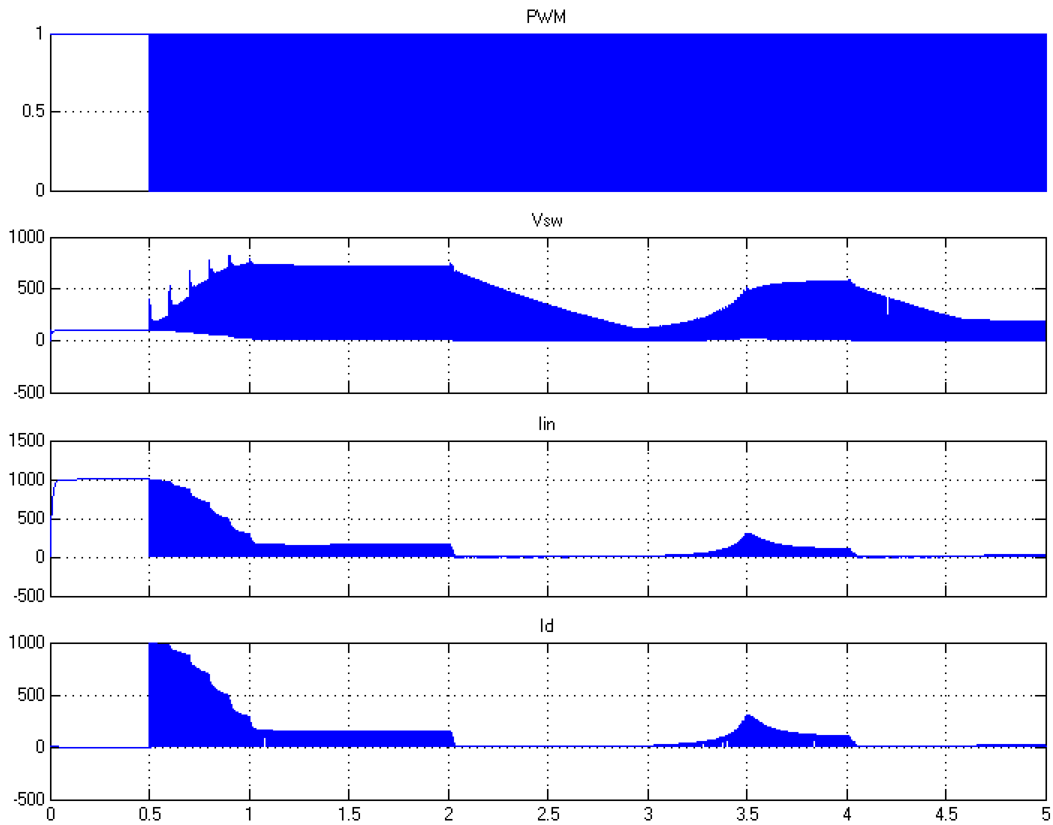

Figure 7. The result is a 5-second variable duty cycle reference signal applied to the flyback converter; PWM signals, MOSFET switch voltage (V_{sw}), welding current (I_n), and diode current (I_d) change graph.

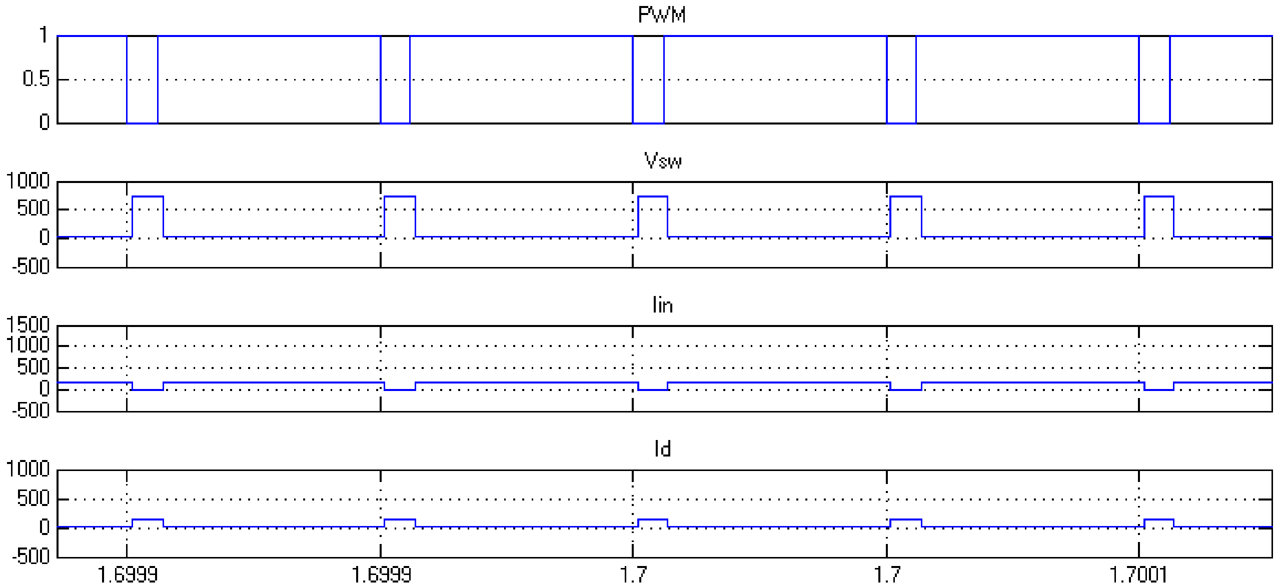

Figure 8. Flyback converter system 1.7. detailed graph of the PWM signal in seconds, the voltage of the MOSFET switch (V_{sw}), the welding current (I_n), and the change of the diode current (I_d).

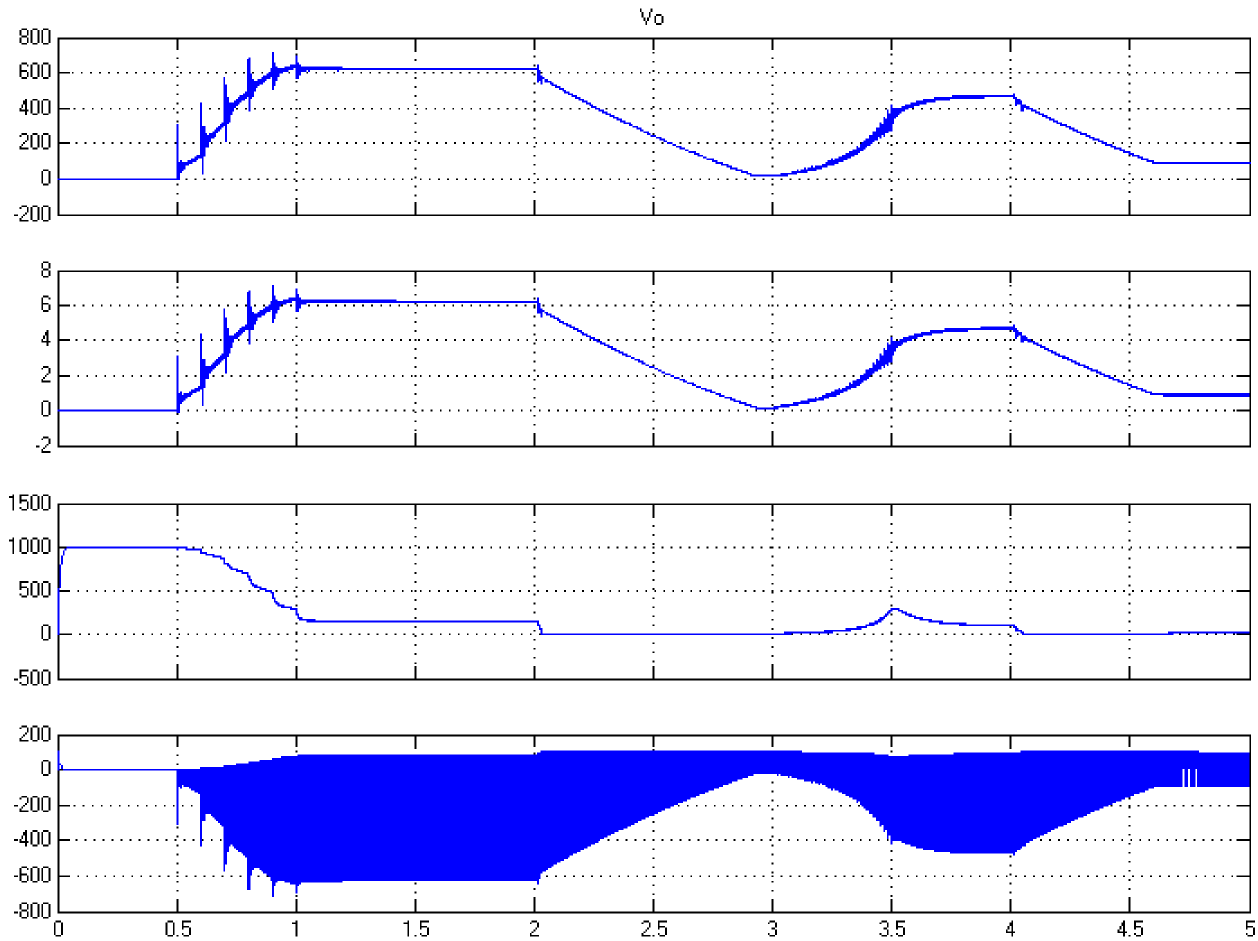

Figure 9. The result is a 5-second variable duty cycle reference signal applied to the flyback converter; Graph of the change of the output voltage (V_o) and current (I_b) signals of the transformer magnetizing current (I_{mag}) and primary winding voltage (U_{wb}).

Conclusion

A flyback converter designed in this study has a 5-second variable duty cycle reference signal followed by the electrical parameters in the system. One of the most important of these parameters is the output voltage (V_o) and its current (I_b) have been observed to follow the reference successfully. Although there are some fluctuations in other parameters in the given graph, the system reacts fast and works in harmony with the control systems. In the studies, Matlab / Simulink has been tested in computer program.

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