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Design and Implementation of Isolated Multi-Output Flyback Converter

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Abstract - *Now-a-days, because of increase in use of DC applications, LVDC microgrids and nano-grids are going to play a vital role in future. In a LVDC microgrid or nanogrid, distributed generation systems are present. In a distributed generation system, supply voltage is taken from renewable sources and battery banks to work in islands mode. Hence, there is need to convert the variable input voltage into various output voltage levels by means of DC-DC converters. Therefore, this need behind the conversion of voltages for various types of known and unknown loads acts as a motivation behind the implementation of isolated multi-output power supply with fixed and programmable output voltage levels*

***Key Words*: DC - DC Converter, Fly-back Converter, Isolated Multi-Output Fly-back Converter.**

1. Introduction

Fly-back converter is the most commonly used SMPS circuit for low output power applications where the output voltage needs to be isolated from the input main supply. The output power of fly-back type SMPS circuits may vary from few watts to less than 100 watts. The overall circuit topology of this converter is considerably simpler than other SMPS circuits.

Input to the circuit is generally unregulated dc voltage obtained by rectifying the utility ac voltage followed by a simple capacitor filter. The circuit can offer single or multiple isolated output voltages and can operate over wide range of input voltage variation. In respect of energy-efficiency, fly-back power supplies are inferior to many other SMPS circuits but its simple topology and low cost makes it popular in low output power range.

The commonly used fly-back converter requires a single controllable switch like, MOSFET and the usual switching frequency is in the range of 100 kHz. A two-switch topology exists that offers better energy efficiency and less voltage stress across the switches but costs more and the circuit complexity also increases slightly. The present lesson is limited to the study of fly-back circuit of single switch topology.

1.1 BASIC TOPOLOGY OF FLYBACK CONVERTER

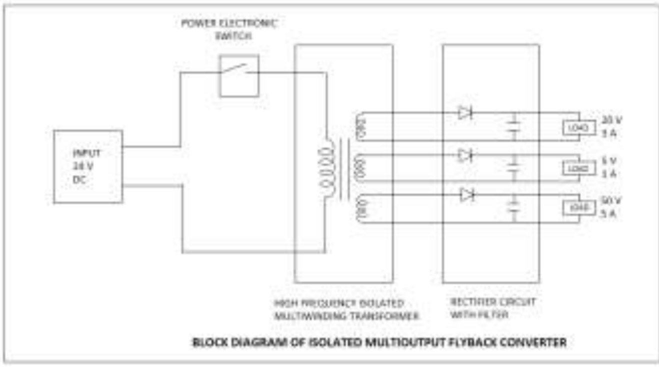


Fig.1 Multi-Output Fly-Back Converter

Fig.1 shows the basic topology of a fly-back circuit. Input to the circuit may be unregulated dc voltage derived from the utility ac supply after rectification and some filtering. The ripple in dc voltage waveform is generally of low frequency and the overall ripple voltage waveform repeats at twice the ac mains frequency. Since the SMPS circuit is operated at much higher frequency (in the range of 100 kHz) the input voltage, in spite of being unregulated, may be considered to have a constant magnitude during any high frequency cycle. A fast switching device ('S'), like a MOSFET, is used with fast dynamic control over switch **duty ratio** (ratio of ON time to switching time-period) to maintain the desired output voltage.

1.2 Significance of Transformer

The transformer is used for voltage isolation as well as for better matching between input and output voltage and current requirements. Primary and secondary windings of the transformer are wound to have good coupling so that they are linked by nearly same magnetic flux. As will be shown in the next section the primary and secondary windings of the fly-back transformer don't carry current simultaneously and in this sense **fly-back transformer works differently from a normal transformer.** In a normal transformer, under load, primary and secondary windings conduct simultaneously such that the ampere turns of primary winding is nearly balanced by the opposing ampere-turns of the secondary winding (the small difference in ampere-turns is required to establish flux in the non-ideal core). Since primary and secondary Since primary and secondary windings of the fly-back transformer don't conduct simultaneously they are more like two magnetically coupled inductors and it may be more appropriate to call the fly-back transformer as inductor-transformer. Accordingly, the magnetic circuit design of a fly-back transformer is done like that for an inductor. The details of the inductor-transformer design are dealt with separately in some later lesson. The output section of the fly-back transformer, which consists of voltage rectification and filtering, is considerably simpler than in most other switched mode power supply circuits. As can be seen from the circuit (Fig.1), the secondary winding voltage is rectified and filtered using just a diode and a capacitor. Voltage across this filter capacitor is the SMPS output voltage.

It may be noted here that the circuit shown in Fig.1 is rather schematic in nature. A more practical circuit will have provisions for output voltage and current feedback and a controller for modulating the duty ratio of the switch. It is quite common to have multiple secondary windings for generating multiple isolated voltages. One of the secondary outputs may be dedicated for estimating the load voltage as well as for supplying the control power to the circuit. Further, as will be discussed later, a snubber circuit will be required to dissipate the energy stored in the leakage inductance of the primary winding when switch 'S' is turned off.

Under this lesson, for ease of understanding, some simplifying assumptions are made. The magnetic circuit is assumed to be linear and coupling between primary and secondary windings is assumed to be ideal. Thus the circuit operation is explained without consideration of winding leakage inductances. ON state voltage drops of switches and diodes are neglected. The windings, the transformer core, capacitors etc. are assumed loss-less. The input dc supply is also assumed to be ripple-free.

2. Working

During its operation fly-back converter assumes different circuit-configurations. Each of these circuit configurations have been referred here as modes of circuit operation. The complete operation of the power supply circuit is explained with the help of functionally equivalent circuits in these different modes.

As may be seen from the circuit diagram of Fig.2(a), when switch 'S' is on, the primary winding of the transformer gets connected to the input supply with its dotted end connected to the positive side. At this time the diode 'D' connected in series with the secondary winding gets reverse biased due to the induced voltage in the secondary (dotted end potential being higher). Thus, with the turning on of switch 'S', primary winding is able to carry current but current in the secondary winding is blocked due to the reverse biased diode. The flux

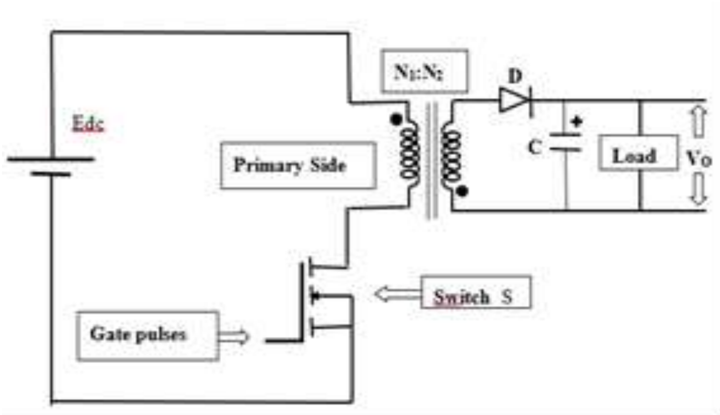


Fig.2 Basic Fly-back Converter

established in the transformer core and linking the windings is entirely due to the primary winding current. This mode of circuit has been described here as

Mode-1 of circuit operation.

- In this mode the switch S1 is turned ON.
- So current starts flowing in the primary coil of the transformer.
- As shown in the figure, observe that the transformers secondary voltage reverse biases diode D when switch S is conducting.
- So, the load current is supplied by capacitor C.

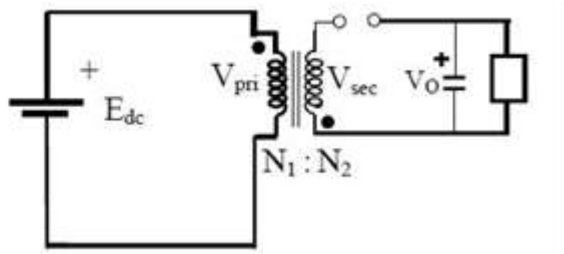


Fig.2(a) Current path during Mode-1 of circuit operation

Mode-2 of circuit operation.

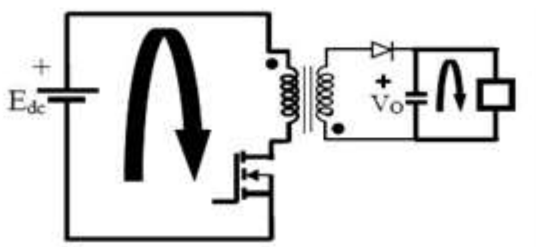


Fig.2(b) Current path during Mode-2 of circuit operation

- Refer the above circuit to understand this mode.
- This mode will start when the switch is turned OFF.
- As shown in the equivalent circuit, the voltage polarity of the transformer's secondary coil is inverted.
- This phenomena, forward biases diode D and the diode starts conducting.

- Thus, the transformer's secondary coil supplies energy to the capacitor C and load.
- Remember that this energy was stored in the transformer when S was conducting in Mode 1

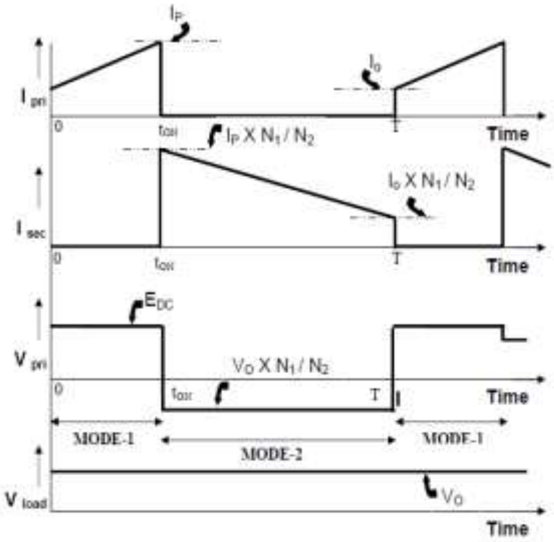
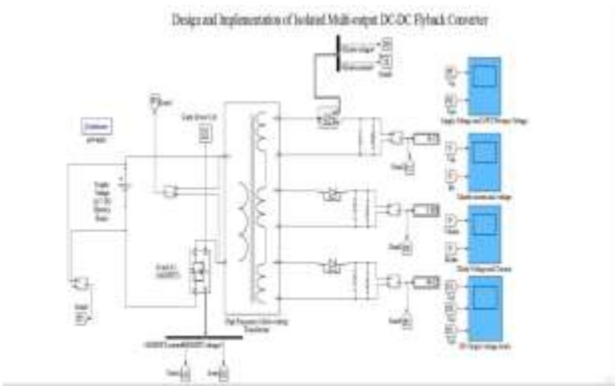
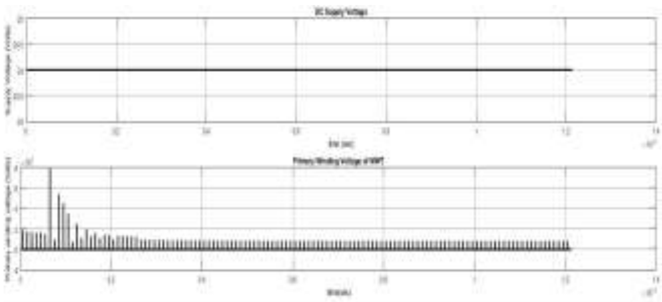
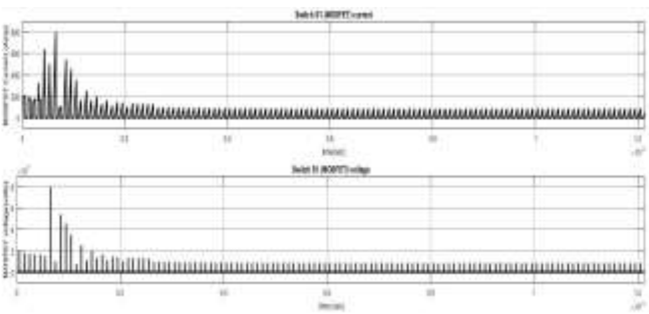


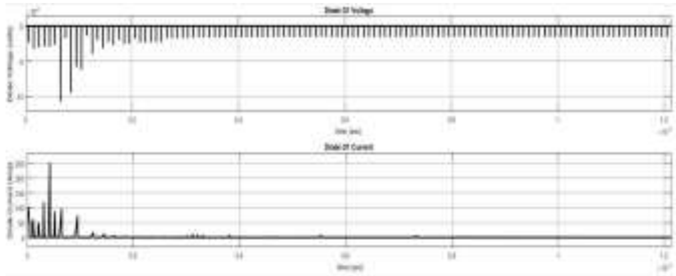
Fig.2(c) Waveform of Basic Fly-Back Converter

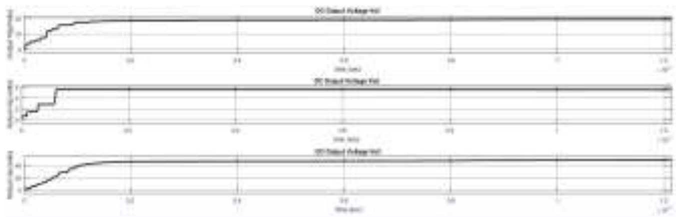
3. Simulation and Output











4. Designed Parameters

VA rating of transformer= 315 VA

Core type of Transformer= T-27 (Toroidal)

Table -4.1: Designed Parameters

Designed parameters	Primary winding	Secondary winding		
		A	B	C
Voltage	24 V	20 V	5 V	50 V
Current	13.56 A	3 A	1 A	5 A
No. of turns	7	6	2	15
Resistance	0.001302	0.00532	0.00520	0.00 74
Wire size(SWG)	12	18	22	16

6. IGBT Specifications

Table-6.1 IGBT Specifications

	Parameter	Max.
VCES	Collector-to-Emitter Voltage	600 V
I_C @ T_C = 25°C	Continuous Collector Current	31 A
I_C @ T_C = 100°C	Continuous Collector Current	17 A
ICM	Pulsed Collector Current	124 A
ILM	Clamped Inductive Load Current	124 A
I_F @ T_C = 100°C	Diode Continuous Forward Current	12 A
IFM	Diode Maximum Forward Current	120 A
VGE	Gate-to-Emitter Voltage	± 20 V

P_D @ T_C = 25°C	Maximum Power Dissipation	100 W
P_D @ T_C = 100°C	Maximum Power Dissipation	42 W
T_J TSTG	Operating Junction and Storage Temperature Range	-55 to +150 °C

7. Conclusion

This paper focuses on design and implementation of isolated multi-output DC-DC power supply with fixed output voltage levels.

since multiple isolated output voltages are required, the fly-back transformer is designed on MATLAB with multiple secondary windings. Thus, each of these secondary winding voltages are rectified and filtered separately.

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