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Analysis of different Flyback Converter Topologies

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***Abstract*- High step-up dc–dc converters have been widely used in the green energy systems. In this paper an analysis of different flyback Converter topologies are proposed. Generally it is more suitable for high voltage and low power (less than 100 W) applications. Its main features are simplicity, low cost and galvanic isolation. In the recent years, many different topologies have been discussed. Important topologies such as Active Clamp, RCD Snubber, Dual output AC and DC, Two Switch and Interleaved flyback Converters are analyzed. Functionalities of these converters are simulated using matlab and their results are compared.**

Index Terms-Flyback Converter, Active clamp, RCD Snubber , Two Switch topology, Interleaved topology , Dual AC and DC output.

I. INTRODUCTION

Power supplies are used extensively for most of the real time applications. They are classified as linear and switched mode power supplies. Efficiency is higher for Switched mode power supplies and suitable for higher load current. There are four configurations of switched mode power supplies [1], [2] used for different applications. In this paper, flyback configuration is chosen for analysis, due its simplicity, low cost and galvanic isolation.

The basic topology of a fly-back circuit is shown in Fig: 1. When Metal Oxide Field Effect transistor (MOSFET) is turned on, the flyback transformer's primary is connected to the supply. The current and magnetic flux in the primary side are increased and energy is stored in it [3],[4]. As the diode in the secondary side is reverse biased, negative voltage is induced in it. Output filter capacitor supplies energy to the load. When MOSFET is turned off, current and magnetic flux in the primary side are decreased. Positive voltage is induced in secondary side, so diode is forward biased. Energy stored in the transformer is delivered to output capacitor and the load.

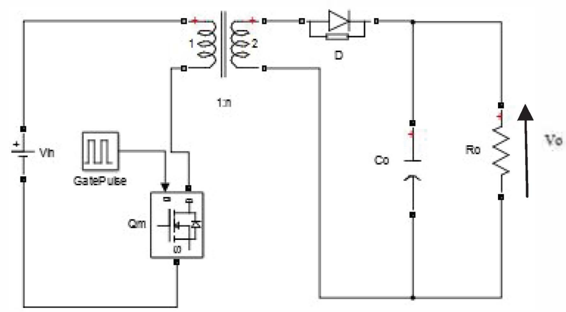

Fig:1 Flyback Converter

The major advantages of Flyback converter is its filtered output, which eliminates inductive filter, saving cost and volume. High voltage freewheeling diode is also eliminated. Because of this, Flyback converters are suitable for high load voltages compared with forward converters. Since output filter capacitor supplies the load current, when the MOSFET switch is ON, its value should be large in Flyback converters **[5].** DC current flows from ground to load through this capacitor. Output filter capacitor decides ripple in output current and voltage.

Energy is stored in the transformer and not delivered to load, when the MOSFET is turned on. Voltage spikes are increased during this period. It causes high voltage and current stress for the semiconductor devices. It leads to discontinuous conduction mode (DCM) of operation, reduced efficiency and Electro Magnetic Interference (EMI) problems. This is the major limitation of flyback converter. Efficiency can be increased by reducing this voltage stress on the semiconductor switches. It is achieved by including suitable components in the flyback topologies. Different flyback converter topologies are used for this purpose.

This paper is organized as follows. Different types of flyback Converter topologies are presented in Section II. Design issues of converters are explained in Section III. Simulation circuits and outputs are presented and compared in Section IV. Future work is discussed in Section V and concludes with the analyses of converters.

II. DIFFERENT FLYBACK CONVERTER TOPOLOGIES

Active clamp fly back converter circuit [6]-[10] shown in Fig: 2, illustrates the basic flyback converter topology with additional auxiliary MOSFET and capacitor. So the leakage energy flow is shared by main MOSFET and auxiliary MOSFET. This will reduce the voltage stress on the main MOSFET and eliminate the DCM mode of operation**.**

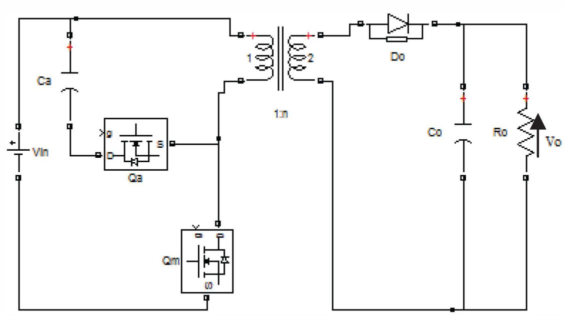

Fig 2: Active clamp flyback converter

With the help of active clamp circuit, zero voltage switching (ZVS) for main MOSFET is achieved. This will reduce the switching loss greatly. Gate drive requirement of auxiliary MOSFET increases the circuit complexity. Also active clamping increases the current stress on MOSFET switches [11]-[13].

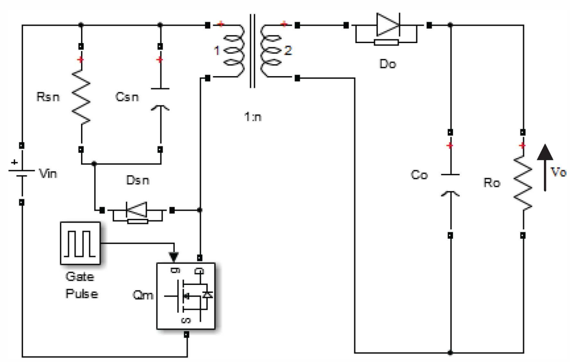

Fig:3 Flyback Converter with RCD Snubber

The circuit diagram of flyback converter with RCD snubber is shown in Fig: 3. Snubber diode is turned on, when the voltage across the main MOSFET exceeds the input voltage and the reflected voltage of transformer. It leads to voltage clamping and leakage inductor current absorptions. [14], [15]. Snubber capacitance value is chosen large enough such that its voltage does not change during one switching period. Voltage across clamping capacitor can be regulated by operating the flyback snubber independently. The purpose of the resistor is to fully dissipate the charge on the capacitor in each cycle.

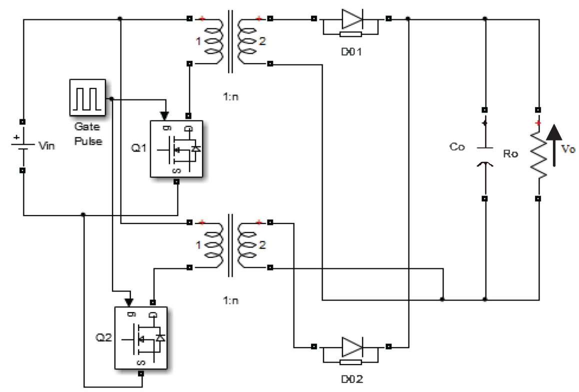

Fig: 4 Interleaved Flyback Converter

Continuous Conduction Mode (CCM) mode of operation results in high DC flux density and requires large transformer. But it reduces the converter power density. Therefore two transformer interleaved flyback converter is used. The circuit diagram is shown in Fig: 4. It consists of two separate fly back converters. DC flux is shared equally between the two primaries of these flyback transformers. Ultimately this will reduce the transformer core loss and copper loss. [16]- [19].

Between the secondary sides of the two transformers, the total load current is balanced using interleaved flyback converter topology. It leads to reduction of rectifier diode conduction loss. Only two MOSFET switches are required. Main MOSFET switch of one converter acts as the auxiliary switch for the other converter, so that both can achieve zero voltage switching operation.

MOSFET switches are operated with less peak voltage stress and double their power transfer frequency. The benefit of interleaving is that the frequency of the ripple components (undesired harmonics) are increased in proportion to the number of interleaved cells. This feature facilitates easy filtering of the ripple components or using smaller sized (single capacitor Co) filtering elements. The ability to reduce the size of passive elements is beneficial for reducing the cost and obtaining a compact converter.

Single MOSFET switch experiences voltage stress, due to addition of input voltage, turnoff voltage spike caused by leakage inductance and reflected transformer voltage.

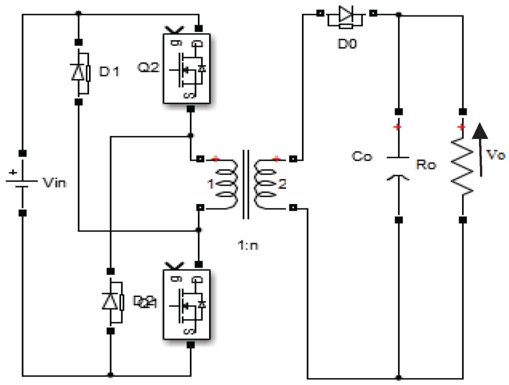

Fig:5 Two Switch Flyback Converter

Therefore single-stage flyback converter is operated only at very low power as micro inverter. [20]. Two switch flyback converter topology is used for higher power levels. The circuit diagram is shown in Fig: 5. Two MOSFETs are switched on or off simultaneously. Diodes D_{01} and D_{02} are used to limit the maximum voltage to input voltage. Two MOSFET switches share the voltage stress, caused by the leakage energy of flyback transformer.

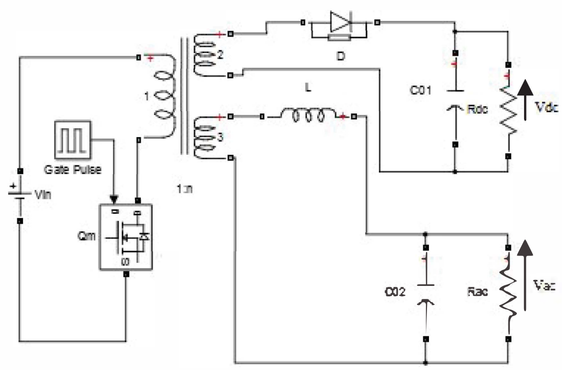

Fig:6 Dual AC and DC output Flyback Converter

In flyback converter, it is possible to get multiple output through multiple secondary winding. Dual output AC and DC flyback Converter topology consists of an additional secondary winding, to generate continuous AC voltage, accompanied with the conventional DC output voltage [21]-[23]. The circuit diagram is shown in Fig:6. The DC output is derived using basic configuration. AC output is derived by adding an LC filter with additional secondary winding. This saves space and semiconductor switching devices. When both DC and AC power are necessary, such as in rural solar-powered standalone systems, this flyback converter is preferred.

III. FLYBACK CONVERTER DESIGN

In this paper the flyback converter design issues are discussed. 72V DC output from 24V DC supply is chosen for the design. For switching purpose, power MOSFET is used. Diode is used for rectification purpose. Specifications of the converter considered for the design are,

Frequency, f= 1MHz
Input Voltage, V_{in}= 24V
Duty Cycle, D = 60%
Transformation ratio, n = N_s/N_p = 2
Output power, P_o= 50w
Load Resistance, R = 100Ω
Forward Voltage of MOSFET, V_t = 1.2V
Forward Voltage of Diode, V_d = 0.7V

Output voltage of the flyback converter is given by,

$$V_o = n \times V_{in} \times [D \div (1-D)] \quad (1)$$

= 72V

Output Current, $I_o = P_o \div V_o$ (2)

= 0.7A

Input Power, $P_{in} = V_{in} \times I_{in}$

Also Input Power, $P_{in} = P_o + P_{Losses}$

Losses are conduction losses of MOSFET switch and secondary side diode.

Drop across MOSFET, $P_t = V_t \times I_{in}$

Drop across Diode, $P_d = V_d \times I_o$

So, $P_{in} = P_o + P_t + P_d$ (3)

Substituting the numerical values in this equation and simplify, we get I_{in}=2.2A

Primary side peak current,

$$I_{pk} = (2 \times I_{in}) \div D \quad (4)$$

= 7.3A

Primary magnetizing inductance,

$$L_p = (V_{in} \times D) \div (f \times I_{pk}) \quad (5)$$

= 2μH

Clamp Capacitor,

$$C_{clamp} = (1-D)^2 \div (\pi^2 \times L_r \times f^2) \quad (6)$$

= 0.16μF

Resonant Inductor, L_r = 5-10% of L_p
= 0.1µH

Snubber Capacitor,

$$C_{sn} = (2 \times L_{lk} \times I_{pk}^{2} \times n^2) \div V_o^{2} \quad (7)$$

= 3.3nF

L_{lk} = 1-2% of L_p

Power dissipated in the snubber resistor,

$$P_{sn} = 0.833 \times L_{lk} \times I_{pk}^{2} \times f \quad (8)$$

= 1.8w

Snubber Resistor,

$$R_{sn} = (6.25 \times V_o^{2}) \div (P_{sn} \times n^2) \quad (9)$$

= 4.5KΩ

Output Capacitance,

$$C_o = (V_o \times D) \div (f \times R \times \Delta V_o) \quad (10)$$

[take 1% of ripple in V_o]

IV. SIMULATION AND OUTPUTS OF DIFFERENT TOPOLOGIES

Different flyback Converter Topologies are simulated using MATLAB simulink and their efficiencies are compared. For illustration, only the simulation circuit of Active clamp flyback converter topology is given in Fig:7. Output voltage and current of Active clamp flyback converter are shown in Fig:8. Similarly, remaining topologies are simulated and their results are compared. Table:I shows the efficiency comparison of different flyback converter topologies.Table:II shows the efficiency comparison of Active clamp flyback converter topology for varying duty cycles with frequency = 1MHz. Table:III shows the efficiency comparison of Active clamp flyback converter topology for varying frequency, with Duty cycle= 0.6.

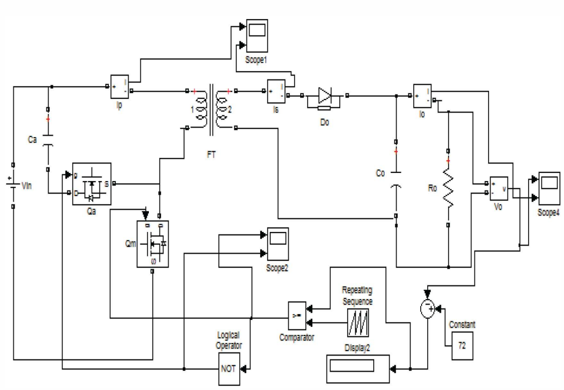

Fig:7 Simulation circuit of Active clamp flyback converter

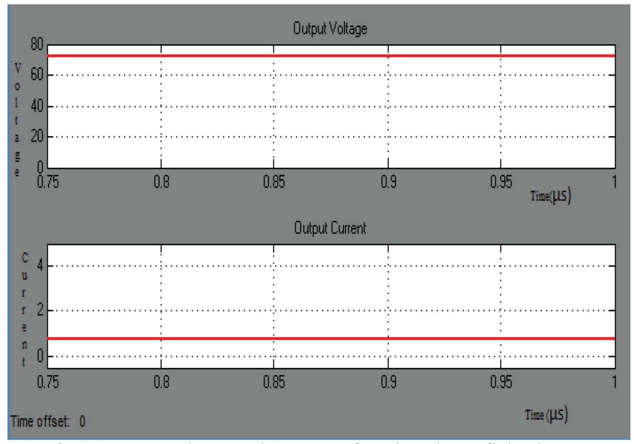

Fig:8 Output Voltage and Current of Active clamp flyback Converter

TABLE I. EFFICIENCY COMPARISON OF DIFFERENT FLYBACK CONVERTER TOPOLOGIES

Sl.No	Flyback Topologies	Efficiency(%)
1	Active clamp flyback converter	76.4
2	Flyback converter with RCD Snubber	47
3	Two Switch flyback converter	62
4	Interleaved flyback converter	45
5	Dual AC and DC output flyback converter	30

TABLE II. EFFICIENCY COMPARISON OF ACTIVE CLAMP FLYBACK CONVERTER TOPOLOGY, IF FREQUENCY= 1MHZ

Sl.No	Duty Cycle	Efficiency(%)
1	0.2	26.4
2	0.4	27.4
3	0.6	76.4
4	0.8	22

TABLE III.EFFICIENCY COMPARISON OF ACTIVE CLAMP FLYBACK CONVERTER TOPOLOGY, IF D=0.6

Sl.No	Frequency	Efficiency(%)
1	20KHz	34
2	50KHz	39.2
3	100KHz	37.14
4	500KHz	49.2
5	1MHz	76.4
6	5MHz	39.2

V. CONCLUSION AND FUTURE WORK

Flyback Converter topology is used in various applications due its less complexity, cost effectiveness and galvanic isolation. In this paper different flyback converter topologies are analyzed with their efficiencies. It is designed to get 72V DC output from 24V input DC Supply and the results are compared. Active clamp flyback Converter topology has higher efficiency than others particularly at 1MHz frequency with 60% duty cycle. Because of this, the voltage stress on the main MOSFET switch is reduced and eliminates the DCM mode of operation. With the help of active clamp circuit, ZVS for primary main MOSFET is achieved. This will reduce the switching loss greatly.

The circuits can be implemented as flyback converter with synchronous rectification for multiple Outputs(AC and DC). RCD snubber circuit performance in the primary circuit will be analyzed. This new topology will reduce the conduction loss and voltage stress on the switches. It is suitable for Photovoltaic(PV) Applications [24]-[26]. Also multiple Outputs(AC and DC) configuration saves cost, outputs(AC and DC) space and devices. So this will increase the overall converter efficiency.

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