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Design of Series Connected Forward Fly Back Step up Dc-Dc Converter

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ABSTRACT
Now a days, small scale solar array and PV module is having low voltage. So to connect them to grid, it is necessary to boost the output voltage higher than 300 V. There are some technologies available like high voltage boost converter, soft switching converters. But they have poor reliability due to absence of isolation and low power conversion efficiency. This paper represent a high step up Dc-Dc converter which has series connected forward converter and flyback converter using transformer technology to increase the utilization with an advantage of high system reliability and high power conversion efficiency. In this paper design and analysis of proposed system are presented along with the performance analysis and simulation. Also, a 125 W hybrid Dc-DC converter hardware model has implemented for experimental verification.

Keywords
Dc-Dc converters, forward-flyback converter, forward flyback transformer**.**

1. INTRODUCTION
The solar power generation has some noticeable advantages in the installation condition and manufacturing cost compared to other sustainable renewable energy sources. Solar arrays can be installed on top of commercial buildings or residential houses. These features have brought about much concern with small-scale solar power generation systems as a highly distributed power sources. Since the electrical characteristic of the typical small-scale solar array is low-voltage output, the high step-up dc to dc converter is necessary for the grid connected power systems. There are some technologies available like high voltage-boost power converters and soft-switching converters. But they have poor reliability due to the absence of isolation. On the other side, an isolation type converter has an advantage of the safety and system reliability, in fact of the high power conversion efficiency. In this project, an output-series forward–flyback (SFFB) dc–dc switching converter has presented, which serially connects the secondary outputs of a multi winding forward–flyback converter in order to solve these isolation type disadvantages. Series connected forward–flyback converters deliver the required energy to the load through a transformer no matter whether the main switch turns ON or OFF, holding an advantage in terms of supplying more power to the load. The proposed scheme improves the weaknesses of insulation type converters, such as low efficiency, bigger size, and much costly, by utilizing the structure of the forward–flyback converter. A utilization factor of the transformer is highly boosts up by continuous power delivery from primary to secondary which contributes to the reduced volume of the forward–flyback converter.

2. SFFB CONVERTER
2.1 Block diagram
Fig.1 shows that the block diagrams of proposed system. The primary has a switching voltages occurred by a single main switch. Structure of the secondary where the forward converter and the fly back converter are separated by transformer winding. Yet the outputs are serially connected for the output voltage boost

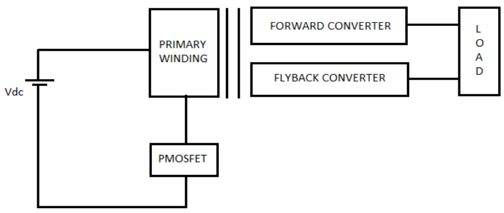

Fig. 1 Block Diagram of SFFB converter

The flyback supplies power to the load during the off time of the transistor and the rectifiers work as peak rectifiers. This means the output voltages follow the peaks of the transformer secondaries during the flyback period. If having multiple outputs, the voltages at the transformer secondaries during the flyback period will tend to follow one another, reason of that transformer action.

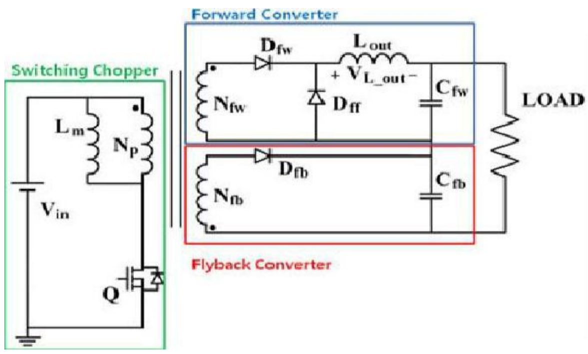

Fig. 2 Equivalent circuit diagram

Because of the peak rectification, it follows that the output voltages will follow each other. In a forward, transformer action is still present, but the power is delivered during the on time and the rectifiers just work as average rectifiers. Fig.2.Circuit Diagram for Flyback Converter gives output voltages are the averages of the voltage at the transformer secondaries at on time. But the averages depend on the duty cycle. And the duty cycle is adjusted to regulate the final output. But that means the duty cycle will only be right for the final output and it could be totally wrong for a slave output, because the output could be fully loaded reason of that needing a large duty-cycle, while the final output is only lightly loaded (needing and forcing a low duty cycle). Or the other way around the final is fully loaded, forcing a large duty cycle; while a slave output is only lightly loaded, thus needing a low duty cycle.

2.2 Operating principle

The proposed system has four operating modes as shown in Fig. 3, 4, 5 and 6, according to the switching state of the circuits.

Mode 1: Current flows to the magnetizing inductance and the primary winding N_p as a result of turning ON the switch Q. The current of primary is transferred to the secondary N_{fw} coil of the forward converter via the magnetic linkage. After, the ac power is rectified into dc which load requires through a forward diode D_{fw} and a low pass filter L_{out} and C_{fw}. Because a flyback diode D_{fb} is reverse biased, the output capacitor provides the load current during this mode.

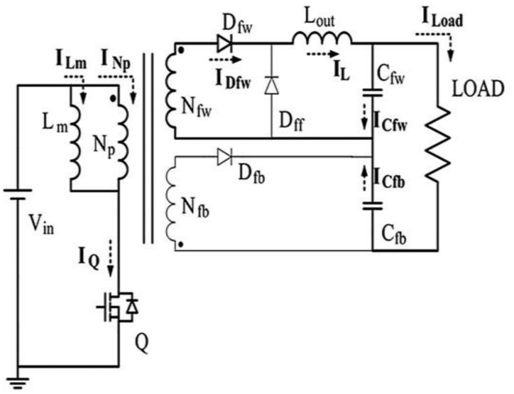

Fig. 3 Equivalent Circuit Diagram of Model

Mode 2: When switch Q is turned OFF, a forward diode D_{fw} is reverse biased and the stored energy in L_{out} is transferred to the load by the freewheeling current via D_{ff}, and at the same time, magnetically stored energy at Lm is also supplied to load through D_{fb} of the flyback converter. Thus, all the free-wheeling current in magnetic devices decreases linearly.

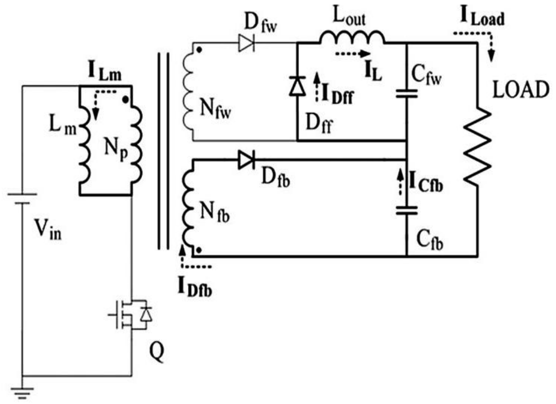

Fig. 4 Equivalent Circuit Diagram Of Mode 2

Mode 3: The forward converter starts operating in DCM when all the energy in L_{out} is discharged, and then a freewheeling diode D_{ff} is reverse biased. Then stored energy in L_m is only supplied to load through the flyback converter.

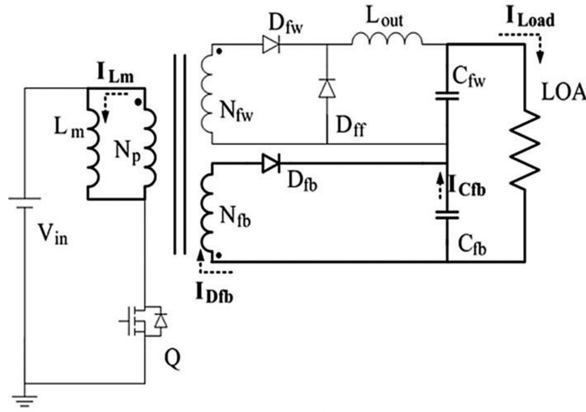

Fig. 5 Equivalent Circuit Diagram Of Mode 3

Mode 4: During this mode the transformer of the forward–flyback converter is demagnetized completely and the output voltage is maintained by the discharge of the output capacitors. C_{fw} and C_{fb} the rectifier diodes are reverse biased.

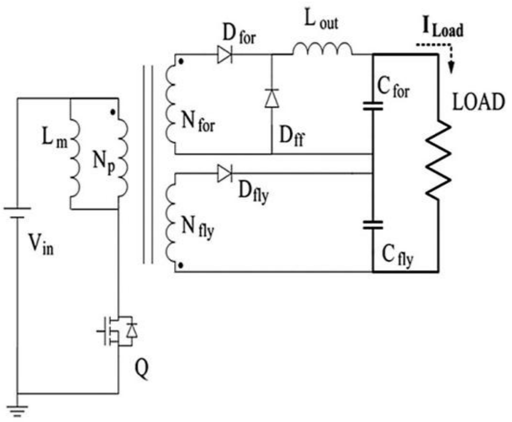

Fig. 6 Equivalent Circuit Diagram Of Mode 4

3. SIMULATION RESULTS

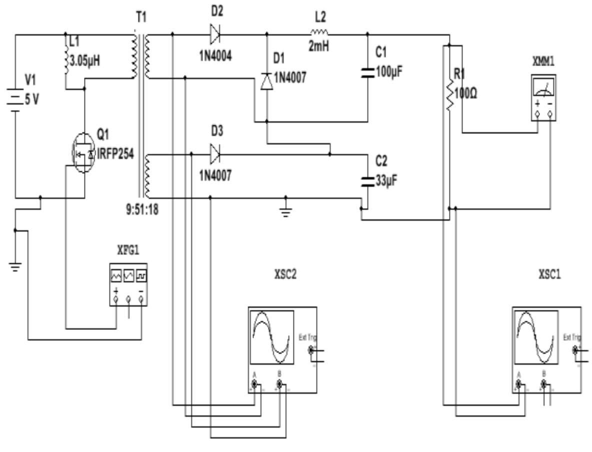

Fig. 7 Simulation on Multisim

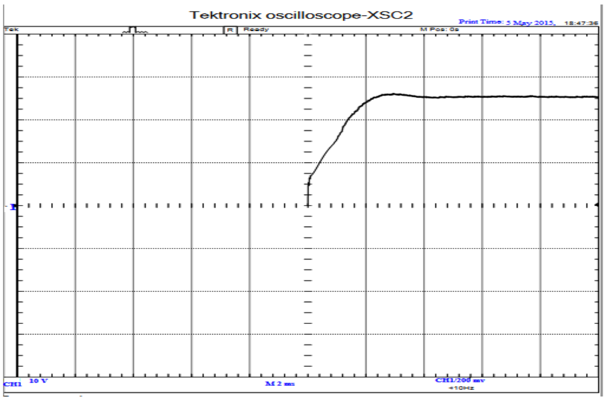

Fig. 8 Output Voltage

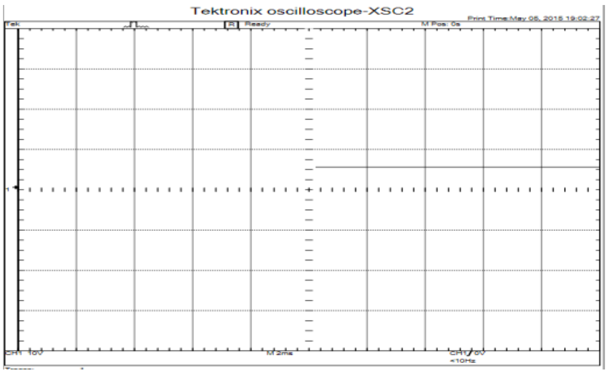

Fig. 9 Input voltage

4. DESIGN AND ANALYSIS

Vi(Min) : 15V, Vi(Max) : 30V, Vo : 200V, P(Max) : 125W, Io(Max) : 0.625A, f : 50kHz,

Ac: 118.5mm^2, η : 80%, B(Max) : 1500T.

Transformer type: EI33- W=34mm, D=29mm, H=31.5mm.

Diodes: UF4007, 800V, 1A, V_d =1.7V

MOSFET: IRFP260N

A. Primary Winding

$$N_1 = \frac{Vi(max) * 10^8}{4.f.Bmax.Ac} \ldots\ldots (1)$$

N_1 = 8.46 turns ~ 9 turns.

B(Max)=1500 Gauss (Range 1300-2000 G).

Actual value of B(max),

From (1), We get,

B(max) =1406.46 G

This is under range.

B. Duty cycle

$$D = 1 - \frac{Vi(max) * \eta}{Vo} \ldots\ldots (2)$$

D = 0.88 / 88%.

C. Secondary Winding

At maximum duty cycle=88%,

Voltage to transformer = 0.88*Vi(max) = 0.88*30=26.4V……………..(3)

Voltage ratio (sec : pri) = 200:26.4 = 7.57.

Since, voltage ratio (sec : pri) = 7.57, turns ratio (sec : pri) must also be 7.57 as turns ratio (sec : pri) = voltage ratio (sec : pri)

Turns ratio is designated as 'N'.

So, in our case, N = 7.57

N_1 = 9 turns,

N_2 = N * N1 = 7.57*9= 68.1 ~ 69 turns………. (4)

So, for FORWARD AND FLYBACK CONVERTERS the windings and the voltage of secondary winding is divided such that we get the N(fw) & N(fb) forward and flyback winding respectively & their voltage is as given below.

N_{fw} = 51 turns, N_{fb} = 18 turns, V_{fw} = 149.6 V, V_{fb}= 52.8 V

D. Output Inductor for Forward Converter

Ripple current, $\Delta I_L = 0.4 * Io(max)$………….. (5)

ΔI_L = 0.4*0.625 = 0.25A,

$$V(fw) = D(max) * \frac{Nfw}{N1} * Vi(max) \ldots\ldots (6)$$

V(fw)= 149.6V

Lo =?

$$\Delta I_L = \frac{1}{f * L} * Vi * \left(1 - \frac{Vi}{V(fw)}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (7)$$

Lo = 1.92mH.

E. Magnetizing Inductance

$$Lm = n^2 * \frac{(1 - D)^2 R(fb)}{2fs} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (8)$$

Where,

n= Turns ratio,

R_{fb} =Flyback Winding Resistance,

D= Duty cycle.

$$n = \frac{N1}{N(fb)}, \qquad R(fw) = \frac{V(fb)}{Io(max)}$$

n= 0.5, R_{fw}= 84.8Ω.

Therefore,

L_m= 3.05µH.

F. Output Capacitor

C(fw) = 100µF & C(fb) = 33µF.

G. Air gap length of a transformer

$$l_g = \frac{\mu_0 * LI^2}{B^2 * A_c} 10^4 \ m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$Lg = 3.53mm$$

$$Lg1 = 1.76mm \ \& \ Lg2 = 1.76mm$$

H. Diameter of Primary & Secondary Winding

According to the current rating the diameter of the enameled copper wire is taken from the table given below.

Hence we get,

N_1= 1.628mm

N_{fw}, N_{fb}= 0.573mm.

5. EFFICIENCY ANALYSIS

Table 1 on load Parameters of SFFB Converter

Serial No.	Parameters	Value
1	Input Voltage (V_i)	27 V
2	Input Current (I_i)	1.75 A
3	Input Power (P_i)	47.25 W
4	Output Voltage (V_o)	145 V
5	Output Current (I_o)	0.31 A
6	Output Power (P_o)	44.95 W

$$\text{Efficiency } (\eta) = \frac{\text{Output Power}}{\text{Input Power}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots (10)$$

$$\eta = \frac{44.95}{47.25} \times 100$$

η = 95.13 %

The Load test of the SFFB converter is done on 100 W load.

6. PROTOTYPE AND OUTPUT

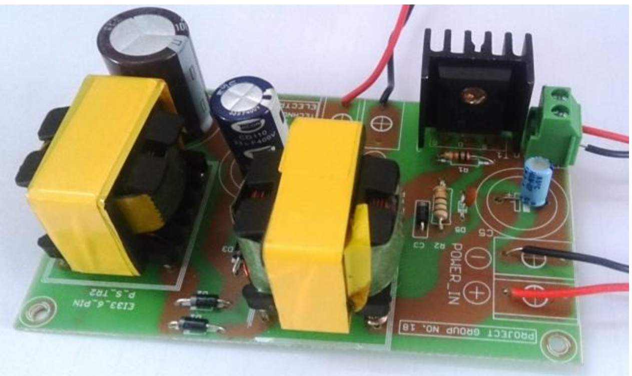

Fig. 10- 125W SFFB Converter Prototype

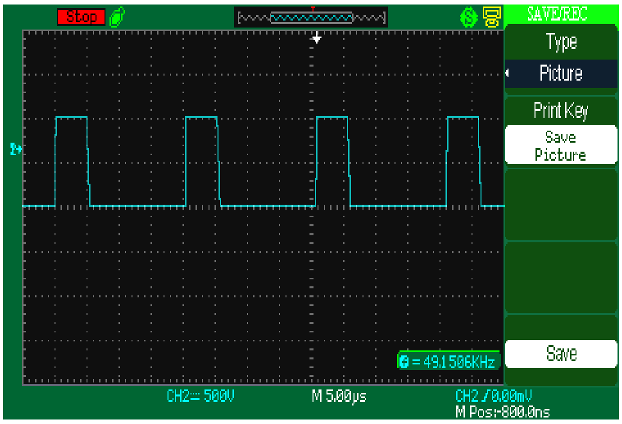

Fig 11- Prototype Output

7. ADVANTAGES

I. As we are giving isolation between the primary & secondary winding of transformer, it will increase the safety and reliability of converter.

II. The separated secondary windings in low turn-ratio reduce the voltage stress of the secondary rectifiers and thus high efficiency can be achieved.

III. Using forward-flyback converter we can reduce the cost and size of circuit.

IV. 'N' number of outputs can be stacked on secondary side.

V. With less input voltage high DC Voltage can be achieved on output side.

8. FUTURE SCOPE

As a future work, it will be effort spent to obtain the soft switching operation in extremely step up applications for the more different specifications such as high-frequency applications, high/low voltage/current applications, etc. in this circuit primary winding uses, PWM technique which belong hard switching of switch. The disadvantage of PWM technique is, it should withstand high voltage and high current when the switch is ON and OFF. Switching losses are occurs and it is directly proportional to the switching frequency, instead of which we can use soft switching technique such as ZVS and ZCS.

9. CONCLUSION

In this project, a pre-regulating dc–dc converter of an SFFB converter for multistage PV power conditioning systems has been proposed. The single-ended forward– flyback operation contributes to high-density power delivery of the transformer with a galvanic isolation and the series connected output is quite beneficial to the enhancement of the output voltage. The high voltage and low-current output has a filter inductor under DCM operation that contributes to better performances by completely removing reverse recovery of the rectifying diodes. The operation principle and the design based analysis of the forward–flyback converter have been presented. The experimental result with a 125-W hardware model is also included to show that the proposed system has a high efficiency greater than 95% with isolation from 20–30-V input range to 145-V output.

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