SERIES CONNECTED FORWARD FLY-BACK CONVERTOR FOR HIGH STEP UP POWER CONVERSION

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Abstract

Global energy consumption is tending to grow continuously. To satisfy the demand and supply of electric power against the background of depletion of the conventional, fossil fuel resources, such as the renewable energy sources are becoming more useful and popular. According to the researchers despite of its fluctuating nature and weather dependency, the capacity of renewable resources can be used to satisfy the overall need of global demand for energy.

Recently, highly-distributed photovoltaic sources have been used for obtaining high generation efficiency even when it is under partial shading conditions severely. However, power conditioning systems for sources needs high step-up voltage boost due to the low output of generating sources. This paper proposes the scheme of high step up topology which employs a Series-connected Forward-FlyBack (SFFB) converter, in which output connected in series is used to obtain high boost in the voltage-transfer gain. SFFB is a hybrid type of forward as well as flyback converter, sharing the secondary of the transformer for increasing the utility of the transformer. By stacking the outputs of the secondary winding, extremely high voltage gain is obtained with small size and high efficiency even with an isolation. The voltage stress is reduced by separating the secondary of the transformer having low turn ratio which leads to greater efficiency. As we have a single-ended scheme, it becomes beneficial to the cost competitiveness.

In this paper, the principle of operation and designing of the proposed scheme are shown, along with the hardware prototype model and analytical comparison. A 100 W resistive bulb is used in the SFFB DC/DC converter prototype which has been implemented for the experimental verification of proposed converter topology.

Keywords: SFFB converter, Photovoltaic system, PWM technique, Multisim.

I. Introduction

The renewable energy sources such as photo voltaic modules, energy storage devices as super capacitors and/or batteries deliver output voltage in the range of 10-80 V dc. There can be installation of solar systems on the top of the residential buildings as well as commercial buildings in urban areas. The small scale generating systems has been developing because the power capacity extension of this kind of systems is quite easy by standardized photo voltaic modules (PV) as compared to some large scale centralized photo voltaic power system of small scale power system.

With the arrival of extremely small scale distributed energy systems that have high power generation efficiency even with the partial shading have become very useful these days. In these systems, very high boost in voltage gain is required from the converters. Since small scale systems give very low output, these cannot be directly used. For such purposes, a high DC – DC conversion is required.

II. Proposed methodology

The circuit diagram of the proposed DC-DC converter system is as shown in Fig.1. The primary has switching voltages which is obtained with the help of a single main switch. In the secondary side, there is a part where forward converter and the flyback converter, both are separated by transformer winding with the help of number of turns.

The secondary side is connected in series to boost the output voltage. A discontinuous mode of conduction is used in this system. Discontinuous conduction mode (DCM) occurs because switching ripple in inductor current or capacitor voltage causes polarity of applied switch current or voltage to reverse, such that the current- or voltage-unidirectional assumptions made in realizing the switch are violated. Here, since the single-ended diagram of the converter is suitable for very small power capacity compared to other bridge type techniques, it mostly has low current level with higher output voltage, allowing a discontinuous conduction mode (DCM).

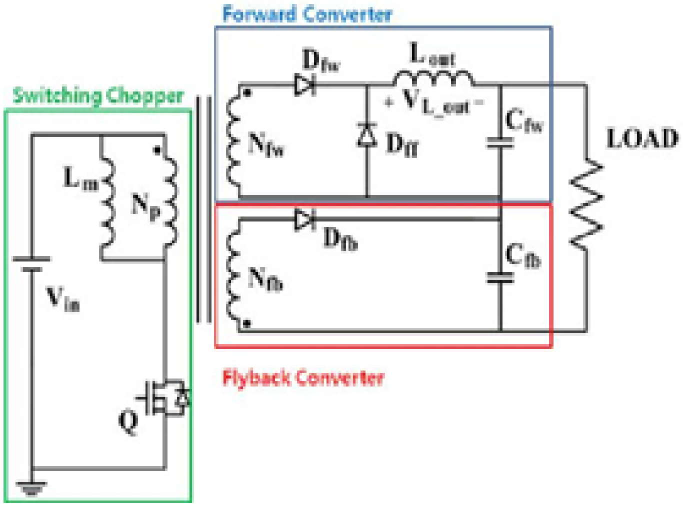


Fig. 1 Proposed SFFB converter

However, for analyzing the steady-state input-output transfer gain of the converter proposed, the forward converter as well as flyback converter analysis can be done by output separation by using an equivalent circuit transformation, as shown in Fig.2. Both of the output currents I_{ofw} (forward output current) and I_{ofb} (flyback output current) are the same because they are connected to the series output in SFFB.

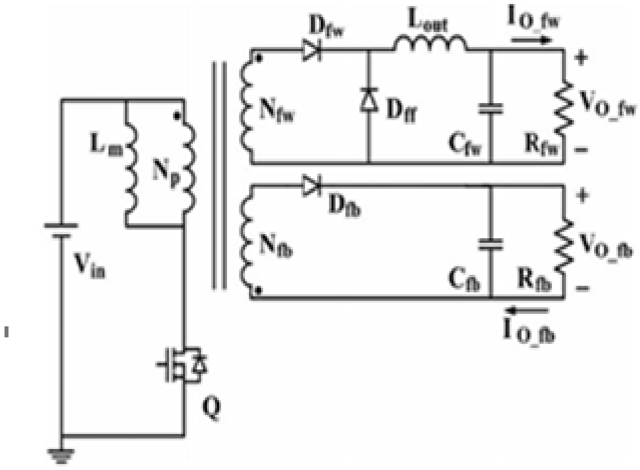


Fig. 2 Proposed SFFB converter with separated output

III. Operating Principle

A. Mode 1

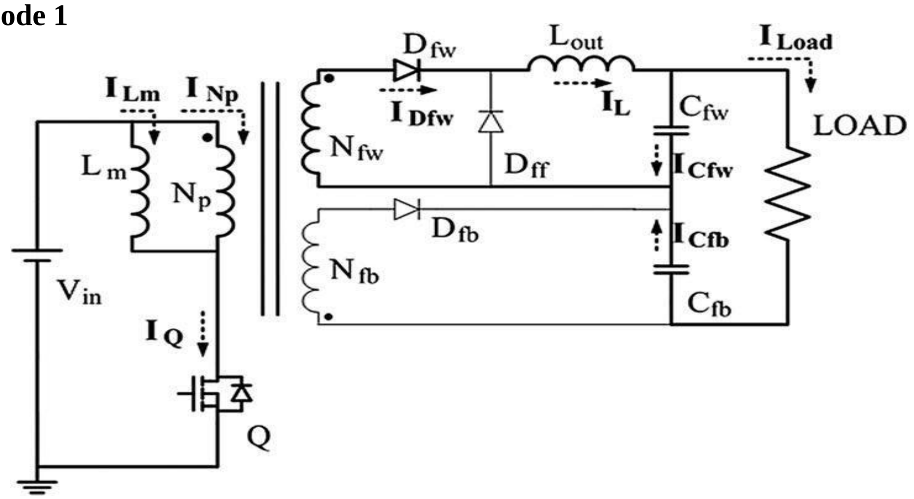


Fig. 3 Equivalent Circuit Diagram of Mode 1

The fig. 3 shows the first mode of operation. When the switch (P- MOSFET) is turned on by giving the supplied input voltage, current flows through the magnetizing inductance along with the primary winding Np. As forward secondary coil N_{fw} is in phase with the primary side, the primary current is transferred to it.

Since, the flyback converter coil N_{fb} is out of phase with the primary, it becomes reverse bias, the current does not get transferred. Now, with the help of the diode D_{fw} ac is rectified to dc which is required by the load. The freewheeling diode is also reverse biased. Hence the process flow can be shown as D_{fw} - Lout – Load – Icfb – Icfw.

B. Mode 2

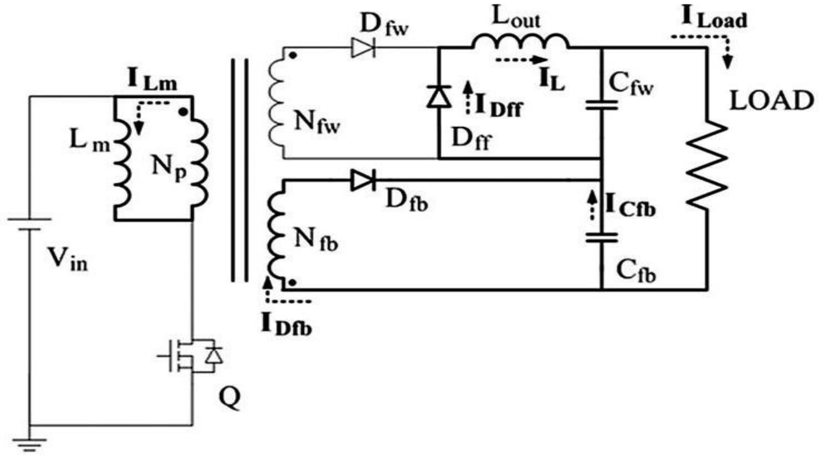


Fig. 4 Equivalent Circuit Diagram Of Mode 2

The fig. 4 shows the second mode of operation. When the switch Q is turned OFF, the magnetizing current flows in the opposite direction. Since, Flyback converter was out of phase it becomes forward biased and the forward converter becomes reverse biased. The energy stored in Lout is transferred to the load with the help of freewheeling diode. Also, the magnetic energy stired in Lm is also transferred to the load. Thus, the freewheeling current starts decreasing slowly and also in Lm. The process flow in this mode is Dfb – Dff – Lout – Load – Idfb & Icfb.

C. **Mode 3**

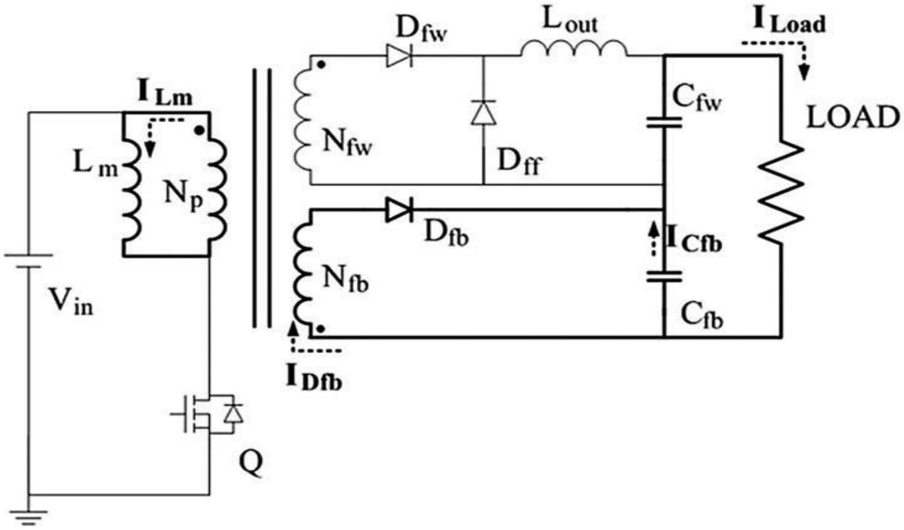


Fig. 5 Equivalent Circuit Diagram of Mode 3

The fig. 5 shows the third mode of operation. In this mode, the forward converter starts to work in discontinuous conduction mode (DCM). Here, all the energy in L_{out} has been discharged, and the freewheeling diode D_{ff} becomes reverse biased. The energy to the load is only given by Lm with the help of flyback converter. The process flow in this mode can be shown as dfb – Icfw – Load – Idfb & Icfb.

D. **Mode 4**

The fig. 6 shows the fourth mode of operation. In this mode, all the energy in Lm is also discharged. Thus, the forward flyback converter gets demagnetized. The, rectifier diodes are also reverse biased. Hence, the load is supplied only with the help of energy stored in the capacitors. When all the energy in the capacitor is lost, the system gets off. The process flow in this mode is as shown Icfw – load – Icfb.

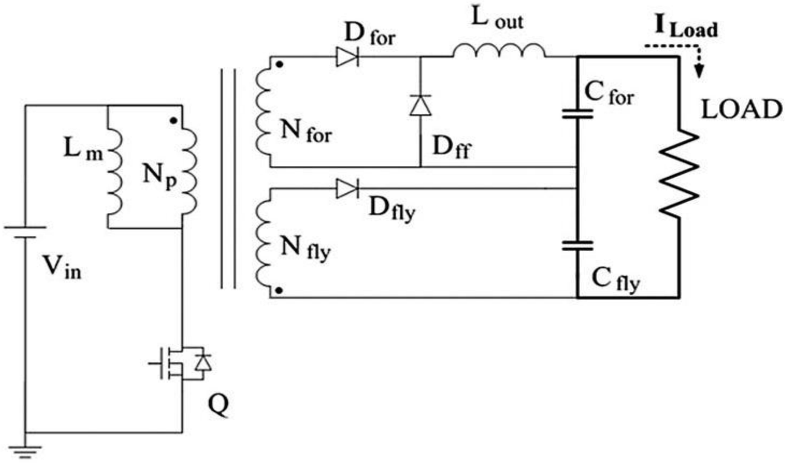


Fig. 6 Equivalent Circuit Diagram of Mode 4

E. Waveforms

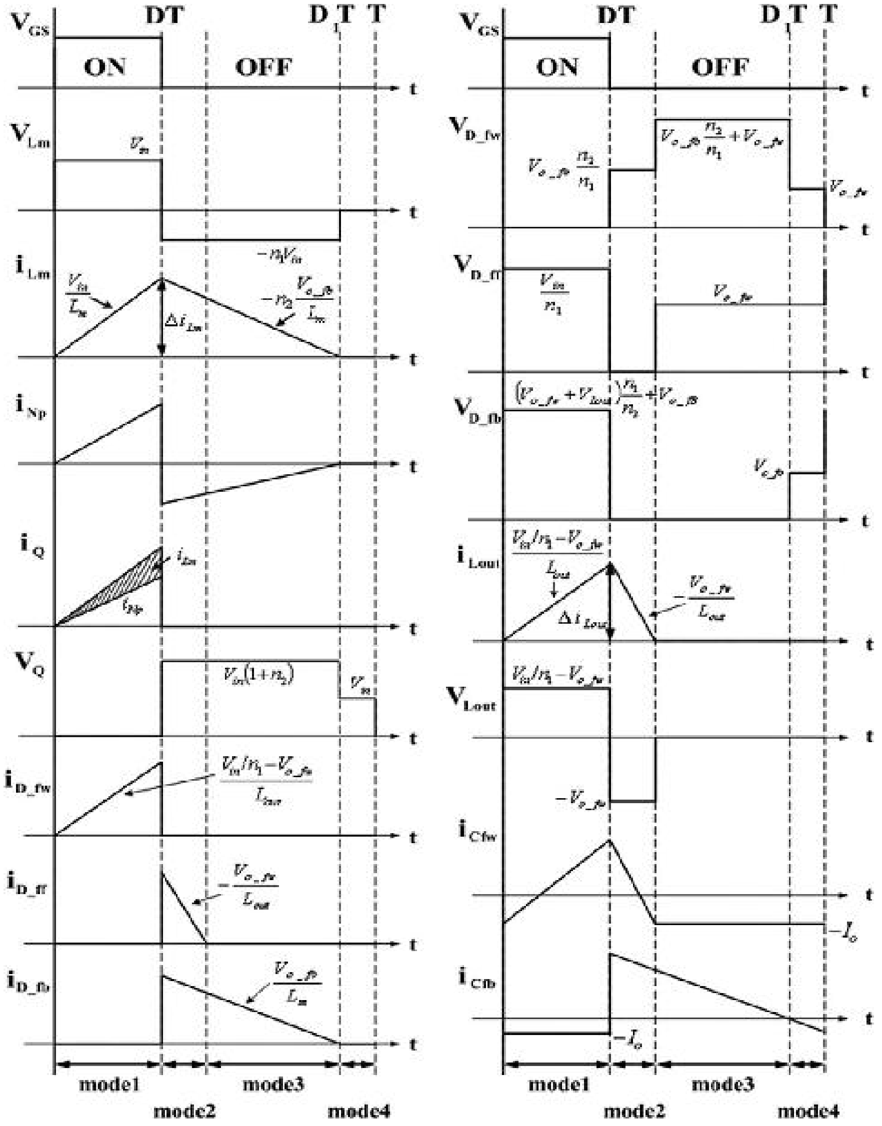


Fig. 7 Waveforms of the Converter

IV. Designing guidelines

Primary winding:

$$N1 = \frac{Vimax}{4.44*f*Bmax*Ac}$$

Duty cycle:

$$D = 1 - \frac{Vimax*\eta}{Vo}$$

Secondary Winding:

Voltage to transformer = 0.88*Vi (max)

$$\frac{V1}{V2} = \frac{N2}{N1}$$

Output Inductor for Forward Converter,

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

$$Lo = \frac{1}{f * \Delta Il} * Vi(max) * (1 - \frac{Vi}{Vfw})$$

Magnetizing Inductance

$$Lm = n^2 * \frac{(1-D)^2 \, Rfb}{2f}$$

$$n = \frac{N1}{Nfb}$$

$$Rfb = \frac{Vfb}{Iomax}$$

Output Capacitor
C(fw) = 100µF & C(fb) = 33µF.
Diameter of primary and secondary winding.
Air gap length of transformer

$$Lg = \frac{\mu_0 * L \, I^2}{B^2 * Ac}$$

Table 1. TRANSFORMER WIRE DIAMETER & GAUGE CHART

AWG	**Diam**	**DiaTot**	**AreaCu**	**AreaSQ**	**I**	**Ohm/m**	**m/kg**
1	7.348		42.4		120	.000414	2.67
2	6.544		33.6		94.8	.000522	3.37
3	5.827		26.7		75.2	.000659	4.25
4	5.189		21.1		59.6	.000830	5.36
5	4.621		16.8		47.3	.00105	6.76
6	4.155		13.6		37.5	.00132	8.53
7	3.665		10.5		29.7	.00167	10.8
8	3.264	3.34	8.37	11.2	23.6	.00210	13.5
9	2.906	2.95	6.63	8.70	18.7	.00265	17.1
10	2.588	2.65	5.26	7.02	14.8	.00334	21.5
11	2.305	2.37	4.17	5.61	11.8	.00421	27.1
12	2.053	2.12	3.31	4.49	9.33	.00531	34.2
13	1.828	1.88	2.62	3.53	7.40	.00670	43.2
14	1.628	1.69	2.08	2.86	5.87	.00844	54.5
15	1.450	1.51	1.65	2.28	4.65	.0106	68.7
16	1.291	1.34	1.31	1.80	3.69	.0134	86.6
17	1.115	1.20	.976	1.44	2.93	.0169	109
18	1.024	1.08	.823	1.17	2.32	.0213	137
19	.912	.962	.653	.925	1.84	.0270	173
20	.812	.864	.518	.746	1.46	.0339	218
21	.723	.767	.411	.588	1.16	.0428	275
22	.644	.686	.326	.471	.918	.0540	348
23	.573	.615	.258	.378	.728	.0681	439
24	.511	.549	.205	.301	.577	.0858	553
25	.455	.491	.163	.241	.458	.108	698
26	.405	.438	.129	.192	.363	.136	881
27	.361	.391	.102	.153	.288	.172	1110
28	.321	.349	.0809	.122	.228	.217	1400
29	.286	.311	.0642	.0967	.181	.274	1766
30	.255	.281	.0511	.0790	.144	.345	2227
31	.227	.251	.0405	.0630	.114	.435	2809
32	.202	.225	.0320	.0506	.090	.549	3542
33	.180	.200	.0254	.0400	.072	.692	4467
34	.160	.178	.0201	.0317	.057	.872	5632
35	.143	.161	.0161	.0260	.045	1.10	7103
36	.127	.145	.0127	.0210	.036	1.39	8953
37	.113	.128	.0100	.0164	.028	1.75	11k2
38	.101	.113	.00801	.0128	.022	2.21	14k2
39	.090	.102	.00636	.0104	.018	2.78	18k0
40	.080	.090	.00503	.0081	.014	3.51	22k6

V. Prototype

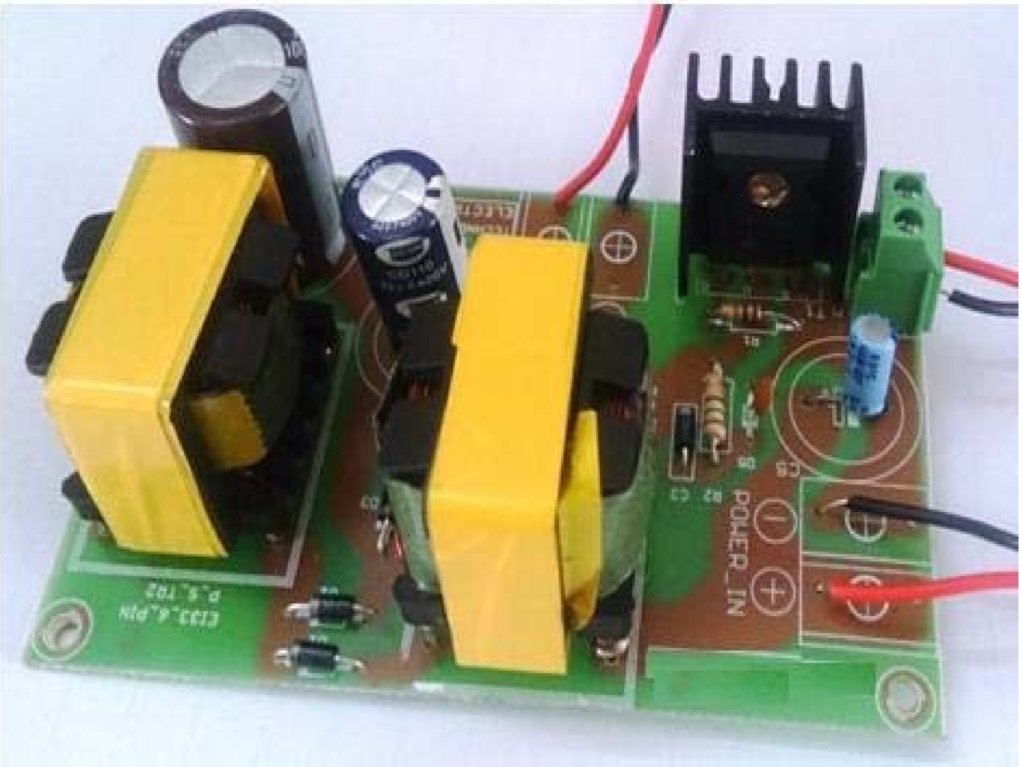


Fig. 8 Prototype of SFFB converter

VI. Experimental setup of SFFB converter

The prototype model of series connected forward flyback converter is shown as follows:

Fig. 9 Experimental setup of the SFFB converter

A. Efficiency Analysis

Table 2 On load Parameters of SFFB Converter

Sr. No	Parameters	Abbreviation	Value
1	Input Voltage	V_i	8.42V
2	Input Current	I_i	0.7A
3	Input Power	P_i	5.894W
4	Output Voltage	V_o	33V
5	Output Current	I_o	0.15A
6	Output Power	P_o	4.95W
7	Efficiency	η	84%

VII. Simulation Results

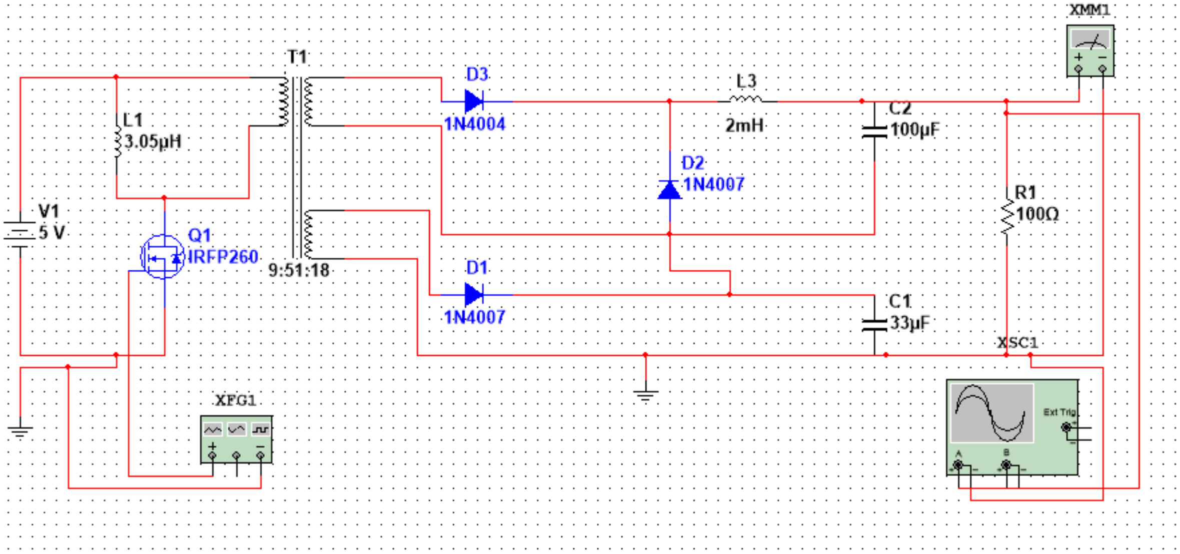
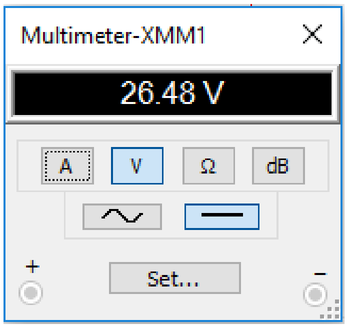
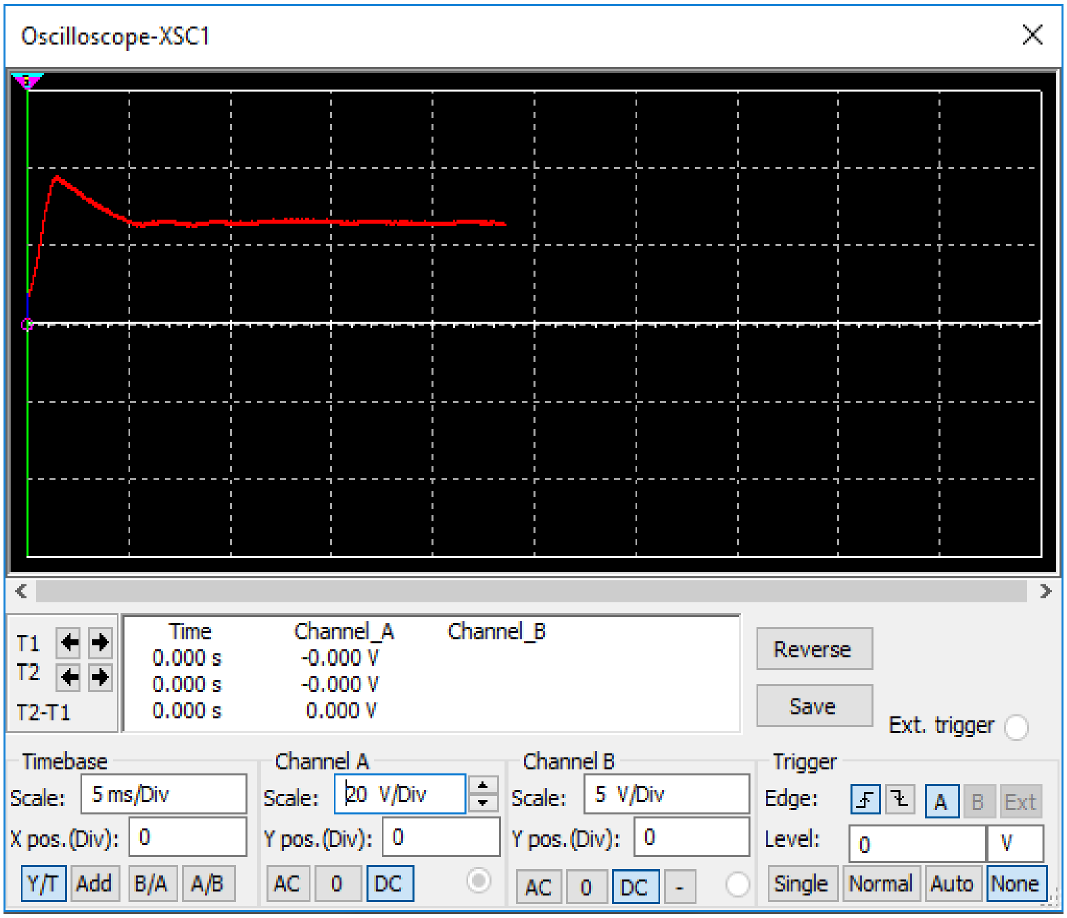


Fig 10 simulation of DC-DC converter on Multi sim


Multimeter-XMM1

26.48 V

Fig 11 Reading on the multimeter



Oscilloscope-XSC1

	Time	Channel_A	Channel_B
T1	0.000 s	-0.000 V	
T2	0.000 s	-0.000 V	
T2-T1	0.000 s	0.000 V	

Timebase
Scale: 5 ms/Div
X pos.(Div): 0

Channel A
Scale: 20 V/Div
Y pos.(Div): 0

Channel B
Scale: 5 V/Div
Y pos.(Div): 0

Trigger
Level: 0 V

Fig. 12 Output Voltage waveforms

VIII. Conclusion

In this project, a pre-regulating DC - DC converter of a series forward flyback converter for multistage systems has been proposed. The operation of single-ended forward–flyback contributes to the high-density power delivery of the transformer along with galvanic isolation and the series connected output is quite a beneficial to the enhancement of the output voltage.

The high voltage, low-current output has an inductor under DCM (Discontinues Conduction Mode) operation that contributes to better performances as it eliminates the reverse recovery of the rectifying diodes. The operation principle and the design based analysis of the forward–flyback converter is presented. The experimental result with a 100-W hardware prototype is experimented to show that the proposed converter has an efficiency of greater than approximately 80%.

IX. References

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