

Design and implementation of solar emulator through flyback converter

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Abstract -Rapidly depleting fossil fuel have set off exhaustive research efforts in the area of non- conventional energy and renewable energy sources such as wind energy, solar PV, tidal, ocean, geothermal, fuel cell etc. The issues while using non-conventional energy sources include high capital cost of the actual energy sources and their auxiliaries, dependence on environmental conditions, unpredictability of environmental conditions, larger space requirement etc

Key Words:converters, emulator, flyback converter, matlab simulation.

1.INTRODUCTION

Rapidly depleting fossil fuel have set off exhaustive research efforts in the area of non- conventional energy and renewable energy sources such as wind energy, solar PV, tidal, ocean, geothermal, fuel cell etc. The issues while using non-conventional energy sources include high capital cost of the actual energy sources and their auxiliaries, dependence on environmental conditions, unpredictability of environmental conditions, larger space requirement etc.

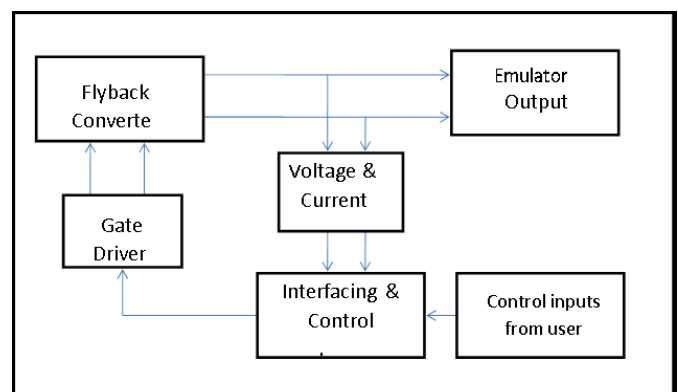
Renewable energy source such as solar PV is one of the important sources as being freely and widely available across the globe. The PV technology has attracted much interest as a new generation energy source. Numerous research and development works are coming off continuously for an efficient utilization of PV energy. However, while an installed Photovoltaic system is installed and operating properly, there are still many ongoing issues that need to be investigated and solved such as the reliability of the PV system, the analysis of its power generation and the electricity network performances due to partial shading. To overcome these issues, repeatable, variable and stable PV source are required for testing. The availability of solar radiation is variable and unpredictable. Generally during the day, sufficient solar radiation is available for about 6-7 hours or less. Therefore, to carry out experimentation under particular desirable operating conditions, the researcher has to completely depend on the environment. This imposes a lot of constraints on carrying out research with the actual solar PV installation. Hence the necessity of the implementation of a PV emulator which

yields to the reproduction of the current-voltage (I-V) output characteristics of a functional PV module under various climatic conditions. Several methods have been suggested to realize the PV emulation. Several methods are based on using various power converter topologies such as the DC-DC buck converter and the DC-DC boost converter. Others are based on modifying a programmable DC power supply, so that the internal resistance of the DC source varies exponentially with the output current. Additionally, several other studies are based on the amplification of a p-n photo sensor output voltage by a DC power amplifier.

2. Flyback Converter

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

Fig -1:Block Diagram of Proposed Emulator



3. Design of flyback converter

3.1 Core selection

Table -1: Core selection chart

Cores without air gap	Mean length per turn le mm	Mean magnetic length lm mm	Core cross section area Acx100 sq.mm	Window area Awx10 ⁴ sq.mm	Area product Apx10 ⁴ (mm) ⁴
T 10	12.8	23.55	0.062	0.196	0.012
T 12	19.2	30.40	0.12	0.442	0.053
T 16	24.2	38.70	0.20	0.785	0.157
T 20	25.2	47.30	0.22	0.950	0.213
T 27	34.1	65.94	0.42	1.651	0.698
T 32	39.6	73	0.61	1.651	1.010
T 45	54.7	114.50	0.93	6.157	5.756

Toroidal Iron Dust Core T 45 selected,
 Ac = 93 sq.mm,
 Aw = 615.7sq.mm,
 Magnetic Length (lm) = 114.50 mm,
 Avg length of turn (le) = 54.7 mm

Primary number of turns:

$$N1 = \frac{V1}{4 \times f \times Bm \times Ac}$$

N1 = 5.37 ≈ 6

Secondary number of turns:

$$N2 = \frac{V2}{4 \times f \times Bm \times Ac}$$

N2 = 26.88 ≈ 27

Wire used in primary

$$Aw(sec) = \frac{I2}{J^3} = 1.75 / (3 \times 10^6)$$

Aw(pri) = 0.5833 × 10⁻⁶ sq.m
 From wire table: SWG=20

Wire used in secondary

$$Aw(sec) = \frac{I2}{J} = 5 / (3 \times 10^6)$$

Aw(sec) = 1.666 × 10⁻⁶ sq.mm
 From wire table: SWG=16

Calculation of resistance

Primary resistance

$$Rp = (R/M) (\text{Mean length per turn}) \times (\text{Total no. of turns}) = (10.35/304.8) \times (69 \times 10^{-3} \times 4)$$

Rp = 9.372 × 10⁻³ Ω

Secondary resistance

$$Rs = (R/M) (\text{Mean length per turn}) \times (\text{Total no. of turns}) = (4.094/304.8) \times (69 \times 10^{-3} \times 20)$$

Rs = 0.0185 Ω

Calculation of magnetizing inductance

$$Lm = (4^2 \times 125 \times 10^{-6} \times 1760) / (69 \times 10^{-3})$$

Lm = 51.01 H

Calculation of inductance

$$L = (N^2 \times A \times \mu) / l$$

Where N – number of turns
 A = core cross section area
 μ = permeability
 l = total length of winding

For primary

$$L1 = \frac{7^2 \times 0.8 \times 10^{-4} \times 1760 \times 4 \times \pi \times 10^{-7}}{0.0879} = 98.63 \mu H$$

For Secondary

$$L2 = \frac{28^2 \times 0.8 \times 10^{-4} \times 1760 \times 4 \times \pi \times 10^{-7}}{1.5316} = 905.6 \mu H$$

Practical value of inductance:

For Primary = 88.06 μH

For Secondary = 1166.4 μH

Voltage sensor

$$V_{out} = \frac{Vin \times R2}{R1 + R2}$$

$$4 = \frac{60 \times R2}{1.4 \times 10 + R2}$$

R2 = 100 Ω

Current sensors

As per requirement selected sensor is Hall Effect-Based Linear Current Sensor ACS 712

Output components

Ultrafast diode : 6.0A SILICON RECTIFIER

RC Filter components

220μF, 500V Capacitor and 2 resistors of 1Ω10W

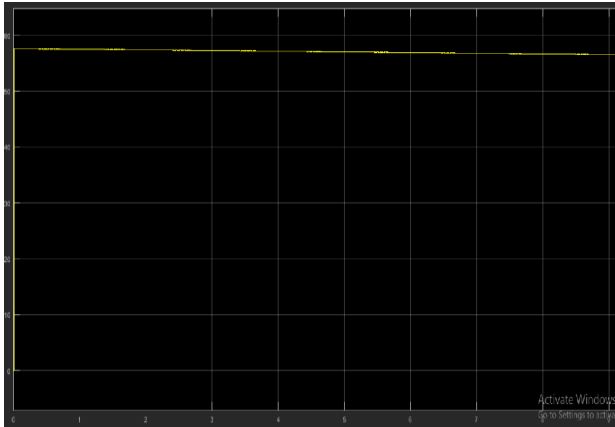


Fig.3 Output of open loop simulation of flyback converter

4. Simulation

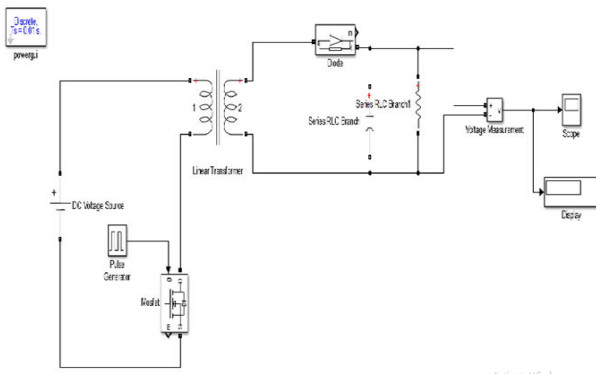


Fig 2. Open loop simulation model of flyback converter

Fig.2 represents the MATLAB simulation of open loop Flyback converter. The linear transformer is used as coupled inductor with all the necessary data entered. The dc source of 12V is used at the primary along with the power MOSFET for switching purpose. The gate pulses are given using the pulse generator to the MOSFET. At the secondary side of coupled inductor the diode, capacitor and resistor are connected as per calculation. The voltage measurement block will measure the output voltage and it will be displayed on the display. The scope will show the output waveform.

Fig.3 shows the output waveform. The X-axis represents the voltage whereas the Y- axis represents time which is here 10 cycles.

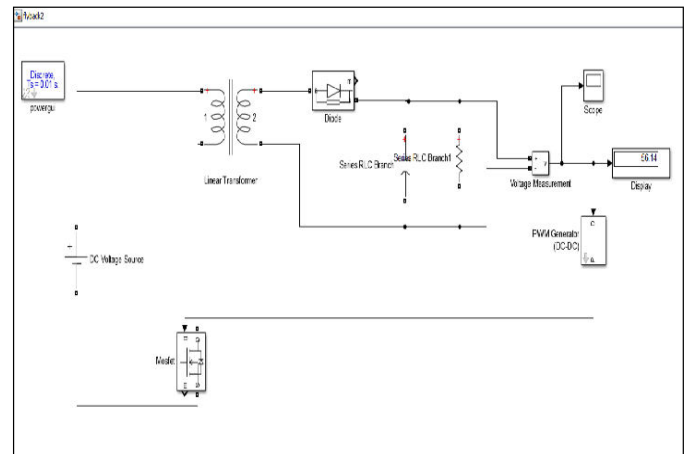


Fig 4: Closed loop simulation model of flyback converter

Fig. 4 shows the close loop version of flyback converter which uses simple PWM generator. This block will measure the output voltage and compares it with reference signal. Any difference between these two will change the duty cycle and it will try to maintain the difference 0. Fig. 5 shows the output waveform of close loop flyback converter. Similar to fig.4.2, this figure has X-axis representing voltage and Y-axis representing time. There is overshoot at the beginning, but it dies out giving the intended Dc output

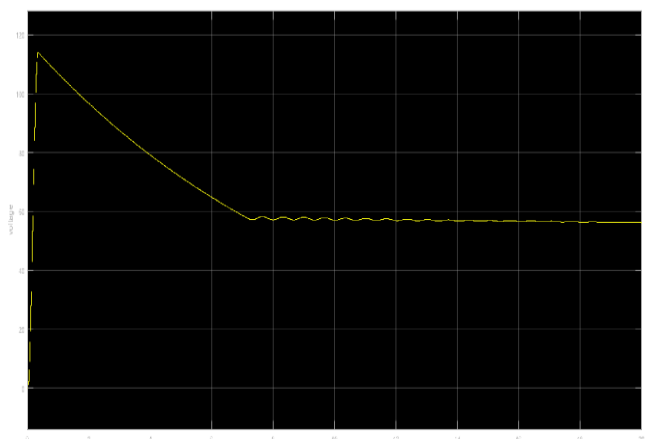


Fig 5: Output of Closed loop simulation model of flyback converter

3. CONCLUSIONS

Applications of solar energy are getting worldwide attention. Laboratory level research involving renewable energy sources possess many difficulties. These difficulties can be sorted out by using a hardware emulator that can accurately mimic the characteristic of a PV panel. The PV cell emulators are widely used for estimating VI characteristics of PV cell at given insolation. The proposed emulator is designed by using flyback converter. The open loop design of converter and MATLAB simulation is included in this paper .

REFERENCES

1. SushilThale, RupeshWandhare and Vive kAgarwal, "A Novel Low Cost Portable Integrated Solar PV, Fuel Cell and Battery Emulator with Fast Tracking Algorithm," 978-1-4799-4398-2/14/\$31.00 ©2014 IEEE
2. RupeshWandhare and VivekAgarwal, "A low cost, light weight and accurate photovoltaic emulator," 978-1-4244-9965-6/11/\$26.00 ©2011 IEEE0018.
3. Dale S.L. Dolan, Joseph Durago and Taufik, "Development of a photovoltaic panel emulator using labview," 1-4244-9965-6/11/\$26.00 ©2011IEEE
4. Ahmed Koran, Kenichiro Sano, Rae-Young Kim and Jih-Sheng (Jason) Lai, "Design of a Photovoltaic Simulator With a Novel Reference Signal Generator and Two- Stage LC Output Filter," 0885-8993/\$26.00 © 2009IEEE
5. Dong, L.; Fujing, D.; Yanbo, W.; Zhe, C. Improved Control Strategy for T-type Isolated DC/DC Converters. *J. Power Electron.* **2017**, *17*, 874–883.
6. Wai, R.J.; Lin, C.Y.; Duan, R.Y.; Chang, Y.R. High-efficiency dc-dc converter with high voltage gain and reduced switch stress. *IEEE Trans. Ind. Electron.* **2007**, *54*, 354–364
7. Huusari, J.; Suntio, T. Origin of cross-coupling effects in distributed DC-DC converters in photovoltaic applications. *IEEE Trans. Power Electron.* **2013**, *28*, 4625–4635
8. Peng, F.Z.; Li, H.; Su, G.J.; Lawler, J.S. A new ZVS bidirectional DC-DC converter for fuel cell and battery application. *IEEE Trans. Power Electron.* **2004**, *19*, 54–55

BIOGRAPHIES



Prof. Kiran Keshyagol Completed Master of Electrical Engineering and completed 'Introduction to Computer Science' Professional Certificate Program from Microsoft through edX, also received young investigator award by IRnet Bhubaneswar and Best teacher award by SITP Ichalkranji. He published many papers in international journals and conferences. Currently he is working as Assistant Professor in Finolex Academy of Management & Technology Ratnagiri Maharashtra India.