

# Single Stage Reconfigurable Inverter Topology for a Solar Powered AC/DC System

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**Abstract**—This project is directed with the purview to derive maximum power from the solar PV source at all times. The endeavor propounds a dual mode inverter based hybrid converter that can support both a grid tied mode along with the islanded mode operation for the aforesaid purpose. Besides, the designing of the project facilitates active power decoupling to draw constant input current using reduced filter sized at the terminals of the PV panel in both AC & DC output power modes. The utilitarian mileage of the project validates itself in environments where there is an impediment to availability of at least 80% of sunlight hours as it produces both AC & DC output together with maintaining the benefits of micro inverters. In advance the DC generated voltage is given to a CUK converter so that the proposed converter could be able to support both the AC grid and also the variable DC load both in positive and negative polarity.

**Key Words**—Flyback Converter, CUK converter, Dual Mode Supply, Grid Tied Mode, Island Mode of operations

## I. INTRODUCTION

A dangerous atmospheric devotion and vitality strategies have turned into a hot point on the worldwide legend in the most recent years. Created nations are attempting to decrease their greenhouse gas outflows. For instance, the EU has resolved to lessen the emanations of green house gas to no less than 20% underneath 1990 levels and to deliver no under 20% of its vitality utilization from sustainable sources by 2020. In this specific situation, photovoltaic (PV) power generation has an essential part to

play because of the way that it is a green source. The main outflows related with PV power generation are those from the creation of its parts. After their establishment they generate power from the solar light without transmitting greenhouse gases. In their lifetime, which is around 25 years, PV boards deliver more vitality than that for their assembling. Likewise they can be introduced in places with no other utilize, such as rooftops and deserts, or they can deliver power for remote areas, where there is no power arrange. The last kind of establishments is known as offgrid offices and in some cases they are the most conservative other option to give power in detached zones.

## II. 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.

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

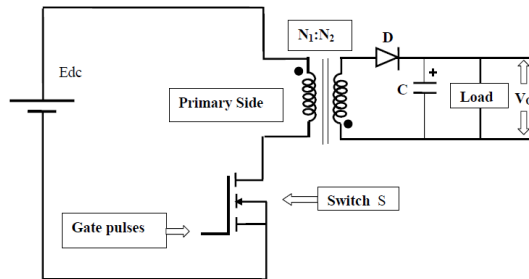


Fig.1 Flyback Converter

### III. BASIC TOPOLOGY

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. The transformer, in Fig.1, 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 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.

### IV. WORKING OF THE SYSTEM

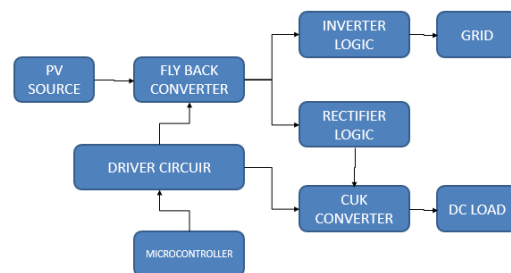


Fig.4. Block diagram

Under **Mode-1**, the input supply voltage appears across the primary winding inductance and the primary current rises linearly. The following mathematical relation gives an expression for current rise through the primary winding:

$$E_{DC} = L_{Pi} \times \frac{d}{dt} i_{Pi}$$

Where  $E_{DC}$  is the input dc voltage,  $L_{Pi}$  is inductance of the primary winding and  $i_{Pi}$  is the instantaneous current through primary winding.

Linear rise of primary winding current during mode 1. As described later, the fly-back circuit may have continuous flux operation or discontinuous flux operation. The waveforms correspond to circuit operations in continuous and discontinuous flux respectively. In case the circuit works in continuous flux mode, the magnetic flux in the transformer core is not reset to zero before the next cyclic turning ON of switch 'S'. Since some flux is already present before 'S' is turned on, the primary winding current in Fig. 2 abruptly rises to a finite value as the switch is turned on. Magnitude of the

current-step corresponds to the primary winding current required to maintain the previous flux in the core.

At the end of switch-conduction (i.e., end of Mode-1), the energy stored in the magnetic field of the fly back inductor-transformer is equal to  $L_{pri} I_p^2 / 2$ , where  $I_p$  denotes the magnitude of primary current at the end of conduction period. Even though the secondary winding does not conduct during this mode, the load connected to the output capacitor gets uninterrupted current due to the previously stored charge on the capacitor. During mode-1, assuming a large capacitor, the secondary winding voltage remains almost constant and

equals to  $V_{Sec} = E_{DC} \times N_2 / N_1$ . During mode-1, dotted end of secondary winding remains at higher potential than the other end. Under this condition, voltage stress across the diode connected to secondary winding (which is now reverse biased) is the sum of the induced voltage in secondary and the output voltage

$$(V_{diode} = V_O + E_{DC} \times N_2 / N_1).$$

**Mode-2** of circuit operation starts when switch 'S' is turned off after conducting for some time. The primary winding current path is broken and according to laws of magnetic induction, the voltage polarities across the windings reverse. Reversal of voltage polarities makes the diode in the secondary circuit forward biased. Fig. 2 shows the current path (in bold line) during mode-2 of circuit operation while Fig.2 shows the functional equivalent of the circuit during this mode.

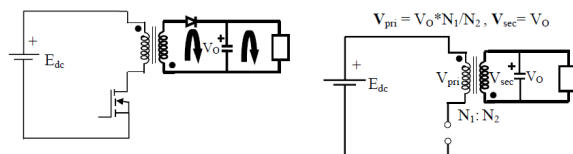


Fig.2 operation of Mode 2

In mode-2, though primary winding current is interrupted due to turning off of the switch 'S', the secondary winding immediately starts conducting such that the net mmf produced by the windings do not change abruptly. (mmf is magneto motive force that is responsible for flux production in the core. Mmf, in this case, is the algebraic sum of the ampere-turns of the two windings. Current entering the dotted ends of the windings may be assumed to produce positive mmf and accordingly current entering the opposite end will produce negative mmf.) Continuity of mmf, in magnitude and direction, is automatically ensured as sudden change in mmf is not supported by a practical circuit for reasons briefly given below.

[mmf is proportional to the flux produced and flux, in turn, decides the energy stored in the magnetic field (energy per unit volume being equal to  $22B\mu$ , B being flux per unit area and  $\mu$  is the permeability of the medium). Sudden change in flux will mean sudden change in the magnetic field energy and this in turn will mean infinite magnitude of instantaneous power, something that a practical system cannot support.]

For the idealized circuit considered here, the secondary winding current abruptly rises from zero to  $I_p N_1/N_2$  as soon

as the switch 'S' turns off.  $N_1$  and  $N_2$  denote the number of turns in the primary and secondary windings respectively. The diode connected in the secondary circuit, as shown in Fig.1, allows only the current that enters through the dotted end. It can be seen that the magnitude and current direction in the secondary winding is such that the mmf produced by the two windings does not have any abrupt change. The secondary winding current charges the output capacitor. The + marked end of the capacitor will have positive voltage. The output capacitor is usually sufficiently large such that its voltage doesn't change appreciably in a single switching cycle but over a period of several cycles the capacitor voltage builds up to its steady state value.  $1/N_2N$

The steady-state magnitude of output capacitor voltage depends on various factors, like, input dc supply, fly-back transformer parameters, switching frequency, switch duty ratio and the load at the output. Capacitor voltage magnitude will stabilize if during each switching cycle, the energy output by the secondary winding equals the energy delivered to the load.

As can be seen from the steady state waveforms, the secondary winding current decays linearly as it flows against the constant output voltage ( $V_O$ ). The linear decay of the secondary current can be expressed as follows:

$$L_{Sec} \times \frac{d}{dt} i_{Sec} = -V_O$$

Where,  $L_{Sec}$  and  $i_{Sec}$  are secondary winding inductance and current respectively.  $V_O$  is the stabilized magnitude of output voltage. Under steady-state and under the assumption of zero on-state voltage drop across diode, the secondary winding voltage during this mode equals  $V_O$  and the primary winding voltage =  $V_O N_1/N_2$  (dotted ends of both windings being at lower potential). Under this condition, voltage stress across switch 'S' is the sum total of the induced emf in the primary winding and the dc supply voltage ( $V_{switch} = +V_{DC} N_1/N_2$ ).

The secondary winding, while charging the output capacitor (and feeding the load), starts transferring energy from the magnetic field of the fly back transformer to the power supply output in electrical form. If the off period of the switch is kept large, the secondary current gets sufficient time to decay to zero and magnetic field energy is completely transferred to the output capacitor and load. Flux linked by the windings remain zero until the next turn-on of the switch, and the circuit is under discontinuous flux mode of operation. Alternately, if the off period of the switch is small, the next turn on takes place before the secondary current decays to zero. The circuit is then under continuous flux mode of operation.

During discontinuous mode, after complete transfer of the magnetic field energy to the output, the secondary winding emf as well as current fall to zero and the diode in series with the winding stops conducting. The output capacitor however continues to supply uninterrupted voltage to the load. This part of the circuit operation has been referred to as **Mode-3** of the circuit operation.

Mode-3 ends with turn ON of switch 'S' and then the circuit again goes to Mode-1 and the sequence repeats.

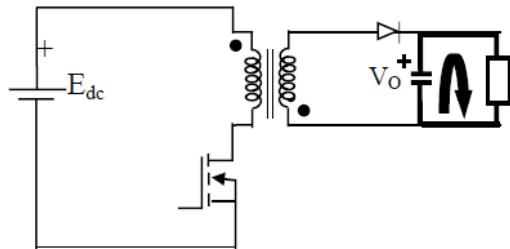


Fig.3 Operation of Mode 3

Fig.3 respectively show the current path and the equivalent circuit during mode-3 of circuit operation. The voltage and current waveforms of the winding over a complete cycle. It may be noted here that even though the two windings of the fly-back transformer don't conduct simultaneously they are still coupled magnetically (linking the same flux) and hence the induced voltages across the windings are proportional to their number of turns.

#### V. RESULTS AND DISCUSSION.

Simulations have been performed to confirm the above analysis. The Hardware setup shown comprises of the flyback converter, Cuk converter (the proposed system) which allows to produce variable DC output and improve its stability and performance.

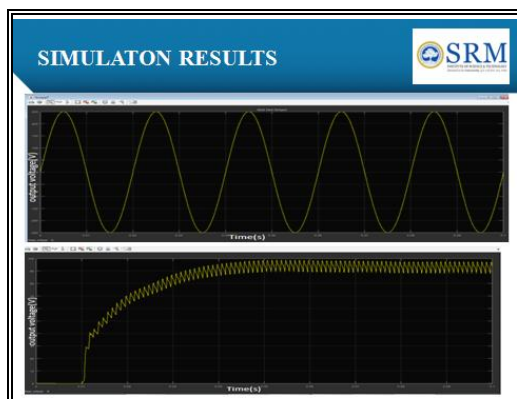


Fig 4. Output voltage waveform.

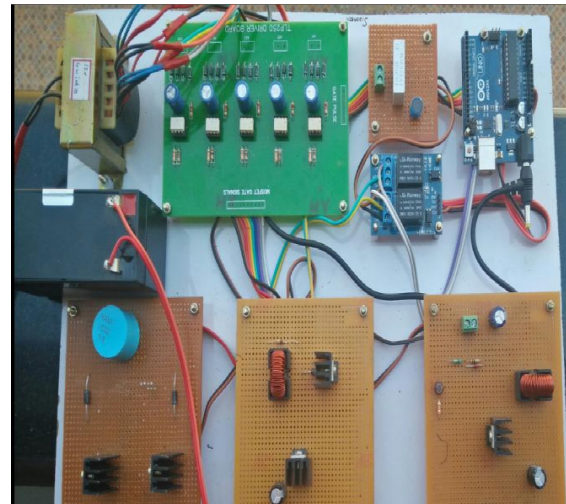


Fig.5. Experimental setup

#### VI. CONCLUSION

A Solar fed Micro inverter was designed using CUK converter which allows us to produce variable DC output and improve its stability and performance. This system produces both AC as well as DC output

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