A Novel Converter Topology For Photo-Voltaic Application

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Abstract*:* This paper proposed a simple dc-dc converter for stand-alone photo-voltaic power conversion in order to reduce the complexity in existing system. The proposed converter topology has the simple structure and has the ability to eliminate the higher order harmonics. Also due to the presence of transformer, the efficiency will be more than that of other converters. The control signal for this converter switch is generated by means of maximum power point tracking (P&O) algorithm. The whole system is modeled by using MATLAB/ Simulink model.

Keywords: Boost Converter, Cuk converter, SEPIC, Fly-Back converter, MPPT, P&O

I. INTRODUCTION

Solar is the most promising source for power generation; that is to meet the energy demand it is must to increase the power generation, to achieve this Renewable Energy Sources are the only method of generating power. There is various renewable energy sources like wind, biomass, fuel cell, ocean are used for this purpose. Comparing to all the sources solar power is the only source which is not depleted at any cost. The advantages of using this power are: Pollution free and Available freely in nature.

The solar power conversion is done by two methods: Solar Photo-Voltaic Power Conversion and Solar Thermal Power Generation. Here Photo-Voltaic conversion method only considered. The power from the solar cell is in the form of DC, it is directly connected to the battery for storage or to the DC load directly. The dc-dc converter is used in this part to reduce the ripples and harmonics.

The dc-dc converter converts the constant dc into the variable dc voltage. There are different types of dc-dc converters are available, it is classified based on the output voltage: Step-up / Boost converter, Step-down or Buck converter, Cuk converter, Buck – Boost converter, Fly-back converter. The overall block diagram is shown below:

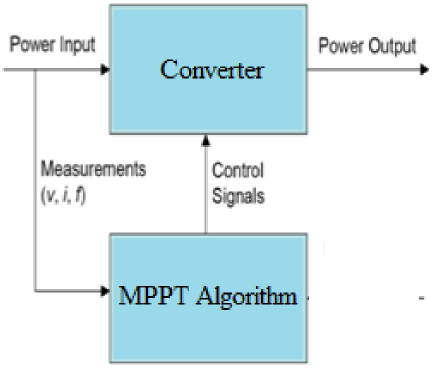


Fig-1 Proposed system Block Diagram

II. DC-DC CONVERTERS

Boost converter [3] will step up the input voltage according to the duty cycle value of the switch used. The output voltage can be varied by changing the duty period. Whereas in buck converter [3] output voltage is less than the input voltage (Step down); the output is varied from 0 to the input value. Both the converters are not capable of eliminating the higher order harmonics itself. So that additional filter capacitor is added to do this.

Cuk [5]converter will perform both steps up and step down operation in a single circuit based on the duty cycle value. But the output is in the opposite form of input; that is if input is positive than the output is negative and vice versa. The SEPIC [6] (single ended primary inductor converter) is also fused with the cuk converter to get the more accurate results. Also this will be used as a single converter for this application.

Fly-back [1] converter is used for both ac/dc and dc/dc conversion. The transformer winding used in this is different from the normal transformer winding. That is it does not transfer the energy from primary to secondary simultaneously. The switch is turned on and off by means of control signal from the controller (MPPT) unit.

When the switch is on, energy is stored in the primary winding and while during off time stored energy is transferred to the secondary winding. The capacitor is connected across the load to provide the filtering action and un-interrupted power to the load. Fig-2 shows the general fly-back converter topology; the practical circuit needs additional snubber circuit and controller to provide the gate pulses to the switch.

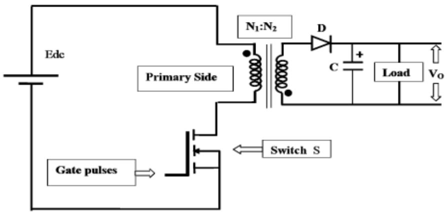


Fig-2 Fly-Back Converter Topology

The transformer design is based on the input and output voltage requirements.

The primary winding current rises from I_P to I_o in δT time.

$I_P - I_o = (E_{dc} / L_{pri})\ \delta T$ (1)

Under steady state Energy to the primary winding during each ON transition

$E_{dc} \times 0.5 x(I_p + I_o)\ \delta T$ (2)

Output energy in each cycle

$V_o I_{load} T$ (3)

$E_{dc} \times 0.5 x(I_p + I_o)\ \delta T = V_o I_{load} T$ (4)

The mean(dc) voltage across primary and secondary windings must be zero

Switch is ON, primary winding voltage equals input voltage. Switch is OFF, the reflected secondary voltage across the primary winding.

$E_{dc}\delta = (N_1/N_2)V_o(1-\delta)$ (5)

Required ratings for switch,

$V_{switch} = E_{dc} + (N_1/N_2)V_o$ (6)

Required ratings for diode,

$V_{diode} = V_o + E_{dc}(N_1/N_2)$ (7)

III. MAXIMUM POWER POINT TRACKING

The generation of gate pulse is based on the maximum power point tracking algorithm. MPPT is a technique [1], used to track the maximum power from the PV panel at all the time to improve the output voltage. This will not rotate the panel; it just modifies the load line from the normal working point to the maximum power point. The fig-3 given below shows the working of tracking algorithm.

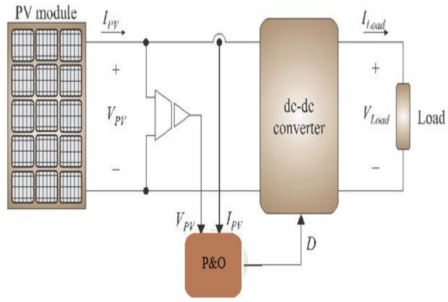


Fig-3 Working of MPPT

There are various algorithms are used for this purpose. Some of them are: Perturbation and Observation (P&O)[1][5], Constant voltage control method, Hill climbing method[6], Incremental conductance method. From those algorithms P&O is the basic for all other algorithms. In this work P&O is only considered for tracking and gate pulse generation. The flowchart given below shows the steps involved in this algorithm. The duty cycle variation can be as follows,

In voltage source region,

$$\frac{\partial \mathrm{Ppv}}{\partial \mathrm{Vpv}} > 0 -> d = d + \Delta \mathrm{d}\ (\mathrm{i.e., increment\ d})$$

In current Source region,

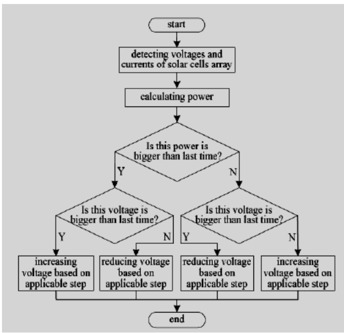
$$\frac{\partial \mathrm{Ppv}}{\partial \mathrm{Vpv}} < 0 -> d = d - \Delta \mathrm{d}\ (\mathrm{i.e., decrement\ d})$$

At MPP,

$$\frac{\partial \mathrm{Ppv}}{\partial \mathrm{Vpv}} = 0 -> d = d\ or\ \Delta \mathrm{d}\ (\mathrm{i.e., retain\ d})$$

As per the above equation if $\frac{\partial \mathrm{Ppv}}{\partial \mathrm{Vpv}}$ is greater than zero ($P_{new} > P_{old}$) the duty cycle is increased (d = d + Δd).

This means that the slope is positive and the module is operating in the constant current region. In case of the slope being negative ($P_{new} < P_{old}$) the duty cycle is reduced (d=d - Δd) as operating region in this case is the constant voltage region.



The solar cell is modeled base on the PV current and voltage rating. The solar radiation can be measured by,

$I_m = I_{pv} - I_0 * Exp((V+I_{rs})/V*T_a) - 1$ (8)

$Ipv = (K_i \Delta t + I_{pv},n) G/G_n$ (9)

$I_0 = I_{scn} + (K*I*\Delta t)/exp(((V_{on}+K_i\Delta t)/V_{ta}))-1$

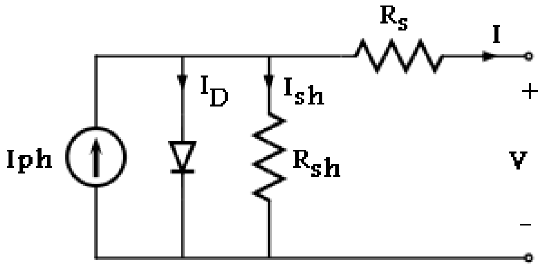


Fig-5 Solar Cell equivalent Circuit

Where,

I_{pv}= Photovoltaic current

I_{pv},n=Light generated current

K_i=Current temperature co-efficient

G=Actual sun irradiation (W/ms)

G_n=Nominal sun irradiation

Δt=Difference between actual and nominal temperature($T-T_n$)

I_0=Diode saturation current

A=Diode identity factor

V_t=Junction thermal voltage = KT/q

K=Boltzman constant

= $1.38065*10^{-33}$ J/k

q=Electron charges = $1.607*10^{-9}$ c

T=Nominal temperature = 298.5 k

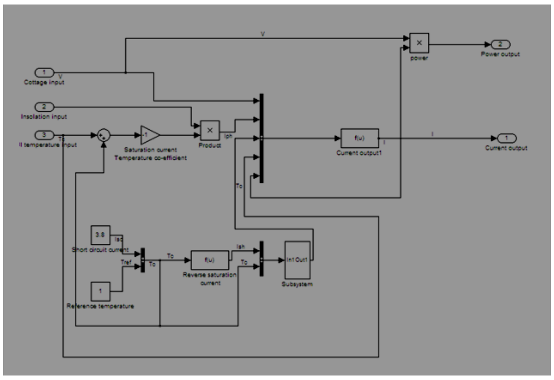


Fig-6 Solar cell modeling in MATLAB

The above fig shows the modeling of solar cell in the Matlab Simulink model. The above equations are the building block of this modeling. From this PV – current and Voltage are taken as output. These two parameters are given as input to the MPPT algorithm block and to the input source for dc-dc converter.

The fly-back converter takes the input from the PV panel and it is given to the primary winding through switch. The switch can be turned on and off by the algorithm. The algorithm compares the power value at present and previous duty period are compared and the duty period is changed accordingly. The fly-back converter can be modeled by using the Matlab as follows:

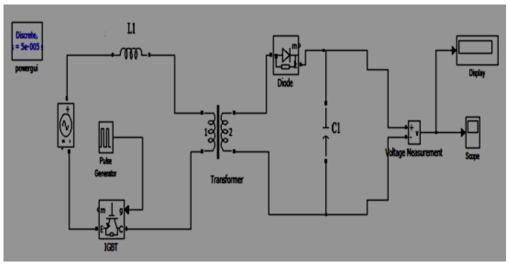


Fig-7 Fly-back converter model in MATLAB

The output taken is power and voltage. The voltage can be stepped down in this configuration. The transformer winding has the 1:n transform ratio. The value of L and C are designed based on the input and output requirement. In the above circuit fly-back converter is simulated with normal dc voltage source.

While using with the PV module controlled voltage source is used, because from the PV array we are getting voltage which is oscillated in nature, so it is not suitable as a direct source for PV array. So the controlled voltage source will provide the controlled/constant voltage to the power circuit without any disturbances.

Then the gate pulse for the switch is generated through the controller block which is based on the power tracking algorithm. The fig given below shows the Simulink model of maximum power point tracking algorithm:

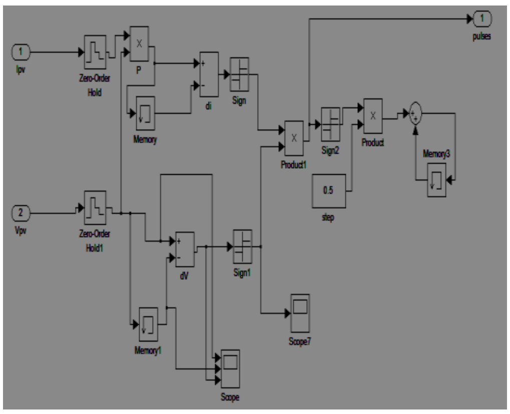


Fig-8 P&O Modeling

The algorithm will take PV voltage and current as an input parameter and calculates the power from those values. Then that is compared with its previous value and the signal passed to the gate terminal of the switch, it will be turned on. The time interval is set to the controller to check the values.

V. SIMULATION RESULTS

The voltage and power are taken as the output, both are in dc form. The results are listed below:

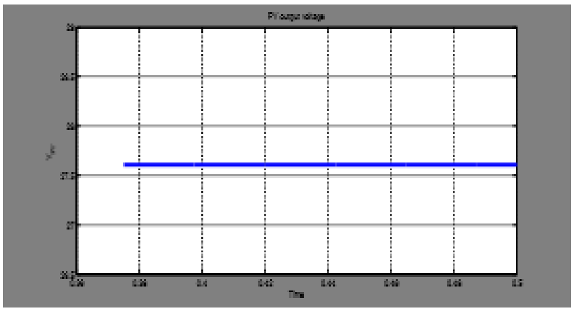


Fig-9 PV Output Voltage

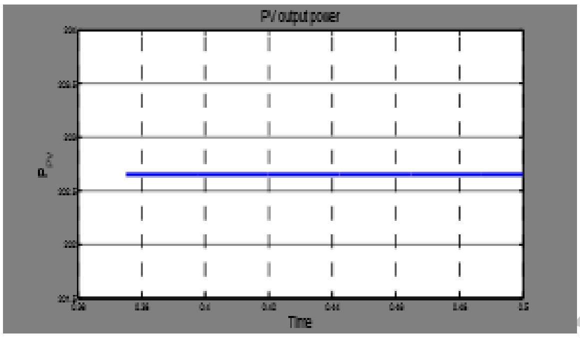


Fig-10 PV output Power

The output from the fly-back converter is depending upon the value of parameters in that circuit, the table below shows the values of different parameters.

Parameter	Values
PV panel output current Ipv	7.35
PV panel output voltage Vpv	27.6V
PV panel output power Ppv	202.86W
Input voltage to the fly-back converter	27.6V
Output voltage from the fly-back converter	30V

Table-1 Parameters used in simulation

VI. CONCLUSION

The simple dc-dc converter for the solar photo-voltaic power conversion is proposed in this work. The proposed fly-back converter is analyzed in detail and the advantages of using this converter are low reactive components and more efficiency. It will provide the more efficient result than the other topologies of dc-dc converter. The fly-back output is compared with the other converter results, which gave the support to this work. The output from the fly-back converter is improved by using the Maximum Power Point Tracking (P&O) algorithm. This will assist the converter circuit to give the constant/maximum output at all the times.

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