OPERATIONAL EFFICIENCY OF SOLAR CELL USING MPPT AND IMPROVEMENT OF ITS EFFICIENCY USING BOOST CONVERTER

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***Abstract*— The present world is facing acute energy crisis and so the need to extract energy from renewable energy source is gaining popularity. Among the renewable energy source solar energy is a very huge and clean source of energy. It is a vital untapped resource in India. The main problem for the reach and penetration of solar pv system is their high capital cost and efficiency. In this paper, we examine a schematic to extract maximum obtainable solar energy from a pv module. It investigates in detail the concept of Maximum Power Point Tracking (MPPT) using boost converter.**

***IndexTerms*— PV Cell, Boost Converter, MPPT, Solar Irradiance**

I. INTRODUCTION (HEADING 1)

As the energy demand is growing rapidly and conventional sources of energy are limited, the best course of action is to invest and research in the renewable sources of energy. The recent trends suggest that all the major countries are planning for big investments in the renewable energy sector. Nowadays renewable energy accounts for around 20-30 percent of global energy production. Some of the renewable sources which can be harnessed are solar energy, wind energy, geothermal energy, tidal energy etc.

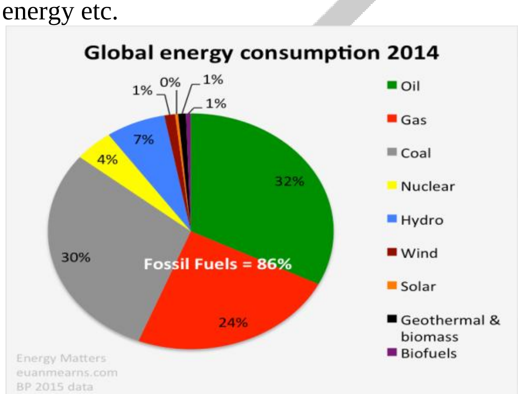

Fig.1 Global energy consumption in the year 2014

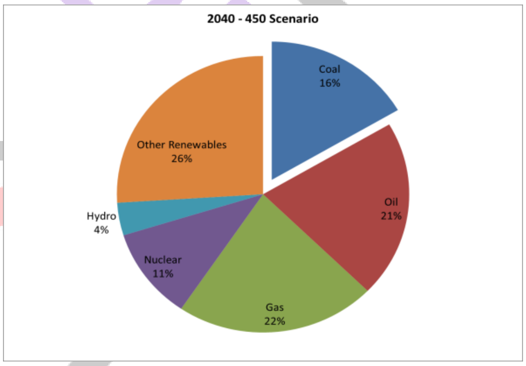

Fig. 2 Expected energy consumption by the year 2040

One of the major problems that the renewable energy harnessing faces is its low efficiency and further development is the need in this regard. Solar energy is one of the major renewable energy. Solar energy has the greatest potentials of all forms of renewable energy and if only a small amount of this form of energy could be put to use, it will be one of the most crucial supplies of energy especially when other sources in the country have depleted. Solar energy can be utilized in two important ways. Firstly, the captured heat can be used as solar thermal energy, which has applications in space heating. Another method is the conversion of incident solar radiation directly to electrical energy with the help of solar photovoltaic cells and/or with concentrating solar power plants. Solar energy however varies with intensity of radiation. Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. An algorithm for Maximum Power Point Tracking is required to increase the efficiency of the solar panel. There are different techniques for MPPT such as Perturb and Observe (hill climbing method) or P&O method, Incremental conductance, Fractional Open Circuit Voltage, Fractional Short Circuit Current, Neural Network Control, Fuzzy Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple and easy implementation, lesser time taken to track the MPP and several other economic reasons. Under abruptly and constantly changing weather conditions (irradiance levels) as MPP varies continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and hence some of the times ends up in calculating wrong MPP. However this problem gets avoided and solved in Incremental Conductance method as the algorithm here takes two samples of voltage and current to calculate MPP. Yet, instead of the required higher efficiency, the complexity of the algorithm is very high compared to the previous one and thus the cost of implementation increases. So a trade off is mitigated between both complexity and efficiency. It is observed that the efficiency of the system also depends upon the converter. Typically it is always maximum for a buck topology, than for buck-boost topology and minimum for a boost topology. When multiple number of solar modules are connected in a parallel order, another analog technique TEODI is also very effective which operates on the principle of equalization of output operating points in correspondence to force displacement of input operating points of the identical operating system. It is very easier and simple to implement, and has high efficiency both under stationary and time varying atmospheric conditions.

II. PHOTOVOLTAIC SYSTEM

PV system is designed to give the electric supply to load and load can be ac type or dc type. Supply can be needed in day time or evening time or both time. PV system can give supply only in day time, for night hours we need supply and for that we have batteries, where power can be stored and utilized. Photovoltaic electricity generation offers the benefits of non-polluting, clean energy generation, production of energy close to the consumer (in case of DPGS), the very little or negligible maintenance requirement, and of exhibiting a very long lifetime. Due to these advantages, today, the photovoltaic is one of the fastest expanding markets in the world. However, PV power is still considered to be expensive, and the reduction of cost of PV systems is even now subject to extensive research.There are various types of PV system such as standalone system, grid interactive system, hybrid PV system.

II.I EQUIVALENT CIRCUIT OF A SOLAR CELL

The solar cell can be represented by an electrical model as shown in Figure 3. Its current voltage characteristic is expressed by the following equation (1):

$$I = I_l - I_0\left(e^{\frac{q(V-IR_S)}{AkT}} - 1\right) - (V - IR_s)/R_{sh} \qquad (1)$$

where I and V are the solar cell output current and voltage respectively, I_{sh} is the dark saturation current, q is the charge of an electron, A is the quality (or ideality) factor of diode, while k denotes the Boltzmann constant, T is the absolute temperature and R_s and R_{sh} are the respective series and shunt resistances of the solar cell. R_s is the resistance offered by the contacts and by the bulk semiconductor material of the solar cell. The output current-voltage characteristic of a PV panel has been expressed by equation (2), where *np* and *ns* are the number of solar cells in parallel and series respectively .

$$I \approx n_p I_l - n_p I_o\left(e^{\frac{q(V-IR_S)}{AkT\,n_s}} - 1\right) \qquad (2)$$

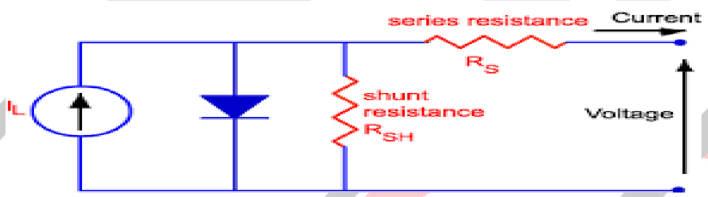

Figure 3: Equivalent circuit of a solar cell.

II.II TEMPERATURE AND IRRADIANCE EFFECT

Two crucial factors that have to be taken into account are the irradiation and the temperature. They affect the characteristics of solar modules strongly. As a result, the MPP keeps varying during the day and it is the main reason why the MPP must constantly be tracked and ensured that the maximum available power is obtained from the panel. The effects caused due to irradiance on the voltage-current (V-I) and voltage-power (V-P) characteristics is depicted in Figure 4 and 5.

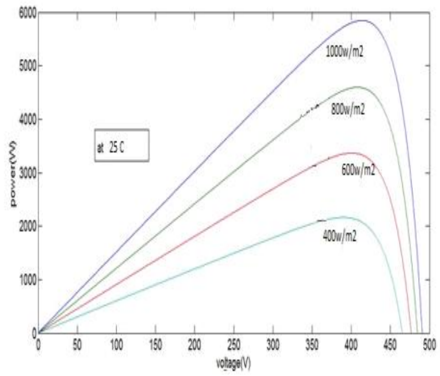

Fig: 4. Variation of P-V Curve with solar irradiation

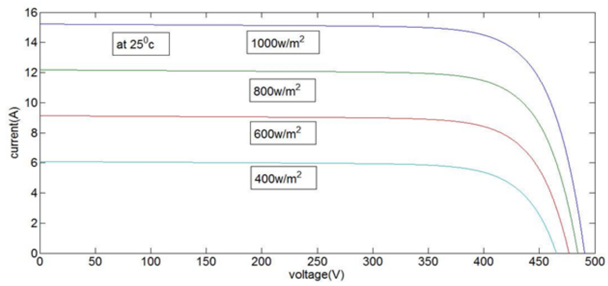

Fig: 5. Variation of I-V curve with solar irradiation

Figure 6 and 7 shows how the voltage-current and the voltage-power characteristics change with temperature.

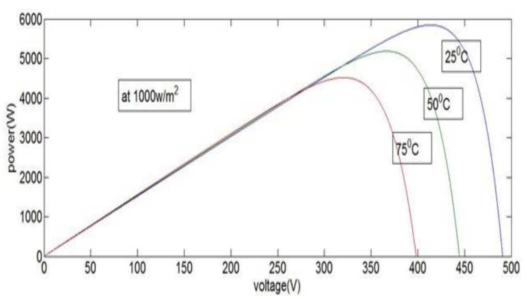

Fig: 6. Variation of P-V Curve with temperature

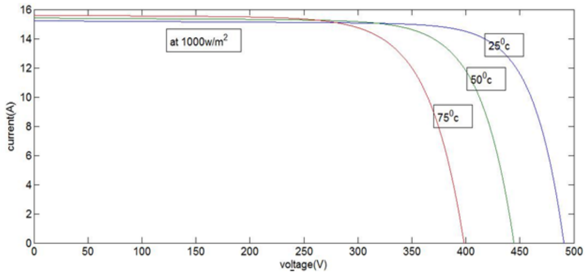

Fig.7 Variation of I-V with temperature

III. MAXIMUM POWER POINT TRACKING (MPPT)

Maximum Power Point Tracking, also referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a particular manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that “physically moves” the PV modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power.

III.I Methods for MPPT

There are many methods used for maximum power point tracking a few are listed below:

- Perturb and Observe (hill climbing method)
- Incremental Conductance method
- Fractional short circuit current
- Fractional open circuit voltage
- Neural networks
- Fuzzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation.

IV. BOOST CONVERTER

The maximum power point tracking is basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required and boost converter is suitable for that. The basic cicuit diagram of a boost converter is shown in the figure 8 below.

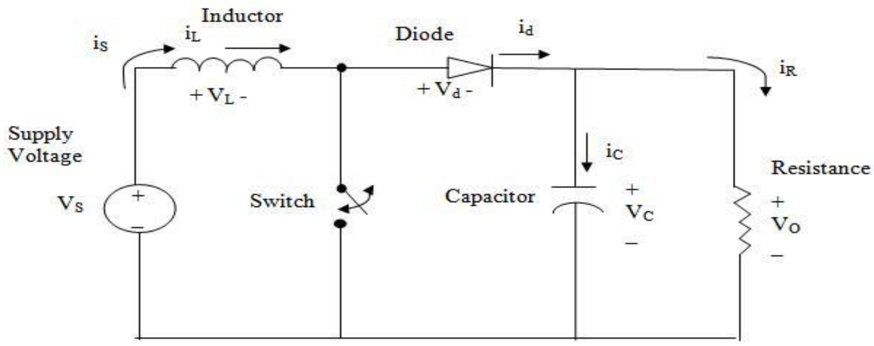

Figure 8: Circuit diagram of a Boost Converter

IV.I CHARGING MODE

When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor. The mode 1 operation of a boost converter is depicted in the figure 9.

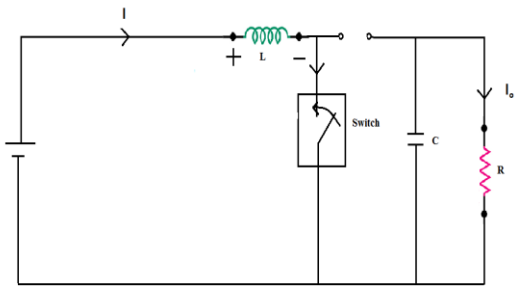

Figure 9: Mode 1 operation of Boost Converter

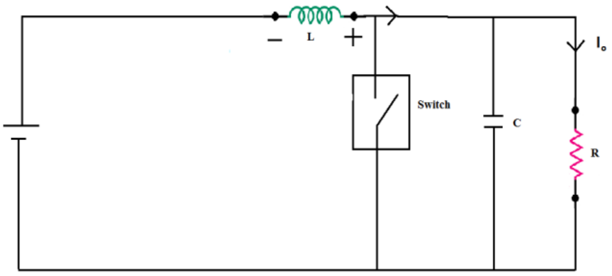

Figure 10: Mode 2 operation of Boost Converter

IV.II DISCHARGING MODE

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation. The mode 2operationof a boost converter is depicted in the figure 10.

IV.III EQUATIONS INVOLVED

For charging mode,

From KVL

$$v_{in} - L\frac{di_l}{dt} = 0$$

From KCL

$$\frac{v_c}{R} + C\frac{dv_c}{dt} = 0$$

In state space form

$$\begin{bmatrix} \frac{di_l}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} i_l \\ v_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} v_{in}; v_o = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_l \\ v_c \end{bmatrix}$$

For discharging mode,

From KVL

$$v_{in} - v_c - L\frac{di_l}{dt} = 0$$

From KCL

$$i_l - \frac{v_c}{R} - C\frac{dv_c}{dt} = 0$$

In state space form

$$\begin{bmatrix} \frac{di_l}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{-1}{L} \\ \frac{1}{C} & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} i_l \\ v_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} v_{in}; v_o = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_l \\ v_c \end{bmatrix}$$

V. RESULT

V.I SIMULATION PROGRAM

```
vp=input('enter pv voltage');
disp(vp);
ip=input('enter pv current');
disp(ip);
d=input('enter duty cycle ');
disp(d);
rl=input('enter load resistence');
disp(rl);
d1=1-d;
l=input('inductance value of the filter');
disp(l);
c=input('capacitance value of the filter');
disp(c);
syms s t tau
```

```
'a'
A=[0 -d1;d1 -1/rl];
B=[1;0];
u=vp;
k=[l 0;0 c];
k1=inv(k);
disp(k1);
X0=-inv(k1*A)*(k1*B)*u;
disp(X0);
I=[1 0;0 1];
E= ((s*I-(k1*A))^(-1));
Fi11=ilaplace(E(1,1));
Fi12=ilaplace(E(1,2));
Fi21=ilaplace(E(2,1));
Fi22=ilaplace(E(2,2));
'Fi(t)'
Fi=[Fi11 Fi12;Fi21 Fi22];
pretty(Fi);
Fitmtau=subs(Fi,t,t-tau);
'Fi(t-tau)'
pretty(Fitmtau);
X=Fi*X0+int(Fitmtau*(k1*B)*u,tau,0,t);
x=simple(X);
x=simplify(X);
'x(t)'
pretty(x);
ezplot(x(2,1),[0,1000]);
pause
```

V.I OUTPUT CURVE

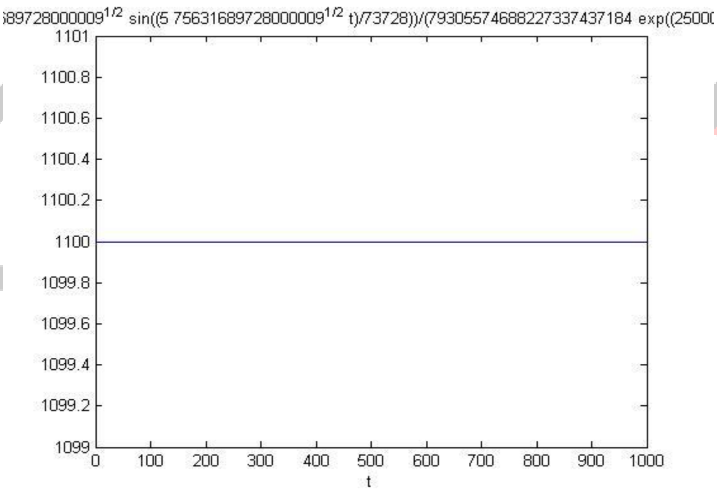

Fig 5.1: Output curve of matlab simulation

VI. ACKNOWLEDGMENT

In this paper, we get to know many MPPT algorithms. The traditional P&O and Incremental Conductance algorithms were proposed, which allow the hill-climbing algorithms to track the MPP even under changing irradiation and adapt the increment in the reference voltage to the operating point, as the variation of the MPP voltage is not linear. It can be concluded that the boost converter not only improves the efficiency of the solar cell but also helps to find the MPP point very quickly and accurately. MATLAB/SIMULATION of modeling of boost converter is done

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