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A study of an analog circuitry MPPT based on P&O algorithm.

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***Abstract*— A Maximum Power Point Tracker (MPPT) is an important tool for obtaining maximum power output from a solar panel at any given intensity of the solar energy. An analog circuitry is attractive because of its low cost and effectiveness and capability ofeasy integration with a normal DC/DC controller such that"plug and play" can be expected for many photovoltaic (PV)applications[1]. In this paper, a study on one of the analog circuitry used in MPPT is carried out. The analog circuit works on the algorithm of perturbation and observation (P&O). Different components are used in the circuitry to optimize its output like storage cells and logic gates.**

***Index Terms*—**Maximum Power Point Tracker, analog circuitry, P&O, controller.

I. Introduction

A **Maximum Power Point Tracker (MPPT)** is an electronic tool t produce triggering pulse to a DC to DC converter that optimizes the match between PV panel and battery bank. To make a PV cell operate at its maximum power point is important for any PV applications. This is mainly because of 3 main reasons. Firstly, the PV panels have unique characteristics Secondly, PV panel are very expensive, most of the installation cost is used by PV panel, thus maximum power output is important to improve the overall cost. Thirdly, the panel efficiency is directly related to the power output. The components of the analog circuitry are chosen as to decrease the total cost without compromising the working efficiency. Today, many MPPT circuits are available in the market which is designed using digital systems,it can be a microcontroller or any other digital controllers. Thepotential benefit from analog solution is the MPPT can beintegrated with DC/DC controller such that "plug and play"can be expected for many low power PV applicationsfor residential application [1-3].

Even though all MPPT available today cannot determine the real maximum power as it works on different algorithms and based on which different components are used. In order to optimize operation this MPPT is inserted.

II. P/V Characteristics of a P V Panel

The PV panel has unique electrical characteristics. The electrical characteristics is a plot between voltage obtained from the panel and calculated power. The characteristics is such that power varies linearly with respect to voltage up till V_{MPP} where maximum power output is obtained and then decreases on further increase in voltage.

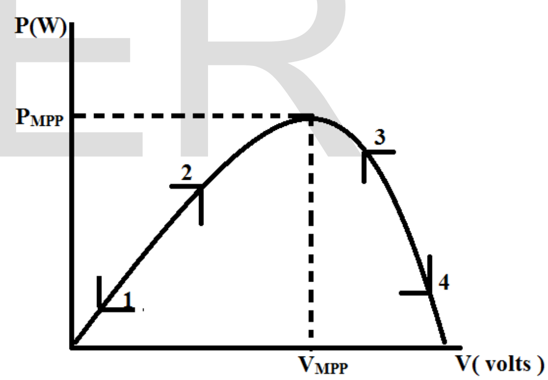

Figure 1: Power-Voltage curve of PV panel

From the plot, it is clear that at a particular voltage point V_{MPP} maximum power is obtained P_{MPP}. Thus a MPPT is designed such that this voltage is traced to obtain this power point.

III. P & O Algorithm and Truth Table

At any instant of time the main aim of MPPT is to trace a voltage level such that maximum power is obtained. From the figure 1; at point 1, the power increases on increasing the voltage, thus the next perturbation would be further increase in voltage level. At point 2, the power decreases on decreasing the voltage level, thus the next perturbation will be increment in voltage level since decreasing it would result in further decrement of power. At point 3, if the voltage level is increased the power will decrease thus the next perturbation would be decrease in voltage level. Again at point 4, if voltage decreases, the power increases thus the next perturbation

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would be further decreasing voltage till V_{MPP} is reached. The main advantage of this algorithm lies in its simplicity. The drawback is that the MPPT cannot detect sudden change in the solar energy. It works well only when the change in the solar energy (irradiation that leads to voltage build up in PV cell) is gradual.The summary of the algorithm so is shown below:

Table 1: Summary of the algorithm.

Perturbation(change in voltage at an instant)	Change in power	Next Perturbation (next change in voltage)
Increase	Increase	Increase
Decrease	Decrease	Increase
Increase	Decrease	Decrease
Decrease	Increase	Decrease

The truth table is obtained by considering any increasedenoted by a high or '1' and decrement is shown by low or '0'. Thus the truth table is as under:

Table 2: Truth table

Perturbation	ChangeinPower	NextPerturbation
1	**1**	**1**
1	**0**	**0**
0	**1**	**0**
0	**0**	**1**

From the truth table we can infer that, this MPPT based on P&O algorithm works on simple XNOR logic. This means when the two inputs are same only than the output is high.

IV. Analog MPPT Circuit and its Component

Fig 2 shows the analog circuit under study [1-3, 8]. This circuit consist of different elementary components like comparators, flip flops and logic gates etc. Combination of this elementary circuits results in different components of the analog circuit like timer, multiplier, controller unit. The entire circuits can be divided into 4 blocks. Block 1 is the portion where the algorithm is implemented, Block 2 and Block 4 where the control signals to the DC-DC chopper is produced. Block 3 is a timer circuit.

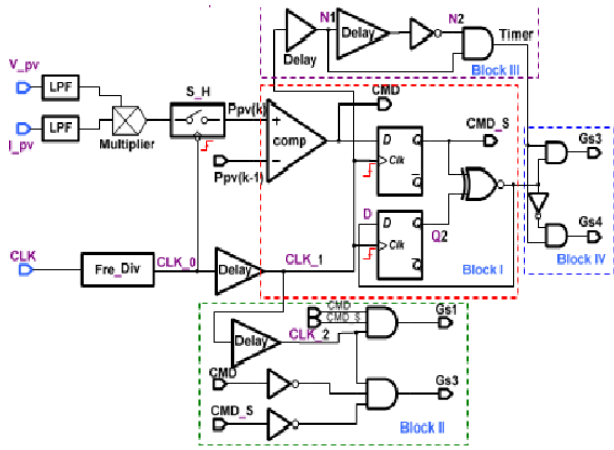

Figure 2: Analog circuitry [1]

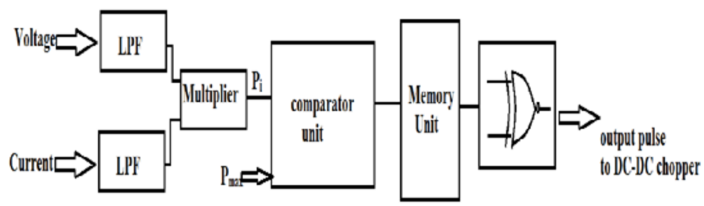

Figure 3: block diagram of the controller

A. *MULTIPLIER*

There are a number of multiplier circuits available. The multiplier here is used to calculate the power considering two inputs current and voltage. Such circuits can be used to implement relative functions such as squares (apply same signals to both inputs).An efficient multiplier should have following characteristics-

- Accuracy
- Speed
- Area (a good multiplier is when it occupies less area)
- Power consumption (the less the better)

The multiplier was constructed using Opamp-741 and resistance configuration as in [5-6].Here since two inputs are analog in nature and are working at real time thus the multiplier used is consisting ofanalog components. Thus the multiplier in [4] is used.

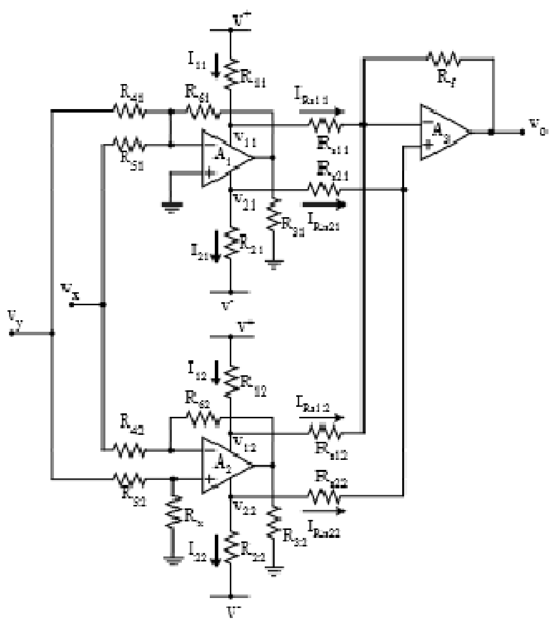

Figure 4: multiplier circuit. [5]

The circuit consists of three general-purpose opamps A1, A2, A3 and resistors. The opamps A1, A2 and resistors R31 = R32 = R3 are connected as a voltage-to-current converter.
The resistors R11, R21, R12 and R22 are used to sense the supply current and set R11 = R12= R1, R21 = R22 = R2, R1 = R2.vx and vy are the input signal voltages. The voltage v01 and v02 are transferred to the difference amplifier formed by the opamp A3 and resistors RS11 = RS21 = RS12 = RS22 = RS and Rf1 = Rf2 = Rf [4-6].

Many other multiplier circuits are also available in the market. A cost effective multiplier is described in [1-3] which can also be used instead.

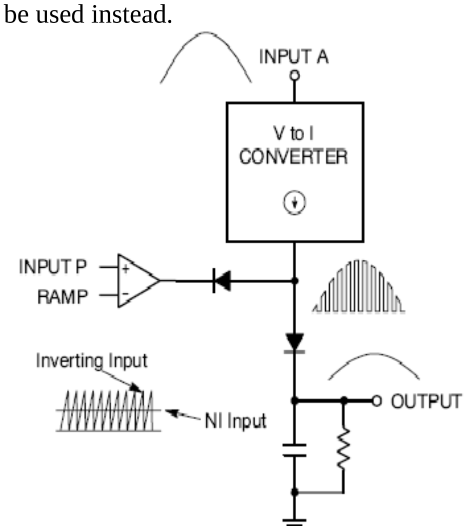

Figure 5: A cost effective multiplier [1] .

B. Timer circuit

Block 3 represents the timer circuit. The analog MPPT controller is an asynchronous circuit thus at an instant it might be possible that both the output pulses are not ready at the same time. Timer is used to synchronize the output G_{s3} and G_{s4} such that both the outputs are available simultaneously by introducing some delays. The "high" time duration of signal "Timer" as well as the charge (discharge) current in storage cell will determine the minimum perturbation step of V_{pv}. The delay unit was constructed using NOT gate IC-7404 and an AND gate IC -7408 in series.

C. Controller circuit

The Block 1 represents the controller circuit where the P&O algorithm has been implemented. The truth table was implemented using a XNOR gate. This unit consisted of D flip-flops. The output of the controller was fed to a DC-DC converter via Block 4. The comparator circuit is used for comparing the instantaneous voltage with the maximum power point voltage v_{mpp} and also the change in power to make a decision for next perturbation. To construct the controller unit D flipflop IC – 74LS74 and XNOR gate was constructed using AND (IC- 7408), OR(IC-7432) and NOT (IC-7404) gates.

D. Storage cell.

Since the value of the perturbation changes continuously thus it is very important to store the value of previous perturbation, thus a storage cell is used for this [1-3]. In this paper for studying the analog circuitry as in [1] a capacitor based storage cell has been used. For circuit simplifications two voltage sources areconnected in order to charge/discharge the capacitor through a resistor R. The value of capacitor chosen for the experiment was 1pF.

V. SIMULATION AND RESULTS

System simulation has been conducted to verify the operation of the new analog MPPT controller. The designed controller sent voltage signals produced by the algorithm used to a DC-DC converter.The maximum power output was observed at 13.6 volts. Now this voltage is compared with the instantaneous voltage produced by the PV panel and the maximum power point is achieved.

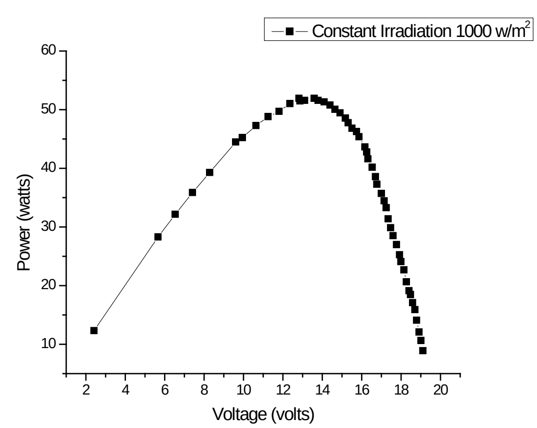

Figure 6: Simulated data from solar panel, P/V curve

The plot in fig.6 shows the PV characteristics of the solar panel. It has been plotted at constant irradiation of 1000 watts/m^2. Due to constant irradiation on the PV panel the

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current produced is same. Thus, in order to obtain varying voltage a variable resistance is connected across the PV panel whose resistance value is varied. The value of the resistance depends upon the panel rating. The resistance chosen for the panel of 100 watts was (5- 360) ohm. After the maximum power point is reached at a particular value of voltage, it is observed that the current decreases. Thus now on further changing the resistance, the power decreases though the resistance value has been increased.

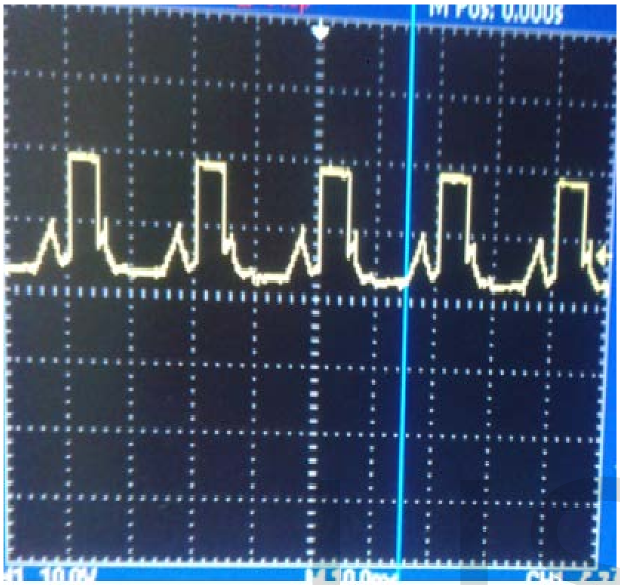

Figure 7: DSO resultant pulse of MPPT

VI. CONCLUSIONS

Analog MPPT controller that works on a truth table derived from P&O algorithm was studied.This controller is attractive for integration due to its simple structure.The pulse generated by the MPPT analog circuit was viewed using DSO and the resultant pulse is shown in figure 7.

The pulse seen from the DSO has some ripples which can be cleared using an adaptive filter and this filtered triggering pulse is given to the Boost chopper through an Opto coupler. Opto coupler is required to isolate the two circuits and to prevent damage to either circuits. The pulse varied when the value the variation of the voltage in the inverting terminal of the comparator. The variation of the voltages needs to be gradual as the MPPT using P and O technique doesn't work well with rapid changes. This might be seen as a future scope for the development of this technique.The curves obtained from the experimental data as shown in figure6 shows that a solar cell has a unique characteristics and can operate at a particular maximum power point.

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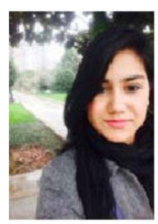

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