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Maximum Power Extraction in Photovoltaic System

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Abstract :- Maximization of power extraction in photovoltaic systems is carried out by using various Maximum Power Point Tracking (MPPT) algorithms. They are mostly based on derivative calculations and more sensitive to the signal fluctuations and sensor noises. This paper proposes the maximum power point tracking by using Golden Section Search (GSS) algorithm with minimum converging iterations. This method is based on characteristics curve of PV array which changes with irradiance and temperature. The power, voltage data is updated by the continuous execution of algorithm by acquiring the input variables such as temperature and irradiation level. This algorithm is implemented to get guaranteed convergence to obtain the maximum power point under continuous variable conditions of the PV characteristics.This method is more robust and also having a fast response as compared to the conventional MPPT algorithms. The basic steps involved in GSS algorithm are presented under different operating conditions. This algorithm is implemented with the PV system along with the boost converter. The performance of the PV system is observed using MATLAB/SIMULINK and verified on LabVIEW hardware.

Keywords :- DC-DC converter , GSS,MPPT,Photovoltaic,PV System

I. INTRODUCTION

The maximum power point tracking methods has a direct impact on utilization of photovoltaic systems. The continuous varying PV characteristic is non-linear and varies with the temperature and irradiations. The maximum power point on this characteristic is observed under given temperature and irradiation and mathematical algorithms are developed to maximize the power extraction.There are various MPPT algorithms based on short circuit current , constant voltage (CV),open circuit voltage, temperature methods[2].perturb and observe(P and O),incremental conductance(IC)[1]-[4].These methods are sensitive to noise and their iterative process depends on the derivative. The Golden Section Search [GSS] technique is used in MPPT algorithm [5].In this application, current is used as search variable. The ripples in the current due to front end DC-DC converter limit its performance in the implementation. The better search variable would be voltage,which is less susptible to DC-DC converter operation.This paper proposes the Golden Section Search based on the voltage .This algorithm for MPPT is developed with the with limiting parameters for fast convergence and tested off-line using simulation tools through MATLAB.The hardware implementation of this algorithm is carried out on LabVIEW platform. The front end DC-DC converter performance is presented. The PV system used in this implementation is shown in Fig.1.

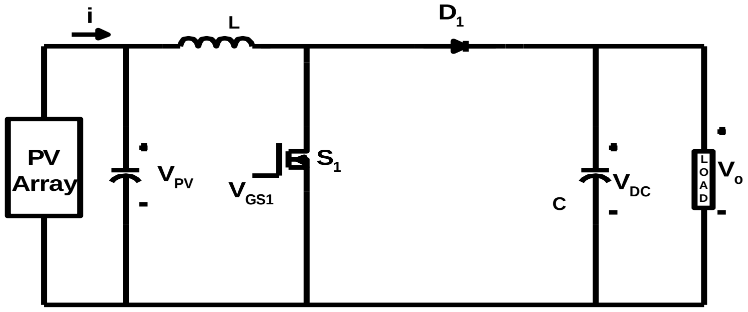

Fig.1 Schematic representation of the proposed PV system

This MPPT algorithm distinctly has certain advantages like noise and signal fluctuations immunity, fast convergence as compared to many other MPPT algorithms, does not have complicated computational load and modular implementation for any PV system is possible.

II. GOLDEN SECTION SEARCH ALGORITHM

The golden section search is a technique for finding extremum (minimum or maximum) by successive narrowing the range of values inside which extremum is known to exist. To find maximum functional value of f(x) ,subject to $a \leq x \leq b$. Starting with an interval in which known maximum must lie which is equal to [a, b]. Now, two points x_1 and x_2 are selected in the interval [a ,b] and function f(x) is evaluated at these points. The points x_1 and x_2 are such selected each point subdivides interval into two parts such that

Length of whole line/ Length of larger fraction = Length of larger fraction/Length of smaller fraction (1)

If we assume a line segment [0, 1] ,then $\frac{1}{r} = \frac{r}{1-r}$, $1-r = r^2$ i.e. $r^2+r-1=0$ (2)

Taking only positive root from quadratic equation, r is given as

$$r = \frac{-1+\sqrt{5}}{3} \quad \text{i.e.} \quad r = 0.618 \tag{3}$$

$x_1 = b- r (b-a)$, i.e. x_1 is 0.618 of interval away from 'b' and $x_2=a+ r (b-a)$, i.e. x_2 is 0.618 of interval away from 'a.

The flowchart for finding the maxima of a function using GSS is shown in Fig.3.When GSS is applied to photovoltaic system for maximum extraction of power f(x) corresponds power which is to be maximized, x_1 and x_2 corresponds to array voltage which is used as the search variable and the range of operation is from zero to open circuit voltage (V_{oc}) i.e. a=0 and b=V_{oc}

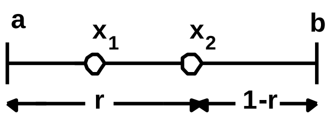

Fig2(a).Division of interval.

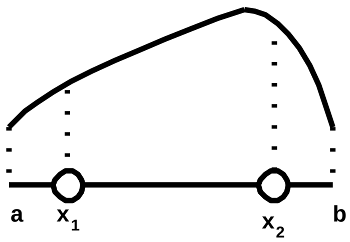

Fig 2(b) Interval marking on characteristics

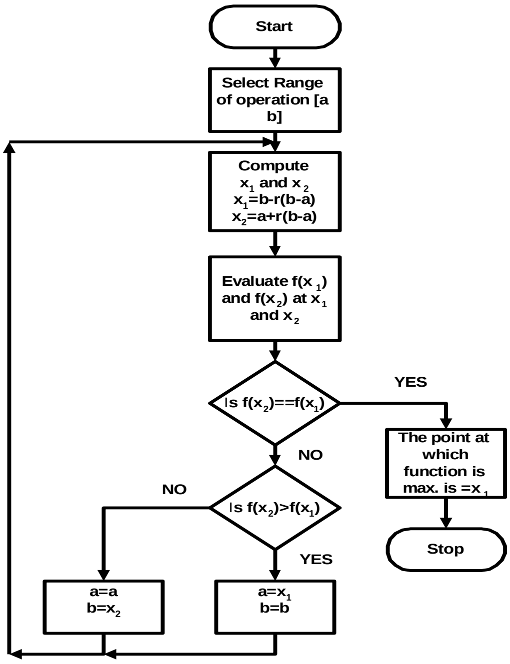

Fig.3 Flowchart for GSS Algorithm

III. PERFORMANCE AND IMPLEMENTATION OF GSS

a. GSS with Voltage as Search Parameter

In photovoltaic system,for a given irradiation level and cell temperature, maximum power is supplied by the photovoltaic cell at a particular operating point, this point is termed as Maximum Power Point (MPP).This MPP varies with irradiance and temperature, therefore Maximum Power Point Tracking (MPPT) techniques are used for extracting maximum power from the system. The detailed GSS algorithm at irradiance of 1000W/m^2, temperature 25° C, open circuit voltage (Voc) of 32.9 volts is illustrated in Table I. These results are obtained in simulation using MATLAB.The PV cell characteristics is modeled to extract the information of power and voltage at a given temperature and irradiation. This model is explained in section IV.

Table I: Search Algorithm (1000W/m^2 and25° C)

Step	a	b	x_1	x_2	P_1	P_2	Comment
1	0	32.9	13	20	98	155	P2>P1
2	13	32.9	21	25	163	192	P2>P1
3	21	32.9	25	28	192	199	P2>P1
4	25	32.9	28	30	199	176	P1>P2
5	25	30	27	28	200	199	P1>P2
6	25	28	26	27	197	200	P2>P1
7	26	28	27	27	200	200	P1=P2

Table II: Number of iterations for different values of S and T

Irradiance(S)	Temperature(T)	Number .of Iterations
1000W/m2	298K	7
800W/m2	298K	7
600W/m2	298K	7
1000W/m2	300K	7
1000W/m2	330K	7
1000W/m2	360K	7

The tracking of the reference voltage i.e. the voltage corresponding to maximum power point by using the GSS algorithm for different value of irradiation(S) is shown in Fig.4 (a)-(b) and that for different cell temperature (T) is shown on Fig.5 (a)-(b).It can be observed that the reference voltage is tracked in minimum time as well as the numbers of iterations required are independent of changes in irradiance and cell temperature. The number of iterations for different irradiance and temperature is shown in Table II.

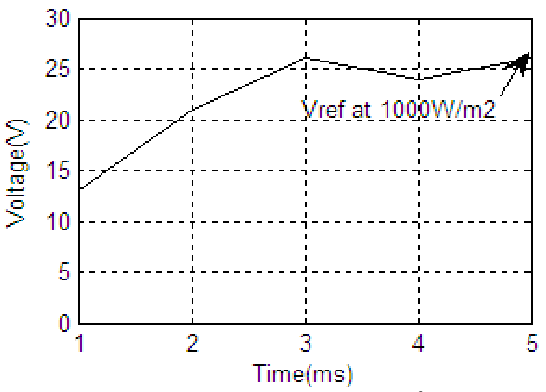

Fig.4(a) Vref tracking at 1000W/m^2 and T=298K

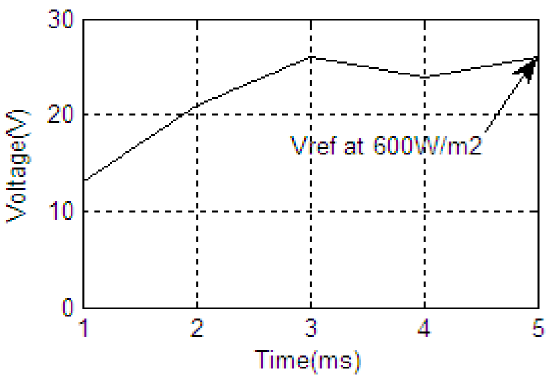

Fig.4(b) Vref tracking at 600W/m^2 and T=298K

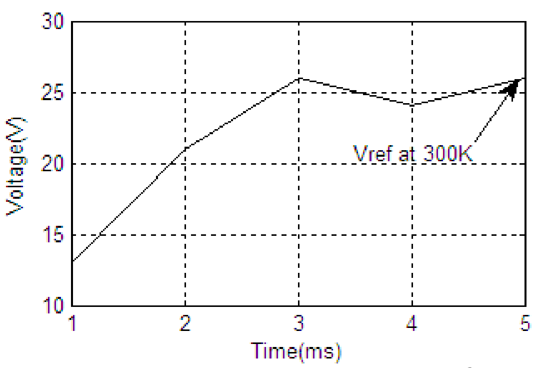

Fig.5(a) V_{ref} tracking at 300K and 1000W/m^2

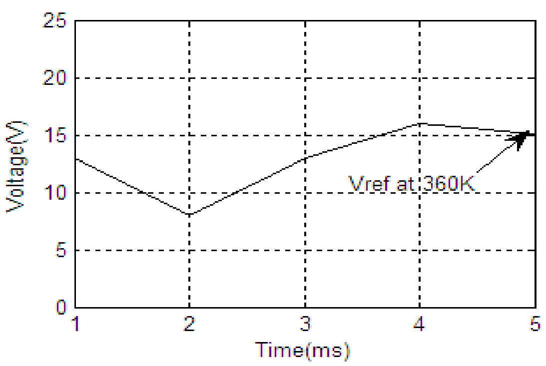

Fig.5(b) V_{ref} tracking at 360K and 1000W/m^2

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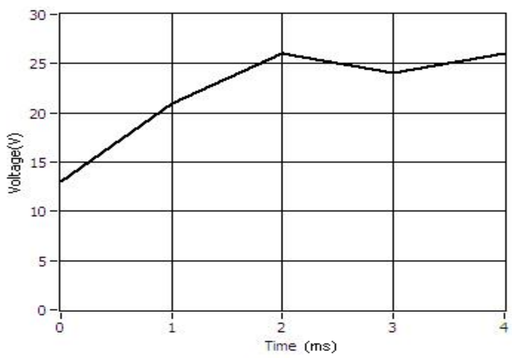
b. GSS Implementation on LabVIEW

GSS algorithm is implemented on hardware using LabVIEW platform.The input variables (temperature/irradiation) are set through the external set values by measuring sensors.These are fed as voltage corresponding to temperature and irradiation.The algorithm is executed on ELVIS with NI PCI-6251 data acquisition card.The results for different irradiation level is shown in Fig.6(a) and 6(b).Similarly,tracking of the reference voltage for different cell temperature is shown in Fig.7(a) and (b).This varifies the functioning of the GSS algorithm to genrate the reference for the DC-DC converter.



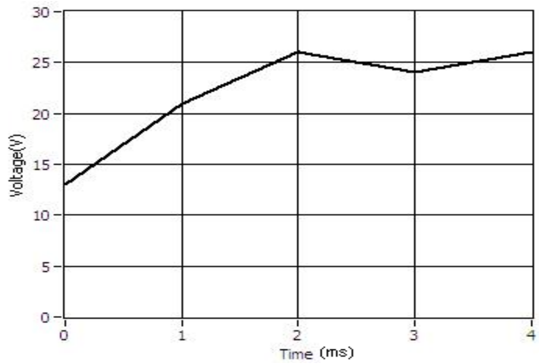
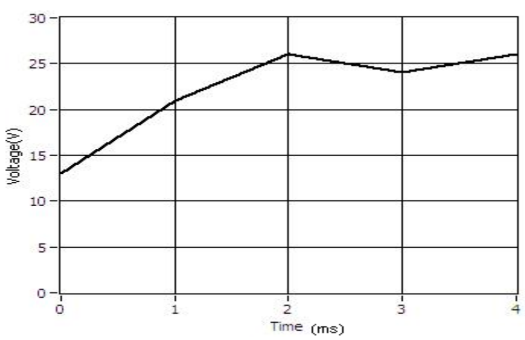


Fig .6(a) Vref tracking at 1000W/m2 and T=298K   Fig.6 (b) V_{ref} tracking at 600W/m2 and T=298K



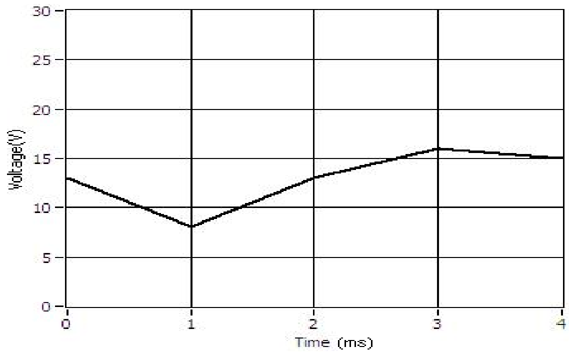


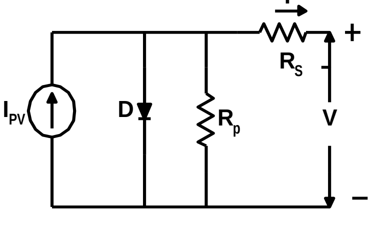
Fig. 7(a) V_{ref} tracking at T=300K and 1000W/m^2 Fig .7(b) V_{ref} tracking at 1000W/m^2 and T=360K

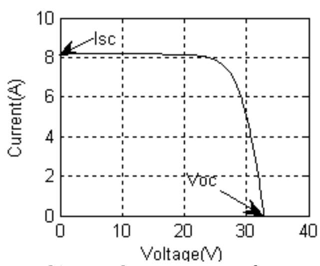
IV. MODELING OF PROPOSED SYSTEM

The schematic diagram of the proposed PV system is shown in Fig.1.It comprises of a PV array, DC-DC boost converter.The mathematical model of the PV is implemented with the basic equations.

a. PV Array

A photovoltaic array is formed when large numbers of solar cells are connected in series, parallel.PV cell is formed by a p-n junction semiconductor, which produces current by photovoltaic effect. An equivalent model of PV cell is shown in Fig.8(a).





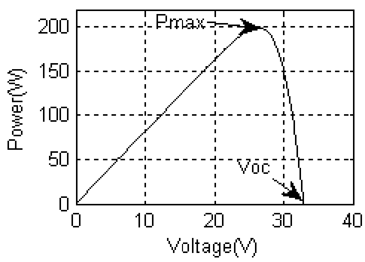


Fig. 8(a) Equivalent model of PV cell   Fig.8 (b) I-V Characteristics of PV array   Fig.8(c) P-V characteristics of PV array

The PV output current is given by [6] equation below

$I = I_{pv} - I_o[\exp(V+RsI)/V_t a)-1]-(V+R_sI)/R_p$ (4)

Where Ipv is light generated current Io is the diode saturation current, V is array output voltage,

$V_t = (N_sKT)/q$ (5)

The light generated current of PV cell depends linearly on irradiance and is also influenced by temperature.

$I_{pv}=(S/S_n)[I_{pvn}+K_i(T-T_n)]$ (6)

The diode saturation current I_o and its dependence on temperature is given by equation below

$Io= Ion\ (T_n/T)^3 \exp[(qEg/aK)(1/Tn-1/T)]$,

where $Ion= (I_{scn})/\exp(V_{ocn}/aV_{tn}) -1$ (7)

Using the above equations(4)-(7)an online computation programme is developed for obtaining the I-V and P-V characteristics of the PV array as shown in Fig.8(b) and Fig.8(c).The specifications of PV array are specified in Table III .

Table III: PV Array Specifications

V_{oc}(Open Circuit Voltage)	32.9 Volts	N_s(number of cells connected in series)	54
I_{sc}(Short Circuit Current)	8.21 Amperes	K_i (temperature coefficient Isc)	0.0032Amp/Kelvin
P_{max}(Maximum power at STC)	200.7271 Watts	R_s (series resistance)	0.221 ohms
T_n(Nominal Cell temperature)	25 °C	R_p (parallel resistance)	415.505 ohms
S_n(nominal irradiance)	1000W/m2	a(ideality factor of diode)	1.3

V. DC-DC Converter

The DC-DC converter is used to boost the output voltage at constant value. The block diagram of the control scheme for the dc-dc converter switching is shown in Fig.9(a). The reference voltage signal is generated using the GSS algorithm that corresponds to MPP which is compared with the output voltage of the boost converter .The error is processed through a PI controller which improves the steady state error as well as the transient response. The output signal of the PI controller is given to the gate signal generator to get the desired PWM pulses as shown in Fig.9 (b).Thus this switching technique helps in extracting maximum power from the photovoltaic system.

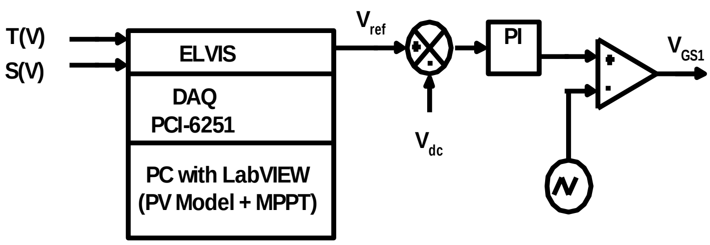


Fig.9 (a) Block Diagram Representation of Control Scheme for operating S_1

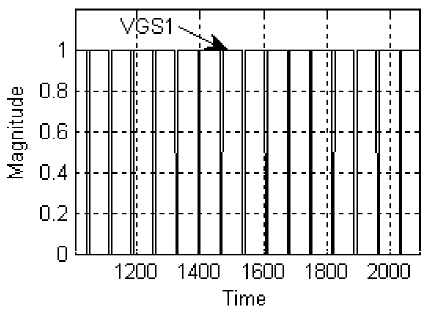


Fig.9 (b) Expanded View of PWM pulses

VI. PV SYSTEM PERFROMANCE

The effect of the irradiance on the output voltage with the PV current is shown in Fig.10 (a)-(b) The output voltage could be maintained almost constant with the supplied current from the PV.In Fig.11 (a)-(b),the output voltage of the boost converter along with the reference voltage is shown. It can be observed that output voltage efficiently follows the reference voltage ensuring maximum extraction of power for a particular operating condition.

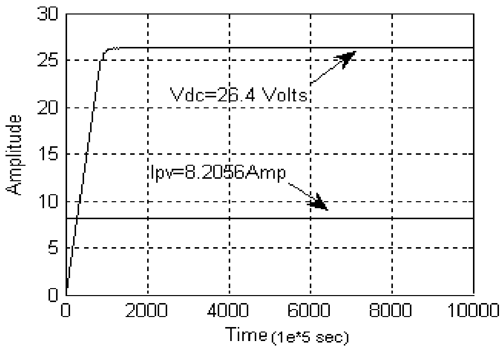


Fig.10 (a) Output DC voltage and PV current at 1000W/m²

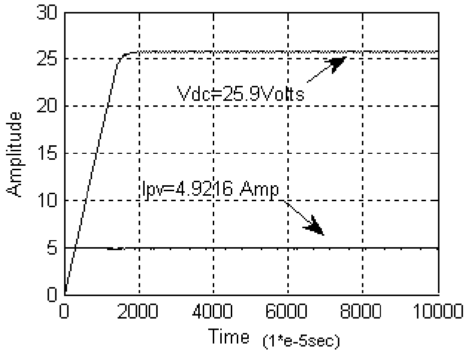


Fig.10(b)) Output DC voltage and PV current at 600W/m²

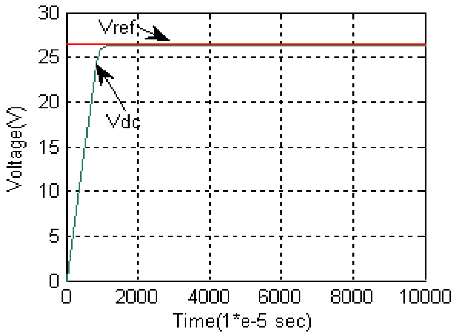


Fig.11 (a) Output DC voltage and reference voltage at 1000W/m²

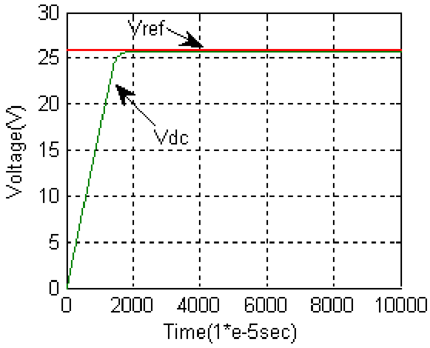


Fig.11 (b) Output DC voltage and reference voltage at 600W/ m²

VII. CONCLUSION

The presented MPPT algorithm based on the GSS technique is implemented with voltage as variable. The convergence under different operating conditions with fixed number of steps indicates its robustness .This technique is immune to noise and fluctuations of the input voltage. This algorithm is tested with the PV model in simulated characteristics having input only temperature and irradiation. This performance is verified on hardware with LabVIEW.The results obtained are confirming the simulated results.

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