Maximum Power Point Tracking for PV Panels using Ant Colony Optimization

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Abstract— **Output power of solar panel varies with respect to irradiance and temperature. So maximum power should be extracted from solar panels using Maximum Power Point Tracking. As irradiance changes continuously during the day, many algorithms fail to give maximum power as they get stuck at local maximum. In order to overcome this problem, we propose Ant Colony Optimization which obtains global maximum and improves the efficiency of solar panels. The proposed work has been implemented using Matlab/Simulink. Also, the hardware results obtained indicate the superiority of Ant Colony Optimization over the conventional Maximum Power Point Tracking methods.**

Keywords— Maximum Power Point Tracking (MPPT); Ant Colony Optimization (ACO); Photovoltaic (PV); Boost Converter

I. INTRODUCTION

Due to over exploitation and depletion of fossil fuels over the past few years, demand for the renewable energy resources has been increasing tremendously. Among the available renewable energy resources, solar energy is considered to be the best because of the various advantages it has (easily available; free of cost; non-polluting) [6].

A. PV Model

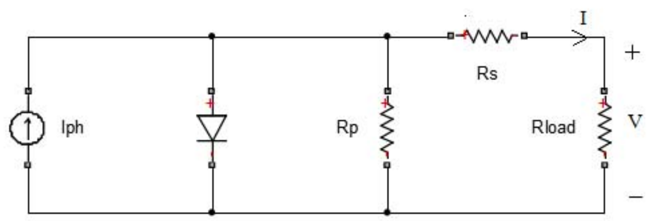

Fig. 1. Equivalent circuit model of a PV cell

$$I = I_{ph} - I_o.[\exp(\frac{V + I.R_s}{V_T}) - 1] - [\frac{V + I.R_s}{R_p}] \qquad (1)$$

I -Cell current
I_{ph} -Insolation current
Io -Reverse saturation current
V -Cell voltage
R_s -Series resistance
R_p -Parallel resistance
V_T-Thermal voltage = KT/q
K-Boltzman constant
T-Temperature in Kelvin
q-Charge of an electron

Eq.1 shows that the output current depends upon irradiance and temperature. Output power (P) of PV cell varies non-linearly with respect to voltage (V) and it has only one maximum power point [10]. Practically, irradiance will not be constant and there are problems of partial shading too [2]. This results in multiple peaks which makes it difficult to track the maximum power point [5]. Also, the efficiency of solar panels is very low which makes MPPT more essential.
There are many other algorithms [3,4], [7,8] like Perturb and Observe (P&O) [9], Incremental Conductance which are more popularly used these days. But these algorithms give best results in uniform irradiance and get stuck at local maxima when irradiance is not constant. So there is a need for efficient algorithm which can overcome all these constraints.
This paper proposes Ant Colony Optimization (ACO) to solve the problem and the results obtained were satisfactory.

I. ANT COLONY OPTIMIZATION

Ant Colony Optimization is generally used to solve non-linear problems. ACO mimics the behavior of ants to find the optimized path. Initially ants move randomly in different directions in search of food. They deposit pheromone on their way for other ants to follow. The deposited pheromone can also evaporate as time passes, so the probability of finding pheromone is more for the shortest path. This process is repeated for a number of iterations so that optimized path can be found.

Consider a problem in which A parameters are to be optimized. Initially Y random solutions where Y≥A are generated. Also new solutions are formed by sampling Gaussian Kernel using the following Eq.2

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$$G_i(x) = \sum_{l=1}^{y} \omega_l g_l^i(x) = \sum_{l=1}^{y} \omega_l \frac{1}{\sigma_l^i \sqrt{2\Pi}} \exp(-\frac{(x-\mu_l^i)^2}{2\sigma_l^{i^2}}) \quad (2)$$

$G_i(x)$ - Gaussian Kernel for ith dimension

$g_l^i(x)$ - lth sub Gaussian function for the ith dimension

σ_l^i and μ_l^i are the i^{th} dimensional standard deviation and mean values for the l^{th} solution.

Using Y initial solutions, mean, standard deviation and weights are calculated as follows:

Mean:

$$\mu^i = \{\mu_1^i, \ldots\ldots \mu_l^i, \ldots \mu_y^i\} = \{s_1^i, \ldots\ldots s_l^i, \ldots\ldots s_y^i\} \quad (3)$$

Standard Deviation:

$$\sigma_l^i = \xi \sum_{j=1}^{y} \frac{|s_j^i - s_l^i|}{Y-1} \quad (4)$$

Weight:

$$\omega_l = \frac{1}{QK\sqrt{2\Pi}} \exp(-\frac{(l-1)^2}{2Q^2K^2}) \quad (5)$$

ξ - Convergence rate

The constants are taken from [1]

The probability of selecting l^{th} Gaussian function can be calculated by

$$p_l = \frac{\omega_l}{\sum_{r=1}^{y} \omega_r} \quad (6)$$

This sampling process will be repeated according to the number of parameters to be optimized. Now Z new solutions that are generated are added to the Y initial solutions. These Z+Y solutions are ranked and Y best solutions are restored again. The entire process is repeated for the required number of iterations.[1]

A. Steps involved

Step 1: Initialize the parameters (Max_Ite, Z, Y, Q, ξ)

Step 2: Obtain voltage, current and calculate power for each ant. Repeat the same till Y ants.

Step 3: Obtain Z new solutions using Gaussian function.

Step 4: Rank M+K solutions and store best K solutions.

Step 5: The above four steps are repeated till maximum number of iterations.

Step 6: The corresponding current and voltage for obtained maximum power is noted. Duty cycle is calculated and is given to the boost converter.

Step 7: Steps 2-6 will be repeated if there is a large change in Irradiance.

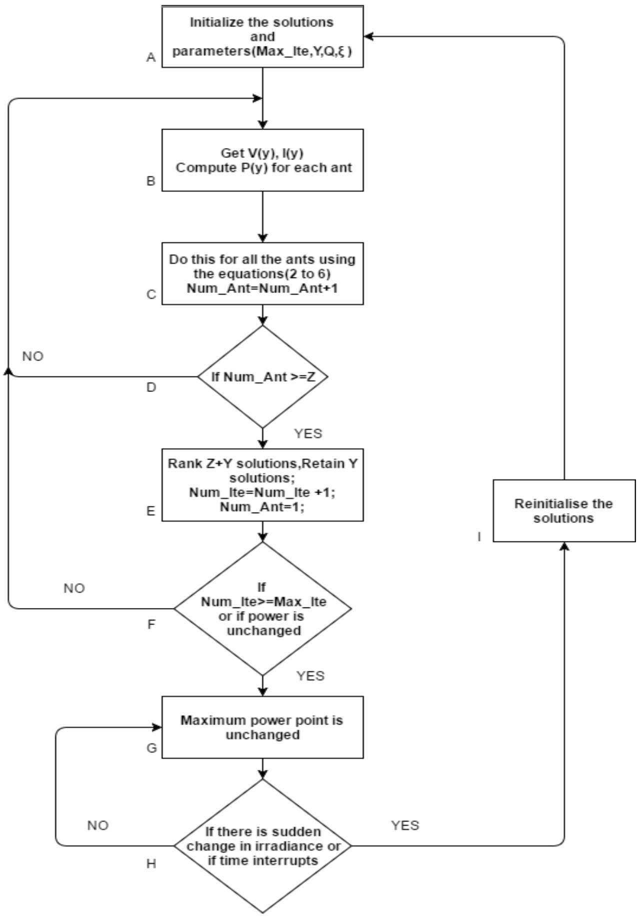

Fig. 2. Flow chart of ACO for MPPT

II. IMPLEMENTATION OF ACO FOR MPPT

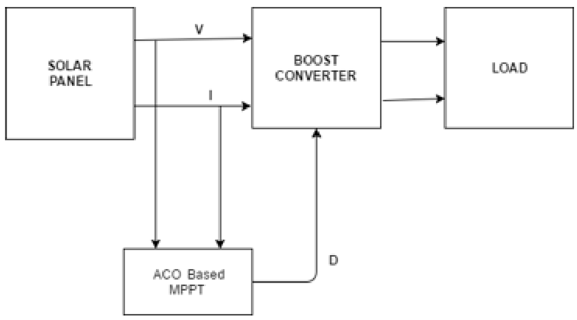

Fig. 3. Control Design of MPPT using ACO.

The basic block diagram of a PV system is shown in Fig.3. The algorithm mentioned in the paper has been tested in Matlab/Simulink and is implemented in hardware.

A. *Simulation Results*

The Simulink model consists of a DC-DC Boost converter whose switching frequency is 20 kHz. Sampling time is 20 µs. The values of inductor and capacitor are 25µH and 1100µF respectively. The type of load used is resistive. The simulation is carried out under constant irradiance (1000 W/m²) and temperature (25ºC).

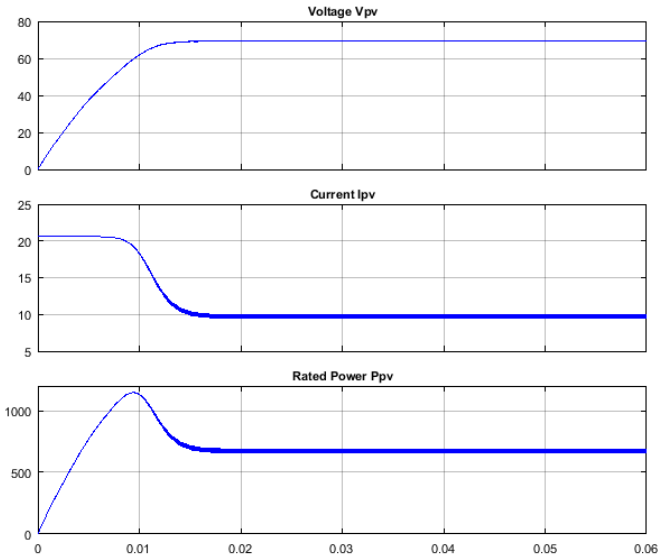

Fig. 4. Output waveforms of Voltage, Current and Power of PV panel

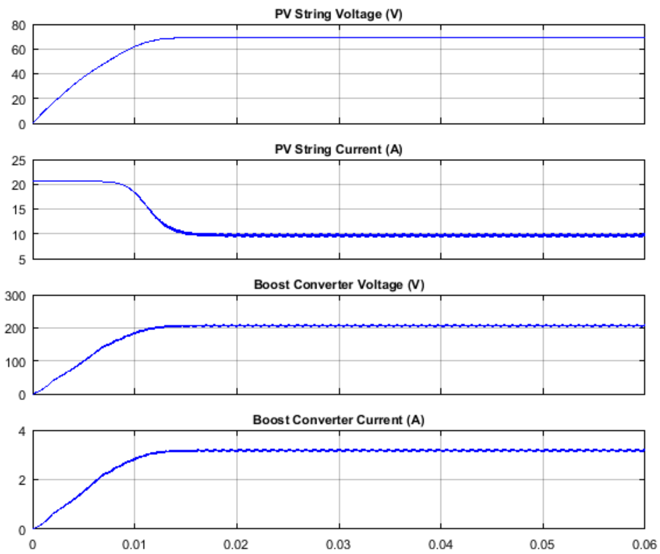

Fig. 5. Input and output waveforms of Boost converter

The simulation results are shown in Fig.4 and Fig.5. It shows that Maximum Power Point can be tracked accurately using ACO algorithm. The output is taken under constant irradiance and temperature. In real time, this is not the case. Following hardware results show the performance of algorithm in practical case.

B. *Hardware Setup*

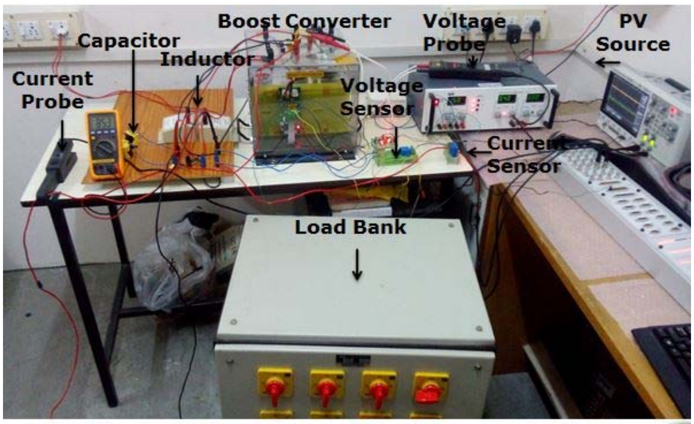

Fig. 6. Hardware setup showing MPPT control

The type of solar panel used is Polycrystalline 250W (EMMVEE). Load that is used is resistive(3A, 67.5ohms). Current and Voltage probes are used to handle the high voltage and current intake and they are measured using sensors(LEM 25-VP,LEM 55-A).

Implementation of the algorithm is done using D-Space 1103 which acts as an interface between hardware and the Matlab/Simulink [11].

C. *Hardware Results*

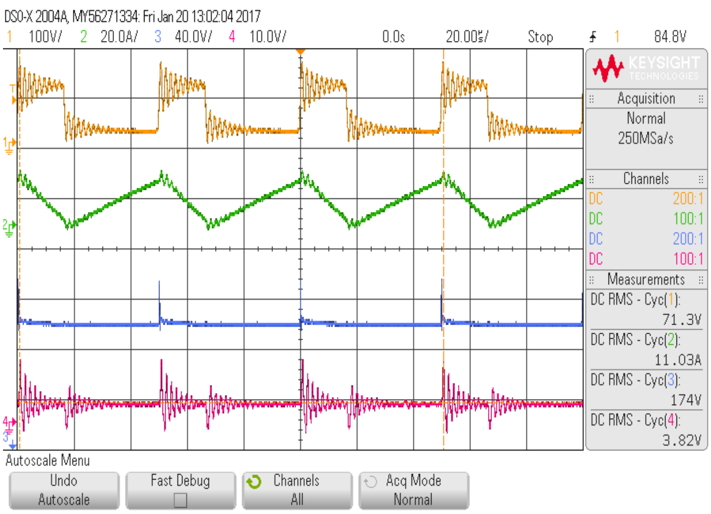

Fig. 7. Input and output waveforms of Boost converter

It can be observed that the algorithm works well in real time where irradiance and temperature are not constant. The output power is found to be almost equal to that of simulation results. The setup is tested for two different loads and the results are satisfactory.

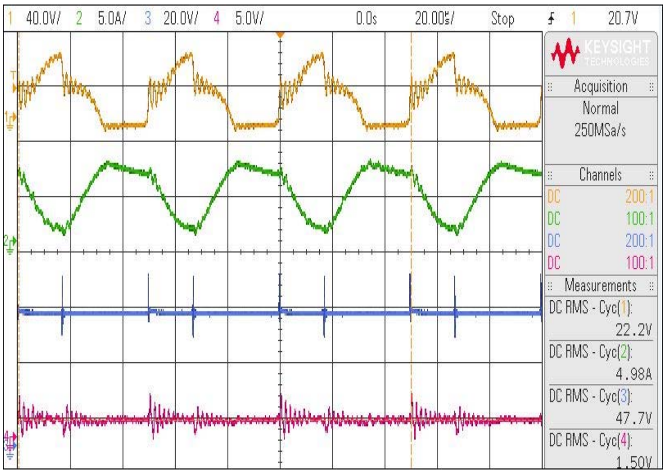

Fig. 8. Input and output waveforms of Boost converter

III. CONCLUSION

ACO algorithm for MPPT has been implemented in this paper. This paper focuses on improving the efficiency of PV panels. This algorithm successfully tracks the global maximum value unlike the conventional algorithms which are used for MPPT. The control design is also made simpler for MPPT. The simulation results are also checked with that of the hardware results and the results are satisfactory, which shows the efficiency of ACO algorithm to get maximum power. The algorithm also has higher convergence rate and lesser number of iterations are required to get the result. Thus this algorithm is more advantageous compared to other algorithms.

ACKNOWLEDGMENT

The authors gratefully acknowledge support from Department of Science and Technology (DST), Government of India, Project No. DST/TSG/NTS/2013/59 and VIT University, Vellore, India.

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