



Implementation of Maximum Power Point Tracking Method in a Photovoltaic System using Bat Optimizer

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Abstract

This paper proposes a novel control technique for landsman converter using BAT optimization. The controller parameters are optimized by BAT algorithm, the proposed algorithm is compared with BMO optimization and the comparative results are presented. Simulation results shows the dynamic performance of BAT controller. Landsman converter reduction in output voltage ripple, reduced settling time, avoiding the power losses due to high frequency switching. The BAT Optimizer has a high accuracy in the global optimization and it can provide good dynamic performance and very quick convergence rate by automatically switching between exploration and exploitation stages during the MPPT process.

Key Words: Partial shading, DC-DC converters, BAT optimization, Landsman converter.

1. Introduction

As partial shading exhibits some degree of uncertainty, efforts have been made to extend traditional analysis into cases where the pattern, number, and shading percentage of shaded PV modules may vary at random. The works of Gautam and Kaushika [N. K. Gautam, 2001] considered several shading patterns in PV arrays of different connection configurations. A randomly generated shading pattern was tested in Wang and Hsu's study [J. Wang, 2011]. Ramaprabha and Mathur [R. Ramaprabha, 2012] applied 15 random patterns to arrays of 10 different sizes. Although the studies [J. Wang, 2011; R. Rama prabha, 2012] have introduced the idea of randomization, further works still need to be undertaken, particularly for deeper theoretical development of a fundamental probabilistic model of partial shading. From this abridged survey of load profile clustering using BAT for metering solutions in the field of electricity market, it is illustrated that it has the potential to offer solutions to several other optimization problems by presenting a significantly desirable behavior in terms of strength and properties. Thereby, this little survey confirms that BAT algorithm's broad applicability, ease of use, and global perspective are the important properties to conclude that the BAT algorithm has greater potential in efficiently addressing the metering issues [T. Chakaravarthy, 2015]. The paper is organized as follows. In Section 2, PV characteristics in both uniform and non-uniform irradiation condition is discussed. Brushless DC motor with Voltage source inverter based landsman converter is discussed in section 3. In section 4 explain the optimization algorithm. Here BAT optimization algorithm based MPPT is used. In section 5 shows the simulation results and finally concluded in section 6.

1.1. Solar Energy System

The block diagram of the photovoltaic cells is shown in the fig.1 in the block diagram shows the photovoltaic system with MPPT, controller and boost converter .Solar energy is one of the world's fastest growing power generation technologies. It's one of the most important of non-conventional sources energy.

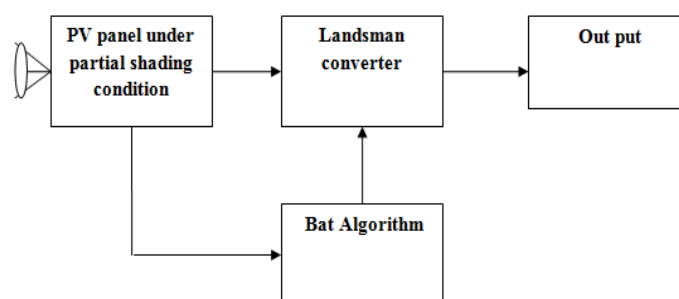


Fig.1: Block Diagram of Proposed Photo Voltaic System

The solar radiation from sun photovoltaic cells and the photovoltaic cells has been generated the electric power in dc output power. It will flow the MPPT, controller and landsman converter. MPPT tracked the maximum power point and it will connect to the boost converter.

2. PV Characteristics in both Uniform and Non-Uniform Irradiance Condition

The power-voltage curve develops multiple maxima, shown in Fig.2 this figure shows how the extractable maximum power point differs in Photo voltaic array with and without bypass diodes.

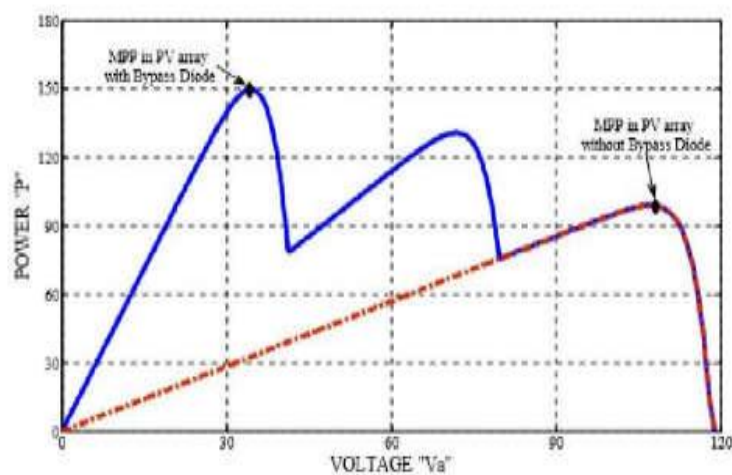


Fig. 2: Power-Voltage Curve of a PV Array (Partial Shading Condition)

The solar PV modules are used to generate a higher level of electrical output power. A partially shaded module can be modeled by two groups of PV cells are connected series with inside a module. Each group receives different level of irradiance. Let's assume there is no bypass diode for the cells inside a module, so Fig.2 shows the circuit model for a partially shaded module. The modules are composed of series connected cells in which s shaded cells are receive irradiance and shaded cells receiving irradiance.

3. Proposed BLDCM with VSI based Landsman Converter

The proposed system consists of an SPV array under partial shading condition, Landsman converter, VSI and the BLDC motor it's coupled to shaft. . The circuit operation is divided into two modes as shown in Figs. 3 a, b, and the associated waveforms are shown in Fig. 3c.

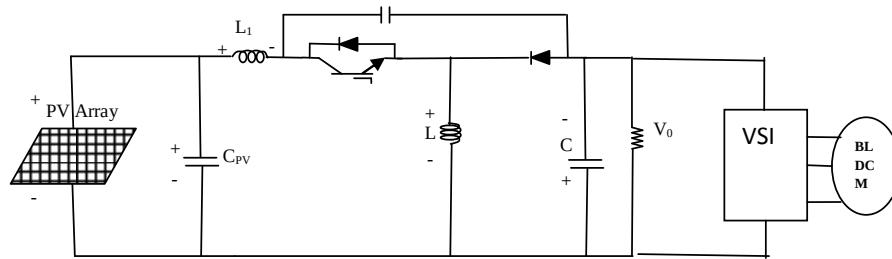


Fig.3 Configuration of SPV array – Landsman converter

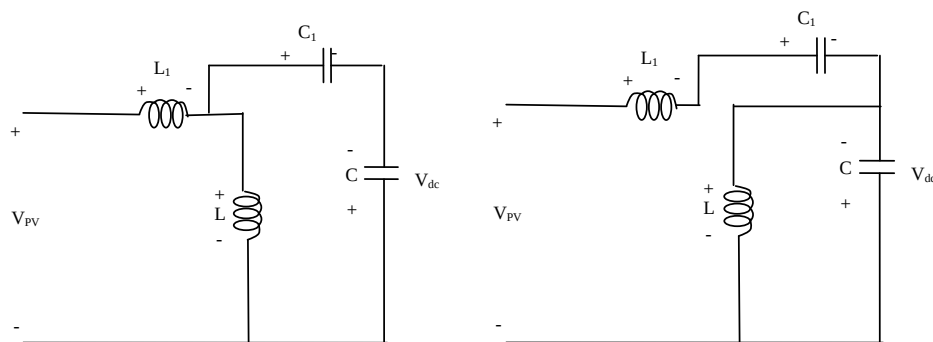


Fig.3 (a) Mode1 and (b) Mode 2 Operation

The Fig.3 illustrates the detailed configuration and operation of the proposed (solar Photovoltaic) SPV array under partial shading condition based BLDC motor using the Landsman converter. The Landsman converter, acting as an interface between the SPV array under partial shading condition and the VSI, is operated by the execution of BAT-MPPT algorithm in order to extract the maximum power available from the SPV array under partial shading condition.

Mode I: When the switch 'S' is on, V_{c1} , the voltage across intermediate capacitor C_1 reverse biases the diode. The inductor current i_L flows through the switch. Since V_{c1} is larger than the output voltage V_{dc} , C_1 discharges through the switch, transferring energy to the inductor L and the output. Therefore, V_{c1} decreases and current i_L increases, as shown in Figure 3. The input feeds energy to the input inductor L_1 .

Mode II: When the switch is off, diode is forward biased. The inductor current i_L flows through the diode. The inductor L transfers its stored energy to output through the diode. On the other hand, C_1 is charged through the diode by energy from both the input and L_1 . Therefore, V_{c1} increases and i_L decreases. The ripple in input current is i_{L1} , that is the current through L_1 . For CCM of operation, assuming that all of the ripple component in i_{L1} flows through C_1 .

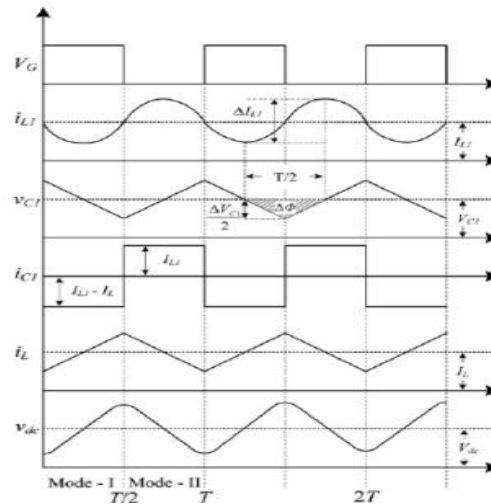


Fig. 3(c): Waveform of Landsman Converter

Design of Landsman Converter

The Landsman converter is designed to operate in CCM irrespective of the operating conditions. Following the atmospheric variation, the converter automatically operates either in buck mode or boost mode.

The ripple in input current, I_{L1} is calculated by considering its waveform as shown in Fig.3 for CCM operation, assuming that all of the ripple component in i_{L1} flows through C_1 . The shaded area in the waveform of V_{C1} represents an additional flux $\Delta\Phi$. Therefore, the peak-to-peak current ripple ΔI_{L1} is written as

$$\Delta I_{L1} = \frac{\Delta\Phi}{L_1} = \frac{1}{L_1} \frac{1}{2} \frac{\Delta V_{C1}}{2} \frac{T}{2} \quad (1)$$

From Fig. 2 during switch off, the current through C_1 is

$$i_{C1} = I_{L1} = C_1 \frac{\Delta V_{C1}}{(1-D)T} \quad (2)$$

where D is the duty ratio and T is the switching period. The voltage ripple content in V_{C1} is estimated from (2) as

$$\Delta V_{C1} = \frac{I_{L1}}{C_1} (1-D)T \quad (3)$$

Therefore, substituting ΔV_{C1} from (3) into (1) gives

$$\Delta I_{L1} = \frac{1}{L_1} \frac{1}{2} \frac{I_{L1}}{2C_1} (1-D)T \quad (4)$$

$$\Delta I_{L1} = \frac{1}{8L_1 C_1} I_{L1} \frac{(1-D)}{f_{sw}^2} \quad (5)$$

It is normalized as

$$\frac{\Delta I_{L1}}{I_{L1}} = \frac{1}{8L_1 C_1} \frac{(1-D)}{f_{sw}^2} \quad (6)$$

where $f_{sw} = 1/T$ is the switching frequency. From the input–output relationship, it is obvious that

$$I_{L1} = I_{dc} \frac{D}{1-D} \quad (7)$$

Therefore, substituting I_{L1} from (8) into (6) and rearranging the terms, it gives

$$L_1 = \frac{Q I_{dc}}{8 f_{sw}^2 c_1 \Delta I_{L1}} \quad (8)$$

4. Maximum Power Point Tracking Optimization Algorithms under Partial Shading Condition

Various MPPT optimization techniques are being addressed in as to chaotic order in this section.

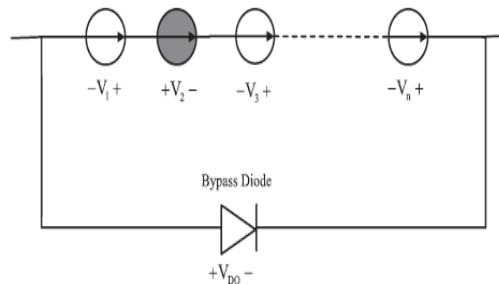


Fig. 4: Bypass Diode Conduction When One Cell is Shaded

A bypass diode is connected to ensure that particular shaded module doesn't get damaged. Voltage mismatch can occur in parallel connected modules. So, a blocking diode is connected for providing protection under such conditions. Fig. 4 shows the conduction of bypass diode takes place under shading condition

4.1. Bird Mating Optimizer (BMO)

BMO is a population based algorithm. Population is referred to as society. Each member of the society represents a feasible solution for a specific problem and is called a bird. The females hold the high quality genes and can be classified into three groups, viz. monogamy, polygyny and promiscuous.

$$x_b = x + w * r * (x_i - x) \quad (1)$$

And if $r_1 > mcf$

$$x_b(c) = l(c) - r_2 * (l(c) - u(c)) \quad (2)$$

Where c is a random number between 1 and n , x_b is a resultant brood, w is a time-varying weight to set the importance of the interesting female, r is equivalent to $1 \times d$ vector whose each element, distributed randomly in $[0, 1]$ affects the elements of the $(x_i - x)$, n indicates the problem dimension, mcf is the mutation control factor varying between 0 and 1, r_i are random numbers

between 0 and 1, and u , l are the upper and lower bounds of the elements, respectively. In polygyny species, better genes for the brood may inherit additional pair copulation. In BMO, and for simplicity, only one brood is the resultant from the mating whose genes are a collection of the female's genes. The formulation of the resultant brood is as follows:

$$x_b = x + w * \sum_{j=1}^{n_i} r_j * (x_j - x) \quad (3)$$

And if $r_1 > mcf$ (then eq.no.2 is used),

Where n_i the number of interesting birds and x_j indicates the j^{th} interesting bird.

In BMO, the same mathematical formulation of monogamous are applied to the promiscuous species.

In Parthenogenesis species, each bird outputs a brood according to the following formula: if $r_1 > mcf_p$

$$x_b(i) = x(i) + \mu * (r_2 - r_3) * x(i) \quad (4)$$

Else

$$x_b(i) = x(i) \quad (5)$$

Where μ the step size and mcf_p is the parthenogenetic mutation control factor.

4.2. Bat Algorithm

Bat algorithm (BA) was based on the echolocation features of microbats and BA uses a frequency-tuning technique to increase the diversity of the solutions in the population, while at the same, it uses the automatic zooming to try to balance exploration and exploitation during the search process by mimicking the variations of pulse emission rates and loudness of bats when searching for prey. As a result, it proves to be very efficient with a typical quick start. Obviously, there is room for improvement.

Applications of Bat Algorithm

Bat algorithms have been applied in almost every area of optimization, classifications, image processing, feature selection, scheduling, data mining and others. In the rest of the paper, we will briefly highlight some of the applications.

Why Bat Algorithm is Efficient

Frequency tuning: BA uses echolocation and frequency tuning to solve problems. It is not directly used to mimic the true function in reality, frequency variations are used

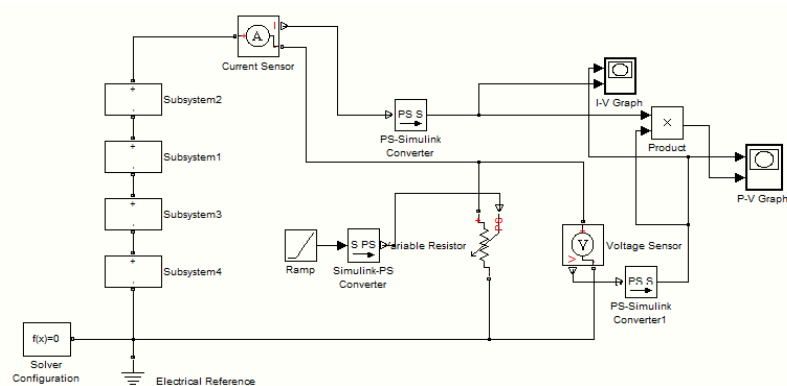
Automatic zooming: BA has a distinct advantage over other meta heuristic algorithms. That is, BA has a capability of automatically zooming into a region where promising solutions have been found.

Parameter control: Many meta heuristic algorithms used fixed parameters by using some, pre-tuned algorithm-dependent parameters. In contrast, BA uses parameter control, which can vary the values of parameters (A and r) as the iterations proceed.

5. Simulation Results & Discussion

5.1. Implementation of Partial Shading Effect

A Solar panel has been simulated in MATLAB/Simulink and is discussed in this section. Twenty solar cells are connected in series to form a string which acts as a module.



Each cell having an open circuit voltage $V_{oc} = 0.9$ V and short circuit current $I_{sc} = 0.63$ A. The combination of such modules forms a solar panel.

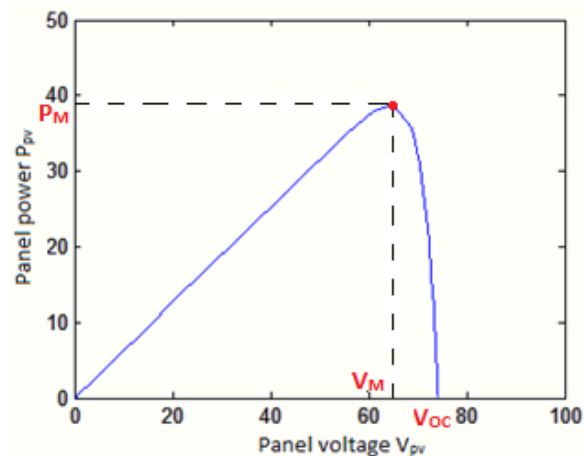


Fig. 5: Shows the Power - Voltage Characteristics Under Normal Irradiation Conditions

The Current-Voltage characteristics of the designed panel are shown in Fig.5 at

1000W/m². Current and voltage magnitudes corresponding to maximum power is represented as IM and VM respectively

5.2. Simulink Model for Solar Array Fed BLDC Motor Under Partial Shading Condition in BMO Algorithm & Bat Algorithm

To verify the effectiveness of the proposed algorithm, a photovoltaic system is simulated on Matlab/Simulink. The different blocks constituting the model are shown in Fig.6. The DC-DC converter used is a landsman converter. It is designed for continuous conduction current mode with the following specifications: $C1 = 440 \mu\text{F}$, $C2 = 330 \mu\text{F}$, $L1 = 0.7 \text{ mH}$, $L2=0.7\text{mH}$ and a chopping frequency of 50 kHz and input voltage is 140V.

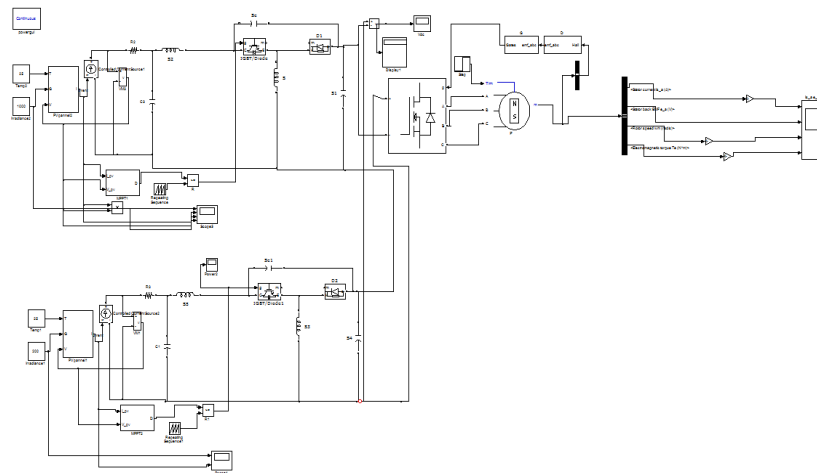


Fig. 6: Simulink Model for Solar array fed BLDC Motor Under Partial Shading Condition in BMO Algorithm & BAT Algorithm

Figure 6 shows the simulation diagram of solar array fed BLDC motor under partial shading condition in BMO algorithm & BAT algorithm.

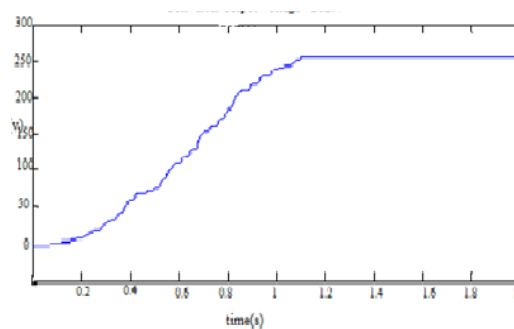


Fig. 7: Simulation Result for Landsman Converter Under Partial Shading Condition in BMO Algorithm

Figure 7 shows the simulation result for Landsman converter under partial shading condition. The converter output voltage is 269.4V.

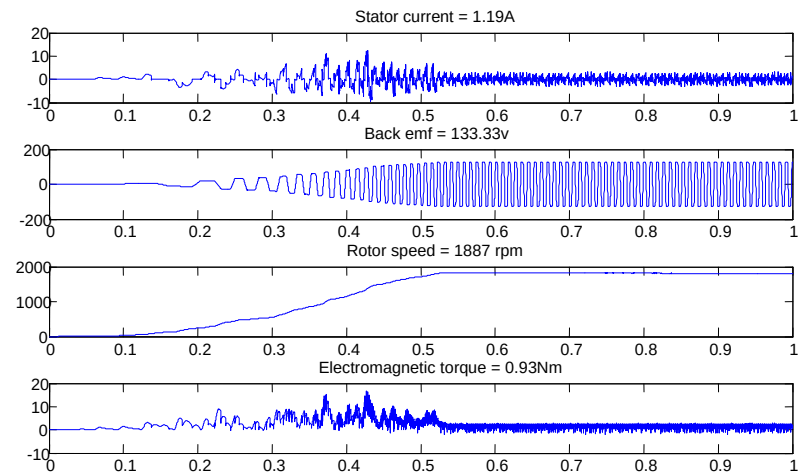


Fig. 8: Simulation Result for BLDC Motor under Partial Shading Condition in BMO Algorithm

Figure.8 shows the simulation result of BLDC motor characteristics under partial shading condition. The stator current is 1.45A. Stator back emf is 132.1V. Rotor speed is 1985 rpm and electromagnetic torque is 0.97Nm

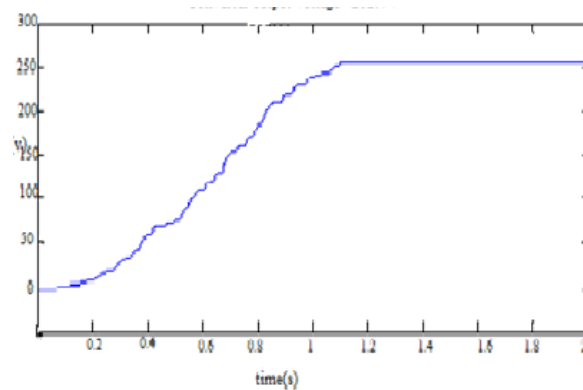


Fig. 9: Simulation Result for Landsman Converter Under Partial Shading Condition in Bat Algorithm

Figure 9 shows the simulation result for Landsman converter under partial shading condition in Bat Algorithm. The converter output voltage is 269.4V.

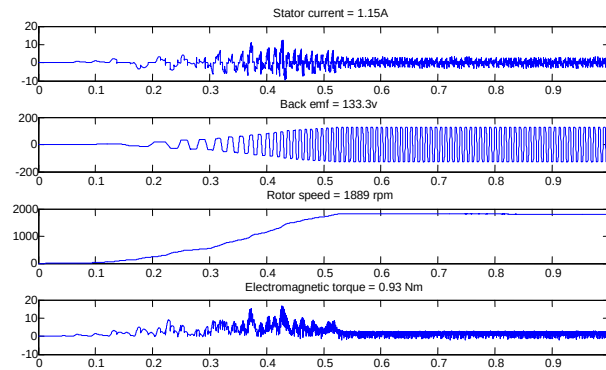


Fig. 10: Simulation Result for BLDC Motor under Partial Shading Condition in Bat Algorithm

Figure.10 shows the simulation result of BLDC motor characteristics under partial shading condition in Bat Algorithm. The stator current is 1.15A. Stator back emf is 133.33V. Rotor speed is 1889rpm and electromagnetic torque is 0.93Nm.

The comparison of solar photovoltaic array fed BLDC motor characteristics under partial shading conditions are given in Table 2.

Table 2: Comparison of BLDC Motor Characteristics

Parameters	Converter output voltage(V)	Stator current(A)	Back emf(V)	Rotor speed(rpm)	Electromagnetic torque(N.m)
Bird Mating Optimization (BMO)	269.4	1.19	133.33	1887	0.93
BAT Optimization	269.4	1.15	133.33	1889	0.93

From the comparative analysis, it is clear that BLDC motor performance is almost same as that of uniform and partial shading conditions.

The graph clearly shows that the Landsman converter using BAT optimization is more efficient than the other existing ones. The converter using BAT optimization algorithm achieves a fast response with low input current for the system. This optimized system has an efficiency equal to 99.9% at full load condition for 100 W whereas for the same operating conditions the system operating in open loop condition, and BMO optimization algorithm can achieve only 84.9%, and 85%, respectively. This is evident from the obtained results.

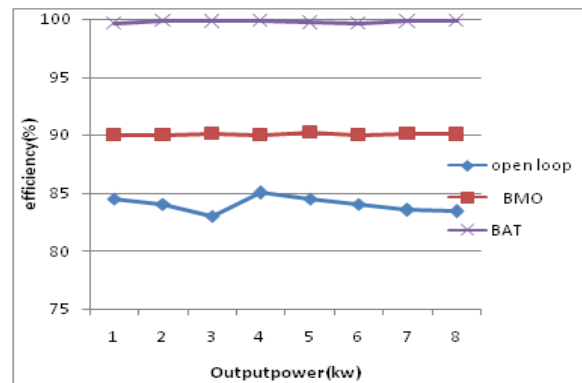


Fig. 11: Efficiency of Landsman Converter

6. Conclusions

In this paper the design analysis of landsman converter is presented. The Proposed system has been simulated in MATLAB SIMILINK environment. This work primarily focuses on the design and development of an efficient solar photovoltaic array utilizing a Landsman Converter in BMO optimization and BAT optimization techniques are used for the optimized control of the converter output voltage. From the simulation results the output of the landsman Converter is checked. The BAT technique shows that the converter response is better than open loop & BMO optimization. The BAT Optimizer has a high accuracy in the global optimization and it can provide good dynamic performance and very quick convergence rate by automatically switching between exploration and exploitation stages during the MPPT process.

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