Crow Search Optimized Control of Photovoltaic Array Fed Landsman Converter for Industrial Applications

1A.R. Gayathri and 2D.M. Mary Synthia Regis Prabha
1Noorul Islam Centre for Higher Education, Kumaracoil.
ar.gayu13@gmail.com
2Noorul Islam Centre for Higher Education, Kumaracoil.
regisprabha@gmail.com

Abstract

Solar Photo Voltaic (SPV) array is receiving wide attention now days because the everlasting solar energy is the best alternative to the conventional energy sources. This work primarily focuses on the design and development of an efficient solar photovoltaic array utilizing a Landsman Converter. PID, Fuzzy logic controller and Crow search optimization techniques are used for the optimized control of the converter output voltage. The crow search optimization technique has been found to provide better results for randomly varying atmospheric conditions as compared to the existing control schemes. This topology is designed and modeled in MATLAB/Simulink platform and its performance under varying environmental conditions is studied. Moreover the efficiency of the PV array for various control schemes is analyzed rigorously.

Key Words: Solar Pv array, landsman converter.
1. Introduction

Nonconventional sources of energy are gaining attention on account of dwindling fossil fuels. Using solar energy in coordination with conventional sources of energy will be more promising. The extreme reduction in the cost of power electronic devices and annihilation of fossil fuels in near future invite to use the solar photovoltaic (SPV) generated electrical energy for various applications as far as possible [4]. The power that one module can produce is not sufficient to meet the requirements of home or business. Most PV arrays use an inverter to convert the DC power into alternating current that can power the motors, loads, lights etc. The modules in a PV array are usually first connected in series to obtain the desired voltages; the individual modules are then connected in parallel to allow the system to produce more current [5].

A DC-DC converter [6], buck–boost converter [7], Luo converter [8], canonical switching cell (CSC) converter [9], zeta converter [10] and Z-source inverter (ZSI) [11] are already utilized with SPV array fed BLDC motor driven water pump systems. Investigating the various non-isolated DC–DC converters viz. buck, boost, buck–boost, Cuk and single-ended primary inductor converter for photovoltaic applications, although not based on water pumping, it is concluded in [17] that the best selection of DC–DC converter in the PV system is buck–boost converter, allowing an unbounded region for MPPT. On the contrary to it, a buck–boost converter always calls for a ripple filter at its both input and output for coveted operation of the overall system, resulting in an associated circuitry. Likewise, the converters used in [8–10] also necessitate filtering elements at either input or output or both. The ZSI used in [11] needs complex control and additional sensing elements, and operated with a high-frequency pulse-width modulation (PWM) switching pulses, resulting in an increased switching loss. On the other hand, any converter besides the buck–boost topology, for example buck and boost converter, is not recommended because of their inability to track MPP independent of the loading and atmospheric conditions [17].

A Landsman converter, one of the topology of a DC–DC buck–boost converter, capable to overcome the aforementioned limitations of various previously used converters in SPV array adapted in this work. This converter is apparently derived by a canonical switching converter (CSC) [15] or topological transformations on a DC–DC boost converter [16]. The modification in CSC with an output inductor, results in a landsman converter [12-14]. The output and input currents have large current ripples which is a disadvantage of the CSC converter. In the addition of a small inductance at the output of this conversion stage yield a true switched-mode topology. These yield to low-output ripple current in the DC link. Amongst various DC–DC converters, Landsman converter meets the desired performance of the system compared to other converter. The ordinary buck-boost converter has the lowest number of components, but has high input and current output current ripples. The proposed
landsman converter possess of an important feature that the input current ripples and output current ripples are low.

The objective of the paper is to develop novel control techniques for landsman converter using PID, fuzzy logic controller and crow search optimization. The controller parameters are optimized by crow search algorithm. The proposed algorithm is compared with PID, fuzzy logic controller and the comparative results are presented. The reduction in output voltage ripple in the order of mV along with reduced time response characteristics and performance indices are compared to the PID and Fuzzy logic controller. The crow search optimization is used to achieve better performance in terms of PV voltage and converter output voltage. The simulated results are executed in MATLAB/SIMULINK.

The remaining sections of this paper are organized as follows: Section II presents the configuration and operation of the system, Section III presents the design of landsman converter. Section IV presents the mathematical modeling of PV panel, Section V includes controllers and optimization of the system and Section VI presents the simulation results. Conclusion is provided in Section VII.

2. Configuration and Operation of Proposed System

A small input inductor of the Landsman converter, as shown in Fig.1, acts as an input-ripple filter, eliminating the external ripple filtering. This inductor also damps the oscillation occurred, due to the snubber elements of insulated gate. Figure 1 illustrates the detailed configuration and operation of the proposed SPV array fed landsman converter. The proposed system consists of an SPV array and Landsman converter.

![Figure 1: Configuration of SPV Array – Landsman Converter](image)

The addition of a small inductance at the output of the conversion stage yields a true switched-mode topology. This yields low-output ripple current in the DC link. The Landsman converter is designed to operate in CCM irrespective of the
variation in irradiance level. The circuit operation is divided into two modes as shown in Figures 2(a) and (b), and the associated waveforms are shown in Figure 3.

**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 $L_1$.

![Figure 2: (a) Mode1 and (b) Mode 2 Operation](image)

**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 $iL_1$, that is the current through $L_1$. For CCM of operation, assuming that all of the ripple component in $iL_1$, flows through $C_1$. 
3. 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 $\Delta I_{L1}$ is written as
\[ \Delta I_{L1} = \frac{\Delta \Phi}{L_1} + \frac{1}{L_1} \frac{\Delta V_{C1}}{2} \frac{1}{T} \] (1)

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

\[ i_{C1} = I_{L1} = C_1 \frac{\Delta V_{C1}}{(1-D)T} \] (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

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

Therefore, substituting \( \Delta V_{C1} \) from (3) into (1) gives

\[ \Delta I_{L1} = \frac{1}{L_1} \frac{I_{L1}}{2} (1-D)T \] (4)

\[ \Delta I_{L1} = \frac{1}{8L_1 C_1} I_{L1} (1-D) \frac{1}{f_{sw}} \] (5)

It is normalized as

\[ \frac{\Delta I_{L1}}{I_{L1}} = \frac{1}{8L_1 C_1} (1-D) \frac{1}{f_{sw}} \] (6)

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

\[ I_{L1} = I_{dc} \frac{D}{1-D} \] (7)

where \( I_{dc} \) is the output current of Landsman converter.

Therefore, substituting \( I_{L1} \) from (7) into (5) and rearranging the terms, it gives

\[ L_1 = \frac{D I_{dc}}{8f_{sw} C_1 \Delta I_{L1}} \] (8)

### 4. Mathematical Modeling of PV Module

Generally, PV module is composed of series and parallel combination of solar cells to provide demanded power range. Usually, the output current of PV module depends on photo current (\( I_{PV} \)) and exponential function of diode saturation current (\( I_o \)) and it can be expressed as follows.

\[ I = I_{PV} - I_0 \left[ \exp \left( \frac{q(V+IR_s)}{A R_{TFA}} \right) - 1 \right] - \left( (V + IR_s)/(R_{sh}) \right) \] (9)

where,
- \( q \) = Electron charge (1.6x10\(^{-19}\) Coulombs)
- \( T \) = PV Module temperature in Kelvin
- \( I_0 \) = Reverse saturation current of diode
- \( A \) = Diode ideality constant of diode
- \( I_{PV} \) = Light generated current of PV cell in Ampere
- \( R_s \) = Series Resistance of PV cell
- \( R_{sh} \) = Shunt Resistance of PV cell
Ns=Number of PV module connected in series
I=Output current of PV cell in Ampere
K=Boltzmann constant (1.38x10-23 Nm/K)

Ideal single diode model is considered. In this model PV module is modeled as a current source and a diode in parallel as shown in Fig. 4 with negligible series and shunt resistances. With reference to Fig.4 the I-V equation (1) becomes

\[ I = I_{PV} - I_0 \left[ \exp \left( \frac{q(V + IR_s)}{N_s K T} \right) - 1 \right] \]  
(10)

Usually, this Model has three unknown parameters (\(I_{PV}\), \(I_o\) and \(A\)). \(I_{PV}\) is determined from the manufacturer datasheet as follows:

\[ I_{PV} = G(I_{sc} + \alpha \Delta T) \]  
(11)

where G is irradiance (kW/m²), \(I_{sc}\) is short circuit current at STC (Standard Temperature Condition), \(\Delta T\) is the temperature difference between the module temperature and the STC temperature and \(\alpha\) is the current temperature coefficient given in the datasheet \(I_o\). Saturation Current can be expressed as follows:

\[ I_0 = \frac{\left[ \frac{G}{N_s K T} \right] I_{sc} \exp \left( \frac{q V_r}{N_s K T} \right)}{G(1+\eta R_s)} \]  
(12)

The unknown parameter “A” can be obtained by solving the equation for MPP \((V_m, I_m)\)

\[ \frac{I_m}{I_{sc}} = e^{\frac{q V_m}{N_s K T \eta R_s}} - \frac{(I_{sc} - I_m)}{I_{sc}} e^{\frac{q V_{oc}}{N_s K T \eta R_s}} \]  
(13)

From the above equation the PV Array can be modeled as a Ideal Single Diode Model (ISDM).

5. Control Techniques Using Proposed System

The block diagram shown in Fig.5 shows the implementation of various controllers for Landsman converter. The actual output voltage \(V_{out}\) of the Landsman converter and the constant reference voltage are compared, to form the error signal. The error signal \(V_e\) is amplified and given to the controller. The
controller generates the control signal based on the error signal for varying the turn on and turns off time of the regulator switch of the landsman converter, to maintain the constant output voltage irrespective of the input voltage and load variations.

![Figure 5: Block Diagram of the Landsman Converter Using Controllers](image)

(i) PID Controller

A PID (proportional-integral-derivative) controller is a control loop feedback mechanism. Feedback mechanism is mainly used in industrial control systems. The PID controller attempts to correct the error between a desired set point & a measured process variable by calculating the error & taking corrective action that can adjust the process accordingly. The PID controller involves calculation of three different (separate) parameters, Proportional (P), Derivative (D) and the Integral (I) values. The Proportional (P) value determines the reaction to current error, the Derivative (D) value is determined reaction based on the rate at which the error has been changed and the Integral (I) value determines the reaction based on the sum of the recent errors. Having these three actions adjusts the process via control elements. PID controller is used for improving the performance of the voltage and peak power. PID controller gain change the value of the output but after a fixed gain the value cannot be change.

\[ u(t) = K_p e(t) + K_i \int e(\tau) d\tau + K_d \frac{de}{dt} \]  \hspace{1cm} (14)

(ii) Fuzzy Logic Controller

Fuzzy logic idea is similar to the human being’s feeling and inference process. Unlike classical control strategy, which is a point-to-point control, fuzzy logic control is a range-to-point or range-to-range control. The output of a fuzzy controller is derived from fuzzification of both inputs and outputs using the associated membership functions. A crisp input will be converted to the different members of the associated membership functions based on its value. From this point of view, the output of a fuzzy logic controller is based on its membership of the different membership functions, which can be considered as a range of inputs. FLCs have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity. The details of using FLC in MPPT of PV system are shown in Eltamaly (2010). The error signal can be calculated as shown in (15). The value of \( \Delta E \) is calculated as shown in (16). The model of the proposed system has been simulated
MATLAB.

\[
E(i) = \frac{P(i) - P(i-1)}{V(i) - V(i-1)} \quad (15)
\]

\[
\Delta E(i) = E(i) - E(i-1) \quad (16)
\]

The output power from the PV system and the voltage are used to determine the
E and \(\Delta E\) based on (16) and (17). The inputs to a FLC are usually E and \(\Delta E\).
The range of E and \(\Delta E\) are fixed judiciously based on trial and error. These
variables are expressed in terms of linguistic variables or labels such as PB (Positive Big), PM (Positive Medium), PS (Positive Small), ZE (Zero), NS (Negative Small), NM (Negative Medium), NB (Negative Big) using basic fuzzy subset. Each of these acronyms is described by mathematical membership functions, MF as shown in Fig.6. Once E and \(\Delta E\) calculated and converted to the linguistic variables based on MF, the FLC output, which is typically a change in duty cycle, \(\Delta D\) of the power converter, can be looked up in a rule base given in Table 1.

![Figure 6: A Fuzzy System with Two Inputs, 1 Output and 7 MFs Each](image)

<table>
<thead>
<tr>
<th>E</th>
<th>(\Delta E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>NB</td>
</tr>
<tr>
<td>NM</td>
<td>NB</td>
</tr>
<tr>
<td>NS</td>
<td>NB</td>
</tr>
<tr>
<td>ZE</td>
<td>NB</td>
</tr>
<tr>
<td>PS</td>
<td>NB</td>
</tr>
<tr>
<td>PM</td>
<td>NB</td>
</tr>
<tr>
<td>PB</td>
<td>NB</td>
</tr>
</tbody>
</table>

Table 1: Rules for a Fuzzy System

A triangular membership function can be used for both inputs and output
variables, as it can easily be implemented on the digital control system. The
linguistic variables assigned to \(\Delta D\) for the different combinations of E and \(\Delta E\)
are based on the power converter being used and also on the knowledge of the
user. These linguistic variables of input and output MFs are then compared to a
set of pre-designed values during aggregation stage. The proper choice of If-
then rules or fuzzy inference is essential for the appropriate response of the FLC.
The inference used in this work is tabulated in Table 1. Some researches proportionate these variables to only five fuzzy subset functions as in (Eltamaly et al., 2010). Table 2 can be translated into 49 fuzzy rules or IF-THEN rules to describe the knowledge of control as follows:

<table>
<thead>
<tr>
<th>Table 2: Translated Fuzzy Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>If E is NM and DE is PS then ∆D is NS</td>
</tr>
<tr>
<td>If E is PS and DE is NB then ∆D is NM</td>
</tr>
<tr>
<td>If E is PM and DE is NS then ∆D is PS</td>
</tr>
</tbody>
</table>

Defuzzification is for converting the fuzzy subset of control form inference back to values. As the plant usually required a non fuzzy value of control, a defuzzification stage is needed. Defuzzification for this system is the height method. The height method is both very simple and very fast method.

\[ \Delta D = \frac{\sum_{k=1}^{n}(c(k) \cdot W_k)}{\sum_{k=1}^{n} W_k} \]

where \( \Delta D \) = change of duty cycle; \( c(k) \) = peak value of each output; \( W_k \) = height of rule \( k \). In the defuzzification stage, FLC output is converted from a linguistic variable to a numerical variable. This provides an analog signal which is \( \Delta D \) of the landsman converter. This value is subtracted from previous value of \( D \) to get its new value.

(iii) CROW Search Optimization

Crow families are considered the most intelligent birds. They contain the largest brain relative to their body size. Based on a brain-to-body ratio, their brain is slightly lower than a human brain. Evidences of the cleverness of crows are plentiful. They have demonstrated self-awareness in mirror tests and have tool-making ability. Crows can remember faces and warn each other when an unfriendly one approaches. Moreover, they can use tools, communicate in sophisticated ways and recall their food’s hiding place up to several months later. Crows have been known to watch other birds, observe where the other birds hide their food, and steal it once the owner leaves. If a crow has committed thievery, it will take extra precautions such as moving hiding places to avoid being a future victim. In fact, they use their own experience of having been a thief to predict the behavior of a pilferer, and can determine the safest course to protect their caches from being pilfered. The principles of Crow Search Algorithm are listed as follows:

- Crows live in the form of flock.
- They memorize the position of their hiding places.
- They follow each other to do thievery.
- They protect their caches from being pilfered by a probability.

The number of crows (flock size) is \( N \) and the position of crow \( i \) at time (iteration) \( \text{iter} \) in the search space is specified by a vector

\[ X_{i,\text{iter}} = [X_{1,\text{iter}}, X_{2,\text{iter}}, \ldots, X_{d,\text{iter}}] \]

where \( X_{i,\text{iter}} \) = \( [X_{1,\text{iter}}, X_{2,\text{iter}}, \ldots, X_{d,\text{iter}}] \) and \( \text{iter}_{\text{max}} \).
is the maximum number of iterations. Each crow has a memory in which the position of its hiding place is memorized. At iteration \( \text{iter} \), the position of hiding place of crow \( i \) is shown by \( m^{i,\text{iter}} \). This is the best position that crow \( i \) has obtained so far. Indeed, in memory of each crow, the position of its best experience has been memorized. Crows move in the environment and search for better food sources (hiding places). Assume that at iteration \( \text{iter} \), crow \( j \) wants to visit its hiding place, \( m^{j,\text{iter}} \). At this iteration, crow \( i \) decides to follow crow \( j \) to approach the hiding place of crow \( j \). In this case, two states may happen:

**State 1:** Crow \( j \) does not know that crow \( i \) is following it. As a result, crow \( i \) will approach the hiding place of crow \( j \). In this case, the new position of crow \( i \) is obtained as follows:

\[
X^{i,\text{iter}+1} = [X^{i,\text{iter}} + r^i \times f^{i,\text{iter}} \times (m^{j,\text{iter}} - X^{i,\text{iter}})]
\]

where \( r^i \) is a random number with uniform distribution between 0 and 1 and \( f^{i,\text{iter}} \) denotes the flight length of crow \( i \) at iteration \( \text{iter} \).

**State 2:** Crow \( j \) knows that crow \( i \) is following it. As a result, in order to protect its cache from being pilfered, crow \( j \) will fool crow \( i \) by going to another position of the search space. Totally, states 1 and 2 can be expressed as follows:

\[
X^{i,\text{iter}+1} = \begin{cases} 
X^{i,\text{iter}} + r^i \times f^{i,\text{iter}} \times (m^{j,\text{iter}} - X^{i,\text{iter}}) & \text{if } r^j \geq A^{p,i,\text{iter}} \\
\text{arandomposition} & \text{otherwise}
\end{cases}
\]

where \( r^j \) is a random number with uniform distribution between 0 and 1, and \( A^{p,i,\text{iter}} \) denotes the awareness probability of crow \( j \) at iteration \( \text{iter} \).

**Crow Search Algorithm Implementation for Optimization**

The step-wise procedure for the implementation of crow search algorithm is given in this section.

**Step 1:** Initialize problem and adjustable parameters

The optimization problem, decision variables and constraints are defined. Then, the adjustable parameters of CROW SEARCH ALGORITHM (flock size \( N \), maximum number of iterations \( \text{iter}_{\text{max}} \), flight length \( f \) and awareness probability \( A^{p} \)) are valued.

**Step 2:** Initialize position and memory of crows

\( N \) crows are randomly positioned in a \( d \)-dimensional search space as the members of the flock. Each crow denotes a feasible solution of the problem, and \( d \) is the number of decision variables.

\[
\text{Crows} = \begin{bmatrix} 
X_{1}^{1} & X_{2}^{1} & \cdots & X_{d}^{1} \\
X_{1}^{2} & X_{2}^{2} & \cdots & X_{d}^{2} \\
\vdots & \vdots & \ddots & \vdots \\
X_{1}^{N} & X_{2}^{N} & \cdots & X_{d}^{N} 
\end{bmatrix}
\]
The memory of each crow is initialized. Since at the initial iteration the crows have no experiences, it is assumed that they have hidden their foods at their initial positions.

\[
\text{Memory} = \begin{bmatrix}
m_1^1 & m_2^1 & \cdots & m_d^1 \\
m_1^2 & m_2^2 & \cdots & m_d^2 \\
\vdots & \vdots & \ddots & \vdots \\
m_1^N & m_2^N & \cdots & m_d^N 
\end{bmatrix}
\] (22)

**Step 3:** Evaluate fitness (objective) function

For each crow, the quality of its position is computed by inserting the decision variable values into the objective function.

**Step 4:** Generate new position

Crows generate new position in the search space as follows: suppose crow \(i\) wants to generate a new position. For this aim, this crow randomly selects one of the flock crows (for example crow \(j\)) and follows it to discover the position of the foods hidden by this crow (\(m^j\)). The new position of crow \(i\) is obtained by Equation. (22). This process is repeated for all the crows.
Step 5: Check the feasibility of new positions

The feasibility of the new position of each crow is checked. If the new position of a crow is feasible, the crow updates its position. Otherwise, the crow stays in the current position and does not move to the generated new position.

Step 6: Evaluate fitness function of new positions

The fitness function value for the new position of each crow is computed.

Step 7: Update memory

The crows update their memory as follows:

\[
m^{i,\text{iter}}_{t+1} = \begin{cases} 
X^{i,\text{iter}}_{t+1} & \text{if } f(X^{i,\text{iter}}_{t+1}) \text{ is better than } f(m^{i,\text{iter}}_t) \\
m^{i,\text{iter}}_t & \text{otherwise}
\end{cases}
\] (23)

Where \( f(.) \) denotes the objective function value.

It is seen that if the fitness function value of the new position of a crow is better than the fitness function value of the memorized position, the crow updates its memory by the new position.

Step 8: Check termination criterion

Steps 4–7 are repeated until \( \text{iter}_{\text{max}} \) is reached. When the termination criterion is met, the best position of the memory in terms of the objective function value is reported as the solution of the optimization problem.

6. Simulation Results & Discussion

Fig. 8 below shows the Simulink diagram of the entire system. This includes the PV module, Landsman converter and control circuit. The modeling and simulation of the whole system has been done in MATLAB-SIMULINK environment.

![Simulink Diagram of a PV Panel Connected to the Load](image)

From the Simulink library browser, the model of PV panel as a constant DC source is created using the subsystem block, which included all the functions of PV panel as shown in Fig. 6. The irradiance, temperature and voltage input are...
the three inputs of the model that is feedback from the system and current represents the output of the block. This model generates current and receives voltage again from the circuit.

Fig.9 shows the SIMULINK model of a PV panel using Landsman converter. The converter output voltage is controlled using various controllers. Table 3 shows the specification of PV array parameters. Fig.10 represents the variation in irradiation of Solar with respect to time. Initially the irradiation is 2000 W/m², at the time of 4 seconds it is dropped to 1600 W/m² and at 7 seconds it is changed to 1400 W/m² and the Fig.11 shows the output response of the PV system under the variable irradiation. When the irradiation is 2000 W/m² the Voltage is 320V When the irradiance is dropped to 1600 W/m² the PV voltage is also dropped to 140V and then the irradiance its decrease to 1400 W/m² PV voltage also decreases to 40V. When the voltage of the PV system is reduced because of the drop in irradiation the load is shared by the converter.

<table>
<thead>
<tr>
<th>HB-12 100 SPV module</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cells in a module (V)</td>
<td>21</td>
</tr>
<tr>
<td>Open circuit voltage (V)</td>
<td>42</td>
</tr>
<tr>
<td>Short circuit current (A)</td>
<td>6.56</td>
</tr>
<tr>
<td>Series resistance (Ω)</td>
<td>0.72</td>
</tr>
<tr>
<td>Irradiance (W/m²)</td>
<td>1000</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>25</td>
</tr>
</tbody>
</table>

Fig.10: Variable Irradiance of Solar
The efficiency of the proposed PV system fed Landsman converter at different solar irradiation is illustrated in Fig. 12. It gives the efficiency of the proposed system only when all modules are subjected to the same solar irradiance level. The system efficiency may deteriorate under shading or fault conditions. The efficiency of the proposed system increases with the solar irradiance and the system efficiency drop significantly below 100 W/m² in solation level. The efficiency of the proposed system is anticipated to be likely a bit lower than Fig. 12, due to the ignored losses.

The estimation of the parameters of Landsman converter is summarized in Table 4.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance C1</td>
<td>5 µF</td>
</tr>
<tr>
<td>Inductance L1</td>
<td>1 mH</td>
</tr>
<tr>
<td>Capacitance C</td>
<td>1000 µF</td>
</tr>
<tr>
<td>Inductance L</td>
<td>1 mH</td>
</tr>
<tr>
<td>Input voltage</td>
<td>320 V</td>
</tr>
<tr>
<td>Output voltage V1</td>
<td>380 V</td>
</tr>
</tbody>
</table>
Fig. 13 shows the output voltage of the PV panel. The PV panel gives 320V input and it’s given to the Landsman converter. Fig. 14 shows the output voltage in the absence of controller. PV panel drives the proposed converter. The performance of the proposed system is compared to the other existing control techniques. In the absence of controller, voltage ripple and settling time are noticed to be high.

Fig. 15 shows the output voltage with PID, fuzzy and CSO. The output of the PV panel is used for the proposed converter. Here the output is compared with the other controller techniques. In case of PID controller, the time domain performance measures such as settling time, rise time and the ripples are more compared to Fuzzy logic controller and Crow search optimization. The crow search optimization gives better results compared to other control techniques.
Table 5: Gain Values of PID Controller

<table>
<thead>
<tr>
<th>PID Controller parameters</th>
<th>$K_P$</th>
<th>$K_I$</th>
<th>$K_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAIN VALUE</td>
<td>0.5</td>
<td>1.5</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 6: Comparison of Time Response Characteristics of All Other Techniques

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Open loop</th>
<th>PID controller</th>
<th>Fuzzy logic controller</th>
<th>Crow search optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settling Time (ms)</td>
<td>25</td>
<td>1.9</td>
<td>1.4</td>
<td>0.75</td>
</tr>
<tr>
<td>Rise Time (ms)</td>
<td>1.5</td>
<td>0.5</td>
<td>0.1</td>
<td>0.016</td>
</tr>
<tr>
<td>Overshoot (%)</td>
<td>18</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The gain values of the PID controller are shown in Table 5. Table 6 shows the comparison of time response characteristics of the converter in open loop, with PID controller, fuzzy logic controller and crow search optimization. From the table, it is evident that crow search optimization exhibits fast settling time and rise time compared to other control techniques. Comparative analysis of various time integral performance indices are shown in Table 7. It can be inferred that the errors are minimized in the crow search optimization compared to the other control techniques.

Table 7: Comparative Analysis of Performance Indices

<table>
<thead>
<tr>
<th>TYPE OF ERROR</th>
<th>PID</th>
<th>FUZZY</th>
<th>CSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISE</td>
<td>1.522</td>
<td>0.902</td>
<td>0.031</td>
</tr>
<tr>
<td>IAE</td>
<td>546.8</td>
<td>212.9</td>
<td>42.37</td>
</tr>
<tr>
<td>ITAE</td>
<td>1088</td>
<td>425.7</td>
<td>12.22</td>
</tr>
</tbody>
</table>

Fig.16 shows the obtained efficiency of the system in open loop, PID controller, fuzzy logic controller and crow search optimization. The graph clearly shows that the Landsman converter using crow search optimization is more efficient than the other existing ones. The converter using crow search optimization algorithm achieves a fast response with low input current for the system. This optimized system has an efficiency equal to 95.2% at full load condition for 100 W whereas for the same operating conditions the system operating in open loop condition, with PID Controller and with fuzzy logic controller can achieve only 84.9%, 91.2% and 94.7%, respectively. This is evident from the obtained results.

![Figure 16: Efficiency of Landsman Converter](image-url)
7. Conclusion

In this paper the design of a CSO controller for a Landsman converter operating in CCM was presented. This novel optimization method was designed to Dynamic closed loop controller. The objective function of the developed CSO algorithm for PID controller of the DC-DC landsman converter produces good responses operating in CCM were obtained. By comparing the results, the CSO has shown the better performance in terms of various time domain performance measures such as rise time, settling time, peak overshoot and time integral performance measures as ISE, IAE and ITAE than the existing control techniques. The CSO technique shows that the converter response is better than that for the PID, fuzzy technique and the CSO gains have been determined with very short time and with a accurate manner.

References


