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Review Article

CUTTLEFISH OPTIMIZATION CONTROL OF SOLAR PV ARRAY FED LANDSMAN CONVERTER

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ABSTRACT
This paper presents a new meta-heuristic bio-inspired optimization algorithm which is called Cuttle Fish Optimization algorithm (CFO).CFO is based on the color changing behavior of cuttlefish to find the optimal solution. The patterns and colors that are seen in cuttlefish are produced by reflected light from different layers of cells and it is the combination of certain cells at once that allows cuttlefish to possess such a large array of patterns and colors. In this paper the Solar Photo Voltaic (SPV) array is used which 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 with PID controller. Fuzzy logic controller and CuttleFish optimization techniques are used for the optimized control of the converter output voltage. The CuttleFish 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, Cuttle Fish Optimization algorithm.

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 converterand 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 un bounded 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 cuttle fish optimization. The controller parameters are optimized by cuttle fish algorithm. The proposed algorithm is compared with PID, fuzzy logic controller and the comparative results are analysed. The reduction in output voltage ripple in the order of mV along with reduced time response characteristics and performance indices are compared with the PID and Fuzzy logic controller. The cuttle fish 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.

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.

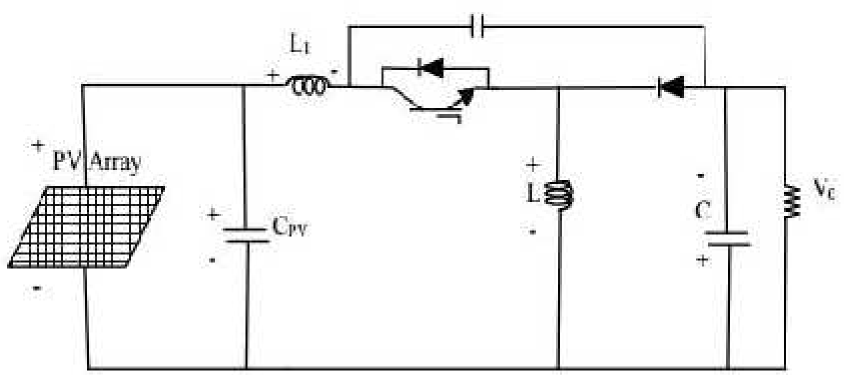

Figure 1: Configuration of SPV Array – Landsman Converter

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, 1 , the voltage across intermediate capacitor 1reverse biases the diode. The inductor current flows through the switch. Since 1 is larger than the output voltage 1 discharges through the switch, transferring energy to the inductor L and the output. Therefore, 1 decreases and current increases, as shown in Figure 3. The input feeds energy to the input inductor 1.

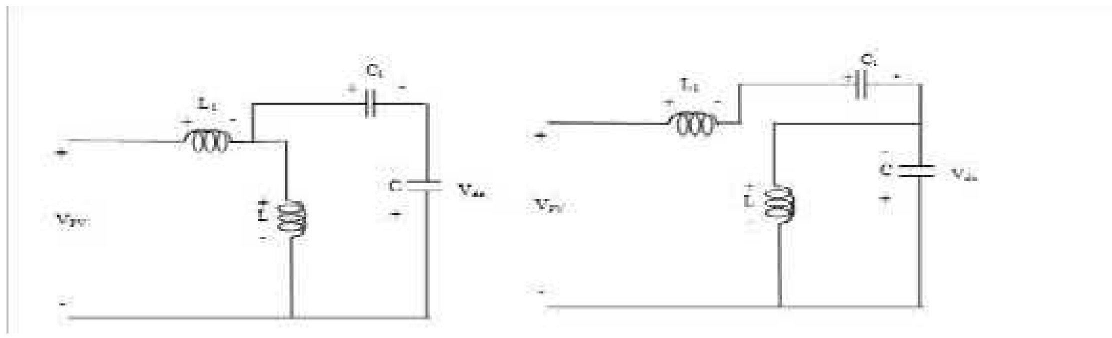

Fig 2: a) mode I operation b) mode II operation

Mode II: When the switch is off, diode is forward biased. The inductor current flows through the diode. The inductor L transfers its stored energy to output through the diode. On the other hand, 1, is charged through the diode by energy from both the input and 1,. Therefore, 1 increases and decreases. The ripple in input current is 1, that is the current through 1, For CCM of operation, assuming that all of the ripple component in 1, flows through 1.

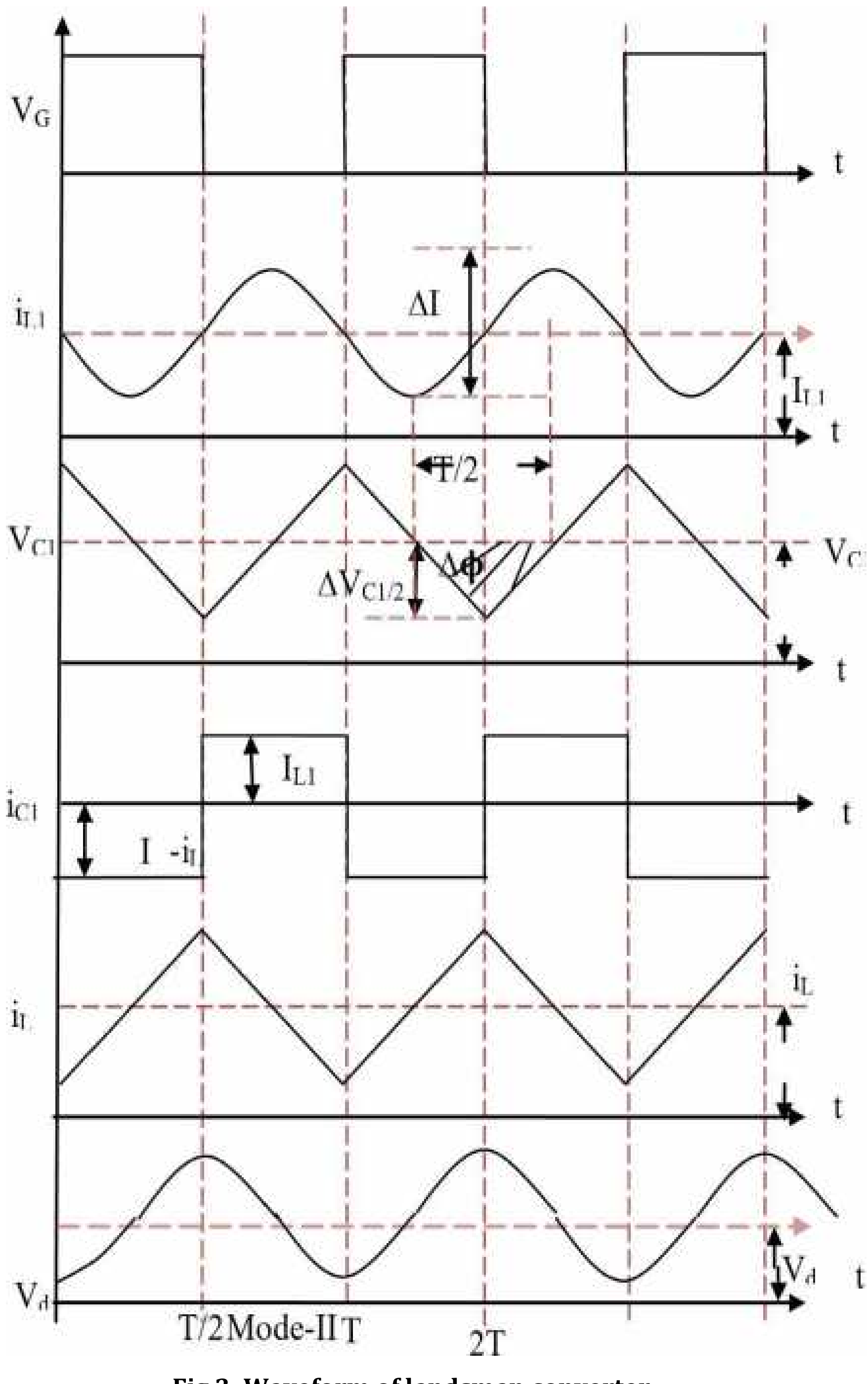

Fig 3: Waveform of landsman converter

Control Techniques Using Proposed System

The block diagram shown in Fig.5shows the implementation of various controllers for Landsman converter. The actual output voltage of the Landsman converter and the constant reference voltage are compared, to form the error signal. The error signal 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.

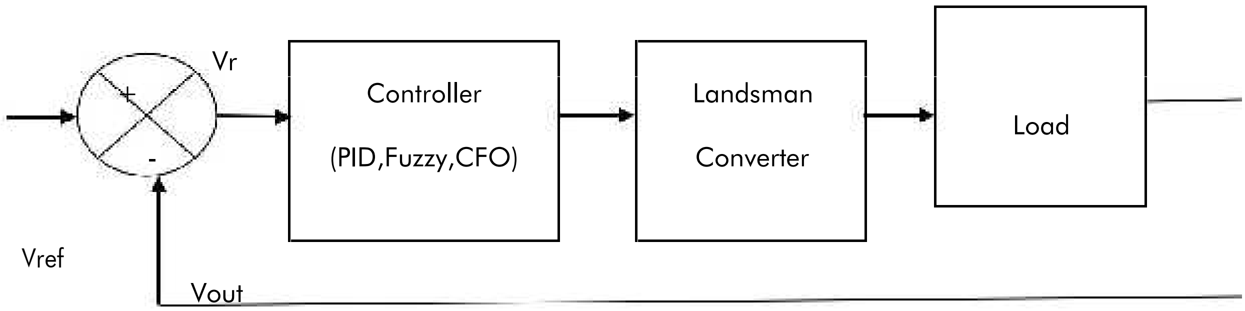

Fig 5: Block diagram of the proposed system

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 &takes 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 determine the reaction to current error, the Derivative (D) value is determines 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.

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 (2010). The model of the proposed system has been simulate. The inputs to a FLC are usually E and Δ . The range of E and Δ 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 Δ calculated and converted to the linguistic variables based on MF, the FLC output, which is typically a change in duty cycle, D of the power converter, can be looked up in a rule base given in Table 1.

Table 1: Rules for a Fuzzy System

E ΔE

NB NM NS ZE PS PM PB NB NB NB NB NB NM NS ZE

NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

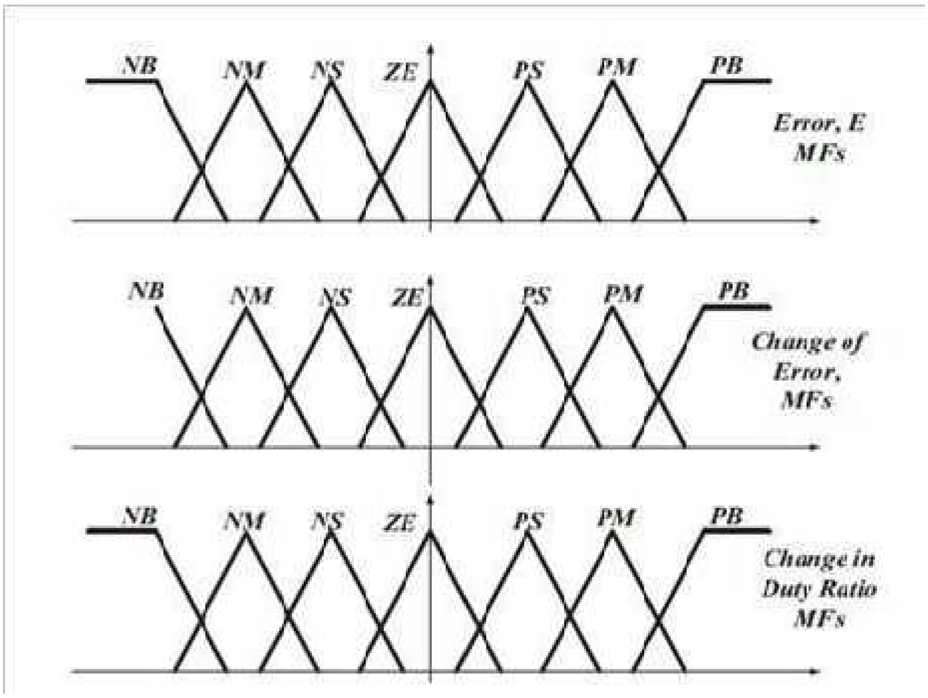

Figure 6: A Fuzzy System with Two Inputs, 1 Output and 7 MFs Each

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 D for the different combinations of E and Δ 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 Ifthen rules or fuzzy inference is essential for the appropriate response of the FLC system. 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 IFTHEN rules to describe the knowledge of control as follows:

Table 2: Translated Fuzzy Rules

If E is NM and DE is PS then D is NS

If E is PS and DE is NB then D is NM

If E is PM and DE is NS then D is PS

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.

$$\Delta D = \sum_{k=1}^{m}(c(k) * W_k) / \sum_{k=1}^{n} W_k$$

where Δ = change of duty cycle; c(k) = peak value of each output; Wk = 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 Δ of the landsman converter. This value is subtracted from previous value of D to get its new value.

Cuttle Fish Optimization

Global optimization algorithms are usually categorized as deterministic and meta-heuristic. Deterministic algorithms tend to use gradient technique and find greater use in solving Uni modal problems, whereas meta-heuristic models end to learn as they run. Therefore, meta-heuristic models are known to be more intelligent and adaptive. They are usually faster when locating a global optimum than the deterministic algorithms. Most of the meta-heuristic algorithms such as Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Bees Algorithm (BA), etc. are bio-inspired in previously been proposed in the literature. Recently, new meta-heuristic approaches are also presented by several researchers such as Collective Animal Behavior (CAB) algorithm, Gravitational Search Algorithm (GSA), Bumble Bees Mating Optimization (BBMO) algorithm, Parliamentary Optimization Algorithm (POA), Bat Algorithm (BA) and Firefly Algorithm (FA). In this paper, a new meta-heuristic optimization algorithm that is inspired by the mechanism of color changing behavior of the cuttlefish is presented to find the optimal solution in numerical optimization problems. The proposed algorithm mimics the light reflection process through the combination of three cell layers, and the visibility of matching pattern process used by the cuttlefish to match its background. The algorithm divides the population (cells) into four groups, each group works independently sharing only the best solution. Two of them are used as a global search, while others are used as a local search.

Cuttlefish skin components

Cuttlefish is a type of cephalopods which is well-known for its abilities to change its color to either seemingly disappear into its environment or to produce stunning displays. The patterns and colors seen in cephalopods are produced by different layers of cells stacked together including Chromatophores, leucophores and iridophores. These layers are described as follows:

Chromatophores

Chromatophores are groups of cells that include an elastic saccule that holds a pigment, as well as 15-25 muscles attached to this saccule. When the muscles contract, they stretch the saccule allowing the pigment inside to cover a larger surface area. When the muscles relax, the saccule shrinks and hides the pigment.

Iridophores

Iridophores are found in the next layer under the chromatophores. Iridophores work by reflecting light and can be used to conceal organs, as is often the case with the silver coloration around the eyes and ink sacs.Additionally, they assist in concealment and communication.

Leucophores

These cells are responsible for the white spots occurring on some species of cuttlefish, squid and octopus. Leucophores are flattened, branched cells that are thought to scatter and reflect incoming light. In this way, the color of the leucophores will reflect the predominant wavelength of light in the environment. In white light they will be white, whereas in blue light they will be blue. Adel Sabry Eesa, Adnan Mohsin Abdulazeez Brifcani, Zeynep Orman.

The Cuttlefish Optimization Algorithm

The cuttlefish optimization algorithm [17, 18] is inspired by the feature camouflage, which changes the color of the cuttlefish allowing it to hide and appear with the same colors of its environment. This feature is based on the behaviour of three cell layers in the skin of cuttlefish, the chromatophores, iridophores and leucophores. These layers are based on two main processes to perform the homochromy:

Reflection: Represents the mechanism used by cuttlefish to reflect incoming light.

Visibility: Represents the color matching of the skin of the cuttlefish to approximate the colors of external environment.

The objective of the algorithm is to find a perfect state of cuttlefish which will allow it to hide in its environment. The algorithm identified six possible cases, divided into four groups, each group works independently of the others, and the best solution obtained by all groups shared between them. The first step of the algorithm is to initialize a population P with *d* chromatophore cells and each cell is a compound of the *N* points (2). The algorithm keeps the cell that has the best cost in Sbest and computes the average of its values AVbest.

$$P = (S_i)_{1 \le i \le d} = (Cell_i)_{1 \le i \le d} = (point_{i,j})_{(1 \le i \le d,\ 1 \le j \le N)}$$

The next step is to generate from each solution of the population a new solution, the population is divided into four groups so that groups 1 and 4 are responsible for local search, and the other two, 2 and 3, for global search:

Group 1: This group simulates the interactions between cells of the chromatophore and the iridophore cells, to produce a reflection of light with a specific color from light coming from external environment. Each cell of the chromatophore enlarges or reduces its pigment bag, while the iridophore cell reflects the light that comes from the chromatophore cell; the reflection of light may or may not penetrate again the chromatophore cell. The cuttlefish optimization algorithm uses the following equations to determine each point of the new solution:

$$Reflection_j = R \times point_{i,j}$$
$$Visibility_j = V \times (bestp_j \ \ point_{i,j}$$

In order to find the new solution Snew such as:
Snew = reflection + visibility

On the other hand, R representing the degree of reflection to find the chromatophore saccule, is chosen randomly in the interval section of the chromatophore bounded by constants r1 and r2. And V which represents the degree of visibility of the final constant limited by v1 and v2 model (6) and (7). In this group, V is 1, and R must be calculated.

$R = random(0,1) \times (r1\ \ r2) + r2$

$V = random(0,1) \times (v1\ \ v2) + v2$

Group 2: This group simulates the reflection of light from the outside by marking the iridophore cells with a specific color, the reflected light can be released into the environment (3rd case) or captured by the chromatophore cells. To determine the new solution, this group uses (4) which calculates the visibility, and (8) calculates reflection. For this group, R is equal to 1, and V is calculated.

$reflectionj = R \times bestpj$

Group 3: This group uses the leucophore characteristic reflecting light from the chromatophore cells in all directions without changing its color. Reflection of the new solution.

Simulation Results & Discussion

Fig.7 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

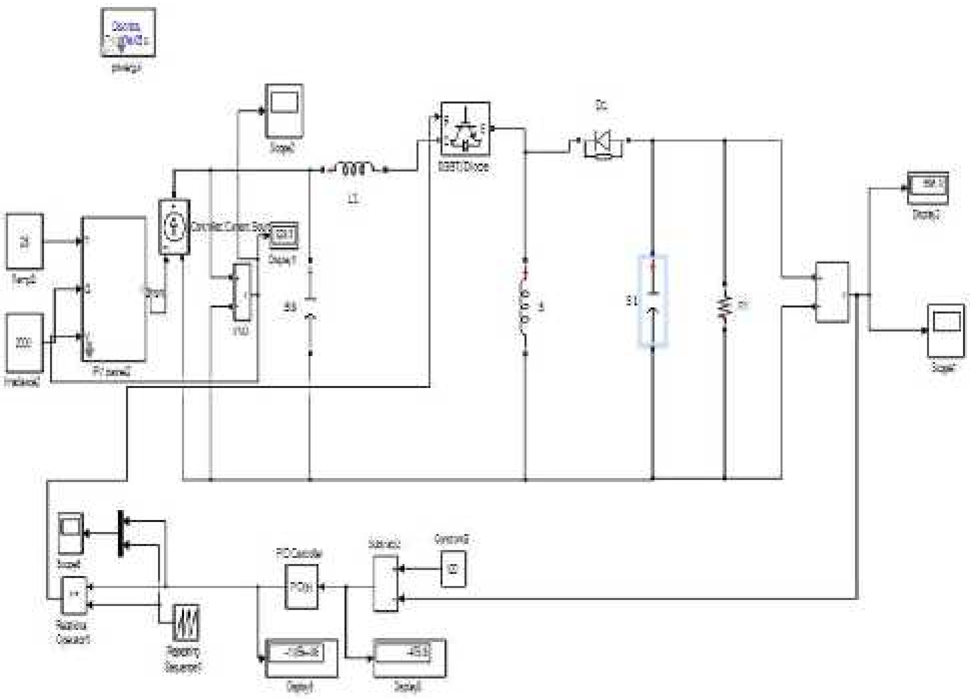

Figure 8: Simulink Model of PV Panel Using Landsman Converter

The converter output voltage is controlled using various controllers. Table 3 shows the specification of PV array parameters.

Table 3: Specification of PV Array Parameters

HB-12 100 SPV module	36
Number of cells in a module(V)	21
Open circuit voltage (V)	42
Short circuit current (A)	6.56
Series resistance (Ω)	0.72
Irradiance(W/m^2)	1000
Temperature(^0C)	25

Table 4: Parameters of Proposed Converter

Parameter	Value
Capacitance, 1 Inductance, 1	5μF 1mH
Capacitance C	1000μF
Inductance, L	1mH
Input voltage	300V
Output voltage V1	600V

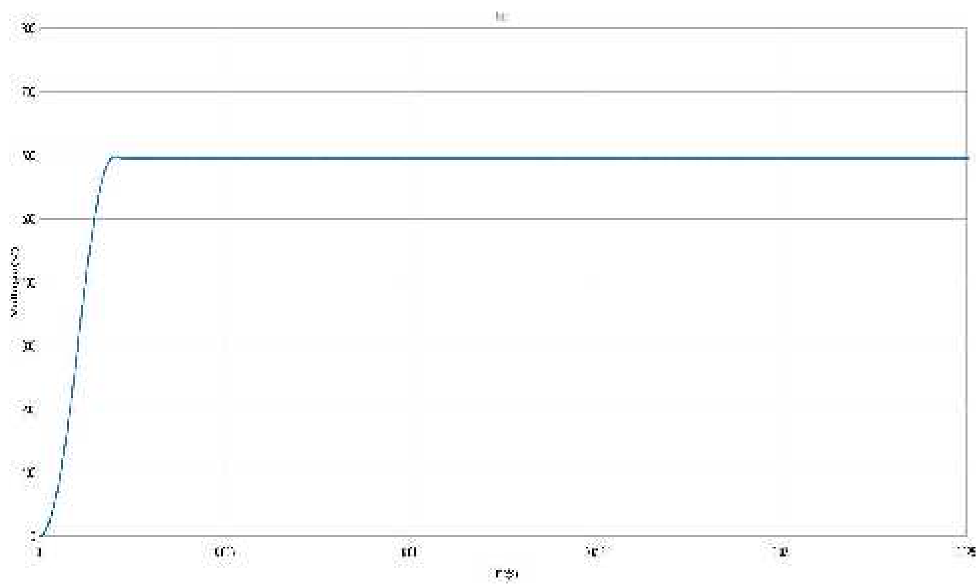

Fig 8. Input voltage of landsman converter

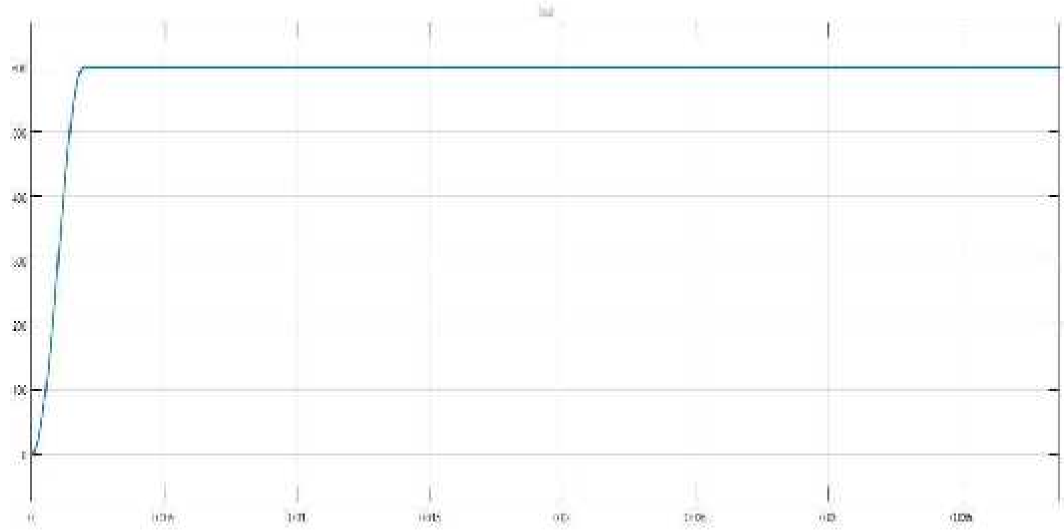

Fig 9. Output voltage of landsman converter

Fig.9 shows the output voltage of the landsman converter in the absence of controller. The PV panel gives 300V input and it's given to the Landsman converter. 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.

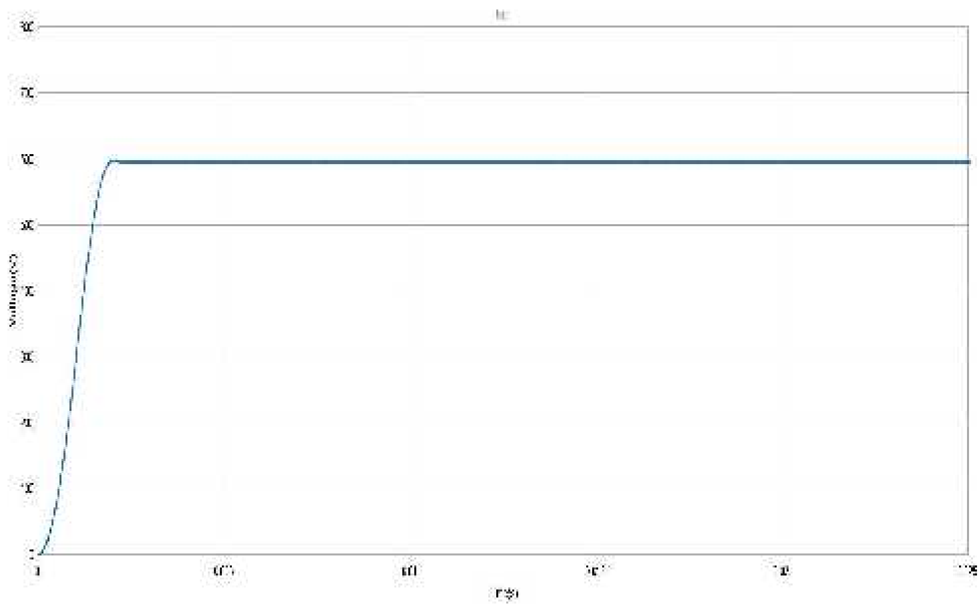

Fig 10: Output voltage of CFO

The output of the PV panel is given to the proposed converter and the output is controlled by a PID controller. In case of PID controller, the time domain performance measures such as settling time, rise time ,ripples are more and hence optimization techniques are implemented to yield better results. Fig 10 shows the output voltage of CFO .The output voltage of CFO gives 595v and its given to the landsman converter The cuttlefish optimization gives better results compared to other control techniques.

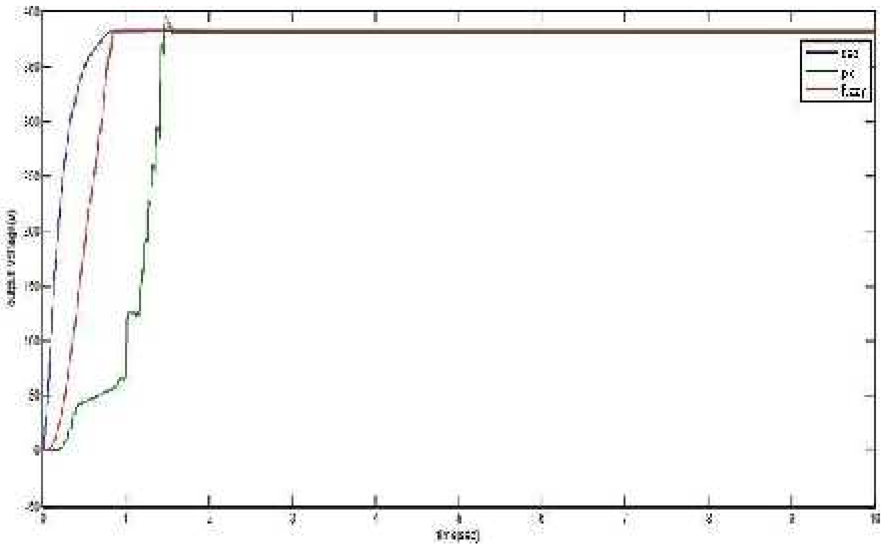

Fig.11. Output voltage with PID, fuzzy and CFO

The graph clearly shows that the Landsman converter using cuttlefish optimization is more efficient than the other existing ones. The converter using cuttlefish optimization algorithm achieves a fast response with low input current for the system.

Table 5: Gain Values of PID Controller

PID Controller parameters	kp	ki	Kd
GAIN VALUE	0.5	1.5	0.05

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

Characteristics	Open loop	PID controller	Fuzzy logic controller	Cuttlefish optimization
Settling-Time(ms)	25	1.9	1.4	0.75
Rise- Time(ms)	1.5	0.5	0.1	0.016
Overshoot (%)	18	5	0	0

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 Cuttlefish optimization. From the table, it is evident that cuttlefish optimization exhibits fast settling time and rise time compared to other control techniques.

Table 7: Comparative Analysis of Performance Indices

TYPE OF ERROR	PID	FUZZY	CFO
ISE	1.522	0.902	0.031
IAE	546.8	212.9	42.37
ITAE	1088	425.7	12.22

Comparative analysis of various time integral performance indices are shown in Table 7.It can be inferred that the errors are minimized in the cuttlefish optimization compared to the other control techniques.

Conclusion

In this paper the design of a CFO based PID 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 CFO algorithm for PID controller of the DC-DC landsman converter produces good responses operating in CCM were obtained. By comparing the results, the CFO 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 CFO technique shows that the converter response is better when compared than that for the PID and fuzzy technique.

References

1. Dursun M., Semih O., Application of solar powered automatic water pumping in Turkey, International Journal of Computer and Electrical Engineering 4(2) (2012).
2. Jones W.V., Motor selection made easy: choosing the right motor for centrifugal pump applications, IEEE Ind. Appl. Mag. 19 (6) (2013), 36–45.
3. Sera D., Mathe L., Kerekes T., Spataru S.V., Teodorescu R., On the perturb-and-observe and incremental conductance MPPT methods for PV systems, IEEE journal of photovoltaics 3(3) (2013), 1070-1078.
4. Elgendy M.A., Zahawi B., Atkinson D.J., Assessment of the incremental conductance maximum power point tracking algorithm, IEEE Trans. Sustain.Energy 4(1) (2013), 108-117.
5. Atlas I.H., Sharaf A.M., A photovoltaic Array Simulation Model for MatlabSimulink GUI Environment, Proc. of IEEE International Conference on Clean Electrical Power (2007).
6. Ouada M., Meridjet M.S., Talbi N., Optimization photovoltaic pumping system based BLDC using fuzzy logic MPPT control, Int. Renewable and Sustainable Energy Conf.(2013), 27– 31.
7. Kumar R., Singh B., Buck–boost converter fed BLDC motor drive for solar PVarray based water pumping, IEEE Int. Conf. on Power Electronics, Drives and Energy Systems (2014).
8. Kumar R., Singh B., Solar photovoltaic array fed Luo converter based BLDC motor driven water pumping system, Ninth Int.
9. Conf. on Industrial and Information Systems (2014).
10. Kumar R., Singh B., Solar photovoltaic array fed canonical switching cell converter based BLDC motor drive for water pumping system, Annual IEEE India Conf. (2014).
11. Parackal R., Koshy R.A., PV powered zeta converter fed BLDC drive, AnnualInt. Conf. on Emerging Research Areas: Magnetics, Machines and Drives (2014).
12. Niapour S.K.M., Danyali S., Sharifian M.B.B., Feyzi M.R., Brushless DC motor drives supplied by PV power system based on Z-source inverter and FL-IC MPPT controller, Energy Conversion and Management 52(8-9) (2011), 3043-3059.
13. Singh B., Bist V., A BL-CSC Converter fed BLDC Motor Drive with Power Factor Correction, IEEE Trans. on Ind. Electron. 62(1) (2015), 172-183
14. Williams B.W., Basic DC-to-DC Converters, IEEE Trans. PowerElectron. 23(1) (2008), 387-401.
15. Williams B.W., DC-to-DC Converters with Continuous Input and Output Power, IEEE Trans. Power Electron 28(5) (2013), 23072316.
16. Landsman E.E, A unifying derivation of switching DC–DC converter Topologies, IEEE Power Electronics Specialists Conf. (1979), 239–243.
17. Williams B.W, Generation and analysis of canonical switching cell DC-DC converters, IEEE Trans. Ind. Electron. 61(1) (2014), 329–346.
18. Taghvaee M.H., Radzi M.A.M., Moosavain S.M., Hizam H.,
19. Marhaban M.H., A current and future study on non-isolated DC– DC converters for photovoltaic applications, Renewable and sustainable energy reviews 17 (2013), 216-227.
20. Youssef, M.Z., Design and performance of a cost-effective BLDC drive for water pump application, IEEE Trans. Ind. Electron. 62(5) (2015), 3277–3284.
21. Caracas J.V.M., de Carvalho Farias G., Teixeira L.F.M., de Souza Ribeiro L.A., Implementation of a high-efficiency, highlifetime, and low-cost converter for an autonomous photovoltaic water pumping

system, IEEE Transactions on Industry Applications 50(1) (2014), 631-641.

22. Kumarasamy K., Kishan Surya, Badri Narayanan, Mahesh, Solar Powered Water Pumping System Using BLDC Motor and Zeta Converter, International Journal of Innovative Research in Science, Engineering and Technology 6(3) (2017).