IMPLEMENTATION OF LION-GH OPTIMIZATION BASED CPD TO IMPROVE POWER QUALITY IN GRID-PV SYSTEM

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ABSTRACT
The three main synchronisation concerns in grid-connected solar systems that affect electricity quality are voltage distortions, flicker, and unbalances. Power quality problems are also brought on by abrupt changes in load, the application of non-linear loads, and switching circumstances. The suggested grid-connected PV system is built with a customised power device to address these issues (Distributed STATCOM). An mppt-based dc-dc converter is used to extract the most power possible from the solar system when designing and implementing the photovoltaic system.The reference signal required for series and shunt converter of UPQC is controlled with optimization techniques. This paper focuses on implementation of Lion Optimization Algorithm (LOA), Grasshopper Algorithm (GH) and hybrid LOA-GH Algorithms.
Keywords: PV System, DSTATCOM, LOA Technique, Grasshopper and Hybrid LOA-GH etc.
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INTRODUCTION
In the presentsystem, PV systems are an important energy source. In general, renewable energy sources are pollution-free energies. The effectiveness of a PV system is identified by the PV panel’s efficiency and efficiency of inverter. The efficiency improvement in the photovoltaic power conversion is required by using MPPT algorithms [2-3]. The output voltage regulation of PV system is regulated with the help of mppt controller. The maximum power from the system can be achieved only when load resistance is equal to internal resistance of PV system as of maximum power transfer theorem. This inequality condition can be recognized by controlling the boost converter duty cycle.

The reference signal required for dc-dc converter generated using MPPT controller. In general, there are different ways to maximizing the PV system power, these ranges are from basic voltage relationships to complex sample-based analysis. Based on the applications and dynamics of irradiance, the power conversion systems need to evaluate the different options. The main aim of present study is to develop an individual and combined MPPT methods on different optimization techniques [4]. The advantage of hybrid MPPT techniques is to improve the efficiency of the PV system under rapid change in atmospheric conditions and load.

The main causes for power quality issues are due to sudden changes in load, switching conditions, utilization of non-linear loads and due to environmental conditions. This paper proposes the concept of power quality problems like harmonics in current and voltage sag and swell conditions. Many techniques available in literature to compensate power quality problems like series and shunt reactors, capacitor banks and many more facts techniques. Out of all techniques custom power device plays a key role due to its unique control action and flexibility in operation. This paper proposes an operation and modelling of custom power device i.e unified power quality conditioner to mitigate problems.

In Literature [7] adopted Particle Swarm Optimization method for solving DSTATCOMplacement problem. DSTATCOM is modelled in the load flow method and the bus which is having minimum power lossis adopted for CPD placement. The disadvantage with thismethod is for large distribution system finding the loss at eachand every bus is time consuming. Hence, in this paper a newoptimization method known as Lion, GH and hybrid combination of LOA-GH Optimization methods are implemented to solve the CPD placement problem. The PI, Lion, Grasshopper and hybrid combination of Lion-Grasshopper algorithms are used in both controllers to regulate the system errors.

LITERATURE SURVEY:

B. W. França [3], carried out an improved-on control procedure for double three-stage bound together force quality conditioner. This iUPQC control structures is an ABC reference outline-based control, where the SAF and PAF are controlled in a free manner. The SAF has a current circle to guarantee a sinusoidal framework current synchronized with the matrix voltage. The PAF has a voltage circle to guarantee a decent controlled burden voltage with low consonant contortion. These control circles are autonomous from one another since they act freely in every dynamic channel. The dc connect voltage control is made in the SAF.Under fault conditions, **BrahimBerbaoui's [4]** optimal control method helps to maintain proper power sharing between series and shunt converters. The hybrid PEM fuel cell and super capacitor power system that is proposed in this paper uses the UPQC to keep the systems in proper synchronisation and to control the harmonic distortion factor.**S. Ganguly et.al [6]** has adopted Particle Swarm Optimization (PSO) method for solving UPQC placement problem. UPQC is modelled in the load flow method and the bus which is having minimum power loss is adopted for UPQC placement. The disadvantage with this method is for large distribution system finding the loss at each and every bus is time consuming.The GOA is proposed by Shahrzad et al [7] in 2017. Grasshoppers are creepy crawlies which harm crop, sway horticulture creation and consequently are named as a nuisance. The existence pattern of a grasshopper goes through three fundamental stages, in particular; egg, fairy, and grown-up. One of the extraordinary parts of the grasshopper swarm is that they can shape swarm in both fairy hood and adulthood. The little advances and sluggish development is one of the significant qualities of the multitude in the larval stage while quick and sudden development is the principle highlight of the multitude in adulthood.

PROPOSED SYETM WITH GRID INTERFACED PV SYSTEM:

Figure 1, shows Photovoltaic system implemented with cpd to improve the power quality. The main causes for Power Quality,improper synchronization between DG and grid system, sudden changes in load and utilization of non-linear loads. Due to these causes the general pq problems are voltage sag/swell, harmonics in current. A CPD is implemented in Grid tied DG system to mitigate the problems [8].In general, the converter at series side is used to mitigate voltage problems and the current harmonics can be compensated with shunt converter of DSTACOM.

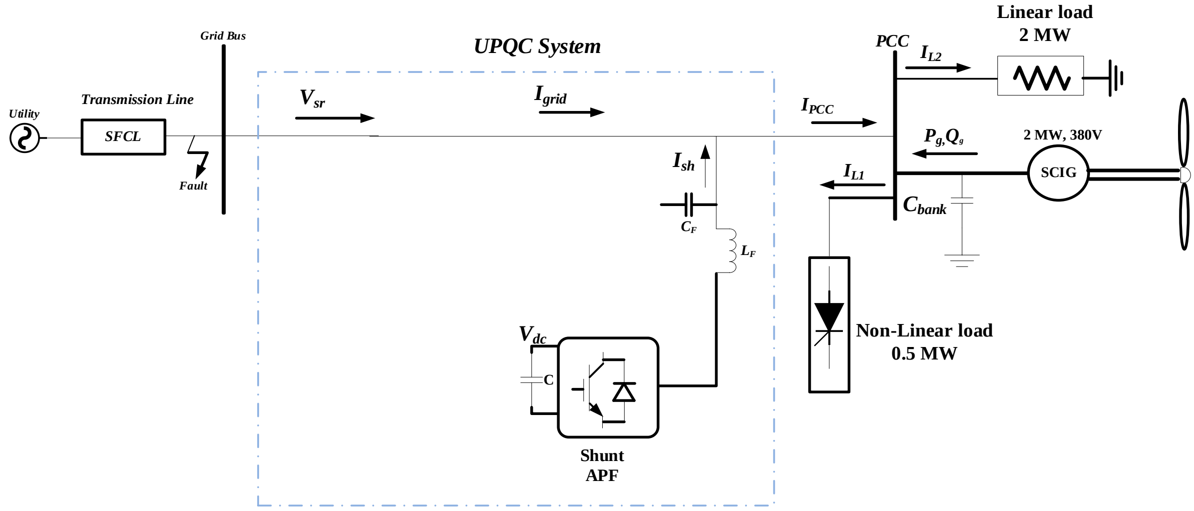

Figure 1: Microgrid with DSTATCOM Controller

The grid connected PV system with conventional converter is shown in figure 1. In this proposed system a PV system is designed as one of the distributed energy sources, because of its freely available in nature and has high efficiency. Due to these parameters PV system plays a key role in Power system. The nature of PV system converters sun radiation into electrical energy. An mppt-based converter is utilised to enhance the performance of the PV system. Based on the parameters of the PV system as depicted in figure 2, the goal of mppt is to produce the reference signal for the boost converter.

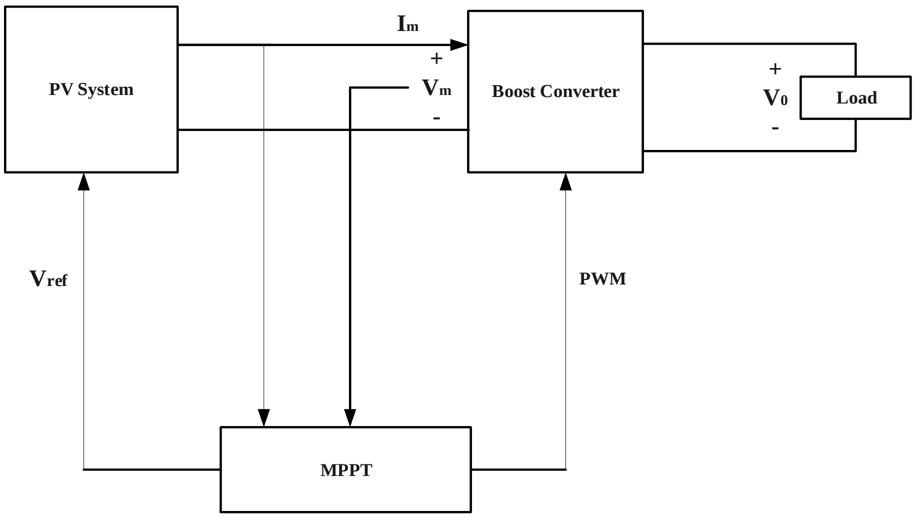

Figure 2: Line Diagram of PV system with MPPT Controller

Here in this paper the PV system is implemented by using mathematical modelling. The expression for PV current is expressed as

$$I = I_{ph1} - I_{D1} - I_{sh1}$$

$$I = I_{ph} - I_o[e^{(\frac{qV_D}{nKT})}] - (\frac{V_D}{R_s})$$

To improve power quality problems different methods available in literature analysis. This paper proposes unified power quality conditioner as compensator, because it uniquely controls all system parameters under all conditions. Basic structure of DSTATCOM [10] is shown in figure 3.

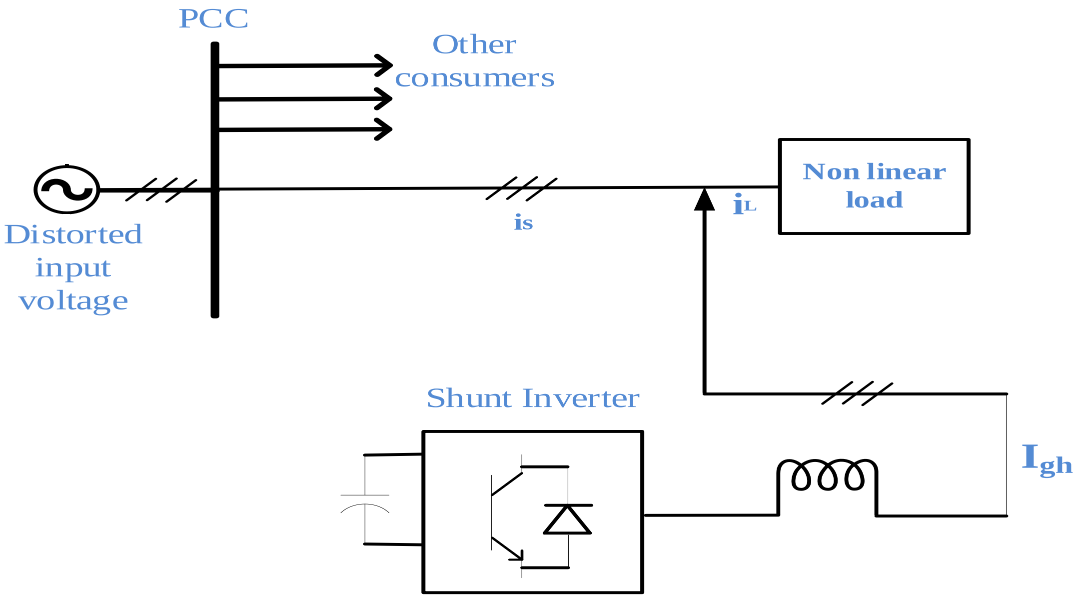

Figure 3: Structure of DSTATCOM

DSTATCOM Structure is shown in figure 3.Reference signal required for the shunt controller reference signal is designed with the help of instantaneous PQ-theory concept.

In series converter controller the reference signal required for PWM controller is obtained by comparing rated and grid voltages. The controlling of dc voltage helps to exchange the active power between grid and distributed system. Hence the regulation of dc-link voltage helps to generate the unit vectors required for series controller. The expressions for three phase unit vectors is shown below,

$$U_a = \sin(\theta)$$
$$U_b \sin(\theta - 120)$$
$$U \ = \sin(\theta + 120)$$

The synchronizing angle (θ) is obtained by using phase locked loop from grid voltages.

$$\Delta V_{dc} = V_{dc(ref)} - V_{dc(actual)}$$

The output of conventional PI controller used for controlling dc-voltage is chosen as I_m.The expressions for generating three phase currents from unit vectors and I_m are expressed below

$$I_{sa}^* = I_m * U_{sa}$$
$$I_{sb}^* = I_m * U_{sb}$$
$$I_{sc}^* = I_m * U_{sc}$$

The reference currents mentioned in above are compared with system grid currents to obtain error currents which is required for hysteresis controller of series converter

$$\Delta I_a = I_a^* - I_{ga}$$
$$\Delta I_b = I_b^* - I_{ga}$$
$$\Delta I_c = I_c^* - I_{gc}$$

In this Instantaneous Power theory is used to generate required reference current as shown in figure 4. Direct axis current is obtained by comparing active powers and by comparison of reactive powers the quadrature axis current is obtained. By parks transformation technique three phase grid currents are transformed to two phase components namely direct and quadrature axis currents. These currents are compared with rated currents to identify the harmonic distortions. A conventional PI controller is used to regulate the steady state error and for generating proportional signals [12]. With the help of inverse parks transformation technique, the dq voltages are converted to three phase voltages and applies to pulse width modulator to generate suitable gate pulses required for shunt controller.

$$P = v_{s\alpha} i_{s\alpha} + v_{s\beta} i_{s\beta} = \tilde{p} + \bar{p}$$
$$q = v_{s\beta} i_{s\alpha} - v_{s\alpha} i_{s\beta} = \tilde{q} + \bar{q} \quad (1)$$

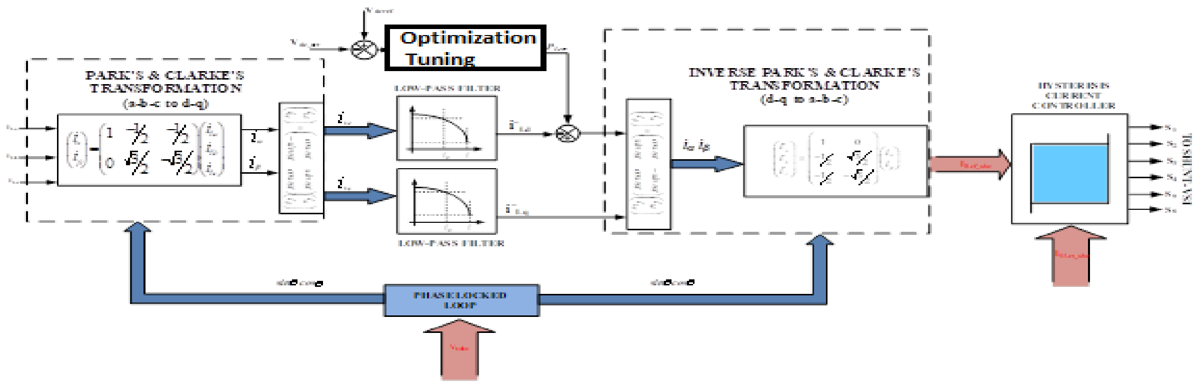

Figure 4: Shunt Converter Controller

The parameters of conventional PI controller is tuned with optimization techniques to achieve good power quality by reducing harmonics and voltage fluctuations [14]. This paper proposes implementation of Lion Optimization, Grasshopper and hybrid combination of Lion-Grasshopper techniques to tune PI parameters.

LION OPTIMIZATION ALGORITHM TO DSTATCOM:

Lion Optimization is works by inspiration of proposed meta-heuristic algorithm. There are two categories of lions available in wield-field namely a) residents and b) nomads. Residents live in what is known as a pride, while nomads are either solitary or live in pairs [15]. Three steps make up the lion optimization process: pride formation, mating, and territorial defence. Figure 6 shows flowchart of Lion Optimization algorithm.

Lion Optimization Algorithm step by step procedure:

Step 1: Read feeder voltage, current and load current harmonic content of proposed system using SRF method.

Step 2: Find the dc voltage error for DSTATCOM using dc voltage controller.

Step 3: Initialize the number of population iterations and positions.

In an N_{var} dimensional problem, the representation of lion is shown below:

Lion = [x1, x2, x3, ….., xavr]

Calculate the fitness function for each lion is identified by using the following function

Fitness value of lion =f(lion)

Step 4: Tune the parameters of PI controller using population function.

Female Lion (Parameters of Kp and Ki)'= Lion Female+@D*rand(0,1){R1}+U(-,1)*tan(Ɵ)*D*{R2}{R1}.{R2}=0.

Step 5: Identify proper Kp and Ki values for population generated.

Step 6: Kp and Ki with low error is the current best solution. Here, P the Lion Success rate at iteration t

$$S(i,t,p)=\begin{cases}1\ Best_{ip}^{t} < Best_{\leq ip}^{t-1}\\ 0\ Best_{ip}^{t} = Best_{\leq ip}^{t-1}\end{cases}$$

Step 7: By using equation shown update the position of lions:

$$K_i(s)=\sum_{j=1}^{n} S(j,t,p) \quad \mathrm{i}=1,2,\ldots,p$$

Step 8: For updated population determine error.

$$offspring_j\ \mathrm{I}=\beta * Female\ \mathrm{Lion}_j+\sum\frac{(1-\beta)}{\sum_{i=1}^{NR} S_i} * MaleLion_j^i * S_i$$

Step 9: If obtained parameters are better, replace with existenceor else go back to step 7 [16]

Step 10: Print the results if maximum iterations reached.

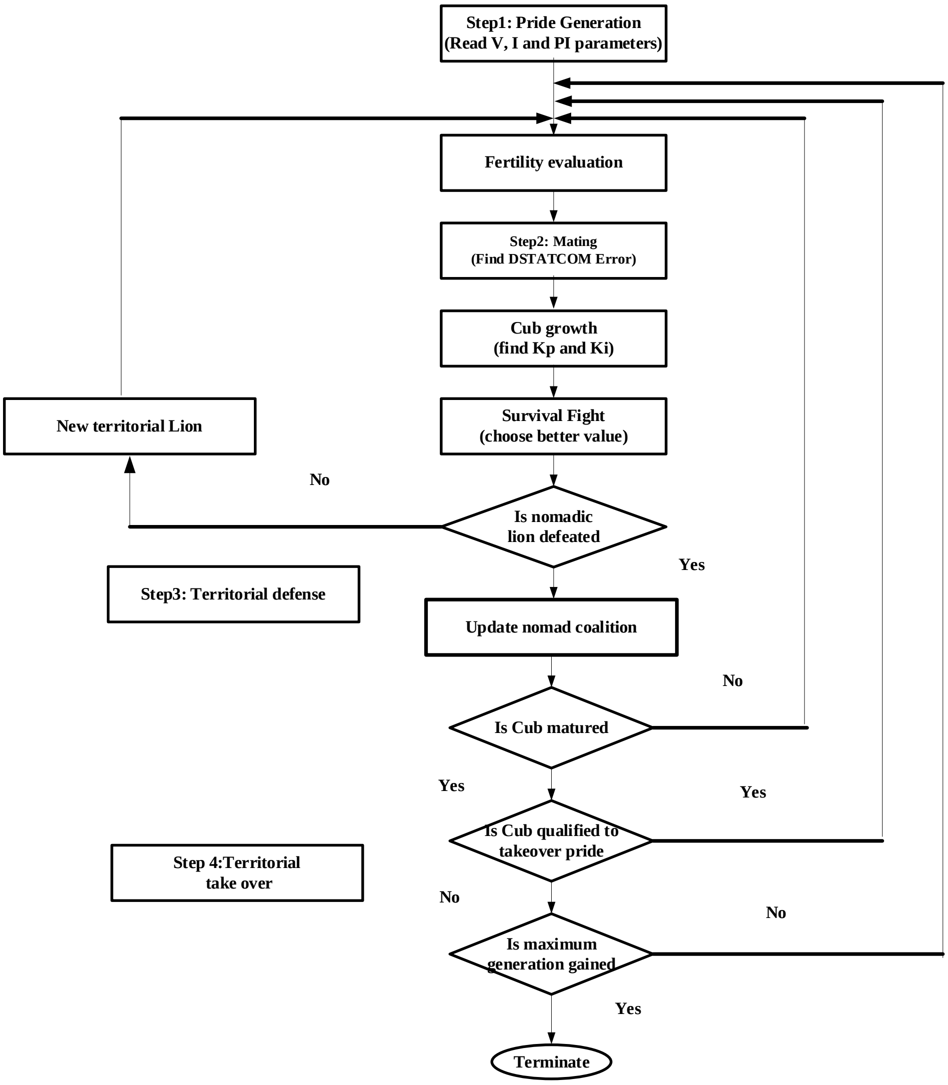

Figure 6: The flow structure of the Lion Optimization Algorithm

GRASSHOPPER OPTIMIZATION TECHNIQUE

A modern complex anatomical method is the Grasshopper Optimization Algorithm (GH) [17]. The GOA method is based on the grasshopper's life cycle, which includes three stages—egg, fairy, and adult—that go through a cycle known as transformation. Grasshoppers travel from egg to sprite as sliding chambers, and when they switch to fairy form, they cause damage to crops. This nature is numerically demonstrated to shape an anatomical enhancement procedure named GH [18].

Procedure of Grosshopper Optimization;

Step 1: Intialize the objective function

$$FF=MAXP$$

Initialize population (dc voltage error) of n grasshoppers

Behavior of 'Grasshoppers' is precisely articulated as follows:

$$Y_m=S_m+G_m+A_m$$

Where the location of Grasshopper at mth position is represented with Y_m, and correlation is S_m, G_m is the gravitational strength, and A_m is the wind in abeyance.

Calculate the fitness of each grasshopper (tuning of PI Controller Parameters)

$$y_i^d = c1\left(\sum_{\substack{j1=1\\ j1\neq 1}}^{N1} c\frac{ub_{d1}-lb_{d1}}{2}s(|y_{j1}^d - y_{i1}^d)|\frac{y_j - y_i}{d}\right) + T_{d1}$$

T = best search agent (dc voltage error)

Step 2: Check the process

Step 3: Updatemin and max values

$$C = C^{\max} - l\frac{C^{\max} - C^{\min}}{L}$$

For each grasshopper in the population **do**

Normalize the distances between grasshoppers

Update the position of the grasshopper

If required, update bounds of grasshopper

End **for**

Step 4: Update T

Exit while

Step 5: Output the T

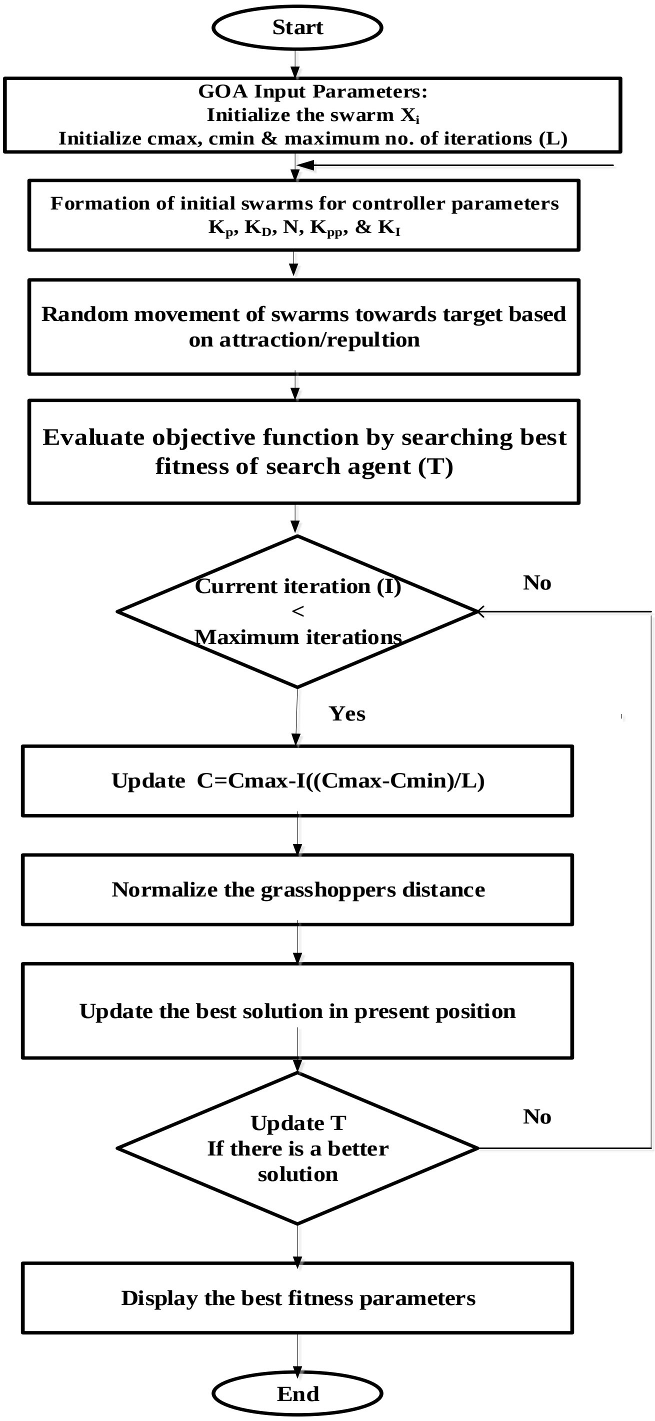

Figure 7: The flow structure of the Grasshopper Algorithm

HYBRID LOA-GH OPTIMIZATION ALGORITHMS:

The data this optimization technique are i,e Dc Voltage Error, initial P and I parameters, No. of Itterationse etc. By comparision of actual and reference signal the dc link voltage error is found. The following expression helps to find the best population solution,

$$S(i,t,p) = \begin{cases} 1 \; Best_{ip}^{t} < Best_{\le ip}^{t-1} \\ 0 \; Best_{ip}^{t} = Best_{\le ip}^{t-1} \end{cases}$$

The output of Lion Optimization Algorithm is given as input to the Grasshopper algorithm to tune the parameters of P and I Controller [19]. The flowchart for hybrid LOA-GH optimization algorithm is shown in figure 7.

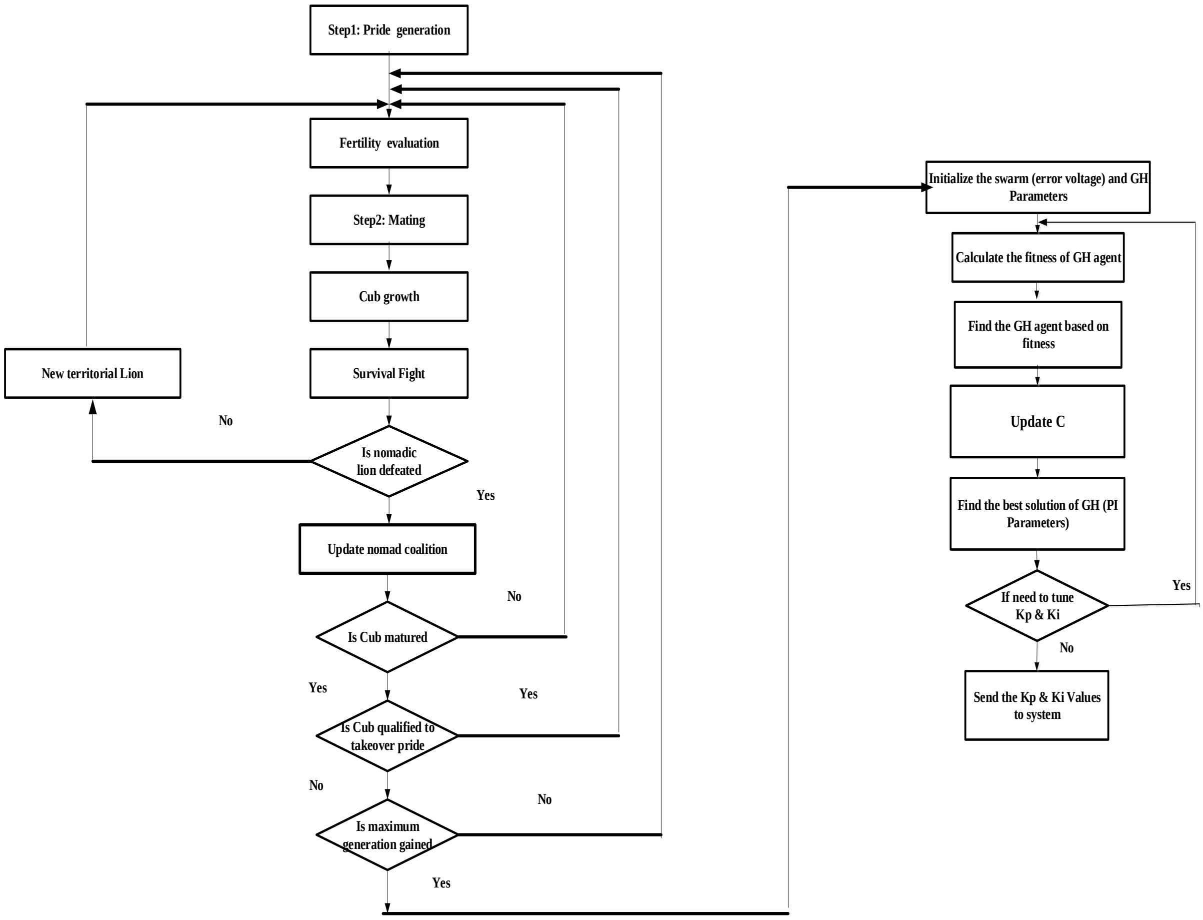

Figure 8: The flow structure of Hybrid Lion-GH Optimization Algorithm

SIMULATION RESULTS:

The grid tied PV system with cpd implemented and verified in Matlab with non-linear load and fault condition. The PV system is designed for 100kW capacity with irradiance of 1000w/m^{2}at temperature of 25^{o}c. The shunt controller of CPD is implemented with Synchronous frmae theory and Instanataneous PQ-theory methods respectively. The matlab diagram for proposed system is shown in figure 9.

Table 1: Proposed System Parameters

Parameters		Values
Grid Voltage		230 V
Fundamental frequency		50Hz
Dc- link Capacitor Voltage		420 V
Dc-link capacitor		200 μF
Shunt APF	R,L	5 $m\Omega$,150 μH
Series APF	R	0.0004 H

Case 1: Implementation ofCPD with Conventional controller

Figures 9 and 10 depict the simulation waveforms for voltage sag and compensated waveforms. The proposed system experiences a fault between the seconds of 0.05 and 0.15.Due to this fault condition the system voltage is reduced to 0.8% of the final value. The sag compensated waveform is shown in figure 10.

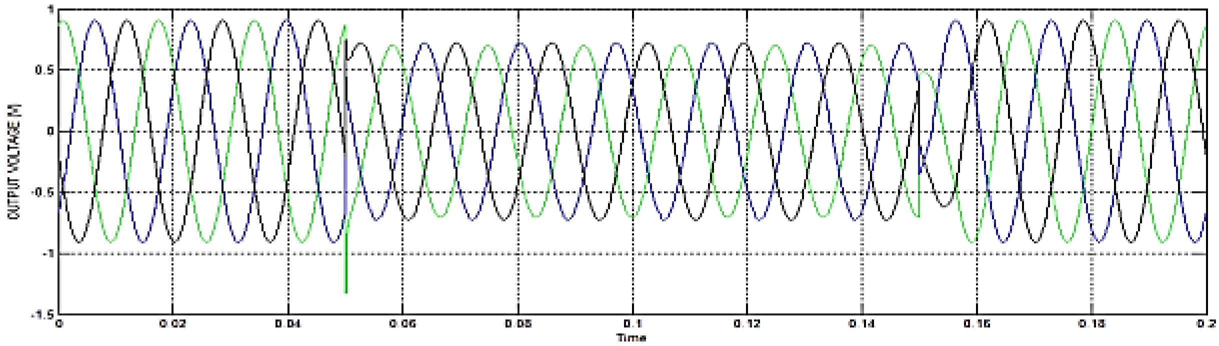

Figure 9: Results for Voltage Sag Condition

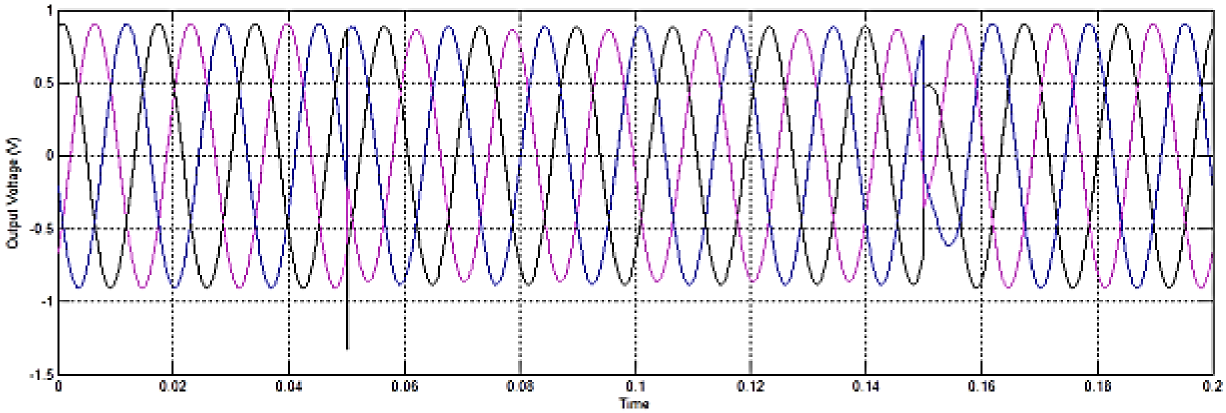

Figure 10: Simulation Results CPD Compensated Voltage

And due to fault condition, the current is increased to 1.2% per unit as shown in Figure 11 and figure 12. Problems in voltage and current occurred due to presence of three phase fault during the period 0.5s to 0.15s is mitigated with CPD. The Total harmonic distortions for Load voltage with conventional PI controller is 3.88% as shown in figure 13.

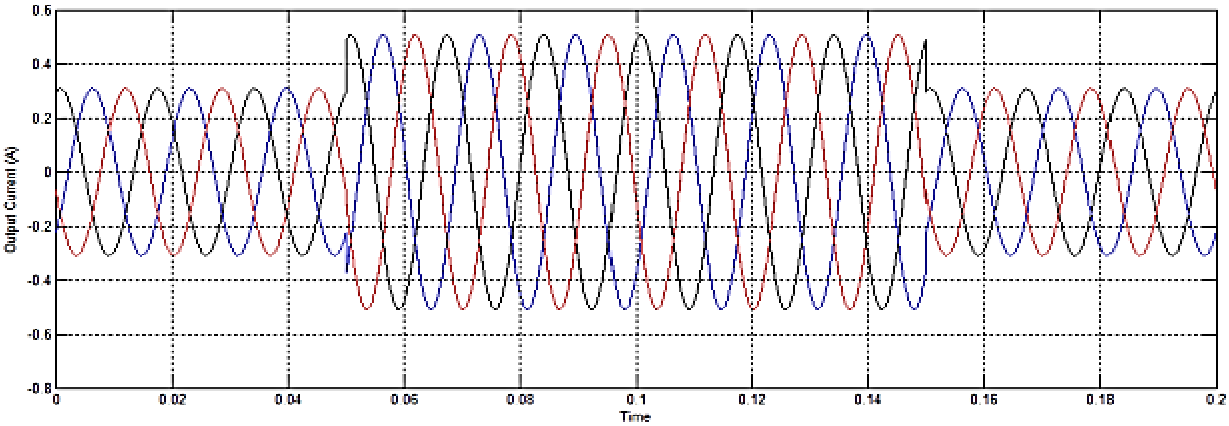

Figure 11: Simulation Results for Current Swell Condition

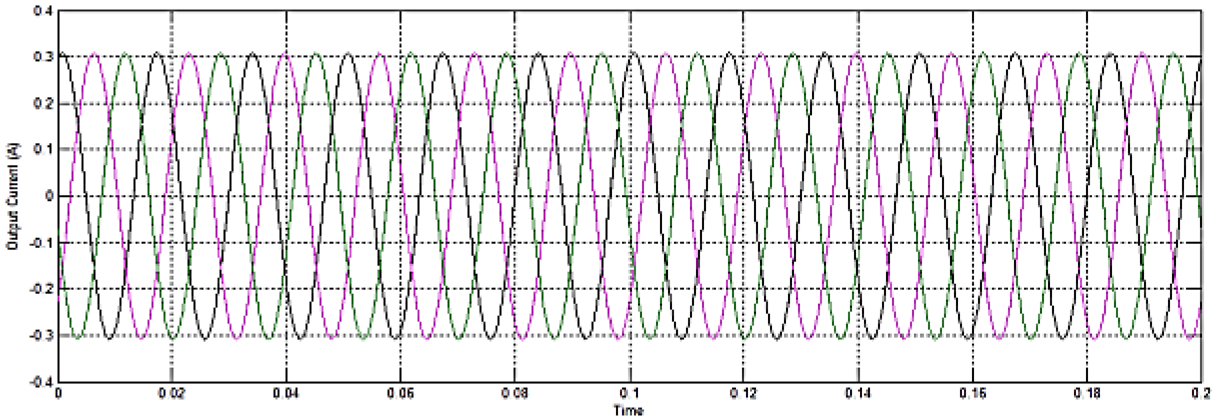

Figure 12: Simulation Results for Compensated Current with CPD

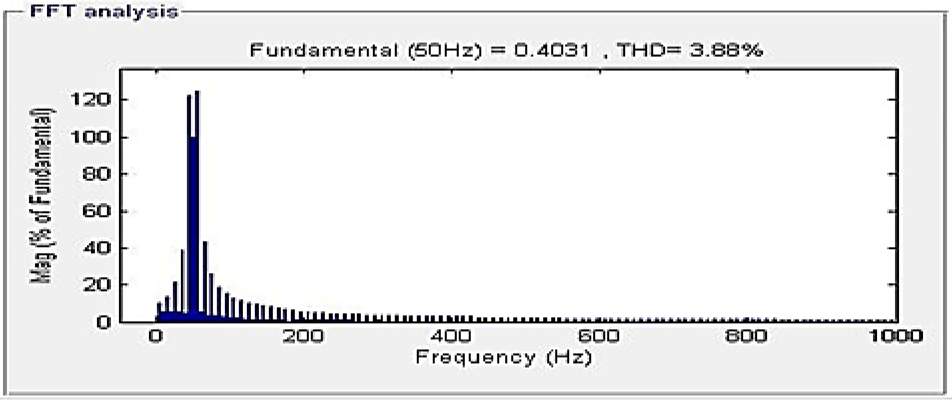

Figure 13: Output Voltage THD under PI

Case 2: Modelling of CPD Shunt Converters with LOA, GH and Hybrid Combination of LOA-GH

The PI controller parameter in shunt converter is tuned with the Lion, Grasshopper and hybrid combination of Lion-grasshopper techniques. Figure 14 shows the simulation of shunt converter controller.

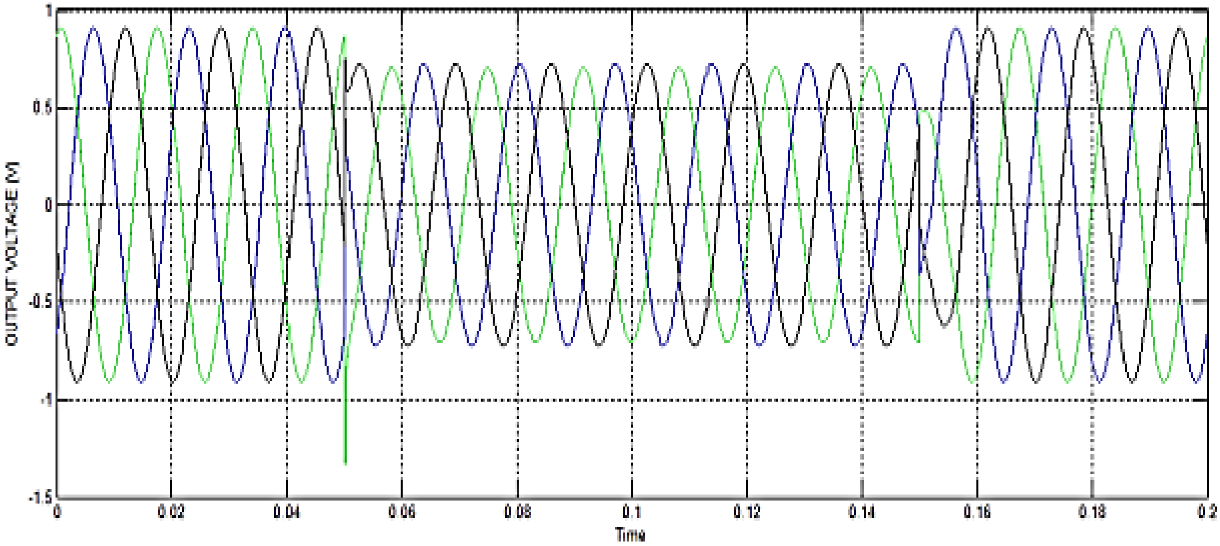

Figure 14: Input Voltage during sag condition

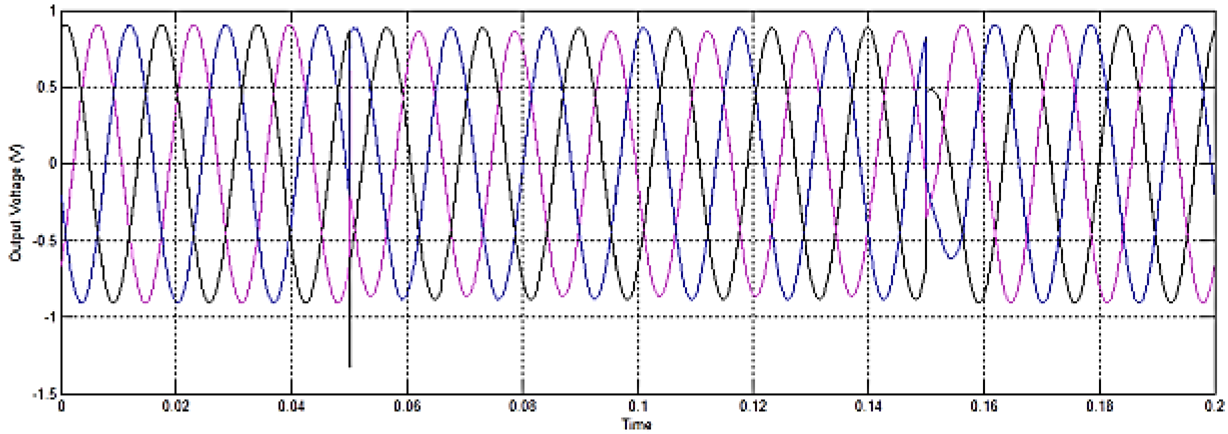

Figure 15: Simulation Results CPD Compensated Voltage

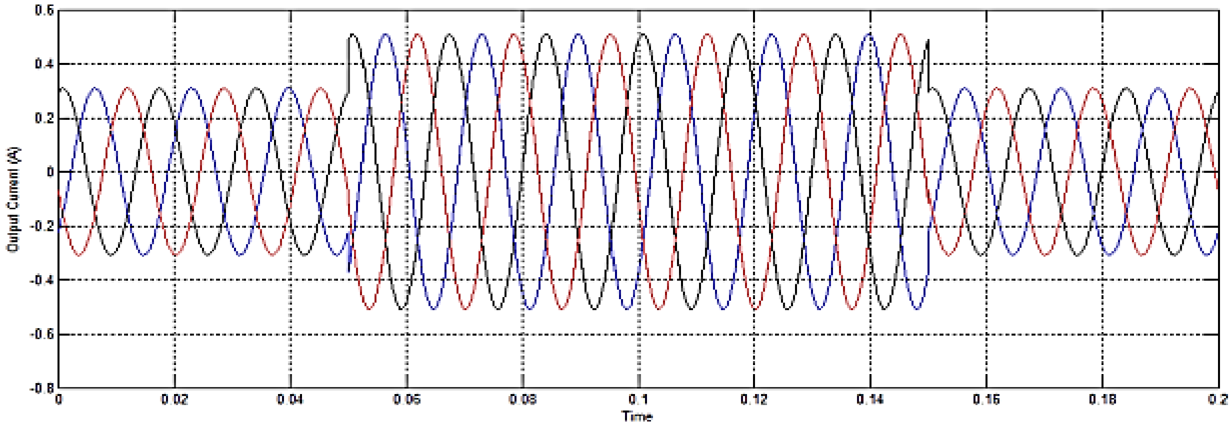

Figure 16: Input Voltage during swell condition

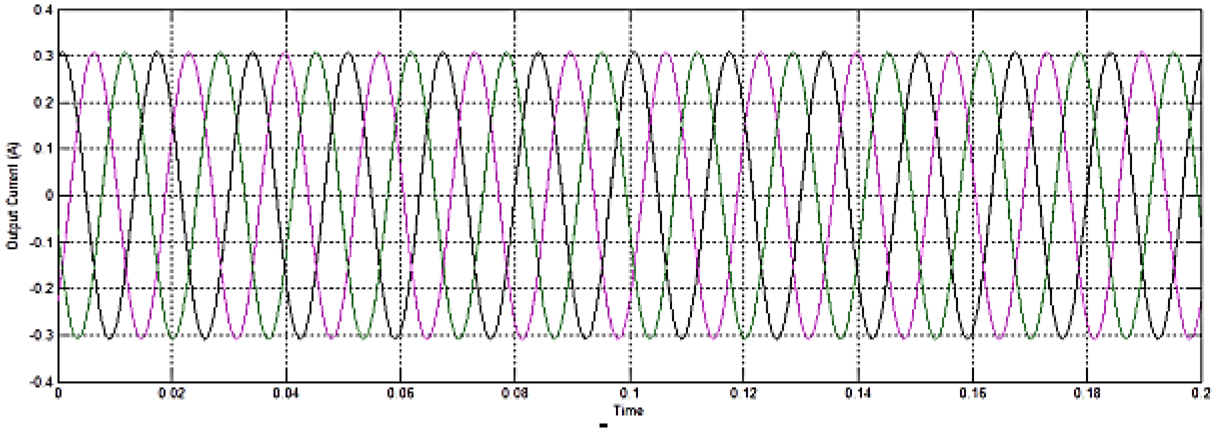

Figure 17: Results for Compensated Current with CPD

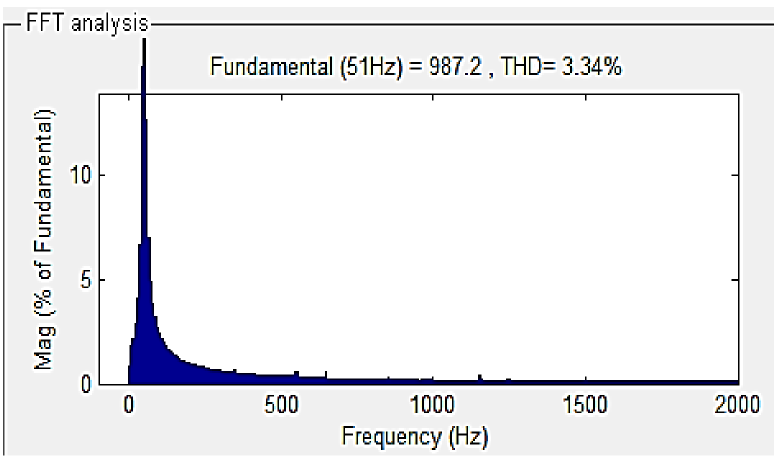

Figure 18: THD value of CPD (Optimization Algorithm) Load Voltage

The suggested system's simulation results with voltage sag and compensated voltages are shown in Figures 14 and 15. Between 0.05 and 0.15 seconds, the system had a three-phase malfunction. As shown in Figure 17, this defect causes the system load current to increase to 1.2% of its original value and the load voltage to decrease to 0.8% of its final value. According to figure 18, the total harmonic distortions for the load voltage with the hybrid LOA-GH optimization controller are 3.34%.

Table-2 THD Analysis for Load Voltage

S.No	Type of Problem	THD (%)			
		With CPD	With LOA-CPD	With GH-CPD	With Hybrid LOA-GH-CPD
1	Swell at feeder 1	10.13%	9.99%	4.99%	4.84%
2	Sag at feeder 1	12.85%	4.86%	3.82%	3.81%

Table-3 THD Analysis for Current

S.No	Type of Problem	THD (%)			
		With CPD	With LOA-CPD	With GH-CPD	With Hybrid LOA-GH-CPD
1	Load Current	**22.14%**	**22.14%**	**22.14%**	**22.14%**
2	Source Current	**12.41%**	**10.34%**	**9.82%**	**8.36%**

The THD is analyzed for the load voltage under three different cases with and without controllers. The comparative analysis for harmonic distortion is shown in table-2 & table-3. From the table, it concludes that Hybrid based CPD controller provides better harmonic distortion as compared with convention controllers.

CONCLUSION

In this study, a unique power device based on hybrid optimization is successfully developed and put to the test for enhancing power quality in grid-connected PV systems. Gross-Hooper and Lion Optimization algorithms make up the hybrid optimization. Simulink is used to test this system, and the LOA, GH, and hybrid LOA-GH algorithms are used to fine-tune the PI parameters. The load voltages are validated under various time constraints, and CPD is implemented using a traditional PI controller to regulate the bus voltages and load currents. Better power quality is offered by the suggested hybrid algorithms. Voltage interruptions and total harmonic factor are the two primary metrics used to assess power quality. Using Matlab, an experimental test of the suggested system using these controllers was conducted, and the results were confirmed.

REFERENCES:

1. S.Mirjalili, & Andrew Lewis, "Grasshopper optimization algorithm: theory and

application." in Advances- in Engineering-Software (2017), pp: 30-47.

2. Schaller GB. "The Serengeti lion: a study of predator–prey relations. Wild life behavior and ecology series," in Chicago, Illinois, USA: University of Chicago Press; 1972.
3. L. F. da Silva, and M. Aredes, "An Improved iUPQC Controller to Provide Additional Grid-Voltage Regulation as a STATCOM," in IEEE Transactions on Industrial Electronics, vol. 62, no. 3, pp. 1345-1352, March 2015, doi: 10.1109/TIE.2014.2345328.
4. BrahimBerbaoui, "Fuzzy multi-objective technique combined with VCS algorithm for unified power quality conditioner based on hybrid power source PEMFC/SC", An International Journal of Hydrogen Energy, Vol.43, No.12, pp.6275-6293, 2018.
5. Panda, Anup Kumar and NishantPatnaik, "Management of reactive power sharing and power quality improvement with SRF-PAC based UPQC under unbalanced source voltage condition", An International Journal of Electrical Power and Energy Systems, Vol.84, pp.182-194, 2017.
6. Sanjib Ganguly, "Unified power quality conditioner allocation for reactive power compensation of radial distribution networks", IET Generation, Transmission and Distribution, vol. 8, issue. 8, pp. 1418–1429,2014.
7. Saremi, S.; Mirjalili, S.; Lewis, A. Grasshopper optimisation algorithm: Theory and application. Adv. Eng. Softw. 2017, 105, 30–47.
8. T. Eswara Rao, Krishna Mohan Tatikonda, S. Elango, and J. Charan Kumar, "MICROGRID TECHNOLOGIES", Edited by C. Sharmeela, P. Sivaraman, P. Sanjeevikumar, and Jens Bo Holm-Nielsen, Scrivener Publishing, ISBN: 9781119710790.
9. Yongsheng Cao, Guanglin Zhang, Demin Li, Lin Wang and Zongpeng Li, "Online Energy Management and Heterogeneous Task Scheduling for Smart Communities with Residential Cogeneration and Renewable Energy", Energies 2018,11, 2104; doi:10.3390/en11082104 www.mdpi.com/journal/energies.
10. Y. Liu, H. Hong, and A. Q. Huang, "Real-time calculation of switching angles minimizing THD for multilevel inverters with step modulation," IEEE Trans. Industrial Electronics, vol. 56, no. 2, pp. 285-293, Feb. 2009.
11. N. Sinha, "Performance Comparison of FACTS devices using CSA optimized controllers in multi-area AGC", JEPE, Volume 65, Feb 2015, pp 316-324.
12. R. J. Millnitz dos Santos, J. C. da Cunha and M. Mezaroba, "A Simplified Control Technique for a Dual Unified Power Quality Conditioner," in IEEE Transactions on Industrial Electronics, vol. 61, no. 11, pp. 5851-5860, Nov. 2014.
13. Udaya K. Renduchintala, Chengzong Pang, Krishna Mohan Tatikonda, and Lin Yang, " ANFIS-fuzzy logic based UPQC in interconnected microgrid distribution systems: Modeling, simulation and implementation," 2021 The Authors. The Journal of Engineering published by John Wiley & Sons Ltd on behalf of The Institution of Engineering and Technology, https://doi.org/10.1049/tje2.12005.
14. Yong Wang; Jialong Xu; Ling Feng; Chengmin Wang, "A Novel Hybrid Modular 3-Level Shunt Filter", Power Electronics in IEEE, Year: 2018 | Volume: 33, Issue: 9.

15. Boothalingam, R. Optimization using lion algorithm: a biological inspiration from lion's social behavior. Evol. Intel. 11, 31–52 (2018). https://doi.org/10.1007/s12065-018-0168-y
16. R. Babers, A. E. Hassanien and N. I. Ghali, "A nature-inspired metaheuristic Lion Optimization Algorithm for community detection," 2015 11th International Computer Engineering Conference (ICENCO), Cairo, Egypt, 2015, pp. 217-222, doi: 10.1109/ICENCO.2015.7416351.
17. PesaranHajiabbas, "Optimization of Power System Problems," in Springer International Publishing, 2020.
18. Shahrzad, SeyedaliMirjalili, Saremi, & Andrew Lewis" Grasshopper optimization algorithm: theory and application." Advances- in Engineering- Software (2017), pp: 30-47.
19. Wang B, JinX, Cheng-B. Lion pride optimizer: an optimization algorithm inspired by lion pride behavior. China Inf. Sci. 2012; 55(10)2369–89.