**International Journal of Emerging Engineering Research and Technology**
**Volume 5, Issue 9, 2017, PP 32-36**
**ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)**

# Parametric Optimization of PN Junction Diode Using Flower Pollination Algorithm

**Sudip Mandal[1*], Sreya Majumdar, Samir Barman, Sukriti Haldar**

*Department of Electronics and Communication Engineering, Global Institute of Management and Technology, Krishna Nagar, India*

***Corresponding Author:** Sudip Mandal, Department of Electronics and Communication Engineering, Global Institute of Management and Technology, Krishna Nagar, India*

## ABSTRACT

*Building accurate model for PN junction diode based on experimental data is crucial for the simulation, evaluation, control, and optimization of PN diode based system. Powerful optimization techniques are necessary to achieve this task. In this study, Flower Pollination Algorithm (FPA) is used efficiently for estimating three model parameters of PN junction diode (Model No: 1N4007). Moreover, we can also able to predict the I-V characteristic of the diode accurately which validate the proposed methodology.*

**Keywords:** *Optimization, Flower Pollination Algorithm, PN Junction Diode, 1N4007Model Parameters.*

## INTRODUCTION

P-N junction diode [1] is the most fundamental and the widely used electronics device. When one side of an intrinsic semiconductor is doped with acceptor i.e., one side is made p-type by doping with n-type material; a p-n junction diode is formed. Current of a PN diode typically [2] depends on Reverse Saturation Current $(I_s)$, Ideality Factor $(\eta)$, Temperature $(T)$, voltage across diode $(V)$. We can consider $I_s$, $\eta$ and $T$ as model parameters of the diode.

An accurate knowledge of PN junction diode parameters from experimental data i.e. building highly accurate mathematical model to describe the non-linear current-voltage (I-V) relationship of the diode is an important task for the engineers to design, quality control of PN diode based system and estimate their performance.

Basically, parameter estimation of PN junction diode is a non-linear optimization problem. Metaheuristic [3, 4] which are typically inspired by physical phenomena, animals' behaviors, or evolutionary concepts, are having become very popular over last few years. However, most popular and efficient subclass of metaheuristics is the Swarm Intelligence (SI). Genetic Algorithm (GA) [11], Particle Swarm Optimization (PSO) [12], Ant Colony Optimization (ACO) [13], Bat Algorithm (BA) [14], Elephant Swarm Water Search Algorithm (ESWSA) [15] and Flower Pollination Algorithm (FPA) [5] etc. are example of such kind of metaheuristic.

In literature, many authors used several metaheuristics like GA [16], PSO [17], FPA [18], Evolutionary Algorithm [19] and Artificial Bee Colony algorithm [20] to the parameter estimation problems of photovoltaic systems using single diode and double diode model. However, no one has tried to estimate the parameter estimation of PN junction diode using optimization technique.

Flower Pollination Algorithm (FPA) [5, 6, 7] is one of the recently proposed, efficient and popular SI based metaheuristic technique which is inspired by pollination of flowers. So far, FPA has been successfully applied to several global optimization [5], multimodal optimization [6, 7], constrained optimization [8], structural engineering problem [9] and reverse engineering problem [10] etc. In this work we have used FPA for parametric optimization of PN junction diode.

Rest of the paper is organized as follows. Section-II describes mathematical description of the parameters estimation problem and preliminary of FPA. Next, experimental data, methodology and simulation results are discussed. In next section, conclusion is given followed by references.

## MATHEMATICAL DESCRIPTION OF THE PROBLEM

### Current Equation for PN junction Diode

The current $(I_d)$ of a PN junction diode [2] can be given as

$$I_d = I_s(e^{\frac{qV_d}{\eta KT}} - 1) \quad (1)$$

where $I_s$ is the reverse saturation current of the diode, $V_d$ is the diode voltage, $\eta$ is the diode ideality factor, $K$ is the Boltzmann constant (1.3806503×10$^{-23}$ J/K), $T$ is the temperature of the junction in Kelvin, and $q$ is the electron charge (1.60217646×10$^{-19}$ C).

So, this diode model contains totally three parameters to be estimated ($I_s$, $\eta$ and $T$).

## Flower Pollination Algorithm

Flower pollination [5] is typically associated with the transfer of pollen for reproduction or flowering of plants, and pollinators such as insects, birds and bats are mainly responsible for such transfer. FPA [5, 6, 7] is a recently proposed metaheuristic which based on following some simplified rules for pollination. Biotic cross-pollination can be assumed as a process of global pollination, and pollen carrying pollinators follow Lévy flights during transport (Rule 1). For local pollination, abiotic pollination and self-pollination are used (Rule 2). Pollinators may develop flower reliability, which is proportional to the resemblance of two flowers i.e. reproduction probability (Rule 3). The switching of local to global pollination can be controlled by a switch probability $p \in [0, 1]$, slightly biased towards local pollination (Rule 4). Here, each pollen or flower corresponds to a solution of optimization problem.

Global and local pollination (i.e. search) are done according to following two equations respectively:

$$x_i^{t+1} = x_i^t + \gamma \, L\acute{e}vy\ (\lambda)(g_* - x_i^t) \quad (2)$$

$$x_i^{t+1} = x_i^t + \varepsilon\ (x_j^t - x_k^t) \quad (3)$$

Where $x_i^t$ is the pollen $i$ or solution vector $x_i$ at iteration $t$, $\gamma$ is scaling factor to control the step, $g_*$ is the current best solution found among all solutions at the current iteration, $x_j^t$ and $x_k^t$ are pollens from the different flowers of the same plant species and $\varepsilon$ stands for random walk step size within a uniform distribution in [0,1]. The reason behind selecting FPA as optimization method is that it gives better convergence and accuracy than others popular metaheuristic technique [5].

## Objective Function

All optimization methods use an objective function or a fitness value to measure the goodness of a solution. The estimation task aims to seek the most optimal values for the unknown parameters so as to minimize the error between the measured and simulated current. The root mean square of the error (RMSE) is defined as Eq. (4) can be used as the objective function [18].

$$RMSE(X) = \sqrt{\frac{1}{N}\sum_{i=1}^{N} f(V_{di}, I_{di}, X)^2} \quad (4)$$

where $N$ is the number of the experimental data i.e. a set of diode voltage and current, $X$ is the set of the estimated parameters i.e. $X = \{I_s, \eta, T\}$. For PN junction diode, $f(V_d, I_d, X)$ can be given as:

$$f(V_d, I_d, X) = I_d - I_s(e^{\frac{qV_d}{\eta KT}} - 1) \quad (5)$$

FPA will minimize the value of the above mentioned function, so that best value of $X = \{I_s, \eta, T\}$ can be obtained.

## Methodology

The overall process of metaheuristic based optimization of PN junction model parameters consist of mainly two steps as follows: a) Experimentation in laboratory where we have observed a set of diode voltage and corresponding diode current in forward bias. b) Implementation of FPA to optimize the model parameters of diode. The details of these steps are described below.

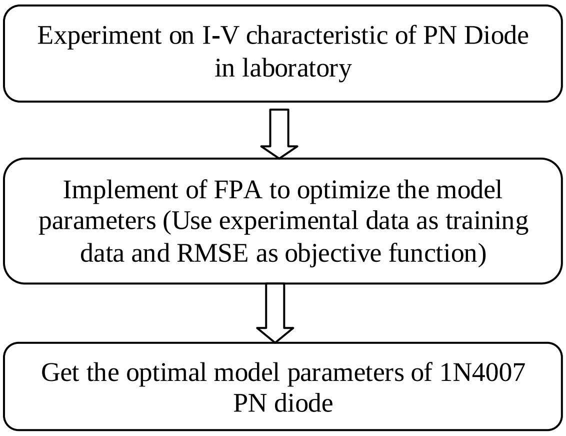


**Figure1.** *Stepwise process of methodology for the optimization model parameters*

For laboratory experiment, we have used 1N4007 diode and connected 1KΩ resistor in series. Then we apply the variable DC power supply across them in forward bias. Next, the voltage is gradually increased and corresponding diode voltage and current are observed consequently. The diode current readings have been recorded when forward diode current flows in mA range. Below that current is considered as zero.

In next phase of this work, Flower Pollination Algorithm (FPA) has been used for optimization of diode parameters. In our present problem, dimension of search for the metaheuristic is 3 as the input variables of optimization process are $I_s$, $\eta$ and $T$. Experimental data is used for training and calculation of the fitness function. RMSE is used as the fitness function.

For FPA, value of probability switch ($p$) is fixed to 0.8 using the guidelines provided by its own reference [5]. The number of population and total number of iteration are set as 50 and 1000 respectively. The lower and upper limit i.e. search range for Reverse Saturation current, Ideality Factor and Temperature are chosen as [0,1×10$^{-6}$A], [1, 2] and [290K, 390K] respectively.

After completion of iteration, FPA will reach the best solution i.e. best combination of $I_s$, $\eta$ and $T$ such that RMSE is minimized. At optimal condition, calculated I-V characteristic should be almost similar to experimental I-V characteristic of diode.

## Results and Discussions

In this section, the results have been shown and discuss them to draw some important remarks about the findings of this work.

Initially, total 12 readings of diode voltage and current have been observed from the PN junction diode operated at forward bias. We have started to note down the current above diode voltage 0.42 V. The experimental I-V characteristic of PN junction diode is shown in figure 2 which is almost exponential in nature.

Next, FPA has been applied to this experimental dataset to find out the optimal values of reverse saturation current, ideality factor and temperature. Using previously mentioned setup, FPA has been executed for 10 times as FPA may give different output depending on the initialization and randomness in search procedure. Then, a statistical analysis has been performed to obtain the final results.

Table 1 shows the fitness value i.e. RMSE for each of program execution. It can be clearly observed that for all cases FPA can able to reach the minima point 0.000997 or surrounding to it. Table 2 shows the statistical analysis of the RMSE. It can be seen from the table that mean, maximum, minimum and mean value of RMSE are almost same. Moreover, standard deviation is negligible which denotes that variation in fitness value is very small. So, it can be concluded that success rate of FPA for this diode optimization problem is very satisfactory.

**Table1.** *RMSE for different run*

| Program Run No. | RMSE |
|---|---|
| 1 | 0.0009987443 |
| 2 | 0.0009969666 |
| 3 | 0.0009972002 |
| 4 | 0.0009976888 |
| 5 | 0.0009969702 |
| 6 | 0.0009969750 |
| 7 | 0.0009974391 |
| 8 | 0.0009969720 |
| 9 | 0.0009970012 |
| 10 | 0.0009970946 |

**Table2.** *Statistical Analysis of RMSE*

| RMSE | | | |
|---|---|---|---|
| Max | Min | Mean | Standard deviation |
| 0.0009987 | 0.0009970 | 0.0009973 | 5.61E-07 |

*Following table shows the value of $I_s$, $\eta$ and $T$ corresponding to each run.*

**Table3.** *Optimal value of parameters of diode for different run*

| Program Run No | $I_s$ | $\eta$ | $T$ |
|---|---|---|---|
| 1 | 3.30E-09 | 1.39 | 294.52 |
| 2 | 3.01E-09 | 1.37 | 297.07 |
| 3 | 3.07E-09 | 1.4 | 291 |
| 4 | 3.24E-09 | 1.34 | 303.49 |
| 5 | 3.03E-09 | 1.38 | 295.04 |
| 6 | 3.02E-09 | 1.39 | 291.25 |
| 7 | 3.18E-09 | 1.32 | 309.63 |
| 8 | 3.02E-09 | 1.34 | 301.95 |
| 9 | 3.05E-09 | 1.32 | 307.62 |
| 10 | 2.98E-09 | 1.35 | 300.37 |

Table 4, 5 and 6 describe the statistical analysis of $I_s$, $\eta$ and $T$ where mean, ,median, standard deviation and value corresponding to best fitness are provided. It can be observed that variation in the value of reverse saturation current is negligible and standard deviation of ideality factor is also small. But the standard deviation of temperature is significant i.e. the variation in output temperature is large enough. So, temperature has less significance in diode current.

**Table4.** *Statistical Analysis of $I_s$*

| Mean | Median | Standard deviation | $I_s$ with least RMSE |
|---|---|---|---|
| 3.09E-09 | 3.04E-09 | 1.1E-10 | 3.01E-09 |

**Table5.** *Statistical Analysis of $\eta$*

| Mean | Median | Standard deviation | $\eta$ with least RMSE |
|---|---|---|---|
| 1.359063 | 1.358089 | 0.029047 | 1.365987 |

**Table6.** *Statistical Analysis of $T$*

| Mean | Median | Standard deviation | $T$ with least RMSE |
|---|---|---|---|
| 299.1938 | 298.7183 | 6.50681 | 297.0702 |

Therefore, in our present problem, we will consider two types of output or results for the estimated optimal parameters of PN junction diode (1N4007). First, we have considered median of all three parameters ($I_s$, $\eta$ and $T$) as final output. In second case, we will consider the set of $I_s$, $\eta$ and $T$ corresponding to the best fitness i.e. least RMSE as the final output. Following table shows the optimal parameters values of 1N4007 diode at two above mentioned conditions.

**Table7.** *Optimal value at different condition*

| Criterion | Parameters | | |
|---|---|---|---|
| | $I_s$ (A) | $\eta$ | $T$ (K) |
| Median | 3.30E-09 | 1.39 | 294.52 |
| Best Fitness | 3.01E-09 | 1.37 | 297.07 |

It can be seen that the value of reverse saturation current and ideality factor are approximate $3.0\text{x}10^{-9}$A and 1.37 respectively at 297 K temperature for 1N4007 diode.

These values can be used for further modelling of electronics system made of 1N4007 PN diode. Next, we have calculated the simulated value of diode current using Eqn. 1 and above mentioned parameters. Figure 2 shows a comparison among experimental I-V characteristic of PN junction diode with simulated output.

It can be observed from above figure that there is very little difference between experimental and calculated or simulated I-V characteristics of PN junction diode.

This statement validates our proposed methodology to infer the optimal parameters of the PN junction (1N4007) diode such that error between experimental and calculated value of diode current is minimized.

It can be observed that there is very little difference between experimental and calculated I-V characteristics of PN junction diode. This statement validate our propose methodology to infer the optimal parameters of the PN junction diode such that error between experimental and calculated value of diode current is minimized.

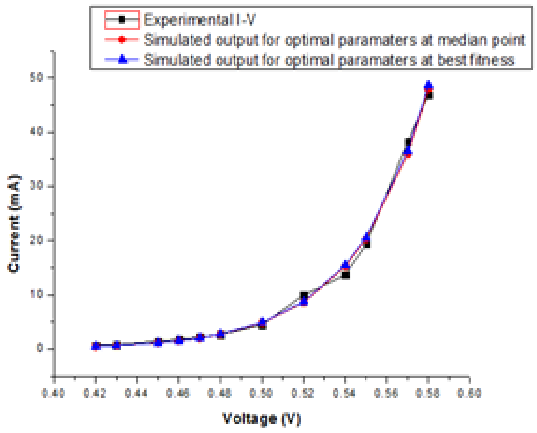


**Figure2.** *Comparison among experimental I-V characteristic of PN junction diode with simulated output.*

## CONCLUSION

Inference of diode parameters is important task for the electronics engineers. In this work, an efficient and accurate method is proposed to find out the optimal parameters of 1N4007 diode. A recently proposed metaheuristic namely Flower Pollination Algorithm (FPA) has been used for the optimization where RMSE error between experimental and calculated value of diode current was used as fitness function.

Two types of optimal values of diode parameters are considered as final output: median and best fitness. In both case calculated I-V characteristic is almost similar to the experimental I-V characteristic of PN diode which validate our proposed methodology.

In future, others advanced and hybrid optimization techniques can be used for better and more accurate parameters optimization of diode.

## REFERENCES

[1] https://www.electrical4u.com/p-n-junction-diode/ [Accessed on 04/11/2017]

[2] Stretman B. G. and Banerjee S. K., "Solid State Electronics Devices", PHI Learning, 6th Ed., New Delhi, 2009.

[3] Gandomi A. H. et al., "Metaheuristic applications in structures and infrastructures", 1st ed. Elsevier, 2013

[4] Bianchi L. et al., "A survey on metaheuristics for stochastic combinatorial optimization", Natural Computing: an international journal, vol. 8, no.2, pp. 239-287, 2009.

[5] Yang X-S., "Flower pollination algorithm for global optimization," Unconventional Computation and Natural Computation 2012,

Lecture Notes in Computer Science, vol. 7445, pp. 240-249, 2012.

[6] Yang X-S., Karamanoglu M. and. He X-S, "Flower pollination algorithm: A novel approach for multiobjective optimization," Engineering Optimization, vol. 46, issue 9, pp 1222-1237, 2014.

[7] Yang X-S., Karamanoglu M., and He X-S.. "Multi-Objective Flower Algorithm for Optimization", Procedia Computer Science, vol. 18, pp. 861–868, 2013.

[8] Raouf O. A., Baset M. A., Henawy I. E., "A New Hybrid Flower Pollination Algorithm for Solving Constrained Global Optimization Problems", International Journal of Applied Operational Research, vol. 4, no. 2, pp. 1-13, 2014.

[9] Nigdeli, S. M., Bekdaş G. l. and Yang, X-S., "Application of the flower pollination algorithm in structural engineering", Metaheuristics and Optimization in Civil Engineering, Springer, pp. 25-42, 2016.

[10] Mandal S., Khan A., Saha G. and Pal R. K., "Large Scale Recurrent Neural Network Based Modeling of Gene Regulatory Network Using Cuckoo Search-Flower Pollination Algorithm", Advances in Bioinformatics, vol. 2016, Article ID 5283937, pp. 1-9, 2016.

[11] Man, K. F., Tang, K.S., Kwong, S., "Genetic algorithms: concepts and applications [in engineering design]", IEEE Transactions on Industrial Electronics, vol.43, no.5, pp.519-534,1996.

[12] Shi Y.H. and Eberhart R.C., "Experimental study of particle swarm optimization", SCI2000 Conference, 2000.

[13] Dorigo M., Maniezzo V., and Colorni A., "Ant System: Optimization by a colony of cooperating agents", IEEE Transactions on Systems, Man, and Cybernetics – Part B, vol. 26, no. 1, pp. 29–41, 1996.

[14] Yang X.-S., "A New Metaheuristic Bat-Inspired Algorithm", Nature Inspired Cooperative Strategies for Optimization (NISCO 2010), vol. 284, pp. 65-74 , 2010.

[15] Mandal S., Saha G., and. Pal R. K, "Recurrent Neural Network Based Modelling Of Gene Regulatory Network Using Elephant Swarm Water Search Algorithm", Journal of Bioinformatics and Computational Biology, vol. 15(4), pp. 1750016(1-23), 2017.

[16] Zagrouba M., Sellami A., Bouaïcha M., Ksouri M., "Identification of PV solar cells and modules parameters using the genetic algorithms: application to maximum power extraction" Sol Energy, vol. 84, pp. 860–866, 2010.

[17] Ye M., Wang X. and Xu Y. "Parameter extraction of solar cells using particle swarm optimization", J. Appl. Phys, vol.105, pp. 094502–94508, 2009.

[18] Xu S., Wang Y. "Parameter estimation of photovoltaic modules using a hybrid flower pollination algorithm", Energy Conversion and Management, vol. 144, pp. 53–68, 2017.

[19] Muhsen D.H., Ghazali A.B., Khatib T., and Abed I.A., "Parameters extraction of double diode photovoltaic module's model based on hybrid evolutionary algorithm", Energy Convers Manage, vol. 105, pp. 552–561, 2015.

[20] Oliva D., Cuevas E., and Pajares G. "Parameter identification of solar cells using artificial bee colony optimization". Energy, vol. 72, pp. 93–102, 2014.

## AUTHOR'S BIOGRAPHY

**Sudip Mandal** received M.Tech. in Electronics and Communication Engineering from Kalyani Govt. of Engineering College in 2011. Now, he held the position of HOD of ECE Department in GIMT, Krishnanagar, India. He is also pursuing Ph.D. degree from University of Calcutta. His current research work includes Computational Biology, Artificial Intelligence, Optimization and Tomography. The author is also member IEEE Computational Intelligence Society. He published 28 articles in different reputed journal and conferences.

**Sreya Majumdar, Samir Barman and Sukriti Haldar** are final year students of the Department of Electronics and Communication Engineering, Global Institute of Management and Technology, Krishna Nagar, West Bengal, India.

**Citation:** *M. Sudip, M. Sreya, B. Samir and H. Sukriti, "Parametric Optimization of PN Junction Diode Using Flower Pollination Algorithm", International Journal of Emerging Engineering Research and Technology, vol. 5, no. 9, pp. 32-36, 2017.*