Free / Unpaid
Peer Reviewed
Multidisciplinary
International

ISSN:2320-3714
Volume 1 Issue 3
March 2023
Impact Factor: 10.2
Subject Physics

A Review on Metaheuristic Techniques used for Optimal Power Flow

[1]Nilesh M. Patel, [2]Dr.Thangadurai N.
[1]Ph.D Scholar, Sankalchand Patel University, Visnagar, Gujarat,
[2]Professor, Sankalchand Patel University, Visnagar, Gujarat,
[1]nileshpatel.82@gmail.com
[2]mrgoldspu2021@gmail.com

***Abstract*:** The non-linear solution referred to as optimal power flow (OPF) is crucial for understanding how the functioning of the power system. This study intends to provide fundamental knowledge about metaheuristic techniques in order to address the issue of optimal power flow in power systems. These methods have the ability to address non-linear problems. Within a variety of metaheuristic search approaches, the performance and essential elements that comparing the efficiency of certain optimization methods. This covers the functioning of the gravitational search algorithm (GSA), particle swarm optimization (PSO), firefly algorithm (FFA) and artificial bee colony (ABC) algorithms. In order to address the OPF issue in the functioning of power systems, this study discusses the essential factors that must be taken into account while choosing metaheuristic methodologies.

Keywords: Problem formulation using OPF and Perspective of Optimization Algorithm, Population based Metaheuristic Techniques, Flow chart for OPF using Metaheuristic Techniques, Comparison between Metaheuristic Techniques.

1. INTRODUCTION:

The optimal power flow or OPF issues are essential to plan economic scheduling, security and functioning of a power system. The solution of OPF issues aims to satisfy multiple system operations while also optimizing a particular fitness function through the best possible adjustment of control variables [1]. With the use of traditional and metaheuristic optimization techniques, the OPF problem has been resolved [2,3]. On a determination of the global optimum, traditional optimization is predicated.
A variety of OPF issues with different objective functions as well as difficult restricted optimization issues have been solved using metaheuristic optimization techniques. Iterative correction of solutions employing stochastic search operators on individuals in the existing population is the core tenet of metaheuristic methods. The ability to quickly search through enormous solution spaces, locate global answers, and avoid local optimum are the main capabilities of metaheuristics [3].
Using these strategies, the system's numerous restrictions are satisfied while the overall cost of operation is decreased [4]. In order to deliver a high-quality optimal solution within a

reasonable timeframe, a number of population-based heuristic search strategies are applied. In this paper, according to the nature of the optimization technique, different parameter settings are established for the gravitational search algorithm (GSA), particle swarm optimization (PSO), firefly algorithm (FFA) and artificial bee colony (ABC) algorithms.

2. PROBLEM FORMULATION USING OPF AND PERSPECTIVE OF OPTIMIZATION ALGORITHM:

The OPF generally minimizes the function, which is known as the fitness function. The OPF problem is used to determine the appropriate transformer tap settings, bus voltage settings, and generator tap settings in any system in order to save total production costs [5]. The process of changing the inputs to or the characteristics of a device, mathematical formula, or experiment in order to determine the lowest or highest output or result is referred to as optimization.

2.1 Formulation of OPF issues:

In order to minimize the system objective function and adhere to system equality and inequality constraints, a standard OPF issue can be written as [1]:

$$\text{Minimize,} \quad j\,(m, n) \tag{1}$$

$$\text{Subject to} \quad k\,(m, n) \leq 0 \tag{2}$$

$$l\,(m, n) = 0 \tag{3}$$

Where:
m = The state (dependent) variables, n = The control (independent variables), j (m, n) = fitness (Objective) functions, k (m, n) = a group of inequality constraints, l (m, n) = a group of equality constraints.

2.2 Exploitation and Exploration:

To create new solutions that are superior to the existing solutions with regard to the topic of interest, algorithm exploitation or intensification is crucial. High convergence rates are possible, although local search is frequently entrapped by this. As opposed to this, exploration and diversification look for information around the globe and are able to produce solutions with a sufficient amount of diversity. This will cause the convergence rate to slow down because it needs to search a broad area. [4].
The present algorithms employ various parameter settings, causing certain algorithms to achieve quick convergence rates or be able to reach global optimums. In order to ensure a quick convergence rate, certain algorithms also incorporate randomization [6].

2.3 Heuristic Techniques:

A problem-solving strategy known as a heuristic involves utilizing a practical approach to learn something new or solve a problem in order to get a good result quickly. This is accomplished by employing comparable rules from a data collection that has been trained to address

ISSN: 2320-3714
Volume1 Issue 3
March 2023
Impact Factor: 10.2
Subject: Physics

problems of a similar nature. Heuristics, metaheuristics, matheuristics, and hyperheuristics are the four subcategories under which heuristic techniques can be categorized.

In order to answer interesting mathematical issues, matheuristics is a hybrid strategy that blends exact and approximatively methods. These methods incorporate enhanced metaheuristic-based mathematical programming tools, and vice versa [7,8].

The heuristics approach, on the other hand, is more concerned with the exploitation that enables the problem to be solved effectively and quickly. However, because they have not explored much, they are frequently stuck in local optima.

Large and complex data can be optimized using metaheuristic methods. This is achievable as a result of the behavior that accepts the solution's temporary deterioration. It has the ability to randomly explore to find the world's best solution through active exploration and exploitation.

The emphasis of hyperheuristics is primarily on exploration than exploitation. Additionally, the set space is not your typical space set of solutions. Rather than dealing with just one type of issue, it is utilized to address others [9].

2.4 Metaheuristic Optimization Methods:

In order to categorize different metaheuristic techniques, four key criteria are used. The first distinction is between trajectory and discontinuous approaches, which are employed for each iteration. The second criterion is how much the method uses memory. There is no distinct group for this requirement because most approaches rely on either short-term memory or long-term memory. The interaction between the algorithm and neighbourhood structures makes up the third criterion. It either uses kick-moves that communicate with a single neighbour or uses operations like mutation and crossover that allow it to engage with other neighbourhoods. The goal function performed by the technology throughout operation is the final criterion taken into account. A static objective function may be used by some algorithms to produce the best results. Algorithms can also change the objective function by using a reward or penalty. With the aid of this dynamic fitness function, the search procedure can be directed in the right direction in order to find the world's best solution.

3. POPULATION BASED METAHEURISTIC TECHNIQUES:

The strategies for population-based stochastic search are called metaheuristic optimization methods. A group of individuals that stand in for possible answers to the optimization issue make up the population. Iterative solution correction is the fundamental component of metaheuristic approaches. The correct setup of the relevant algorithmic parameters determines the effectiveness and performance of metaheuristic optimization approaches [10].

The methodologies for modern, well-known algorithms like the Gravitational Search Algorithm (GSA), Particle Swarm Optimization (PSO), Firefly Algorithm (FFA) and Artificial Bee Colony Algorithm (ABC) algorithm are the main emphasis of this section. The ability of such algorithms to apply optimization strategies to a variety of problems as well as the advancement of various study and hybridization techniques lead to comparisons between them.

3.1 Gravitational Search Algorithm (GSA):

AIRO JOURNALS
Free / Unpaid Peer Reviewed Multidisciplinary International
ISSN: 2320-3714
Volume 1 Issue 3
March 2023
Impact Factor: 10.2
Subject: Physics

By Rashedi and other authors, they created the GSA, a metaheuristic optimization method. [11]. The search agents in GSA are a group of masses that communicate with one another according to the principles of motion and Newtonian gravity. The mass's gravitational and inertial masses are calculated using a fitness function, and their positions are in agreement with how the issue was solved. Alternatively said, every mass offers a solution. Correctly altering the gravitational and inertial masses is necessary to navigate the algorithm.

Once the fitness of the existing population has been evaluated, each agent's mass is calculated by:

$$M_i(t) = m_i(t) \Big/ \sum_{j=1}^{N} m_j(t) \qquad (4)$$

where:

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \qquad (5)$$

In this scenario, $fit_i(t)$ stands with regard to agent (i)'s fitness value at iteration (t), while best(t) and worst(t) indicate the best and worst fitness of all agents, respectively.

The total force acting on the i^{th} agent at iteration (t) is defined as follows by Newton gravitation theory:

$$\mathbf{F}_i(t) = \sum_{j \in Kbest, j \neq i} r \cdot G(t) \frac{M_j(t) \cdot M_i(t)}{R_{i,j}(t) + \varepsilon} \left(\mathbf{u}_j(t) - \mathbf{u}_i(t) \right) \qquad (6)$$

In this case, r is a random number between [0, 1]. G(t) is the gravitational constant at iteration (t), Mi(t) and Mj(t) are the agents' respective masses, ε is a tiny constant, and Rij(t) is their distance in Euclid's triangle. Kbest is the collection of the first K agents with the highest fitness value and largest masses.

The following equation describes how the i^{th} agent accelerates at iteration t in accordance with the law of motion:

$$\mathbf{a}_i(t) = \mathbf{F}_i(t) / M_i(t) \qquad (7)$$

Following are the updates to an agent's position and velocity:

$$\mathbf{v}_i(t+1) = r_i \cdot \mathbf{v}_i(t) + \mathbf{a}_i(t) \qquad (8)$$
$$\mathbf{u}_i(t+1) = \mathbf{u}_i(t) + \mathbf{v}_i(t+1) \qquad (9)$$

A uniform random variable in the range [0, 1] is called ri in this situation.

A function of the starting value G_0 and the passing of time (t) is the gravitational constant G(t) in Eq. (6):

$$G(t) = G_0 \cdot \exp(-\alpha \cdot t / tmax) \qquad (10)$$

The performance of GSA is governed by the parameters of maximum iteration t_{max}, population size N, initial gravitational constant G_0, and α is constant.

AIRO JOURNALS
Free / Unpaid
Peer Reviewed
Multidisciplinary
International

ISSN: 2320-3714
Volume 1 Issue 3
March 2023
Impact Factor: 10.2
Subject: Physics

3.2 Particle Swarm Optimization Algorithm (PSO):

Kennedy and Eberhart [12] created the PSO algorithm, which is based on a simulation of a flock of birds in two dimensions. For the purpose of locating the ideal answer, it employs a number of particles (candidate solutions) that flutter about in the search space [13]. The best particle (best solution) in the path is what all the particles are examining in the meantime. Thus, particles take into account both their own best solutions and the best solution so far discovered. Each particle makes an attempt to change its position using the following data: its current position, velocity, distance from p_{best} and g_{best}, and the distance between the current position and p_{best}.

The following equation is used in each iteration to determine the particle velocities:

$$\mathbf{v}_i(t+1) = w \cdot \mathbf{v}_i(t) + C_1 \cdot r_1 \cdot (\mathbf{pbest}_i(t) - \mathbf{u}_i(t)) + C_2 \cdot r_2 \cdot (\mathbf{gbest}(t) - \mathbf{u}_i(t)) \qquad (11)$$

The particle locations can be determined by updating the velocities as follows:

$$\mathbf{u}_i(t+1) = \mathbf{u}_i(t) + \mathbf{v}_i(t+1) \qquad (12)$$

Where: $\mathbf{v}_i(t)$ is the current position of particle (i) at iteration (t), p_{besti} is the individual best of particle (i) at iteration (t), and g_{best} is the best result so far, *w* is a weighting function, C1 and C2 are positive constants; r_1 and r_2 are uniformly distributed random values in [0, 1], and $\mathbf{u}_i(t)$ is the current position of particle (i) at iteration (t).

The initial section of equation (11), gives PSO the capacity to explore. The second and third sections depict individual thought and particle cooperation, respectively.

3.3 Firefly Algorithm (FFA):

Xin-She Yang created the "firefly algorithm," which was motivated by fireflies' flickering lights [14]. The attraction of all fireflies is inversely correlated with the power of their flash, making them all unisexual. Therefore, if a firefly particle had the option of travelling in the direction of either of two fireflies, it would be more drawn to the firefly with more brightness and move in that direction. The firefly will fly in an arbitrary direction if there are no other fireflies around. Flash brightness and fitness function are related. The attractiveness (β) of a firefly can be characterized as a function of the Cartesian distance r between the fireflies since it is proportional to the light intensity seen by nearby fireflies [14,15] and it is expressed by:

$$\beta = \beta_0 \exp(-\gamma r^2) \qquad (13)$$

Where, γ is the absorption coefficient and β_0 is the attraction at r = 0.

When one firefly (i) approaches another more alluring (brighter) firefly (j) can be find by:

$$\mathbf{u}_i(t+1) = \mathbf{u}_i(t) + \beta_0 \exp(-\gamma r_{ij}^2)(\mathbf{u}_j(t) - \mathbf{u}_i(t)) + \alpha\varepsilon \qquad (14)$$

AIRO JOURNALS
Free / Unpaid Peer Reviewed Multidisciplinary International
ISSN: 2320-3714
Volume 1 Issue 3
March 2023
Impact Factor: 10.2
Subject: Physics

When the randomization parameter (α) and the vector of random values (ε) drawn from a Gaussian distribution. The firefly with the maximum brightness, or the one with the best fitness value, is determined to be the best solution to the issue at the conclusion of every generation.

3.4 Artificial Bee Colony Algorithm (ABC):

Karaboga and Basturk created the artificial bee colony algorithm after being impressed by the intelligence behavior of bees [16]. There are three categories of bees in the ABC algorithm: working bees, observers, and scouts. A food source's position symbolizes a potential solution to the optimization problem, and the nectar amount of a food source corresponds to the effectiveness of the solution that food source is representing [17].
During the employed bee phase, the employed bees are in charge of determining the nectar content of each potential new food source in the vicinity of potential new food sources. The steps taken to pinpoint the new food sources is:

$$\mathbf{u}_i(t+1) = \mathbf{u}_i(t) + \phi \cdot (\mathbf{u}_i(t) - \mathbf{u}_k(t)) \;, \qquad i = 1, 2, \ldots, N; \qquad k \in \{1, \ldots, N\} \quad (15)$$

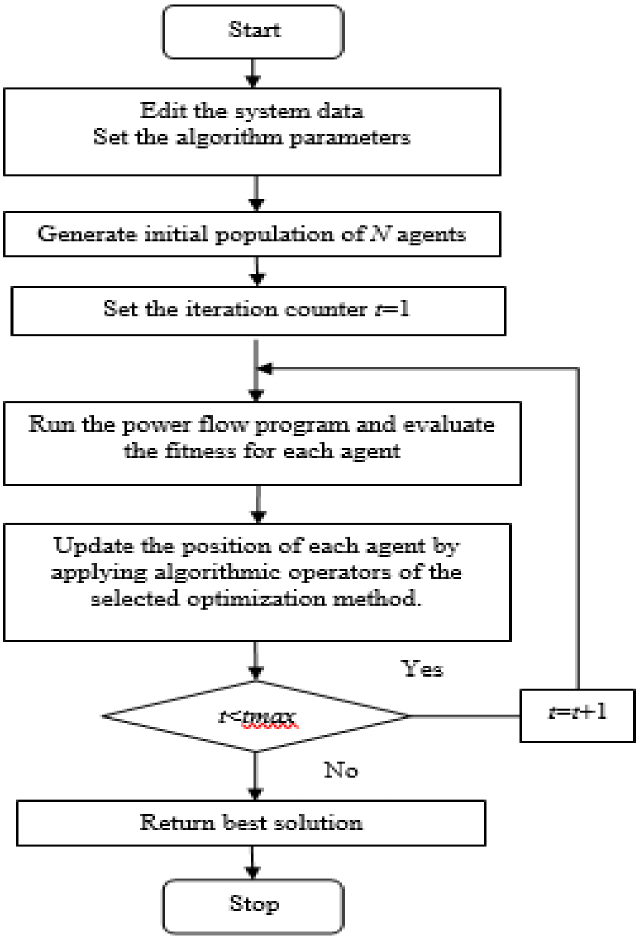
Where: $\mathbf{u}_k(t)$ is a randomly chosen solution different from $\mathbf{u}_i(t)$, and $\mathbf{u}_i(t+1)$ is the new solution (food source). ϕ is a uniform random number between [-1, 1].
By employing equation (15), observers try for a better food supply nearby their current food source. If the new nectar yield is higher than the yield of the previous resource, the former gets dropped. Otherwise, the food resource's abandonment counter is raised by one. Repeat this procedure until all onlookers are dispersed among the food sources [17]. Without receiving any direction from the search space, this scout begins haphazardly searching a new food source. The algorithm is helped to avoid local optimal conditions by this abandoning and scouting technique [18].

4. GENERAL FLOW CHART FOR OPF USING METAHEURISTIC TECHNIQUES:

The following figure illustrates the general process flow for the OPF solution using metaheuristic optimization techniques [3].

AIRO JOURNALS
Free / Unpaid
Peer Reviewed
Multidisciplinary
International

ISSN:2320-3714
Volume1 Issue 3
March 2023
Impact Factor:10.2
Subject:Physics



5. COMPARISION BETWEEN METAHEURISTIC TECHNIQUES:

The basic comparison of metaheuristic optimization methods is shown in following table [19].

Algorithm	Merits	Demerits
Gravitational Search Algorithm (GSA)	It is straightforward and simple to use.	GSA has limited local search capabilities.
	The individual moves have a considerable degree of randomness.	It is not initialization-resistant.
	As a result, it offers a thorough search space exploration.	A single objective optimization problem was used to formulate the issue at hand.
Particle Swarm Optimization (PSO) algorithm	Simple in concept.	Slow convergence rate.
	Easy to be implemented.	Trapping into local optima.
	Suitable convergence speed Efficient.	The learning constants and inertia weight both play a role.
	Requiring minimal adjustment of the parameters.	Initializing parameters by trial and error.
Firefly Algorithm (FA)	FFA is simple to understand and simple to apply.	FFA often traps into local optima.
	It is good at exploration.	It has fixed settings that don't alter over time.
	It incorporates the process of	It is treated as a single aim optimization

AIRO JOURNALS
Free / Unpaid Peer Reviewed Multidisciplinary International
ISSN: 2320-3714
Volume 1 Issue 3
March 2023
Impact Factor: 10.2
Subject: Physics

	self-improvement into the existing space and enhances its own space over the earlier phases.	to minimize power losses or improve voltage profiles.
Artificial Bee Colony (ABC) algorithm	It is exactly as simple to use as PSO and FFA after a few control parameters, such as colony size and maximum cycle number, are set.	ABC exhibits weak exploitation traits.
	It is robust against initialization.	In some circumstances, the convergence speed is also a problem.
	It is capable of looking at regional options.	It might get stuck in a local optimum.

6. CONCLUSION:

It is suggested that metaheuristic optimization is a method for using metaheuristic algorithms to solve optimization problems. In this research, we find that these algorithms can be used in many different areas, whether as a direct method or as any modified variant. The optimal integration problem was solved using metaheuristic algorithms, which were reviewed in this study along with their dynamic implementation for objective function solving. Metaheuristic algorithms were analyzed and classified as evolutionary, swarm intelligence, physics, hybrid, and combination. The OPF problem was solved using a variety of metaheuristic optimization techniques, which have all been thoroughly reviewed and contrasted in this study.

7. REFERENCES:

[1]. Abou El Ela, A. A., Abido, M. A., and Spea, S. R., "Optimal power flow using differential evolution algorithm," *Electrical Eng*ineering, Vol. 91, pp. 69–78, 2009.

[2]. Frank, S., Steponavice, I., and Rebennack, S., "Optimal power flow: a bibliographic survey-I Formulations and deterministic methods," *Energy Syst*em, Vol. 3, No. 3, pp. 221–258, 2012.

[3]. J. Radosavljević, Metaheuristic Optimization in Power Engineering, The Institution of Engineering and Technology (IET), London, 2018.

[4]. Chakraborty and A. K. Kar, "Swarm Intelligence : A Review of Algorithms Swarm Intelligence : A Review of Algorithms," no. March, 2017.

[5]. A. J. Wood and B. F. Wollenberg, "*Power Generation Operation and Control"*, Wiley and Sons, 1996.

[6]. D. H. Wolpert and W. G. Macready, "No free lunch theorems for optimization," *IEEE Trans. Evol. Comput*., vol. 1, no. 1, pp. 67– 82, 1997.

[7]. M. A. Boschetti, V. Maniezzo, M. Roffilli, and A. B. Röhler, "Matheuristics: Optimization, Simulation and Control," Hybrid metaheuristics, pp. 171–177, 2009.

[8]. I. Dumitrescu and T. Stützle, "Usage of exact algorithms to enhance stochastic local search algorithms," *Matheuristics*, pp. 103–134, 2010.

[9]. M. Fischetti and A. Lodi, "Local branching," *Math. Program*., vol. 98, no. 1–3, pp. 23–47, 2003.

[10]. S. Janković, Heuristic approach to solving problem of location and relocation of ambulance vehicles in base stations, Master thesis, University of Belgrade, Faculty of Mathematics, 2015.
[11]. Rashedi E., Nezamabadi-pour H., and Saryazdi S. "GSA: A gravitational search algorithm," Information Science, Vol. 179, pp. 2232–2248, 2009.
[12]. R. C. Eberhart and J. Kennedy, A new optimizer using particle swarm theory. In: Micro machine and human science, Proceedings of the 6th international symposium, Vol. 1, 1995, pp.39-43.
[13]. S. Mirjalili and S. Z. M. Hashim, A new hybrid PSOGSA algorithm for function optimization, International Conference on Computer and Information Application (ICCIA 2010), pp. 374–377, Tianjin, China, 3–5 December 2010.
[14]. X. S. Yang, Nature-inspired metaheuristic algorithms, UK: Luniver Press; 2008.
[15]. P. Balachennaiah, M. Suryakalavathi and P. Nagendra, Firefly algorithm based solution to minimize the real power loss in a power system, Ain Shams Eng J, 2015, http://dx.doi.org/10.1016/j.asej.2015.10.005
[16]. D. Karaboga and B. Basturk, A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm, J Global Optim, Vol. 39, 2007, pp. 459-471.
[17]. I. Ilhan, Mobile device based test tool for optimization algorithms, Computer Applications in Engineering Education, Vol. 24, Iss. 5, 2016, pp: 744–754.
[18]. M. Rezaei Adaryani, A. Karami, Artificial bee colony algorithm for solving muli-objective optimal power flow problem, Electr. Power Energy Syst., Vol. 53, 2013, pp. 219-230.
[19]. AbdullahM.Shaheena, ShimaaR.Speab, SobhyM.Farragc, MohammedA.Abido, "A review of meta-heuristic algorithms for reactive power planning problem, Ain Shams Engineering Journal (2018)9,215–231, Production and hosting by Elsevier B.V.

Author's Declaration

I as an author of the above research paper/article, hereby, declare that the content of this paper is prepared by me and if any person having copyright issue or patentor anything otherwise related to the content, I shall always be legally responsible for any issue. For the reason of invisibility of my research paper on the website/amendments/updates, I have resubmitted my paper for publication on the same date. If any data or information given by me is not correct, I shall always be legally responsible. With my whole responsibility legally and formally I have intimated the publisher (Publisher) that my paper has been checked by my guide (if any) or expert to make it sure that paper is technically right and there is no unaccepted plagiarism and hentriacontane is genuinely mine. If any issue arises related to Plagiarism /Guide Name /Educational Qualification /Designation/Address of my university/college/institution/Structure or Formatting/ Resubmission / Submission /Copyright / Patent/Submission for any higher degree or Job/Primary Data/Secondary Data Issues. I will be solely/entirely responsible for any legal issues. I have been informed that the most of the data from the website is invisible or shuffled or vanished from the data base due to some technical fault or hacking and therefore the process of resubmission is there for the scholars/students who finds trouble in getting their paper on the website. At the time of resubmission of my paper I take all the legal and formal responsibilities, If I hide or do not

ISSN: 2320-3714
Volume1 Issue 3
March 2023
Impact Factor: 10.2
Subject: Physics

submitthe copy of my original documents (Aadhar/Driving License/Any Identity Proof and Photo) in spite of demand from the publisher then my paper may be rejected or removed from the website anytime and may not be consider for verification. I accept the fact that as the content of this paper and the resubmission legal responsibilities and reasons are only mine then the Publisher (Airo International Journal/Airo National Research Journal) is never responsible. I also declare that if publisher finds any complication or error or anything hidden or implemented otherwise, my paper maybe removed from the website or the watermark of remark/actuality maybe mentioned on my paper. Even if anything is found illegal publisher may also take legal action against me

Nilesh M. Patel
[2]Dr.Thangadurai N

******