

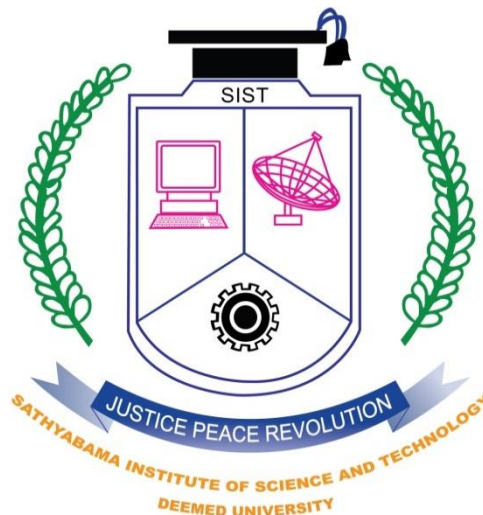
CONGESTION MANAGEMENT IN ELECTRICAL POWER SYSTEM USING GRASSHOPPER OPTIMISATION ALGORITHM

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in
Electrical and Electronics Engineering

by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL 2021



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This is to certify that this Project Report is the bonafide work of **ELAKKIYA M** (Reg. No. 37140029) and **GAYATHRI V** (Reg. No. 37140032) who carried out the project entitled "**CONGESTION MANAGEMENT IN ELECTRICAL POWER SYSTEM USING GRASSHOPPER OPTIMISATION ALGORITHM**" under our supervision from December 2020 to April 2021.

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Paper Title :

**Comparison of Grasshopper Optimization Algorithm &
Flower Pollination Algorithm in Congestion Management**

Dr. H. Anandakumar
Conference Chair

Dr. R. Subha
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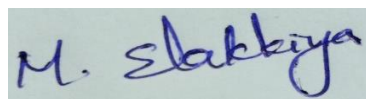
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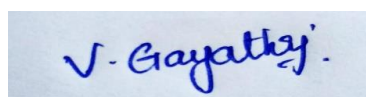
DECLARATION

We **ELAKKIYA.M** (Reg. No. 37140029) and **GAYATHRI.V** (Reg. No. 37140032) hereby declare that the Project Report entitled “**CONGESTION MANAGEMENT IN ELECTRICAL POWER SYSTEM USING GRASSHOPPER OPTIMISATION ALGORITHM**” done by us under the guidance of **Mrs. C. BHUVANESWARI** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

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DATE: 06-04-2021

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Abstract

Congestion is defined as overloading the transmission line. Congestion is the superior problem in the power system and the system operator would face some issue in the post deregulated system. Congestion management is defined as any approach focused on avoiding, dropping, or eliminating network congestion and its negative impact on network performance. The increased power transaction is associated with increased demand. The generation companies are result in the stress on power network for satisfy the demand. It will cause the hazard to voltage security, high line losses, violation of line flow limits, hazard to power system stability, high requirement of reactive power and overload of the lines in the power system. The most apparent technique is rescheduling the values generator outputs. But need not to rescheduling the values of all the generators.

We should reschedule the generator output in effective way. But this method has few drawbacks. to relieve the congestion many optimisation algorithms like Genetic algorithm (GA), Flower pollination algorithm (FPA), Particle swarm optimisation algorithm (PSO) where used. In this paper proposes Grasshopper optimisation algorithm (GOA) to solve the optimisation problem. The proposed algorithm imitates and inspired by the behaviour of grasshopper swarms in nature. A mathematical model will suggest to simulate repulsion and attraction forces between the grasshoppers. Repulsion forces permits grasshoppers to discover the search space, whereas attraction forces encouraged them to exploit capable regions. This algorithm minimizes the congestion cost and the deviation of reschedule value of generator outputs. The result will reveal that the proposed algorithm is able to provide superior results compared to popular and modern algorithm in the literature. In solving real problems with unknown search spaces. The merits of GOA will prove by the result of real application.

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LIST OF SYMBOLS AND ABBREVIATIONS

FACTS	-	Flexible AC Transmission line
SVC	-	Static Var Compensator
TCSC	-	Thyristor Controlled Series Capacitor
FPA	-	Flower pollination algorithm
PSO	-	Particle Swarm Optimisation Algorithm
GOA	-	Grasshopper Optimisation Algorithm

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Congestion is an abnormal condition that occurs when transmission network fails to transfer the power based on the load demand. Congestion management is deregulated power system and it takes place when the transmission line exceeds their limits and the actions taken to avoid or relieve congestion. Congestion management considered as any systematic approach used in matching and scheduling generation and manage congestion. The method of finding the most effective value for the variable of the particular problems to minimize undesirable things like cost, energy loss, error, etc or maximize desirable things like profit, quality, efficiency, etc subject to objective function or some constraints is called optimisation. To solve an optimisation problem Different steps are required. 1) Identify the parameters 2) Recognise the constraints 3) Consider the objective of the problem 4) Select a suitable optimiser. Several natures inspired algorithm are used to solve the optimisation problems. Mathematical optimisation mainly relies on gradient-based information of the involved functions in order to find the optimal solution.

Despite the fact that such methods are still used by various researchers, they have some drawbacks. Mathematical optimisation approaches suffer from local optima entrapment. This is an algorithm that fails to find the global optimum since it assumes a local solution is the global solution. They're also ineffective for problems where the derivation is unknown or computationally costly. The main goal of this paper is to suggest a method for minimising the number of participating generators and optimal rescheduling of their outputs while maintaining congestion in a pool at the

lowest possible cost of rescheduling. The gradual or decremented changes in power outputs of all generators do not affect the power transmitted on the congested line to the same degree in a congested power grid. As a result, the outputs of generators whose generations are less important to the congested line flow do not need to be rescheduled. The generators that are actually helping to relieve congestion are selected using a criterion that limits the number of generators involved.

1.2 LITERATURE SURVEY

Sudipta Dutta and S. P. Singh (2008) proposes an Optimal Rescheduling of Generators for Congestion Management Based on Particle Swarm Optimization algorithm, IEEE Transactions on power system, it proposes one of the common techniques used to solve the congestion is rescheduling the power outputs of generators and development of sound formulation. In this technique firstly, we have to find the congested line and secondly, to minimize the deviation of rescheduled values. The aim of this paper is to demonstrate a technique for optimum generator selection for congestion management, as well as the use of PSO to solve the congestion management problem. The system's generators are chosen for congestion management based on their sensitivity to the congested line's power flow, accompanied by corrective rescheduling. Congestion is modelled as an optimization problem, and the particle swarm optimization technique is used to solve it. The approach has been successfully tested on the 39-bus New England system, the IEEE 30-bus system, and the 118-bus system. The findings of the 39bus New England method were compared to those recorded using three other techniques. The suitability of the methodology for generator selection has also been compared to techniques recorded on the IEEE 30bus. As well as 118bus a framework. PSO calculation has numerous benefits, for example, straightforward idea and simple understanding; the whole complex dynamic is displayed by two basic (1) and (2). The algorithm's robustness is shown by its ability to solve three distinct networks of varying sizes and complexities with equal success. Since the PSO algorithm's convergence is based on the proper selection of particle size, inertia weight, and maximum velocity of particles, Improper parameter selection may result in subpar results or nonconvergence. However, test results show that the proposed implementation is successful and outperforms in terms of congestion management.

Xin-She Yang (2012), proposes a Flower Pollination Algorithm for Global Optimization, *Unconventional Computation and Natural Computation 2012*, Lecture Notes in Computer Science, Flower pollination algorithm is simulated by the nature of pollination process of flower and its developmental characteristics. Bloom calculation used to tackle a nonlinear plan benchmark, and it shows the assembly rate. For the sake of convenience, we've assumed that each flower only produces one pollen gamete in this algorithm; this greatly simplifies the implementation. However, to assign each flower with multiple pollen gametes and each plant with multiple flowers can have some advantages for some applications such as image compression, multi objective optimization, and graph colouring. This can form a topic for further research, another possibility is to use other design schemes for flower consistency. Currently, a basic formula is used to achieve this consistency. Other, more exotic forms can be useful in some situations, but the exact change may necessitate detailed simulations. Furthermore, the flower algorithm can be extended to a discrete edition that can solve problems involving combinatorial optimization All of these add-ons would be extremely useful. We hope that this paper will spur on more metaheuristic's studies in the near future.

M.M.Raghuwanshi , May (2005), proposes a Survey on multi-objective evolutionary and real coded genetic algorithms, Complex International, in continues search space with binary coded genetic algorithm has some complications. Real coded genetic algorithm denotes the solution very near to natural formulation. This algorithm intended to get fast and reliable convergence along the good distribution and to work with real parameters. The aim of this paper is to investigate the use of a real-coded genetic algorithm to find the best generation rescheduling for congestion management in a deregulated environment. Transmission line outages, generator outages, changes in energy demand, and uncoordinated transactions can all cause congestion in the power system. N-1 contingency analysis is used in this study to classify the most extreme lines, which are then considered for analysis. The proposed problem is formulated as an optimization problem having large number of constraints. Since it is an effective heuristic algorithm for search and optimization, RCGA is used as an optimization tool. It optimises variables that have floating point representations. The approach has been successfully tested on the IEEE 30 bus system. It was compared to SA to show the algorithm's effectiveness. The reproduction results

demonstrated that the RCGA yield efficient arrangement than SA for all the experiments along these lines upgrades framework security. Furthermore, the line overloads are relieved completely by generation rescheduling alone without any load curtailment.

R. Prathiba, M. Balasingh Moses, S. Sakthivel, (2014), proposes a Flower Pollination Algorithm Applied for Different Economic Load Dispatch, International Journal of Engineering and Technology (IJET), In the power system the main optimisation mission is economic load dispatch. The target of ELD problem is reducing the fuel cost. we can write this algorithm in any programming language. In this algorithm is being free from large number of parameter and it is easily suit for different problem. In this paper, a new bio-inspired algorithm is used to solve various ELD problems. The numerical results demonstrate that the proposed algorithm produces superior results. The FPA optimization algorithm outperforms the other algorithms that have recently been published. The algorithm's power is demonstrated in all three forms of ELD problems. Since the three objective functions are so dissimilar in nature and necessitate algorithms with different strengths, the algorithm may be used to solve a variety of power system optimization problems. The robustness of the algorithm is demonstrated by the convergence efficiency of the FPA algorithm in various objectives. The algorithm is simple to implement and can be written in any programming language. This algorithm can be used to solve problems related to power system operation optimization. This algorithm can be used by power system operators for a variety of optimization tasks.

Gopalakrishnan and A. Krishnan, proposes an efficient technique to solve combined economic and emission dispatch problem using modified Ant colony optimization (2013), In large scale system, economic load dispatch problem is more complicate and find out the optimal solution is difficult. The main scope of economic load dispatch is to diminish the production cost and fulfil the required equality and inequality limitation. But it results slower convergence and higher computational complexity. For CEED, optimization algorithms have been found to produce substantial results the pollution-causing emissions increase as the cost is controlled. As a result, a procedure known as pollution dispatch must be used to monitor the cost reduction. Controlling emissions, on the other hand, would increase the cost of power

generation. As a result, the Hybrid Economic and Emission Dispatch technique arises. Various researchers have proposed various approaches to dealing with the CEED crisis. The current method has its own set of benefits and drawbacks. The use of optimization techniques such as PSO, GA, and others to optimise the parameters used for power generation is a widely used technique for CEED problems. But all those techniques require more time for optimization. This thesis employs the MACO optimization technique to address these challenges. The simulation result demonstrates the proposed technique's efficiency, and it can be concluded that the proposed technique lowers both the fuel cost and the emission production. Furthermore, optimization takes less time and needs less iterations.

Vora Animesh J (2012), propose a Congestion Management in Deregulated Power System, International Journal of Science and Research (IJSR), In the deregulated environment vital problem for secure and consistent power system operation is transmission overloading. To rectify the problem there is two methods are there. Which are cost-free method and non-cost-free method. Cost-free method dismiss the congestion technically and non-cost-free method relieve the congestion economically. In the transmission network to manage the congestion many cost-free methods were used. For secure operation of electrical power system, the transmission network loading has to be maintained within specified limits. Congestion on transmission lines causes cascading tripping, which causes the device to fail. The generators which are participating in congestion alleviation based on the congested line. They have been used for corrective rescheduling and minimizing the FACTS devices to alleviate congestion. The use of FACTS equipment and reactive power rescheduling results in lower rescheduling costs and a better voltage profile. It is noted that the minimum cost of rescheduling is observed when the generator and capacitor provide reactive support. When compared to other approaches, the proposed approach produces better performance.

From literature survey we learned many problem-solving methods by using popular algorithm, based on this we propose the Grasshopper optimisation algorithm to solve the optimisation problem in electrical power system.

1.3 SCOPE OF THE PROJECT

In this work, grasshopper optimisation algorithm has been proposed. At first, a mathematical model was employed to simulate the behaviour of grasshopper swarm and proposed Grasshopper optimization algorithm. An archive and target selection mechanism are then integrated into this algorithm to solve problems. A set of test functions was used to test the performance of the pro-posed GO algorithm. The results were compared with popular algorithms like PSO and FPA. It was observed that the GO algorithm is very efficient and reliable. Further, the simulation of proposed work has been carried out using MATLAB/SIMULINK values are validated with simulation parameters.

1.4 ADVANTAGES AND APPLICATIONS OF PROPOSED TECHNIQUE

- The proposed algorithm has
 - Reduce the congestion cost
 - decrease the power losses
 - high efficiency
 - low convergence rate
 - transmission line overloading problem can relieved

CHAPTER 2

PROJECT DESCRIPTION

2.1 PROBLEM FORMULATION

Electrons move across power lines almost like cars down a road. In both cases, congestion occurs when too many converge on an equivalent path. Traffic jams are frustrating, but electricity congestion is often costly and should even cause power outages. Grid congestion occurs thanks to transmission constraints – a scarcity of cable capacity to deliver electricity without exceeding thermal, voltage and stability limits designed to make sure reliability. Constraints can lead to inefficiencies. Line loss – the dissipation of electricity along a wire – increases when transmission lines exceed thermal power, for example. Lost energy means lost money. Transmission congestion may be a phenomenon that happens in electrical power markets. It occurs when power flow over a transmission element exceeds the elements available capacity due to scheduled market transactions (generation and load). Since grid operators must make sure that physical overloads don't occur, They are going to dispatch generation so as to prevent them. The functions that provide this advantage provide lower-cost energy, reduce device loading, transfer load to off-peak hours, or enable the grid operator to control electricity flow across restricted interfaces (i.e. dynamic line capability or power flow control).

The sum collected by the owners of the transmission line's rights is known as congestion cost. In a one-line network these rights would typically pay the owners an amount adequate to the roads capacity times the difference between the costs at the 2 ends of the line. Congestion management may be a tool for efficiently making use of the facility available without violating the system constraints. Congestion management refers to avoiding or relieving congestion. To remove the congestion and to reduce the congestion cost, we proposed intelligence algorithms such as, Grasshopper Optimisation Algorithm, particle swarm optimization algorithm and flower pollination algorithm.

The objective function is to minimize the congestion cost due adjustment of generating pattern. The mathematical equation governs the problem is given below

2.1.1 Objective function:

$$\text{Minimize } \sum_{k=1}^{NG} \left| C_k (P_{gk}^0 + \Delta P_{gk}) - C_k (P_{gk}^0) \right| + \sum r_d^{down} \Delta P_{redi}^{down} . d_i$$

The constraints of the considered problem is listed below and classified as equality and inequality constraints

2.1.2 Subjected To:

Equality Power balance equation

$$(P_g - P_d) = \sum_i (V_i . V_j . Y_{ij} . \cos(\delta_i - \delta_j - \theta_{ij}))$$

$$(Q_g - Q_d) = \sum_i (V_i . V_j . Y_{ij} . \sin(\delta_i - \delta_j - \theta_{ij}))$$

In-equality constraints

$$P_{gk}^{\min} \leq P_{gk} \leq P_{gk}^{\max}$$

$$Q_{gk}^{\min} \leq Q_{gk} \leq Q_{gk}^{\max}$$

$$X_{TCSC}^{\min} \leq X_{TCSC} \leq X_{TCSC}^{\max}$$

$$B_{SVC}^{\min} \leq B_{SVC} \leq B_{SVC}^{\max}$$

In the objective function, C_k is generation cost of k^{th} generator. P_{gk}^0 is the scheduled real power generation, ΔP_{gk} is the change in real power generation. r_d^{down} is the price offered by demand response, d_i is the demand response commitment variable which has a binary value.

In the equality constraint P_g , Q_g , P_d , and Q_d are real, reactive power generation and real, reactive power demand respectively. V_i , V_j are bus voltage magnitude of i^{th} , j^{th} bus. δ_i , δ_j are bus voltage angle of i^{th} , j^{th} bus. Y_{ij} is line admittance which connects bus i - j . Θ_{ij} is the admittance angle. The power balance equation is the difference of power generation and demand is must the losses in the power system.

In in-equality constraints P_{gk} , Q_{gk} are real and reactive power generation of k^{th} generator which should be within its minimum and maximum limit. X_{TCSC} , and B_{SVC} are TCSC reactance and SVC susceptance which should be within its minimum and maximum limit.

2.2 BUS SYSTEM BLOCK DIAGRAM

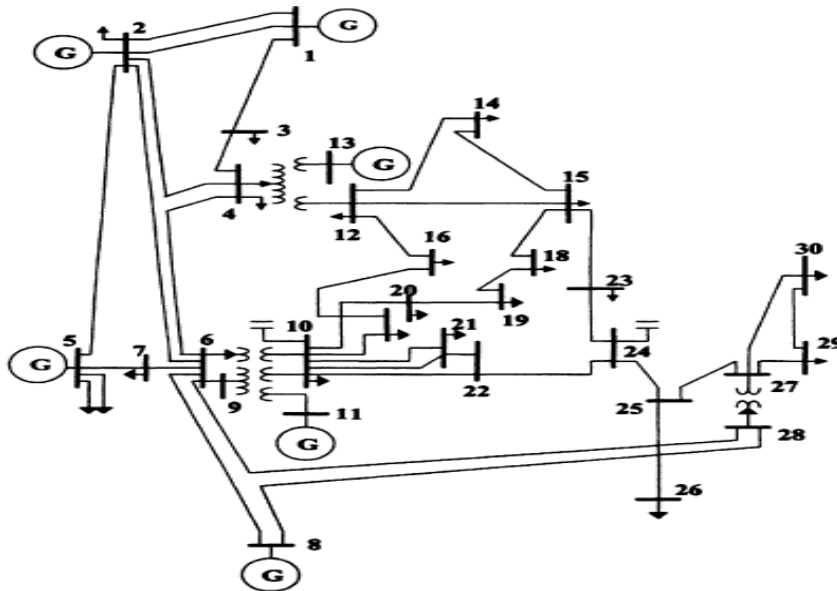


Fig 2.2 Block diagram of IEEE30 bus system

2.2.1 CONCEPT EXPLANATION

Block diagram IEEE30 bus system is shown in fig 2.2. IEEE30 bus is standard bus system. There are many bus systems like 3 bus, 5 bus, 14 bus, etc. IEEE 30 bus system is American electrical power system. It is the benchmark because all test is conducted based on this system only. In IEEE30 bus system all the data are available in the system itself. In 30 bus system, 6 buses are used for generation and other 24 buses are used for load.

2.3 COMPONENTS

Loads, capacitor banks, transmission lines, and generators build up the system.

2.3.1 LOADS

An electrical load is an electrical component or portion of a circuit that consumes (active) electrical power, like electrical appliances and lights inside the house. The term can also ask the facility consumed by a circuit. This is against an influence source, like A battery or generator, which produces power. For example, it is often a resistor, or a capacitor or an inductor, or a transistor, or a motor, or an air conditioning etc.

2.3.2 CAPACITOR BANK

A capacitor may be a device that stores electricity in an electrical field. It's a two-terminal passive electronic component. Two metal plates are separated by a dielectric in a capacitor. The dielectric are often made from many insulating materials like air, glass, paper, plastic etc. A capacitor is a device that can store electrical charge as well as electricity. The higher the worth of capacitance, the more charge the capacitor can store. Capacitors are widely utilized in electronic circuits for blocking DC while allowing AC to pass. Capacitor Bank may be a combination of various capacitors of comparable rating that are joined in parallel or series with each other to gather electricity. The subsequent bank is then wont to balance or address an impact factor slack or stage move in an AC power supply. Capacitors are wont to control the extent

of the voltage supplied to the customer by reducing or eliminating the drop within the system caused by inductive reactive loads. The diagram for capacitor bank is shown in 2.3.2.

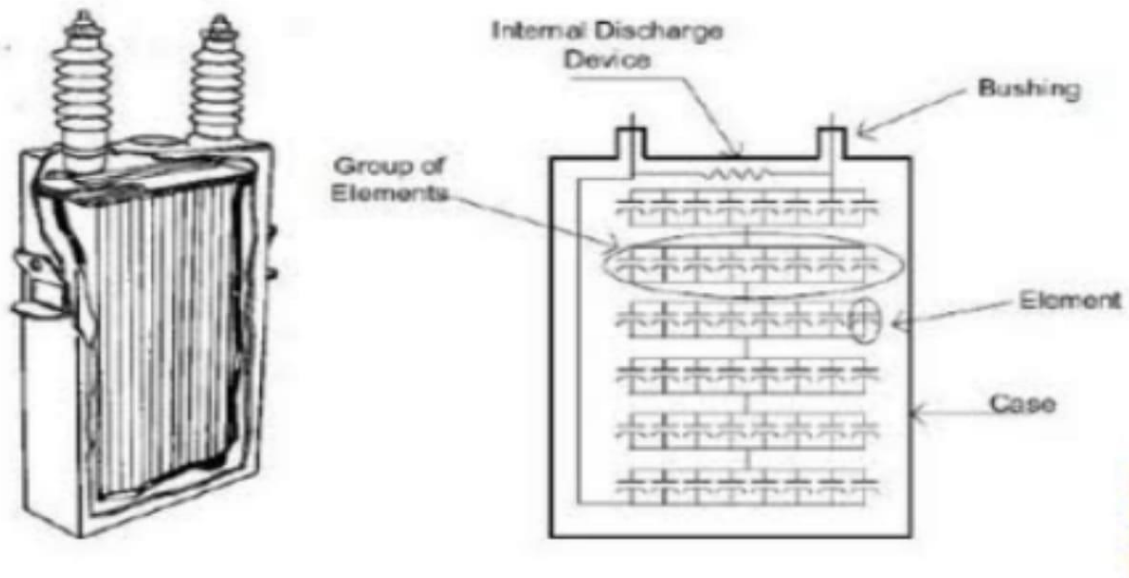


Fig 2.3.2 capacitor banks

Reducing the phase difference between voltage and current is one way to increase power factor. A capacitor bank installed parallel to the load provides this reactive power. They act as a source of local reactive power, and thus less reactive power flows through the road. Pure capacitors and inductors do not consume power. The power associated with these are only reactive power unless there is some internal resistance. If there's some internal resistance, it'll consume power.

2.3.3 TRANSMISSION LINE

A cable may be a specialized cable or other structure designed to conduct electromagnetic waves during a contained manner. The term applies when the conductors are long sufficient that the wave idea of the transmission should be thought about. Electrical power is transmitted from a generating substation to various distribution units through a transmission line. It transmits the wave of voltage and

current from one end to the other. The cable is formed from a conductor having a consistent cross-section along the road. The diagram for different rating of transmission line is shown in fig 2.3.3.

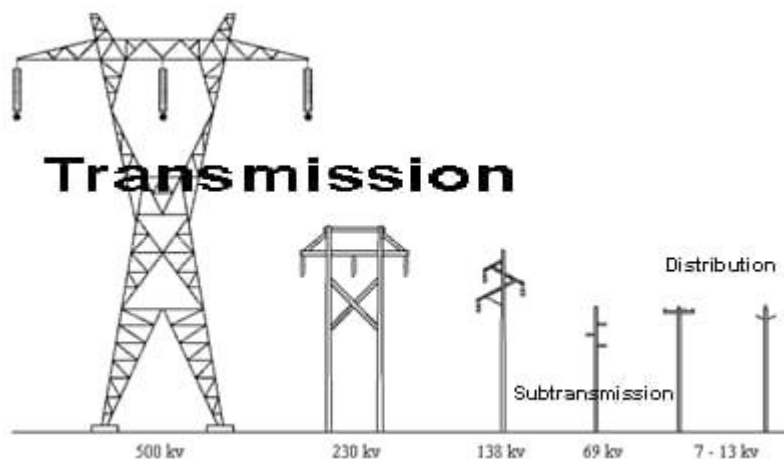


Fig 2.3.3 different rating of Transmission line

Overhead transmission lines and underground cables are also included in the word Transmission Lines. The key function of a cable is to transfer bulk power between generation sources and cargo centres. In Transmission Line, Electrical Wave Transmits to Electrical Path to complete the transmission path is known as transmission line. Transmission lines carry electric energy from one point to a difference in an electrical power grid . They can carry AC or DC or a system are often a mixture of both. Also, current is often carried by either overhead or underground lines.

2.3.4 GENERATOR

A generator may be a device that converts energy into electric power to be used in an external circuit. Generators generate electrical current by electromagnetic induction and are powered by a fuel source such as oil, gasoline, wind, or flowing

water. The relation between magnetism, motion, and electricity is provided by generators. Generators typically use an electromagnet, which is made by electricity and a rapidly spinning turbine to supply massive amounts of current.

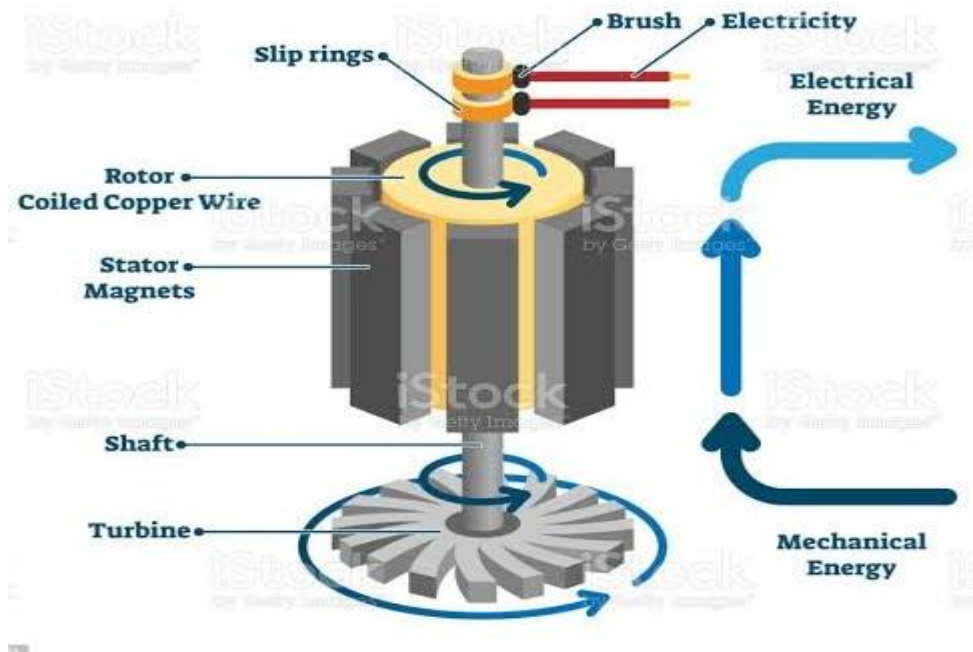


Fig 2.3.4 Generator

In fig 2.3.4 the diagram for the generator is given. The standard generator contains a gaggle of insulated wire coils within the shape of a cylinder. Within the cylinder is a rotary electromagnet. When the magnet spins, it induces a small current in each part of the wire coil. Each piece of the wire loop then transforms into a little, singular electric transmitter and subsequently the minuscule flows of individual areas converge to make one huge flow. The resulting electricity is then distributed to consumers through power lines. There are two predominant categories of electrical generators, people who use non-renewable energy sources, and people that use renewable energy.

2.3.5 BUS

A bus may be a node where a line or several lines are connected and should also include several components like loads and generators during a power grid . Each bus or node is connected to one of four values: (1) voltage magnitude, (2) voltage phase angle, (3) active power or true power, and (4) reactive power. In a specific load

flow, two out of the four quantities have a particular value, while the opposite two will have to be determined by calculating using power flow equations. Single and double bus systems are shown in fig 2.3.5.1 and fig 2.3.5.2.

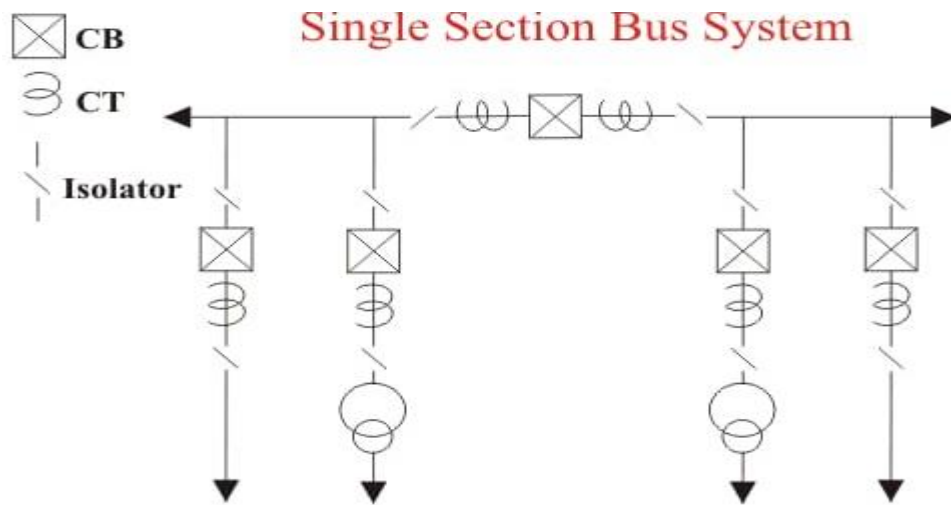


Fig 2.3.5.1 Single section bus system

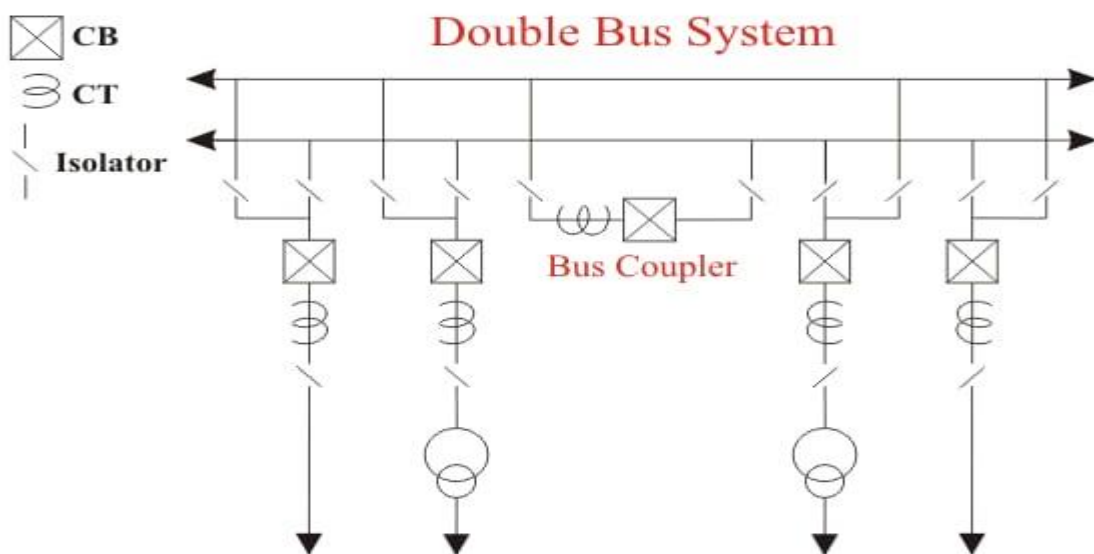


Fig 2.3.5.2 Double bus system

The unknown and known variables are not constant and shift with the bus form. A conduit or a gathering of conveyors that ingests electrical energy from approaching feeders and appropriates it to active feeders is known as an electrical transport bar. To put it another way, it's a type of electrical intersection where all approaching and active electrical flows meet.

2.3.6 BUS CLASSIFICATION

In a load flow analysis, buses are divided into three categories based on the defined quantities: generation, load, and slack.

2.3.6.1 GENERATOR BUS

A power system's generator stations are represented by the generator bus, also known as the PV bus, voltage-controlled bus, or generator bus. The quantities specified for this sort of bus are voltage magnitude and therefore the real power. It means that the unknown variables for the generator bus are the phase angle of voltage and reactive power. The diagram for generator bus is shown in fig 2.3.6.1.

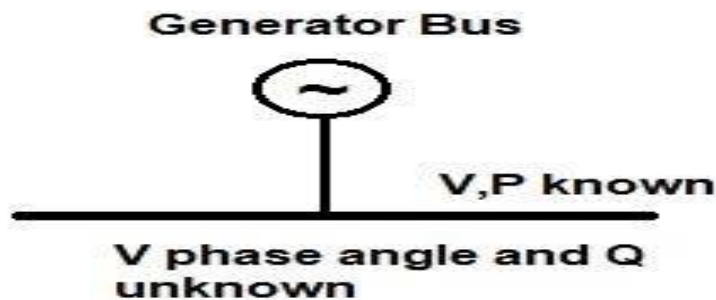
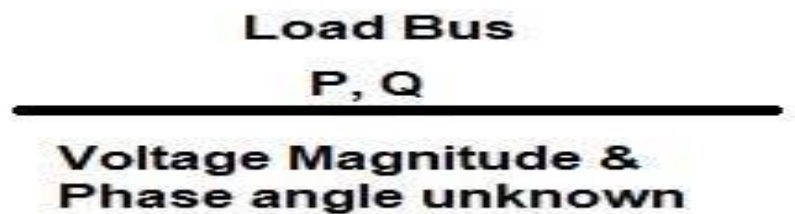


Fig 2.3.6.1 generator bus

Generator in the power system is connected to this type of bus. Therefore, the bus voltage corresponds to the generator's voltage, and therefore the generation of active power is correlated to the generator rating specific to the bus. The synchronous generator's field current is adjusted to maintain a constant voltage magnitude on the generator bus. Real power generation for each generator is assigned concerning economic dispatch.

2.3.6.2 LOAD BUS

The load bus, also known as the PQ bus, is a network node that integrates both reactive and active control. It means the phase and voltage magnitude are unknown and wish to be calculated using the load flow equation. The diagram for load bus is shown in fig 2.3.6.2.

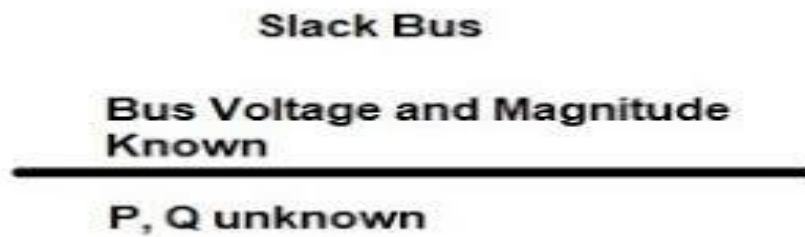


2.3.6.2 Load bus

No generator is connected to the load bus. Voltage during this sort of bus may vary within tolerable values, while the phase of the voltage isn't very crucial for the load. The heap transport is the most various transport type commonly found inside the force framework.

2.3.6.3 SLACK BUS

The slack bus is usually mentioned because of the swing bus or reference bus. It doesn't carry any load yet assumed to be real in order that losses are often considered during the transmission of power. The generator bus delivers active power, but it does mean that each one of it'll be consumed by the load bus. The diagram for slack bus is shown in fig 2.3.6.3.



2.3.6.3 Slack bus

It leads to a difference or power loss, which may only be calculated following the load flow solution. The slack bus supplies the complex losses and always has an attached generator in order that unfulfilled demand from other buses are often met. The slack bus is where the generation is made available and retains the system's power balance. The phase and magnitude are given, with the angle set to a point of reference or zero degrees. All the opposite phase angles of the opposite buses are expressed using the swing bus voltage phasor as their reference.

2.4 FACTS DEVICES

FACTS devices are static power-electronic devices that are mounted in AC transmission networks to boost the networks' power transfer capacity, reliability, and controllability by compensating for series and/or shunt losses. These machines are also used for loss optimization and congestion management.

2.4.1 Types of FACTS Controllers

Shunt connected controllers (SVC).

Series connected controllers (TCSC).

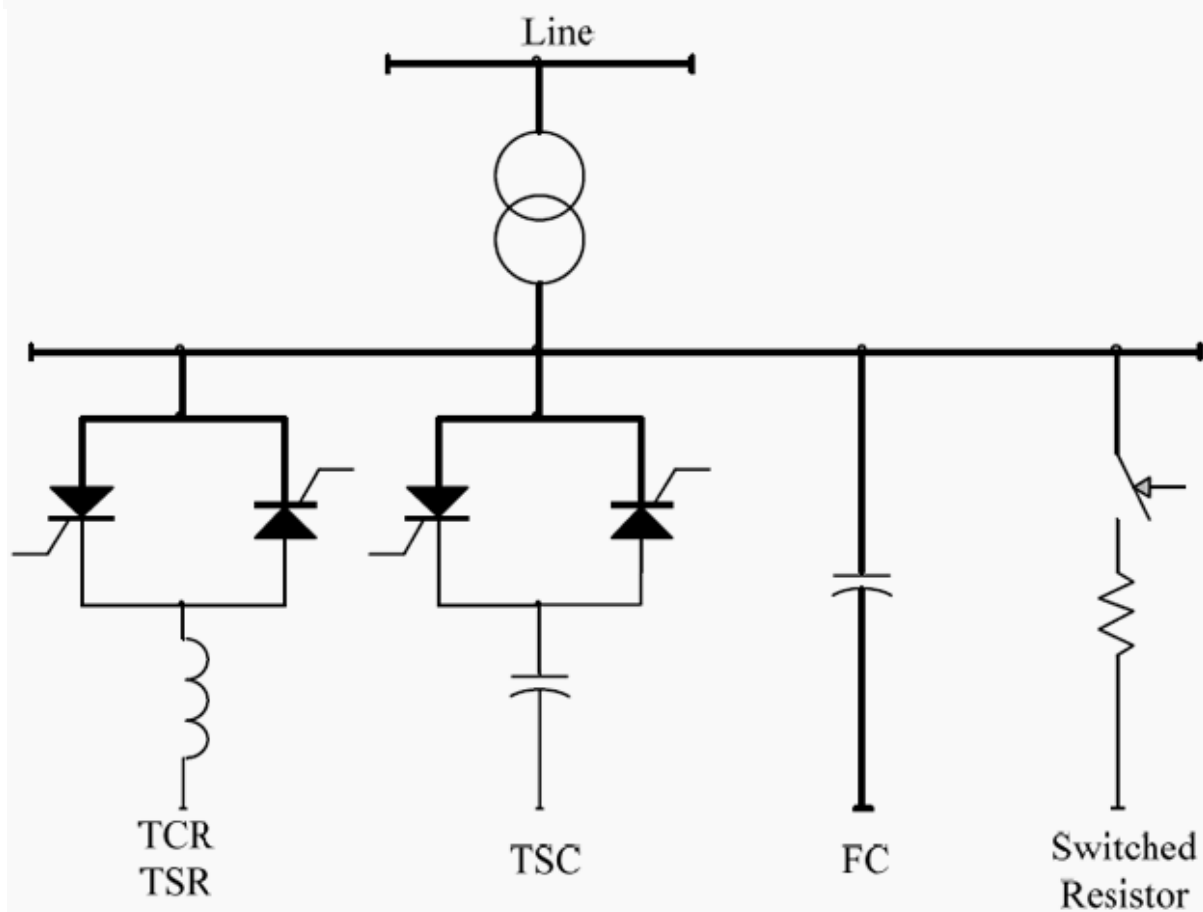
Combined series-series controllers (IPFC).

Combined shunt-series controllers (UPFC).

2.4.1.1 SVC

A shunt-associated static Var generator or safeguard whose yield is adjusted to share capacitive or inductive flow to keep up or control explicit boundaries of the electric force framework, as indicated by the maker the Static Var Compensator (normally transport voltage). SVC is predicated on thyristors without gate turn-off capability. SVC variable reactive impedance is accomplished by the operating theory and characteristics of thyristors. Thyristor-controlled and Thyristor-switched Reactor (TCR and TSR) and Thyristor-switched capacitor are the two main components of SVC (TSC).

Figure 2.4.1.1 - diagram of SVC:



Static VAR Compensators (SVC) (Figure 2.4.1.1): TCR/TSR, TSC, FC, and Mechanically Switched Resistor TCR/TSR, TSC, FC, and Mechanically Switched Resistor.

TCR and TSR both use a shunt-connected reactor with two parallel, reverse-connected thyristors to power it. TSR is operated without firing angle control, resulting in a phase change in reactance, while TCR is controlled with proper firing angle input to function in a continuous manner. TSC has a similar composition and operating mode to TSR, but a capacitor replaces the reactor. Due to the capacitor's characteristic, the reactance may only be completely connected or fully disconnected. A SVC can absorb/supply reactive power to the cable in a variety of ways using different combinations of TCR/TSR, TSC, and glued capacitors.

2.4.1.2 TCSC

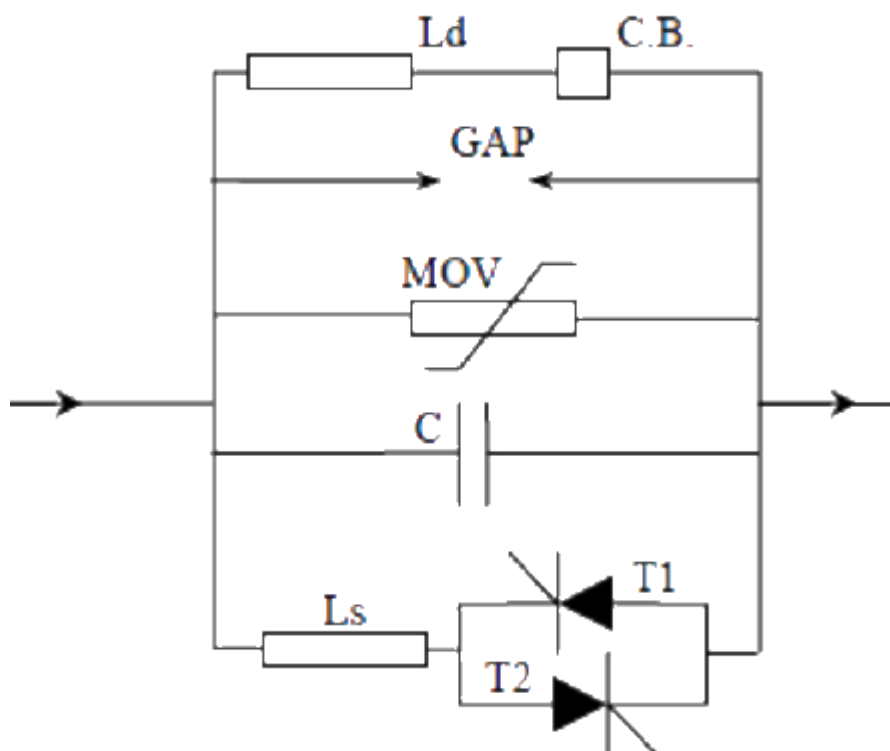


Fig 2.4.1.2 diagram of TCSC

Thyristor-Controlled Series Compensation (TCSC) is employed in power systems to dynamically control the reactance of a cable so as to supply sufficient load

compensation. The diagram for TCSC is given fig 2.4.1.2. The advantages of TCSC can be seen in its ability to monitor the amount of compensation applied to a cable and its ability to operate in several modes. These traits are very desirable since loads are constantly changing and can't always be predicted. TCSC designs work in the same way as Fixed Series Compensation, but they allow for variable control of the capacitor device's reactance. TCSC operates in several modes counting on when the thyristors for the inductive branch are triggered. The modes of operation are as listed:

- Blocking mode
- Bypass mode
- Capacitive boost mode

2.4.2 ADVANTAGES

- power flow control,
- increase of transmission capability,
- voltage control,
- reactive power compensation,
- stability improvement,
- power quality improvement,
- power conditioning,
- flicker mitigation.

2.4.3 FEATURES

- Fast voltage regulation,
- Increased power transfer over long AC lines,
- Damping of active power oscillations, and
- Load flow control in meshed systems

CHAPTER 3

SIMULATION METHODOLOGIES

In this section we are going to discuss about existing methodologies. In existing system following two algorithms are there,

- Particle swarm optimisation algorithm (PSO)
- Flower pollination algorithm (FPA)

In this section we are going to discuss about proposed methodologies.

- Grasshopper optimisation algorithm

3.1 EXISTING METHODOLOGY

3.1.1 PARTICLE SWARM OPTIMISATION

Kennedy and Eberhart invented the particle swarm optimization approach in 1995, and it is an evolutionary algorithm. Fish schooling and bird flocking were used as examples of social behaviour in organisms. A flock of birds has been observed to locate food in an environment in a stochastic manner. Not all birds in a flock know the exact location of food but they know the position closest to it (the food). Searching the region around the current best spot, i.e. the position nearest to food, is the easiest and most accurate way to look for food.



Fig 3.1.1 swarm behaviour of birds and fish

In fig 3.1.1 swarm behaviour of birds and fish is given. The solution to an optimization problem, or the best solution, is discovered from a solution space using a population-based search technique in which the particles, like birds, change positions (states) over time. Each particle represents a potential solution to a problem in an N dimensional space (where the number of dimensions corresponds to the number of variables). The particles are randomly generated (a particle size between 10 to 100 is usually considered sufficient) initially with two parameters each-position and velocity in the dimensional space such as position $X_i = (x_{i1}, x_{i2}, \dots, x_{iN})$ and velocity $V_i = (v_{i1}, v_{i2}, \dots, v_{iN})$.

Every particle is then flown over the search space to locate possible solution regions of the landscape, changing its flying velocity and direction in response to its own and its neighbours' flying experiences. The positions of the particles (tentative solutions) are compared to an objective or fitness value at the end of each iteration. Particles are thought to recall their best positions when travelling and share this knowledge with the rest of the party. The collective best positions of all the particles taken together is termed as the global best position given as $GB = gb_1, gb_2, \dots, gb_N$ and the best position achieved by the individual The i th particle is referred to as the local best or place best, and the i th particle is referred to as $P_i =$

$p_{i1}, p_{i2}, \dots, p_{iN}$). Particles use both of these information to update their positions and velocities as given in the following equations

$$v_i^{j+1} = \omega v_i^j + C1 * r1 * (P_i^j - X_i^j) + C2 * r2 * (GB^j - X_i^j) \quad \text{-----}(1)$$

$$X_i^{j+1} = X_i^j + V_i^{j+1}$$

where ω is the inertia weight; $r1$ and $r2$ are random values between 0 and 1; $C1$ and $C2$ are two positive constants, called acceleration constants; generally $C1=C2=2$; j represents iteration number.

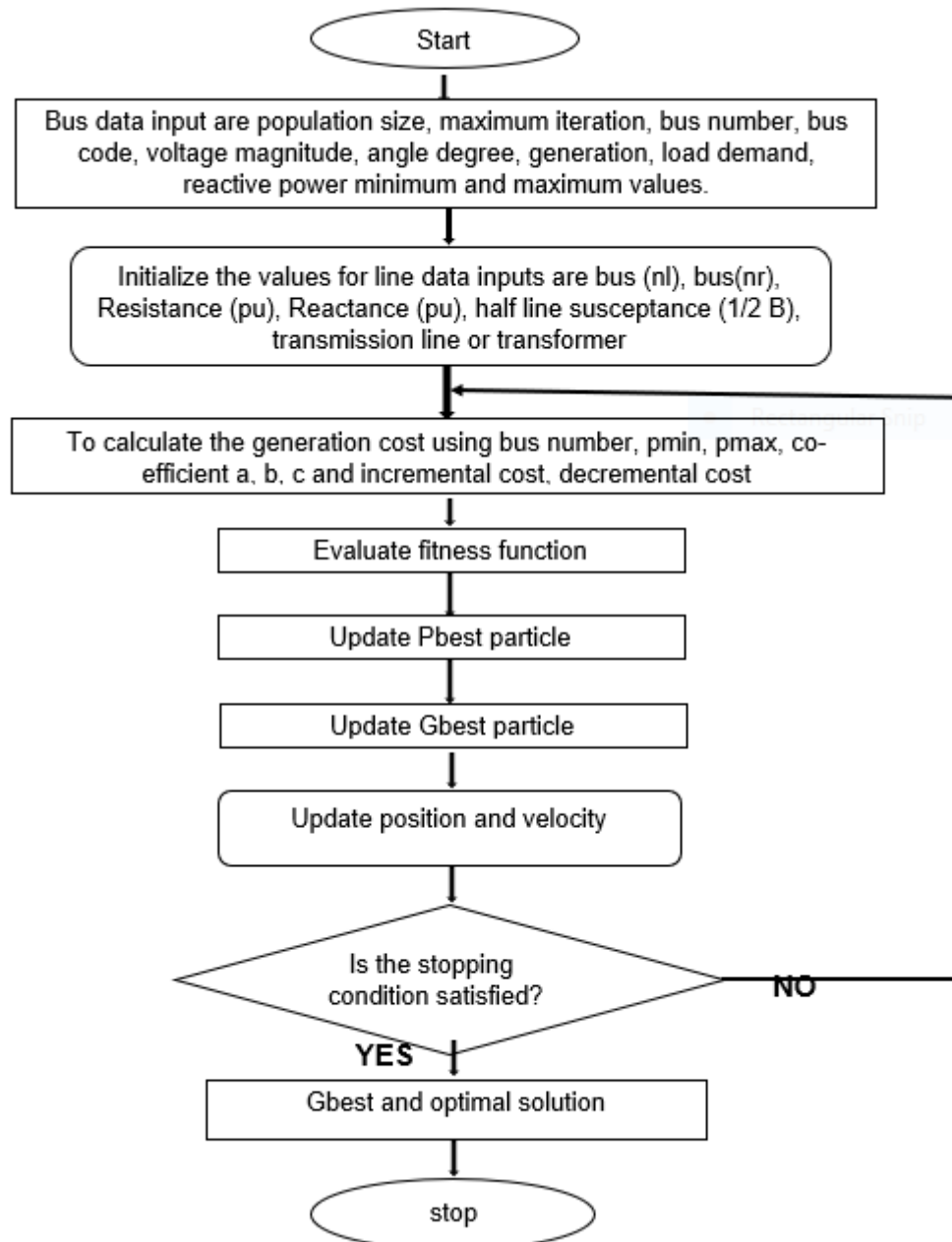
The algorithm continues until a predetermined number of maximum iterations is exceeded or exit conditions are met, in which case the particles continue to fly and seek a solution. The exactness and pace of assembly of the calculation relies upon the proper decision of molecule size, greatest speed of particles and the latency weight. However, there is no clear rule for determining particle size. Moreover, it also varies from problem to problem. As a consequence, it must be chosen by trial and error. Individual particle maximum velocities should be carefully selected. If the maximum velocity, V_{max} , is too high, the particles may fly past the best solution without discovering it and if it is too low particles may fail to explore sufficiently beyond local solutions. For the algorithm's convergence, the inertia weight parameter is critical. It regulates the local and global exploration capabilities of particles by controlling the effect of previous history of velocities on current velocities.

Exploration, i.e., searching newer areas, is facilitated by a large inertia weight, while exploitation, i.e., finer searching of the current search field, is facilitated by a small value. The inertia weight parameter is usually set to a value between 0.4 and 0.9. As a result, choosing an inertia weight should be performed with caution. PSO does not include knowledge about the derivative of functions in the process model, unlike conventional optimization algorithms. The algorithm will continue to run as long as fitness values for the optimization model can be computed. Furthermore, the PSO algorithm is simple enough for everyone to understand while still having a solid intellectual base.

PSO has already been used to solve a variety of power system optimization problems. PSO has been used to address the problem of cost-effective generator dispatch in a power grid. In order to preserve power system security from the

perspective of voltage stability, a technique for regulating reactive power and voltage has been proposed. The use of PSO for sensitivity-based congestion management has been addressed. It does not, however, disclose the method for dealing with constraints. The PSO algorithm used in this paper has been tweaked to handle constraints differently than the conventional penalty function process.

3.1.1.1 FLOWCHART OF PARTICLE SWARM OPTIMISATION ALGORITHM



3.1.1.2 Explanation

To solve the optimisation problem the solution produced with particle swarm optimisation algorithm. Start the program and give Bus data input are population size, maximum iteration, bus number, bus code, voltage magnitude, angle degree, generation, load demand, reactive power minimum and maximum values. Initialize the values for line data inputs are bus (nl), bus(nr), Resistance (pu), Reactance (pu), half line susceptance($1/2 B$), transmission line or transformer. The generation cost is calculated by using bus number, pmin, pmax, co-efficient a,b,c and incremental cost, decremental cost. Fitness function evaluated. Position and velocity of the particle is updated. If the solution satisfy the condition, take it has the solution is best solution. Stop the program. otherwise, go to the calculation of generation cost and do these steps till get the best solution which is satisfy the condition and stop the program.

3.1.1.3 Advantages

- simple concept
- easy implementation
- robustness to control parameters
- better computational efficiency

3.1.1.4 Disadvantages

- In a high-dimensional space, it's easy to collapse into a local optimum.
- The iterative method has a poor convergence rate.
- The computational complexity is not suitable for solving the high-dimensional and complex problems.

3.1.2 FLOWER POLLINATION ALGORITHM

In this paper we propose the flower pollination algorithm. It is a nature inspired algorithm. This algorithm is stimulated by pollination processes of flowers and its developmental characteristics. It is estimated that there are over a quarter of a million types flowering plants in Nature and that about 80% of all plant species are flowering species. The origins of flowering plants in the Cretaceous period are still a mystery. Flowers have had such an effect on nature that we can't imagine what the plant world would be like without them. Flowering plants have been growing for over 125 million years, and flowers have been so influential in evolution that we can't imagine what the plant world would be like without them.

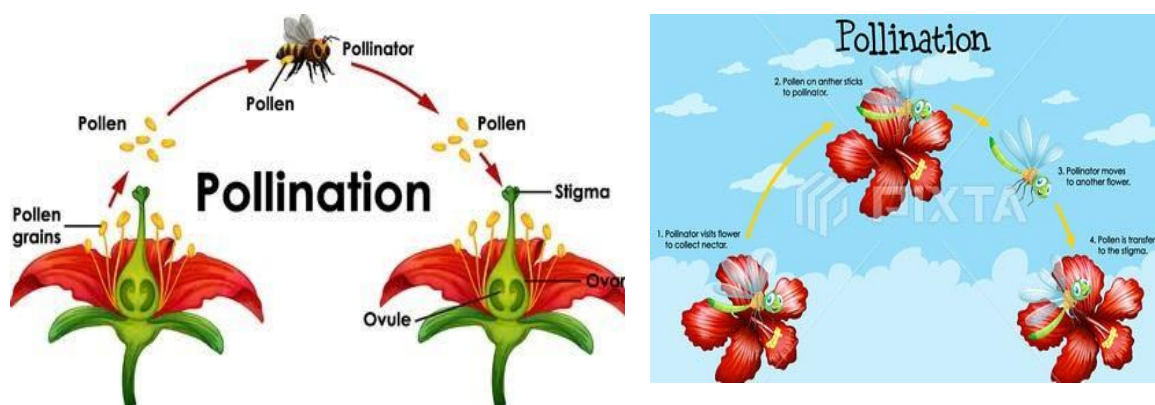


Fig 3.1.2 pollination process of flowers

The main aspect of flower pollination is reproduction of flowering plants. This is the optimisation method of plants. The reproduction occurs through pollination in the flower. In the diagram for pollination process of flowers in fig 3.2.6. Pollination is the act of transferring pollen by using pollinated such as insects, birds and other animals. In reality, some flowers and insects have established a highly specialised flower-pollinator relationship. Some flowers, for example, can only attract and rely on a particular species of insect for pollination success.

3.1.2.1 Two types of pollination

- Biotic or Cross pollination
- Abiotic or Self pollination

The diagram for types of pollination are given in fig 3.1.2.1 and fig 3.1.2.1.1

Biotic - pollen is transferred from one flower to other flower in different plant by using pollinated. It may appear at long distance. This also called as global pollination.

Abiotic – the pollen is transferred to the flower itself or other flower in same plant. In this process pollen is transferred to wind and water. It is also called as local pollination.

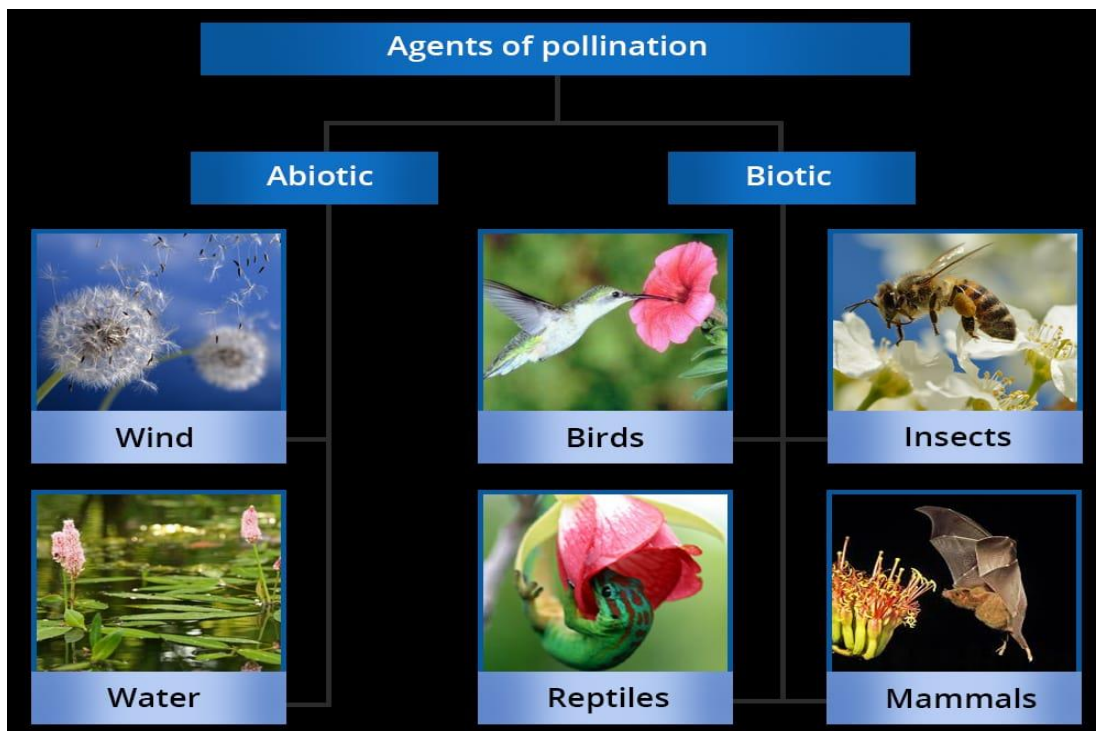


Fig 3.1.2.1 Agents of pollination

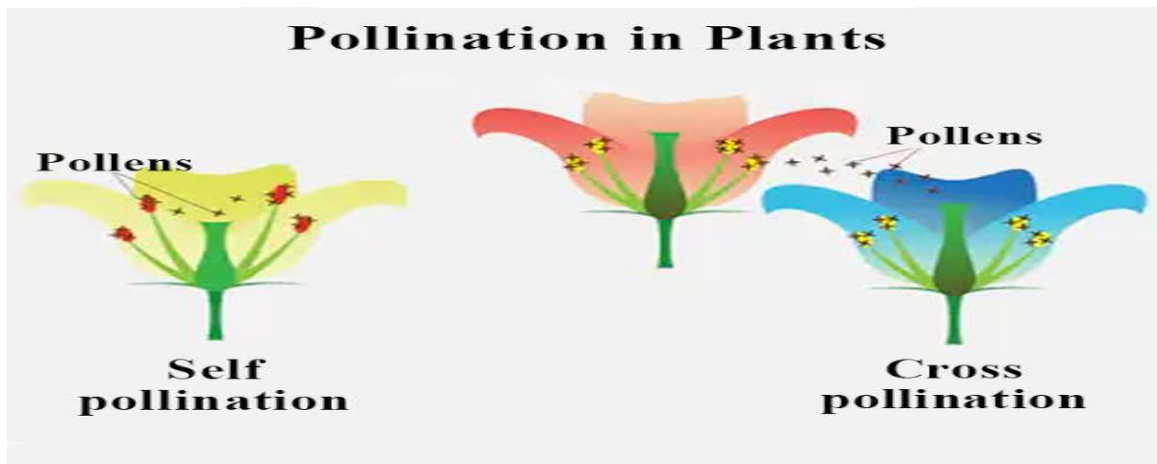


Fig 3.1.2.1.1 Types of pollination

The following rules apply to the above characteristics of pollination mechanism, flower constancy, and pollinator behaviour:

1. With pollen-carrying pollinators conducting Levy flights, biotic and cross-pollination is considered a global pollination method.
2. Local pollination includes abiotic and self-pollination.
3. Flower constancy is characterised as the likelihood of two flowers reproducing in proportion to their similarity.
4. A switch probability p determines whether local or global pollination occurs. 1 and 0

Local pollination can account for a significant proportion p of overall pollination activities due to physical proximity and other factors such as wind. In fact, each plant can produce multiple flowers, and each flower patch can produce millions, if not billions, of pollen gametes. For the sake of convenience, we'll say that each plant has only one flower and that each flower produces only one pollen gamete. As a result, there is no need to differentiate between a pollen gamete, a flower, a plant, or a problem solution. Because of this, a solution x_i is the same as a flower and/or a pollen gamete. For multi-objective optimization problems, we can easily expand to multiple pollen gametes for each flower and multiple flowers in future studies. We may develop a flower-based algorithm, namely, flower pollination algorithm, based on the above discussions and idealised characteristics (FPA). Global pollination and local pollination

are the two most important steps in this algorithm. Flower pollens are carried by pollinators such as insects in the global pollination step, and pollens can travel a long distance because insects can also fly and move across a much longer area. As a result, we represent the most fittest as g^* , which ensures pollination and reproduction of the most fittest.

Mathematical representation of flower

$$X_i^{t+1} = X_i^t + L(X_i^t - g^*) \quad \text{-----}(2)$$

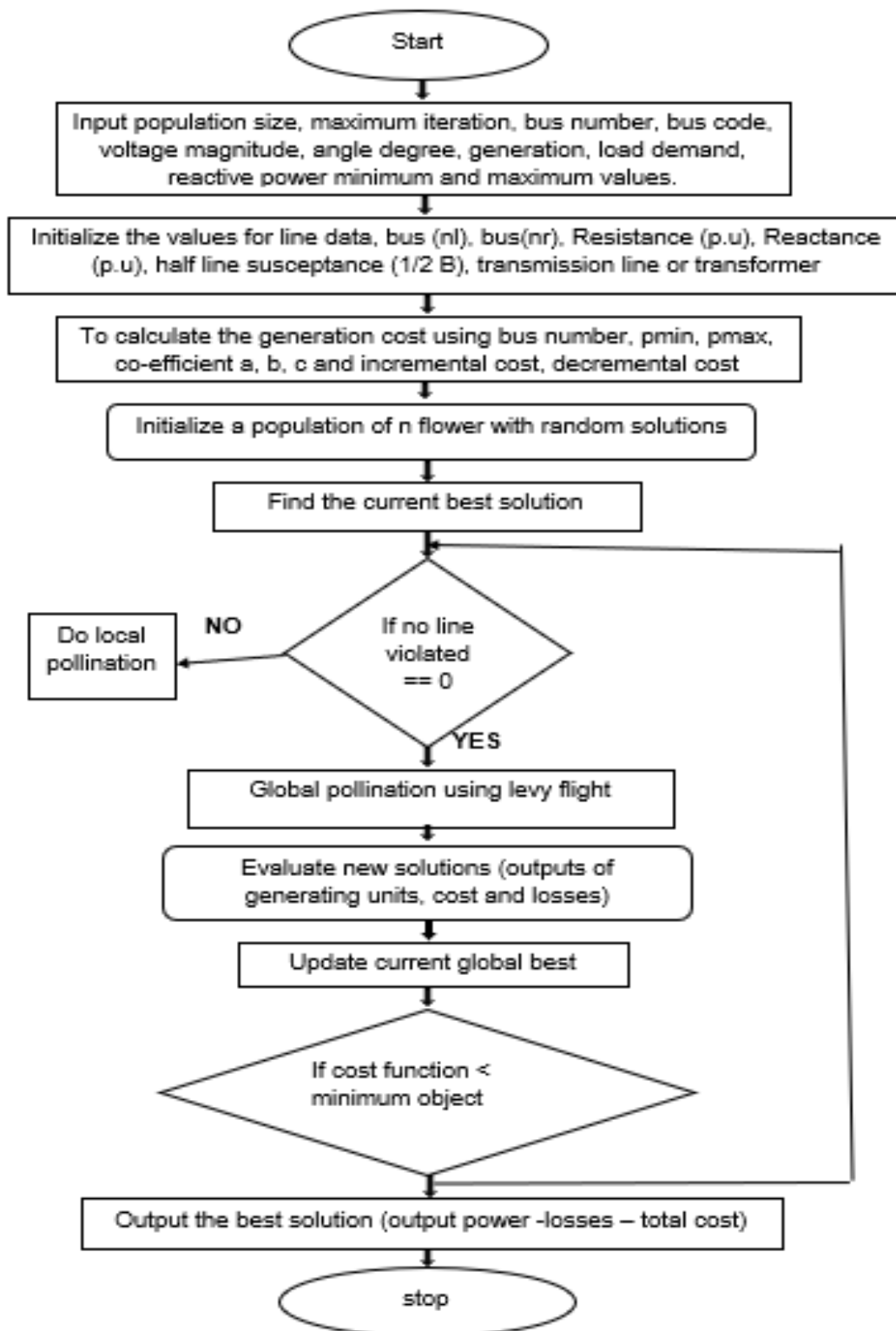
X_i = pollen, t = iteration, g^* = current solution, L = strength of pollination

3.1.2.2 The following steps are required to solving optimisation problem

- Define a minimum and maximum of pollen or flower.
- Initialize a population flower or pollen with arbitrary solution.
- Calculate the best solution in the initial population.
- Define a switch probability
- Do the local or global pollination
- Find the current solution

FPA also satisfies the exploration and exploitation and it has quick convergence.

3.1.2.3 FLOWCHART OF FLOWER POLLINATION ALGORITHM



3.1.2.4 Explanation

To solve the optimisation problem the solution produced with Flower pollination algorithm. Start the program and take the Bus data input are population size, maximum iteration, bus number, bus code, voltage magnitude, angle degree, generation, load demand, reactive power minimum and maximum values. Initialize the values for line data inputs are bus (nl), bus(nr), Resistance (pu), Reactance (pu), half line susceptance ($1/2 B$), transmission line or transformer. The generation cost is calculated by using bus number, pmin, pmax, co-efficient a,b,c and incremental cost, decremental cost. Population of N flower is initialized and find the current solution. If no line is violated do local pollination. If line is violated than zero do the global pollination. Then, evaluate new solution from the output of generating unit, cost and losses. Update the current solution. If the result of cost function is lessor than the minimum object, take the output as the best solution. The output power of best solution is greater than the sum of losses and total cost. The stop the program. If the cost function is greater than the minimum object check the line is violated or not. Repeat these steps till get the best solution and then stop the program.

3.1.2.5 Advantages

- Simple implementation
- flexible and exponentially better to solve optimization problems.
- FPA can be used for solving both single objective and multi-objective optimization problems.
- As compared to other optimization strategies, FPA saves time, improves results, and improves performance.
- FPA appears to be very interesting and is still in its infancy, but it can be used for medical image analysis.

3.1.2.6 Disadvantages

- premature convergence
- poor exploitation ability
- this simple evolution pattern is inefficient

- the different solution vector may contain different quality of components.
- Subsequently, some top notch parts at certain measurements may improve the current individual, while some sub-par segments may bring about a degeneration marvel at some specific measurements.

3.2 PROPOSED METHODOLOGY

3.2.1 GRASSHOPPER OPTIMISATION ALGORITHM

In this section we are going to discuss about Grasshopper optimisation algorithm as a proposed methodology. In this paper we propose the Grasshopper optimisation algorithm and challenging problems are solved by this algorithm. For solving optimisation problems, this algorithm was inspired by the behaviour of grasshopper swarms in nature. It is a nature inspired, population-based algorithm and swarm intelligence optimisation technique.

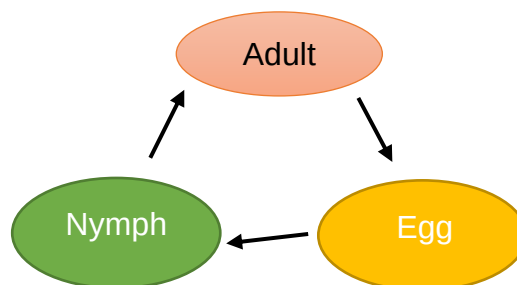


Fig 3.2.1 Grasshopper and its lifecycle

Grasshopper are kind of insects. The lifecycle of grasshopper has three stages.

- Egg
- Nymph
- Adult

Grasshopper are damage the crop production and agriculture. Grasshopper are normally, seen individually in nature. They join in the largest swarm. Swarming

behaviour is both nymph and adult are the unique feature of the grasshopper. In fig 3.3.1 the diagram for grasshopper and its lifecycle is given.

3.2.1.1 Nymph

- Millions of grasshoppers jump and move like rolling cylinders.
- The grasshopper's larval phase is characterised by slow movement and small steps.
- Migrate over small distances.

3.2.1.2 Adult

- adult grasshopper forms the largest swarm in the air.
- Larval phase is long range and abrupt moment.
- The adult grasshopper migrates over large distances.

Another feature of grasshopper swarm is food source seeking.

Nature inspired algorithm divide the search process into two types:

- Exploration – using for multi-modal step function
- Exploitation – using for unimodal step function

Repulsion force search allow grasshopper to explore. Attraction force allow then to explored in the regions.

Swarming behaviour of grasshopper

$$X_i = S_i + G_i + A_i \quad \text{-----}(3)$$

X_i -position of the i-th grasshopper

S_i -social interaction

G_i -gravity force on the i-th grasshopper

A_i -wind advection

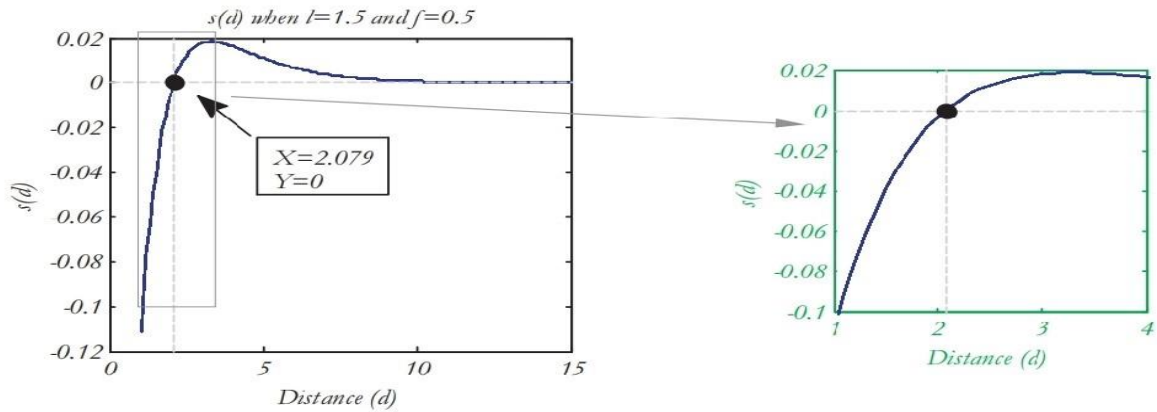


Fig 3.2.1.1 Function s when $l = 1.5$ and $f = 0.5$, range of function s when x is in $[1, 4]$

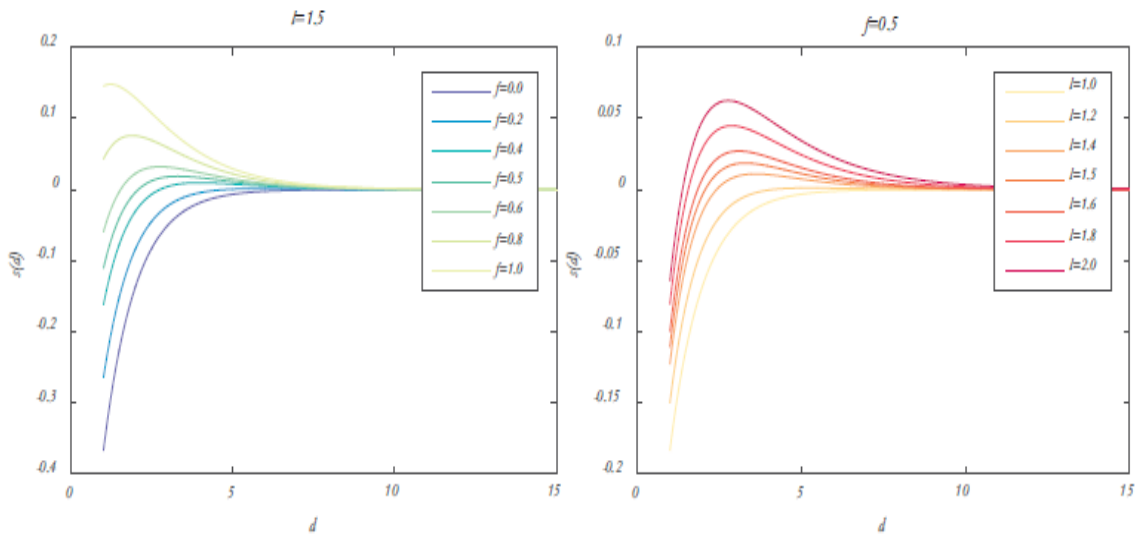


Fig. 3.2.1.2 Behaviour of the function s when varying l or f .

The function s is illustrated in Fig.3.2.1.1 to show how it impacts on the social interaction (attraction and repulsion) of grasshoppers. This diagram shows that distances between 0 and 15 are taken into account. Repulsion occurs in the interval $[0, 2.079]$. There is neither attraction nor repulsion when a grasshopper is 2.079 units away from another grasshopper. The "comfortable distance" or "comfortable zone" is the term used to describe this situation. Fig. 3.2.1.2 also shows that the attraction increases from 2.079 unit of distance to nearly 4 and then gradually decreases. Changing the l and f parameters in causes artificial grasshoppers to behave in various ways. The function s is re-drawn in Fig. 3.2.1.2 with l and f independently varied to see the effects of these two parameters. This figure shows that the boundaries l and f

change safe place, fascination area, and aversion locale altogether. It should be noted that the attraction or repulsion regions are very small for some values ($l = 1.0$ or $f = 1.0$ for instance). We selected $l = 1.5$ and $f = 0.5$ from all of these options. A conceptual model of the interactions between grasshoppers and the comfort zone using the function s is illustrated in Fig.3.2.1.2. This social interaction was the driving force behind some earlier locust swarming models, in a simplified form. Although the function s can divide the space between two grasshoppers into repulsion, comfort, and attraction zones, with distances greater than 10 it returns values close to zero, as shown in Figs. 3.2.1.2 and 3.2.1.3. As a result, this feature is unable to apply strong forces between grasshoppers separated by a wide distance. We mapped the grasshopper's distance to solve this problem.

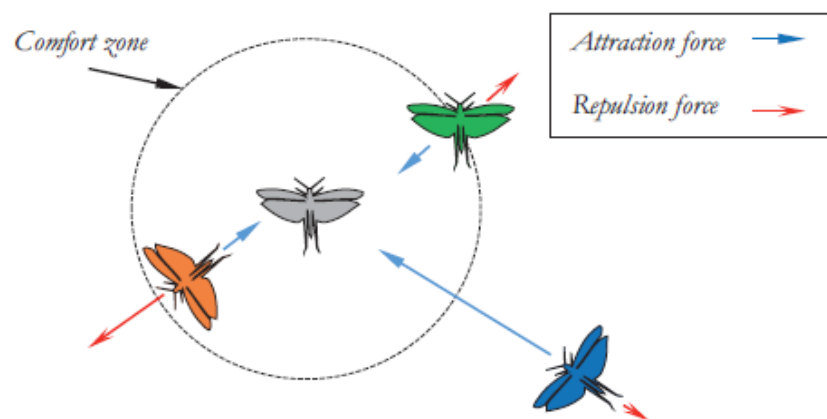


Fig 3.2.1.3 Primitive corrective patterns between individuals in a swarm of grasshoppers.

A grasshopper's next position is calculated using its current position, the target's position, and the positions of all other grasshoppers. It's worth noting that the first part of this equation takes into account the current grasshopper's position in relation to other grasshoppers. In fact, the status of all grasshoppers was taken into account when determining the position of search agents around the target. This is not to be confused with PSO, which is the most well-known swarm

intelligence strategy in the literature. In PSO, there are two vectors for each particle: position and velocity vector. In GOA, however, each search agent has only one location vector. PSO changes particle positions in relation to current position, personal best, and global best, which is another major distinction between these two algorithms. GOA, on the other hand, updates a search agent's position based on its current position, global best, and all other search agents' positions. This means that in PSO, none of the other particles help update a particle's location, while in GOA, all search agents must participate in determining each search agent's next position.

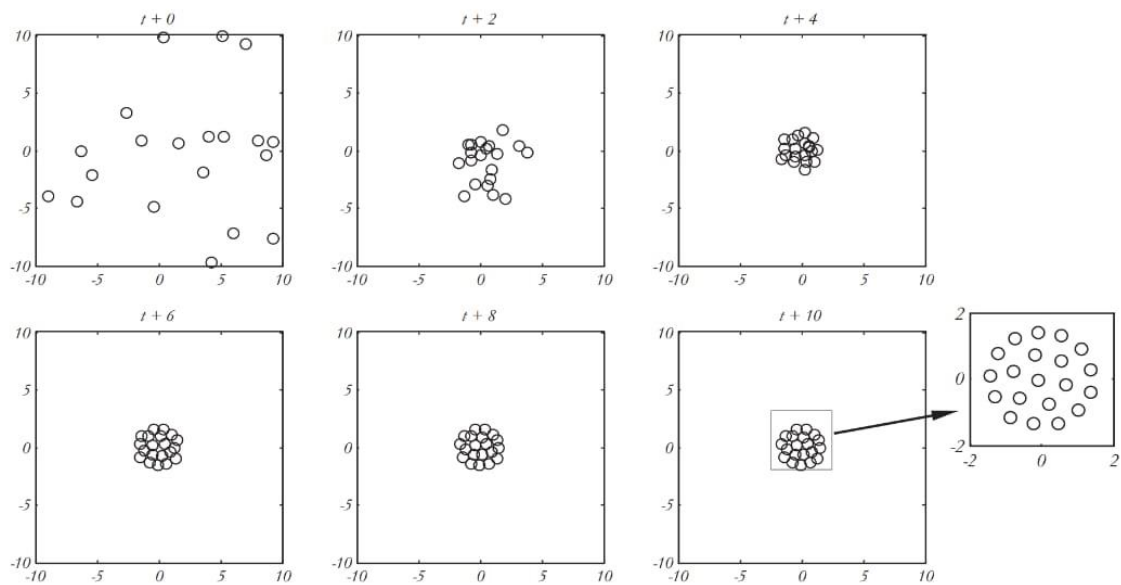


Fig. 3.2.1.4. Behaviour of swarm in a 2D space.

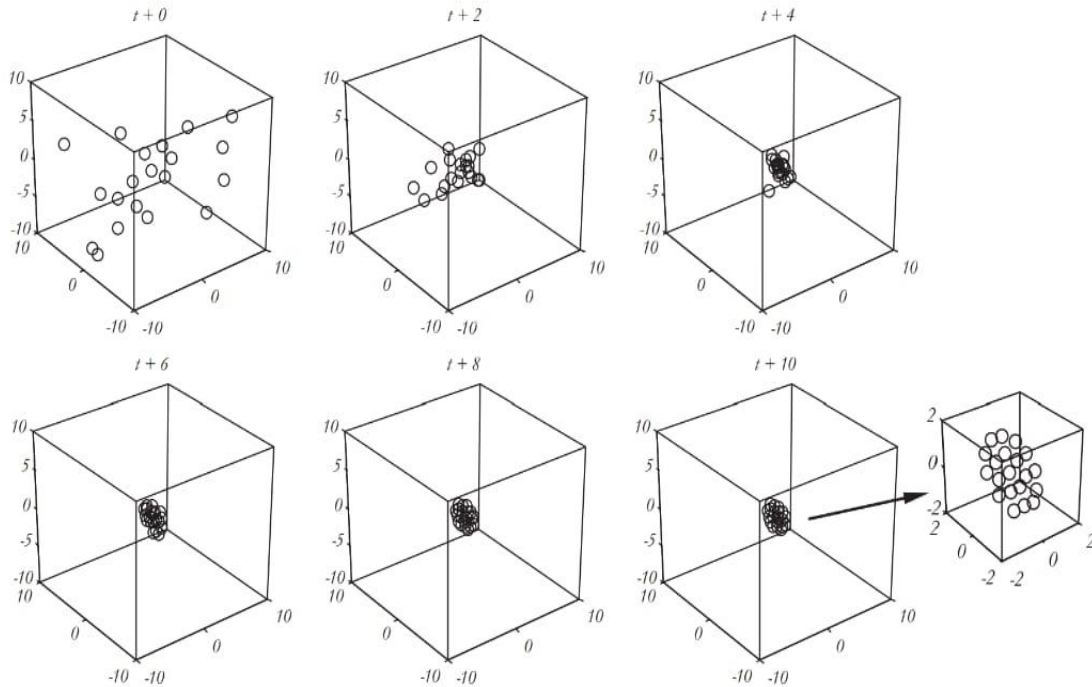


Fig. 3.2.1.5. Behaviour of swarm in a 3D space.

The behaviour of two swarms in 2D and 3D space are shown in Figs 3.2.1.4 and 3.2.1.5. In these two diagrams, a total of 20 artificial grasshoppers must move in ten units of time. Fig. 3.2.1.4 shows the initial random population closer until they form a united, regulated swarm. After ten units of time, all of the grasshoppers have entered their comfort zone and have stopped moving. The same behaviour is observed in a 3D space in Fig 3.2.1.5. This demonstrates that the mathematical model can simulate a swarm of grasshoppers in two-dimensional, three-dimensional, and hyper-dimensional spaces. However, since the grasshoppers easily enter their comfort zone and the swarm does not converge to a specific stage, this mathematical model cannot be used to solve optimisation problems directly. The inner b contributes to the reduction of repulsion/attraction forces between grasshoppers proportional to the number of iterations, while the outer b reduces the search coverage around the target as the iteration count increases. Takes into account the location of other grasshoppers and simulates grasshopper interaction in nature. The c parameter simulates grasshoppers decelerating as they approach and consume food. Individual words may be multiplied with random values to generate unpredictable actions in grasshopper interaction or food source choice.

The mathematical formulations presented here are capable of exploring and exploiting the search space. However, there should be a mechanism to require the search agents to tune the level of exploration to exploitation. Since grasshopper larvae lack wings, they must travel and hunt for food locally in nature. They can then freely travel through the air and explore a much larger area. However, in stochastic optimisation algorithms, discovery comes first since promising regions of the search space must be found. Following the discovery of promising areas, exploitation forces search agents to look for a reliable approximation of the global optimum locally.

For balancing exploration and exploitation, the parameter b is required. The co-efficient b is proportional to number of iterations.

$$b = b_{max} - \frac{t(b_{max} - b_{min})}{T} \text{-----(4)}$$

b = co-efficient

b_{max} = maximum value

b_{min} = minimum value

t = current iteration

T = maximum number of iterations.

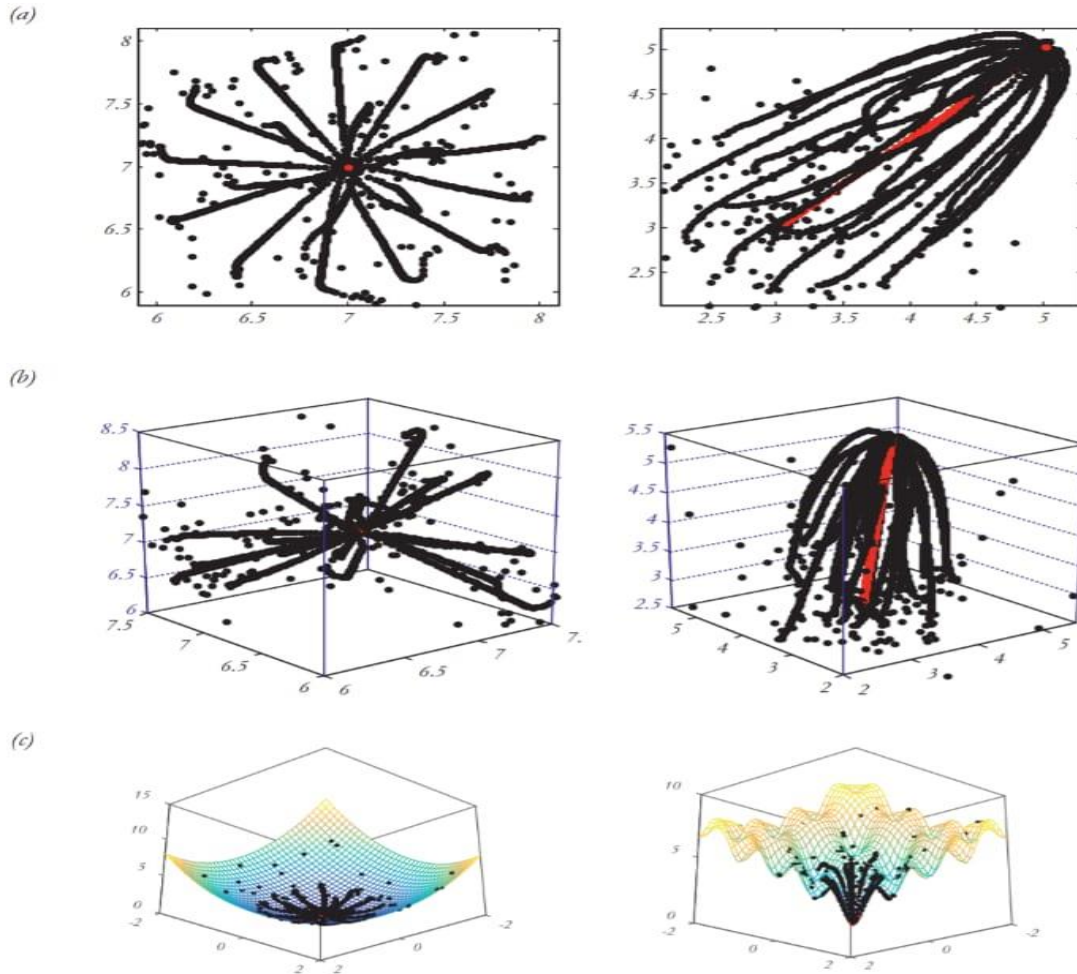
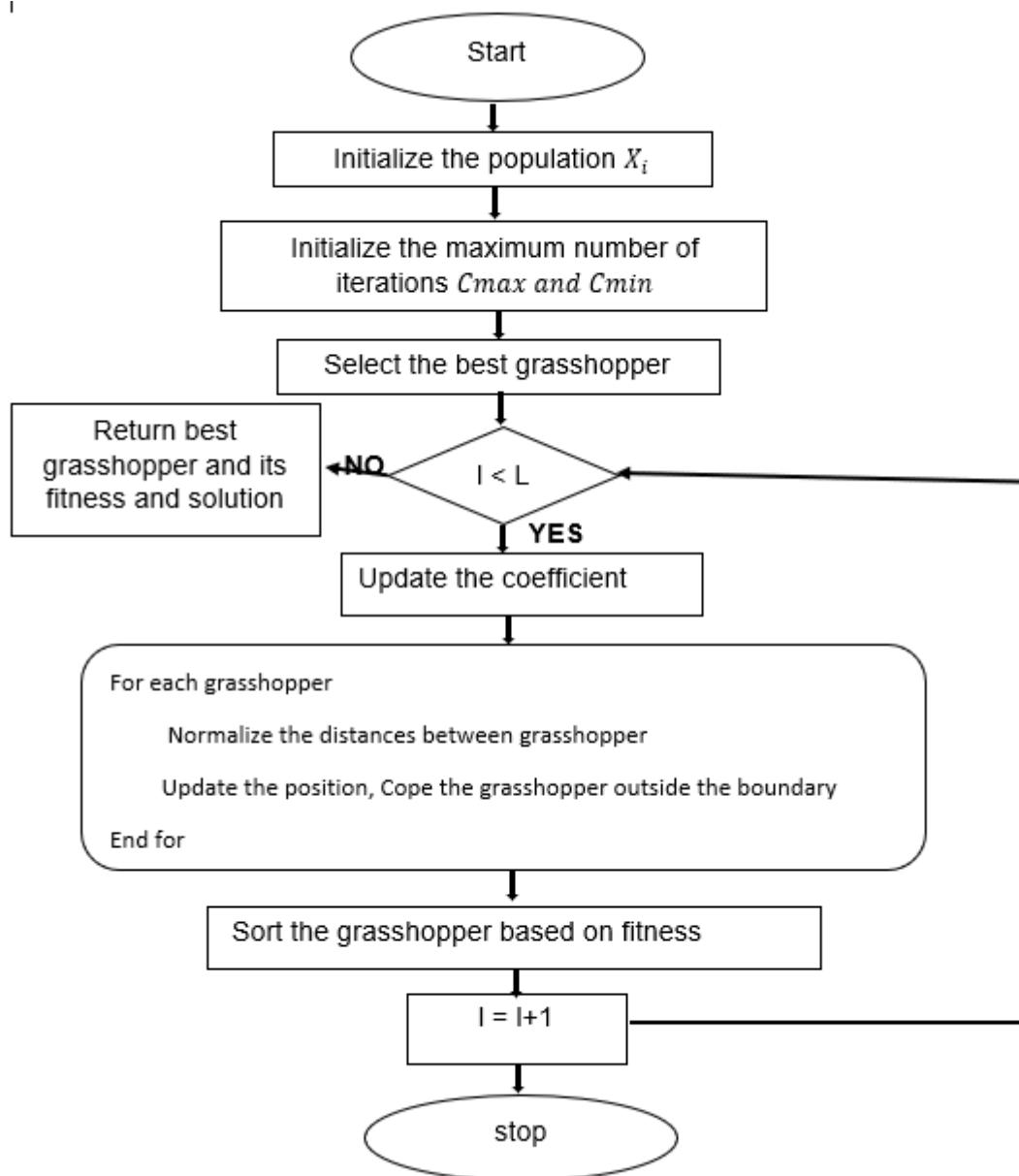


Fig. 3.2.1.6. (a) Behaviour of grasshoppers around a fixed and versatile objective in 2D space and (b) 3D space (c) Behaviour of grasshoppers on a unimodal test work and a multi-modular test work.

Figure 3.2.1.6 depicts the influence of this parameter on grasshopper movement and convergence. The sub-figures show the evolution of grasshopper positions over 100 iterations. We tested the swarm's behaviour on both stationary and mobile targets to see how it approaches and chases them. In both 2D and 3D spaces, the swarm converges gradually towards a stationary target, as seen in this diagram. This behaviour is due to reducing the comfort zone by the factor c Fig3.2.1.6 also shows that the swarm properly chases a mobile target as well. Grasshoppers are

attracted towards the target. The gradual convergence of grasshoppers towards the goal over the course of iteration, which is again due to decreasing the factor c , is an intriguing pattern. These behaviours can help the GOA algorithm avoid being stuck in local optima by allowing it to converge to the target more slowly. Grasshoppers, on the other hand, can converge as far as possible towards the target in the final stages of optimization, which is crucial in exploitation.

3.2.1.7 FLOWCHART OF Grasshopper optimisation algorithm



3.2.1.8 Explanation

To start the program. The position of swarm, Population size, Max number of iterations, maximum and minimum of coefficients, and fitness function definition are initialized. The best grasshopper is selected. The fitness of each search agent is calculated. The best search agent is assigned. Check the number of iterations is less than the maximum number of iterations. If the condition is satisfied Update the coefficients and position of current search agent. For each Grasshopper the between the grasshopper is normalized after, checking the boundaries of current search agent. Increase the number of iterations and check the above condition. If the condition is satisfied proceed these steps again and again. Otherwise, set the output as the best solution and return best grasshopper and its fitness. The optimisation criterion is evaluated and generation cost is calculated. Stop the program.

3.2.1.9 Advantages

- One of the most common modern meta-heuristic optimization algorithms is the grasshopper algorithm.
- It's been used to solve optimization problems in a number of fields, including engineering design, wireless networking, machine learning, image processing, power system management, and more. Grasshopper optimization algorithm avoids local optima and able to find the global optima in the given space.
- GOA balances exploration and exploitation to find the global optimum solution of optimization problem.
- Grasshoppers are able to find the most promising region from the given search space.
- For unconstrained optimization problem the GOA gives accurate solutions. The GOA-derived optimum point is precise and promising.

The GOA also gives correct and promising results for constrained optimization problem.

CHAPTER 4

RESULT AND DISCUSSION

In this section we are going to discuss about the result which is obtain from the algorithm such as PSO, FPA and GOA in congestion management.

4.1 PARTICLE SWARM OPTIMISATION ALGORITHM

We discuss about the result which is obtain from Particle Swarm optimisation algorithm

4.1.1 Facts device are connected to remove congestion

TCSC connected in the line 31 and its value = 1.05 pu

SVC connected in the bus 28 and its value = 0.14 pu

Operating limit	TCSC (pu)	SVC (pu)
Minimum limit	-1.05	-0.15
Maximum limit	1.05	0.15
Location	3	28

In the system, facts devices are connected to remove congestion using Particle Swarm Optimisation Algorithm (PSO). Those facts devices are Thyristor controlled series capacitor (TCSC), Static var compensator (SVC). The data for TCSC and SVC are given in table5. The data are obtained in terms of reactance-susceptance limit.

4.1.2 COST

In this
we

S.No	Description	PSO
1.	Gen. Cost (\$/hr)	899.485
2.	Cong. Cost(\$/hr)	4225.859
3.	Operating Cost (\$/hr)	5125.344
4.	Power Loss (MW)	11.672

table

described the different cost amount and power loss in congestion management using Particle Swarm Optimisation Algorithm.

4.2 FLOWER POLLINATION ALGORITHM

We discuss about the result which is obtain from Flower Pollination Algorithm.

4.2.1 Facts device are connected to remove congestion

TCSC connected in the line 31 and its value = 1.05 pu

SVC connected in the bus 28 and its value = 0.15 pu

Operating limit	TCSC (pu)	SVC (pu)
Minimum limit	-1.05	-0.15
Maximum limit	1.05	0.15
Location	3	28

In the system, facts devices are connected to remove congestion using Flower pollination algorithm (FPA). Those facts devices are Thyristor controlled series capacitor (TCSC), Static var compensator (SVC). The data for TCSC and SVC are given in table5. The data are obtained in terms of reactance-susceptance limit.

4.2.2 COST

S.No	Description	FPA
1.	Gen. Cost (\$/hr)	906.211
2.	Cong. Cost(\$/hr)	3015.044
3.	Operating Cost (\$/hr)	3921.255
4.	Power Loss (MW)	11.297

In this table we described the different cost amount and power loss in congestion management using Flower Pollination Algorithm.

4.3 GRASSHOPPER OPTIMISATION ALGORITHM

We discuss about the result which is obtain from Grasshopper optimisation algorithm.

4.3.1 Table I. LOAD DEMANDS

Bus number	Load demand
1	0
2	0
3	322
4	500
5	0
6	0
7	233.8
8	522
9	0
10	0
11	0
12	7.5
13	0
14	0
15	320
16	329
17	0
18	158
19	0
20	680
21	274
22	0
23	247.5
24	308.6
25	244
26	139
27	281

28	206
29	283.5
30	9.2

In this table load demands are presented with respective bus numbers. Load demand is determined by applying the demand factor to each of connected load and a diversity factor to the sum total. Here, power factor is 0.9, so the losses will be reduced.

4.3.2 Table II. DEMAND RESPONSE IMPLEMENTATION

Demand response number	Bus number
1	4
2	8
3	15
4	20
5	24
6	26
7	28

Table 4.3.2 contains selected buses for response implementation. To reduce the transmission line congestion, seven load buses are selected for participation of demand response based on their potential according to generation shift factor. Demand response is a policy used by electric utility companies to decrease or modify the energy dissipation from peak hours of the day, when the demand for electricity is the highest to leaner demand periods.

4.3.3 Table III. SELF AND CROSS ELASTICITY

Description	Peak	Off-peak	Low
Peak	-0.1	0.016	0.012
Off-peak	0.016	-0.1	0.01
Low	0.012	0.01	-0.1

Self and cross elasticity values are presented in table 4.3.3. These elasticity values are used for simulating the demand response participants. When the load is high in peak hours, to manage the congestion shift the load from peak hours to off-peak hours or low peak hours. The elasticity of demand is an economic concept. It assesses how responsive consumers are to changes in the quantity demanded of one good as the price of another changes.

4.3.4 Table IV. GENERATION COST FUNCTION COEFFICIENT

Generator bus number	Co-efficient A	Co-efficient B	Co-efficient C
1	0	1	0.0175
31	0	2	0.0037
32	0	1.75	0.0175
33	0	1	0.0625
34	0	3.25	0.0083
35	0	3	0.025
36	0	3	0.025
37	0	2	0.0037
38	0	1.75	0.0175
39	0	1	0.0625

The values of generation co-efficient are presented in table 4.3.4. These co-efficient are useful for cost minimization. The incentive and penalty amount for demand response are consider as fixed values. The cost function is used for calculate the cost of power generated by the generator.

$$\text{cost function} = A_i \cdot x^2 + B_i \cdot x + C \quad \text{-----}(5)$$

$i=1,2,3,\dots,N$ where, A,B,C - cost function coefficients. N = number of generators.

4.3.5 Table V. POWER GENERATION

Generation bus number	Generation (MW)
1	514.627
31	372.441
32	589.117
33	629.263
34	641.873
35	650.937
36	555.205
37	635.941
38	631.02
39	974.392

The data for Generation participation in electricity market are presented in table 4.3.4. Generator bus number and their respective generated power in MW are scheduled in this table4.3.5.

4.3.6 Table VI. Facts device are connected to remove congestion

TCSC connected in the line 31 and its value = -0.048pu

SVC connected in the bus 28 and its value = -0.15pu

Operating limit	TCSC(pu)	SVC(pu)
Minimum limit	-1.05	-0.15
Maximum limit	1.05	0.15
Location	31	28

In the system, facts devices are connected to remove congestion using Grasshopper optimisation algorithm (GOA). Those facts devices are Thyristor controlled series capacitor (TCSC), Static var compensator (SVC). The data for TCSC and SVC are given in table5. The data are obtained in terms of reactance-susceptance limit.

4.3.7 Table VII. Cost

S.no	Description	Values
1	Generation Cost (\$/hr)	897.78
2	Congestion Cost(\$/hr)	3016.297
3	Operating Cost (\$/hr)	3914.077
4	Power Loss (MW)	5.979

In this table we described the different cost amount and power loss in congestion management using Grasshopper Optimisation Algorithm.

4.4 COMPARISON ALGORITHM

In this section we are going to discuss about the comparison of existing and proposed methodology based on the result obtain from facts devices, cost details, power loss and convergence curve.

4.4.1 Facts devices data

	PSO		FPA		GOA	
Description	TCSC (pu)	SVC (pu)	TCSC (pu)	SVC (pu)	TCSC (pu)	SVC (pu)
Maximum limit	1.05	0.15	1.05	0.15	1.05	0.15
Minimum limit	-1.05	-0.15	-1.05	-0.15	-1.05	-0.15
Location	32	29	34	30	31	28
Values	1.05	0.14	1.05	0.15	-0.048	-0.15

PSO and FPA gives the maximum limit values as the best value and it is not good for optimal result

GOA gives the optimal value between minimum and maximum limit and gives better optimal result for removing the congestion

4.4.2 Cost

S.NO	Description	PSO	FPA	GOA
1	Generation Cost (\$/hr)	899.485	906.211	897.78
2	Congestion Cost(\$/hr)	4225.859	3015.044	3016.297

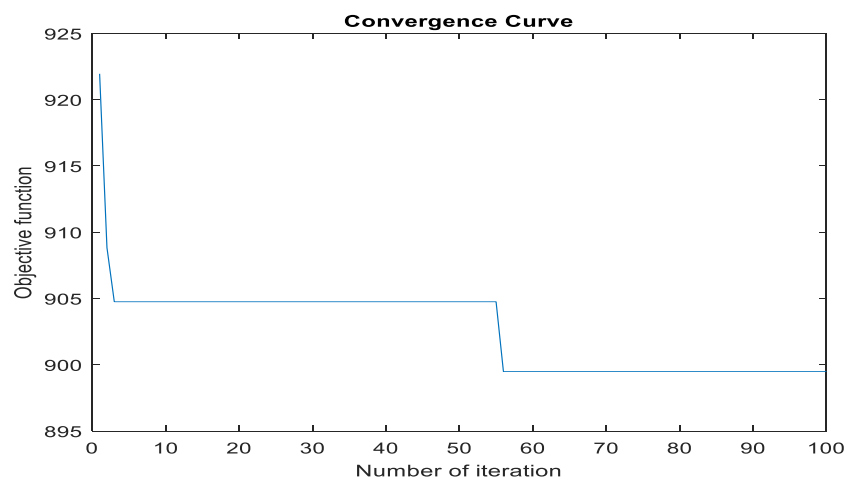
3	Operating Cost (\$/hr)	5125.344	3921.255	3914.077
4	Power Loss (MW)	11.672	11.297	5.979

PSO and FPA gives the more power losses and high cost has best solution it is not economical.

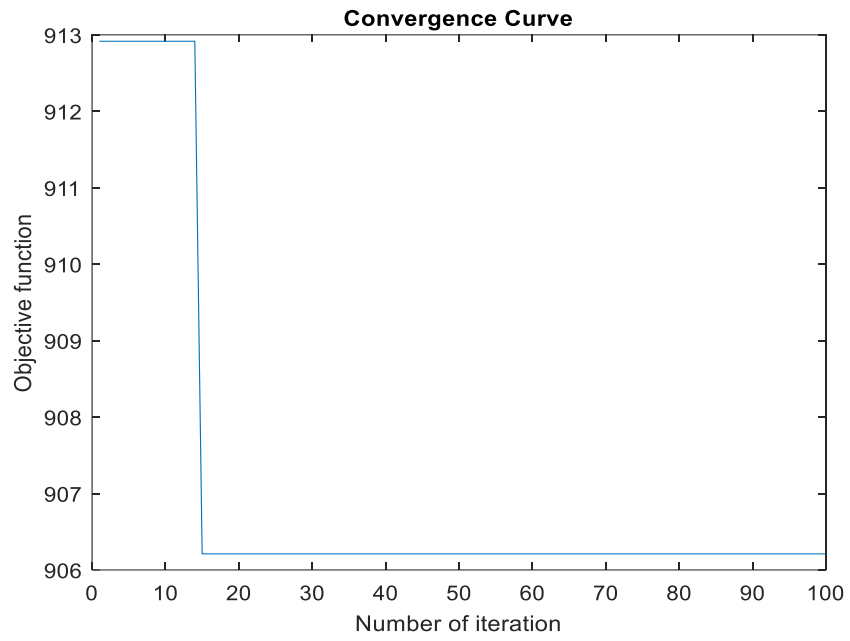
GOA gives less power loss and low cost has best solution. It is better than FPA.

4.5 CONVERGENCE CURVE

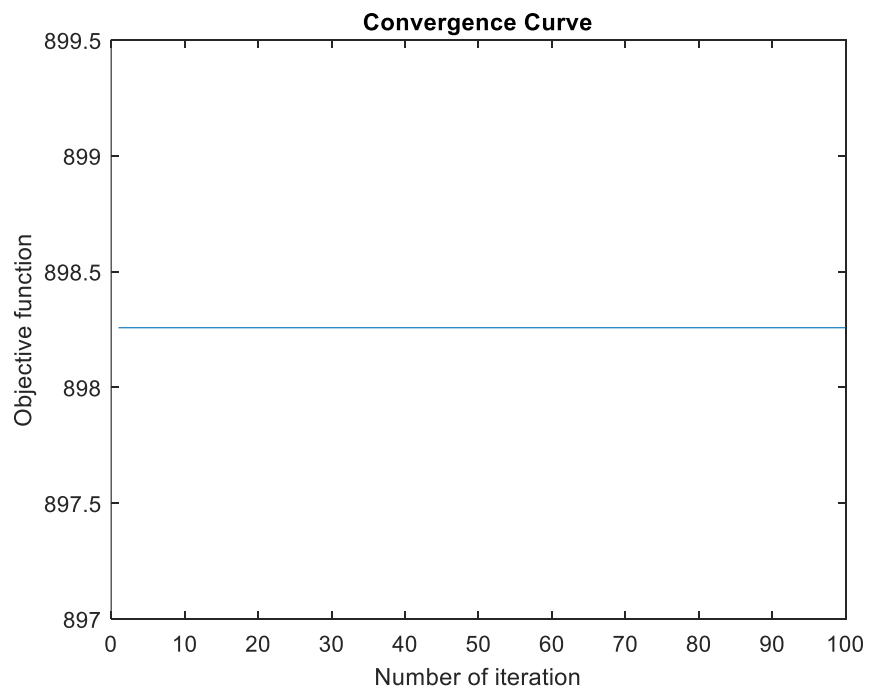
4.5.1 PSO



4.5.2 FPA



4.5.3 GOA



CHAPTER 5

5.1 Conclusion

In this paper we proposed the comparison of Grasshopper optimisation algorithm and flower pollination algorithm in congestion management. For solving optimisation problems, the grasshopper optimisation algorithm mathematically modelled and mimicked the swarming behaviour of grasshoppers in nature. GOA was proposed to simulate repulsion and attraction forces between the grasshoppers. Repulsion forces permit grasshoppers to explore and attraction forces allow them to exploit. Grasshopper optimization algorithm was furnished with a coefficient to balance exploration and exploitation. The best solution gained by the GOA. Flower pollination algorithm is inspired by the pollination process of flowers, its evolutionary characteristics can be used to solve the optimisation problem. FPA was proposed to simulate long distance pollinators and flower consistency. Long distance pollinators act as exploration moves. Flower consistency is essential for exploitation step. The particle swarm optimisation algorithm inspired by the social behaviour of organisms such as fish schooling and bird flocking. Using this algorithm the best solution is found out from a solution space with a population based search procedure in which the particles change their position with time. The convergence of the PSO algorithm depends on the acceptable selection of particle size, inertia weight and maximum velocity of particles, improper choice of those parameters may cause inferior results or nonconvergence. Finally, results have shown that the grasshopper optimisation algorithm is more efficient than flower pollination algorithm. GOA has the potential to significantly outperform several current algorithms when solving a variety of current or new optimisation. Grasshopper optimisation algorithm is able to improve the initial random population for a real problem and goa gives accurate global optimum which is proportional to the number of iterations. GOA is able to solve real problems with unknown search spaces and has a good convergence rate which is better than the convergence rate of FPA.

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