"CONGESTION MANAGEMENT IN POWER SYSTEM USING SOFT COMPUTING TECHNIQUE"

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power Systems)

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CERTIFICATE

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ABSTRACT

During previous couple of eras, restructuring has handed all viable areas comprising the electrical energy deliver industry. Restructuring has carried out sizeable benefits such that energy is these days a commodity. Competitive marketplace additionally paved manner for several participants. This ends in congestion in transmission lines. Furthermore, transmission community in open get right of entry to has bolstered the congestion problem. Therefore, energy device congestion control is maximum sizeable to the energy industry. A evaluate on one soft computing primarily based totally approach specifically Particle Swarm Optimization (PSO) is carried out on this report.

Keywords: power system; congestion management; congestion; optimization; methods.

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LIST OF ACHRONYMS

PSO	: Particle Swarm Optimization
OPF	: Optimal Power Flow
ATC	: Available Transfer Capacity
GA	: Genetic Algorithm
ACO	: Ants Colony Optimization
Pbest	: Personal Best
Gbest	: Global Best
GS	: Generator Sensitivity
TC	: Total Congestion Cost
NR	: Newton Raphson

LIST OF NOMENCLATURE

V_i	: Velocity of the particle
X_i	: Particles coordinate in the k^{th} dimension.
Pij	: Real power which flows through overloaded k^{th} line
Pg	: Useful power which is generated by generator g
G_{ij}	: Conductance between i^{th} and j^{th} bus
B_{ij}	: Admittance between i^{th} and j^{th} bus
θ_{ij}	: Phase difference of voltages between i^{th} and j^{th} bus
V_{ij}	: Voltage dimension of voltages between i^{th} and j^{th} bus
GSg	: Generator sensitivity of Generators
P_{gi}	: Active and Reactive power of i^{th} generator
P_{di}	: Active and Reactive power of i^{th} load bus
s_j^t	: Swarm is the j^{th} particle position in iteration t
v_j^{t+1}	: Velocity of the particle j in $(t+1)^{th}$ iteration
$pbest_j$	: The best position of the j^{th} particle
gbest	: The best position among all the particles in the swarm
ω	: Inertia weight
C1, C2	: Cognitive parameter and Social parameter
R1, R2	: Random numbers
t	: Iteration number
t_{max}	: Maximum iteration
L_{max}	: Voltage Stability

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CHAPTER 1: INTRODUCTION OF CONGESTION MANAGEMENT

1.1 DEFINITION OF CONGESTION

Whenever the physical or operational constraints in a transmission network become active, the system is said to be in a state of congestion. The possible limits that may be hit in case of congestion are: line thermal limits, transformer emergency ratings, bus voltage limits, transient or oscillatory stability, etc. These limits constrain the amount of electric power that can be transmitted between two locations through a transmission network. Flows should not be allowed to increase to levels where a contingency would cause the network to collapse because of voltage instability, etc. The peculiar characteristics associated with electrical power prevent its direct comparison with other marketable commodities. First, electrical energy cannot be stored in large chunks. In other words, the demand of electric power has to be satisfied on a real time basis. Due to other peculiarities, the flexibility of directly routing this commodity through a desired path is very limited. The flow of electric current obeys laws of physics rather than the wish of traders or operators. Thus, the system operator has to decide upon such a pattern of injections and take-offs, that no constraint is violated. How Transfer capability is limited? Congestion, as used in deregulation parlance, generally refers to a transmission line hitting its limit. The ability of interconnected transmission networks to reliably transfer electric power may be limited by the physical and electrical characteristics of the systems including any or more of the following:

- **Thermal Limits:** Thermal limits establish the maximum amount of electrical current that a transmission line or electrical facility can conduct over a specified time period before it sustains permanent damage by overheating.
- **Voltage Limits:** System voltages and changes in voltages must be maintained within the range of acceptable minimum and maximum limits. The lower voltage limits determine the maximum amount of electric power that can be transferred.
- **Stability Limits**: The transmission network must be capable of surviving disturbances through the transient and dynamic time periods (from milliseconds to several minutes, respectively).
  Immediately following a system disturbance, generators begin to oscillate relative to each other, causing fluctuations in system frequency, line loadings, and system voltages. For the system to be stable, the oscillations must diminish as the electric system attains a new stable operating point. The line loadings prior to the disturbance should be at such a level that its tripping does not cause system-wide dynamic instability.

The limiting condition on some portions of the transmission network can shift among thermal, voltage, and stability limits as the network operating conditions change over time. For example, for a short line, the line loading limit is dominated by its thermal limit. On the other hand, for a long line, stability limit is the main concern. Such differing criteria further lead to complexities while determining transfer capability limits. Importance of congestion management in the deregulated environment If the network power carrying capacity is infinite and if there are ample resources to keep the system variables within limits, the most efficient generation dispatch will correspond to the least cost operation. Kirchoff's laws combined with the magnitude and location of the generations and loads, the line impedances and the network topology determine the flows in each line. In real life, however, the power carrying capacity of a line is limited by various limits as explained earlier. These power system security constraints may therefore necessitate a change in the generator schedules away from the most efficient dispatch. In the traditional vertically integrated utility environment, the generation patterns are fairly stable. From a short term perspective, the system operator may have to deviate from the efficient dispatch in order to keep line flows within limits. However, the financial implication of such re-dispatch does not surface because the monopolist can easily socialize these costs amongst the various participants, which in turn, are under his direct control. From planning perspective also, a definite approach can be adopted for network augmentation. However, in deregulated structures, with generating companies competing in an open transmission access environment, the generation / flow patterns can change drastically over small time periods with the market forces. In such situations, it becomes necessary to have a congestion management scheme in place to ensure that the system stays secure. However, being a competitive environment, the re-dispatch will have direct financial implications affecting most of the market players, creating a set of winners and losers. Moreover, the congestion bottlenecks would encourage some strategic players to exploit the situation. The effects that congestion is likely to cause are discussed next. Effects of Congestion the network congestion essentially leads to out-of-merit dispatch. The main results of these can be stated as follows:

- **Market Inefficiency:** Market efficiency, in the short term, refers to a market outcome that maximizes the sum of the producer surplus and consumer surplus, which is generally known as social welfare. With respect to generation, market efficiency will result when the most cost-effective generation resources are used to serve the load. The difference in social welfare between a perfect market and a real market is a measure of the efficiency of the real market. The effect of transmission congestion is to create market inefficiency.
- **Market Power:** If the generator can successfully increase its profits by strategic bidding or by any means other than lowering its costs, it is said to have market power. Imagine a two area system with cheaper generation in area 1 and relatively costlier generation in area 2. Buyers in both the areas would prefer the generation in area 1 and eventually the tie-lines between the two areas would start operating at full capacity such that no further power transfer from area 1 to 2 is possible. The sellers in area 2 are then said to possess market power. By exercising market power, these sellers can charge higher price to buyers if the loads are inelastic. Thus, congestion may lead to market power which ultimately results in market inefficiency.

In multi-seller/multi-buyer environment, the operator has to look after some additional issues which crop up due to congestion. For example, in a centralized dispatch structure, the system operator changes schedules of generators by rising generation of some while decreasing that of others. The operator compensates the parties who were asked to generate more by paying them for their additional power production and giving lost opportunity payments to parties who were ordered to step down. The operator has to share additional workload of commercial settlements arising due to network constraints which, otherwise, would have been absent. One important thing to be noted is that creation of market inefficiency arising due to congestion in a perfectly competitive market acts as an economic signal for network reinforcement. The market design should be such that the players are made to take a clue from these signals so as to reinforce the network, thus mitigating market inefficiency. Desired Features of Congestion Management Schemes Tackling the congestion problem takes different forms in different countries. It really depends on what type of deregulation model is being employed in a particular region. Certain network topologies, demographic factors and political ideologies influence the implementation of congestion management schemes in conjunction with overall market design. Any congestion management scheme should try to accommodate the following features:

- **Economic Efficiency:** Congestion management should minimize its intervention into a competitive market. In other words, it should achieve system security, forgoing as little social welfare as possible. The scheme should lead to both, short term and long term efficiency. The short term efficiency is associated with generator dispatch, while long term efficiency pertains to investments in new transmission and generation facilities.

- **Non discriminative:** Each market participant should be treated equally. For this, the network operator should be independent of market parties and he should not derive any kind of benefit from occurrence of congestion. Otherwise it provides perverse signals for network expansion.
- **Be transparent:** The implementation should be well defined and transparent for all participants.
- **Be robust:** Congestion management scheme should be robust with respect to strategic manipulation by the market entities. This again refers back to principle of economic efficiency.

Though a variety of forms of congestion management schemes are practiced throughout the power markets of the world, the nodal pricing or the optimal power flow based congestion management scheme is said to satisfy most of the desired features of the same, especially the feature of economic efficiency. Each practiced method has strengths and flaws and also interrelationships to some extent. Each maintains power system security but differs in its impact on the economics of the energy market.

1.2 CLASSIFICATION OF CONGESTION MANAGEMENT MECHNISMS

The congestion management schemes are strongly coupled with the overall market design. Efficient allocation of scarce transmission capacity to the desired participants of the market is one of the main objectives of congestion management schemes. Thus, distinction among them can be made based on market based congestion management methods and other methods. Market-based solutions to congestion are deemed fairer as they contribute better to economic efficiency than other methods. Methods other than market based make use of some criteria to allocate the transmission capacity. These methods are supposed to introduce some kind of arbitrariness as they do not contribute towards efficient pricing of congested link. Classification of congestion management schemes on these lines is shown in Table 1.1.

Non – market Methods		**Market Based Methods**	
1	Type of contract	1	Explicit Auctioning of network capacity
2	First come first serve	2	Nodal pricing (OPF based congestion management)
3	Pro - rata methods	3	Zonal pricing
4	Curtailment	4	Price area congestion management
		5	Re - dispatch
		6	Counter trace

Table 1.1: Classification of congestion management schemes

Before moving on to see details of these methods, we first see various phases of the entire process of congestion management on timeline. This is explained with the help of Figure 1.1. As the transactions keep on committing, the system operator continuously updates the available transfer capability between various regions / areas / nodes in the system. This becomes essential because as the day-ahead (or the

spot) market approaches, the operator should have knowledge about the network capacity left for settling the market. The transmission network capacity allocation in acoordinated market may take an explicit or implicit form. In other words, there can be a separate market for transmission capacityvreservation or it may bevintegrated with the coordinated market.
Even after capacity allocation, the real time flows may lead to violation of transmission capacities. In order to relieve congestion during real time, congestion alleviation methods are employed.

1.2.1 NON-MARKET METHODS OF CONGETSION MANAGEMENT

The non-market methods of congestion management essentially refer to network capacity allocation based on some pre-defined set of rules that neglect th ability or the willingness of a player to pay for the transmission capacity. For such schemes and also for explicit market based methods, the system operator is required to know the capacity remaining with the grid, after accommodating the transactions which is nothing but ATC.

1. Capacity Allocation based on Type of Contract:
   In this type of capacity allocation, network capacity is allocated to a particular type of transactions. For example, capacity is first allocated to firm or long term transaction and in the rest of capacity, maximum possible number of short term transactions are accommodated. If in the real time operation, the re-dispatching of injections is required to be done, the short term transactions are curtailed first ahead of long term or firm transactions.

2. Capacity Allocation on First Come First Serve Basis:
   There are some systems in which the bilateral contracts are awarded for transmission network access on first come first served basis. The calculation of ATC facilitates a participant to determine whether there is enough capacity available for him to do the transaction between two nodes of concern. If enough capacity is left on the network so as to make a transaction, the participant books his transaction with the system operator. After this, the system operator updates the ATC. The nextvtransaction in line again checks whether there is enough corridor capacity available to do the transaction. The drawback associated with this mechanism is that the willingness to pay for transmission usage is not taken into account. Those participants with high valuation of transmission network may not get scheduled.

3. Capacity Allocation based on Pro-rata Methods:
   Various norms canbe set to assign network capacities on pro-rata basis. The capacities can be allocated on average load or generation, or percentage of long term transactions or maximum demand, etc. In other words, all participants receive an equal percentage of the total amount of capacity they apply for. These norms are used for capacity allocation as well as for congestion alleviation, which is used in real time. This scheme also has same limitations as in first come first served method.
   Another limitation of this method is possible strategic behaviour of the market participants. The system of pro-rata distribution of capacity can lead to market parties applying for transmission capacity much more than what they want, knowing that the actual amount that they will receive is physically limited.

4. Curtailment:
   As mentionedvearlier, a transaction-based curtailment approach is another methodology that is used for congestion management. An example is NERC's TLR procedure (Transmission Loading Relief). This method is used by PJM as a last resort after its alternative congestion management (based on LMPs as discussed earlier). In real-time operation, the ISO monitors the system for possible security violations. In the event of such violations occurring or being imminent, the TLR method of curtailing transactions is exercised. The transactions are prioritized for curtailment on the basis of criteria that consider the size of the transaction, its relative impact on the congested line flows, and the firmness level that was fixed before dispatch. We have seen that PTDFs can be used to determine the incremental impact of any system injection (or any bilateral transaction) on any line flow of interest. This method of congestion management is more reliability-driven than market-driven. In this scheme, price and the actual value of transmission are not important considerations. So, whereas this method gains reliability-wise, it might lose on the economic front.

1.2.2 MARKET METHODS OF CONGETSION MANAGEMENT

1. Explicit Auctioning of network capacity:
   The principle of explicit auctioning is based on selling the available capacity of the tie line to the highest bidder through auction. This is nothing but auctioning of the tie line capacity. The explicit auctioning separates the energy market from transmission capacity market.

   This approach is commonly used in Europe for capacity allocation at several borders. In explicit auctioning, the system operators (or the TSO in Europe) determine ex-ante, the available transmission capacity (ATC) considering security analysis, accepts bids from potential buyers and allocates the capacity to the ones that value it most. Thus, explicit auctioning is a market based concept, which provides economic signals. Thus, with perfect foresight, bidders for transmission capacity would predict the electricity market outcome with efficient use of transmission.

   A limitation of this mechanism is the increased complexity which may complicate trading activities of market participants. Another limitation is that the mechanism fails to account for parallel flows in meshed networks. In this context, a new method has been proposed called coordinated auctioning.

   <u>Coordinated Auctioning</u>:
   The coordinated auctioning splits the markets into energy market and transmission capacity market. Participants have to ensure that they own sufficient transmission rights to conclude their energy exchanges. However, coordinated auctioning tries to overcome problems associated with explicit auctioning by accounting for the effects of loop flows in the network. A central auctioneer is introduced who manages capacity allocation at all borders included in the Internal European Market (IEM).
   For coordinated auctioning, three steps are necessary:
   - Each system operator informs the central auctioneer about the available transmission capability.
   - Market participants submit their bids to the central auctioneer.
   - The auctioneer allocates transmission capacity using a model similar to nodal pricing.

Market participants may value their willingness to pay for transmission rights by comparing the different zonal prices. Hence, rational bidders for transmission rights will submit bids equal to the zonal difference in energy prices, as savings for cheaper energy are traded off against the transmission costs. With perfect foresight and all information available, a coordinated auction will lead to the same allocation as the nodal pricing approach, which in turn is considered as an economically efficient decision.

2. Nodal pricing (OPF based congestion management):
   The fashionable concept of nodal pricing is to version an power marketplace with its numerous economical and technical specifications, including turbines fee functions, call for elasticity, era limits, line electricity float limits and optimize the machine for maximizing social welfare. This hassle represents one of the generally employed formulations of Optimal Power Flow (OPF). The call OPF does now no longer stand for any particular optimization hassle, alternatively some of optimization issues falls into the OPF category. The simple purpose of an OPF evaluation is to attain an optimum electricity switch scenario with out violating the community constraints. In other words, the congestion control hassle is tackled with the aid of using fixing an optimization hassle, with a fixed of constraints representing community constraints.One of the results of this optimization hassle is the fee at each node called nodal fee. It displays the temporal and spatial variant of strength fee regarding the call for on that node. Nodal pricing can be interpreted as a completely coordinated implicit auction. The marketplace members do now no longer explicitly take part into auctions for transmission potential. On the contrary, they put up bids for strength injection and take-off and that they are scheduled such that transmission potential is implicitly allotted to them based on their strength bids, with out violating the community constraints.The sensible OPF makes use of a system in which ac electricity float equations are introduced to the monetary dispatch as equality constraints with inequality constraints concerning the float MW, MVA or contemporary on a transmission line and voltages at a substation bus. A model of OPF is advanced that takes into consideration numerous contingencies called a safety restrained OPF or SCOPF.
   OPF problems are formulated with a number of objectives. A brief list is outlined here:
   - Minimize the total cost of production
   - Maximize total social welfare
   - Minimize total system loss
   - Minimize the re-dispatch cost
   - Minimize the total adjustment
   - Minimize load curtailment

3. Zonal pricing:
   In Zonal pricing system buses with similar LMPs are aggregated into zones. The market is first settled constraint free. Each zonevwill have a price for energy that buyers can pay and sellers receive. In the case that congestion occurs the ISO receives supplementary bids for increase and decrease of generation. The most expensive supplemental bid for increase of generation becomes the price for that zone and the cheapest supplemental bid for decrease of generation becomes the price for that zone. In this way the ISO earns congestion rent over the congested lines. In case that there is no congestion the zonal prices will be the same. The California market migrated from this CM mechanism to the zonal pricing method.

4. Price area congestion management:
   This is a simplified model of the inter-zonal and intra-zonal congestion control scheme. This approach includes splitting a power trade into geographical bid regions with confined capacities of trade. When congestion is predicted, the gadget operator announces that the gadget is cut up into regions at predicted congestion bottlenecks. Spot marketplace bidders need to publish separate bids for each charge region wherein they have got technology or load. If no congestion occurs at some point of marketplace settlements, the marketplace will settle at one charge, on the way to be similar to if no charge regions existed. If congestion does occur, charge regions are one after the other settled at charges that fulfill transmission constraints. Areas with extra inexpensive technology could have decrease charges, and regions with extra load - better charges. Market earnings from this charge distinction is paid to the SO and he in addition makes use of it for grid enhancement. Bilateral contracts that span charge regions need to buy the load's electricity in its charge region in an effort to account for the contribution to congestion and to show the settlement to the monetary consequences oficongestion.

   An advantage about the market splitting method is that on a long-term basis, new gencos may decide to add capacity in deficit zones, attracted by high sale prices, and thus introduce more competition and cause overall prices to decrease. A limitation associated with this type of system is that it can be used only when physical zones are connected in radial fashion. In a meshed system, clear cut boundaries of physical zones can not be established. This type of congestion management system is used in Norway.

5. Re – dispatch:
   Re-dispatching is exercised as a command and control scheme, i.e., ISO curtails or increases injections without market based incentives. As generators have to be reimbursed, the ISO has an incentive to keep re-dispatch cost low.

6. Counter trace:
   Counter trading is based on the same principles as re-dispatching, however, it may be considered market oriented. Rather than applying command and control, the ISO will buy and sell electricity at prices determined by a bidding process. The principle of counter trading is thus a buy back principle which consists of replacing the generation of one generator ill- placed on the grid as regards to congestion by the generation of a better placed generator. The ISO has to buy electricity downstream of the congestion at higher cost and sell it upstream. Thus, there is no congestion rent, instead a congestion cost for ISO. This cost exposure is also regarded as an incentive for investment into gridvcapacity. Counter trading is used for real time congestion relief in the Norwegian system.

1.3 COMPARISON OF CONGESTION MANAGEMENT METHODS

The rescheduling of generation and load resources and corresponding pricing have been added with a new dimension to the operation of power market as well as system operation after deregulation. The solution methodology for this problem is referred to as congestion management. This chapter brings out various congestion management schemes that are employed in various markets across the world. The methods can be coarsely classified as market based and non-market based methods. In the market based methods, the system operator is bothered about the economical efficiency of the generation re-adjustment process. On the other hand the non-market based methods are driven by the simplicity and ease of procedure.

The congestion management techniques are strongly coupled to the overall market design. The nodal pricing or OPF based schemes require a centralized dispatch. In this scheme, the ISO schedules generators and loads based on their bid data such that social welfare is maximized. While doing so, network constraints are added to the optimization problem so that the most economic nodal injection pattern is obtained without creating congestion. The physical bilateral transaction is scheduled as if the generation injection submitted a zero bid and the load submitted an infinite bid. Such a transaction is then subject to an ex-post charge that equals the opportunity cost of transaction, i.e., the cost difference of selling the power to the pool at the injection node price and buying it back at the take-off node price. Bilateral traders then opt for buying financial instruments to hedge the price difference risk. Bilateral traders can also manage transmission price risk by actively participating in congestion relief by providing incremental/ decremental bids. The nodal pricing scheme achieves economical efficiency, however, at the cost of complexity and transparency. The scheme is commonly employed in LMP markets which work according to standard market design in USA.

The inter-zonal/ intra-zonal scheme tries to strike a balance between the complexity and economic significance. The basic idea in this approach is to divide the grid into few predefined congestion zones, which have separate markets whose respective market clearing prices set the uniform price within the zone. It makes calculation for larger systems simpler. In this scheme, different objectives are used to correct for inter-zonal and intra-zonal line loadings. When inter-zonal congestion occurs, bilateral transactions across zones are subject to ex-post congestion fee based on congestion relief cost between the zones. Zonal pricing schemes were employed in Californian market.

Price area congestion management scheme used in Nordic pool forms a special version of zonal congestion management scheme. It divides the system into different price areas when there is congestion. These areas are divided at congestion bottlenecks. Each area will have its own market. Price areas are defined pragmatically, based on experience and engineering judgment. Some additional criteria for analytical determination of price areas is required if the system is not radial inter-connected .

In contrast with the nodal pricing scheme, where implicit auctioning of transmission capacity is done, the transmission facilities in European interconnections are allocated by means of explicit auctioning. This separates transmission and energy markets. The mechanisms to account for the effect of loop flows, a scheme called coordinated auctioning is being proposed, that requires centralized auctioning of transmission interconnections.

The term - congestion management generally refers to the capacity allocation to various participants before finalizing the actual schedules of nodal injections. It is possible that the commonly employed mechanism may not lead to a feasible solution. The last resortvavailable with system operator is the forceful curtailment of some of the transactions, based on some criteria. Again, the real time unscheduled flows may hit the line flow limits. For this, congestion alleviation methods are employed which may take the form of market based or non market based solution.

Presently congestion management is a challenging aspect in the deregulated market. Implementation of a particular scheme in a system is driven by historical developments, demographic parameters, network topology, political openness and so on. Table 1.2 shows comparison of practical congestion management schemes.

Method	Characteristic	Market Based?	Allocation	Alleviation	Example
Explicit Auctioning	Decentralized auctioning of transmission capacity	Yes	Yes	No	European interconnection
Nodal Pricing	Requires centralized dispatch, implemented in pool based markets	Yes	Yes	No	PJM, New England, New York
Zonal Pricing	Can be used with centralized dispatch or using market splitting	Yes	Yes	No	Australia and Nordic pool
Re-dispatch	-	Yes	No	Yes	-
Counter Trade	Replacement of ill placed producer with better placed producer	Yes	No	Yes	Sweden
Pro-rata methods	Some norm of allocation, not necessarily economically	No	No	Yes	Most of the developing countries

Table 1.2: Capacity Allocation: Comparison of congestion management methods

1.4 CONSEQUENCES OF CONGESTION IN A SEQUENCE:

1. Line outage
2. Overload on other transmission lines
3. Generator outage
4. Affects system security
5. Cascading failures

1.5 DESIRED FEATURES AND METHODS FOR CONGESTION MANAGEMENT:

Features:

For challenging the congestion problem every country has different forms in different ways. It really depends on what type of neutrality model is being employed for a particular region. Certain network topologies, demographic factors and political ideologies influence the execution of congestion management schemes in conjunction with overall market design. Any method which is considered for managing the congestion should always acquire following qualities.

1. Non-discriminative: Every market member should be treated evenly. For this, the network operator should be individualistic of market parties and he should not obtain any kind of benefit from happening of congestion. Or else this provides uncooperative signals for network extension.
2. Transparent: The execution should be very well elucidated and transparent for every participant.
3. Robust: Scheme for managing the congestion should be like sturdy along with strategic manipulation by the market entities. This once more refer back to theory of economic efficiency.

Methods:

1. Generator rescheduling:

   If there is a fault in any line connected to particular generator, and the line fails there will be overloading in the other line of transmission system. This can lead to violation of limits in the other line so there will be congestion in that particular line. In this case we can manage the amount of generation done by the generators in a particular manner so that all the lines can work properly without violating any of the limit. While doing that we also have to make sure that the demand of consumer is fulfilled constantly and also generation capacity of generator should also be maintained during the whole time.

2. Distributed generation:

   Distributed generation is a small-scale power generation unit that is slightly closer to consumer than central generation station. So, these are the sources that are not directly connected to bulky main power transmission line. It includes engines, small turbines, fuel cell, photovoltaic etc. It can reduce overall load, can provide independence from grid, can also be used as a backup power source and also, we can supply energy back to grid. By supplying energy back to the grid, we can earn money as well.

3. Using FACTS devices:

   It is termed as flexible AC transmission system. It is used to increase the loading ability of transmission system. it can increase ATC for any transmission system here ATC stands for available transfer capacity which is basically the excess amount of power which a transmission line can still transmit. It is calculated by considering total transmission capability, amount of power currently being transferred and few margins. These FACTS devices are used for reduction in reactive power.

4. Load shedding:

   As per the name suggests the consumer load here is casted off to manage congestion this can be used in various ways like by providing incentive to consumer who uses power at off peak time or to the consumer who uses less amount of power then a particular limit. The power industry can also shed the load of particular area to manage congestion. The government should also penalize the customers for using large amount of power. This objective function looks after the economical constraint of congestion management.

CHAPTER 2: SOFT COMPUTING TECHNIQUES

2.1 INTRODUCTION OF SOFT COMPUTING TECHNIQUES

The technology of reasoning, wondering and discount that examine and uses the real-international phenomena of grouping, participation, and class of diverse portions below examine is known as Soft Computing technique. Basically, it's miles an prolonged model of herbal regulations and it's miles able to dealing with complicated structures as it does now no longer have any requirement of strict and complicated mathematical definitions for the machine components. A appropriate instance for tender computing is the human psyche so it is usually an impact of human nature wondering. The center price of tender computing strategies is to Exploit the resistance for imprecision, vulnerability and fractional fact to perform tractability, electricity and low association cost. tender computing strategies are of diverse kinds like evolutionary computing, synthetic neural networks, and fuzzy common sense and Bayesian statistics. The largest gain of a tender computing- primarily based totally machine is that it could utilized in a separate in addition to in union. There are few issues that can not be solved the use of traditional mathematical techniques then tender computing strategies may be used collectively which can produce answers to issues that are too compound or inherently noisy to address with. The programs of tender computing have added human understanding of learning, understanding, mental processing and rethinking to the sphere of computing other than that it additionally made fixing nonlinear issues, wherein mathematical fashions aren't available, smooth and possible. This resulted within side the opportunity of constructing intelligent structures consisting of self sufficient self-tuning structures, and automatic designed structures.

Sometimes nature can be the best source to find all the solutions now in the actual world, we are confronting numerous issues which are practically difficult to settle intelligently, or there are issues which could be understood by hypothetical strategies however its prerequisite of colossal assets and immense time for computation can be an issue. For these issues, strategies spurred ordinarily now and then work proficiently and adequately. Delicate figuring depends on normal just as counterfeit thoughts. We generally can't find the most exact solutions following this strategy yet a close to ideal worth can be an answer in pretty much every down to earth reason. These naturally roused techniques are called Soft Computing. Thus, these techniques are a blend of different processing strategies. It refers to a collection of computational techniques in computer science, artificial intelligence, machine l earning applied in engineering areas such as Aircraft, spacecraft, cooling and heating, communication ne twork, mobile robot, inverters and converters, electric power system, power electronics and motion contr ol etc.

The Professor Lotfi Zadeh only invented this term who earlier developed the fuzzy logic theory. It differs from conventional computing as it was hard computing.

Soft computing strategies are certifiably not a changed blend of techniques rather, it very well may be called an association is which every one of the innate accomplices contributes a clear strategy for settling the issue in its space. In this point of view, the central constituent procedures in soft computing are strong. Truth be told, the primary trait of soft computing methods is its inalienable limit of making a half and half framework that depends on the coordination of different constituent innovations. This combination gives correlative thinking and looking through strategies that permit us to create adaptable processing devices and take care of complex issues. Mixture processing is the mix of hard computing and soft computing which having their characteristic points of interest and weaknesses. To get the best out of both these strategies their people's impediments are diminished for taking care of an issue all the more productively by Hybrid computing. These models are for the most part being applied to countless characterizations, forecast, and control issues.

2.2 VARIOUS SOFT COMPUTING TECHNIQUES

2.2.1 Genetic Algorithm:

The essential ideas were created by Holland. Genetic Algorithms (GA) is a soft computing approach. Genetic Algorithms are universally useful hunt calculations, which use standards of common genetic qualities to develop answers for issues. We can figure that genetic algorithms are propelled by Darwin's hypothesis about development. This has been effectively applied to countless logical and building issues, for example, streamlining, AI, programmed programming, transportation issues, versatile control and so forth.

The procedure begins with a population of arbitrarily produced chromosomes, each speaking to an applicant answer for the issue being solved and advances towards better chromosomes by applying genetic administrators enlivened by the hereditary procedures happening in nature. GAs has an extraordinary durable ability to get the data gathered about an at first not known to discover the region and in light of that measure it picked up parcel of accomplishment in search and improvement issues. Especially GA is uncommonly utilized in enormous, complex, and inadequately comprehended hunt spaces where old great techniques are wasteful or tedious. The GA's fundamental thought is to keep up a populace of chromosomes. This chromosomes populace creates after some time through a progressive emphasis procedure of rivalry and controlled variety. In this procedure each state is called age. There is constantly wellness esteem partners with chromosome at each age which delineates the nature of the arrangement, spoke to by the chromosome esteems. These wellness esteems are utilized in the determination of the chromosomes, which structure the new age, happens. Much the same as in nature where, the new chromosomes are made utilizing genetic administrators. For example, hybrid and change.

2.2.2 Particle Swarm Optimization:

GA provides good solution but they not keep any detail about the best solution in the whole community. By the introduction of memory in this, the strategy extends search. In Particle Swarm optimization, a global best solution is also stored somewhere in the memory along with the local best solution, so that all particles not just trapped into local optima but also moves to the global optima. PSO is an algorithm developed by Kennedy and Eberhart that imitates the social behaviors of bird flocking or fish schooling and the methods by which they find places for perching, find foods sources or another suitable habitat. The algorithm maintains a population potential in which each particle represents a potential solution to an optimization problem. The PSO does the working by at the same time keeping up a few up-and-comer arrangements in the inquiry space. During every cycle of the calculation, every up-and-comer arrangement is assessed by the target work being streamlined, choosing the fitness of that arrangement. Every applicant arrangement can be viewed as a particle "flying" through the fitness scene finding the most extreme or least of that specific target work.From the start, the PSO calculation chooses competitor arrangements arbitrarily inside the pursuit space. PSO calculation has no extra data of the hidden target work in this way has no chance to get of knowing whether any of the applicant arrangements are close to or distant from a neighborhood or global most extreme. PSO calculation at that point utilizes the target capacity to assess its up-and-comer arrangements and works upon the resultant fitness values. Every particle at that point keeps up its own position, made out of the applicant arrangement, and it's surveyed fitness and its speed.

Not with standing that it additionally recalls the best fitness value it has accomplished so far during the activity of the calculation, alluded to as the individual best fitness and the applicant arrangement that picked up this fitness, alluded to as the individual best competitor arrangement. Toward the end, PSO calculation keeps up the best fitness value accomplished among all particles in the multitude, it is named as the global best fitness. The competitor arrangement that accomplished this fitness is known as the global best position or is called as the global best applicant arrangement.

CHAPTER 3: PARTICLE SWARM OPTIMIZATION ALGORITHM

PSO is a smooth computing approach that's primarily based totally on a big wide variety of people i.e populace and become proposed in 1995. Particle Swarm Optimization portrayed into the gap of Artificial Intelligence. The time period Computerized reasoning or Fake Life alludes to the speculation of mimicking human behavior via calculation. It consists of making plans such PC frameworks that can execute errands which require human perception. For eg, prior simply human beings had the ability to understand the discourse of an individual. However at this point, discourse acknowledgment is a standard detail of any automated gadget. This has became out to be viable via automated reasoning. Different times of human perception might also additionally contain basic leadership, language interpretation, and visible discernment and so forth. There are distinctive techniques which make it viable. These strategies to actualize man-made attention into PCs are famously referred to as methodologies of automated reasoning'. As depicted before, Swarm Intelligence is part of Artificial Intelligence in which we watch nature and undertaking to parent out how unique natural wonders may be imitated in a PC framework to strengthen the making plans calculations. In swarm perception, we middle at the combination conduct of basic creatures and their affiliation with the earth. In PSO, the focal point in on a institution of birds. This institution of birds is known as a '*swarm*'. Let's try and recognize the Particle Swarm Optimization from the subsequent scenario.

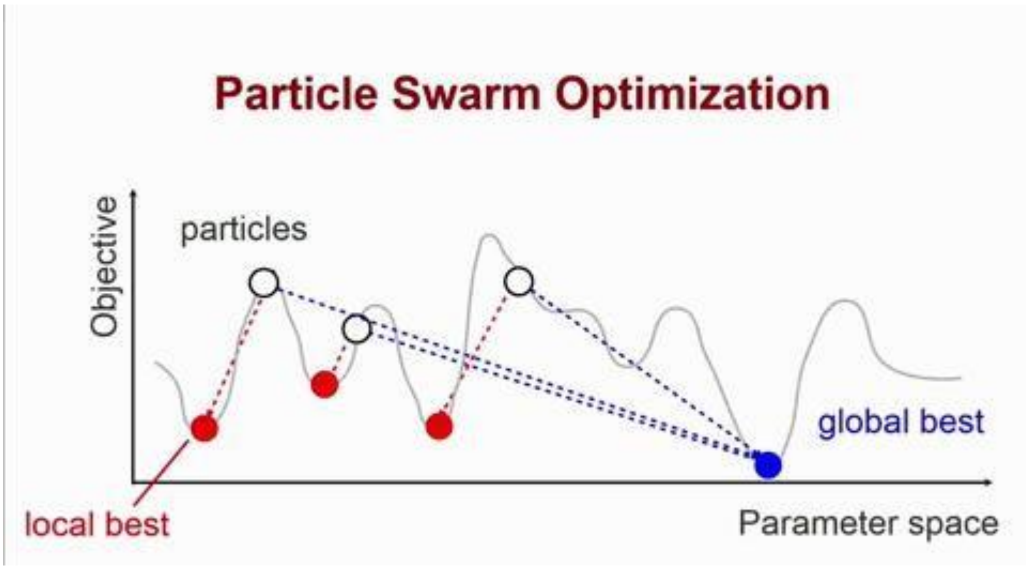

Fig 3.1: Particle Swarm Optimization local best and global best

Example: Suppose there is a swarm (a gathering of flying creatures). Presently, every one of the winged animals are eager and are hunting down nourishment. These ravenous winged creatures can be connected with the errands in a calculation framework which are eager for assets. Presently, in the area of these winged creatures, there is just a single sustenance molecule. This sustenance molecule can be associated with an asset. As we probably am aware, assignments are many, assets are constrained. So this has turned into a comparative condition as in a specific calculation condition. Presently, the winged creatures don't have a clue where the nourishment molecule is covered up or found. In such a situation, how the calculation to discover the sustenance molecule ought to be planned. On the off chance that each winged animal will endeavor to discover the sustenance all alone, it might cause destruction and may expend a lot of time. Consequently on cautious perception of this swarm, it was understood that however the winged creatures don't have the foggiest idea where the nourishment molecule is found, they do know their separation from it. In this manner the best way to deal with finding that sustenance molecule is to pursue the flying creatures which are closest to the nourishment molecule. This conduct of winged creatures is mimicked in the calculation condition and the calculation so structured is named as Particle Swarm Optimization Algorithm.

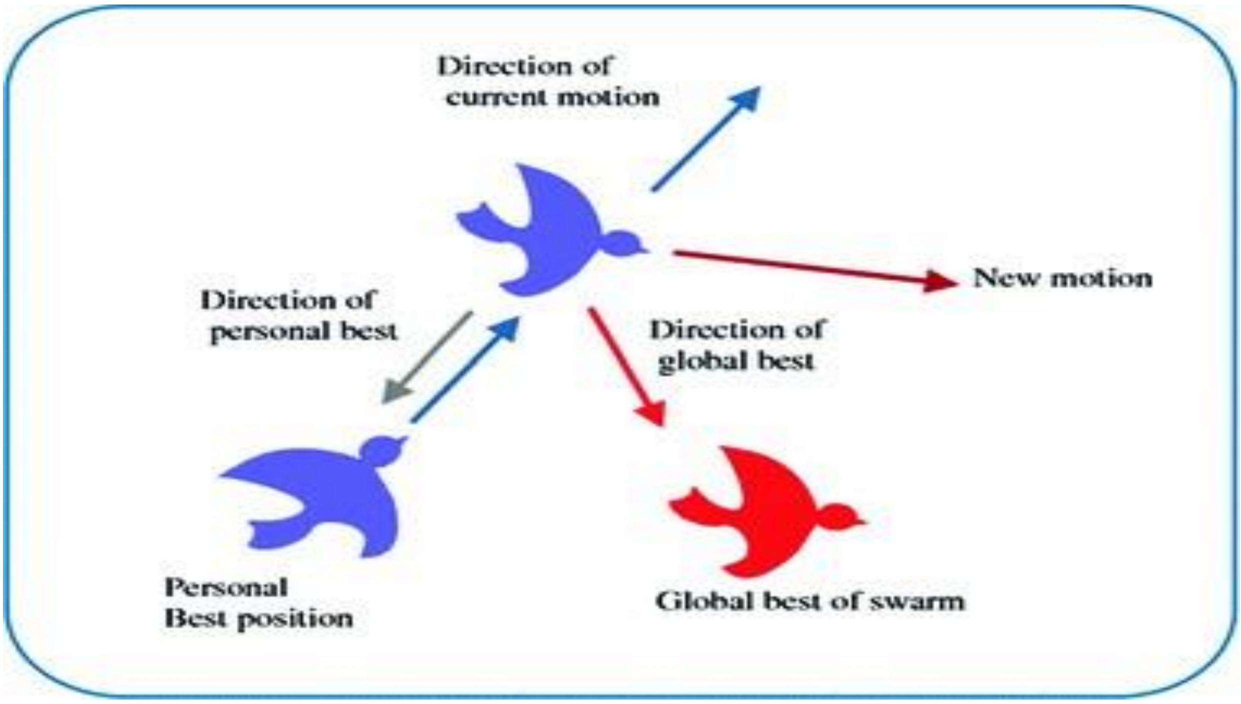

Fig 3.2: Bird flocking in Particle Swarm Optimization

What is coined as artificial life is something that has a man-made approach to it which has a portion and some fundamental characteristics of basic human life and it inculcates the following two points.

1. Artificial life gives us a direction so as to how do processes of computing can be of help.
2. How can nature be also useful is also tried and answer.

The main point of our work is on the above mentioned 2nd point. All things considered, there are now heaps of computational procedures motivated by organic frameworks. For instance, fake neural system is an unknotted version of man's cerebrum; hereditary calculation is enlivened by the human development.
Here we examine another kind of natural framework - social framework, all the more explicitly, the aggregate practices of basic people interfacing with their condition and one another. Somebody called it as swarm insight. The majority of the recreations used nearby procedures, for example, those displayed by cell automata, and might underlie the eccentric gathering elements of social conduct. Both of the recreations were made to translate the development of living beings in a winged creature rush or fish school. These reenactments are ordinarily utilized in PC liveliness or PC helped plan. In general the well known swarm motivated strategies in computational insight zones: Ant province enhancement and molecule swarm advancement. ACO was enlivened by the practices of ants and has numerous productive usesin discrete improvement issues.
The molecule swarm idea started as a recreation of disentangled social framework. The first purpose was to graphically reenact the movement of winged creature of a flying creature square or fish school. In any case, it was discovered that molecule swarm model can be utilized as a streamlining agent.

3.1 MAIN OBJECTIVE OF PSO:

Particle Swarm Optimization procedure is enlivened by the social conduct of winged animal rushing and fish tutoring so what is the best technique for them to find the nourishment. Assume a gathering of fowls is looking through nourishment in a region and just one bit of nourishment is accessible however all flying creatures don't have any information about the area of the nourishment rather they know how far the nourishment is from their current area, so the best procedure is to follow the winged creature closest to the nourishment. Suppose that a flying winged animal has a position and a speed whenever looking for nourishment, the feathered creature changes its situation by modifying the speed. The speed changes dependent on his past experience and furthermore the criticisms got from his neighbor. This looking through the procedure can be falsely reproduced for taking care of non-straight improvement issues. Along these lines, this is a populace based stochastic enhancement method propelled by the social conduct of flying creature rushing.

The similarity of honey bees with PSO strategy, suppose there is amassing of honey bees in a field their fundamental objective is to take care of themselves from blossoms in the field. With no information on the field in an earlier, the honey bees start in arbitrary areas with irregular speeds searching for blossoms. Every honey bee can recall the areas that it found the most blossoms, and some way or another knows the areas where different honey bees found a wealth of blossoms. Overflying areas of most prominent focus, at that point, being pulled back toward them. They are checking the domain they fly over against recently experienced areas of most noteworthy fixation wanting to locate irrefutably the most noteworthy convergence of blossoms.

3.2 DEVELOPMENT OF PSO ALGORITHM:

1. Define the Solution Space: First the parameters which are needed to be optimized in the given problem should be picked and then a reasonable range should be assigned for searching for the optimal solutions to them. This thing requires min and max value for every dimension in an N-dimension plane optimization.

2. Define a Fitness Function: For providing the link between the optimization algorithm and the around globe fitness function is needed. This obtains the location in the solution space and in return it gives a single number which expresses the value of that position.

3. Initialize Random Swarm Location and Velocities: For finding of optimal location in solution world, particles begin on their own, at their random position along with a random speed. Initial position is the only location hence it is Pbest (Personal Best). Gbest (Global Best) is selected among the initial locations.

4. Systematically Fly the Particles through the Solution Space: Particle should then roam through the solution space. Algorithm executes on every particle one after another, moving them by small distance and roaming around the whole swarm.

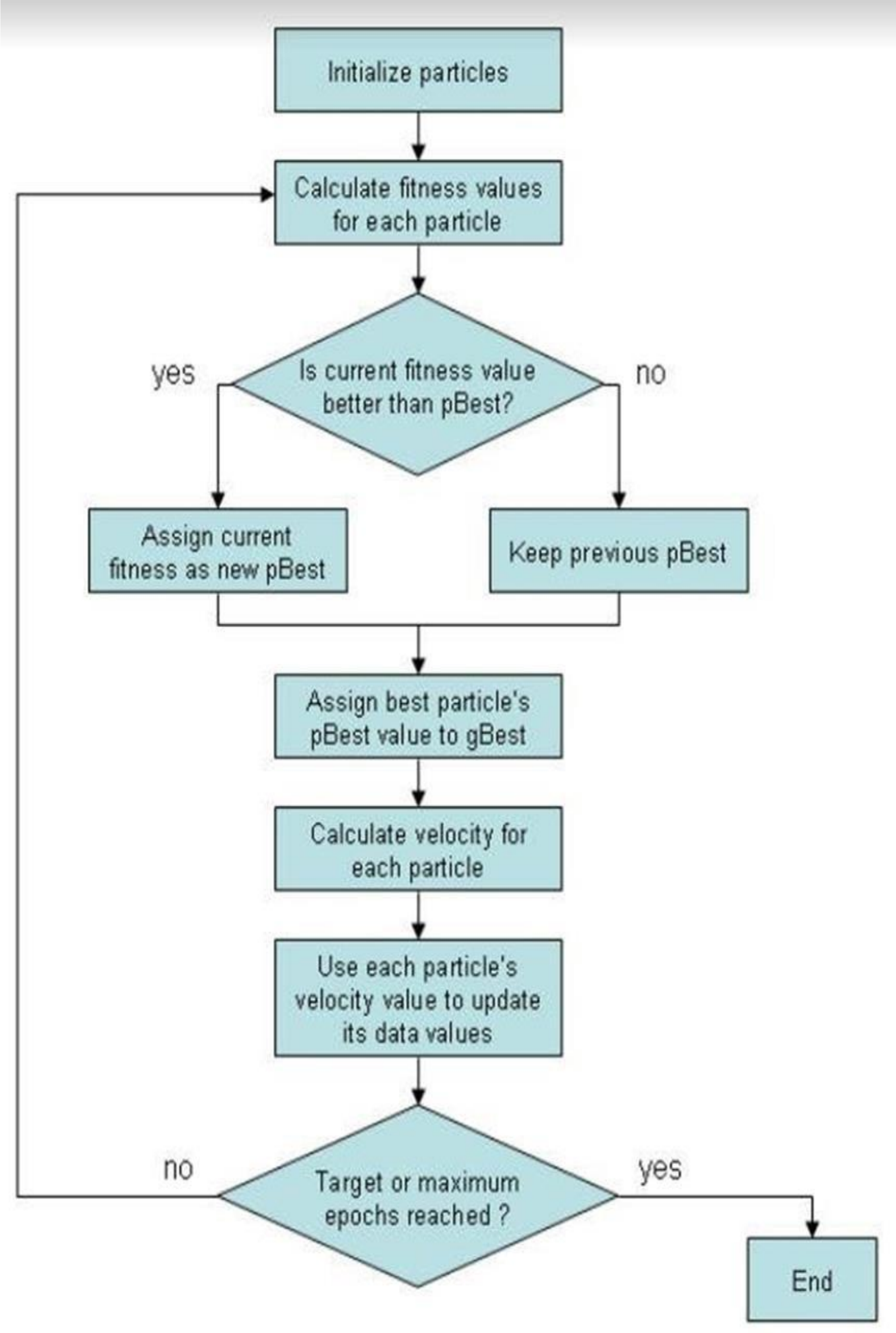

Fig 3.3: Particle Swarm Optimization flowchart

3.3 STEPS ON EACH PARTICLE INDIVIDUALLY

1. Evaluate the Particle's Fitness, compare to gbest, pbest: Fitness function, use the coordinates of the particle in solution surrounding, returns a fitness value to be defined to the current location. If that value is greater than the value at the respective pbest or gbest, then the corresponding positions are replaced with the current position.
2. Update the Particle's Velocity: Speed of the particle is changed according to the relative positions of Pbest and Gbest. Accelerated in the directions of these locations of greatest fitness according to the velocity equation given below.

$$V_i(k+1) = \omega \times V_i(k) + C_1 \times random_1() \times (PBest_i - X_i(k)) + C_2 \times random_2() \times (PBest_i - X_i(k))$$

   Vi is the velocity of the particle in the kth dimension. Xi is the particles coordinate in the kth dimension.

   C1 & C2: scaling factors, determines relative "pull" of pbest and gbest referred

   as the cognitive and social rates.c1 & c2 determines how much the particle is influenced by the memory & rest of the swarm respectively.

   Random (): It returns a number between 0.0 and 1.0.

   w: It is an "inertial weight," (between 0.0 and 1.0) determines extent of the particle remains along its original course unaffected by the pull of gbest and pbest.
3. Move the Particle: First when the speed has been obtained after that it is simple to shift the particle to its next position. According to the position equation given below.

$$Xi\ (k+1) = Xi(k) + Vi(k+1)$$

Repeat : Whole process is repeated again and again for every particle in the swarm. The aim of developing this algorithm is to create optimal balance between global best and local maxima.

Problems face during PSO execution was talent to control the finding area covered by the swarm. Without any restrictions or fencing on the velocity, particles could definitely go out of the physically meaningful solution space.

3.4 MATLAB CODE DESCRIPTION FOR OPTIMIZATION USING PSO:

Here, in our work along with removing congestion from overloaded lines we also need to the cost which will increase during the time of rescheduling of generators.

As we know every generator owner will specify some rate for increasing the generation or else decreasing the generation from previous state when grid or sector was under stable condition. This cost increases additional burden on power engineers and energy engineers to look at power demand and cost budget at a time.

So, during such scenarios it becomes essential for us to understand how we can optimize the rescheduling process because of which we can reduce the cost function also.

So, considering the cost as main objective function of optimization technique we tried to learn through online tutorial that how can make code of PSO for minimizing the objective function which in our case is cost-function of generation.

CHAPTER4: CONGESTION MANAGEMENT PROBLEM FORMULATION

4.1 GENERATOR SENSITIVITY FACTOR:

The generators considered in system each have sensitivities of different level for power flowing through any congested line. Change in value of real power which flows through transmission line k which is connected between two different buses j and i due to difference in power generated by generator g is called as GENERATOR SENSITIVITY (GS) of that specific line which is facing overloading.

Mathematically, GS of line kth can be observed like this;

$GSg = \Delta Pij\ \Delta Pg$ ……………………………………………………………………………..(1)

Where,

Pij is real power which flows through overloaded kth line

Pg is the useful power which is generated by generator g

The common equation of useful power flowing through the congested line can be like this,

$Pij = -Vij2.Gij + Vi.Vj.Gij.\cos(\theta i - \theta j) + Vi.Vj.Bij.\cos(\theta i - \theta j)$ ……….…………………...(2)

Where,

V and θ is value of voltage dimension and phase angle of both ith and jth buses

Bij and Gij is the susceptance and conductance of the line which is connected between buses i and j

by ignoring P-V coupling equation (1) can be shown as,

$GSg = \partial Pij\ \partial\theta i\ .\ \partial\theta i\ \partial Pg + \partial Pij\ \partial\theta j\ .\ \partial\theta j\ \partial Pg$ ……………………………………………….....(3)

Now, $\partial Pij\ \partial\theta i$ and $\partial Pij\ \partial\theta j$ can be obtained by differentiating the equation (2) with θ,

$\partial Pij\ \partial\theta i = -Vi.Vj.Gij.\sin(\theta i - \theta j) + Vi.Vj.Bij.\cos(\theta i - \theta j)$ ……………………………….…...(4)

$\partial Pij \partial\theta j = +Vi.Vj.Gij.\sin(\theta i - \theta j) - Vi.Vj.Bij.\cos(\theta i - \theta j)$ ……………………………..………. (5)

$\partial Pij \partial\theta i = -\partial Pij \partial\theta j$ ………………………………………………………………………... (6)

Now, if we consider sth bus then power difference of generated and demand at that bus is,

$Ps = Pg - Pd$ ……………………………………………………………………..………… (7)

here, active load at bus is Pd and Ps can be written as

Ps=$|Vs|2Gss$+$|Vs|\{\Sigma(Gst.\cos(\theta s-\theta t)+Bst.\sin(\theta s-\theta t))nt=1t\neq s|Vt|\}$……………………..….(8.1)

Ps=$|Vs|\{\Sigma(Gst.\cos(\theta s-\theta t)+Bst.\sin(\theta s-\theta t))nt=1|Vt|\}$……………….…………………….(8.2)

Now, differentiating Ps w.r.t to θs and θt obtain as follows;

$\partial Ps\partial\theta t=|Vs|.|Vt|\ (Gst.\sin(\theta s-\theta t)-Bst.\cos(\theta s-\theta t))$…………………………..…………...(9)

$\partial Ps\partial\theta t=|Vs|\ \Sigma\{(-Gst.\sin(\theta s-\theta t)+Bst.\cos(\theta s-\theta t)).|Vt|\}nt=1t\neq s$……………………..…….. (10)

By, ignoring P-V coupling we can see relation between change with increment in useful power with change in phase angle can be mentioned as,

$[\Delta P]=[H].[\Delta\theta]$…………………………………………………………..…………. (11)

Where,

$$[H]_{n\times n}=\begin{bmatrix}\frac{\partial P_1}{\partial\theta_1} & \cdots & \frac{\partial P_1}{\partial\theta_n}\\ \vdots & \ddots & \vdots\\ \frac{\partial P_n}{\partial\theta_1} & \cdots & \frac{\partial P_n}{\partial\theta_n}\end{bmatrix}$$

thus,

$[\Delta\theta]=[H]-1.[\Delta P]$...(12)

$[\Delta\theta]=[M].[\Delta P]$...(13)

$[M]n*n=[H]-1\ n*n$..(14)

$[H]n*n=[J11]n*n$..(15)

n= number of buses

where,
$J11$ is jacobian matrix obtained from NR load flow;

$$[H]_{n\times n}=\begin{bmatrix}0 & 0 & \cdots & 0\\ 0 & \frac{\partial\theta_2}{\partial P_2} & \cdots & \frac{\partial\theta_2}{\partial P_n}\\ \vdots & \vdots & \ddots & \vdots\\ 0 & \frac{\partial\theta_n}{\partial P_2} & \cdots & \frac{\partial\theta_n}{\partial P_n}\end{bmatrix}$$ ………………………………………………………...…. (16)

$[\Delta\theta_{n\times n}]=[M_{-1}][P_{-1}]$ ……………..…………………………………………………..…. (17)

$$[\Delta\theta]_{n\times 1} = \begin{bmatrix} 0 & 0 \\ 0 & M_{-1} \end{bmatrix} [\Delta P]_{n\times 1} \quad \text{.................} \quad (18)$$

Thus, remaining two terms that we need for equation (3) can be obtained from above equation (18). And after evaluating all terms of equation (3) we obtain generator sensitivity factor for all generators for given congested line with reference of slack bus. Thus, GSF of slack bus is zero.

The system operator chooses that generators which have non-uniform and enormous extents of sensitivity values as the ones generally sensitive to the useful power flow through the overloaded line and to take part in managing the congestion by rescheduling their capacity yield s.

4.2 MAIN OBJECTIVE FUNCTION:

The objective proposed for this work is to maintain the active power flow generation which in return helps to minimize the total congestion cost. After getting bidding price from all generators for congestion management, the rescheduling of values of generators optimally by solving the optimization problem.

The main objective function for this application is as follows,

$$TC=\Sigma(Ck.\Delta Pgj++Dk.\Delta Pgj-)j\in Ng\$/hr \quad \text{.................} \quad (19)$$

Where,

Ck and Dk is price bid of specific generator for pool power schedule of increment and decrement for congestion management and $\Delta Pgj+$ and $\Delta Pgj-$ is incremental and decremental change in power generation and TC is total congestion cost.

Equality Constraint:

$$PGk-PDk=\Sigma|Vj.Vk.Yjk|j\in NB.\cos(\theta k-\theta j-\theta kj) \quad \text{.................} \quad (20)$$

$$QGk-QDk=\Sigma|Vj.Vk.Yjk|j\in NB.\sin(\theta k-\theta j-\theta kj) \quad \text{.................} \quad (21)$$

$$PGk=PGkC+\Delta PGk+-\Delta PGk-;\ k= 1, 2\ldots., Ng \quad \text{.................} \quad (22)$$

$$PDj=PDjC;\ j = 1, 2, \ldots, Nd \quad \text{.................} \quad (23)$$

Where,

(20) and (21) equations shows real and reactive power balance at each node and (22) and (23) equations expresses final power as market clearing values.

Inequality Constraint:

Limits of equipment operating state and loading requirements comprises of its maximum and minimum loading limit which is one type of inequality constraint;

$PGkmin \leq PGk \leq PGkmax$ ……………………………………………………………..…... (24)

$QGkmin \leq QGk \leq QGkmax$ ………………………………………………………..………... (25)

$(PGk - PGkmin) \leq \Delta PGk \leq (PGkmax - \Delta PGk)$ ………………………………...……. (26)

$\Delta PGk+ \geq 0$; $\Delta PGk- \geq 0$ ……………………………………………………………...……. (27)

Where,
from (24) to (26) equations shows the upper and lower bound of both real and reactive power flow and equation (27) ensures that incremental or decremental change always remains positive.

Security Constraint:

For security of system loading of any line is limited by its upper limit;

$Lij = (PijPijmax) \leq 1$ ……………………………………………………………………. (28)

$Vnmin \leq Vn \leq Vnmax \ \forall \ n \in NL$ ………………………………………..………………….. (29)

Here, Lij is limiting loading factor of a line and Pij is real power flowing through the specific line which is connecting bus i and bus j.
Vn is voltage of nth bus where n belongs to number of load buses.

So, further using these many equations we need to develop PSO code for optimally rescheduling generation values in order to incur low total congestion cost.

$$GS_{pg} = \frac{\Delta P_{ij}}{\Delta PG}$$

CHAPTER 5: SIMULATION RESULTS AND DISCUSSION

5.1 MODIFIED IEEE 30 BU SYSTEM:

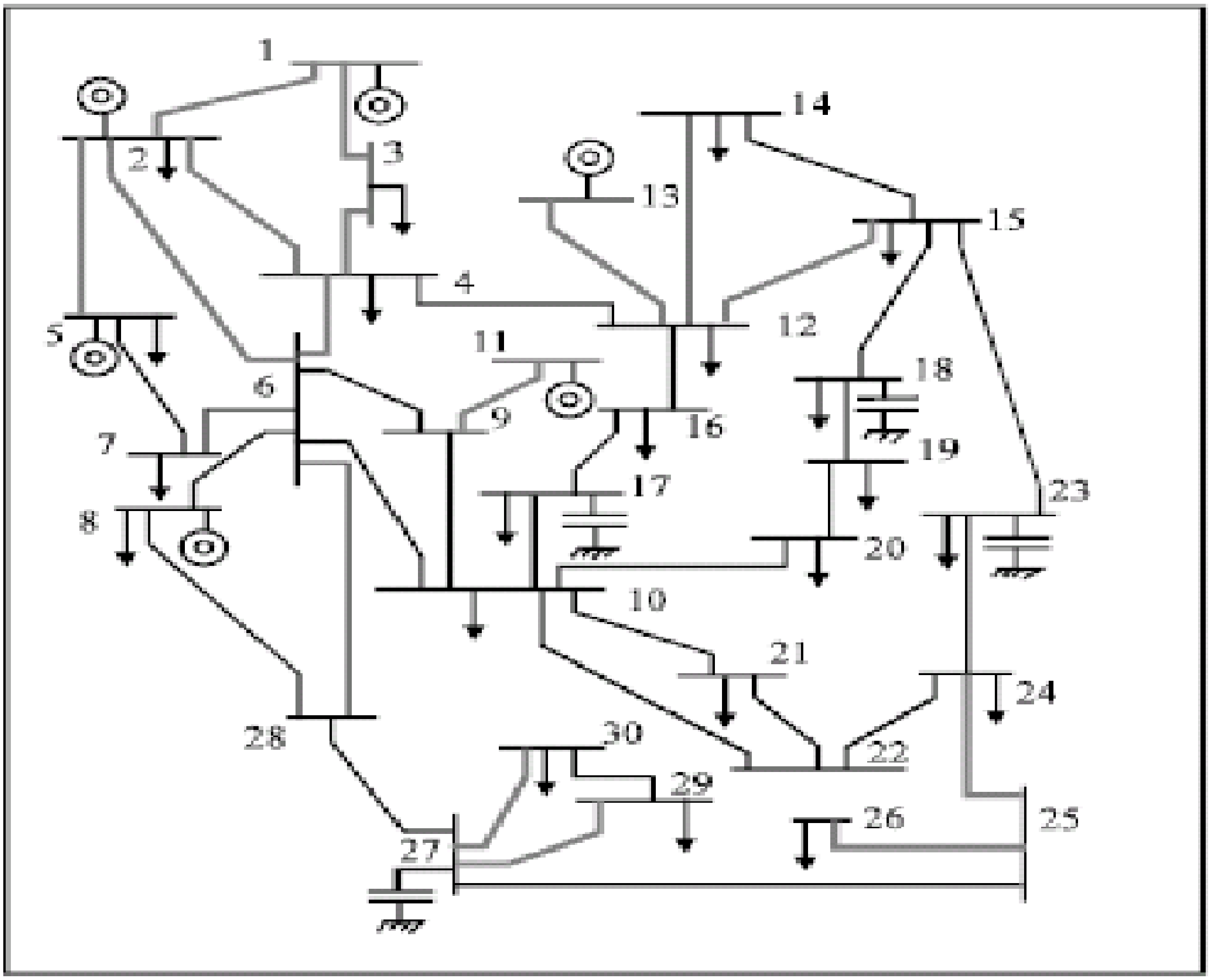

Fig. 5.1 modified IEEE system of 30 bus

Here for analyzing the congestion management we considered n-1 contingency and implemented it through MATLAB programming using NR load flow method. After this we removed each and every line turn by turn to see which line creates congestion. From this we obtained various output.

The IEEE 30 bus system has been used to test the proposed algorithm. It consists of 6 generator buses, 24 load buses and 41 transmission lines. Slack bus generator is assigned number 1. Remaining generators are assigned numbers 2,3,4,5 and 6 respectively. Load buses are numbered from 7 to 30. Here, two lines i.e. line no. 1 (between buses 1 and 2) and line no. 6 (between buses 2 and 9) is found to be congested.

Congested line	Power flow (MW)	Power flow limit (MW)
1-2	170.30	130
2-9	68.75	65

Table 5.1: Details of Power Flow of Congested lines

Table 5.1 shows the values of generator sensitivity factors computed for the lines 1-2 and 2-9. A negative value of sensitivity factor of a generator indicates that an increase in generation for that generator decreases the power flow in the congested line. Whereas, a positive value of sensitivity factor of a generator indicates that an increase in generation increases power flow in the congested line.

It is seen that the generators 1,2,3,4 and 6 have negative sensitivity factors, while the generator 5 has positive sensitivity factor. So, only generators 1,2,3,4 and 6 would take part in removing congestion from the congested lines. The generator 5 does not take part in removing congestion. PSO is applied to optimally reschedule the output powers of generators to manage congestion.

		Proposed method
Cost of active power rescheduling ($/day)		31,286
Resultant Power flow (MW)	**Line 1-2**	128.16
	Line 2-9	63.24
Active power rescheduling (MW)	ΔP_1	-43.20
	ΔP_2	+16.67
	ΔP_3	+10.06
	ΔP_4	+14.20
	ΔP_5	Not participated
	ΔP_6	+2.75
Total active power rescheduling (MW)		86.88

Table 5.2: Results obtained by PSO

Table 5.3 show Losses are also reduced by the proposed method. Furthermore, reactive power rescheduling helps in improving voltage stability of the load buses and it takes the system far away from voltage collapse point. Voltage stability has been increased because L-index values of load buses have been considerably decreased in post-rescheduling state. Reactive power rescheduling also decreases deviation in voltage of load buses from the specified 1.0 pu value. Thus, it improves voltage profile of the load buses.

	Pre-rescheduling	**Post-rescheduling**
Lmax	0.1007	0.0815
Voltage deviation	1.205	0.659

Table 5.3: Voltage stability and Voltage deviation indicators in pre-rescheduling and post-rescheduling states

Table 5.4 shows the effect of various parameters of PSO such as: population size, acceleration constants, constriction factor, inertia weight and velocity of particles, on the convergence of the algorithm were studied for 50 different trials. Finally, those values of parameters were selected which gave the best rescheduling costs.

Population size	50
Acceleration constants (C1, C2)	2.1 and 2.0
Constriction factor	0.729
Max. and Min. inertia weights	1 and 0.2
Max. and Min. velocity of particles	0.45 and -0.45
Convergence criterion	200 iterations

Table 5.4: Selected parameters of PSO

	Worst cost	**Best cost**	**Average cost**
Active power rescheduling cost ($/day)	41,000	28,130	31,286
Reactive power rescheduling cost ($/day)	8,200	6,051	7,641

Table 5.5: Statistical results of rescheduling costs

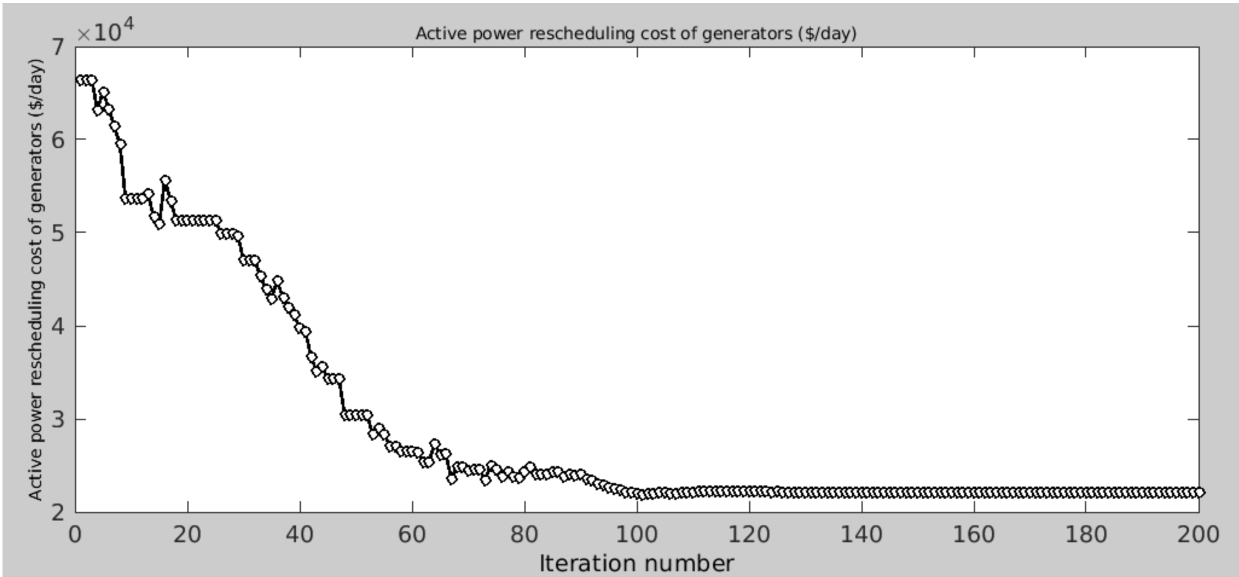

Fig. 5.2 convergence characteristic of PSO

Fig. 5.2 suggests the convergence function of PSO. It is visible that PSO primarily based totally set of rules can do away with congestion from the overloaded traces inside 120 iterations which justifies the truth that it's miles a quick approach. An average simulation time required with the aid of using the proposed approach become about 4.5 minutes.

CONCLUSION:

With the speedy increase of deregulated strength markets, congestion control has turn out to be a essential technique for overcoming congestion issues. New demanding situations and elements attention on using more recent technology to create green strategies that decorate strength device overall performance withinside the shortest amount of time to alleviate congestion. A evaluate of congestion control strategies and strategies from the literature are presented. A complete try turned into made to expose the significance of the congestion control approach to alleviate the congestion problem, that is an rising fashion in many researches.

PSO primarily based totally set of rules has been advised for minimizing lively strength rescheduling price and reactive strength rescheduling price of the taking part turbines to alleviate congestion in IEEE 30 bus check device. The contribution of this paper can be summarized as follows:

(1) The turbines which take element in congestion control can be decided on primarily based totally upon their sensitivities to the congested lines.

(2) The impact of reactive strength of turbines must be taken into consideration in handling congestion. Rescheduling of reactive strength era together with their lively strength decreased universal rescheduling price to manage congestion.

(3) Reactive strength rescheduling enables in enhancing voltage balance and voltage profile of the burden buses in post-rescheduling state.

(4) Losses received with the aid of using the proposed approach had been appreciably decrease than the ones of different reported strategies.

So, Simulations confirmed encouraging results, suggesting that the proposed approach turned into successful of correctly figuring out better pleasant answers addressing congestion control.

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